

Switzerland's Greenhouse Gas Inventory 1990–2014

National Inventory Report

Including reporting elements under the Kyoto Protocol

Submission of 15 April 2016
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol



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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
AREA4	Swiss Land Use Statistics, forth survey 2013/18
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
Cemuisse	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
chp.	Chapter
CNG	Compressed natural gas
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
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 Emission Information System
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)
FCA	Federal Customs Administration
FEDRO	Swiss Federal Roads Office
FiBL	Research Institute of Organic Agriculture
FMRL	Forest management reference level
FOAG	Federal Office for Agriculture
FOCA	Federal Office of Civil Aviation
FOD	First order decay (model)
FOEN	Federal Office for the Environment (former name SAEFL until 2005)
FOITT	Federal Office of Information Technology, Systems and Telecommunication
Gg	Gigagram (10^9 g = 1'000 tonnes)
GHG	Greenhouse gas
GL	Guidelines
g	Gramme
GVS	Swiss Foundry Association
GWP	Global Warming Potential
ha	hectare
HFC	Hydrofluorocarbons (e.g. HFC-32 difluoromethane)
HWP	Harvested Wood Products
ICAO	International Civil Aviation Organization
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 tonne (1'000 tonnes)
LPG	Liquefied Petroleum Gas (Propane/Butane)
LTO	Landing-Take-off-Cycle (Aviation)
LULUCF	Land Use, Land-Use Change and Forestry
MOFIS	Swiss federal vehicle registration database
MSW	Municipal solid waste
NABO	Swiss Soil Monitoring Network
NCV	Net calorific value
NF ₃	Nitrogen trifluoride 2006 IPCC GWP: 17'200 (UNFCCC 2014a, Annex III)
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 ₂ O	Nitrous oxide; 2006 IPCC GWP: 298 (UNFCCC 2014a, Annex III)
NO _x	Nitrogen oxides
ODS	Ozone-depleting substances (CFCs, halons etc.)
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)
SFOE	Swiss Federal Office of Energy
SFSO	Swiss Federal Statistical Office
SGWA	Swiss Gas and Water Industry Association (see SVGW/SSIGE)
SKW	Schweizerischer Kosmetik- und Waschmittelverband (Swiss association of cosmetics and detergents)
SO ₂	Sulphur dioxide
SOC	Soil organic carbon
SOLV	Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector
SVGW/SSIGE/	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
VOC	Volatile organic compounds
VSG	Verband der Schweizerischen Gasindustrie / Association Suisse de l'Industrie Gazière (ASIG) (Swiss gas industry association)
VSZ	Verband Schweizerische Ziegelindustrie (Swiss association of brick and tile industry)
VSLF	Swiss association for coating and paint applications
VSTB	Swiss Association of Grass Drying Plants
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
WWT	Wastewater treatment
ZPK	Verband der Schweizerischen Zellstoff-, Papier- und Kartonindustrie

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 the 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 with a volume loss of 12% since 1999 (FOEN 2014d).

The observed trends in precipitation are less pronounced 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. Furthermore, higher intensity of storms as well as 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. This in turn would 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 the temperature rises 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 would 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 in combination with 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 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 was implemented and is fully operational.

The 2016 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 1990–2014, the Kyoto Protocol LULUCF tables 2008–2014 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), Agroscope, the Swiss centre of excellence for agricultural research, 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 the preparation of the inventory.

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 changes in response to the review process are documented in chp. 10.1.1)

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 shows the additional obligations under the Kyoto Protocol and several

Annexes provide 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 Emission Information System (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 2006 IPCC Guidelines (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 transfers 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 Core 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

improving the inventory, e.g. by performing tasks defined 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 the 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.
- 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. It 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 Registry, and **Chapter 14** includes information on minimization of adverse impacts in accordance with Article 3, paragraph 14.

ES.1.3 Background information on supplementary information required under article 7.1. of the Kyoto Protocol (KP)

As described above, Chapter 11 of PART 2 provides information on KP-LULUCF.

Switzerland only accounts for the mandatory activity Forest management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2016c). 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 is set at 3.5% of the 1990 emissions (excluding LULUCF).

Switzerland chooses 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 2016c). In addition to the mandatory submission of the inventory years 2013 and 2014, 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 2014

In 2014, Switzerland emitted 48'605 kt (kilo tonnes) of CO₂ equivalent, corresponding to 5.9 tonnes of CO₂ equivalent per capita (CO₂: 4.8 tonnes per capita), to the atmosphere,

excluding emissions from international bunkers (aviation and marine), excluding indirect greenhouse gas emissions 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.

Key category analysis

Several key category analyses are carried out by level (years 1990 and 2014) and trend assessment (period 1990–2014), both including LULUCF categories.

- Approach 1: in 2014, 30 categories among a total of 150 are identified as level key categories. Half of these categories are part of sector 1 Energy, accounting for the largest share of total national emissions.
- Approach 2: in 2014, 26 categories among a total of 157 categories are identified as key categories. Under Approach 2, the most important categories stem from sectors 3 Agriculture and 4 LULUCF.

Key category analyses are also performed excluding LULUCF categories. They are not represented in the NIR but are available on request.

Switzerland's GHG emissions by gases

Table E- 1 shows Switzerland's annual GHG emissions by individual gases from 1990 (base year) to 2014. Total emissions excluding LULUCF reach a minimum in 2014, which is 8.8% below base year emissions in 1990.

Table E- 1 Switzerland's GHG emissions in CO₂ equivalent (kt) by gas; 1990–2014. The column below on the far right indicates the percentage change in emissions in 2014 as compared to the base year 1990. HFCs increased by 6'056'832% when compared to 1990 levels (1990 = 0.025 kt CO₂ equivalent).

Greenhouse Gas Emissions	1990	1995	2000
	CO ₂ equivalent (kt)		
CO ₂ emissions including net CO ₂ from LULUCF	43'122	39'535	48'368
CO ₂ emissions excluding net CO ₂ from LULUCF	44'116	43'368	43'546
CH ₄ emissions including CH ₄ from LULUCF	6'116	5'796	5'404
CH ₄ emissions excluding CH ₄ from LULUCF	6'091	5'780	5'392
N ₂ O emissions including N ₂ O from LULUCF	2'939	2'781	2'632
N ₂ O emissions excluding N ₂ O from LULUCF	2'854	2'702	2'556
HFCs	0	246	626
PFCs	117	17	50
SF ₆	137	93	144
NF ₃	0	0	0
Total (including LULUCF)	52'430	48'469	57'223
Total (excluding LULUCF)	53'314	52'207	52'314

Greenhouse Gas Emissions	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Change baseyear to 2014 (%)
	CO ₂ equivalent (kt)										
CO ₂ emissions including net CO ₂ from LULUCF	43'342	44'997	42'173	42'716	40'957	42'849	39'201	40'160	41'284	38'236	-11.3%
CO ₂ emissions excluding net CO ₂ from LULUCF	45'778	45'351	43'360	44'677	43'509	45'027	40'973	42'242	43'182	39'265	-11.0%
CH ₄ emissions including CH ₄ from LULUCF	5'317	5'332	5'313	5'389	5'305	5'285	5'221	5'178	5'108	5'108	-16.5%
CH ₄ emissions excluding CH ₄ from LULUCF	5'306	5'320	5'299	5'378	5'294	5'274	5'208	5'167	5'097	5'097	-16.3%
N ₂ O emissions including N ₂ O from LULUCF	2'525	2'527	2'551	2'571	2'534	2'582	2'531	2'517	2'481	2'508	-14.7%
N ₂ O emissions excluding N ₂ O from LULUCF	2'450	2'449	2'474	2'498	2'463	2'512	2'460	2'448	2'412	2'439	-14.5%
HFCs	1'071	1'118	1'194	1'243	1'253	1'329	1'410	1'489	1'513	1'501	see caption
PFCs	44	52	49	58	63	65	68	71	52	44	-62.3%
SF ₆	203	186	172	222	180	148	160	209	252	259	88.9%
NF ₃	0	0	0	0	5	8	6	0.4	0.1	0.4	-
Total (including LULUCF)	52'503	54'211	51'451	52'199	50'297	52'266	48'597	49'625	50'691	47'656	-9.1%
Total (excluding LULUCF)	54'852	54'475	52'548	54'076	52'767	54'363	50'285	51'626	52'508	48'605	-8.8%

With regard to the distribution of emissions by individual greenhouse gases, CO₂ is the largest single contributor to emissions, accounting for about 80% of total gross GHG emissions (excluding LULUCF). The shares of CH₄ and N₂O are about 10% and 5%, respectively. The shares of the three gases show slightly decreasing trends in the period 1990–2014, whereas F-gases, which contributed with only 0.5% in 1990, increased to reach almost 4% in 2014 (Table E- 2).

Table E- 2 Switzerland's total gross GHG emissions (excluding LULUCF) and the contribution of individual gases in CO₂ equivalent (kt), selected years.

Greenhouse Gas Emissions (excluding LULUCF)	1990		1995		2000		2005		2010	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
CO ₂	44'116	82.7%	43'368	83.1%	43'546	83.2%	45'778	83.5%	45'027	82.8%
CH ₄	6'091	11.4%	5'780	11.1%	5'392	10.3%	5'306	9.7%	5'274	9.7%
N ₂ O	2'854	5.4%	2'702	5.2%	2'556	4.9%	2'450	4.5%	2'512	4.6%
HFCs	0	0.0%	246	0.5%	626	1.2%	1'071	2.0%	1'329	2.4%
PFCs	117	0.2%	17	0.0%	50	0.1%	44	0.1%	65	0.1%
SF ₆	137	0.3%	93	0.2%	144	0.3%	203	0.4%	148	0.3%
NF ₃	0	0.0%	0	0.0%	0	0.0%	0	0.0%	8	0.0%
Total (excluding LULUCF)	53'314	100%	52'207	100%	52'314	100%	54'852	100%	54'363	100%

Greenhouse Gas Emissions (excluding LULUCF)	2011		2012		2013		2014	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
CO ₂	40'973	81.5%	42'242	81.8%	43'182	82.2%	39'265	80.8%
CH ₄	5'208	10.4%	5'167	10.0%	5'097	9.7%	5'097	10.5%
N ₂ O	2'460	4.9%	2'448	4.7%	2'412	4.6%	2'439	5.0%
HFCs	1'410	2.8%	1'489	2.9%	1'513	2.9%	1'501	3.1%
PFCs	68	0.1%	71	0.1%	52	0.1%	44	0.1%
SF ₆	160	0.3%	209	0.4%	252	0.5%	259	0.5%
NF ₃	6	0.0%	0	0.0%	0	0.0%	0	0.0%
Total (excluding LULUCF)	50'285	100%	51'626	100%	52'508	100%	48'605	100%

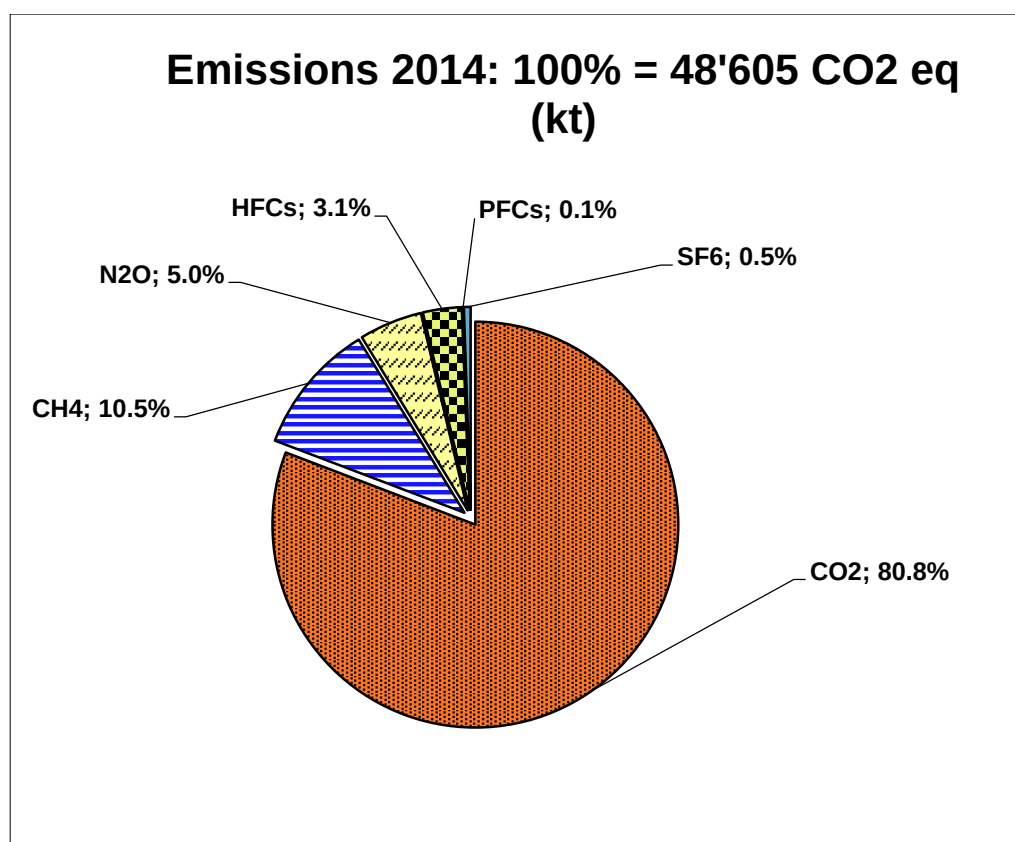


Figure E- 1 Contribution of individual gases to Switzerland's GHG emissions (excluding LULUCF) in 2014. 100% = 48'605 kt CO₂ eq. (Numbers may not add to total due to rounding.)

Uncertainty Analyses

Uncertainties were assessed with Approach 1 and 2 for Switzerland's GHG inventory including and excluding LULUCF categories for the years 1990 and 2014 (level) and for the period 1990–2014 (trend). The uncertainty results for Approach 2 are displayed in Table E-3. When excluding LULUCF, Approach 2 level uncertainty amounts to 3.58% and trend uncertainty to 2.61%. Due to high uncertainties in sector 4 LULUCF, overall uncertainties are generally higher for the analyses including LULUCF categories (level: 4.52%, trend: 4.09%).

Table E- 3 Switzerland's relative uncertainties for national total GHG emission excluding and including the LULUCF sector – Approach 2: Level uncertainties 2014 and trend uncertainties 1990–2014.

Approach 2 Uncertainty Analysis		
Inventory	Level uncertainty	Trend uncertainty
	2014	1990-2014
excl. LULUCF	3.58%	2.61%
incl. LULUCF	4.52%	4.09%

Recalculations

In order to facilitate the review of the inventory, all recalculations made since the last inventory review in 2014 are summarized in the NIR on hand and grouped according to the corresponding submission year. Recalculations made until April 2015 have already been documented in the NIR submission of April 2015. However, due to substantial technical problems with the reporting software, it was impossible to generate the corresponding reporting tables (CRF) at the time. The preparation of the reporting tables (CRF) over the past months revealed several issues that have been addressed in the meantime, but were not described in the NIR 2015. For the current submission, reporting tables (CRF) and NIR are consistent.

For the latest recalculated year, 2012, the total national emissions (excluding LULUCF) increased from 51'493 kt CO₂ eq (Subm. 2014) to 51'623 kt CO₂ eq (Subm. 2015) and up to 51'626 kt CO₂ eq (Subm. 2016). See detailed explanations of the recalculations in the sectoral chapters and the summary in chp. 10.

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 total contribution of these activities is shown in Table E- 4 and corresponds with values of the KP-reporting tables. All activities include emissions and removals of all GHG from HWP, biomass burning, drainage and N-mineralization, where appropriate (see chp. 11.3). The final proof-reading revealed a few errors in the reporting tables with a small impact on total emissions and removals. They are described in chp. 11.1.5 and will be corrected in the next submission.

Table E- 4 Emissions (positive sign) and removals (negative sign) of activities accounted for under Article 3, paragraph 3 and paragraph 4 (Forest management) of the Kyoto Protocol, kt CO₂ eq., 1999–2014. All activities include emissions and removals from HWP, biomass burning, drainage and N mineralization, where appropriate.

Greenhouse gas source and sink activities	1999	2000	2001	2002	2003	2004	2005	2006
	Net CO ₂ equivalent emissions/removals (kt CO ₂ eq)							
A. Article 3.3 activities (incl. HWP, N ₂ O)	105.17	110.70	106.92	105.69	107.93	106.92	94.85	82.46
B. Article 3.4 FM (incl. HWP, CH ₄ , N ₂ O)	-3241.67	4451.74	-1848.13	-3224.34	-3117.10	-3003.30	-3177.05	-1528.84
Greenhouse gas source and sink activities	2007	2008	2009	2010	2011	2012	2013	2014
	Net CO ₂ equivalent emissions/removals (kt CO ₂ eq)							
A. Article 3.3 activities (incl. HWP, N ₂ O)	67.19	96.54	48.14	108.44	111.56	112.07	111.75	116.64
B. Article 3.4 FM (incl. HWP, CH ₄ , N ₂ O)	-1372.49	-2459.63	-3258.46	-3322.59	-1969.79	-3231.24	-3227.38	-1843.58

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 shows the GHG emissions and removals by the main source and sink categories. Sector 1 Energy clearly dominates national emissions, accounting for more than three quarters of the total GHG emissions (excluding LULUCF), as shown in Table E- 6. Sectors 2 Industrial processes and product use and 3 Agriculture contribute a considerable share of GHG emissions as well, while sectors 5 Waste and 6 Other are of minor importance. LULUCF categories from sector 4 are an emission sink.

Overall, Switzerland's GHG emissions decreased in 2014 compared to 1990. This effect is mainly driven by decreases in the sectors Energy and Agriculture, which exceed the increase in the sector Industrial processes and product use.

Table E- 5 Switzerland's GHG emissions and removals by source and sink categories in CO₂ equivalent (kt), 1990–2014.

Greenhouse Gas Source and Sink Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CO ₂ equivalent (kt)									
1. Energy	41'837	44'271	44'259	42'075	40'953	41'862	42'761	41'782	43'324	43'123
2. Industrial processes and product use	3'521	3'157	2'997	2'691	2'881	2'873	2'749	2'667	2'782	2'846
3. Agriculture	6'804	6'766	6'649	6'545	6'529	6'503	6'460	6'275	6'231	6'137
5. Waste	1'139	1'054	1'057	1'009	952	955	951	942	928	917
6. Other	12	12	13	13	13	13	13	14	14	14
Total (excluding LULUCF)	53'314	55'259	54'975	52'332	51'328	52'207	52'935	51'678	53'279	53'037
4. Land use, land-use change and forestry	-884	-4'049	-3'781	-4'042	-2'220	-3'738	-5'207	-3'435	-2'124	-1'965
Total (including LULUCF)	52'430	51'211	51'194	48'290	49'108	48'469	47'728	48'243	51'155	51'071

Greenhouse Gas Source and Sink Categories	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CO ₂ equivalent (kt)									
1. Energy	42'139	43'549	41'933	43'157	43'501	43'996	43'602	41'567	42'926	41'819
2. Industrial processes and product use	3'099	3'199	3'237	3'328	3'621	3'776	3'757	3'823	3'902	3'797
3. Agriculture	6'123	6'187	6'153	6'077	6'056	6'098	6'133	6'191	6'298	6'219
5. Waste	939	954	977	957	976	968	968	952	936	917
6. Other	14	14	14	14	14	14	14	14	14	14
Total (excluding LULUCF)	52'314	53'903	52'315	53'533	54'168	54'852	54'475	52'548	54'076	52'767
4. Land use, land-use change and forestry	4'910	-624	-2'344	-1'977	-2'745	-2'349	-263	-1'096	-1'877	-2'470
Total (including LULUCF)	57'223	53'278	49'971	51'556	51'423	52'503	54'211	51'451	52'199	50'297

Greenhouse Gas Source and Sink Categories	2010	2011	2012	2013	2014	2014 vs. 1990
	CO ₂ equivalent (kt)					%
1. Energy	43'191	39'147	40'539	41'473	37'467	-10.4%
2. Industrial processes and product use	4'011	4'046	4'050	4'074	4'091	16.2%
3. Agriculture	6'241	6'185	6'152	6'083	6'174	-9.3%
5. Waste	906	893	871	864	860	-24.6%
6. Other	14	14	14	14	14	16.1%
Total (excluding LULUCF)	54'363	50'285	51'626	52'508	48'605	-8.8%
4. Land use, land-use change and forestry	-2'097	-1'688	-2'001	-1'817	-949	7.4%
Total (including LULUCF)	52'266	48'597	49'625	50'691	47'656	-9.1%

It becomes apparent in Figure E- 2 that the GHG emission trend in the period 1990–2014 is subject to fluctuations but with a decreasing trend starting in 2005. The fluctuations emerge from the year-to-year variability of the energy sector emissions caused by changing winter temperatures. In addition, since 2005 a growing decoupling of fuel combustion emissions and winter temperature conditions is visible. That is, the emission reductions are not only caused by weather conditions, but are also the result of emission reduction measures.

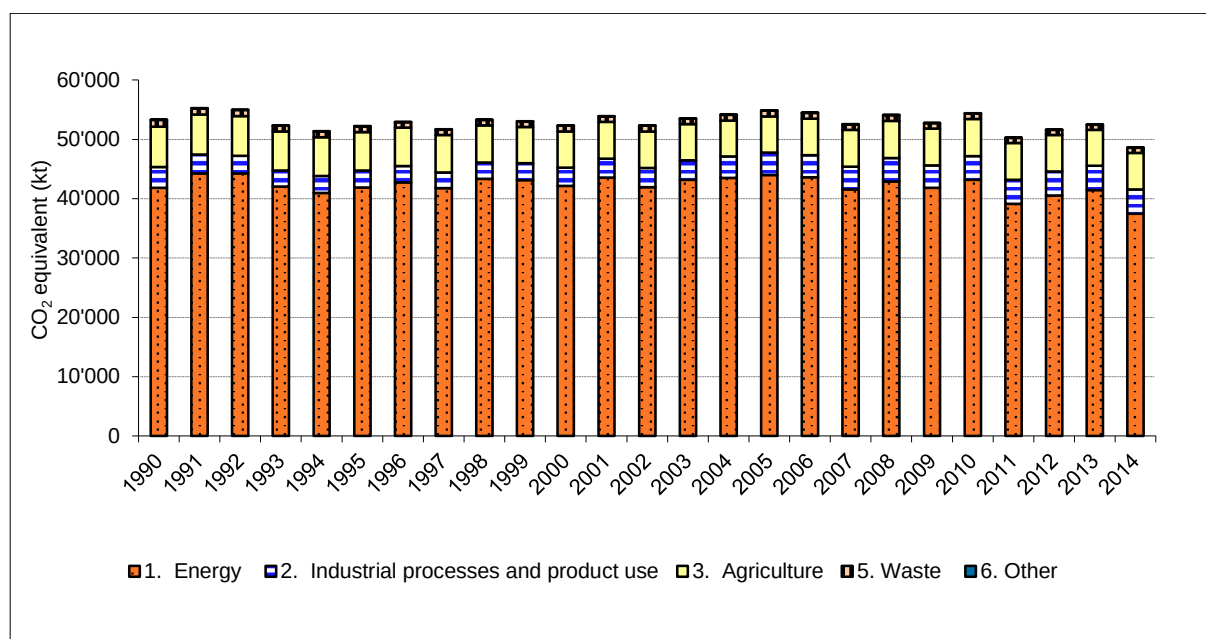


Figure E- 2 Switzerland's greenhouse gas emissions in CO₂ equivalent (kt) by main source categories, 1990–2014 (excluding LULUCF).

Table E- 6 gives a more detailed impression of individual sectors' contributions to total emissions for selected years (excluding LULUCF). In general, the relative contributions of the different sectors have been rather stable between 1990 and 2014. When comparing the contributions in 2014 to 1990, the following development can be observed:

- Smaller relative contributions in sectors 1 Energy, 3 Agriculture and 5 Waste.
- Larger relative contributions in sector 2 Industrial processes and product use.
- Almost equal relative contribution in sector 6 Other.

In 2014, the sector 4 LULUCF acted as a sink comprising ca. 2% of the total emissions (including LULUCF). This contribution is slightly larger in comparison to 1990.

Table E- 6 Switzerland's total gross GHG emissions (excluding LULUCF) in CO₂ equivalent (kt) and the contribution of individual source categories, selected years.

Source and Sink Categories	1990		1995		2000		2005		2010	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
1. Energy	41'837	78.5%	41'862	80.2%	42'139	80.6%	43'996	80.2%	43'191	79.4%
1A1 Energy industries	2'521	4.7%	2'632	5.0%	3'149	6.0%	3'817	7.0%	3'847	7.1%
1A2 Manufacturing industries and construction	6'457	12.1%	6'210	11.9%	5'932	11.3%	6'003	10.9%	5'829	10.7%
1A3 Transport	14'660	27.5%	14'263	27.3%	15'924	30.4%	15'851	28.9%	16'323	30.0%
1A4 Other sectors	17'632	33.1%	18'170	34.8%	16'631	31.8%	17'879	32.6%	16'777	30.9%
1A5 Other	220	0.4%	163	0.3%	151	0.3%	139	0.3%	138	0.3%
1B Fugitive emissions from fuels	346	0.6%	424	0.8%	352	0.7%	309	0.6%	277	0.5%
2. Industrial processes and product use	3'521	6.6%	2'873	5.5%	3'099	5.9%	3'776	6.9%	4'011	7.4%
3. Agriculture	6'804	12.8%	6'503	12.5%	6'123	11.7%	6'098	11.1%	6'241	11.5%
5. Waste	1'139	2.1%	955	1.8%	939	1.8%	968	1.8%	906	1.7%
6. Other	12	0.0%	13	0.0%	14	0.0%	14	0.0%	14	0.0%
Total (excluding LULUCF)	53'314	100.0%	52'207	100.0%	52'314	100.0%	54'852	100.0%	54'363	100.0%

Source and Sink Categories	2011		2012		2013		2014	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
1. Energy	39'147	77.8%	40'539	78.5%	41'473	79.0%	37'467	77.1%
1A1 Energy industries	3'600	7.2%	3'643	7.1%	3'739	7.1%	3'602	7.4%
1A2 Manufacturing industries and construction	5'389	10.7%	5'397	10.5%	5'498	10.5%	5'117	10.5%
1A3 Transport	16'142	32.1%	16'259	31.5%	16'169	30.8%	16'062	33.0%
1A4 Other sectors	13'610	27.1%	14'850	28.8%	15'698	29.9%	12'317	25.3%
1A5 Other	125	0.2%	133	0.3%	134	0.3%	139	0.3%
1B Fugitive emissions from fuels	281	0.6%	258	0.5%	235	0.4%	230	0.5%
2. Industrial processes and product use	4'046	8.0%	4'050	7.8%	4'074	7.8%	4'091	8.4%
3. Agriculture	6'185	12.3%	6'152	11.9%	6'083	11.6%	6'174	12.7%
5. Waste	893	1.8%	871	1.7%	864	1.6%	860	1.8%
6. Other	14	0.0%	14	0.0%	14	0.0%	14	0.0%
Total (excluding LULUCF)	50'285	100.0%	51'626	100.0%	52'508	100.0%	48'605	100.0%

ES.3.2 KP-LULUCF activities

An overview of net CO₂ 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 and in Figure E- 3.

Detailed quantitative information of the years 1999–2014 is reported in chp. 11.4, chp. 11.5, and displayed in Table 11-4. From this submission on, emissions and removals in the forest sector are no longer averaged over three years; instead annual values are reported. Annual changes in the emissions from Afforestation and Deforestation can directly be attributed to the changes in the area of Deforestations. 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. The extraordinary high losses in 2000 are the result of the storm Lothar, which caused large-scale damaged in Swiss forests in December 1999. Fluctuations in the HWP pool can mainly be attributed to changes in the production of sawn wood (see chp. 6.11), which is strongly linked to 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 Harvested wood products HWP) of the Kyoto Protocol, kt CO₂ eq., 1999–2014. C_{HWP}: carbon in HWP.

Greenhouse gas source and sink activities	1999	2000	2001	2002	2003	2004	2005	2006
Net CO ₂ equivalent emissions/removals (kt CO ₂ eq)								
A. Article 3.3 activities	105.17	110.70	106.92	105.69	107.93	106.92	94.85	82.46
A.1. Afforestation and Reforestation incl. N ₂ O	-15.12	-15.72	-16.32	-16.92	-17.53	-18.13	-18.82	-19.62
A.2. Deforestation incl. HWP, N ₂ O	120.29	126.42	123.24	122.62	125.45	125.05	113.67	102.08
B. Article 3.4 activities	-3241.67	4451.74	-1848.13	-3224.34	-3117.10	-3003.30	-3177.05	-1528.84
B.1. Forest management incl. HWP, CH ₄ , N ₂ O	-3241.67	4451.74	-1848.13	-3224.34	-3117.10	-3003.30	-3177.05	-1528.84
gainC _{I_ag}	-9740.42	-9747.46	-9754.49	-9761.52	-9768.56	-9775.59	-9785.49	-10049.09
gainC _{I_bg}	-2765.70	-2768.32	-2770.94	-2773.56	-2776.19	-2778.81	-2782.44	-2871.67
lossC _{I_ag}	7815.64	14015.30	8997.61	7417.71	8215.44	8209.85	8488.19	9288.21
lossC _{I_bg}	2290.41	3907.48	2606.83	2191.89	2419.70	2393.00	2462.10	2666.49
changeC _h	-142.32	37.43	-171.30	216.95	-519.10	-237.07	-553.98	382.60
changeC _d	-258.02	-196.76	-216.36	-118.56	-295.48	-214.39	-278.15	-356.45
changeC _{s_m}	-3.39	-3.53	-3.69	-3.76	-3.90	-4.60	-5.04	-5.20
changeC _{s_o}	36.40	36.43	36.46	36.50	36.53	36.56	36.61	36.66
CH ₄ & N ₂ O from biom. burning	0.23	0.98	0.27	8.53	10.89	0.51	0.81	2.30
N ₂ O from drainage	5.01	5.01	5.02	5.02	5.02	5.03	5.03	5.04
HWP: changeC _{HWP}	-479.50	-834.82	-577.53	-443.52	-441.45	-637.80	-764.70	-627.73

Greenhouse gas source and sink activities	2007	2008	2009	2010	2011	2012	2013	2014
Net CO ₂ equivalent emissions/removals (kt CO ₂ eq)								
A. Article 3.3 activities	67.19	96.54	48.14	108.44	111.56	112.07	111.75	116.64
A.1. Afforestation and Reforestation incl. N ₂ O	-20.35	-20.99	-21.56	-20.40	-18.81	-18.48	-17.65	-15.61
A.2. Deforestation incl. HWP, N ₂ O	87.54	117.53	69.70	128.85	130.37	130.55	129.40	132.25
B. Article 3.4 activities	-1372.49	-2459.63	-3258.46	-3322.59	-1969.79	-3231.24	-3227.38	-1843.58
B.1. Forest management incl. HWP, CH ₄ , N ₂ O	-1372.49	-2459.63	-3258.46	-3322.59	-1969.79	-3231.24	-3227.38	-1843.58
gainC _{I_ag}	-10075.05	-10088.18	-10098.30	-10101.28	-10104.09	-10106.92	-10110.27	-10113.74
gainC _{I_bg}	-2880.00	-2884.67	-2888.40	-2889.97	-2891.45	-2892.94	-2894.58	-2896.27
lossC _{I_ag}	9227.26	8574.61	8015.01	8428.31	8371.77	7713.73	7955.38	8170.06
lossC _{I_bg}	2670.95	2503.81	2357.23	2492.75	2475.75	2287.08	2363.98	2427.43
changeC _h	601.02	205.83	6.76	-468.46	546.50	113.60	-151.73	654.82
changeC _d	-225.93	-286.40	-311.97	-410.79	-151.55	-216.12	-267.48	-18.44
changeC _{s_m}	-4.74	-4.29	-4.27	-4.63	-4.85	-4.46	-4.56	-4.42
changeC _{s_o}	36.71	36.70	36.74	36.74	36.75	36.76	36.77	36.79
CH ₄ & N ₂ O from biom. burning	4.86	0.77	1.00	0.53	3.46	0.48	0.50	0.89
N ₂ O from drainage	5.05	5.05	5.05	5.05	5.05	5.06	5.06	5.06
HWP: changeC _{HWP}	-732.61	-522.86	-377.32	-410.86	-257.14	-167.51	-160.46	-105.76

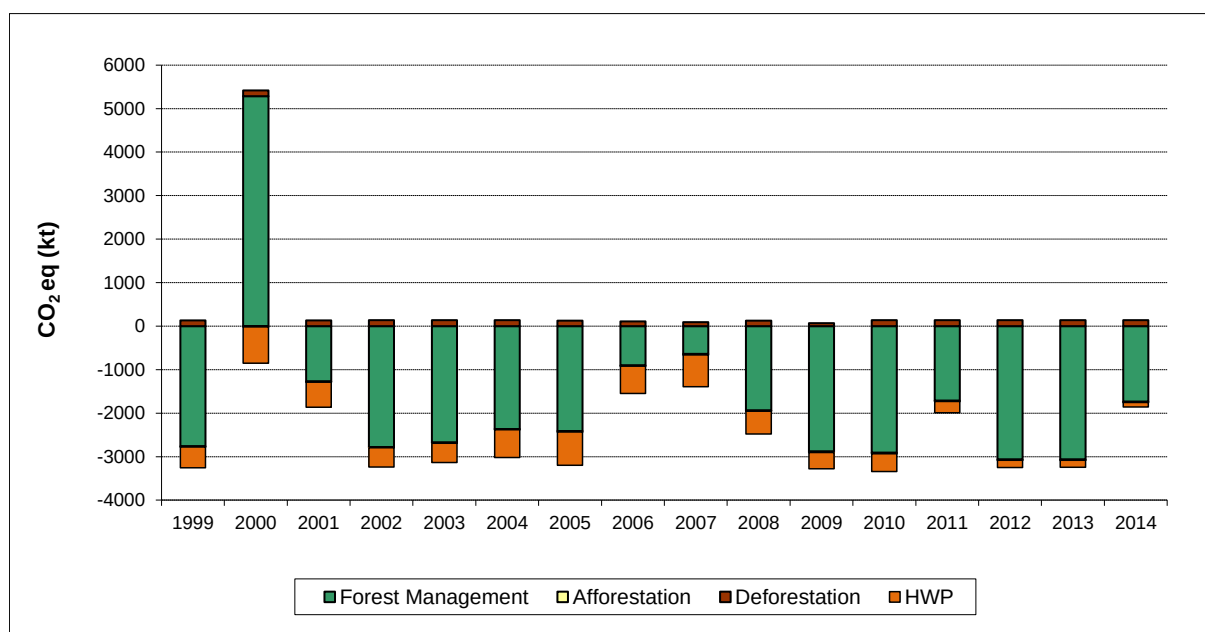


Figure E- 3 CO₂ eq emissions (positive sign) and removals (negative sign) from Afforestation (too small to be distinguishable) and Deforestation under Article 3, paragraph 3 and Forest management and HWP under Article 3, paragraph 4, 1999–2014. Data in the forest sector were no longer averaged over three years; instead annual values are reported. The reason for the positive value in 2000 (and the small removal in 2001) is the winter storm “Lothar” in December 1999, which caused great damages in the forest stands and increased harvesting.

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 GHG respectively. The reported total emissions differ from those reported under the UNFCCC, because sector 6 Other as well as LULUCF and international bunkers are 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) and the indirect CO₂ emissions 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 for calculating the cap on activities under Art. 3.4 (see decision 2/CMP.7, paragraph 13), will be reported in the Second Initial Report (FOEN 2016c).

Table E- 8 Summary of Switzerland's GHG emissions in CO₂ equivalent (kt), 1990–2014 excluding emissions from sectors LULUCF, Other and International bunkers.

Annex A sources	Sector	Base year initial report	1990	1991	1992	1993	1994	1995	1996	1997	1998
		CO ₂ equivalent (kt)									
Annex A sources	1 Energy + indirect CO ₂ from this sector	41'881	41'881	44'316	44'304	42'115	40'982	41'890	42'789	41'808	43'347
	2 Industrial processes and product use + indirect CO ₂ from this sector	3'893	3'893	3'499	3'312	2'975	3'147	3'118	2'974	2'874	2'972
	3 Agriculture	6'804	6'804	6'766	6'649	6'545	6'529	6'503	6'460	6'275	6'231
	5 Waste + indirect CO ₂ from this sector	1'142	1'142	1'056	1'059	1'011	954	957	952	943	930
	Total (Annex A sources)	53'719	53'719	55'637	55'324	52'646	51'612	52'468	53'175	51'900	53'480

Annex A sources	Sector	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
		CO ₂ equivalent (kt)									
Annex A sources	1 Energy + indirect CO ₂ from this sector	43'140	42'156	43'566	41'948	43'172	43'515	44'009	43'615	41'579	42'939
	2 Industrial processes and product use + indirect CO ₂ from this sector	3'026	3'269	3'359	3'384	3'463	3'743	3'892	3'870	3'932	4'012
	3 Agriculture	6'137	6'123	6'187	6'153	6'077	6'056	6'098	6'133	6'191	6'298
	5 Waste + indirect CO ₂ from this sector	918	940	955	979	958	977	969	969	954	937
	Total (Annex A sources)	53'222	52'488	54'067	52'465	53'670	54'291	54'969	54'588	52'657	54'186

KP-LULUCF	Art. 3.3	Sector	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO ₂ equivalent (kt)									
KP-LULUCF	Art. 3.3	Afforestation & reforestation										-21
		Deforestation										118
	Art. 3.4	Forest management excl. HWP										-1'937
		Cropland management										NA
		Grazing land management										NA
		Revegetation										NA
		Harvested wood products (HWP)										-523

Annex A sources	Sector	2009	2010	2011	2012	2013	2014	2014 vs. 1990
		CO ₂ equivalent (kt)						%
Annex A sources	1 Energy + indirect CO ₂ from this sector	41'831	43'202	39'158	40'548	41'484	37'478	-11%
	2 Industrial processes and product use + indirect CO ₂ from this sector	3'907	4'122	4'157	4'160	4'182	4'198	8%
	3 Agriculture	6'219	6'241	6'185	6'152	6'083	6'174	-9%
	5 Waste + indirect CO ₂ from this sector	919	908	894	872	865	861	-25%
	Total (Annex A sources)	52'876	54'472	50'394	51'733	52'614	48'711	-9%

KP-LULUCF	Art. 3.3	Sector	2009	2010	2011	2012	2013	2014
			CO ₂ equivalent (kt)					
KP-LULUCF	Art. 3.3	Afforestation & reforestation	-22	-20	-19	-18	-18	-16
		Deforestation	70	129	130	131	129	132
	Art. 3.4	Forest management excl. HWP	-2'881	-2'912	-1'713	-3'064	-3'067	-1'738
		Cropland management	NA	NA	NA	NA	NA	NA
		Grazing land management	NA	NA	NA	NA	NA	NA
		Revegetation	NA	NA	NA	NA	NA	NA
		Harvested wood products (HWP)	-377	-411	-257	-168	-160	-106

Table E- 9 Switzerland's total GHG emissions (excluding LULUCF, Other and International bunkers) and the contribution of individual gases in CO₂ equivalent (kt), 1990–2014.

Annex A sources	GHG	Base year initial report	1990	1991	1992	1993	1994	1995	1996	1997	1998
		CO ₂ equivalent (kt)									
	CO ₂ + indirect CO ₂	44'521	44'521	46'524	46'325	43'871	42'898	43'631	44'330	43'194	44'724
	CH ₄	6'091	6'091	6'028	5'947	5'839	5'788	5'780	5'740	5'597	5'527
	N ₂ O	2'853	2'853	2'846	2'814	2'747	2'716	2'701	2'697	2'601	2'596
	HFCs	0	0	2	16	33	82	246	298	362	457
	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	0.0	0.0	0.0	0.0	0.0
	Total (Annex A sources)	53'719	53'719	55'637	55'324	52'646	51'612	52'468	53'175	51'900	53'480

Annex A sources	GHG	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
		CO ₂ equivalent (kt)									
	CO ₂ + indirect CO ₂	44'542	43'722	45'168	43'525	44'726	45'273	45'896	45'466	43'471	44'788
	CH ₄	5'425	5'392	5'432	5'398	5'320	5'288	5'305	5'319	5'298	5'377
	N ₂ O	2'560	2'555	2'571	2'547	2'499	2'458	2'449	2'448	2'473	2'497
	HFCs	530	626	724	803	898	1'021	1'071	1'118	1'194	1'243
	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	0.0	0.0	0.0	0.0	0.1
	Total (Annex A sources)	53'222	52'488	54'067	52'465	53'670	54'291	54'969	54'588	52'657	54'186

KP-LULUCF	GHG	2009	2010	2011	2012	2013	2014	2014 vs.1990
		CO ₂ equivalent (kt)						%
Annex A sources	CO ₂ + indirect CO ₂	43'619	45'138	41'083	42'350	43'289	39'372	-12%
	CH ₄	5'293	5'273	5'208	5'166	5'096	5'096	-16%
	N ₂ O	2'462	2'511	2'460	2'447	2'411	2'438	-15%
	HFCs	1'253	1'329	1'410	1'489	1'513	1'501	NA
	PFCs	63	65	68	71	52	44	-62%
	SF ₆	180	148	160	209	252	259	89%
	NF ₃	5.1	8.5	6.2	0.4	0.1	0.4	NA
	Total (Annex A sources)	52'876	54'472	50'394	51'733	52'614	48'711	-9%
KP-LULUCF	CO ₂	46	106	109	110	110	115	
	CH ₄	0	0	0	0	0	0	
	N ₂ O	2.2	2.1	2.1	2.1	2.1	2.1	
	CO ₂	-3'265	-3'328	-1'978	-3'237	-3'233	-1'850	
	CH ₄	1.0	0.5	3.5	0.5	0.5	0.9	
	N ₂ O	5.1	5.1	5.1	5.1	5.1	5.1	

ES.4. Other information

Emission trends for precursor gases show a very pronounced decline (see Table 2-6 and Figure 2-9). A strict air pollution control policy led to strong decreases of slightly over 50% (NO_x) up to 80% (SO₂) in the period 1990–2014 in emissions of precursor gases and SO₂. 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 the Environment 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 compared to the period 1980–2009 (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 km² of Alpine glacier area in the mid-1970s, only 2'100 km² remained in 2003 and an estimated 1'900 km² 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 (CH2011 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 temperatures 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. Switzerland has recently 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 several times with the latest audit on 18th November 2015 (ISO 9001:2008, Swiss-TS 2013). The quality management system includes the accounting and reporting of the National Registry as well. 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.

On 28 August 2015, Switzerland submitted its instrument of acceptance of the Doha amendment to the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The Initial Report for the second commitment period (FOEN 2016c) is submitted simultaneously with the current inventory 2016.

The 2015 inventory submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol was 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 could not be completed in 2015 due to the problems with the UN software (CRF Reporter). The first

1 Introduction: 1.1 Background information on Swiss greenhouse gas inventories, climate change and supplementary information of the Kyoto Protocol (KP)

part of the submission included the NIR submitted on 27 April 2015 and the SEF tables (CP2 on 27 April 2015, CP1 on 27 May 2015). The second part consisting of the reporting tables (CRF tables and Kyoto Protocol LULUCF tables) is submitted in April 2016.

The 2016 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 to 2014, the Kyoto Protocol LULUCF tables 2008 to 2014 in the common reporting format and the SEF tables as well as the standard independent assessment report (SIAR) from the National Registry.

1.1.3 Supplementary information required under art. 7.1. KP

Information on KP-LULUCF is provided in chp. 11 of PART 2.

Switzerland only accounts for the mandatory activity Forest management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2016c). 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 2016c). In addition to the mandatory submission of the inventory years 2013 and 2014, 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.

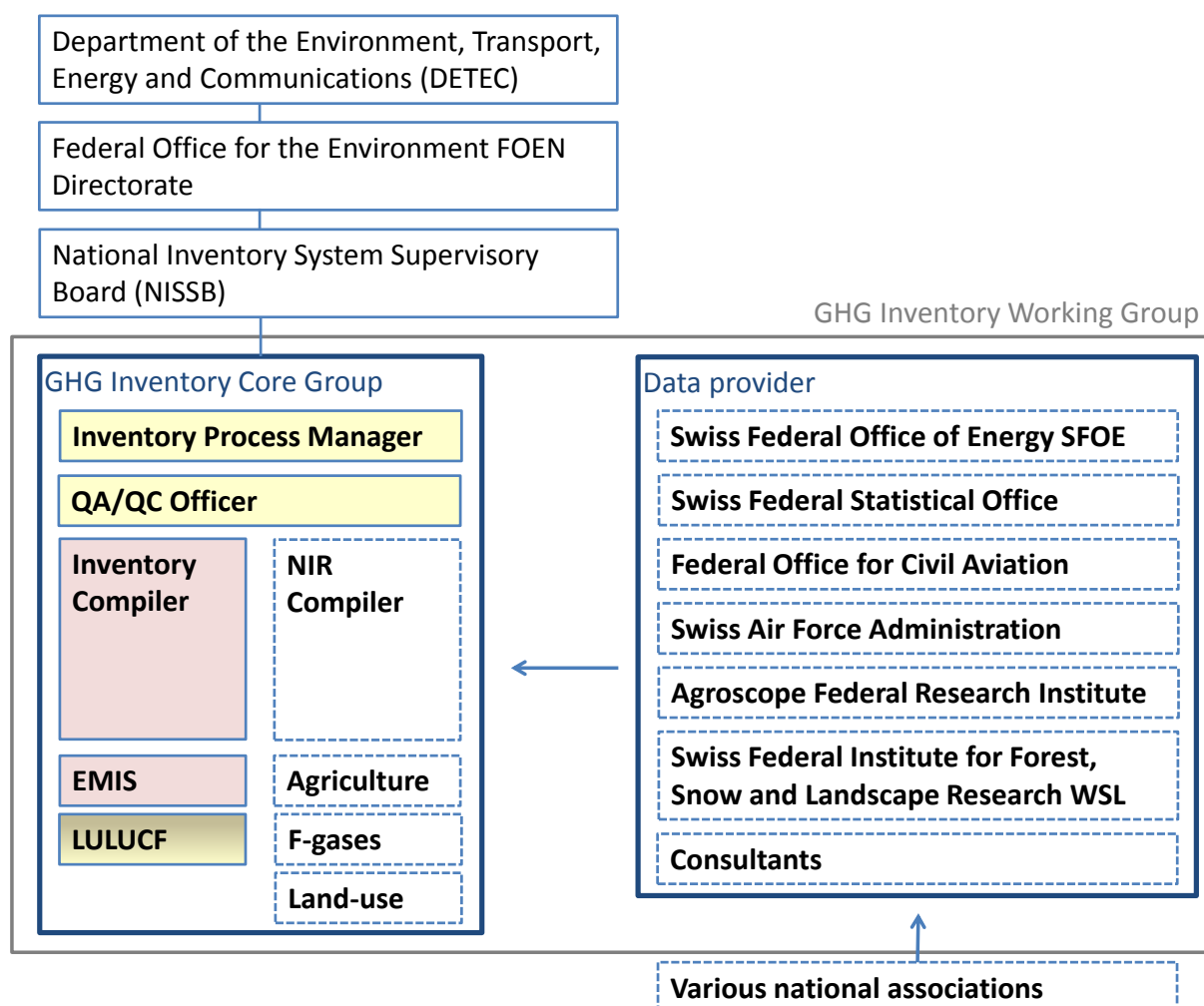


Figure 1-1 Institutional arrangements of the National Inventory System. Colours refer to divisions at FOEN. yellow: Climate division, red: Air Pollution Control and Chemicals division, beige: Forest division.

Legal arrangements

The CO₂ act (Swiss Confederation 2011) and the CO₂ 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 gases 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 (until 30 June 2016)

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Table 1-1 Overview of the institutional arrangements

Institutions of the federal administration	
FOEN Climate division	Overall responsibility 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 (Swiss Emission Information System) 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 reporting tables (CRF) 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 performed 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, 2016a) – 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 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

has 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 reporting tables (CRF) and in the preparation of the NIR. QC procedures regarding the reporting tables (CRF) comprise a detailed comparison of the reporting tables (CRF) 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, due to the delay of the CRF Reporter, these checks were made based on database exports rather than on reporting tables (CRF). The reporting tables (CRF) were then compared to the database exports.

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.climate reporting.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 2016a), 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 (Ryttec 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 chp. 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 chp. 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 5.1.

Furthermore, a research project is developing an independent estimate of CH₄ emissions in Switzerland based on atmospheric CH₄ measurements and inverse modelling of atmospheric transport. The initial research project showed very promising results leading to a follow-up project which is currently on-going. The first results show a very good agreement between modelled emissions and emission estimates according to the greenhouse gas inventory. A summary is provided in Annex 5.2.

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, 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, 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.

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 in 2014. 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)):

As described above under institutional arrangements, editing of the NIR is partly handed over to a contractor. Two collaborators of the contractor were replaced over the past year. 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 since the 2014 submission. 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. Recurrent problems with accessibility of the CRF Reporter delayed the work of the inventory compiler significantly, so that the normal QA/QC procedures were severely hampered. There still seem to be errors in the CRF Reporter (version v5.12.5.). In Annex 6, a list of problems identified during spot checks of the reporting tables (CRF) is provided. There are instances where the data could not be entered into the appropriate cells of the reporting tables (CRF), or where the numerical output in the reporting tables (CRF) was incorrect.

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. Emissions of road and non-road transportation are provided by INFRAS, a consultancy mandated by Traffic Section of 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 by FOEN 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 reporting tables (CRF).

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 2016/(NFR-Code)” in this report.

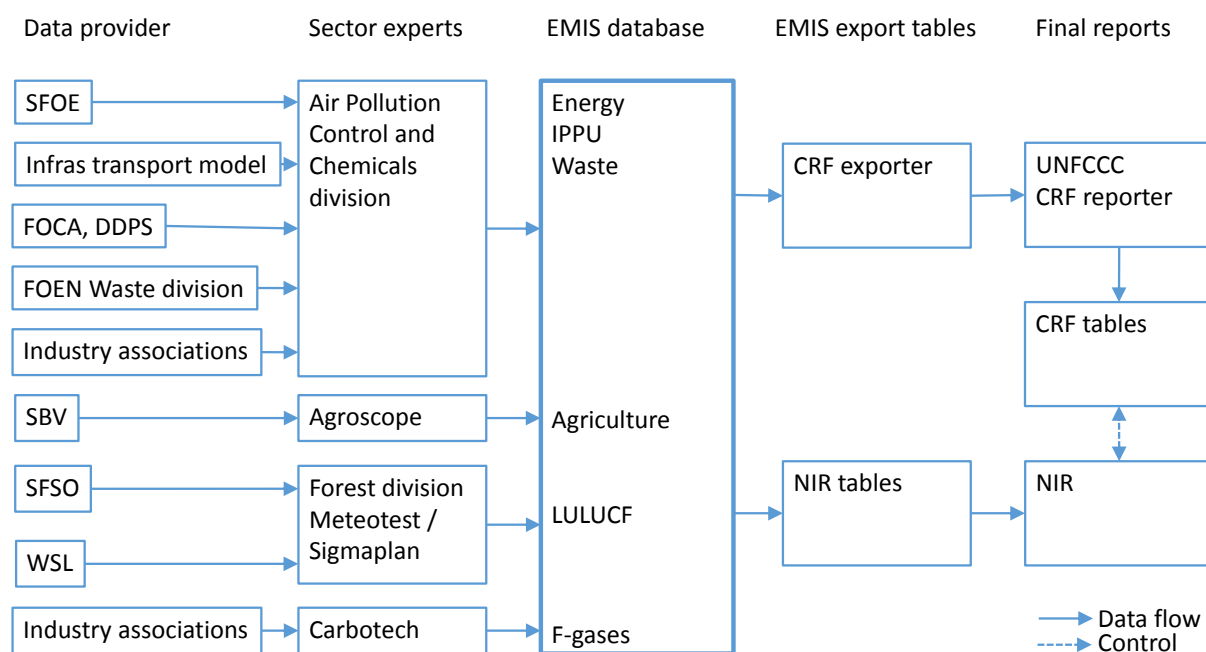


Figure 1-2 Schematic overview: Data collection and processing, compilation in EMIS database, export to CRF Reporter and National Inventory Report (NIR). Abbreviations: see glossary.

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 Infrac, 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 reporting tables)										
		1A1	1A2	1A3	1A4	1A5	1B	2	3	4 / KP	5	6
FOEN, Air Pollution Control and Chemicals division	EMIS database											
FOEN, Climate division	monitoring data due to ordinance of reduction of CO ₂ (Confederation 2012)											
FOEN, Waste division	Waste statistics											
INFRAS	Road transportation 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 SF ₆ 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, chp. 4) and Decision 24/CP.19 (UNFCCC 2014a, Annex 1, Para. 39) for 1990 and the latest reported year (2014) including all GHG (CO₂, CH₄, N₂O, HFCs, PFCs, SF₆ and NF₃). A total of 157 categories are used to disaggregate Switzerland's total GHG emissions for the purpose of this key category analysis. The disaggregation level of the categories is selected based on country-specific relevance, i.e. the most important sources in Switzerland are disaggregated on a more detailed level. Uncertainty data for key category analysis Approach 2 stems from the uncertainty analysis Approach 1 (see chp. 1.6.1.2) and therefore does not incorporate correlations.

Both, Approach 1 (with a proposed threshold of 95%) and Approach 2 (with a proposed threshold of 90%) level and trend assessments are applied, including emissions from sector 4 LULUCF. Indirect CO₂ and N₂O emissions are not considered for the key category analysis.

For the full key category analysis including all 157 categories, see Annex 1.

1.5.1.2 KCA (including LULUCF categories)

A complete overview of the key category analysis for the inventory 1990–2014, also including all categories which are not key, is given in Annex 1, Table A – 1. In the following, the results for Approach 1 and Approach 2 are presented, focussing on key categories only.

Approach 1

For 2014, among the total of 157 categories, 30 are identified as level key categories under Approach 1 (Table 1-4).

Half of the key categories belong to sector 1 Energy, accounting for the largest share of CO₂ equivalent emissions in 2014. The other key categories are more or less equally distributed between sectors 2 Industrial processes and product use, 3 Agriculture, 4 LULUCF and 5 Waste.

There are three major key sources each contributing more than 10% to the level assessment, all being part of sector 1 Energy:

- 1A3b Fuel Combustion, Road Transportation, Gasoline, CO₂
- 1A3b Fuel Combustion, Road Transportation, Diesel, CO₂
- 1A4b Fuel Combustion, Other Sectors, Residential, Liquid Fuels, CO₂

Within the ten most relevant key categories (level contribution), only 3A Enteric fermentation and 2A1 Cement production are not part of sector 1 Energy.

Table 1-4 Switzerland's Approach 1 level key categories for the year 2014 including LULUCF categories, sorted by emission contribution to the national total.

Approach 1 key category analysis - Level Assessment for the year 2014									
No.	IPCC source categories and fuels if applicable					GHG	Year 2014 estimate [Gg CO ₂ eq]	Level assessment	Cumulative total of level assessment
1	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO ₂	8276.97	15.8%	15.8%
2	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO ₂	7297.02	14.0%	29.8%
3	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO ₂	5549.06	10.6%	40.4%
4	3A	3. Agriculture	A. Enteric fermentation			CH ₄	3365.33	6.4%	46.9%
5	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO ₂	2538.93	4.9%	51.7%
6	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO ₂	2402.23	4.6%	56.3%
7	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO ₂	2318.49	4.4%	60.8%
8	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO ₂	2278.18	4.4%	65.1%
9	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO ₂	1912.91	3.7%	68.8%
10	2A1	2. Industrial processes and product use	A. Mineral industry	1. Cement production		CO ₂	1858.10	3.6%	72.4%
11	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO ₂	-1674.57	3.2%	75.6%
12	2F1	2. Industrial processes and product use	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	1398.55	2.7%	78.3%
13	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO ₂	1244.62	2.4%	80.6%
14	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N ₂ O	1111.39	2.1%	82.8%
15	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO ₂	965.17	1.8%	84.6%
16	3B	3. Agriculture	B. Manure management			CH ₄	782.15	1.5%	86.1%
17	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO ₂	521.18	1.0%	87.1%
18	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO ₂	-503.37	1.0%	88.1%
19	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N ₂ O	499.67	1.0%	89.0%
20	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO ₂	410.12	0.8%	89.8%
21	5A	5. Waste	A. Solid waste disposal			CH ₄	367.74	0.7%	90.5%
22	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO ₂	366.03	0.7%	91.2%
23	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO ₂	332.11	0.6%	91.9%
24	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO ₂	318.25	0.6%	92.5%
25	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO ₂	288.18	0.6%	93.0%
26	3B5	3. Agriculture	B. Manure management	5. Indirect N ₂ O emissions		N ₂ O	283.54	0.5%	93.6%
27	2G	2. Industrial processes and product use	G. Other product manufacture and use			SF ₆	204.26	0.4%	93.9%
28	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH ₄	196.87	0.4%	94.3%
29	4C2	4. LULUCF	C. Grassland	2. Land converted to grassland		CO ₂	183.10	0.4%	94.7%
30	5D	5. Waste	D. Wastewater treatment and discharge			CH ₄	174.59	0.3%	95.0%

For the base year 1990, 31 categories are identified as level key categories under Approach 1 (Table 1-5). The following categories are key according to level in 1990, but not in 2014:

- 1A3a Domestic aviation CO₂
- 1A5 Other, Liquid fuels, CO₂
- 2A4 Other process uses of carbonates, CO₂
- 2C3 Aluminium production, CO₂
- 4G Harvested wood products, CO₂

On the other hand, the following categories are key according to level in 2014, but not in 1990:

- 2F1 Refrigeration and air conditioning, HFC
- 2G Other product manufacture and use, SF₆
- 4C2 Land converted to grassland, CO₂
- 5D Wastewater treatment and discharge, CH₄

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 CO ₂ eq]	Cumulative total of level assessment
1	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO ₂	11334.49	20.0%
2	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO ₂	10098.96	17.8%
3	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO ₂	4259.54	7.5%
4	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO ₂	3890.57	6.9%
5	3A	3. Agriculture	A. Enteric fermentation			CH ₄	3584.87	6.3%
6	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO ₂	2632.66	4.6%
7	2A1	2. Industrial processes and product use	A. Mineral industry	1. Cement production		CO ₂	2524.45	4.4%
8	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO ₂	1491.86	2.6%
9	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO ₂	1451.63	2.6%
10	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO ₂	1274.70	2.2%
11	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N ₂ O	1239.22	2.2%
12	4G	4. LULUCF	G. Harvested wood products			CO ₂	-1231.92	2.2%
13	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO ₂	1059.63	1.9%
14	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO ₂	981.49	1.7%
15	3B	3. Agriculture	B. Manure management			CH ₄	923.97	1.6%
16	5A	5. Waste	A. Solid waste disposal			CH ₄	763.39	1.3%
17	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO ₂	687.24	1.2%
18	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N ₂ O	658.57	1.2%
19	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO ₂	-570.45	1.0%
20	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO ₂	485.09	0.9%
21	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO ₂	394.54	0.7%
22	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO ₂	-369.23	0.7%
23	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO ₂	364.91	0.6%
24	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH ₄	319.77	0.6%
25	1A3a	1. Energy	A. Fuel combustion activities	3. Transport; Domestic aviation	Kerosene	CO ₂	252.55	0.4%
26	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO ₂	243.40	0.4%
27	3B5	3. Agriculture	B. Manure management	5. Indirect N ₂ O emissions		N ₂ O	242.32	0.4%
28	1A5	1. Energy	A. Fuel combustion activities	5. Other	Liquid Fuels	CO ₂	217.65	0.4%
29	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO ₂	196.02	0.3%
30	2A4	2. Industrial processes and product use	A. Mineral industry	4. Other process uses of carbonates		CO ₂	156.11	0.3%
31	2C3	2. Industrial processes and product use	C. Metal industry	3. Aluminium production		CO ₂	139.26	0.2%

Regarding the trend assessment between the base year 1990 and the most recent year 2014, 33 categories are identified as trend key categories under Approach 1 (Table 1-6).

Table 1-6 Switzerland's Approach 1 trend key categories between 1990 and 2014 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 2014 estimate [Gg CO2 eq]	Trend assessment	Contribution to trend [%]	Cumulative total of contribution to trend	
1	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	2632.66	7297.02	0.08637	19.0%	19.0%
2	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	10098.96	5549.06	0.06395	14.1%	33.1%
3	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO2	11334.49	8276.97	0.03568	7.9%	41.0%
4	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO2	3890.57	1912.91	0.02860	6.3%	47.3%
5	2F1	2. Industrial processes and product use	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	0.02	1398.55	0.02463	5.4%	52.7%
6	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO2	4259.54	2538.93	0.02348	5.2%	57.9%
7	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	1059.63	2278.18	0.02316	5.1%	63.0%
8	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO2	-369.23	-1674.57	0.02240	4.9%	67.9%
9	4G	4. LULUCF	G. Harvested wood products			CO2	-1231.92	-105.80	0.02181	4.8%	72.7%
10	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	1451.63	2402.23	0.01907	4.2%	76.9%
11	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	1491.86	2318.49	0.01695	3.7%	80.6%
12	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	1274.70	521.18	0.01123	2.5%	83.1%
13	2A1	2. Industrial processes and product use	A. Mineral industry	1. Cement production		CO2	2524.45	1858.10	0.00769	1.7%	84.8%
14	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	981.49	1244.62	0.00621	1.4%	86.2%
15	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO2	687.24	965.17	0.00600	1.3%	87.5%
16	5A	5. Waste	A. Solid waste disposal			CH4	763.39	367.74	0.00574	1.3%	88.8%
17	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	196.02	366.03	0.00331	0.7%	89.5%
18	2C3	2. Industrial processes and product use	C. Metal industry	3. Aluminium production		CO2	139.26	0.00	0.00223	0.5%	90.0%
19	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO2	-570.45	-503.37	0.00210	0.5%	90.4%
20	3A	3. Agriculture	A. Enteric fermentation			CH4	3584.87	3365.33	0.00188	0.4%	90.8%
21	2C3	2. Industrial processes and product use	C. Metal industry	3. Aluminium production		PFC	116.46	0.00	0.00186	0.4%	91.3%
22	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N2O	136.88	19.81	0.00184	0.4%	91.7%
23	4C2	4. LULUCF	C. Grassland	2. Land converted to grassland		CO2	91.50	183.10	0.00176	0.4%	92.1%
24	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N2O	658.57	499.67	0.00174	0.4%	92.4%
25	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH4	319.77	196.87	0.00165	0.4%	92.8%
26	1A3a	1. Energy	A. Fuel combustion activities	3. Transport; Domestic aviation	Kerosene	CO2	252.55	139.83	0.00158	0.3%	93.1%
27	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CH4	116.04	19.86	0.00151	0.3%	93.5%
28	2G	2. Industrial processes and product use	G. Other product manufacture and use			SF6	137.01	204.26	0.00140	0.3%	93.8%
29	5B	5. Waste	B. Biological treatment of solid waste			CH4	35.64	107.96	0.00133	0.3%	94.1%
30	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	CH4	109.97	24.66	0.00133	0.3%	94.4%
31	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	N2O	5.61	73.08	0.00120	0.3%	94.6%
32	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO2	243.40	288.18	0.00118	0.3%	94.9%
33	3B5	3. Agriculture	B. Manure management	5. Indirect N2O emissions		N2O	242.32	283.54	0.00111	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. 26 out of 157 categories are identified as key categories for both, 1990 and 2014 (Table 1-7, Table 1-8).

The most relevant sources in 2014 contributing more than 10% to the level assessment are the following:

- 3Da Direct emissions from managed soils, N₂O
- 4C1 Grassland remaining grassland, CO₂
- 3Db Indirect emissions from managed soils, N₂O

Several categories being key categories in Approach 1 are not key anymore when assessed with Approach 2. Nevertheless, there are seven categories only being key under Approach 2 (year 2014):

- 4C1 Grassland remaining grassland, CO₂
- 5D Wastewater treatment and discharge, N₂O
- 4D1 Wetlands remaining wetlands, CO₂
- 4 III N mineralization, N₂O
- 3B1-3B4 Manure management N₂O

- 4G Harvested wood products, CO₂
- 4F2 Land converted to other land, CO₂

Table 1-7 Switzerland's Approach 2 level key categories for the year 2014 including LULUCF categories, sorted by emission contribution to the national total. Categories in grey are key under Approach 1 as well.

Key categories resulting from Approach 2 key category analysis - Level Assessment for the year 2014 (categories which are already KCs under Approach 1 are shown in grey)										
No.	IPCC source categories and fuels if applicable					GHG	Year 2014 estimate [Gg CO ₂ eq]	Combined Uncertainty	Level assessment	Cumulative total of level assessment
1	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N ₂ O	1111.39	106.3%	13.8%	13.8%
2	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO ₂	115.70	839.4%	11.3%	25.1%
3	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N ₂ O	499.67	175.5%	10.2%	35.3%
4	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO ₂	-1674.57	47.9%	9.3%	44.6%
5	3B5	3. Agriculture	B. Manure management	5. Indirect N ₂ O emissions		N ₂ O	283.54	244.5%	8.1%	52.7%
6	3A	3. Agriculture	A. Enteric fermentation			CH ₄	3365.33	18.1%	7.1%	59.8%
7	3B	3. Agriculture	B. Manure management			CH ₄	782.15	54.4%	5.0%	64.7%
8	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO ₂	2318.49	10.5%	2.8%	67.6%
9	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO ₂	-503.37	47.9%	2.6%	70.4%
10	5D	5. Waste	D. Wastewater treatment and discharge			N ₂ O	144.47	150.0%	2.5%	72.9%
11	2F1	2. Industrial processes and product use	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	1398.55	15.0%	2.4%	75.4%
12	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO ₂	318.25	50.2%	1.9%	77.2%
13	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO ₂	332.11	37.8%	1.5%	78.7%
14	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO ₂	2402.23	5.1%	1.4%	80.1%
15	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO ₂	2278.18	5.1%	1.4%	81.5%
16	5A	5. Waste	A. Solid waste disposal			CH ₄	367.74	30.0%	1.3%	82.8%
17	5D	5. Waste	D. Wastewater treatment and discharge			CH ₄	174.59	48.2%	1.0%	83.7%
18	4D1	4. LULUCF	D. Wetlands	1. Wetlands remaining wetlands		CO ₂	70.77	104.4%	0.9%	84.6%
19	4 III	4. LULUCF	N mineralization			N ₂ O	52.01	135.1%	0.8%	85.4%
20	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO ₂	7297.02	0.9%	0.8%	86.2%
21	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO ₂	1244.62	5.1%	0.7%	86.9%
22	3B1-3B4	3. Agriculture	B. Manure management	1. Cattle, 2. Sheep, 3. Swine, 4. Other livestock		N ₂ O	86.09	72.2%	0.7%	87.6%
23	4G	4. LULUCF	G. Harvested wood products			CO ₂	-105.80	57.1%	0.7%	88.3%
24	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH ₄	196.87	30.0%	0.7%	89.0%
25	4F2	4. LULUCF	F. Other land	2. Land converted to other land		CO ₂	117.35	50.2%	0.7%	89.7%
26	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO ₂	8276.97	0.7%	0.7%	90.4%

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. Categories in grey are key under Approach 1 as well.

Key categories resulting from Approach 2 key category analysis - Level Assessment for the base year 1990 (categories which are already KCs under Approach 1 are shown in grey)										
No.	IPCC source categories and fuels if applicable					GHG	Year 1990 estimate [Gg CO ₂ eq]	Combined Uncertainty	Level assessment	Cumulative total of level assessment
1	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N ₂ O	1239.22	106.3%	15.2%	15.2%
2	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N ₂ O	658.57	175.5%	13.3%	28.5%
3	4G	4. LULUCF	G. Harvested wood products			CO ₂	-1231.92	57.1%	8.1%	36.6%
4	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO ₂	79.05	839.4%	7.6%	44.2%
5	3A	3. Agriculture	A. Enteric fermentation			CH ₄	3584.87	18.1%	7.5%	51.7%
6	3B5	3. Agriculture	B. Manure management	5. Indirect N ₂ O emissions		N ₂ O	242.32	244.5%	6.8%	58.6%
7	3B	3. Agriculture	B. Manure management			CH ₄	923.97	54.4%	5.8%	64.4%
8	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO ₂	-570.45	47.9%	3.1%	67.5%
9	5A	5. Waste	A. Solid waste disposal			CH ₄	763.39	30.0%	2.6%	70.1%
10	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO ₂	394.54	50.2%	2.3%	72.4%
11	5D	5. Waste	D. Wastewater treatment and discharge			N ₂ O	118.27	150.0%	2.0%	74.5%
12	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO ₂	-369.23	47.9%	2.0%	76.5%
13	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO ₂	1491.86	10.5%	1.8%	78.3%
14	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO ₂	364.91	37.8%	1.6%	79.9%
15	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH ₄	319.77	30.0%	1.1%	81.0%
16	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO ₂	1274.70	7.1%	1.0%	82.1%
17	2G	2. Industrial processes and product use	G. Other product manufacture and use			N ₂ O	105.87	80.0%	1.0%	83.0%
18	4 III	4. LULUCF	N mineralization			N ₂ O	58.71	135.1%	0.9%	83.9%
19	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO ₂	11334.49	0.7%	0.9%	84.9%
20	3B1-3B4	3. Agriculture	B. Manure management	1. Cattle, 2. Sheep, 3. Swine, 4. Other livestock		N ₂ O	105.65	72.2%	0.9%	85.7%
21	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO ₂	1451.63	5.1%	0.9%	86.6%
22	2A1	2. Industrial processes and product use	A. Mineral industry	1. Cement production		CO ₂	2524.45	2.8%	0.8%	87.4%
23	4D1	4. LULUCF	D. Wetlands	1. Wetlands remaining wetlands		CO ₂	67.56	104.4%	0.8%	88.2%
24	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO ₂	10098.96	0.7%	0.8%	89.0%
25	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N ₂ O	136.88	50.0%	0.8%	89.8%
26	5D	5. Waste	D. Wastewater treatment and discharge			CH ₄	130.92	48.2%	0.7%	90.5%

Regarding the trend assessment between the base year 1990 and the most recent year 2014, 31 categories are identified as trend key categories under Approach 2 (Table 1-9).

Table 1-9 Switzerland's Approach 2 trend key categories between 1990 and 2014 including LULUCF categories, sorted by contribution to the trend assessment. Categories in grey are key under Approach 1 as well.

Approach 2 key category analysis - Trend Assessment (categories which are already KCs under Approach 1 are shown in grey)												
No.	IPCC source categories and fuels if applicable				GHG	Base year 1990 estimate [Gg CO2 eq]	Year 2014 estimate [Gg CO2 eq]	Combined Uncertainty	Trend assessment	Contribution to trend [%]	Cumulative total of contribution to trend	
1	4G	4. LULUCF	G. Harvested wood products		CO2	-1231.92	-105.80	57.1%	1.24479	20.0%	20.0%	
2	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land	CO2	-369.23	-1674.57	47.9%	1.07315	17.3%	37.3%	
3	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland	CO2	79.05	115.70	839.4%	0.64819	10.4%	47.7%	
4	2F1	2. Industrial processes and product use	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning	HFC	0.02	1398.55	15.0%	0.36947	5.9%	53.6%	
5	3D6	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils		N2O	658.57	499.67	175.5%	0.30695	4.9%	58.6%	
6	3B5	3. Agriculture	B. Manure management	5. Indirect N2O emissions	N2O	242.32	283.54	244.5%	0.27245	4.4%	62.9%	
7	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	1491.86	2318.49	10.5%	0.17774	2.9%	65.8%
8	5A	5. Waste	A. Solid waste disposal		CH4	763.39	367.74	30.0%	0.17235	2.8%	68.6%	
9	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	1059.63	2278.18	5.1%	0.11859	1.9%	70.5%
10	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land	CO2	-570.45	-503.37	47.9%	0.10041	1.6%	72.1%	
11	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	1451.63	2402.23	5.1%	0.09764	1.6%	73.7%
12	5D	5. Waste	D. Wastewater treatment and discharge		N2O	118.27	144.47	150.0%	0.09764	1.6%	75.2%	
13	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N2O	136.88	19.81	50.0%	0.09213	1.5%	76.7%
14	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	1274.70	521.18	7.1%	0.07991	1.3%	78.0%
15	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	2632.66	7297.02	0.9%	0.07641	1.2%	79.2%
16	2G	2. Industrial processes and product use	G. Other product manufacture and use		N2O	105.87	43.93	80.0%	0.07371	1.2%	80.4%	
17	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CH4	118.04	19.86	37.0%	0.05579	0.9%	81.3%
18	3B	3. Agriculture	B. Manure management		CH4	923.97	782.15	54.4%	0.05533	0.9%	82.2%	
19	5B	5. Waste	B. Biological treatment of solid waste		CH4	35.64	107.96	41.2%	0.05487	0.9%	83.1%	
20	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production	CH4	319.77	196.87	30.0%	0.04956	0.8%	83.9%	
21	4C2	4. LULUCF	C. Grassland	2. Land converted to grassland	CO2	91.50	183.10	27.7%	0.04868	0.8%	84.7%	
22	5D	5. Waste	D. Wastewater treatment and discharge		CH4	130.92	174.59	48.2%	0.04715	0.8%	85.4%	
23	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	10098.96	5549.06	0.7%	0.04418	0.7%	86.1%
24	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	CH4	109.97	24.66	30.0%	0.03978	0.6%	86.8%
25	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements	CO2	394.54	318.25	50.2%	0.03574	0.6%	87.3%	
26	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	196.02	366.03	10.5%	0.03469	0.6%	87.9%
27	4E1	4. LULUCF	E. Settlements	1. Settlements remaining settlements	CO2	17.27	54.32	50.2%	0.03417	0.5%	88.5%	
28	3A	3. Agriculture	A. Enteric fermentation		CH4	3584.87	3365.33	18.1%	0.03406	0.5%	89.0%	
29	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/Institutional	Gaseous Fuels	CO2	981.49	1244.62	5.1%	0.03179	0.5%	89.5%
30	2G	2. Industrial processes and product use	G. Other product manufacture and use		SF6	137.01	204.26	20.5%	0.02879	0.5%	90.0%	
31	3D6	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils		N2O	1239.22	1111.39	106.3%	0.02817	0.5%	90.4%	

1.5.1.3 Summary of combined KCA including LULUCF categories

A summary of the key category analysis for 2014 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 2014 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, Level and Trend, 2014							
No.	IPCC source categories and fuels if applicable				GHG	Identification criteria	
1	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO2	L1, T1
2	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO2	L1, T1
3	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO2	L1, L2, T1, T2
4	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO2	L1, L2, T1, T2
5	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO2	L1, T1
6	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO2	L1, T1, T2
7	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO2	L1, T1, T2
8	1A3a	1. Energy	A. Fuel combustion activities	3. Transport; Domestic aviation	Kerosene	CO2	T1
9	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CH4	T1, T2
10	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	CO2	L1, L2, T1, T2
11	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	CO2	L1, L2, T1
12	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Diesel	N2O	T1
13	1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Gasoline	N2O	T1, T2
14	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO2	L1, L2, T1, T2
15	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO2	L1, T1
16	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	CH4	T1, T2
17	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO2	L1, L2, T1, T2
18	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO2	L1, T1, T2
19	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO2	L1
20	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH4	L1, L2, T1, T2
21	2A1	2. Industrial processes and product use	A. Mineral industry	1. Cement production		CO2	L1, T1
22	2C3	2. Industrial processes and product use	C. Metal industry	3. Aluminium production		CO2	T1
23	2C3	2. Industrial processes and product use	C. Metal industry	3. Aluminium production		PFC	T1
24	2F1	2. Industrial processes and product use	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	L1, L2, T1, T2
25	2G	2. Industrial processes and product use	G. Other product manufacture and use			SF6	L1, T1, T2
26	2G	2. Industrial processes and product use	G. Other product manufacture and use			N2O	T2
27	3A	3. Agriculture	A. Enteric fermentation			CH4	L1, L2, T1, T2
28	3B	3. Agriculture	B. Manure management			CH4	L1, L2, T2
29	3B1-3B4	3. Agriculture	B. Manure management	1. Cattle, 2. Sheep, 3. Swine, 4. Other livestock		N2O	L2
30	3B5	3. Agriculture	B. Manure management	5. Indirect N2O emissions		N2O	L1, L2, T1, T2
31	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from managed soils			N2O	L1, L2, T2
32	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from managed soils			N2O	L1, L2, T1, T2
33	4 III	4. LULUCF	N mineralization			N2O	L2
34	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO2	L1, L2, T1, T2
35	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO2	L1, L2, T1, T2
36	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO2	L1, L2
37	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO2	L2, T2
38	4C2	4. LULUCF	C. Grassland	2. Land converted to grassland		CO2	L1, T1, T2
39	4D1	4. LULUCF	D. Wetlands	1. Wetlands remaining wetlands		CO2	L2
40	4E1	4. LULUCF	E. Settlements	1. Settlements remaining settlements		CO2	T2
41	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO2	L1, L2, T2
42	4F2	4. LULUCF	F. Other land	2. Land converted to other land		CO2	L2
43	4G	4. LULUCF	G. Harvested wood products			CO2	L2, T1, T2
44	5A	5. Waste	A. Solid waste disposal			CH4	L1, L2, T1, T2
45	5B	5. Waste	B. Biological treatment of solid waste			CH4	T1, T2
46	5D	5. Waste	D. Wastewater treatment and discharge			CH4	L1, L2, T2
47	5D	5. Waste	D. Wastewater treatment and discharge			N2O	L2, T2

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 chp. 11.6.1.

1.6 General uncertainty evaluation

1.6.1 GHG inventory

1.6.1.1 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 on a yearly basis.

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. Detailed results of both approaches as well as further methodological information concerning Approach 2 are presented in Annex A2.

1.6.1.2 Data used

The evaluation includes uncertainties regarding activity data, emission factors and – in a few cases – emissions. 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 (triangular) were adopted.

For 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. However, no explicit information on uncertainties is available for a few key categories. 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. 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 expert judgement.

Table 1-11 Semi-quantitative (combined) uncertainties (U) for the emission of categories with no quantitative uncertainty data available. Note that there is no source of NF₃, for which a semi-quantitative uncertainty value is required.

Gas	Uncertainty Category	Combined Uncertainty
CO ₂	low	2%
	medium	10%
	high	40%
CH ₄	low	15%
	medium	30%
	high	60%
N ₂ O	low	40%
	medium	80%
	high	150%
HFC	medium	20%
PFC	medium	20%
SF ₆	medium	20%

The uncertainties of sector 1 Energy were broadly updated for the current submission. They are described in detail in chp. 3.2.4.7. Main result of the new evaluation is the lowering of the uncertainty of CO₂.

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.

1.6.1.3 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 2014 and trend uncertainties 1990–2014.

Approach 1 Uncertainty Analysis		
Inventory	Level uncertainty	Trend uncertainty
	2014	1990-2014
excl. LULUCF	3.81%	1.44%
incl. LULUCF	4.76%	2.31%

Uncertainty analysis results for the Switzerland's GHG inventory 2014 with Approach 1:

- The level uncertainty 2014 is **3.81%** excluding LULUCF and **4.76%** including LULUCF. Explanations are given below in the chapter on Approach 2 results.
- The trend uncertainty 1990–2014 is **1.44%** excluding LULUCF and **2.31%** including LULUCF.

Compared to the results of the previous inventory 2013 (FOEN 2015):

- In 2013, level uncertainty was **3.69%** excl. LULUCF and **7.08%** incl. LULUCF
- In the period 1990–2013, trend uncertainty was **1.95%** excl. LULUCF and **2.99%** incl. LULUCF.

The level uncertainty excluding LULUCF slightly increased (from 3.69% to 3.81%) compared to the previous uncertainty analysis although uncertainty values in sector 1 Energy have been reduced. But a higher weight of absolute uncertainties in sector 3 Agriculture, due to an increase of emissions in this sector whilst emissions in sector 1 Energy are decreasing, is cancelling out this effect. The level uncertainty when including LULUCF, however, has clearly decreased in 2014 compared to 2013 (from 7.08% to 4.76%). This is mainly a result of improving the uncertainty value in category 4C1 Grassland remaining grassland (see sectoral chapters on uncertainties). Trend uncertainties, excluding and including LULUCF, decreased for the current submission, which can be explained by the combined effect of lower uncertainties in the energy sector and the general decrease of the national total in 2014 compared to 2013.

Detailed results of the Approach 1 uncertainty analysis for GHG emissions 2014 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 and product use, 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.

1.6.1.4 Results of Approach 2 uncertainty evaluation (Monte Carlo)

Approach 2 requires Monte Carlo analysis (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 2014 and in emission trends 1990–2014, 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 2014 and trend uncertainties 1990–2014. The emission trend 1990–2014 is -8.83% excl. LULUCF and -9.10% incl. LULUCF.

Approach 2 (Monte Carlo) Uncertainty Analysis						
Version	Level uncertainty 2014			Trend uncertainty 1990-2014		
	2.5 percentile	97.5 percentile	mean	2.5 percentile	97.5 percentile	mean
excl. LULUCF	-3.38%	3.79%	3.58%	-11.50%	-6.28%	2.61%
incl. LULUCF	-4.40%	4.64%	4.52%	-13.22%	-5.04%	4.09%

Approach 2 uncertainties excluding LULUCF:

- The total uncertainty level of Switzerland's 2014 national total GHG emissions excluding LULUCF is **3.58%** with a slightly asymmetric 95% confidence interval between 96.62% and 103.79%.
- The trend in national total emissions excluding LULUCF between 1990 and 2014 is -8.83%. With a probability of 95% the trend lies within the range of -11.50% to -6.28%, which corresponds to a **mean trend uncertainty of 2.61%**.

Approach 2 uncertainties including LULUCF:

- The total uncertainty level of Switzerland's 2014 national total GHG emissions including LULUCF is **4.52%** with a slightly asymmetric 95% confidence interval between 95.60% and 104.64%.
- The trend in national total emissions including LULUCF between 1990 and 2014 is -9.10%. With a probability of 95%, the trend lies within the range of -13.22% to -5.04%, which corresponds to a **mean trend uncertainty of 4.09%**.

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

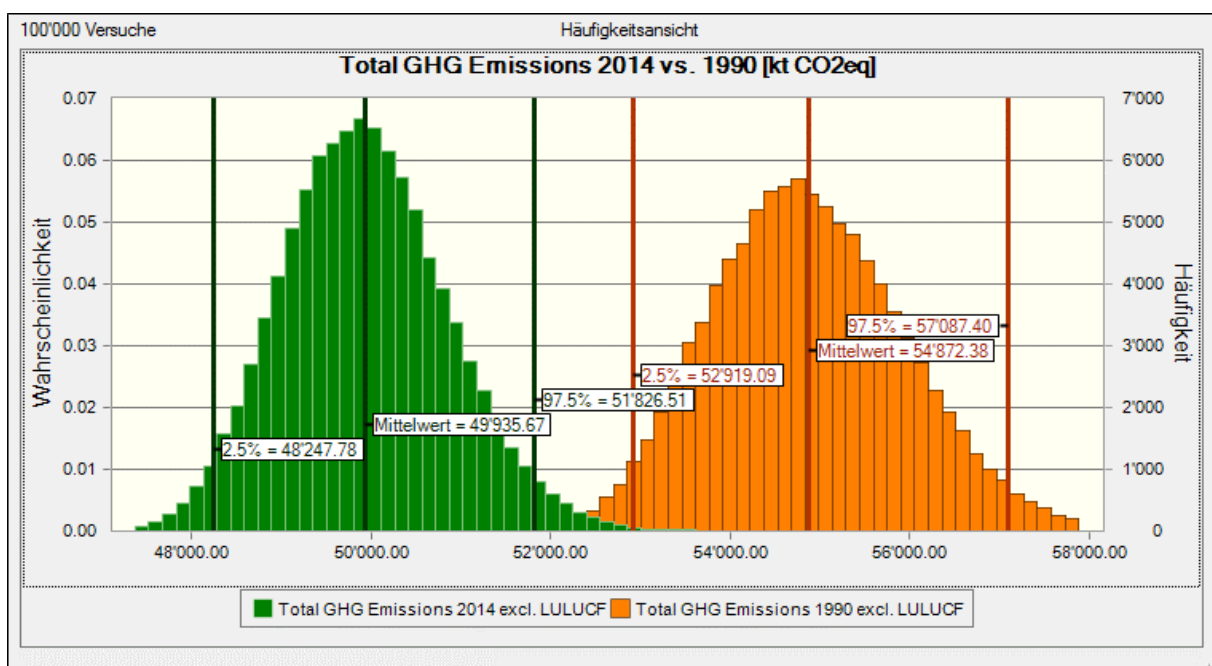


Figure 1-3 Probability distributions of the simulated total emissions excluding LULUCF for the base year 1990 (in orange) and year 2014 (in green). The vertical lines show simulated mean and percentile values (black for 2014, red for 1990). The number of Monte Carlo runs is 100'000. X-axis: total emissions (excl. LULUCF) [kt CO₂ eq]. Y-axis: Probability (left) and Frequency (right). The simulated values deviate from the reported inventory values (see Table A – 8 for detailed deviations: E.g. the simulated value 2014 is 49'936 kt CO₂ eq, whereas the reported value is 48'612 kt CO₂ eq, 2.7% lower than the simulated value).

In the course of Monte Carlo simulation, the uncertainties are also evaluated by gas (see Table 1-14). As expected, CO₂ emissions have the highest precision or the lowest uncertainties among the Kyoto gases.

Table 1-14 Approach 2 level uncertainties by gas for the total national emissions 2014 excluding LULUCF.

Gas	Emission 2014 (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	39'272	38'989	39'560	285	0.73%
CH ₄	5'097	4'182	6'018	918	18.0%
N ₂ O	2'439	1'564	3'493	964	39.5%
HFC	1'501	1'293	1'711	209	13.9%
PFC	44	38	50	6	13.0%
SF ₆	259	215	303	44	16.9%
NF ₃	0.40	-0.36	1.17	0.76	189%
Total	48'612	46'969	50'453	1'742	3.58%

Detailed results per category of the Monte Carlo simulation are presented in Table A – 7, inputs on probability distributions and correlation coefficients in Tables Table A – 4 to Table A – 6.

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 2014.

Categories 3Da Direct N₂O emissions from managed soils, 4C1 Grassland remaining grassland (CO₂) and 4A1 Forest land remaining forest land (CO₂) are the most important contributors to level uncertainty. The fact that two out of the three most important contributors stem from the LULUCF sector explains the result given above that the level uncertainty including LULUCF is higher than without LULUCF.

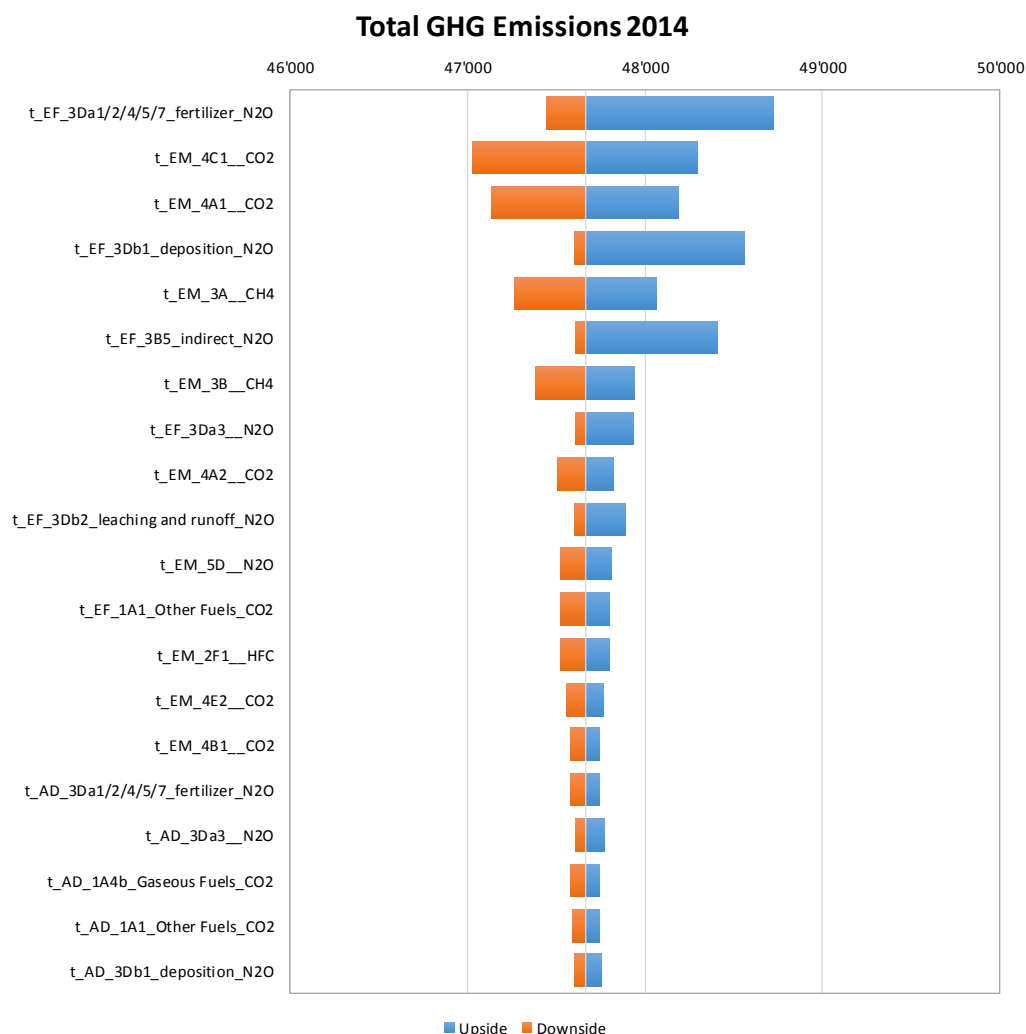


Figure 1-4 Tornado plot of the uncertainties by category. Abbrev.: “t” refers to 2014, “EF” emission factor, “AD” activity data, “EM” emissions. X-axis: Simulated national total of CO₂ eq emissions (in kt) including LULUCF in 2014 (the simulated value deviate from the reported inventory values, see Table A – 8 for details). The width of the bar shows the combined uncertainty introduced by the corresponding uncertainty.

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

1.6.1.5 Comparison of Approach 1 and Approach 2

In the GHG inventory, the variability of the uncertainties is high, 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 method 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 extent, any statistical distribution and any correlated parameters. 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 leads to an overall level uncertainty of 3.58%, which is lower than the result of Approach 1 (3.81%). The correct treatment of large uncertainties, asymmetric distributions for agricultural sources and accounting for relevant correlations lead all together to a slight decrease in the level uncertainty.

The same holds for the level uncertainty incl. LULUCF. With Approach 2, an overall level uncertainty of 4.52% is computed, which is also slightly lower than the result of Approach 1 (4.76%).

Trend uncertainty

In terms of trend uncertainty, the results of Approach 2 show considerably higher uncertainties than the results of Approach 1. If LULUCF categories are excluded, Approach 2 leads to an uncertainty of 2.61% and Approach 1 to 1.44%, whereas when LULUCF categories are included, the numbers are 4.09% and 2.31%, respectively. Positive correlations for activity data and emission factors between the base year and 2014 tend to increase trend uncertainty. This effect is enforced for the analysis including LULUCF due to the high uncertainty values in this sector.

1.6.2 KP-LULUCF inventory

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

1.7 General assessment of completeness

1.7.1 GHG inventory

Source and sink categories that are not estimated or included elsewhere are listed in CRF Table 9. The only categories for which notation key “not estimated” is used are CH₄ emissions from drained soils (CRF Table4(II)) and CH₄ and N₂O emissions from biomass burning in settlements (CRF Table4(V)). Notation key “included elsewhere” is used in 1A2c and 2B1 for reasons of confidentiality, and in 1A3a / aviation gasoline, 3G2 / Dolomite, 4(I)E, 4(IV), 4(V), 5C1 and 5D1 because data for further disaggregation are not available.

1.7.2 KP-LULUCF inventory

For all known sources and sinks, complete estimates are accomplished for the current submission. Notation keys for the activity coverage and the reported pools are displayed in CRF NIR-1 (Table 11-1). A detailed justification for the reported method is given in chapter 11.3.1.2.

2 Trends in greenhouse gas emissions and removals

This chapter provides an overview of Switzerland's GHG emissions and removals in 2014 as well as trends for the period 1990–2014. Numbers in chp. 2.1-2.4 are relevant for reporting under the UNFCCC, whereas numbers in chp. 2.5 refer to accounting under the Kyoto Protocol.

2.1 Aggregated greenhouse gas emissions 2014 (UNFCCC)

Table 2-1 shows the aggregated emissions of all GHG 2014 for each sector and the relative shares of the sectors. Furthermore, emission data on international aviation and marine bunkers are provided. As the table indicates, CO₂ is the main contributor to total greenhouse gas emissions followed by CH₄, N₂O and the F-gases. Sector 1 Energy is the main source concerning climate-related emissions followed by sectors 3 Agriculture, 2 IPPU and 5 Waste. In contrast, sector 4 LULUCF is a net sink regarding GHG emissions in 2014.

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 emissions of each GHG. Trends in GHG emissions are given in chp. 2.2 to 2.5.

Table 2-1 Switzerland's GHG emissions in CO₂ equivalent (kt) by gas and sector in 2014.

Emissions 2014	CO ₂	CH ₄	N ₂ O	HFCs	PFCs	SF ₆	NF ₃	Total	Share
	CO ₂ equivalent (kt)								
1 Energy	36'960	289	217					37'467	77.1%
2 Industrial processes and product use	2'236	2	48	1'501	44	259	0	4'091	8.4%
3 Agriculture	46	4'147	1'981					6'174	12.7%
5 Waste	10	658	192					860	1.8%
6 Other	13	1	1					14	0.0%
Total (excluding LULUCF)	39'265	5'097	2'439	1'501	44	259	0	48'605	100.0%
4 Land use, land-use change and forestry	-1'029	11	69					-949	-2.0%
Total (including LULUCF)	38'236	5'108	2'508	1'501	44	259	0	47'656	98.0%
<i>International aviation bunkers</i>	4'732	2	45					4'779	
<i>International marine bunkers</i>	23	0.00	0.22					23	

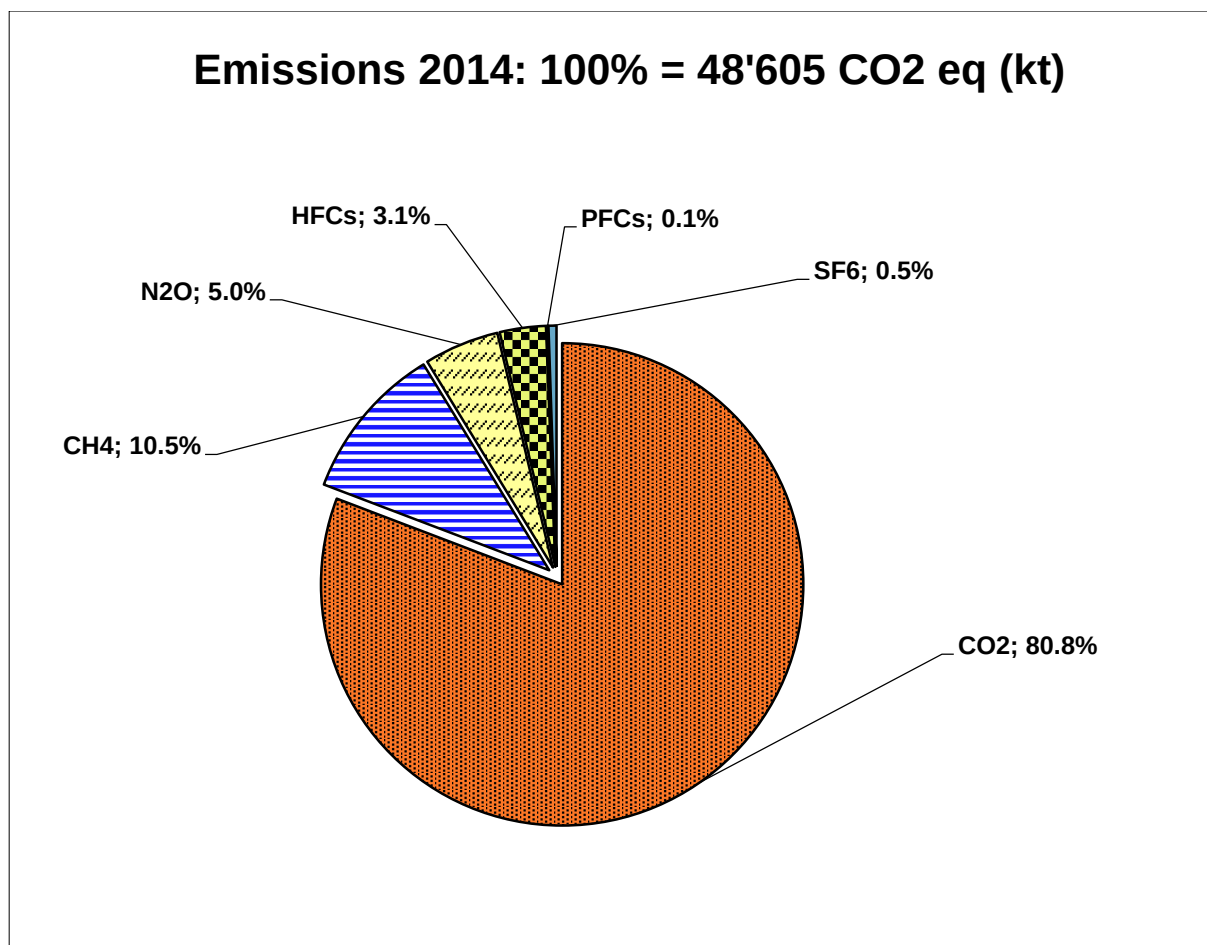


Figure 2-1 Contribution of individual gases to Switzerland's GHG emissions (excluding LULUCF) in 2014.

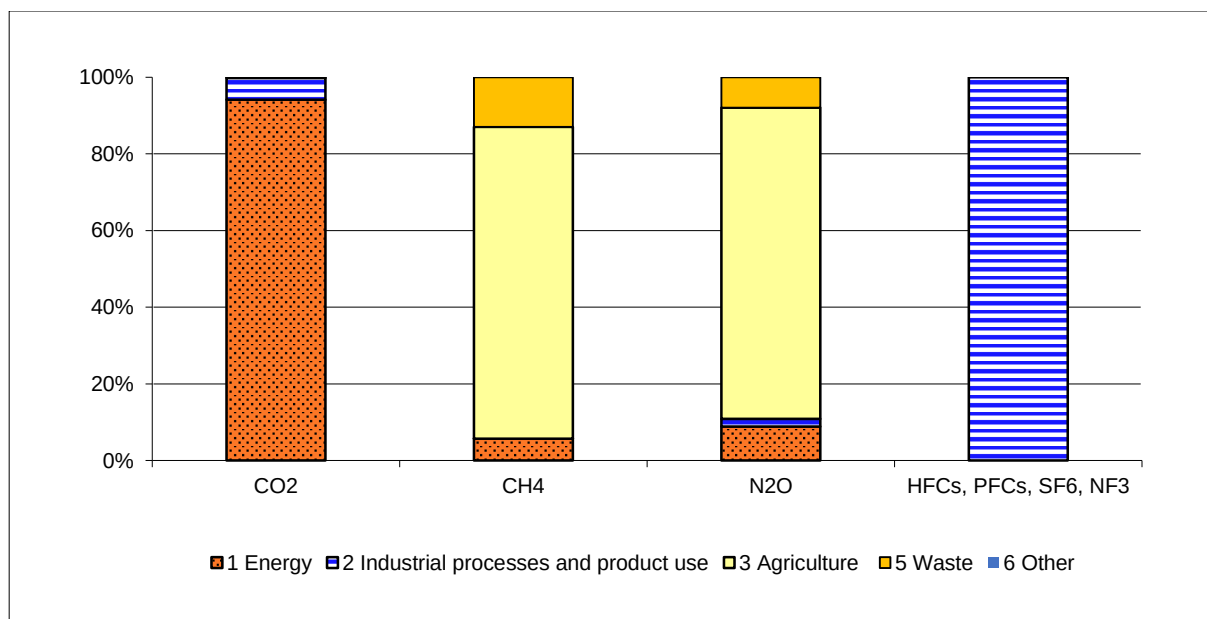


Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2014.

A clear dominance of CO₂ emissions in 2014 is related to source category 1A Fuel combustion within sector 1 Energy. CH₄ and N₂O emissions mainly originate from agriculture, while F-gas emissions by definition only stem from industrial processes.

2.2 Emission trends by gas

Emission trends by gas for the period 1990–2014 are summarized in Table 2-2.

Table 2-2 Switzerland's GHG emissions in CO₂ equivalent (kt) by gas; 1990–2014. The column below on the far right (digits in italic) indicates the percentage change in emissions in 2014 as compared to the base year 1990. HFCs increased by 6'056'832% when compared to 1990 levels (1990 = 0.025 kt CO₂ equivalent).

Greenhouse Gas Emissions	1990	1995	2000
	CO ₂ equivalent (kt)		
CO ₂ emissions including net CO ₂ from LULUCF	43'122	39'535	48'368
CO ₂ emissions excluding net CO ₂ from LULUCF	44'116	43'368	43'546
CH ₄ emissions including CH ₄ from LULUCF	6'116	5'796	5'404
CH ₄ emissions excluding CH ₄ from LULUCF	6'091	5'780	5'392
N ₂ O emissions including N ₂ O from LULUCF	2'939	2'781	2'632
N ₂ O emissions excluding N ₂ O from LULUCF	2'854	2'702	2'556
HFCs	0	246	626
PFCs	117	17	50
SF ₆	137	93	144
NF ₃	0	0	0
Total (including LULUCF)	52'430	48'469	57'223
Total (excluding LULUCF)	53'314	52'207	52'314

Greenhouse Gas Emissions	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Change baseyear to 2014 (%)
	CO ₂ equivalent (kt)										
CO ₂ emissions including net CO ₂ from LULUCF	43'342	44'997	42'173	42'716	40'957	42'849	39'201	40'160	41'284	38'236	-11.3%
CO ₂ emissions excluding net CO ₂ from LULUCF	45'778	45'351	43'360	44'677	43'509	45'027	40'973	42'242	43'182	39'265	-11.0%
CH ₄ emissions including CH ₄ from LULUCF	5'317	5'332	5'313	5'389	5'305	5'285	5'221	5'178	5'108	5'108	-16.5%
CH ₄ emissions excluding CH ₄ from LULUCF	5'306	5'320	5'299	5'378	5'294	5'274	5'208	5'167	5'097	5'097	-16.3%
N ₂ O emissions including N ₂ O from LULUCF	2'525	2'527	2'551	2'571	2'534	2'582	2'531	2'517	2'481	2'508	-14.7%
N ₂ O emissions excluding N ₂ O from LULUCF	2'450	2'449	2'474	2'498	2'463	2'512	2'460	2'448	2'412	2'439	-14.5%
HFCs	1'071	1'118	1'194	1'243	1'253	1'329	1'410	1'489	1'513	1'501	see caption
PFCs	44	52	49	58	63	65	68	71	52	44	-62.3%
SF ₆	203	186	172	222	180	148	160	209	252	259	88.9%
NF ₃	0	0	0	0	5	8	6	0.4	0.1	0.4	-
Total (including LULUCF)	52'503	54'211	51'451	52'199	50'297	52'266	48'597	49'625	50'691	47'656	-9.1%
Total (excluding LULUCF)	54'852	54'475	52'548	54'076	52'767	54'363	50'285	51'626	52'508	48'605	-8.8%

As shown in Table 2-2, Table 2-3, and Figure 2-3, total emissions excluding LULUCF reach a minimum in 2014, being clearly below base year emissions. There is no discernible trend in the period 1990–2005. Only from 2005 onwards, a decreasing trend starts to develop. The emission maximum occurred in 1991. The decrease to a minimum of total emissions in 2014 compared to the base year 1990 is also visible when including LULUCF, although the net CO₂ sink generated by LULUCF categories was generally smaller after 1997.

There is a strong correlation between CO₂ emissions and winter climatic conditions (number of heating degree days, see footnote 1, page 63) in the period 1990–2014 (see Figure 2-7). A significantly lower number of heating degree days in 2014 compared to 2013 is an important driver for the CO₂ emission reduction in fuel combustion. However, the relative development of heating degree days and CO₂ emissions is clearly drifting apart in the years since 2003, which indicates that also other effects and measures than winter climatic conditions are contributing to emission reductions (Figure 2-7).

Between 1990 and 2014, CH₄ (excluding LULUCF) decreased mainly due to a reduction of livestock that led to a reduction of emissions from enteric fermentation. Moreover, from 2000 onwards, a change in waste legislation banning the disposal of municipal solid waste in landfills contributed to this trend.

As a consequence of the declining livestock population and reduced input of synthetic fertilizers, N₂O emissions mainly stemming from manure management and agricultural soils decrease between 1990 und 2014 as well.

HFC emissions increased significantly due to their application as substitutes for CFCs, while PFC emissions declined. SF₆ emissions show relatively large fluctuations between 1990 and 2014. This is the effect of annual fluctuations of the market volumes in the production of electrical equipment and on the other hand the effect of changes in other applications. The increase of SF₆ emissions in recent years is due the disposal of sound proof windows. NF₃ has been used only short-term in the photovoltaic industry.

Table 2-3 Switzerland's total GHG emissions (excluding LULUCF) in CO₂ equivalent (kt), selected years.

Greenhouse Gas Emissions (excluding LULUCF)	1990		1995		2000		2005		2010	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
CO ₂	44'116	82.7%	43'368	83.1%	43'546	83.2%	45'778	83.5%	45'027	82.8%
CH ₄	6'091	11.4%	5'780	11.1%	5'392	10.3%	5'306	9.7%	5'274	9.7%
N ₂ O	2'854	5.4%	2'702	5.2%	2'556	4.9%	2'450	4.5%	2'512	4.6%
HFCs	0	0.0%	246	0.5%	626	1.2%	1'071	2.0%	1'329	2.4%
PFCs	117	0.2%	17	0.0%	50	0.1%	44	0.1%	65	0.1%
SF ₆	137	0.3%	93	0.2%	144	0.3%	203	0.4%	148	0.3%
NF ₃	0	0.0%	0	0.0%	0	0.0%	0	0.0%	8	0.0%
Total (excluding LULUCF)	53'314	100%	52'207	100%	52'314	100%	54'852	100%	54'363	100%

Greenhouse Gas Emissions (excluding LULUCF)	2011		2012		2013		2014	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
CO ₂	40'973	81.5%	42'242	81.8%	43'182	82.2%	39'265	80.8%
CH ₄	5'208	10.4%	5'167	10.0%	5'097	9.7%	5'097	10.5%
N ₂ O	2'460	4.9%	2'448	4.7%	2'412	4.6%	2'439	5.0%
HFCs	1'410	2.8%	1'489	2.9%	1'513	2.9%	1'501	3.1%
PFCs	68	0.1%	71	0.1%	52	0.1%	44	0.1%
SF ₆	160	0.3%	209	0.4%	252	0.5%	259	0.5%
NF ₃	6	0.0%	0	0.0%	0	0.0%	0	0.0%
Total (excluding LULUCF)	50'285	100%	51'626	100%	52'508	100%	48'605	100%

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

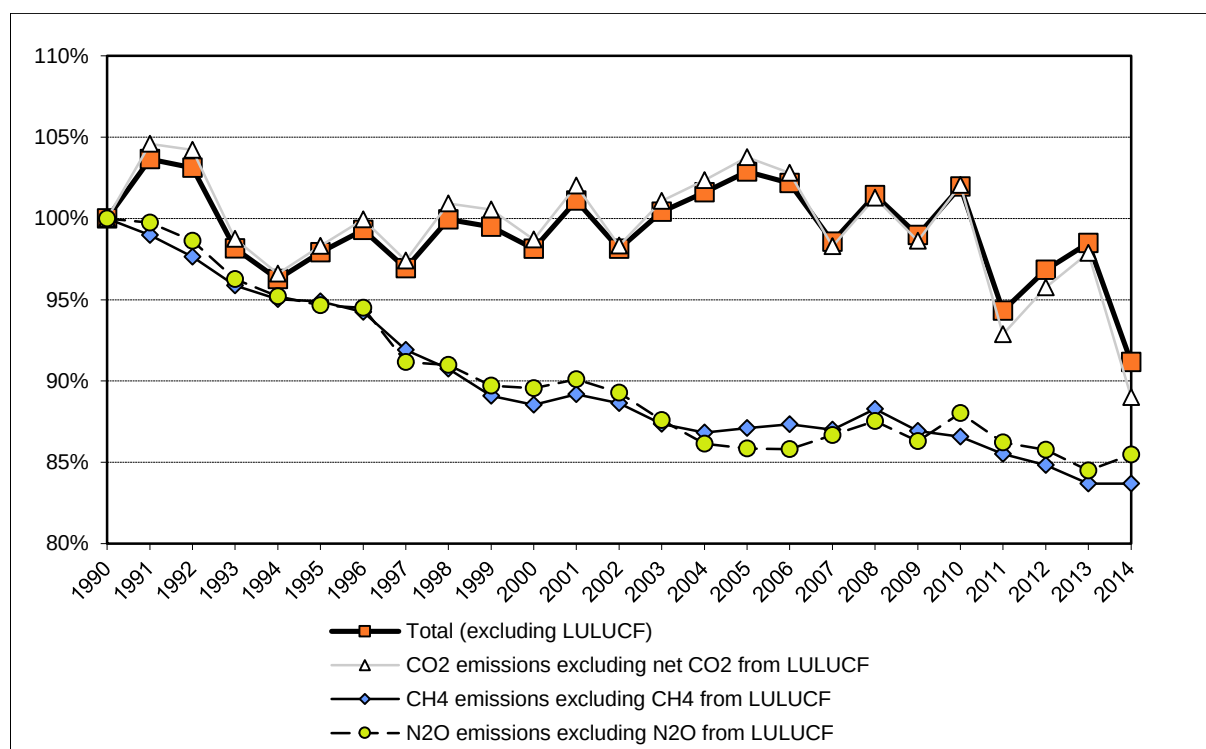


Figure 2-3 Relative trend of Switzerland's main GHG emissions by gas (excluding LULUCF), 1990–2014 (base year 1990 = 100%). F-gases are not illustrated (see Figure 4-3).

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 originates from sector 1 Energy, the table includes further information concerning the contributions of energy-related source categories.

2.3.1 Overview

In order to understand trends within the sector 1 Energy, the individual source categories are considered separately. See “Emission trends in sector 1 Energy” and Figure 2-6 below.

In line with economic development, overall emissions in sector 2 Industrial processes and other product use (IPPU) show a decreasing trend in the early 90s and a gradual increase between 1998 and 2014, 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. The dominant source category of sector 2 is 2A Mineral industry although the emissions decreased by approximately 1/3 since 1990. If sources are analysed in more detail 2A1 Cement production is the most relevant emitter in this category. Emissions of 2F Product uses as substitutes for ODS, the second most important source in sector 2 increased by some orders of magnitude since 1990 due to the replacement of CFCs by HFCs. Source category 2G Other product manufacture and use with SF₆ and PFC emissions from electrical equipment and other product use, as well as N₂O emissions from the application in households and hospitals has increased by approximately factor 2 since 1990.

Other source categories in sector 2 are of minor importance with regard to the overall greenhouse gas emissions.

GHG emissions in sector 3 Agriculture are driven by populations of cattle and swine and fertilizer use. Both factors have been declining, thus leading to a decrease in CH₄ and N₂O emissions until 2004. Subsequently emissions increased slightly until 2008 and decreased again afterwards mainly due to the evolution of the cattle population.

Total emissions from the source category 5 Waste continuously decrease between 1990 and 2014, with a short increasing phase from 2000 until 2003. The main driver of the decreasing trend is the emission reduction in solid waste disposal, which was reinforced through a change of legislation in 2000 that banned disposal of combustible waste in landfills. Therefore, an increasing amount of municipal solid waste is being incinerated, with emissions reported under source 1A1 Energy industries rather than sector 5 Waste. Altogether, “waste-related” emissions (including emissions from all waste management activities reported in 1 Energy, 3 Agriculture, and 5 Waste) are increasing since 1990 and show a stagnation since 2006 (see Figure 7-3 in chp. 7.1.1).

The total emissions from sector 6 Other (fire damages) increased throughout the period 1990–2000. Since 2000 the emissions are stable. Emissions from sector 6 Other are not accounted for under the Kyoto Protocol and are of minor importance only.

Table 2-4 Switzerland's GHG emissions in CO₂ equivalent (kt) by sources and sinks, 1990–2014. The column below on the far right (digits in italic) indicates the percentage change in emissions in 2014 as compared to the base year 1990.

Source and Sink Categories	1990	1995	2000
	CO ₂ equivalent (kt)		
1. Energy	41'837	41'862	42'139
1A1 Energy industries	2'521	2'632	3'149
1A2 Manufacturing industries and construction	6'457	6'210	5'932
1A3 Transport	14'660	14'263	15'924
1A4 Other sectors	17'632	18'170	16'631
1A5 Other	220	163	151
1B Fugitive emissions from fuels	346	424	352
2. Industrial processes and product use	3'521	2'873	3'099
3. Agriculture	6'804	6'503	6'123
5. Waste	1'139	955	939
6. Other	12	13	14
Total (excluding LULUCF)	53'314	52'207	52'314
4. Land use, land-use change and forestry	-884	-3'738	4'910
Total (including LULUCF)	52'430	48'469	57'223

Source and Sink Categories	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2014 vs. 1990
	CO ₂ equivalent (kt)										%
1. Energy	43'996	43'602	41'567	42'926	41'819	43'191	39'147	40'539	41'473	37'467	-10.4%
1A1 Energy industries	3'817	4'032	3'720	3'837	3'674	3'847	3'600	3'643	3'739	3'602	42.9%
1A2 Manufacturing industries and construction	6'003	6'172	5'983	6'025	5'714	5'829	5'389	5'397	5'498	5'117	-20.8%
1A3 Transport	15'851	15'966	16'289	16'639	16'434	16'323	16'142	16'259	16'169	16'062	9.6%
1A4 Other sectors	17'879	17'001	15'163	16'021	15'600	16'777	13'610	14'850	15'698	12'317	-30.1%
1A5 Other	139	143	136	131	133	138	125	133	134	139	-36.8%
1B Fugitive emissions from fuels	309	288	276	272	266	277	281	258	235	230	-33.5%
2. Industrial processes and product use	3'776	3'757	3'823	3'902	3'797	4'011	4'046	4'050	4'074	4'091	16.2%
3. Agriculture	6'098	6'133	6'191	6'298	6'219	6'241	6'185	6'152	6'083	6'174	-9.3%
5. Waste	968	968	952	936	917	906	893	871	864	860	-24.6%
6. Other	14	14	14	14	14	14	14	14	14	14	16.1%
Total (excluding LULUCF)	54'852	54'475	52'548	54'076	52'767	54'363	50'285	51'626	52'508	48'605	-8.8%
4. Land use, land-use change and forestry	-2'349	-263	-1'096	-1'877	-2'470	-2'097	-1'688	-2'001	-1'817	-949	7.4%
Total (including LULUCF)	52'503	54'211	51'451	52'199	50'297	52'266	48'597	49'625	50'691	47'656	-9.1%

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

Table 2-5 Switzerland's total GHG emissions (excluding LULUCF) in CO₂ equivalent (kt) and the contribution of individual source categories for selected years.

Source and Sink Categories	1990		1995		2000		2005		2010	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
1. Energy	41'837	78.5%	41'862	80.2%	42'139	80.6%	43'996	80.2%	43'191	79.4%
1A1 Energy industries	2'521	4.7%	2'632	5.0%	3'149	6.0%	3'817	7.0%	3'847	7.1%
1A2 Manufacturing industries and construction	6'457	12.1%	6'210	11.9%	5'932	11.3%	6'003	10.9%	5'829	10.7%
1A3 Transport	14'660	27.5%	14'263	27.3%	15'924	30.4%	15'851	28.9%	16'323	30.0%
1A4 Other sectors	17'632	33.1%	18'170	34.8%	16'631	31.8%	17'879	32.6%	16'777	30.9%
1A5 Other	220	0.4%	163	0.3%	151	0.3%	139	0.3%	138	0.3%
1B Fugitive emissions from fuels	346	0.6%	424	0.8%	352	0.7%	309	0.6%	277	0.5%
2. Industrial processes and product use	3'521	6.6%	2'873	5.5%	3'099	5.9%	3'776	6.9%	4'011	7.4%
3. Agriculture	6'804	12.8%	6'503	12.5%	6'123	11.7%	6'098	11.1%	6'241	11.5%
5. Waste	1'139	2.1%	955	1.8%	939	1.8%	968	1.8%	906	1.7%
6. Other	12	0.0%	13	0.0%	14	0.0%	14	0.0%	14	0.0%
Total (excluding LULUCF)	53'314	100.0%	52'207	100.0%	52'314	100.0%	54'852	100.0%	54'363	100.0%

Source and Sink Categories	2011		2012		2013		2014	
	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%	kt CO ₂ eq	%
1. Energy	39'147	77.8%	40'539	78.5%	41'473	79.0%	37'467	77.1%
1A1 Energy industries	3'600	7.2%	3'643	7.1%	3'739	7.1%	3'602	7.4%
1A2 Manufacturing industries and construction	5'389	10.7%	5'397	10.5%	5'498	10.5%	5'117	10.5%
1A3 Transport	16'142	32.1%	16'259	31.5%	16'169	30.8%	16'062	33.0%
1A4 Other sectors	13'610	27.1%	14'850	28.8%	15'698	29.9%	12'317	25.3%
1A5 Other	125	0.2%	133	0.3%	134	0.3%	139	0.3%
1B Fugitive emissions from fuels	281	0.6%	258	0.5%	235	0.4%	230	0.5%
2. Industrial processes and product use	4'046	8.0%	4'050	7.8%	4'074	7.8%	4'091	8.4%
3. Agriculture	6'185	12.3%	6'152	11.9%	6'083	11.6%	6'174	12.7%
5. Waste	893	1.8%	871	1.7%	864	1.6%	860	1.8%
6. Other	14	0.0%	14	0.0%	14	0.0%	14	0.0%
Total (excluding LULUCF)	50'285	100.0%	51'626	100.0%	52'508	100.0%	48'605	100.0%

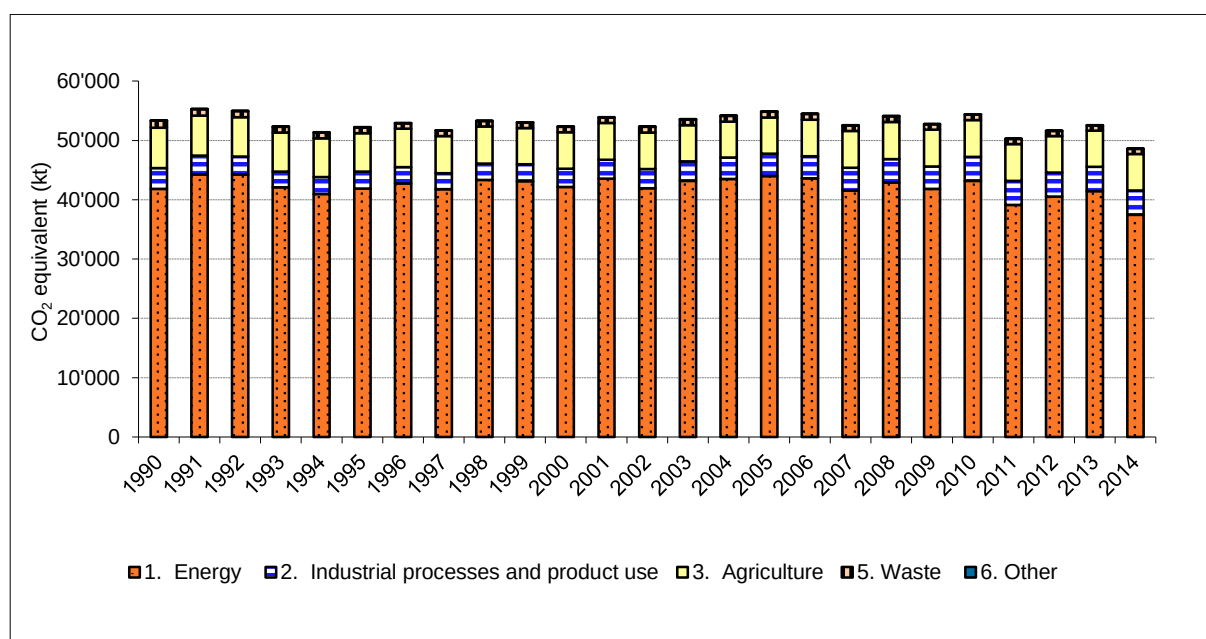


Figure 2-4 Switzerland's GHG emissions in CO₂ equivalent (kt) by sectors, 1990–2014 (excluding LULUCF).

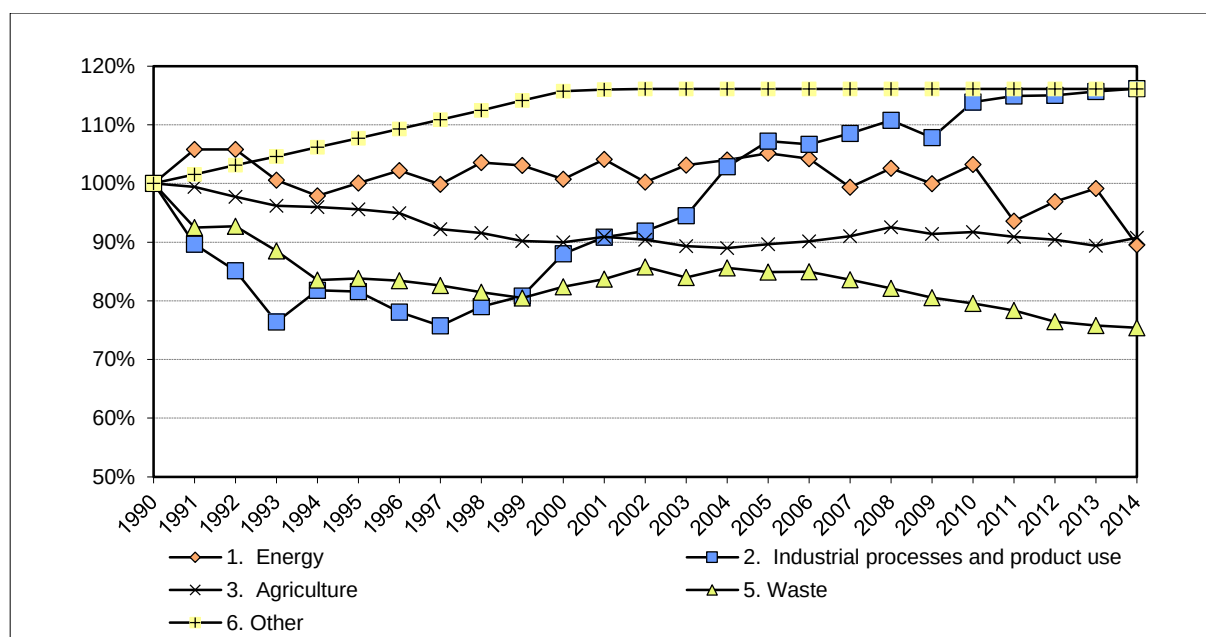


Figure 2-5 Relative emission trends (CO₂ eq.) by main source categories (base year 1990 = 100%).

2.3.2 Emission trends in sector 1 Energy

The main source categories within sector 1 Energy – representing the major sources of Switzerland's GHG emissions – are shown in Figure 2-6. Values are given in Table 2-5.

It is noteworthy that due to Switzerland's electricity production structure (the most of it is generated by hydroelectric and nuclear power plants in 2014; see SFOE 2015: Table 24), category 1A1 Energy industries plays only a minor role. It does not represent thermal power stations as in many other countries, but primarily waste incineration plants. The following emission trends emerge within the sector 1 Energy:

- Despite differing trends of individual source categories, the overall emissions from the sector 1 Energy remain at a relatively constant level (orange/bold line in Figure 2-6) in the period 1990–2005. From 2005–2014 the combination of effective reduction measures and warm winters (see Figure 2-7) led to decreasing emissions (see details below under 1A4 Other sectors).
- Overall emissions 2014 from source category 1A1 Energy industry are higher than in 1990. The time series shows an increase until 2006 and a slight decrease from then on, fluctuations being 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 2-6 and values in Table 2-5). Only a minor part of the total sector 1 Energy emissions stem from 1A1.
- The trend for category 1A3 Transport is quite stable with minor fluctuations. These fluctuations are representing the overall economic development in Switzerland fairly well (gross domestic product) (SFSO 2009a, SFSO 2015f). Since 2008 transport

emissions show a slight decrease which points to a relative decoupling from overall economic development (see also Table 2-5).

- The trend for source category 1A4 Other sectors reflects the impact of climatic variations on energy 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 CO₂ emissions from source category 1A4 Fuel combustion – Other sectors (only stationary sources) and the number of heating degree days. The number of heating degree days in 2014 decreased compared to 2013. CO₂ emissions caused by fuel combustion in source category 1A4 Other sectors – stationary sources decreased simultaneously (see Figure 2-7). In the period 1990–2014, 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 one third. 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.

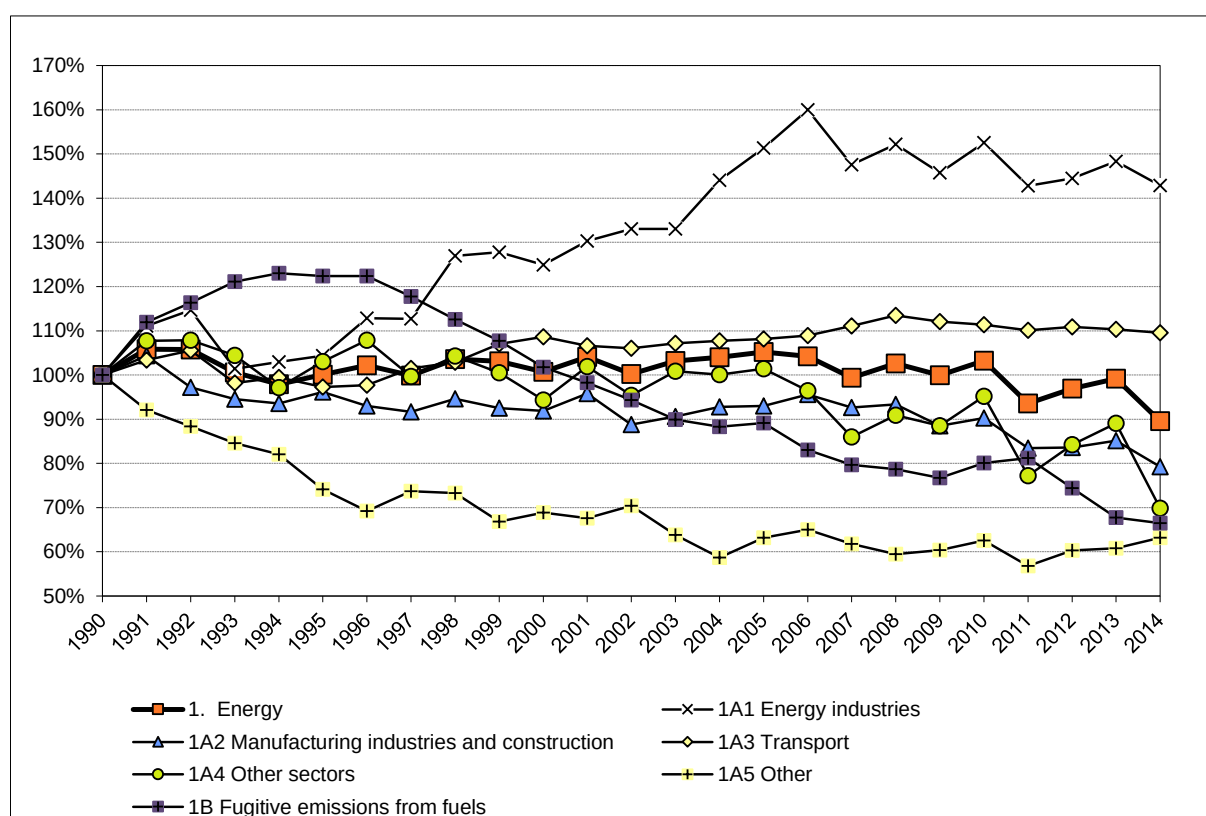


Figure 2-6 Emission trends (CO₂ eq.) for the source categories in sector 1 Energy. The trend for the entire sector 1 Energy is represented by the bold line with orange dots. Not shown in the figure is the trend for 1B Fugitive emissions, which decreased from 100% in 1990 to 67.6% in 2014.

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 .

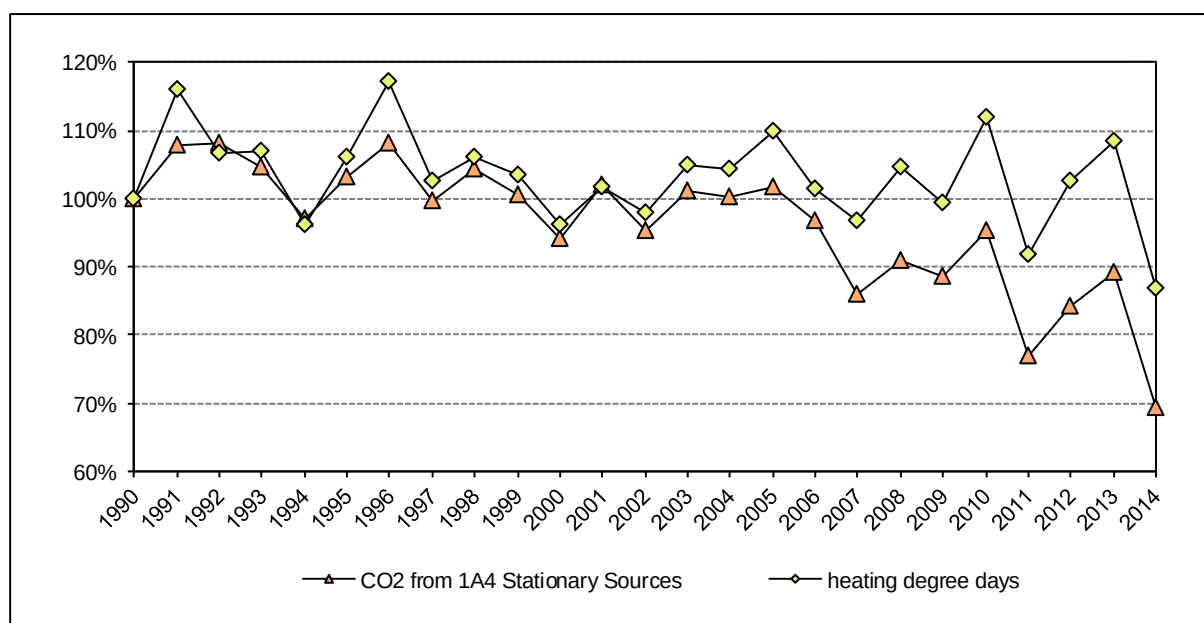


Figure 2-7 Relative trend for CO₂ emissions from 1A4 Fuel Combustion - Other Sectors (stationary sources only) compared with the number of heating degree days.

2.3.3 Emission trends in sector 4 LULUCF

Figure 2-8 illustrates the net emissions and removals of sector 4 LULUCF in Switzerland. Specific values are given in Table 2-4. LULUCF emissions are dominated by biomass dynamics in forests. Except for the year 2000, the removals in sector 4 LULUCF were higher than the emissions throughout the period 1990–2014. A strong year to year variation is evident over the whole period. The reasons for the positive values for LULUCF excluding HWP in 1990 and in 2000 (and the very small removal in 2001) are the storms Vivian (February 1990) and Lothar (December 1999), respectively, which caused great damages in the forest stands and increased harvesting. Harvesting rates in Swiss forests tended to increase since 1991 with maxima in 2006 and 2007 resulting in a net emission from LULUCF excluding HWP in 2006. Because harvesting rates started to decline in 2008 due to the international and domestic economic framework conditions, removals from LULUCF excluding HWP increased again. The annual contributions of CH₄ and N₂O emissions from LULUCF in the period 1990–2014 are relatively small compared to the CO₂ emissions and removals.

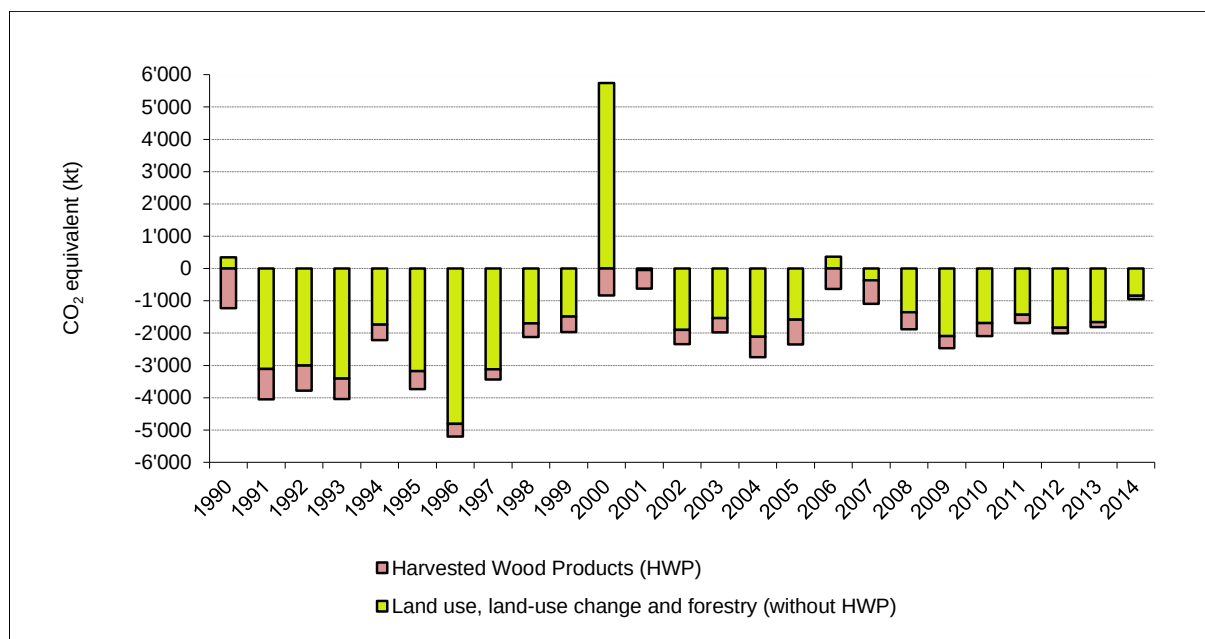


Figure 2-8 Switzerland's net GHG emissions and removals of sector 4 Land use, land-use change and forestry (LULUCF), Harvested Wood Products (HWP) are highlighted, 1990–2014 (in kt CO₂ eq). Positive values refer to emissions, negative values refer to removals.

2.4 Emission trends for precursor gases and SO₂

Emission trends for precursor 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 50% and 80% in emissions of precursor gases and SO₂ over the period 1990–2014. 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 the industry (FOEN 2010i, Swiss Confederation 1985, 1997).

Table 2-6 Switzerland's precursor gases and SO₂ emissions (kt), 1990–2014 (without NMVOC from LULUCF).

Precursor gases and SO ₂	1990	1995	2000							
	kt									
NO _x	143	118	107							
CO	799	534	427							
NMVOC	297	196	141							
SO ₂	40	26	15							
Precursor gases and SO ₂	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	kt									
NO _x	93	90	86	85	79	77	72	72	71	67
CO	332	307	288	277	260	249	228	221	213	196
NMVOC	101	97	94	92	90	88	85	83	82	80
SO ₂	15	14	12	12	10	10	9	9	9	8

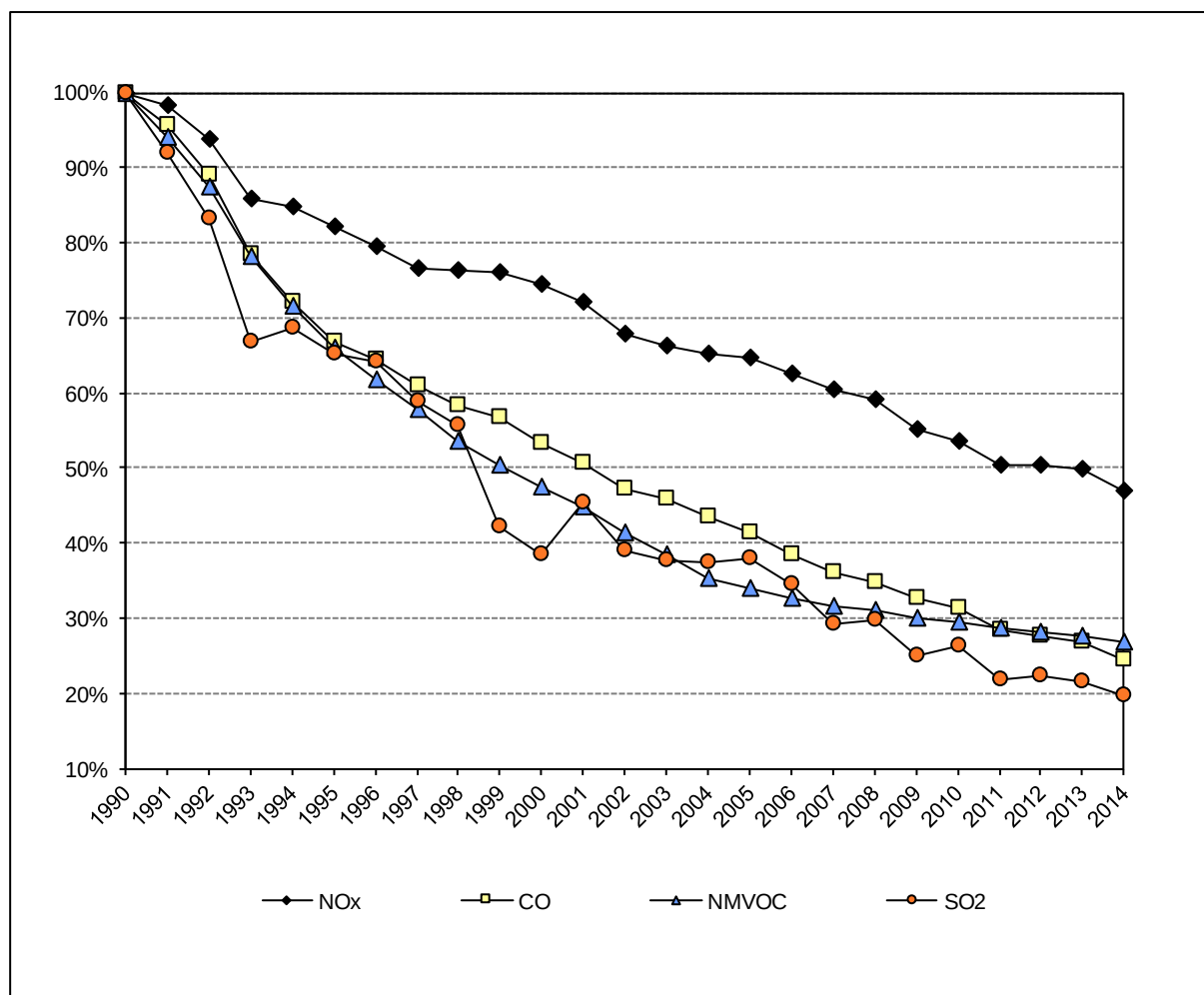


Figure 2-9 Relative trends for precursor and SO₂ emissions (without NMVOC from LULUCF), 1990–2014 (base year 1990 = 100%).

The sector 1 Energy is by far the largest source of precursor gas emissions (see Table 2-7), with the only exception being NMVOC, where sector 2 Industrial processes and product use is the dominant source (also see Figure 2-10). The total shown in Table 2-7 includes NMVOC emissions from LULUCF, which are estimated at 95.5 kt per year according to SAEFL (1996a).

Table 2-7 Precursor and SO₂ emissions (kt) by source, 2014. The total NMVOC emissions including NMVOC from LULUCF.

Sectors	NO _x		CO		NMVOC		SO ₂	
	kt	%	kt	%	kt	%	kt	%
1 Energy	63.25	94.1%	186.67	95.4%	24.65	14.1%	6.93	88.3%
2 IPPU	0.33	0.5%	5.60	2.9%	48.73	27.8%	0.81	10.3%
3 Agriculture	3.16	4.7%	NO	NO	3.91	2.2%	NO	NO
4 LULUCF	IE, NE	IE, NE	IE, NE	IE, NE	95.55	0.54	NE	NE
5 Waste	0.39	0.6%	2.58	1.3%	2.36	1.3%	0.10	1.2%
6 Other sources	0.09	0.1%	0.80	0.4%	0.13	0.1%	0.01	0.1%
Total	67.22	100.0%	195.65	100.0%	175.33	100.0%	7.84	100.0%

Figure 2-10 shows the relative contributions of the various sectors for each individual gas excluding LULUCF (data from Table 2-7).

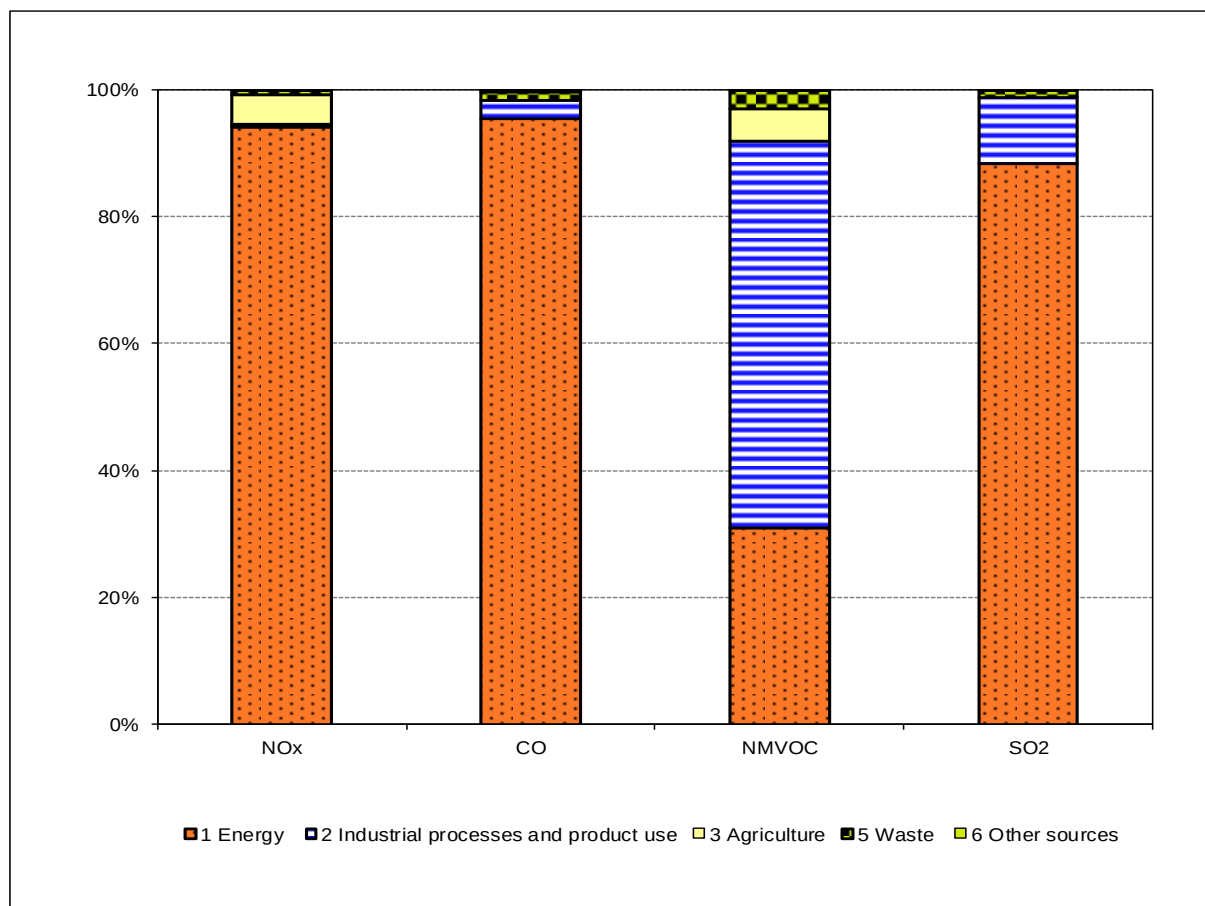


Figure 2-10 Relative contributions of individual sectors to precursor and SO₂ emissions in 2014 (without NMVOC from LULUCF).

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 are reported in the second Initial Report (FOEN 2016c).

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 Art. 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.

Table 2-8 Summary of Switzerland's GHG emissions in CO₂ equivalent (kt), 1990–2014 by sectors, excluding emissions from sectors 4 LULUCF, 6 Other and International bunkers.

Annex A sources		Sector	Base year initial report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO ₂ equivalent (kt)									
		1 Energy + indirect CO ₂ from this sector	41'881	41'881	44'316	44'304	42'115	40'982	41'890	42'789	41'808	43'347
	2 Industrial processes and product use + indirect CO ₂ from this sector	3'893	3'893	3'499	3'312	2'975	3'147	3'118	2'974	2'874	2'972	
	3 Agriculture	6'804	6'804	6'766	6'649	6'545	6'529	6'503	6'460	6'275	6'231	
	5 Waste + indirect CO ₂ from this sector	1'142	1'142	1'056	1'059	1'011	954	957	952	943	930	
	Total (Annex A sources)	53'719	53'719	55'637	55'324	52'646	51'612	52'468	53'175	51'900	53'480	

Annex A sources		Sector	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO ₂ equivalent (kt)									
		1 Energy + indirect CO ₂ from this sector	43'140	42'156	43'566	41'948	43'172	43'515	44'009	43'615	41'579	42'939
	2 Industrial processes and product use + indirect CO ₂ from this sector	3'026	3'269	3'359	3'384	3'463	3'743	3'892	3'870	3'932	4'012	
	3 Agriculture	6'137	6'123	6'187	6'153	6'077	6'056	6'098	6'133	6'191	6'298	
	5 Waste + indirect CO ₂ from this sector	918	940	955	979	958	977	969	969	954	937	
	Total (Annex A sources)	53'222	52'488	54'067	52'465	53'670	54'291	54'969	54'588	52'657	54'186	

KP-LULUCF	Art.3.3	Afforestation & reforestation										-21
		Deforestation										118
	Art.3.4	Forest management excl. HWP										-1'937
		Cropland management										NA
		Grazing land management										NA
		Revegetation										NA
		Harvested wood products (HWP)										-523

Annex A sources		Sector	2009	2010	2011	2012	2013	2014	2014 vs. 1990
			CO ₂ equivalent (kt)						%
		1 Energy + indirect CO ₂ from this sector	41'831	43'202	39'158	40'548	41'484	37'478	-11%
	2 Industrial processes and product use + indirect CO ₂ from this sector	3'907	4'122	4'157	4'160	4'182	4'198	8%	
	3 Agriculture	6'219	6'241	6'185	6'152	6'083	6'174	-9%	
	5 Waste + indirect CO ₂ from this sector	919	908	894	872	865	861	-25%	
	Total (Annex A sources)	52'876	54'472	50'394	51'733	52'614	48'711	-9%	

KP-LULUCF	Art.3.3	Afforestation & reforestation	-22	-20	-19	-18	-16		
		Deforestation	70	129	130	131	129	132	
	Art.3.4	Forest management excl. HWP	-2'881	-2'912	-1'713	-3'064	-3'067	-1'738	
		Cropland management	NA	NA	NA	NA	NA	NA	
		Grazing land management	NA	NA	NA	NA	NA	NA	
		Revegetation	NA	NA	NA	NA	NA	NA	
		Harvested wood products (HWP)	-377	-411	-257	-168	-160	-106	

Table 2-9 Switzerland's total GHG emissions (excluding 4 LULUCF, 6 Other and International bunkers) and the contribution of individual gases in CO₂ equivalent (kt), 1990–2014.

Annex A sources	GHG	Base year initial report	1990	1991	1992	1993	1994	1995	1996	1997	1998	
		CO ₂ equivalent (kt)										
		CO ₂ + indirect CO ₂	44'521	44'521	46'524	46'325	43'871	42'898	43'631	44'330	43'194	44'724
		CH ₄	6'091	6'091	6'028	5'947	5'839	5'788	5'780	5'740	5'597	5'527
		N ₂ O	2'853	2'853	2'846	2'814	2'747	2'716	2'701	2'697	2'601	2'596
		HFCs	0	0	2	16	33	82	246	298	362	457
		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	0.0	0.0	0.0	0.0	0.0
		Total (Annex A sources)	53'719	53'719	55'637	55'324	52'646	51'612	52'468	53'175	51'900	53'480

Annex A sources	GHG	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
		CO ₂ equivalent (kt)										
		CO ₂ + indirect CO ₂	44'542	43'722	45'168	43'525	44'726	45'273	45'896	45'466	43'471	44'788
		CH ₄	5'425	5'392	5'432	5'398	5'320	5'288	5'305	5'319	5'298	5'377
		N ₂ O	2'560	2'555	2'571	2'547	2'499	2'458	2'449	2'448	2'473	2'497
		HFCs	530	626	724	803	898	1'021	1'071	1'118	1'194	1'243
		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	0.0	0.0	0.0	0.0	0.1
		Total (Annex A sources)	53'222	52'488	54'067	52'465	53'670	54'291	54'969	54'588	52'657	54'186

KP-LULUCF	Art.3.3	CO ₂									94
		CH ₄									0
		N ₂ O									2.1
	Art.3.4	CO ₂									-2'465
		CH ₄									0.8
		N ₂ O									5.0

Annex A sources	GHG	2009	2010	2011	2012	2013	2014	2014 vs.1990	
		CO ₂ equivalent (kt)						%	
		CO ₂ + indirect CO ₂	43'619	45'138	41'083	42'350	43'289	39'372	-12%
		CH ₄	5'293	5'273	5'208	5'166	5'096	5'096	-16%
		N ₂ O	2'462	2'511	2'460	2'447	2'411	2'438	-15%
		HFCs	1'253	1'329	1'410	1'489	1'513	1'501	NA
		PFCs	63	65	68	71	52	44	-62%
		SF ₆	180	148	160	209	252	259	89%
		NF ₃	5.1	8.5	6.2	0.4	0.1	0.4	NA
		Total (Annex A sources)	52'876	54'472	50'394	51'733	52'614	48'711	-9%

KP-LULUCF	Art.3.3	CO ₂	46	106	109	110	115	
		CH ₄	0	0	0	0	0	
		N ₂ O	2.2	2.1	2.1	2.1	2.1	
	Art.3.4	CO ₂	-3'265	-3'328	-1'978	-3'237	-3'233	-1'850
		CH ₄	1.0	0.5	3.5	0.5	0.5	0.9
		N ₂ O	5.1	5.1	5.1	5.1	5.1	

3 Energy

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

3.1 Overview

This chapter provides information on the estimation of the greenhouse gas emissions from the sector 1 Energy. The following source categories are reported:

- 1A Fuel combustion
- 1B Fugitive emissions from fuels

In Switzerland, the sector 1 Energy is the most relevant source of greenhouse gases. The emissions of the period 1990–2014 are depicted in Figure 3-1 and Table 3-1.

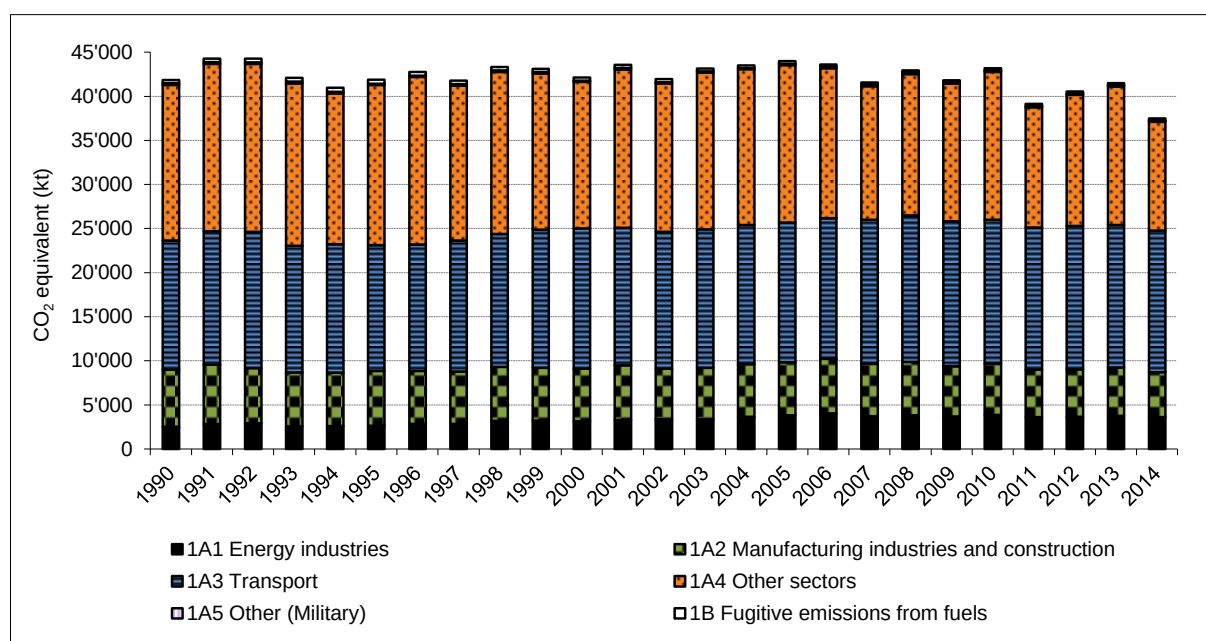


Figure 3-1 Switzerland's GHG emissions of sector 1 Energy 1990–2014 in CO₂ equivalent (kt).

Considering total emissions of sector 1 Energy, fluctuations are observed in the period 1990–2014 but there is no trend between 1990 and 2006. After 2006, a decreasing trend can be identified. 2014 shows the lowest value of the entire period 1990–2014. Four source categories dominate the emissions:

- 1A3 Transport and 1A4 Other sectors are the main sources of the sector 1 Energy.

- 1A1 Energy industries and 1A2 Manufacturing industries and construction are less important.
- 1A5 Other (Military) and 1B Fugitive emissions play only a minor role.

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

- By far the most important gas emitted from sector 1 Energy is CO₂. Fluctuations reflect inter alia the climatic variability in Switzerland (see Figure 2-7 and related comments).
- The decreasing trend of CH₄ emissions since 1990 is the result of improved gas transmission networks, 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 contribute to the decreasing trend.
- The changes in N₂O emissions can 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 N₂O as an unintended by-product in the exhaust gases, leading to an increase in N₂O emissions until 2000. With new converter materials being used, the emission factors are decreasing since 2001. For further details see chp. 3.2.9.2.2.

Table 3-1 GHG emissions of source category 1 Energy by gas in CO₂ equivalent (kt)

Gas	1990	1995	2000
	CO ₂ equivalent (kt)		
CO ₂	40'907	40'910	41'312
CH ₄	636	636	508
N ₂ O	294	317	319
Sum	41'837	41'862	42'139

Gas	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2013 to 2014	1990 to 2014
	CO ₂ equivalent (kt)										%	
CO ₂	43'357	42'989	40'986	42'342	41'249	42'603	38'601	39'994	40'933	36'960	-10%	-10%
CH ₄	416	396	371	365	352	362	334	322	309	289	-6%	-55%
N ₂ O	224	217	211	219	219	225	212	223	231	217	-6%	-26%
Sum	43'996	43'602	41'567	42'926	41'819	43'191	39'147	40'539	41'473	37'467	-10%	-10%

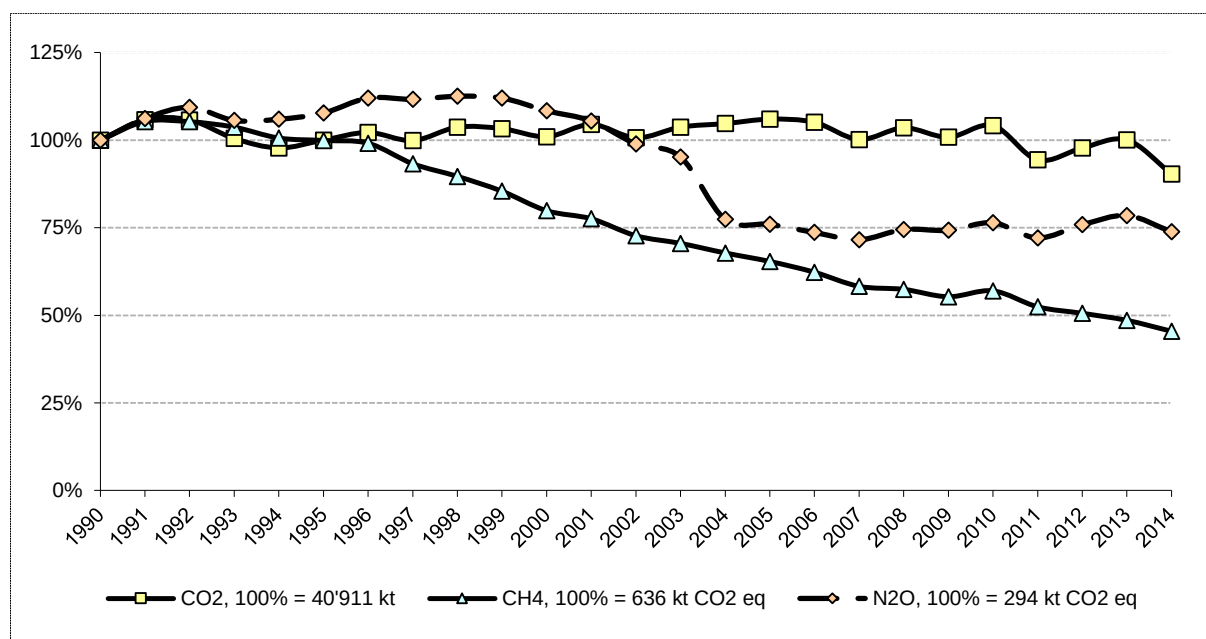


Figure 3-2 Relative trends of the greenhouse gases of sector 1 Energy in the period 1990–2014. The base year 1990 represents 100%.

The following table summarises the emissions of sector 1 Energy in 2014. The table also includes emissions from international bunkers (aviation and marine) as well as CO₂ emissions from biomass burning, which both are not accounted for under the Kyoto Protocol but are included in the reporting tables.

Table 3-2 Summary of sector 1 Energy, emissions in 2014 in kt CO₂ equivalent (Total: rounded values). For full biomass CO₂ emissions see Table 3-20.

Emissions	CO ₂	CH ₄	N ₂ O	Total
	CO ₂ equivalent (kt)			
1 Energy	36'960	289.1	217.4	37'467
1A Fuel combustion	36'927	92.3	217.1	37'237
1A1 Energy industries	3'572	1.0	28.9	3'602
1A2 Manufacturing industries and construction	5'078	5.1	33.8	5'117
1A3 Transport	15'943	21.2	97.9	16'062
1A4 Other sectors	12'197	64.7	55.2	12'317
1A5b Other (mobile)	138	0.2	1.4	139
1B Fugitive emissions from fuels	33	196.9	0.3	230
International bunkers	4'755	1.7	45.3	4'802
CO ₂ emissions from biomass	6'658	-	-	6'658

In 2014, 47 key source categories are identified in the Swiss greenhouse gas inventory according to level or trend (Table 1-10). Amongst these, 20 belong to the sector 1 Energy. The key categories (according to level and trend) from sector 1 Energy are depicted in Figure 3-3 (Approach 1) and Figure 3-4 (Approach 2). Most dominant are the CO₂ emissions from 1A3b Transport (gasoline, CO₂), 1A3b Transport (diesel oil, CO₂) and 1A4b Other sectors (liquid fuels, CO₂).

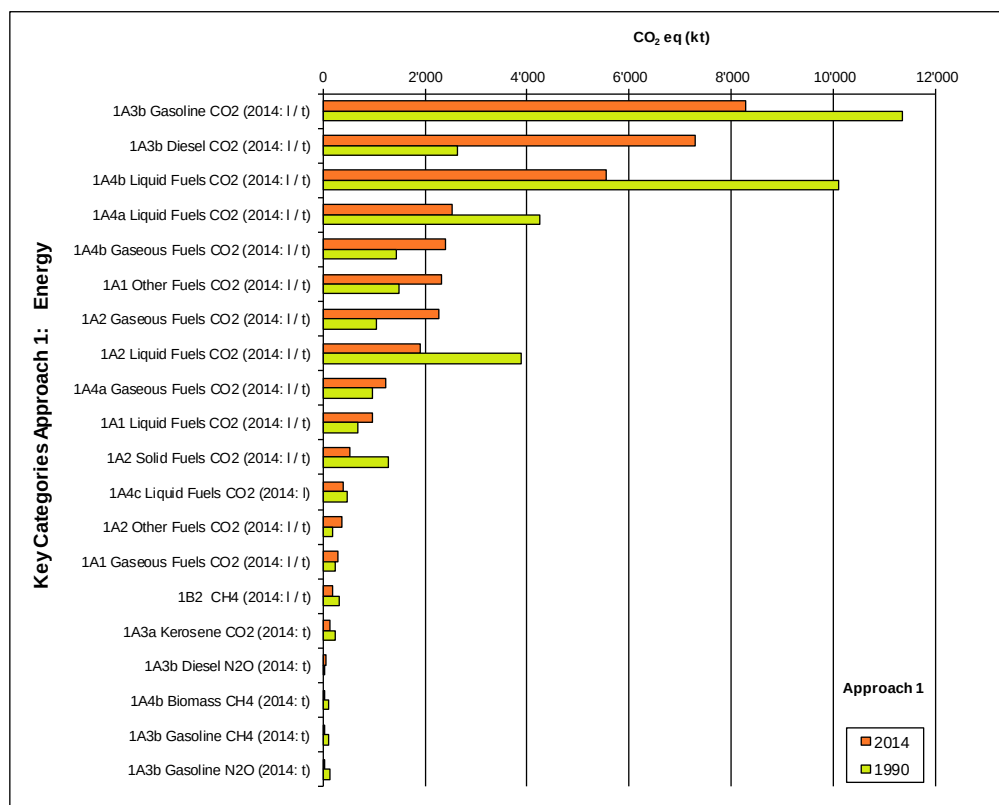


Figure 3-3 Key categories in the Swiss GHG inventory from the sector 1 Energy determined by Approach 1 (l = key category according to level in 2014; t = key category according to trend in 2014).

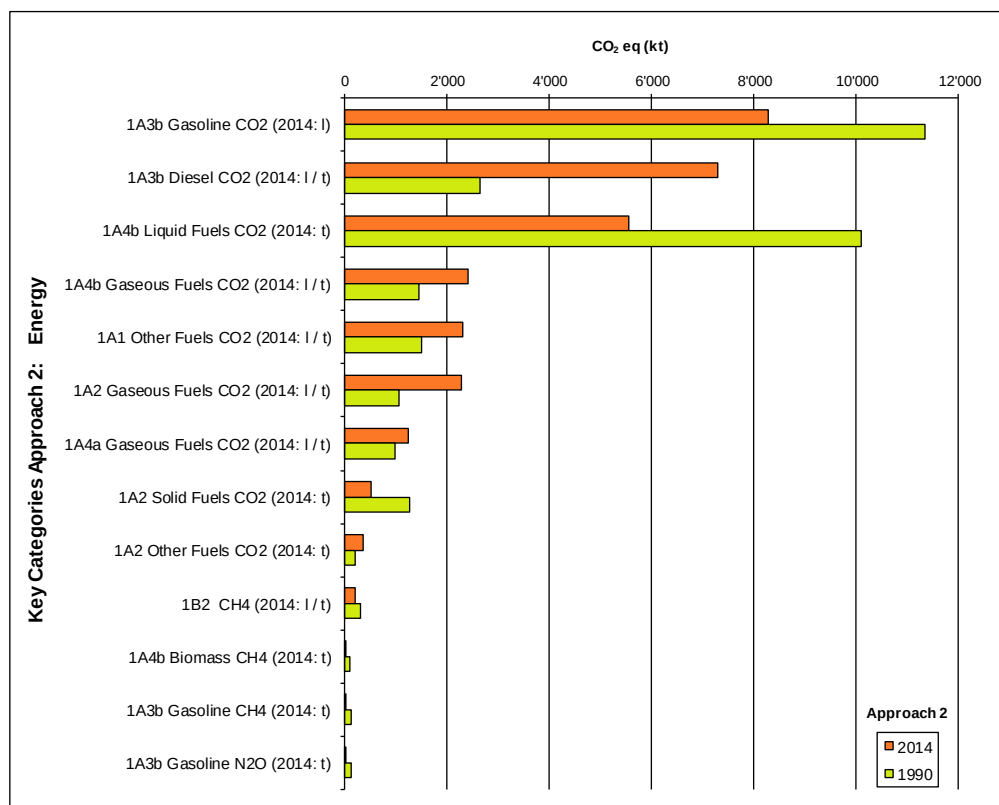


Figure 3-4 Key categories in the Swiss GHG inventory from the energy sector determined by Approach 2 (l = key category according to level in 2014; t = key category according to trend in 2014).

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 CO₂ emissions from the sector 1 Energy, 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, showing the input data used and the disaggregation of fuel types that ultimately allows for comparing the two approaches.

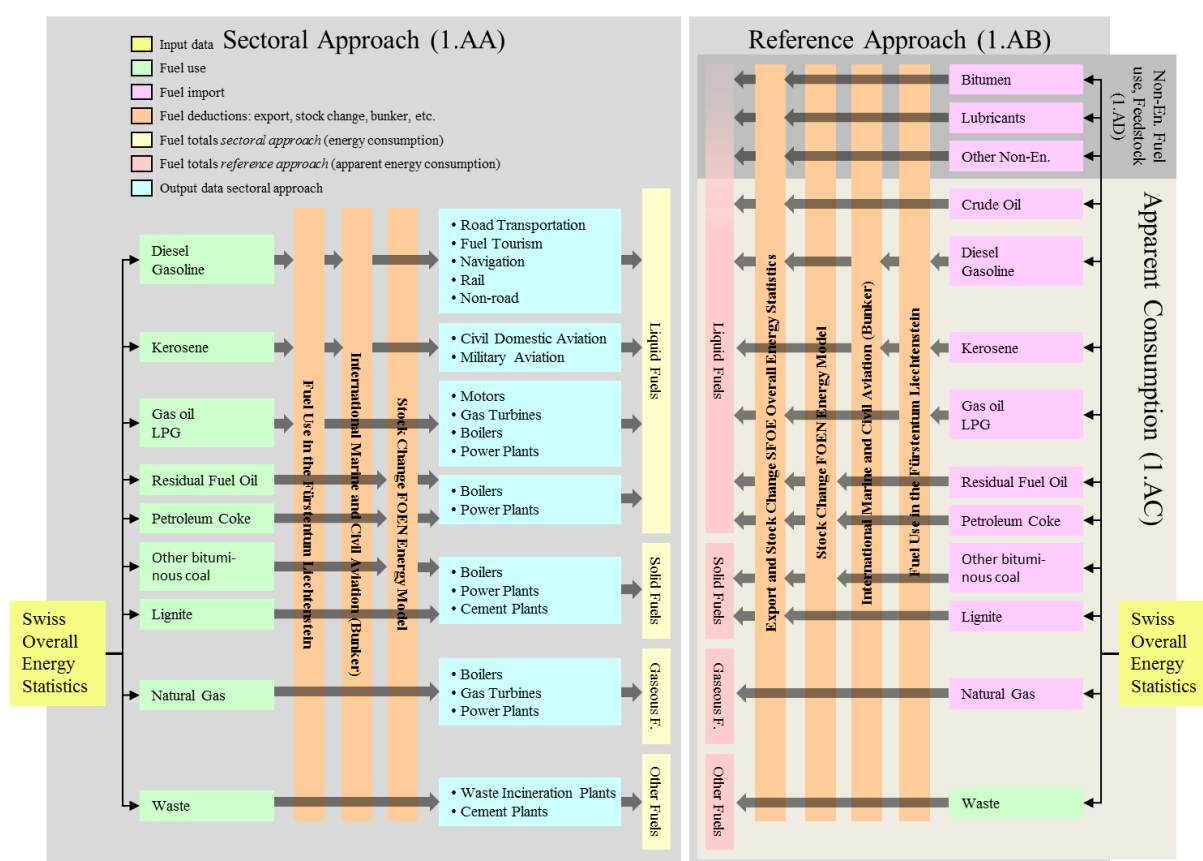


Figure 3-5 Calculation of Reference and Sectoral Approach. The input data for both approaches stem from the Swiss overall energy statistics (SFOE 2015). While the Reference Approach considers the net import/export balance, the Sectoral Approach considers the fuel consumption. The dark grey arrows depict fuel deductions where occurring.

The Sectoral Approach is based on sectoral energy consumption data from the Swiss overall energy statistics (SFOE 2015) and additional source-specific information. In the Sectoral Approach, fossil fuel consumption statistics are combined with bottom-up data and modelling of fuel consumption. A detailed description of the Sectoral Approach is provided in chp. 3.2.4.

The Reference Approach on the other hand corresponds to a top-down approach based on net quantities of fuel imported into Switzerland as listed in the energy supply statistics of the

Swiss overall energy statistics (SFOE 2015). Apparent consumption (in tonnes) is derived from imports and exports of primary fuels (crude oil, natural gas, coal²), 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 3-9 Table 3-10, Table 3-12 and Table 3-13 in chp. 3.2.4.2). After the exclusion of feedstocks and non-energy use of fuels (see chp. 3.2.3), the net carbon emissions and the effective CO₂ emissions are calculated for the Reference Approach as shown in the reporting tables 1A(b)–1A(d). The oxidation factor is set to 1 (see chp. 3.2.4.4.1). The Reference Approach covers the CO₂ emissions of all net imported primary fuels and emissions of imported secondary fuels. In 2014, 44% of all liquid fossil fuels sold in Switzerland (without kerosene) were produced in Swiss refineries (EV 2015).

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 in the EMIS database under the following conditions:

- For the Reference Approach, gas oil and diesel oil are reported together, since the reporting table template structure requires this aggregation. Accordingly, a weighted average NCV is calculated based on values given in Table 3-9. 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 (2015), as the Swiss overall energy statistics includes Liechtenstein's liquid fuel consumption (see also chp. 3.2.4).

For the previous submission (April 2015), the Reference Approach was revised and the calculation of individual fuels for the entire time series was improved. The differences in energy consumption and CO₂ emissions between Reference and Sectoral Approach are calculated within the EMIS database. Differences for the entire period are below 1% as shown in Table 3-3 and in Figure 3-6. The difference in total energy consumption of Table 3-3 and Figure 3-6 deviate from the numbers given in the reporting tables 1A(c). This is due to the fact that the reporting tables 1A(c) comprise incorrect data for the apparent energy consumption (excluding non-energy use, reductants and feedstocks) of the Reference Approach for liquid, solid and other fossil fuels yielding thus wrong numbers for the differences in energy consumption.

The difference between Reference and Sectoral Approach is influenced by various effects. On the one hand, energy and carbon contents of crude oil may vary over time. However, no data are available to quantify this effect. On the other hand, 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 4.2.

² Coking coal is included under other bituminous coal.

Table 3-3 Differences in energy consumption and CO₂ emissions between the Reference and the Sectoral Approach. The difference is calculated according to $[(RA-SA)/SA] \cdot 100\%$ with RA = Reference Approach, SA = Sectoral Approach.

	1990	1995	2000
	%		
Energy consumption	0.6	0.8	0.4
CO ₂ emissions	0.6	0.8	0.5

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	%									
Energy consumption	0.5	0.6	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3
CO ₂ emissions	0.6	0.8	0.6	0.6	0.9	0.8	0.8	0.6	0.7	0.7

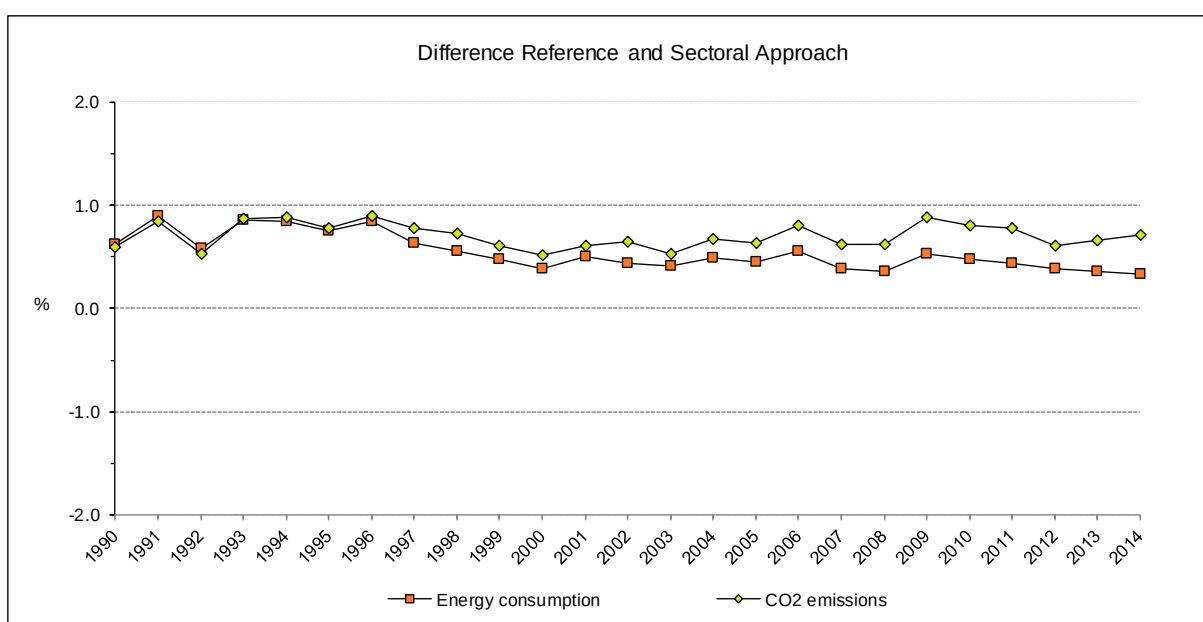


Figure 3-6 Time series for the differences between Reference and Sectoral Approach. Numbers are taken from Table 3-3. See caption there for further information.

3.2.2 International bunker fuels (1D)

3.2.2.1 Source category description for 1D

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 Source category description of International bunkers.

1D	Source	Specification
1D1	International aviation (aviation bunkers)	Bunker fuels include fuel used for international aviation only.
1D2	International navigation (marine bunkers)	Marine bunkers of the Rhine river and crossborder navigation on Lake Geneva and Lake Constance.

3.2.2.2 Methodological issues for 1D

3.2.2.2.1 International aviation/aviation bunkers (1D1)

Following the decision tree of the 2006 IPCC guidelines (IPCC 2006, Volume 2 Energy, chp. 3 Mobile Combustion, Figure 3.6.1), the emissions from aviation bunkers are calculated with a Tier 3A method because of availability of data on the origin and destination of flights and also on air traffic movements delivered by the Federal Office of Civil Aviation (FOCA).

The Tier 3A method follows standard modelling procedures at the level of single aircraft movements based on detailed movement statistics. For international aviation (aviation bunkers), the flights departing from Switzerland to a destination abroad are selected. The emission factors are country-specific based on measurement and analyses of fuel samples. The activity data of the bunker is summarised in Table 3-5 (see also Table 3-68). Given that detailed information about activity data is 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 2015). In 1990, the modelled consumption adds up to 1.01 million tonnes, whereas 1.05 million tonnes of fuel was sold. Such difference of 4% is considered acceptable, because discrepancies up to 10% can easily result from fuelling strategies of airlines (FOCA 2006a). Investigation showed, that airlines are calculating whether it is economically beneficial to refuel at a place with lower fuel price. 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 2014, the correction factor is 0.96 (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	2014
	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	44'462
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	1'561'678
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	1'606'140
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	1'549'228
Difference between FOCA and GEST	3.8%	2.6%	3.2%	3.4%	4.6%	3.2%	4.3%	3.1%	2.0%	3.7%
Correction factor	0.962	0.974	0.968	0.966	0.954	0.969	0.957	0.969	0.980	0.963

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

1D1 International aviation	1990	1995	2000
Fuel consumption in TJ			
Total international aviation (1D1)	41'884	49'918	63'687
1990 = 100%	100%	119%	152%

1D1 International aviation	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fuel consumption in TJ										
1D1 International aviation	47'671	50'109	53'543	57'844	55'238	58'118	62'211	63'627	64'709	65'006
1990 = 100%	114%	120%	128%	138%	132%	139%	149%	152%	154%	155%

3.2.2.2 International navigation / navigation bunkers (1D2)

According to the decision tree concerning navigation bunkers (IPCC 2006, Volume 2 Energy, chp. 3 Mobile Combustion, Figure 3.5.1), emissions from international navigation are calculated with a Tier 2 approach for CO₂ (with country-specific carbon contents) and with a Tier 1 approach for CH₄ and N₂O using IPCC default emission factors. On the river Rhine and on the lakes of Geneva and Konstanz, some of the boats cross the border and go abroad (Germany, France). Fuels bought in Switzerland will therefore become bunker fuel. Accordingly, the amount of bunker diesel oils is reported as a memo item "International bunker / navigation".

- Only diesel oil is relevant for navigation on the river Rhine. 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 1997–2014 (FCA 2015a).
- For navigation on two border lakes (Lake Constance, Lake Geneva), bunker fuel consumption was reported in INFRAS (2011a) after having performed surveys among the shipping companies involved. Activity data of these bunkers is summarised in Table 3-7. Data from 1995–2012 have been provided by the three navigation companies concerned 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 2014) this approach is justified. The emission factor for CO₂ is country-specific and in accordance with Table 3-12.

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

1D2 International navigation	1990	1995	2000
Fuel consumption in TJ			
1D2 International navigation	812	755	525
1990 = 100%	100%	93%	65%

1D2 International navigation	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fuel consumption in TJ										
1D2 International navigation	499	461	475	458	433	470	419	377	354	309
1990 = 100%	61%	57%	59%	56%	53%	58%	52%	46%	44%	38%

3.2.2.3 Uncertainties and time-series consistency for 1D

International aviation: see general remarks in chp. 3.2.4.7.

Consistency: Time series of 1D are all considered consistent.

3.2.2.4 Category-specific QA/QC and verification for 1D

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 3.2.4.8.

3.2.2.5 Category-specific recalculations for 1D

No category-specific recalculations were carried out in 2015 and 2016.

3.2.2.6 Category-specific planned improvements for 1D

No category-specific improvements are planned.

3.2.3 Feedstocks and non-energy use of fuels

The Swiss overall energy statistics (SFOE 2015) reports feedstocks and non-energy fuel use on an aggregated level only. Some disaggregation is provided by the petroleum balance of the annual report of the Swiss petroleum association (EV 2015). To complement this source, bottom-up information from surveys of individual companies is used to provide a detailed breakdown into specific petroleum products and coal type. For submission 2015, a new and more differentiated breakdown of feedstocks and non-energy use of fuels was 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 reporting tables 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 reporting 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 under 4.5.2.2).
- 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 under 4.5.2.1). According to the 2006 IPCC guidelines (IPCC 2006), 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 silicon 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 2015). Accordingly, activity data are confidential and included in fuel type Other oil

in reporting 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 reporting 1.A(d). The information used comes from the statistics of the Swiss petroleum association (EV 2015). Use of paraffin waxes is considered partly emissive (see source category 2D2 under 4.5.2.1). According to the 2006 IPCC guidelines (IPCC 2006), 20% of paraffin waxes are oxidized during use (ODU).
- Other oil comprises all other unspecified petroleum products for non-energy use.
- 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 reporting 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 CO₂ emissions from feedstocks and non-energy use of fuels.

Category-specific recalculations

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out in 2016.

3.2.4 Country-specific issues of 1A Fuel combustion

3.2.4.1 System boundaries: Differences between UNFCCC and CLRTAP reporting

Switzerland reports its greenhouse gas emissions according to the requirements of the UNFCCC as well as other air pollutants according to the requirements of the CLRTAP. The nomenclature for both reportings is (almost) the same (NFR), but there are differences concerning the system boundaries. Under the UNFCCC, the national total for assessing compliance is based on fuel sold within the national territory, whereas under the CLRTAP, the national total for assessing compliance is based on fuel used within the territory. Thus, fuel sold in Switzerland but consumed abroad (“fuel tourism”) is accounted for in Switzerland’s GHG inventory, but not in the reporting under the CLRTAP. The difference between the two approaches amounts to several percent, with considerable variation from

year to year due to fluctuating fuel price differences between Switzerland and its neighbouring countries.

Also emissions from civil aviation are differentiated under the UNFCCC and the CLRTAP: Only emissions from domestic flights are accounted for in the GHG inventory, while emissions from international flights are reported as memo items. For the reporting under the CLRTAP, landing and takeoff (LTO) emissions of domestic and international flights are accounted for, while emissions of international and domestic cruise flights are reported under memo items only (see Figure 3-7).

Differences between reporting under CLRTAP and UNFCCC concerning the accounting to the national total			CLRTAP / NFR-Templates			UNFCCC / CRF-Tables	
			accounted to				
			National total	National total for compliance	Memo item	National total	Bunker 1 D
Road transportation 1 A 3 b	Fuel sold in 1 A 3 b	Fuel used 1 A 3 b i-vii	Yes	Yes	Yes	Yes	No
		Fuel tourism and statistical difference 1 A 3 b viii	Yes	No	No	Yes	No
Aviation 1 A 3 a	Civil/Domestic aviation	Landing and Take-Off (LTO)	Yes	Yes	No	Yes	No
		Cruise	No	No	Yes	Yes	No
	International aviation	Landing and Take-Off (LTO)	Yes	Yes	No	No	Yes
		Cruise	No	No	Yes	No	Yes

Figure 3-7 Accounting rules for emissions from 1A3a Civil aviation and 1A3b Road transportation for CLRTAP and UNFCCC

3.2.4.2 Net calorific values (NCV)

Table 3-9 summarizes the net calorific values (NCV) which are used in order to convert from energy amounts in tonnes into energy quantities in gigajoules (GJ). For gasoline, jet kerosene, diesel oil and gas oil, values for 1998 and 2013 are based on measurements. Constant values are used for the period 1990 to 1998 and from 2013 onwards. For residual fuel oil measurements for 1998 are available. For liquefied petroleum gas, petroleum coke, other bituminous coal, lignite and wood, NCVs are given by Swiss Federal Office for Energy (SFOE 2015, 2015b) and partly by measurements from the cement industry (Cemsuisse 2010a). NCV of natural gas is annually reported by the Swiss Gas and Water Industry Association (SGWA), see Table 3-10. More detailed explanations including information about the origin of the NCV for individual energy sources are given below.

Table 3-9 Net calorific values of fuels (NCV) 1990–1998 and from 2013 onwards. For years between 1998 and 2013, the NCVs are linearly interpolated. Natural gas see Table 3-10. Data source SGWA stands for annually updated reports of the Swiss Gas and Water Industry Association, latest report is SGWA (2015).

Net calorific values (NCV)		1990-1998	≥ 2013
Fuel	Data Sources	NCV [GJ/t]	
Gasoline	EMPA (1999), SFOE/FOEN (2014)	42.5	42.6
Jet kerosene	EMPA (1999), SFOE/FOEN (2014)	43.0	43.2
Diesel oil	EMPA (1999), SFOE/FOEN (2014)	42.8	43.0
Gas oil	EMPA (1999), SFOE/FOEN (2014)	42.6	42.9
Residual fuel oil	EMPA (1999)	41.2	41.2
Liquefied petroleum gas	SFOE (2015)	46.0	46.0
Petroleum coke	SFOE (2015), Cemsuisse (2010a)	35.0	31.8
Other bituminous coal	SFOE (2015), Cemsuisse (2010a)	28.1	25.5
Lignite	SFOE (2015), Cemsuisse (2010a)	20.1	23.6
Natural gas	SGWA	see table below	
Biofuel	Data Sources	NCV [GJ/t]	
Biodiesel	assumed equal to diesel oil	42.8	43.0
Bioethanol	assumed equal to gasoline	42.5	42.6
Biogas	assumed equal to natural gas	see table below	
Wood	SFOE (2015b)	9.4-10.4	9.4-10.4

Gasoline, jet kerosene, diesel oil and gas oil

The net calorific values for gasoline, jet kerosene, diesel oil and gas oil are provided by a national measurement campaign. The campaign was realized by the EMPA (Swiss Federal Laboratories for Materials Science and Technology) in 1998 for the first time (EMPA 1999). Previous data are not available. The values for 1990–1998 are therefore assumed to be constant at the 1998 levels. An updated study, commissioned by the Federal Office for the Environment (FOEN) and the Federal Office for Energy (SFOE) was conducted in 2013 (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 amongst other. These updated values are used from 2013 onwards, while the NCVs 1999 – 2012 are linearly interpolated between the measured values of 1998 and 2013.

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 campaign in 2013. Thus, respective NCVs refer to the measurement campaign by EMPA (1999) in 1998. The NCV for residual fuel oil is assumed to be constant for the entire time series. The same approach is applied for the CO₂ emission factor (see Table 3-12).

Liquefied petroleum gas

The net calorific value (NCV) attributed to liquefied petroleum gas is taken from the Swiss overall energy statistics (SFOE 2015)³.

Petroleum coke, other bituminous coal, lignite

NCVs of petroleum coke, other bituminous coal and lignite are based on data from the SFOE and on measurements of samples taken from Switzerland's cement plants. Cement plants are the largest consumers of these fuels in Switzerland. The samples from the individual plants were compiled over nine months in 2009 and analysed for calorific value by an independent analytical laboratory. The original data is collected in an internal documentation provided by the Swiss Association of the Swiss Cement Industry – Cemsuisse (Cemsuisse 2010a). For each fuel type, the measurements from the individual plants were weighted according to the relative consumption of each plant. Between 1999 and 2010 the values are linearly interpolated (see SFOE 2015, p. 63). This approach is also used in order to derive CO₂ emission factors for the three fuels (see chp. 3.2.4.3.3).

Natural gas

The net calorific value of natural gas (and also the CO₂ emission factor of natural gas, see Table 3-13) is 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. Import shares are available for 2003, 2006, 2009 and from 2011 onwards on an annual basis. Estimated import shares for years before 2011 are taken from Quantis (2014). This study focused on gas imports of the Swiss gas grid for the years 1991, 1995 and 2000. Missing values for the years in between are interpolated. The calculation procedure is documented in FOEN (2015h).

³ It is assumed that LPG consists of 50% propane and 50% butane.

Table 3-10 Net calorific values of natural gas for selected years. Years in-between are linearly interpolated. Data source annual reports of the Swiss Gas and Water Industry Association SGWA.

Net calorific value of natural gas	
Year	NCV [GJ/t]
1990	46.5
1991	46.5
1995	47.5
2000	47.2
2005	46.6
2007	46.3
2009	46.4
2010	46.3
2011	46.1
2012	45.8
2013	45.7
2014	45.7

Wood

The net calorific value of wood depends on the wood product used as fuel (for e.g. log wood, wood chips, pellets) and are based on the Swiss wood energy statistics (SFOE 2015b).

Table 3-9 illustrates the range of the NCV for all wood types.

Biofuels

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

3.2.4.3 Swiss energy model and final energy consumption

3.2.4.3.1 Swiss overall energy statistics

The fundamental data on final energy consumption is provided by the Swiss overall energy statistics (SFOE 2015). 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, given by Liechtenstein's energy statistics (OS 2015), is subtracted from the numbers provided by the Swiss overall energy statistics. In all years of the reporting period the sum of liquid fossil fuels used in Liechtenstein was less than half a percent of the Swiss consumption.

The energy-related activity data in the energy model and thus in the GHG inventory correspond to the energy balance provided in the Swiss overall energy statistics (SFOE 2015). The energy statistics are updated annually and contain 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 (see energy balance in Annex 4).

The main data sources of the Swiss overall energy statistics are:

- The Swiss organisation for the compulsory stockpiling of oil products - Carbura (Carbura 2015) and the Swiss petroleum association (EV) for data on import, export, sales, stocks of oil products and for processing of crude oil in refineries (EV 2015).
- Annual import data for natural gas from the Swiss gas industry association (VSG 2015).
- Annual import data for petroleum products and coal from the Federal Customs Administration (FCA).
- Data provided by industry associations (GVS, SGWA, Cemsuisse, VSG, VSTB).
- Annual wood energy statistics (SFOE 2015b).
- Swiss renewable energy statistics (SFOE 2015a).
- Swiss statistics on combined heat and power generation (SFOE 2015c)

As can be seen in Figure 3-8, fossil fuels amount to slightly more than half of primary energy consumption. The main end-users of fossil fuels are the transport and the housing sector, as electricity generation is predominantly based on hydro- and nuclear power stations. The most recent energy balance is given in Annex 4.

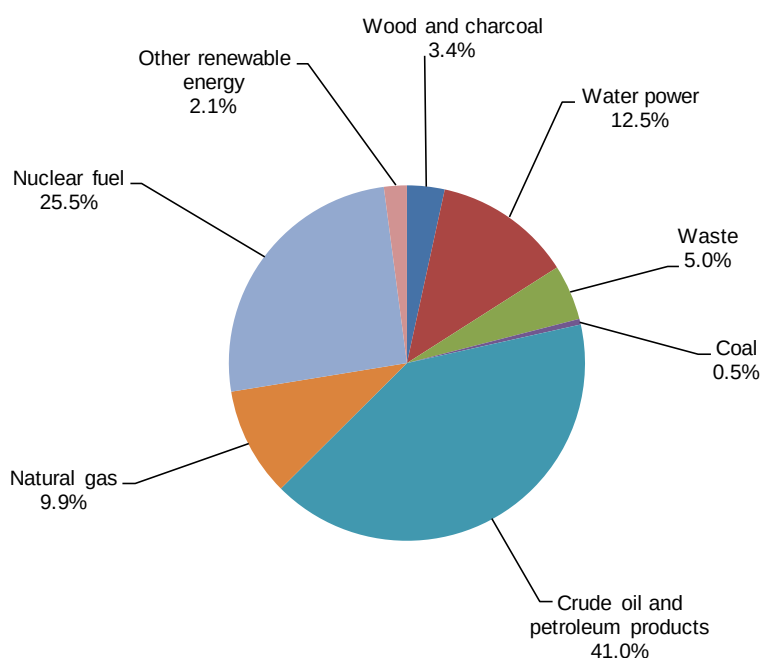


Figure 3-8 Switzerland's primary energy consumption in 2014 by fuels (see corresponding data in SFOE 2015).

Table 3-11 shows primary energy consumption but without nuclear fuel and water power. Liquid fossil fuel consumption changed only little since 1990. This is the combined effect of a marked increase of the consumption in the transport sector and a substantial decrease of gas oil use in the residential and industry sector. Natural gas consumption increased since 1990, compensating to some extent the decreasing use of gas oil.

Table 3-11 Switzerland's energy consumption in 1990–2014 by fuel type. Only those fuels are shown that are implemented in the EMIS database (no water or nuclear power). The numbers are based on the fuels sold principle, thus they include consumption from fuel tourism, all fuels sold for domestic and international aviation and liquid fuels consumed in Liechtenstein.

Year	Gasoline	Kerosene	Diesel	Gas oil	Residual fuel oil	Refinery gas & LPG	Petroleum coke	Solid fuels	Natural gas	Other fuels	Bio fuels	Total
	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ
1990	155'785	48'067	47'557	218'510	23'360	8'890	1'400	14'901	68'599	19'160	46'687	652'917
1991	162'225	46'562	48'154	238'602	23'608	12'437	980	12'662	76'902	18'596	48'682	689'409
1992	168'100	49'099	46'706	236'809	24'184	11'492	315	8'758	80'808	19'009	47'570	692'850
1993	155'897	50'776	44'978	225'920	17'180	12'388	1'120	7'342	84'758	19'158	47'849	667'365
1994	156'087	52'109	47'748	207'141	17'881	13'455	1'470	7'432	83'587	19'154	45'822	651'886
1995	151'290	54'947	48'604	217'523	17'304	12'756	1'260	7'962	92'123	19'687	47'846	671'303
1996	155'209	56'753	45'597	226'289	15'120	13'939	1'015	5'956	99'710	20'584	51'332	691'503
1997	161'171	58'774	47'385	212'223	12'607	14'236	280	4'590	96'260	21'655	48'261	677'442
1998	162'477	61'268	49'209	222'407	15'903	15'259	455	3'810	99'065	23'803	49'743	703'398
1999	168'025	65'224	52'184	212'349	11'083	15'805	521	3'875	102'588	24'403	50'471	706'529
2000	168'165	68'019	55'677	196'137	7'952	13'649	551	5'970	101'970	26'536	50'117	694'742
2001	163'543	64'150	56'709	213'089	9'970	14'069	410	6'073	106'132	27'068	53'429	714'644
2002	160'375	59'335	58'721	196'655	6'468	15'584	679	5'325	104'170	27'877	53'036	688'226
2003	159'636	53'358	62'251	208'040	7'086	13'642	202	5'713	110'116	27'643	55'491	703'179
2004	156'812	50'350	66'893	203'370	7'581	16'429	1'819	5'420	113'615	28'845	56'406	707'540
2005	152'062	50'994	73'065	205'729	5'809	16'432	2'906	6'040	116'646	29'236	58'463	717'382
2006	147'436	53'443	79'063	195'926	6'427	18'578	3'324	6'517	113'412	31'233	61'404	716'764
2007	146'012	57'010	84'885	171'356	5'150	15'587	2'830	7'296	110'395	30'015	60'262	690'800
2008	142'801	60'967	93'143	178'833	4'614	16'288	3'516	6'562	117'589	30'854	63'880	719'046
2009	138'968	58'471	94'569	173'219	3'584	16'301	3'254	6'193	112'807	29'811	63'860	701'036
2010	134'043	61'397	98'247	182'305	3'042	15'463	3'498	6'208	126'013	31'185	68'288	729'690
2011	128'856	65'438	100'876	143'760	2'311	14'856	2'957	5'842	111'774	30'882	64'724	672'277
2012	124'301	67'021	106'996	154'448	2'804	12'247	3'148	5'269	122'521	31'145	70'668	700'569
2013	118'634	68'068	111'824	162'532	1'978	15'053	2'720	5'667	129'027	30'925	74'249	720'676
2014	113'876	68'541	114'688	122'704	1'730	14'473	3'163	5'908	111'770	31'320	70'014	658'187

3.2.4.3.2 Energy model – Conceptual overview

For the elaboration of the greenhouse gas and air pollutants inventories, information about energy consumption is needed at a much more detailed level than provided by the Swiss overall energy statistics (SFOE 2015). Activity data in sector 1 Energy are therefore calculated and disaggregated by the Swiss energy model, which is an integral part of the emission database EMIS. The model is developed and updated annually by the Swiss Federal Office for the Environment (FOEN). It relies on the Swiss overall energy statistics and is complemented with further data sources, e.g. Liechtenstein's liquid fuel sales (OS 2015), the energy consumption statistics in the industry and services sectors (SFOE 2014d) as well as additional information from the industry and the Swiss wood energy statistics (SFOE 2015b).

The Swiss overall energy statistics are not only the main data input into the energy model, but also serve as calibration and quality control instrument: The total energy consumption

given by the Swiss overall energy statistics has to be equal to the sum of the disaggregated activity data of all source categories within the energy sector (including memo items/bunker). Differences are explicitly taken into account as “statistical differences” (see chp. 3.2.4.1).

As shown in Figure 3-9, the energy model consists of several sub-models, such as the industry model, the civil aviation model, the road transportation model, the non-road transportation model, and the energy model for wood combustion. A brief overview of each of these models is given below. However, depending on the scope of these sub-models, they are either described in the corresponding source category chapter or in an overarching chapter preceding the detailed description of the individual source-categories. In chp. 3.2.4.3.3, the resulting sectoral disaggregation is shown separately for each fuel type.

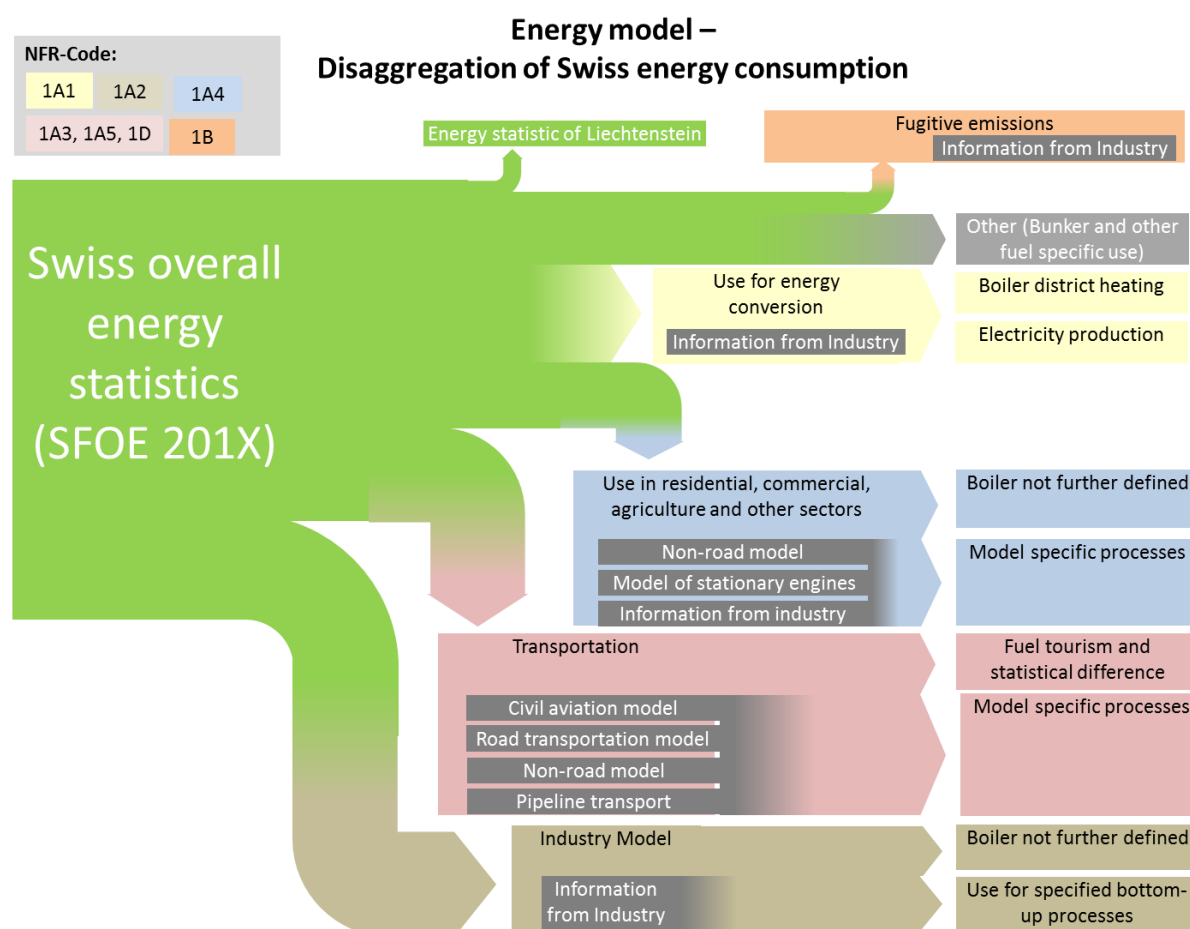


Figure 3-9 Overview of Switzerland's energy model. In the abbreviation SFOE 201X the “X” refers to the latest edition of the Swiss overall energy statistics.

Industry model (Details are given in chp. 3.2.6.2.2)

In order to produce consistent time-series, the industry model is a composite of the energy consumption statistics in the industry and services sectors (SFOE 2014d), which is based on a comprehensive annual survey, and a bottom-up industry model (Prognos 2013), which is periodically calibrated to the Swiss overall energy statistics. The resulting industry model provides a split of energy consumption by source category and fuel type. Further

disaggregation is then achieved by using plant-level industry data for specific processes, as far as available.

Civil aviation model (Details are given in chp. 3.2.9.2.1)

The civil aviation model is developed and updated by the Federal Office for Civil Aviation FOCA. It aggregates single aircraft movements according to detailed movement statistics of the Swiss airports. Differentiation of domestic and international aviation is based on the information on departure and destination of each flight in the movement database.

Road transportation model (Details are given in chp. 3.2.9.2.2)

The road transportation model is a territorial model, accounting for traffic on Swiss territory only. The model is based on detailed vehicle stock data (from the vehicle registration database of the Federal Roads Office FEDRO), mileage per vehicle category differentiated into different driving patterns and specific consumption and emission factors. The difference between fuel sales and the territorial model (road and non-road models combined) is reported under fuel tourism and statistical difference.

Non-road transportation model (Details are given in chp. 3.2.4.5.1)

The non-road transportation model covers all remaining mobile sources, i.e. industrial vehicles, construction machinery, agricultural and forestry machinery, gardening machinery as well as railways, navigation and military vehicles (except for aviation, which is considered separately (see chp. 3.2.11.2.1)). The model combines vehicle numbers, their operation hours, engine power, and load factors to derive specific fuel consumption, emission factors and resulting emissions. Data stem from surveys among producers, various user associations, and the national database of non-road vehicles run by FEDRO.

Energy model for wood combustion (Details are given in chp. 3.2.4.5.2)

Based on the Swiss wood energy statistics (SFOE 2015b), total wood consumption is disaggregated into source categories (public electricity and heat production, industry, commercial/institutional, residential, agriculture/forestry/fisheries) and into 24 different combustion installations (ranging from open fireplaces to large-scale automatic boiler or heat and power plants). Where available, industry data on wood combustion is taken into account to allocate parts of the wood consumption as given by the Swiss wood energy statistics to a specific source category.

3.2.4.3.3 Disaggregation of the energy consumption by source category and fuel types

The energy model as outlined above disaggregates total energy consumption as provided by the Swiss overall energy statistics (SFOE 2015) into the relevant source categories 1A1–1A5. For each fuel type, the disaggregation process of the energy model as shown

schematically in Figure 3-9, the interaction between the different sub-models and additional data sources are visualized separately in Figure 3-11 to Figure 3-19.

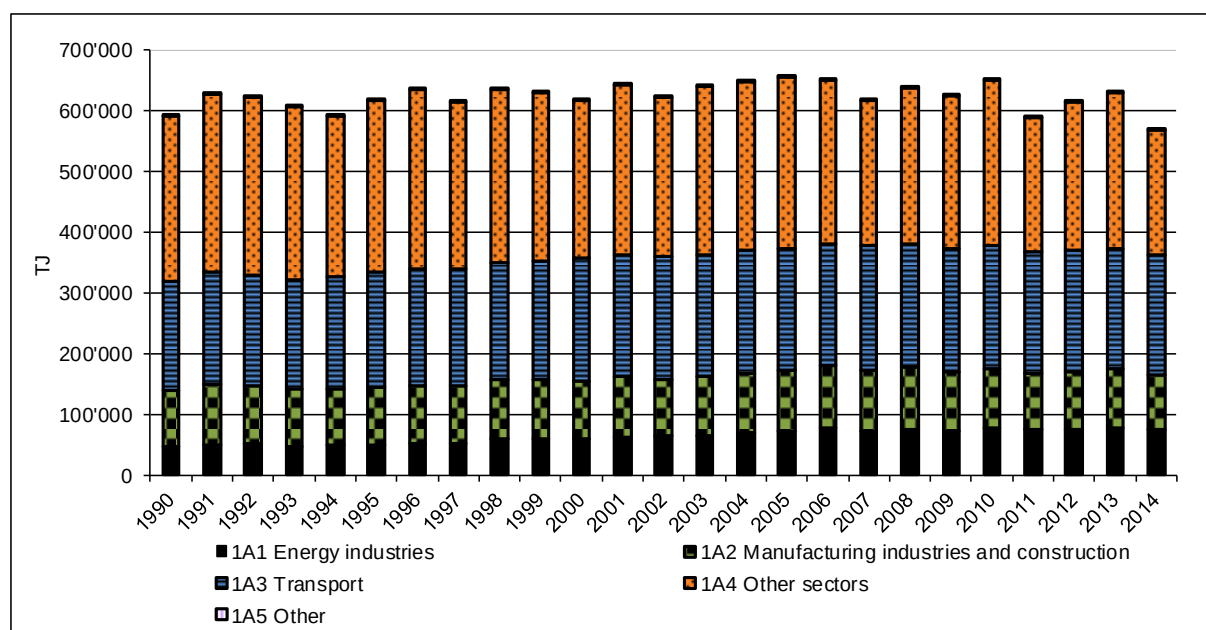


Figure 3-10: Switzerland's energy consumption 1990–2014 by source categories 1A1–1A5 as based on the Swiss energy model. In the same period population increased by about 20%, industrial production by almost 70% and the motor vehicle fleet by 50% (SFOE 2015, table 43a).

Starting from the total energy consumption from the Swiss energy statistics for each fuel type, the energy is assigned to the relevant source categories based on the various sub-models of the energy model, mentioned in chp. 3.2.4.3.2 above. In addition the following assignments are considered as well.

Within source categories 1A4a and 1A4b, the amount of gas oil and natural gas used for co-generation in turbines and engines is derived from a model of stationary engines developed by Eicher + Pauli (Kaufmann 2015) for the statistics on combined heat and power generation (SFOE 2015c). The residual energy is then assigned to boilers which are not further specified.

For source category 1A4c Other sectors – Agriculture/forestry/fishing, specific bottom-up industry information is available for grass drying. Its fuel consumption is determined by the Swiss association of grass drying plants (VSTB) and is subtracted from the total fuel consumption of 1A2.

In order to report all energy consumption, the statistical differences as reported in the Swiss overall energy statistics are allocated to source category 1A4a Other sectors – Commercial/institutional (stationary combustion) and 1A3b Fuel tourism and statistical differences.

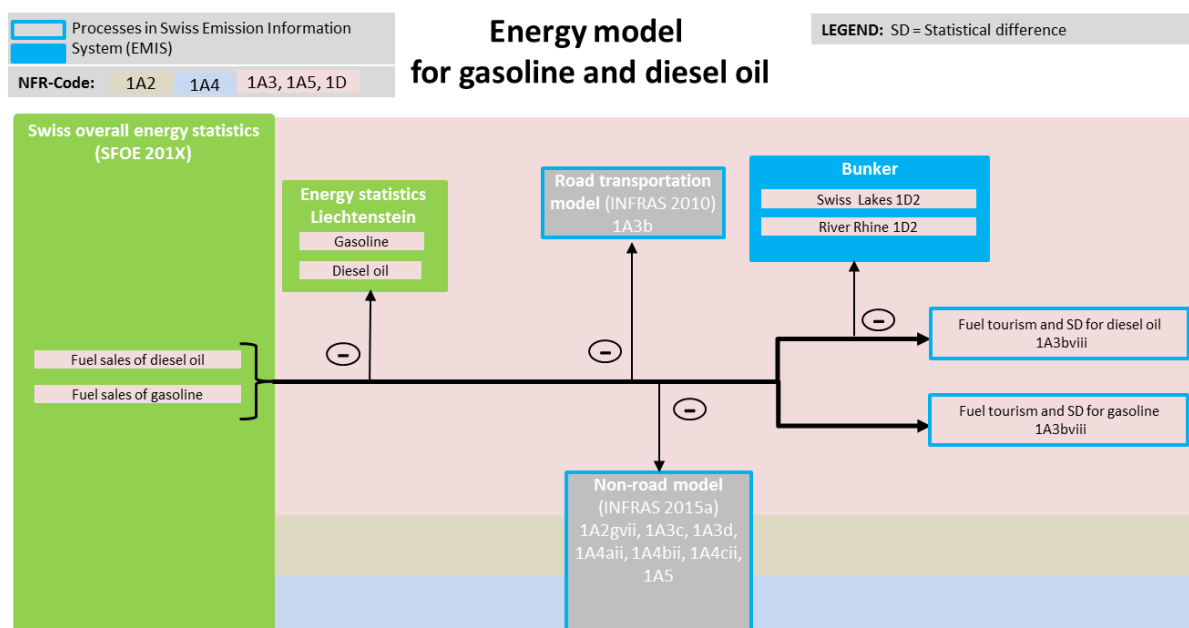


Figure 3-11: Schematic disaggregation of 1A Fuel consumption for gasoline and diesel oil. Marine bunker fuel consumption is based on the national customs statistics (see chp. 3.2.2.2.2 on memo items)

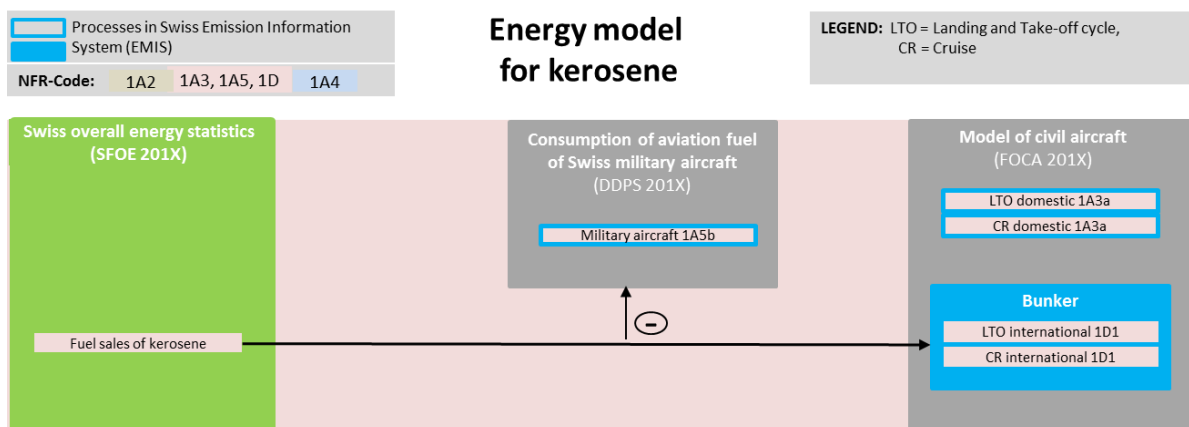


Figure 3-12: Schematic disaggregation of 1A Fuel consumption for kerosene. Fuel consumption for military aircraft is provided by the Federal Department of Defence, Civil Protection and Sport. The differentiation between domestic and international aviation as well as between CR and LTO is provided by the civil aviation model (see chp. 3.2.2.2.1)

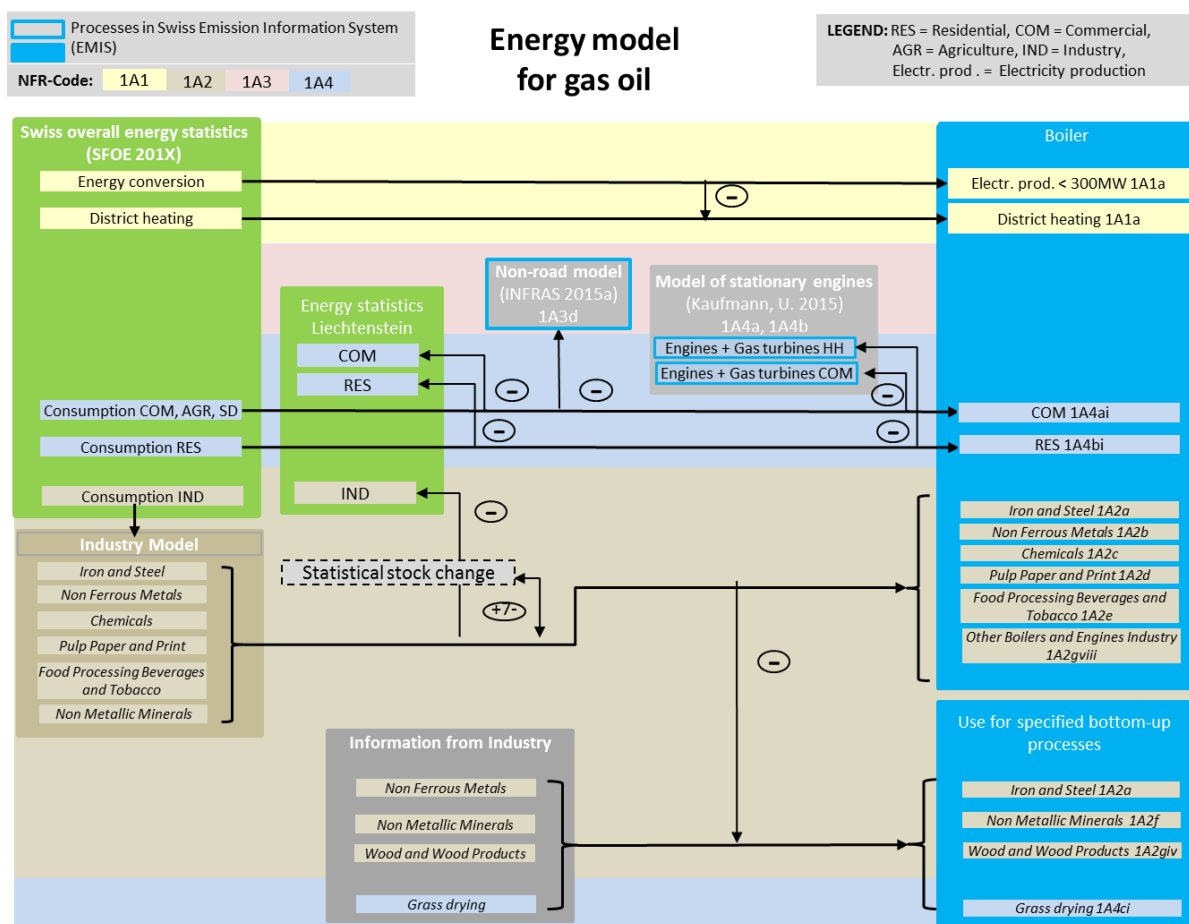


Figure 3-13: Schematic disaggregation of 1A Fuel consumption for gas oil. The Swiss overall energy statistics provide gas oil use for energy conversion and the amount thereof being used for district heating. Based on this information, gas oil use is split into 1A1a i Electricity generation and 1A1a iii Heat plants. According to the non-road model, a small amount of gas oil is consumed in source category 1A3d navigation (steam-powered vessels). This amount is subtracted from the final consumption of gas oil provided by the Swiss overall energy statistics.

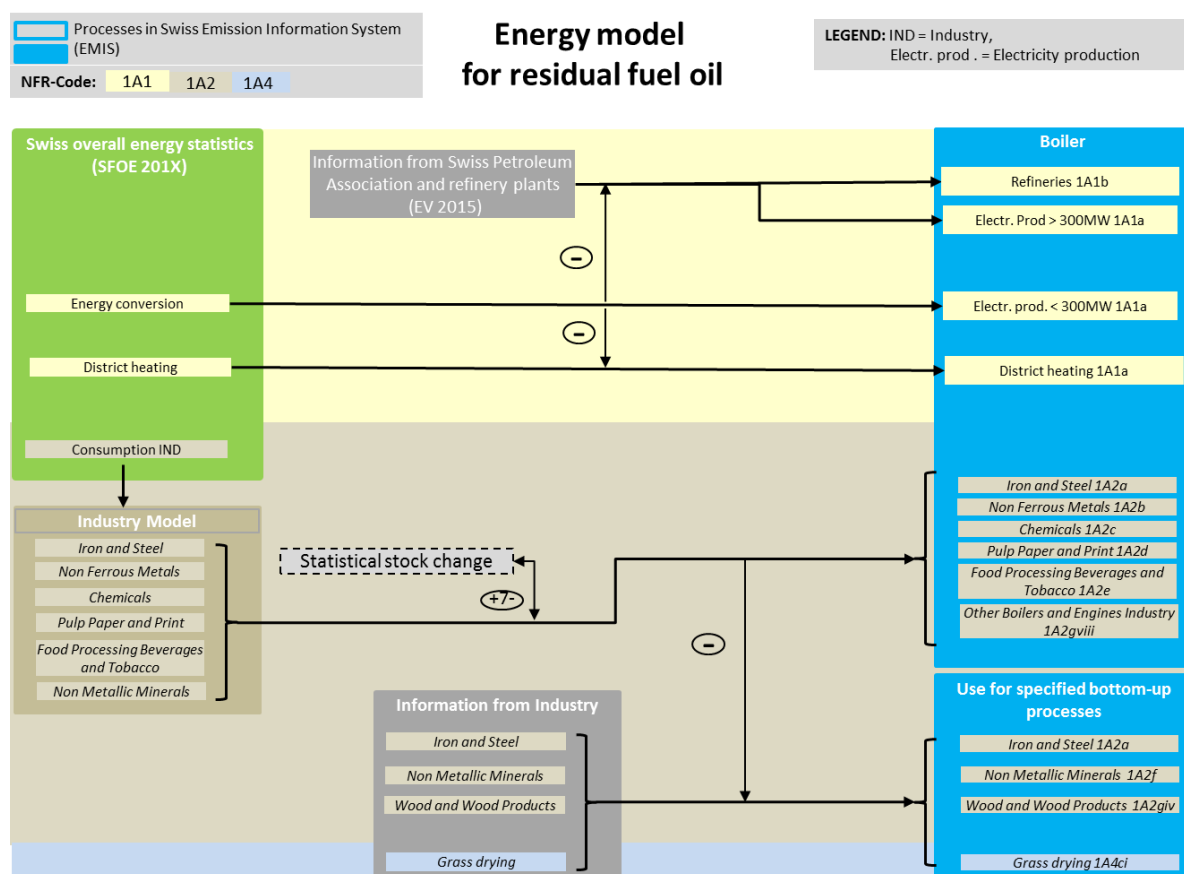


Figure 3-14: Schematic disaggregation of 1A Fuel consumption for residual fuel oil. The Swiss energy statistics report residual fuel oil use in energy conversion and the amount thereof consumed in electricity production (one single fossil fuel power station, operational from 1985 to 1994), district heating, and in petroleum refineries. Based on this information, residual fuel oil use in Energy industries is split into 1A1a i Electricity generation, 1A1a iii Heat plants and 1A1b Petroleum refining.

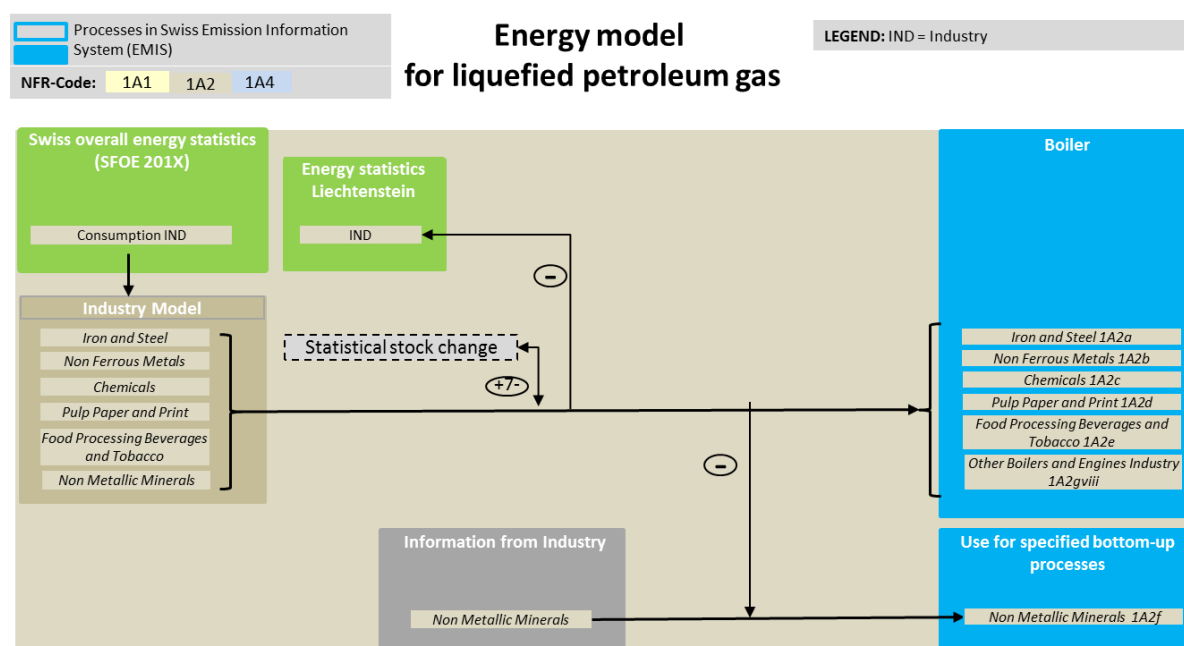


Figure 3-15 Schematic disaggregation of 1A Fuel consumption for liquefied petroleum gas (LPG).

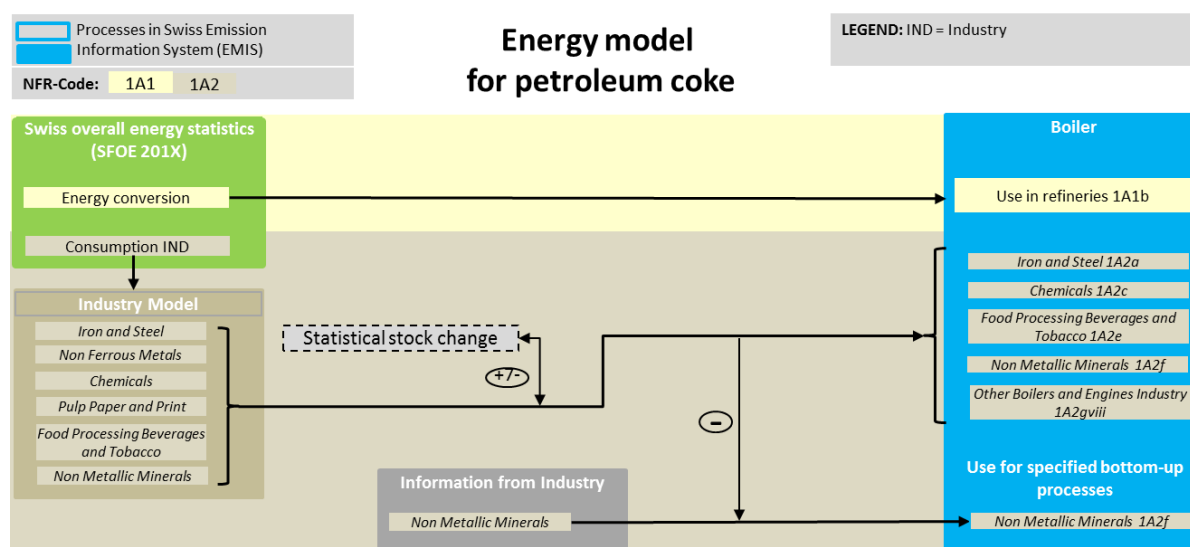


Figure 3-16: Schematic disaggregation of 1A Fuel consumption for petroleum coke.

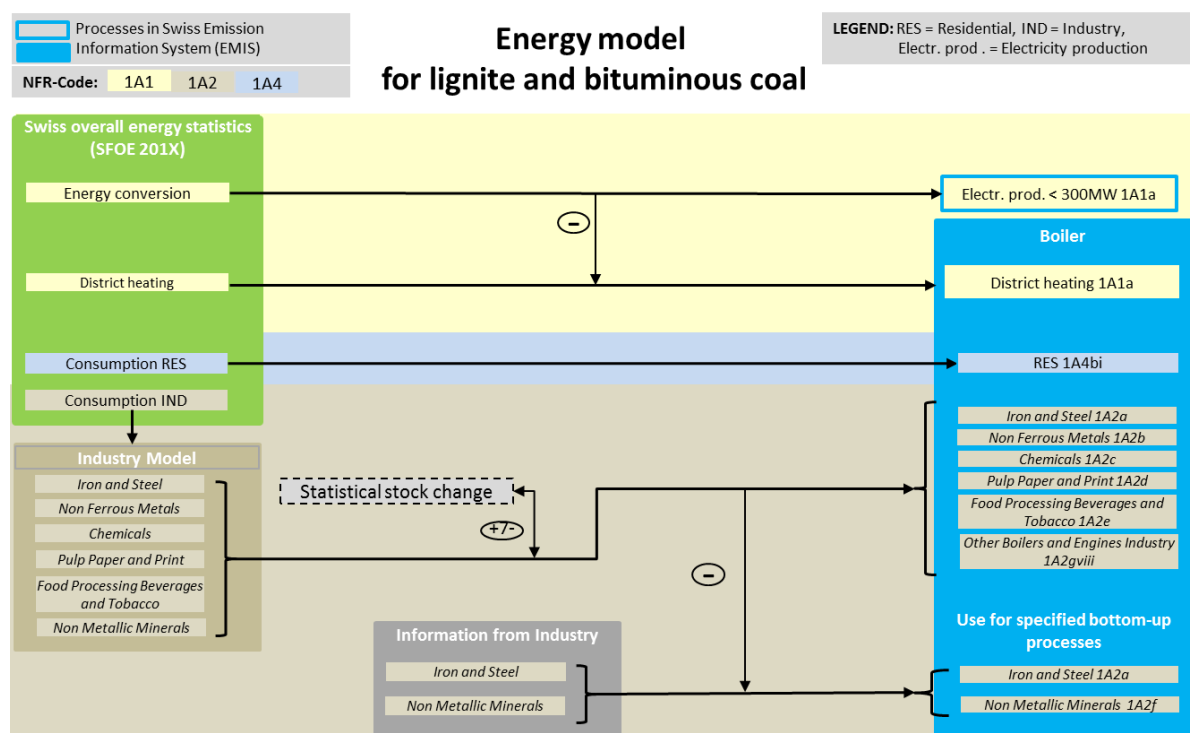


Figure 3-17: Schematic disaggregation of 1A Fuel consumption for lignite and bituminous coal. The Swiss overall energy statistics provide bituminous coal use for energy conversion and the amount thereof being used for district heating. Based on this information, use of bituminous coal in energy industries is split into 1A1a i Electricity generation and 1A1a iii Heat plants up to 1995. Coal consumption for Public electricity or heat production ceased thereafter.

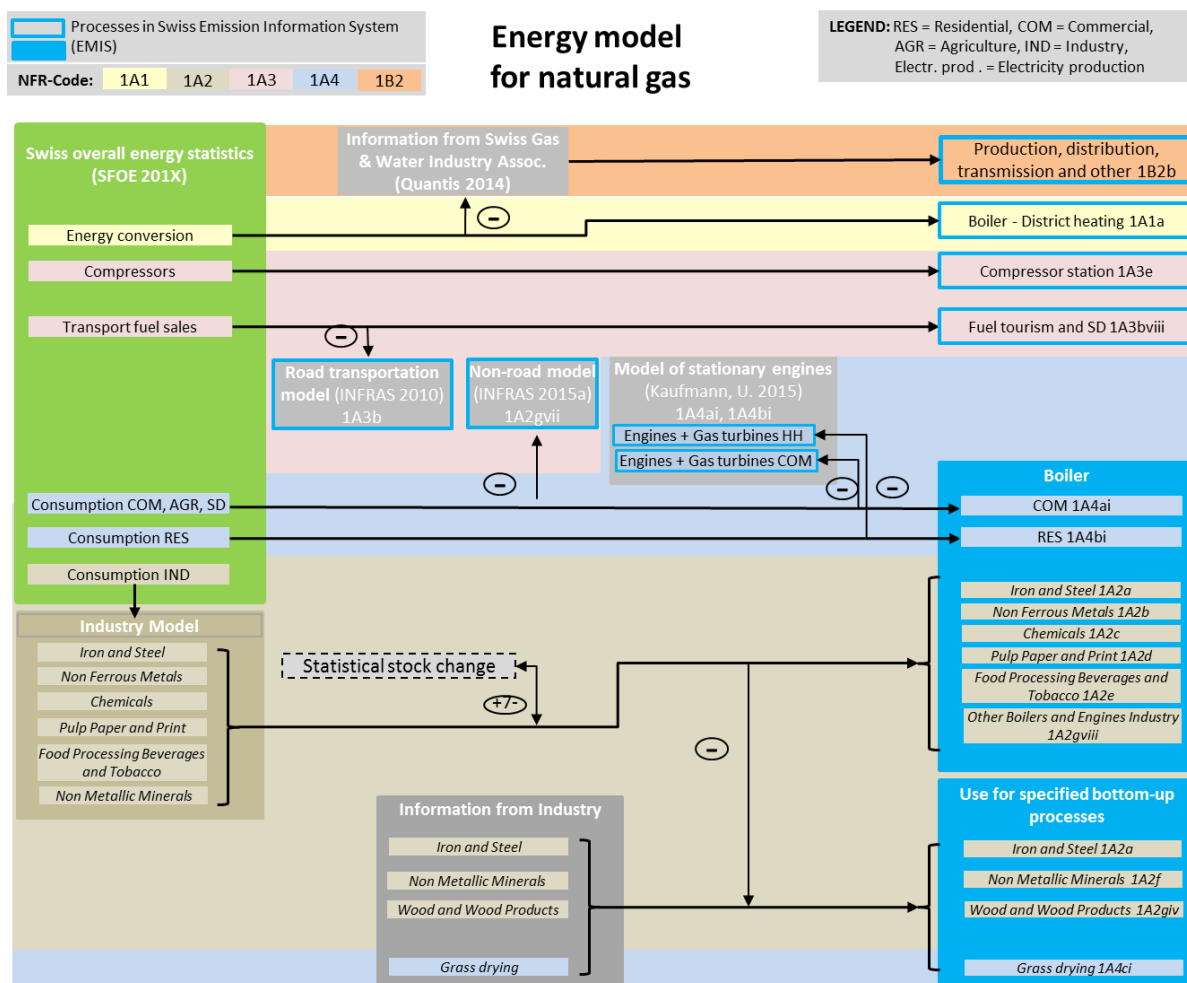


Figure 3-18: Schematic disaggregation of 1A Fuel consumption for natural gas. The Swiss overall energy statistics (SFOE 2015) provide gas use in the transformation sector (energy conversion and distribution losses). Distribution losses as estimated by the Swiss Gas and Water Industry Association SVGW are subtracted and reported under source category 1B2 Fugitive emissions from fuels. The remaining fuel consumption for natural gas is reported under 1A1a Public electricity and heat production.

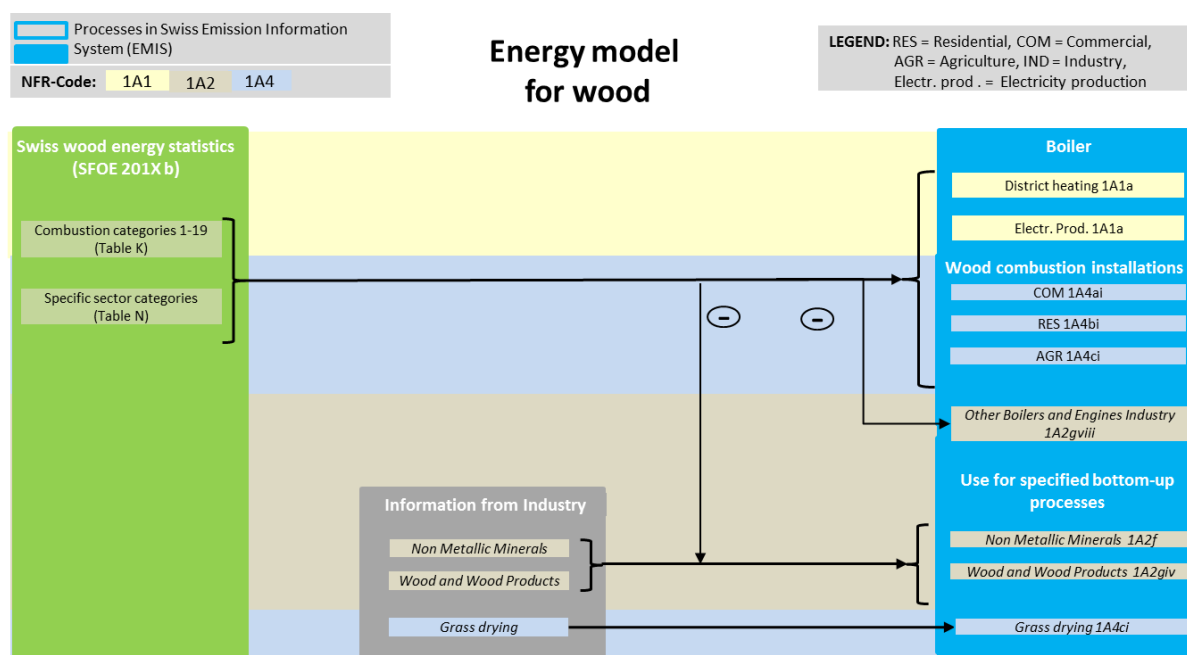


Figure 3-19: Schematic disaggregation of 1A Fuel consumption for wood. For a detailed description of the energy model for wood combustion see chp. 3.2.4.5.2.

3.2.4.4 Emission factors of 1A Fuel combustion

3.2.4.4.1 Oxidation factor for 1A Fuel combustion

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 Emissions Trading Scheme (ETS), where also a default oxidation factor of 100% was applied.

Because an oxidation factor of 100% is assumed, indirect CO₂ emissions from CO and NMVOC are implicitly reported as direct CO₂ emissions in sector 1A Energy and no indirect emissions are reported for sector 1A in chp. 9.

3.2.4.4.2 CO₂ Emission factors for 1A Fuel combustion

General CO₂ emission factors

The CO₂ emission factors applied for the time series 1990–2014 are given in Table 3-12. Detailed information regarding the underlying data and assumptions are provided in chp. 3.2.4.2 Net calorific values (NCV), since in most cases, NCVs and carbon content were determined jointly.

Table 3-12 CO₂ emission factors 1990–1998 and years from 2013 onwards. For years between 1998 and 2013, the factors are linearly interpolated. Data source SGWA stands for annually updated reports of the Swiss Gas and Water Industry Association.

CO ₂ emission factors			1990-1998	≥ 2013
Fossil fuel	CS/D	Data sources	t CO ₂ / TJ	
Gasoline	CS	EMPA (1999), SFOE/FOEN (2014)	73.9	73.8
Jet kerosene	CS	EMPA (1999), SFOE/FOEN (2014)	73.2	72.8
Diesel oil	CS	EMPA (1999), SFOE/FOEN (2014)	73.6	73.3
Gas oil	CS	EMPA (1999), SFOE/FOEN (2014)	73.7	73.7
Residual fuel oil	CS	EMPA (1999)	77.0	77.0
Liquefied petroleum gas	CS	FOEN (2015d)	65.5	65.5
Petroleum coke	CS	Cemsuisse (2010a)	91.4	91.4
Other bituminous coal	CS	Cemsuisse (2010a)	92.7	92.7
Lignite	CS	Cemsuisse (2010a)	96.1	96.1
Natural gas	CS	SGWA	see table below	
Biofuel	CS/D	Data sources	t CO ₂ / TJ	
Biodiesel	CS	assumed equal to diesel oil	73.6	73.3
Bioethanol	CS	assumed equal to gasoline	73.9	73.8
Biogas	CS	assumed equal to natural gas	see table below	
Wood	CS	Cemsuisse (2010a)	99.9	99.9

CO₂ emission factors for natural gas

Table 3-13 Time series of CO₂ emission factors of natural gas. SGWA refers to annual updates of properties of natural gas that are provided by the Swiss Gas and Water Industry Association.

CO ₂ emission factors			1990	1995	2000
Fuel	CS/D	Data sources	t CO ₂ / TJ		
Natural gas/Biogas	CS	SGWA	56.1	55.7	56.2

CO ₂ emission factors			2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fuel	CS/D	Data sources	t CO ₂ / TJ									
Natural gas/Biogas	CS	SGWA	56.4	56.5	56.5	56.5	56.4	56.4	56.6	56.5	56.4	56.7

CO₂ emission factors for wood

The CO₂ emission factor for wood combustion activities is taken from Cemsuisse (2010a).

3.2.4.4.3 CH₄ Emission factors for 1A Fuel combustion

General CH₄ emission factors

An overview of the general CH₄ emission factors is given in Table 3-14. These emission factors are used for most stationary combustion processes (exceptions are discussed in the detailed sectoral chapters where they occur). For stationary combustion, mainly IPCC default emission factors are used for the entire time period. For wood, country-specific factors are used. Details are given below in Table 3-15. CH₄ emission factors related to transport activities (aviation, road and non-road transportation) are category specific and given in the corresponding chapters.

Table 3-14 CH₄ emission factors for stationary combustion for the whole time period.

CH ₄ emission factors			1990-2014
Fuel	CS/D	Data sources	g CH ₄ / GJ
Gas oil	D	IPCC (2006)	3
Residual fuel oil	D	IPCC (2006)	3
Liquefied petroleum gas	D	IPCC (2006)	3
Petroleum coke	D	IPCC (2006)	1
Other bituminous coal	D	IPCC (2006)	1
Lignite	D	IPCC (2006)	10
Natural gas	D	IPCC (2006)	10
Biofuel	CS/D	Data Sources	
Biogas	D	IPCC (2006)	1
Wood	CS	Nussbaumer and Hälgi (2015)	1.3 - 240

CH₄ emission factors for wood

There are many different combustion installations in use which have very different CH₄ emission factors. A detailed overview of all applied wood related CH₄ emission factors for the entire time series is given in Table 3-15.

The CH₄ emission factor for each combustion type is modelled based on VOC measurements at wood combustion installations (Nussbaumer and Hälgi 2015), assuming a CH₄ to VOC ratio of 0.4.

The EF for the different combustion installations varies between 1.8 and 240 g CH₄/GJ depending on the year, 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 gradually decreasing emission factors.

Table 3-15 CH₄ emission factors for wood combustion installations.

1A Wood combustion	Unit	CH ₄		
		1990	1995	2000
Open fireplaces	g/GJ	160	149	138
Closed fireplaces, log wood stoves	g/GJ	160	149	138
Pellet stoves	g/GJ	16.0	14.9	13.8
Log wood hearths	g/GJ	240	229	218
Log wood boilers	g/GJ	200	161	122
Log wood dual chamber boilers	g/GJ	240	229	218
Automatic chip boilers < 50 kW	g/GJ	20.0	16.7	13.3
Automatic pellet boilers < 50 kW	g/GJ	6.7	5.6	4.5
Automatic chip boilers 50-500 kW w/o wood proc. companies	g/GJ	20.0	16.3	12.6
Automatic pellet boilers 50-500 kW	g/GJ	6.7	5.4	4.1
Automatic chip boilers 50-500 kW within wood proc. companies	g/GJ	20.0	16.3	12.6
Automatic chip boilers > 500 kW w/o wood proc. companies	g/GJ	13.3	10.7	8.1
Automatic pellet boilers > 500 kW	g/GJ	6.7	5.4	4.1
Automatic chip boilers > 500 kW within wood proc. companies	g/GJ	13.3	10.7	8.1
Combined chip heat and power plants	g/GJ	13.3	10.7	8.1
Plants for renewable waste from wood products	g/GJ	13.3	10.7	8.1

1A Wood combustion	Unit	CH ₄									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Open fireplaces	g/GJ	127	124	122	120	120	120	120	120	120	120
Closed fireplaces, log wood stoves	g/GJ	127	124	122	120	117	113	110	107	103	100
Pellet stoves	g/GJ	12.7	12.4	12.2	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Log wood hearths	g/GJ	207	204	202	200	193	187	180	173	167	160
Log wood boilers	g/GJ	83	76	68	60	58	57	55	53	52	50
Log wood dual chamber boilers	g/GJ	207	204	202	200	193	187	180	173	167	160
Automatic chip boilers < 50 kW	g/GJ	10.0	9.3	8.7	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Automatic pellet boilers < 50 kW	g/GJ	3.4	3.1	2.9	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Automatic chip boilers 50-500 kW w/o wood proc. companies	g/GJ	8.9	8.2	7.4	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Automatic pellet boilers 50-500 kW	g/GJ	2.8	2.5	2.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Automatic chip boilers 50-500 kW within wood proc. companies	g/GJ	8.9	8.2	7.4	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Automatic chip boilers > 500 kW w/o wood proc. companies	g/GJ	5.6	5.0	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Automatic pellet boilers > 500 kW	g/GJ	2.8	2.5	2.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Automatic chip boilers > 500 kW within wood proc. companies	g/GJ	5.6	5.0	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Combined chip heat and power plants	g/GJ	5.6	5.0	4.5	4.0	3.6	3.1	2.7	2.2	1.8	1.3
Plants for renewable waste from wood products	g/GJ	5.6	5.0	4.5	4.0	3.6	3.1	2.7	2.2	1.8	1.3

3.2.4.4.4 N₂O Emission factors for 1A Fuel combustion

Table 3-16 shows the N₂O emission factors in source category 1A. Most N₂O emission factors are kept constant over the whole period, with the exception for 1A1a Waste incineration (see Table 3-30). N₂O emission factors related to transport activities (aviation, road and non-road transportation) are category specific and given in the corresponding chapters.

Table 3-16 N₂O emission factors. Default emission factors are used for all fuels for the whole time period.

N ₂ O emission factors			
Fuel	CS/D	Data sources	g N ₂ O / GJ
Gas oil	D	IPCC (2006)	0.6
Residual fuel oil	D	IPCC (2006)	0.6
Liquefied petroleum gas	D	IPCC (2006)	0.1
Petroleum coke	D	IPCC (2006)	0.6
Other bituminous coal	D	IPCC (2006)	1.5
Lignite	D	IPCC (2006)	1.5
Natural gas	D	IPCC (2006)	0.1
Biofuel	CS/D	Data sources	
Biogas	D	IPCC (2006)	0.1
Wood	D	IPCC (2006)	4

3.2.4.5 Models overlapping more than one source category

3.2.4.5.1 Non-road transportation model (excl. aviation)

Choice of method

- The GHG emissions are calculated by a Tier 3 method based on the decision tree Fig. 3.3.1 in chp. 3. Mobile Combustion in IPCC (2006), complemented with
- Tier 2 for railways CO₂, Fig. 3.4.1 in IPCC (2006)
- Tier 3 for railways CH₄, N₂O and precursors / SO₂, Fig. 3.4.2 in IPCC (2006)
- Tier 2 for navigation, Fig. 3.5.1 (Box 1) in IPCC (2006)

Methodology

The emissions of the non-road sector underwent an extended revision in 2014/2015, resulting in an update of GHG emissions including precursors and SO₂. Emission factors and activity data were updated and additional machinery types included, e.g. power generators in all industry branches (not only construction sites), airside vehicles and machinery at international airports (reported under industrial vehicles), freight ships on the river Rhine (reported under domestic navigation). Results are documented in FOEN (2015j). The non-road categories considered are listed in Table 3-17. All of them include several technologies (diesel oil, 2- or 4-stroke gasoline, natural gas, gas oil), and emission standards according to the classification shown in Figure 3-20.

Table 3-17 Non-road categories as specified in FOEN (2015j) and the corresponding nomenclature in the CRF.

Non-road categories (by Corinair)	Nomenclature CRF
Construction machinery	1.A.2.g.vii Off-road vehicles and other machinery
Industrial machinery	1.A.2.g.vii Off-road vehicles and other machinery
Railway machinery	1.A.3.c. Railways
Navigation machinery	1.A.3.d. Domestic Navigation
Garden-care/professional appliances	1.A.4.a.ii Commercial/institutional, Off-road vehicles and other machinery
Garden-care/hobby appliances	1.A.4.b.ii Residential, Off-road vehicles and other machinery
Agricultural machinery	1.A.4.c.ii Agriculture/forestry/fishing, Off-road vehicles and other machinery
Forestry machinery	1A.4.c.ii Agriculture/forestry/fishing, Off-road vehicles and other machinery
Military machinery (excl. aviation)	1.A.5.b Other, mobile, Military

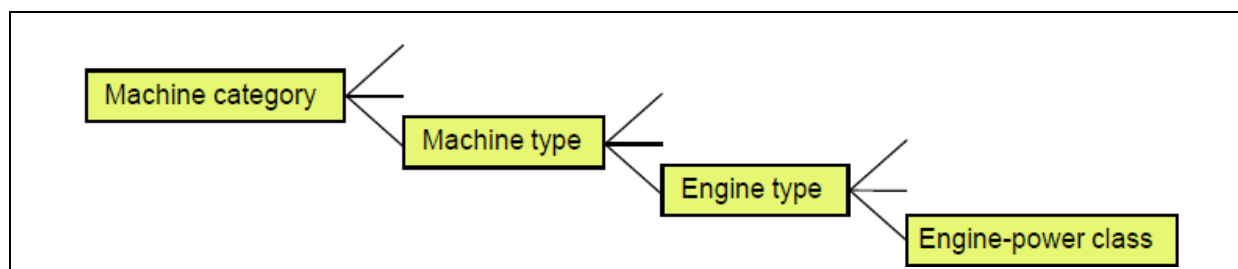


Figure 3-20: Each non-road vehicle is classified by its engine-power class, engine type, machine type and machine category (INFRAS 2015a).

The emission modelling is based on activity data and emission factors by means of the following equation, which holds on the most disaggregated level of engine power class (Figure 3-20):

$$Em = N \cdot H \cdot P \cdot \lambda \cdot \varepsilon \cdot CF_1 \cdot CF_2 \cdot CF_3 \cdot$$

with

Em	=	emission per engine type (in g/a)
N	=	number of vehicles (--)
H	=	number of operation hours per year (h/a)
P	=	engine power output (kW)
λ	=	effective load factor (--)
ε	=	emission factor (g/kWh)
CF_1	=	correction factor for the effective load (--)
CF_2	=	correction factor for dynamical engine use (--)
CF_3	=	degradation factor due to aging (--)

With this equation, the emissions of the following gases are calculated:

- GHG: CH₄, N₂O
- precursor gases: NO_x, CO
- air pollutant: VOC
- fuel consumption: in this case, ε represents the consumption instead of emission factor (in g/kWh)
- For other gases, the following method is applied:
- CO₂ is calculated as product of fuel consumption and CO₂ emission factors (Table 3-12)
- SO₂ is calculated as product of fuel consumption and SO₂ emission factors (Table A – 18)

- NMVOC is calculated as the difference between VOC and CH₄

The total emission and consumption per non-road category is calculated by summing over all engine-power classes, engine types, and machine types.

Emissions are only calculated in steps of 5 years 1980, 1985, 1990, ... 2050. Emissions for years in-between (1981, 1982 etc.) are interpolated linearly. A more detailed description of the analytical details is given in the Annex of FOEN (2015j).

Emission factors

Emission factors are taken from various sources based on measurement, modelling and literature.

- CO₂ and SO₂ emission factors are country-specific, see Table 3-12 and Table A – 18
- For other gases, the main data sources are EPA (2010), IFEU (2010), EMEP/EEA (2013) and Integer (2013).

For a detailed description of emission factors and their origin, see tables in the annex of FOEN (2015j) and online in the database belonging to INFRAS (2015a)⁴.

Activity data

Activity data were collected by surveys among producers and several user associations in Switzerland (FOEN 2015j), and by evaluating information from the national database of non-road vehicles (MOFIS) run by the the Federal Roads Office (FEDRO 2014). In addition, several publications serve as further data sources:

- SBV (2013) for agricultural machinery
- SFSO (2013a) for agricultural machinery
- Jardin Suisse (2012) for garden care /hobby and professional appliances
- KWF (2012) for forestry machinery
- The national statistics on imports/exports of non-road vehicles was assessed by EZV (2015a)
- Off-Highway Research (2005, 2008, 2012) provided information on the number of non-road vehicles.
- Federal Department of Defence, Civil Protection and Sport: List of military machinery with vehicle stock, engine-power classes and operating hours (DDPS 2014a).

⁴ <http://www.bafu.admin.ch/luft/00596/06906/offroad-daten/index.html?lang=en>

From these data sources, all necessary information was developed like size distributions, modelling of the fleets, annual operating hours (age-dependent), load factors, year of placing on the market and age distribution. Details are documented in FOEN (2015j). All activity data (vehicle stocks, operating hours, consumption factors) can be downloaded by query from the public part of the non-road database INFRAS (2015a), which is the data pool of FOEN (2015j). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels.

3.2.4.5.2 Energy model for wood combustion

Choice of method

The emissions from wood combustion in 1A Fuel cocombustion activities are calculated by a Tier 2 method based on the decision tree for stationary fuel combustion (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1 on page 2.15).

Methodology

The Swiss wood energy statistics (SFOE 2015b) provides both the annual wood consumption for specified categories of combustion installations (table K, categories 1–19), see Table 3-18 below, 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 at the level of combustion installation categories directly to the source categories 1A1a Public electricity and heat production, 1A2gviii Other, 1A4ai Commercial/Institutional, 1A4bi Residential and 1A4ci Agriculture/forestry/fishing (EMIS 2016/1A Holzfeuerungen).

Table 3-18 Categories of wood combustion installations based on SFOE 2015b.

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

Emission Factors

Emission factors are described in chp. 3.2.4.4.2 for CO₂, 3.2.4.4.3 for CH₄, and 3.2.4.4.4 for N₂O.

Activity Data

Total activity data are based on the Swiss wood energy statistics (SFOE 2015b). As additional data source, specific bottom-up information from the industry is used in order to allocate wood combustion emissions directly to a particular source category. Thus, activity data of wood combustion within 1A2f, 1A2giv and 1A4ci are allocated on the basis of industry information (see Figure 3-19 and EMIS 2015/1A Holzfeuerungen):

- Wood energy consumption in source categories 1A2f Brick and tile production, 1A2f Cement production and 1A2giv Fibreboard are subtracted from the activity data of 1A2gviii Automatic chip boiler >500 kW without wood processing companies and 1A2gviii Plants for renewable waste from wood products, respectively.
- Since 2013, also the wood energy consumption in 1A4ci Grass drying is available and has been subtracted from the activity data in 1A4ci Automatic chip boiler >500 kW without wood processing companies.

Table 3-19 Wood energy consumption in 1A Fuel combustion.

1A Wood combustion	Unit	1990	1995	2000
Total	TJ	28'168	29'454	27'070
Open fireplaces	TJ	227	271	196
Closed fireplaces, log wood stoves	TJ	7'275	7'178	6'493
Pellet stoves	TJ	0	0	7
Log wood hearths	TJ	8'524	7'030	4'744
Log wood boilers	TJ	5'308	5'571	5'109
Log wood dual chamber boilers	TJ	1'964	1'779	978
Automatic chip boilers < 50 kW	TJ	239	434	550
Automatic pellet boilers < 50 kW	TJ	0	0	56
Automatic chip boilers 50-500 kW w/o wood proc. companies	TJ	690	1'327	1'786
Automatic pellet boilers 50-500 kW	TJ	0	0	2
Automatic chip boilers 50-500 kW within wood proc. companies	TJ	1'286	1'725	1'760
Automatic chip boilers > 500 kW w/o wood proc. companies	TJ	324	1'021	1'626
Automatic pellet boilers > 500 kW	TJ	0	0	0
Automatic chip boilers > 500 kW within wood proc. companies	TJ	1'352	2'054	2'233
Combined chip heat and power plants	TJ	0	3	186
Plants for renewable waste from wood products	TJ	979	1'060	1'345

1A Wood combustion	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total	TJ	30'832	31'185	29'808	33'780	35'130	37'401	33'130	37'487	41'257	35'391
Open fireplaces	TJ	181	171	150	150	137	123	87	84	83	62
Closed fireplaces, log wood stoves	TJ	7'047	6'939	6'282	6'827	7'011	7'913	6'632	7'570	8'499	6'915
Pellet stoves	TJ	48	65	72	93	109	140	129	161	192	166
Log wood hearths	TJ	4'029	3'604	2'914	2'839	2'491	2'268	1'576	1'485	1'351	900
Log wood boilers	TJ	5'366	5'162	4'586	4'892	4'751	4'905	3'691	3'826	3'884	2'822
Log wood dual chamber boilers	TJ	481	423	348	338	289	272	195	190	181	125
Automatic chip boilers < 50 kW	TJ	754	775	727	833	861	1'008	801	867	943	740
Automatic pellet boilers < 50 kW	TJ	805	1'193	1'248	1'562	1'731	2'104	1'814	2'153	2'499	2'102
Automatic chip boilers 50-500 kW w/o wood proc. companies	TJ	2'689	2'889	2'808	3'202	3'267	3'751	3'237	3'816	4'318	3'558
Automatic pellet boilers 50-500 kW	TJ	97	176	251	353	422	521	500	606	704	675
Automatic chip boilers 50-500 kW within wood proc. companies	TJ	1'920	1'884	1'751	1'871	1'871	2'009	1'742	1'882	2'023	1'677
Automatic chip boilers > 500 kW w/o wood proc. companies	TJ	2'304	2'496	2'525	3'124	3'369	3'985	3'647	4'360	5'011	4'434
Automatic pellet boilers > 500 kW	TJ	9	44	61	85	89	98	139	161	186	186
Automatic chip boilers > 500 kW within wood proc. companies	TJ	2'537	2'465	2'287	2'377	2'377	2'479	2'164	2'311	2'471	2'078
Combined chip heat and power plants	TJ	127	242	1'058	2'467	3'423	2'756	3'900	5'010	5'446	5'306
Plants for renewable waste from wood products	TJ	2'438	2'657	2'740	2'764	2'933	3'071	2'877	3'005	3'465	3'646

3.2.4.6 Emissions from Biomass (memo item)

CO₂ emissions from biomass do not count for the national total emissions and therefore are a memo item only. The CO₂ emissions from biomass as reported in the reporting tables are incomplete as the following CO₂ emissions are not foreseen for reporting in the reporting tables: 2G4 Use of tobacco, 2H2 Food and beverages, 5A Solid waste disposal, 5B Biological treatment of solid waste and 5D Wastewater treatment and discharge.

Table 3-20 provides an overview of effective CO₂ emissions from biomass in 2014 and their reporting in the reporting tables (without land-use, land-use change and forestry). For further information on the biomass CO₂ emissions refer to the respective source category chapters.

Table 3-20 Effective biomass CO₂ emissions in 2014 and their representation in the reporting tables.

Biomass CO ₂ emissions	Unit	2014	Note
1A1 Energy industries (without MSW incineration)	kt	597	Included in CRF
1A1 Energy generation from MSW Incineration	kt	2'136	Included in CRF
1A2 Manufacturing industry and construction	kt	1'327	Included in CRF
thereof use of waste derived fuels in cement production	kt	56	
thereof use of bio fuels (1A2gvii)	kt	6	
1A3 Transport	kt	80	Included in CRF
1A4 Other sectors (Commercial/institutional, residential)	kt	2'518	Included in CRF
1A5 Other	kt	0.18	Included in CRF
2H2 Food and beverages industry	kt	14	Not included in CRF
2G Other product use (Consumption of tobacco)	kt	11	Not included in CRF
5A Solid waste disposal on land	kt	48	Not included in CRF
5B Biological treatment of waste (composting and anaerobic digestion)	kt	370	Not included in CRF
5C Waste incineration (without MSW incineration)	kt	157	Included in CRF
5D Wastewater handling	kt	133	Not included in CRF
Total biomass combustion CO ₂ emissions included in CRF	kt	6'814	
Total energy related biomass combustion CO ₂ emissions included in CRF 1A	kt	6'658	See table "Summary 2" in CRF
Total biomass CO ₂ emissions in Switzerland in 2014	kt	7'391	

3.2.4.7 Uncertainty and time series consistency for source category 1A

Basic uncertainties (AD, EF CO₂) by fuel type

Table 3-21 Uncertainties of activity data and CO₂ emission factors for 1A Fuel combustion.

Fuel type	Uncertainties		
	Activity data	CO ₂ emission factors	CO ₂ emissions
	%		
kerosene	0.96	0.16	0.97
gasoline	0.69	0.13	0.70
diesel oil	0.88	0.07	0.88
liquid fuels	0.69	0.08	0.69
solid fuels	5.00	5.06	7.12
gaseous fuels	5.00	1.10	5.12
other fuels	5.00	9.22	10.5
biomass	10.0	--	--

Liquid fuels

Uncertainty of the CO₂ emission factors: In 2013, a large measurement campaign was carried out to determine the CO₂ emission factors of the dominant liquid fuels (SFOE/FOEN 2014). From the standard deviation presented in this study, the 95% uncertainties are derived and are shown in Table 3-22 as lower and upper values as well as relative uncertainties.

Compared to formerly used uncertainties, the new values are smaller. The former values were also based on measurements carried out in 1998 (EMPA 1999), but with a smaller number of samples (between 10 and 30 samples per fuel type). The former uncertainties were then 1.16% for kerosene, 1.36% for gasoline and 0.47% for diesel oil and 0.61% for gas oil.

For mobile combustion, the 2006 IPCC Guidelines provide default uncertainties for the CO₂ emission factor of kerosene as 2%, gasoline 4% and diesel oil 1% (IPCC 2006, vol. 2, TABLE 3.2.1). Switzerland's measurements indicate much lower uncertainties. For stationary combustion, the 2006 IPCC Guidelines give no default values but show instead a summary of an uncertainty assessment of CO₂ emission factors for stationary combustion for selected countries (IPCC 2006, vol 2, TABLE 2.13). The values lie in the range between 0.5% and 3% and are again higher than the values derived from the Swiss measurements.

Table 3-22 Uncertainties of aggregated results of measurements of the CO₂ emission factors of selected liquid fuels (SFOE/FOEN 2014).

Fuel type	CO ₂ emission factors (measurements)			95% uncertainties EF(CO ₂)		no. samples
	mean t/TJ	lower t/TJ	upper t/TJ	absolute t/TJ	relative	
kerosene	72.81	72.70	72.93	0.12	0.16%	24
gasoline	73.80	73.71	73.90	0.10	0.13%	138
diesel oil	73.30	73.25	73.35	0.05	0.07%	75
gas oil	73.67	73.61	73.73	0.06	0.08%	138

Uncertainties of activity data: The values shown in Table 3-23 are based on a written message of SFOE to FOEN (SFOE 2012a). It lists two kinds of relevant errors: errors of measurements and errors of the conversion from mass to energy units. For gasoline and diesel oil, a third source of errors stems from the transformation of products. These errors are multiplicative, therefore the relative uncertainties have to be summed up.

For the previous submissions, a single expert estimate has been used, being the same for all liquid fuels (1%). The updated and more sophisticated uncertainties are equal (kerosene) or slightly lower.

Table 3-23 Sources of errors contributing to the total uncertainty of the activity data of selected liquid fuels (SFOE 2012a).

source of uncertainty	kerosene	gasoline	diesel oil	gasoil
	activity data uncertainty in %			
Measurement	0.39%	0.39%	0.39%	0.39%
Conversion mass to energy	0.57%	0.29%	0.29%	0.29%
Product transformation	0.00%	0.00%	0.20%	0.00%
Total uncertainty	0.96%	0.69%	0.88%	0.69%

Gaseous fuels

Uncertainty of the CO₂ emission factor: The composition of the imported gas is analysed in detail at the import stations. From this information, the FOEN annually calculates the CO₂ emission factor for each import station and the weighted mean. To estimate the uncertainty of the emission factor, the weighted standard deviation is calculated and is multiplied by the factor 1.96 to extend the standard deviation to 95% uncertainty interval. This calculation has been carried out for 13 years within the period 1990 and 2014. The uncertainties fluctuate between 0.72% and 1.48% with a mean of 1.1%, which is used as the uncertainty of the CO₂ emission factor for gaseous fuels.

Uncertainty of activity data: There is no country-specific estimate of the uncertainty for the consumption of natural gas. It is taken from 2006 IPCC Guidelines (IPCC 2006, vol. 2, TABLE 2.15), which give a range of 2%-5% for industrial combustion and 3%-5% for commercial, institutional and residential combustion. For Switzerland, an overall value of 5% is used.

Solid fuels

Uncertainty of the CO₂ emission factor: There is no country-specific uncertainty available. The 2006 IPCC Guidelines suggest a range from 0.5% to 10% (IPCC 2006, vol. 2 TABLE 2.13). For Switzerland, an uncertainty of 5% is chosen (medium of suggested range).

Uncertainty of activity data: There is no country-specific estimate of the uncertainty for the consumption of coal. It is taken from 2006 IPCC Guidelines (IPCC 2006, vol. 2, TABLE 2.15, which give a range of 2%-5% for industrial combustion and 3%-5% for commercial, institutional and residential combustion. For Switzerland, an overall value of 5% is used (like for natural gas).

Other fuels (waste to energy)

Uncertainty of the CO₂ emission factor: There are two factors influencing the uncertainty of CO₂ emissions from municipal solid waste incineration (1A1): the carbon content of waste and the fossil carbon fraction of the carbon content.

- The carbon content is determined in a study by Fellner et al. (2007). A relation between the calorific value of waste and the carbon content is derived therein, which provides upper and lower limits. The relation is tested by measurements. The

difference between upper and lower limits (5.9%) is interpreted as 95% confidence interval for the carbon content.

- The fossil fraction of the carbon content is determined in another study by Mohn et al. (2008). A field application of the radio carbon (^{14}C) method was developed to calculate the ratio of biogenic versus fossil CO_2 emissions from three waste-to-energy plants. Gas samples for $^{14}\text{CO}_2$ analysis were taken at three plants during one month each. Results were compared to an alternative approach based on mass and energy balances. The 95% confidence interval of the three measurement campaigns result in a biogenic fraction of $52.0\% \pm 3.7\%$, which corresponds to an uncertainty of 7.1%.
- The fossil- CO_2 emission factor results from a multiplication of the carbon content and the fossil fraction. The uncertainty of the CO_2 emission factor is thus the addition of the corresponding uncertainties by error propagation: $[(5.9\%)^2 + (7.1\%)^2]^{0.5} = 9.2\%$. (For the previous submission an expert estimate of 30% had been applied).

Uncertainty of activity data: There is no country-specific estimate of the uncertainty for the consumption of waste. It is taken from 2006 IPCC Guidelines (IPCC 2006, vol. 2, p. 2.40), which states: "Experts believe that the uncertainty resulting from the two errors (*systematic, random*) combined is probably in the range of $\pm 5\%$ for most developed countries." In accordance with that statement, the value of 5% is used. (In the previous submissions an expert estimate of 10% had been assumed).

Biomass

Uncertainty of activity data: no country-specific uncertainty of the activity data is available. The 2006 IPCC Guidelines suggest 2% to 5% for industrial, institutional and residential combustion and 10% to 30% for biomass burning in small sources (IPCC 2006, vol. 2, TABLE 2.15). About 80% of the CO_2 emissions from biomass burning stem from industrial, institutional and residential combustion and 20% from small residential installations with less developed statistical systems (see Table 3-19). An average uncertainty of 10% is applied for biomass burning in all source categories.

Uncertainty of CH_4 and N_2O emission factors

Since the CO_2 emissions vastly dominate the GHG emissions of source category 1A (almost 99%), the uncertainty evaluation of the non- CO_2 emissions is carried out on a semi-quantitative level (see Table 3-24).

Only for **1A3b Road transportation** a quantitative analysis has been performed. Following a study for the road transportation in Germany (IFEU/INFRAS 2009), where the same handbook of emission factors is used as in Switzerland (INFRAS 2010), the uncertainties for the CH_4 and N_2O emission factors have been determined (see lines 1A3b gasoline and diesel oil in Table 3-24). The uncertainties of CH_4 and N_2O emissions of CNG (1A3b), which were not investigated in IFEU/INFRAS (2009), have been estimated qualitatively as "medium" according to Table 1-11, except for N_2O /diesel oil ("high").

Summary

Table 3-24 below provides a summary of the uncertainties of 1A Fuel combustion as derived in the preceeding sections. The uncertainty of the CO₂ emissions ("combined uncertainty") are calculated from the uncertainties of the activity data and the emission factors by Approach 1 error propagation.

Table 3-24 Uncertainties of 1A Fuel combustion categories for activity data, emission factors and combined uncertainties. The latter are calculated by Approach 1. (For 1A2/Other Fuels a mean uncertainty is assumed based on semi-quantitative estimations from Table 1-11. The emission factor uncertainty is calculated "backward"⁵ from the combined and the activity data uncertainty). CH₄ and N₂O: semi-quantitative uncertainties (see Table 1-11).

1A Fuel Combustion Categories	Fuel type	Uncertainties				
		Activity data	CO ₂ em. factors	CO ₂ emissions	CH ₄ emissions	N ₂ O emissions
		%	%	%	--	--
1. Energy industries	liquid fuels	0.7	0.1	0.7	medium	medium
1. Energy industries	solid fuels	5.0	5.1	7.1	medium	medium
1. Energy industries	gaseous fuels	5.0	1.1	5.1	medium	medium
1. Energy industries	other fuels	5.0	9.2	10.5	medium	medium
2. Manufacturing industries and construction	liquid fuels	0.7	0.1	0.7	medium	medium
2. Manufacturing industries and construction	solid fuels	5.0	5.1	7.1	medium	medium
2. Manufacturing industries and construction	gaseous fuels	5.0	1.1	5.1	medium	medium
2. Manufacturing industries and construction	other fuels	5.0	9.2	10.5	medium	medium
3a. Transport; Domestic aviation	kerosene	1.0	0.2	1.0	high	high
3b. Transport; Road transportation	gasoline	0.7	0.1	0.7	37.0	50.0
3b. Transport; Road transportation	diesel oil	0.9	0.1	0.9	20.0	22.0
3b. Transport; Road transportation	gaseous fuels	5.0	1.1	5.1	medium	medium
3c. Transport; Railways	diesel oil	0.9	0.1	0.9	medium	high
3d. Transport; Domestic navigation	liquid fuels	0.7	0.1	0.7	medium	high
3e. Transport; Other transportation	gaseous fuels	5.0	1.1	5.1	medium	medium
4a. Other sectors; Commercial/institutional	liquid fuels	0.7	0.1	0.7	medium	medium
4a. Other sectors; Commercial/institutional	gaseous fuels	5.0	1.1	5.1	medium	medium
4b. Other sectors; Residential	liquid fuels	0.7	0.1	0.7	medium	medium
4b. Other sectors; Residential	solid fuels	5.0	5.1	7.1	medium	medium
4b. Other sectors; Residential	gaseous fuels	5.0	1.1	5.1	medium	medium
4c. Other sectors; Agriculture/forestry/fishing	liquid fuels	0.7	0.1	0.7	medium	medium
4c. Other sectors; Agriculture/forestry/fishing	gaseous fuels	5.0	1.1	5.1	medium	medium
5. Other	liquid fuels	0.7	0.1	0.7	medium	high
1A Stationary sources	biomass	10.0	--	--	medium	medium
1A Mobile sources	biomass	10.0	--	--	high	high

Time series consistency 1A

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

⁵ $U(EF) = \sqrt{U(EM)^2 - U(AD)^2}$

3.2.4.8 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 CO₂ 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 (SFOE 2015). The differences in total CO₂ emissions for the entire time period 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 chp. 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.

The gross carbon supply in the Reference Approach has been adjusted for fossil fuel carbon destined for non-energy use. The numbers in the Swiss overall energy statistics (SFOE 2015) are consistent with those provided by international organisations, e.g. IEA.

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 CO₂ emission factors of gas oil, diesel oil, gasoline, and kerosene (SFOE/FOEN 2014), see description under 3.2.4.2 Net calorific values (NCV). The values differ only marginally from previously used values. The CO₂ emission factors compare well with the IPCC default values (see Table 3-25).

Table 3-25: Comparison of default CO₂ emission factors from IPCC 2006 with country-specific values for selected fuels in 2013.

CO ₂ 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

The CO₂ 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 CO₂ emission factor has been reassessed for submission 2015. A country-specific CO₂ emission factor, based on measurements of gas properties and corresponding import shares of individual gas import stations is calculated (see also chp. 3.2.4.2). The resulting values are largely consistent with the CO₂ EF used by the countries from which gas is imported (Germany (IEF: 55.5–56.0 t CO₂/TJ), the Netherlands (IEF: 56.5–56.8 t CO₂/TJ), Norway (IEF: 56.1 t CO₂/TJ), France (IEF: 56.0–57.0 t CO₂/TJ), Italy (IEF: 55.3 to 56.9 t CO₂/TJ) and Denmark (IEF: 56.9–57.5 t CO₂/TJ). It lies within the range given by the IPCC (lower 54.3 t CO₂/TJ, upper 58.3 t CO₂/TJ, compared to the country-specific value of 56.4 t CO₂/TJ for 2013).

The CH₄ EF from combustion of wood has been scrutinized and is revised based on Nussbaumer and Hälgl (2015). The range of country-specific values is not entirely consistent with the upper and lower IPCC default values (Table 3-26). However, as the country-specific emission factor is based on an extensive measurement campaign, it is considered representative for Swiss circumstances.

Table 3-26: Comparison of default CH₄ emission factors from 2006 IPCC guidelines (IPCC 2006) with country-specific values

CH ₄ Emission factors	IPCC 2006			Switzerland
	Lower	Upper	Default	CS
	kg CH ₄ / TJ			
Wood	10	100	30	1.3 - 240

Expert review

As described in chp. 1.2.3, data from source category 1A 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.

3.2.4.9 Category-specific recalculations for source category 1A in general

Recalculations reported in submission 2015

- No general recalculations for source category 1A.

Recalculations reported in submission 2016

- The net calorific value of bituminous coal was adapted to the one used in the Swiss overall energy statistics (SFOE 2015). For 1990–1998 a value of 28.1 GJ/t is used and interpolated to the value of 25.5 GJ/t in 2010. In previous submissions it was constant 25.46 GJ/t.

- The net calorific value of lignite was adapted to the one used in the Swiss overall energy statistics (SFOE 2015). For 1990–1998 a value of 20.097 GJ/t is used and interpolated to the value of 23.6 GJ/t in 2010. In previous submissions it was constant 23.56 GJ/t.
- The net calorific value of petroleum coke was adapted to the one used in the Swiss overall energy statistics (SFOE 2015). For 1990–1998 a value of 35.0 GJ/t is used and interpolated to the value of 31.8 GJ/t in 2010. In previous submissions it was constant 31.78 GJ/t.
- Changes in the consumption of other bituminous coal, lignite and natural gas in the end consumption (1A2–1A4) 2008–2013 (SFOE 2015).
- Changes in the consumption of diesel oil and gasoline 2008–2013 (SFOE 2015).
- Changes in the consumption of gas oil 2002 / 2007 / 2010 / 2013 (SFOE 2015).
- Changed CH₄ emission factors for gas oil, residual fuel oil, petroleum coke, natural gas and biogas to IPCC 2006 default values:
 - gas oil: from 1 g/GJ to 3 g/GJ
 - residual oil: from 4 g/GJ to 3 g/GJ
 - petroleum coke: from 10 g/GJ to 3 g/GJ
 - natural gas/biogas: from 6 g/GJ to 1 g/GJ
- Changed N₂O emission factors for residual fuel oil, liquefied petroleum gas, Other bituminous coal and lignite to IPCC 2006 default values:
 - residual oil: from 0.8 g/GJ to 0.6 g/GJ
 - Liquefied petroleum gas: from 0.6 g/GJ to 0.1 g/GJ
 - other bituminous coal and lignite: from 1.6 g/GJ to 1.5 g/GJ
- Recalculations in the Swiss wood energy statistics resulted in revised AD in 1A1a, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion for 1990–2013.
- For 1A1a, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion the EF of SO₂ have been revised for the entire time series.
- Recalculation in natural gas consumption reported by Swiss overall energy statistics (SFOE 2015) for 2012–2013.
- Recalculation in wood consumption reported by Swiss overall energy statistics (SFOE 2015) for the entire time series.
- Recalculations in energy statistics of Liechtenstein lead to small changes in totals of Swiss energy consumption (years 1995–2013 for gasoline, 1991–2013 for diesel oil, 1990–2013 for gas oil, 2013 for liquefied petroleum gas).
- The CO₂ emission factor for the use of wood was set to the emission factor of 99.9 kg/GJ (Cemsuisse 2010a) instead of the old one of 92 kg/GJ (SAEFL 2000).

3.2.4.10 Planned improvements for source category 1A in general

No improvements for 1A general are planned. (See planned improvements for 1A3b in chp. 3.2.9.6).

3.2.5 Source category 1A1 - Energy industries (stationary)

3.2.5.1 Source category description for 1A1 (stationary)

Approach 1 key categories 1A1

CO₂ from the combustion of Liquid Fuels (level and trend)

CO₂ from the combustion of Gaseous Fuels (level and trend)

CO₂ from the combustion of Other Fuels (level and trend)

Approach 2 key categories 1A1

CO₂ 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. Activities in source category 1A1c Manufacture of Solid Fuels and other energy industries is virtually not occurring in Switzerland (apart from a tiny charcoal production activity in historic trade).

Within source category 1A1a, heat and electricity production in waste incineration plants cause the largest emissions, as electricity production in Switzerland is dominated by hydroelectric power plants and nuclear power stations (SFOE 2015). Emissions from industries producing heat and/or electricity (CHP) for their own use are included in category 1A2 Manufacturing Industries and Construction.

Table 3-27 Specification of source category 1A1 Energy Industries.

1A1	Source	Specification
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.
1A1b	Petroleum refining	Combustion activities supporting the refining of petroleum products, excluding evaporative emissions.
1A1c	Manufacture of solid fuels and other energy industries	Charcoal production

3.2.5.2 Methodological issues for 1A1 (stationary)

3.2.5.2.1 Public electricity and heat production (1A1a)

Public electricity and heat production in Switzerland encompasses different plant types where various fuels are used (Table 3-28 and Table 3-31). Energy recovery from municipal solid waste and special waste incineration is mandatory in Switzerland and plants are equipped with energy recovery systems. The emissions from municipal solid waste and special waste incineration plants are therefore reported under category 1A1a.

Table 3-28 Plant type and fuels used in source category 1A1a.

Plant type	Fuel type
Heat plants for renewable wastes	wood waste (biomass)
Heating boilers >300 MW (Vouvry)	residual fuel oil
Heating boilers <300 MW	gas oil, residual fuel oil, bituminous coal
Central heating boilers for district heating	natural gas, gas oil, residual fuel oil, bituminous coal
Wood combined heat and power generation	wood, wood waste (biomass)
Engines and boilers at fermentation plants	digestion gas (biogas)
Engines on landfill sites	landfill gas (biogas)
Municipal solid waste incineration plants	municipal solid wastes (other, waste-to-energy)
Special waste incineration plants	special wastes (other, waste-to-energy)

Methodology (1A1a)

For Public electricity and heat production (1A1a) a country-specific approach, as explained in chp. 3.2.4.5 is used combining Tier 2 and Tier 3 methods (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1).

Emission factors (1A1a)

The following table presents the emission factors used in 1A1a. Emission factors for gas oil, residual fuel oil and natural gas are further explained in section 3.2.4.4

Table 3-29 Emission Factors for 1A1a Public Electricity and Heat Production in 2014.

1A1a Public electricity and heat production	CO ₂	CO ₂ bio.	CH ₄	N ₂ O	NO _x	NM VOC	SO ₂	CO
	t/TJ	t/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Gas oil	73.7	NA	3	0.6	34	2.0	19	7
Residual fuel oil	77.0	NA	3	0.6	125	4.0	291	11
Petroleum coke	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	56.7	NA	1	0.1	18	2.0	0.5	10
Other (waste-to-energy), fossil	88.9	NA	NA	1.6	33	2.4	4	8
Other (waste-to-energy), biogenic	NA	92.4	NA	1.4				
Biomass (wood, renewable waste)	NA	99.9	1.3	4.0	118	2.0	11	100
Biogas (co-generation from landfills, fermentation engines)	NA	100.2	2	0.1	48	3.0	15	65

Emission factors for waste incineration and biogas use

Specific emission factors within 1A1a Public electricity and heat production apply for municipal solid waste incineration, special waste incineration and for biogas use (landfill gas and fermentation gas). The emission factors for CO₂, CH₄, N₂O, NO_x, CO, NM VOC and SO₂ emissions per tonne of waste incinerated are country-specific and based on measurements and expert estimates, as documented in EMIS 2016/1A1a Kehrlichtverbrennungsanlagen, EMIS 2016/1A1a Sondermüllverbrennungsanlagen, EMIS 1A1a Vergärung IG, EMIS 2016/1A1a Vergärung LW und 1A1a Kehrlichtdeponien.

Source-specific CO₂ emission factors for municipal solid waste incineration plants

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, 2015). In deviation from the general description of oxidation factors in 3.2.4.4.1 an oxidation factor of 0.99 is assumed here.

The fossil fraction of waste incinerated in MSWIP is based on a study conducted in the year 2014 (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). The CO₂ emission factor in MSWIPs fluctuates over the reporting period because of gradual changes in the net calorific values of the waste.

Source-specific CO₂ emission factors for carbonate use in municipal solid waste incineration plants

The data for EF CO₂ geogenic are based on the stoichiometric composition. A conversion factor of 100% is assumed for both sodium bicarbonate and calcium carbonate. During the time period 1990–2006 only calcium carbonate is applied in flue gas treatment of MSWIP. 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 MSWIP was not applied. In 2013 and 2014 a MSWIP 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 2016/1A1a Kehrichtverbrennungsanlagen).

Source-specific CO₂ emission factors for special waste incineration plants

Based on detailed information regarding waste composition and estimated emission factors in the years 1992–2004 a weighted average emission factor for special waste incineration was calculated. Special waste is assumed to be of entirely fossil origin. Overall, a specific emission factor of 1.45 t CO₂/t waste 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 2016/1A1a Sondermüllverbrennungsanlagen.

Source-specific CH₄ emission factors in municipal and special waste incineration plants

Emissions of CH₄ 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 N₂O emission factors for municipal solid waste incineration

In 2013, a study evaluated N₂O 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 Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (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) and without Denox-equipment). For installations without Denox-equipment the emission factor 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 2016/1A1a Kehricht- und Sondermüllverbrennungsanlagen. The emission factor is not constant over time.

Source-specific N₂O 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 3-30 N₂O emission factors of 1A1a Municipal solid and special waste incineration and CO₂ emission factors for carbonate use.

1A1a Public electricity and heat production, Other fossil fuels	Unit	1990	1995	2000
N ₂ O (MSWIP)	g/GJ	5.26	2.96	2.06
N ₂ O (SWIP)	g/GJ	3.06	4.23	5.41
CO ₂ (carbonate use in MSWIP)	g/t	439'710	439'710	439'710

1A1a Public electricity and heat production, Other fossil fuels	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
N ₂ O (MSWIP)	g/GJ	1.44	1.41	1.40	1.38	1.41	1.40	1.40	1.43	1.44	1.42
N ₂ O (SWIP)	g/GJ	5.48	5.16	4.84	4.53	4.21	3.89	3.57	3.25	2.94	2.62
CO ₂ (carbonate use in MSWIP)	g/t	439'710	439'710	NO	NO	NO	NO	NO	NO	523'880	523'880

Activity data (1A1a)

Activity data for liquid, gaseous, solid fuels and wood are based on the Swiss overall energy statistics (SFOE 2015) and additional data sources as described in 3.2.4.3. Activity data for Other fuels are based on the amount of waste incinerated in MSWIPs and SWIPs (FOEN 2015k, see Table 3-32). Activity data for combined heat and power generation in landfills and in biogas facilities are taken from the Swiss renewable energy statistics (SFOE 2015a).

Table 3-31 Activity data in 1A1a Public Electricity and Heat Production.

1A1a Public electricity and heat production	Unit	1990	1995	2000
Total fuel consumption	TJ	40'433	39'242	50'047
Gas oil	TJ	980	554	790
Residual fuel oil	TJ	3'232	1'839	368
Petroleum coke	TJ	NO	NO	NO
Other bituminous coal	TJ	530	46	NO
Lignite	TJ	NO	NO	NO
Natural gas	TJ	4'339	5'422	8'292
Other (waste-to-energy), fossil	TJ	16'605	16'870	22'482
Other (waste-to-energy), biogenic	TJ	14'163	13'394	16'889
Biomass (wood, renewable waste)	TJ	301	466	547
Biogas (co-generation from landfills, fermentation engines)	TJ	282	651	679

1A1a Public electricity and heat production	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total fuel consumption	TJ	57'235	60'582	58'234	59'496	58'527	62'653	60'856	64'752	64'898	61'020
Gas oil	TJ	1'300	1'280	843	490	540	500	400	800	670	780
Residual fuel oil	TJ	294	309	191	189	139	55	29	24	19	30
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	9'827	8'663	7'910	8'468	8'073	9'926	7'512	8'213	8'459	5'082
Other (waste-to-energy), fossil	TJ	24'711	26'940	25'791	25'880	24'853	26'002	25'575	26'262	25'738	26'049
Other (waste-to-energy), biogenic	TJ	19'797	21'940	21'415	21'464	21'249	22'275	22'272	23'051	22'489	23'112
Biomass (wood, renewable waste)	TJ	844	939	1'458	2'311	2'877	2'958	3'982	5'032	5'966	4'310
Biogas (co-generation from landfills, fermentation engines)	TJ	462	511	625	695	796	937	1'086	1'370	1'556	1'657

In Table 3-31, activity data for biomass as reported in the reporting tables (CRF) are further differentiated into Other (waste-to-energy), biogenic, Biomass (wood, renewable waste), and Biogas (co-generation from landfills, fermentation engines).

Since 1990 the use of waste-derived fuels increased considerably. 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. During the reporting period the consumption of natural gas increased, and the consumption of liquid fuels decreased. This is due to a fuel shift in combined heat and power generation and the closure of the only fossil fuel power station (Vouvry) in the 1990ies.

Municipal solid waste incineration

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. The amount of municipal solid waste reported in Table 3-32 is the total amount of waste burned (it includes fossil and biogenic shares).

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. In 2013 one and in 2014 two MSWIP applied sodium bicarbonate in its flue gas treatment.

Table 3-32 Activity data for 1A1a Other fuels: municipal solid waste and special waste incinerated with heat and/or power generation 1990 to 2014. The amount of municipal solid waste is the total amount of waste burned.

1A1a Public electricity and heat production, Other fossil fuels	Unit	1990	1995	2000
Total Other fossil fuels in 1A1a	kt	2'603	2'433	3'040
Municipal solid waste	kt	2'470	2'270	2'801
Special waste	kt	133	163	239
Carbonate use in MSWIP	kt	0.71	0.76	0.82

1A1a Public electricity and heat production, Other fossil fuels	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total Other fossil fuels in 1A1a	kt	3'527	3'896	3'816	3'865	3'827	3'968	3'924	4'104	4'035	4'066
Municipal solid waste	kt	3'297	3'646	3'580	3'610	3'597	3'717	3'676	3'841	3'773	3'817
Special waste	kt	230	250	236	255	230	252	247	263	262	249
Carbonate use in MSWIP	kt	0.61	0.10	NO	NO	NO	NO	NO	NO	2.72	2.76

3.2.5.2.2 Petroleum refining (1A1b)

Methodology (1A1b)

Up to 2015, two refineries were in operation in Switzerland. Since one of the refineries ceased operation in 2015, the data are considered confidential. Data are available to reviewers on request. Based on the generalised decision tree Fig. 2.1 for stationary combustion (IPCC Guidelines 2006, vol.2, chp. 2), a model Tier 3 method is used. The calculations are based on measurements and data from the refining industry as documented in the EMIS database (EMIS 2016/1A1b Heizkessel Raffinerien).

Emission factors (1A1b)

Emission factors of residual fuel oil, petroleum coke and refinery gas are estimated based on measurements from the two refineries for the years 2005 – 2011 and 2013 – 2014 provided in the framework of the Swiss emissions trading system. From 2005 onwards, the measured emission factors are applied. The emission factors for 2012 are interpolated between 2011 and 2013. In years before 2005, the emission factors of residual fuel oil and petroleum coke are based on the weighted mean of the available data (2005 – 2011 and 2013 – 2014). The CO₂ emission factor of refinery gas is based on an estimate provided by one of the two refining plants for the years 1990–2004, which is assumed to be constant. Since several years the annual emission factor is derived from annual monitoring reports (since 2013) and the allocation report (2005–2011), which provide plant-specific data.

The resulting CO₂ emission factors are all within the given ranges in IPCC (2006). For emission factors of N₂O and CH₄ default values according to IPCC 2006 are used.

Table 3-33 Emission factors for 1A1b Petroleum refining in 2014.

1A1b Petroleum refining	CO ₂	CH ₄	N ₂ O	NO _x	NM VOC	SO ₂	CO
	t/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Residual fuel oil	C	C	C	C	C	C	C
Refinery gas	C	C	C	C	C	C	C
Petroleum coke	C	C	C	C	C	C	C

Activity data (1A1b)

Activity data on fuel combustion for petroleum refining (1A1b) is provided by the Swiss overall energy statistics (SFOE 2015) and by the industry (bottom-up data). The data from the industry is collected by Carbura and forwarded to the Swiss Federal Office of Energy for inclusion in the Swiss overall energy statistics (SFOE 2015).

Refinery gas is the most important fuel used in source category 1A1b. 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 (EV 2014).

Table 3-34 Activity data for 1A1b Petroleum refining.

1A1b Petroleum refining	Unit	1990	1995	2000
Total fuel consumption	TJ	5'629	9'836	9'636
Residual fuel oil	TJ	1'259	1'786	1'908
Refinery gas	TJ	4'370	8'050	7'728
Petroleum coke	TJ	NO	NO	NO

1A1b Petroleum refining	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total fuel consumption	TJ	14'548	16'013	13'774	15'118	14'473	14'176	13'169	11'242	13'834	14'173
Residual fuel oil	TJ	902	692	1'182	692	733	891	764	1'212	1'094	C
Refinery gas	TJ	11'833	13'508	11'033	11'978	11'706	11'282	10'720	8'249	11'055	C
Petroleum coke	TJ	1'813	1'813	1'558	2'449	2'035	2'003	1'685	1'781	1'685	C

3.2.5.2.3 Manufacture of solid fuels and other energy industries (1A1c)

Methodology (1A1c)

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.

Based on the generalised decision tree in Fig. 2.1 for stationary combustion (IPCC Guidelines 2006, vol.2, chp. 2), emissions are estimated using a Tier 2 approach.

Emission factors (1A1c)

The CO₂ emission factor is based on literature (USEPA 1995) and CH₄, NO_x, CO and NMVOC emission factors are taken from the revised 1996 IPCC Guidelines (EMIS 2016/1A1c).

Table 3-35 Emission factors for 1A1c Manufacture of Solid Fuels and other energy industries in 2014. The CO₂ emission factor refers to CO₂ of biogenic origin.

1A1c Charcoal	Unit	CO ₂ biog.	CH ₄	NO _x	NM VOC	SO ₂	CO
Charcoal production	kg/TJ	16'900	1'000	10	1'700	NE	7'000

Activity data (1A1c)

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 2016/1A1c. 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 between 1990 and 2014 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 3-36 Activity data for 1A1c Manufacture of Solid Fuels and other energy industries.

1A1c Charcoal	Unit	1990	1995	2000
Charcoal production	TJ	1.25	1.43	2.20

1A1c Charcoal	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Charcoal production	TJ	3.37	3.33	3.48	3.52	3.48	3.19	3.30	3.62	2.82	3.82

3.2.5.3 Uncertainties and time-series consistency for 1A1 (stationary)

The uncertainty of CO₂ emission factors is described in section 1.6.1.2 and 3.2.4.7. The uncertainty in emissions of non-CO₂ gases are estimated to be medium, i.e. 30% for CH₄ and 80% for N₂O (see also chp. 1.6, Table 1-11).

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

3.2.5.4 Category-specific QA/QC and verification for 1A1 (stationary)

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 3.2.4.8.

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 for 1A1 (stationary)

Recalculations reported in submission 2015

- 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 CH₄, CO and NMVOC.
- 1A: For wood combustion, the previously used country-specific value of the N₂O EF (1.6 g/GJ) has been replaced by the default value of the 2006 IPCC Guidelines (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 CO₂ 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 N₂O 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 CO₂ 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 N₂O 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 CO₂ compensation projects. This leads to lower amounts of digestate.
- 1A1a: In source category 1A1a iv Municipal solid waste incineration plants, the CO₂ 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.

Recalculations reported in submission 2016

- 1A1a: The emissions of carbonate used in the municipal waste incineration (1A1a) were not taken into account due to a mistake in calculations in the last submission.

- 1A1a: Activity data for Municipal solid waste incineration plants has been corrected in waste statistics and value for 2013 is slightly larger.
- 1A1a: Changed amount of used other bituminous coal in boilers for electricity generation (1990–1995) (SFOE 2015).
- 1A1a: Changed amount of used other bituminous coal in boilers for heat production (1992–1995) (SFOE 2015).
- 1A1a: Changed emission factor CH₄ for boilers in district heating from 6 to 1 g/GJ.
- 1A1b: Introduction of new bottom-up Information out of the Swiss Emissions Trading Scheme for the entire time series. New EF CO₂ as average from the past years from bottom-up information.
- 1A1b: N₂O and CH₄ changed to IPCC 2006 default.

3.2.5.6 Category-specific planned improvements for 1A1 (stationary)

No category-specific improvements are planned.

3.2.6 Source category 1A2 - Manufacturing industry and construction (stationary without 1A2g vii)

3.2.6.1 Source category description for 1A2 (stationary)

Approach 1 key categories 1A2

CO₂ from the combustion of Liquid Fuels (level and trend)

CO₂ from the combustion of Solid Fuels (level and trend)

CO₂ from the combustion of Gaseous Fuels (level and trend)

CO₂ from the combustion of Other Fuels (level and trend)

Approach 2 key categories 1A2

CO₂ from the combustion of Solid Fuels (trend)

CO₂ from the combustion of Gaseous Fuels (level and trend)

CO₂ from the combustion of Other Fuels (trend)

[Source category 1A2 contains the sum of emissions of stationary and mobile sources – the statement on key categories holds for the aggregated emission only. However, the CO₂ emissions of 1A2 from Liquid Fuels are dominated by the stationary sources, 88%, which means that the emissions of 1A2g vii only play a minor role within category 1A2.]

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.

Table 3-37 Specification of source category 1A2 Manufacturing industries and construction in Switzerland.

1A2	Source	Specification
1A2a	Iron and steel	Iron and steel industry: boilers, cupola furnaces in iron foundries and heating furnaces in steel production
1A2b	Non-ferrous metals	Non-ferrous metals industry: secondary aluminium production, copper alloys production
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)
1A2d	Pulp, paper and print	Pulp, paper and print industry, geogenic emissions from carbonate use for fluegas purification in cellulose production
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).
1A2f	Non-metallic minerals	Fine ceramics, container glass, glass, glass wool, lime, rock wool, mixed goods, cement, brick and tile
1A2giv	Wood and wood products	Fibreboard production
1A2gviii	Other	Industrial fossil fuel and biomass boilers and engines that do not provide heat or electricity to the public.

3.2.6.2 Methodological issues for 1A2 (stationary)

3.2.6.2.1 Methodology (1A2)

For fuel combustion in source category 1A2 Manufacturing industries and construction, a country-specific approach is used combining Tier 2 and Tier 3 methods (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1).

3.2.6.2.2 Industry model

Overview

The industry model is one sub-model of the Swiss energy model (see chp. 3.2.4.3). The industry model disaggregates the stationary fuel consumption into the source categories and processes under 1A2 Manufacturing industries and construction. The following figure visualizes the disaggregation process.

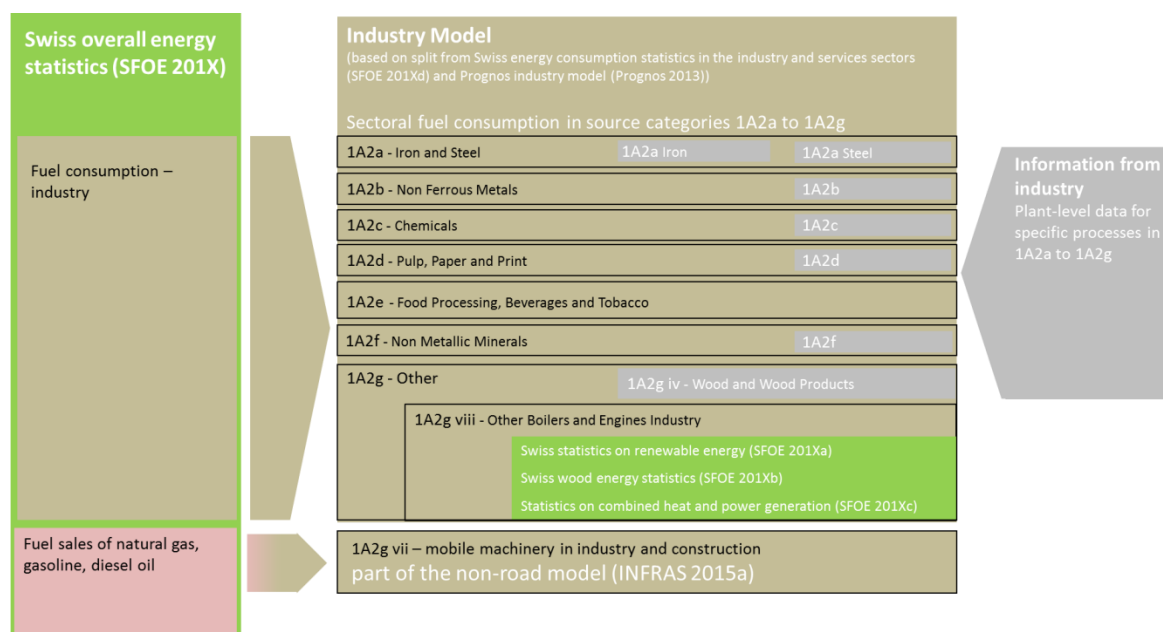


Figure 3-21 Schematic presentation of the data sources used for the industrial sectors 1A2a – 1A2g. The reference SFOE 201X refers to SFOE 2015. For each fuel type, the Swiss overall energy statistics provide the total consumption for industry. The total consumption is then distributed to the different source categories based on the energy consumption statistics in the industry and services sectors (SFOE 2014d) and the Prognos industry model (Prognos 2013). The grey 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 statistics.

The total fuel consumption regarding each fuel type in the industry sector is provided by the Swiss overall energy statistics (see description of the Swiss overall energy statistics in chp. 3.2.4.3). The energy disaggregation into the source categories 1A2a to 1A2g is carried out for each fuel type individually based on the energy consumption statistics in the industry and services sectors (SFOE 2014d). These statistics are available since 1999 for gas oil and natural gas. For all the other fossil fuels (i.e. residual fuel oil, liquefied petroleum gas, petroleum coke, other bituminous and lignite) data are available since 2002. In order to generate a consistent time series since 1990, additional data from an industry model is applied (Prognos 2013) as described in the following subsection.

In addition, the share of fuel used for co-generation in turbines and engines within 1A2 is derived from a model of stationary engines developed by Eicher + Pauli (Kaufmann 2015) for the statistics on combined heat and power generation (SFOE 2015c).

Energy consumption statistics in the industry and services sectors

The energy consumption statistics in the industry and services sectors (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 fuel types (i.e. industrial waste, residual fuel oil, other bituminous coal and lignite) the survey represents a census covering all fuel consumed. The surveys are available for all years since 1999 or 2002, depending on the fuel type.

Since the energy consumption statistics in the industry and services sectors for 2014 was not available in time, the fuel consumption in different sectors for 2014 is derived based on the total fuel consumption in the industry and services sectors from the Swiss overall energy statistics (SFOE 2015) by applying the same shares as in 2013 based on SFOE (2014d).

Modelling of industry categories

The energy consumption statistics in the industry and services sectors (SFOE 2014d) is complemented by a bottom-up industry model (Prognos 2013). 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.

It provides data on the disaggregation of total fuel consumption according to different industries and services between 1990 and 2012. For the time period, where the two disaggregation methods overlap, systematic differences between the two time series can be detected. These two data sets have been combined in order to obtain consistent time series of the shares of each source category 1A2a-1A2gviii for each fuel type. For this purpose, the approach to “generate consistent time series from overlapping time series” is used according to the 2006 IPCC Guidelines, Volume 1, chp. 5, consistent overlap (IPCC 2006). To illustrate the approach, an example for gas oil attributed to source category 1A2c is provided in the following figure. A detailed description for all fuel types and source categories (1A2a-1A2g), including further assumptions, is provided in the underlying documentation of the EMIS database (EMIS 2016/1A2_Sektorgliederung Industrie).

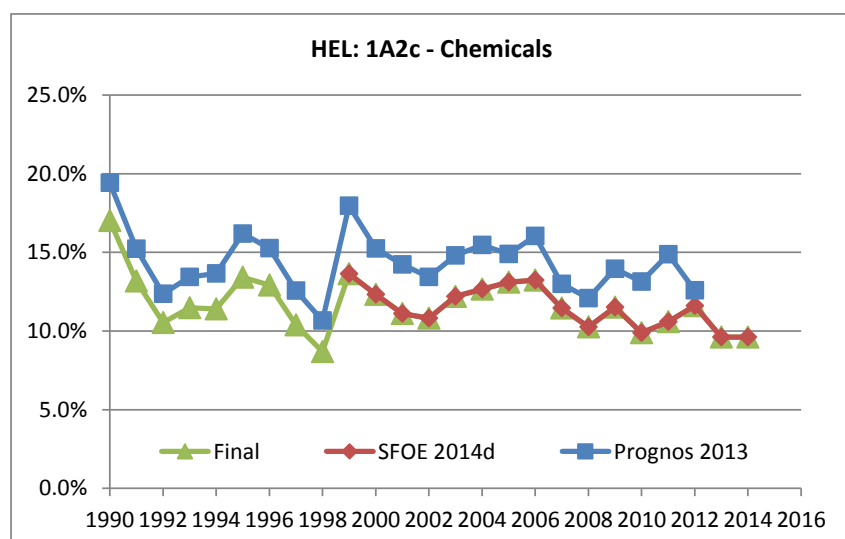


Figure 3-22 Illustrative example for combining time series with consistent overlap according to 2006 IPCC Guidelines (IPCC 2006). The y-axis indicates the share of source category 1A2c of total gas oil consumption in the industry sector. The green line, which is based on the combination of the shares from the energy consumption statistics in the industry and services sectors (SFOE 2014d, red line from 1999 to 2014) and the bottom-up industry model (Prognos 2013, blue line from 1990 to 2012), corresponds to the share finally used to calculate the fuel consumption in 1A2c. Similar calculations are performed for each source category and fuel type, see also EMIS database documentation (EMIS 2016/1 A 2_Sektorgliederung Industrie).

Bottom-up industry data

Grey colored boxes in Figure 3-21 represent source categories, i.e. 1A2a-d, 1A2f and 1A2g for which bottom-up data from the industry are used in order to disaggregate the fuel consumption within a particular source category. These data consist of partly validated and verified monitoring data from the Swiss emissions trading scheme implemented under the Ordinance for the Reduction of CO₂ Emissions (Swiss Confederation 2012) and are discussed in depth in the following chapters 3.2.6.2.3 to 3.2.6.2.9.

The bottom-up information provides activity data for specific industrial production processes and forms a subset of the total fuel consumption allocated to each source category by the approach described above. Therefore the fuel consumptions of the bottom-up industry processes are subtracted from the total fuel consumption of the respective source category and the remaining fuel consumptions are considered as fuels used in boilers of each source category. This method ensures that the sum of fuel consumption over all processes of a source category corresponds to the total fuel consumption as documented in the energy consumption statistics in the industry and services sectors (SFOE 2014d).

There is a difference in calculating the emissions of precursors from boilers and bottom-up industry processes. For boilers, fuel consumption is used as activity data whereas for bottom-up processes production data is used.

Further specific statistical data

Fuel consumption of wood, wood waste, biogas and sewage gas in manufacturing industries is based on the Swiss wood energy statistics (SFOE 2015b) as well as on data from the Swiss renewable energy statistics (SFOE 2015a) and the Statistics on combined heat and

power generation in Switzerland (SFOE 2015c), respectively. Emissions from these sources are reported under 1A2gviii Other due to insufficient information regarding sectoral disaggregation.

Emission factors (1A2)

The following table presents the emission factors of fuel consumption in source category 1A2 Manufacturing industry and construction (see also chp. 3.2.4.4).

Table 3-38 Emission factors for 1A2 Manufacturing industries and construction in 2014. Values that are not shaded in grey are implied emission factors.

1A2 Emission factors for GHG	CO ₂ fossil	CO ₂ bio.	CH ₄	N ₂ O
	t/TJ	t/TJ	kg/TJ	kg/TJ
Gas oil	73.7		3	0.6
Residual fuel oil	77.0		2.5	0.6
Liquefied petroleum gas	65.5		1	0.1
Petroleum coke	91.4		0.007	0.6
Other bituminous coal	92.7		3.7	1.5
Lignite	96.1		0.6	1.5
Natural gas	56.7		1	0.1
Other fossil fuels	69.3		5.3	3.5
Biomass		90.7	5.4	3.2

Other fossil fuels comprise various fossil waste derived fuels used in 1A2f Cement production as well as cracker by-products, i.e. gasolio and heating gas used for steam production in a chemical plant in source category 1A2c. The emission factors of CO₂, CH₄ and N₂O are implied emission factors based on the fossil waste fuel mix in cement production plants. In addition the CH₄ emission factor includes the total CH₄ 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 and emission declarations according to the Ordinance on Air Pollution Control. Implied CH₄ emission factors of source category 1A2 for residual fuel oil, petroleum coke, other bituminous coal and lignite are lower than the default emission factors of source category 1A documented in section 3.2.4.4.3 (see detailed description below in chapter Cement (1A2f i)).

The emission factors of the precursors NO_x, CO, NMVOC and SO₂ for all fuels in source category 1A2 are provided in Annex A3.1.1. The emission factors for NO_x and CO for natural gas and gas oil used in boilers are derived from a large number of air pollution control measurements of combustion installations (Leupro 2012). This study analysed a large dataset from various cantons in Switzerland that was collected between 2000 and 2011. The emission factors for NO_x and CO for residual fuel oil, petroleum coke, other bituminous coal and lignite used in boilers are country-specific and documented in the Handbook on emission factors for stationary sources (SAEFL 2000) The implied emission factors for NO_x decreased significantly. NMVOC and SO₂ emission factors are country-specific and documented in SAEFL (2000).

Emission factors for fuel combustion in bottom-up industry processes are other than combustion in boilers, bottom-up industry data are used to derive production weighted emission factors based on various air pollution control measurements under the Ordinance on Air Pollution Control (Swiss Confederation 1985).

Activity data (1A2)

The following table shows the total fuel consumption reported in source category 1A2 as described above in the industry model and displays the fuel switch within Swiss industry. Since 1990, the use of residual fuel oil and other bituminous coal has decreased. In the same period, natural gas consumption has more than doubled. Regarding the fuels used within Swiss industry in 2014, natural gas consumption accounts for the largest share followed by biomass and gas oil.

Source category 1A2gviii Other comprising emissions from boilers and engines is the most important category within source category 1A2 Manufacturing Industries and construction in 2014. 1A2f Non-metallic minerals and 1A2c Chemicals are the second and third most important fuel consumers.

Table 3-39 Activity data fuel consumption in 1A2 Manufacturing industries and construction..

Source	Unit	1990	1995	2000
1A2 Manufacturing industries and constr. (stationary sources)	TJ	88'205	89'184	87'878
Gas oil	TJ	21'773	23'542	25'155
Residual fuel oil	TJ	18'870	13'678	5'675
Liquefied petroleum gas	TJ	4'520	4'706	5'921
Petroleum coke	TJ	1'400	1'260	551
Other bituminous coal	TJ	13'476	7'303	5'716
Lignite	TJ	265	153	124
Natural gas	TJ	18'721	27'898	31'383
Other fossil fuels	TJ	2'555	2'817	4'054
Biomass	TJ	6'625	7'825	9'298

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2 Manufacturing industries and constr. (stationary sources)	TJ	91'697	94'270	92'327	93'476	87'878	90'542	84'138	85'395	87'369	82'144
Gas oil	TJ	24'719	23'547	21'610	21'393	21'011	20'693	16'776	17'163	17'902	12'340
Residual fuel oil	TJ	4'613	5'427	3'776	3'734	2'713	2'096	1'518	1'568	848	351
Liquefied petroleum gas	TJ	4'599	5'070	4'554	4'310	4'595	4'181	4'136	3'998	3'998	3'538
Petroleum coke	TJ	1'093	1'512	1'271	1'067	1'219	1'495	1'272	1'367	1'034	1'255
Other bituminous coal	TJ	4'899	4'186	4'959	4'445	4'263	4'348	3'818	3'694	3'910	2'407
Lignite	TJ	742	1'931	1'937	1'717	1'531	1'460	1'624	1'175	1'357	3'102
Natural gas	TJ	34'372	35'840	36'910	38'719	35'126	38'042	36'903	38'013	39'400	39'946
Other fossil fuels	TJ	4'525	4'293	4'224	4'975	4'958	5'183	5'307	4'883	5'186	5'270
Biomass	TJ	12'136	12'463	13'084	13'117	12'464	13'045	12'784	13'534	13'734	13'935

The following chapters describe the fuel consumption of the different source categories 1A2a-1A2gviii, the specific industrial production processes based directly on bottom-up industry data and additional source-specific emission factors. Further information is documented in the respective EMIS documentation (EMIS 2015/1A2a-g).

3.2.6.2.3 Iron and steel (1A2a)

The source category 1A2a Iron and steel consists both of fuels used in boilers and specific industrial production processes, i.e. reheating furnaces in steel plants and cupola furnaces in iron foundries.

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 using other bituminous coal. Part of the other bituminous coal is also used to increase the carbon content of the raw material steel scrap to produce iron alloys with higher carbon content. The share of induction furnaces increased since 1990 with a sharp increase in 2009 due to 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. Due to the reduced iron production and the switch from cupola to induction furnaces in iron foundries the consumption of other bituminous coal has decreased.

Today, steel is only produced in two steel production plants after closure of two plants in 1994. Both plants use electric arc furnaces (EAF) with carbon electrodes for melting the steel scrap. Therefore, only emissions from the reheating furnaces are reported in source category 1A2a. Since 1995, these furnaces use natural gas only 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 and the use of residual fuel oil ceased 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 due to the 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 higher natural gas consumption.

Today fuel consumption of source category 1A2a consists mainly of natural gas but also liquefied petroleum gas and small amounts of gas oil and other bituminous coal are used.

Table 3-40 Activity data fuel consumption in 1A2a Iron and steel.

Source	Unit	1990	1995	2000
1A2a Iron and steel	TJ	3'310	2'570	3'351
Gas oil	TJ	480	262	338
Residual fuel oil	TJ	346	131	20
Liquefied petroleum gas	TJ	408	193	286
Petroleum coke	TJ	NO	NO	NO
Other bituminous coal	TJ	433	289	266
Lignite	TJ	NO	NO	NO
Natural gas	TJ	1'643	1'695	2'440

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2a Iron and steel	TJ	3'389	4'208	4'415	4'156	3'190	3'773	3'805	3'634	3'487	3'431
Gas oil	TJ	401	311	326	307	279	315	271	172	148	102
Residual fuel oil	TJ	39	52	36	51	39	51	2	NO	NO	NO
Liquefied petroleum gas	TJ	217	313	295	246	214	219	226	438	438	388
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	154	150	160	177	70	64	73	55	55	52
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	2'578	3'382	3'598	3'374	2'588	3'125	3'233	2'969	2'847	2'889

3.2.6.2.4 Non-ferrous metals (1A2b)

The source category 1A2b Non-ferrous metals consists both of fuels used in boilers and specific industrial production processes, i.e. secondary aluminium production and non-ferrous metal foundries, producing mainly copper alloys.

Until 1993, secondary aluminium production 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) providing production data.

Fuel consumption of source category 1A2b represents only a small amount of the total fuel consumption in source category 1A2 in 2014. Fuels consumed in 2014 are mainly natural gas as well as gas oil and small amounts of residual fuel oil and liquefied petroleum gas. Fuel consumption within this source category decreased since 1990 due to the closing down of the secondary aluminium production and the strong reduction of the non-ferrous metal production since 2000.

Table 3-41 Activity data fuel consumption in 1A2b Non-ferrous metals.

Source	Unit	1990	1995	2000
1A2b Non-ferrous metals	TJ	2'379	1'969	1'560
Gas oil	TJ	587	347	236
Residual fuel oil	TJ	NO	NO	NO
Liquefied petroleum gas	TJ	27	17	15
Petroleum coke	TJ	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO
Lignite	TJ	NO	NO	NO
Natural gas	TJ	1'765	1'605	1'309

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2b Non-ferrous metals	TJ	977	1'162	1'022	1'042	1'006	1'218	1'177	1'746	1'619	1'593
Gas oil	TJ	125	72	94	112	167	112	76	153	127	88
Residual fuel oil	TJ	NO	NO	NO	0	0	0	0	1	23	16
Liquefied petroleum gas	TJ	7	10	8	7	7	8	8	11	11	10
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	845	1'080	920	924	833	1'098	1'093	1'581	1'457	1'479

3.2.6.2.5 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 (see also descriptions in chp. 3.2.3 for feedstock use). 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. For reasons of confidentiality, fuel consumption and emissions of these by-products are included

in Other fossil fuels of 1A2f in the reporting tables. The CO₂ emission factors of gasolio and heating gas are plant specific based on monitoring reports of the Swiss ETS. Since the fuel quality of gasolio and heating gas are of similar quality as residual fuel oil and gas oil, respectively, the same default IPCC emission factors are assumed for CH₄ and N₂O (see Table 3-38 and Table 3-14 (CH₄ EF of residual fuel oil)).

The fuels consumed in 2014 include mainly natural gas as well as gas oil. Fuel consumption in this source category has slightly decreased between 1990 and 2014. Consumption of gas oil and residual fuel oil have decreased in that period, while natural gas consumption has increased.

Table 3-42 Activity data fuel consumption in 1A2c Chemicals.

Source	Unit	1990	1995	2000
1A2c Chemicals	TJ	14'436	15'158	13'500
Gas oil	TJ	3'942	3'313	3'215
Residual fuel oil	TJ	1'434	693	252
Liquefied petroleum gas	TJ	15	13	12
Petroleum coke	TJ	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO
Lignite	TJ	NO	NO	NO
Natural gas	TJ	9'044	11'138	10'020
Other fossil fuels	TJ	IE	IE	IE

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2c Chemicals	TJ	15'477	14'995	14'810	14'610	12'611	11'814	12'167	13'909	13'859	13'536
Gas oil	TJ	3'345	3'210	2'556	2'261	2'498	2'103	1'847	2'055	1'745	1'206
Residual fuel oil	TJ	36	71	6	79	91	66	0.2	0.2	1	39
Liquefied petroleum gas	TJ	10	11	10	9	9	8	7	10	10	9
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	12'086	11'704	12'239	12'261	10'014	9'637	10'312	11'845	12'102	12'283
Other fossil fuels	TJ	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

3.2.6.2.6 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 CO₂ emissions that resulted from carbonate use in cellulose production for flue gas treatment of sulphur oxide removal are reported in this source category.

Fuel consumption in 1A2d consists both of fuels used in boilers and specific industrial production processes. In this source 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 chapter 3.2.4.6. Data on limestone use in flue gas treatment and its CO₂ emission factor are based on expert estimates on the specific consumption of limestone per tonne of cellulose and on default emission factor for limestone of IPCC (2006) (vol. 3, chp. 2.1) as documented in the EMIS database (EMIS 2016/1 A 2 d Zellulose Produktion).

The overall fuel consumption within the Swiss pulp and paper industry has considerably decreased since 1990, due to the closure of the cellulose production plant in 2008 and of several paper producers in the last years. The fuels used in 2014 are mainly natural gas as

well as gas oil. Since 1990 residual fuel oil and gas oil have decreased, while natural gas consumption increased.

Table 3-43 Activity data of fuel consumption in 1A2d Pulp, paper and print.

Source	Unit	1990	1995	2000
1A2d Pulp, paper and print	TJ	11'762	13'700	11'580
Gas oil	TJ	1'188	1'751	1'403
Residual fuel oil	TJ	5'250	3'061	1'417
Liquefied petroleum gas	TJ	86	141	148
Petroleum coke	TJ	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO
Lignite	TJ	NO	NO	NO
Natural gas	TJ	3'153	7'389	6'918
Biomass	TJ	2'085	1'358	1'694

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2d Pulp, paper and print	TJ	11'379	11'493	10'236	9'455	6'124	6'773	6'051	5'374	5'567	5'427
Gas oil	TJ	1'456	1'291	1'096	1'019	948	852	561	623	714	493
Residual fuel oil	TJ	2'092	3'305	1'885	1'887	1'084	279	4	3	0	17
Liquefied petroleum gas	TJ	100	79	71	60	62	61	62	67	67	60
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	5'678	4'742	5'085	5'164	4'030	5'581	5'424	4'681	4'786	4'857
Biomass	TJ	2'053	2'076	2'099	1'324	NO	NO	NO	NO	NO	NO

Table 3-44 Activity data of limestone use in 1A2d Pulp, paper and print.

1A2d Pulp, paper and print	Unit	1990	1995	2000
Limestone use	kt	8'500	9'400	9'300

1A2d Pulp, paper and print	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Limestone use	kt	8'300	8'000	7'800	6'500	NO	NO	NO	NO	NO	NO

3.2.6.2.7 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, milk products and convenience food. Further productions comprise chocolate, sugar or baby food (Fial 2013). Fossil fuels are used for steam production and drying processes. Fuel consumption in 1A2e is exclusively based on information from the energy consumption statistics in the industry and services sectors (SFOE 2014d) and Prognos (2013).

In 2014, the fuels used in this category were mainly natural gas as well as gas oil and small amounts of liquefied petroleum gas. There was an increase in fuel consumption between 1990 and 2014. This is due to the increased production in this sector. The consumption of residual fuel oil and gas oil ceased and has decreased, respectively, whereas natural gas and liquefied petroleum gas consumption has increased significantly.

Table 3-45 Activity data fuel consumption in 1A2e Food processing, beverages and tobacco.

Source	Unit	1990	1995	2000
1A2e Food processing, beverages and tobacco	TJ	9'859	8'784	10'439
Gas oil	TJ	7'410	5'511	5'515
Residual fuel oil	TJ	1'160	466	137
Liquefied petroleum gas	TJ	204	308	535
Petroleum coke	TJ	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO
Lignite	TJ	NO	NO	NO
Natural gas	TJ	1'085	2'500	4'251

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2e Food processing, beverages and tobacco	TJ	10'239	11'519	11'221	10'975	12'558	13'161	11'374	11'310	12'564	11'481
Gas oil	TJ	4'070	3'811	3'500	3'376	3'687	3'778	3'197	3'237	3'548	2'452
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	534	678	596	535	736	659	675	935	935	828
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	5'635	7'031	7'126	7'064	8'135	8'723	7'502	7'138	8'081	8'201

3.2.6.2.8 Non-metallic minerals (1A2f)

The source category 1A2f Non-metallic minerals includes several large fuel consumers within mineral industry, e.g. cement, brick and tile, glass and rock wool production. All fuel consumption of these specific industrial production processes are based on bottom-up industry data.

The fuels consumed in this source category are very diverse, depending on the fuel use within the specific industry process (see detailed documentation below). Fuel consumption in 2014 comprises mainly other fossil fuels, natural gas, lignite, biomass and other bituminous coal.

Between 1990 and 2014 there has been a switch in fuel consumption from other bituminous coal and residual fuel oil to other fossil fuels, natural gas, lignite and biomass. The most important emission source within this category is cement production. Information on bottom-up data of fuel consumption and some source-specific emission factors are described in the following. Detailed data at process level cannot be provided, since they are mostly confidential. Therefore, aggregated data for 1A2f are shown in the following table.

Table 3-46 Activity data fuel consumption in 1A2f Non-metallic minerals.

Source	Unit	1990	1995	2000
1A2f Non-metallic minerals	TJ	25'590	19'883	18'055
Gas oil	TJ	1'871	1'629	1'642
Residual fuel oil	TJ	5'382	5'578	3'649
Liquefied petroleum gas	TJ	523	498	468
Petroleum coke	TJ	774	300	480
Other bituminous coal	TJ	12'418	6'758	5'415
Lignite	TJ	265	153	124
Natural gas	TJ	1'769	1'566	1'496
Other fossil fuels	TJ	2'555	2'817	4'054
Biomass	TJ	33	585	728

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2f Non-metallic minerals	TJ	17'832	17'769	18'035	17'901	17'102	18'196	17'801	16'956	17'119	17'642
Gas oil	TJ	1'388	1'482	1'343	1'298	1'260	1'269	1'238	1'097	1'174	1'182
Residual fuel oil	TJ	2'420	1'704	1'744	1'598	1'374	1'519	1'403	1'456	801	209
Liquefied petroleum gas	TJ	324	227	181	160	95	102	127	108	113	45
Petroleum coke	TJ	638	903	912	1'036	994	1'130	1'081	920	815	1'252
Other bituminous coal	TJ	4'364	3'661	4'348	3'912	3'940	3'992	3'474	3'403	3'478	1'772
Lignite	TJ	737	1'834	1'790	1'596	1'379	1'348	1'493	1'081	1'283	2'912
Natural gas	TJ	1'861	2'057	2'017	1'919	1'731	2'048	1'938	2'085	2'506	3'098
Other fossil fuels	TJ	4'525	4'293	4'224	4'975	4'958	5'183	5'307	4'883	5'186	5'270
Biomass	TJ	1'575	1'609	1'476	1'406	1'371	1'604	1'739	1'923	1'764	1'901

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.

Cement: Emission factors

The CH₄ emission factor includes the overall CH₄ emissions of the cement industry based on direct exhaust measurements at the chimneys of the cement plants. Therefore, these CH₄ emissions are reported under the fuel type other fossil fuels in the CRF-tables.

Table 3-47 Emission factors for cement industry in 2014. Emission factors for CO₂ and N₂O are fuel-specific (see Table 3-39).

Cement industry (part of 1A2f)	CO ₂	N ₂ O	CH ₄	NO _x	NM VOC	SO ₂	CO
	t/TJ		g/t clinker				
Cement	fuel specific		6	930	59	270	1'900

The NCVs and CO₂ emission factors for waste oil, solvents and residues from distillation, plastics, mix of special waste with saw dust (CSS), sewage sludge, wood waste, animal meal and saw dust are based on a study of Cemsuisse (Cemsuisse 2010a). The values for waste tyres are taken from Hackl and Mauschwitz (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 emission factor of N₂O for all waste derived fuels is the same and is taken from IPCC 2006 guidelines (IPCC 2006, vol 2, chp.2 table 2.3 industrial wastes).

Table 3-48 NCV, CO₂ and N₂O emission factors as well as biomass fraction of waste derived fuels (Other fossil fuels and Biomass) used in the cement industry in 2014.

Cement industry (part of 1A2f)	NCV	EF CO₂ Tot.	EF N₂O	Fraction biomass-C
Waste derived fuel	MJ/kg	kg CO₂/GJ	g/GJ	%
Waste oil	32.48	74.35	4.0	0
Waste coke from coke filters	23.70	97.00	4.0	0
Mixed industrial waste	18.34	74.00	4.0	0
Other fossil waste fuels	20.85	97.00	4.0	0
Solvents and residues from distillation	23.63	73.99	4.0	0.9
Waste tyres and rubber	26.40	84.00	4.0	27
Plastics	25.24	84.66	4.0	27.7
Mix of special waste with saw dust (CSS)	9.22	102.40	4.0	78.5
Sewage sludge (dried)	9.39	94.52	4.0	100
Wood waste	16.26	99.90	4.0	100
Animal meal	16.81	86.66	4.0	100
Sawdust	16.26	99.90	4.0	100
Agricultural waste / other biomass	12.72	110.00	4.0	100

Cement: Activity data

Data on fuel consumption is provided by the industry, for recent years based on monitoring reports of the Swiss ETS as documented in the EMIS database (EMIS2016/1A2f Zementwerke Feuerung).

In 2014, the Swiss cement industry used about similar amounts of fossil and waste derived fuels. Fossil fuels used in cement industry are mainly lignite, other bituminous coal and petroleum coke. In addition, also fossil and biogenic waste derived fuels are used. Fossil wastes comprise plastics, solvents and residues from distillation, waste tyres and rubbers, and waste oil whereas biogenic wastes contain mainly wood waste, animal residues and sewage sludge. The main fossil fuels used in 1990 were other bituminous coal, residual fuel oil and other fossil fuels.

Fuel consumption in cement plants has decreased between 1990 and 2014. This is partly due to a decrease in production since 1990 and an increase in energy efficiency. In the same period the fuel mix has changed significantly from mainly fossil fuels to the above mentioned mix of fuels, including biogenic fractions of waste derived fuels.

All fossil waste derived fuels in the reporting tables are reported under fuel type Other fossil fuels, whereas the biogenic waste derived fuels are reported in fuel type Biomass.

Table 3-49 Activity data: Overview on fuel use in 1A2f cement industry.

Cement industry (part of 1A2f)	Unit	1990	1995	2000
Cement industry				
Cement, total incl. waste	TJ	17'193	12'772	11'018
Cement fossil without waste	TJ	15'319	9'993	7'332
Gas oil	TJ	0	0	0
Residual fuel oil	TJ	1'907	2'825	1'530
Petroleum coke	TJ	550	300	480
Other bituminous coal	TJ	12'235	6'547	5'176
Lignite	TJ	265	153	124
Gas	TJ	362	168	22
Cement, waste derived fuel	TJ	1'874	2'780	3'686
Other fossil fuels	TJ	1'841	2'195	2'998
Waste oil	TJ	1'169	1'485	1'519
Waste coke from coke filters	TJ	59	59	59
Mixed industrial waste	TJ	0	0	0
Other fossil waste fuels	TJ	0	0	0
Solvents and residues from distillation	TJ	284	181	427
Waste tyres and rubber	TJ	330	415	421
Plastics	TJ	0	55	572
Biomass	TJ	33	585	688
Mix of special waste with saw dust (CSS)	TJ	23	136	158
Sewage sludge (dried)	TJ	9	128	332
Wood waste	TJ	0	321	0
Animal meal	TJ	0	0	198
Sawdust	TJ	0	0	0
Agricultural waste / other biomass	TJ	0	0	0

Cement industry (part of 1A2f)	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cement industry											
Cement, total incl. waste	TJ	11'623	11'719	12'022	11'954	11'816	12'388	12'187	11'462	11'866	12'339
Cement fossil without waste	TJ	6'208	6'401	6'914	6'389	6'127	6'278	5'859	5'406	5'512	5'847
Gas oil	TJ	72	57	NO	NO	NO	5	1	0	88	75
Residual fuel oil	TJ	637	220	175	135	100	112	101	297	86	58
Petroleum coke	TJ	638	903	912	1'036	994	1'130	1'081	920	815	1'252
Other bituminous coal	TJ	4'120	3'383	4'033	3'618	3'650	3'662	3'167	3'097	3'203	1'512
Lignite	TJ	737	1'834	1'790	1'596	1'379	1'348	1'493	1'081	1'283	2'912
Gas	TJ	4	4	4	4	4	21	16	11	38	37
Cement, waste derived fuel	TJ	5'415	5'319	5'108	5'565	5'689	6'109	6'329	6'056	6'354	6'492
Other fossil fuels	TJ	3'931	3'814	3'727	4'237	4'394	4'580	4'685	4'225	4'599	4'596
Waste oil	TJ	1'411	1'279	844	866	1'278	1'253	1'170	839	876	923
Waste coke from coke filters	TJ	58	60	NO	NO	NO	NO	NO	NO	NO	NO
Mixed industrial waste	TJ	NO	NO	2	1	1	NO	NO	NO	NO	NO
Other fossil waste fuels	TJ	NO	NO	48	105	137	45	55	36	25	19
Solvents and residues from distillation	TJ	976	981	1'295	1'476	1'032	1'189	1'264	1'294	1'414	1'273
Waste tyres and rubber	TJ	645	568	525	794	828	842	1'033	964	985	1'021
Plastics	TJ	841	926	1'013	995	1'119	1'252	1'163	1'092	1'299	1'360
Biomass	TJ	1'484	1'504	1'381	1'328	1'295	1'530	1'644	1'831	1'756	1'896
Mix of special waste with saw dust (CSS)	TJ	133	146	164	157	131	123	96	100	96	103
Sewage sludge (dried)	TJ	494	560	549	511	475	477	483	527	418	428
Wood waste	TJ	NO	NO	NO	NO	61	292	409	586	732	886
Animal meal	TJ	856	799	664	658	621	624	614	572	479	457
Sawdust	TJ	NO	NO	NO	NO	NO	6	24	17	32	21
Agricultural waste / other biomass	TJ	NO	NO	5	2	7	7	18	28	NO	NO

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 was dominated by residual fuel oil. 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.

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 2014, fuel consumption for container glass production includes only natural gas. 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 share 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 as residual fuel oil was eliminated in 1995. Since 1990, fuel consumption for tableware glass strongly decreased because of the closure of one production plant in 2006.

Currently, fuel consumption for glass wool production includes only natural gas. Production of glass wool has increased since 1990, but the natural gas consumption decreased. This can be explained by an increase in energy efficiency in the production process between 1990 and 2014.

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 ceramic 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 consisted of natural gas and gas oil. Since then, it 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 compared to the reduction in production between 1990 and 2014.

Brick and tile

In Switzerland there are about 20 plants producing bricks and tiles. Mainly fossil fuels but also paper production residues, animal grease and wood are used for drying and burning of the clay blanks.

Brick and tile: Emission factors

The CO₂ emission factors for wood and animal grease are based on a study of Cemsuisse (Cemsuisse 2010a), see Table 3-48, whereas the one for paper production residues is taken from a German study on secondary fuels (UBA 2006) as documented in the EMIS database (EMIS 2016/1A2f Ziegeleien).

For CH₄ and N₂O emission factors of paper production residues and animal grease default values for wood waste and other liquid fuels, respectively, according to IPCC 2006 are used. For wood the CH₄ and N₂O emission factors according to the energy model for wood combustion (automatic chip boiler >500 kW, w/o wood processing companies), see chp. 3.2.4.5.2, are taken.

Brick and tile: Activity data

Since 2013, plant-specific activity data are available from monitoring reports of the Swiss ETS. Fuels used in the brick and tile production in 2014 are mainly natural gas but also residual fuel oil and gas oil. Apart from a production recovery in the years around 2004, the production has gradually decreased since 1990 which is also represented in the overall fuel consumption decrease. Regarding the fuels used, there has been a considerable shift from residual fuel oil to natural gas from 1990 onwards as well as to a lesser extent minor shift from liquefied petroleum gas and gas oil to natural gas from 2004 onwards. Small amounts of paper production residues, wood and animal grease are used since 2000.

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 and natural gas are used in the production process. Until 2004 also gas oil and liquefied petroleum gas were used. In 2005, these fuels were substituted by natural gas.

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 fuels used in 2014 are gas oil and natural gas. Since 1990, there has been a fuel switch from gas oil to natural gas.

3.2.6.2.9 Other (1A2g stationary)

Methodology (1A2g stationary)

Source category 1A2giv Wood and wood products includes fuel consumption of fibreboard production. Fibreboards are produced in two companies in Switzerland, where thermal energy is used for heating and drying processes.

Source category 1A2gviii Other covers fossil fuel combustion in boilers of manufacturing industries and construction mainly within non-metallic mineral industries as well as combustion of wood, wood waste, biogas and sewage gas in all manufacturing industries.

This source category accounts for about one third of the overall fuel consumption in 2014 of 1A2 Manufacturing industries and construction.

Methodologically, the fossil fuel consumption in boilers of 1A2gviii comprises also all the residual entities of the industry installations that could not be allocated to any other source categories 1A2a-f.

Emission factors (1A2g stationary)

The CO₂ emission factors for wood waste and animal grease in 1A2giv Fibreboard production are based on a study of Cemsuisse (Cemsuisse 2010a), see Table 3-48. For wood waste the respective CH₄ and N₂O emission factors of the energy model for wood combustion, see chp. 3.2.4.5.2, are taken whereas for animal grease the default values of IPCC 2006 for other liquid biofuels are used. For biogas and sewage gas in 1A2gviii Other boilers and engines industry the same emission factors as for natural gas are assumed.

Activity data (1A2g stationary)

1A2giv Fibreboard production: Activity data

In source category fibreboard production the main fuels currently used are wood waste and natural gas. Since 1990, the production of fibreboard and thus the fuel consumption have increased significantly. The fuel mix has strongly shifted between 1990 and 2014 from fossil fuels to biomass (wood waste). Between 2001 and 2013, also animal grease was used for fibre board production. Since 2004, data on annual fuel consumption is taken from monitoring reports of the industry as documented in the EMIS database (EMIS 2016/1A2g iv).

1A2g viii Other boilers and engines industry: Activity data

Activity data for wood combustion is based on wood statistics (SFOE 2015b) whereas sewage and biogas consumption is based on data from the Swiss renewable energy statistics (SFOE 2015a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2015c). Further information on wood energy consumption is provided in chapter 3.2.4.5.2.

Since 1990, the consumption of residual fuel oil and liquefied petroleum gas decreased. Solid fossil fuel consumption also decreased, whereas biomass and natural gas consumption increased.

Table 3-50 Activity data fuel consumption in 1A2giv Wood and wood products and 1A2gviii Other (stationary).

Source	Unit	1990	1995	2000
1A2g iv: Wood and wood products, 1A2g viii: Other (stationary)	TJ	20'870	27'120	29'394
Gas oil	TJ	6'295	10'730	12'807
Residual fuel oil	TJ	5'298	3'749	199
Liquefied petroleum gas	TJ	3'256	3'536	4'457
Petroleum coke	TJ	626	960	71
Other bituminous coal	TJ	624	256	34
Lignite	TJ	0	0	0
Natural gas	TJ	262	2'005	4'948
Other fossil fuels	TJ	0	0	0
Biomass	TJ	4'507	5'883	6'876

Source	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2g iv: Wood and wood products, 1A2g viii: Other (stationary)	TJ	32'405	33'122	32'587	35'337	35'286	35'607	31'763	32'464	33'154	29'034
Gas oil	TJ	13'934	13'370	12'696	13'019	12'173	12'263	9'586	9'826	10'445	6'817
Residual fuel oil	TJ	26	295	105	119	124	182	109	109	22	69
Liquefied petroleum gas	TJ	3'407	3'753	3'392	3'293	3'473	3'124	3'031	2'428	2'424	2'199
Petroleum coke	TJ	456	609	360	31	224	365	191	447	219	3
Other bituminous coal	TJ	380	375	452	355	252	293	270	236	376	582
Lignite	TJ	5	97	147	121	152	111	131	95	75	189
Natural gas	TJ	5'689	5'845	5'926	8'012	7'796	7'828	7'400	7'713	7'622	7'139
Other fossil fuels	TJ	0	0	0	0	0	0	0	0	0	0
Biomass	TJ	8'508	8'778	9'510	10'387	11'092	11'441	11'045	11'611	11'970	12'034

3.2.6.3 Uncertainties and time-series consistency for 1A2 (stationary)

The uncertainty of CO₂ emissions from fuel combustion is described in the uncertainty analysis of source category 1A Fuel combustion in chp. 3.2.4.7. Uncertainty in emissions of other non-CO₂ gases is estimated to be medium, i.e. 30% for CH₄ and 80% for N₂O (see Table 1-11).

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

3.2.6.4 Category-specific QA/QC and verification for 1A2 (stationary)

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 3.2.4.8.

3.2.6.5 Category-specific recalculations for 1A2 (stationary)

Recalculations reported in submission 2015

- 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 CH₄, CO and NMVOC.
- 1A: For wood combustion, the previously used country-specific value of the N₂O EF (1.6 g/GJ) has been replaced by the default value of the 2006 IPCC Guidelines (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 (SFOE 2015).
- 1A: The default CO₂ 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 N₂O 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 CO₂ emission factors have been revised to plant-specific values whereas for CH₄ and N₂O emission factors default values according to 2006 IPCC Guidelines have been assumed.
- 1A2d: In source category 1A2d Cellulose production the CO₂ 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 tonnes of clinker, and not to tonnes 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 CO₂. 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 NO_x from 1A2f Mineral wool production has been revised for 2000–2012 based on air pollution control measurements

Recalculations reported in submission 2016

- 1A2: AD for natural gas has changed for sector industry in SFOE 2015 (2013).
- 1A2a: For 1A2a Steel production, reheating furnaces the EF of NO_x and CO have been revised from 1995 onwards based on air pollution control measurements (1995–2013, 2012–2015).
- 1A2d: The emissions of carbonate used in 1A2d Cellulose production were not taken into account due to a mistake in calculations in the last submission.
- 1A2f: The emission factor for the use of natural gas in the production of glass was set to the emission factor of gas oil 73.7 kg/GJ. This is now corrected to the one of natural gas 56.1 kg/GJ for the year 1990, etc.
- 1A2f: The AD (residual fuel oil, liquefied petroleum gas) of 1A2f Glass production (speciality tableware) have been revised based on new industry data for 1990–1999 and 1990–2006, respectively.
- 1A2f: The EF of NO_x from 1A2f Glass production (speciality tableware) have been revised from 1996 onwards based on air pollution control measurements.
- 1A2f: The AD (natural gas) from 1A2f Container glass production has been revised for 2013 based on corrected industry data.
- 1A2f: The EF of CH₄ and N₂O for use of paper production residues in 1A2f Brick and tile production have been revised according to default values of 2006 IPCC Guidelines.
- 1A2f: For 1A2f Fine ceramics production the EF of NO_x, CO, NMVOC and SO₂ have been revised from 1991 onwards based on air pollution control measurements.
- 1A2f: For 1A2f Brick and tile production erroneous CH₄ EF of wood use have been corrected for 2000–2007 and 2009–2012.
- 1A2f: For 1A2f Brick and tile production the EF of NO_x, CO, NMVOC and SO₂ have been revised from 1990 onwards based on air pollution control measurements.
- 1A2f: Changed amount of used other bituminous coal and lignite in cement production (1990–2004) in 1A2f based on bottom-up industry data.
- 1A2f: CH₄ emissions for cement production (furnace) are assumed to be approx. 10% of NMVOC emissions. An error has been corrected in the EF for NMVOC for 2008 and the CH₄ values have been recalculated accordingly. Besides that the EF for CH₄ has been recalculated with the percentage referring to g NMVOC/t clinker and not to g NMVOC/t cement as it was the case until submission 2014.
- 1A2g: Recalculation in Swiss renewable energy statistics (SFOE 2015a) concerning use of sewage gas (2000, 2005, 2012, 2013) in 1A2gviii.
- 1A2g: Recalculation in Swiss renewable energy statistics (SFOE 2015a) concerning use of biogas (2010–2013) in 1A2gviii.
- 1A2g: CH₄ emission factor from sewage gas in 1A2gviii was changed to the one from biogas and natural gas of 1g/GJ.

- 1A2g: CO₂ biog. emission factor from sewage gas was changed to the one from biogas and natural gas in 1A2gviii.

3.2.6.6 Category-specific planned improvements for 1A2 (stationary)

No category-specific improvements are planned.

3.2.7 Source category 1A4 – Other sectors (stationary 1A4 ai/bi/ci)

3.2.7.1 Source category description for 1A4 (stationary)

Approach 1 key categories 1A4

CO₂ from the combustion of Liquid Fuels in 1A4a Commercial/Institutional (level and trend)

CO₂ from the combustion of Gaseous Fuels in 1A4a Commercial/Institutional (level and trend)

CO₂ from the combustion of Gaseous Fuels in the 1A4b Residential (level and trend)

CO₂ from the combustion of Liquid Fuels in 1A4b Residential (level and trend)

CH₄ from the combustion of biomass in 1A4b Residential (trend)

Approach 2 key categories 1A4

CO₂ from the combustion of Gaseous Fuels in the Commercial/Institutional (level and trend)

CO₂ from the combustion of Gaseous Fuels in 1A4b Residential (level and trend)

CO₂ from the combustion of Liquid Fuels in 1A4b Residential (trend)

CH₄ from the combustion of biomass in 1A4b Residential (trend)

[Each of the source categories 1A4a, 1A4b, 1A4c contain the sum of emissions of stationary and mobile sources – the above statements on key categories hold for the aggregated emissions of 1A4a etc. only. The CO₂ emissions of 1A4a and 1A4b from Liquid Fuels are vastly dominated by the stationary sources, which means that the emissions of 1A4aii and 1A4bii only play a minor role within category 1A4a and 1 A4b. For 1A4c, however, the emissions of 1A4cii are dominating those of 1A4ci.]

Table 3-51 Specification of source category 1A4 Other sectors.

1A4	Source	Specification
1A4ai	Commercial/institutional	Emissions from stationary combustion in commercial and institutional buildings.
1A4bi	Residential	Emissions from stationary fuel combustion in households.
1A4ci	Agriculture/forestry/fishing	Emissions from stationary fuel combustion of agriculture and grass drying.

3.2.7.2 Methodological issues for 1A4 (stationary)

Methodology (1A4 stationary)

Emissions from stationary combustion in source categories 1A4ai, 1A4bi and 1A4ci are estimated using a Tier 2 approach according to the decision tree for stationary combustion of the 2006 IPCC guidelines (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1). Direct emission measurements are not available. For the calculation of the emissions from the use of gas oil and natural gas the following sources are differentiated: (a) heat only boilers, (b) combined heat and power production in turbines and (c) combined heat and power production in engines.

Emissions from 1A4ci originate from fuel combustion for grass drying and wood combustion for heating in agriculture and forestry. For grass drying, information is provided by the grass drying association.

Emission factors (1A4 stationary)

Table 3-52 Emission factors for stationary combustion in 1A4ai Other sectors commercial/institutional in 2014.

Source/fuel	CO ₂	CO ₂ biog.	CH ₄	N ₂ O	NO _x	CO	NMVOC	SO ₂
	t/TJ		kg/TJ					
1A4a Other sectors: Commercial/institutional								
Gas oil (weighted average)	73.7		10	0.6	34.4	6.7	6	19.2
Gas oil (heat only boilers)	73.7		10	0.6	34.4	6.6	6	19.2
Gas oil (engines)	73.7		0.6	0.6	40	30	8	18.1
Natural gas (weighted average)	56.7		2.2	0.1	23.6	13.3	1.9	0.5
NG (heat only boilers)	56.7		1	0.1	17.8	10.2	2	0.5
NG (turbines)	56.7		2	0.1	60	15	0.1	0.5
NG (engines)	56.7		20	0.1	106	57.5	1	0.5
Other bituminous coal	NO		NO	NO	NO	NO	NO	NO
Lignite	NO		NO	NO	NO	NO	NO	NO
Biomass (weighted average)		86.5	20.8	3.1	94.5	660	31	7.8
Biomass (wood)		92.2	24.6	3.7	109	785	37	9.2
Biomass (biogas)		56.7	1	0.1	17.8	10.2	2	0.5

Table 3-53 Emission factors for stationary combustion in 1A4bi Other sectors residential in 2014.

Source/fuel	CO ₂	CO ₂ biog.	CH ₄	N ₂ O	NO _x	CO	NMVOC	SO ₂
	t/TJ		kg/TJ					
1A4b Other sectors: Residential								
Gas oil (weighted average)	73.7		10	0.6	36	12.2	6	19.2
Gas oil (heat only boilers)	73.7		10	0.6	36	12.2	6	19.2
Gas oil (engines)	73.7		2	0.6	40	30	8	18.1
Natural gas (weighted average)	56.7		1.2	0.1	17	13.6	4	0.5
NG (heat only boilers)	56.7		1	0.1	16.8	13.2	4	0.5
NG (turbines)	56.7		2	0.1	60	15	0.1	0.5
NG (engines)	56.7		20	0.1	35	57.5	1	0.5
Other bituminous coal	92.7		300	1.5	65	2000	100	350
Lignite	NO		NO	NO	NO	NO	NO	NO
Biomass		94.8	52.2	3.8	88.4	1395	78.3	9.5

Table 3-54 Emission factors for stationary combustion in 1A4ci Agriculture/forestry/fishing in 2014.

1A4c Agriculture/forestry/fishing	Unit	CO₂ fossil	CO₂ biog.	CH₄	N₂O
Drying of grass (fossil, biogenic)	kg/TJ	62'288	95'001	7.3	1.0
Biomass	kg/TJ	NA	119'791	20	4.8

Charcoal and bonfires

Emission factors concerning CO₂, CH₄ and N₂O emissions of charcoal use in the residential source categories (1A4bi) are taken from the 2006 IPCC guidelines (IPCC 2006). Default emission factors according to the guidelines are also applied for CH₄ and N₂O emissions resulting from bonfires. The CO₂ emission factor for bonfires in the residential category (1A4bi) is based on literature (SAEFL 2000). Regarding precursors the values are taken from the EMEP/EEA Guidebook (2013).

Table 3-55 Emission factors for use of charcoal and bonfires in 1A4bi Other sectors residential in 2014.

1A4bi Other sectors: residential stationary combustion	Unit	CO₂ biog.	CH₄	N₂O	NO_x	NMVOC	SO₂	CO
Use of charcoal	kg/TJ	112'000	200	1	50	600	11	6'000
Bonfires	kg/TJ	99'900	300	4	50	600	11	6'000

Activity data (1A4 stationary)

General energy sources

Activity data about the energy sources gas oil, residual fuel oil, natural gas and biomass are calculated by the Swiss energy model (see 3.2.4.3 for further information). For other energy sources such as other bituminous coal, activity data is provided directly by the Swiss overall energy statistics (SFOE 2015). Grass drying activities for source category 1A4ci are reported by the Swiss association of grass drying plants (VSTB) (as standard tonne of dried grass) as documented in the EMIS database (EMIS 2016/ 1A4ci Grastrocknung). Since submission 2015, the actual fuel consumption for grass drying is available and used for emission calculations.

Table 3-56 Activity data in 1A4a Commercial/Institutional.

Source/Fuel	Unit	1990	1995	2000
1A4a Other sectors:	TJ	78'060	85'341	81'622
Commercial/institutional				
Gas oil	TJ	57'605	58'799	53'004
Gas oil heat only boilers	TJ	57'581	58'623	52'653
Gas oil engines	TJ	24	175	351
Natural gas	TJ	17'495	22'715	24'234
NG heat only boilers	TJ	17'219	21'544	22'498
NG turbines	TJ	85	78	NO
NG engines	TJ	192	1'093	1'737
Other bituminous coal	TJ	NO	NO	NO
Lignite	TJ	NO	NO	NO
Biomass (total)	TJ	2'960	3'828	4'383
Biomass (wood)	TJ	2'936	3'794	4'325
Biomass (biogas)	TJ	24	34	58

Source/Fuel	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A4a Other sectors:	TJ	87'766	82'581	74'751	78'979	76'966	83'324	69'052	75'923	80'784	64'465
Commercial/institutional											
Gas oil	TJ	54'930	51'547	45'443	47'579	45'693	48'772	38'895	41'809	44'328	34'191
Gas oil heat only boilers	TJ	54'612	51'253	45'262	47'410	45'539	48'653	38'791	41'715	44'242	34'109
Gas oil engines	TJ	318	293	181	169	154	119	105	94	86	82
Natural gas	TJ	27'440	25'034	23'511	24'987	24'496	27'207	23'805	26'783	28'211	21'951
NG heat only boilers	TJ	25'407	23'082	21'585	23'130	22'683	25'503	22'224	25'231	26'714	20'515
NG turbines	TJ	28	23	28	29	26	23	17	5	7	7
NG engines	TJ	2'004	1'929	1'898	1'829	1'787	1'681	1'564	1'548	1'490	1'429
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass (total)	TJ	5'396	6'000	5'797	6'412	6'777	7'344	6'352	7'331	8'245	8'323
Biomass (wood)	TJ	5'250	5'784	5'484	5'982	6'278	6'700	5'620	6'504	7'194	6'981
Biomass (biogas)	TJ	146	216	313	431	499	644	732	827	1'050	1'341

Table 3-57 Activity data in 1A4b Residential.

Source/Fuel	Unit	1990	1995	2000
1A4b Other sectors: Residential	TJ	185'318	189'265	170'432
Gas oil	TJ	136'886	133'547	116'294
Gas oil heat only boilers	TJ	136'885	133'543	116'241
Gas oil engines	TJ	1	4	53
Natural gas	TJ	25'876	34'087	36'270
NG heat only boilers	TJ	25'816	33'829	35'831
NG turbines	TJ	NO	NO	NO
NG engines	TJ	60	258	439
Other bituminous coal	TJ	630	460	130
Lignite	TJ	NO	NO	NO
Biomass	TJ	21'926	21'171	17'738

Source/Fuel	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A4b Other sectors: Residential	TJ	185'940	178'775	159'077	170'182	166'791	180'864	145'339	160'393	171'470	134'522
Gas oil	TJ	124'023	118'885	102'728	108'715	105'295	111'731	86'988	94'103	99'373	75'136
Gas oil heat only boilers	TJ	123'960	118'822	102'663	108'663	105'254	111'695	86'955	94'071	99'344	75'109
Gas oil engines	TJ	63	63	65	52	42	36	34	32	29	27
Natural gas	TJ	42'632	40'922	39'159	42'388	42'468	48'232	40'913	47'041	50'957	42'367
NG heat only boilers	TJ	42'102	40'380	38'614	41'847	41'931	47'726	40'443	46'576	50'509	41'938
NG turbines	TJ	NO	NO	3	3	NO	NO	NO	NO	NO	NO
NG engines	TJ	530	542	542	537	538	506	470	466	448	430
Other bituminous coal	TJ	400	400	400	400	400	400	400	400	400	400
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	18'885	18'568	16'790	18'679	18'627	20'501	17'038	18'849	20'740	16'618

Table 3-58 Activity data in 1A4ci Agriculture/forestry/fishing.

Source/Fuel	Unit	1990	1995	2000
1A4c Agriculture/forestry/fishing	TJ	2'323	2'032	1'703
Drying of grass (fossil, biogenic)	TJ	1'895	1'544	1'223
Biomass	TJ	428	488	479
1990=100%		100%	87%	73%

Source/Fuel	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A4c Agriculture/forestry/fishing	TJ	1'646	1'439	1'507	1'445	1'485	1'436	1'461	1'399	1'037	1'151
Drying of grass (fossil, biogenic)	TJ	994	845	948	822	856	739	891	685	458	524
Biomass	TJ	652	594	558	622	628	697	570	713	579	627
1990=100%		71%	62%	65%	62%	64%	62%	63%	60%	45%	50%

Charcoal and bonfires

Besides the main energy sources, also charcoal use and bonfires are accounted for in source category 1A4bi. The energy source charcoal is only used for charcoal grills. The total charcoal consumption under 1A4bi is very small compared to other fuels used for heating purposes. The activity data are the sum of charcoal production under 1A1c and net imports provided by the Swiss overall energy statistics (SFOE 2015).

The total wood demand for bonfires is assumed to be constant over time. Per capita wood demand is decreasing since 1990 due to an increasing number of inhabitants (for further details see documentation in EMIS 2015/1A4bi Lagerfeuer).

Table 3-59 Activity data in 1A4bi Charcoal and bonfires.

1A4bi Other sectors: residential stationary combustion	Unit	1990	1995	2000
Use of charcoal	TJ	311	291	292
Bonfires	TJ	160	160	160

1A4bi Other sectors: residential stationary combustion	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Use of charcoal	TJ	313	303	313	354	343	343	343	344	343	354
Bonfires	TJ	160	160	160	160	160	160	160	160	160	160

3.2.7.3 Uncertainties and time-series consistency for 1A4 (stationary)

The uncertainty of CO₂ emissions from fuel combustions is described in the uncertainty analysis in chp. 3.2.4.7. Uncertainty in emissions of other non-CO₂ gases is estimated to be medium: 30% for CH₄ and 80% for N₂O (see Table 1-11).

Consistency: Time series for 1A4 Other sectors are all considered to be consistent.

3.2.7.4 Category-specific QA/QC and verification for 1A4 (stationary)

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 3.2.4.8.

3.2.7.5 Category-specific recalculations for 1A4 (stationary)

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- 1A4: Recalculation in energy use in residential and commercial engines and gas turbines in 1A4 (2010–2013) based on (SFOE 2015c).
- 1A4a: Changed activity data (statistical difference) of use of biogas in Boilers due to recalculation of biogas use in 1A1a municipal waste disposal sites.
- 1A4bi: The emission factor for N₂O from charcoal use was changed to the value of 1 g/GJ instead of 4 g/GJ because due to a mistake last year it was changed to the one of wood (4g/GJ).
- 1A4bi: The AD of 1A4bi Charcoal use have been revised based on additional data from 2001 onwards.
- 1A4bi: The EF of NMVOC, SO₂ and CO of 1A4bi Charcoal use and 1A4bi Bonfires have been revised for the entire time series according to Tier 2 EF of the EMEP/EEA guidebook – 2013 (chap. 1A4, tab. 3-14 „open fireplaces burning biomass“).
- 1A4ci: The AD (gas oil and natural gas) of 1A4ci Grass drying have been corrected for 2013 since they were mixed up in last year's submission.

3.2.7.6 Category-specific planned improvements for 1A4 (stationary)

No category-specific improvements are planned.

3.2.8 Source category 1A2 – Manufacturing industry and construction (mobile 1A2g vii)

3.2.8.1 Source category description for 1A2 Manufacturing industry and construction (mobile 1A2g vii)

Approach 1 key categories 1A2

CO₂ from the combustion of Liquid Fuels (level and trend)

[Source category 1A2 contains the sum of emissions of stationary and mobile sources – the statement on key categories holds for the aggregated emission only. However, the CO₂ emissions of 1A2 from Liquid Fuels are dominated by the stationary sources, 88%, which means that the emissions of 1A2g vii only play a minor role within category 1A2].

Table 3-60 Specification of source category 1A2 Manufacturing industries and construction (mobile).

Source	Specification
Mobile Combustion in manufacturing industries and construction	industry sector: forklifts and snow groomers etc. construction machines: excavators, loaders, dump trucks, mobile compressors etc.

3.2.8.2 Methodological issues for 1A2 Manufacturing industry and construction (mobile 1A2g vii)

Methodology (1A2g vii)

Based on the decision tree Fig. 3.3.1 in chp. “3. Mobile Combustion” in IPCC (2006) the emissions of industry and construction vehicles and machinery are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.4.5.1.

Emission factors (1A2g vii)

- The CO₂ emission factors applied for the time series 1990–2014 for diesel oil, gasoline and compressed natural gas are country-specific and are given in Table 3-12.
- The CH₄ and N₂O emission factors are country-specific and are shown in Table 3-61 to Table 3-63 for diesel oil, gasoline and CNG engines for all emission standards.
- For SO₂ the emission factors are country-specific. The implied emission factor 2014 is shown in Table 3-64. See also Table A – 18 in Annex 3.1.5 for diesel oil, gasoline, gas oil.
- The emission factors for precursors are country-specific and are given in FOEN (2015j).
- NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference between VOC and CH₄ emissions.

All emission factors (GHG, precursors, SO₂) can be downloaded by query from the public part of the non-road database INFRAS (2015a)⁶. They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels.

⁶ <http://www.bafu.admin.ch/luft/00596/06906/offroad-daten/index.html?lang=en>

Table 3-61 Emission factors CH₄ and N₂O for industry and construction vehicles with diesel engines by emission standards including the year of enforcement.

Gas	Power class	PreEU-A <1996	PreEU-B 1996	EU-I 2002/03	EU-II 2002/04	EU-III A 2006/08	EU-III B 2011/12	EU-IV 2014
	kW	g/kWh						
CH ₄	<18	0,0547	0,0547	0,0384	0,0240	0,0142	0,0142	0,0142
CH ₄	18–37	0,0578	0,0578	0,0221	0,0134	0,0089	0,0089	0,0089
CH ₄	37–56	0,0319	0,0319	0,0156	0,0110	0,0079	0,0055	0,0058
CH ₄	56–75	0,0319	0,0319	0,0156	0,0110	0,0079	0,0031	0,0031
CH ₄	75–130	0,0218	0,0218	0,0108	0,0084	0,0067	0,0031	0,0031
CH ₄	130–560	0,0218	0,0218	0,0103	0,0072	0,0053	0,0031	0,0031
CH ₄	>560	0,0218	0,0218	0,0103	0,0072	0,0053	0,0031	0,0031
N ₂ O	0–3000	0,035	0,035	0,035	0,035	0,035	0,035	0,035

Table 3-62 Emission factors CH₄ and N₂O for industry and construction vehicles with gasoline engines by emission standards including the year of enforcement.

Gas	Power class	PreEU-A <1996	PreEU-B 1996	PreEU-C 2000	EU-I 2004	EU-II 2005/09
	ccm	g/kWh				
CH ₄	<66	2,04	2,04	2,04	1,394	1,394
CH ₄	66–100	1,36	1,36	1,36	1,088	1,088
CH ₄	100–225	0,68	0,68	0,68	0,408	0,408
CH ₄	>225	0,68	0,68	0,68	0,34	0,306
N ₂ O	0–3000	0,03	0,03	0,03	0,03	0,03

Table 3-63 Emission factors CH₄ and N₂O for industry and construction vehicles with CNG engines.

Gas	without catalyst	with catalyst
	g/kWh	
CH ₄	0,552	0,035
N ₂ O	0,05	0,05

Table 3-64 Implied emission factors for industry and construction vehicles in 2014.

1A2gvii Non-road vehicles and other machinery	CO ₂	CH ₄	N ₂ O	NO _x	NM VOC	SO ₂	CO
	t/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Gasoline	73.8	46.5	1.1	107	870	2.0	19532
Diesel oil	73.3	0.9	3.3	413	36	0.5	177
Natural gas	56.7	NA	NA	NA	NA	NA	NA

Activity data (1A2g vii)

Activity data for non-road (1A2gvii) are described in. chp. 3.2.4.5.1 (non-road transportation model). Values are taken from FOEN (2015j). Data on biofuels are provided by the statistics of renewable energies (SFOE 2015a). Activity data are shown in Table 3-65 and in Annex A3.1.4. Detailed data can be downloaded from the online database of INFRAS (2015a).

Table 3-65 Activity data for industry and construction vehicles.

Source/Fuel	Unit	1990	1995	2000
1A2gvii Non-road vehicles and other machinery	TJ	5'722	6'861	7'644
Gasoline	TJ	196	224	227
Diesel oil	TJ	5'359	6'380	7'108
Natural gas	TJ	167	257	301
Biodiesel	TJ	NO	NO	8
Bioethanol	TJ	NO	NO	NO

Source/Fuel	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A2gvii Non-road vehicles and other machinery	TJ	8'170	8'292	8'414	8'536	8'657	8'779	8'810	8'841	8'873	8'904
Gasoline	TJ	225	224	223	222	221	220	212	205	197	189
Diesel oil	TJ	7'629	7'755	7'881	8'007	8'133	8'259	8'295	8'331	8'367	8'403
Natural gas	TJ	292	288	283	279	274	270	261	252	243	234
Biodiesel	TJ	24	25	27	28	29	31	42	53	63	74
Bioethanol	TJ	0.02	0.03	0.04	0.05	0.07	0.08	0.72	1.36	2.00	2.64

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can also be downloaded by query from the public part of the non-road database INFRAS (2015a), see footnote 6. They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels.

3.2.8.3 Uncertainties and time-series consistency for 1A2g vii (mobile)

Uncertainties by fuel type are given in Table 3-24.

3.2.8.4 Category-specific QA/QC and verification for 1A2g vii (mobile)

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 3.2.4.8.

3.2.8.5 Category-specific recalculations for 1A2g vii (mobile)

Recalculations reported in submission 2015

- 1A: New calorific values for gasoline, diesel, gas oil based on new measurements for the year 2013. Therefore new CO₂ emission factor time series were generated.
- 1A: The default CO₂ emission factor for natural gas was replaced by a country-specific emission factor for the entire time period from 1990–2013.

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A2g vii, industry and construction vehicles (FOEN 2015j).

3.2.8.6 Category-specific planned improvements for 1A2g vii (mobile)

No category-specific improvements are planned.

3.2.9 Source category 1A3 - Transport

3.2.9.1 Source category description for 1A3

Key Categories in source category 1A3 Transport:

Approach 1 key categories 1A3a

CO₂ 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

CO₂ from the combustion of gasoline in Road transportation (level and trend)

CO₂ from the combustion of diesel oil in Road transportation (level and trend)

CH₄ from the combustion of gasoline in Road transportation (trend)

N₂O from the combustion of gasoline in Road transportation (trend)

N₂O from the combustion of diesel oil in Road transportation (trend)

Approach 2 key categories 1A3b

CO₂ from the combustion of diesel oil in Road transportation (level and trend)

CO₂ from the combustion of gasoline in Road transportation (level)

CH₄ from the combustion of gasoline in Road transportation (trend)

N₂O from the combustion of gasoline in Road transportation (trend)

Table 3-66 Specification of source category 1A3 Transport.

1A3	Source	Specification
1A3a	Domestic aviation	Large (jet, turboprop) and small (piston) aircrafts, helicopters
1A3b i	Road Transportation	Passenger cars
1A3b ii		Light duty trucks
1A3b iii		Heavy duty trucks and buses
1A3b iv		Motorcycles
1A3b v		Other
1A3c	Railways	Diesel locomotives
1A3d	Domestic navigation	Passenger ships, motor and sailing boats on the Swiss lakes and the river Rhine
1A3e	Other transportation - Pipeline compressors	Compressor station in Ruswil, Lucerne

For information on international bunker fuel emissions from international aviation and navigation, see chp. 3.2.2.

3.2.9.2 Methodological issues for 1A3

3.2.9.2.1 Domestic aviation (1A3a)

Methodology (1A3a)

The emissions of domestic aviation are modelled by a Tier 3A method (IPCC 2006, Volume 2, chp. 3 Mobile Combustion, Table 3.6.2 and figure 3.6.2) developed by FOCA (2006) and based on origin and destination of single movements by aircraft type according to detailed movement statistics. LTO emissions are modelled based on the individual engine type. The emissions of domestic aviation are modelled together with the international aviation reported in 1D1 (aviation bunker, see chp. 3.2.2.2.1).

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. 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 3-23.

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 2013), 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, aircraft performance tables and from confidential airline data. Pollutant emissions factors are adjusted to cruise conditions by using the Boeing Fuel Flow Method 2. For N₂O, the IPCC default emission factor is used. For the methane split of unburned hydrocarbons, the 10% methane share given in IPCC 2006 is used. Activity data are derived from a detailed movement statistics.

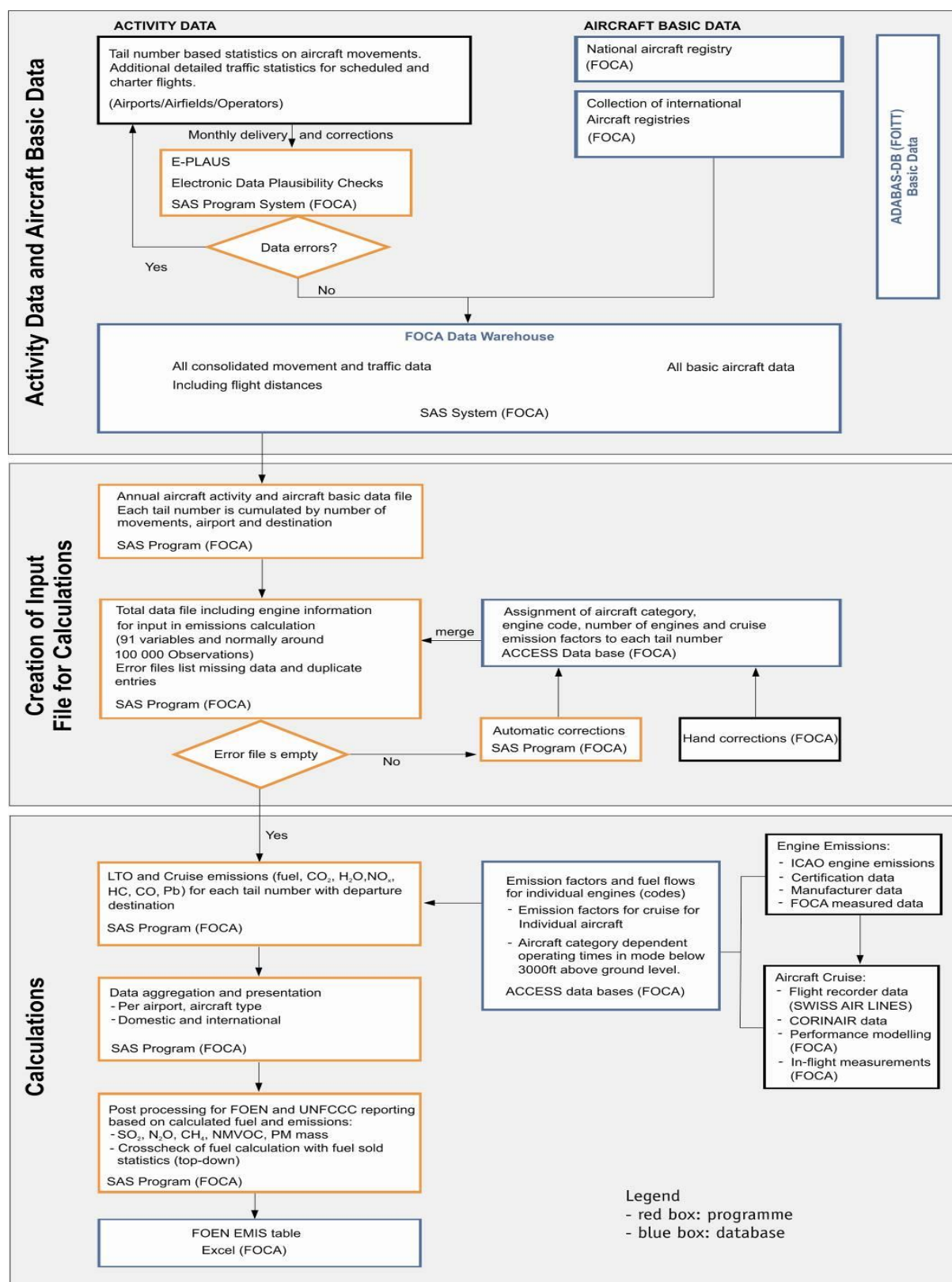


Figure 3-23 Modelling scheme (activity data, emission factors, emissions) for domestic aviation.

A complete emission modelling (LTO and cruise emissions for domestic and international flights) has been carried out by FOCA for 1990, 1995, 2000, 2002, 2004–2014. 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 (1A3a)

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 database. 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. GHG 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. For older aircraft types (pre 2003), part of the cruise emission factors were taken from EMEP/CORINAIR (EMEP/EEA 2013) and from former CROSSAIR (FOCA 1991). For new aircraft type entries, the FOCA models the cruise emission factors based on the aircraft type characteristics and the engine models fitted to the aircraft. The model uses proprietary aircraft information as well as public information from the ICAO engine database. For those aircraft types, which dominate the fuel consumption in Switzerland, flight data recorder information has been used to calibrate emission factors. The factors are updated periodically to take account of flight operational improvements, as well. Calculation results for international aviation emissions are periodically compared to Eurocontrol results. For piston engine aircraft and helicopters, Swiss FOCA has produced its own data, which were taken under real flight conditions (2005 data, FOCA 2009a).

Kyoto gases

- CO₂: the emission factor of 72.8 t/TJ in 2014 is country-specific and is based on measurements and analyses of fuel samples (see Table 3-12 and Table 3-67)
- CH₄, NMVOC (country-specific; CORINAIR): VOC emissions (see Precursors below) are split into CH₄ and NMVOC by a constant share of 0.1 (CH₄) and 0.9 (NMVOC)⁷. The implied emission factor for CH₄ is shown in Table 3-67.
- The N₂O emission factor regarding jet kerosene is default given by the 2006 IPCC guidelines (IPCC 2006). It is assumed that the emission factor for international cruise is sufficient for all kind of flight periods (LTO and cruise) and remains stable over the entire time period 1990–2014 (see Table 3-67).

Precursors

- 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 and 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 – 12 Aircraft Engine Combinations).

FOCA determines the emission factors of different gases as follows given in Table 3-67.

Table 3-67 Implied emission factors of 1A3a in 2014.

1A3a Aviation	Unit	CO ₂ fossil	CH ₄	N ₂ O	NO _x	NMVOC	SO ₂	CO
Kerosene, domestic, LTO	kg/TJ	72'800	9.2	2.3	157	83.2	21.3	2'301
Kerosene, domestic, CR	kg/TJ	72'800	4.7	2.3	322	41.9	20.7	923
Kerosene, international, LTO	kg/TJ	72'800	3.4	2.3	288	31.0	23.2	306
Kerosene, international, CR	kg/TJ	72'800	0.8	2.3	299	7.4	23.1	44

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).

Activity data (1A3a)

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 454'837 aircraft movements in the total of scheduled and charter traffic in 2014 as provided by FOCA 2015).

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 statistics of the Swiss Helicopter Association (Unternehmensstatistik der Schweizer Helikopterunternehmen). These statistics are officially collected by FOCA and updated annually (see FOCA 2004 as illustrative example for all subsequent years).
- Since 2007, the data of the statistics of the Swiss Helicopter Association are included electronically in the data warehouse of the model and undergo 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). All emissions from helicopter flights without using an official airport or an official airfield are considered as domestic emissions.

Fuel consumption: Table 3-68 summarises the activity data for domestic aviation (1A3a). It also includes international aviation, which belongs to the memo items, international bunkers/aviation (see also chp. 3.2.2). In order to split the fuel consumption for domestic and international flights, the FOCA calculates the fuel for each domestic and international flight bottom up. A first validation of this calculation can be done top down for the sum of all flights: The total annual aviation fuel sold known from robust energy statistics in a country should correspond very closely (within a few percent) to the modelled total fuel consumption of

domestic and international flights together. For 2014, the modelled total fuel consumption in Switzerland was 3.6% higher than the fuel sold value, so the model showed a slight overestimation. The total fuel sold as reported in the Swiss overall energy statistics is considered the most robust value for reporting, so the modelled total fuel consumption is scaled downwards such that the sum of domestic and international fuel consumption becomes identical with the fuel sold. The scaling is only done on the international fuel for the following reasons: Eurocontrol calculations for Switzerland's international flights fuel consumption are usually a few percent lower than the FOCA result. For domestic flights, the FOCA takes every movement including the smallest aircraft into account and applies conservative emission factors. An indication of this is the fact that Eurocontrol calculations for Switzerland's domestic flight fuel consumption is usually only around half the value reported by Switzerland. In summary, Switzerland reports the domestic fuel consumption 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 3-68 Fuel consumption of civil aviation in TJ for separated for domestic / international and LTO / cruise. Domestic consumption and the corresponding emissions are reported under 1A3a, international consumption is reported under Memo items, international bunkers (FOCA 2007, 2007a, 2008–2014).

1A3a/1D1 Civil aviation	1990	1995	2000
Fuel consumption in TJ			
Kerosene, domestic, LTO	1'050	935	772
Kerosene, domestic, CR	2'401	2'139	1'767
Kerosene, international, LTO (not part of national total)	4'277	5'097	6'503
Kerosene, international, CR (not part of national total)	37'608	44'821	57'184
Sum	45'334	52'993	66'225
1990 = 100%	100%	117%	146%

1A3a/1D1 Civil aviation	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fuel consumption in TJ										
Kerosene, domestic, LTO	517	506	544	512	497	463	507	502	494	525
Kerosene, domestic, CR	1'182	1'152	1'347	1'106	1'207	1'225	1'301	1'365	1'323	1'396
Kerosene, international, LTO (not part of national total)	4'868	5'095	5'401	5'737	5'449	5'622	6'017	6'199	6'208	6'142
Kerosene, international, CR (not part of national total)	42'804	45'013	48'142	52'107	49'789	52'496	56'194	57'428	58'501	58'864
Sum	49'370	51'766	55'434	59'462	56'942	59'805	64'019	65'494	66'526	66'927
1990 = 100%	109%	114%	122%	131%	126%	132%	141%	144%	147%	148%

3.2.9.2.2 Road transportation (1A3b)

Methodology (1A3b)

Choice of method

- The CO₂ emissions are calculated by a Tier 2 method based on the decision tree Fig. 3.2.2 in chp. 3. Mobile Combustion in IPCC (2006).
- The CH₄ and the N₂O emissions are calculated by a Tier 3 method based on the decision tree Fig. 3.2.3 in chp. 3. Mobile Combustion in IPCC (2006).
- The use of urea in urea-based catalysts is reported in chp. 4.5.2.2 under 2D3d as recommended in the reporting table's footnotes.

Connections between road model, non-road model and Swiss overall energy statistics

For the source categories related to transport, INFRAS developed a territorial emission model for road transportation (1A3b, INFRAS 2010 / FOEN 2010i; for details refer to Annex A3.1.3) and a model for non-road transportation (mobile sources in 1A2g vii, 1A3c, 1A3d, 1A4aii, 1A4bii, 1A4cii, 1A5b (excl. military aviation; (FOEN 2015j, see also “non-road transportation model” in chp. 3.2.4.5.1).

Due to fuel price differences in the vicinity of the national borders, gasoline stations sell relevant amounts of fuels to foreign car owners. This amount of fuel is mainly consumed abroad, called **fuel tourism**, is not captured by the territorial road model, but has to be included in the GHG inventory for the UNFCCC reporting. No fuel tourism is assumed for the non-road model.

The Swiss overall energy statistics provide information on the amounts of fuel sold, which contains territorial consumption **and** fuel tourism. From the amounts of fuel sold, the consumptions modelled by the territorial road and non-road models – i.e. fuel used – are subtracted. The resulting differences to the amount of fuels sold represent the amount of fuel tourism and statistical differences. Figure 3-24 shows how the models and the Swiss overall energy statistics are linked to determine the GHG emissions from road and non-road transportation:

- CO₂ emissions are calculated by using fuel sales and country-specific CO₂ emission factors.
- CH₄ and N₂O emissions are calculated in three steps:
 - From fuel used and country-specific CH₄ and N₂O emission factors, the territorial emissions are calculated.
 - The differences between fuels sold and fuels used (territorial) are interpreted as fuel tourism (and statistical differences⁸). These amounts of gasoline and diesel oil are multiplied with implied CH₄ and N₂O emission factors, which are deduced from the road transportation, to form the CH₄ and N₂O emissions resulting from fuel tourism (and statistical differences).
 - CH₄ and N₂O emissions from the territorial model plus CH₄ and N₂O from fuel tourism are added to the total CH₄ and N₂O emissions reported to the UNFCCC.

⁸ The amount of fuel tourism has been estimated by SFOE (2010d). 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”.

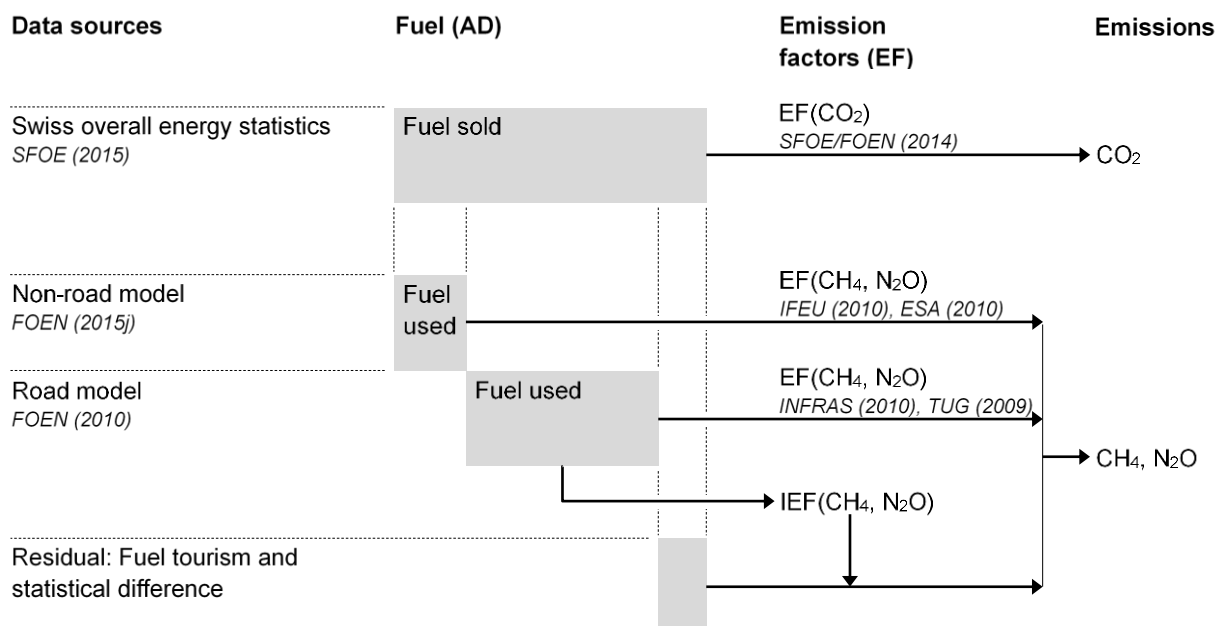


Figure 3-24: Connections between fuel sold and fuel used for road and non-road transportation. Fuel sold is provided by the Swiss overall energy statistics (minus Liechtenstein's gasoline and diesel oil consumption and bunker fuels for navigation). Fuel used results from the territorial road and non-road models. The residual fuel consists of fuel tourism and a statistical difference. Its emissions are calculated by means of implied emission factors deduced from the territorial road model. The diagram holds separately for gasoline and diesel oil.

Methodology of the territorial road transportation model

The emission computation is based on two sets of data (FOEN 2010i):

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

Emission modelling consists of three parts:

hot emissions: $E_{hot} = VKT \cdot EF_{hot}$

start emissions: $E_{start} = N_{start} \cdot EF_{start}$

evaporative emissions: $E_{evap,i} = N_{evap,i} \cdot EF_{evap,i}$,

with

- EF_{hot} , EF_{start} , EF_{evap} : Emission factors for ordinary driving conditions (hot motor), cold start and evaporative (VOC) emissions (after stops, running losses, diurnal losses)
- VKT : Vehicle km travelled
- N_{start} : Number of starts
- i runs over three evaporation categories: stops, running losses, diurnal losses

- $N_{evap,i}$: Number of stops (i= "after stops") or number of vehicles (i = "running losses" and "diurnal losses")

Emission factors (1A3b)

CO₂

- The country-specific CO₂ emission factors are described in chp.3.2.4.4.2. Values are shown in Table 3-12 (gasoline, diesel oil) and in Table 3-13 (natural gas). The values in 2014 are also shown in Table 3-69.
- The same emission factors are also applied for the calculation of the emissions resulting from fuel tourism.

CH₄

- Country-specific emission factors are applied. Details see below ("*Country-specific emission factors*").
- CH₄ emissions from fuel tourism: From the territorial model, implied emission factors for CH₄ are derived per vehicle category and per fuel type corresponding to mean emission factors for Switzerland (see Figure 3-24). These factors are then applied to calculate the emissions resulting from fuel tourism. To verify this approach, a comparison of these emission factors with implied emission factors of the neighbouring countries have been carried out. The differences are small between Switzerland, Austria, and Germany because all three countries use the same emission factors (INFRAS 2010, TUG 2009), whereas there are some differences compared to France and Italy that use other emission factors (COPERT). Nevertheless, the use of the mean Swiss emission factors seems to be the consistent approach.
- For biofuels, no country-specific EFs for CH₄ 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).

N₂O

- Country-specific emission factors are applied. Details see below ("*Country-specific emission factors*").
- N₂O emissions from fuel tourism: The same approach as for CH₄ is applied (see paragraph above)
- For biofuels no country-specific EFs for N₂O 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.

Country-specific emission factors

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” (see INFRAS 2010, TUG 2009). Version 3.1 is presented and documented on the website <http://www.hbefa.net/>. The general emission factor methodology is documented in TUG (2009). The resulting emission factors are published on CD ROM (“Handbook of emission factors for Road Transport”, INFRAS 2010). They refer to the so-called “traffic situations”, which represents characteristic patterns of driving behaviour and which serve as a key to the disaggregation of the activity data. 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.

Implied emission factors for GHG, precursors and SO₂

The following Table 3-69 presents mean emission factors for the GHG, the precursors and SO₂ in 2014. More or less pronounced decreases of the emission factors have occurred in the last years 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 N₂O, leading to an emission increase until 1998. Recent converter technologies have overcome this problem resulting in a decrease of the (mean) emission factor.

Table 3-69 Mean emission factors in 2014 for road transportation. For more details see Annex A3.1.3.

1A3b Road Transportation Gasoline / Bioethanol	CO₂	CH₄	N₂O	NO_x	NMVOC	SO₂	CO
	kg/TJ						
Passenger cars	73'800	5.1	0.5	59	85	0.36	661
Light duty vehicles	73'800	10.7	2.3	169	168	0.38	2287
Heavy duty vehicles	NO	NO	NO	NO	NO	NO	NO
Motorcycles	73'800	65.8	1.4	139	520	0.38	4631
Fuel tourism and statistical differences	73'800	7.1	0.6	63	107	0.36	812

1A3b Road Transportation Diesel / Biodiesel	CO₂	CH₄	N₂O	NO_x	NMVOC	SO₂	CO
	kg/TJ						
Passenger cars	73'300	0.29	2.1	230	12	0.44	59
Light duty vehicles	73'300	0.27	1.5	333	11	0.48	66
Heavy duty vehicles	73'300	0.21	3.3	368	8	0.47	122
Motorcycles	NO	NO	NO	NO	NO	NO	NO
Fuel tourism and statistical differences	73'300	0.26	2.5	293	10	0.46	83

1A3b Road Transportation Gas / Biogas	CO₂	CH₄	N₂O	NO_x	NMVOC	SO₂	CO
	kg/TJ						
Passenger cars	56'700	7.5	2.5	31.6	0.65	0.02	221
Light duty vehicles	56'700	0.1	0.0	0.0	0.01	0.00	0.6
Heavy duty vehicles	55'708	2.3	6.9	167.8	0.20	0.01	107
Motorcycles	NO	NO	NO	NO	NO	NO	NO
Fuel tourism and statistical differences	56'700	2.8	3.9	187	0.25	0.01	126

Activity data (1A3b)

Energy-related activity data (basis for modelling the CO₂ emissions)

The amount of gasoline and diesel fuel sold in Switzerland serves as the activity data for the calculation of the CO₂ emissions. The Swiss overall energy statistics provides the amount of gasoline and diesel oil sold in Switzerland and the Principality of Liechtenstein (SFOE 2015). From these numbers, Liechtenstein's sales, the non-road consumption, the bunker fuels 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 CO₂ emissions. It contains the fuel consumption of the traffic model plus the amount of fuel tourism and statistical differences.

The consumption of biofuels is based on the Swiss overall energy statistics (SFOE 2015), the Swiss renewable energy statistics (SFOE 2015a) and the Federal Customs Administrations (FCA 2015).

Table 3-70 shows the split of fuel sales into territorial road transportation model, the territorial non-road transportation model and fuel tourism (incl. statistical differences).

- 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".

- 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 FCA (2014).
- Consumption of biofuels for road transportation (biodiesel, bioethanol and biogas) starts in Switzerland in 1997.

Table 3-70 Split of fuel sales between territorial “on-road consumption (model)”, “non-road consumption (models)” and “fuel tourism and statistical differences” (residual value to sales amounts) for gasoline, diesel oil, natural gas (CNG) and biofuels (Vegetable/Waste oil is included in the numbers of Biodiesel) in PJ. Numbers may not add to totals due to rounding.

Activity data for fossil fuels on-road and non-road categories	Source category	1990	1995	2000
		PJ		
Gasoline				
on-road consumption (model)	1A3b	135.6	140.8	146.9
fuel tourism and statistical differences	1A3b	17.8	8.1	19.0
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	2.4	2.4	2.3
Gasoline sold in Switzerland		155.8	151.3	168.2
Diesel oil				
on-road consumption (model)	1A3b	36.5	39.8	44.9
fuel tourism and statistical differences	1A3b	-0.7	-4.4	-3.2
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	11.0	12.4	13.5
Diesel oil sold in Switzerland		46.7	47.8	55.2
Natural gas				
on-road consumption (model)	1A3b	NO	NO	NO
fuel tourism and statistical differences	1A3b	NO	NO	NO
non-road consumption (models)	1A2gvii	0.2	0.3	0.3
Natural gas sold in on- and non-road categories		0.2	0.3	0.3
Biodiesel				
on-road consumption (model)	1A3b	NO	NO	0.1
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	NO	NO	0.0
Biodiesel sold in Switzerland		NO	NO	0.1
Bioethanol				
on-road consumption (model)	1A3b	NO	NO	NO
non-road consumption (models)	1A2gvii; 1A3dii; 1A4bii; cii; 1A5b	NO	NO	NO
Bioethanol sold in Switzerland		NO	NO	NO
Biogas				
on-road consumption (model)	1A3b	NO	NO	NO
non-road consumption (models)		NO	NO	NO
Biogas sold in Switzerland		NO	NO	NO

Activity data on-road and non-road categories	Source category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
		PJ									
Gasoline											
on-road consumption (model)	1A3b	136.1	132.1	129.1	126.4	122.8	119.3	116.0	112.7	109.4	106.1
fuel tourism and statistical differences	1A3b	13.9	13.2	14.9	14.4	14.2	12.9	11.0	9.8	7.5	6.1
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	2.1	2.1	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.7
Gasoline sold in Switzerland		152.1	147.4	146.0	142.8	139.0	134.0	128.9	124.3	118.6	113.9
Diesel oil											
on-road consumption (model)	1A3b	57.4	61.1	65.3	68.2	70.8	73.9	75.1	76.3	77.5	78.8
fuel tourism and statistical differences	1A3b	1.2	3.4	4.9	10.1	8.7	9.1	10.6	15.5	19.1	20.8
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	13.9	14.1	14.3	14.4	14.6	14.8	14.8	14.8	14.8	14.8
Diesel oil sold in Switzerland		72.6	78.6	84.4	92.7	94.1	97.8	100.5	106.6	111.5	114.4
Natural gas											
on-road consumption (model)	1A3b	NO	NO	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3
fuel tourism and statistical differences	1A3b	0.1	0.1	0.2	0.3	0.5	0.5	0.5	0.4	0.4	0.3
non-road consumption (models)	1A2gvii	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
Natural gas sold in on- and non-road categories		0.4	0.4	0.6	0.7	0.9	1.0	1.0	0.9	0.9	0.9
Biodiesel											
on-road consumption (model)	1A3b	0.2	0.3	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.7
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Biodiesel sold in Switzerland		0.3	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.5	0.8
Bioethanol											
on-road consumption (model)	1A3b	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2
non-road consumption (models)	1A2gvii; 1A3dii; 1A4bii; cii; 1A5b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bioethanol sold in Switzerland		0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2
Biogas											
on-road consumption (model)	1A3b	NO	NO	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3
non-road consumption (models)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas sold in Switzerland		0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3

Mileage-related activity data (basis for modelling of the non-CO₂ 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 2011–2014 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, TUG 2009).
- 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)⁹.
- 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 are 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 (per vehicle category, size class, fuel type, emissions standard and per traffic situation) allows to calculate the **territorial** road traffic consumption of gasoline and diesel oil.

Table 3-71 shows the time series of the mileage per vehicle category. The total mileage has constantly been growing by about 1 per cent per year. The major part of vehicle kilometres was driven by passenger cars over the whole period. In the same period, on-road fuel

⁹ As reported in the NIR of submission 2015 (FOEN 2015), 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.

consumption increased less strongly indicating improved fuel efficiency. This effect is also reflected in Table 3-72 that depicts the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990–2014.

Table 3-71 Mileages in millions of vehicle kilometres. PC: passenger cars, LDV: light duty vehicles, HDV: heavy duty vehicles).

Veh. category	1990	1995	2000
	million vehicle-km		
PC	42'650	43'824	48'063
LDV	2'758	2'746	2'978
HDV	1'992	2'107	2'273
Coaches	108	110	99
Urban Bus	174	192	200
2-Wheelers	2'025	1'744	1'999
Sum	49'707	50'724	55'612
(1990=100%)	100%	102%	112%

Veh. category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	million vehicle-km									
PC	50'465	50'812	51'208	51'949	52'852	53'341	54'000	54'730	55'424	56'085
LDV	3'300	3'374	3'473	3'529	3'584	3'621	3'663	3'701	3'735	3'765
HDV	2'127	2'189	2'203	2'223	2'172	2'210	2'250	2'290	2'329	2'369
Coaches	106	118	120	114	119	119	119	118	118	118
Urban Bus	229	233	240	245	249	251	254	257	261	264
2-Wheelers	2'204	2'262	2'300	2'366	2'385	2'407	2'436	2'465	2'494	2'523
Sum	58'432	58'989	59'544	60'426	61'361	61'950	62'722	63'562	64'362	65'123
(1990=100%)	118%	119%	120%	122%	123%	125%	126%	128%	129%	131%

Table 3-72 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	1995	2000
		specific fuel cons. (MJ/veh-km)		
PC	Gasoline	3.18	3.23	3.14
	Diesel	2.91	2.90	2.80
	CNG	0.00	0.00	0.00
LDV	Gasoline	3.17	3.18	3.18
	Diesel	3.86	3.86	3.75
HDV	Diesel	10.91	10.85	10.33
Coach	Diesel	11.84	11.69	11.33
Urban Bus	Diesel	16.22	16.29	15.80
	CNG	0.00	0.00	0.00
2-Wheeler	Gasoline	1.11	1.22	1.25
Average		3.46	3.54	3.42
		100%	102%	99%

Veh. cat.	Fuel	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
		MJ/veh-km									
PC	Gasoline	3.04	2.99	2.97	2.93	2.90	2.86	2.81	2.77	2.71	2.66
	Diesel	2.46	2.41	2.40	2.35	2.33	2.30	2.28	2.24	2.21	2.17
	CNG	0.00	0.00	2.91	2.88	2.85	2.83	2.53	2.51	2.49	2.46
LDV	Gasoline	3.19	3.21	3.21	3.20	3.19	3.18	3.17	3.15	3.13	3.10
	Diesel	3.42	3.37	3.34	3.32	3.31	3.31	3.30	3.29	3.26	3.22
HDV	Diesel	10.77	10.71	10.73	10.65	10.59	10.55	10.50	10.46	10.41	10.37
Coach	Diesel	11.22	11.23	11.22	11.18	11.16	11.16	11.15	11.14	11.12	11.11
Urban Bus	Diesel	15.37	15.24	15.23	15.05	14.94	14.81	14.76	14.72	14.68	14.64
	CNG	0.00	0.00	20.34	20.32	20.36	20.58	20.52	20.46	20.38	20.31
2-Wheeler	Gasoline	1.28	1.29	1.31	1.33	1.35	1.34	1.34	1.34	1.34	1.33
Average		3.24	3.20	3.17	3.12	3.07	3.03	2.99	2.94	2.89	2.85
		94%	92%	91%	90%	89%	87%	86%	85%	84%	82%

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 3-73. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific surveys (ARE/SFSO 2005).

Table 3-73 Vehicle stock numbers and average number of starts per vehicle per day (PC: passenger cars, LDV: light duty vehicles).

Veh. Category	1990	1995	2000
stock in 1000 vehicles			
PC	2'985	3'229	3'545
LDV	221	238	260
2-Wheelers	764	704	732
starts per vehicle per day			
PC	2.61	2.53	2.46
LDV	1.97	1.97	1.96
2-Wheelers	1.59	1.54	1.50

Veh. Category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
stock in 1000 vehicles										
PC	3'862	3'894	3'956	3'990	4'010	4'076	4'195	4'302	4'396	4'477
LDV	291	298	307	312	317	326	328	331	334	337
2-Wheelers	770	784	789	804	807	816	815	815	816	818
starts per vehicle per day										
PC	2.40	2.39	2.38	2.37	2.35	2.34	2.34	2.33	2.33	2.32
LDV	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96
2-Wheelers	1.54	1.54	1.55	1.56	1.56	1.57	1.57	1.57	1.58	1.58

Further details are given in Annex A3.1.3.

3.2.9.2.3 Railways (1A3c)

Methodology (1A3c)

As mentioned in chp. 3.2.4.5.1, the emissions are calculated by the non-road transportation model, using approach at

- Tier 2 for CO₂ (based on decision tree Fig. 3.4.1 in IPCC 2006)
- Tier 3 for CH₄, N₂O and precursors/SO₂ (based on decision tree Fig. 3.4.2 in IPCC 2006).

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 are calculated for the years 1990, 1995, 2000, 2005 etc. up to 2015 based on fuel used. For the years in-between, the emissions are interpolated linearly.

Emission factors (1A3c)

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

- The CO₂ emission factor applied for the time series 1990–2014 for diesel oil is country-specific and is given in Table 3-12.
- The CH₄ and N₂O emission factors of diesel locomotives are shown in Table 3-74.
- For SO₂ the emission factors are country-specific. The implied emission factor 2014 is shown in Table 3-75. See also Table A – 18 (row diesel oil).
- The emission factors for precursors are country-specific and are given in FOEN (2015j).
- NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference between VOC and CH₄ emissions.

Implied emission factors are shown in Table 3-75.

All emission factors (GHG, precursors, SO₂) can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

Table 3-74 CH₄ and N₂O emission factors for rail vehicles

Gas	Power class	Rail vehicles with diesel oil engines				
		PreEU <2000	UIC1 2000	UIC2 2003	EU3a 2006	EU3b 2012
	kW	g/kWh				
CH ₄	<18	0.0547	0.0384	0.024	0.0142	0.0142
CH ₄	18–37	0.0578	0.0221	0.0134	0.0089	0.0089
CH ₄	37–56	0.0319	0.0156	0.011	0.0079	0.0055
CH ₄	56–75	0.0319	0.0156	0.011	0.0079	0.0031
CH ₄	75–130	0.0218	0.0108	0.0084	0.0067	0.0031
CH ₄	>130	0.0218	0.0103	0.0072	0.0053	0.0031
N ₂ O	all	0.035	0.035	0.035	0.035	0.035

Table 3-75 Implied emission factors 2014 for rail vehicles

1A3c Railways	Unit	CO ₂ fossil	CO ₂ biogen	CH ₄	N ₂ O	NO _x	NMVOC	SO ₂	CO
Diesel oil	kg/TJ	73'300	NA	1.3	3.6	1'023	118	0.47	536
Biodiesel	kg/TJ	NA	73'312	1.1	3.1	887	102	0.40	466

Activity data (1A3c)

Activity data for non-road (1A3c) are described in chp. 3.2.4.5.1 (non-road transportation model). Values are taken from FOEN (2015j). Data on biofuels are provided by the statistics of renewable energies (SFOE 2015a). Activity data are shown in Table 3-76 and in Annex A3.1.4.

Table 3-76 Activity data (diesel oil consumption) for railways.

1A3c Railways	Unit	1990	1995	2000
Diesel oil	TJ	390	441	455
Biodiesel	TJ	NO	NO	1
1990=100%		100%	113%	117%

1A3c Railways	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Diesel oil	TJ	472	476	480	484	488	492	472	452	432	412
Biodiesel	TJ	1	2	2	2	2	2	2	3	3	4
1990=100%		121%	123%	124%	125%	126%	127%	122%	117%	112%	107%

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

3.2.9.2.4 Domestic navigation (1A3d)

Methodology (1A3d)

Based on the decision tree Fig. 3.5.1 Box 1 of the 2006 IPCC Guidelines (IPCC 2006) the emissions of navigation are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.4.5.1.

There are passenger ships, dredgers, fishing boats, motor and sailing boats on the lakes and rivers of Switzerland. The emissions are calculated for the years 1990, 1995, 2000, 2005 etc. up to 2015 based on fuel used. For the years in-between, the emissions are linearly interpolated.

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

Emission factors (1A3d)

- The CO₂ emission factor applied for the time series 1990–2014 for diesel oil, gasoline and gas oil are country-specific and are given in Table 3-12.
- The CH₄ and N₂O emission factors are country-specific and are shown below in the Table 3-77 to Table 3-79 for all fuel types and emission standards.
- For SO₂ the emission factors are country-specific. The implied emission factor 2014 is shown in Table 3-80. See also Table A – 18 in Annex A3.1.5 rows diesel oil, gasoline, gas oil.
- The emission factors for precursors are country-specific and are given in FOEN (2015j).

- NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference between VOC and CH₄ emissions.

The implied emission factors are shown in Table 3-80.

All emission factors (GHG, precursors, SO₂) can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

Table 3-77 CH₄ and N₂O emission factors for ships with diesel engines.

Gas	Power class	Ships with diesel oil engines				
		PreSAV (<1995)	SAV 1995	EU-I 2003	EU-II 2008	EU-III A 2009
	kW	g/kWh				
CH ₄	<18	0.0547	0.0547	0.0384	0.024	0.0142
CH ₄	18–37	0.0578	0.0578	0.0221	0.0134	0.0089
CH ₄	37–56	0.0319	0.0319	0.0156	0.011	0.0079
CH ₄	56–75	0.0319	0.0319	0.0156	0.011	0.0079
CH ₄	75–130	0.0218	0.0218	0.0108	0.0084	0.0067
CH ₄	>130	0.0218	0.0218	0.0103	0.0072	0.0053
N ₂ O	all	0.035	0.035	0.035	0.035	0.035

Table 3-78 CH₄ and N₂O emission factors for ships with gasoline engines by emission standards including the year of enforcement.

Gas	Power class	boats with 2-stroke gasoline engines			boats with 4-stroke gasoline engines		
		PreSAV <1995	SAV 1995	SAV/EU 2007	PreSAV <1995	SAV 1995	EU 2007
	kW	g/kWh					
CH ₄	<4.4	18.2	1.54	1.75	1.25	1.10	1.25
CH ₄	4.4–7.4	18.2	0.84	0.91	1.00	0.60	0.65
CH ₄	7.4–37	18.2	0.42	0.56	1.00	0.30	0.40
CH ₄	37–74	18.2	0.42	0.56	1.00	0.20	0.30
CH ₄	74–100	18.2	0.42	0.56	1.00	0.17	0.25
CH ₄	>100	18.2	0.42	0.56	1.00	0.10	0.25
N ₂ O	0–300	0.01	0.01	0.01	0.03	0.03	0.03

Table 3-79 CH₄ and N₂O emission factors for steamboats by the year of enforcement.

Gas	steamboats		
	<2000	2000–2004	>2004
	g/kWh		
CH ₄	0.0218	0.0103	0.0072
N ₂ O	0.035	0.035	0.035

Table 3-80 Implied emission factors 2014 for navigation

1A3d Navigation	Unit	CO ₂ fossil	CO ₂ biog.	CH ₄	N ₂ O	NO _x	NM VOC	SO ₂	CO
Gasoline	kg/TJ	73'800	NA	19.1	1.9	540	352	0.7	6'997
Diesel oil	kg/TJ	73'300	NA	1.9	3.4	963	311	0.5	540
Gas oil	kg/TJ	73'700	NA	0.2	0.7	26	1.6	14	6.9
Biodiesel	kg/TJ	NA	73'312	1.7	3.0	837	270	0.4	469
Bioethanol	kg/TJ	NA	73'804	11.1	1.2	342	211	0.2	4'326

Activity data (1A3d)

Activity data for navigation (1A3d) are described in chp. 3.2.4.5.1 (non-road transportation model). Values are taken from FOEN (2015j). Data on biofuels is provided by the statistics of renewable energies (SFOE 2015a). Activity data are shown in Table 3-81 and in Annex A3.1.4.

Table 3-81 Fuel consumption of (domestic) navigation.

1A3d Navigation	Unit	1990	1995	2000
Gasoline	TJ	701	654	616
Diesel oil	TJ	738	724	792
Gas oil	TJ	110	139	147
Biodiesel	TJ	NO	NO	1
Bioethanol	TJ	NO	NO	NO
Sum	TJ	1'550	1'517	1'556
1990 = 100%		100%	98%	100%

1A3d Navigation	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Gasoline	TJ	800	814	827	841	855	868	871	874	877	879
Diesel oil	TJ	565	559	553	547	541	534	529	524	518	513
Gas oil	TJ	150	152	154	155	157	159	157	156	154	153
Biodiesel	TJ	2	3	3	3	3	3	4	5	7	8
Bioethanol	TJ	0	0	0	0	0	0	2	4	6	8
Sum	TJ	1'518	1'527	1'537	1'546	1'556	1'565	1'564	1'563	1'562	1'561
1990 = 100%		98%	99%	99%	100%	100%	101%	101%	101%	101%	101%

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

3.2.9.2.5 Other transportation (1A3e)

Methodology (1A3e i)

The emissions are calculated with a Tier 2 method (the 2006 IPCC Guidelines (IPCC 2006) do not contain a decision tree to determine the Tier level specifically).

Source 1A3e includes only pipeline transportation (1A3e i) from a compressor station located in Ruswil. Emissions of CO₂, CH₄, N₂O, NO_x, CO, NM VOC and SO₂ are reported. The compressor station uses a centrifugal compressor according to Transitgas AG (the company operating the compressor station and the pipeline network).

Emission factors (1A3e)

- The CO₂ emission factor applied for the time series 1990–2014 for natural gas is country-specific and is given in Table 3-12.
- The CH₄ emission factor corresponds to the one used for gas turbines in Switzerland (SAEFL 2000) as suggested by expert judgement. The CH₄ 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 CH₄ emissions of the gas turbine. For the value 2014 see Table 3-82.
- For N₂O emission factors the IPCC 2006 default value is used as displayed in Table 3-82.
- For SO₂ the emission factors are country-specific. The implied emission factor 2014 is shown in Table 3-82. See also Table A – 18 in Annex A3.1.5 row natural gas.
- The emission factors for precursors are country-specific and are given in SAEFL (2000); see also EMIS 2015/1A3e “Gasturbinen; Erdgas”.

Table 3-82 Emission factors of 1A3e i Pipeline transportation / compressor station located in Ruswil in 2014

1A3e Other transportation	Unit	CO ₂ fossil	CH ₄	N ₂ O	NO _x	NM VOC	SO ₂	CO
Gas	kg/TJ	56'700	2	0.1	60	0.1	0.5	15

Activity data (1A3e)

The data on fuel consumption for the operation of the compressor station in Ruswil is based on the Swiss overall energy statistics (SFOE 2015; Table 17).

Table 3-83 Activity data of 1A3e.

1A3ei Pipeline transport	Unit	1990	1995	2000
Natural gas	TJ	560	310	340
1990=100%		100%	55%	61%

1A3ei Pipeline transport	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Natural gas	TJ	1'070	1'700	1'430	1'460	950	830	840	810	410	830
1990=100%		191%	304%	255%	261%	170%	148%	150%	145%	73%	148%

3.2.9.3 Uncertainties and time-series consistency for 1A3

For a general description of the uncertainty analysis and time series consistency of the Energy sector see chp. 3.2.4.7 where uncertainties of activity data and emission factors of fuels are shown (Table 3-24) and explained in detail.

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

3.2.9.4 Category-specific QA/QC and verification for 1A3

General

The general QA/QC measures are described in section 1.2.3 and partly also in chp. 3.2.4.8.

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 2014 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 percents.
- 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%.

Specific: Road transportation (1A3b)

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

- CO₂ (see also Table 3-25): 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 73.7 and 73.9 t/TJ for gasoline – 6% higher than IPCC – and between 73.3 and 73.4 t/TJ for diesel oil – about 1% below IPCC default value.
- CH₄: 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 5.1 kg/TJ (2014) 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.
- N₂O: 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 0.5 kg/TJ (2014) 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 0.2–2.5 kg/TJ.

The international project for the update of the emission factors for road vehicles is overseen by a group of external national 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 extensive plausibility checks and comparisons with earlier estimates.

The emission factors CH₄ and N₂O 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 CH₄ and N₂O 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 93% of the gasoline sold 2014 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.

3.2.9.5 Category-specific recalculations for 1A3

Recalculations reported in submission 2015

- 1A3: New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO₂ emission factor time series were generated.

- 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 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.

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A3c Railways and 1A3d Navigation.
- Recalculation in Swiss energy statistics of renewable energy concerning use of biogas results in a recalculation of the AD of 1A3b in 2013.

3.2.9.6 Category-specific planned improvements for 1A3

1A3a Civil aviation: No category-specific improvements are planned.

1A3b Road Transportation: Recently, activity data and emission factors of territorial road transportation were updated. The new data will be implemented in the EMIS database, thereby leading to a recalculation of the GHG emissions of all time series 1A3b 1990–2014.

1A3c, 1A3d, 1A3e: No category-specific improvements are planned.

3.2.10 Source category 1A4 – Other sectors (mobile)

3.2.10.1 Source category description for 1A4 Other sectors (mobile)

Approach 1 key categories 1A4

See key categories mentioned in chp. 3.2.7.1, which are vastly dominated by the emissions of the stationary sources with one exception:

CO₂ from the combustion of Liquid Fuels in 1A4c Agriculture/Forestry/Fishing (level).

Table 3-84 Specification of source category 1A4 Other sectors (mobile 1A4 aii/bii/cii).

1A4	Source	Specification
1A4a ii	Commercial/ institutional	Emission from non-road vehicles (professional gardening) and motorised equipment
1A4b ii	Residential	Emissions from mobile machinery (hobby, gardening) and motorised equipment
1A4c ii	Agriculture/forestry	Emissions from non-road vehicles and machinery in agriculture and forestry

3.2.10.2 Methodological issues for 1A4 Other sectors (mobile)

Methodology (1A4 Other sectors, mobile)

Based on the decision tree Fig. 3.3.1 in chp. “3. Mobile Combustion” in the 2006 IPCC Guidelines (IPCC 2006), the emissions of vehicles and machinery in 1A4 are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.4.5.1.

Emission factors (1A4 Other sectors, mobile)

In the categories 1A4a ii and 1A4b ii only gasoline is being used as fuel. In category 1A4c ii mainly diesel oil is consumed, but there is also a certain amount of gasoline consumed (e.g. chainsaws), which can not be neglected.

- The CO₂ emission factors applied for the time series 1990–2014 are country-specific and are given in Table 3-12.
- The CH₄ and N₂O emission factors are country-specific and are shown in Table 3-61 and Table 3-62 for diesel oil and gasoline engines for all emission standards.
- For SO₂ the emission factors are country-specific. The implied emission factor 2014 is shown in Table 3-85. See also Table A – 18 in Annex A3.1.5 for diesel oil, gasoline, gas oil.
- The emission factors for precursors are country-specific and are given in FOEN (2015j).
- NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference between VOC and CH₄ emissions.

Implied emission factors are shown in Table 3-85.

All emission factors (GHG, precursors, SO₂) can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

Table 3-85 Implied emission factors 2014 for 1A4 Other sectors (1A4a ii – 1A4c ii mobile).

1A4 Non-road machinery	Unit	CO ₂ fossil	CH ₄	N ₂ O	NO _x	NMVOC	SO ₂	CO
1A4a ii Gardening professional, gasoline	kg/TJ	73'800	109	1	178	1'704	6	25'909
1A4b ii Gardening, gasoline	kg/TJ	73'800	56	1	158	1'119	2	24'847
1A4c ii Forestry and agriculture, gasoline	kg/TJ	73'800	96	1	169	1'665	4	23'633
1A4c ii Forestry and agriculture, diesel oil	kg/TJ	73'300	2	3	553	66	0	334

Activity data (1A4 Other sectors, mobile)

Activity data are described in chp. 3.2.4.5.1 (non-road transportation model) and are shown in Table 3-86 and in Annex A3.1.4.

Table 3-86 Activity data for non-road vehicles and machinery in 1A4 Other sectors (mobile).

1A4 Non-road machinery	Unit	1990	1995	2000
1A4a ii Gardening professional, gasoline	TJ	191	245	295
1A4b ii Gardening, gasoline	TJ	142	155	165
1A4c ii Forestry and agriculture, gasoline	TJ	1'160	1'070	963
1A4c ii Forestry and agriculture, diesel oil	TJ	4'269	4'604	4'921
Sum	TJ	5'761	6'073	6'343
1990=100%		100%	105%	110%

1A4 Non-road machinery	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1A4a ii Gardening professional, gasoline	TJ	295	293	292	290	288	287	280	272	265	258
1A4b ii Gardening, gasoline	TJ	165	165	164	164	163	163	161	160	158	156
1A4c ii Forestry and agriculture, gasoline	TJ	823	797	770	743	716	689	664	638	613	588
1A4c ii Forestry and agriculture, diesel oil	TJ	4'804	4'820	4'836	4'852	4'868	4'884	4'883	4'881	4'880	4'878
Sum	TJ	6'088	6'075	6'062	6'049	6'036	6'023	5'987	5'952	5'916	5'880
1990=100%		106%	105%	105%	105%	105%	105%	104%	103%	103%	102%

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

3.2.10.3 Uncertainties and time-series consistency for 1A4 Other sectors, mobile

Uncertainties by fuel type are given in Table 3-24.

3.2.10.4 Category-specific QA/QC and verification for 1A4 Other sectors, mobile

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 3.2.4.8.

3.2.10.5 Category-specific recalculations for 1A4 Other sectors, mobile

Recalculations reported in submission 2015

- New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO₂ emission factor time series were generated.

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A4aii, 1A4bii, 1A4cii (FOEN 2015j).

3.2.10.6 Category-specific planned improvements for 1A4 Other sectors, mobile

No category-specific improvements are planned.

3.2.11 Source category 1A5b – Other (mobile)

3.2.11.1 Source category description for 1A5b (mobile)

Approach 1 and 2 key categories 1A5

Source category 1A5b – Other (mobile) is not a key source category.

All of the Swiss source categories of 1A5 refer to mobile sources of military activities (1A5b). Stationary activities are not occurring.

Table 3-87 Specification of Swiss source category 1A5 Other.

1A5	Source	Specification
1A5bi	Military aviation	Emissions from military aircrafts
1A5bii	Military non-road vehicles and machines	Emissions from machines like power generators, tanks, bulldozers, boats etc.

3.2.11.2 Methodological issues for 1A5b Other (mobile)

3.2.11.2.1 Military aviation (1A5b i)

Methodology (1A5b i Other, military aviation)

To calculate the emissions from military aviation, a Tier 2 method is used.

Emission factors (1A5b i Other, military aviation)

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 1996–2014, the factors for 1995 are used. The emissions are then calculated yearly based on average emission factors.

The extension of the emission modelling to CO₂, CH₄, N₂O, NMVOC and SO₂ is also accomplished by FOEN.

- The CO₂ emission factor applied for the time series 1990–2014 for kerosene is country-specific and is given in Table 3-12.
- CH₄: The division of VOC into CH₄ and NMVOC is carried out by a constant split of 10% CH₄ and 90% NMVOC like in 1A3a civil aviation (see also footnote 7). VOC: see below.
- N₂O: The emission factor is set equal to the emission factor of 1A3a Civil aviation (FOCA 2015).
- 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 2000. For

1991–1999 the values are linearly interpolated between 1990 and 2000. For 2001–2014, the values 2000 are used.

- SO_2 : The emission factor is taken from the EMEP/EEA Guidebook (EMEP/EEA 2013) and is assumed to be constant over the period 1990–2014.

Table 3-88 Implied emission factors 1A5b i military aviation in 2014.

1A5bi Military aviation	Unit	CO ₂ fossil	CH ₄	N ₂ O	NO _x	NM VOC	SO ₂	CO
Jet kerosene	kg/TJ	72'800	3.6	2.3	133	32	23	672

Activity data (1A5b i Other, military aviation)

The fuel consumption 1990–2014 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, chp. 3.6.1.4).

Table 3-89 Activity data (fuel consumption) for military aviation.

1A5 Other	1990	1995	2000
	TJ		
Military aviation			
Jet kerosene	2'733	1'955	1'794

1A5 Other	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	TJ									
Military aviation										
Jet kerosene	1'624	1'676	1'577	1'505	1'529	1'592	1'420	1'527	1'542	1'615

3.2.11.2.2 Military non-road vehicles (1A5b ii Other, military machinery)

Methodology (1A5b ii Other, military machinery)

Emissions are calculated as part of the non-road transportation model (chp. 3.2.4.5.1) corresponding to a Tier 3 according to the the decision tree Fig. 3.3.1 in chp. 3. Mobile Combustion in IPCC (2006).

Emission factors (1A5b ii Other, military machinery)

- The CO₂ emission factors applied for the time series 1990–2014 for diesel oil, gasoline and compressed natural gas are country-specific as shown in Table 3-12.

- The CH₄ and N₂O emission factors are country-specific and are shown in Table 3-61 to Table 3-63 for diesel oil and gasoline engines for all emission standards.
- For SO₂ the emission factors are country-specific. Implied emission factors 2014 are shown in Table 3-90. See also Table A – 18 in Annex A3.1.5, rows diesel oil, gasoline.
- The emission factors for precursors are country-specific and are given in FOEN (2015j).
- NMVOC is not modelled bottom-up. The NMVOC emissions are calculated as the difference between VOC and CH₄ emissions.

Implied emission factors are shown in Table 3-90.

All emission factors (GHG, precursors) can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

Table 3-90 Implied emission factors 1A5b ii military non-road vehicles 2014.

1A5bii Military non-road	Unit	CO ₂ fossil	CO ₂ biog.	CH ₄	N ₂ O	NO _x	NMVOC	SO ₂	CO
Gasoline	kg/TJ	73'800	NA	50.4	1.5	134	911	2.1	23838
Diesel	kg/TJ	73'300	NA	1	3	503	41	0.5	215
Biodiesel	kg/TJ	NA	73'300	0.9	2.6	438	36	0.4	187
Bioethanol	kg/TJ	NA	73'800	11.8	1	74	330	0.2	14934

Activity data (1A5b ii Other, military machinery)

Activity data for military non-road vehicles (1A5b ii) are described in chp. 3.2.4.5.1 (non-road transportation model). Values are taken from FOEN (2015j). Data on biofuels are provided by the statistics of renewable energies (SFOE 2015a). Activity data are shown in Table 3-91 and in Annex A3.1.4.

Table 3-91 Activity data (fuel consumption) for military non-road vehicles.

1A5bii Military non-road	1990	1995	2000
	TJ		
Military non-road	239	248	252
Gasoline	19	19	19
Diesel	220	228	233
Biodiesel	NO	NO	0.3
Bioethanol	NO	NO	NO

1A5bii Military non-road	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	TJ									
Military non-road	257	261	265	268	272	275	275	275	275	275
Gasoline	19	19	19	18	18	18	18	17	17	17
Diesel	238	241	245	249	253	256	256	256	256	255
Biodiesel	0.7	0.8	0.8	0.9	0.9	1.0	1.3	1.6	1.9	2.3
Bioethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can be downloaded by query from the public part of the non-road database INFRAS (2015a). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels (see footnote 6).

3.2.11.3 Uncertainties and time-series consistency for 1A5b Other (mobile)

For a general description of the uncertainty analysis and time series consistency of the Energy sector see chp. 3.2.4.7 where uncertainties of activity data and emission factors of fuels are shown (Table 3-24) and explained in detail.

Consistency: Time series for 1A5b Other are all considered consistent.

3.2.11.4 Category-specific QA/QC and verification for 1A5b Other (mobile)

The general QA/QC measures are described in section 1.2.3 and partly also in chp. 3.2.4.8.

The activity data of military aviation (1A5b), kerosene consumption, 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).

Recalculations reported in submission 2015

- New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO₂ emission factor time series were generated.

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A5b ii, military non-road vehicles.

3.2.11.5 Category-specific planned improvements for 1A5b Other (mobile)

No category-specific improvements are planned.

3.3 Source category 1B – Fugitive emissions from fuels

3.3.1 Source category description for 1B

Approach 1 key categories 1B2

CH₄ from fugitive emissions of Oil and Natural gas (level and trend)

Approach 2 key categories 1B2

CH₄ from fugitive emissions of Oil and Natural gas (level and trend)

The only relevant source categories of fugitive emissions in Switzerland are:

- Oil (1B2a)
- Natural gas (1B2b)
- Venting and flaring (1B2c)

3.3.2 Source category 1B1 – Solid Fuels

Coal mining is not occurring in Switzerland. There are no greenhouse gas emissions from coal handling.

3.3.3 Source category fugitive emissions from 1B2a – Oil

3.3.3.1 Source category description for 1B2a

In Switzerland, oil production is not occurring. Fugitive emissions in the oil industry result exclusively from the refineries and several fuel handling stations. At the beginning of 2015, one of the two refineries ceased operation. The extents of the two existing oil pipelines in Switzerland are approximately 40 km and 70 km, respectively. The pipelines are mainly laid underground.

Table 3-92 Specification of source category fugitive emissions from 1B2a Oil in Switzerland.

1B2	Source	Specification
1B2a	Fugitive emissions attributed to oil	Emissions from refining/storage of oil and the distribution of oil products: transport of crude oil in pipelines.

3.3.3.2 Methodological issues for 1B2a

Methodology (1B2a)

According to the decision tree for crude oil transport, refining and upgrading, Switzerland estimates 1B2a fugitive emissions from oil based on a Tier 2 approach (IPCC 2006, Volume 2 Energy, chp. 4 Fugitive Emissions, Figure 4.2.3). For emission calculations plant-specific emission factors as well as activity data are available.

For source 1B2a fugitive emissions from oil, fugitive emissions of CH₄ are reported, which occur only in 1B2a iii Transport and 1B2a iv Refining/storage. Indirect CO₂ emissions resulting from NMVOC emissions in this source category are reported in chp. 9.

Emission factors (1B2a)

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 3-93 are converted using a crude oil density of 0.82 t/m³.

For oil refining and storage (1B2a iv), plant-specific emission factors for CH₄ and NMVOC are used. The emission factors for CH₄ are delineated from an emission estimation project in one of the refineries in 1992 called CRISTAL. The estimation from the other refinery is assumed to be twice as high, because the technology of the plant is older. Then a weighted mean based on the quantity of crude oil used in both refineries was calculated (for further details see the internal documentation of the EMIS database, EMIS 2016 1B2a iv).

For oil distribution from storage tanks and gasoline stations (1B2a v), 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 internal database documentation in EMIS 2016/1B2a v Benzinumschlag Tanklager and EMIS 2016/1B2a 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 3-93 Emission factors for fugitive emissions of source category 1B2a Oil in 2014.

Source/fuel	CO ₂ g/t	CH ₄ g/t	N ₂ O kg/TJ	NO _x kg/TJ	NMVOC g/t	SO ₂ kg/TJ	CO kg/TJ
1B2a Oil							
Exploration	NO	NO	NO	NO	NO	NO	NO
Production	NO	NO	NO	NO	NO	NO	NO
Transport	NA	6.59	NA	NA	65.9	NA	NA
Refining/Storage	NA	45	NA	NA	430	NA	NA
Distribution of oil products: Gasoline storage tank	NA	NA	NA	NA	293	NA	NA
Distribution of oil products: Gasoline station	NA	NA	NA	NA	394	NA	NA

Activity data (1B2a)

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 2015).

For oil distribution from storage tanks and gasoline stations (1B2a v), gasoline sales based on the Swiss overall energy statistics (SFOE 2015), corrected for consumption of Liechtenstein, are used as activity data.

In analogy to Figure 3-11 to Figure 3-19, Figure 3-25 shows how the energy model (chp. 3.2.4.3.3) attributes imported crude oil (as provided by the Swiss overall energy statistics, SFOE 2015), losses of gasoline and of natural gas to source category 1B.

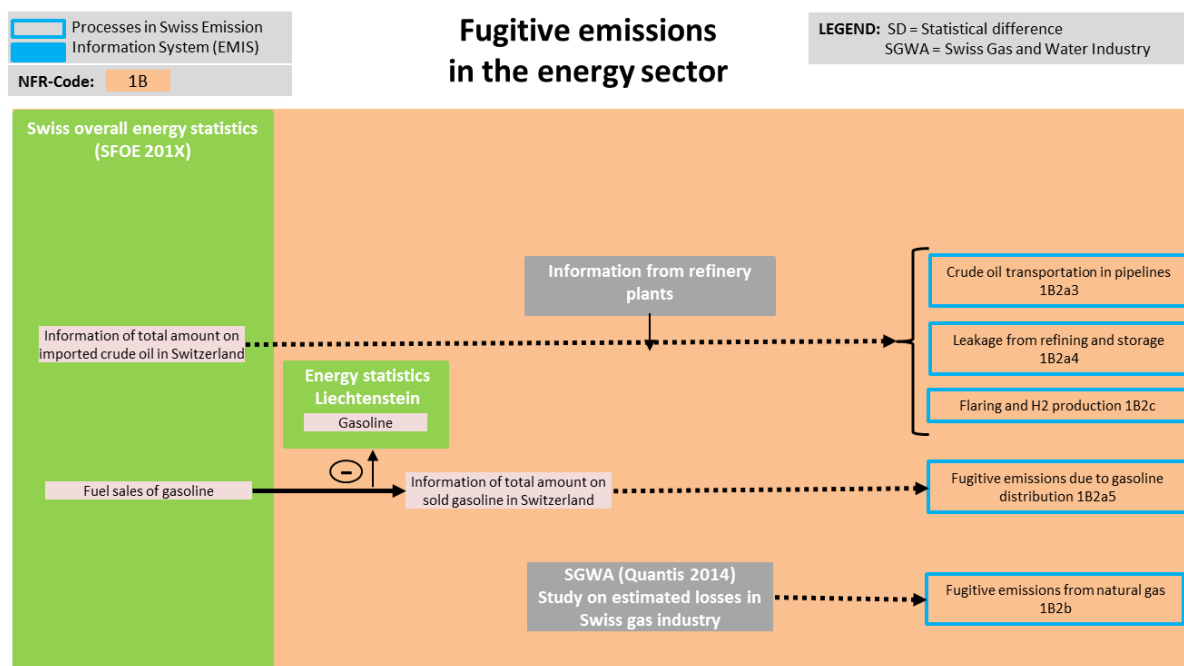


Figure 3-25: Attribution of fugitive emissions to source categories of 1B Fugitive emissions from fuels.

Table 3-94 Activity data for fugitive emissions from 1B2a Oil.

1B2a Oil products	Unit	1990	1995	2000
Crude oil	t	3'127'000	4'657'000	4'649'000
Gasoline transport	t	3'682'727	3'568'755	3'958'535

1B2a Oil products	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	1990 to 2014 (%)
Crude oil	t	4'877'000	5'563'000	4'720'000	5'133'000	4'833'000	4'546'000	4'452'000	3'455'000	4'935'000	4'975'000	59%
Gasoline transport	t	3'575'651	3'466'316	3'432'228	3'356'124	3'265'563	3'149'168	3'026'898	2'919'440	2'785'960	2'672'960	-27%

3.3.3.3 Uncertainties and time-series consistency for 1B2a

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.

3.3.3.4 Category-specific QA/QC and verification for 1B2a

The general QA/QC measures are described in section 1.2.3 and partly also in 3.2.4.8. No further source specific activities undertaken for fugitive emissions from oil (1B2a).

3.3.3.5 Category-specific recalculations for 1B2a

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- Changes in the consumption of residual fuel oil in refineries due to adaptation to rounded values used in the Swiss overall energy statistic concerning (SFOE 2015).
- Recalculation in the Swiss overall energy statistic concerning (SFOE 2015) use of crude oil.

3.3.3.6 Category-specific planned improvements for 1B2a

No category-specific improvements are planned.

3.3.4 Source category fugitive emissions from 1B2b – Natural gas

3.3.4.1 Source category description for 1B2b

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). Emissions from transmission include leakages from gas pipelines, small-scale damages, revision processes of the pipeline network and leakage of network components. Emissions from accidents in the gas pipeline system are reported under source category (1B2b vi).

Table 3-95 Specification of source category fugitive emissions from 1B2b Natural gas in Switzerland.

1B2	Source	Specification
1B2b	Fugitive emissions attributed to natural gas	Emissions from gas network

3.3.4.2 Methodological issues for 1B2b

Methodology (1B2b)

According to the decision tree for natural gas systems, Switzerland follows a Tier 2 approach for emissions attributed to 1B2b iv Transmission and storage as well as 1B2b v and a Tier 1

approach for emissions concerning 1B2b ii Production in order to estimate fugitive emissions under 1B2b fugitive emissions from natural gas (IPCC 2006, Volume 2 Energy, chp. 4 Fugitive Emissions, Figure 4.2.1). For emission calculations country-specific emission factors (partly) as well as activity data are available for source category 1B2b. Emissions from source category 1B2 are key, however, the contribution from 1B2b ii is small and therefore the use of a Tier 1 method for this source category is justified.

For source category 1B2b ii, emissions are calculated based on annual production data and default emission factors (IPCC Tier 1 approach). Production data under 1B2b ii are only available for the years 1990–1994 because the single production site was closed in 1994.

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). Losses from end-users' appliances (household or industry) are reported in the corresponding source category in sector 1A.

Emission factors (1B2b)

CO₂, CH₄ and NMVOC default emission factors for natural gas production are taken from the 2006 IPCC Guidelines (IPCC 2006) as documented in the internal emission database documentation (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 by Quantis (2014). 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.

Table 3-96 Emission factors for fugitive emissions of source category 1B2b Natural gas in 2014.

Source/fuel	CO ₂ g/GJ	CH ₄ g/GJ	N ₂ O g/GJ	NO _x g/GJ	NMVOC g/GJ	SO ₂ g/GJ	CO g/GJ
1B2b Natural gas							
Production	NO	NO	NO	NO	NO	NO	NO
Transmission	312	17'888	NA	NA	1'427	NA	NA
Distribution	312	17'888	NA	NA	1'427	NA	NA

Emission factors for gas distribution losses due to accidents in the gas pipeline system are also based on the same study by Quantis (2014) and reported under 1B2b vi Other leakage.

Table 3-97 Emission factors for 1B2b vi Other leakage in 2014.

Source/fuel	CO ₂ g/GJ	CH ₄ g/GJ	N ₂ O g/GJ	NO _x g/GJ	NMVOC g/GJ	SO ₂ g/GJ	CO g/GJ
1B2b vi Other Leakage	312	17'888	NA	NA	1'427	NA	NA

Activity data (1B2b)

Activity data for fugitive emissions from gas production (1B2b ii) are the actual gas production data for the years 1990–1994 (SFOE 2015). For gas transmission (1B2b iv), distribution (1B2v), and other (1B2b vi), activity data shown in Table 3-98 and Table 3-99 represent the actual amount of gas lost.

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 2015) is used as activity data (see Quantis 2014).

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 CH₄ emissions from gas transmission and distribution decreased due to gradual replacement of cast-iron pipes with polyethylene pipes.

Table 3-98 Activity data for fugitive emissions from 1B2b

1B2b Natural Gas / 1B2d Other	Unit	1990	1995	2000							
1B2b Natural gas	GJ	832'181	832'934	671'875							
Production	GJ	130'000	NO	NO							
Transmission	GJ	26'135	29'189	30'923							
Distribution	GJ	676'046	803'745	640'952							
1B2b Natural Gas / 1B2d Other	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1B2b Natural Gas		535'013	515'652	511'645	497'610	485'484	472'966	465'376	461'196	425'593	425'593
Production	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Transmission	GJ	31'813	31'902	32'786	32'864	32'887	32'699	32'678	32'682	33'309	33'309
Distribution	GJ	503'200	483'750	478'859	464'746	452'597	440'267	432'698	428'514	392'284	392'284

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 the recent reassessment of fugitive emissions from the gas industry (Quantis 2014).

Table 3-99 Activity data for 1B2b Other leakage.

1B2b Natural Gas / 1B2d Other	Unit	1990	1995	2000							
1B2b vi Other Leakage	GJ	NO	NO	NO							
1B2b Natural Gas / 1B2d Other	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1B2b vi Other Leakage	GJ	NO	NO	NO	NO	NO	35'225	27'940	NO	NO	NO

3.3.4.3 Uncertainties and time-series consistency for 1B2b

According to the assessment by Quantis (2014), an uncertainty of 30% is estimated for fugitive CH₄ 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.

3.3.4.4 Category-specific QA/QC and verification for 1B2b

The general QA/QC measures are described in section 1.2.3.

As suggested by the 2006 IPCC guidelines (IPCC 2006) the gas industry was involved in the reassessment of fugitive emissions from the natural gas system (Quantis 2014).

3.3.4.5 Category-specific recalculations for 1B2b

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

3.3.4.6 Category-specific planned improvements for 1B2b

No category-specific improvements are planned.

3.3.5 Source category 1B2c – Venting and flaring

3.3.5.1 Source category description for 1B2c

In Switzerland, oil and natural gas production is not occurring. Emissions from flaring result from the torches, which were operational at the two refineries (1B2c i Flaring). Since 2015, there is only one refinery in operation. In addition, CO₂ emissions from H₂ production are also reported under 1B2c.

Table 3-100 Specification of source category 1B2c Venting and flaring in Switzerland.

1B2	Source	Specification
1B2 c	Fugitive emissions attributed to venting and flaring.	The combustion of excess gas at the oil refinery (flaring) only. Emissions from H ₂ production

3.3.5.2 Methodological issues for 1B2c

Methodology (1B2c)

According to the decision tree for crude oil transport, refining and upgrading, Switzerland follows a Tier 2 method for emissions attributed to 1B2c i Flaring of gas in order to estimate fugitive emissions under 1B2c fugitive emissions from venting and flaring (IPCC 2006, Volume 2 Energy, chp. 4 Fugitive Emissions, Figure 4.2.3). For emission calculations plant-specific emission factors and activity data are available from the refining industry.

For source category 1B2c i Flaring, emissions of CO₂ as well as CH₄, N₂O, NO_x, CO and NMVOC are considered. Since the CO₂ emission factor assumes oxidation of 100%, no

indirect emissions need to be accounted for. Therefore, from this sources category no indirect emissions are reported in chp. 9.

One of the refining plants produces H₂ from butane leading to process emissions of CO₂. Emissions are estimated based on plant-specific data.

Emission factors (1B2c)

Emission factors are based on data from the refining industry as documented in the internal emission database documentation (EMIS 2016/1B2c Raffinerie Abfackelung). Since 2005 (with the exception of 2012), the refining industry provides annual data on the emissions from flaring under the Federal Act on the Reduction of CO₂ Emissions (Swiss Confederation 2011) based on daily measurements of CO₂ emission factors of the flared gases. From these data annual emission factors are derived. Since 2005, the evolution of the other emission factors (CH₄, N₂O, NO_x, CO and NMVOC) is assumed to vary proportionally to the CO₂ emission factor. Emission factors are considered confidential and are available to reviewers on request.

The CO₂ emission factor of H₂ production from butane, which is produced in one of the refineries since the end of 2004, is equal to the stoichiometric emission factor.

Table 3-101 Emission factors for 1B2c Venting and flaring in 2014.

Source/fuel	CO ₂ g/t	CH ₄ g/t	N ₂ O g/t	NO _x g/t	NMVOC g/t	SO ₂ g/t	CO g/t
1B2c Venting and flaring	C	C	C	C	C	C	C
Other: H2 production refinery (butane)	C	NA	NA	NA	NA	NA	NA

Activity data (1B2c)

Before 2005, the amount of flared gas is assumed to be proportional to the amount of crude oil processed in the refineries. The Swiss petroleum association provides data on the use of crude oil on an annual basis (EV 2015). Between 2001 and 2004, one of the two refineries made major changes to their installations (new cracker, new flaring installation) and their standard operation process. Therefore, emissions from flaring decreased significantly thereafter. Since 2005, the industry provides data on the amount of gas flared.

For H₂ production in one of the refining plants, annual data on butane consumption are provided by the industry since 2005. Data are confidential and they are available to reviewers on request.

Table 3-102 Activity data for 1B2c Venting/flaring.

1B2c Venting and flaring	Unit	1990	1995	2000
Crude oil used	t	3'127'000	4'657'000	4'649'000
Other: H2 production refinery (butane)	GJ	NO	NO	NO

1B2c Venting and flaring	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Crude oil used	t	4'877'000	5'563'000	4'720'000	5'133'000	4'833'000	4'546'000	4'452'000	3'455'000	4'935'000	4'975'000
Other: H2 production refinery (butane)	GJ	C	C	C	C	C	C	C	C	C	C

3.3.5.3 Uncertainties and time-series consistency for 1B2c

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.

3.3.5.4 Category-specific QA/QC and verification for 1B2c

The general QA/QC measures are described in section 1.2.3. No category-specific QA/QC activities were undertaken.

3.3.5.5 Category-specific recalculations for 1B2c

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- 1B2: Recalculation in the Swiss overall energy statistics (SFOE 2015) concerning use of crude oil for 1996 and 2003.
- 1B2c: Based on detailed information from the refineries, emissions from flaring were reassessed. From 2005, activity data and emissions factors for flaring were adjusted according to the reports of the refineries.
- 1B2c: During the reassessment of refinery emissions, it emerged that one refinery operates a H₂-production unit since 2005. The resulting CO₂ emissions are now also reported in the inventory.

3.3.5.6 Category-specific planned improvements for 1B2c

No category-specific improvements are planned.

3.4 Source category 1C – CO₂ transport and storage

CO₂ transport and CO₂ storage is not occurring in Switzerland.

4 Industrial processes and product use

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

4.1 Overview

This chapter provides information on the estimation of the GHG 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 GHG 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 also information on the GHG emissions from solvent and product use. CO₂ 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 (chp. 7).

Indirect emissions from fossil CO and NMVOC emissions are reported in chapter 9. Biogenic NMVOC and CO emissions occur in source category 2H2 and 2G4 tobacco consumption and are not reported as indirect CO₂ emissions.

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 evolution of greenhouse gas emissions in sector 2 between 1990 and 2014.

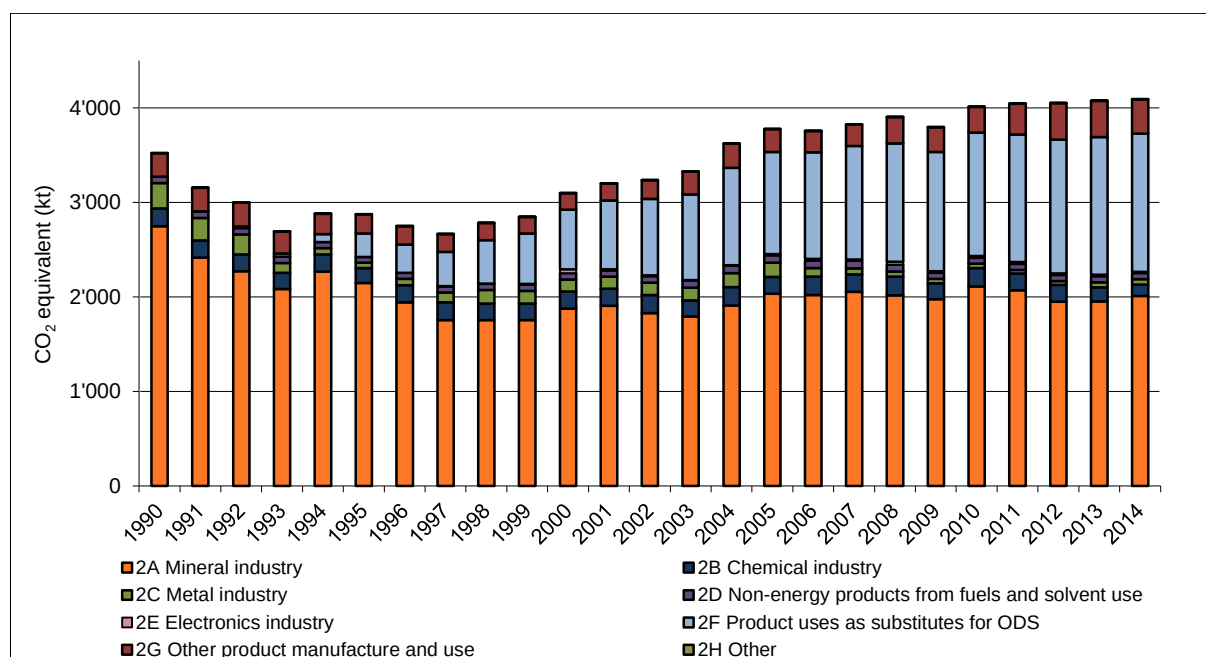


Figure 4-1 Switzerland's greenhouse gas emissions of sector 2 Industrial processes and product use 1990–2014.

2A Mineral industry remains the dominant source of sector 2 accounting for around half of the GHG emissions in 2014 although absolute emissions have decreased since 1990. 2B Chemical industry accounts for a small share and shows a decreasing trend since 1990. 2C Metal industry shows a strong decreasing trend and accounts only for a small share in 2014. 2D Non-energy products also only have a minor contribution in 2014.

2F Product uses as substitutes for ODS is of increasing importance: The emissions have increased since 1990 and account for about nearly a third of total GHG emissions in sector 2 in 2014. This is primarily due to the replacement of CFCs by HFCs in many technical applications. 2G Other product manufacture and use shows no clear trend since 1990. 2E Electronic industry and 2H Other are of little importance with regard to the overall GHG emissions of sector 2.

In Table 4-1, the development of GHG emissions in sector 2 Industrial processes and product use are given by gases. Dominant gases are CO₂ and F-gases in 2014 whereas N₂O and CH₄ have only a minor contribution. 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 GHG emissions of sector 2 Industrial processes and product use by gases in kt CO₂ equivalent.

Gas	1990	1995	2000
	CO ₂ equivalent (kt)		
CO ₂	3'095	2'375	2'163
CH ₄	1.8	1.8	1.7
N ₂ O	171	140	115
F-gases	254	357	820
Sum	3'521	2'873	3'099

Gas	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	CO ₂ equivalent (kt)									
CO ₂	2'354	2'295	2'304	2'267	2'195	2'356	2'305	2'183	2'183	2'236
CH ₄	2.6	2.3	2.6	2.9	1.9	2.7	2.8	2.8	2.1	2.1
N ₂ O	100	104	101	109	99	102	94	94	71	48
F-gases	1'319	1'355	1'415	1'523	1'501	1'550	1'644	1'770	1'818	1'804
Sum	3'776	3'757	3'823	3'902	3'797	4'011	4'046	4'050	4'074	4'091

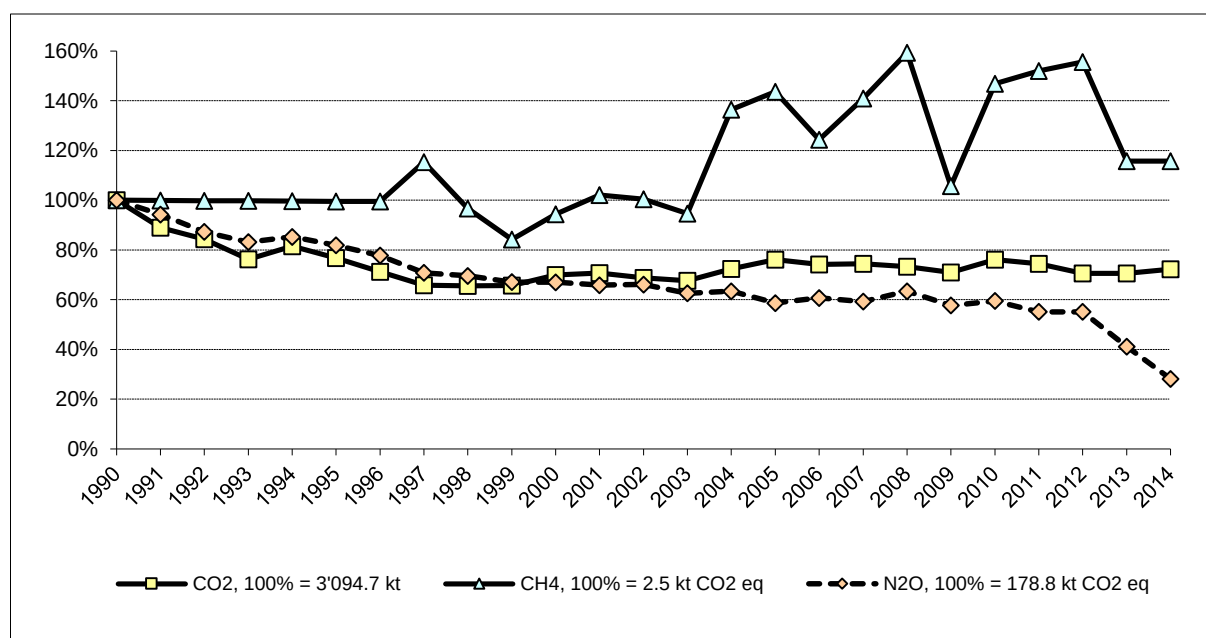


Figure 4-2 Relative trends of the GHG (without F-gases, see Figure 4-3) of sector 2 Industrial processes and product use in the period 1990–2014. The base year 1990 represents 100%.

Figure 4-2 shows that since 1990 the emissions of CO₂ and N₂O from sector 2 Industrial processes and product use have both decreased. Emissions of CH₄ have increased in the same time period although the time series shows considerable fluctuation.

Figure 4-3 shows that the emissions of F-gases have largely increased compared to the year 1990. Main contributions in the inventory 1990 result from the PFC emissions in the smelting process of aluminium production (chp. 4.4.2.2) and from the use of SF₆ in electrical equipment and sound proof windows (chp. 4.8.2.1 and chp. 4.8.2.2). The increase afterwards is due to the increasing product uses as substitutes for ODS (chp. 4.7), most

relevant and main source of F-gases emissions in 2014 is the use of HFC in refrigeration and air conditioning.

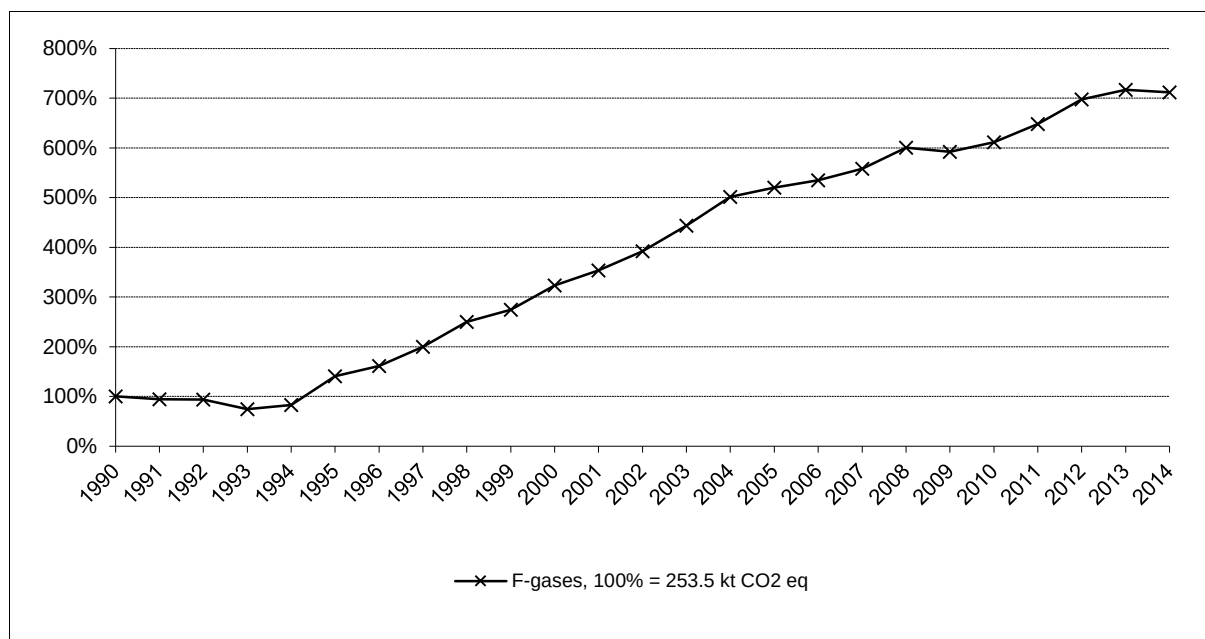


Figure 4-3 Relative trends of the F-gases of sector 2 Industrial processes and product use in the period 1990–2014. The base year 1990 represents 100%.

4.2 Source category 2A – Mineral industry

4.2.1 Source category description

Approach 1 key category 2A1

CO₂ emissions from Cement production (level and trend).

Table 4-2 Specification of source category 2A Mineral industry in Switzerland.

2A	Source	Specification
2A1	Cement production	Geogenic CO ₂ emissions from calcination process in cement production; Emissions of CO ₂ , NO _x , CO, NMVOC and SO ₂ from blasting operations
2A2	Lime production	Geogenic CO ₂ emissions from calcination process in lime production; Emissions of CO ₂ , NO _x , CO, NMVOC and SO ₂ from blasting operations
2A3	Glass production	Geogenic CO ₂ emissions from production of container and tableware glass, and glass wool
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 , NO _x , CO, NMVOC and SO ₂ from blasting operations in plaster production

4.2.2 Methodological issues

4.2.2.1 Cement production (2A1)

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.

Emissions of geogenic CO₂ 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 (CaCO₃), is heated (calcined) to produce lime (CaO) and CO₂ as by-product. The CaO reacts subsequently with minerals in the raw materials and yields clinker. During this reaction step no further CO₂ is emitted. Clinker is then mixed with other components such as gypsum to make cement.

Blasting operations in the limestone quarries are another source of emissions for both CO₂ and precursor greenhouse gases such as NO_x, CO, NMVOC and SO₂.

Methodology

Calcination process

The geogenic CO₂ emissions from the calcination process in cement production are determined by a Tier 2 method according to the decision tree Fig. 2.1. of 2006 IPCC Guidelines (vol. 3, chp. 2.1 Cement production). For cement production in Switzerland this results in the following formula:

$$\text{CO}_2 \text{ Emissions} = M_{\text{Clinker}} \cdot EF_{\text{Clinker}} \cdot \text{CKD}_{\text{Correction factor}}$$

In Switzerland, no long wet or long dry kilns are used. 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 (cement kiln 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 degree of decarbonization of the CKD is almost equal to that of the kiln feed, meaning, that this CKD has not been decarbonised yet. Therefore, the CKD correction factor is equal to 1.00.

Blasting operations

Emissions resulting from blasting operations during the digging of limestone are calculated by a Tier 2 method according to EMEP/EEA Guidebook 2013 (EMEP/EEA 2013, chp. 2A1, Fig. 3.1) using country-specific emission factors. The CO₂ emissions from "blasting" are related only to the usage of explosives in the quarries and not to fuel consumption of e.g. bulldozers etc.

Total emissions reported for the production of cement are the sum of emissions from calcination process and blasting operations. The share of CO₂ emissions from blasting operations in limestone quarries is well below one tenth of a per cent of the geogenic CO₂ emissions from the calcination process.

Emission factors

Calcination process

The emission factor for CO₂ for calcination is a country-specific value depending on the composition of the raw material (EMIS 2016/2A1 Zementwerke Rohmaterial). It is provided per tonne of clinker. Before 2004 a constant emission factor is assumed. Between 2005 and 2011 plant-specific data are provided by the cement industry association (Cemsuisse) and since 2011 the emission factor is assumed constant. The IPCC method neglects CO₂ emissions from decomposition of MgCO₃, which are taken into account in this country-specific value.

Table 4-3 CO₂ emission factor for calcination in 2A1 Cement Production 1990 to 2014.

2A1 Cement production	Unit	1990 - 2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Calcination, CO ₂	kg/t clinker	525.0	530.6	527.9	528.6	529.3	531.0	532.1	530.6	530.6	530.6	530.6

Blasting operations

The emission factors are country-specific based on emission factors of civil explosives and information on the specific consumption of explosives in the quarries as documented in the Handbook on emission factors for stationary sources (SAEFL 2000) as documented in EMIS 2016/2A1 Zementwerke übriger Betrieb. They are assumed to be constant over the entire time period and are given per tonne of clinker.

Table 4-4 Emission factors for CO₂, NO_x, CO, NMVOC and SO₂ from blasting operations in g/t clinker from source category 2A1 Cement Production in 2014

2A1 Cement production	Unit	CO ₂	NO _x	CO	NMVOC	SO ₂
Blasting operations	g/t clinker	34.1	3.3	3.3	8.6	0.1

Activity data

Since 1990, data on annual clinker production are provided by the industry association (Cemsuisse as documented in the EMIS database (EMIS2016/ 2A1_Zementwerke Rohmaterial). From 2008 onwards they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Table 4-5 Activity data of clinker production

2A1 Cement production	Unit	1990	1995	2000
Clinker production	kt	4'808	3'706	3'214

2A1 Cement production	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Clinker production	kt	3'442	3'452	3'512	3'461	3'443	3'642	3'587	3'368	3'415	3'502

4.2.2.2 Lime production (2A2)

During the production of lime calcium carbonate (CaCO₃) is heated (calcined) yielding burnt lime (CaO) and CO₂ 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 both sugar producing plants confirmed that indeed they produce lime from limestone in own shaft kilns. However, the CO₂ is re-captured in the sugar production process and thus no CO₂ emissions occur.

Blasting operations in quarries are another source of emissions for both CO₂ and precursor emissions such as NO_x, CO, NMVOC and SO₂.

Methodology

Calcination process

The geogenic CO₂ emissions from the calcination process in lime production are determined by a country-specific method according to the decision tree Fig. 2.2. of 2006 IPCC guidelines (vol. 3, chp. 2.2 Lime production).

Blasting operations

Emissions resulting from blasting operations during the digging of limestone are calculated by a Tier 2 method according to EMEP/EEA Guidebook 2013 (EMEP/EEA 2013, chp. 2A2, Fig. 3.1) using country-specific emission factors. The CO₂ emissions from "blasting" are related only to the usage of explosives in the quarries and not 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. CO₂ emissions from blasting operations in limestone quarries account only for a small share of the total emissions.

Emission factors

Calcination process

The emission factor for CO₂ from calcination of limestone depends both on the purity of the limestone and the degree of calcination (i.e. amount of rest CO₂ remaining in the lime produced). A plant-specific value has been calculated based on industry declaration and it is assumed to be constant for the years 1990–2012 (EMIS 2016/2A2 Kalkproduktion, Rohmaterial). The value is confidential and is available to reviewers on request. Since 2013, emission factors are derived from annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Blasting operations

The emission factors are country-specific as documented in EMIS 2016/2A2 Kalkproduktion, übriger Betrieb. The values are confidential and they are available to reviewers on request.

Table 4-6 CO₂ emission factor for the calcination process in lime production in kg/t lime and emission factors for CO₂, NO_x, CO, NMVOC and SO₂ from blasting operations in g/t lime in 2014

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 provided by the only existing plant in Switzerland, as documented in the EMIS database (EMIS 2016/2A2 Kalkproduktion, Rohmaterial and EMIS 2016/2A1 Kalkproduktion übriger Betrieb). From 2008 onwards, they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS). Detailed activity data are not reported since they are 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 CO₂ 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 remaining for container glass and tableware glass after the other plants closed in 2002 and 2006, respectively. Glass wool is produced in two plants.

Methodology

For determination of geogenic CO₂ emissions from glass production, a Tier 2 method according to the decision tree Fig. 2.3 of 2006 IPCC guidelines (vol. 3, chp. 2.4 Glass production) is used. For glass production in Switzerland this results in the following formula:

$$\text{CO}_2 \text{ Emissions} = M_{\text{Glass type}} \cdot EF_{\text{Glass type}} \cdot (1 - \text{cullet ratio})$$

The cullet ratio describes the share of recycled glass material which is used in the production. The melting of cullet causes no geogenic CO₂ emissions.

From 2005 onwards, the geogenic CO₂ 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, chp. 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 time.

From 2005 onwards, effective amounts of carbonate containing raw materials (soda ash, dolomite and limestone) are available for the container glass production and thus the

corresponding CO₂ emission factors are taken from IPCC 2006 (vol. 3, chp. 2.1, Table 2.1). As these emission factors are material properties, they remain constant over time.

Table 4-8 Geogenic CO₂ emission factor for glass production in g/t glass and g/t carbonate containing raw material (IPCC 2006).

2A3 Glass production	Unit	CO₂ geogenic	
Glass wool (fibre glass insulation)	g/t	250'000	
Glass (speciality tableware)	g/t	100'000	
		1990–2004	2005–2014
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 of tableware and container glass production are based on data from Swiss glass producers. For glass wool production, activity data are based on data from the two glass wool production plants in Switzerland. Since 2008, activity data are based on plant-specific annual monitoring reports.

Source category 2A3 Glass production is dominated by the emissions from the production of container glass and glass wool.

Detailed information on activity data for container glass production and tableware production is confidential as there is only one production plant for container glass and tableware glass, respectively. Data are available to the reviewers on request (EMIS 2016/2A3 Hohlglass Produktion, EMIS 2016/2A3 Glas übrige Produktion and EMIS 2016/2A3 Glaswolle Produktion Rohprodukt).

Table 4-9 Activity data of glass production in Switzerland and cullet ratio in % as well as consumption of carbonate containing raw materials in container glass production

2A3 Glass production	Unit	1990	1995	2000
Container glass				
Production	kt	C	C	C
Cullet ratio	%	C	C	C
Soda use	kt	NA	NA	NA
Dolomite use	kt	NA	NA	NA
Limestone use	kt	NA	NA	NA
Glass (speciality tableware)				
Production	kt	C	C	C
Cullet ratio	%	C	C	C
Glass wool				
Production	kt	24.3	24.2	31.1
Cullet ratio	%	21	45	69

2A3 Glass production	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Container glass											
Production	kt	C	C	C	C	C	C	C	C	C	C
Cullet ratio	%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Soda use	kt	C	C	C	C	C	C	C	C	C	C
Dolomite use	kt	C	C	C	C	C	C	C	C	C	C
Limestone use	kt	C	C	C	C	C	C	C	C	C	C
Glass (speciality tableware)											
Production	kt	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	kt	37.5	38.1	44.5	44.4	33.5	35.7	41.4	38.7	33.4	32.3
Cullet ratio	%	65	73	71	69	69	71	72	61	67	67

4.2.2.4 Other process uses of carbonates (2A4)

Source category 2A4 Other process uses of carbonates comprises geogenic CO₂ 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)

Source category 2A4a Ceramics consists of the production of fine ceramics and brick and tile.

Fine ceramics (2A4a)

In Switzerland, the main production of fine ceramics is sanitary ware. The carbonate containing raw materials limestone and dolomite as well as small amounts of soda ash are

used in product glazes only. All information on the fine ceramics production is documented in EMIS 2016/2A4a Feinkeramik Produktion.

Methodology

The geogenic CO₂ emissions from fine ceramics production are determined by a Tier 2 method according to the decision tree Fig. 2.4 of 2006 IPCC guidelines (IPCC 2006, vol. 3, chp. 2.5 Other process uses of carbonates).

For fine ceramics production in Switzerland, this results in the following formula:

$$\text{CO}_2 \text{ Emissions} = (M_{\text{Limestone}} \cdot EF_{\text{Limestone}}) + (M_{\text{Dolomite}} \cdot EF_{\text{Dolomite}}) + (M_{\text{Soda Ash}} \cdot EF_{\text{Soda Ash}})$$

Emission factors

The CO₂ emission factors of limestone, dolomite and soda ash are taken from IPCC 2006 (vol. 3, chp. 2.1, Table 2.1). As these emission factors are material properties, they remain constant over time.

Table 4-10 Geogenic CO₂ emission factors used for fine ceramics and the production of brick and tile in g/t carbonate containing raw material and g/t product, respectively.

2A4a Ceramics	Unit	CO₂ geogenic		
Fine ceramics		1990–2014		
Limestone use	g/t limestone	439'710		
Dolomite use	g/t dolomite	477'320		
Soda use	g/t soda	414'920		
		1990–2012	2013	2014
Brick and tile production	g/t	117'000	100'000	110'000

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. They are available to the reviewers on request.

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

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. Detailed data on the composition of carbonate containing raw materials from the Swiss brick and tile industry were not available before 2013. Therefore, for the period 1990 until 2012 data from a comparison of geogenic CO₂ 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 Swiss association of brick and tile industry (Verband Schweizerische Ziegelindustrie, VSZ) in 2012 (see EMIS 2016/2A4a Ziegeleien).

Since 2013, the Swiss brick and tile production plants are legally obliged to report geogenic emissions from carbonate containing raw materials annually (Federal Act on the Reduction of CO₂ Emissions, Swiss Confederation 2011 and Ordinance for the Reduction of CO₂ Emissions, Swiss Confederation 2012). The emissions are estimated from analyses of the carbonate content of the raw materials and an assumed calcination factor of 100%. This procedure corresponds to a Tier 3 method according to the decision tree Fig. 2.4 of 2006 IPCC guidelines (IPCC 2006, vol. 3, chp. 2.5 Other process uses of carbonates). Between 1990 and 2012 a Tier 2 method is applied.

Emission factors

According to the above mentioned study, bricks emit a weighted average of 13.2% of geogenic CO₂ (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 CO₂ emission factor of 117 kg CO₂/t brick and tile, which was assumed constant for the time period 1990 to 2012.

Since 2013, a production weighted emission factor is derived based on the plant-specific monitoring data of the geogenic CO₂ emissions from the carbonate containing raw materials. 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 (VSZ) (EMIS 2016/2A4).

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 in kt.

2A4a Ceramics	Unit	1990	1995	2000
Fine ceramics production	kt	C	C	C
Limestone use	kt	C	C	C
Dolomite use	kt	C	C	C
Soda use	kt	C	C	C
Brick and tile production	kt	1'271	1'115	959
2A4d Other				
Rock wool production	kt	C	C	C
Other use of carbonates	kt	5.9	5.4	7.0
Plaster production	kt	319	304	288

2A4a Ceramics	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fine ceramics production	kt	C	C	C	C	C	C	C	C	C	C
Limestone use	kt	C	C	C	C	C	C	C	C	C	C
Dolomite use	kt	C	C	C	C	C	C	C	C	C	C
Soda use	kt	C	C	C	C	C	C	C	C	C	C
Brick and tile production	kt	1'086	1'065	975	865	701	879	800	792	785	765
2A4d Other											
Rock wool production	kt	C	C	C	C	C	C	C	C	C	C
Other use of carbonates	kt	7.3	7.0	7.0	7.4	6.6	6.9	6.4	7.6	6.1	6.6
Plaster production	kt	327	323	314	295	293	335	293	271	213	166

Other uses of soda ash (2A4b)

Soda ash is mainly used 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 accounted for 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 as documented in the EMIS database (EMIS 2016/2A4d Steinwolle Produktion).

Methodology

Since 2013, rock wool manufacturers are legally obliged to report geogenic CO₂ emissions from carbonate containing raw material annually. For the years 2005–2011 and 2013 plant-specific data on raw material consumption and emission factors is available from monitoring reports of the Swiss ETS. From this information, data for the other years are interpolated for calculating an implied emission factor.

The geogenic CO₂ emissions from rock wool production are determined by a Tier 3 method according to IPCC 2006 (vol. 3, chp. 2.5 Other process uses of carbonates).

Emission factors

For rock wool production in Switzerland, the CO₂ emission factor is based on measurements of the oxides (CaO, MgO, Na₂O, K₂O, MnO) of the carbonate containing raw materials and the product for the years 2005 to 2011 as well as 2013 to 2014. Based on the difference in the oxide content in the raw material and the products, the total geogenic CO₂ 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 CO₂ emission factors are confidential. They are available to reviewers on request.

Table 4-12 Geogenic CO₂ emission factors used for rock wool production and other carbonate uses, CO₂ fossil, NO_x, CO, NMVOC and SO₂ emission factors for plaster production in g/t carbonate containing raw material and g/t product, respectively for 2014.

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 CO₂ emission factors 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 (monitoring reports of the Swiss ETS) and are therefore confidential. They are available to reviewers on request.

Other carbonate uses (2A4d)

Methodology

In 2014, an assessment was carried out in order to identify sources of CO₂ 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 (CaCO₃), dolomite (CaMg(CO₃)₂), sodium bicarbonate (NaHCO₃) and soda ash (Na₂CO₃).

Besides applications of calcium hydroxide and sodium hydroxide in flue gas treatment also a few applications of limestone and sodium bicarbonate could be identified in Switzerland. Limestone had 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 CO₂ 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 applications of sodium bicarbonate result in a complete conversion to CO₂. 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 identified.

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.

The method for calculating emissions from applications of sodium bicarbonate corresponds to a Tier 2 method according to the decision tree Fig. 2.4 of 2006 IPCC guidelines (IPCC 2006, vol. 3, chp. 2.5 Other process uses of carbonates).

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 2015). 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 plants has been subtracted and is reported in source category 1A1a. For activity data see Table 4-11.

Plaster production (2A4d)

Methodology

There are two plaster production sites in Switzerland. The emissions stem mainly from blasting operations.

Emissions from blasting operations are determined by a country-specific method analogous to a Tier 2 method of EMEP/EEA Guidebook 2013 (EMEP/EEA 2013).

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 raw material are required for production of 1 t of cement). This method is documented in EMIS 2016/2A4d Gips-Produktion übriger Betrieb. For emission factors see Table 4-12.

Activity data

The activity data of the annual amount of raw material processed in the plaster production are based on industry data and expert estimates as documented in EMIS 2016/2A4d Gips-Produktion übriger Betrieb (see Table 4-11).

4.2.3 Uncertainties and time-series consistency

The uncertainty for CO₂ emissions in cement production (2A1), which is a key category regarding level and trend, amounts to 2.8%. The uncertainty of CO₂ emissions was calculated following the steps in Table 3.2 in 2006 IPCC Guidelines (IPCC 2006, vol. 1, chp. 3, p. 3.30–3.31). As CO₂ emissions are calculated based on plant level CaO and MgO contents of the clinker (Tier 2 method), an uncertainty of 2% is assumed both for activity data and emission factor (step 3 in table 3.2).

The uncertainties for CO₂ 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 CO₂ emissions in source category 2A4 Other process uses of carbonates, an overall uncertainty of 5% and an uncertainty of 1.4% for activity data and 4.8% for the emission factor is taken. Most of the data stems from industrial plants participating in the Swiss ETS, which requires that the uncertainty in the emissions does not exceed a given limit (1.5%-7.5%, depending on the amount of emissions resulting from a given source). Thus an overall uncertainty of 5% is assumed.

Consistency: Time series for 2A Mineral industry are all considered consistent.

4.2.4 Category-specific QA/QC and verification

The general QA/QC measures are described in chp. 1.2.3.

For submission 2015, an assessment of the geogenic CO₂ 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 CO₂ Emissions (Swiss Confederation 2012) (FOEN).

For submission 2015, an assessment of carbonate use for sulphur oxide removal and acid neutralization was carried out (INFRAS 2015).

4.2.5 Category-specific recalculations

Recalculations reported in submission 2015

- 2A1 Cement production: AD and EF of cement production (blasting operations) are now related to tonnes of clinker, and not cement as it was before. Therefore all data from 1990–2012 have been converted to this unit.
- 2A1 Cement production: The EF of fossil CO₂ 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 CO₂ 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 which are still used for the years 1990–2004.
- 2A3 Glass production (specialty tableware): the EF of geogenic CO₂ 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 CO₂ 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 CO₂ emissions from the use of ammonium bicarbonate are newly included in the inventory for the entire time period.

Recalculations reported in submission 2016

- 2A2: The EF of geogenic CO₂ from 2A2 Lime production has been revised for 2013 based on effective carbonate contents in the raw material.
- 2A3: The AD of 2A3 Glass production (speciality tableware) has been revised based on industry data from 1996 onwards.
- 2A4a: The EF of geogenic CO₂ from 2A4a Fine ceramics production has been revised for 2012 and 2013 based on updated data of the carbonate contents of the glazes.
- 2A4d: The EF of geogenic CO₂ from 2A4d Rockwool production has been updated for 1990–2004 and 2012 based on revised mean value of the carbonate content in the raw material.

4.2.6 Category-specific planned improvements

2A1: Since 2013, the Swiss cement plants participate in the Swiss Emissions Trading Scheme, which requires annual monitoring of geogenic CO₂ emissions. Based on these reports, geogenic CO₂ emissions will be estimated again based on plant-specific emission factors.

4.3 Source category 2B – Chemical industry

4.3.1 Source category description

Approach 1 and 2 key category 2B

Source category 2B Chemical industry is not a key category.

Table 4-14 Specification of source category 2B Chemical industry in Switzerland.

2B	Source	Specification
2B1	Ammonia production	Emissions of CO ₂ and NMVOC are reported in 2B8b Ethylene production
2B2	Nitric acid production	Emissions of N ₂ O and NO _x from the production of nitric acid
2B5	Carbide production	Emissions of CO ₂ , CH ₄ and SO ₂ from the production of silicon carbide
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
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

4.3.2 Methodological issues

4.3.2.1 Ammonia production (2B1)

Ammonia (NH₃) 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, C₂H₄), 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 (CO₂ and NMVOC) to every single product such as, e.g., ethylene, acetylene (ethyne, C₂H₂), cyanic acid or ammonia. Therefore, all CO₂ 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, CO₂ and NMVOC emissions are reported as included elsewhere (IE). All information on the ammonia production and the cracking process is documented in EMIS 2016/2B1 Ammoniak-Produktion and EMIS 2016/2B8b Ethen-Produktion, respectively.

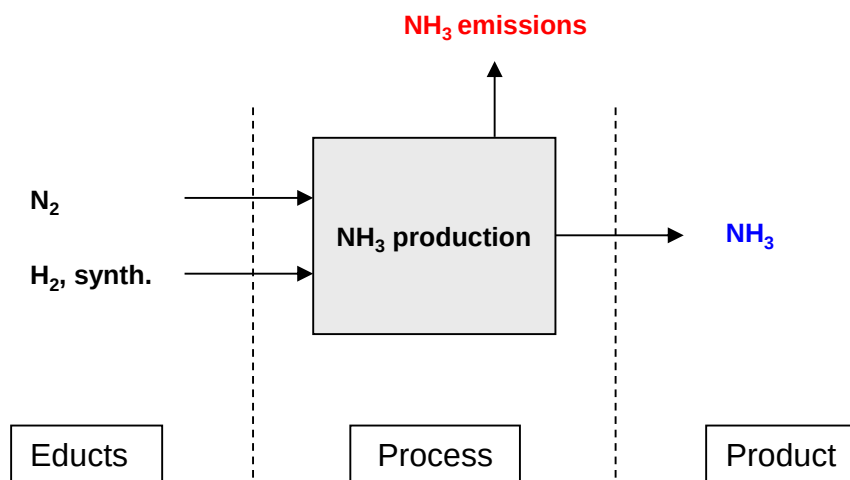


Figure 4-4 Process flow chart for the production of ammonia (NH₃) from nitrogen (N₂) and hydrogen (H₂, synth.). Hydrogen is derived from the thermal cracking process in the same plant (see Figure 4-5).

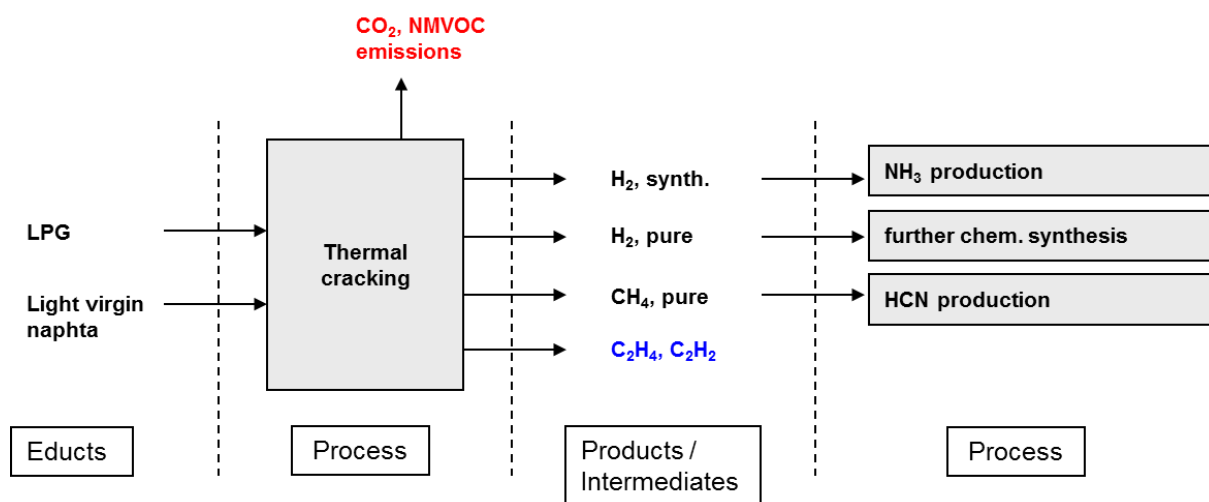


Figure 4-5 Process flow chart for the production of ethylene (C₂H₄) and acetylene (C₂H₂) by thermal cracking of liquefied petroleum gas (LPG) and light virgin naphtha. The intermediate product H₂, synth. is used as educt in the ammonia production in the same plant (see Figure 4-4).

4.3.2.2 Nitric acid production (2B2)

In Switzerland, there is one single plant producing nitric acid (HNO₃). Nitric acid is produced by catalytic oxidation of ammonia (NH₃) with air. At temperatures of 800°C nitric monoxide (NO) is formed. During cooling, nitrogen monoxide reacts with excess oxygen to form nitrogen dioxide (NO₂). The nitrogen dioxide reacts with water to form 60% nitric acid (HNO₃). 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 this process, nitrous oxide (N₂O) can be formed as an unintentional by-product. In addition, also some nitrogen oxide (NO_x) is produced. In the Swiss production plant abatement of NO_x is done by selective catalytic reduction (SCR, installed in 1988), which reduces NO_x to N₂ and O₂ (the SCR in this plant is also used for treatment of other flue gases and was not installed for the HNO₃ production specially). In 1990, an automatic control

system for the dosing of ammonia to the SCR process was installed. A new catalyst installed in 2013 reduced the N₂O emissions.

No additional abatement technique is installed to destroy N₂O. A decomposition of N₂O occurs, to some extent, simultaneously in the NO_x reduction process.

Methodology

According to decision tree Fig. 3.2 of the IPCC 2006 guidelines (vol. 3, chp. 3.3 Nitric acid production), the N₂O emissions from nitric acid production are determined by a Tier 2 method during the time period 1990–2012 and by a Tier 3 method since 2013, based on direct measurements. The NO_x emissions are calculated by a Tier 2 method according to the decision tree Fig. 3.1 in EMEP/EEA (2013) (chp. 2B Chemical industry) using a plant-specific emission factor.

Emission factors

The N₂O and NO_x emission factors for nitric acid production in Switzerland are based on measurements from the single nitric acid production plant.

The measurement of N₂O 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 N₂O 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 N₂O concentration is then measured using a gas chromatograph with an electron capture detector. The measurement uncertainty is ±20% (minimum ± 0.5 mg/m³). 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 modifications were made in the production line until 2012. Therefore, a constant N₂O-emission factor is assumed for this time period. A new catalyst installed in 2013 reduced the N₂O emissions, which are measured online by NDIR photometry from 2013 onwards.

The NO_x 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 between 1990 and 2012 a constant emission factor is assumed for this time period. In 2013, the volume of the SCR-plant was duplicated. This modification together with the new catalyst in the production line slightly reduced the NO_x emission factor. The values are documented in EMIS 2016/2B2 Salpetersäure Produktion. They are considered confidential and are available to reviewers on request.

Table 4-15 Emission factors for N₂O and NO_x for nitric acid production in Switzerland in kg/t nitric acid for 2014. Data refers to 100% nitric acid

2B2 Nitric acid production	Unit	N ₂ O	NO _x
	kg/t	C	C

Activity data

Activity data on annual production of nitric acid (100%) are provided annually by the Swiss production plant for the entire time period 1990–2014. Since 2013, activity data of the annual nitric acid production is taken from annual monitoring reports from the Swiss Emissions Trading Scheme (ETS). The data are confidential but available to reviewers (see EMIS 2016/2B2 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 2000°C 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

According to decision tree Fig. 3.5 of the IPCC 2006 guidelines (vol. 3, chp. 3.6 Carbide production), the CO_2 and CH_4 emissions from silicon carbide production are determined by a Tier 2 method. The SO_2 emissions are calculated by a Tier 2 method according to the decision tree Fig. 3.1 in EMEP/EEA (2013) (chp. 2B Chemical industry) using plant-specific emission factors.

Emission factors

The CO_2 , CH_4 and SO_2 emission factors are confidential and available to reviewers on request. The values are partly based on measurements from the single silicon carbide production plant and are documented in EMIS 2016/2B5 Graphit und Siliziumkarbid Produktion.

Table 4-17 Emission factors for CO_2 , CH_4 and SO_2 for carbide production in kg/t silicon carbide in Switzerland in kg/t for 2014.

2B5 Carbide production	Unit	CO_2	CH_4	SO_2
2B5a Silicon carbide	kg/t	C	C	C

Activity data

Activity data on annual production of silicon carbide are provided annually 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 2016/2B5 Graphit und Siliziumkarbid Produktion).

Table 4-18 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 naphtha. 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 chp. 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 (see Figure 4-5 and for further information see EMIS 2016/2B8b Ethen-Produktion). Therefore, CH_4 emissions are reported as NA for ethylene production and only CO_2 and NMVOC emissions are reported.

Methodology

According to decision trees Fig. 3.8 of the IPCC 2006 guidelines (vol. 3, chp. 3.9 Petrochemical and carbon black production) and Fig. 3.1 of EMEP/EEA (2013) (chp. 2B Chemical industry), the CO_2 and NMVOC emissions, respectively, from ethylene production are determined by a Tier 2 method using plant-specific emission factors (EMIS 2016/2B8b Ethen-Produktion).

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 4-19 Emission factors for CO₂ and NMVOC in ethylene production, NMVOC in acetic acid production, CO₂ in limestone pit and niacin production and SO₂ in sulphuric acid production for 2014 in kg/t product.

	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

Activity data

Activity data on the annual production of ethylene are provided annually by the single ethylene production plant in Switzerland. The data are considered confidential but available to reviewers on request.

Table 4-20 Activity data for the production of ethylene, acetic acid, niacin, PVC and sulphuric acid as well as for limestone pit in Switzerland in kt.

	Unit	1990	1995	2000
2B8 Petrochemical and carbon black production				
2B8b Ethylene	kt	C	C	C
2B10 Other				
Acetic acid production	kt	30	27	24
Limestone pit	kt	C	C	C
Niacin production	kt	C	C	C
PVC production	kt	43	43	0
Sulphuric acid production	kt	C	C	C

	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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	8	8	9	18	28	20	18	12	C	C
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

4.3.2.5 Other (2B10)

Source category 2B10 Other 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 2014 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 occur.

Methodology

In order to determine emissions of CO_2 and CH_4 from acetic acid a country-specific method analogous to a Tier 2 method according to the IPCC 2006 guidelines (vol. 3) is used. The CO and NMVOC emissions are calculated by a Tier 2 method according to the decision tree Fig. 3.1 in EMEP/EEA (2013) (chp. 2B Chemical industry).

Emission factors

The emission factors for CO_2 , CH_4 , CO and NMVOC from acetic acid production in Switzerland are plant-specific and based on data from industry and expert estimates documented in EMIS 2016/2B10 Essigsäure-Produktion (see Table 4-19 for NMVOC).

In the plant which ceased production by the end of 2012 process emissions had been treated in a flue gas incineration. Thus, the reported emissions of CH_4 , CO and NMVOC only occurred in case of malfunction, which resulted 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 4-21 In the confidential NIR, the respective table with emission factors for CO_2 and CH_4 in acetic acid production are separately reported and available to reviewers.

Activity data

The annual amount of produced acetic acid is based on data from industry and from the Swiss industry association for the chemical, pharmaceutical and biotech industry (scienceindustries) documented in EMIS 2016/2B10 Essigsäure-Produktion (see Table 4-20). The data for acetic acid production since 2013 are confidential, since there is only one manufacturer remaining. The data are available for reviewers on request.

Limestone pit (2B10)

In one chemical plant acids are neutralized in a so-called limestone pit yielding geogenic CO_2 emissions.

Methodology

According to decision tree Fig. 2.4 of the IPCC 2006 guidelines (vol. 3, chp. 2.5 Other process uses of carbonates), the CO₂ emissions from the limestone pit are determined by Tier 2 method.

Emission factors

The CO₂ emission factor is considered confidential but available to reviewers on request.

Activity data

Activity data of annual consumption of calcium carbonate are provided by the chemical plant from 1999 onwards as documented in EMIS 2016/2B10 Kalksteingrube. For the years 2005–2011 and 2013 they are based on monitoring reports of the Swiss ETS. Since no data are available of the limestone pit for the time period 1990–1998, the annual activity is derived from the average annual consumption between 1999 and 2014.

Activity data is considered confidential but available to reviewers on request.

Niacin production (2B10)

CO₂ emissions from niacin production of the single manufacturer in Switzerland are reported since submission 2015. CO₂ is released in the last reaction step of the niacin production.

Methodology

In order to determine emissions of CO₂ from niacin production, a country-specific method analogous to a Tier 2 method according to the IPCC 2006 guidelines (vol. 3) is used.

Emission factors

The CO₂ emission factor is plant-specific based on monitoring reports of the Swiss ETS and is assumed to be constant as documented in the EMIS database (EMIS 2016/2B10 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 2016/2B10 Niacin-Produktion. For the years 2005–2011 and 2013 they are based on monitoring reports of the Swiss ETS. 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 Tier 2 method according to the decision tree Fig. 3.1 of EMEP/EEA (2013) (chp. 2B Chemical industry) with plant-specific emission factors is used.

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 the EMIS database (EMIS 2016/2B10 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 2016/2B10 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 2016/2B10 Schwefelsäure-Produktion and EMIS 2016/2B10 PVC-Produktion (see Table 4-20). 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, the uncertainty is assumed to be 7.5% since the Swiss ETS requires that an uncertainty of 7.5% is not exceeded for continuous N_2O measurements.

Consistency: Time series for 2B Chemical industry are all considered consistent.

4.3.4 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

4.3.5 Category-specific recalculations

Recalculations reported in submission 2015

- 2B10 Other: CO₂ 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 SO₂ emission factor from 2B10 Sulphuric acid production has been revised for 1990–2009 based on the updated EF value for 2013.

Recalculations reported in submission 2016

- 2B8b: The AD of 2B8b Ethylene production has been corrected for 2013 due to a mistake in last year's submission.
- 2B10: The EF of SO₂ of 2B10 Sulphuric acid production has been corrected for 2009 due to a typing error in last year's submission.

4.3.6 Category-specific planned improvements

No category-specific improvements are planned.

4.4 Source category 2C – Metal industry

4.4.1 Source category description

Approach 1 key category 2C3

CO₂ emissions from Aluminium production (trend).

PFC emissions from Aluminium production (trend).

Table 4-22 Specification of source category 2C Metal industry in Switzerland.

2C	Source	Specification
2C1	Iron and steel production	Emissions of CO ₂ , NO _x , CO, NMVOC and SO ₂ from the production of iron and steel
2C2	Ferroalloys production	Production is not occurring in Switzerland
2C3	Aluminium production	Emissions of PFC, CO ₂ , NO _x , CO, NMVOC, and SO ₂ from the production of primary aluminium (ceased in 2006)
2C4	Magnesium production	Emissions from use of SF ₆ in magnesium foundries (emissions from use of SF ₆ in aluminium foundries included)
2C7	Other	Emissions of CO and NMVOC from non-ferrous metal foundries Emissions of CO ₂ , NO _x , CO and SO ₂ from battery 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 CO₂ emissions occur mainly from scrap, electrodes and carburization coal whereas the produced steel, filter dust and slag act as carbon sinks. Emissions of precursors such as NO_x, CO, NMVOC and SO₂ 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 are emitted. In cupola furnaces also CO₂ emissions occur. Those CO₂ emissions are accounted for in source category 1A2a.

Methodology

For determination of CO₂ emission from iron and steel production a mixture of a Tier 2 and a Tier 3 method according to decision tree Fig. 4.7 IPCC 2006 (vol. 3, chp. 4.2 Iron & steel and metallurgical coke production) is used. For the years 2005–2011 and 2013 plant-specific data on the carbon mass balance is available from monitoring reports of the Swiss ETS, since under the Ordinance for the Reduction of CO₂ Emissions (Swiss Confederation 2012) the plants are required to report their emissions annually (Tier 3). From this information, data for the other years are interpolated for calculating an implied emission factor. In Switzerland, no CH₄ emissions occur in the EAF process.

Emissions of all precursors are determined by a Tier 2 method based on the decision tree Fig. 3.1 in chapter 2C1 in EMEP/EEA (2013) using country-specific emission factors (EMIS 2016/2C1).

Emission factors

The emission factors for iron and steel production in Switzerland are country-specific and are based on measurements from industry and expert estimates documented in the EMIS database (EMIS 2016/2C1 Eisengiessereien Elektroschmelzofen/übriger Betrieb, EMIS 2016/2C1 Stahl-Produktion Elektroschmelzöfen and EMIS 2016/2C1 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 2013–2014 were taken into account. Based on these carbon mass balances, a mean plant-specific CO₂ emission factor results. The plant-specific data are confidential but available to reviewers on request. The reported CO₂ emission factor for Swiss steel industry is the production-weighted average.

Table 4-23 CO₂ emission factor of electric arc furnaces in 2C1 Steel production in kg/t.

2C1 Steel production	Unit	1990	1995	2000
CO ₂	kg/t	8.3	8.0	7.7

2C1 Steel production	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO ₂	kg/t	8.8	9.1	8.5	6.8	6.8	7.6	7.1	7.9	8.5	8.2

Emission factors for all precursors emitted from steel production are based on air pollution control measurements of the steel plants. For submission 2016, emission factors of NO_x, NMVOC, SO₂, and CO have been revised based on air pollution control measurements at the electric arc furnaces of the two plants in 1999, 2005 and 2010 and in 1998, 2009 and 2014, respectively. The emission factors from iron production in foundries are provided by the Swiss foundry association (GVS).

Table 4-24 Emission factors for NO_x, CO and NMVOC in iron production, for CO₂, NO_x, CO, NMVOC and SO₂ in steel production, for CO and NMVOC in non-ferrous metal production and for CO₂, NO_x, CO and SO₂ in battery recycling for 2014.

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	8.2	0.14	0.7	0.1	0.014
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 annually by the Swiss foundry association (Giesserei-Verband Schweiz, GVS) and the steel plants, respectively. Since 2009, activity data of the annual steel production is taken from annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Table 4-25 Production of iron, steel, aluminium and non-ferrous metals as well as amount of batteries recycled in Switzerland in kt.

2C Metal industry	Unit	1990	1995	2000
2C1 Iron production	kt	170	130	120
2C1 Steel production	kt	1'108	716	1'022
2C3 Aluminium production	kt	87	21	36
2C7a Non-ferrous metals	kt	55	60	70
2C7c Battery recycling	kt	3.0	3.0	3.0

2C Metal industry	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2C1 Iron production	kt	67	67	72	78	49	53	61	46	45	43
2C1 Steel production	kt	1'159	1'254	1'267	1'315	935	1'218	1'322	1'252	1'231	1'315
2C3 Aluminium production	kt	45	12	0	0	0	0	0	0	0	0
2C7a Non-ferrous metals	kt	33	30	28	21	15	20	12	18	7	7
2C7c Battery recycling	kt	2.8	2.4	2.4	2.5	3.4	3.3	2.4	2.4	2.3	2.6

4.4.2.2 Aluminium production (2C3)

Methodology

The last production site for primary aluminium in Switzerland closed down in April 2006. According to 2006 IPCC Guidelines (IPCC 2006, vol.3, chp. 4.4, fig. 4.11) CO₂ emissions were calculated by a Tier 2 method using a country-specific emission factor. For PFC emissions a more specific Tier 3 method with facility-specific data according to the 2006 IPCC Guidelines (IPCC 2006) was used. Operating smelter emissions have been monitored periodically by the industry for selected years.

FOEN import statistics indicate SF₆ imports for the aluminium industry, referring to cleaning process in foundries. The 2006 IPCC Guidelines mention use of SF₆ 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 CO₂ of 1.6 tonnes per tonne of aluminium is country-specific. It is based on measurements and data from industry and expert estimates, documented in the EMIS database (EMIS 2016/2C3 Aluminium Produktion). CO₂ emissions from aluminium production stem from the oxidation of the anode in the electrolysis process. In Switzerland only prebake anode technology was used. For the anode consumption a constant mean value of 0.43 tonnes per tonne of aluminium was applied. It is assumed that the anode consisted completely of carbon and that it was fully oxidized during the process.

For PFC emissions from aluminium production, emission factors of operating smelters 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 (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 (CF₄ and C₂F₆) 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 within the uncertainty range according to the 2006 IPCC Guidelines (variations by a factor 10 using same technologies). Emission factors for the years 2001 to 2006 are not measured and therefore they are estimated based on an interpolation proportional to the European data. For the ratio of CF₄ to C₂F₆, 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 between 1990 and 2006 due to technical efforts to reduce emissions (Alcan 2003).

Table 4-26 PFC emissions factors for aluminium production in Switzerland. Aluminium production in Switzerland ceased in 2006.

Gas	Unit	1990	1995	2000
CF ₄	kg/t	0.1530	0.0833	0.0360
C ₂ F ₆	kg/t	0.0170	0.0093	0.0040

Gas	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CF ₄	kg/t	0.0315	0.0315	NO	NO	NO	NO	NO	NO	NO	NO
C ₂ F ₆	kg/t	0.0035	0.0035	NO	NO	NO	NO	NO	NO	NO	NO

Activity data

In 2006, the last aluminium production site 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, data were provided directly by the aluminium industry. Activity data for aluminium production in Switzerland are given in Table 4-25.

4.4.2.3 Magnesium production (2C4)

Use of SF₆ in aluminium and magnesium foundries (2C4)

Use of SF₆ in aluminium foundries (2C3) is included in source category 2C4 (use of SF₆ in aluminium production related to magnesium alloys is mentioned in the 2006 IPCC Guidelines). SF₆ is used in Swiss aluminium and magnesium foundries since 1997. There have been two magnesium foundries known to be using SF₆. In 2007 one of them closed down.

Methodology

SF₆ 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 method is used.

Emission factors

There are no measurements of SF₆ emissions available to identify the fraction of SF₆ destroyed or transformed in the process. For SF₆ 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 tonne of imported substance).

Activity data

Activity data on SF₆ 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 2014 the mean value of 2013 and 2014 import data are used). It is assumed that the total imported amount is emitted within one year. The remaining magnesium foundry reported activity data for 2008 to 2014 to the SWISSMEM statistics. The fact that only one magnesium foundry uses SF₆ was confirmed by a survey, which has been carried out in 2011 among members of the Swiss Foundry Association (GVS). SF₆ has not been used in aluminium foundries in Switzerland since 2011. The amount of imported SF₆ 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 SF₆ 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 SF₆ are used for aluminium 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 pyrolysed 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 directed to a flue gas treatment installation. 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 CO₂, NO_x, CO and SO₂ from battery recycling and of CO and NMVOC from non-ferrous metal foundries, Tier 2 methods according to EMEP/EEA Guidebook 2013 (EMEP/EEA 2013, chp. 2C7c and 2C7a) with country-specific emission factors are used.

Emission factors

The emission factors of CO₂, NO_x, CO and SO₂ 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 the EMIS database (EMIS 2016/2C7 Batterie-Recycling and 2015/2C7 Buntmetallgiessereien Elektroöfen) (see Table 4-24).

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 the EMIS database (EMIS 2016/2C7 Batterie-Recycling and 2015/2C7 Buntmetallgiessereien Elektroöfen), (see Table 4-25).

4.4.3 Uncertainties and time-series consistency

The uncertainty of CO₂ 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%. The uncertainty for the CO₂ emission factor is estimated at 40%.

For the emission of CO₂ 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, CO₂ and PFC.

For the emissions of SF₆ from the use in 2C4 Magnesium production an uncertainty of 25% is assumed based on a Monte Carlo simulation (for further details see Carbotech 2016).

The uncertainty of CO₂ 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 Category-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, a reassessment of CO₂ 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 CO₂ 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 Category-specific recalculations

Recalculations reported in submission 2015

- 2C3 Aluminium production, 2C4 Magnesium production: following the 2006 IPCC Guidelines new GWP values for SF₆ and PFC have been applied for the entire time period 1990 to 2013.

Recalculations reported in submission 2016

- 2C1: The CO₂ EF from 2C1 Steel production, electric arc furnace has been revised for 2013 based on corrected data in the carbon mass balance of one of the two steel plants.
- 2C1: The EF of NO_x, CO, NMVOC and SO₂ of 2C1 Steel production, electric arc furnace have been revised from 1991 onwards based on air pollution control measurements.
- 2C1: The AD of 2C1 Steel production, rolling mill has been revised for 2013 based on industry data.

4.4.6 Category-specific planned improvements

No category-specific improvements are planned.

4.5 Source category 2D – Non-energy products from fuels and solvent use

4.5.1 Source category description

Approach 1 and 2 key category 2D

Source category 2D is not a key category.

Table 4-27 Specification of source category 2D Non-energy products from fuels and solvent use in Switzerland.

2D	Source	Specification
2D1	Lubricant use	Emissions of CO ₂ from primary usage of lubricants in machinery and vehicles
2D2	Paraffin wax use	Emissions of CO ₂ from primary usage of paraffin waxes
2D3a	Solvent use	Emissions of NMVOC from coating applications, degreasing, dry cleaning and chemical products as well as emissions of CO ₂ resulting from post-combustion of NMVOC in exhaust gases of these sources
2D3b	Road paving with asphalt	Emissions of NMVOC from road paving with asphalt
2D3c	Asphalt roofing	Emissions of CO and NMVOC from asphalt roofing;
2D3d	Urea use in SCR catalysts of diesel engines	Emissions of CO ₂ from urea use in SCR catalysts of diesel engines (heavy motor vehicles)

4.5.2 Methodological issues

4.5.2.1 Lubricant use (2D1) and Paraffin wax use (2D2)

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. Lubricants in engines are

primarily used for their lubricating properties and associated CO₂ emissions are therefore considered as non-combustion emissions reported in 2D1 Lubricant use.

The source category 2D2 Paraffin wax use includes products such 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 occur primarily when the waxes or derivatives of paraffins are combusted during use (e.g. candles).

Methodology

CO₂ emissions from oxidation of lubricants and paraffin wax are calculated by a Tier 1 method according to the 2006 IPCC Guidelines (IPCC 2006, vol. 3, chp. 5.2 and 5.3) applying the IPCC default oxidation fraction of 0.2.

Emission factors

The emission factors of CO₂ from lubricant and paraffin wax use in Switzerland are based on default IPCC values for NCV, carbon content and oxidation fraction documented in vol. 2, chap.1 and vol. 3, chap. 5.2 and 5.3, respectively, of IPCC 2006, see also EMIS 2016/2D1 Lubricant use and EMIS 2016/2D2 Paraffin wax use.

Table 4-28 CO₂ emission factor of 2D1 Lubricant use and 2D2 Paraffin wax use for 2014 in kg/t.

	Unit	CO ₂
2D1 Lubricant use	kg/t	590
2D2 Paraffin wax use	kg/t	590

Activity data

The annual amount of lubricant and paraffin wax used in Switzerland is derived from the Swiss petroleum association (EV 2015).

Table 4-29 Use of lubricants in Switzerland.

	Unit	1990	1995	2000
2D1 Lubricant use	kt	80	61	63
2D2 Paraffin wax use	kt	11	10	12

	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2D1 Lubricant use	kt	72	68	71	66	52	55	54	51	53	54
2D2 Paraffin wax use	kt	10	11	9	9	6	5	5	3	4	4

4.5.2.2 Other (2D3)

Solvent use (2D3a)

Since the 2006 IPCC Guidelines (vol. 3, chp. 5.5) refer to the EMEP/EEA Guidebook 2013 regarding methodologies for estimating NMVOC emissions from solvent use, the respective NFR codes are indicated as reference as well. 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. These CO₂ emissions from post-combustion of NMVOC are estimated based on industry data and expert estimates (Carbotech 2014a).

The source categories paint application in construction, paint application on wood, industrial and non-industrial paint application, production of fine chemicals and cleaning of parts in metal processing account for the largest share of NMVOC emissions from 2D3a in 2014.

Coating applications (2D3d NFR)

Methodology

For the determination of NMVOC emissions from coating applications a Tier 2 method according to the EMEP/EEA Guidebook 2013 is used based on the consumption of paints, lacquers, thinners etc. and their solvent content. Switzerland's Informative Inventory Report 2016 contains a detailed description of the methods and country-specific data used for estimating the NMVOC emissions from 2D3d NFR Coating applications (FOEN 2016f).

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 2016/2D3a).

Table 4-30 NMVOC emission factors of coating applications, degreasing, dry cleaning, chemical products, manufacture and processing in 2D3a Solvent use for 2014.

2D3a Solvent use	Unit	NMVOC
Coating applications (2D3d NFR)		
Paint application, construction	kg/t paint	56
Paint application, households	kg/t paint	88
Paint application, industrial & non-industrial	kg/t paint	348
Paint application, wood	kg/t paint	293
Paint application, car repair	kg/t paint	400
Degreasing (2D3e NFR)		
Cleaning of electronic components	kg/t solvent	500
Degreasing of metal	kg/t solvent	460
Other industrial cleaning	kg/t solvent	610
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	3.6
Pharmaceutical production	kg/t pharmaceutical	7.8
Polyester processing	kg/t polyester	50
Polystyrene processing	kg/t polystyrene	16
Polyurethane processing	kg/t polyurethane	3.8
PVC processing	kg/t PVC	4.0
Rubber processing	kg/tyres	0.14
Tanning of leather	kg/employee	0.68

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.

Table 4-31 Activity data of coating applications, degreasing, dry cleaning and chemical products, manufacture and processing in Switzerland.

2D3a Solvent use	Unit	1990	1995	2000
Coating applications (2D3d NFR)				
Paint application, construction	t	122'000	65'750	32'667
Paint application, households	t	12'000	12'625	13'000
Paint application, industrial & non-industrial	t	20'100	21'288	20'933
Paint application, wood	t	6'000	6'313	6'500
Paint application, car repair	t	2'700	2'200	2'000
Degreasing (2D3e NFR)				
Cleaning of electronic components	t	900	556	350
Degreasing of metal	t	15'500	10'019	5'937
Other industrial cleaning	t	625	616	563
Dry cleaning (2D3f NFR)	t	1'300	1'011	722
Chemical products, manufacture and processing (2D3g NFR)				
Fine chemicals production	prod. index	70	100	163
Glue production	t	19'000	31'682	44'364
Handling and storing of solvents	prod. index	70	100	163
Ink production	t	20'200	17'575	18'000
Paint production	t	138'000	121'500	117'333
Pharmaceutical production	t	16'100	20'975	20'233
Polyester processing	t	10'800	7'043	6'467
Polystyrene processing	t	19'600	19'100	18'800
Polyurethane processing	t	17'300	34'500	44'500
Production of adhesive tape	t	1'520	0	0
PVC processing	t	94'000	94'000	78'000
Rubber processing	tyres	120'000	119'375	103'667
Tanning of leather	employees	110	108	102

2D3a Solvent use	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Coating applications (2D3d NFR)											
Paint application, construction	t	42'000	43'500	45'000	48'000	51'000	54'000	56'333	58'667	61'000	61'000
Paint application, households	t	20'000	20'000	20'000	22'667	25'333	28'000	28'000	28'000	28'000	28'286
Paint application, industrial & non-industrial	t	8'767	8'933	9'100	8'833	8'567	8'300	8'170	8'040	7'910	7'780
Paint application, wood	t	7'667	7'833	8'000	8'667	9'333	10'000	10'000	10'000	10'000	10'136
Paint application, car repair	t	1'867	1'833	1'800	1'767	1'733	1'700	1'533	1'367	1'200	1'243
Degreasing (2D3e NFR)											
Cleaning of electronic components	t	643	607	570	602	634	666	698	730	730	730
Degreasing of metal	t	2'557	2'483	2'410	2'316	2'222	2'128	2'034	1'940	1'934	1'928
Other industrial cleaning	t	1'427	1'313	1'200	1'202	1'204	1'206	1'208	1'210	1'204	1'199
Dry cleaning (2D3f NFR)	t	433	375	317	259	201	144	86	28	28	28
Chemical products, manufacture and processing (2D3g NFR)											
Fine chemicals production	prod. index	224	246	283	280	295	314	299	302	305	308
Glue production	t	59'767	62'033	64'300	63'969	63'638	63'308	62'977	62'646	62'315	61'985
Handling and storing of solvents	prod. index	224	246	283	280	295	314	299	302	305	308
Ink production	t	17'767	18'133	18'500	18'667	18'833	19'000	21'433	23'867	26'300	25'586
Paint production	t	122'333	123'667	125'000	125'333	125'667	126'000	126'000	126'000	126'000	125'143
Pharmaceutical production	t	27'600	28'300	29'000	29'250	29'500	29'750	30'000	30'100	30'200	30'300
Polyester processing	t	6'867	7'233	7'600	6'200	4'800	3'400	3'500	3'700	3'700	3'700
Polystyrene processing	t	23'500	25'800	26'000	28'575	31'150	33'725	36'300	31'000	31'500	32'000
Polyurethane processing	t	53'900	59'200	69'600	67'400	51'700	54'200	40'300	40'200	38'200	37'743
Production of adhesive tape	t	0	0	0	0	0	0	0	0	0	0
PVC processing	t	64'000	68'800	78'400	72'900	62'300	51'700	55'200	39'700	38'488	37'275
Rubber processing	tyres	67'000	70'000	70'000	72'500	75'000	77'500	80'000	80'000	81'000	82'000
Tanning of leather	employees	88	88	87	87	87	87	87	86	85	85

Degreasing and dry cleaning (2D3e NFR, 2D3f NFR)

Methodology

For the determination of NMVOC emissions from degreasing and dry cleaning a Tier 2 method according to the EMEP/EEA Guidebook 2013 is used based on the consumption of solvents. Switzerland's Informative Inventory Report 2016 contains a detailed description of the methods and country-specific data used for estimating the NMVOC emissions from 2D3e NFR, 2D3f NFR Degreasing and dry cleaning (FOEN 2016f).

Emission factors

Emission factors for NMVOC emissions are based on data from the association of Swiss mechanical and electric engineering industries, NMVOC balances, import statistics and

expert estimates, documented in the EMIS database (EMIS 2016/2D3a). For emission factors in 2014 see Table 4-30.

Activity data

Activity data correspond to the annual consumption of solvents for degreasing and dry cleaning. Data are based on data from the association of Swiss mechanical and electric engineering industries, NMVOC balances, import statistics and expert estimates, documented in the EMIS database (EMIS 2016/2D3a). Activity data is provided in Table 4-31.

Chemical products, manufacture and processing (2D3g NFR)

Methodology

For determination of NMVOC emissions from chemical products, manufacture and processing a Tier 2 method according to the EMEP/EEA Guidebook 2013 is used. Based on the decision tree Fig. 3.1 in chapter 2D3g in EMEP/EEA (2013), for source category 2D3 Chemical products a Tier 2 method using country-specific emission factors is used for calculating the NMVOC emissions (EMIS 2016/2D3).

The emissions from production of fine chemicals and from handling and storage of solvents are based on production indices. The emissions from production of pharmaceuticals, manufacturing of paint, glues, inks and adhesive tape as well as the processing of polyurethane, PVC and rubber are calculated based on production numbers. The emissions from processing of expanded polystyrene foam and polyester are calculated based on their consumption.

Switzerland's Informative Inventory Report 2016 contains a detailed description of the methods and country-specific data used for estimating the NMVOC emissions from 2D3g NFR Chemical products, manufacture and processing (FOEN 2016f).

Emission factors

Emission factors for NMVOC emissions are mainly based on data from Swiss industry associations, documented in the EMIS database (EMIS 2016/2D3). For emission factors see Table 4-30.

Activity data

The activity data are mainly production output or consumption data provided by industry association. Activity data on fine chemicals production and handling and storing of solvents are production indices provided by the Swiss Federal Office of Statistics, (EMIS 2016/2D3). For activity data see Table 4-31.

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 Tier 2 method according to the EMEP/EEA Guidebook 2013 as documented in EMIS 2016/2D3b Strassenbelagsarbeiten.

Emission factors

The emission factor for NMVOC emissions from 2D3b Road paving with asphalt comprises NMVOC emissions from the use of prime coatings and from the bitumen content in asphalt products (about 5%). The NMVOC content in the bitumen has decreased considerably between 1990 and 2010. The values are based on industry data from 1990, 1998, 2007, 2010 and 2013. All other years are interpolated and complemented with expert estimates documented in the EMIS database.

Table 4-32 Emission factors of 2D3b Road paving with asphalt and 2D3c Asphalt roofing for 2014.

	Unit	CO	NMVOC
2D3b Road paving	kg/t asphalt concrete	NA	0.54
2D3c Asphalt roofing	kg/t asphalt sealing sheeting	123	22

Activity data

Activity data on the amount of asphalt products (so-called mixed goods) used for road paving is based on annual data from the association of asphalt production industry (SMI) for 1990 and from 1998 onwards and expert estimates for the years between.

Table 4-33 Activity data for road paving with asphalt, asphalt roofing and urea use in SCR catalysts.

	Unit	1990	1995	2000
2D3b Road paving with asphalt				
Asphalt concrete	kt	5'500	4'800	5'170
2D3c Asphalt roofing				
Asphalt sealing sheeting	kt	50	45	41
2D3d Urea use in SCR catalysts				
AdBlue	kt	0	0	0

	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2D3b Road paving with asphalt											
Asphalt concrete	kt	4'780	5'400	5'100	5'160	5'200	5'250	5'300	4'770	4'770	4'750
2D3c Asphalt roofing											
Asphalt sealing sheeting	kt	30	28	26	26	25	25	25	24	24	24
2D3d Urea use in SCR catalysts											
AdBlue	kt	0	3	6	10	14	17	19	21	23	24

Asphalt roofing (2D3c)

Methodology

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) (see EMIS 2016/2D3c Dachpappen Produktion und Verlegung). According to the EMEP/EEA Guidebook 2013, a Tier 2 method is used.

Emission factors

The emission factors from Asphalt roofing are based on information from the industry association, literature and expert estimates as documented in the EMIS database (see Table 4-32).

Activity data

Activity data is based on data from industry and expert estimates as documented in the EMIS database (see Table 4-33).

Urea use in SCR catalysts of diesel engines (2D3d)

This source category encompasses CO₂ emissions from the use of urea containing AdBlue in diesel engines with SCR-catalysts in road transportation (Euro V/VI).

Methodology

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, chp. 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:

$$\text{CO}_2 \text{ Emissions} = \text{EF} \cdot \text{FC} \cdot \text{Share of SCR vehicles mileage} \cdot \text{Specific urea share}$$

“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 CO₂ emissions from urea use in SCR-catalysts in vehicles is a default value (EMEP/EEA 2013) considering the molecular mass conversion of urea into CO₂ during the reaction with water and the content of 32.5% of the aqueous AdBlue urea solution.

Activity data

Activity data on AdBlue consumption as well as annual mileage are provided by INFRAS (INFRAS 2010) on a yearly basis as documented in EMIS 2016/2D3d Urea (AdBlue) Einsatz Strassenverkehr. For activity data see Table 4-33.

4.5.3 Uncertainties and time-series consistency

The uncertainty of total CO₂ 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 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3 and partly also in chp. 3.2.4.8.

4.5.5 Category-specific recalculations

Recalculations reported in submission 2015

- 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.
- 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: CO₂ emissions are newly reported in the inventory for the entire time series 1990–2013 according to the CRF templates.

Recalculations reported in submission 2016

- 2D2: The AD of 2D2 Paraffin wax use has been revised for 2013 based on corrected data from the Swiss petroleum association.
- 2D3a: The AD and EF of NMVOC of 2D3a Paint applications, household, 2D3a Paint applications, car repair and 2D3a Paint production have been updated for 2013 resulting in revised interpolated values of 2011 and 2012 as well.
- 2D3a: The AD and EF of NMVOC of 2D3a Cleaning of electronic components, 2D3a Degreasing of metal and 2D3a Other industrial cleaning have been updated for 2012 resulting in revised interpolated values for 2008–2011 and 2013 as well.
- 2D3a: The so-called direct emissions of 2D3a Other industrial cleaning have been converted into AD and EF but yielding no recalculations.
- 2D3c: The interpolated AD of 2D3c Asphalt roofing have changed from 2008 onwards due to revised projections.

4.5.6 Category-specific planned improvements

No category-specific improvements are planned.

4.6 Source category 2E – Electronics industry

4.6.1 Source category description

Approach 1 and 2 key category 2E

Source category 2E Electronics industry is not a key category.

Source category 2E Electronics industry comprises HFC, PFC, NF₃ and SF₆ emissions from consumption of the applications listed below in Table 4-34.

Table 4-34 Specification of source category 2E Electronics industry in Switzerland.

2E	Source	Specification
2E1	Integrated circuit or semiconductor	Etching and cleaning processes in the production of IC and semiconductors (similar cleaning services for printed wiring boards included in the evaluation)
2E2	TFT flat panel display	No production of TFT flat panel displays in Switzerland, activities contained in the production of displays for watches
2E3	Photovoltaics	Emissions from photovoltaic manufacturing
2E4	Heat transfer fluids	No application in Switzerland assumed*
2E5	Other	Test activities (for example related to printed wiring boards), research activities

* 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 electronics industry covering different source categories as listed in Table 4-34 (until 2010 import declarations for electronic industry under solvents). Process-specific transformation and emission rates are used. A survey within the electronics industry was carried out for the submission in 2015 to distribute the imported substances to the different source categories of electronic industry.

Methodology

A Tier 2a approach with process gas-specific parameters is used for emission calculations. IPCC default values for gas-specific transformation rate of different processes and general values for exhaust treatment efficiency are applied.

Imports of electronics industry were included in FOEN statistics under solvents until 2010. For the inventory report 2011 (FOEN 2011) interviews were conducted with the industry to get in-depth information on allocation of imported PFC volumes to different applications and to obtain process-specific information from consumers. Until 2010 most PFC imports declared as 2F5 Solvents or 2F6 Other were related to the electronics industry (2E). Since 2011, PFC import declarations have been improved and information is provided for the source category 2E separately. A survey was carried out for the submission in 2015 to determine contributions of different source categories 2E1–2E5 (Table 4-34). 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 according to the 2006 IPCC Guidelines are used for production and waste-air treatment. An exhaust treatment is assumed probable for most applications due to 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 74% (PFC), 59% (SF_6), 189% (NF_3) based on a Monte Carlo simulation (for further details see Carbotech 2016).

Consistency: Time series for 2E Electronics industry are all considered consistent.

4.6.4 Category-specific QA/QC and verification

The entire time series are compared between the current and the previous submissions (evaluations in the first commitment period 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 Category-specific recalculations

Recalculations reported in submission 2015

- 2006 IPCC Guidelines (IPCC 2006) introduce a new categorization for electronic industry, new substances and new model approaches for sub-categories with process gas-specific transmission rates.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

4.6.6 Category-specific planned improvements

No category-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 4-35.

Table 4-35 Specification of source category 2F Product uses as substitutes for ozone depleting substances in Switzerland.

2F	Source	Specification
2F1	Refrigeration and air conditioning	Emissions from refrigeration and air conditioning (incl. heat pumps and tumble dryers)
2F2	Foam blowing agents	Emissions from foam blowing, incl. polyurethane spray
2F4	Aerosols	Emissions from use as aerosols, incl. metered dose inhalers
2F5	Solvents	Emissions from use as solvents

The following graph shows HFC and PFC emissions from different applications in source category 2F. 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. Further, emissions are dominated by HFCs and only a very minor contribution comes from PFCs.

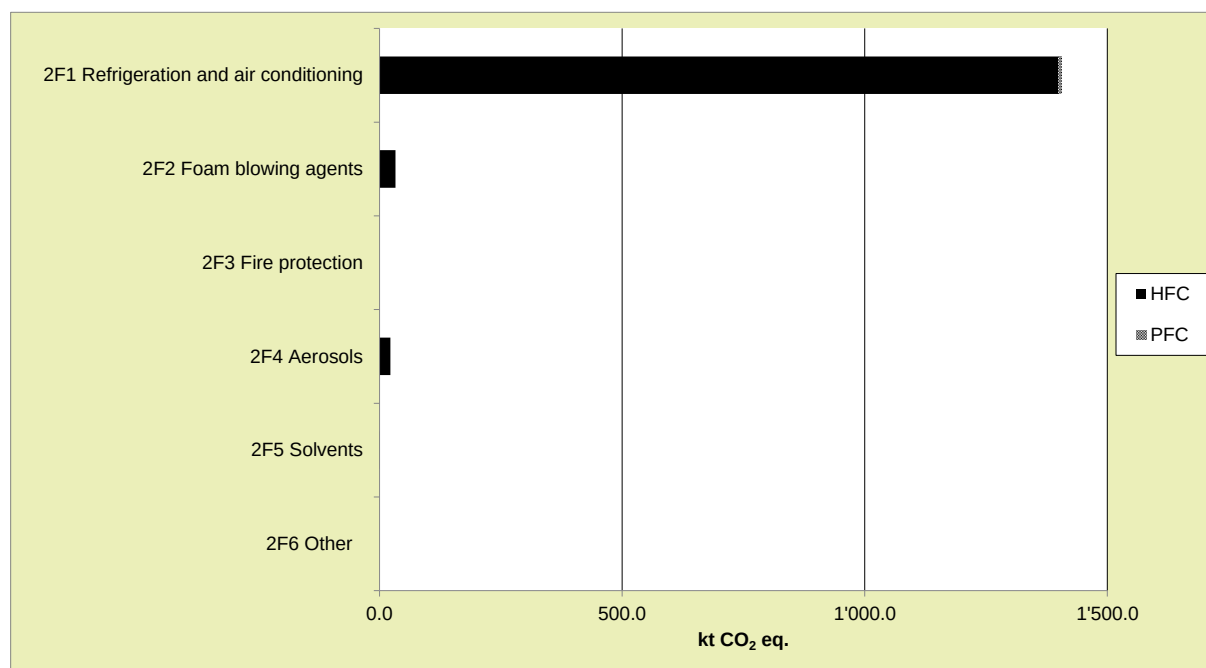


Figure 4-6 Distribution of emissions under source category 2F Product uses as substitutes for ozone depleting substances (2014). HFC and PFC have been used short-term only as substitutes for ozone depleting substances except for refrigeration and air conditioning. Most relevant today are emissions from the built up refrigerant stock in equipment (mainly HFCs, small amount of PFCs used in refrigerant blends).

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 4-36). Detailed documentation of the individual data and 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 source category 2F1 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 the 2006 IPCC Guidelines Tier 2a approach (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. In a first step the refrigerant need for the production and maintenance of equipment is calculated for most applications based on the bottom up calculations of stock (example of mobile air conditioning in Annex A3.2). The reported import amount of bulk refrigerant is split in a second step top down to different applications based on the results of the bottom up approach and considering the surplus of imported refrigerant for the production and maintenance of industrial and commercial refrigeration equipment.

The import data as reported to FOEN are 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.

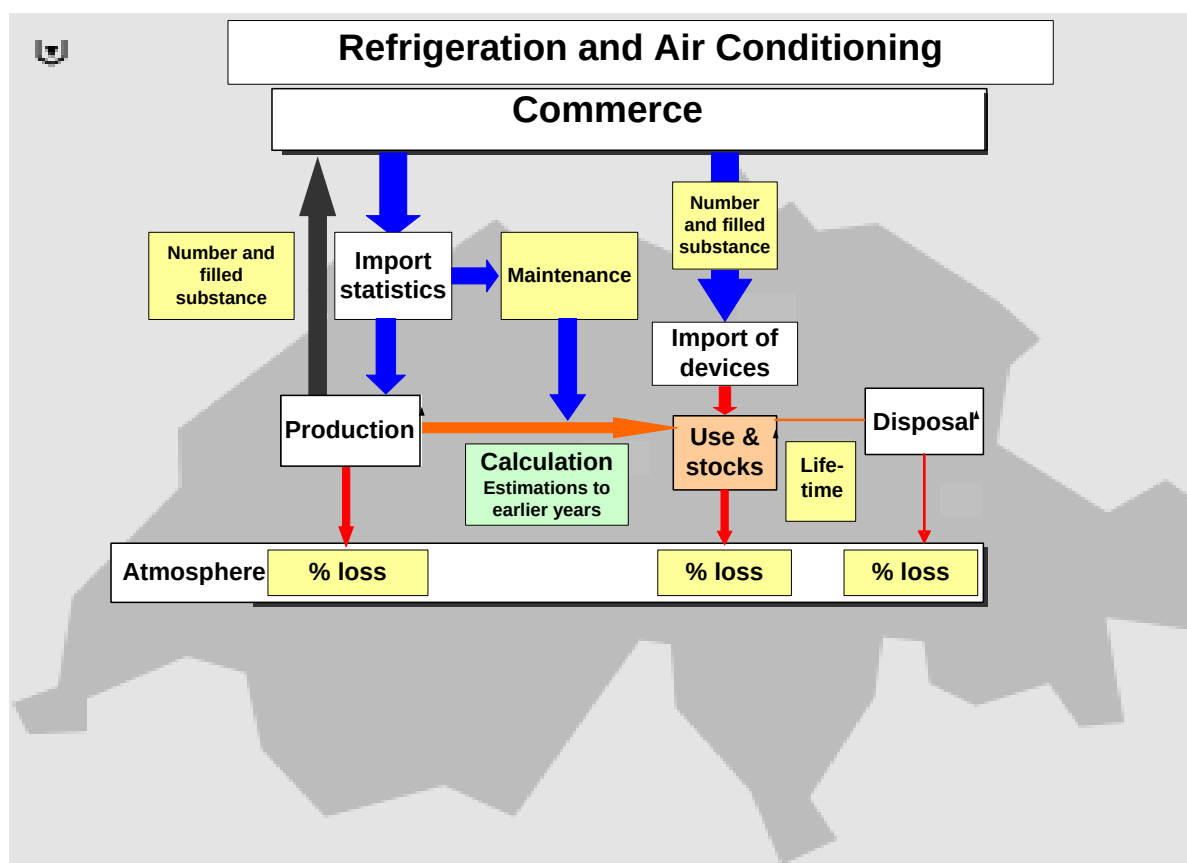


Figure 4-7 Required data for the model to calculate emissions from refrigeration and air conditioning in Switzerland.

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 for internal use (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 the revised Chemical Risk Reduction Ordinance (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. This data source provides valuable information and has been used to improve the estimates used for modelling emissions under source category 2F. However, it did not allow to directly draw the stock data or emission factors for the national inventory. With the versions of the revised Chemical Risk Reduction Ordinance introduced in 2013 and 2015 the obligatory registration of HFC containing equipment was replaced with a ban on HFC for specific equipment type and capacity. CO₂ compensation programmes have been introduced on the other hand with a focus on the early replacement of HFC in installed equipment.

Table 4-36 displays the detailed model parameters used for the present submission. Changes of model parameters within the period 1990 to 2014 are indicated with values in brackets. The parameters in brackets are applied for the inventory 2014. For product life emission factors of some equipment types a dynamic model is applied, which implies that emission decrease linearly between 1995 and 2014 due to improved 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 4-36 Typical values of lifetime, charge and emission factors used in model calculations 1990 to 2014 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 charge of 4.7–7.5 kg was applied for heat pumps until 2000 and a lower charge of 2.8–4.5 kg from 2000 onwards. A linear interpolation is applied for the product life emission factor of commercial and industrial refrigeration, stationary air conditioning and for the emission factor of mobile air conditioning between the starting year and 2014.

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 (2014:3)	19 ****)
Commercial and industrial refrigeration	10	NR	0.5	Sinking from 12 in 1990 to 6.7 in 2014	78-90	NA	19
Transport refrigeration: trucks/vans	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 (2005: 1)	Sinking from 10 in 1995 to 4 in 2010	74-89	NA	28
Stationary air conditioning: indirect cooling systems	15	NR	1	Sinking from 6 in 1995 to 4 in 2010	85-89	NA	19
Stationary air conditioning: heat pumps	15	4.7-7.5 (2000: 2.8-4.5)	3 (2005: 1)	2	86	NA	19
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 2014	NO	8.5	58	31-72 (2014: 44)	50
Mobile air conditioning: truck/van cabins	12	1.1	NO	10 (2010: 8.5)	69-73	90 trucks (50 vans)	50
Mobile air conditioning: buses	12	7.5	NO	20 (2001: 15)	100	50	50
Mobile air conditioning: trains	16	20	NO	5.5	100	NA	20

*) Calculated value taking into account annual loss and portion refilled over the whole product life where applicable.

**) allocation of disposal losses to export country

***) Calculated value taking into account share of total refrigerant loss and emission factor of professional disposal. 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). 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 HFC-134a 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 source category 2F1, no table on time

series of activity data is provided here. 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 (CO₂ eq) of 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 by other factors as e.g. 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 source category 2F2.

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 default values according to the 2006 IPCC Guidelines (IPCC 2006, Volume 3, p. 7.37) are used. For PU spray, expert estimates and specific default values according to the 2006 IPCC Guidelines (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 4-37 Typical values on lifetime, charge and emission factors used in model calculations for foam blowing

Product	Product lifetime	Charge of new product	Manufacturing emission factor	Product life emission factor	Charge at end of life
Foam type	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	50	6.5	NR	NR / 0.7**	
XPS foam HFC-152a				100 / 0**	
PU spray all HFC	50	13.6 / 0 *	<1%	95 / 2.5 **	
Unknown use:					
HFC 134a, HFC 227ea, HFC 365 mfc	20	NR	10	10 / 4.5 **	
HFC 152a			100	100 / 0 **	

* The first value represents the charge of HFC 1995 (start of HFC use as substitutes for ozone depleting substances). The HFC amount was reduced continuously between 1995 and 2008. Since 2009 the production of PU spray is HFC free in Switzerland.

** 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 was about 96.5% of total production volume in the time period of HFC use. 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 CO₂). 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 source category are available at FOEN, but not reported due to confidentiality.

4.7.2.3 Fire protection (2F3)

No emissions occur in source category 2F3 within Switzerland. The application of HFCs, PFCs and SF₆ 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 the 2006 IPCC Guidelines.

Activity data

In most aerosol applications, HFCs have 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 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 a 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 are 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 both the first and the second year 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 HFC and PFC 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 reduced by 0.5%. The reduction 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 2016). 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 4-38 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 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 1997–2014 led to the estimations given in Table 4-38.

Table 4-38 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 – 2014	-10%	10%	Data can be incomplete or possible double declaration

Table 4-39 summarises the results for the application-specific emission models. The “value 2014” represents the reported emissions in kt CO₂ equivalent for the specific application for the year 2014. The average, median, uncertainty, minimum and maximum values are output values of the Monte Carlo analysis. The uncertainty of the resulting total emissions from source category 2F Product uses as substitutes for ODS is about 15%. Higher values result for the contributions of single applications.

Uncertainties of more than 20% have been calculated for the following applications:

- Stationary air conditioning
- Commercial and industrial refrigeration
- Domestic refrigeration
- Foam blowing
- Aerosols
- Solvents

Uncertainties of 15% to 20% have been calculated for the following applications:

- Mobile air conditioning
- 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 in Carbotech (2015). For stocks maximum uncertainties of 30–40% result for HFC-32 and HFC-134a 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 4-39 Summary of results for model parameter “emissions” from Monte Carlo analysis for 2014 data on selected emission sources.

Application	Model parameter	Value 2014 kt CO ₂ eq.	Average kt CO ₂ eq.	Median kt CO ₂ eq.	min. kt CO ₂ eq.	max. kt CO ₂ eq.	Uncertainty %
2F1 Refrigeration and air conditioning	Emissions in kt CO ₂ eq.	1'404	1'460	1'453	1'179	1'822	15
- Commercial / Industrial refrigeration		742	778	774	553	1'119	27
- Mobile air conditioning		426	425	426	295	592	14
- Stationary air conditioning		201	219	219	148	291	22
- Transport refrigeration		29.2	31.9	31.8	25.1	43.5	18
- Domestic refrigeration		5.3	6.2	4.8	0.1	26.0	*)
2F2 Foam blowing agents		32.9	37.0	36.6	28.3	151.7	35
2F4 Aerosols		22.4	22.7	22.7	8.7	35.6	41
2F5 Solvents		0.7	0.7	0.8	0.1	1.3	57
Total 2F Product use as substitutes for ODS		1'460	1'521	1'515	1'162	1'938	15

*) very asymmetric distribution, therefore standard deviation not indicated.

Consistency: Time series for 2F are all considered consistent.

4.7.4 Category-specific QA/QC and verification

The entire time series are compared between the current and the previous submission.

Recalculations were identified and explained. All modelling results produced by Carbotech (2015) have been checked in detail by FOEN specialists.

The assumptions of decreasing emission factors for the different equipment types under 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 Chemical Risk Reduction Ordinance (Swiss Confederation 2005) is in place that ensures the proper handling and disposal of halocarbons and SF₆. 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. Estimated emissions based on measurements at Jungfraujoch agree fairly well with the emission estimates HFC-134a, HFC-125, HFC-143 and HFC-32 of the Swiss greenhouse gas inventory. Larger differences result for less relevant contributions of HFC-152a. The allocations of first year emissions of foam blowing agents to the country of production might be the reason for the gap.

4.7.5 Category-specific recalculations

Recalculations reported in submission 2016

- 2F1 Refrigeration and air conditioning: Optimizations of model calculations including number of vehicles in the model of mobile air conditioning of van, extrapolation of emission factor for stationary air conditioning equipment, changes of refrigerant blend applied in transport refrigeration of trains.
- 2F5 Solvents: Revision of import amounts (correction of import declarations of a specific import company).

Recalculations reported in submission 2015

- A new categorization was introduced with the 2006 IPCC Guidelines for fluorinated substances. The former source category 2F Consumption of HFC, PFC and SF₆ of the first commitment period 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 4-40 for the remaining applications in the new category 2F Product uses as substitutes for ODS. The different improvements carried out are related to the source categories with the highest emissions (in 2F1).
- A direct comparison of results in source category 2F with results from the first commitment period is not possible due to the new categorization. The recalculation of

the emissions 2012 lead to 19% higher emissions in the former source category 2F consumption of HFC, PFC and SF₆ than reported in the last submission of the first commitment period (278 kt CO₂ 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 4-40 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 ₃ F 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 conditioning (1991 to 1996)
2F1	Refrigeration and air conditioning	AD	2004-2012	HFC-245fa, HFC-235fa, CF ₄	New model calculations 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 ₃ F ₈ , C ₄ F ₈ , C ₄ F ₁₀ , C ₆ F ₁₄	Shift of substances to other applications. HFC-134a and HFC-245fa to 2F4 Aerosols (IPCC 2006: aerosol solvents included under aerosols), shift of PFCs to 2E Electronics industry and 2G2 Other PFC and SF ₆ use

4.7.6 Category-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, changes are expected in this area due to the revision of the Chemical Risk Reduction Ordinance and CO₂ compensation programmes (share of products with HFC, recycling of HFC, early replacement of HFC).

4.8 Source category 2G – Other product manufacture and use

4.8.1 Source category description

Approach 1 key category 2G

SF₆ emissions from Other product manufacture and use (level and trend).

Approach 2 key category 2G

SF₆ emissions from Other product manufacture and use (trend).

N₂O emissions from Other product manufacture and use (trend).

Table 4-41 Specification of source category 2G Other product manufacture and use in Switzerland.

2G	Source	Specification
2G1	Electrical equipment	Emissions of SF ₆ from use in electrical equipment
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)
2G3	N ₂ O from product uses	Emissions of N ₂ O from the use of N ₂ O in hospitals; Emissions of N ₂ O from the use of aerosol cans
2G4	Other	Emissions of NMVOC from domestic solvent use, printing, other solvent and product use as well as emissions of CO ₂ resulting from post-combustion of NMVOC in exhaust gases of these sources Emissions of CO ₂ , CO, NO _x , CO and SO from use of fireworks; Emissions of HFC not accounted in other source categories

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 SF₆ on basis of a mass-balance approach (Tier 3a). The mass balance includes mainly data for the production, installation, operation and disposal of electrical equipment, but included in past years also small amounts of SF₆ for other applications (i.e. research, magnesium foundry). SWISSMEM is collecting data from its members and is cross-checking the reported SF₆ consumption data with data from importers of SF₆. Installations in operation with electrical equipment containing SF₆ are periodically inspected for leakage, and losses are refilled (topping up). The refilled quantities and any SF₆ charge required during repair are reported as emissions at the time of filling. A product lifetime of 35 years is assumed.

Emission factors

Emission factors for source category 2G1 are based on industry information and are calculated values based on the mass-balance data. The discontinuity in emission factor from 2005 to 2006 data is due to the inspection intervals, optimised data collection 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 SF₆ emissions.

Activity data

Activity data are based on industry information. The wide annual fluctuation of SF₆ 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 SF₆ charge in the equipment. Import declarations obtained for FOEN import statistics are cross-checked regularly in order to eliminate double counting between SWISSMEM data and other import declarations.

4.8.2.2 SF₆ and PFCs from other product use (2G2)

Methodology

The emissions reported under 2G2 are related to the use of SF₆ for industrial particle accelerators (2G2b), the use of SF₆ for soundproof windows (2G2c) and other PFC and SF₆ use (2G2e). 2G2e summarizes research/analytics and further applications (including the unallocated difference in SF₆ emissions based on the FOEN import statistics and the SWISSMEM mass balance).

Under an agreement with FOEN, the industry association SWISSMEM is reporting actual emissions of SF₆ 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 is applied. Therefore, the unallocated amount of SF₆ 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 confidentiality. Data are available from FOEN (confidential report Carbotech, 2015).

Emission factors

For the unallocated amount of SF₆ assigned to cables and electrical control systems, the emission factor is assumed to be 4% for manufacturing and 1% per year during the product life. 100% of the remaining charge is emitted at the time of disposal after a lifetime of 40 years. Because of the long lifetime, the disposal emissions are not relevant for the 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 SF₆ 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 SF₆ assigned to cables and electrical control systems an export rate of 80% is assumed similar to electrical equipment 2G1. Also for the inventory report 2013 (FOEN 2015), 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 source category 2G2e Other.

4.8.2.3 N₂O from product uses (2G3)

Methodology

Emissions of N₂O 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 Tier 2 method based on the production/consumption of N₂O is used (IPCC 2006 (vol. 3 chp. 8.4)).

Emission factors

For source category 2G3a Medical applications the emission factor is calculated based on the amount of N₂O sold in Switzerland divided by the number of inhabitants. The yearly amount of N₂O sold for anaesthesia purpose is derived from sales data from the companies concerned based on annual data from 2005 onwards (EMIS 2016/2G3a Lachgasanwendung Spitäler).

Source category 2G3b Other includes N₂O emissions from whipped-cream makers using gas capsules for private households and restaurants. The emission factor is calculated based on sales data and N₂O content of gas capsules sold in Switzerland divided by the number of inhabitants (EMIS 2016/2G3b Lachgasanwendung Haushalt).

Table 4-42 N₂O emission factors for the source categories 2G3a Medical applications and 2G3b Other in 2014.

2G3a Use of N ₂ O for anaesthesia	Unit	1990	1995	2000
N ₂ O	g/inhabitant	43	29.8	16.6
2G3b N ₂ O from aerosol cans				
N ₂ O	g/inhabitant	9.3	9.6	9.8

2G3a Use of N ₂ O for anaesthesia	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
N ₂ O	g/inhabitant	12.0	10.0	9.0	8.0	7.0	7.0	6.0	5.8	5.6	5.3
2G3b N ₂ O from aerosol cans											
N ₂ O	g/inhabitant	10.5	10.8	11.0	11.3	11.5	11.8	12.0	12.2	12.4	12.7

Activity data

For the source categories 2G3a Medical applications and 2G3b Other the activity data correspond to the Swiss population (SFSO 2015a) (EMIS 2016/2G3a Lachgasanwendung Spitäler and EMIS 2016/2G3b Lachgasanwendung Haushalt).

Table 4-43 Activity data for the source categories 2G3a Use of N₂O for anaesthesia and 2G3b N₂O from aerosol cans.

2G3 N ₂ O from product uses	Unit	1990	1995	2000
2G3a, 2G3b	inhabitants	6'796'000	7'081'000	7'209'000

2G3 N ₂ O from product uses	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2G3a, 2G3b	inhabitants	7'501'000	7'558'000	7'619'000	7'711'000	7'801'000	7'878'000	7'912'000	7'997'000	8'089'000	8'189'000

4.8.2.4 Other (2G4)

Since the 2006 IPCC Guidelines (vol. 3, chp. 5.5) refer to the EMEP/EEA Guidebook 2013 regarding methodologies for estimating NMVOC emissions from solvent use, the respective NFR codes are indicated as reference as well. 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 CO₂, NO_x, CO and SO₂ 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. These CO₂ emissions from post-combustion of NMVOC are estimated based on industry data and expert estimates (Carbotech 2014a).

Switzerland's Informative Inventory Report 2016 contains a detailed description of the methods and country-specific data used for estimating the NMVOC emissions from the most important sources within source category 2G4 Other (FOEN 2016f).

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 by a Tier 2 method according to the EMEP/EEA Guidebook 2013 using the Swiss population as activity data. 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

In a study conducted in 2013/2014 in Switzerland more accurate data of household cleaning agents, personal hygiene products and domestic spray cans was collected (Hubschmid 2014). As a result of the study the emission factor of spray cans was adjusted in 2013.

From 2001 until 2010 a constant EF is assumed for domestic use of cleaning agents. The value is based both on information from the Swiss association of cosmetics and detergents (SKW 2010) and from a German study on NMVOC emissions from solvent use and

abatement possibilities by Theloke (2005). There were no significant improvements in the solvent compositions of the employed detergents. The study by Hubschmid (2014) indicates again an increase in NMVOC emission factors in 2013. Emission factors of domestic use of pharmaceutical products are available from the Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries) and from literature, as documented in the EMIS database.

Table 4-44 Emission factors for NMVOC for source category 2G4 Other: domestic solvent use, printing, other solvent use, other product use in 2014.

2G4 Other	Unit	NMVOC
Domestic solvent use (2D3a NFR)		
Domestic use of spray cans	g/inhabitant	324
Domestic use of pharmaceuticals	g/inhabitant	30
Household cleaning agents	g/inhabitant	994
Printing (2D3h NFR)		
Printing	kg/t ink	280
Package printing	kg/t ink	186
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	731
Commercial & industrial use of cleaning agents	g/employee	464
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	284
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

As described in the methodology chapter, the activity data used for calculating the NMVOC emissions from domestic solvent use corresponds to the Swiss population (SFSO 2015a), see Table 4-45.

Table 4-45 Activity data for source category 2G4 domestic solvent use, printing, other solvent use, other product use.

2G4 Other	Unit	1990	1995	2000
Domestic solvent use (2D3a NFR)	inhabitants	6'796'000	7'081'000	7'209'000
Printing (2D3h NFR)				
Printing	t ink	12'600	13'350	13'900
Package printing	t ink	5'900	5'900	5'467
Other solvent use (2D3i NFR)				
Fat, edible & non-edible oil extraction	t	40'000	37'500	12'000
Production of cosmetics	employees	2'200	2'200	2'267
Production of paper and paperboard	t	1'510'000	1'560'000	1'780'000
Production of perfume and flavour	employees	2'200	2'325	2'567
Production of textiles	employees	25'200	26'763	24'300
Production of tobacco	employees	3'300	2'988	2'729
Removal of paint and lacquer	inhabitants	6'796'000	7'081'000	7'209'000
Scientific laboratories	employees	10'194	18'604	23'217
Vehicles dewaxing	vehicles	200'000	166'250	72'667
Other product use (2G NFR)				
Application of glues and adhesives	t	4'000	3'000	2'000
Commercial & industrial use of cleaning agents	employees	3'950'000	3'867'500	3'954'667
Cosmetic institutions	employees	2'600	3'100	3'533
De-icing of airplanes	t	1'300	1'300	1'300
Fireworks	t	840	1'030	1'520
Glass wool enduction	t	24'278	24'191	31'052
Hairdressers	employees	20'553	22'826	23'530
Health care, other	employees	113'000	129'250	145'667
Medical practices	employees	27'625	42'047	50'833
Preservation of wood	t paint	6'000	7'875	8'667
Rock wool enduction	t	38'375	39'745	50'567
Underseal treatment & conservation of vehicles	t	60	60	76
Use of concrete additives	t	24'000	25'250	28'667
Use of cooling lubricants	t	5'000	5'188	5'833
Use of lubricants	t	1'300	1'269	1'250
Use of pesticides	t	2'400	1'950	1'700
Use of tobacco	Mio cigarette eq.	16'192	15'774	14'751

2G4 Other	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Domestic solvent use (2D3a NFR)	inhabitants	7'501'000	7'558'000	7'619'000	7'711'000	7'801'000	7'878'000	7'912'000	7'997'000	8'089'000	8'189'000
Printing (2D3h NFR)											
Printing	t ink	5'467	4'033	2'600	2'533	2'467	2'400	2'217	2'033	1'850	1'943
Package printing	t ink	9'133	10'867	12'600	12'600	12'600	12'600	12'783	12'967	13'150	13'171
Other solvent use (2D3i NFR)											
Fat, edible & non-edible oil extraction	t	0	0	0	0	0	0	0	0	0	0
Production of cosmetics	employees	2'100	2'100	2'100	2'100	2'100	2'100	2'100	2'100	2'100	2'100
Production of paper and paperboard	t	1'750'000	1'690'000	1'734'000	1'700'000	1'540'000	1'540'000	1'380'000	1'391'111	1'402'222	1'413'333
Production of perfume and flavour	employees	3'200	3'300	3'400	3'425	3'450	3'475	3'500	3'521	3'542	3'563
Production of textiles	employees	17'067	16'733	16'400	16'200	14'200	13'800	14'800	14'789	14'778	14'767
Production of tobacco	employees	2'710	2'705	2'700	2'825	2'950	3'075	3'200	3'200	3'200	3'200
Removal of paint and lacquer	inhabitants	7'501'000	7'558'000	7'619'000	7'711'000	7'801'000	7'878'000	7'912'000	7'997'000	8'089'000	8'189'000
Scientific laboratories	employees	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'083	23'167	23'250
Vehicles dewaxing	vehicles	0	0	0	0	0	0	0	0	0	0
Other product use (2G NFR)											
Application of glues and adhesives	t	1'500	1'400	1'300	1'225	1'150	1'075	1'000	1'900	1'000	991
Commercial & industrial use of cleaning agents	employees	4'133'667	4'208'333	4'283'000	4'323'333	4'363'667	4'404'000	4'333'333	4'262'667	4'192'000	4'236'000
Cosmetic institutions	employees	3'800	4'000	4'200	4'400	4'600	4'800	5'000	5'111	5'222	5'333
De-icing of airplanes	t	2'533	2'117	1'700	2'380	3'060	3'740	4'420	5'100	5'100	5'100
Fireworks	t	1'358	1'546	1'746	1'951	1'990	1'685	2'017	1'928	2'327	1'807
Glass wool enduction	t	37'483	38'060	44'487	44'364	33'467	35'698	41'414	38'747	33'350	32'262
Hairdressers	employees	22'200	22'200	22'200	23'000	23'000	23'000	23'000	23'000	23'000	23'000
Health care, other	employees	161'667	163'333	165'000	163'000	163'000	163'000	163'000	163'000	163'000	163'000
Medical practices	employees	55'357	56'471	57'586	58'700	58'700	58'700	58'700	58'700	58'700	58'700
Preservation of wood	t paint	7'167	7'033	6'900	6'083	5'267	4'450	3'633	2'817	2'000	2'009
Rock wool enduction	t	46'270	52'559	62'756	57'761	52'966	56'376	57'413	56'959	54'094	53'455
Underseal treatment & conservation of vehicles	t	118	126	134	142	150	159	167	175	175	175
Use of concrete additives	t	36'000	35'000	34'000	34'000	34'000	41'000	44'000	38'000	37'875	37'750
Use of cooling lubricants	t	6'375	5'650	4'925	4'200	2'800	3'600	4'000	3'700	3'700	3'700
Use of lubricants	t	3'700	2'600	1'500	400	290	350	490	370	370	370
Use of pesticides	t	1'520	1'510	1'500	1'675	1'850	2'025	2'200	2'200	2'200	2'200
Use of tobacco	Mio cigarette eq.	13'369	13'808	13'072	13'310	13'667	12'443	11'856	12'705	12'162	10'628

Printing (2D3h NFR)

Methodology

The source category 2G4 Printing (2D3h NFR) has been split into 2G4 Printing and 2G4 Package printing. A Tier 2 method according to the EMEP/EEA Guidebook 2013 is applied for calculating the NMVOC emissions from ink applications.

Emission factors

Emission factors for NMVOC are country-specific based on data from industry associations, VOC balances in printing industry, studies on NMVOC emissions from solvent use (Theloke 2005) and expert estimates, as documented in the EMIS database (EMIS 2016/2G4). For emission factors of 2014 see Table 4-44.

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, VOC balances in printing industry and expert estimates, documented in the EMIS database (EMIS 2016/2G4). For activity data see Table 4-45.

Other solvent use (2D3i NFR)

Methodology

Source category 2G4 Other solvent use (NFR 2D3i) consists of a number of solvent uses in various production processes and services. Based on the decision tree Fig. 3.1 in chapter 2D3i in EMEP/EEA (2013), a Tier 2 method based on information from industry and services, industry associations, German studies on NMVOC emissions from solvent use (Theloke et al. 2000, Theloke 2005) and expert estimates are used for calculating the emissions from the different solvent applications (EMIS 2016/2G4). Country-specific emission factors are applied.

For the majority of production processes and services – such as production of perfume and flavour and production of textiles – the NMVOC emissions are estimated based on the respective number of employees. The quantity of NMVOC emission per employee originates from the bottom-up method 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 a few production processes – such as production of paper and paperboard – the NMVOC emissions are calculated on the basis of production volumes. For the source category 2G4 Other solvent use (NFR 2D3i) Not attributable solvent emissions so-called direct emission data is available only.

Emission factors

Emission factors for NMVOC are country-specific based on data from industry and services, industry associations, studies on NMVOC emissions from solvent use (Theloke et al. 2000 and Theloke 2005) and expert estimates, as documented in the EMIS database (EMIS 2014/2G4). For emission factors see Table 4-44.

Activity data

The activity data used for calculating the NMVOC emissions correspond to the annual production volumes, which stem from industry, services, industry associations and expert estimates, as documented in the EMIS database (EMIS 2016/2G4), as well as the number of employees (SFSO 2015e) and the Swiss population (SFSO 2015a). For activity data see Table 4-45.

Other product use (2G NFR)

Methodology

Within source category 2G Other product use, the major NMVOC emission sources in 2014 are 2G Commercial and industrial use of cleaning agents, 2G De-icing of airplanes and 2G Health care, other.

Based on the decision tree Fig. 3.1 in chapter 2G in EMEP/EEA (2013), for source category 2G Other product use Tier 2 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 (EMIS 2016/2G). Country-specific emission factors are applied.

For one part of the production processes – such as 2G Enduction of glass and rock wool – and applications – such as 2G Preservation of wood and 2G Application of glues and adhesives – the NMVOC emissions are calculated on the basis of production volume or employed agents. For the other part – such as 2G House cleaning in services, commerce and industry and 2G Medical practices – the NMVOC emissions are estimated based on the respective number of employees. The quantity of NMVOC emission per employee originates from the bottom-up method 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 2G Gas applications, 2G Renovation of corrosion inhibiting coatings and 2G Use of aerosol cans in commerce and industry so-called direct emission data is available only.

Indirect CO₂ emissions from CO and NMVOC emissions from tobacco use are of biogenic origin and are therefore not reported in chp. 9 Indirect CO₂ and N₂O emissions.

Emission factors

Emission factors for NMVOC are based on data from industry and services, industry associations, German studies on NMVOC emissions from solvent use (Theloke et al. 2000 and Theloke 2005) and expert estimates, as documented in the EMIS database (EMIS 2016/2G4). For emission factors see Table 4-44.

Emission factors of CO₂, NO_x, CO and SO₂ from 2G Use of fireworks and tobacco (EMIS 2016/2G) are displayed in the following table. Emission factors of fireworks are documented in FOEN (2014p).

Table 4-46 Emission factors for CO₂, NO_x, CO, SO₂ for source category 2G4 Fireworks in 2014

2G4 Other	Unit	CO ₂	NO _x	CO	SO ₂
Other product use (2G NFR)					
Fireworks	kg/t	43	0.26	7.4	4.1
Use of tobacco	kg/Mio cigarette eq.	1'000	NA	80	NA

Activity data

As described in the methodology section, the activity data used for calculating the NMVOC emissions correspond to the annual production volumes, solvents and products used, number of employees and the Swiss population. These data stem from industry, services, industry associations, Swiss federal statistical office and expert estimates and are documented in the EMIS database. Activity data for annual tobacco consumption are provided by the Swiss addiction prevention foundation ("Sucht Schweiz"). Data on annual firework sales are provided in the statistics of the Swiss federal office for police (FEDPOL 2015), as documented in the EMIS database (EMIS 2016/2G4). For activity data see Table 4-45.

HFC not accounted in other source categories

Emissions of HFC not accounted for in any other source categories are reported 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 is applied for HFCs with prompt emissive applications based on import statistics and industry data.

Emission factors

Prompt emissions of HFC are calculated following the 2006 IPCC Guidelines assuming a total loss of product within two years (50% loss in the the first and 50% in the second year).

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 CO₂ emissions from the entire source category 2G is estimated at 50% (expert estimate).

The uncertainty of N₂O 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 SF₆, HFC and PFC emissions in source category 2G is estimated at 21%, 10% and 9% respectively based on a Monte Carlo analysis (for further details see previous simulation by Carbotech 2015). Source category 2G is a key category for SF₆ regarding level according to Approach 1 and regarding trend according to Approach 1 and 2.

Time series is consistent, with exception of the source category 2G2 Electrical equipment 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 2G2 Electrical equipment retroactively.

4.8.4 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

4.8.5 Category-specific recalculations

Recalculations reported in submission 2015

- Interviews with industry were carried out to improve model calculations of HFC, PFC and SF₆ emissions under 2G2e and 2G4 (no details are given for confidentiality reason). New GWP values were applied for PFC, HFC and SF₆ 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 2015).

- 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.

Recalculations reported in submission 2016

- 2G4: The AD and EF of NMVOC of 2G4 Preservation of wood have been updated for 2013 resulting in revised interpolated values for 2008–2012 and 2011–2012, respectively, as well.
- 2G4: The AD of 2G4 Application of glues and adhesives consisted of two solvent types so far. This differentiation has been revised for this submission yielding small recalculations due to rounding in AD and EF of NMVOC for the entire time series.
- 2G4: Tobacco consumption for 2013 has been slightly increased in the statistics provided by "Suchtschweiz".
- 2G4: An EF for CO has been introduced for 2G4 Tobacco consumption.
- 2G4: The EF of NMVOC of 2G4 Household cleaning agents has been corrected for 2013 due to a mistake in last year's submission resulting in revised interpolated EF of 2011 and 2012 as well.

4.8.6 Category-specific planned improvements

No category-specific improvements are planned.

4.9 Source category 2H – Other

4.9.1 Source category description

Approach 1 and 2 key category 2H

Source category 2H Other is not a key category.

Table 4-47 Specification of source category 2H Other in Switzerland.

2H	Source	Specification
2H1	Pulp and paper	Emissions from NMVOC from pulp and paper including chipboard, fibreboard and cellulose production (ceased in 2008)
2H2	Food and beverages industry	Emissions of CO and NMVOC from production of food and drink
2H3	Other	Emissions of CO ₂ , NO _x , CO, NMVOC and SO ₂ from blasting and shooting; Emissions of SO ₂ from Claus units in refineries

4.9.2 Methodological Issues

4.9.2.1 Pulp and paper (2H1)

Methodology

In 2014, 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 methods are applied.

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 2016/2H1. The implied emission factor given in Table 4-48 is production-weighted and related to chipboard and fibreboard production.

Table 4-48 Emission factors for CO and NMVOC in pulp and paper production and food and beverages industry, CO₂, NO_x, CO, NMVOC and SO₂ from blasting and shooting and SO₂ from Claus units in refineries for 2014.

2H Other	Unit	CO ₂	NO _x	CO	NMVOC	SO ₂
2H1 Pulp and paper	g/t	NA	NA	NA	560	NA
2H2 Food and beverage industry (exc. beer, wine, spirits)	g/t	NA	NA	250	3'510	NA
2H2 Food and beverage industry (beer, wine, spirits)	g/m ³	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 2016/2H1.

Table 4-49 Pulp and paper production, food and beverages production, amount of used explosives and processed crude oil in Switzerland.

2H Other	Unit	1990	1995	2000
2H1 Pulp and paper	kt	604	593	641
2H2 Food and beverage industry (exc. beer, wine, spirits)	kt	2'254	2'116	2'301
2H2 Food and beverage industry (beer, wine, spirits)	m3	560'972	516'519	492'208
2H3 Blasting and shooting; blasting agent and powder	kt	2.6	1.3	1.9
2H3 Claus units in refineries; Crude oil	kt	3'127	4'657	4'649

2H Other	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2H1 Pulp and paper	kt	660	696	752	728	514	570	534	502	482	488
2H2 Food and beverage industry (exc. beer, wine, spirits)	kt	2'138	2'167	2'344	2'428	2'437	2'400	2'483	2'418	2'388	2'382
2H2 Food and beverage industry (beer, wine, spirits)	m3	452'877	451'924	462'141	479'293	465'753	467'699	462'446	454'903	449'070	446'567
2H3 Blasting and shooting; blasting agent and powder	kt	0.8	1.5	1.1	1.4	2.1	2.4	2.9	2.3	2.2	2.1
2H3 Claus units in refineries; Crude oil	kt	4'877	5'563	4'720	5'133	4'833	4'546	4'452	3'455	4'935	4'975

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.

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 as documented in the EMIS database (EMIS 2016/2H2). The implied emission factors are production-weighted (Table 4-48).

Indirect CO₂ emissions from CO and NMVOC emissions from food and beverages industry are of biogenic origin and are therefore not reported in chp. 9 Indirect CO₂ and N₂O emissions.

Activity data

The annual amount of food and beverages produced in Switzerland is based on data from industry and the farmers' association (SBV) and expert estimates as documented in EMIS 2016/2H2 (Table 4-49).

4.9.2.3 Other (2H3)

Blasting and shooting and Claus units in refineries (2H3).

Methodology

For determination of emissions of CO₂, NO_x, CO, NMVOC and SO₂ from blasting and shooting, a country-specific method is used as documented in the EMIS database (EMIS 2016/2H3 Sprengen und Schiessen).

Emission factors

The emission factors for CO₂, NO_x, CO, NMVOC and SO₂ from blasting and shooting activities in Switzerland and for SO₂ emissions from Claus units in refineries are country-specific and based on measurements and data from industry and expert estimates (see Table 4-48).

Activity data

The annual amount of used explosives and of processed crude oil in Claus units is based on the Federal statistics on explosives (FEDPOL 2015) and the Swiss overall energy statistics (SFOE 2015), respectively (Table 4-49).

4.9.3 Uncertainties and time-series consistency

The uncertainty for CO₂ 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 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

4.9.5 Category-specific recalculations

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

4.9.6 Category-specific planned improvements

No category-specific improvements are planned.

5 Agriculture

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

5.1 Overview

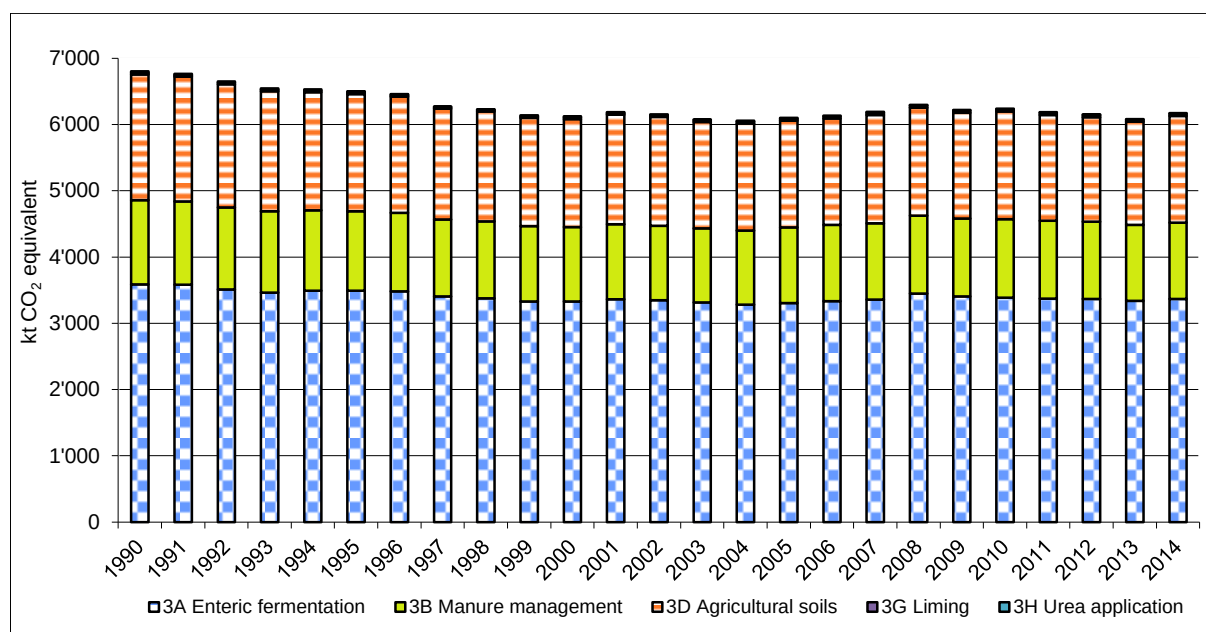
This chapter provides information on the estimation of the greenhouse gas emissions from the sector Agriculture. The following source categories are reported:

- 3A Enteric fermentation, CH₄ emissions from domestic livestock,
- 3B Manure management, emissions of CH₄, N₂O and NO_x,
- 3D Agricultural soils, emissions of N₂O, NO_x and NMVOC,
- 3G Liming, emissions of CO₂
- 3H Urea application; emission of CO₂

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.

CO₂ emissions from soils are reported under Land use, land-use change and forestry. CO₂ emissions from energy use in agriculture are reported under 1A4c Agriculture/forestry/fishing.

Total greenhouse gas emissions from the agriculture sector in 2014 were 6'174 kt CO₂ equivalents which is a contribution of 12.7% to the total of Swiss greenhouse gas emissions (including indirect CO₂, excluding LULUCF, Table 2-1, Table 5-1). Main agricultural sources of greenhouse gases in 2014 were 3A Enteric fermentation, emitting 55% of all agricultural greenhouse gases, followed by 3D Agricultural soils with 26% and 3B Manure management with 19% (Figure 5-1). 3G Liming and 3H Urea application contributed 0.5% and 0.2% respectively.

Figure 5-1 Greenhouse gas emissions of the agriculture sector in kt CO₂ equivalents 1990–2014.Table 5-1 Greenhouse gas emissions of the agriculture sector in kt CO₂ equivalents 1990–2014.

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	4'509	4'496	4'410	4'353	4'373	4'363	4'332	4'235	4'200	4'135
N ₂ O	2'246	2'228	2'197	2'150	2'114	2'098	2'086	2'002	1'995	1'965
Sum	6'804	6'766	6'649	6'545	6'529	6'503	6'460	6'275	6'231	6'137

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	4'119	4'155	4'129	4'091	4'060	4'099	4'136	4'158	4'262	4'214
N ₂ O	1'964	1'991	1'983	1'946	1'952	1'957	1'956	1'987	1'993	1'964
Sum	6'123	6'187	6'153	6'077	6'056	6'098	6'133	6'191	6'298	6'219

Gas	2010	2011	2012	2013	2014
	kt CO ₂ equivalent				
CO ₂	44	43	41	42	46
CH ₄	4'197	4'177	4'162	4'119	4'147
N ₂ O	2'000	1'965	1'948	1'922	1'981
Sum	6'241	6'185	6'152	6'083	6'174

CH₄ and N₂O emissions generally declined from 1990 until 2004 (Figure 5-2). Subsequently emissions increased slightly until 2008. After a downward trend in the most recent inventory years emissions increased again in 2014. This general development can be explained by the development of 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 (Agroscope 2016b, 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. CO₂ emissions display high year to year variability due to variability of urea application, which depends among others on the relative price levels of different industrial fertilisers.

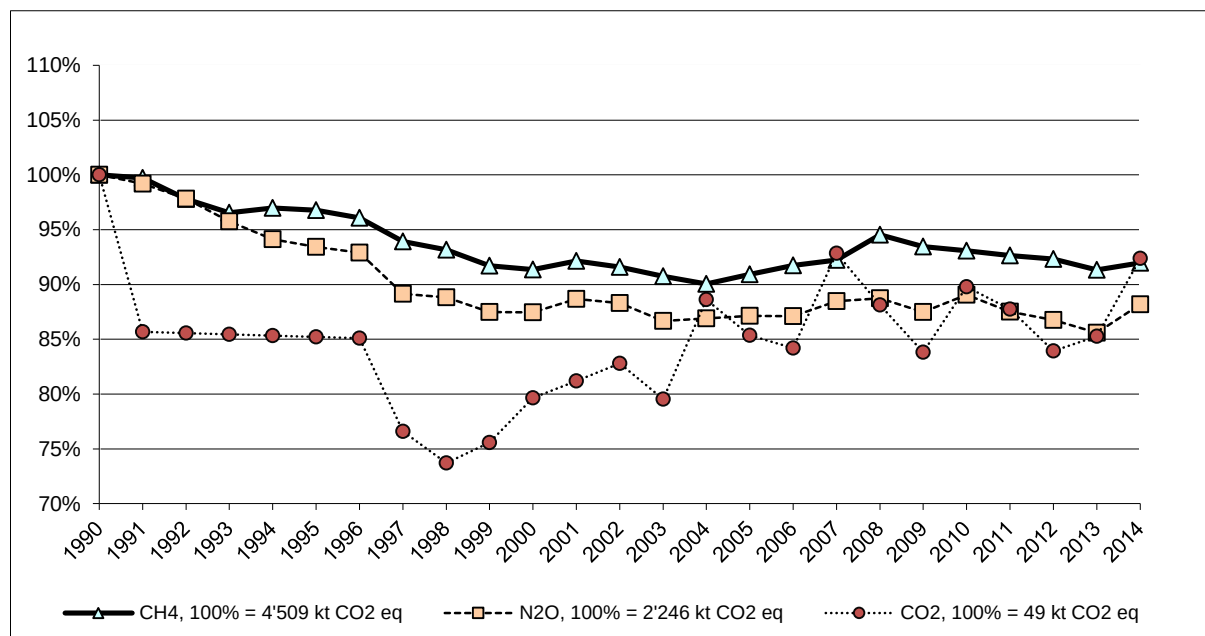


Figure 5-2 Trend of the greenhouse gases of the agricultural sector 1990–2014. The base year 1990 represents 100%.

Among the key categories of the Swiss inventory, six are from the agricultural sector (Figure 5-3).

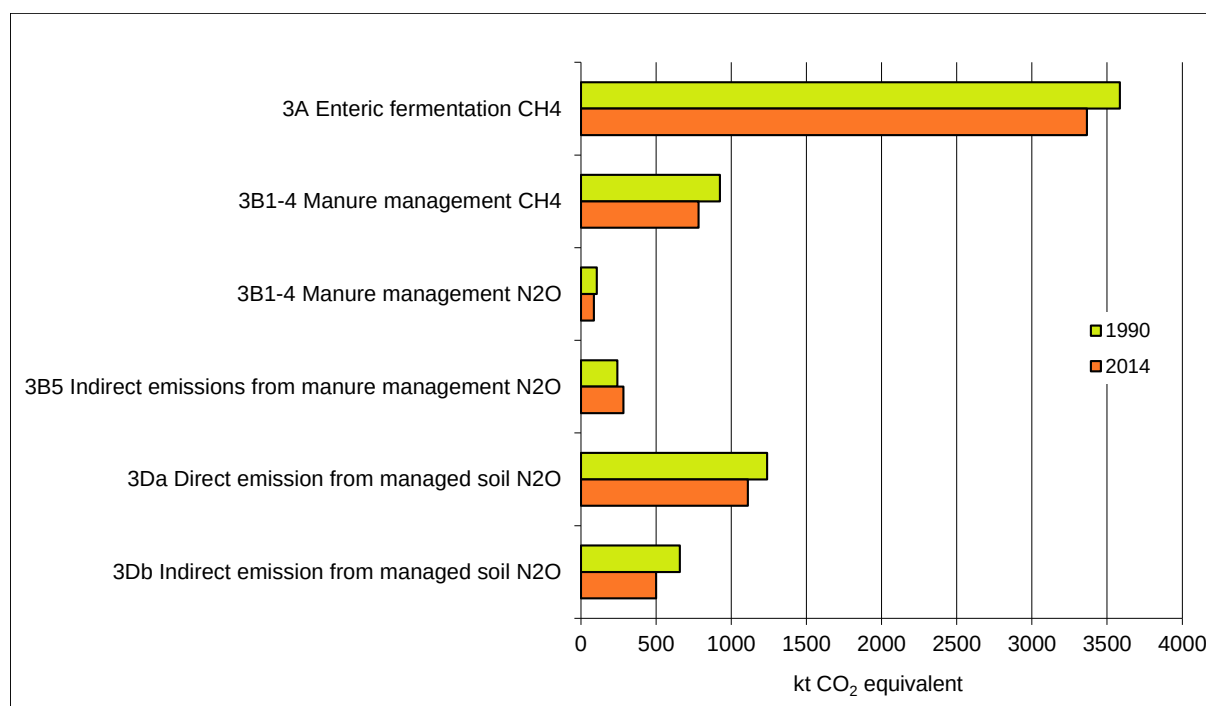


Figure 5-3 Key categories (Approach 1 and Approach 2) in agriculture 1990 and 2014.

5.2 Source category 3A – Enteric fermentation

5.2.1 Source category description

Approach 1 key category 3A

CH₄ emissions from Enteric fermentation (level and trend)

Approach 2 key category 3A

CH₄ 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 3A 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 CH₄ emissions increased, whereas since 2008 they have been decreasing again.

Cattle contribute over 94% to the overall emissions from 3A Enteric fermentation and the contribution of mature dairy cattle is more than 62%.

Table 5-2 Specification of source category 3A Enteric fermentation.

3A	Source	Specification
3A1	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, Fattening Cattle (Fattening Calves 0-4 months, Fattening Cattle 4-12 months))
3A2	Sheep	Lambs < 1 year Mature Sheep
3A3	Swine	
3A4a	Buffalo	Bisons < 3 years Bisons > 3 years
3A4b	Camels	Llamas < 2 years Llamas > 2 years
		Alpacas < 2 years Alpacas > 2 years
3A4c	Deer	Fallow Deer Red Deer
3A4d	Goats	
3A4e	Horses	Horses < 3 years Horses > 3 years
3A4f	Mules and Asses	Mules Asses
3A4g	Poultry	
3A4h i	Rabbits	
3A4h ii	Livestock NCAC	Sheep Goats Horses < 3 years Horses > 3 years Mules Asses

5.2.2 Methodological issues

5.2.2.1 Methodology

For mature dairy cattle a detailed Tier 3 model approach is applied, predicting gross energy intake by the means of a feeding model that takes into account animal performance and diet chemical composition. A country-specific methane conversion rate (Y_m) was derived from a series of studies representing Swiss specific feeding conditions.

Emission estimation for all other cattle categories follows a Tier 2 approach. This means that detailed country-specific data on nutrient requirements and feed intake were used. CH_4 conversion rates were taken from the 2006 IPCC Guidelines.

Methods for all other animal categories are based on a Tier 2 approach, estimating country-specific energy intake rates. Methane conversion rates were taken from the 2006 IPCC Guidelines or from published peer reviewed literature.

The calculation of CH_4 emissions is conducted in Agroscope 2016.

5.2.2.2 Emission factors

All emission factors for 3A Enteric fermentation are country-specific, based on IPCC equation 10.21 (IPCC 2006):

$$EF = \frac{GE * (Y_m + 100) * 365 \text{ days / y}}{55.65 \text{ MJ / kg CH}_4}$$

EF = annual CH₄ 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.

5.2.2.2.1 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 used. 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) and Morel et al. (2015). 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.

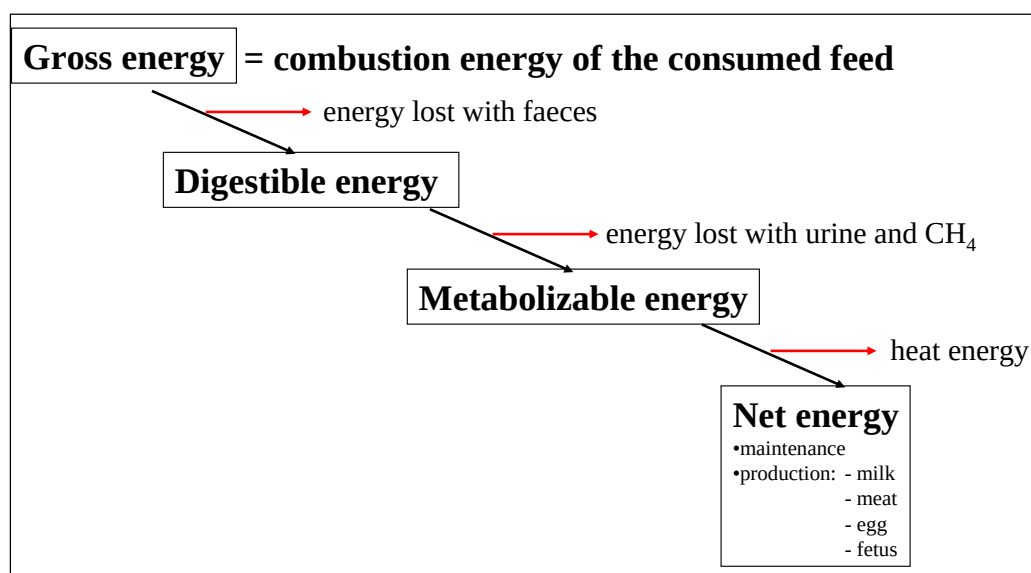


Figure 5-4 Levels of feed energy conversion (Soliva 2006).

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 2014.

Livestock Category		Conversion Factors	
Mature Dairy Cattle		NEL to GE	0.341
Other Mature Cattle		NEL to GE	0.265
Growing Cattle	<i>Fattening Calves</i>	<i>ME to GE</i>	0.939
	<i>Pre-Weaned Calves</i>	<i>NEL to GE</i>	0.299
	<i>Breeding Calves</i>	<i>NEL to GE</i>	0.358
	<i>Breeding Cattle (4-12 months)</i>	<i>NEL to GE</i>	0.319
	<i>Breeding Cattle (> 1 year)</i>	<i>NEL to GE</i>	0.313
	<i>Fattening Calves (0-4 months)</i>	<i>NEV to GE</i>	0.355
	<i>Fattening Cattle (4-12 months)</i>	<i>NEV to GE</i>	0.397
Sheep	<i>Fattening Sheep</i>	<i>NEV to GE</i>	0.350
	<i>Milksheep</i>	<i>NEL to GE</i>	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). An average body weight of 650 kg was assumed for the typical Swiss mature dairy cattle. Statistics of annual milk production are provided by the Swiss Farmers Union (SBV 2015, Table 5-4). 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. During the dry months additional energy requirements for pregnancy were accounted for.

To cover total animal energy and protein requirements, typical Swiss specific basic feed rations were defined as model inputs. The average 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 1990–2014.

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 (Table 5-5).

A more exhaustive model description is contained in Agroscope 2016b.

Table 5-4 Average daily milk production during 305 days of lactation in Switzerland 1990–2014.

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	2014
Population Size Mature Dairy Cattle	head	589'024	589'239	591'212	586'609	587'385
Lactation Period	day	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	22.46	22.63	22.57	22.27	22.87
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	8.20	8.20	8.20

For **other mature cattle** and **growing cattle**, data on energy intake were based on the feeding requirements according to RAP (1999) and Morel et al. (2015). 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) but has been revised slightly since. 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 reporting tables (CRF) are displayed in *italic*. Whole time series on a livestock sub-category 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	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6
	Growing Cattle (weighted average)	101.0	101.5	101.0	97.7	97.7	97.4	97.3	97.0	96.9	96.6
	<i>Fattening Calves</i>	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1
	<i>Pre-Weaned Calves</i>	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1
	<i>Breeding Calves</i>	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8
	<i>Breeding Cattle (4-12 months)</i>	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1
	<i>Breeding Cattle (> 1 year)</i>	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6
	<i>Fattening Calves (0-4 months)</i>	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
	<i>Fattening Cattle (4-12 months)</i>	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3
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	34.3	36.9	37.2

Gross Energy Intake		2012-2014		
		2012	2013	2014
		MJ/head/day		
Cattle				
	Mature Dairy Cattle	301.2	299.8	302.5
	Other Mature Cattle	250.6	250.6	250.6
	Growing Cattle (weighted average)	96.1	96.0	96.0
	<i>Fattening Calves</i>	47.1	47.1	47.1
	<i>Pre-Weaned Calves</i>	38.1	38.1	38.1
	<i>Breeding Calves</i>	27.8	27.8	27.8
	<i>Breeding Cattle (4-12 months)</i>	90.1	90.1	90.1
	<i>Breeding Cattle (> 1 year)</i>	143.6	143.6	143.6
	<i>Fattening Calves (0-4 months)</i>	50.0	50.0	50.0
	<i>Fattening Cattle (4-12 months)</i>	126.3	126.3	126.3
Sheep		22.5	22.4	22.5
Swine		27.0	27.3	27.1
Buffalo (weighted average)		135.9	136.0	134.6
Camels (weighted average)		31.6	31.9	31.8
Deer (weighted average) ¹⁾		57.0	58.1	58.0
Goats		25.7	25.6	26.2
Horses (weighted average)		107.9	108.0	108.1
Mules and Asses (weighted average)		39.9	39.6	39.6
Poultry ²⁾		1.2	1.2	1.1
Rabbits		1.2	1.2	1.2
Livestock NCAC (weighted average)		37.9	38.2	38.6

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 (Morel et al. 2015).

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. Furthermore, no methane is generated from milk. Therefore, the energy intake from milk or milk products is not considered when estimating methane emissions factors from enteric fermentation of calves. Since the composition of the growing cattle category changed over time (e.g. more pre-weaned calves, fewer fattening calves, see Table 5-6), the average gross energy intake for growing 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 2015, Giuliani 2015). These estimates are not officially published anymore in the statistical yearbooks (e.g. SBV 2015) 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 (2016). Resulting estimates are provided in Table 5-5 (main categories) and in Annex 3 A3.3 (all years and all sub-categories).

5.2.2.2.2 Methane conversion rate (Y_m)

For the methane conversion rate (Y_m), few country-specific data exist. Accordingly, for most animal categories default or literature values were used. Due to its great importance a country-specific Y_m was used for **mature dairy cattle**. A value of 6.9% was derived from a series of measurements conducted under Swiss specific feeding and husbandry conditions at the Federal Institute of Technology in Zürich (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 **other cattle categories, sheep and buffalo** default values recommended by the IPCC for developed countries in Western Europe were used (IPCC 2006: Table 10.12, 10.13, 10A.2, 10A.3). 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 methane conversion rate of 0.6% was used. This value was 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 GHG 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 was obtained from statistics published by the Swiss Farmers Union (SBV 2015) and the Swiss Federal Statistical Office (SFSO 2015b)(Table 5-6). All activity data 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).

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 reporting tables (CRF). 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 growing 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 chp. 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 reporting tables (CRF). Additional data on a livestock sub-category level is 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 was 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, 2009) and Schmidlin et al. (2013). For sheep and goats, data from individual cantons having full livestock census was 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 2015c).

Table 5-6 Activity data for calculating methane emissions from 3A Enteric fermentation (ART/SHL 2012, SBV 2015, SFSO 2015b, SFSO 2015c). The complete time series on a livestock sub-category level are provided in Annex 3 A3.3.

	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	90	91	99

Population Size	2012-2014		
	2012	2013	2014
	1'000 head		
Cattle	1'565	1'557	1'563
Mature Dairy Cattle	591	587	587
Other Mature Cattle	114	117	118
Growing Cattle	859	854	857
Fattening Calves	99	97	97
Pre-Weaned Calves	91	93	93
Breeding Cattle 1st Year	212	210	211
Breeding Calves	73	72	72
Breeding Cattle (4-12 months)	140	138	139
Breeding Cattle (> 1 year)	311	308	310
Breeding Cattle 2nd Year	200	198	199
Breeding Cattle 3rd Year	112	111	111
Fattening Cattle	146	146	146
Fattening Calves (0-4 months)	34	34	34
Fattening Cattle (4-12 months)	112	111	112
Sheep	417	409	403
Swine	1'544	1'485	1'498
Buffalo	1	0	1
Camels	6	6	6
Deer ¹⁾	6	6	6
Goats	85	85	85
Horses	58	57	57
Mules and Asses	20	20	20
Poultry	9'955	10'079	10'723
Rabbits	28	28	27
Livestock NCAC	112	107	106

1) Deer: numbers correspond to animal places i.e. mother with offspring.

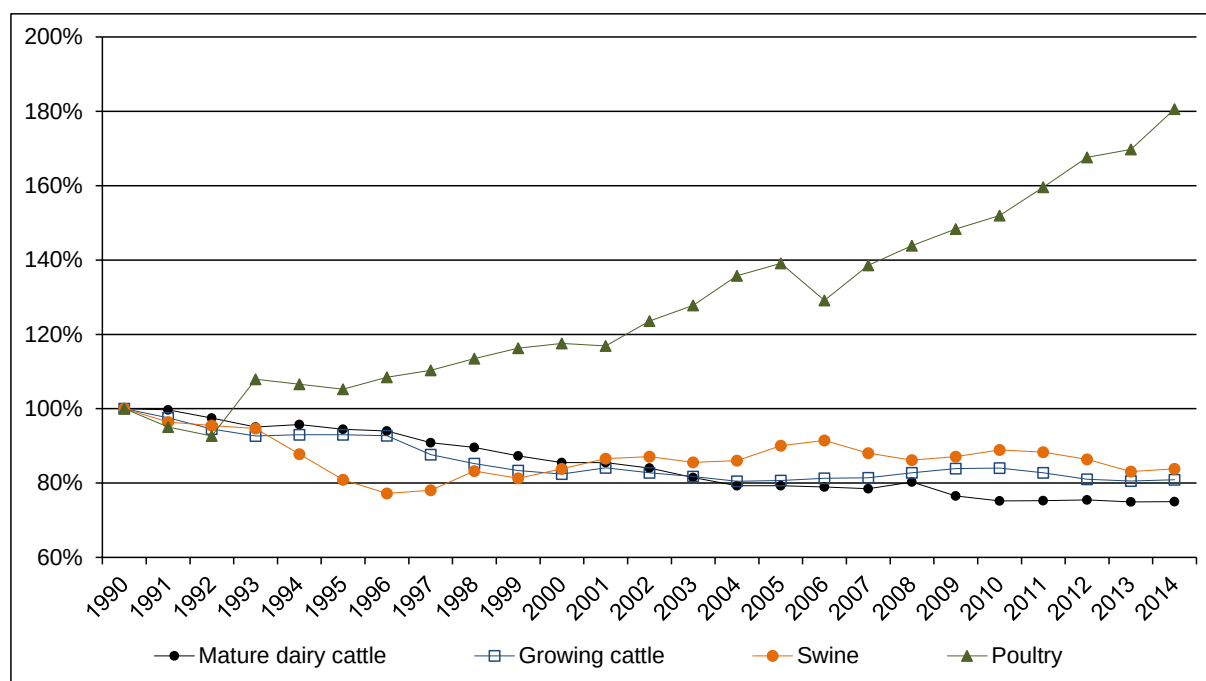


Figure 5-5 Relative development of main animal categories 1990–2014. The category with the strongest increase, i.e. other mature cattle, is not displayed, as it increases to over 980% of the 1990 value by 2014.

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 growing cattle. Since 2008 the cattle population was decreasing again, possibly due to the suspension of the milk quotation system 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 2014 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 was more or less constant while the number of goats 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) was used and was 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 A2, Table A – 7).

For further uncertainty-results also consult chp. 1.6.1 and Annex A2.

The time series 1990–2014 are all considered consistent, although the following issues should be considered:

- Gross energy intake of some of the aggregated animal categories reveals 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 six inventory years the population statistics of growing cattle were not available in the usual format. Data for 2009 to 2014 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 Category-specific QA/QC and verification

General QA/QC measures are described in NIR chp. 1.2.3.

All further category-specific QA/QC activities are described in a separate document (Agroscope 2016b). 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. Agroscope 2016b 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 $\pm 2\%$) 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 differentiates between 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 $\pm 3\%$ with census data (April) always slightly above the annual mean.

Data from the animal traffic database (i.e. cattle populations for the years 2009–2014) refer to annual mean population.

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).

Country-specific energy-intake rates for all cattle categories were compared to intake rates estimated with the IPCC Tier 2 default methodology (see Agroscope 2016b for details). Both approaches are comparable in the assessment of net energy requirements. However, the IPCC approach resulted in higher estimates of GE-intake. Further analyses suggest that the IPCC conversion rates of net energy into gross energy are unrealistic for conditions in Switzerland. Given the experimentally verified high feed quality standards in Switzerland, the results of the country-specific inventory method are thus much more plausible than the estimates using the unaltered IPCC default method. Moreover, a discrepancy of approximately 8.5% was found when comparing the overall GE-intake of the cattle population with the respective estimate of the Swiss Farmers Union (Giuliani 2015). As found for the comparison with the IPCC approach, different assumptions on net energy densities of the feed might explain the divergence.

During the past years a couple of studies were conducted to verify methane emissions at the regional scale, comparing bottom-up estimates with atmospheric measurements. While virtually all these measurements are subjects to great uncertainties, the overall picture support the bottom-up approach in the Swiss GHG inventory or at least does not indicate the omission of a significant methane source. Hiller et al. (2014a) found that methane emissions could be underestimated by the inventory method when they measured atmospheric CH₄ concentrations over the Reuss-valley with an airplane. However, the methodological approach applied by Hiller et al. (2014a) still relies on a number of rather uncertain basic assumptions and is therefore not beyond doubts. Additionally, it should be noted, that methane emission estimates from the agriculture sector in the Swiss GHG inventory were revised since and currently lie approximately 10% above the estimates used in this study. Stieger (2014) and Stieger et al. (2015) reported a very good accordance of bottom-up estimates and flux measurements with a tethered balloon system. Bamberger et al. (2014) conducted regional CH₄ measurements with a measurement device mounted on a car. Measurement precision and duration was not sufficient to validate bottom-up inventory estimates. Nonetheless, they concluded that a locally relevant emission source considered negligible in the emission inventory would have been identified. Finally Henne et al. (2015) utilised continuous CH₄ observations originating from four sites of the CarboCount CH network on the Swiss Plateau and two additional sites. These observations were combined with atmospheric transport simulations and an inverse modelling framework in order to deduce the spatial distribution of CH₄ emissions in Switzerland and the adjacent countries. Total Swiss emissions were estimated to 200 ± 20 kt CH₄/yr as mean and standard deviation. This value is in very good agreement with the value of 206 ± 33 kt CH₄/yr given in the revised 2015 submission for the year 2013 (FOEN 2015)(see also Annex 5 A 5.2).

5.2.5 Category-specific recalculations

General information on recalculations is provided in chp. 10.

Recalculations reported in submission 2015

- Several new livestock categories were reported for the first time in the 2015 submission (buffalo, camels, deer, rabbits, livestock NCAC). On average, the respective emissions summed up to 0.45% of total methane emissions from 3A Enteric fermentation (14.9 kt CO₂ 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 chp. 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 shift to the 2006 IPCC Guidelines.

Submissions 2016

- CH₄ emission factors for the whole time series of all non-dairy cattle categories were revised due to new methodological guidance in the Swiss feeding recommendations (other mature cattle) and due to a harmonisation of the respective methods (growing cattle). New estimates are substantially higher than before (1990: ~+90 kt CO₂ equivalents; 2013: ~+120 kt CO₂ equivalents).
- CH₄ emission factors for the year 2013 of sheep, goats, swine and poultry and "other" (livestock NCAC) were revised due to updates of provisional net energy intake data by the Swiss Farmers Union (Giuliani 2015). The effect of the recalculation on overall greenhouse gas emissions is negligible.
- CH₄ emission of the livestock category "other" (livestock NCAC) were revised due to the revision of AD for the years 2009–2013. The amount of horses and mules and asses not covered by agricultural census was revised due to new data in Schmidlin et al. 2013. Emission factors changed due to the new weighting of the livestock sub-categories. Across the years 2009–2013 overall greenhouse gas emissions have increased by ~7 kt CO₂ equivalents on average.

5.2.6 Category-specific planned improvements

Planned improvements for future submissions are the further development, adaptation and verification of the dairy cattle 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 categories 3B

CH₄ emissions from Manure management (level)

Indirect N₂O emissions from Manure management (level and trend)

Approach 2 key categories 3B

CH₄ emissions from Manure management (level and trend)

(Direct) N₂O emissions from Manure management (level)

Indirect N₂O 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 (CH₄) respectively five (N₂O) different manure management systems are considered as well as indirect N₂O emissions from 3B Manure management (Table 5-8). Additionally NO_x emissions from manure management are estimated.

The total emissions from 3B 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 CH₄ emissions from 3B Manure management are cattle with approximatively 75% and swine with approximatively 22%. Likewise, cattle and swine contribute significantly to N₂O emissions with 70% and 16% respectively.

Table 5-7 Specification of source category 3B Manure management by livestock categories.

3B	Source	Specification
3B1	Cattle	Mature Dairy 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 (Breeding Cattle 2 nd year + Breeding Cattle 3 rd year), Fattening Cattle (Fattening Calves 0-4 months + Fattening Cattle 4-12 months))
3B2	Sheep	Lambs < 1 year Mature Sheep Fattening Sheep Milk Sheep
3B3	Swine	Piglets Fattening Pig over 25 kg Dry Sows Nursing Sows Boars
3B4a	Buffalo	Bisons < 3 years Bisons > 3 years
3B4b	Camels	Llamas < 2 years Llamas > 2 years Alpacas < 2 years Alpacas > 2 years
3B4c	Deer	Fallow Deer Red Deer
3B4d	Goats	Goat Places
3B4e	Horses	Horses < 3 years Horses > 3 years
3B4f	Mules and Asses	Mules Asses
3B4g	Poultry	Growers Layers Broilers Turkey Other Poultry
3B4h i	Rabbits	
3B4h ii	Livestock NCAC	Sheep Goats Horses < 3 years Horses > 3 years Mules Asses

Table 5-8 Specification of source category 3B Manure management by manure management systems.

3B	Source	Specification
3B6a	Direct Emissions	Liquid systems
3B6b		Solid storage and dry lot
3Bc / 3D		Pasture, range and paddock
3B6d		Digesters (anaerobic digestion)
3B6e		Other Deep litter Poultry system
3B5a	Indirect Emissions	Atmospherical deposition
3B5b		Leaching and run-off

5.3.2 Methodological issues

5.3.2.1 Methodology

The calculation is based on methods described in the 2006 IPCC Guidelines (CH₄: IPCC 2006 equation 10.23; N₂O: IPCC 2006 equation 10.25).

CH₄ emissions from 3B Manure management were generally estimated using a 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. Due to lacking default values, VS excretion from buffalo, camels and deer was equally estimated based on gross energy intake. For the remaining livestock categories default parameters were used. Methane conversion factors (MCF) are from IPCC (2006; solid storage, pasture range and paddock, anaerobic digesters, deep litter, poultry manure) or were modelled according to Mangino et al. (2001).

N₂O emissions from 3B 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 N₂O emissions (EF₃) are based on IPCC (2006) whereas the emission factor for indirect emissions from atmospheric deposition is country-specific (Bühlmann et al. 2015 and Bühlmann 2014). Leaching of NO₃⁻ from manure management systems was considered negligible and is thus not included in the estimates. The N₂O 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 CH₄ and N₂O emissions, slightly different livestock sub-categories were used (Table 5-9). The livestock categories reported in the reporting tables (CRF) are the same, but the respective sub-categories as a basis for the calculation are different. The categorization for the estimation of CH₄ emissions had to be adapted to data availability for energy requirements, while the categorisation for the estimation of N₂O 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 CH₄ and N₂O 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 CH₄ and N₂O emissions is conducted in Agroscope 2016.

Table 5-9 Livestock categories for estimating CH₄ and N₂O emissions from 3B Manure management.

3B	CH ₄	N ₂ O
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 CH₄

Calculation of CH₄ emissions from 3B Manure management is based on methods described in the 2006 IPCC Guidelines (IPCC 2006, equation 10.23):

$$EF_T = VS_T \cdot 365 \text{ days / year} \cdot B_{0T} \cdot 0.67 \text{ kg / m}^3 \cdot \sum_S MCF_S \cdot MS_{TS}$$

EF_T = annual CH₄ 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 CH₄ producing capacity for manure produced by livestock category *T* (m³/kg)

0.67 kg/m³ = conversion factor of m³ CH₄ to kilograms CH₄

MCF_S = CH₄ conversion factors for each manure management system *S* (%)

MS_{TS} = fraction of livestock category *T*'s manure handled using manure management system *S* (dimensionless)

5.3.2.2.1 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):

$$VS = \left[GE \cdot \left(1 - \frac{DE\%}{100} \right) + (UE \cdot GE) \right] \cdot \left[\frac{1 - ASH}{EDF} \right]$$

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 chp. 5.2.2.2.1. In the case of **mature dairy cattle** the same model was used as for the estimation of CH₄ emissions from 3A 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 cattle 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).

For **calves and other growing cattle** IPCC default values of 65% respectively 60% were taken for the feed digestibility. 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 considered 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 in the 2006 IPCC Guidelines 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).

5.3.2.2.2 *Maximum CH₄ producing capacity (B₀)*

For the methane producing capacity (B₀) default values were used (IPCC 2006). For deer the same value as for sheep was applied as no default value was available (i.e. 0.19 m³/kg).

5.3.2.2.3 *Methane conversion factor (MCF)*

For estimating CH₄ 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 responsible for the major part of methane emissions from Manure management (90% on average). 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 practice 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. The higher the share of manure dropped on pasture, range and paddock, the lower is the overall MCF (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).

Anaerobic digestion of animal manure is increasing in Switzerland since the 1990s but is still not widespread (3.4% of all animal manure in 2014). Emissions from the digestion plant itself are reported under source category 5B2 (Anaerobic digestion at biogas facilities) and described in chp. 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 mainly 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 without being stored (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).

According to this methodology 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:

$$MCF_{PSAD} = MCF_{LS} * \left(\frac{14.49 * (e^{-k*AI_j} - 1)}{AI_j} + 1 \right)$$

MCF_{PSAD} = CH₄ conversion factor for pre-storage of liquid manure before delivery to biogas plants (%)

MCF_{LS} = CH₄ conversion factor for liquid/slurry systems (%)

k = Degradation rate constant (0.069)

AI_j = average pre-storage time period (day)

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 2014.

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

5.3.2.2.4 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 (Swiss Confederation, 2008). Accordingly, the share of mature dairy cattle (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 cattle 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.

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) as described under 5.3.2.2.3.

5.3.2.3 Activity data CH₄

Activity data of all livestock categories covered by the official census was obtained from SBV (2015) and the SFSO (2015b). The respective data 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 was assessed (Poncet et al. 2007, Poncet et al. 2009, Schmidlin et al. 2013, SFSO 2015c). For further details and additional data on a livestock sub-category level refer to chp. 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 sub-category 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	39.8	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	29.1	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	70.1	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		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		67.5	13.6	17.7	1.3	0.0	67.0	14.3	16.9	1.7	0.0
Other Mature Cattle		49.5	20.2	29.0	1.3	0.0	47.9	17.9	32.4	1.7	0.0
Growing Cattle (weighted average)		45.6	23.9	25.3	1.3	4.0	45.2	25.6	23.4	1.7	4.1
	Fattening Calves	21.8	0.0	0.2	1.3	76.7	16.9	0.0	0.2	1.7	81.1
	Pre-Weaned Calves	50.0	18.6	30.1	1.3	0.0	44.6	32.8	20.9	1.7	0.0
	Breeding Cattle 1st Year	41.0	34.5	23.3	1.3	0.0	43.4	33.4	21.5	1.7	0.0
	Breeding Cattle 2nd Year	41.4	20.8	36.5	1.3	0.0	43.2	20.8	34.3	1.7	0.0
	Breeding Cattle 3rd Year	45.6	21.3	31.8	1.3	0.0	46.3	21.4	30.6	1.7	0.0
	Fattening Cattle	62.3	29.2	4.3	1.3	2.9	57.7	33.2	4.0	1.7	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		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	39.6	27.5	0.0	32.9

5.3.2.4 Emission factors N₂O

Estimation of direct N₂O emissions from Manure management relies basically on the same animal waste management systems as the estimation of CH₄ emissions (compare chp. 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 N₂O emission factor that ranges from 0.0000 to 0.0004 kg N₂O-N / kg N, respectively.

Table 5-12 Emission factors for calculating N₂O emissions from manure management. Blue: annually changing parameters, value for 2014.

Animal waste management system	Emission factor
	kg N ₂ O-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 N₂O emissions after volatilisation of NH₃ 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 N₂O

Activity data for N₂O emissions from 3B Manure management was estimated according to equation 10.25 of the 2006 IPCC Guidelines:

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T (N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)}) \right] \cdot EF_{3(S)} \right] \cdot \frac{44}{28}$$

N₂O_{D(mm)} = direct N₂O emissions from manure management (kg N₂O/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 N₂O emissions from manure management system *S* (kg N₂O-N/kg N)

44/28 = conversion of (N₂O-N)_(mm) emissions to N₂O_(mm) emissions

5.3.2.5.1 Livestock population

Activity data of all livestock categories covered by the official census was obtained from SBV (2015) and the SFSO (2015b). 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 was assessed (Poncet et al. 2007, Poncet et al. 2009, Schmidlin et al. 2013, SFSO 2015c). For further details and additional data on a livestock sub-category level refer to chp. 5.2.2.3, Table 5-6 as well as Annex 3 A3.3.

5.3.2.5.2 Nitrogen excretion (N_{ex})

Data on nitrogen excretion per animal category (kg N/head/year) is country-specific and was 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).

As an exception, nitrogen excretion of **mature dairy cattle** was separately calculated within the same feeding model that was used for CH₄ emissions from 3A Enteric fermentation and from 3B Manure management (Agroscope 2014c, see also chp. 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 2014.

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, 1990–2014. The complete time series on a livestock sub-category 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
	<i>Fattening Calves</i>	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
	<i>Pre-Weaned Calves</i>	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
	<i>Breeding Cattle 1st Year</i>	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	<i>Breeding Cattle 2nd Year</i>	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
	<i>Breeding Cattle 3rd Year</i>	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
	<i>Fattening Cattle</i>	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	13.1	14.3	14.8

Nitrogen Excretion	2012-2014		
	2012	2013	2014
	kg N/head/year		
Mature Dairy Cattle	114.9	114.7	115.2
Other Mature Cattle	80.0	80.0	80.0
Growing Cattle (weighted average)	33.3	33.3	33.4
	<i>Fattening Calves</i>	13.0	13.0
	<i>Pre-Weaned Calves</i>	34.0	34.0
	<i>Breeding Cattle 1st Year</i>	25.0	25.0
	<i>Breeding Cattle 2nd Year</i>	40.0	40.0
	<i>Breeding Cattle 3rd Year</i>	55.0	55.0
	<i>Fattening Cattle</i>	33.0	33.0
Sheep (weighted average)	8.5	8.6	8.5
Swine (weighted average)	9.1	9.2	9.2
Buffalo (weighted average)	36.9	36.9	36.4
Camels (weighted average)	12.8	12.9	12.8
Deer (weighted average) ¹⁾	22.5	23.0	23.0
Goats	10.8	10.9	10.9
Horses (weighted average)	43.7	43.8	43.8
Mules and Asses (weighted average)	15.7	15.7	15.7
Poultry (weighted average)	0.5	0.5	0.5
Rabbits	1.0	1.0	1.0
Livestock NCAC (weighted average)	15.3	15.5	15.6

1) Deer: Excretion per animal place

5.3.2.5.3 Manure management system distribution (MS)

The split of nitrogen flows into the different animal waste management systems and its temporal dynamics 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 CH₄ emissions from 3B Manure management (for further information refer to chp. 5.3.2.2.4).

5.3.2.5.4 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 ammonia 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 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 (EMEP/EEA 2013). 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 chp. 1.6.1 and Table A – 7.

Table 5-14 Uncertainties for 3B Manure management 2014. (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	88	83
N_2O indirect	Indirect emissions	46.5	240.0	244.5	-77	126	102

The time series 1990–2014 are all considered consistent, although the following issues should be considered:

- For time series consistency of livestock population data and gross energy intake see chp. 5.2.3.
- The MCF for liquid/slurry systems varies according to the development of the grazing management over the years as described under chp. 5.3.2.2.3.
- Input data from the AGRAMMON-model is 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 chp. 5.3.2.4.

5.3.4 Category-specific QA/QC and verification

General QA/QC measures are described in NIR chp. 1.2.3.

All further category-specific QA/QC activities are described in a separate document (Agroscope 2016b). 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. Agroscope 2016b is continuously updated with the most recent inventory data.

For quality of livestock population data and livestock energy intake consult chp. 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).

VS excretion of various animal categories is based on IPCC default values. To cross check these estimate, VS excretion of the total livestock population was estimated by using exclusively equation 10.24 of the 2006 IPCC Guidelines and GEI data for all animal categories. Total VS excretion in 2014 was 4.1% higher than currently reported in the Swiss inventory. Most of the discrepancy can be attributed to swine, for which the default value for VS excretion is rather low (i.e. 0.31 kg/head/day as weighted mean for 2014 compared to 0.43 kg/head/day from the approach based on equation 10.24). However, Minonzio et al. 1998 also suggest a low VS-excretion of 0.30 kg/head/day on average, based on the Swiss typical feeding recommendations. They assume a digestibility of the organic matter of 83%. Using this value in IPCC equation 10.24 would also yield a VS-excretion of 0.31 kg/head/day. This finding supports the adoption of the IPCC default VS-excretion for swine. As for swine, equation 10.24 yields higher VS-excretion values for sheep and goats. Also in these cases

the default values for feed digestibility (i.e. 60%) might be too low for Swiss specific conditions. In summary there is no clear indication that the approach using exclusively equation 10.24 would result in a better estimate of overall VS excretion. As for some of the parameters used in equation 10.24 (such as e.g. feed digestibility for swine) no reliable country-specific data was available, it was thus decided to still use the IPCC default values for VS excretion of the animal categories concerned.

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 for liquid/slurry system, without natural crust cover, at a temperature ≤ 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 (Bamberger et al. 2014, Henne et al. 2015, Hiller et al. 2014, Hiller et al. 2014a, Stieger 2014, Stieger et al. 2015). For further information on these studies see section 5.2.4.

5.3.4.2 QA/QC and verification N₂O

N₂O 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 N₂O emissions such as nitrogen excretion rates, manure management system distribution and N₂O emission factors were checked for consistency and were compared to the corresponding values of other countries and to the IPCC default value if available (Agroscope 2016b).

As one of the most important parameters, nitrogen excretion rates were analysed in more detail. For mature dairy cattle, all model inputs were compared to available data on feeding regimes as applied in the field (e.g. rations composition, amount of feed concentrates and silage, nitrogen content of the feed). Furthermore, 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 supporting the excretion rates. 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). In order to validate the total nitrogen excretion of the whole livestock population a cross check was conducted comparing the bottom up inventory estimates with an independent top down approach. Thereby, the total amount of nitrogen contained in animal livestock products such as meat, milk or eggs (output) was subtracted from the total amount of nitrogen in animal feedstuff produced in or imported to the country (input). Under the condition that the nitrogen pool in the animal population remains constant, the result should be equal to the amount of nitrogen excreted in the manure (e.g. Spiess 2011). Accordance was good (average discrepancy of

$\pm 2\%$) for the years 1990 – 2005. However, for later years the top down estimates were on average 10% higher than the bottom up estimates. Reasons for this behaviour are not yet clear and this finding will be subject to further analysis. N_{ex} -values for the most important animal categories (mature dairy cattle and swine, being responsible for 65% of total nitrogen excretion) were compared to the values of the alternative gross energy approach suggested in equation 10.32 in the 2006 IPCC Guidelines. Differences were smaller than 3% for years after 2005. For swine, the IPCC approach estimated on average 18% lower N_{ex} values for the years 1990–2004. This is probably due to an underestimation of the feed protein content in this model calculation and the inventory estimates are considered more realistic. All QA/QC checks of the N_{ex} values will be further elaborated in Agroscope 2016b.

5.3.5 Category-specific recalculations

General information on recalculations is provided in chp. 10.

Recalculations reported in submission 2015

- Several new livestock categories were reported for the first time in the 2015 submission (buffalo, camels, deer, rabbits, livestock NCAC). On average the respective emissions summed up to 0.31% of total CH_4 emissions from 3B Manure management (2.4 kt CO_2 equivalents) and 0.84% of total N_2O emissions from 3B Manure management (2.9 kt CO_2 equivalents).
- For the recalculation of energy requirements and milk yield see chp. 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 chp. 7.3).
- The nitrogen excretion rate of mature dairy cattle was revised using the Agroscope feeding model (Agroscope 2014c). New nitrogen excretion rates were considerably higher than before (+ 6.6% on average).
- New emission factors for NO_x volatilisation from 3B Manure management were adopted based on EMEP/EEA (2013).
- Emission factors for direct N_2O emissions from 3B Manure management were adjusted to the 2006 IPCC Guidelines. Additionally the emission factor for indirect N_2O emissions from 3B Manure management was revised. New country-specific estimates are based on the studies of Bühlmann et al. (2015) and Bühlmann (2014).

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- CH_4 emission factors for the whole time series of all non-dairy cattle categories were revised due to new estimates for GEI (see chp. 5.2.5). New estimates are higher than before (1990: $\sim +16$ kt CO_2 equivalents; 2013: $\sim +19$ kt CO_2 equivalents).

- CH₄ and N₂O emission of the livestock category "other" (livestock NCAC) were revised due to the revision of AD for the years 2009–2013. The amount of horses and mules and asses not covered by agricultural census was revised due to new data in Schmidlin et al. 2013. Emission factors changed due to the new weighting of the livestock sub-categories. Across the years 2009–2013 overall greenhouse gas emissions have increased by ~0.5 kt CO₂ equivalents on average.
- The share of manure managed in anaerobic digesters was revised for the years 2001–2012 due to updated estimates of the respective AD in the waste sector. Effects on overall CH₄ and N₂O emissions are negligible.
- The MCF for liquid/slurry systems was slightly revised due to new model runs. Effects on overall CH₄ emissions are negligible.

5.3.6 Category-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).

New country-specific values for N_{ex} for most livestock categories will become available in the next years due to a revision of the “Principles of Fertilization in Arable and Forage Crop Production (Flisch et al. 2009)”. Furthermore new updated estimates on manure management system distribution (MS) and ammonia volatilization factors will become available in the next years due to an update of the AGRAMMON model projections with new census data.

In addition, further QA/QC checks of the new methodologies will be conducted and the respective documentation should 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 2015). There is only some insignificant upland rice cultivation in the southern part of Switzerland. CH₄ 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 key categories 3D

Direct N₂O emissions from managed soils (level)

Indirect N₂O emissions from managed soils (level and trend)

Approach 2 key categories 3D

Direct N₂O emissions from managed soils (level and trend)

Indirect N₂O emissions from managed soils (level and trend)

The source category 3D includes direct and indirect N₂O 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 N₂O emissions are further subdivided in 1. Atmospheric deposition and 2. Nitrogen leaching and run-off. All indirect N₂O emissions after deposition of NO_x and NH₃ or after leaching of NO₃⁻ are reported under source category 3Db Indirect N₂O Emissions from managed soils. This includes indirect N₂O emissions after NO₃⁻ leaching from N mineralisation in cropland remaining cropland and grassland remaining grassland. To avoid double counting the respective emissions are not reported under source category 4(IV) Indirect N₂O emissions from managed soils or in CRF Table6 “Indirect emissions of N₂O and CO₂” (see also chp. 9).

Table 5-15 Specification of source category 3D Agricultural soils.

3D	Source	Specification
3Da	Direct N ₂ O 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 (incl. 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)
3Db	Indirect N ₂ O emissions from managed soils	1. Atmospheric deposition 2. Nitrogen leaching and run-off

Furthermore, NO_x emissions from managed soils as well as NMVOC emissions are estimated.

Direct and indirect N₂O emissions from managed soils have decreased since 1990 in almost all major sub-categories. Only N₂O 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 almost 30% 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 (Agroscope 2016b, Leifeld and Fuhrer 2005). Major changes occurred mainly in the 1990's while most emissions were more or less stable after the year 2000.

The most significant N₂O 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 N₂O emissions from 3D 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 N₂O 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 N₂O emissions from atmospheric deposition, new estimates for nitrogen leaching and run-off as well as new NO_x emission factors were implemented.

The modelling of the N₂O emissions is conducted in Agroscope (2016) and is consistent with source category 3B N₂O 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.

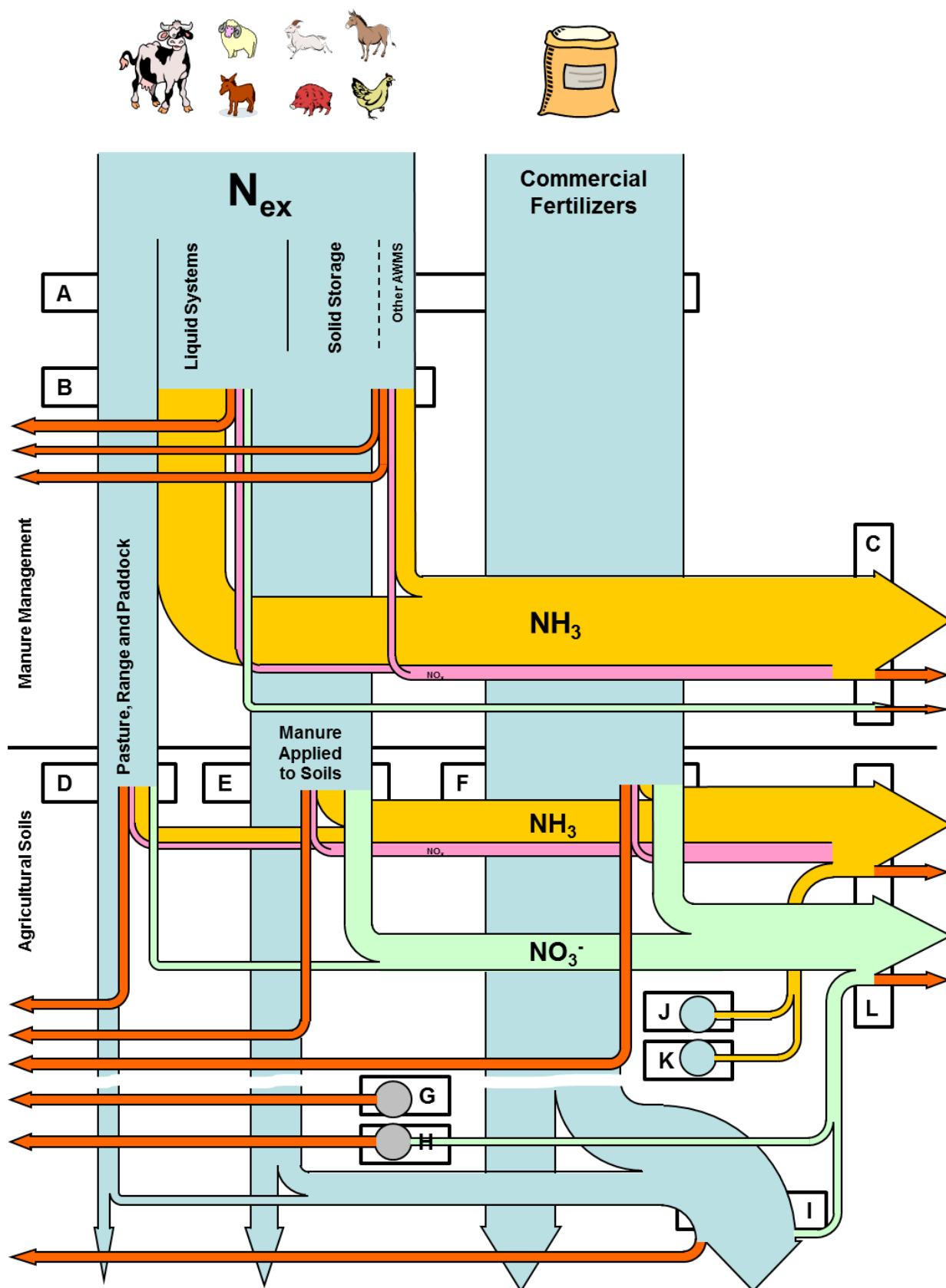


Figure 5-6 Diagram depicting the methodology of the approach to calculate the N_2O emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-16. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical 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	2014		
		tN			
A	1 Pasture, range and paddock	13'578	23'736	= B	3.Da3
	2 Liquid/slurry systems	91'925	74'165		3.B(b)
	3 Solid storage	35'913	21'221		3.B(b)
	4 Other AWMS	8'430	15'065		3.B(b)
	5 Commercial fertiliser	75'339	56'230	= F	3.Da1,2,7
B	1 Pasture, range and paddock	13'578	23'736	= A1-A4	3.Da3
	2 NH ₃ volatilisation housing	11'347	15'260		3.B(b)5
	3 N ₂ O 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	87'358		3.Da2
	7 N ₂ O emission solid storage	180	106		3.B(b)
	8 N ₂ O emission other AWMS	46	55		3.B(b)
	9 NO _x volatilisation solid storage and deep litter	109	79		3.B(b)5
	10 NH ₃ volatilisation storage	9'388	7'566		3.B(b)5
C	1 NH ₃ deposition manure management	20'734	22'826	= B2+B10	3.B(b)5
	2 NO _x deposition manure management	114	83	= B4+B9	
	3 Leaching manure management	0	0	= B5	
D	1 Available N PR&P	9'389	16'767	= B1	
	2 N ₂ O emission PR&P	260	450		3.Da3
	3 NO _x volatilisation PR&P	75	131		
	4 NH ₃ volatilisation PR&P	674	1'217		
	5 Leaching and run-off PR&P	3'181	5'171		
E	1 Available N animal manure	55'391	46'223	= B6	
	2 N ₂ O emission application animal manure	1'152	874		3.Da2
	3 NO _x volatilisation application animal manure	634	480		
	4 NH ₃ volatilisation application animal manure	31'034	20'749		
	5 Leaching and run-off application animal manure	26'985	19'032		
F	1 Available N com. fertiliser	51'927	40'458	= A5	
	2 N ₂ O emission application com. fertiliser	753	562		3.Da1,2,7
	3 NO _x volatilisation application com. fertiliser	414	309		
	4 NH ₃ volatilisation application com. fertiliser	4'595	2'650		
	5 Leaching and run-off application com. fertiliser	17'649	12'250		
G	1 Cultivation of organic soils (ha)	18'039	17'408		3.Da6
H	1 Mineralisation/immobilisation soil organic matter	620	709		3.Da5
I	1 N in crop residues pasture, range and paddock	21'689	21'724		3.Da4
	2 N in crop residues arable crops	11'347	12'369		
J	1 NH ₃ volatilisation agricultural area	2'134	2'102		
K	1 NH ₃ volatilisation alpine area	269	238		
L	1 NH ₃ deposition fertiliser appl. and PR&P	36'303	24'615	= D4+E4+F4	3.Db1
	2 NO _x deposition fertiliser appl. and PR&P	1'123	920	= 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	36'453	= D5+E5+F5	3.Db2
	5 Leaching and run-off mineralisation SOM	145	155		
	6 Leaching and run-off crop residues	7'739	7'428		

5.5.2.2 Direct N₂O emissions from managed soils (3Da)

Calculation of Direct N₂O emissions from managed soils is based on IPCC 2006 equation 11.2 including six terms for activity data and three different emission factors:

$$N_2O_{Direct} - N = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_1 + F_{OS} \bullet EF_2 + F_{PRP} \bullet EF_3$$

N₂O_{Direct}-N = annual direct N₂O–N emissions produced from managed soils (kg N₂O–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)

EF₁ = emission factor for N₂O emissions from N inputs (kg N₂O–N/kg N input)

EF₂ = emission factor for N₂O emissions from drained/managed organic soils (kg N₂O–N/ha/year)

EF₃ = emission factor for N₂O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (kg N₂O–N/kg N input)

5.5.2.2.1 Emission factors

Emission factors for calculating 3Da Direct N₂O emissions from managed soils are 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 EF₁. 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 N₂O emissions from managed soils (IPCC 2006). Blue: annually changing parameters, value for 2014.

Emission Source	Emission factor
EF ₁ Inorganic N fertilisers (kg N ₂ O-N/kg)	0.0100
EF ₁ Organic N fertilisers (kg N ₂ O-N/kg)	0.0100
EF ₁ Crop residue (kg N ₂ O-N/kg)	0.0100
EF ₁ Mineralisation/immobilisation soil organic matter (kg N ₂ O-N/kg)	0.0100
EF ₁ Other (domestic synthetic fertilisers) (kg N ₂ O-N/kg)	0.0100
EF ₂ Cultivation of organic soils (kg N ₂ O-N/ha)	8.0000
EF ₃ Urine and dung deposited by grazing animals (kg N ₂ O-N/kg)	0.0190

5.5.2.2.2 Activity data

Activity data for calculation of 3Da 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 (2015). Fertiliser statistics are 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. In the reporting tables (CRF) they are reported under 3Da7 **Other (Domestic inorganic fertilisers)** while emission calculation is conducted together with 3Da1. In some occasions, as for instance for the estimation of Indirect N₂O 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 chp. 5.3.2.5. As suggested in chp. 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 chp. 5.3.2.5, compare also Figure 5-6 and Table 5-19). $Frac_{GASM}$ in CRF Table3.D represents the amount of nitrogen volatilised as NH₃, NO_x and N₂O 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 Table3.D can thus be calculated with the numbers given in CRF Table3.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; Table 5-11). 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 approximately 3000 farms (2000, 2007, 2010).

N₂O 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 2015). 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:

$$F_{CR,AC} = \sum_T \left(Y_T \cdot \frac{NR_T}{SY_T} \right)$$

$F_{CR,AC}$ = 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:

$$F_{CR,MP} = \sum_P \left(A_P \cdot \frac{SY_{DM,P}}{10} \cdot N_{DM,P} \div 1000 \cdot R_P \right)$$

$F_{CR,MP}$ = 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 (2015) and from the SFSO (2015b). Standard dry matter yields per area, nitrogen content of dry matter as well as % yield losses were based on the original 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 sub-category 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 reporting tables (CRF). 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 3Da Direct N₂O emissions from managed soils (1990–2014).

Activity Data		1990-1999									
		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	1'421	1'457	1'494	1'531
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	11'347	11'181	11'067	11'263	10'649	10'854	12'161	11'759	11'820	10'572
	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		620	615	616	591	670	648	670	655	729	735
6. Cultivation of organic soils (ha)		18'039	18'014	17'990	17'965	17'942	17'914	17'885	17'855	17'824	17'794
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		2000-2009									
		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	86'284	86'510	86'650	88'539	87'679
	b. Sewage sludge	3'356	2'934	2'513	2'091	1'670	1'248	1'054	859	573	286
	c. Other organic fertilisers	1'569	1'785	1'949	2'116	2'332	2'525	2'789	3'096	3'503	3'888
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	24'372
4. Crop residues	Arable crops	11'907	10'415	11'479	9'771	11'846	11'546	10'567	11'544	11'523	11'907
	Residues PR&P	21'900	21'932	21'922	22'020	22'029	21'845	21'849	21'928	21'905	21'916
5. Min./imm. associated with loss/gain of SOM		735	735	735	735	735	698	640	550	443	688
6. Cultivation of organic soils (ha)		17'763	17'733	17'702	17'672	17'641	17'613	17'595	17'579	17'566	17'538
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		2010-2014				
		2010	2011	2012	2013	2014
		t N/yr				
1. Inorganic N fertilisers	Urea	7'424	6'788	5'589	6'015	8'245
	Other mineral fertilisers	45'856	40'156	39'723	37'857	41'260
2. Organic N fertilisers	a. Animal manure	87'648	87'420	87'465	86'702	87'358
	b. Sewage sludge	0	0	0	0	0
	c. Other organic fertilisers	4'326	4'369	4'472	4'588	4'663
3. Urine and dung deposited by grazing animals		23'979	23'775	23'777	23'647	23'736
4. Crop residues	Arable crops	10'473	12'209	11'272	10'113	12'369
	Residues PR&P	21'918	21'965	21'919	21'786	21'724
5. Min./imm. associated with loss/gain of SOM		721	721	721	716	709
6. Cultivation of organic soils (ha)		17'512	17'485	17'458	17'433	17'408
7. Other (domestic inorganic fertilisers)		2'220	1'956	1'888	1'828	2'063

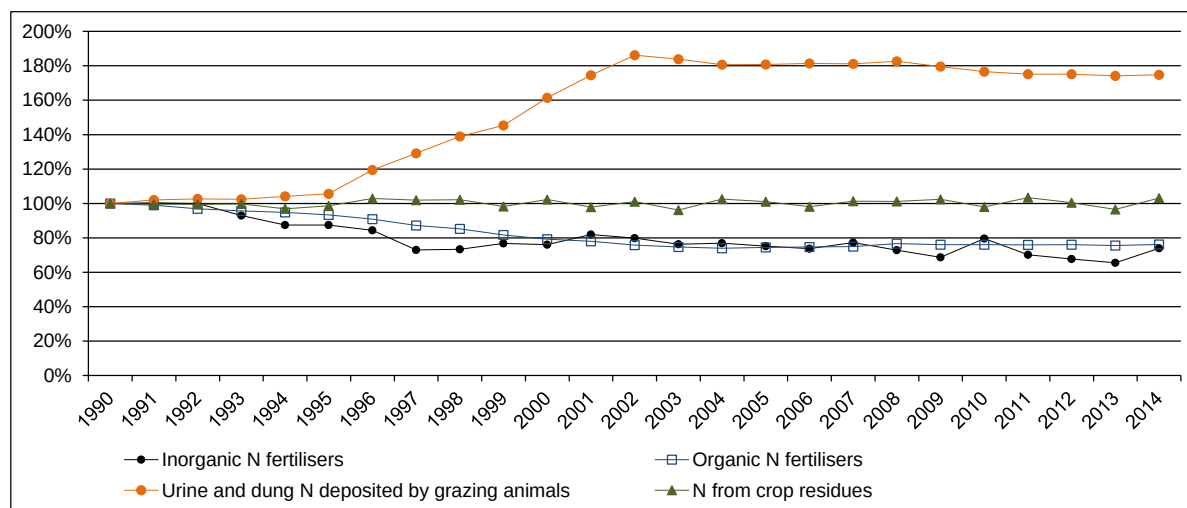


Figure 5-7 Relative development of the most important activity data for 3Da Direct N₂O emissions from managed soils 1990–2014.

Figure 5-7 depicts the development of the most important activity data for Direct N₂O 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 21st century (see also chp. 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 N₂O emissions from atmospheric deposition of N volatilised from managed soils (3Db1)

N₂O 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:

$$N_{2O_{(ATD)}} - N = \left[\begin{aligned} &\sum_i (F_{CN_i} \cdot \text{Frac}_{GASF_i}) \\ &+ \sum_T (F_{AM_T} \cdot \text{Frac}_{GASM_T}) \\ &+ \sum_T (F_{PRP_T} \cdot \text{Frac}_{GASP_T}) \\ &+ NH3_{AS} + NH3_{AA} \end{aligned} \right] + \left[(F_{CN} + F_{AM}) \cdot \text{Frac}_{NOXA} + F_{PRP} \cdot \text{Frac}_{NOXP} \right] \cdot EF_4$$

$N_{2O_{(ATD)}} - N$ = annual amount of N₂O–N produced from atmospheric deposition of N volatilised from managed soils (kg N₂O–N/year)

F_{CNi} = annual amount of commercial fertiliser N of type i applied to soils (kg N/year)

$\text{Frac}_{\text{GASFi}}$ = 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)

$\text{Frac}_{\text{GASMT}}$ = 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)

$\text{Frac}_{\text{GASPT}}$ = 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)

$\text{NH}_{3\text{AS}}$ = ammonia volatilised from the vegetation cover on agricultural soils (kg N/ha)

$\text{NH}_{3\text{AA}}$ = 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)

$\text{Frac}_{\text{NOXA}}$ = 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)

$\text{Frac}_{\text{NOXP}}$ = 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 $\text{N}_2\text{O-N}$ / kg N volatilised).

5.5.2.3.1 Emission factor

The emission factor for indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils is the same as 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 chp. 5.3.2.4.

5.5.2.3.2 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 $\text{Frac}_{\text{GASF}}$ as reported in CRF Table3.D declined considerably from 6.6% in 1990 to 5.3% in 2014 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 $\text{Frac}_{\text{GASMT}}$ for animal manure applied to soils slightly declined from 27% in the early 1990s to 24% in 2014.

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 ($\text{Frac}_{\text{GASPT}}$) 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 $\text{NH}_3\text{-N/ha}$ and 0.5 kg $\text{NH}_3\text{-N/ha}$ 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 3Db 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 NH₃ and NO_x emission factors used for the assessment of 3Db Indirect N₂O emissions from atmospheric deposition (1990–2014). Complete time series on a livestock sub-category 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 _{GASF})		6.10	5.83	5.35	4.41	4.30	4.76	4.48	4.21	4.26	4.40
	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	20.29	14.14	13.91	13.86	13.35	12.31	11.00	11.10
	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	24.40	23.80	23.79
	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	12.03	12.28	12.34
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	8.91	8.41	8.47
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		2012-2014		
		2012	2013	2014
		%		
NH ₃ from commercial fertiliser N (Frac _{GASF})		4.21	4.43	4.71
	Urea	15.00	15.00	15.00
	Other Mineral Fertilisers	2.00	2.00	2.00
	Recycling Fertilisers (weighted average)	11.33	11.57	11.73
	Sewage Sludge	26.07	26.07	26.07
	Compost	3.43	3.43	3.43
	Digestate Liquid	21.00	21.00	21.00
	Digestate Solid	4.00	4.00	4.00
NH ₃ from application of animal manure N (Frac _{GASMT})		23.76	23.76	23.75
	Mature Dairy Cattle	26.13	26.13	26.13
	Other Mature Cattle	26.21	26.21	26.21
	Growing Cattle (weighted average)	25.72	25.72	25.72
	Sheep (weighted average)	10.96	10.96	10.96
	Swine (weighted average)	19.15	19.14	19.15
	Other Livestock (weighted average)	12.33	12.36	12.42
NH ₃ from urine and dung N deposited on PR&P (Frac _{GASPT})		5.11	5.12	5.13
	Mature Dairy Cattle	4.80	4.80	4.80
	Other Mature Cattle	4.98	4.98	4.98
	Growing Cattle (weighted average)	4.98	4.98	4.98
	Sheep (weighted average)	5.00	5.00	5.00
	Swine (weighted average)	14.00	14.00	14.00
	Other Livestock (weighted average)	8.38	8.52	8.65
NH ₃ from Agricultural Soils (kg/ha/year)		2.00	2.00	2.00
NH ₃ from Alpine Area (kg/ha/year)		0.50	0.50	0.50
NO _x from applied fertilisers (Frac _{NOXA})		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

Table 5-20 Overview of N pools and flows for calculating 3Db Indirect N₂O emission from managed soils (1990–2014). Complete time series on a livestock sub-category 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	86'284	86'510	86'650	88'539	87'679	87'648	87'420
	Commercial fertiliser	75'339	67'321	57'925	56'173	55'243	57'855	54'876	52'074	59'826	53'269
	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 volatilised N (NH ₃ and NO _x)	39'829	36'888	30'520	28'658	28'833	29'447	29'162	28'091	27'927	27'608
	NH ₃ emissions from commercial fertilisers	4'595	3'922	3'096	2'480	2'375	2'755	2'458	2'194	2'551	2'345
	NH ₃ emissions from applied animal manure	31'034	28'805	22'981	21'619	21'896	22'119	22'140	21'390	20'862	20'799
	NH ₃ emissions from pasture, range and paddock	674	717	1'110	1'267	1'274	1'279	1'280	1'251	1'224	1'214
	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	309	304	318	302	286	329	293
	NO _x emissions from applied animal manure	634	585	500	475	476	477	487	482	482	481
	NO _x emissions from PR&P	75	79	121	135	135	135	136	134	132	131
Leaching and run-off	Sum leaching and run-off	55'699	49'831	44'719	43'811	43'449	44'252	44'027	43'275	44'567	43'432
	Leaching and run-off from commercial fertilisers	17'649	15'157	12'619	12'238	12'035	12'604	11'955	11'345	13'034	11'605
	Leaching and run-off from applied animal manure	26'985	23'962	19'800	18'798	18'847	18'878	19'289	19'102	19'095	19'045
	Leaching and run-off from pasture, range and paddock	3'181	3'227	4'774	5'349	5'365	5'358	5'403	5'310	5'224	5'180
	Leaching and run-off from crop residues	7'739	7'340	7'365	7'275	7'062	7'292	7'282	7'369	7'057	7'445
	Leaching and run-off from mineralisation of SOM	145	146	160	152	139	120	97	150	157	157

Nitrogen Pools and Flows		2012-2014		
		2012	2013	2014
		t N/yr		
	Animals manure N applied to soils	87'465	86'702	87'358
	Commercial fertiliser	51'672	50'288	56'230
	Area of agricultural soils (ha)	1'051'063	1'049'923	1'051'183
	Alpine area (ha)	481'394	479'760	475'788
Deposition	Sum volatilised N (NH ₃ and NO _x)	27'410	27'265	27'876
	NH ₃ emissions from commercial fertilisers	2'177	2'227	2'650
	NH ₃ emissions from applied animal manure	20'778	20'604	20'749
	NH ₃ emissions from pasture, range and paddock	1'216	1'211	1'217
	NH ₃ emissions from agricultural soils	2'343	2'340	2'340
	NO _x emissions from commercial fertilisers	284	277	309
	NO _x emissions from applied animal manure	481	477	480
Leaching and run-off	NO _x emissions from PR&P	131	130	131
	Sum leaching and run-off	42'881	42'102	44'035
	Leaching and run-off from commercial fertilisers	11'257	10'956	12'250
	Leaching and run-off from applied animal manure	19'055	18'889	19'032
	Leaching and run-off from pasture, range and paddock	5'180	5'152	5'171
	Leaching and run-off from crop residues	7'231	6'949	7'428
	Leaching and run-off from mineralisation of SOM	157	156	155

Figure 5-8 depicts the development of the most important activity data for 3Db Indirect N₂O 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 chp. 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 NH₃ (Frac_{GASMT}) declined slightly and also contributed to the decreasing trend.

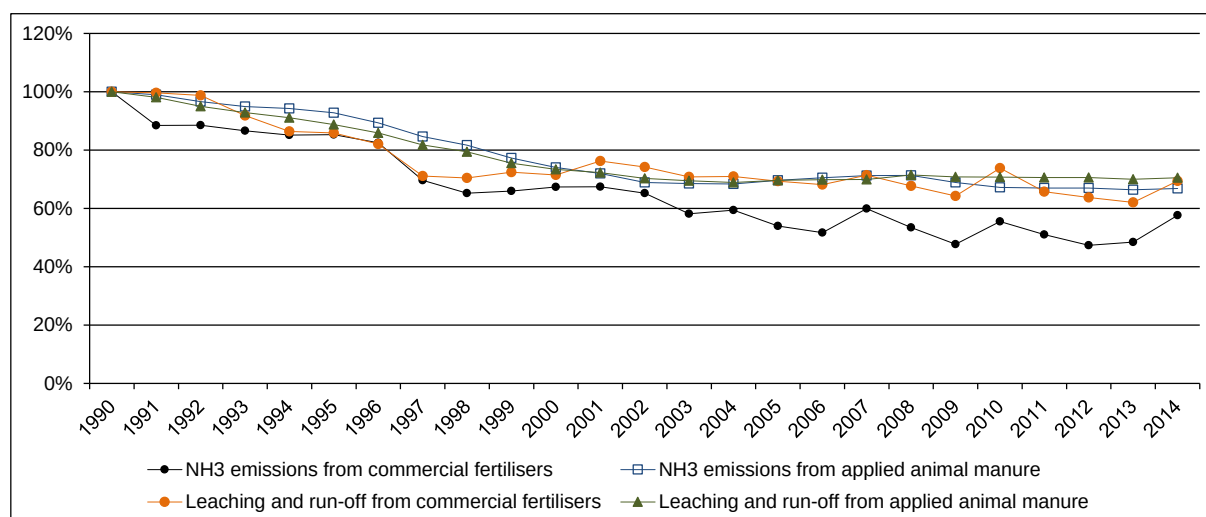


Figure 5-8 Relative development of the most important activity data for 3Db Indirect N₂O emissions from managed soils 1990–2014.

5.5.2.4 Indirect N₂O emissions from leaching and run-off from managed soils (3Db2)

N₂O emissions from leaching and run-off from managed soils are estimated based on equation 11.10 of the 2006 IPCC Guidelines:

$$N_2O_{(L)} - N = (F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}) \cdot \text{Frac}_{\text{LEACH-(H)}} \cdot EF_5$$

N₂O_(L)–N = annual amount of N₂O–N produced from leaching and run-off of N additions to managed soils (kg N₂O–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)

EF₅ = emission factor for N₂O emissions from N leaching and run-off (kg N₂O–N/kg N leached and run-off)

5.5.2.4.1 Emission factor

The emission factor for indirect N₂O emissions from leaching and run-off from managed soils is 0.0075 kg N₂O–N/kg N according to the 2006 IPCC guidelines.

5.5.2.4.2 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 chp. 5.5.2.2 and numbers are contained in Table 5-18.

$\text{Frac}_{\text{LEACH}}$ 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 $\text{Frac}_{\text{LEACH}}$ of 23.4% for 1990. The same loss rates were 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 ($\text{Frac}_{\text{LEACH}}$).

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 (see Table A – 7).

For further results also consult chp. 1.6.1.

Table 5-21 Uncertainties for 3D Agricultural soils. (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	98	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 1990–2014 are all considered consistent, although the following issues should be considered:

- Input data from the AGRAMMON-model is 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 N₂O emissions following volatilisation of NH₃ and NO_x from applied fertilisers and urine and dung excreted on PR&P varies according to varying land use as described in chp. 5.3.2.4.
- For more details on time-series consistency see also chp. 5.2.3 and 5.3.3.

5.5.4 Category-specific QA/QC and verification

General QA/QC measures are described in NIR chp. 1.2.3.

All further category-specific QA/QC activities are described in a separate document (Agroscope 2016b). General information on agricultural structures and policies is provided and eventual differences between national and (IPCC) standard values are being analysed and discussed.

The Swiss ammonium emission model AGRAMMON is documented in Kupper et al. (2013) and Agrammon (2010). Generally the Reporting of N₂O emissions in the Swiss national GHG inventory is consistent with the reporting of other nitrogen compounds (NH₃, NO_x) under the CLRTAP.

All relevant parameters 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 chp. 5.3.4.2.

For quality of livestock population data consult chp. 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 $17'000 \pm 5'000$ ha which is close to the numbers reported in the LULUCF sector (17'700 ha on average).

The country-specific value of $\text{Frac}_{\text{LEACH}}$ 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 (Agroscope 2016b).

5.5.5 Category-specific recalculations

General information on recalculations is provided in chp. 10.

For recalculation of livestock numbers see chp. 5.2.5.

For recalculation of the nitrogen excretion rates of mature dairy cattle see chp. 5.3.5.

Recalculations reported in submission 2015

- 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.
- $\text{Frac}_{\text{LEACH}}$ 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.

Submissions 2016

- N-inputs from co-substrates in agricultural biogas plants were estimated in 2016 for the first time increasing N₂O emissions from commercial fertilisers for 2014 by 7.1 kt CO₂ equivalent.
- A general recalculation for the year 2013 was carried out due to some updates of crop yield data from the Swiss Farmers Union (SBV 2015). The respective changes are only of minor importance for total emission estimates. Additionally, nitrogen inputs from crop residues of berries are reported in 2016 for the first time. The respective increase in emissions is on average 0.07 kt CO₂ equivalent.
- The dry matter fraction of hops was changed to 1 since crop yield data in SBV 2015 is already provided in dry matter. As the area of hops is small, repercussion on overall N₂O emissions is minimal.
- The areas of “Natural meadows” and “Pasture” used for the estimation of N₂O emissions from crop residues on meadows and pasture were revised for the years 2009–2012 based on updated values from SFSO (2015c). Emissions sank on average by 0.04 kt CO₂ equivalent.
- The input of N that is mineralised/immobilised in association with loss of soil C in mineral soils was revised due to an error correction. Emissions increased by a factor of 100 respectively by 3.5 kt CO₂ equivalent on average.
- The area of histosols was revised according to new results from an extensive study for the localisation of organic soils in Switzerland (Wüst-Galley et al. 2015). The respective changes of overall N₂O emissions are of minor importance.

5.5.6 Category-specific planned improvements

New country-specific values for N_{ex} for most livestock categories will become available in the next years due to a revision of the “Principles of Fertilization in Arable and Forage Crop Production (Flisch et al. 2009)”. Furthermore new updated estimates on manure management system distribution (MS) and ammonia volatilization factors will become available in the next years due to an update of the AGRAMMON model projections.

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 were reported here in the past. However, since branches in agriculture and forestry are burned only after being translocated from their place of origin, the respective emissions 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, chp. 7.4.

5.8 Source category 3G – Liming

5.8.1 Source category description

CO₂ emission from 3G Liming is not a key category.

Emissions from the application of lime (Ca(CO₃)) and dolomite (CaMg(CO₃)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(CO₃) and CaMg(CO₃)₂.

The emissions due to liming of agricultural soils range from 22.6 to 32.6 kt CO₂ 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(CO₃) 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 (2008–2014). It was estimated by Agroscope in 2009 for the period 1990–2008. For 2009–2014 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 $\pm 40\%$ was used as an approximation (Agroscope 2014a). For the emission factor of lime a lower uncertainty of $\pm 5\%$ was chosen, because it is a simple chemical process. The combined Approach 1 uncertainty is thus $\pm 40.3\%$. Approach 2 uncertainties do not differ significantly from Approach 1 uncertainties.

For further results also consult chp. 1.6.1.

Consistency: Time series for 3G Liming are all considered consistent.

5.8.4 Category-specific QA/QC and verification

General QA/QC measures are described in NIR chp. 1.2.3.

No further category-specific quality assurance activities were conducted.

5.8.5 Category-specific recalculations

No category-specific recalculations were carried out.

General information on recalculations is provided in chp. 10.

5.8.6 Category-specific planned improvements

No category-specific improvements are planned.

5.9 Source category 3H – Urea application

5.9.1 Source category description

CO₂ emission from 3H Urea application is not a key category.

Adding urea to soils during fertilisation leads to a loss of CO₂ that was fixed during the industrial production process of the fertilizer. Emissions in Switzerland range from 8.7 to 26.7 kt CO₂ per year with a general decreasing trend from 1990 to 2014.

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 (2015). 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 $\pm 5\%$ for the activity data was estimated according to ART (2008a). An uncertainty of $\pm 5\%$ was assumed for the emission factor since it is a simple chemical process. The combined Approach 1 uncertainty is hence $\pm 7.1\%$. Approach 2 uncertainties do not differ significantly from Approach 1 uncertainties.

For further results also consult chp. 1.6.1.

Consistency: Time series for 3H Urea application are all considered consistent.

5.9.4 Category-specific QA/QC and verification

General QA/QC measures are described in NIR chp. 1.2.3.

No further category-specific quality assurance activities were conducted.

5.9.5 Category-specific recalculations

No category-specific recalculations were carried out.

General information on recalculations is provided in chp. 10.

5.9.6 Category-specific planned improvements

No category-specific improvements are planned.

6 LULUCF

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

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 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). In many sub-categories country-specific emission factors are used.

The land areas in the period 1990–2014 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 surveys 1, 2 and 3 had been completed in 2013 and the interpretation of the entire Swiss territory is available for three time slices. In this submission, first results of AREA4 survey were included.

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 "elevation" (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 three completed National Forest Inventories (NFI 1–NFI 3; finalized in 1985, 1995, and 2006, respectively) and the first five annual tranches of the continuous NFI 4 (2009–2013). The inventories comprehended ca. 3'400 (NFI 4), 6'500 (NFIs 2 and 3) and 11'000 (NFI 1) 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 CO₂ emissions and removals as a result of carbon losses and gains for the years 1990–2014. The total net emissions and removals of CO₂ from 1990 to 2014 vary between -5'299 kt (1996) and 4'822 kt (2000).

Table 6-1 and Figure 6-1 show a breakdown of Switzerland's CO₂ 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. Taken together, both components persistently represent a source of carbon in the period under investigation.
- 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 year 2000. Overall, the LULUCF sector was a sink of on average -2'123 kt CO₂ yr⁻¹ between 1990 and 2014 (see Table 6-1 and Figure 6-2).

Table 6-1 Switzerland's annual CO₂ emissions and removals (kt) of sector 4 (LULUCF) 1990–2014. Positive values refer to emissions; negative values refer to removals. In this data set, emissions of CH₄ and N₂O are not included.

LULUCF	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt CO ₂									
Gains of living biomass	-12'734	-12'712	-12'856	-12'814	-12'754	-12'999	-12'952	-12'940	-12'631	-12'643
Losses of living biomass	11'968	9'228	8'874	8'670	9'647	9'231	9'062	9'850	10'999	10'905
Net change in dead organic matter	242	-472	128	-113	509	-270	-1'782	-911	-937	-611
Net change in organic and mineral soils and wildfires	761	762	761	759	765	767	770	764	779	777
LULUCF (excluding HWP)	238	-3194	-3093	-3498	-1834	-3271	-4901	-3237	-1791	-1572
Net change in Harvested Wood Products (HWP)	-1'232	-943	-775	-631	-478	-562	-397	-315	-425	-480
Total LULUCF	-994	-4137	-3869	-4129	-2312	-3833	-5299	-3552	-2215	-2052
LULUCF	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt CO ₂									
Gains of living biomass	-13'058	-12'659	-12'713	-12'675	-13'374	-12'796	-13'024	-13'568	-13'144	-13'176
Losses of living biomass	18'316	12'341	10'063	11'274	11'049	11'368	12'686	12'186	11'283	10'763
Net change in dead organic matter	-375	-588	-116	-1'000	-636	-1'018	-190	135	-335	-503
Net change in organic and mineral soils and wildfires	776	774	772	770	767	776	802	792	759	742
LULUCF (excluding HWP)	5658	-132	-1995	-1632	-2192	-1670	274	-454	-1437	-2174
Net change in Harvested Wood Products (HWP)	-836	-578	-444	-442	-638	-765	-628	-733	-523	-378
Total LULUCF	4822	-710	-2438	-2074	-2831	-2436	-354	-1188	-1960	-2552

LULUCF	2010	2011	2012	2013	2014	Mean
	kt CO ₂					
Gains of living biomass	-13'103	-13'739	-13'116	-13'120	-13'165	-12'979
Losses of living biomass	11'622	11'274	10'729	11'207	11'036	11'025
Net change in dead organic matter	-1'038	200	-279	-583	452	-404
Net change in organic and mineral soils and wildfires	752	751	752	760	753	766
LULUCF (excluding HWP)	-1767	-1515	-1914	-1737	-924	-1'591
Net change in Harvested Wood Products (HWP)	-411	-258	-168	-161	-106	-532
Total LULUCF	-2178	-1772	-2082	-1897	-1029	-2'123

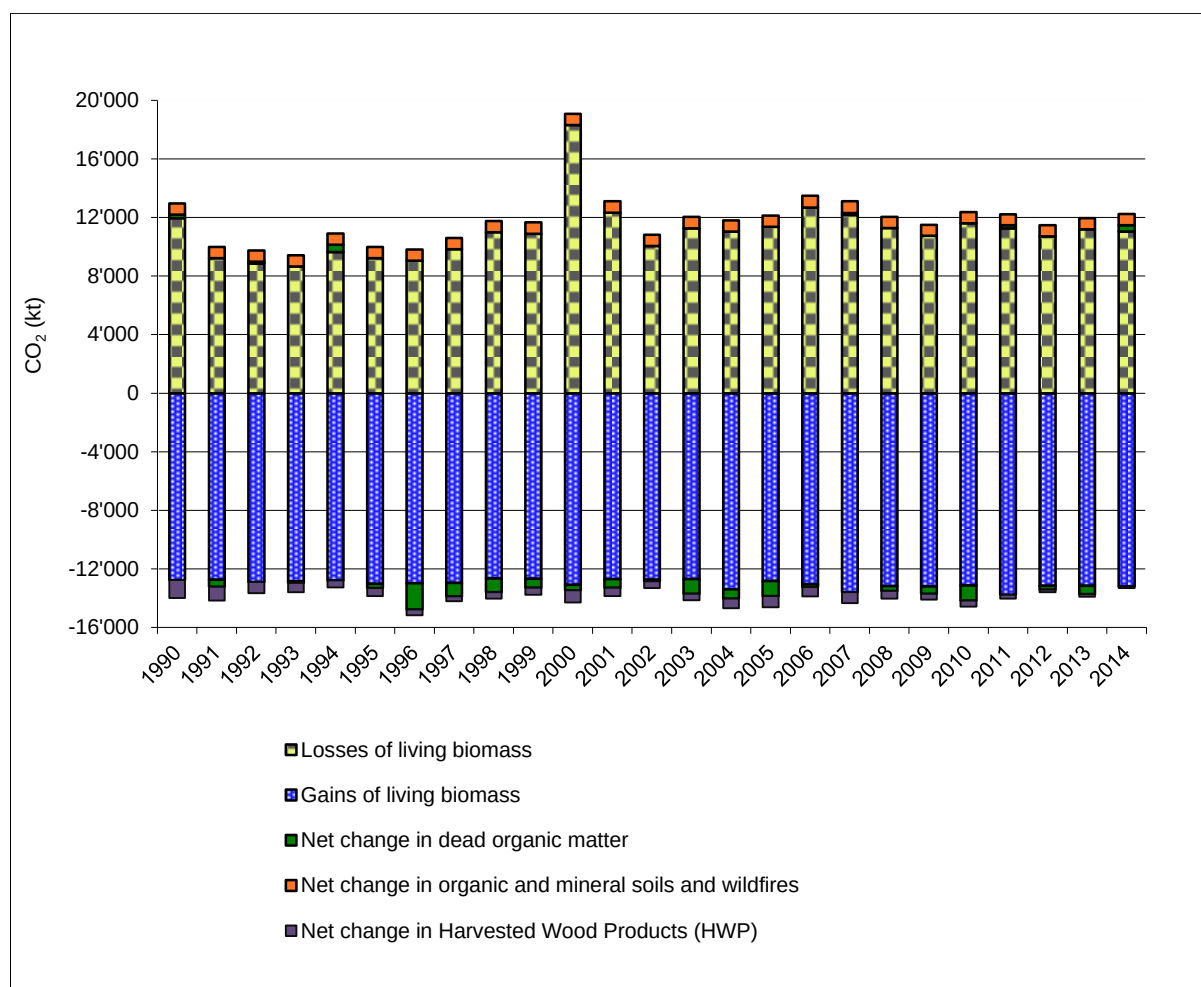


Figure 6-1 (i) CO₂ removals due to the gain (growth) of living biomass, (ii) CO₂ emissions due to the loss (harvest and mortality) of living biomass, (iii) net CO₂ emissions and removals due to changes in dead organic matter, (iv) net CO₂ emissions from soils and wildfires, and (v) net CO₂ removals from harvested wood products, 1990–2014. Positive values indicate emissions, negative values indicate removals.

The non-CO₂ emissions associated with land use, land-use change and forestry are relatively small. Between 1990 and 2014 annual CH₄ emissions add up to less than 1.13 kt yr⁻¹, and annual N₂O emissions equal at maximum 0.30 kt. The emissions arise from drained organic soils (N₂O; CRF-table 4(II)), flooded land/reservoirs (CH₄; CRF-table 4(II)), nitrogen mineralization associated with loss of soil organic matter resulting from land use and land-use change (N₂O; CRF-table 4(III)), nitrogen leaching and run-off on non-agricultural soils (indirect N₂O emissions; CRF-table 4(IV)), and wildfires on forest land and grassland (CH₄ and N₂O; 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 the LULUCF sector 1990–2014 including all CO₂ and non-CO₂ fluxes. Further representations of LULUCF CO₂ eq data can be found in chp. 2 “Trends in Greenhouse Gas Emissions and Removals”.

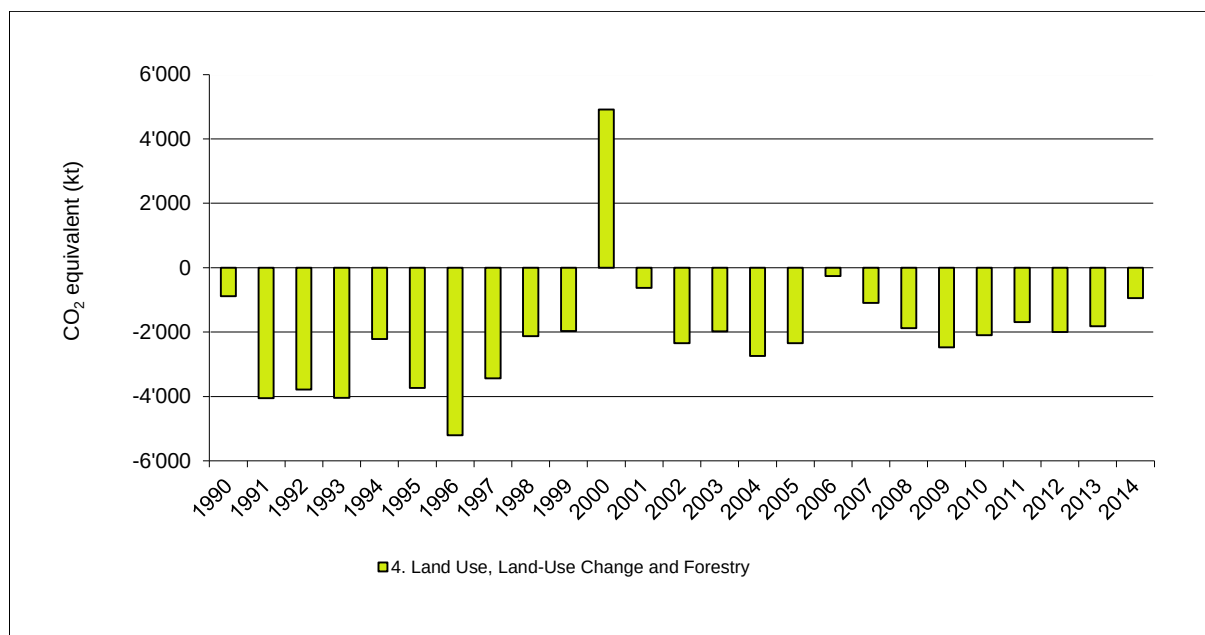


Figure 6-2 Switzerland's net GHG emissions and removals of the sector Land Use, Land-Use Change and Forestry, 1990–2014 (in kt CO₂ eq). Positive values refer to emissions, negative values refer to removals.

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 (Vol. 4, chp. 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). 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 (ΔC_l), in dead wood (ΔC_d), in litter (ΔC_h) and in soil (ΔC_s) 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.
- Calculate emissions and removals of the carbon pool in harvested wood products (HWP) as described in chp. 6.11.

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) were 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 (gross growth) of carbon in living biomass (t C ha ⁻¹ yr ⁻¹)
lossC _{l,i,CC}	annual loss (cut 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):

$$\text{stockC}_{\text{dom},i,\text{CC}} = \text{stockC}_{\text{d},i,\text{CC}} + \text{stockC}_{\text{h},i,\text{CC}}$$

$$\text{changeC}_{\text{dom},i,\text{CC}} = \text{changeC}_{\text{d},i,\text{CC}} + \text{changeC}_{\text{h},i,\text{CC}}$$

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) were calculated for all cells of the land-use change matrix. Each cell is characterized by a land-use category before the conversion (b), a land-use category after the conversion (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 was used in cases of no land-use change. It was 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:

$$\text{deltaC}_{\text{l},i,\text{ba}} = (\text{gainC}_{\text{l},i,\text{a}} - \text{lossC}_{\text{l},i,\text{a}}) * A_{i,\text{ba}} \quad (6.1)$$

$$\text{deltaC}_{\text{d},i,\text{ba}} = \text{changeC}_{\text{d},i,\text{a}} * A_{i,\text{ba}} \quad (6.2)$$

$$\text{deltaC}_{\text{h},i,\text{ba}} = \text{changeC}_{\text{h},i,\text{a}} * A_{i,\text{ba}} \quad (6.3)$$

$$\text{deltaC}_{s,i,ba} = \text{changeC}_{s,i,a} * A_{i,ba} \quad (6.4)$$

The stock-difference approach is defined as:

$$\text{deltaC}_{l,i,ba} = [(\text{stockC}_{l,i,a} - \text{stockC}_{l,i,b}) / \text{CT}] * A_{i,ba} \quad (6.5)$$

$$\text{deltaC}_{d,i,ba} = [(\text{stockC}_{d,i,a} - \text{stockC}_{d,i,b}) / \text{CT}] * A_{i,ba} \quad (6.6)$$

$$\text{deltaC}_{h,i,ba} = [(\text{stockC}_{h,i,a} - \text{stockC}_{h,i,b}) / \text{CT}] * A_{i,ba} \quad (6.7)$$

$$\text{deltaC}_{s,i,ba} = [(\text{stockC}_{s,i,a} - \text{stockC}_{s,i,b}) / \text{CT}] * A_{i,ba} \quad (6.8)$$

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 chp. 6.1.3.3

Table 6-3 pinpoints which approach was used for calculating the carbon fluxes for the various types of land-use conversion and carbon pools (living biomass, dead wood/litter and mineral soil). On organic soils, always the gain-loss approach was applied to calculate the carbon loss by mineralization of soil organic carbon. However, for "Buildings and Constructions" (CC51) a stock-difference reduced by 50% was applied in addition to the emissions from the gain-loss approach for organic soils (see chp. 6.8.2.2).

The gain-loss approach was generally used for continuous transitions, e.g. the growth of living biomass on land converted to forest land. The stock-difference approach was used for abrupt 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 chp. 6.1.3.3).

For the conversions between different forest combination categories the approach was 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 soil carbon stocks before and after the conversion was reported as a source or sink, respectively; for a detailed documentation see chp. 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. On organic soils, always the gain-loss approach was applied (for exceptional case CC51 see main text). 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	Mineral 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 (50%)	Buildings/constructions; soil: stock-difference reduced by 50% in changes from/to CC51
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, and 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/chp. 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 was applied to all soil carbon stock changes (except land converted to surface water). Accordingly, the reporting tables Table4.A to Table4.F (category

2., respectively) 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 Table4.A under category A.2. 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 Table4.A under category A.1. and are merged with productive forests (CC12).

Table 6-3 shows 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 2015I) 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 was 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 reporting tables Table4.A and Table4.F, 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 ΔC are accordingly summarised. Positive values of $\Delta C_{l,i,ba}$ were inserted in the column "Gains" and negative values in the column "Losses", respectively. The values of $\Delta C_{d,i,ba}$, $\Delta C_{h,i,ba}$ were inserted into columns "Net carbon stock change in dead wood" and "Net carbon stock change in litter" in CRF Table4.A, and the values of $\Delta C_{dom,i,ba}$ were inserted into columns "Net carbon stock change in dead organic matter" in the reporting tables Table4.B to Table4.F. The values of $\Delta C_{s,i,ba}$ were inserted in column "Net carbon stock change in soils" in the reporting tables Table4.A to Table4.F.

The reporting tables Table4.B to Table4.F 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 reporting tables. For example, the area of "shrub vegetation" (CC32) converted to "permanent grassland" (CC31) would be reported in under 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 chp. 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 stratified by combination category (CC) and spatial strata for the year 1990. These values remain constant during the period 1990–2014 with the following exceptions (highlighted cells):

- Carbon stock, gain and loss of living biomass, carbon stock and net change in dead wood, net change in litter as well as net change in mineral soils of productive forest

(CC12): Derivation of the data and the annual values of CC12 are described in chp. 6.4.2.5, 6.4.2.6 and 6.4.2.7.

- Carbon stock, gain and loss of living biomass of cropland (CC21): Annual data of CC21 are listed in chp. 6.5.2.

The derivation of the individual carbon stocks and emission factors is explained in detail in chp. 6.4 to 6.9. Positive values refer to gains in carbon stock; negative values refer to losses in carbon stock.

Table 6-4 Carbon stocks and changes in living biomass, in dead wood, in litter and in soils for the combination categories (CC), stratified by elevation, NFI region, and soil type. The values are valid for the period 1990–2014 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	elevation zone z	carbon stock in living biomass (stockC _{l,i})	carbon stock in dead wood (stockC _{d,i})	carbon stock in litter (stockC _{h,i})	carbon stock in mineral soil (stockC _{s,i})	carbon stock in organic soil (stockC _{s,i})	gain of living biomass (gainC _{l,i})	loss of living biomass (lossC _{l,i})	net change in dead wood (changeC _{d,i})	net change in litter (changeC _{h,i})	net change in mineral soil (changeC _{s,i})	net change in organic soil (changeC _{s,i})
	Strata		[t C ha ⁻¹]					[t C ha ⁻¹ yr ⁻¹]					
11 Afforestations	1	1	10.00	0	0	82.65	145.6	2.39	-0.21	0	0	0	-2.6
	1	2	10.00	0	0	102.03	145.6	2.39	-0.21	0	0	0	-2.6
	1	3	7.50	0	0	121.34	145.6	1.35	-0.1	0	0	0	-2.6
	2	1	10.00	0	0	55.40	145.6	2.39	-0.21	0	0	0	-2.6
	2	2	10.00	0	0	62.12	145.6	2.39	-0.21	0	0	0	-2.6
	2	3	7.50	0	0	122.00	145.6	1.35	-0.1	0	0	0	-2.6
	3	1	10.00	0	0	66.10	145.6	2.39	-0.21	0	0	0	-2.6
	3	2	10.00	0	0	75.91	145.6	2.39	-0.21	0	0	0	-2.6
	3	3	7.50	0	0	95.78	145.6	1.35	-0.1	0	0	0	-2.6
	4	1	10.00	0	0	66.47	145.6	2.39	-0.21	0	0	0	-2.6
	4	2	10.00	0	0	74.39	145.6	2.39	-0.21	0	0	0	-2.6
	4	3	7.50	0	0	69.48	145.6	1.35	-0.1	0	0	0	-2.6
	5	1	10.00	0	0	102.37	145.6	2.39	-0.21	0	0	0	-2.6
	5	2	10.00	0	0	108.99	145.6	2.39	-0.21	0	0	0	-2.6
	5	3	7.50	0	0	107.08	145.6	1.35	-0.1	0	0	0	-2.6
12 Productive forest	1	1	126.76	5.75	9.51	82.65	145.6	3.60	-2.38	-0.02	-0.11	0.00	-2.6
	1	2	124.81	6.01	7.53	102.03	145.6	3.21	-2.28	-0.05	-0.09	0.00	-2.6
	1	3	84.75	6.76	7.76	121.34	145.6	1.95	-1.36	0.03	-0.18	0.00	-2.6
	2	1	133.95	8.96	8.70	55.40	145.6	4.63	-4.77	-0.06	-0.14	0.00	-2.6
	2	2	146.61	8.75	11.42	62.12	145.6	4.63	-4.61	-0.06	-0.06	0.00	-2.6
	2	3	101.51	8.75	11.42	122.00	145.6	1.60	-1.05	-0.06	-0.06	0.00	-2.6
	3	1	135.29	10.79	7.51	66.10	145.6	4.56	-3.35	0.24	0.10	0.00	-2.6
	3	2	147.51	9.36	16.29	75.91	145.6	4.15	-3.78	0.00	-0.09	0.00	-2.6
	3	3	119.40	7.74	26.21	95.78	145.6	2.48	-2.75	-0.18	-0.12	0.00	-2.6
	4	1	94.68	8.49	3.15	66.47	145.6	3.24	-3.19	0.21	-0.11	0.00	-2.6
	4	2	104.44	7.86	19.99	74.39	145.6	2.49	-2.59	-0.09	-0.11	0.00	-2.6
	4	3	96.36	7.98	33.37	69.48	145.6	1.81	-2.47	0.00	-0.08	0.00	-2.6
	5	1	71.66	2.81	8.22	102.37	145.6	2.74	-0.92	-0.10	-0.15	0.00	-2.6
	5	2	76.87	3.44	11.03	108.99	145.6	2.20	-0.61	0.08	-0.17	0.00	-2.6
	5	3	76.48	2.92	30.77	107.08	145.6	1.61	-0.30	-0.04	0.00	0.00	-2.6
13 Unproductive forest	1	1	38.53	0.00	9.51	82.65	145.6	0	0	0	0	0	-2.6
	1	2	51.10	0.00	7.53	102.03	145.6	0	0	0	0	0	-2.6
	1	3	51.34	0.00	7.76	121.34	145.6	0	0	0	0	0	-2.6
	2	1	20.45	0.00	8.70	55.40	145.6	0	0	0	0	0	-2.6
	2	2	35.83	0.00	11.42	62.12	145.6	0	0	0	0	0	-2.6
	2	3	51.33	0.00	11.42	122.00	145.6	0	0	0	0	0	-2.6
	3	1	20.45	0.00	7.51	66.10	145.6	0	0	0	0	0	-2.6
	3	2	47.53	0.00	16.29	75.91	145.6	0	0	0	0	0	-2.6
	3	3	42.36	0.00	26.21	95.78	145.6	0	0	0	0	0	-2.6
	4	1	21.60	0.00	3.15	66.47	145.6	0	0	0	0	0	-2.6
	4	2	31.48	0.00	19.99	74.39	145.6	0	0	0	0	0	-2.6
	4	3	29.88	0.00	33.37	69.48	145.6	0	0	0	0	0	-2.6
	5	1	20.83	0.00	8.22	102.37	145.6	0	0	0	0	0	-2.6
	5	2	23.82	0.00	11.03	108.99	145.6	0	0	0	0	0	-2.6
	5	3	24.35	0.00	30.77	107.08	145.6	0	0	0	0	0	-2.6

(Table 6-4 continued)

land-use code CC	NFI region	elevation 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													
elevation zones:			NFI-regions:					n.s. = no stratification					
1	< 601 m					1	Jura	annually changing data					
2	601 - 1200 m					2	Central Plateau						
3	> 1200 m					3	Pre-Alps						
						4	Alps						
						5	Southern Alps						

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 chp. 6.3.3). For categories 4(II)–4(V) and 4G other data sources are relevant; they are presented in detail in the respective chp. (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	48	
4A2	Land converted to Forest Land	CO ₂	2	48	
4B1	Cropland remaining Cropland	CO ₂	5	37	
4B2	Land converted to Cropland	CO ₂	6	21	
4C1	Grassland remaining Grassland	CO ₂	6	839	
4C2	Land converted to Grassland	CO ₂	6	27	
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 ₂ O	30	138	
4IID2	Flooded land	CH ₄	10	70	
4III	N Mineralization	N ₂ O	6	135	
4IV2	Indirect emissions Leaching	N ₂ O	20	162	
4V	Wildfires	CO ₂	10	70	
4V	Wildfires	CH ₄	10	70	
4V	Wildfires	N ₂ O	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 chp. 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. The definition of the CCs 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 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. chp. 6.2.2) with the 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 annual crops and leys in arable rotations. All perennial crops are included in the grassland sub-categories.

[illegible]

6.2.2 Spatial stratification

In order to quantify carbon stocks and GHG emissions and removals in the LULUCF sector as accurately as possible, Switzerland's territory was stratified by means of three site criteria: soil type (mineral or organic), elevation and forest production region.

Most soils in Switzerland are mineral soil types. A digital map showing estimates of the surface of organic soils in Switzerland was elaborated by Wüst-Galley et al. (2015). As there is no single data set from which the location of organic soils across the country could be adequately deduced, the authors evaluated numerous spatial and non-spatial data sets providing information on geology, soils, habitats and vegetation. According to Wüst-Galley et al. (2015) the total area of organic soils is 28 kha (0.8% of the total area covered by soils).

For Forest Land (CC11–CC13) and permanent grassland (CC31), three elevation 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). Elevation data from Swisstopo (swisstopo.ch) on a 25x25 m raster (product DHM25) were used to map the three zones.

Forest Land was furthermore differentiated into the five production regions of the National Forest Inventory (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 chp. 6.1.3.2) would be theoretically possible. Not all of them, but altogether 29 have been actually realised and applied for the calculation of LULUCF-associated carbon emissions and removals.

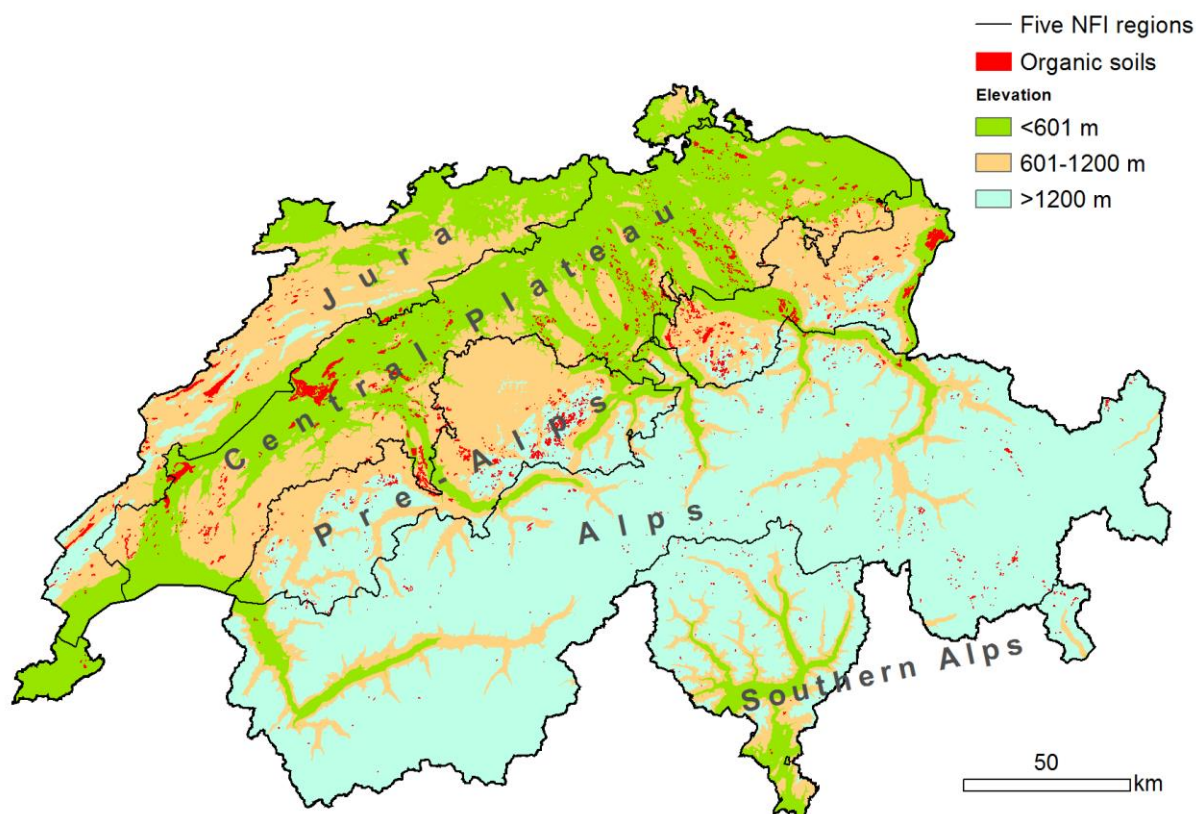


Figure 6-3 Map showing the spatial stratification according to NFI region, elevation, and soil type.

6.2.3 The land-use tables and change matrices

In Table 6-7 the land-use statistics resulting from spatial stratification (chp. 6.2.2) and interpolation in time (chp. 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 elevation (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
Elevation																			
<601	1.1	224.8	6.2	299.8	153.8	2.6	22.5	32.4	1.2	0.5	2.9	138.6	5.2	116.7	47.5	2.8	18.6	2.0	1079.1
601-1200	1.4	504.2	18.1	131.7	358.2	8.7	3.9	29.9	0.3	2.5	1.5	9.7	5.7	46.4	17.0	0.9	5.3	8.1	1153.9
>1200	1.4	377.8	79.9	0.4	425.4	144.4	0.0	27.1	0.0	148.7	61.9	13.3	14.3	11.4	3.7	0.2	1.0	585.2	1896.1
	3.9	1106.9	104.2	432.0	937.4	155.7	26.5	89.3	1.6	151.6	66.3	161.6	25.1	174.6	68.2	3.9	24.9	595.3	4129.0
Soil																			
mineral	3.9	1103.3	104.1	420.3	931.8	155.6	26.4	89.0	1.6	151.6	66.1	161.3	21.4	173.3	67.7	3.9	24.8	595.3	4101.3
organic	0.0	3.6	0.2	11.7	5.6	0.1	0.0	0.4	0.0	0.0	0.2	0.3	3.7	1.2	0.5	0.0	0.1	0.025	27.7
	3.9	1106.9	104.2	432.0	937.4	155.7	26.5	89.3	1.6	151.6	66.3	161.6	25.1	174.6	68.2	3.9	24.9	595.3	4129.0
NFI-region																			
1	0.7	197.2	8.3	78.0	122.6	0.9	4.7	11.9	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	227.2	4.1	307.0	152.4	0.9	9.9	27.4	1.0	0.2	1.6	70.4	4.1	84.9	34.7	1.6	12.6	0.7	941.5
3	1.0	214.3	13.0	30.2	261.3	10.4	0.8	17.8	0.1	8.5	6.8	30.6	12.0	26.8	9.2	0.5	2.9	15.0	661.2
4	1.1	331.6	56.1	13.8	365.4	110.2	9.5	24.5	0.2	118.1	49.2	26.2	7.2	26.9	9.8	0.8	3.0	524.8	1678.2
5	0.3	136.6	22.6	3.0	35.7	33.3	1.5	7.8	0.0	24.6	8.1	10.7	0.7	9.2	3.7	0.6	1.9	54.2	354.6
	3.9	1106.9	104.2	432.0	937.4	155.7	26.5	89.3	1.6	151.6	66.3	161.6	25.1	174.6	68.2	3.9	24.9	595.3	4129.0

Table 6-8 shows the overall trends of land-use changes between 1990 and 2014. For example, the area of afforestations (CC11) decreased by 78% during this period, while the area of unproductive forests (CC13) increased by 3%. 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 2014, in kha.

CC:	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
Year:																			
1990	3.9	1106.9	104.2	432.0	937.4	155.7	26.5	89.3	1.6	151.6	66.3	161.6	25.1	174.6	68.2	3.9	24.9	595.3	4129.0
1991	3.8	1109.1	104.5	431.2	935.6	155.2	26.5	88.3	1.5	151.4	66.2	161.6	25.1	176.2	68.7	4.0	25.3	595.0	4129.0
1992	3.7	1111.3	104.7	430.4	933.8	154.7	26.6	87.3	1.4	151.1	66.0	161.6	25.1	177.9	69.3	4.0	25.6	594.6	4129.0
1993	3.5	1113.4	104.9	429.5	932.3	154.2	26.5	86.2	1.4	150.9	65.8	161.6	25.1	179.5	69.8	4.1	25.9	594.2	4129.0
1994	3.4	1115.4	105.0	428.1	931.5	153.7	26.5	85.2	1.3	150.7	65.7	161.6	25.1	181.1	70.4	4.2	26.2	593.9	4129.0
1995	3.2	1117.2	105.2	426.2	931.3	153.1	26.5	84.3	1.3	150.6	65.6	161.6	25.1	182.7	71.1	4.2	26.2	593.5	4129.0
1996	3.0	1118.7	105.4	424.4	931.3	152.7	26.4	83.4	1.3	150.5	65.4	161.6	25.2	184.3	71.8	4.2	26.2	593.2	4129.0
1997	2.8	1120.2	105.6	422.5	931.6	152.2	26.3	82.5	1.2	150.4	65.3	161.7	25.2	185.8	72.6	4.2	26.1	592.8	4129.0
1998	2.6	1121.5	105.6	420.5	931.8	152.0	26.2	81.6	1.2	150.4	65.2	161.7	25.2	187.3	73.5	4.2	25.9	592.5	4129.0
1999	2.4	1122.8	105.7	418.6	932.0	151.8	26.1	80.7	1.2	150.5	65.1	161.7	25.2	188.9	74.3	4.2	25.8	592.1	4129.0
2000	2.2	1124.1	105.8	416.7	932.1	151.6	26.0	79.8	1.1	150.5	64.9	161.8	25.2	190.4	75.1	4.2	25.6	591.8	4129.0
2001	2.0	1125.4	105.9	414.7	932.3	151.4	25.9	78.9	1.1	150.5	64.8	161.8	25.2	191.9	75.9	4.2	25.5	591.5	4129.0
2002	1.7	1126.8	105.9	412.8	932.5	151.2	25.9	78.0	1.1	150.6	64.6	161.8	25.2	193.5	76.7	4.2	25.4	591.1	4129.0
2003	1.5	1128.1	106.0	410.8	932.7	151.0	25.8	77.1	1.1	150.6	64.5	161.9	25.3	195.0	77.5	4.2	25.2	590.8	4129.0
2004	1.3	1129.4	106.1	408.9	932.9	150.8	25.7	76.2	1.0	150.6	64.4	161.9	25.3	196.5	78.3	4.2	25.1	590.5	4129.0
2005	1.2	1131.2	106.2	407.5	932.7	150.6	25.6	75.0	1.0	150.6	64.1	162.0	25.3	198.0	79.0	4.2	24.8	590.1	4129.0
2006	1.1	1133.0	106.4	407.0	932.4	150.3	25.4	73.5	1.0	150.6	63.9	162.0	25.3	199.4	79.4	4.1	24.4	589.7	4129.0
2007	1.0	1134.8	106.6	406.7	932.1	150.2	25.2	72.1	0.9	150.6	63.7	162.1	25.3	200.6	79.7	4.1	24.0	589.2	4129.0
2008	1.0	1137.0	106.9	406.6	932.0	149.6	25.0	70.9	0.9	150.6	63.4	162.2	25.2	201.5	79.9	4.0	23.7	588.5	4129.0
2009	0.9	1138.5	107.0	405.1	931.7	149.4	24.9	69.9	0.9	150.6	63.2	162.3	25.2	203.1	80.6	4.0	23.6	588.0	4129.0
2010	0.9	1139.5	107.1	403.5	931.3	149.2	24.9	69.3	0.9	150.6	63.1	162.3	25.3	204.6	81.2	4.0	23.5	587.8	4129.0
2011	0.9	1140.6	107.1	402.0	930.9	149.1	24.8	68.6	0.8	150.7	63.0	162.4	25.3	206.1	81.9	4.0	23.4	587.5	4129.0
2012	0.9	1141.6	107.2	400.4	930.5	148.9	24.7	67.9	0.8	150.7	62.8	162.4	25.3	207.7	82.6	4.0	23.3	587.3	4129.0
2013	0.9	1142.7	107.2	399.2	930.0	148.8	24.6	67.2	0.8	150.7	62.7	162.4	25.3	209.2	83.2	4.0	23.1	587.0	4129.0
2014	0.9	1143.8	107.3	397.7	929.5	148.6	24.5	66.5	0.8	150.7	62.6	162.5	25.3	210.7	83.9	4.1	23.0	586.8	4129.0
Change:	-78	3	3	-8	-1	-5	-7	-26	-49	-1	-6	1	1	21	23	3	-8	-1	0

The annual rates of change in the entire territory of Switzerland (change-matrices, see examples for 1990 and 2014 in Table 6-9) were obtained by adding up the annual change rates of all hectares per combination category (CC). For calculating the carbon stock changes, fully stratified (cf. chp. 6.2.2) land-use change tables were used for each year (Meteotest 2016). More aggregated change-matrices are reported in CRF Table4.1 for each year 1990–2014.

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 reporting tables Table4.A to Table4.F (category 2, respectively), 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 chp. 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 2014 (change matrices). Units: ha/year, rounded values. Empty cells indicate that no change has occurred.

1990		change to CC																			decrease
		11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61		
change from CC	11		369	1	0	0	1		0					0	0	0		0	372		
	12			158	5	125	86	6	59		12	19	11	7	117	27	11	17	49	709	
	13		678		8	354	48	5	89	0	3	3	1	3	41	20	3	15	10	1280	
	21	8	1	5		663	6	181	35	1	4	4	4	4	632	317	21	18	22	1926	
	31	136	166	480	717		1007	123	311	4	46	43	9	11	870	490	27	44	67	4554	
	32	24	1022	715	2	126		9	309		14	15	6	0	24	8	5	3	30	2313	
	33	1	2	4	126	65	4		28	2	0	1	0		50	26	4	3	5	323	
	34	20	536	63	143	866	49	35		11	9	23	4	3	171	94	6	41	14	2087	
	35		0	0	8	13	0	4	46						4	2	0	1	0	80	
	36	3	27	26	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	2		0	13	384	
	41	0	4	1	2	2	6	0	4		4	1		17	11	2	1	0	99	156	
	42	5	27	6	1	3	2	0	2		0	0	6		4	1	0	0	1	59	
	51	38	18	4	86	158	11	5	7		3	5	6	4		271	58	46	5	726	
	52	7	4	1	16	32	3	1	1		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	0	1	2	0	0	3			0	0	1	78	152	8		0	253	
	61	4	41	17	16	67	93	8	31		287	33	96	2	13	1	0	1		709	
	increase	261	2936	1489	1140	2653	1794	381	1036	18	394	236	152	55	2425	1443	211	621	361	17607	
2014		change to CC																			decrease
		11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61		
change from CC	11		63	0		0								0					64		
	12			282	1	190	138	2	72		31	20	17	15	93	26	12	10	72	981	
	13		630		2	369	72	2	52		4	2	1	2	28	16	1	8	11	1200	
	21	1	1	1		1374	5	131	16	1	5	10	6	7	496	267	12	4	14	2351	
	31	17	86	347	580		773	70	176	2	78	30	7	9	778	422	17	9	82	3483	
	32	3	658	531	2	139		3	278		19	12	7	1	13	4	2	1	33	1704	
	33	0	2	2	123	91	3		18	1	1	0		0	36	25	2	2	5	310	
	34	2	466	57	46	559	58	12		4	10	22	6	0	99	57	2	17	16	1431	
	35				1	6		1	16						1	0				25	
	36	1	17	22	2	81	203	0	44			54	4		4	1			43	475	
	37	2	15	3	1	3	197		46		16		3	1	4	1			12	304	
	41	0	3	0	0	1	5		2		3	3		9	5	1	0		99	132	
	42		23	4	0	0	1		1		0	0	8		2	1		0	1	42	
	51	15	9	2	59	145	8	2	4		6	7	6	3		304	48	20	7	643	
	52	6	3	1	15	41	3	1	2		1	2	1	2	438		59	239	0	814	
	53	2	12		4	10	3	0	1			0	0	0	51	41		38	0	164	
	54	1	4	0	0	1	0		1			0	0	0	105	312	20			445	
	61	1	26	12	14	45	72	5	29		302	14	103	1	5	1	0			630	
	increase	50	2016	1264	849	3055	1541	230	757	7	477	178	169	50	2158	1477	174	350	395	15198	

6.3 Approaches used for representing land areas, 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 2015d) form the basis of activity data. In the course of the AREA surveys, every hectare of Switzerland's territory (4'129 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).

For the reconstruction of the land use conditions in Switzerland during the period 1990–2014 four datasets are used:

- Land Use Statistics “1979/85” (AREA1), complete cover of territory

- Land Use Statistics "1992/97" (AREA2), complete cover of territory
- Land Use Statistics "2004/09" (AREA3), complete cover of territory
- Land Use Statistics "2013/18" (AREA4), covering 10.8% of territory

The aerial photos for AREA1, AREA2 and AREA3 were taken 1977–1986, 1990–1998 and 2004–2009, respectively. In the course of AREA3 all photos were simultaneously (re-) interpreted according to the newly designed AREA set of land-use and land-cover categories based on the nomenclature 'NOAS04' (SFSO 2006a). The AREA4 survey was started in 2014; in this submission data based on aerial photos 2012–2014 were included.

The inter-survey period is not identical throughout the Swiss territory, but varies regionally. It averages approximately 12 years for AREA1, AREA2 and AREA3; for AREA4 the period will be shorter, approximately 9 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 was assumed that the probability of a land-use change from AREA1 to AREA2, from AREA2 to AREA3 and from AREA3 to AREA4 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, AREA3 and AREA4 for every hectare were used for these calculations. An example is shown in Figure 6-4: A hectare had been assigned to the land-use category Cropland in AREA1 (aerial photo in 1980). A land-use change to 'Surrounding of Buildings' was discovered 10 years later (1990) in AREA2.

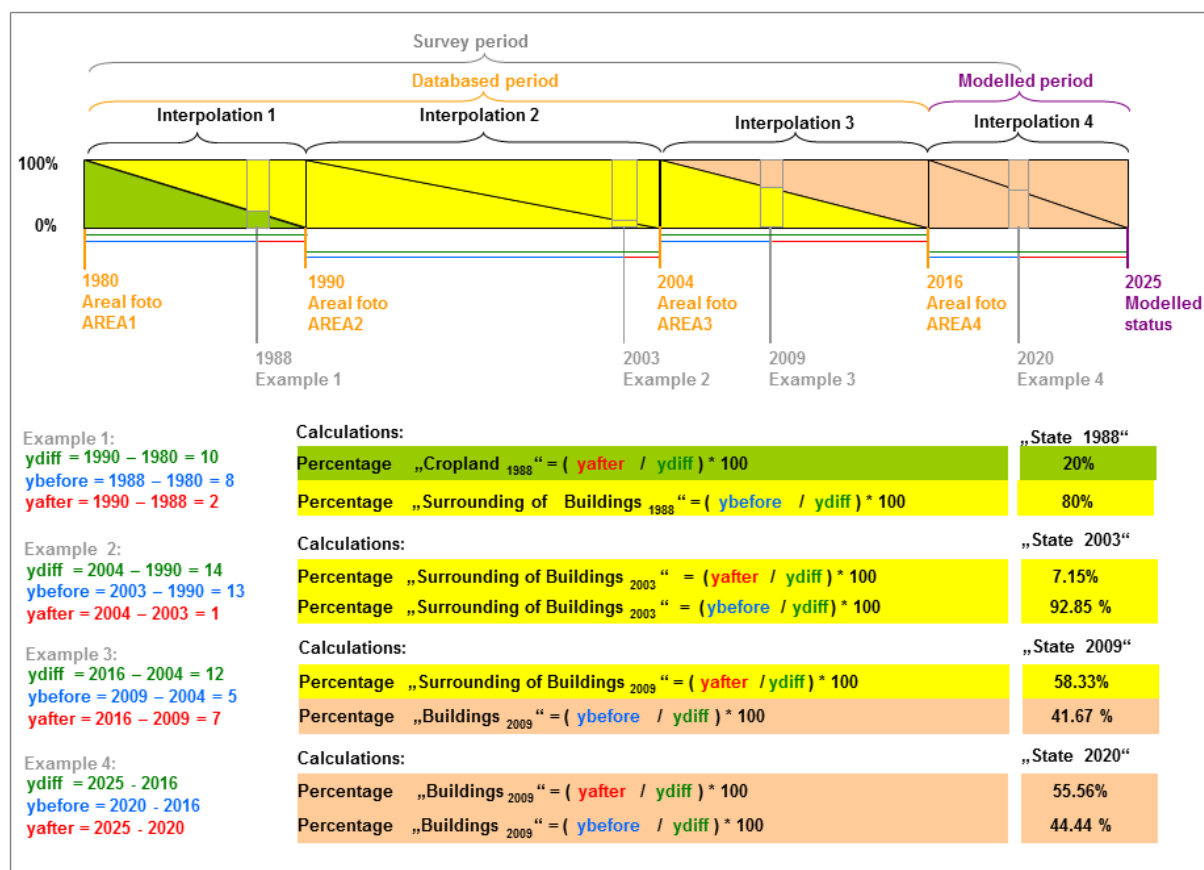


Figure 6-4 Hypothetical development of land use for a supposed survey period 1980–2020. The linear land-use changes between AREA1, AREA2, AREA3 and AREA4 considering as example a hectare changing from “Cropland” to “Surrounding of Buildings” and later from “Surrounding of Buildings” to “Buildings”. For 2020, a linear interpolation has been carried out between AREA4 and a virtual fifth survey (AREA5v) that was modelled for the year 2025 (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 was assumed. Thus, in 1988 the hectare was 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”) or between AREA3 and AREA4 (period 2004–2016, highlighting “state 2009”).

After completion, AREA4 will comprehend aerial photos from 2013–2018.

I) For those hectare points that currently have no data in AREA4, the land-use states after AREA3 are interpolated between AREA3 and a “virtual” 4th survey (AREA4v). AREA4v was modelled for each sample point using a Markov-chain approach, where transition probabilities between AREA3 and AREA4v were assessed based on the transition distribution between AREA2 and AREA3 within each spatial stratum (Sigmaplan 2016).

II) For those hectare points that have already been covered by AREA4, the land-use states after the flight year of AREA4 are interpolated between AREA4 and a “virtual” 5th survey (AREA5v). AREA5v was modeled for each sample point using a Markov-chain approach, where transition probabilities between AREA4 and AREA5v were assessed based on the

transition distribution between AREA3 and AREA4 within each spatial stratum (Sigmaplan 2016). Therefore, the land-use changes occurring after AREA4 are calculated from the linear development detected between AREA4 and the virtual 5th survey AREA5v (see Figure 6-4: example “state 2020”).

The approach used in I) and II) was evaluated successfully by modelling a virtual AREA3 from transition probabilities between AREA1 and AREA2 and comparing the results to the published AREA3 data (Sigmaplan 2016).

The status for each individual year in the period 1990–2014 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 (such as wild fires and consumption of harvested wood products) and emission factors are presented in the respective chp. (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 were quantified on the basis of the AREA data (SFSO 2015d) as follows:

1) Interpretation error: In the AREA survey, the first classification 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 was 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 was calculated as

$$U_{\text{sampling}} = 100 * 1.96 * (\text{number of points})^{-0.5}$$

The number of sampling points lies between 2'472 (for 4D2) and 1'374'367 (for 4C1) leading to values of U_{sampling} between 3.9% and 0.2%.

The overall uncertainty was calculated as:

$$U_{\text{overall}} = (U_{\text{interpret}}^2 + U_{\text{sampling}}^2)^{0.5}$$

Finally, conservatively rounded values of the calculated overall uncertainties were chosen for further processing in the uncertainty analysis.

In category 4D1 (Wetland remaining wetland) CO₂ emissions are dominated by net carbon stock losses in organic soils. The uncertainty of the area of organic soils is ca. 30% according to Leifeld et al. (2003: 61).

Consistency: Time series for activity data are all considered consistent; they were 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 (2015d).

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 chp. 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 (2015d) were checked for consistency (Sigmaplan 2016).

The temporal interpolation and extrapolation of the AREA sample is quite a complex procedure, whose internal consistency was checked systematically as described in Sigmaplan (2016). Further checks (interannual comparisons, plausibility) were carried out after producing the land-use change tables presented in chp. 6.2.3.

A systematic cross-check between the activity data reported under LULUCF category 4A and under the KP activity Forest management was carried out (see chp. 11.2.3).

It was checked and confirmed that the total country area remains constant over the inventory period.

6.3.5 Recalculations of activity data

Recalculations reported in submission 2015

- No recalculations were carried out.

Recalculations reported in submission 2016

Several updates and modifications related to land area data led to recalculations for all years 1990–2013:

- The most recent land-use data from the fourth area survey (AREA4) were included (SFSO 2015d). They are based on aerial photographs from 2012 and 2014. The interpolation and projection procedures were adapted accordingly (see chp. 6.3.2 and Sigmaphan 2016).
- Along with the AREA4 the SFSO also performed consistency checks and corrections in the data of AREA3 (2004–2009). As a consequence, there was a 1% decrease in the area of cropland in favour of grassland (see Sigmaphan 2016 for details). Furthermore, the total country area increased slightly (from 4'128.4 to 4'129.0 kha) as the AREA survey was extended to the official territorial boundaries, especially on lakes. Thus, the additional area is mainly covered by surface waters.
- The definition of the land-use category CC13 (unproductive forest) in terms of land-use (LU) and land-cover (LC) codes was updated as follows (see Table 6-6): The combinations LC47/LU222 and LC47/LU223 were defined as CC13 instead of CC34 (Copse). As a consequence, the area of CC13 increased by approximately 15 kha. This update was made in order to improve the compatibility of the forest areas measured in the AREA surveys with the definition of forest for the Kyoto Protocol given in Switzerland's Initial Reports (FOEN 2006h; FOEN 2016c). In 2007 the LU/LC definitions for CC13 were derived on the basis of the AREA survey that covered only 20% of the territory. Now, the full cover of AREA was available and the LU/LC definition for CC13 could be derived without bias, using forest data from the National Forest Inventory (NFI) as a supporting dataset (Didion 2015).
- The combination LU62/LC423 was attributed to CC61 (see Table 6-6); so far this combination had been undefined. Less than 0.01 kha were affected.
- A more complete, consistent and reliable dataset defining the geographical distribution of organic soils in Switzerland was integrated (Wüst-Galley et al. 2015). The new mapping approach differs largely from the method used so far, but the resulting change in total area of organic soils is small (from 28.3 to 27.7 kha).

6.3.6 Planned improvements for activity data

The uncertainty of Switzerland's activity data for land areas will decrease gradually with the increase in the sample size of the current survey AREA4. Full coverage of AREA4 is expected in 2020.

6.4 Category 4A – Forest Land

6.4.1 Description

Approach 1 key category 4A1

CO₂ from Forest land remaining forest land (level and trend)

Approach 1 key category 4A2

CO₂ from Land converted to forest land (level and trend)

Approach 2 key category 4A1

CO₂ from Forest land remaining forest land (level and trend)

Approach 2 Key category 4A2

CO₂ 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 were not considered as forests (FOEN 2006h).

For reporting in the reporting tables, the different forest types were 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 chp. 6.4.2.8.

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 NFIs (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 annually a nationally representative

subsample of approximately 12% of the Swiss forests is surveyed and evaluated. Otherwise, the methodology remained identical to Brändli (2010).

For assembling the results for the GHG inventory 1990–2014, NFI 4 data for the years 2009–2013 were available in addition to the data from the NFIs 1-2-3. Results of the 5-year subset of the NFI 4 were 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 Stratification

Spatial strata

Forests in Switzerland reveal a high heterogeneity in terms of elevation, 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 were:

- 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 for each of these 30 strata.

Since only the data for the years 2009 to 2013 of the continuously sampled NFI 4 (see chp. 6.4.2.1) were 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 neighbouring 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 had to be divided according to the species mixture. The emission factor per stratum was then calculated as the weighted mean of both species. The required ratio of coniferous forest area (R_c) per spatial stratum was calculated by dividing the sum of the biomass of the conifers (B_c) over the sum of the biomass of all trees (B). The ratios for each spatial stratum are displayed in Table 6-13.

$$R_{ci} = B_{ci} / B_i \quad i = \text{spatial strata}$$

As both species add up to 1 (or 100%) the rate of deciduous forest area (R_d) is:

$$R_{di} = 1 - R_{ci} \quad i = \text{spatial strata}$$

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	Elevation [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) was 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	
Elevation [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

6.4.2.3 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).

6.4.2.4 Carbon content

A mean carbon content of 50% was used to convert the volume of alive trees to biomass. The carbon content estimate represents an approximation which was based on carbon fractions for coniferous and broadleaved trees in temperate forests provided in Tab. 4.3 in IPCC (2006), Vol 4 and on the fact that in Switzerland coniferous trees are more abundant than broadleaved trees (see Table 6-13 and Table 051 in Brändli 2010).

6.4.2.5 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_i) and losses (cut and mortality, lossC_i) 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 chp. 6.4.2.2 and in Thürig et al. (2015). Positive values refer to gains in carbon stock; negative values refer to losses in carbon stock.

NFI region	Elevation [m]	gainC_i [$\text{t C ha}^{-1} \text{ yr}^{-1}$] NFI 1-2	lossC_i [$\text{t C ha}^{-1} \text{ yr}^{-1}$] NFI 1-2	gainC_i [$\text{t C ha}^{-1} \text{ yr}^{-1}$] NFI 2-3	lossC_i [$\text{t C ha}^{-1} \text{ yr}^{-1}$] NFI 2-3	gainC_i [$\text{t C ha}^{-1} \text{ yr}^{-1}$] NFI 3-4b	lossC_i [$\text{t C ha}^{-1} \text{ yr}^{-1}$] 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 chp. 6.4.2.2 and in Thürig et al. (2015). Positive values refer to gains in carbon stock; negative values refer to losses in carbon stock.

NFI region	Elevation [m]	gain _{C_i} [t C ha ⁻¹ yr ⁻¹] NFI 1-2	loss _{C_i} [t C ha ⁻¹ yr ⁻¹] NFI 1-2	gain _{C_i} [t C ha ⁻¹ yr ⁻¹] NFI 2-3	loss _{C_i} [t C ha ⁻¹ yr ⁻¹] NFI 2-3	gain _{C_i} [t C ha ⁻¹ yr ⁻¹] NFI 3-4b	loss _{C_i} [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 biomass - gross growth

Annual values of gross growth were 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 2006–2014. 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.

Annual loss of living biomass - cut and mortality

An average value for cut and mortality (CM) was 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 2006–2014. To calculate annual values of cut and mortality (CM_y) for the years 1985 to 1994, 1995 to 2005 and 2006 to 2014, 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 2015) and

former editions; Swiss Federal Statistical Office: Wood production in Switzerland 1975–2014, <https://www.pxweb.bfs.admin.ch/>). Relative harvesting amounts were calculated for each year per NFI-intersurvey period.

Data from the forest statistics (Table 6-18) show that harvesting rates were extraordinary high in 1990 after storm Vivian (February 1990) and in 2000 after the storm Lothar (December 1999). Harvesting rates in Swiss forests tended to increase since 1991. In 2008 harvesting rates started to decline due to the international and domestic economic framework conditions.

Table 6-18 Annual harvesting amount in m³ merchantable timber specified for five NFI production region as well as for coniferous and deciduous tree species for the period 1990–2014 (FOEN 2015I and former editions; <https://www.pxweb.bfs.admin.ch/>).

Year	1. Jura		2. Central plateau		3. Pre-Alps		4. Alps		5. Southern Alps		Total
	Conif. [m ³]	Dec. [m ³]	Conif. [m ³]	Dec. [m ³]	Conif. [m ³]	Dec. [m ³]	Conif. [m ³]	Dec. [m ³]	Conif. [m ³]	Dec. [m ³]	
1990	687'327	358'647	1'769'813	606'718	1'285'639	138'126	1'301'313	70'064	21'575	22'456	6'261'678
1991	476'956	354'002	1'017'232	489'742	877'851	133'155	1'064'650	72'229	24'356	26'736	4'536'909
1992	555'523	372'249	1'199'596	571'610	735'680	128'934	736'230	70'706	47'388	28'637	4'446'553
1993	550'536	373'298	1'206'294	562'232	723'565	132'676	649'938	63'940	42'511	32'785	4'337'775
1994	621'726	392'967	1'270'296	530'906	798'449	136'103	717'840	66'896	40'986	33'746	4'609'915
1995	650'572	407'119	1'388'932	570'552	774'040	154'108	590'859	56'714	51'643	33'869	4'678'408
1996	520'335	381'365	1'066'770	567'769	654'554	151'164	506'107	59'674	48'288	38'889	3'994'915
1997	599'981	394'846	1'176'333	576'415	742'830	153'719	574'152	63'650	61'043	40'189	4'383'158
1998	604'703	422'216	1'330'973	627'633	836'806	164'348	657'409	108'848	50'626	41'485	4'845'047
1999	602'652	398'648	1'342'905	639'150	824'142	173'845	593'844	68'786	44'556	39'181	4'727'709
2000	994'262	387'183	3'916'680	934'372	2'241'486	213'858	436'743	57'105	21'236	35'049	9'237'974
2001	443'612	338'751	2'020'561	594'616	1'477'489	157'710	510'730	60'152	22'237	35'722	5'661'580
2002	442'519	329'480	1'406'758	493'905	1'090'875	134'603	528'144	63'303	31'236	35'794	4'556'617
2003	557'454	315'096	1'669'605	518'273	1'195'090	142'055	588'062	62'739	37'111	35'486	5'120'971
2004	655'757	305'681	1'774'841	515'877	1'119'243	164'745	488'722	70'090	29'995	35'571	5'160'522
2005	653'049	359'808	1'810'839	614'845	1'010'979	180'546	514'905	70'603	35'462	33'614	5'284'650
2006	735'256	405'850	1'779'973	687'428	1'116'868	229'781	569'673	84'656	43'443	48'599	5'701'527
2007	793'459	425'790	1'587'494	699'076	1'144'370	230'284	621'234	82'414	62'799	43'638	5'690'558
2008	705'815	459'994	1'281'782	727'581	1'018'497	224'634	664'086	82'623	53'064	44'123	5'262'199
2009	598'292	461'055	1'149'202	701'188	878'565	224'490	678'212	90'001	56'375	42'316	4'879'696
2010	647'176	494'739	1'090'994	722'644	992'435	248'151	720'659	99'773	60'391	52'037	5'128'999
2011	617'887	513'720	1'061'986	741'587	983'040	253'300	686'797	101'644	61'822	53'305	5'075'088
2012	566'782	488'626	970'748	719'003	825'019	225'988	665'506	94'480	51'475	50'757	4'658'384
2013	576'744	521'122	948'706	739'180	834'166	254'726	670'170	117'841	64'745	50'928	4'778'328
2014	619'002	539'721	945'695	777'852	863'150	259'888	654'300	110'816	95'192	47'603	4'913'219

Growing stock: calculation of time series

In order to develop a consistent time series, annual growing stocks (GS) were calculated backward or forward starting from the growing stock 2005, determined from NFI 3:

$$GS_{iy} = GS_{2005} - \sum_y [GG_y] + \sum_y [CM_y] \quad \text{for } iy < 2005$$

$$GS_{iy} = GS_{2005} \quad \text{for } iy = 2005$$

$$GS_{iy} = GS_{2005} + \sum_y [GG_y] - \sum_y [CM_y] \quad \text{for } iy > 2005$$

where “iy” indicates the inventory year and “y” the number of years between 2005 and the inventory year iy.

The backward calculation was used for the time period 1985–2004 ($i_y < 2005$), where the annual growing stock equals the growing stock 2005 minus the net change based on the gains due to the annual gross growth (GGy) and the losses due to the annual amounts of cut and mortality (CMy).

The forward calculation was used for the time period after 2005 ($i_y > 2005$), where the annual growing stock equals the growing stock 2005 plus the net change based on the gains due to the annual gross growth (GGy) and the losses due the annual amounts of cut and mortality (CMy)

An overview of the annual values of gross growth (gains in carbon stock of living biomass), cut and mortality (losses in carbon stock of living biomass) and calculated growing stock for the period 1990 to 2014 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 1990–2014 are summarized in FOEN (2016b).

Table 6-19 Annual carbon data of living biomass for productive forest (CC12) disaggregated for NFI region (NFI) and elevation zone (Elev.), 1990–2014, for stocks (stockCl), gains (gross growth, gainCl) and losses (cut and mortality, lossCl) of living biomass. Highlighted data for 1990 are displayed in Table 6-4.

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC12: carbon stock in living biomass (stockCl,i) [t C ha ⁻¹]											
1	1	126.76	127.98	129.46	130.77	132.09	133.23	134.28	133.76	132.96	131.95
1	2	124.81	125.74	127.12	128.29	129.47	130.45	131.34	132.06	132.55	132.96
1	3	84.75	85.34	86.31	87.13	87.96	88.65	89.29	90.06	90.71	91.33
2	1	133.95	133.81	135.28	136.19	137.13	138.05	138.65	139.44	140.01	140.13
2	2	146.61	146.63	148.28	149.41	150.55	151.66	152.45	153.52	154.34	154.73
2	3	101.51	102.05	103.03	103.89	104.75	105.58	106.34	106.76	107.11	107.35
3	1	135.29	136.50	138.24	140.19	142.11	143.89	145.45	147.60	149.61	151.41
3	2	147.51	147.87	149.24	150.97	152.71	154.25	155.76	157.31	158.59	159.55
3	3	119.40	119.13	119.71	120.60	121.51	122.26	123.05	124.14	125.04	125.75
4	1	94.68	94.73	94.88	95.29	95.99	96.54	97.67	99.62	101.43	102.44
4	2	104.44	104.35	104.63	105.46	106.47	107.36	108.43	109.50	110.42	110.82
4	3	96.36	95.70	95.48	95.87	96.43	96.86	97.53	98.28	98.88	99.26
5	1	71.66	73.49	75.13	76.69	78.08	79.43	80.77	81.37	81.93	82.44
5	2	76.87	78.46	79.93	81.29	82.57	83.82	85.05	86.55	88.01	89.47
5	3	76.48	77.78	79.04	80.08	81.15	82.22	83.20	84.41	85.49	86.67

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: carbon stock in living biomass (stockCl,i) [t C ha ⁻¹]											
1	1	131.12	129.46	129.41	129.44	129.30	128.99	128.92	128.61	128.36	128.38
1	2	133.44	133.04	134.06	135.11	135.94	136.57	136.63	136.49	136.47	136.73
1	3	91.97	92.07	92.98	93.89	94.66	95.30	96.31	97.26	98.27	99.38
2	1	140.20	134.70	133.69	134.12	133.99	133.68	132.28	131.29	130.93	130.95
2	2	155.06	149.42	148.47	149.00	148.95	148.67	145.66	144.18	143.47	143.19
2	3	107.58	106.09	105.90	106.14	106.20	106.19	145.66	144.18	143.47	143.19
3	1	153.15	152.66	153.65	155.34	156.83	158.25	157.27	157.44	157.95	158.80
3	2	160.50	157.22	156.38	156.77	156.82	156.97	157.27	157.44	157.95	158.80
3	3	126.48	124.26	123.64	123.83	123.80	123.92	124.75	125.54	126.54	127.77
4	1	104.16	106.22	108.16	110.03	111.84	113.65	117.75	118.55	119.26	119.89
4	2	111.66	112.89	113.95	114.96	115.85	116.88	117.75	118.55	119.26	119.89
4	3	99.81	100.71	101.45	102.14	102.71	103.49	104.61	105.66	106.64	107.60
5	1	83.03	83.78	84.51	85.23	85.97	86.70	87.69	88.85	89.99	91.20
5	2	90.97	92.59	94.19	95.77	97.34	98.93	100.27	101.60	102.98	104.37
5	3	87.91	89.41	90.89	92.28	93.61	95.02	96.40	97.64	98.96	100.26

NFI	Elev.	2010	2011	2012	2013	2014					
CC12: carbon stock in living biomass (stockCl,i) [t C ha ⁻¹]											
1	1	128.13	127.87	127.84	127.65	127.26					
1	2	136.76	136.82	137.07	137.21	137.19					
1	3	100.43	101.49	102.62	103.72	104.77					
2	1	131.04	131.15	131.53	131.91	132.18					
2	2	143.01	142.87	143.03	143.19	143.27					
2	3	143.01	142.87	143.03	143.19	143.27					
3	1	159.28	159.76	160.74	161.59	162.34					
3	2	159.28	159.76	160.74	161.59	162.34					
3	3	128.80	129.84	131.16	132.45	133.69					
4	1	120.36	120.88	121.49	121.89	122.37					
4	2	120.36	120.88	121.49	121.89	122.37					
4	3	108.49	109.43	110.41	111.37	112.35					
5	1	92.08	92.92	93.84	94.76	95.79					
5	2	105.55	106.71	107.96	109.15	110.22					
5	3	101.49	102.71	104.02	105.22	106.17					

(Table 6-19 continued)

NFI	Elev.	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	3.37	3.37	3.37	3.37
1	2	3.21	3.21	3.21	3.21	3.21	3.21	3.04	3.04	3.04	3.04
1	3	1.95	1.95	1.95	1.95	1.95	1.95	1.80	1.80	1.80	1.80
2	1	4.63	4.63	4.63	4.63	4.63	4.63	4.54	4.54	4.54	4.54
2	2	4.63	4.63	4.63	4.63	4.63	4.63	4.56	4.56	4.56	4.56
2	3	1.60	1.60	1.60	1.60	1.60	1.60	1.28	1.28	1.28	1.28
3	1	4.56	4.56	4.56	4.56	4.56	4.56	4.23	4.23	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	2.50	2.50	2.50	2.50
4	1	3.24	3.24	3.24	3.24	3.24	3.24	3.44	3.44	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	1.90	1.90	1.90	1.90
5	1	2.74	2.74	2.74	2.74	2.74	2.74	2.04	2.04	2.04	2.04
5	2	2.20	2.20	2.20	2.20	2.20	2.20	2.18	2.18	2.18	2.18
5	3	1.61	1.61	1.61	1.61	1.61	1.61	1.79	1.79	1.79	1.79

NFI	Elev.	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	3.55	3.55	3.55	3.55
1	2	3.04	3.04	3.04	3.04	3.04	3.04	3.14	3.14	3.14	3.14
1	3	1.80	1.80	1.80	1.80	1.80	1.80	1.87	1.87	1.87	1.87
2	1	4.54	4.54	4.54	4.54	4.54	4.54	4.63	4.63	4.63	4.63
2	2	4.56	4.56	4.56	4.56	4.56	4.56	4.68	4.68	4.68	4.68
2	3	1.28	1.28	1.28	1.28	1.28	1.28	4.68	4.68	4.68	4.68
3	1	4.23	4.23	4.23	4.23	4.23	4.23	3.89	3.89	3.89	3.89
3	2	4.15	4.15	4.15	4.15	4.15	4.15	3.89	3.89	3.89	3.89
3	3	2.50	2.50	2.50	2.50	2.50	2.50	2.78	2.78	2.78	2.78
4	1	3.44	3.44	3.44	3.44	3.44	3.44	2.55	2.60	2.60	2.60
4	2	2.50	2.50	2.50	2.50	2.50	2.50	2.55	2.60	2.60	2.60
4	3	1.90	1.90	1.90	1.90	1.90	1.90	1.99	1.99	1.99	1.99
5	1	2.04	2.04	2.04	2.04	2.04	2.04	2.60	2.60	2.60	2.60
5	2	2.18	2.18	2.18	2.18	2.18	2.18	2.50	2.50	2.50	2.50
5	3	1.79	1.79	1.79	1.79	1.79	1.79	1.90	1.90	1.90	1.90

NFI	Elev.	2010	2011	2012	2013	2014					
CC12: gain of living biomass (gainCl,i) [t C ha ⁻¹ yr ⁻¹]											
1	1	3.55	3.55	3.55	3.55	3.55					
1	2	3.14	3.14	3.14	3.14	3.14					
1	3	1.87	1.87	1.87	1.87	1.87					
2	1	4.63	4.63	4.63	4.63	4.63					
2	2	4.68	4.68	4.68	4.68	4.68					
2	3	4.68	4.68	4.68	4.68	4.68					
3	1	3.89	3.89	3.89	3.89	3.89					
3	2	3.89	3.89	3.89	3.89	3.89					
3	3	2.78	2.78	2.78	2.78	2.78					
4	1	2.60	2.60	2.60	2.60	2.60					
4	2	2.60	2.60	2.60	2.60	2.60					
4	3	1.99	1.99	1.99	1.99	1.99					
5	1	2.60	2.60	2.60	2.60	2.60					
5	2	2.50	2.50	2.50	2.50	2.50					
5	3	1.90	1.90	1.90	1.90	1.90					

(Table 6-19 continued)

NFI	Elev.	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	-2.38	-2.12	-2.29	-2.29	-2.46	-2.55	-3.89	-4.17	-4.37	-4.20
1	2	-2.28	-1.83	-2.04	-2.03	-2.23	-2.32	-2.32	-2.54	-2.63	-2.56
1	3	-1.36	-0.99	-1.13	-1.12	-1.26	-1.32	-1.03	-1.15	-1.18	-1.16
2	1	-4.77	-3.17	-3.72	-3.70	-3.71	-4.03	-3.75	-3.97	-4.41	-4.47
2	2	-4.61	-2.98	-3.50	-3.49	-3.53	-3.84	-3.50	-3.74	-4.18	-4.23
2	3	-1.05	-0.62	-0.74	-0.74	-0.77	-0.84	-0.86	-0.93	-1.04	-1.05
3	1	-3.35	-2.82	-2.60	-2.64	-2.77	-2.99	-2.09	-2.22	-2.44	-2.49
3	2	-3.78	-2.78	-2.42	-2.41	-2.60	-2.63	-2.61	-2.87	-3.19	-3.20
3	3	-2.75	-1.90	-1.60	-1.57	-1.73	-1.69	-1.41	-1.59	-1.79	-1.77
4	1	-3.19	-3.10	-2.83	-2.55	-2.69	-2.27	-1.49	-1.62	-2.42	-1.72
4	2	-2.59	-2.21	-1.66	-1.48	-1.61	-1.33	-1.43	-1.59	-2.10	-1.67
4	3	-2.47	-2.03	-1.41	-1.25	-1.38	-1.14	-1.15	-1.30	-1.51	-1.35
5	1	-0.92	-1.09	-1.18	-1.35	-1.38	-1.40	-1.44	-1.49	-1.54	-1.45
5	2	-0.61	-0.72	-0.84	-0.92	-0.94	-0.98	-0.67	-0.72	-0.72	-0.67
5	3	-0.30	-0.35	-0.57	-0.54	-0.53	-0.63	-0.58	-0.71	-0.61	-0.54

NFI	Elev.	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	-5.03	-3.41	-3.35	-3.51	-3.67	-4.05	-3.63	-3.86	-3.80	-3.53
1	2	-3.43	-2.02	-1.99	-2.21	-2.41	-2.56	-3.08	-3.29	-3.16	-2.88
1	3	-1.70	-0.89	-0.88	-1.03	-1.16	-1.20	-0.87	-0.93	-0.86	-0.77
2	1	-10.04	-5.54	-4.12	-4.67	-4.85	-5.23	-6.03	-5.62	-4.99	-4.61
2	2	-10.20	-5.52	-4.03	-4.62	-4.83	-5.14	-6.65	-6.15	-5.39	-4.96
2	3	-2.77	-1.47	-1.05	-1.22	-1.29	-1.34	-6.65	-6.15	-5.39	-4.96
3	1	-4.72	-3.24	-2.54	-2.74	-2.82	-2.80	-3.65	-3.72	-3.39	-3.04
3	2	-7.44	-4.99	-3.77	-4.10	-4.00	-3.77	-3.65	-3.72	-3.39	-3.04
3	3	-4.72	-3.12	-2.31	-2.53	-2.38	-2.16	-1.95	-1.99	-1.78	-1.55
4	1	-1.37	-1.50	-1.57	-1.62	-1.63	-1.67	-1.73	-1.80	-1.88	-1.97
4	2	-1.28	-1.44	-1.50	-1.61	-1.48	-1.53	-1.73	-1.80	-1.88	-1.97
4	3	-1.00	-1.16	-1.20	-1.33	-1.12	-1.18	-0.87	-0.95	-1.01	-1.03
5	1	-1.29	-1.32	-1.32	-1.31	-1.31	-1.24	-1.60	-1.44	-1.46	-1.40
5	2	-0.56	-0.58	-0.59	-0.60	-0.59	-0.57	-1.15	-1.17	-1.12	-1.11
5	3	-0.29	-0.31	-0.40	-0.46	-0.38	-0.44	-0.51	-0.66	-0.58	-0.60

NFI	Elev.	2010	2011	2012	2013	2014					
CC12: loss of living biomass (lossCl,i) [t C ha ⁻¹ yr ⁻¹]											
1	1	-3.80	-3.82	-3.58	-3.75	-3.93					
1	2	-3.11	-3.09	-2.88	-3.00	-3.17					
1	3	-0.83	-0.81	-0.75	-0.77	-0.82					
2	1	-4.54	-4.52	-4.25	-4.25	-4.36					
2	2	-4.86	-4.83	-4.52	-4.51	-4.60					
2	3	-4.86	-4.83	-4.52	-4.51	-4.60					
3	1	-3.42	-3.41	-2.91	-3.05	-3.14					
3	2	-3.42	-3.41	-2.91	-3.05	-3.14					
3	3	-1.75	-1.73	-1.46	-1.49	-1.54					
4	1	-2.13	-2.08	-1.98	-2.20	-2.11					
4	2	-2.13	-2.08	-1.98	-2.20	-2.11					
4	3	-1.10	-1.05	-1.02	-1.03	-1.01					
5	1	-1.72	-1.76	-1.68	-1.68	-1.57					
5	2	-1.31	-1.34	-1.24	-1.31	-1.42					
5	3	-0.66	-0.68	-0.59	-0.70	-0.94					

Separation of above- and below-ground living biomass

Carbon stock of total living biomass can be separated into above- and below-ground components using the ratios listed in Table 6-20. Under the UNFCCC both pools were merged, under the Kyoto Protocol the pools were reported separately (see chp. 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 below-ground living biomass. The ratios are retrieved from the NFI (Brändli 2010: Table 95).

NFI region	Elevation [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

6.4.2.6 Productive forests (CC12): carbon stocks in dead wood, litter and in soils

Dead wood - carbon stock

Carbon stock in dead wood depends on the available volume in different decay stages, and on the associated wood density and carbon content. The influence of wood decay on wood density and on carbon content of dead wood was investigated by Dobbertin and Jüngling (2009). For the two dominant tree species in Swiss forests, Norway spruce (*Picea abies*) and European beech (*Fagus sylvatica*), a significant decrease in wood density from alive trees to wood in advanced decay (duff wood) was found, i.e., Norway spruce (0.39 to 0.247 g cm⁻³) and beech (0.56 to 0.233 g cm⁻³; cf. Tab. 1 in Didion et al. 2014a). Carbon content varied very little (± 1.2 to 1.4%) between alive trees and dead wood in different decay stages. The findings by Dobbertin and Jüngling (2009) are consistent with recent data from Switzerland for Norway spruce (Wunder and Bund 2015).

The total amount of carbon in the total dead wood pool (TDW) in Switzerland consists of two components:

$$\text{TDW} = \text{CWD} + \text{DRoots}$$

where

- CWD (coarse woody debris) comprises a) stemwood of standing dead trees ≥ 12 cm (diameter at breast height; dbh) and of lying dead trees ≥ 7 cm dbh, b) branchwood ≥ 7 cm in diameter
- DRoots consist of dead coarse roots $> \text{ca. } 5$ mm in diameter

A time series of carbon stocks in dead wood was simulated with the soil carbon model Yasso07 (Didion and Thürig 2015; see description in chp. 6.4.2.7). 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 stocks

Soil carbon stocks were estimated by Nussbaum et al. (2012, 2014) based on soil profiles and robust geostatistical methods. The soil profiles are part of a database maintained at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). The data were collected over the past 30 years ($N=1033$ sites) distributed among different forest types throughout Switzerland. The same dataset was re-analysed ($N=1030$; Nussbaum et al. 2012) to update estimates of carbon stocks in litter (organic soil horizons L - litter, F - fermentation and H - humus) prepared by Moeri (2007).

The data for litter and soil carbon stocks were stratified by the five NFI production regions and three elevation levels (Table 6-21). The estimated national average carbon stocks in mineral forest soils are 79.9 t C ha^{-1} (0–30 cm topsoil) and $125.8 \text{ t C ha}^{-1}$ (0–100 cm), respectively (Nussbaum et al. 2014), and 16.7 t C ha^{-1} in the organic soil horizons (litter) of mineral forest soils (Tab. 3 in Nussbaum et al 2012).

The sites in the WSL soil database which were used by Nussbaum et al. (2012, 2014) and by Moeri (2007) 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 1990–2014.

Table 6-21: Dead wood stock (TDW; stockC_d) in Swiss productive forests (CC12) by spatial stratum in t C ha⁻¹ for 1990 (Didion and Thürig 2015). Carbon stock in organic soil horizons (litter; stockC_h; Tab. 3 in Nussbaum et al. 2012) used for CC12, CC13 and in mineral soil (0–30 cm; stockC_s; Table 5 in Nussbaum et al. 2012, Nussbaum et al. 2014) of forest soils are assumed to be representative for 1990–2014. The data are stratified by five NFI production regions and three elevation zones. Dead wood and litter stocks in NFI region 2, 601–1200 and >1200 m are aggregated due to the low number of samples >1200 m. Average values ± single standard errors are given.

NFI region	Elevation [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	5.74 ± 0.01	9.51 ± 1.57	82.65 ± 3.34
1	601-1200	6.01 ± 0.01	7.53 ± 0.70	102.03 ± 3.56
1	>1200	6.75 ± 0.06	7.76 ± 1.74	121.34 ± 5.39
2	<601	8.96 ± 0.04	8.70 ± 0.68	55.40 ± 1.55
2	601-1200	8.75 ± 0.01	11.42 ± 1.45	62.12 ± 1.68
2	>1200	8.75 ± 0.01	11.42 ± 1.45	122.00 ± 7.07
3	<601	10.78 ± 0.01	7.51 ± 1.25	66.10 ± 2.06
3	601-1200	9.35 ± 0.01	16.29 ± 1.55	57.91 ± 2.00
3	>1200	7.74 ± 0.01	26.21 ± 4.77	95.78 ± 3.27
4	<601	8.48 ± 0.01	3.15 ± 0.47	66.47 ± 2.44
4	601-1200	7.85 ± 0.02	19.99 ± 2.64	74.39 ± 2.42
4	>1200	7.97 ± 0.01	33.37 ± 3.53	69.48 ± 1.85
5	<601	2.80 ± 0.01	8.22 ± 1.62	102.37 ± 4.07
5	601-1200	3.44 ± 0.01	11.03 ± 2.11	108.99 ± 4.09
5	>1200	2.92 ± 0.01	30.77 ± 5.43	107.08 ± 4.11
Switzerland		7.46 ± 0.00	16.73 ± 0.83	79.93 ± 1.52

Table 6-22 Carbon stock in dead wood for CC12, 1990–2014. Highlighted data for 1990 are displayed in Table 6-4 and 6-21.

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC12: carbon stock in dead wood (stockCd,i) [t C ha ⁻¹]											
1	1	5.75	5.77	5.76	5.76	5.72	5.71	6.14	6.51	6.82	7.08
1	2	6.01	6.00	5.96	5.93	5.87	5.85	5.91	5.95	5.98	6.00
1	3	6.76	6.81	6.84	6.87	6.87	6.91	6.66	6.40	6.18	5.98
2	1	8.96	8.97	8.94	8.90	8.83	8.79	9.14	9.43	9.67	9.86
2	2	8.75	8.75	8.72	8.68	8.61	8.58	8.97	9.29	9.57	9.81
2	3	8.75	8.75	8.72	8.68	8.61	8.58	8.97	9.29	9.57	9.81
3	1	10.79	11.05	11.27	11.45	11.56	11.72	11.40	11.09	10.81	10.55
3	2	9.36	9.40	9.40	9.41	9.37	9.39	9.91	10.34	10.74	11.10
3	3	7.74	7.61	7.45	7.33	7.18	7.07	7.02	6.93	6.86	6.80
4	1	8.49	8.73	8.91	9.08	9.20	9.35	9.10	8.87	8.67	8.49
4	2	7.86	7.80	7.72	7.65	7.57	7.52	7.50	7.46	7.43	7.40
4	3	7.98	8.00	8.00	8.01	8.00	8.02	7.95	7.85	7.78	7.71
5	1	2.81	2.72	2.64	2.56	2.49	2.43	2.37	2.32	2.26	2.22
5	2	3.44	3.52	3.58	3.63	3.67	3.73	3.48	3.24	3.03	2.85
5	3	2.92	2.89	2.85	2.82	2.78	2.76	2.74	2.71	2.68	2.66

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: carbon stock in dead wood (stockCd,i) [t C ha ⁻¹]											
1	1	7.32	7.54	7.72	7.99	8.16	8.35	8.49	8.57	8.68	8.81
1	2	6.01	6.03	6.03	6.07	6.09	6.12	6.33	6.49	6.66	6.82
1	3	5.78	5.61	5.44	5.29	5.16	5.06	4.87	4.70	4.55	4.42
2	1	10.03	10.18	10.31	10.53	10.67	10.83	10.91	10.93	10.98	11.06
2	2	10.01	10.20	10.36	10.59	10.75	10.93	11.11	11.23	11.38	11.53
2	3	10.01	10.20	10.36	10.59	10.75	10.93	11.11	11.23	11.38	11.53
3	1	10.30	10.09	9.87	9.75	9.60	9.48	10.11	10.61	11.06	11.47
3	2	11.41	11.71	11.95	12.22	12.47	12.73	12.71	12.66	12.65	12.66
3	3	6.73	6.68	6.61	6.56	6.52	6.49	6.50	6.51	6.53	6.55
4	1	8.32	8.17	8.02	7.93	7.83	7.76	8.11	8.39	8.66	8.92
4	2	7.35	7.33	7.28	7.26	7.25	7.26	7.34	7.40	7.46	7.52
4	3	7.62	7.56	7.48	7.43	7.40	7.39	7.41	7.42	7.43	7.46
5	1	2.17	2.13	2.09	2.06	2.03	2.01	2.13	2.22	2.30	2.37
5	2	2.68	2.53	2.39	2.27	2.15	2.06	2.10	2.14	2.18	2.21
5	3	2.63	2.62	2.59	2.58	2.56	2.57	2.77	2.94	3.11	3.26

NFI	Elev.	2010	2011	2012	2013	2014					
CC12: carbon stock in dead wood (stockCd,i) [t C ha ⁻¹]											
1	1	8.95	9.03	9.11	9.21	9.23					
1	2	6.99	7.10	7.22	7.34	7.40					
1	3	4.31	4.17	4.06	3.96	3.85					
2	1	11.17	11.22	11.27	11.33	11.31					
2	2	11.72	11.82	11.93	12.05	12.08					
2	3	11.72	11.82	11.93	12.05	12.08					
3	1	11.87	12.15	12.45	12.74	12.89					
3	2	12.71	12.67	12.68	12.72	12.65					
3	3	6.59	6.57	6.58	6.61	6.59					
4	1	9.20	9.40	9.58	9.78	9.90					
4	2	7.61	7.63	7.67	7.73	7.73					
4	3	7.50	7.49	7.49	7.51	7.50					
5	1	2.45	2.51	2.57	2.62	2.65					
5	2	2.25	2.28	2.31	2.34	2.36					
5	3	3.42	3.54	3.65	3.77	3.86					

6.4.2.7 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 mineral forest soil (0–100 cm), 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 and Thürig (2015). 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. 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. For an overview Table 6-21 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 litter and deadwood can be found in Table 6-23 (mineral soil is not shown as those values are very small, -0.003 to $0.004 \text{ t C ha}^{-1} \text{ yr}^{-1}$). Carbon stocks and carbon stock changes were validated as described in Didion et al. (2015).

Table 6-23 Net carbon stock change in dead wood and in litter for productive forest (CC12), 1990–2014.
Highlighted data for 1990 are displayed in Table 6-4. Positive values refer to gains in carbon stock; negative values refer to losses in carbon stock.

NFI	Elev.	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	-0.02	0.02	-0.01	0.00	-0.04	-0.01	0.43	0.37	0.31	0.26
1	2	-0.05	-0.01	-0.04	-0.03	-0.06	-0.03	0.06	0.04	0.03	0.02
1	3	0.03	0.06	0.03	0.03	0.00	0.03	-0.25	-0.26	-0.22	-0.20
2	1	-0.06	0.01	-0.03	-0.03	-0.08	-0.03	0.34	0.30	0.24	0.19
2	2	-0.06	0.00	-0.03	-0.03	-0.07	-0.03	0.38	0.32	0.28	0.24
2	3	-0.06	0.00	-0.03	-0.03	-0.07	-0.03	0.38	0.32	0.28	0.24
3	1	0.24	0.27	0.21	0.18	0.12	0.16	-0.32	-0.31	-0.28	-0.26
3	2	0.00	0.04	0.00	0.01	-0.03	0.01	0.52	0.43	0.40	0.36
3	3	-0.18	-0.14	-0.15	-0.13	-0.15	-0.10	-0.05	-0.09	-0.06	-0.06
4	1	0.21	0.24	0.19	0.17	0.12	0.15	-0.25	-0.23	-0.19	-0.19
4	2	-0.09	-0.06	-0.08	-0.06	-0.09	-0.05	-0.01	-0.04	-0.03	-0.04
4	3	0.00	0.03	0.00	0.02	-0.02	0.02	-0.07	-0.09	-0.07	-0.08
5	1	-0.10	-0.09	-0.08	-0.08	-0.07	-0.06	-0.06	-0.06	-0.05	-0.05
5	2	0.08	0.08	0.06	0.06	0.04	0.05	-0.25	-0.24	-0.21	-0.18
5	3	-0.04	-0.03	-0.04	-0.03	-0.04	-0.02	-0.02	-0.03	-0.02	-0.02

NFI	Elev.	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	0.24	0.22	0.18	0.26	0.18	0.19	0.13	0.08	0.11	0.12
1	2	0.01	0.02	0.00	0.04	0.02	0.04	0.20	0.16	0.17	0.16
1	3	-0.20	-0.17	-0.17	-0.14	-0.13	-0.11	-0.18	-0.17	-0.15	-0.14
2	1	0.17	0.15	0.13	0.22	0.14	0.16	0.08	0.02	0.06	0.08
2	2	0.21	0.19	0.16	0.23	0.16	0.18	0.18	0.12	0.15	0.15
2	3	0.21	0.19	0.16	0.23	0.16	0.18	0.18	0.12	0.15	0.15
3	1	-0.25	-0.21	-0.22	-0.13	-0.15	-0.12	0.64	0.50	0.45	0.42
3	2	0.31	0.30	0.24	0.27	0.25	0.25	-0.02	-0.05	-0.01	0.01
3	3	-0.07	-0.05	-0.07	-0.06	-0.04	-0.02	0.01	0.01	0.02	0.02
4	1	-0.16	-0.15	-0.15	-0.09	-0.10	-0.06	0.34	0.28	0.27	0.26
4	2	-0.05	-0.03	-0.05	-0.02	-0.01	0.01	0.08	0.06	0.06	0.07
4	3	-0.08	-0.06	-0.08	-0.05	-0.03	-0.02	0.02	0.01	0.01	0.02
5	1	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	0.11	0.09	0.08	0.07
5	2	-0.17	-0.15	-0.14	-0.12	-0.11	-0.09	0.04	0.04	0.04	0.03
5	3	-0.03	-0.02	-0.02	-0.01	-0.01	0.00	0.20	0.18	0.16	0.15

NFI	Elev.	2010	2011	2012	2013	2014					
CC12: net change in dead wood (changeCd,i) [t C ha ⁻¹ yr ⁻¹]											
1	1	0.14	0.09	0.08	0.09	0.02					
1	2	0.17	0.11	0.12	0.12	0.06					
1	3	-0.11	-0.14	-0.11	-0.10	-0.12					
2	1	0.11	0.05	0.05	0.06	-0.02					
2	2	0.18	0.10	0.11	0.12	0.02					
2	3	0.18	0.10	0.11	0.12	0.02					
3	1	0.40	0.29	0.30	0.29	0.14					
3	2	0.06	-0.04	0.01	0.03	-0.07					
3	3	0.05	-0.02	0.01	0.02	-0.02					
4	1	0.28	0.20	0.19	0.20	0.11					
4	2	0.09	0.02	0.04	0.06	0.00					
4	3	0.05	-0.01	0.00	0.02	-0.02					
5	1	0.08	0.06	0.06	0.05	0.04					
5	2	0.04	0.03	0.03	0.03	0.02					
5	3	0.16	0.12	0.12	0.12	0.10					

(Table 6-23 continued)

NFI	Elev.	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	-0.11	0.10	-0.06	-0.02	-0.15	-0.04	0.26	0.13	0.02	-0.03
1	2	-0.09	0.07	-0.06	-0.02	-0.14	-0.01	0.24	0.08	0.07	0.02
1	3	-0.18	-0.06	-0.13	-0.07	-0.15	-0.02	0.06	-0.06	0.00	-0.02
2	1	-0.14	0.08	-0.06	-0.05	-0.16	-0.03	0.24	0.13	0.04	-0.03
2	2	-0.06	0.12	-0.01	-0.01	-0.14	0.01	0.23	0.09	0.06	0.00
2	3	-0.06	0.12	-0.01	-0.01	-0.14	0.01	0.23	0.09	0.06	0.00
3	1	0.10	0.23	0.09	0.05	-0.10	0.07	0.09	-0.01	-0.04	-0.04
3	2	-0.09	0.06	-0.07	-0.03	-0.16	0.02	0.27	0.05	0.09	0.06
3	3	-0.12	0.01	-0.11	-0.02	-0.17	0.03	0.36	0.07	0.17	0.13
4	1	-0.11	0.04	-0.07	-0.05	-0.14	-0.01	0.08	0.00	0.03	-0.03
4	2	-0.11	0.01	-0.10	-0.03	-0.15	0.02	0.19	0.02	0.08	0.01
4	3	-0.08	0.05	-0.11	0.00	-0.17	0.05	0.25	0.04	0.13	0.02
5	1	-0.15	-0.09	-0.11	-0.09	-0.10	-0.01	0.36	0.21	0.20	0.15
5	2	-0.17	-0.10	-0.13	-0.09	-0.12	-0.01	0.34	0.16	0.16	0.13
5	3	0.00	0.07	-0.06	0.02	-0.10	0.09	0.50	0.20	0.23	0.19

NFI	Elev.	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	-0.06	0.24	0.00	0.08	-0.23	-0.27	-0.12	-0.05
1	2	0.00	0.02	-0.05	0.14	0.02	0.10	-0.02	-0.09	0.01	0.05
1	3	-0.05	0.00	-0.06	0.02	0.02	0.06	0.04	0.00	0.05	0.05
2	1	-0.03	-0.03	-0.05	0.21	0.00	0.08	-0.20	-0.27	-0.12	-0.04
2	2	-0.03	0.00	-0.06	0.17	0.01	0.10	-0.18	-0.24	-0.10	-0.04
2	3	-0.03	0.00	-0.06	0.17	0.01	0.10	-0.18	-0.24	-0.10	-0.04
3	1	-0.08	-0.03	-0.10	0.13	-0.01	0.07	0.07	-0.13	-0.03	0.03
3	2	-0.01	0.05	-0.06	0.07	0.05	0.10	-0.21	-0.22	-0.10	-0.06
3	3	0.03	0.11	-0.03	0.03	0.11	0.14	-0.22	-0.17	-0.06	-0.06
4	1	-0.02	-0.02	-0.08	0.10	0.02	0.10	-0.05	-0.13	-0.04	0.00
4	2	-0.03	0.04	-0.08	0.10	0.08	0.14	-0.04	-0.11	-0.04	0.02
4	3	-0.04	0.06	-0.09	0.11	0.13	0.19	-0.10	-0.13	-0.07	0.02
5	1	0.08	0.12	0.04	0.13	0.04	0.15	0.21	0.07	0.06	0.06
5	2	0.06	0.10	0.02	0.12	0.04	0.16	0.17	0.04	0.06	0.06
5	3	0.09	0.15	0.02	0.14	0.09	0.29	0.15	0.04	0.09	0.08

NFI	Elev.	2010	2011	2012	2013	2014					
CC12: net change in litter (changeCh,i) [t C ha ⁻¹ yr ⁻¹]											
1	1	0.03	-0.10	-0.07	0.00	-0.17					
1	2	0.14	-0.09	0.00	0.05	-0.15					
1	3	0.14	-0.09	0.03	0.06	-0.10					
2	1	0.04	-0.08	-0.05	0.00	-0.17					
2	2	0.06	-0.11	-0.03	0.02	-0.20					
2	3	0.06	-0.11	-0.03	0.02	-0.20					
3	1	0.11	-0.11	0.04	0.07	-0.22					
3	2	0.07	-0.18	-0.02	0.03	-0.20					
3	3	0.11	-0.24	-0.02	0.04	-0.19					
4	1	0.09	-0.08	-0.01	0.03	-0.16					
4	2	0.14	-0.14	-0.01	0.06	-0.15					
4	3	0.15	-0.18	-0.07	0.05	-0.16					
5	1	0.14	0.00	0.03	0.03	-0.09					
5	2	0.15	-0.04	0.02	0.04	-0.07					
5	3	0.23	-0.11	0.00	0.07	-0.08					

Carbon stock changes in the soil pool are small (Figure 6-5). The Yasso07 data are supported by measurements of the Swiss Soil Monitoring Network (see chp. 6.4.4). Carbon stock changes in litter are higher and more erratic than changes in the dead wood and soil pools (). 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 after 2000 is to a large extent driven by the increase in the dead wood stocks following the hurricane Lothar (1999). As Lothar occurred between the NFI 2 (1993–1995) and NFI 3 (2004–2006), 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 windthrown trees were removed from the forest, the dead wood stock 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 carbon over the coming decades. The trend of decreasing harvest rates for several years after NFI 3 (Table 6-18; harvesting rates slightly increase in 2013, 2014) further sustained the carbon sink of dead wood as mature trees, which could be harvested remain in the forest to potentially contribute to the dead wood pool. Large-scale disturbance events like Lothar that occur between two consecutive NFIs strongly affected 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).

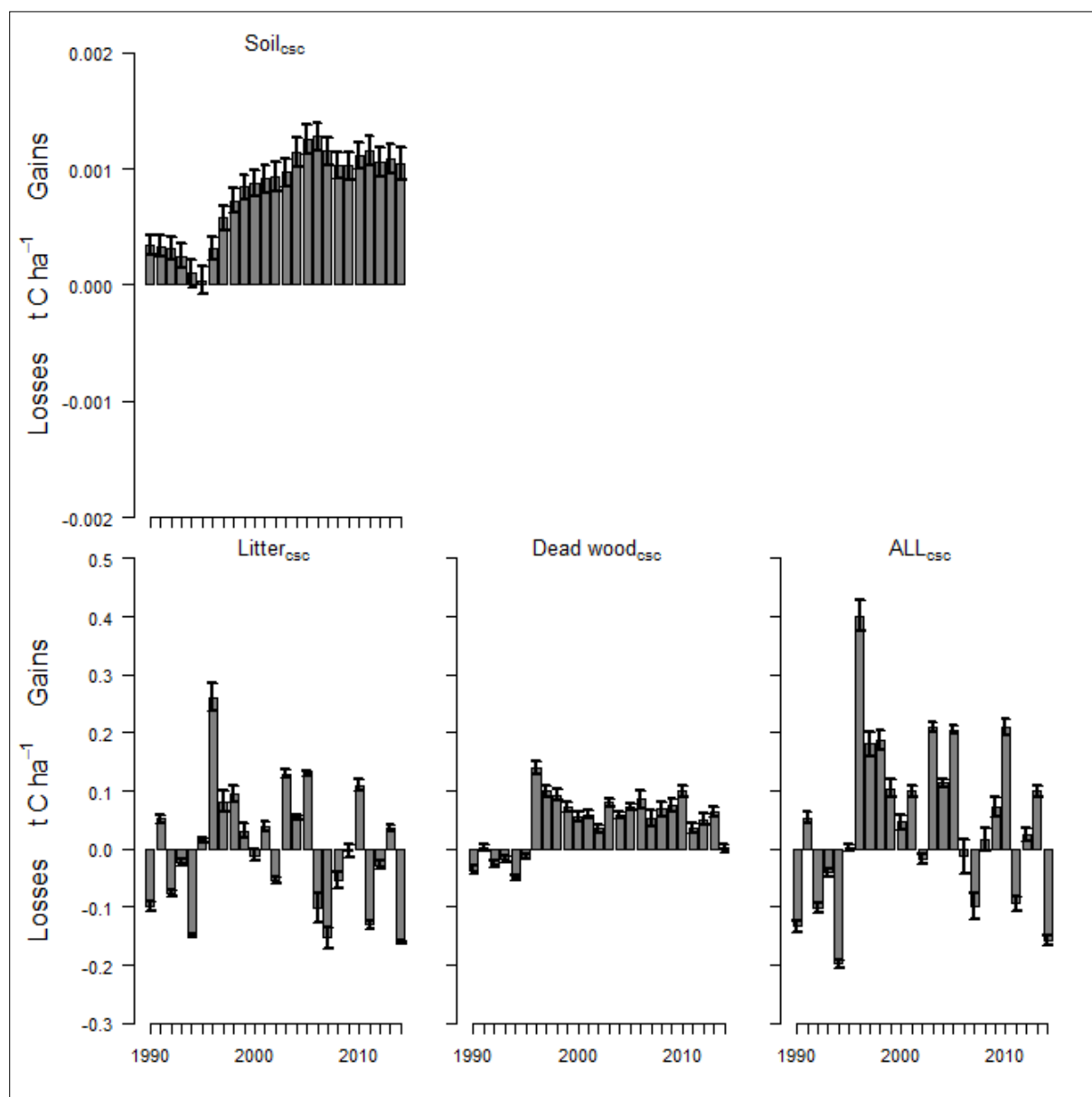


Figure 6-5 Mean carbon stock change (CSC) for three pools soil (0–100 cm), litter, dead wood and their sum (ALL) in t C ha⁻¹ (equals Mg C ha⁻¹). Note the difference of the y-axis scale between Soil_{CSC} and Litter_{CSC}, Dead wood_{CSC} and ALL_{CSC}, respectively. Negative values indicate losses in carbon stock, positive values gains in carbon stock. The error bars indicate the double standard error.

6.4.2.8 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 the NFI. Unproductive forests 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 on 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 2015l) are distributed over the productive forests, total harvesting in Swiss forests was accounted for under productive forests (CC12 remaining), and thus all harvesting amounts were accounted for.

The NFI does not include 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 were visited for the first time, but only a limited number of attributes such as tree species, stem diameter and crown cover were collected.
- **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, including rocky sites and 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 combination categories of “pastures or grasslands with cluster of trees” (LC47/LU222, LC47/LU223, LC47/LU242; cf. Table 6-6).

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 Duggelin 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. In a case study, Duggelin 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 (LU 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 vegetation (LC 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 m³ ha⁻¹ was 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 $51.38 \text{ t C ha}^{-1}$ (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:

$$[\text{weighted C content}]_i = \text{RS}_i * \text{CS} + (1 - \text{RS}_i) * \text{CI}$$

where RS_i is the rate of the brush and inaccessible forest per spatial stratum i ,

CS is the carbon content of brush and inaccessible forest ($20.45 \text{ t C ha}^{-1}$),

CI is the carbon content of forest on unproductive areas ($51.38 \text{ t C ha}^{-1}$).

Table 6-24 shows the carbon content per spatial stratum in t C ha^{-1} .

Table 6-24 Area of brush forest, inaccessible 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, inaccessible forest and forest not covered by NFI were determined based on AREA data where brush forest corresponds to land use forest LU3XX classified as CC13, inaccessible stands to LU403 and LU422 classified as CC13, and forest not covered by NFI to LU242 classified as CC13 (see Table 6-6).

NFI region	Altitude [m]	Brush forest [ha]	Inaccessible 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 (stock _{C_{i,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 were assumed to be the same as for productive forests CC12, which were 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 was 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 similarly to 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 were assumed to be in balance. This approach is confirmed by two studies in which basal area and crown cover were used as a proxy for the stock of living biomass. An increase in basal area or crown cover, respectively, was positively correlated with an increase in living biomass (e.g. Nowak and Crane 2002). Living biomass in brush forests was increasing during the stage of establishment: the stand developed 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 was observed when natural disturbances like avalanches or rock fall partially damaged the stand. The following studies provide evidence that living biomass in unproductive forests is not a source of carbon:

- 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 had increased over this 6 years period. Since no allometric functions were available for these stands, it was not possible to calculate stocks from these data. The authors estimated an increase in the mean basal area from 4.59 m² ha⁻¹ in 2006 to 5.47 m² 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 were expanding as summer pastures were abandoned. At these sites, an increase in crown cover was 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 was concluded that living biomass in unproductive forests was 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 reporting tables, this is transcribed into “gains (gain_{C_{l,i,13}}) = losses (loss_{C_{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 is 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 was concluded that mineral soils, litter, and dead wood in unproductive forest were not a net source of carbon. Carbon changes in mineral soils, litter, and dead wood were 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 or small-to-medium rock fall (Huber and Frehner 2014). By stabilizing soils, brush forests act as a very good protection against soil erosion (Richard 1995; Stangle 2004).
- Green Alder has an ameliorative effect on the soil 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 were calculated because carbon stocks of litter and soil carbon are equal for CC12 and CC13. Reasons why these stocks were assumed to be equal are (1) data are not available (see above) and (2) this assumption 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 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) was applied for all pools of unproductive forests.

6.4.2.9 Afforestations (CC11)

Living biomass: growing stock and changes in growing stock

Thürig and Traub (2015; Table 6) estimated the average carbon stock and gains and losses in living biomass of afforestations in Switzerland. Data are shown in Table 6-4.

In Switzerland, land-use change from non-forest to forest is usually not caused by plantation but by abandonment of agricultural land-use (Rutherford et al. 2008). These newly forested areas are often characterized by continuously growing trees with a large diversity in diameter at breast height (DBH) and tree age. Afforested stands established by plantation or even-aged young forest stands, however, are more characterized by a large amount of trees in small DBH classes and sometime a very few trees in large DBH classes. Thürig and Traub (2015) selected NFI-plots to represent both types of afforestation. Young stands were defined as stands that changed from non-forest land to forest land between two consecutive NFIs with at least 85% of the trees with a dbh smaller or equal to 20 cm. As there is almost no land-use change from non-forest to forest below 600 m above sea level, results were stratified for below 1200 m above sea level and above 1200 m. As a consequence of the plot selection, small losses caused by natural mortality or cut of single trees occur.

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 stocks in litter and dead wood were conservatively assumed to be zero (IPCC 2006, chp. 4.3.2; see also chp. 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 were zero.

Soil: carbon stock and carbon stock changes

The estimates for soil carbon stocks from Nussbaum et al. (2012, 2014) were used for afforestations (CC11; see Table 6-4 and Table 6-21). Carbon stock changes were calculated with the stock-difference method (see Table 6-3).

6.4.2.10 Organic soils

Organic soils - carbon stock

The mean soil organic carbon stock (0–30 cm) for organic soils under forest land is $145.6 \pm 24.1 \text{ t C ha}^{-1}$ (Wüst-Galley et al. 2016; cf. Table 6-4).

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 were conservatively reported to be drained (which is definitely an overestimation).

In order to calculate CO₂ emissions due to drainage, the default emission factor of 2.6 t CO₂-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).

6.4.2.11 N₂O emissions from forest land

Fertilization of forests is prohibited by the Swiss forest law and adherent ordinances (Swiss Confederation 1991, 1992). The Law on Forests (cf. Art. 18 in Swiss Confederation 1991) states: "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. Additionally, the "Ordinance on Chemical Risk Reduction" (Swiss Confederation 2005) prohibits the application of fertilizers, including liming, in forests. Furthermore, these management practices have never been common practice in Swiss forestry. There is thus considerable evidence to justify the assumption that this situation is valid since 1990. Therefore, no emissions were reported in category A. in CRF Table4(I).

N₂O emissions from drainage of organic soils was calculated for forest land with an emission factor of 2.8 kg N₂O-N ha⁻¹ and reported in category A in CRF Table4(II) This is the default value given in the Wetlands Supplement (IPCC 2014a, Table 2.5) for temperate forest land.

The calculation of emissions reported in CRF Table4(III) and Table4(IV), i.e. N₂O emissions from Nitrogen Mineralization, is described in chp. 6.10.

6.4.2.12 Emissions from wildfires

Data on wildfires affecting Swiss forest land were obtained from cantonal authorities and were compiled by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL, Swissfire database, <http://www.wsl.ch/swissfire>). Table 6-25 shows the time series 1990 to 2014 of the area burnt and the associated emissions.

As controlled burning is not allowed in Switzerland all fires were considered "wildfires". The number and area of the fires were 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 (or afforestations under KP Art. 3.3) 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 lightning strikes.

CO₂ emissions from wildfires were encompassed ("IE") in the data in CRF Table4.A. Losses in living biomass are reflected in the NFI data-set. Changes in dead wood, litter and soil

carbon calculated with Yasso07 also cover the influence of forest fires and other disturbances by using NFI-data as an input (see chp. 2.2.3 in Didion and Thürig 2015).

CH₄ and N₂O emissions from wildfires (Table 6-25) were calculated using Equation 2.27 in Volume 4 of IPCC (2006) with the following parameters:

- For CH₄ the default emission factor of 4.7 g kg⁻¹ dry matter burned and for N₂O, the default emission factor of 0.26 g (kg combusted biomass)⁻¹ was applied (IPCC 2006 Volume 4, Table 2.5).
- The mass of available fuel encompasses carbon stock of living biomass, litter and dead wood. On average, the amount of living biomass amounts to 92.84 t C ha⁻¹ or 185.67 t biomass ha⁻¹. This value was 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) as a weighted value of the regions affected by forest fires (82% of the fires occur in the southern Alps, 15% in the Central Alps; FOEN 2015). The average amount of litter in Swiss forests was 16.73 t C ha⁻¹ or 33.40 t biomass ha⁻¹ (Nussbaum et al. 2012, 2014) and the average stock of dead wood amounted to 8.46 t C ha⁻¹ or 16.93 t biomass ha⁻¹ (Didion and Thürig 2015).
- The fraction of the biomass combusted was 0.45 (IPCC 2006 Volume 4, Table 2.6).

CH₄ and N₂O emissions caused by wildfires were reported in CRF Table4(V). CO₂ emissions caused by wildfires are included in CRF Table4.A ("IE"; as described above). In CRF Table4(V), the emissions from all forest fires were 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 6-25 Productive forest land affected by wildfires (WSL, Swissfire database) and resulting GHG emissions 1990–2014.

Year	Area burnt [ha]	CH ₄ [t]	N ₂ O [t]
1990	1061	529.38	29.28
1991	70	35.18	1.95
1992	27	13.42	0.74
1993	18	8.82	0.49
1994	233	116.38	6.44
1995	363	181.03	10.01
1996	232	115.73	6.40
1997	1386	692.01	38.28
1998	197	98.57	5.45
1999	11	5.59	0.31
2000	47	23.63	1.31
2001	13	6.43	0.36
2002	412	205.50	11.37
2003	526	262.46	14.52
2004	25	12.28	0.68
2005	39	19.50	1.08
2006	111	55.34	3.06
2007	235	117.23	6.48
2008	37	18.67	1.03
2009	48	24.19	1.34
2010	26	12.78	0.71
2011	167	83.52	4.62
2012	23	11.67	0.65
2013	24	12.08	0.67
2014	43	21.56	1.19

6.4.2.13 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 by Andreani-Aksoyoglu and Keller (1995). Approximately 97% of the total emissions were monoterpene and the rest consisted 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 2014 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 $8.95 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$, mean C&M $-7.64 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$, resulting mean net change in stem volume $1.31 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$
 - relative uncertainty of mean net change in volume: 54% (double Standard Error (2SE); for calculation see Thürig et al. 2015)
- Carbon content in solid wood: The uncertainty was estimated to be 2% (2SE) based on Monni et al. 2007 (2% relative Standard Deviation; RSD), and Lamtom and Savidge 2003 (4–8% RSD);
- Biomass expansion function (for the Swiss GHG inventory, allometric functions for individual trees are applied) and conversion into mass with wood density: The uncertainty related to the expansion and conversion of stem volume to whole tree biomass was based on Lehtonen and Heikkinen 2015 including 21.2% (2SE) sampling uncertainty and 22.2% (2SE) model uncertainty.

Thus, the total uncertainty of net carbon stock change in living biomass ($U_{\text{liv.biom}}$) in terms of carbon per unit area can be calculated following equation 3.1 in chp. 'Quantifying Uncertainties' (volume 1 of IPCC 2006)

- $U_{\text{liv.biom}} = (54^2 + 2^2 + 21.2^2 + 22.2^2)^{0.5} = 62.15\%$
- The corresponding mean gain $X_{\text{liv.biom}}$ is $-0.53 \text{ t C ha}^{-1} \text{ yr}^{-1}$, i.e. a removal.

The uncertainty in the estimates of annual stock changes derived with the Yasso07 model originates from the following sources as described in Didion et al. (2015):

- spatial interpolation of the gridded climate data prepared by the Federal Office of Meteorology and Climatology MeteoSwiss (MeteoSwiss 2013a, b) (chp. 3.3 in Didion et al. 2015);
- C input estimates obtained from the NFI (measurement errors, allometries, etc.) (chp. 2.2.3 in Didion et al. 2015);
- decomposition parameters used in the Yasso07 model (chp. 2.2.1 in Didion et al. 2015).

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. Based on preliminary results from MeteoSwiss (Vogel 2013), the additional uncertainty for carbon stock change estimates was expected to be minor.

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 chp. 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, Natural Resources Institute Finland. 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. (2015).

Based on this approach the absolute uncertainty (double standard error) of the estimates of C stock changes are:

$$U_{\text{Soil.abs}} = 0.00014, U_{\text{Litter.abs}} = 0.00371 \text{ and } U_{\text{Deadwood.abs}} = 0.00708 \text{ t C ha}^{-1} \text{ yr}^{-1}$$

which correspond to the relative uncertainties (2SE) of

$$U_{\text{Soil}} = 13.18\%, U_{\text{Litter}} = 2.31\% \text{ and } U_{\text{Deadwood}} = 679.46\%$$

based on the mean carbon stock change in 2014 in soil X_{Soil} of $0.001 \text{ t C ha}^{-1} \text{ yr}^{-1}$, in litter X_{Litter} of $-0.160 \text{ t C ha}^{-1} \text{ yr}^{-1}$, and in dead wood X_{Deadwood} of $0.001 \text{ t C ha}^{-1} \text{ yr}^{-1}$ where positive values refer to gains in carbon stock; negative values refer to losses in carbon stock. The total uncertainty associated with carbon stock change in all four pools was estimated using equation 3.2 in chp. 'Quantifying Uncertainties' (volume 1 of IPCC 2006):

$$U_{\text{tot}} = \frac{\sqrt{(U_{\text{liv.biom}} * X_{\text{liv.biom}})^2 + (U_{\text{soil}} * X_{\text{soil}})^2 + (U_{\text{litter}} * X_{\text{litter}})^2 + (U_{\text{Deadwood}} * X_{\text{Deadwood}})^2}}{|X_{\text{liv.biom}} + X_{\text{soil}} + X_{\text{litter}} + X_{\text{Deadwood}}|}$$

with

$$U_{\text{tot}} = \frac{\sqrt{(62.15 * -0.53)^2 + (13.18 * -0.001)^2 + (2.31 * 0.160)^2 + (679.46 * -0.001)^2}}{|(-0.53) + (-0.001) + 0.160 + (-0.001)|}$$

Thus, the resulting relative uncertainty of the total carbon stock change for forest land is 47.87%. For the combined stock change from soil, litter and dead wood the uncertainty is 5%.

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-CO₂ emissions in the Good Practice Guidance (IPCC 2003, section 3.2.1.4.2.4) and also corresponds to the uncertainty of the combustion factor from IPCC 2006 (Table 2.6, mean=0.45, 2SE=0.32).

Uncertainties of activity data of category 4A Forest land are described in chp. 6.3.3. Table 6-5 lists the relative uncertainties in the LULUCF sector: an uncertainty of 48% was calculated for afforestations (4A2), 50% for Deforestations (4E2) and 48% 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 chp. 6.4.2.5).

Consistent time series of dead wood, litter and soil carbon were calculated with the model Yasso07 (see Didion and Thürig 2015 and chp. 6.4.2.7).

6.4.4 Category-specific QA/QC and verification

The general QA/QC measures are described in chp. 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 IPCC-default values and NFI-data from neighbouring countries is included in Thürig and Traub (2015). The study supports the plausibility of the Swiss estimates: they are well within the range of the IPCC default values, as well as the Austrian and German estimates.

Swiss estimates were also compared with literature values. Based on data of the German forest inventory (*Bundeswaldinventur II*), Paul et al. (2009) reported a carbon sequestration rate of $2.8 \text{ t C ha}^{-1} \text{ a}^{-1}$ in the first 20 years following an afforestation.

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 accumulation rates of $0.17\text{--}0.20 \text{ t C ha}^{-1} \text{ yr}^{-1}$. Further relevant studies are discussed in chp. 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. Rühr and Eugster (2009) 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 permanent observation sites throughout Switzerland. Based on the classification of the NABO sites according to the 18 LULUCF combination categories (CC), 28 sites are located in forests (SAEFL 1993).

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 is measured with a modified Walkley and Black method (ACW/ART 1998) in the same laboratory since 2006. In 2012 a parallel SOC analysis by a C/N- Analyser (ThruSpec, Leco company) was introduced and since then the soil samples of almost all sites are measured 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 regression between SOC-Walkley and Black measurements to TOC showed a high coefficient of determination of 97%. Therefore, the dataset was harmonized by correcting the SOC values (Walkley and Black) to the measurements of the C/N-Analyser; in future soil campaigns, only the C/N-Analyser method will be used for SOC analysis. The applied procedure ensures that the SOC dataset (n =

1'884 measurements) presented here and in chp. 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 was included in calculating the carbon pools. Bulk density measurements and soil skeleton ($>2\text{mm}$) were measured at the monitoring sites in the 4th (2000–04) and 5th (2005–09) resampling 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 was subtracted 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 . It was presumed that the bulk density of the first three sampling campaigns ranged within the values measured in the 4th and 5th resampling campaign, and the variability of the measurements was propagated 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 one coniferous forest site was excluded as it 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 resampling campaign.

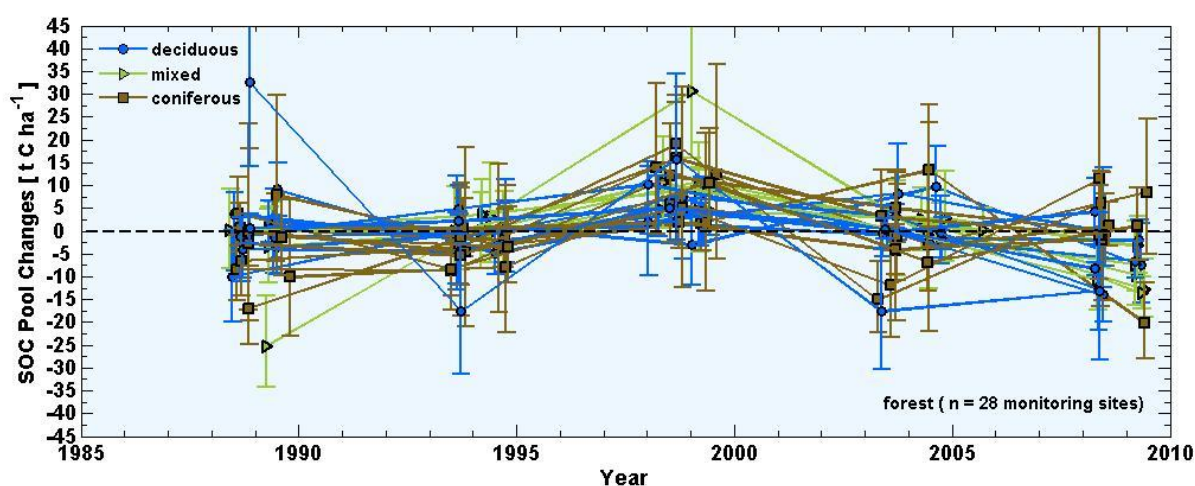


Figure 6-6 Time series of measured SOC pool changes in the top soil (0–20 cm) at the 28 NABO forest sites from the 1st to the 5th resampling campaigns. SOC pools were centred by the median SOC pool of all resamplings of the monitoring site. Each pool value presents the median of four bulked soil samples 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 elevation 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 resamplings within three years revealed short-term variation of the SOC content between $\pm 1.8\%$ and $\pm 0.6\%$ (simple standard error). Therefore, the majority of the measured temporal variation for all forest sites was interpreted as natural variation (noise) and not as real SOC changes (signal). This hypothesis 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 $\pm 1.5 \text{ t C ha}^{-1}$. 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 $< 2 \text{ mm}$. In this way, the 95% confidence interval of the mean SOC pool can probably be reduced to some degree.

In comparison, the mean change in SOC which was obtained with Yasso07 for the period 1991–2010 was $-0.00076 \pm 0.000026 \text{ t C ha}^{-1} \text{ yr}^{-1}$ (2SE; based on data in Didion et al. 2015). This value would correspond to $-0.0152 \text{ t C ha}^{-1}$ 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 2013 emission factor for mineral soil in South Finland, 26.2% in North Finland, and 24.1% for the net change in the whole country (Statistics Finland 2015: chp. 6.4.3.2). For living biomass, Finland reported 21.1% (Statistics Finland 2015: chp. 6.4.3.1).

6.4.5 Category-specific recalculations

Recalculations reported in submission 2015

- The most recent NFI data at the time (NFI 4b, covering the period 2009–2013) were applied for productive forests (CC12) (Thürig et al. 2015; see chp. 6.4.2.1).
- Carbon stocks of unproductive forests were updated using the data of Duggelin and Abegg (2011).
- N_2O emissions from drained organic soils were 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 $-2.6 \text{ t C ha}^{-1} \text{ yr}^{-1}$, i.e. the default emission factor for temperate drained forest according to the Wetland Supplement (IPCC 2014a, Table 2.1).

- Errors in the derivation of litter and dead wood inputs for the Yaso07 model were corrected (chapter 2.3 in Didion et al. 2014).

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).
- Country-specific values for growing stock and changes in growing stock of afforestations from a study by Thürig and Traub (2015) were implemented.
- According to IPCC (2006) carbon stock changes of all pools in forests were no longer averaged over three years; instead annual values were reported. Following these revisions, the complete time series since 1990 for carbon stocks and carbon stock changes in all pools were recalculated. In comparison to previous submissions (e.g. FOEN 2015), this recalculation resulted in a higher variability between individual years.
- The accuracy of the estimates of carbon stocks and carbon stock changes in dead wood, litter, and soil was improved by eliminating errors in the derivation of climate data driving the model simulations (see chp. 2.3 in Didion et al. 2015). The effect of the revised climate data on the estimates of carbon stock changes was negligible as the recalculated data were mainly within one and consistently within two standard errors of the results reported in the previous inventory (FOEN 2015).
- A country-specific value for soil carbon stocks of organic soils under forests was used (Wüst-Galley et al. 2016).
- Activity data on wildfires 1990–2013 were updated using data from the Swissfire database. The updates encompassed a correction of cantonal data and the reclassification of fires to the LULUCF categories. This reclassification concerned especially the category “non-productive” in the Swissfire database, which is no longer assigned to forest land but to grassland.

6.4.6 Category-specific planned improvements

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 next years.

The implementation of the model Yasso07 to improve the accuracy in the estimates of temporal changes in soil carbon, litter and dead wood will be further developed by, for example, deriving more accurate estimates of the inputs to the model. Also, further developments of the model by the developers at the Finnish Environment Institute and Tampere University of Technology will be evaluated for suitability for application in Switzerland; new parameters and a new model version are expected to be released in the course of 2016 (Järvenpää et al. in prep.). A preliminary version is currently being tested in Switzerland and a workshop for model users is planned for spring 2016 in Helsinki. 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>) aim 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

CO₂ from Cropland remaining cropland (level).

Approach 2 key category 4B1

CO₂ from Cropland remaining cropland (level).

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 above-ground 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 was applied.

In 2014, category 4B1 Cropland remaining cropland was a net source of 332.11 kt CO₂ mainly due to emissions from organic soils. Average living biomass was increasing slightly over the period 1990–2014. However, annual fluctuations in carbon stocks of biomass are considerable (see Table 6-26). Carbon stocks on mineral soils are assumed to be in balance (i.e. no carbon stock changes occur in mineral soils). Thus, all soil emissions in 4B1 are considered to originate from carbon mineralization in organic soils, mainly in the lowest elevation zone (z1: 84%). Overall, organic soils accounted for 2.8% of cropland area in Switzerland (Table 6-7).

Category 4B2 Land converted to cropland was a small net source of 28.66 kt CO₂ in 2014 mainly due to carbon losses in mineral soils under Grassland converted to cropland.

6.5.2 Methodological issues

6.5.2.1 Carbon in living biomass

Annual biomass carbon stocks are shown in Table 6-26. They were 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 was calculated as:

$$\text{Biomass cropland} = \sum f (A_f / A_t) * C_f$$

where A_f = Area of crop type f , A_t = total cropping area and C_f = yield (annual crops, leys) for the particular crop (t C ha^{-1}). Annual values for A_f , A_t and C_f were published by the Swiss Farmers Union (SBV 2014). For the year 2014 provisional values were calculated (mean 1991–2013) as the most recent publication of the Farmers Union was not yet available.

The resulting mean biomass stock for Swiss cropland over the inventory time period was 4.71 ± 0.34 (1 SD) t C ha^{-1} .

Table 6-26 Annual values for arable crop yields and resulting area-weighted means of the carbon stock (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	2014	mean 1990-2014			
	CC21: yield [t C ha^{-1}]								
Barley	2.56	2.75	2.75	2.45	2.46	2.55			
Wheat	2.48	2.72	2.49	2.32	2.33	2.48			
Maize	3.61	4.13	3.85	3.12	3.14	3.70			
Silage maize	7.47	8.42	8.06	7.64	7.67	6.97			
Sugar beet	8.03	10.38	9.58	7.61	7.65	7.95			
Fodder beet	6.49	6.65	5.58	4.67	4.70	6.10			
Potatoes	4.26	5.04	4.52	3.40	3.42	4.35			
Leys	6.11	6.11	6.11	6.11	6.11	6.11			
Mean	4.99	5.44	5.23	4.90	4.93	4.71			

6.5.2.2 Carbon in soils

Soil carbon stocks in mineral soils under cropland were calculated based on Leifeld et al. (2003, 2005). The approach correlated 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 used the Swiss digital soil map (SFSO 2000a), and average stocks were calculated as weighted means using the area of arable land and leys. The mean soil organic carbon stock (0–30 cm) for cropland was $53.40 \pm 5 \text{ t C ha}^{-1}$ (uncertainty 9%).

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 were calculated based on Leifeld et al. (2003, 2005). The approach used measured carbon stocks in Swiss organic soils. The mean soil organic carbon stock (0–30 cm) for cultivated organic soils was $240 \pm 48 \text{ t C ha}^{-1}$ (uncertainty 20%).

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 4.93 t C ha^{-1} in 2014 (Table 6-267; SBV 2014, provisional data for 2013 and 2014). The difference in biomass stock between a specific year and the preceding year was reported as gain or loss of carbon (see Table 6-27). The resulting values are in the range between -0.33 and $0.49 \text{ t C ha}^{-1} \text{ yr}^{-1}$ with an average of $0.02 \text{ t C ha}^{-1} \text{ yr}^{-1}$ for the inventory time period. This average value was used for the year 1990 as there are no data for 1989.

Changes of carbon stocks in mineral soils were assumed to be zero for cropland remaining cropland.

The annual net carbon stock change in organic soils was estimated to $-9.52 \text{ t C ha}^{-1}$ according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and verified by ART (2009b).

In the case of land-use change, the net changes in biomass and soil were calculated as described in chp. 6.1.3.

Table 6-27 Annual carbon data for living biomass for cropland (CC21), 1990–2014. Annual carbon stocks are broken down for arable crops in Table 6-26. 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	2014	mean 1990-2014
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	4.93	4.71
gain	0.00	0.45	0.00	0.00	0.02	0.02
loss	-0.20	0.00	-0.21	-0.33	0.00	0.00

6.5.2.4 N₂O emissions from cropland

N₂O emissions from drainage of organic soils (category 4(II)) on cropland are reported in the agriculture sector (CRF Table3.D).

The calculation of emissions for categories 4(III) and 4(IV) (direct N₂O emissions from nitrogen mineralization in mineral soils and indirect N₂O emissions from managed soils) is described in chp. 6.10.

6.5.3 Uncertainties and time-series consistency

A range of possible carbon stock changes in mineral soils was determined by the Swiss Soil Monitoring Network (NABO). The upper and lower margin of the 95% confidence interval for carbon stock changes under cropland was 0 ± 0.4 t C ha⁻¹ for a 20–years period (see chp. 6.5.4) or 0 ± 0.09 t C ha⁻¹ for one year ($0.4/20^{0.5}=0.09$). This absolute uncertainty was used to calculate relative uncertainties for 4B1 and 4B2 by dividing with the mean net carbon stock change per hectare of 4B1 and 4B2, respectively. In 2014, the mean net carbon stock changes were -0.24 t C ha⁻¹ for 4B1 and -0.43 t C ha⁻¹ for 4B2 (calculated from CRF Table4.B). The resulting relative uncertainties are 37% for 4B1 and 21% for 4B2, respectively (Table 6-5).

In the uncertainty analysis, these values were chosen for the overall emission factor uncertainties for CO₂ in categories 4B1 and 4B2 as they dominated the remaining sources of uncertainty:

- Uncertainties for soil carbon stocks are given together with the mean value in chp. 6.5.2.2: 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 was estimated as 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) were 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 chp. 6.3.3.

Consistency: Time series for category 4B Cropland are all considered consistent; they were 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 chp. 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 range of the respective default values provided in the Guidelines (IPCC 2006). 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 chp. 6.5.6).

Changes in SOC pools

The Tier 1 assumption that changes of carbon stocks in mineral soils are zero for Cropland remaining cropland is applied. In response to the ERT recommendation to develop appropriate methods to support this assumption (UNFCCC 2011: §94), the following evidence is provided: The SOC pool changes measured at 38 cropland monitoring sites of the Swiss Soil Monitoring Network (NABO; see chp. 6.4.4) showed a slight, statistically not significant trend towards decreasing SOC pools since 1985 (Figure 6-7). The range of the calculated SOC pools was large (27.7 - 598 t C ha⁻¹), as three cropland soil monitoring sites were on peat soils. These three sites were 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 interval 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 study by Keller et al. (2006; chp. 6.4.4), where six resamplings of two cropland sites within three years revealed natural SOC content variation of ± 0.23% in the topsoil. The temporal variations 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.

The results provide evidence that Swiss cropland mineral soils did not act as a net carbon source or sink during the last 20 years.

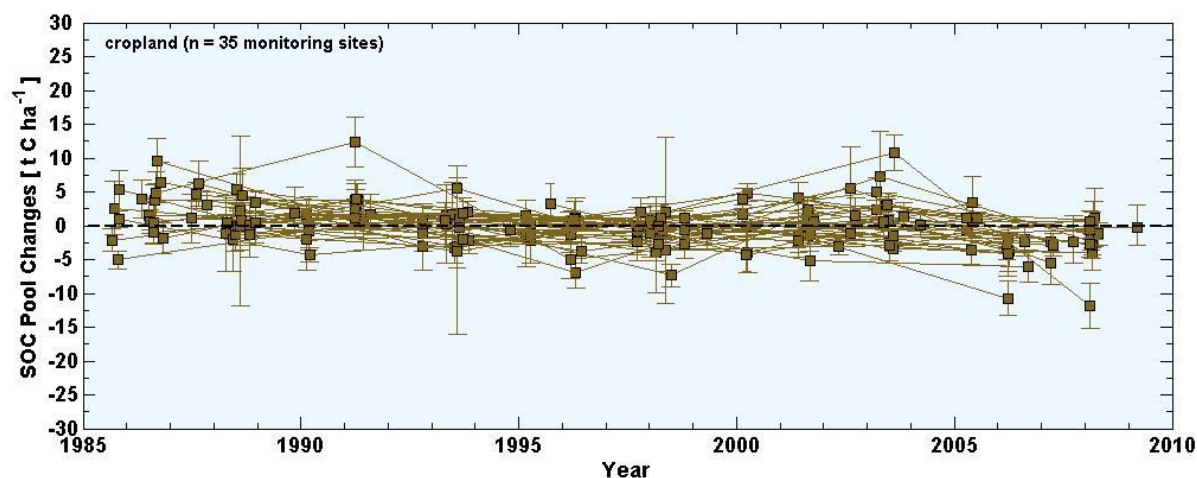


Figure 6-7 Time series of measured SOC pool changes in the top soil (0–20 cm) at 35 NABO cropland sites on mineral soil from the 1st to the 5th resampling campaigns. SOC pools were centred by the median SOC pool of all resamplings of the monitoring site. Each pool value presents the median of four bulked 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 elevation 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 were allocated to cropland by the Swiss Land Use Statistics (AREA) and were 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 were adequately reported in the Swiss GHG inventory.

6.5.5 Category-specific recalculations

Recalculations reported in submission 2015

- The provisional value of carbon stock in living biomass for the year 2012 was replaced by the definitive value. The carbon stock change in living biomass was recalculated for 1990 (it is the long-term average 1991–2013; cf. Table 6-26).

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).

6.5.6 Category-specific planned improvements

Information on 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 was completed (Köck et al. 2013). Based on this, an evaluation of four soil carbon models was started in 2015, using data from Swiss long-term experiments. Model evaluation is scheduled to be finalized in 2017.

A 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 the 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

CO₂ from Land converted to grassland (level and trend).

Approach 2 key category 4C1

CO₂ from Grassland remaining grassland (level and trend).

Approach 2 key category 4C2

CO₂ from Land converted to grassland (trend)

Swiss grasslands belong to the cold temperate wet climatic zone.

Grasslands were 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 were estimated for every subclass and considered accordingly in the calculation scheme.

In category 2. in CRF Table 4.C, the land-use types CC32, CC33, CC34 and CC35 were merged under the notation 'woody' and CC36 and CC37 were merged under 'unproductive' (see Table 6-2).

In 2014, category 4C1 Grassland remaining grassland was a net source of 115.70 kt CO₂. Carbon stocks in living biomass and carbon stocks in mineral soils under unchanged land use are assumed to be in balance (i.e. no carbon stock changes do occur). The highest contribution to the CO₂ emissions of category 4C1 was thus generated by carbon mineralization in organic soils under permanent grasslands (CC31), although only 0.6% of CC31 soils in Switzerland are organic soils. Contributions of other Grassland remaining grassland categories (CC32–CC37) were of minor importance.

Category 4C2 Land converted to grassland was a net source of 183.10 kt CO₂ in 2014. The highest individual contribution came from 4C2.1 Forest Land converted to Grassland being responsible for a net source of 357.05 kt CO₂. Most of this source was 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 CO₂ 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 elevation 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 elevation zones (corresponding to those used in category 4A Forest Land).

Standing stocks for permanent grasslands (t C ha⁻¹) were calculated as the annual cumulative yield of differentially managed grasslands (meadows, pastures, alpine pastures and meadows) based on FAL/RAC (2001; Table 6-28), 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 6-28 Annual yields of differentially managed permanent grassland (CC31). Each value represents the mean of two fertilization levels.

Management	Elevation [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 were 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 was added to above-ground biomass to derive the total living biomass for CC31. Table 6-29 shows the living biomass of permanent grassland for the three altitudinal zones presented as the cumulated annual yield including roots.

Table 6-29 Root biomass C_{root} and total living biomass C_l of permanent grassland (CC31).

Elevation [m]	C _{root} [t C ha ⁻¹]	C _l [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 accurate data, the living biomass of shrub vegetation and copse was assumed to be equal to the living biomass of brush forest as described in chp. 6.4.2.8, 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. This is justified because tree nurseries comprise only ca. 8% (1'378 ha tree nurseries, SFSO

2002) of the total area of CC33, i.e., 17'054 ha, 15'436 ha vineyards (SFSO 2005) and 240 ha low-stem orchards (Widmer 2006).

The standing carbon stock of living biomass per ha (CI) for CC33 was therefore calculated as:

$$CI = [(CI \text{ vineyards} * \text{area vineyards}) + (CI \text{ low-stem orchards} * \text{area low-stem orchards})] / (\text{area vineyards} + \text{area low-stem orchards})$$

CI of vineyards is 3.61 t C ha⁻¹, calculated based on the mean stand density (5'556 vines ha⁻¹) and the mean carbon content in the woody biomass of one 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, the following assumptions were made: Diameter at breast height (DBH) of such trees was assumed to be 10 cm and the stem height was assumed to be 1 m. The bole shape of low-stem apple trees can be approximated by a cylinder shape.

$$\text{Stem wood volume} = r^2 * \pi * \text{height} = (5 \text{ cm})^2 * 3.1 * 100 \text{ cm} = 7.75 \text{ dm}^3$$

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% (IPCC 2006, chp. V4_5.2.2.2) were assumed. With these assumptions the carbon content of a tree of the type low-stem ('Niederstamm') was calculated as follows:

$$\begin{aligned} C \text{ low-stem} &= \text{stem wood volume} * \text{BEF} * \text{wood density} * \text{carbon content} \\ &= 7.75 \text{ dm}^3 * 2.3 * 0.55 \text{ kg/dm}^3 * 0.5 = 4.9 \text{ kg C} \end{aligned}$$

The mean stand density of low-stem orchards was estimated as 2500 ha⁻¹ (Widmer 2006), resulting in a CI of 12.25 t C ha⁻¹.

The resulting CI for CC33 is 3.74 t C ha⁻¹.

Orchards (CC35)

Orchards consists of larger fruit trees ('Hochstammobst') planted at a low density with grass understory. CI of orchards trees was calculated as:

$$CI \text{ biomass} = (\text{carbon per fruit tree [t C]} * \text{number of fruit trees} / \text{area orchards [ha]}) + \text{carbon in grass [t C ha}^{-1}]$$

The carbon content of a large fruit tree with a DBH of 25–35 cm was calculated as follows:

$$C \text{ (Hochstamm)} = \text{Stem wood volume} * \text{KE-Factor} = 225 \text{ kg C}$$

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 m³, and

- 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 low-stem trees (240 ha, see CC33) was subtracted, and the remaining area of 41'240 ha was divided by the number of large fruit trees calculated as the mean of the counts in 1991 (3'616'301 trees) and 2001 (2'900'000 trees; SFSO 2002). This resulted in 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. Since orchards are located below 1000 m a.s.l., 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 6-29) 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 stock of brush forest (20.45 t C ha^{-1} ; cf. chp. 6.4.2.8; Düggelein and Abegg 2011) was multiplied by 0.35 to account for the 35% vegetation coverage. This results in a carbon stock for stony grassland 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 elevation zones, 7.01 t C ha^{-1} (cf. Table 6-29), was assumed to be representative for the biomass on unproductive grassland 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 were 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 made use of the Swiss digital soil map (SFSO 2000a) and topography. Mean carbon stock values calculated for grasslands CC31 are given in Table 6-30. Their uncertainty is between 12% and 21%.

It should be noted that the 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).

Table 6-30 Mean carbon stocks under permanent grassland on mineral soils (0–30 cm).

Elevation [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 were calculated based on Leifeld et al. (2003, 2005). The approach used 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 (uncertainty 20%).

Shrub vegetation (CC32)

Due to the lack of data, the values of CC31 (Table 6-30) 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 with the estimate of carbon stocks in biomass, only vineyards and low-stem orchards were considered. Both land-use types were assumed to have grass undercover. Therefore, the soil carbon stock may range between the values for grassland and cropland. It was decided to take 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) for CC33 (see chp. 6.5.2.2).

Copse (CC34)

Due to the lack of data, the values of CC31 (Table 6-30) 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)

The carbon stock in soils under orchards was calculated in accordance to the biomass calculation. No specific value for orchards was available, and the mean value of grassland mineral soil carbon stocks from the two lower elevation zones (i.e. 64.76 t C ha⁻¹; cf. Table 6-30) 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 chp. 6.6.2.1, i.e. it was 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 elevations >1200m a.s.l. Thus, using the respective value from Table 6-30, the carbon stock of CC36 was calculated as:

$$\text{Cs of CC36} = 0.35 * \text{Cs permanent grassland} > 1200 \text{ m} = 26.31 \text{ t C ha}^{-1} \text{ (0–30 cm)}$$

The mean soil organic carbon stock (0–30 cm) for organic soils is 240 t C ha⁻¹. It was assumed that the small area covered by organic soils in CC36 (cf. category 1 in CRF Table 4.C '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 combination category CC37 'unproductive grassland' 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, soil carbon stock data are currently available. In accordance with the procedure followed for biomass, the soil carbon stock of CC37 was assumed to correspond to the mean value of carbon stocks under permanent grassland on mineral soils for all elevation zones (Table 6-30). The carbon stock in soils under 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 were 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 verified by ART (2009b). For extensively 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 were calculated as described in chp. 6.1.3.

6.6.2.4 N₂O emissions from grassland

N₂O emissions from drainage of organic soils (category 4(II)) on grassland are reported in the agriculture sector (CRF Table3.D).

The calculation of emissions for categories 4(III) and 4(IV) (direct N₂O emissions from nitrogen mineralization in mineral soils and indirect N₂O emissions from managed soils) is described in chp. 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 6-31 shows the annual burnt area from 1990 to 2014. The Swissfire database differentiates between 'grassland' and 'unproductive land'. As 'unproductive land' can partially cover the grassland categories CC32, CC34, CC36 and CC37 the sum of both categories was reported. Controlled burning is not a common practice in Switzerland. Therefore, all fires were assigned to "wildfires".

The CH₄ and N₂O emissions were calculated using Equation 2.27 in Volume 4 of IPCC (2006) with the following parameters:

- For CH₄ the default emission factor of 2.3 g (kg combusted biomass)⁻¹ and for N₂O, the default emission factor of 0.21 g (kg combusted biomass)⁻¹ was applied (IPCC 2006, Volume 4, Table 2.5, Savanna and Grassland).
- The mass of available fuel encompasses the stock of living biomass (litter and dead wood stocks are zero for grassland). On average, the amount of living biomass amounted to 18.19 t biomass ha⁻¹, or a corresponding C stock of 9.09 t C ha⁻¹. This value was derived from the carbon stocks of all grassland categories (CC31 to CC37, see Table 6-4) as an area-weighted mean using the geographical extensions in 2013.
- The fraction of the biomass combusted was 0.74 (IPCC 2006 Volume 4, Table 2.6, Savanna and Grassland).

The resulting annual emissions 1990–2014 on burnt areas in category 4C Grassland are shown in Table 6-31 and are reported in CRF Table4(V).

Table 6-31 Area of 4C Grassland affected by wildfires (WSL, Swissfire database) and resulting CH₄ and N₂O emissions, 1990–2014.

Year	Area burnt ha	CH ₄ t	N ₂ O t
1990	637	19.720	1.801
1991	22	0.690	0.063
1992	6	0.186	0.017
1993	17	0.586	0.054
1994	175	5.403	0.493
1995	82	2.537	0.232
1996	43	1.324	0.121
1997	373	11.508	1.051
1998	73	2.229	0.203
1999	19	0.586	0.054
2000	22	0.676	0.062
2001	8	0.232	0.021
2002	257	7.962	0.727
2003	138	4.269	0.390
2004	4	0.133	0.012
2005	4	0.119	0.011
2006	6	0.175	0.016
2007	88	2.712	0.248
2008	29	0.904	0.083
2009	3	0.085	0.008
2010	1	0.041	0.004
2011	56	1.742	0.159
2012	4	0.136	0.012
2013	3	0.104	0.009
2014	2	0.071	0.006

6.6.2.6 NMVOC emissions

Estimates for annual biogenic emissions of NMVOC (CRF Table4) 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 was determined by the Swiss Soil Monitoring Network (NABO). The upper and lower margin of the 95% confidence interval for carbon stock changes under grassland was $0 \pm 0.9 \text{ t C ha}^{-1}$ for a 20-years period (see chp. 6.6.4) or $0 \pm 0.2 \text{ t C ha}^{-1}$ for one year ($0.9/20^{0.5}=0.2$). This absolute uncertainty was used to calculate relative uncertainties for 4C1 and 4C2 by dividing with the mean net carbon stock change per hectare of 4C1 and 4C2, respectively. In 2014, the mean net carbon stock changes were $-0.024 \text{ t C ha}^{-1}$ for 4C1 and $-0.745 \text{ t C ha}^{-1}$ for 4C2 (calculated from CRF Table4.C). The resulting relative uncertainties are 839% for 4C1 and 27% for 4C2, respectively (Table 6-5).

In the uncertainty analysis, these values were chosen for the overall emission factor uncertainties for CO₂ in categories 4C1 and 4C2 as they dominated the remaining sources of uncertainty:

- Uncertainties for soil carbon stocks are given together with the mean value in chp. 6.6.2.2: 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 intensively managed grassland is 23% as reported by Leifeld et al. (2003: 56). For extensively managed grassland this uncertainty is 117% according to ART (2011b).
- The relative uncertainty in yield determination has been estimated as 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 chp. 6.3.3. For wildfires, the emission factor uncertainties of CH₄ and N₂O were set to 70% (identical to forest land, see chp. 6.4.3).

Consistency: Time series for category 4C Grassland are all considered consistent; they were calculated based on consistent methods and homogeneous databases.

6.6.4 Category-specific QA/QC and verification

The general QA/QC measures are described in chp. 1.2.3.

Changes in living biomass

The assumption of a constant carbon stock in living biomass was 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 is 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 range of the respective default values provided in the Guidelines (IPCC 2006). 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 chp. 6.6.6).

Changes in SOC pools

In response to the ERT recommendation to improve the documentation for the procedure to estimate changes in the SOC pool (UNFCCC 2007: §97), the following evidence is provided: The SOC pool measured at 33 grassland monitoring sites in the Swiss Soil Monitoring Network (NABO; see chp. 6.4.4) showed, on 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.

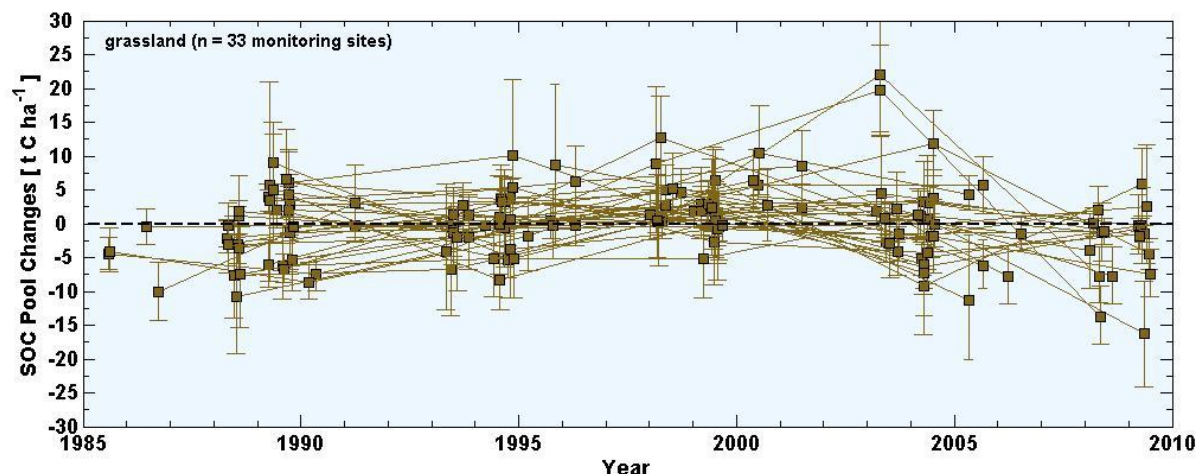


Figure 6-8 Time series of measured SOC pool changes in the top soil (0–20 cm) at the 33 NABO grassland sites from the 1st to the 5th resampling campaigns. SOC pools were centred by the median SOC pool of all resamplings of the monitoring site. Each pool value presents the median of four bulked soil samples 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 elevation of the grassland sites ranges between 265 and 2340 m a.s.l.

The slight increase and decrease will be subject of further detailed analysis. Partly, it may be attributed to natural variation of soil sampling (see chp. 6.4.4). The temporal change of the SOC content at grassland sites with intensive management and large manure application may also be 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 permitted 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 chp. 6.5.4.

6.6.5 Category-specific recalculations

Recalculations reported in submission 2015

- The carbon stock in living biomass of brush forests was revised based on Düggelein and Abegg (2011), cf. chp. 6.4.2.8. As a consequence, carbon stocks of the combination categories CC32, CC34 and CC36 were adjusted for all years.

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).
- The calculation method for wildfires was updated for 1990 to 2013. The default factors of the IPCC (2006) guidelines were used and the amount of fuel was recalculated with consistent activity data and biomass pools used in this report.

6.6.6 Category-specific planned improvements

Information on 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) was completed (Köck et al. 2013). Based on this, an evaluation of four soil carbon models was started in 2015, using data from Swiss long-term experiments. Model evaluation is scheduled to be finalized in 2017.

A 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 the 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

CO₂ from Wetlands remaining wetlands (level).

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 extensively managed grassland, bushes or tree groups. The pool of living biomass was estimated as 6.50 t C ha^{-1} (Mathys and Thürig 2010).

6.7.2.2 Carbon in soils

The soil carbon stock for surface waters (CC41) is zero. However, for CC41 situated in areas with organic soil (see chp. 6.2.2 and Table 6-7), a soil carbon stock of 240 t C ha^{-1} (0–30 cm) was assumed. These surface waters were 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 chp. 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 approximation, it was assumed that the soil carbon stock of unproductive wetlands is similar to unproductive grassland (CC37) on mineral soils (mean value: $68.23 \text{ t C ha}^{-1}$; 0–30 cm).

6.7.2.3 Changes in carbon stocks

Changes of carbon stock in biomass and in mineral soils were assumed to be zero for wetlands remaining wetlands.

The emission from organic soils under CC41 was assumed to be zero because the respective areas are not drained.

The emission from organic soils under CC42 was estimated to be $5.30 \text{ t C ha}^{-1} \text{ yr}^{-1}$ 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 were calculated as described in chp. 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 assumption was reviewed as recommended by the ERT (UNFCCC 2009: §82), and

it was concluded that it is justified because the exact year of the land use change is not known (cf. chp. 6.3.2). For carbon stock changes in soil the conversion time is 20 years.

6.7.2.4 Non-CO₂ emissions from wetlands

An estimate of 0.43 kt CH₄ yr⁻¹ emitted by reservoirs (flooded lands) was 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 category 2. in CRF Table4(II)D.

N₂O emissions from drainage of organic soils was calculated for unproductive wetlands (CC42) and reported in category 3. in CRF Table4(II)D. The emission factor of 1.6 kg N₂O-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 emissions for categories 4(III) and 4(IV) (direct N₂O emissions from nitrogen mineralization in mineral soils and indirect N₂O emissions from managed soils) is described in chp. 6.10.

6.7.3 Uncertainties and time-series consistency

Based on expert judgement, a value of 50% was chosen for the emission factor uncertainty in category 4D2. The uncertainty of the emission factor for carbon stock losses in organic soils (dominant process in category 4D1) was 100% based on monitoring values compiled by ART (2011b) (cf. Table 6-5).

The uncertainty for CH₄ emitted by flooded lands can be very high (IPCC 2006, Volume 4, Appendix 3). As a best guess, a value of 70% was chosen for the emission factor of 4(II)D.2 (cf. Table 6-5).

For N₂O emissions from drainage of organic soils (category 4(II)) the uncertainties for agricultural soils given in the 2006 IPCC Guidelines was used. The arithmetic mean of the lower and upper bound uncertainty (137.5%) was used for the emission factor (see also chp. 5.5.3).

Uncertainties of activity data of category 4D Wetlands are described in chp. 6.3.3.

Consistency: Time series for category 4D Wetlands are all considered consistent; they were 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 chp. 1.2.3.

No category-specific QA/QC activities were carried out.

6.7.5 Category-specific recalculations

Recalculations reported in submission 2015

- N₂O emissions from drained organic soils are reported for the first time on unproductive wetlands (category 4(II)).

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).

6.7.6 Category-specific planned improvements

A 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, was shown to be a large emitter of CH₄ (DeSontro et al. 2010). Sediments cores from the reservoir were sampled in March 2014 by the University of Bern. The project 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

CO₂ from Land converted to settlements (level)

Approach 2 key category 4E1

CO₂ from Settlements remaining settlements (trend)

Approach 2 key category 4E2

CO₂ from Land converted to settlements (level and trend)

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.

Switzerland decided not to prepare estimates of CH₄ emissions by drainage of organic soils in settlements (not mandatory).

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 stocks in mineral and organic soils for CC51 (buildings and construction) were assumed as zero.

In case of land-use changes to CC51 or from CC51 on mineral or organic soils, 50% of the difference between carbon stocks before and after the change was reported as emission and removal, 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 chose 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 chp. 6.1.3.2 was adjusted as follows if $a=CC51$ or $b=CC51$:

$$\Delta C_{s,i,ba} = [0.5 * (stock_{Cs,i,a} - stock_{Cs,i,b}) / CT] * A_{i,ba}$$

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
$A_{i,ba}$	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 for CC52, CC53, and CC54 was assumed as 240 t C ha⁻¹ (0–30 cm).

6.8.2.3 Changes in carbon stocks

Changes of carbon stock in biomass and in mineral soils were 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 verified by ART 2009b).
- 5.30 t C ha⁻¹ yr⁻¹ for CC53 and CC54. This corresponds to the value used for extensively managed grasslands (ART 2011b).

In the case of land-use change, the net changes in biomass and soil of CC51, CC52, CC53, and CC54 were calculated as described in chp. 6.1.3.

6.8.2.4 N₂O emissions from settlements

The calculation of emissions for categories 4(III) and 4(IV) (direct N₂O emissions from nitrogen mineralization in mineral soils and indirect N₂O emissions from managed soils) is described in chp. 6.10.

6.8.3 Uncertainties and time-series consistency

Based on expert judgement, a value of 50% was chosen for the emission factor uncertainty in sector 4E (Table 6-5).

Uncertainties of activity data of category 4E Settlements are described in chp. 6.3.3.

Consistency: Time series for category 4E Settlements are all considered consistent; they were 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 chp. 1.2.3.

No category-specific QA/QC activities were carried out.

6.8.5 Category-specific recalculations

Recalculations reported in submission 2015

- No recalculations were carried out.

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5)

6.8.6 Category-specific planned improvements

No category-specific improvements are planned.

6.9 Category 4F – Other land

6.9.1 Description

Approach 2 key category 4F2

CO₂ from Land converted to other land (level)

The category 4F1 Other land remaining other land is not a key category.

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 were 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 were calculated as described in chp. 6.1.3.

The calculation of emissions on land converted to other land for categories 4(III) and 4(IV) (direct N₂O emissions from nitrogen mineralization in mineral soils and indirect N₂O emissions from managed soils) is described in chp. 6.10.

6.9.3 Uncertainties and time-series consistency

Based on expert judgement, a value of 50% was chosen for the emission factor uncertainty in sector 4F2 (Table 6-5).

Uncertainties of activity data of category 4F Other Land are described in chp. 6.3.3.

Consistency: Time series for Other Land are all considered consistent; they were 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 chp. 1.2.3.

No category-specific QA/QC activities were carried out.

6.9.5 Category-specific recalculations

Recalculations reported in submission 2015

- There were no recalculations carried out.

Recalculations reported in submission 2016

- Activity data were updated (see chp. 6.3.5).

6.9.6 Category-specific planned improvements

No category-specific improvements are planned.

6.10 Categories 4(III), 4(IV) – N₂O emissions from nitrogen mineralization

6.10.1 Description

Approach 2 key category 4(III)

N₂O from N mineralization (level)

The category 4(IV) Indirect Emissions is not a key category.

This chapter presents the methods for calculating direct (4(III)) and indirect (4(IV)) N₂O emissions from nitrogen (N) mineralization in mineral soils. The source of nitrogen is N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils. As the approaches applied are not tier 3, no N₂O immobilization is reported.

- In category 4(III), direct N₂O emissions from nitrogen mineralization associated with loss of soil organic matter are reported.
- In category 4(IV)2, indirect emissions of N₂O due to nitrogen leaching and run-off after mineralization of soil organic matter are reported.

The following N₂O emissions are included in the agriculture sector:

- N₂O emissions associated with inputs from N (fertilizers, crop residues) (CRF Table4(I); see chp. 5.5).
- N₂O emissions on cropland remaining cropland and on grassland remaining grassland (CRF Table4(III), see chp. 5.5). In Switzerland, grassland belongs to the agricultural area.
- Indirect N₂O emissions due to atmospheric deposition and leaching and run-off on agricultural land (grassland remaining grassland and cropland remaining cropland) (category 1. in CRF Table4(IV), see chp. 5.3).

6.10.2 Methodological issues

Direct N₂O emissions (category 4(III)) as a result of the disturbance of mineral soils associated with land use and land-use change were calculated according to IPCC (2006, Vol. 4, chp. 11):

$$\text{Emission(N}_2\text{O)} = - \text{deltaCs} * 1 / (\text{C:N}) * \text{EF1} * 44 / 28, \text{ if } \text{deltaCs} < 0 \quad [\text{kt N}_2\text{O}]$$

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 N₂O-N (kg N)⁻¹, IPCC 2006 (Volume 4, Table 11.1)

deltaCs was calculated according to the methodology described in chp. 6.1.3.2. If deltaCs is zero or positive (carbon gain) there are no N₂O 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, CC53, CC54). For forest land, the default value of C:N=15 was used (IPCC 2006, Vol. 4, Equation 11.8).

The indirect N₂O emissions (4(IV)) as a result of N leaching and run-off after mineralization of soil organic matter were calculated as follows using default emission factors (IPCC 2006, Vol. 4, Table 11.3):

$$\text{Emission(N}_2\text{O)} = - \text{deltaCs} * \text{Frac}_{\text{LEACH}} / (\text{C:N}) * \text{EF5} * 44 / 28, \text{ if deltaCs} < 0 \quad [\text{kt N}_2\text{O}]$$

where:

- $\text{Frac}_{\text{LEACH}}$: fraction of mineralized N lost by leaching or run-off, $\text{Frac}_{\text{LEACH}}=21.8\%$, see chp. 5.5.2.4.2.
- EF5: default emission factor = $0.0075 \text{ kg N}_2\text{O-N (kg N)}^{-1}$, IPCC 2006 (Vol. 4, Table 11.3)

If deltaCs is zero or positive (carbon gain) there are no N₂O emissions.

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 Table4(III) and Table4(IV). For Switzerland, also the N₂O emissions for grassland remaining grassland are reported in the agriculture sector 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 (chp. 6.4.2.7). These changes were deliberately not considered for the calculation of N₂O 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 estimated as the mean of the upper and the lower limit of the uncertainty ranges listed in IPCC (2006), Vol 4, Tables 11.1 and 11.3.:

Uncertainty (EF1): 135%

Uncertainty (EF5): 162%

The uncertainty of the activity data for category 4(III) corresponds to the uncertainty of the area converted to cropland or to grassland, i.e. 6% (Table 6-10).

The uncertainty of the activity data (20%) for category 4(IV2) was adopted from ART (2008a).

Consistency: Time series for categories 4(III) and 4(IV) N₂O emissions from nitrogen mineralization are all considered consistent; they were 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 chp. 1.2.3.

No category-specific QA/QC activities were carried out.

6.10.5 Category-specific recalculations

Recalculations reported in submission 2015

- Category 4(III): N₂O emissions from mineralisation of organic matter in mineral soils due to land-use changes were recalculated to meet the requirements of IPCC (2006). The default emission factor was applied: 0.01 kg N₂O-N (kg N)⁻¹ instead of 0.0125 kg N₂O-N (kg N)⁻¹.
- Category 4(IV): Indirect N₂O 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 and land-use change on mineral soils, excluding cropland remaining cropland and grassland remaining grassland.

Recalculations reported in submission 2016

- In category 4(IV) a new country-specific value for F_{LEACH} (fraction of mineralized N lost by leaching or run-off) was used: 21.8% (instead of 30%). See chp. 5.5.2.4.2 for more details.

6.10.6 Category-specific planned improvements

No category-specific improvements are planned.

6.11 Category 4G – Harvested wood products (HWP)

6.11.1 Description

Approach 1 key category 4G

CO₂ from Harvested wood products (trend).

Approach 2 key category 4G

CO₂ from Harvested wood products (level and 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 same methodology was used for reporting under the UNFCCC and accounting under the KP for HWPs in Switzerland. This approach is consistent with Decision 2/CMP.7, paragraph 29. Therefore, in this chapter the terminology of the Kyoto Protocol is used, i.e. it is referred to the activities Afforestation, Deforestation and Forest management (as defined in FOEN 2006h; see chp. 11.1.3) besides the corresponding UNFCCC categories.

The approach to calculate carbon stock changes in HWP could be generally characterized as a production approach as described in chp. 12, Volume 4 of IPCC (2006). Changes in carbon stocks in Swiss forests are presented in chp. 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 in use in other countries.

To calculate carbon stock changes in HWP, product categories and half-lives were used following the methodologies described in IPCC (2006) and IPCC (2014).

6.11.2 Methodological issues

The same methodology was used for reporting under the UNFCCC and accounting under the KP for HWPs in Switzerland consistent with Decision 2/CMP.7, paragraph 29 stating 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 in i) the estimate of the proportion of the national harvest used for producing paper, ii) the use of recycled products, and due to the fact that the share of this product is too negligible to justify the (financial) effort to elaborate higher quality data (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 pools is 1900.
- The feedstock from domestic harvest was calculated according to equation 2.8.1 in IPCC (2014).
- The change in carbon stocks of HWPs was estimated separately for each product category and differentiating HWPs originating from Afforestation, Deforestation and from Forest management by applying equation 2.8.4 in IPCC (2014). Applying instantaneous oxidation to HWPs originating from Deforestation, the same results are obtained for changes in carbon stocks of HWP reported under the UNFCCC (CRF Table 4.Gs1) and under the KP (CRF Table 4(KP-I)C). However, in this submission HWP from Deforestation was accidentally reported and accounted for under the Kyoto Protocol. Furthermore, there was a problem with data input (some decimal places have not been correctly imported in the CRF Reporter; see chp. 11.1.5) resulting in slightly different values in the reporting tables (see Table 11-5).
- Based on the available datasets it was not possible to differentiate between HWP from Afforestation and HWP from Forest management. Since tree diameters from afforested areas since 1990 are small, the amount of HWP from Afforestation is not existing or negligibly small. Therefore, all carbon stock changes in HWPs were reported under Forest management.

6.11.2.1 Activity data

Activity data for production of HWPs for the product categories sawnwood and wood panels were based on national statistics (FOEN 2015I) and FAO forest product statistics (<http://faostat3.fao.org/download/F/FO/E>) and are described in detail in FOEN (2015I). The time series are shown in the CRF Table4.Gs2. For the second commitment period, activity data were restricted exclusively to Swiss national statistics.

Data on production of sawnwood was derived from national saw mill statistics (FOEN 2015I). Data on production of wood panels was derived from surveys of the processing industries (FOEN 2015I). 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 were used (FOEN 2015I).

In order to estimate carbon amounts in each HWP category and sub-category, default conversion factors were taken from 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; eq. 2.8.5).

6.11.2.3 Results

Gains and losses per product category are listed in Table 6-32 and Figure 6-9 shows the resulting emissions and removals.

Table 6-32 Changes in carbon stocks (positive values refer to emissions, negative values refer to removals) from Harvested Wood Products derived from sawnwood ($\text{changeC}_{\text{HWP-sawnwood}}$) and panels ($\text{changeC}_{\text{HWP-panels}}$) between 1990 and 2014 originating from Forest management, in kt CO₂. HWPs originating from Deforestation were calculated using instantaneous oxidation.

Greenhouse gas emissions and removals	1990	1991	1992	1993	1994	1995	1996	1997	1998
Net CO ₂ emissions/removals (kt CO ₂)									
HWP: 4G (UNFCCC)	-1231.92	-942.72	-775.16	-631.44	-478.08	-562.30	-397.34	-314.84	-424.59
changeC _{HWP-sawnwood}	-751.75	-526.74	-327.29	-225.33	-154.15	-312.84	-191.94	-135.80	-227.40
changeC _{HWP-panels}	-480.17	-415.97	-447.88	-406.11	-323.93	-249.47	-205.40	-179.04	-197.20

Greenhouse gas emissions and removals	1999	2000	2001	2002	2003	2004	2005	2006	2007
Net CO ₂ emissions/removals (kt CO ₂)									
HWP: 4G (UNFCCC)	-480.15	-835.80	-578.23	-443.75	-441.87	-638.16	-765.44	-628.27	-733.31
changeC _{HWP-sawnwood}	-298.63	-428.21	-213.99	-149.59	-133.57	-273.21	-343.72	-329.19	-288.48
changeC _{HWP-panels}	-181.52	-407.59	-364.25	-294.17	-308.30	-364.95	-421.73	-299.08	-444.83

Greenhouse gas emissions and removals	2008	2009	2010	2011	2012	2013	2014		
Net CO ₂ emissions/removals (kt CO ₂)									
HWP: 4G (UNFCCC)	-523.44	-377.65	-411.42	-257.61	-167.65	-160.56	-105.80		
changeC _{HWP-sawnwood}	-230.84	-183.89	-170.84	-69.84	45.20	141.43	36.54		
changeC _{HWP-panels}	-292.60	-193.76	-240.58	-187.76	-212.85	-302.00	-142.34		

Some decimal places are not correctly imported in or displayed by the CRF Reporter. Therefore there are some small differences between HWP reported in the CRF Table4.Gs1 (see also Table 6-1) and the CRF Table 4(KP-I)C. These calculations will be matched for the

next submission (see chp. 11.1.5). The values reported in the UNFCCC CRF Table 4.Gs1 and in Table 6-32 are considered to be the correct values.

Fluctuations in the HWP-pool can mainly be attributed to changes in the production of sawnwood (see Table 6-35), which correlates strongly with the domestic harvesting rate.

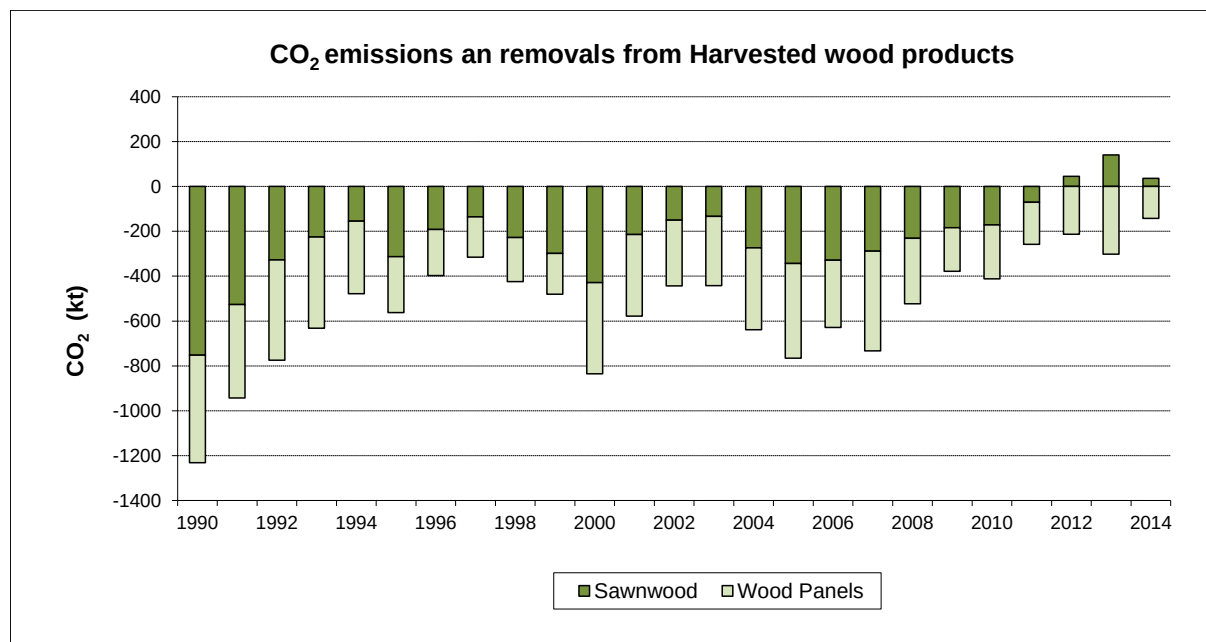


Figure 6-9 Carbon stock changes from Harvested wood products (positive values refer to emissions, negative values refer to removals) between 1990 and 2014 originating from land under Forest management (KP), in kt CO₂ eq.

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 2015I)
 - 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 2015I)
- 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 relative uncertainty of the emission factors for HWP amounts to 57%:

$$U_{\text{HWP EF}} = \sqrt{25^2 + 10^2 + 50^2} = 57\%$$

The total relative uncertainty of carbon losses and gains in HWP was thus calculated as:

$$U_{\text{HWP Sawnwood}} = \sqrt{5^2 + 5^2 + 25^2 + 10^2 + 50^2} = 57\%$$

$$U_{\text{HWP Panels}} = \sqrt{5^2 + 4^2 + 25^2 + 10^2 + 50^2} = 57\%$$

Consistency: Time series for category 4G Harvested wood products are all considered consistent (FOEN 2015i).

6.11.4 Category-specific QA/QC and verification

The general QA/QC measures are described in chp. 1.2.3.

No category-specific QA/QC activities was carried out.

6.11.5 Category-specific recalculations

The activity data were updated for the whole time-series. More specifically, the share of domestic to total HWP was revised.

6.11.6 Category-specific planned improvements

Improved estimates of the share of domestic to total HWP will be available for the next submission.

Values for HWP reported in the CRF Tables 4.Gs1 (see also Table 6-1) and CRF Table 4(KP-I)C should be identical. Data import and the output of the CRF Reporter will be checked for the next submission (see chp. 11.1.5).

7 Waste

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

7.1 Overview

7.1.1 Greenhouse gas emissions

Within sector 5 Waste, emissions from five source categories are considered:

- 5A Solid waste disposal
- 5B Biological treatment of solid waste
- 5C Incineration and open burning of waste
- 5D Wastewater treatment and discharge
- 5E Other (no emissions)

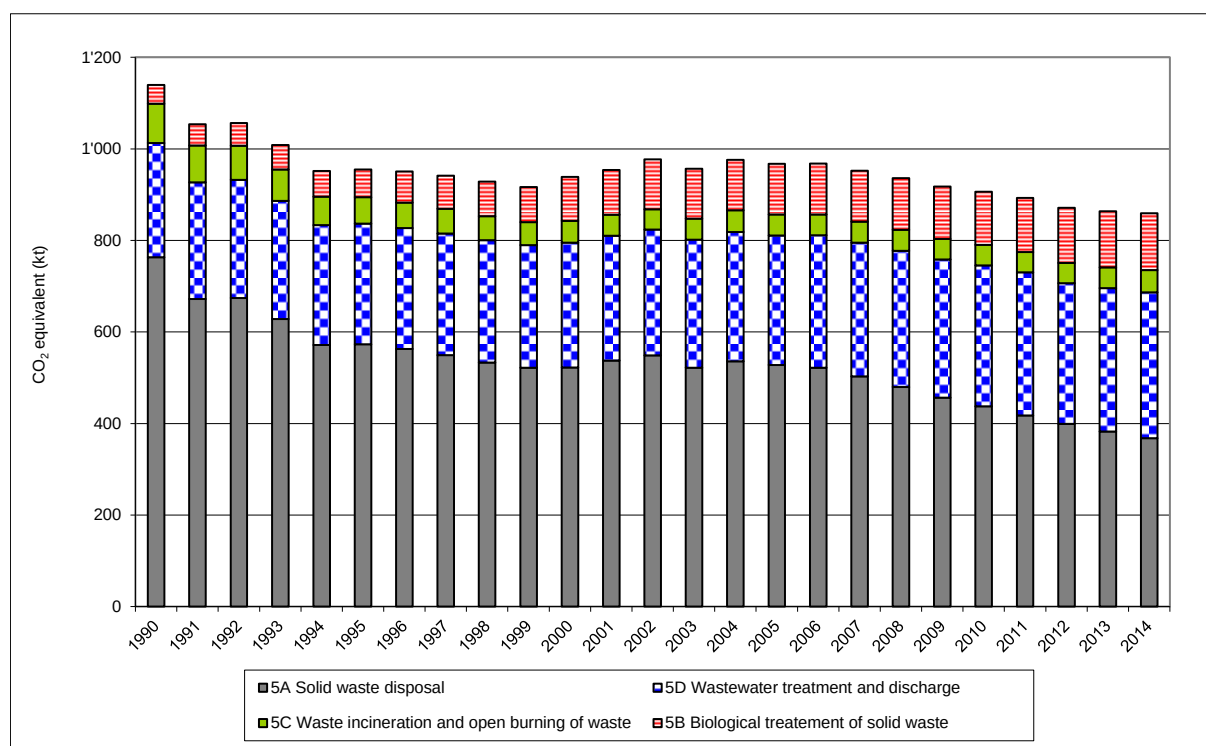


Figure 7-1 Switzerland's greenhouse gas emissions from sector 5 Waste 1990–2014. There are no greenhouse gas emissions from sector 5 E Other.

The total greenhouse gas emissions from sector 5 Waste show a decrease within the reporting period. The greenhouse gas emissions from 5A Solid waste disposal and 5D Wastewater treatment and discharge are the two dominant source categories.

Table 7-1 Trend of total GHG emissions from sector 5 Waste in Switzerland 1990–2014.

Gas	1990	1995	2000
CO ₂ equivalent (kt)			
CO ₂	54	30	19
CH ₄	944	779	763
N ₂ O	142	146	157
Sum	1139	955	939

Gas	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO ₂ equivalent (kt)										
CO ₂	12	13	12	12	11	11	11	10	10	10
CH ₄	787	784	767	747	726	711	694	679	667	658
N ₂ O	168	171	174	177	180	184	188	182	187	192
Sum	968	968	952	936	917	906	893	871	864	860

CH₄ is the most important greenhouse gas in sector 5 Waste over the whole period. Nevertheless, CH₄ emissions have decreased. Two processes determine the trend: a dominating decreasing trend from 5A Solid waste disposal and a distinct increasing trend from 5B Biological treatment of solid waste (refer to Figure 7-3 and Table 7-12).

The relative trends of the gases are shown in Figure 7-2.

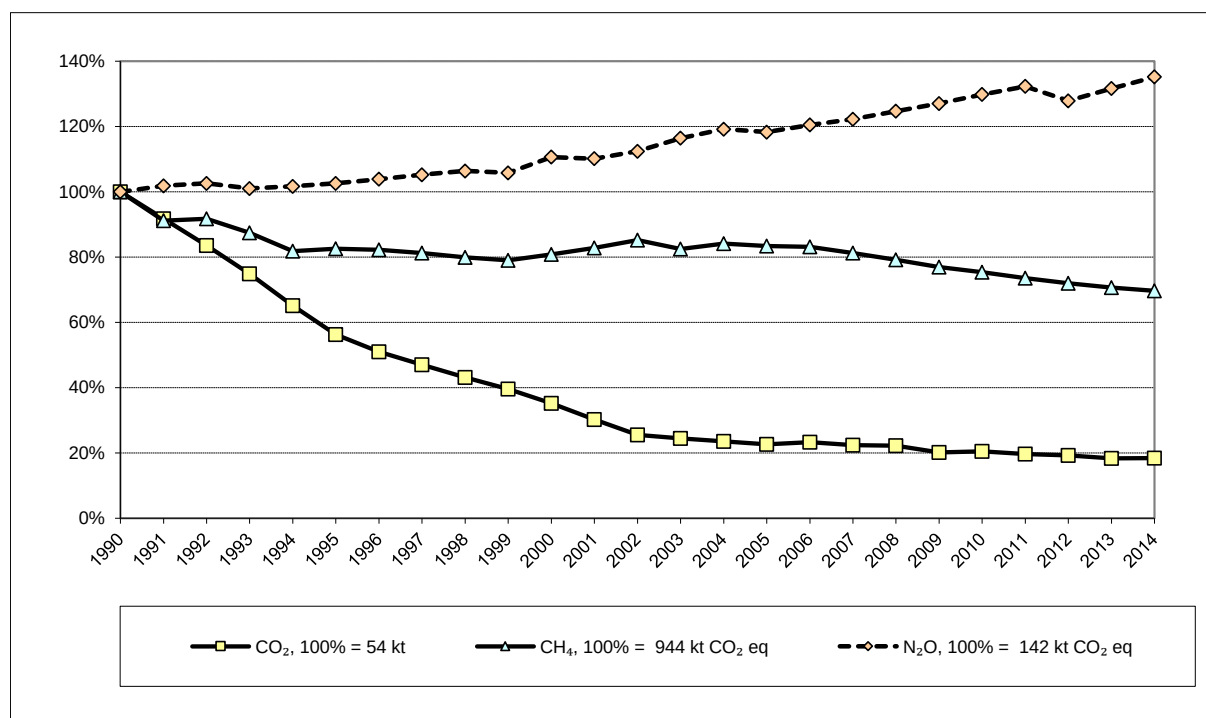


Figure 7-2 Relative trends of total emissions of CO₂, CH₄ and N₂O from sector 5 Waste in Switzerland 1990–2014.

According to the 2006 IPCC Guidelines (IPCC 2006) 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. This is illustrated in Figure 7-3, which provides an overview of all waste-related GHG emissions in Switzerland, reported in chp. 7 and elsewhere in the NIR (see also Figure 7-4).

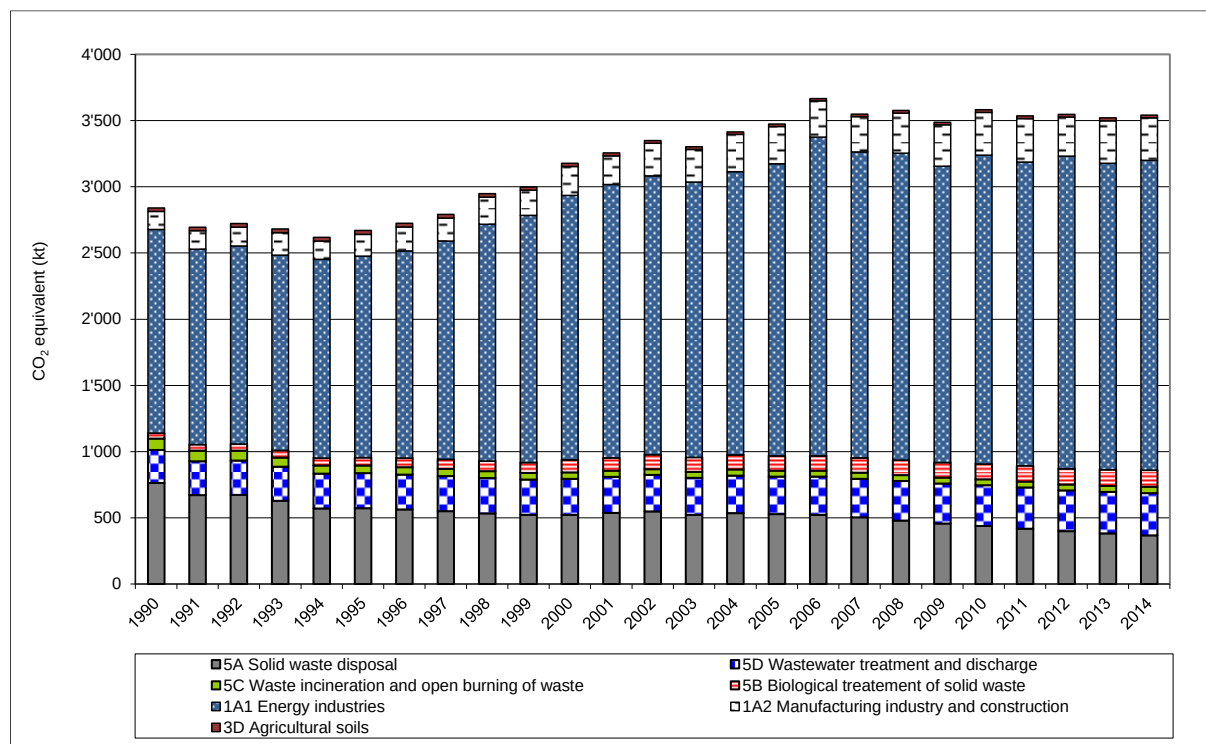


Figure 7-3 Total waste-related GHG emissions from 1990–2014, reported in different sectors.

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), in the Waste Concept for Switzerland (SAEFL 1992) and in the ordinance regarding waste avoidance and waste management (Swiss Confederation 2015). 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 treated in the respective sectors in Switzerland, including imports and exports. Only waste fractions

that are emission-relevant are shown. The figure further illustrates where the processes related to the waste management system are reported in the NIR. The following details can be provided regarding the different sectors:

- **1 Energy:** In accordance with the 2006 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 and the use of landfill gas is also reported in sector 1 Energy, as such biogas is used for combined heat and power generation. The energy production from renewable goods, such as the use of wood waste in wood-fired power stations, is reported under 1A2, 1A4ai and 1A4bi.
- **3 Agriculture:** Since 2003 it is forbidden in Switzerland to use sewage sludge as a fertilizer. In 2014, within sector 3 Agriculture only compost used as fertilizer was emission-relevant (due to N₂O emissions as described in chp. 5.5.2.2, Table 5-18).
- **5 Waste:** Only emissions from waste management activities not used for energy production are reported under sector 5 Waste. Solid waste disposal does not occur anymore in Switzerland as incineration is the mandatory disposal option for combustible waste since 2000. Emissions from composting are described under 5B1. Emissions related to digestion, but not directly related to energy production (such as the storage of digested biomass), are reported under 5B2. 5C Waste incineration and open burning of waste accounts for a small fraction only, consisting of illegal waste incineration, sewage sludge incineration, burning of residues in agriculture and forestry, and cremations. Special waste incineration without energy recovery, such as cable incineration or hospital waste incineration, no longer takes place in Switzerland and is thus crossed out in the figure. These waste fractions are also incinerated in MSWIP and therefore reported under sector 1 Energy. Emissions related to wastewater treatment are reported under 5D.

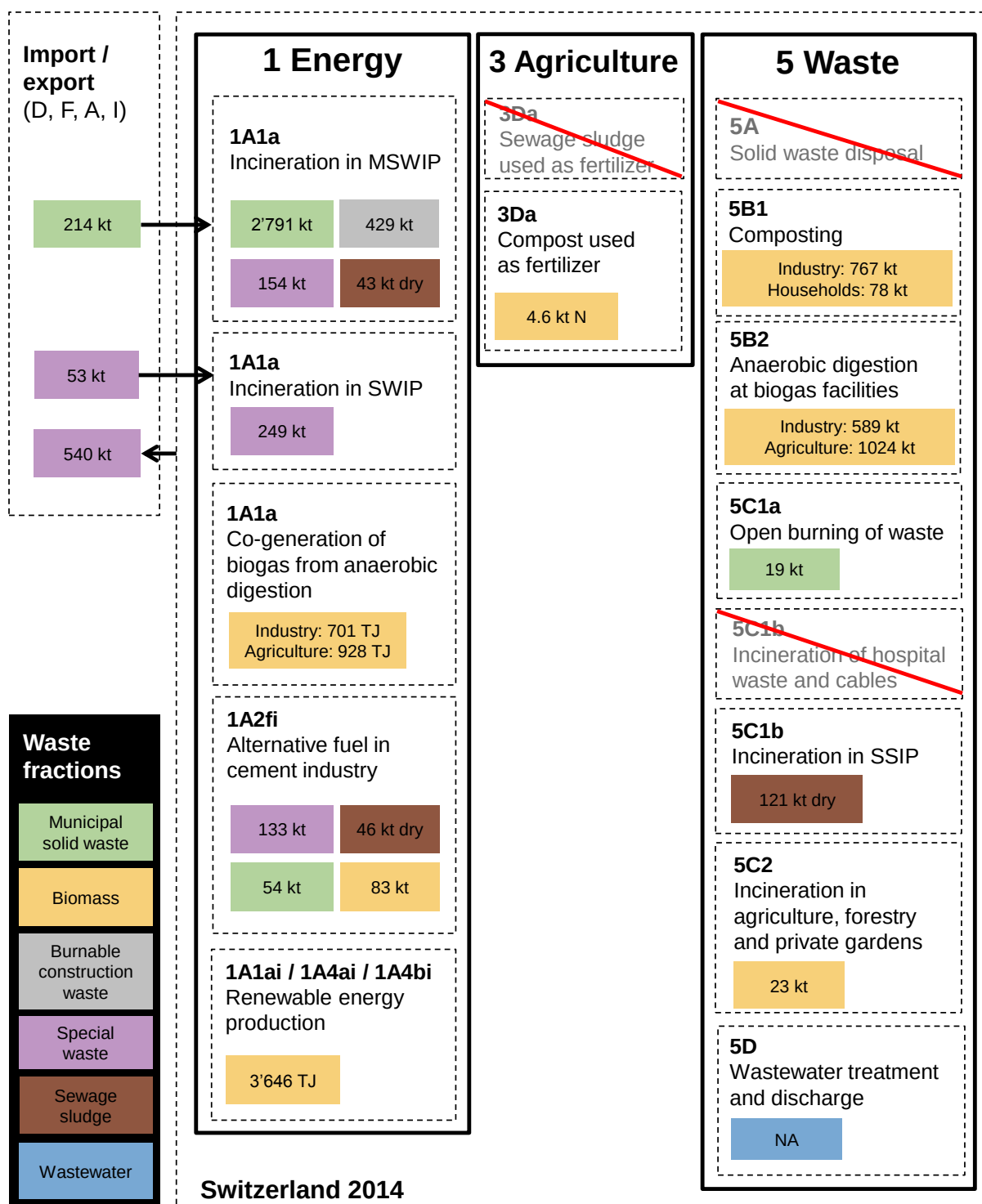


Figure 7-4 Overview on the type of treatment and amounts of waste treated in the respective sectors in Switzerland in 2014. Abbreviations: MSWIP: Municipal Solid Waste Incineration Plant, SWIP: Special Waste Incineration Plant, SSIP: Sewage Sludge Incineration Plant, D: Germany, F: France, A: Austria, I: Italy.

Regarding the treatment and amounts of relevant waste types the following details can be provided (state in 2014, recycled amounts are not shown in Figure 7-4 because they are not emission-relevant):

- **Municipal solid waste:** In Switzerland more than 50% of the municipal solid waste is collected separately and recycled (FOEN 2015m). The amount of waste incinerated includes imported MSW, 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.
- **Construction waste:** More than half of the construction waste is recycled. About half of the recycling takes place at the construction sites, e.g. by reusing material left after breaking up the road cover. The other half is separated at the construction sites and recycled individually, e.g. used glass, metals, concrete etc. (EMPA 2004a). A minor amount of combustible construction waste is incinerated in MSWIP. The remaining, inert construction waste is 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.. The special waste is either recycled, biologically treated, landfilled or exported for landfilling in foreign countries (FOEN 2015k, FOEN 2015o). Only the amount of incinerated special waste is emission-relevant (EMIS 2016/1A1a Kehrichtverbrennungsanlagen and EMIS 2016/1A1a Sondermüllverbrennungsanlagen). Special waste is also used as an alternative fuel in the cement production (EMIS 2016/1A2f i Zementwerke Feuerung).
- **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. Therefore, all sewage sludge is incinerated, either in MSWIP or in SSIP without energy recovery (internal information provided by the waste section of FOEN). Sewage sludge is also used as an alternative fuel in the cement industry (EMIS 2016/1A2fi Zementwerke Feuerung).
- **Biomass:** The term biomass refers to a broad range of materials such as garden waste, grass, wood waste, liquid manure and production remains from the food industry or further fractions, depending on the process concerned. Biomass from agriculture, forestry and private gardens are burned without energy recovery (EMIS 2016/5C2 Abfallverbrennung Land- und Forstwirtschaft), Biomass is also digested or composted (in large-scale composting facilities or backyards). Quantities of biomass refer to wet matter. Biomass such as used wood or animal fat is used as an alternative fuel in the cement industry (EMIS 2016/1A2fi Zementwerke Feuerung). Compost is used as a fertilizer (see Table 5-18 "Other organic fertilisers"). Wood is used for energy production, for example in wood-fired power stations, chimneys or pellet heating systems (SFOE 2015b).

7.2 Source category 5A – Solid waste disposal

7.2.1 Source category description

Approach 1 key category 5A

CH₄ emissions from solid waste disposal (level and trend)

Approach 2 key category 5A

CH₄ 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 combustible 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 to date 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 landfill sites were equipped to recover landfill gas in 2014 (SFOE 2015a). 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 small amount of the landfill gas is flared (Consaba 2016).

Table 7-2 Specification of source category 5A Solid waste disposal in Switzerland.

5A	Source	Specification
5A1	Managed waste disposal sites	Emissions from managed solid waste landfill sites.
5A2	Unmanaged waste disposal sites	Officially no unmanaged waste disposal sites exist (included in 5A1)

7.2.2 Methodological issues

Methodology (5A)

Emissions are calculated by a Tier 1 method based on the decision tree in Fig. 3.1 of chp. 3. Solid waste disposal in IPCC (2006). The spreadsheet for the First Order Decay (FOD) model provided by IPCC (2006) has been applied and parametrised for Swiss conditions (FOEN 2016g).

The values for the parameter degradable organic carbon (DOC) are provided for each waste fraction (Table 7-3). For all waste types the IPCC default values are used, except for industrial waste. For industrial waste the default value for wood and straw is used, as most of the industrial waste deposited in Switzerland is assumed to be wood waste.

Table 7-3 Degradable organic carbon (DOC) values for fractions of different waste compositions (weight fraction, wet basis).

Waste composition (weight fraction, wet basis)	IPCC default value		Country-specific parameters	
	Range	Default	Swiss Value	Reference and remarks
Food waste	0.08-0.20	0.15	0.15	
Garden	0.18-0.22	0.2	0.2	
Paper	0.36-0.45	0.4	0.4	
Wood and straw	0.39-0.46	0.43	0.43	
Textiles	0.20-0.40	0.24	0.24	
Disposable nappies	0.18-0.32	0.24	NO	not relevant/no activity data
Sewage sludge	0.04-0.05	0.05	0.05	
Industrial waste	0.00-0.54	0.15	0.43	all waste wood

The methane generation rate [1/yr] is chosen according to wet temperate conditions (Table 7-4). For all waste types the IPCC default values are used, except for industrial waste. For industrial waste the default value for wood and straw is used, again based on the fact that most of it is assumed to be wood waste.

Table 7-4 Methane generation rate [1/yr] according to waste by composition for wet temperature conditions.

Waste composition (weight fraction, wet basis)	IPCC default value		Country-specific parameters	
	Range	Default	Swiss Value	Reference and remarks
Food waste	0.1–0.2	0.185	0.185	
Garden	0.06–0.1	0.1	0.1	
Paper	0.05–0.07	0.06	0.06	
Wood and straw	0.02–0.04	0.03	0.03	
Textiles	0.05–0.07	0.06	0.06	
Disposable nappies	0.06–0.1	0.1	NO	not relevant/no activity data
Sewage sludge	0.1–0.2	0.185	0.185	
Industrial waste	0.08–0.1	0.09	0.03	all waste wood

The general parameters are set as follows:

- DOC_f (fraction of DOC dissimilated) = 0.5 (IPCC default value)
- Delay time (months) = 6 (IPCC default value)
- Fraction of methane (F) in developed landfill gas = 0.5 (IPCC default value)
- Conversion factor, C to CH₄ = 1.33 (IPCC default value)
- Oxidation factor (OX) = 0.1

The oxidation factor OX has been set to 0.1 according to IPCC guideline, chp. 3 (IPCC 2006), since it is standard practice in Switzerland to cover the landfills, e.g. with soil.

For the methane correction factors (MCF) for the different landfill site types IPCC default values are used. Between 1950 and 2030 waste distribution to the following three solid waste disposal site types has taken place (for both MSW and IW):

- Methane correction factor (MCF) for unmanaged, shallow SWDS = 0.4 (IPCC default value)
- Methane correction factor (MCF) for unmanaged, deep SWDS = 0.8 (IPCC default value)
- Methane correction factor (MCF) for managed SWDS = 1 (IPCC default value)

The other two MCF (managed, semi-aerobic and uncategorised) are not relevant because such SWDS are not occurring in Switzerland, i.e. no waste has been distributed to such sites.

The waste composition of MSW generated and going to solid waste disposal sites has changed during the last 60 years (see Table 7-5).

Table 7-5 Composition of MSW going to solid waste disposal sites (sources BUS 1978, BUS 1984, . FOEN 2014o).

Food	Garden	Paper	Wood	Textile	Nappies	Plastics, other inert	Time period
23.8%	4.2%	36.0%	4.0%	4.0%	0.0%	28.0%	1950-1979
26.5%	2.9%	30.6%	4.3%	3.1%	0.0%	32.6%	1980-1989
21.4%	1.6%	28.0%	5.0%	3.0%	0.0%	41.0%	1990-1999
26.6%	1.4%	21.0%	2.0%	3.0%	0.0%	46.0%	2000-2009
31.5%	1.7%	17.2%	1.8%	3.2%	0.0%	44.6%	2010 -

With these parametrisations and the activity data for municipal solid waste (MSW), industrial waste (IW) and sewage sludge (SS) the amount of CH₄ generated in landfills is calculated. The amount of CH₄ recovered and used as fuel for combined heat and power generation or flared is then subtracted.

For combined heat and power generation and flaring, the emissions of other gases are considered to be proportional to the amount of CH₄ burnt (Table 7-6).

Emission factors (5A)

Emission factors for CO₂, CH₄, CO, NMVOC and SO₂ are country-specific based on measurements and expert estimates, as documented in EMIS 2016/1A1 & 5A Kehrichtdeponien. CO₂ emissions from non-biogenic waste are included, while CO₂ emissions from biogenic waste are excluded from total emissions. Table 7-6 presents the emission factors used in 5A1.

Table 7-6 Emission Factors for 5A1 Managed waste disposal sites in 2014.

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	3.0	NA	1.0	NA	NA	NA	NA
	kg / t CH ₄ burned						
Flaring	2750	NA	NA	1.0	17	NA	NA

Activity data (5A)

There are three kinds of activity data for 5A1 Managed waste disposal sites: Waste quantities disposed on landfills, direct CH₄ emissions and CH₄ flared.

For the calculation of these three kinds of activity data the amounts of MSW, IW and SS deposited on SWDS are relevant.

Table 7-7 Activity data in 5A1: Waste disposed on managed waste disposal sites from 1990 to 2014 (documented in EMIS 2016/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1990	1995	2000
Municipal solid waste (MSW)	kt	650.0	540.0	291.7
Construction waste (CW)	kt	150.0	60.0	53.9
Sewage sludge (SS)	kt (dry)	60.0	28.1	4.2
Open burned waste	kt	NO	NO	NO
Total waste quantity	kt	860.0	628.1	349.7

5A1 Managed waste disposal sites	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Municipal solid waste (MSW)	kt	13.7	3.6	1.5	1.2	NO	NO	NO	NO	NO	NO
Construction waste (CW)	kt	1.4	0.8	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge (SS)	kt (dry)	1.0	0.3	NO	NO	NO	NO	NO	NO	NO	NO
Open burned waste	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total waste quantity	kt	16.1	4.7	1.5	1.2	NO	NO	NO	NO	NO	NO

Table 7-7 documents the amounts of municipal solid waste, construction waste and sewage sludge disposed of on managed waste disposal sites over the time period 1990–2014 (as documented in EMIS 2016/1A1a & 5A Kehrichtdeponien). The continuous decline of the waste amounts landfilled happened due to changes in the legislative framework, making incineration the mandatory disposal option for combustible waste and banning its disposal on landfills from 1 January 2000. The amounts of combustible waste disposed of on managed waste disposal sites reached zero in 2009. Open burning of waste on SWDS has occurred in the past but is assumed to have ceased since 1990 (expert judgement) and is therefore NO in Table 7-7.

With these primary activity data total CH₄ emissions generated are calculated using the spreadsheet FOD model provided by IPCC (2006). For the calculation of direct CH₄ emissions, CH₄ flared and used in co-generation units is determined and subtracted from total CH₄ emissions (Table 7-8). 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.

The amount of CH₄ used in co-generation stems from the Swiss statistics of renewable energies (SFOE 2015a). The amount of landfill gas flared has been assessed in a separate investigation in the year 2015 (Consaba 2016). The study distinguishes four types of managed landfill sites according to their equipment and CH₄ management:

- landfills with gas recovery in combined heat and power generation, boiler and torch.
- landfills with gas recovery or thermal treatment (boiler, torch, non-catalytic oxidation, flameless oxidation)
- landfill gas recovery without methane elimination (biofilter, aerobiosation)
- landfills without gas treatment (direct release)

The estimation of landfill gas flared is based on measurements in some representative SWDS of the first two landfill types, taking into account the different CH₄ treatment techniques. The amount flared deduced for these representative sites is then extrapolated to all managed SWDS and finally expressed as a percentage of CH₄ produced in all SWDS in Switzerland. The percentage flared varies between 5 and 15% in the years since 1990.

Table 7-8 Activity data in 5A1: Direct CH₄ emissions, CH₄ flared and CH₄ used in co-generation units (CHPG) from 1990 to 2014 (as documented in EMIS 2016/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1990	1995	2000
CH ₄ direct emissions	kt	30.5	22.9	20.9
CH ₄ flared	kt	1.8	5.2	5.6
CH ₄ used in co-generation units (reported under 1A1a)	kt	4.9	12.1	11.3

5A1 Managed waste disposal sites	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CH ₄ direct emissions	kt	21.1	20.9	20.1	19.2	18.3	17.5	16.7	16.0	15.3	14.7
CH ₄ flared	kt	3.4	3.2	2.9	2.6	2.4	2.4	2.1	1.8	1.6	1.4
CH ₄ used in co-generation units (reported under 1A1a)	kt	4.1	2.7	2.1	1.8	1.5	1.0	0.9	0.9	0.8	0.6

The CH₄ generated in landfills decreased since 1990 because waste quantities disposed of in landfills have been decreasing. Together with the relative increase of CH₄ recovery from 1990 until 2014 this is the reason for CH₄ emissions from the source category 5A being a key source regarding trend.

7.2.3 Uncertainties and time-series consistency

Uncertainty in CH₄ and CO₂ emissions from 5A Solid waste disposal

For lack of a detailed uncertainty analysis with the new FOD model, a combined uncertainty of 30% is assumed for the CH₄ emissions (EMIS 2016/1A1a & 5A Kehrichtdeponien).

Consistency: Time series for 5A Solid waste disposal are all considered consistent.

7.2.4 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

7.2.5 Category-specific recalculations

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- The FOD model used to calculate activity data (direct emissions, flaring, use in CHP) has been completely revised. FOEN now uses the official IPCC 2006 model template. At the same time, parameters have been changed to be in accordance with default values in the template, shares of waste deposited to different types of SWDS and waste composition information have been updated, as well as the amount of CH₄ flared on the sites.
- In the course of the complete revision of the FOD model (see recalculation above) activity data for open burning on solid waste disposal sites has been reconsidered. It is now assumed that open burning did not take place after 1990, which is more plausible than the former assumption of open burning taking place until 2020.
- The amount of CH₄ flared on SWDS has been assessed in a separate study. Therefore AD for the entire reporting period have changed.

7.2.6 Category-specific planned improvements

No category-specific improvements are planned.

7.3 Source category 5B – Biological treatment of solid waste

7.3.1 Source category description

Approach 1 key category 5B

CH₄ from biological treatment of solid waste (trend).

Approach 2 key category 5B

CH₄ from biological treatment of solid waste (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 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 tonnes of organic matter per year. Backyard composting is also common practice in Switzerland and taken into account.

In 5B2 Anaerobic digestion at biogas facilities, the digested matter (solid leftovers 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 digested matter as well as the CH₄ losses resulting from biogas upgrading are included. The emissions related to the use of biogas for combined heat and power generation as well as emissions from biogas-upgrading are reported under the sector 1 Energy.

Table 7-9 Specification of source category 5B Biological treatment of solid waste.

5B	Source	Specification
5B1	Composting	Process-related emissions from composting of organic waste
5B2	Anaerobic digestion at biogas facilities	Process-related emissions from digesting of organic waste

7.3.2 Methodological issues

Methodology (5B)

Emissions are calculated by a Tier 2 method based on chp. 4.1.1 Biological treatment of solid waste in IPCC (2006).

For the emissions from 5B2 Anaerobic digestion at biogas facilities, a Tier 2 method is used. Digestion plants lead to GHG emissions from the interim storage of organic waste, losses due to leakages and diffusion, interim storage of fermented liquid waste, composting of fermented solid waste and flaring.

Because of the increase in composting and digesting organic waste the source category 5B Biological treatment of solid waste is a key source regarding trend.

Within 5B2 Anaerobic digestion at biogas facilities two plant types are distinguished: i) industrial biogas plants and ii) agricultural biogas plants. Furthermore biogas upgrading is another separate process covered in this source category.

Figure 7-5 depicts a schematic design of industrial biogas plants. Six process steps are taken into account, where GHG are emitted. For each process step, separate activity data and emission factors are used:

- P1: GHG release during organic waste storage
- P2: GHG release during fermentation
- P3: GHG release during interim storage of liquid digestate
- P4: GHG emissions during composting of solid digestate

- P5: GHG emissions from the utilisation of biogas in the CHP units
- P6: Emissions from flaring of biogas

P5 is dealt with in source category 1A1a (energy-related GHG emissions).

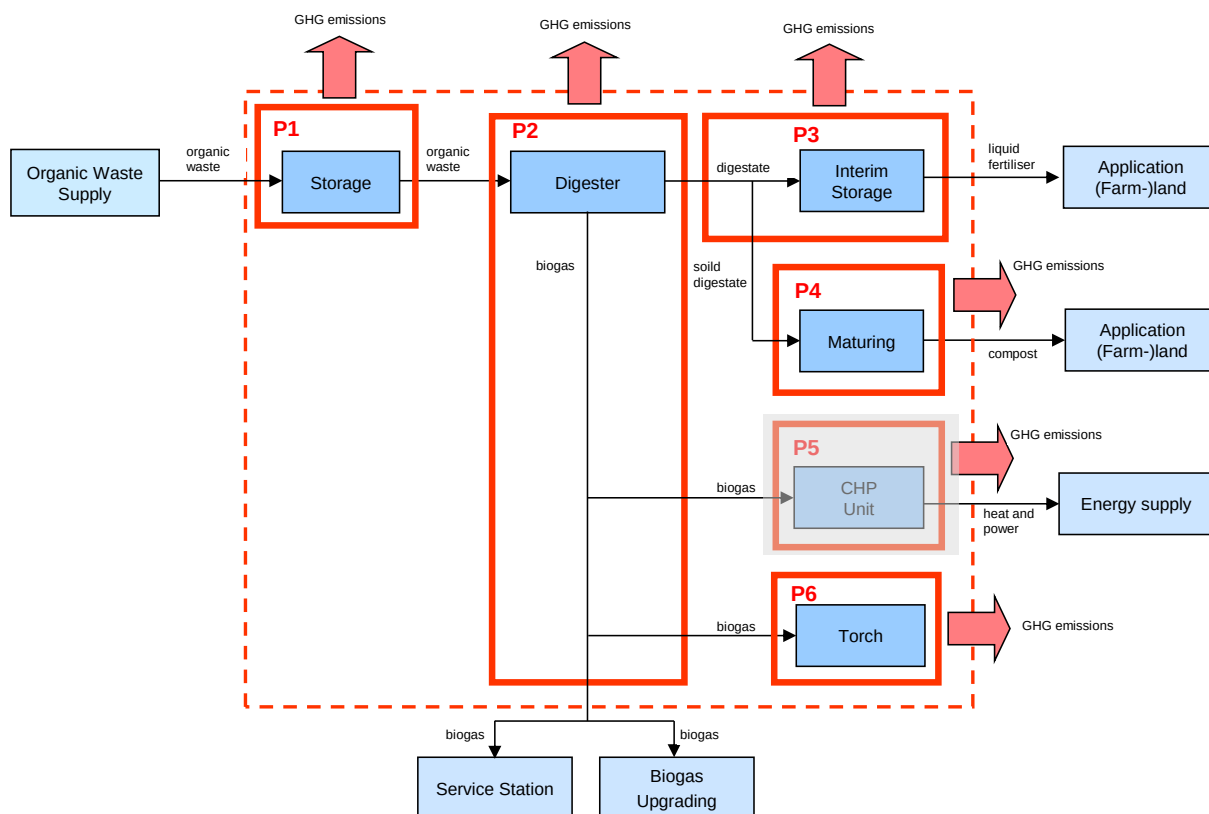


Figure 7-5 Schematic Design of industrial biogas plants.

Figure 7-6 depicts a schematic design of agricultural biogas plants. Seven process steps are taken into account, where GHG are emitted. For each process step, separate activity data and emission factors are used:

- P1: Emissions from intermediate storage of the waste from animal husbandry (liquid manure and manure) and the additional co-substrate.
- P2: Losses of biogas due to leakage from the fermenter und gas piping, and overproduction
- P3: Emissions from the storage of the liquid digestate
- P4: Emissions from aerobic after treatment of the solid digestate-
- P5: Emissions from the utilisation of biogas in the CHP units
- P6: Emissions from the utilisation of biogas in the gas boiler
- P7: Emissions from flaring of biogas

Emissions from P1 are reported in sector 3 Agriculture, and emissions from P5 and P6 are reported in sector 1 Energy.

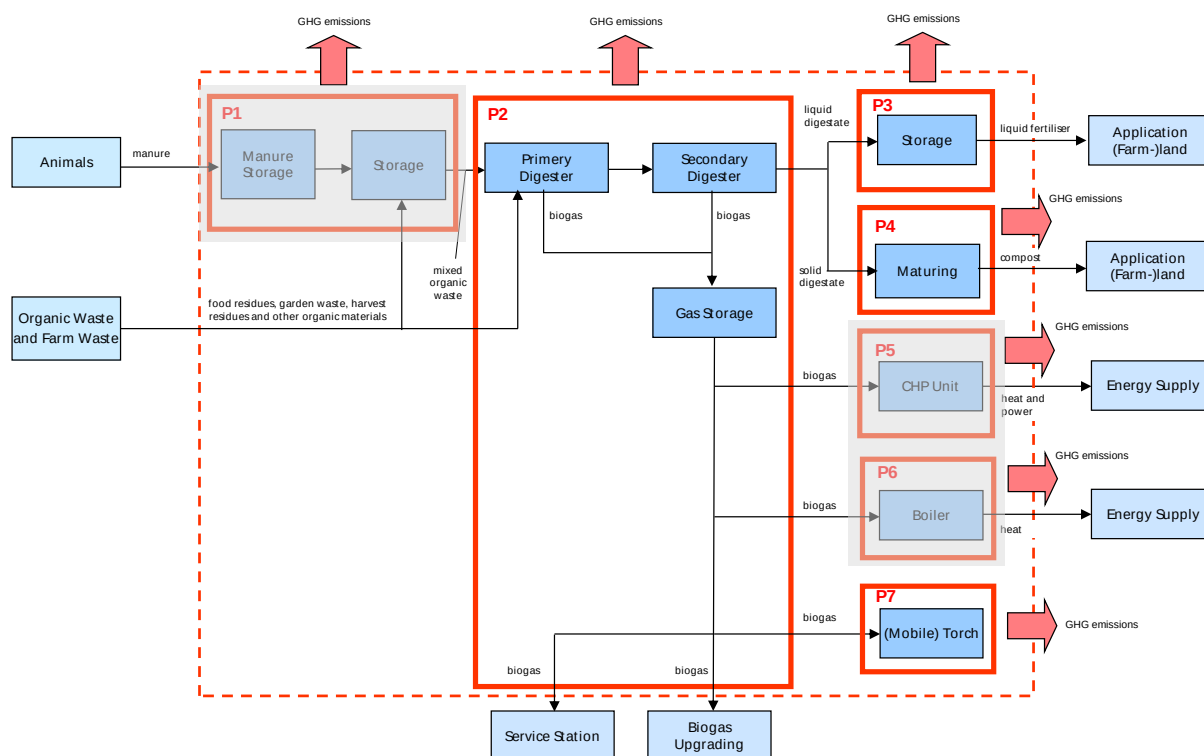


Figure 7-6 Schematic Design of agricultural biogas plants.

Emissions for air pollutants are calculated for each process step P1 to P6 for industrial and P1 to P7 for agricultural biogas facilities as shown in Figure 7-5 and Figure 7-6. Emissions depend on the amount of substrate processed and emission factors are process step specific with material throughput as activity data for each step. As mentioned above some of the process steps are reported in source category Energy or Agriculture.

In contrast, emissions for greenhouse gases from industrial and agricultural biogas facilities are estimated per biogas facility and not per process step as described above. This is due to the fact that an evaluation of measurement data for methane losses has shown that those losses are not dependent on the amount of substrate processed in a particular facility. Therefore CH₄-emissions are calculated based on an emission factor per plant multiplied by the number of industrial and agricultural biogas facilities, respectively.

Emission factors (5B)

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 2016/5B1 Kompostierung Industrie
- EMIS 2016/5B2 Biogasaufbereitung
- EMIS 2016/1A1a und 5B2 Vergärung IG
- EMIS 2016/1A1a und 5B2 Vergärung LW

Table 7-10 presents the emission factors used in 5B, where composting, industrial and agricultural biogas plants are distinguished. Furthermore, the digestion process in industrial and agricultural biogas plants is split into different activities.

New EF for CH₄ have been determined for anaerobic digestion at agricultural as well as at industrial biogas facilities. The reassessment is based on i) reports in the framework of the GHG emission compensation projects (including field investigations), ii) official regulations regarding maximal CH₄ leakage in the case of CH₄ upgrading, and iii) studies focussing on CH₄ emissions from biogas upgrading. Measurements indicate that there is no correlation between the produced amount of biogas and the amount of biogas lost to the atmosphere. The data show that in average each biogas facility loses 1.23 t CH₄ per year. This value is used to estimate the emissions from agricultural as well as industrial biogas facilities in Switzerland (FOEN 2015n).

N₂O emissions from source category 5B2 are considered to be negligible in the 2006 IPCC Guidelines (IPCC 2006) and it is suggested to set them to zero.

The EF for CH₄ leakage from biogas upgrading has been re-estimated according to regulations by the Swiss Gas and Water Association (SGWA 2015a). An assessment of measurement data from the years 2007, 2013 and 2014 shows that the plants are generally operating within the range of the emission limit (few plants below and some above). Therefore, the CH₄ leakage is estimated to be 5% in the year 1990 and 2.5% in the year 2014 and onwards. Between 1990 and 2014 the yearly values are linearly interpolated.

Emissions from composting encompass CO₂, CH₄, NH₃, N₂O and NMVOC and are based on measured or estimated values reported in the literature. CH₄ emission factors are taken from SFOE (1999), N₂O emission factors from Schenk (1997) and SFOE (1999).

Table 7-10 Emission factors for 5B Biological treatment of solid waste in 2014.

5B Biological treatment of solide waste	Unit	CH ₄	N ₂ O	NO _x	CO	NMVOC	SO ₂
Composting	g/t composted waste	5'000	70	NA	NA	1'700	NA
Digestion (industrial)	t/facility	1.2	NA	NA	NA	NA	NA
Digestion (ind., digestable waste / storage)	g/t digestable waste	NA	NA	NA	NA	70	NA
Digestion (ind., digested waste liquid / power water)	g/t digested waste (liquid)	NA	NA	NA	NA	400	NA
Digestion (ind., digested waste solid / rotting)	g/t digested waste (solid)	NA	NA	NA	NA	230	NA
Digestion (ind., flaring, CH ₄)	g/t CH ₄	40	NA	4'066	2'054	82	616
Digestion (agricultural)	t/facility	1.2	NA	NA	NA	NA	NA
Digestion (agr., digested waste liquid / power water)	g/t digested waste (liquid)	NA	NA	NA	NA	400	NA
Digestion (agr., digested waste solid / rotting)	g/t digested waste (solid)	NA	NA	NA	NA	230	NA
Digestion (agr., flaring, CH ₄)	g/t CH ₄	246	NA	4'066	2'054	82	616
Biogas up-grade	g/GJ	538	NA	NA	NA	NA	NA

Activity data (5B)

Activity data for composting are documented in EMIS 2016/5B1 Kompostierung Industrie. The activity data for industrial composting from 1990 to 2002 and for 2007 are based on waste statistics. The quantities from 2003 to 2006 are interpolated and the quantities from 2008 to the projection value in 2020 are 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 calculated based on data from the Swiss renewable energy statistics (SFOE 2015a). The activity data for each process step are estimated according to the number of biogas facilities, the waste amounts treated and the total amount of biogas produced (see Figure 7-5 and Figure 7-6).

The biogas used as fuel for combined heat and power generation is reported under 1A1 Energy in accordance with the 2006 IPCC Guidelines (IPCC 2006).

Table 7-11 Activity data in 5B Biological treatment of solid waste.

5B Biological treatment of solide waste	Unit	1990	1995	2000
Composting	kt wet	260	400	640
Digestion (industrial)	Numb.	NO	4	11
Digestion (ind., digestable waste / storage)	kt wet	NO	27	60
Digestion (ind., digested waste liquid / power water)	kt wet	NO	15	33
Digestion (ind., digested waste solid / rotting)	kt wet	NO	9	20
Digestion (ind., flaring, CH ₄)	kt	NO	0.03	0.10
Digestion (agricultural)	Numb.	102	76	68
Digestion (agr., digested waste liquid / power water)	kt wet	113	94	125
Digestion (agr., digested waste solid / rotting)	kt wet	6	5	7
Digestion (agr., flaring, CH ₄)	kt	NO	NO	NO
Biogas up-grade	GJ	NO	NO	19'866

5B Biological treatment of solide waste	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Composting	kt wet	735	737	739	747	754	762	770	778	786	794
Digestion (industrial)	Numb.	14	13	16	16	21	22	28	26	26	25
Digestion (ind., digestable waste / storage)	kt wet	107	137	163	176	224	288	371	507	560	589
Digestion (ind., digested waste liquid / power water)	kt wet	60	76	91	98	125	161	207	283	312	328
Digestion (ind., digested waste solid / rotting)	kt wet	37	47	56	60	77	98	127	173	191	201
Digestion (ind., flaring, CH ₄)	kt	0.17	0.23	0.27	0.30	0.39	0.48	0.60	0.80	0.86	0.85
Digestion (agricultural)	Numb.	72	80	77	75	75	72	80	89	97	98
Digestion (agr., digested waste liquid / power water)	kt wet	181	261	383	436	463	541	583	686	799	921
Digestion (agr., digested waste solid / rotting)	kt wet	10	14	20	23	24	29	31	36	42	48
Digestion (agr., flaring, CH ₄)	kt	NO	NO	NO	NO	NO	0.12	0.13	0.16	0.20	0.22
Biogas up-grade	GJ	40'637	41'710	50'966	71'721	85'008	121'627	168'170	236'074	283'503	368'862

To improve transparency the CH₄ and N₂O emissions of source category 5B Biological treatment of solid waste are shown on a completely disaggregated level in Table 7-12.

Table 7-12 CH₄ and N₂O emissions of 5B Biological treatment of solid waste.

5B Biological treatment of solide waste	Gas	Unit	1990	1995	2000
Composting	CH ₄	t	1'300	2'000	3'200
	N ₂ O	t	18.2	28.0	44.8
Digestion (industrial)	CH ₄	t	NO	4.9	13.6
Digestion (agricultural)	CH ₄	t	125.5	93.5	83.6
Biogas up-grade	CH ₄	t	NO	NO	16.9

5B Biological treatment of solide waste	Gas	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Composting	CH ₄	t	3'676	3'685	3'693	3'733	3'772	3'811	3'851	3'890	3'929	3'969
	N ₂ O	t	51.5	51.6	51.7	52.3	52.8	53.4	53.9	54.5	55.0	55.6
Digestion (industrial)	CH ₄	t	17.2	16.0	19.7	19.7	25.9	27.1	34.5	32.0	32.0	30.8
Digestion (agricultural)	CH ₄	t	88.6	98.4	94.7	92.3	92.3	88.6	98.4	109.5	119.4	120.6
Biogas up-grade	CH ₄	t	30.0	29.9	35.4	48.2	55.3	76.3	101.7	137.4	158.8	198.4

7.3.3 Uncertainties and time-series consistency

Uncertainty in CH₄ emissions from composting and digestion

The uncertainty of the CH₄ emission factors in source category 5B1 from composting of organic waste is estimated at 40% (EMIS 2016/5B1 Kompostierung Industrie). The

contribution of 5B1 to the CH₄ emissions of 5B is about 75%. For 5B2 the same uncertainty is assumed.

The uncertainty of the related activity data is estimated at 10% (EMIS 2016/5B1 Kompostierung Industrie) due to a high reliability of the waste statistics.

The uncertainty of the N₂O emission factor is unknown. Therefore, the uncertainty of N₂O 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 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

7.3.5 Category-specific recalculations

Recalculations reported in submission 2015

- 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 CO₂ compensation projects. This leads to changes in the activity data of industrial biogas facilities.

Recalculations reported in submission 2016

- New EF for CH₄ have been determined for anaerobic digestion at industrial biogas facilities. This leads to lower CH₄ emission for the whole time series. N₂O emissions are considered to be negligible in the 2006 IPCC Guidelines.
- New EF for CH₄ have been determined for anaerobic digestion at agricultural biogas facilities. This leads to lower CH₄ emission for the whole time series. N₂O emissions are considered to be negligible in the 2006 IPCC Guidelines.
- EF for methane leakage from biogas upgrading has been re-estimated according to requirements by Swiss regulations. This leads to lower emissions for the whole time series.
- Activity data of composting for the years 2008 and later has slightly changed due to interpolations between the last value that is set (2007) and the projection for 2020.
- Slightly revised projections for composting for the years 2020 and later have lead to small recalculations of AD for composting (households and industrial) because the last specified AD value is in the year 2007 and the years in between 2007 and 2020 are interpolated.

7.3.6 Category-specific planned improvements

No category-specific improvements are planned.

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 waste-to-energy activities are dealt with in 1A1a Public electricity and heat production.

5C1 encompasses incineration of hospital wastes, illegal waste incineration, incineration of insulation of materials from cables, of sewage sludge and in 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 7-13 Overview of waste incineration sources reported under 5C.

5C	Waste incineration	Specification
5C1	Hospital waste incineration	Emissions from incinerating hospital waste in hospital incinerators
	Illegal waste incineration	Emissions from illegal incineration of municipal solid wastes at home. Emissions from waste incineration at construction sites (open burning)
	Insulation material from cables	Emissions from incinerating cable insulation materials
	Sewage sludge	Emissions from sewage sludge incineration plants
	Crematoria	Emissions from the burning of bodies in crematoria
5C2	Open burning of branches	Open burning of branches in agriculture, forestry and gardening.

7.4.2 Methodological issues

Methodology (5C)

Emissions are calculated by a Tier 2 method based on chp. 5.2. in IPCC (2006). 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 burnt (in kt of wood equivalent) by emission factors (IPCC default method).

Emission factors (5C)

Emission factors of all categories within 5C1 for CO₂, CH₄, N₂O, CO, NMVOC and SO₂ are country-specific based on measurements and expert estimates, as documented in EMIS 2016/5C1. Table 7-14 presents an overview of the emission factors for 5C in 2014.

Table 7-14 Emission factors for 5C Waste incineration and open burning of waste in 2014.
Documentation/sources: EMIS 2016/5C1 and EMIS 2016/5C2 (details see Table 7-13), EMEP/EEA (2013).

5C Waste incineration and open burning of waste	CO ₂ t/t	CH ₄ kg/t	N ₂ O g/t	NO _x kg/t	CO kg/t	NMVOC kg/t	SO ₂ kg/t
Hospital waste incineration	0.9	NA	60	1.5	1.4	0.3	1.3
Municipal waste incineration (illegal)	0.5	6.0	150	2.5	50	16	0.75
Industrial waste incineration	1.3	NA	NA	1.3	2.5	0.5	6.0
Sewage sludge incineration	NA	0.1	800	0.7	0.19	0.005	0.47
Open burning of natural residues in agriculture	NA	6.8	180	1.4	49	1.5	0.03
Open burning of natural residues in forestry	NA	6.8	180	1.4	49	1.5	0.03
Open burning of natural residues in private households	NA	6.8	180	1.4	49	1.5	0.03
	CO ₂ t/crem.	CH ₄ kg/crem.	N ₂ O g/crem.	NO _x kg/crem.	CO kg/crem.	NMVOC kg/crem.	SO ₂ kg/crem.
Cremation	NA	NA	NA	0.21	0.09	0.009	NA

Comments to the CO₂ emission factors:

- For all waste incineration categories, only CO₂ emissions from non-biogenic waste are taken into account.
- Hospital waste incineration: The waste is mainly of fossil origin. The default value for the CO₂ emission factor is taken from SAEFL (2000). Since 2002, no emissions from hospital waste incineration occur, as all hospital waste incinerator plants have been closed and hospital waste is incinerated in municipal solid waste incineration plants (accounted for in 1A1a).
- Illegal waste incineration: The CO₂ emission factor is estimated by using the same assumption as in case of MSW incineration: The C-content is based on the study by FOEN (2014I) and the fossil fraction of C was determined by Ryttec (2014). See also chp. 3.2.5.2. Detailed information is given in EMIS 2016/1A1a Kehrichtverbrennungsanlagen (pp. 5–7).
- Industrial waste (consists of cable insulation materials): The CO₂ emission factor is based on measurements of the flue gas treatment of a cable disassembling site where O₂ was measured in the flue gas. Assuming that the ratio of CO₂/O₂ is the same as in municipal solid waste incineration plants, a fraction of 7% of CO₂ 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: As sewage sludge is biogenic waste, the emission factor for CO₂ is zero. 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-CO₂) gases:

- Hospital waste incineration: All emission factors are taken from SAEFL (2000).
- Illegal waste incineration: The emission factor for N₂O is taken from the 2006 IPCC Guidelines (IPCC 2006, vol. Waste), the emission factors for CH₄, SO₂, NO_x, NMVOC from SAEFL (2000) and USEPA (1995a).
- Industrial waste (cable 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, SO₂ and CH₄ 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 for installations with retrofitted flue gas treatment as well as non-retrofitted installations. The emission factors are calculated as weighted averages of cremations taking place in retrofitted and non-retrofitted cremation plants (EMIS 2016/5C1 Krematorien).
- The emission factors of burning of branches in agriculture and forestry are calculated based on EMEP/EEA (2013) except for CH₄ and N₂O which are based on EMEP/CORINAIR (EMEP/EEA 2002), see also documentation in EMIS 2016/5C2 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.
- General remark: Indirect CO₂ emissions from fossil CO and NMVOC emissions are reported in chp. 9 Indirect CO₂ and N₂O emissions.

Activity data (5C)

The activity data for 5C Waste incineration are the quantities of waste incinerated, see Table 7-15.

Table 7-15 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	1995	2000
Hospital waste incineration	kt	30.0	17.5	5.0
Municipal waste incineration (illegal)	kt	32.3	26.2	24.9
Industrial waste incineration	kt	7.5	NO	NO
Sewage sludge incineration	kt dry	57.0	50.2	64.3
Open burning of natural residues in agriculture	kt	16.5	15.2	14.0
Open burning of natural residues in forestry	kt	28.8	24.5	20.2
Open burning of natural residues in private households	kt	6.1	4.9	3.6
Total	kt	178.2	138.5	132.0
Cremation	Numb.	37'513	40'968	44'821

5C Incineration and open burning of waste	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Clinical waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Municipal waste incineration (illegal)	kt	21.7	22.6	22.1	22.4	20.7	21.0	20.3	20.3	19.4	19.3
Industrial waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge incineration	kt dry	94.9	92.7	95.2	97.7	100.1	102.6	102.4	100.8	109.0	121.0
Open burning of natural residues in agriculture	kt	12.8	12.5	12.3	12.0	11.8	11.5	11.5	11.6	11.6	11.6
Open burning of natural residues in forestry	kt	15.9	15.0	14.1	13.3	12.4	11.5	11.6	11.6	11.7	11.7
Open burning of natural residues in private households	kt	2.4	2.2	1.9	1.7	1.5	1.2	1.2	1.2	1.3	1.3
Total	kt	147.6	145.0	145.6	147.1	146.5	147.9	147.1	145.5	152.9	164.9
Cremation	Numb.	48'169	48'083	49'413	51'116	52'402	52'813	52'530	50'567	53'205	55'616

7.4.3 Uncertainties and time-series consistency

The uncertainty assessment is based on expert judgment results in high uncertainties for CO₂ and CH₄ of 40% and 60% of emission estimates, respectively, and for N₂O 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 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

7.4.5 Category-specific recalculations

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

7.4.6 Category-specific planned improvements

No category-specific improvements are planned.

7.5 Source category 5D – Wastewater treatment and discharge

7.5.1 Source category description

Approach 1 key category 5D

CH₄ emissions from wastewater treatment and discharge (level).

Approach 2 key category 5D

CH₄ emissions from wastewater treatment and discharge (level and trend).

N₂O emissions from wastewater treatment and discharge (level and trend).

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 about 850 WWT plants and 40'000–50'000 km of public sewers – is now practically complete (FOEN 2012h). The vast majority of WWT plants apply an anaerobic sludge treatment with sewage gas recovery, and use the sewage gas for heat production. About 290 WWT plants also apply 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, about 20 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 7-16 Specification of source category 5D Wastewater treatment and discharge

5D	Source	Specification
5D1	Domestic wastewater	Emissions from liquid waste handling and sludge from housing and commercial sources
5D2	Industrial wastewater	Emissions of precursors from handling of liquid wastes and sludge from industrial processes (emissions of CH ₄ and N ₂ O are implemented in 5D1)

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 7-7 below.

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 Figure 7-7. 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).

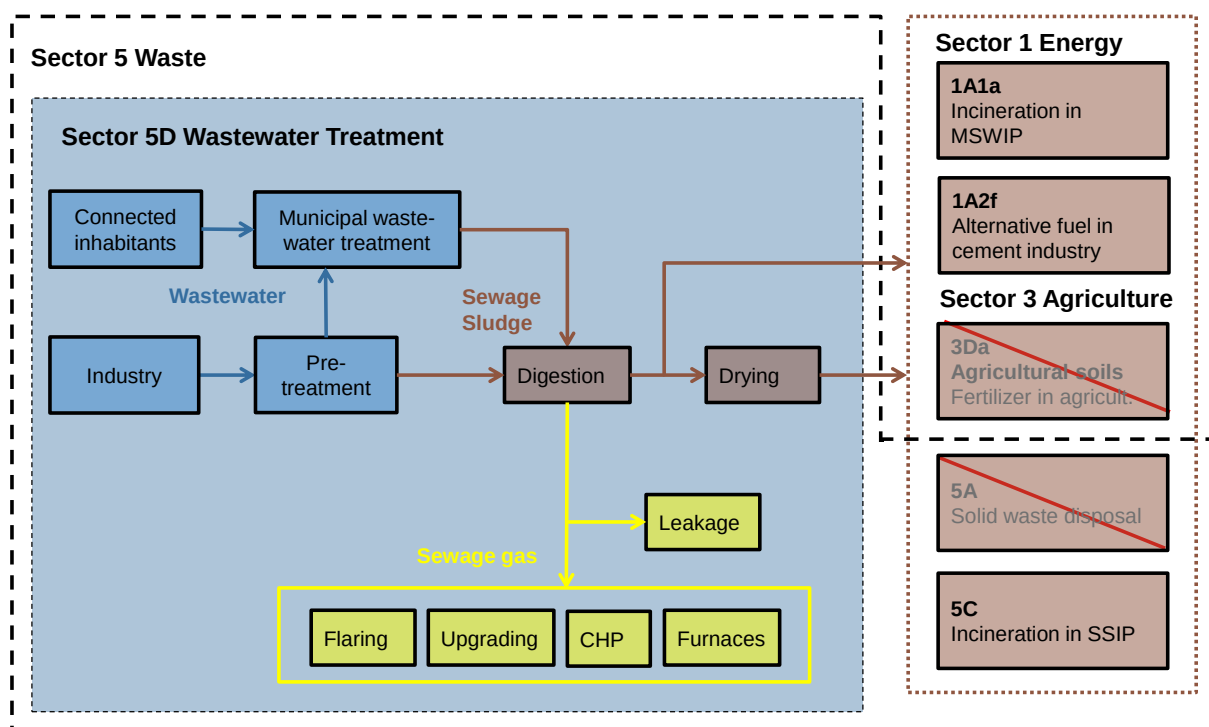


Figure 7-7 System boundaries of processes related to wastewater treatment. CHP= Combined heat and power generation. MSWIP = Municipal solid waste incineration plant. SSIP = Sewage sludge incineration plant.

7.5.2 Methodological issues

Emissions are calculated by a Tier 2 method based on the decision tree in Fig. 6.2 and Fig. 6.3 in chp. 6. Wastewater treatment and discharge in IPCC (2006). Details for CH₄ and N₂O are provided in the following.

a) CH₄ emissions

Methodology (5D)

CH₄ 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 CH₄ emissions from wastewater is thus taken into account in the calculation of CH₄ 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 CH₄ 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 sewerage 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 CH₄ in an anaerobic environment is strongly temperature dependent and significant CH₄ production is unlikely below 15°C due to the inactivity of methanogens (2006 IPCC). 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 CH₄ emissions. CH₄ 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 CH₄ 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 ($EF_{\text{sewage gas}}$, see below), which is normalized with population (P):

$$CH_{4,\text{sewage gas}} = EF_{\text{sewage gas}} * P$$

Emission factors (5D)

(i) Wastewater

The wastewater of all connected inhabitants, i.e. virtually all wastewater generated in Switzerland, is seweraged 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 CH₄ producing potential (B_0 , default value 0.60 kgCH₄/kgBOD) and the methane correction factor (MCF) for the wastewater treatment and discharge system. For the wastewater seweraged 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 CH₄ 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 CH₄ 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 1990–2014:

$$EF_{\text{wastewater}} = B_0 * MCF = 0.60 \frac{\text{kgCH}_4}{\text{kgBOD}} * 0.05 = 0.03 \frac{\text{kgCH}_4}{\text{kgBOD}}$$

As mentioned above the maximum CH₄ 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 CH₄. Accordingly, the EF for wastewater not treated in WWT plants is zero and the corresponding emissions are zero, too.

(ii) Sewage gas

To calculate the country-specific implied emission factor $EF_{\text{sewage gas}}$ for CH₄ 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 (SFOE 2015a). 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 from the upgraded gas, 5% leaks in 1990 and 2.5% in 2014 (linear decrease in-between). 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 CH₄ emission factors for 5D Wastewater treatment and discharge are summarized in Table 7-17.

Table 7-17 Country-specific CH₄ emission factors 5D Wastewater treatment and discharge 2014 referred to the number of inhabitants. Detailed information is given in EMIS 2016/5D1_5D2 Kläranlagen GHG (Wastewater Handling - Emissions of Nitrous Oxide (N₂O) and Methane (CH₄), Update to the 2006 IPCC Guidelines).

5D Wastewater treatment and discharge	Unit	2014
Population	in 1000	8'189
Emissions from WW sewered to WWT plants	kg CH ₄ /inhabitant/a	0.80
Emissions from WW not sewered to WWT plants	kg CH ₄ /inhabitant/a	NA
Emissions from losses during sludge treatment	kg CH ₄ /inhabitant/a	0.06

Activity data (5D)

(i) Wastewater

In correspondence with the emission factor $EF_{\text{wastewater}}$ 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), TOW is calculated by

$$TOW = P * BOD * 0.001 * I * 365$$

TOW is given in kg BOD/yr (BOD: biochemical oxygen demand) and P is the population (see Table 7-18). For BOD the default value for Europe given by the 2006 IPCC Guidelines (IPCC 2006) is used for Switzerland (60 g/inhabitant/day). The parameter I 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 7-18.

(ii) Sewage gas

As elaborated above, a per capita CH₄ emission factor ($EF_{\text{sewage gas}}$) is calculated for CH₄ emissions from separate sewage sludge treatment, and the respective activity data is population (Table 7-18).

b) N₂O emissions**Methodology (5D)**

Direct N₂O emissions from centralized WWT plants and N₂O emissions from wastewater effluent are calculated in accordance with the 2006 IPCC Guidelines (IPCC 2006).

(i) N₂O emissions from WWT plants

Direct N₂O emissions from WWT plants are determined with equation 6.9 of the 2006 IPCC Guidelines (IPCC 2006):

$$N_2O_{PLANTS} = EF_{PLANT} * P * T_{PLANT} * F_{IND-COM}$$

N_2O_{PLANTS} corresponds to the total N₂O emissions from WWT plants in kg N₂O/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) N₂O emissions from wastewater effluents

The following equation from the 2006 IPCC Guidelines (IPCC 2006) for the N₂O emissions from wastewater effluent is used:

$$N_2O_{EFFLUENT} = EF_{EFFLUENT} * N_{EFFLUENT} * 44/28$$

$N_2O_{Effluent}$ corresponds to the total N₂O emissions from effluents (kg N₂O/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 N₂O emissions from discharged wastewater (kg N-N₂O/kg N). The following equation allows for the calculation of the total amount of nitrogen in the wastewater ($N_{EFFLUENT}$, kg N/yr, 2006 IPCC Guidelines):

$$N_{EFFLUENT} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{SLUDGE} - N_{WWT}$$

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 its 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 (5D)

(i) N_2O emissions from WWT plants

The IPCC default emission factor is applied: $EF_{PLANT} = 3.2 \text{ g } N_2O/\text{inhabitant}/\text{yr}$ (IPCC 2006).

(ii) N_2O emissions from wastewater effluents

The IPCC default emission factor is applied: $EF_{EFFLUENT} = 0.005 \text{ kg } N_2O/\text{kg N}$ (IPCC 2006).

Activity Data (5D)

(i) N_2O emissions from WWT plants

The needed time-dependent and country-specific activity data are summarized in Table 7-18:

- 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: $F_{IND-COM} = 1.25$ (IPCC 2006)

(ii) N_2O emissions from wastewater effluents

The time-dependent and country-specific activity data are also summarized in Table 7-18:

- Population (P)
- Annual per capita protein consumption (Protein) (SBV 2015)
- 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: $F_{NPR} = 0.16 \text{ kg N/kg protein}$ (IPCC 2006).
- Factor accounting for non-consumed protein added to the wastewater, IPCC default value: $F_{NON-COM} = 1.1$ (IPCC 2006). 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 Confederation 1998a).

- Industrial/commercial co-discharged protein, IPCC default value: $F_{IND-COM} = 1.25$ (IPCC 2006).

Table 7-18 Activity data 5D Wastewater Treatment.

5D Wastewater treatment and discharge	Unit	1990	1995	2000
Population	inhabitants in 1000	6'796	7'081	7'209
Fraction of population connected to wastewater treatment plants	%	90.0	93.5	95.4
Connected inhabitants	inhabitants in 1000	6'116	6'621	6'877
Protein consumption	kg/person/a	38	37	37
N removed with sludge (N_{sludge})	N in t/a	9'465	9'009	8'831
N directly emitted (N_{WWT})	N in t/a	15.6	16.9	17.5
Total org. degr. material (TOW)	t/a	186'041	193'842	197'346

5D Wastewater treatment and discharge	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Population	inhabitants in 1000	7'501	7'558	7'619	7'711	7'801	7'878	7'912	7'997	8'089	8'189
Fraction of population connected to wastewater treatment plants	%	96.8	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0
Connected inhabitants	inhabitants in 1000	7'261	7'331	7'390	7'480	7'567	7'642	7'675	7'757	7'846	7'943
Protein consumption	kg/person/a	36	37	37	37	38	38	39	37	37	37
N removed with sludge (N_{sludge})	N in t/a	9'026	9'135	9'135	9'135	9'135	9'135	9'135	9'135	9'135	9'135
N directly emitted (N_{WWT})	N in t/a	18.5	18.7	18.8	19.0	19.3	19.5	19.5	19.7	20.0	20.2
Total org. degr. material (TOW)	t/a	205'340	206'900	208'570	211'089	213'552	215'660	216'591	218'918	221'436	224'174

c) Other gases

The sewage gas production generates emissions of further gases from flaring: CO₂ (biogenic), NO_x, CO, NMVOC, SO₂. The emissions are calculated by multiplying population (as activity data, see Table 7-18) with country-specific emission factors based on measurements and expert estimates, documented in EMIS 2016/5D1 Wastewater Treatment Plants and EMIS 2016/5D2 Pre-treatment of industrial wastewater. The emission factors used are summarized in Table 7-19.

Table 7-19 Emission factors of CO₂ (biogenic), CH₄, N₂O, NO_x, CO, NMVOC and SO₂ for 5D Wastewater treatment and discharge in 2014.

5D Wastewater treatment and discharge	CO ₂ biog.	N ₂ O	CH ₄	NO _x	CO	NMVOC	SO ₂
	kg/inhabitant						
5D1 Domestic wastewater	14.1	59	853	23	39	0.5	2.5
5D2 Industrial wastewater	2.2	IE	IE	3.0	4.9	0.1	0.3

7.5.3 Uncertainties and time-series consistency

Uncertainty in CH₄ and N₂O emissions from 5D

a) CH₄ emissions

The default values of the 2006 IPCC Guidelines (IPCC 2006) are adopted to estimate the uncertainty of CH₄ emissions. The following specifications are given:

- Activity data: Uncertainties of the single factors $U(\text{population}) = 5\%$, $U(\text{BOD}) = 30\%$, $U(I) = 20\%$ lead to an aggregated uncertainty of $U(\text{AD}) = 36\%$.
- CH_4 emission factor: Uncertainties of the single factors $U(B_0) = 30\%$, $U(\text{MCF}) = 10\%$ (well managed plants) lead to an aggregated uncertainty of $U(\text{EF}) = 32\%$.
- Combined uncertainty $U(\text{Em CH}_4) = 48\%$.

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 assuming a high uncertainty of N_2O emissions from 5D Wastewater treatment and discharge 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 in chp. 1.7.

Consistency: Time series for 5D Wastewater treatment and discharge are all considered consistent.

7.5.4 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

7.5.5 Category-specific recalculations

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- Energy used in combined heat and power installations (CHP) of wastewater treatment has been revised in the statistics for renewable energy by the SFOE for the years 2011–2013.
- The EF for CH_4 losses for sewage gas treatment/upgrading now linearly decreases from 5% in 1990 to 2.5% in 2014 (percentage of gas treated). This leads to lower emissions of CH_4 .

7.5.6 Category-specific planned improvements

No category-specific improvements are planned.

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 7-20 Specification of source category 5E Other (car shredding)

5E	Source	Specification
5E	Car shredding plants	Emissions from car shredding plants

7.6.2 Methodological issues

Methodology (5E)

For the emissions from car shredding a Tier 2 method is used.

Indirect CO₂ emissions from fossil CO and NMVOC emissions are described in chp. 9 Indirect CO₂ and N₂O emissions.

Emission factors (5E)

An emission factor of 100 g NMVOC per tonne 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. The NMVOC emission factor are based on measurements at 4 plants in the years from 2002 to 2008 (EMIS 2016/5E Shredder Anlagen). For CO a constant emission factor is applied over the whole period.

Table 7-21 CO and NMVOC emission factors for 5E Other (car shredding) in 2014.

5E Other waste	Unit	CH ₄	N ₂ O	NO _x	CO	NMVOC	SO ₂
Shredding	g/t scrap	NA	NA	NA	5	200	NA

Activity data (5E)

The waste quantities from 1990 to 1999 are data provided by the Swiss Shredding Association. The data from 2000 to 2007 are taken from Swiss waste statistics. From then

onwards the quantities are assumed to remain constant due to the lack of data (see also EMIS 2016/5E Shredder Anlagen).

Table 7-22 Activity data 5E Other (car shredding).

5E Other waste	Unit	1990	1995	2000
Shredding	kt	280	300	300

5E Other waste	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Shredding	kt	300	300	300	300	300	300	300	300	300	300

7.6.3 Uncertainties and time-series consistency

Uncertainties 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 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

7.6.5 Category-specific recalculations

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

7.6.6 Category-specific planned improvements

No category-specific improvements are planned.

8 Other

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

8.1 Overview

8.1.1 Greenhouse gas emissions

Within the sector 6 Other emissions from two sources are considered:

- Fire damage estates
- Fire damage motor vehicles

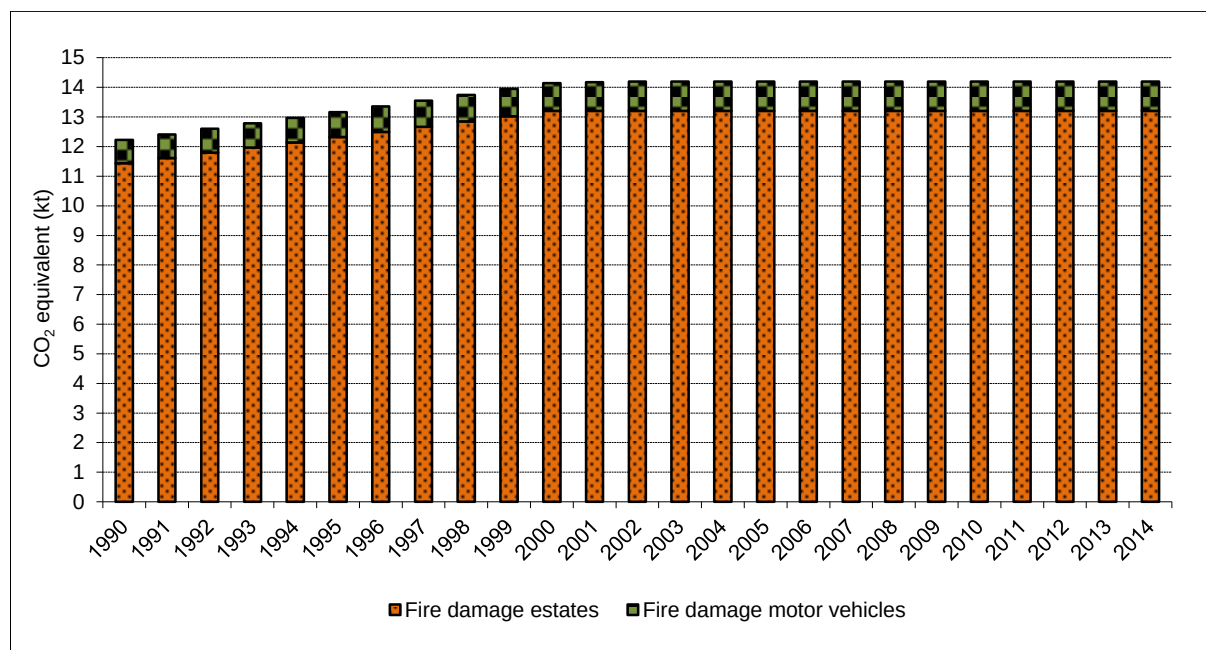


Figure 8-1 Switzerland's greenhouse gas emissions in the sector 6 Other 1990–2014.

Table 8-1 Trend of total GHG emissions from the sector 6 Other in Switzerland 1990–2014.

Gas	1990	1995	2000
	CO ₂ equivalent (kt)		
CO ₂	11.0	11.9	12.9
CH ₄	0.7	0.7	0.7
N ₂ O	0.6	0.6	0.6
Sum	12.2	13.2	14.1

Gas	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	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 ₂ O	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sum	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2

In the sector 6 Other “fire damage estates” account for most of the emissions, the rest stems from “fire damage motor vehicles”. The total greenhouse gas emissions of this sector show a slight increase from 1990 to 2003 and remain constant thereafter. However, sector 6 Other is an emission source of minor importance for the national total.

8.2 Source category 6 – Other

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.

6	Source	Specification
6Ad	Fire damage estates	Emissions from fires in buildings.
6Ad	Fire damage motor vehicles	Emissions from fires in motor vehicles.

8.2.2 Methodological issues

Methodology (6 Other)

a) Fire damage estates

This source category describes the emissions from fire damages in estates and its furniture. For the emissions from fire damages in estates a Tier 2 method is used. The AD and EF are country specific. The estimation of GHG emission is based on damage sums and fires reported from insurance companies.

b) Fire damage motor vehicles

This source category describes the emissions from fire damages in motor vehicles. For the emissions from fire damages in motor vehicles a Tier 2 method is used. The AD and EF are country specific. The estimation of GHG emission is based on damage sums and fires reported from insurance companies.

Emission factors (6 Other)

a) Fire damage estates

Emission factors for CO₂, CO, NO_x and SO₂ are country-specific based on measurements and expert estimates originally completed for illegal waste incineration. It is assumed that for fire damage in estates emissions are similar (EMIS 2016/6Ad "Brand- und Feuerschäden Immobilien").

The fraction between fossil and biogenic CO₂ emissions is assumed to remain constant since 2000 with 80% being fossil and 20% biogenic CO₂ emissions. Before 2000, it is assumed that the fraction of fossil CO₂ emissions from burnt goods has been increasing linearly from 20% in 1950 to 80% in 2000.

Indirect CO₂ emissions from fossil CO and NMVOC emissions are documented in chp. 9 Indirect CO₂ and N₂O emissions.

b) Fire damage motor vehicles

Emission factors for CO₂, CO, NO_x and SO₂ are country-specific based on measurements and expert estimates originally gained from the combustion of cable insulation materials, documented in EMIS 2016/6Ad "Brand- und Feuerschäden Motorfahrzeuge".

Emissions for CH₄ from fire damage in motor vehicles are reported as well, while N₂O emissions have not been estimated for this source.

Indirect CO₂ emissions from fossil CO and NMVOC emissions are documented in chp. 9 Indirect CO₂ and N₂O emissions.

Table 8-3 Emission factors for fire damages in 2014 (EMIS 2016/6Ad).

6Ad Fire damages	CO ₂ biogenic	CO ₂ fossil	CH ₄	N ₂ O	NO _x	CO	NMVOC	SO ₂
	t / kt burned good							
Fire damage estates	400	1'500	3	0.25	2.0	100	16	1
Fire damage motor vehicles	NO	1'500	5	NE	1.3	2	2	5

Activity data (6 Other)

a) Fire damage 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 combustible material per fire case. Further assuming that not the whole quantity 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 2016/6Ad "Brand- und Feuerschäden Immobilien"). Accordingly, activity data for estates is not estimated on a year to year basis but is assumed to be at a constant 8 kt per year for the whole time period since 1990.

b) Fire damage motor vehicles

Based on data from a Swiss insurance company with 25% market share in 2002, the number of reported vehicle fires is extrapolated between 1990 and 2002. Based on this estimate and the total vehicle number of Switzerland it is estimated that one fire case per 790 vehicles occurs per year. Multiplied with the actual vehicle number, the number of burnt vehicles in Switzerland per year is obtained. From 2003 and onwards a constant amount of burnt goods is assumed (EMIS 2016/6Ad "Brand- und Feuerschäden Motorfahrzeuge").

Activity data is the weight of burnt goods, assuming 100 kg of burnt goods per vehicle fire (EMIS 2016/6D "Brand- und Feuerschäden Motorfahrzeuge").

Table 8-4 Activity data: Burnt goods from 1990 to 2014 (documented in EMIS 2016/6Ad).

6Ad Fire damages	Unit	1990	1995	2000
Fire damage estates	kt	8	8	8
Fire damage motor vehicles	kt	0.5	0.5	0.6

6Ad Fire damages	Unit	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fire damage estates	kt	8	8	8	8	8	8	8	8	8	8
Fire damage motor vehicles	kt	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

8.2.3 Uncertainties and time series consistency

Uncertainties of CO₂, CH₄ and N₂O emissions are estimated to be high (according to Table 1-11).

Consistency: Time series for 6Ad Fire damages are all considered consistent.

8.2.4 Category-specific QA/QC and verification

The general QA/QC measures are described in section 1.2.3.

8.2.5 Category-specific recalculations

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

8.2.6 Category-specific planned improvements

No category-specific improvements are planned.

9 Indirect CO₂ and N₂O emissions

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

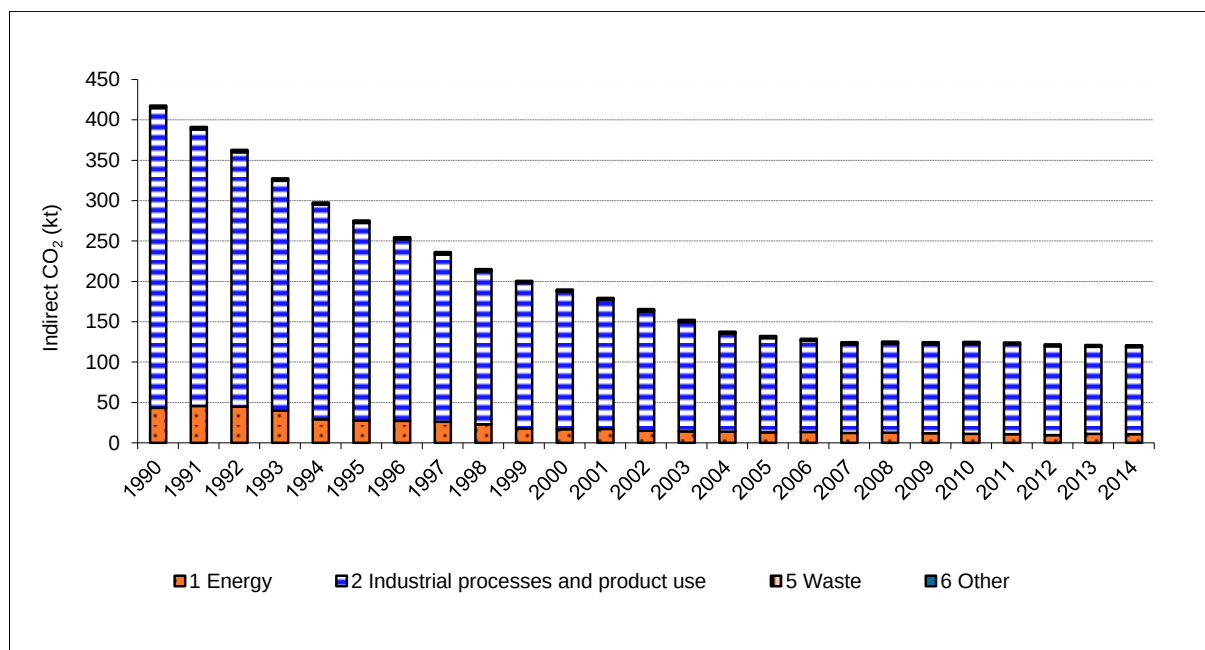
9.1 Overview

In this chapter, indirect CO₂ emissions that result from the atmospheric oxidation of NMVOC and CO as well as indirect N₂O emissions that are induced by the deposition of NO_x and NH₃ are documented. While indirect CO₂ emissions reported in this chapter are accounted for in the national total, indirect N₂O emissions are not.

Indirect emissions of CO₂ and N₂O are shown in CRF table 6, together with the source emissions of CH₄, CO, NMVOC, NO_x and NH₃. While all emissions of precursor gases are shown in both CRF table 6 and in the respective sectors, the indirect emissions of CO₂ and N₂O shown in CRF table 6 only represent emissions not already included together with direct emissions in other sectors (in order to avoid double counting). Further, in the case of indirect CO₂ emissions, only carbon of fossil origin is considered. Accordingly, while e.g. NMVOC and CO of biogenic origin are shown as precursor gases in CRF table 6, they are not included for the calculation of indirect CO₂ emissions. Consequently, the implied emission factors may vary from sector to sector and also from year to year. Indirect CO₂ emissions resulting from the atmospheric oxidation of CH₄ are generally not considered.

Chapter 9.2 explains in detail the methodological issues to derive indirect CO₂ and N₂O emissions based on the emissions of the precursor gases NMVOC and CO, as well as NO_x and NH₃ from the different sectors. As an overview, the resulting indirect CO₂ emissions are shown in Table 9-1, as well as in Figure 9-1 and Figure 9-2. The resulting indirect N₂O emissions are shown in Table 9-2, as well as in Figure 9-3 and Figure 9-4.

Indirect CO₂ and N₂O emissions are not considered for the uncertainty analysis (see chp. 1.6), nor for the key category analysis (see chp. 1.5).

Figure 9-1 Switzerland's indirect fossil CO₂ emissions 1990–2014.Table 9-1 Indirect fossil CO₂ emissions from 1990 to 2014.

Indirect fossil CO ₂ emissions by source category	1990	1995	2000
	(kt CO ₂)		
1 Energy	43.43	27.48	16.93
1B Fugitive emissions from fuels	43.43	27.48	16.93
2 Industrial processes and product use	371.21	245.05	170.13
2A Mineral industry	0.15	0.12	0.11
2B Chemical industry	1.34	0.39	0.05
2C Metal industry	10.77	4.87	5.68
2D Non-energy products from fuels and solvent use	231.91	140.12	93.54
2G Other product manufacture and use	124.21	97.54	68.83
2H Other	2.83	2.01	1.93
5 Waste	2.01	1.66	1.60
5A Solid waste disposal	NO	NO	NO
5C Waste incineration and open burning of waste	1.95	1.56	1.47
5E Other	0.06	0.10	0.13
6 Other	1.04	1.13	1.22
6Ad Fire damages	1.04	1.13	1.22
Total	417.70	275.31	189.89

Indirect fossil CO ₂ emissions by source category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	(kt CO ₂)									
1 Energy	13.18	13.46	12.32	12.49	11.93	11.01	10.77	9.57	10.98	10.81
1B Fugitive emissions from fuels	13.18	13.46	12.32	12.49	11.93	11.01	10.77	9.57	10.98	10.81
2 Industrial processes and product use	116.55	112.86	109.70	110.48	110.10	111.48	110.94	110.13	107.84	107.57
2A Mineral industry	0.11	0.11	0.12	0.11	0.11	0.12	0.12	0.11	0.10	0.10
2B Chemical industry	0.06	0.06	0.06	0.08	0.06	0.09	0.06	0.06	0.06	0.05
2C Metal industry	5.48	3.49	2.80	2.94	1.98	2.40	2.65	2.33	2.30	2.37
2D Non-energy products from fuels and solvent use	55.90	54.94	53.14	53.45	53.77	54.23	53.12	51.38	50.81	50.40
2G Other product manufacture and use	53.75	52.52	52.03	52.15	52.22	52.41	52.52	54.21	52.60	52.74
2H Other	1.24	1.73	1.56	1.75	1.98	2.22	2.47	2.05	1.99	1.91
5 Waste	1.38	1.42	1.38	1.39	1.29	1.30	1.25	1.24	1.19	1.18
5A Solid waste disposal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5C Waste incineration and open burning of waste	1.25	1.29	1.25	1.28	1.15	1.16	1.11	1.10	1.06	1.05
5E Other	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
6 Other	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
6Ad Fire damages	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
Total	132.33	128.95	124.63	125.58	124.53	125.00	124.18	122.15	121.23	120.79

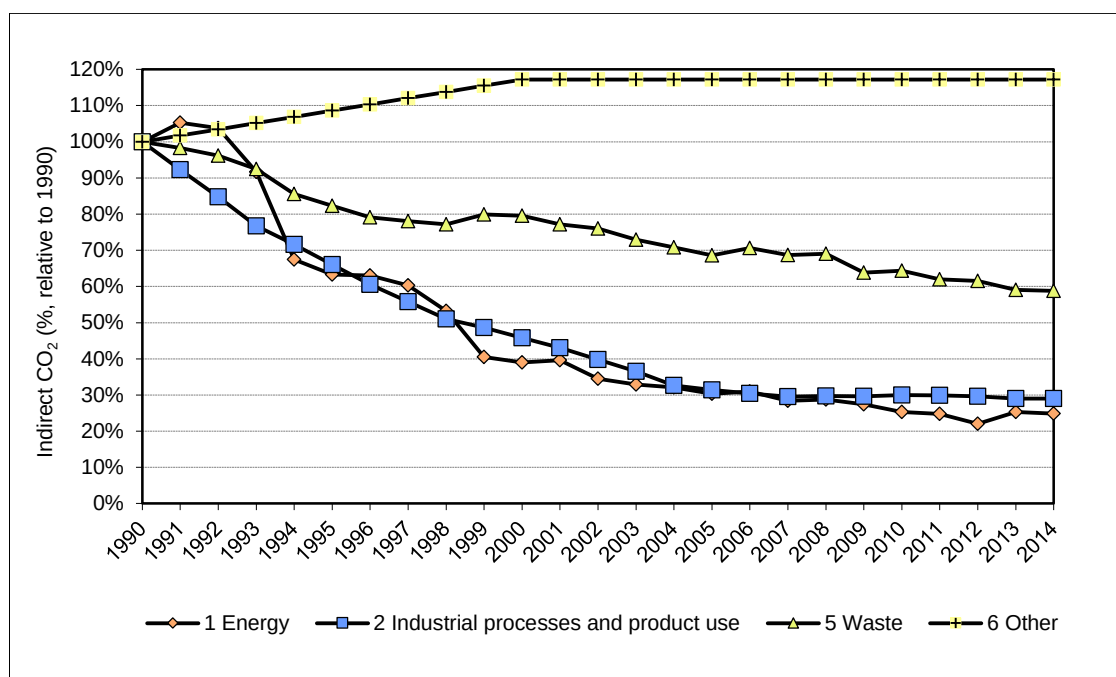


Figure 9-2 Relative trends of the indirect fossil CO₂ emissions in the period 1990–2014. The base year 1990 represents 100%.

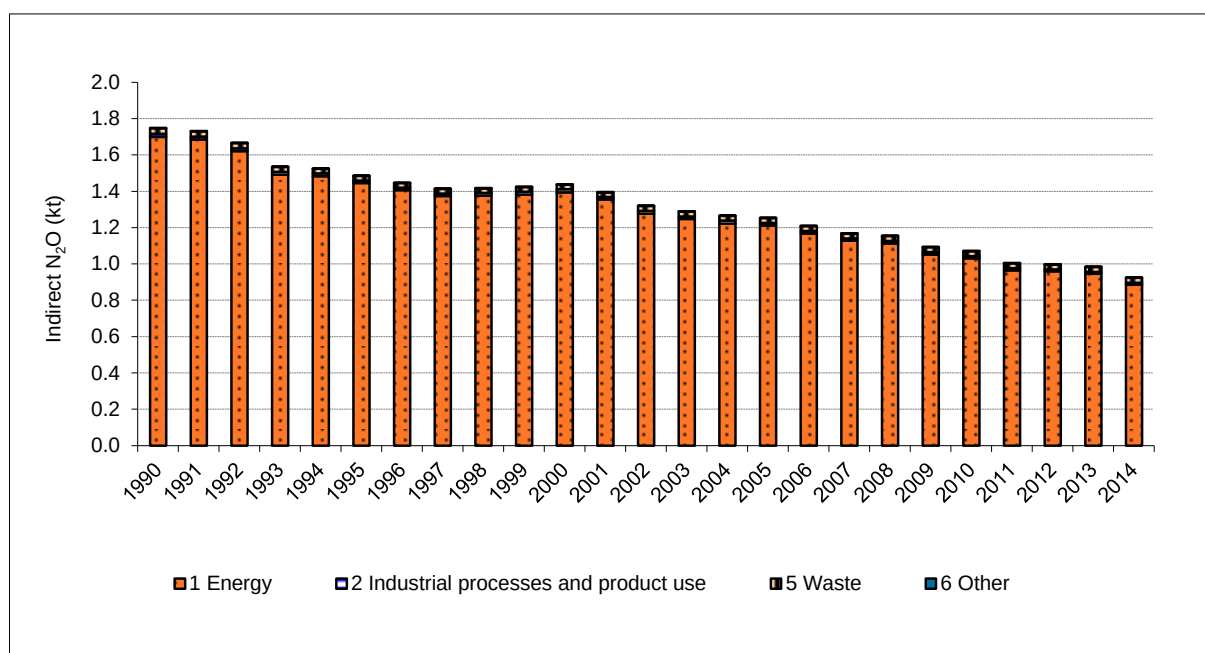
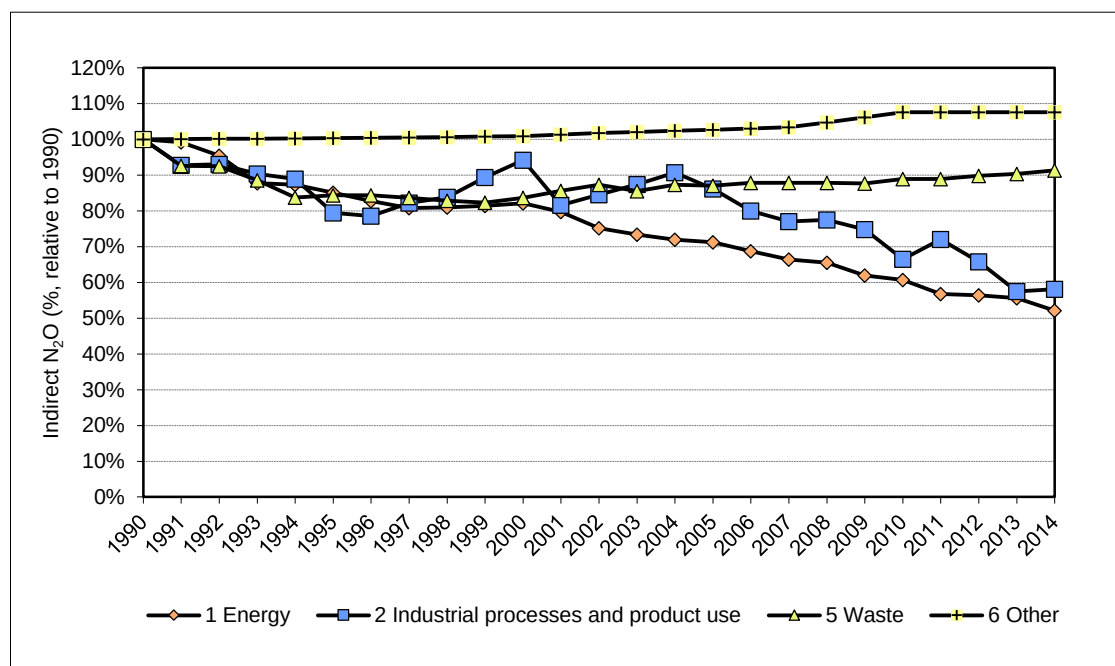


Figure 9-3 Switzerland's indirect N₂O emissions 1990–2014.

Table 9-2 Indirect N₂O emissions from 1990 to 2014.

Indirect N ₂ O emissions by source category	1990	1995	2000
	(kt)		
1 Energy	1.70	1.44	1.39
1A Fuel combustion activities	1.70	1.44	1.39
1B Fugitive emissions from fuels	0.00	0.00	0.00
2 Industrial processes and product use	0.02	0.01	0.02
2A Mineral industry	0.00	0.00	0.00
2B Chemical industry	0.00	0.00	0.00
2C Metal industry	0.00	0.00	0.00
2G Other product manufacture and use	0.01	0.01	0.01
2H Other	0.01	0.00	0.01
5 Waste	0.03	0.03	0.03
5A Solid waste disposal	0.02	0.01	0.01
5B Biological treatment of solid waste	0.00	0.00	0.00
5C Waste incineration and open burning of waste	0.01	0.00	0.00
5D Wastewater handling and discharge	0.00	0.01	0.01
6 Other	0.00	0.00	0.00
6Ad Fire damages	0.00	0.00	0.00
Total	1.75	1.48	1.44

Indirect N ₂ O emissions by source category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	(kt)									
1 Energy	1.21	1.17	1.13	1.11	1.05	1.03	0.96	0.96	0.95	0.89
1A Fuel combustion activities	1.21	1.17	1.13	1.11	1.05	1.03	0.96	0.96	0.94	0.89
1B Fugitive emissions from fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 Industrial processes and product use	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2A Mineral industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2B Chemical industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2C Metal industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2G Other product manufacture and use	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2H Other	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
5 Waste	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
5A Solid waste disposal	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5B Biological treatment of solid waste	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5C Waste incineration and open burning of waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5D Wastewater handling and discharge	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6 Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6Ad Fire damages	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.25	1.21	1.17	1.15	1.09	1.07	1.00	1.00	0.98	0.92

Figure 9-4 Relative trends of the indirect N₂O emissions in the period 1990–2014. The base year 1990 represents 100%.

9.2 Methodological issues

9.2.1 Methodological issues to derive indirect CO₂ emissions

Indirect CO₂ emissions from the atmospheric oxidation of NMVOC are calculated based on the stoichiometric conversion (carbon content fraction * molecular weight of carbon dioxide / molecular weight of carbon). Thereby, a constant carbon content of NMVOC of 60% is assumed, based on the 2006 IPCC Guidelines (IPCC 2006). Indirect CO₂ emissions from the atmospheric oxidation of CO are also calculated based on the stoichiometric conversion (molecular weight of carbon dioxide / molecular weight of carbon monoxide). Thus, indirect CO₂ emissions (Em) result from the following equations:

$$Em_{CO_2, \text{ indirect from NMVOC}} = Em_{NMVOC, \text{ fossil}} * 0.6 * 44/12$$

$$Em_{CO_2, \text{ indirect from CO}} = Em_{CO, \text{ fossil}} * 44/28$$

Activity data for the calculation of indirect CO₂ emissions

Activity data to calculate indirect CO₂ emissions consists of NMVOC and CO emissions as reported in each individual sector and source category, carefully excluding NMVOC and CO emissions of biogenic origin and emissions already included as direct (CO₂) emissions (e.g. when using an oxidation factor of 100%). For the different sectors and source categories the situation is as follows:

1A Energy: Since according to the 2006 IPCC Guidelines (IPCC 2006) emission factors in source category 1A Energy are based on the assumption of complete oxidation (100%), CO₂ resulting from the atmospheric oxidation of CO and NMVOC emitted from this source category is already accounted for in the corresponding emission factors for direct CO₂ emissions. The respective emissions are thus implicitly reported as direct CO₂ emissions in 1A and no indirect CO₂ emissions from 1A Energy are reported (see chp. 3.2.4.4.1).

1B Fugitive emissions from fuels: CO₂ resulting from the atmospheric oxidation of NMVOC and CO emitted from source category 1B is reported as indirect CO₂ emissions unless it is already accounted for implicitly as direct CO₂ emissions in 1B (chp. 3.3). For 1B, Table 9-3 illustrates in which processes CO and NMVOC emissions occur and whether the related CO₂ emissions are reported as indirect CO₂ emissions or implicitly as direct CO₂ emissions. In summary, all CO₂ resulting from the atmospheric oxidation of CO emitted from 1B is implicitly included in 1B as direct CO₂ and is therefore not reported as indirect CO₂. CO₂ resulting from the atmospheric oxidation of NMVOC emitted from 1B is reported as indirect CO₂, except for CO₂ from source category 1B2c, where an oxidation factor of 100% is applied to calculate direct CO₂ emissions.

Table 9-3: Sources of indirect CO₂ emissions from source category 1B Fugitive emissions from fuels.

Source category name	CO emissions	NMVOC emissions
1B1a Coal mining and handling	-	-
1B2a Oil		
1B2a iii Oil – Transport	-	Indirect CO ₂ emissions reported in chp. 9
1B2a iv Oil – Refining/storage:	<i>Leakage:</i> -	<i>Leakage:</i> Indirect CO ₂ emissions reported in chp. 9
	<i>Crude oil:</i> -	<i>Crude oil:</i> -
1B2a v, Oil - Distribution of oil products:	<i>Gasoline storage tank:</i> -	<i>Gasoline storage tank:</i> Indirect CO ₂ emissions reported in chp. 9
	<i>Gasoline station:</i> -	<i>Gasoline station:</i> Indirect CO ₂ emissions reported in chp. 9
1B2b Natural gas		
1B2b ii, Natural gas - Production	-	Indirect CO ₂ emissions reported in chp. 9
1B2b iv, Natural gas – Transmission and storage	-	Indirect CO ₂ emissions reported in chp. 9
1B2b v, Natural gas - Distribution	<i>Distribution:</i> -	<i>Distribution:</i> -
	<i>Leakage gas pipeline:</i> -	<i>Leakage gas pipeline:</i> Indirect CO ₂ emissions reported in chp. 9
	<i>Other leakage:</i> -	<i>Other leakage:</i> Indirect CO ₂ emissions reported in chp. 9
1B2c Venting and flaring	<i>Flaring:</i> CO ₂ emissions from CO are reported in 1B2c a as direct CO ₂ emissions (CO ₂ EF assumes an oxidation of 100%)	<i>Flaring:</i> CO ₂ emissions from NMVOC are reported in 1B2c a as direct CO ₂ emissions (CO ₂ EF assumes an oxidation of 100%)
	<i>H₂ Production:</i> -	<i>H₂ Production:</i> -

2 Industrial processes and product use: None of the CO₂ emissions resulting from the atmospheric oxidation of NMVOC and CO emitted from sector 2 are already considered under the direct CO₂ emissions of this sector. However, before indirect CO₂ emissions are calculated, biogenic NMVOC and CO need to be subtracted from the total NMVOC and CO emissions from sector 2. Biogenic NMVOC and CO emissions occur in the source categories 2H2 Food and beverages industry and 2G4 Other (tobacco consumption only), see chp 4.2.

3 Agriculture and 4 LULUCF: NMVOC and CO emissions from the sectors 3 Agriculture and 4 LULUCF are of biogenic origin. Accordingly, no indirect CO₂ emissions are reported for these sectors.

5 Waste: NMVOC and CO emissions from sector 5 Waste contain fossil and biogenic shares. Only CO₂ resulting from the atmospheric oxidation of fossil NMVOC and CO is reported as indirect CO₂. Emissions of fossil NMVOC and CO stem from the following processes:

- Landfills with open burning: Partly fossil, 0 since 1990.
- Illegal waste incineration: Partly fossil, fossil share is assumed to be the same as for waste incinerated in MWIP, see chp. 7.4 Incineration and open burning of waste (5C1).
- Insulation material from cables: See chp. 7.4 Incineration and open burning of waste (5C1).
- Hospital waste incineration: See chp. 7.4 Incineration and open burning of waste (5C1).
- Shredding: See chp. 7.6 Other.

6 Other: NMVOC and CO emissions from sector 6 Other contain fossil and biogenic shares. Only CO₂ resulting from the atmospheric oxidation of fossil NMVOC and CO is reported as indirect CO₂. Emissions of fossil NMVOC and CO stem from the following processes:

- Fire damage estate: Partly fossil, see chp. 8.2 (6Ad).
- Fire damage motor vehicles: See chp. 8.2 (6Ad).

9.2.2 Methodological issues to derive indirect N₂O emissions

Indirect N₂O emissions are estimated using a country-specific method according to a study of indirect N₂O emissions induced by nitrogen deposition in Switzerland (Bühlmann 2014, Bühlmann et al. 2015). In this study, ecosystem-specific emission factors for indirect N₂O resulting from nitrogen deposition were developed, based on a comprehensive literature survey. Thereby, the land cover types forests, grassland and wetlands were distinguished. In a next step, the ecosystem-specific emission factors were combined with a highly-resolved nitrogen deposition map of Switzerland as well with the geo-referenced dataset of the Swiss Land Use Statistics (allowing for the localisation and estimation of spatial extent of the different ecosystems). This resulted in detailed and spatially resolved indirect N₂O emissions for Switzerland. To facilitate a simple application in the greenhouse gas inventory, the resulting total emissions were used to come up with a total emission factor expressed as indirect N₂O-N per N-deposition (deposited in form of NO_x or NH₃, see also chp. 5.3.2.4). The resulting total emission factor is in the order of 2.5% and slightly varies with time as the shares of the different ecosystems are not constant over time. Based on this country-specific emission factor, higher indirect N₂O emissions result compared to the emissions that would result by applying the 2006 IPCC Guidelines (IPCC 2006, see also Bühlmann et al. 2015).

To calculate indirect N₂O emissions induced by the deposition of NO_x and NH₃ according to Bühlmann (2014) and Bühlmann et al. (2015), total N-deposition is needed. It is derived from NO_x (which is always reported in NO₂ equivalents) and NH₃ emissions using the stoichiometric conversion according to the following equation:

$$\text{Mass-N} = \text{Mass-NO}_{2,\text{eq}} * 14/46 + \text{Mass-NH}_3 * 14/17$$

Activity data for the calculation of indirect N₂O emissions

The activity data to calculate indirect N₂O emissions from a specific sector corresponds to the NO_x and NH₃ emissions reported in the respective source categories. However, the following exceptions need to be considered:

- Indirect N₂O emissions from sector 3 Agriculture are reported in the respective sector together with direct N₂O emissions (chp. 5.3.2.5.4 Volatilisation of NH₃ and NO_x from manure management systems, chp. 5.5.2.3 Indirect N₂O emissions from atmospheric deposition of N volatilised from managed soils (3Db1) and chp. 5.5.2.4 Indirect N₂O emissions from leaching and run-off from managed soils (3Db2)).
- Indirect N₂O emissions from sector 4 LULUCF are reported in the respective sector together with direct N₂O emissions (chp. 6.10.2 Indirect emissions of N₂O due to nitrogen leaching and run-off (4IV2)).
- For sector 6, the only indirect N₂O emissions to be considered are those resulting from NO_x emissions in source category 6Ad Fire damages. All other indirect N₂O emissions are included in sector 3 Agriculture together with direct N₂O emissions.

9.2.3 Uncertainties and time series consistency

Uncertainties are not estimated since the indirect CO₂ and N₂O emissions are not included in the uncertainty analysis.

Consistency: Time series for indirect CO₂ and N₂O emissions are all considered consistent.

9.2.4 Category-specific QA/QC and verification

The same QA/QC and verification procedures are conducted as for NMVOC, CO, NO_x and NH₃ related source categories in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.

9.2.5 Category-specific recalculations

Recalculations reported in submission 2015

- See NMVOC related recalculations reported in chp. 4 Industrial processes and product use.

Recalculations reported in submission 2016

- See NMVOC related recalculations reported in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.
- See CO related recalculations reported in chp. 4 Industrial processes and product use, 7 Waste and 8 Other.

- See NO_x and NH₃ related recalculations reported in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.
- While the indirect CO₂ emissions resulting from the atmospheric oxidation of CO were not reported in previous submissions, they are included starting from submission 2016.
- In previous submissions, indirect CO₂ emissions from sector 2 Industrial processes and product use were reported together with direct CO₂ emissions. For submission 2016, these emissions are reallocated as indirect emissions.

9.2.6 Category-specific planned improvements

No category-specific improvements are planned.

10 Recalculations and improvements

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

10.1 Explanations and justifications for recalculations, including response to the review process

10.1.1 Recommendations and encouragements from ERT and implementation

The Inventory Development Plan (IDP) 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 most recent expert review team’s recommendations and encouragements in the course of inventory preparation and compilation led to several recalculations and improvements (Table 10-1 and Table 10-2). 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 2015/2016.

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 CO ₂ EFs and net calorific values (NCVs) for liquid fuels	Submission 2015	The results of the study reassessing the CO ₂ 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 CO ₂ EFs	Submission 2015	Country-specific CO ₂ 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 3.2.4.4. The revised EF have been now used for the estimation of CO ₂ -Emissions.
1A1a	36. Include the table with N ₂ O EFs for municipal waste incineration plants, with brief and relevant explanatory information in the NIR	Submission 2015	N ₂ O emission factors of 1A1a Municipal Solid and Special Waste Incineration are now described in the NIR chapter 3.2.5 and listed in table 3-30.
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.

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 N ₂ O emission factor for 1990-2012 is assumed. A new catalyst installed in 2013 reduced the N ₂ O-emissions which are measured online from 2013 onwards. The NO _x emission factor for 1990-2012 is the mean value based on three plant specific measurements. The increased volume of the DeNO _x plant and the new catalyst reduced the EF in 2013. Further details on NO _x and N ₂ O 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 N ₂ O 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 NF14b 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	<i>As of 2nd March 2015, the CRF tables are not available yet due to problems with the CRF-Reporter.</i>
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 consequently been replaced by "digestion" throughout chp. 7.3. Additional information given in chp. 7.3.2, sub-section "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 Guidelines 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 2015/2016.

NFR Code	Summary of encouragement in ARR (excerpt of paragraphs of ARR)	Implemented	Details
2C	41. In 2014, the CO ₂ 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 CO ₂ 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 CO ₂ 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 CH ₄ 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	CH ₄ 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 (Y _m) 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 CH ₄ 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 CH ₄ 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 Y _m values in its CH ₄ emission estimates in the annual submission.	Sub 2015	New Y _m 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 CH ₄ recovered from landfill gas as the sum of the amount of CH ₄ flared and the amount of CH ₄ used in cogeneration units. ... Also, noting that the reported amounts of CH ₄ flared are not based on the metered data, the ERT is of the view that the reported amounts of CH ₄ flared are undocumented estimates of landfill gas recovery and, therefore, the subtraction of the undocumented amount of CH ₄ 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 CH ₄ recovered by flaring together with references documenting the amount of recovered CH ₄ that is flared, or estimate the CH ₄ emissions from solid waste disposal on land considering the amount of CH ₄ 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 CH ₄ flared to be zero. The impact of these revised emission estimates was an increase in CH ₄ emissions from solid waste disposal on land by 12.5 per cent (122.96 Gg CO ₂ 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 CH ₄ flared.	Sub 2016	The flaring of landfill gas in Switzerland from 1990 - 2014 has been assessed in 2015. The quantity of flared landfill gas is now based on a survey at all landfill operators. Furthermore solid waste disposal before 1990 has been evaluated, and its impact on landfill gas generation, or flaring quantities, respectively.

10.1.2 Recalculations reported for 2015 and 2016

In order to facilitate the review of the inventory, all recalculations made since the last inventory review in 2014 are summarized here, grouped according to the corresponding submission year. Recalculations made until April 2015 have already been documented in the NIR submission of April 2015. However, due to substantial technical problems with the reporting software, it was impossible to generate the corresponding reporting tables (CRF) at the time. The preparation of the reporting tables (CRF) revealed several issues that have been addressed in the meantime, so that the NIR 2015 does not reflect the final status of the reporting tables (CRF) 2015, submitted in April 2016. For the current submission, reporting tables (CRF) and NIR are consistent.

10.1.3 General recalculations

10.1.3.1 Feedstocks and non-energy use of fuels

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out in 2016.

10.1.3.2 Category-specific recalculations for 1A

Recalculations reported in submission 2015

- No general recalculations for source category 1A.

Recalculations reported in submission 2016

- The net calorific value of bituminous coal was adapted to the one used in the Swiss overall energy statistics (SFOE 2015). For 1990–1998 a value of 28.1 GJ/t is used and interpolated to the value of 25.5 GJ/t in 2010. In previous submissions it was constant 25.46 GJ/t.
- The net calorific value of lignite was adapted to the one used in the Swiss overall energy statistics (SFOE 2015). For 1990–1998 a value of 20.097 GJ/t is used and interpolated to the value of 23.6 GJ/t in 2010. In previous submissions it was constant 23.56 GJ/t.

- The net calorific value of petroleum coke was adapted to the one used in the Swiss overall energy statistics (SFOE 2015). For 1990–1998 a value of 35.0 GJ/t is used and interpolated to the value of 31.8 GJ/t in 2010. In previous submissions it was constant 31.78 GJ/t.
- Changes in the consumption of other bituminous coal, lignite and natural gas in the end consumption (1A2–1A4) 2008–2013 (SFOE 2015).
- Changes in the consumption of diesel oil and gasoline 2008–2013 (SFOE 2015).
- Changes in the consumption of gas oil 2002 / 2007 / 2010 / 2013 (SFOE 2015).
- Changed CH₄ emission factors for gas oil, residual fuel oil, petroleum coke, natural gas and biogas to IPCC 2006 default values:
 - gas oil: from 1 g/GJ to 3 g/GJ
 - residual oil: from 4 g/GJ to 3 g/GJ
 - petroleum coke: from 10 g/GJ to 3 g/GJ
 - natural gas/biogas: from 6 g/GJ to 1 g/GJ
- Changed N₂O emission factors for residual fuel oil, liquefied petroleum gas, Other bituminous coal and lignite to IPCC 2006 default values:
 - residual oil: from 0.8 g/GJ to 0.6 g/GJ
 - Liquefied petroleum gas: from 0.6 g/GJ to 0.1 g/GJ
 - other bituminous coal and lignite: from 1.6 g/GJ to 1.5 g/GJ
- Recalculations in the Swiss wood energy statistics resulted in revised AD in 1A1a, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion for 1990–2013.
- For 1A1a, 1A2gviii, 1A4ai, 1A4bi and 1A4ci Wood combustion the EF of SO₂ have been revised for the entire time series.
- Recalculation in natural gas consumption reported by Swiss overall energy statistics (SFOE 2015) for 2012–2013.
- Recalculation in wood consumption reported by Swiss overall energy statistics (SFOE 2015) for the entire time series.
- Recalculations in energy statistics of Liechtenstein lead to small changes in totals of Swiss energy consumption (years 1995–2013 for gasoline, 1991–2013 for diesel oil, 1990–2013 for gas oil, 2013 for liquefied petroleum gas).
- The CO₂ emission factor for the use of wood was set to the emission factor of 99.9 kg/GJ (Cemsuisse 2010a) instead of the old one of 92 kg/GJ (SAEFL 2000).

10.1.4 Energy

10.1.4.1 Category-specific recalculations for 1A1 (stationary)

Recalculations reported in submission 2015

- 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 CH₄, CO and NMVOC.
- 1A: For wood combustion, the previously used country-specific value of the N₂O EF (1.6 g/GJ) has been replaced by the default value of the 2006 IPCC Guidelines (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 CO₂ 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 N₂O 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 CO₂ 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 N₂O 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 CO₂ compensation projects. This leads to lower amounts of digestate.
- 1A1a: In source category 1A1a iv Municipal solid waste incineration plants, the CO₂ 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.
-

Recalculations reported in submission 2016

- 1A1a: The emissions of carbonate used in the municipal waste incineration (1A1a) were not taken into account due to a mistake in calculations in the last submission.
- 1A1a: Activity data for Municipal solid waste incineration plants has been corrected in waste statistics and value for 2013 is slightly larger.
- 1A1a: Changed amount of used other bituminous coal in boilers for electricity generation (1990–1995) (SFOE 2015).
- 1A1a: Changed amount of used other bituminous coal in boilers for heat production (1992–1995) (SFOE 2015).
- 1A1a: Changed emission factor CH₄ for boilers in district heating from 6 to 1 g/GJ.
- 1A1b: Introduction of new bottom-up Information out of the Swiss Emissions Trading Scheme for the entire time series. New EF CO₂ as average from the past years from bottom-up information.
- 1A1b: N₂O and CH₄ changed to IPCC 2006 default.

10.1.4.2 Category-specific recalculations for 1A2 (stationary)

Recalculations reported in submission 2015

- 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 CH₄, CO and NMVOC.
- 1A: For wood combustion, the previously used country-specific value of the N₂O EF (1.6 g/GJ) has been replaced by the default value of the 2006 IPCC Guidelines (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 (SFOE 2015).
- 1A: The default CO₂ 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 N₂O 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 CO₂ emission factors have been revised to plant-specific values whereas for CH₄ and N₂O emission factors default values according to 2006 IPCC Guidelines have been assumed.

- 1A2d: In source category 1A2d Cellulose production the CO₂ 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 tonnes of clinker, and not to tonnes 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 CO₂. 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 NO_x from 1A2f Mineral wool production has been revised for 2000–2012 based on air pollution control measurements

Recalculations reported in submission 2016

- 1A2: AD for natural gas has changed for sector industry in SFOE 2015 (2013).
- 1A2a: For 1A2a Steel production, reheating furnaces the EF of NO_x and CO have been revised from 1995 onwards based on air pollution control measurements (1995–2013, 2012–2015).
- 1A2d: The emissions of carbonate used in 1A2d Cellulose production were not taken into account due to a mistake in calculations in the last submission.
- 1A2f: The emission factor for the use of natural gas in the production of glass was set to the emission factor of gas oil 73.7 kg/GJ. This is now corrected to the one of natural gas 56.1 kg/GJ for the year 1990, etc.

- 1A2f: The AD (residual fuel oil, liquefied petroleum gas) of 1A2f Glass production (speciality tableware) have been revised based on new industry data for 1990–1999 and 1990–2006, respectively.
- 1A2f: The EF of NO_x from 1A2f Glass production (speciality tableware) have been revised from 1996 onwards based on air pollution control measurements.
- 1A2f: The AD (natural gas) from 1A2f Container glass production has been revised for 2013 based on corrected industry data.
- 1A2f: The EF of CH₄ and N₂O for use of paper production residues in 1A2f Brick and tile production have been revised according to default values of 2006 IPCC Guidelines.
- 1A2f: For 1A2f Fine ceramics production the EF of NO_x, CO, NMVOC and SO₂ have been revised from 1991 onwards based on air pollution control measurements.
- 1A2f: For 1A2f Brick and tile production erroneous CH₄ EF of wood use have been corrected for 2000–2007 and 2009–2012.
- 1A2f: For 1A2f Brick and tile production the EF of NO_x, CO, NMVOC and SO₂ have been revised from 1990 onwards based on air pollution control measurements.
- 1A2f: Changed amount of used other bituminous coal and lignite in cement production (1990–2004) in 1A2f based on bottom-up industry data.
- 1A2f: CH₄ emissions for cement production (furnace) are assumed to be approx. 10% of NMVOC emissions. An error has been corrected in the EF for NMVOC for 2008 and the CH₄ values have been recalculated accordingly. Besides that the EF for CH₄ has been recalculated with the percentage referring to g NMVOC/t clinker and not to g NMVOC/t cement as it was the case until submission 2014.
- 1A2g: Recalculation in Swiss renewable energy statistics (SFOE 2015a) concerning use of sewage gas (2000, 2005, 2012, 2013) in 1A2gviii.
- 1A2g: Recalculation in Swiss renewable energy statistics (SFOE 2015a) concerning use of biogas (2010–2013) in 1A2gviii.
- 1A2g: CH₄ emission factor from sewage gas in 1A2gviii was changed to the one from biogas and natural gas of 1g/GJ.
- 1A2g: CO₂ biog. emission factor from sewage gas was changed to the one from biogas and natural gas in 1A2gviii.

10.1.4.3 Category-specific recalculations for 1A4 (stationary)

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- 1A4: Recalculation in energy use in residential and commercial engines and gas turbines in 1A4 (2010–2013) based on (SFOE 2015c).
- 1A4a: Changed activity data (statistical difference) of use of biogas in Boilers due to recalculation of biogas use in 1A1a municipal waste disposal sites.
- 1A4bi: The emission factor for N₂O from charcoal use was changed to the value of 1 g/GJ instead of 4 g/GJ because due to a mistake last year it was changed to the one of wood (4g/GJ).
- 1A4bi: The AD of 1A4bi Charcoal use have been revised based on additional data from 2001 onwards.
- 1A4bi: The EF of NMVOC, SO₂ and CO of 1A4bi Charcoal use and 1A4bi Bonfires have been revised for the entire time series according to Tier 2 EF of the EMEP/EEA guidebook – 2013 (chap. 1A4, tab. 3-14 „open fireplaces burning biomass“).
- 1A4ci: The AD (gas oil and natural gas) of 1A4ci Grass drying have been corrected for 2013 since they were mixed up in last year's submission.

10.1.4.4 Category-specific recalculations for 1A2g vii (mobile)

Recalculations reported in submission 2015

- 1A: New calorific values for gasoline, diesel, gas oil based on new measurements for the year 2013. Therefore new CO₂ emission factor time series were generated.
- 1A: The default CO₂ emission factor for natural gas was replaced by a country-specific emission factor for the entire time period from 1990–2013.

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A2g vii, industry and construction vehicles (FOEN 2015j).

10.1.4.5 Category-specific recalculations for 1A3

Recalculations reported in submission 2015

- 1A3: New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO₂ emission factor time series were generated.
- 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 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.

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A3c Railways and 1A3d Navigation.
- Recalculation in Swiss energy statistics of renewable energy concerning use of biogas results in a recalculation of the AD of 1A3b in 2013.

10.1.4.6 Category-specific recalculations for 1A4 aii/bii/cii mobile

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A4aii, 1A4bii, 1A4cii (FOEN 2015j).

10.1.4.7 Category-specific recalculations for 1A5b (mobile)

Recalculations reported in submission 2015

- New calorific values for gasoline, diesel, gas oil and kerosene based on new measurements for the year 2013. Therefore new CO₂ emission factor time series were generated.

Recalculations reported in submission 2016

- The non-road model was fully updated in 2014/2015. All time series have been recalculated including those of 1A5b ii, military non-road vehicles.

10.1.4.8 Category-specific recalculations for 1B2a

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- Changes in the consumption of residual fuel oil in refineries due to adaptation to rounded values used in the Swiss overall energy statistic concerning (SFOE 2015).
- Recalculation in the Swiss overall energy statistic concerning (SFOE 2015) use of crude oil.

10.1.4.9 Category-specific recalculations for 1B2b

Recalculations reported in submission 2016

- No category-specific recalculations.

Recalculations reported in submission 2015

- No category-specific recalculations.

10.1.4.10 Category-specific recalculations for 1B2c

Recalculations reported in submission 2015

- No category-specific recalculations.

Recalculations reported in submission 2016

- 1B2: Recalculation in the Swiss overall energy statistics (SFOE 2015) concerning use of crude oil for 1996 and 2003.
- 1B2c: Based on detailed information from the refineries, emissions from flaring were reassessed. From 2005, activity data and emissions factors for flaring were adjusted according to the reports of the refineries.
- 1B2c: During the reassessment of refinery emissions, it emerged that one refinery operates a H₂-production unit since 2005. The resulting CO₂ emissions are now also reported in the inventory.

10.1.5 Industrial processes and other product use

10.1.5.1 Category-specific recalculations for 2A

Recalculations reported in submission 2015

- 2A1 Cement production: AD and EF of cement production (blasting operations) are now related to tonnes of clinker, and not cement as it was before. Therefore all data from 1990–2012 have been converted to this unit.
- 2A1 Cement production: The EF of fossil CO₂ 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 CO₂ 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 which are still used for the years 1990–2004.
- 2A3 Glass production (specialty tableware): the EF of geogenic CO₂ 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 CO₂ 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 CO₂ emissions from the use of ammonium bicarbonate are newly included in the inventory for the entire time period.

Recalculations reported in submission 2016

- 2A2: The EF of geogenic CO₂ from 2A2 Lime production has been revised for 2013 based on effective carbonate contents in the raw material.
- 2A3: The AD of 2A3 Glass production (speciality tableware) has been revised based on industry data from 1996 onwards.
- 2A4a: The EF of geogenic CO₂ from 2A4a Fine ceramics production has been revised for 2012 and 2013 based on updated data of the carbonate contents of the glazes.
- 2A4d: The EF of geogenic CO₂ from 2A4d Rockwool production has been updated for 1990–2004 and 2012 based on revised mean value of the carbonate content in the raw material.

10.1.5.2 Category-specific recalculations for 2B

Recalculations reported in submission 2015

- 2B10 Other: CO₂ 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 SO₂ emission factor from 2B10 Sulphuric acid production has been revised for 1990–2009 based on the updated EF value for 2013.

Recalculations reported in submission 2016

- 2B8b: The AD of 2B8b Ethylene production has been corrected for 2013 due to a mistake in last year's submission.
- 2B10: The EF of SO₂ of 2B10 Sulphuric acid production has been corrected for 2009 due to a typing error in last year's submission.

10.1.5.3 Category-specific recalculations for 2C

Recalculations reported in submission 2015

- 2C3 Aluminium production, 2C4 Magnesium production: following the 2006 IPCC Guidelines new GWP values for SF₆ and PFC have been applied for the entire time period 1990 to 2013.

Recalculations reported in submission 2016

- 2C1: The CO₂ EF from 2C1 Steel production, electric arc furnace has been revised for 2013 based on corrected data in the carbon mass balance of one of the two steel plants.
- 2C1: The EF of NO_x, CO, NMVOC and SO₂ of 2C1 Steel production, electric arc furnace have been revised from 1991 onwards based on air pollution control measurements.
- 2C1: The AD of 2C1 Steel production, rolling mill has been revised for 2013 based on industry data.

10.1.5.4 Category-specific recalculations for 2D

Recalculations reported in submission 2015

- 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.
- 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: CO₂ emissions are newly reported in the inventory for the entire time series 1990–2013 according to the CRF templates.

Recalculations reported in submission 2016

- 2D2: The AD of 2D2 Paraffin wax use has been revised for 2013 based on corrected data from the Swiss petroleum association.
- 2D3a: The AD and EF of NMVOC of 2D3a Paint applications, household, 2D3a Paint applications, car repair and 2D3a Paint production have been updated for 2013 resulting in revised interpolated values of 2011 and 2012 as well.
- 2D3a: The AD and EF of NMVOC of 2D3a Cleaning of electronic components, 2D3a Degreasing of metal and 2D3a Other industrial cleaning have been updated for 2012 resulting in revised interpolated values for 2008–2011 and 2013 as well.
- 2D3a: The so-called direct emissions of 2D3a Other industrial cleaning have been converted into AD and EF but yielding no recalculations.
- 2D3c: The interpolated AD of 2D3c Asphalt roofing have changed from 2008 onwards due to revised projections.

10.1.5.5 Category-specific recalculations for 2E

Recalculations reported in submission 2015

- 2006 IPCC Guidelines (IPCC 2006) introduce a new categorization for electronic industry, new substances and new model approaches for sub-categories with process gas-specific transmission rates.

Recalculations reported in submission 2016

- No category-specific recalculations.

10.1.5.6 Category-specific recalculations for 2F

Recalculations reported in submission 2015:

- 2F Product uses as substitutes for ODS: The former source category 2F Consumption of HFC, PFC and SF₆ was split into the source 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 calculations including lower charge of equipment in mobile air conditioning, new application tumble dryers, included under stationary air conditioning, general harmonizations 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 under aerosols), shift of PFCs to 2E Electronics industry and 2G2 Other PFC and SF₆ use.

Table 10-3 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 ₃ F 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 conditioning (1991 to 1996)
2F1	Refrigeration and air conditioning	AD	2004-2012	HFC-245fa, HFC-235fa, CF ₄	New model calculations 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 ₃ F ₈ , C ₄ F ₈ , C ₄ F ₁₀ , C ₆ F ₁₄	Shift of substances to other applications. HFC-134a and HFC-245fa to 2F4 Aerosols (IPCC 2006: aerosol solvents included under aerosols), shift of PFCs to 2E Electronics industry and 2G2 Other PFC and SF ₆ use

Recalculations reported in submission 2016:

- 2F1 Refrigeration and air conditioning: Optimizations of model calculations including number of vehicles in the model of mobile air conditioning of van, extrapolation of emission factor of stationary air conditioning equipment, changes of refrigerant blend applied in transport refrigeration of trains.
- 2F5 Solvents: Revision of import amounts (correction of import declarations of a specific import company).

10.1.5.7 Category-specific recalculations for 2G

Recalculations reported in submission 2015

- Interviews with industry were carried out to improve model calculations of HFC, PFC and SF₆ emissions under 2G2e and 2G4 (no details are given for confidentiality reason). New GWP values were applied for PFC, HFC and SF₆ 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 2015).
- 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.

Recalculations reported in submission 2016

- 2G4: The AD and EF of NMVOC of 2G4 Preservation of wood have been updated for 2013 resulting in revised interpolated values for 2008–2012 and 2011–2012, respectively, as well.
- 2G4: The AD of 2G4 Application of glues and adhesives consisted of two solvent types so far. This differentiation has been revised for this submission yielding small recalculations due to rounding in AD and EF of NMVOC for the entire time series.
- 2G4: Tobacco consumption for 2013 has been slightly increased in the statistics provided by "Suchtschweiz".
- 2G4: An EF for CO has been introduced for 2G4 Tobacco consumption.
- 2G4: The EF of NMVOC of 2G4 Household cleaning agents has been corrected for 2013 due to a mistake in last year's submission resulting in revised interpolated EF of 2011 and 2012 as well.

10.1.5.8 Category-specific recalculations for 2H

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

10.1.6 Agriculture

10.1.6.1 Category-specific recalculations for 3A

Recalculations reported in submission 2015

- Several new livestock categories were reported for the first time in the 2015 submission (buffalo, camels, deer, rabbits, livestock NCAC). On average, the respective emissions summed up to 0.45% of total methane emissions from 3A Enteric fermentation (14.9 kt CO₂ 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 chp. 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 shift to the 2006 IPCC Guidelines.

Recalculations reported in submission 2016

- CH₄ emission factors for the whole time series of all non-dairy cattle categories were revised due to new methodological guidance in the Swiss feeding recommendations (other mature cattle) and due to a harmonisation of the respective methods (growing cattle). New estimates are substantially higher than before (1990: ~+90 kt CO₂ equivalents; 2013: ~+120 kt CO₂ equivalents).
- CH₄ emission factors for the year 2013 of sheep, goats, swine and poultry and "other" (livestock NCAC) were revised due to updates of provisional net energy intake data by the Swiss Farmers Union (Giuliani 2015). The effect of the recalculation on overall greenhouse gas emissions is negligible.
- CH₄ emission of the livestock category "other" (livestock NCAC) were revised due to the revision of AD for the years 2009–2013. The amount of horses and mules and asses not covered by agricultural census was revised due to new data in Schmidlin et al. 2013. Emission factors changed due to the new weighting of the livestock sub-categories. Across the years 2009–2013 overall greenhouse gas emissions have increased by ~7 kt CO₂ equivalents on average.

10.1.6.2 Category-specific recalculations for 3B

Recalculations reported in submission 2015

- Several new livestock categories were reported for the first time in the 2015 submission (buffalo, camels, deer, rabbits, livestock NCAC). On average the respective emissions summed up to 0.31% of total CH₄ emissions from 3B Manure

management (2.4 kt CO₂ equivalents) and 0.84% of total N₂O emissions from 3B Manure management (2.9 kt CO₂ equivalents).

- For the recalculation of energy requirements and milk yield see chp. 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 chp. 7.3).
- The nitrogen excretion rate of mature dairy cattle was revised using the Agroscope feeding model (Agroscope 2014c). New nitrogen excretion rates were considerably higher than before (+ 6.6% on average).
- New emission factors for NO_x volatilisation from 3B Manure management were adopted based on EMEP/EEA (2013).
- Emission factors for direct N₂O emissions from 3B Manure management were adjusted to the 2006 IPCC Guidelines. Additionally the emission factor for indirect N₂O emissions from 3B Manure management was revised. New country-specific estimates are based on the studies of Bühlmann et al. (2015) and Bühlmann (2014).

Recalculations reported in submission 2016

- CH₄ emission factors for the whole time series of all non-dairy cattle categories were revised due to new estimates for GEI (see chp. 5.2.5). New estimates are higher than before (1990: ~+16 kt CO₂ equivalents; 2013: ~+19 kt CO₂ equivalents).
- CH₄ and N₂O emission of the livestock category "other" (livestock NCAC) were revised due to the revision of AD for the years 2009–2013. The amount of horses and mules and asses not covered by agricultural census was revised due to new data in Schmidlin et al. 2013. Emission factors changed due to the new weighting of the livestock sub-categories. Across the years 2009–2013 overall greenhouse gas emissions have increased by ~0.5 kt CO₂ equivalents on average.
- The share of manure managed in anaerobic digesters was revised for the years 2001–2012 due to updated estimates of the respective AD in the waste sector. Effects on overall CH₄ and N₂O emissions are negligible.
- The MCF for liquid/slurry systems was slightly revised due to new model runs. Effects on overall CH₄ emissions are negligible.

10.1.6.3 Category-specific recalculations for 3D

Recalculations reported in submission 2015

- 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 N₂O emissions from N inputs (EF₁) and N₂O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (EF₃) were adapted to the new IPCC default values (IPCC 2006).
- The area of agricultural land and the alpine area used to estimate NH₃ 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 N₂O 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 N₂O emissions substantially.
- Frac_{LEACH} was recalculated due to new model estimates from Hürdler et al. (2015).
- The emission factor for indirect N₂O emissions from leaching and run-off (EF₅) was adapted to the 2006 IPCC Guidelines. Accordingly the indirect N₂O emissions due to leaching and run-off on agricultural soils decreased substantially in the new inventory model.

Recalculations reported in submission 2016

- N-inputs from co-substrates in agricultural biogas plants were estimated in 2016 for the first time increasing N₂O emissions from commercial fertilisers for 2014 by 7.1 Gg CO₂ equivalent.
- A general recalculation for the year 2013 was carried out due to some updates of crop yield data from the Swiss Farmers Union (SBV 2015). The respective changes are only of minor importance for total emission estimates. Additionally, nitrogen inputs from crop residues of berries are reported in 2016 for the first time. The respective increase in emissions is on average 0.07 Gg CO₂ equivalent.
- The dry matter fraction of hops was changed to 1 since crop yield data in SBV 2015 is already provided in dry matter. As the area of hops is small, repercussion on overall N₂O emissions is minimal.
- The areas of “Natural meadows” and “Pasture” used for the estimation of N₂O emissions from crop residues on meadows and pasture were revised for the years 2009–2012 based on updated values from SFSO (2015c). Emissions sank on average by -0.04 Gg CO₂ equivalent.
- The input of N that is mineralised/immobilised in association with loss of soil C in mineral soils was revised due to an error correction. Emissions increased by a factor of 100 respectively by 3.5 Gg CO₂ equivalent on average.
- The area of histosols was revised according to new results from an extensive study for the localisation of organic soils in Switzerland (Wüst-Galley et al. 2015). The respective changes of overall N₂O emissions are of minor importance.

10.1.6.4 Category-specific recalculations for 3G

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

10.1.6.5 Category-specific recalculations for 3H

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

10.1.7 Land Use, Land-Use change and Forestry

10.1.7.1 Category-specific recalculations for 4A

Recalculations reported in submission 2015

- The most recent NFI data (NFI 4b, covering the period 2009–2013) were applied for productive forests (CC12) (Thürig et al. 2015; see chp. 6.4.2.1).
- Carbon stocks of unproductive forests were updated using the study of Duggelin and Abegg (2011).
- N₂O 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).
- Errors in the derivation of litter and dead wood inputs for the Yaso07 model were corrected (chapter 2.3 in Didion et al. 2014).

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).
- Country-specific values for growing stock and changes in growing stock of afforestations from a study by Thürig and Traub (2015) were implemented.
- According to IPCC (2006) carbon stock changes of all pools in forests (living biomass, litter, dead wood, mineral and organic soils) were no longer averaged over three years; instead annual values were reported. Following these revisions, the complete

time series since 1990 for carbon stocks and carbon stock changes in all pools were recalculated.

- The accuracy of the estimates of carbon stocks and carbon stock changes in dead wood, litter, and soil was improved by eliminating errors in the derivation of climate data driving the model simulations (see chp. 2.3 in Didion et al. 2015).
- A country-specific value for soil carbon stocks of organic soils under forests was used (Wüst-Galley et al. 2016).
- Activity data on wildfires 1990–2013 were updated using data from the Swissfire database.
- The activity data for the calculation of HWP have been updated for the whole time-series (see chp. 6.11.5).

10.1.7.2 Category-specific recalculations for 4B

Recalculations reported in submission 2015

- The provisional value of carbon stock in living biomass for the year 2012 was replaced by the definitive value. The carbon stock change in living biomass was recalculated for 1990 (it is the long-term average 1991–2013).

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).

10.1.7.3 Category-specific recalculations for 4C

Recalculations reported in submission 2015

- The carbon stock in living biomass of brush forests was revised based on Düggelein and Abegg (2011), cf. chp. 6.4.2.8. As a consequence, carbon stocks of the combination categories CC32, CC34 and CC36 were adjusted for all years.

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).
- The calculation method for wildfires was updated for 1990 to 2013. The new default factors of the IPCC (2006) guidelines were used and the amount of fuel was recalculated with consistent activity data and biomass pools used in this report.

10.1.7.4 Category-specific recalculations for 4D

Recalculations reported in submission 2015

- N₂O emissions from drained organic soils are reported for the first time on unproductive wetlands (in category 4(II)).

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).

10.1.7.5 Category-specific recalculations for 4E

Recalculations reported in submission 2015

- There were no recalculations carried out.

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).

10.1.7.6 Category-specific recalculations for 4F

Recalculations reported in submission 2015

- There were no recalculations carried out.

Recalculations reported in submission 2016

- Activity data 1990–2013 were updated (see chp. 6.3.5).

10.1.7.7 Category-specific recalculations for 4(III), 4(IV)

Recalculations reported in submission 2015

- Category 4(III): N₂O emissions from mineralisation of organic matter in mineral soils due to land-use changes were recalculated to meet the requirements of IPCC (2006). The default emission factor was applied: 0.01 kg N₂O-N (kg N)⁻¹ instead of 0.0125 kg N₂O-N (kg N)⁻¹.
- Category 4(IV): Indirect N₂O 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 and land-use change on mineral soils, excluding cropland remaining cropland and grassland remaining grassland.

Recalculations reported in submission 2016

- In category 4(IV) a new country-specific value for Frac_{LEACH} (fraction of mineralized N lost by leaching or run-off) was used: 21.8% (instead of 30%). See chp. 5.5.2.4.2 for more details.

10.1.7.8 Category-specific recalculations for 4G

Recalculations reported in submission 2015

- There were no recalculations since category 4G HWP was not reported previously.

Recalculations reported in submission 2016

- The activity data were updated for the whole time-series. More specifically, the share of domestic to total HWP was revised.

10.1.8 Waste

10.1.8.1 Category-specific recalculations for 5A

Recalculations reported in submission 2015

- 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.

Recalculations reported in submission 2016

- The FOD model used to calculate activity data (direct emissions, flaring, use in CHP has been completely revised. FOEN now uses the official IPCC 2006 model template provided for the inventory. At the same time, parameters have been changed to be in accordance with default values in the template, shares of waste deposited to different types of SWDS and waste composition information have been updated, as well as the amount of methane flared on the sites.
- In the course of the complete revision of the FOD model (see recalculation above) activity data for open burning on solid waste disposal sites has been recalculated. It is now assumed that open burning did not take place after 1990 anymore, which is more plausible than the former assumption of open burning taking place until today (2020).
- The amount of methane flared on SWDS has been assessed in a separate study. Therefore AD for the entire reporting period have changed.

10.1.8.2 Category-specific recalculations for 5B

Recalculations reported in submission 2015

- 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 CO₂ compensation projects. This leads to changes in the activity data of industrial biogas facilities.

Recalculations reported in submission 2016

- New EF for CH₄ have been determined for anaerobic digestion at industrial biogas facilities. This leads to lower CH₄ emission for the whole time series. N₂O emissions are considered to be negligible in the 2006 IPCC Guidelines.
- New EF for CH₄ have been determined for anaerobic digestion at agricultural biogas facilities. This leads to lower CH₄ emission for the whole time series. N₂O emissions are considered to be negligible in the 2006 IPCC Guidelines.
- EF for methane leakage from biogas upgrading has been re-estimated according to requirements by Swiss regulations. This leads to lower emissions for the whole time series.
- Activity data of composting for the years 2008 and later has slightly changed due to interpolations between the last value that is set (2007) and the projection for 2020.

10.1.8.3 Category-specific recalculations for 5C

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

10.1.8.4 Category-specific recalculations for 5D

Recalculations reported in submission 2015

- The methods to calculate emissions from wastewater have been updated according to the 2006 IPCC Guidelines (IPCC 2006). The time series of CH₄ and N₂O emissions have fully been recalculated.

Recalculations reported in submission 2016

- Energy used in combined heat and power installations (CHP) of wastewater treatment has been revised in the statistics for renewable energy by the SFOE for the years 2011–2013.
- EF for methane losses for sewage gas treatment/upgrading has been lowered for the years 1991–2013 (percentage of gas treated). This leads to lower emissions of CH₄.

10.1.8.5 Category-specific recalculations for 5E

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

10.1.9 Other

Recalculations reported in submission 2015

- No category-specific recalculations were carried out.

Recalculations reported in submission 2016

- No category-specific recalculations were carried out.

10.1.10 Indirect CO₂ and N₂O Emissions

Recalculations reported in submission 2015

- See NMVOC related recalculations reported in chp. 4 Industrial processes and product use and 9 Indirect CO₂ and N₂O emissions.

Recalculations reported in submission 2016

- See NMVOC related recalculations reported in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.
- See CO related recalculations reported in chp. 4 Industrial processes and product use, 7 Waste and 8 Other.
- See NO_x and NH₃ related recalculations reported in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.
- While the indirect CO₂ emissions resulting from the atmospheric oxidation of CO were not reported in previous submissions, they are included starting from submission 2016.
- In previous submissions, indirect CO₂ emissions from sector 2 Industrial processes and product use were reported together with direct CO₂ emissions. For submission 2016, these emissions are reallocated as indirect emissions.

10.1.11 KP- LULUCF Inventory

Recalculations reported in submission 2015

- The calculation of carbon stock changes in living biomass after Afforestation was 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 chp. 11.3.1.1).
- Net CO₂ emissions and removals from harvested wood products (HWP) were reported for the first time using the methodology from the KP-Supplement (IPCC 2014).
- N₂O emissions from mineralisation of organic matter in mineral forest soils due to land-use changes were reported for the first time.

Recalculations reported in submission 2016

- The activity data for the calculation of HWP have been updated for the whole time-series (see chp. 6.11.5).

10.2 Implications for emission levels

Table 10-4 shows the effect of the recalculations on the results for the base year 1990. The recalculations resulted in an increase of the total emissions in CO₂ equivalents (without emissions/removals from CO₂ from LULUCF) of 310 kt CO₂ eq (0.97%) in submission 2015 and 319 kt CO₂ eq (0.59%) in submission 2016 as compared to submission 2014. If the LULUCF sector is included, there is a increase of 497 kt CO₂ eq (0.97%) for submission 2015 and an increase of 4388 kt CO₂ eq (8.59%) for submission 2016 as compared to submission 2014.

Table 10-4 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submissions in 2014 and 2015 (FOEN 2014, FOEN 2015) and after the recalculation according to the present submission 2016. "Subm. 2015" refers to data of NIR submitted in Apr. 2015 (without CRF tables).

Source and Sink Categories	CO ₂			CH ₄			N ₂ O			Sum (CO ₂ , CH ₄ and N ₂ O)		
	Emissions for 1990 in CO ₂ eq (kt)											
	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF
1 Energy	41'199	40'814	40'907	507	597	636	305	297	294	42'011	41'708	41'837
2 IPPU (without F-gases)	3'366	3'095	3'095	2	2	2	178	171	171	3'546	3'268	3'268
3 Agriculture	NA	49	49	3'307	4'420	4'509	2'785	2'244	2'246	6'092	6'713	6'804
4 LULUCF excl. HWP	-1'962	-1'857	-994	30	36	24	11	87	85	-1'921	-1'734	-884
5 Waste	63	63	54	822	1'150	944	210	142	142	1'095	1'355	1'139
6 Other	11	11	11	1	1	1	1	1	1	12	12	12
Sum (without F-gases, HWP)	42'677	42'175	43'122	4'668	6'206	6'116	3'489	2'942	2'939	50'834	51'322	52'176

	HFC			PFC			SF ₆			Sum (synthetic gases)		
	Emissions for 1990 in CO ₂ eq (kt)											
	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF
2 Ind. Processes (only F-gases)	0.02	0.02	0.02	100	117	117	144	137	137	244	254	254

										Sum (all gases)		
										Em. for 1990 in CO ₂ eq (kt)		
										Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF
Total CO ₂ eq Em. incl. LULUCF										51'078	51'576	52'430
										100%	100.97%	102.65%
Total CO ₂ eq Em. excl. LULUCF										53'000	53'310	53'314
										100%	100.59%	100.59%

Table 10-5 shows the effect of the recalculations on the results for the year 2012. The recalculations resulted in an increase of the total emissions in CO₂ equivalents (without emissions/removals from CO₂ from LULUCF) of 129 kt CO₂ eq (0.25%) in submission 2015 and 137 kt CO₂ eq (0.27%) in submission 2016 compared to submission 2014. If the LULUCF sector is included, there is a decrease of 185 kt CO₂ eq (0.37%) for submission 2015 and a decrease of 568 kt CO₂ eq (1.13%) for submission 2016.

Table 10-5 Overview of implications of recalculations on 2012 data. Emissions are shown before the recalculation according to the previous submission in 2014 "Prev." (FOEN 2014, FOEN 2015) and after the recalculation according to the present submission 2016. "Subm. 2015" refers to data of NIR submitted in Apr. 2015 (without CRF tables).

Source and Sink Categories	CO ₂			CH ₄			N ₂ O			Sum (CO ₂ , CH ₄ and N ₂ O)		
	Emissions for 2012 in CO ₂ eq (kt)											
	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF
1 Energy	41'000	39'994	39'994	265	304	322	236	227	223	41'501	40'525	40'539
2 IPPU (without F-gases)	2'225	2'183	2'183	2	3	3	98	94	94	2'326	2'280	2'280
3 Agriculture	NA	41	41	3'143	4'039	4'162	2'395	1'935	1'948	5'539	6'015	6'152
4 LULUCF excl. HWP	-1'142	-1'525	-2'082	9	11	11	4	72	69	-1'129	-1'442	-2'001
5 Waste	12	10	10	307	805	679	292	197	182	611	1'012	871
6 Other	13	13	13	1	1	1	1	1	1	14	14	14
Sum (without F-gases, HWP)	42'109	40'716	40'160	3'727	5'162	5'178	3'025	2'526	2'517	48'862	48'404	47'855

Source and Sink Categories	HFC			PFC			SF ₆			Sum (synthetic gases)		
	Emissions for 2012 in CO ₂ eq (kt)											
	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF	Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF
2 Ind. Processes (only F-gases)	1245	1495	1489	33	71	71	224	209	209	1'502	1'775	1'769

										Sum (all gases)		
										Em. for 2012 in CO ₂ eq (kt)		
										Subm 2014 NIR/CRF	Subm 2015 NIR	Subm 2016 NIR/CRF
Total CO ₂ eq Em. incl. LULUCF										50'364	50'179	49'625
										100%	99.63%	98.53%
Total CO ₂ eq Em. excl. LULUCF										51'493	51'622	51'626
										100%	100.25%	100.26%

10.3 Implications for emissions trends, including time series consistency

Due to recalculations, the emission trend 1990–2012 reported in the present 2016 submission has slightly changed. Compared to 1990, 2012 emissions (national total excl. LULUCF) showed a decrease of 2.84% before recalculation (Submission 2014). After recalculation in 2015 and 2016, the decrease is slightly larger with a change 1990–2012 of 3.17% (for both submission 2015 and submission 2016 as compared to submission 2014).

Table 10-6 Change of the emission trend 1990–2012 due to recalculation.

Recalculation	1990			2012			change 2012/1990		
	Subm 2014NIR/CRF	Subm 2015NIR	Subm 2016NIR/CRF	Subm 2014NIR/CRF	Subm 2015NIR	Subm 2016NIR/CRF	Subm 2014NIR/CRF	Subm 2015NIR	Subm 2016NIR/CRF
Unit	CO ₂ eq (kt)						%		
Total excl. LULUCF	53'000	53'310	53'314	51'493	51'622	51'626	-2.84%	-3.17%	-3.17%

All time series in the present submission are consistent.

10.4 Planned improvements, including in response to the review process

- 1A3b Road Transportation: Due to a recent update of the emissions, the new results will be implemented in the EMIS database, thereby leading to a recalculation in the GHG inventory of all time series 1A3b 1990–2014.
- 2A1: Since 2013, the Swiss cement plants participate in the Swiss Emissions Trading Scheme, which requires annual monitoring of geogenic CO₂ emissions. Based on these reports, geogenic CO₂ emissions will be estimated from on plant-specific emission factors and activity data.
- 2F1: As in the past years, emission models will be updated during the yearly process of F-gas inquiry. The focus will be on HFC-emission calculations from refrigeration and air-conditioning equipment, changes are expected in this area due to the revision of the ChemRRV and CO₂ compensation programmes (share of products with HFC, recycling of HFC, early replacement of HFC).
- 3B / 3D: New country-specific values for Nex for most livestock categories will become available in the next years due to a revision of the “Principles of Fertilization in Arable and Forage Crop Production (Flisch et al. 2009)”. Furthermore new updated estimates on manure management system distribution (MS) and ammonia volatilization factors will become available in the next years due to an updated of the AGRAMMON model projections with new census data.

For further planned improvements please refer to respective chp. “planned improvements” for each category.

PART 2

11 KP-LULUCF

The generation of the reporting tables with the CRF web application poses a challenge, as there are still several instances where data are not displayed the way they were imported originally. A non-exhaustive list of issues and errors identified so far is provided in Annex 6 and should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

The final proof-reading revealed a few errors in the reporting tables, which will be corrected in the next submission. The influence on the total GHG emissions and removals is small and described in chp. 11.1.5.

Switzerland has chosen 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 2016c). In addition to the mandatory submission of the inventory years 2013 and 2014, 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 2016c). Switzerland applies the condition of “direct human-induced” in relation to Afforestation and Deforestation very strictly for both activities (see chp. 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. Detailed information on completeness of the activity coverage and reported pools is given in chpt. 11.3.1.2. 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 CRF Table NIR1 – Summary-Table.

TABLE NIR 1. SUMMARY TABLE
Activity coverage and other information relating to activities under Article 3, paragraph 3, forest management under Article 3.4, and elected activities under Article 3.4

Activity	CHANGE IN CARBON POOL REPORTED ⁽¹⁾						GREENHOUSE GAS SOURCES REPORTED ⁽²⁾								
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP ⁽⁴⁾	Fertilization ⁽⁵⁾	Drained, rewetted and other soils ⁽⁶⁾		Nitrogen mineralization in mineral soils ⁽⁶⁾	Indirect N ₂ O emissions from managed soil ⁽³⁾	Biomass burning ⁽⁹⁾		
					Mineral	Organic ⁽³⁾			CH ₄ ⁽⁷⁾	N ₂ O			CO ₂ ⁽¹⁰⁾	CH ₄	N ₂ O
Article 3.3 activities															
Afforestation and reforestation	R	R	NR	NR	R	R	NO	NO	NA	R	R	NA	IE	IE	IE
Deforestation	R	R	R	R	R	R	R	NO	NA	NA	R	NA	NO	NO	NO
Article 3.4 activities															
Forest management	R	R	R	R	R	R	R	NO	NA	R	NO	NA	IE	R	R
Cropland management	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Grazing land management	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Revegetation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Wetland drainage and rewetting	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

⁽¹⁾ Indicate R (reported), NR (not reported), IE (included elsewhere) or NO (not occurring), for each relevant activity under Article 3.3, forest management or any elected activity under Article 3.4, or instantaneous oxidation (IO) for carbon stock changes in harvest wood products (HWP). With the exception of HWP, if changes in a carbon pool are not reported, verifiable information in the national inventory report (NIR) must be provided that demonstrates that these unaccounted pools were not a net source of anthropogenic greenhouse gas emissions. Indicate NA (not applicable) for each activity that is not elected under Article 3.4.

⁽²⁾ Indicate R (reported), NE (not estimated), IE (included elsewhere) or NO (not occurring) for greenhouse gas sources reported, for each relevant activity under Article 3.3, forest management or any elected activity under Article 3.4. Indicate NA (not applicable) for each activity that is not elected under Article 3.4.

⁽³⁾ Includes CO₂ emissions/removals from organic soils, including CO₂ emissions from dissolved organic carbon associated with drainage and rewetting. On-site CO₂ emissions/removals from drainage and rewetting from organic soils and off-site CO₂ emissions via water-borne carbon losses from organic soils should be reported from lands reported under deforestation, which originated from the deforestation event at the time of the land-use change shall be accounted for on the basis of instantaneous oxidation (IO).

⁽⁴⁾ HWP from lands reported under deforestation, which originated from the deforestation event at the time of the land-use change shall be accounted for on the basis of instantaneous oxidation (IO).

⁽⁵⁾ N₂O emissions from fertilization of afforestation/reforestation, deforestation, forest management, revegetation and wetland drainage and rewetting should be reported here when these emissions are not reported under the agriculture sector.

⁽⁶⁾ CH₄ and N₂O emissions from drained and rewetted organic soils should be reported here, as appropriate, when emissions are not reported under the agriculture sector. For wetland drainage and rewetting only emissions from organic soils are included.

⁽⁷⁾ CH₄ emissions from drained soils and drainage ditches should be reported here, as appropriate.

⁽⁸⁾ N₂O emissions from nitrogen mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils under afforestation/reforestation, deforestation, forest management, cropland management, grazing land management and revegetation should be reported from burning of organic soils should also be included here, as appropriate.

⁽¹⁰⁾ If CO₂ emissions from biomass burning are not already included under changes in carbon stocks, they should be reported under biomass burning. Parties that include CO₂ emissions from biomass burning in their carbon stock change estimates should report IE (included elsewhere).

Table NIR 1.1 Additional information
Selection of parameters for defining "Forest" under the Kyoto Protocol

Parameter	Range	Selected value
Minimum land area	0.05 - 1 ha	0.06
Minimum crown cover	10 - 30 %	20.00
Minimum height	2 - 5 m	3.00

Table 11-2 CRF Table NIR 2 – Land Transition Matrix for the current Inventory Year. The total Swiss area has been updated since the last submission and should be 4'129.03 kha and not 4'128.42. Accordingly, the area under "Other" should be recalculated (see chp. 11.1.5).

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES					Total area at the end of the previous inventory year ⁽⁷⁾	
	Afforestation and reforestation	Deforestation	Forest management ⁽³⁾	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		Other ⁽⁶⁾
(kha)									
Article 3.3 activities									
Afforestation and reforestation	2.44	NO							2.44
Deforestation		7.39							7.39
Article 3.4 activities									
Forest management		0.31	1250.55						1250.86
Cropland management ⁽³⁾ (if elected)	NO		NO	NO	NO	NO	NO	NO	NO
Grazing land management ⁽³⁾ (if elected)	NO		NO	NO	NO	NO	NO	NO	NO
Revegetation ⁽³⁾ (if elected)	NO		NO	NO	NO	NO	NO	NO	NO
Wetland drainage and rewetting ⁽³⁾ (if elected)	NO		NO	NO	NO	NO	NO	NO	NO
Other ⁽⁴⁾	0.05	NO	0.16	NO	NO	NO	NO	2867.53	2867.74
Total area at the end of the current inventory year	2.49	7.70	1250.71	NO	NO	NO	NO	2867.53	4128.42

⁽¹⁾ This table should be used to report land area subject to the various activities in the inventory year. For each activity it should be used to report area change between the end of the previous inventory year and the end of the current inventory year. For example, the total area of land subject to forest management in the previous inventory year and which was deforested in the current inventory year, should be reported in the deforestation column and in the forest management row.

⁽²⁾ In accordance with relevant decisions. Some of the transitions in the matrix are not possible and the cells concerned have been shaded.

⁽³⁾ Lands subject to cropland management, grazing land management, revegetation or wetland drainage and rewetting that after 2013 are subject to activities other than those under Article 3.3 and 3.4, should still be tracked and reported under cropland management, grazing land management, revegetation or wetland drainage and rewetting for the first time. This footnote does not apply to the cell belonging to the column and the row "other" to "other".

⁽⁴⁾ Other refers to the area that is reported under Article 3.3 or 3.4 in the current inventory for the first time. This footnote does not apply to the cell belonging to the column and the row "other" to "other".

⁽⁵⁾ Changes in area from cropland management, grazing land management, revegetation and wetland drainage and rewetting to forest management should be reported only in the case of carbon equivalent forest conversions.

⁽⁶⁾ "Other", in this column, is the area of the country that has never been subject to any activity under Article 3.3 or 3.4.

⁽⁷⁾ The value in the cell of row "Total area at the end of the current inventory year" corresponds to the total land area of a country. The total land area should be the same for the current inventory year and the previous inventory year in this matrix.

Table 11-3 CRF Table NIR 3 – Summary Overview for Key Categories for LULUCF Activities under the KP in the current inventory year. A detailed description of the KCA for Article 3.3 and 3.4 activities is given in chp. 11.6.1.

TABLE NIR 3. SUMMARY OVERVIEW FOR KEY CATEGORIES FOR LAND USE, LAND-USE CHANGE AND FORESTRY ACTIVITIES UNDER THE KYOTO PROTOCOL

KEY CATEGORIES OF EMISSIONS AND REMOVALS	Gas	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			Comments ⁽⁶⁾
		Associated category in UNFCCC inventory ⁽¹⁾ is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory ⁽²⁾ (including LULUCF)	Other ⁽³⁾	
Specify key categories according to the national level of disaggregation used ⁽¹⁾					
Afforestation and Reforestation					
CO2	CO2	Land converted to forest land	No	Not considered as Afforestation under KP	level and KC trend (L1, L2, T1, T2)
Deforestation					
CO2	CO2	Land converted to settlements	Yes	See NIR chp. 11.6.25	level and KC trend (L1, L2, T2)
Forest Management					
CO2	CO2	Forest land remaining forest land	Yes	Yes and the UNFCCC inventory category	level and KC trend (L1, L2, T1, T2)

An overview of net CO₂ 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. From this submission on, emissions and removals of all pools in the forest sector are no longer averaged over three years; instead annual values are reported. Differences in the annual removals and emissions from Afforestation and Deforestation can mainly be attributed to the changes in their respective areas (see Table 11-6 and Figure 11-2). 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. In 2000, Forest management was a net source of CO₂ eq due to the damages caused by the storm Lothar (December 1999). Harvesting rates in Swiss forests gradually increased since 1991 until 2007; in 2008 harvesting rates started to decline due to the international and domestic economic framework conditions (Table 6-18). Fluctuations in the HWP-pool can mainly be attributed to changes in the production of sawnwood (see chp. 6.11 and Table 6-32), which is strongly linked to the domestic harvesting rate.

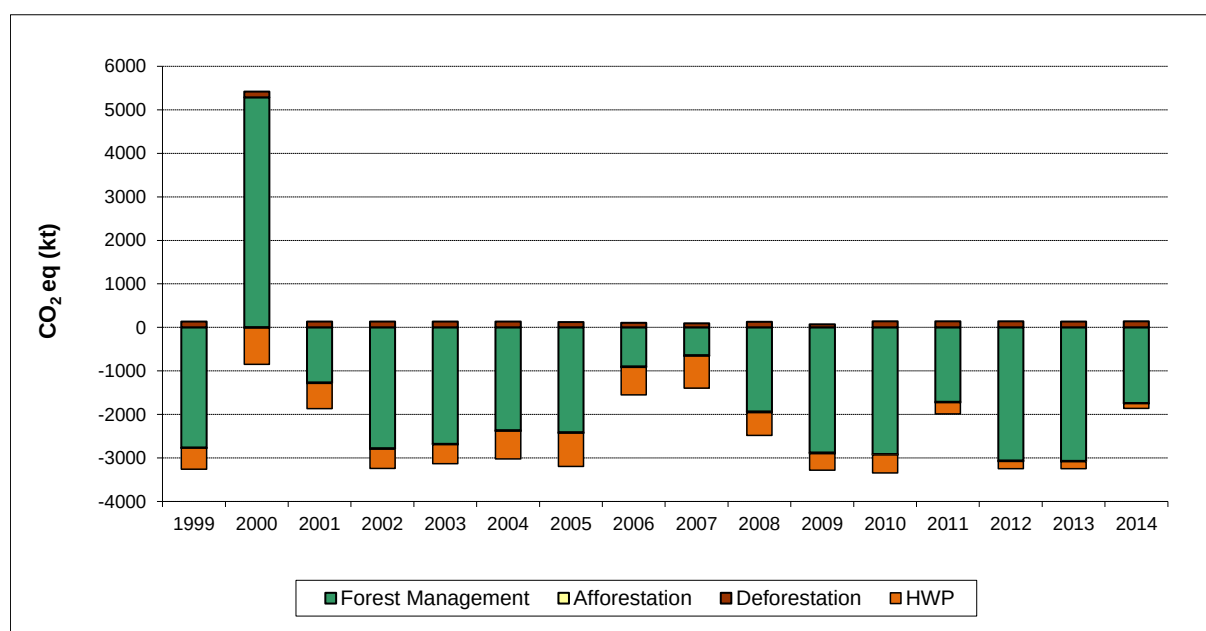


Figure 11-1 CO₂ eq emissions (positive sign) and removals (negative sign) from Afforestation (too small to be distinguishable) and Deforestation under Article 3, paragraph 3 and Forest management and HWP under Article 3, paragraph 4, 1999–2014. Emissions and removals in the forest sector are no longer averaged over three years. The reason for the positive value in 2000 and the small removal in 2001 is the winter storm “Lothar” end of 1999, which caused great damages in the forest stands and increased harvesting.

Table 11-4 Overview on net CO₂ equivalent emissions (positive sign) and removals (negative sign) for activities under Article 3, paragraph 3 and Forest management under Article 3, paragraph 4 of the Kyoto Protocol, 1999–2014. Used abbreviations explained in chp. 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; C_{HWP}: C in HWP. Few errors in the KP-reporting tables with a small impact on total emissions and removals will be corrected in the next submission (see chp. 11.1.5).

Greenhouse gas source and sink activities	1999	2000	2001	2002	2003	2004	2005	2006
	Net CO ₂ equivalent emissions/removals (kt CO ₂ eq)							
A. Article 3.3 activities	105.17	110.70	106.92	105.69	107.93	106.92	94.85	82.46
A.1. Afforestation and Reforestation incl. N ₂ O; 4(KP)	-15.12	-15.72	-16.32	-16.92	-17.53	-18.13	-18.82	-19.62
Afforestation ≤ 20 y	-15.18	-15.79	-16.39	-16.99	-17.60	-18.20	-18.89	-19.70
Afforestation > 20 y	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N ₂ O from drainage	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08
A.2. Deforestation incl. HWP, N ₂ O; 4(KP)	120.29	126.42	123.24	122.62	125.45	125.05	113.67	102.08
Deforestation incl. N ₂ O	132.30	133.41	133.66	134.57	135.74	136.74	123.85	107.89
HWP: changeC _{HWP}	-12.01	-6.99	-10.42	-11.96	-10.28	-11.69	-10.19	-5.81
B. Article 3.4 activities	-3241.67	4451.74	-1848.13	-3224.34	-3117.10	-3003.30	-3177.05	-1528.84
B.1. Forest management incl. HWP, CH ₄ , N ₂ O; 4(KP)	-3241.67	4451.74	-1848.13	-3224.34	-3117.10	-3003.30	-3177.05	-1528.84
gainC _{l,ag}	-9740.42	-9747.46	-9754.49	-9761.52	-9768.56	-9775.59	-9785.49	-10049.09
gainC _{l,bg}	-2765.70	-2768.32	-2770.94	-2773.56	-2776.19	-2778.81	-2782.44	-2871.67
lossC _{l,ag}	7815.64	14015.30	8997.61	7417.71	8215.44	8209.85	8488.19	9288.21
lossC _{l,bg}	2290.41	3907.48	2606.83	2191.89	2419.70	2393.00	2462.10	2666.49
changeC _h	-142.32	37.43	-171.30	216.95	-519.10	-237.07	-553.98	382.60
changeC _d	-258.02	-196.76	-216.36	-118.56	-295.48	-214.39	-278.15	-356.45
changeC _{s,m}	-3.39	-3.53	-3.69	-3.76	-3.90	-4.60	-5.04	-5.20
changeC _{s,o}	36.40	36.43	36.46	36.50	36.53	36.56	36.61	36.66
HWP: changeC _{HWP}	-479.50	-834.82	-577.53	-443.52	-441.45	-637.80	-764.70	-627.73
sum FM incl. HWP; excl. CH ₄ and N ₂ O; 4(KP-I)B.1	-3246.91	4445.75	-1853.41	-3237.88	-3133.01	-3008.84	-3182.90	-1536.18
CH ₄ & N ₂ O from biom. burning	0.23	0.98	0.27	8.53	10.89	0.51	0.81	2.30
N ₂ O from drainage	5.01	5.01	5.02	5.02	5.02	5.03	5.03	5.04
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

Greenhouse gas source and sink activities	2007	2008	2009	2010	2011	2012	2013	2014
	Net CO ₂ equivalent emissions/removals (kt CO ₂ eq)							
A. Article 3.3 activities	67.19	96.54	48.14	108.44	111.56	112.07	111.75	116.64
A.1. Afforestation and Reforestation incl. N ₂ O	-20.35	-20.99	-21.56	-20.40	-18.81	-18.48	-17.65	-15.61
Afforestation ≤ 20 y	-20.43	-21.07	-21.65	-19.69	-17.84	-16.01	-14.43	-13.25
Afforestation > 20 y	0.00	0.00	0.00	-0.79	-1.04	-2.53	-3.27	-2.41
N ₂ O from drainage	0.08	0.08	0.09	0.08	0.07	0.06	0.05	0.05
A.2. Deforestation incl. HWP, N ₂ O	87.54	117.53	69.70	128.85	130.37	130.55	129.40	132.25
Deforestation incl. N ₂ O	91.74	125.80	70.75	137.75	138.11	138.60	136.60	138.88
HWP: changeC _{HWP}	-4.20	-8.27	-1.05	-8.90	-7.75	-8.05	-7.20	-6.64
B. Article 3.4 activities	-1372.49	-2459.63	-3258.46	-3322.59	-1969.79	-3231.24	-3227.38	-1843.58
B.1. Forest management incl. HWP, CH ₄ , N ₂ O; 4(KP)	-1372.49	-2459.63	-3258.46	-3322.59	-1969.79	-3231.24	-3227.38	-1843.58
gainC _{l,ag}	-10075.05	-10088.18	-10098.30	-10101.28	-10104.09	-10106.92	-10110.27	-10113.74
gainC _{l,bg}	-2880.00	-2884.67	-2888.40	-2889.97	-2891.45	-2892.94	-2894.58	-2896.27
lossC _{l,ag}	9227.26	8574.61	8015.01	8428.31	8371.77	7713.73	7955.38	8170.06
lossC _{l,bg}	2670.95	2503.81	2357.23	2492.75	2475.75	2287.08	2363.98	2427.43
changeC _h	601.02	205.83	6.76	-468.46	546.50	113.60	-151.73	654.82
changeC _d	-225.93	-286.40	-311.97	-410.79	-151.55	-216.12	-267.48	-18.44
changeC _{s,m}	-4.74	-4.29	-4.27	-4.63	-4.85	-4.46	-4.56	-4.42
changeC _{s,o}	36.71	36.70	36.74	36.74	36.75	36.76	36.77	36.79
HWP: changeC _{HWP}	-732.61	-522.86	-377.32	-410.86	-257.14	-167.51	-160.46	-105.76
sum FM incl. HWP; excl. CH ₄ and N ₂ O; 4(KP-I)B.1	-1382.40	-2465.45	-3264.51	-3328.18	-1978.31	-3236.78	-3232.94	-1849.53
CH ₄ & N ₂ O from biom. burning	4.86	0.77	1.00	0.53	3.46	0.48	0.50	0.89
N ₂ O from drainage	5.05	5.05	5.05	5.05	5.05	5.06	5.06	5.06
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

The KP-CRF Table “Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol” gives an overview of the CO₂ eq emissions and removals from Afforestation and Deforestation under Article 3, paragraph 3 and Forest management under Article 3, paragraph 4.

In 2014, Forest management including HWP, biomass burning and drainage of organic soils in Switzerland caused removals of -1843.58 kt CO₂ eq. The debit incurred from activities under Article 3.3 is 116.64 kt CO₂ 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 chp. 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 chp. 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 it is still valid for the second commitment period (FOEN 2016c; see also chp. 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 parameters are listed in KP-CRF Table NIR1 (reproduced in Table 11-1).

Some source categories were explicitly excluded from the category "Forest Land", although they may partly fulfil the requirements of the Swiss forest definition used under the Kyoto Protocol (see chp. 6.2.1, Table 6-6; chp. 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 only accounts for the mandatory activity Forest management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2016c). 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 2016c). 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 m²) is fulfilled, and the conversion is a direct human-induced activity (FOEN 2006h).

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 2015d; see also chp. 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 m²) to areas not fulfilling the definition of forest as a consequence of direct human influence (FOEN 2006h).

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 chp. 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 were still deforested after 20 years, whereas 14% were temporary removals of tree cover, which 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 an overestimation. Accordingly, emissions are overestimated since implied emission factors for Deforestations are higher than for Forest management (see CRF Table 4(KP-I)A.2 for Deforestations and CRF Table 4(KP-I)B.1 for Forest management). The area of the current land-use after Deforestation is given as information item in CRF Table 4(KP-I)A.2. Since no additional activities besides Forest management are elected under Art. 3.4, only the activity data are given and no information on changes in carbon stocks is provided.

Reforestation

Reforestation does not occur in Switzerland (FOEN 2006h, Sect. E; see also chp. 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 only accounts 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.

11.1.5 KP-reporting tables: identified errors and planned improvements for the next submission

The final proof-reading revealed a few errors in the reporting tables, which will be corrected in the next submission. The influence on the total GHG emissions and removals is small (Table 11-5). The following errors have been identified:

- The total area has been updated since the last submission: the total country area increased slightly (from 4'128.4 to 4'129.0 kha) as the AREA survey was extended to the official territorial boundaries, especially on lakes (see chpt. 6.3.5). Accordingly, the area under "Other" should be recalculated.
- The area of Deforestation in KP-CRF Table 4(KP-I)A.2 under "area subject to the activity" is the cumulative area for the past 20 years. The area which should be reported is the cumulated deforested area since 1990. This error, however, has no influence on calculated carbon stock changes, since a conversion time of 20 years is used for the calculation of carbon stock changes. The area reported under the information item is the cumulated area of deforestations since 1990, but only until the year before the inventory year (i.e. until 2013 in the inventory year 2014). For the next submission, values for the current inventory year will be provided. Please note: The corresponding values in CRF Table NIR2 (Table 11-2) are correct.
- Values for HWP from deforestations at the time of land-use change are displayed in KP-CRF Table 4(KP-I)C. However, HWP from deforestation at the time of land-use change should be accounted for on the basis of instantaneous oxidation. In the next submission, reported values for HWP from deforestations will be zero.
- The area of unproductive forest (CC13 and CC12 to CC13) on organic soils under Forest management is reported to be zero in KP-CRF Table 4(KP-I)B.1. This is the result of an error in the calculations. The corresponding emissions of these small areas are minor, but will be corrected in the next submission.
- Values for HWP from Forest management: Some decimal places have not been correctly imported in or displayed by the CRF Reporter software resulting in slightly different values in the CRF Table 4.Gs1 (see also Table 6-1) and the KP-CRF Table 4(KP-I)C. Data import and the output of the CRF Reporter will be checked for the next submission (see chpt. 11.1.5).

The errors described above influence the corresponding values in the summary KP-CRF Table 4(KP) and in the CRF Table "Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol".

Table 11-5 Description of the errors in the reporting tables, the corresponding CRF Tables, the erroneous and correct values for the inventory year 2014.

Error	Description	CRF Table	Value CRF Table	Correct value
Total area LULUCF	The total area has been updated since the last submission.	Table NIR2 Table4.1	Other = 2867.53 Total area = 4128.42	Other = 2868.13 Total area = 4129.03
Deforestation	The area reported is the cumulated deforested area over 20 years. The area under the information item is the cumulated area since 1990 until the previous inventory year.	Table 4(KP-I)A.2		
HWP from deforestation	HWP from deforestations after land-use change is not accounted for with instantaneous oxidation.	Table 4(KP-I)A.2 Table 4(KP-I)C	-6.64 Gg CO ₂ eq.	0 Gg CO ₂ eq.
Forest management	The area of unproductive forest on organic soils is not reported correctly for 2008-2014. Corresponding emissions of organic soils under CC13 and CC1213 are not reported.	Table 4(KP-I)B.1	Total area under FM 1250.65 kha	Total area under FM 1250.71 kha; Emissions not reported: < 0.01 Gg CO ₂
HWP from Forest management	Some decimal places are not correctly imported in or displayed by CRF-Reporter resulting in small differences between HWP reported under LULUCF and KP-LULUCF.	Table 4(KP-I)B.1 Table 4(KP-I)C Table4.Gs1	-105.76 Gg CO ₂ eq.	-105.80 Gg CO ₂ eq.

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-reporting tables covers the entire territory of Switzerland, i.e. 4'129.03 kha (see 6.3.5).

All activity data for reporting the activities under the Kyoto Protocol are retrieved from the Swiss Land Use Statistics (SFSO 2015d; see also chp. 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 chp. 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 area of deforestations displayed under "Total for activity A.2" in CRF Table 4(KP-I)A.2 encompasses the cumulated area of deforestations of the last 20 years, which are relevant to calculate CSC. The cumulated area of deforestations since 1990 until the inventory year -1 (2013) is shown in the information item in this reporting table; the cumulated area of deforestations since 1990 until the inventory year (2014) is displayed in CRF Table NIR2.

The calculation of changes in carbon stocks is described in chp. 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-CRF Table NIR2 (see Table 11-2).

The area under Forest management is subdivided into productive forests (CC12) and unproductive forests (CC13; for a description see chp. 6.4.2.8). Productive forests in Switzerland reveal a high heterogeneity in terms of elevation, growth conditions and tree species composition (see chp. 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 elevation zones (Z1: <601 m, Z2: 601–1200 m, Z3: >1200 m) and two soil types (mineral soils and organic soils). In the KP reporting tables, the stratification of the activity data into production region (L) and elevation 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 since 1990 of Afforestations and Deforestations are listed in Table 11-6. The total Swiss area remains constant and amounts to 4'129.03 kha.

In this submission there are two errors in the reporting tables (see chp. 11.1.5), which will be corrected for the next submission:

- The area of Deforestation in KP-CRF Table 4(KP-I)A.2 under “area subject to the activity” is the cumulative area for the past 20 years. The area which should be reported is the cumulated deforested area since 1990 (correct value in Table 11-5). The corresponding values in CRF Table NIR2 (Table 11-2) are correct.
- The area of unproductive forest (CC13 and CC12 to CC13) on organic soils under Forest management is reported to be zero in KP-CRF Table 4(KP-I)B.1. Because of this error in the calculation of the activity data, which has an insignificant influence on total GHG emissions or removals, the area under Forest management is not listed in Table 11-6.

Table 11-6 Activity data for activities under Article 3, paragraphs 3, 1990–2014. Data for Afforestation and Deforestation are derived from the Swiss Land Use Statistics (AREA) (derived from SFSO 2006a, 2014). See also KP-CRF Table NIR2 (Table 11-2)

Year	Deforestation area [kha]	Cumulated area Deforestation since 1990 [kha]	Afforestation area [kha]	Cumulated area Afforestation since 1990 [kha]
1990	0.30	0.30	0.26	0.26
1991	0.30	0.61	0.25	0.51
1992	0.30	0.91	0.25	0.76
1993	0.31	1.22	0.22	0.98
1994	0.33	1.55	0.17	1.16
1995	0.33	1.87	0.12	1.28
1996	0.32	2.20	0.11	1.39
1997	0.33	2.52	0.08	1.48
1998	0.35	2.87	0.06	1.53
1999	0.35	3.22	0.06	1.59
2000	0.35	3.57	0.06	1.65
2001	0.35	3.92	0.06	1.71
2002	0.34	4.26	0.06	1.77
2003	0.34	4.60	0.06	1.83
2004	0.34	4.94	0.06	1.88
2005	0.30	5.24	0.07	1.95
2006	0.25	5.50	0.08	2.03
2007	0.21	5.70	0.07	2.11
2008	0.15	5.85	0.07	2.17
2009	0.28	6.13	0.06	2.23
2010	0.31	6.45	0.05	2.28
2011	0.31	6.76	0.05	2.33
2012	0.31	7.08	0.05	2.38
2013	0.31	7.39	0.05	2.44
2014	0.31	7.70	0.05	2.49

Afforestation

Activity data for Afforestations are derived from the Swiss Land Use Statistics (AREA; SFSO 2006a, 2015d; see also chp. 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; SFSO 2006a, 2015d; see also chp. 6.3.1). A detailed description of the identification of Deforestations

under the Kyoto Protocol from the AREA dataset is given in FOEN (2010d) and Sigmaphan (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 are used to 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 common forest management practices, natural dynamics or hazards: Tree loss is temporally limited, i.e., 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 chp. 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 chp. 11.1.3). Further, a study by Sigmaphan (2012a) showed that, although the aspect of "temporal limitation" 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, i.e., 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 applies also to the case of a Swiss-specific silvo-pastoral system of 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 time, 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) which do not meet 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 m².
- 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.

It was ensured that the criteria and the application to identify conversions which do not correspond to Deforestations under KP do not result in inconsistencies in the estimates of

changes in carbon stocks on the converted areas. If a sample point in the AREA dataset is not classified as Kyoto Deforestation, it remains classified as Forest management. Since the changes in carbon stocks on these are under Forest management are based on NFI data (see NIR chp. 6.4.2.1), they are reflected in the Implied Emission Factors in the reporting tables and are thus completely accounted for.

Forest management

Since all forests in Switzerland are subject to certain forest management practices, the area under the activity Forest management corresponds to the forest area (see FOEN 2006h, Sect. E; FOEN 2016c) as derived from the Swiss Land Use Statistics (AREA; SFSO 2006a, 2015d; see also chp. 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. The Land-use change matrix (Table 6-9) shows that these conversions are 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. Evidence for this process is provided by, for example, the studies by 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 chp. 6.1.3.2. The methodological approach is based on the details provided in Table 6-3, and on equations 6.1–6.8 and it is displayed in detail for each carbon pool in Table 11-7. Annual values for carbon stocks and carbon stock changes in the pools of living biomass (for a description of separation in above- and below-ground living biomass see chp. 6.4.2.5), 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, and Table 6-23. All working steps and data required to reproduce the calculation of emission factors the reporting tables are summarized in FOEN (2015c).

Table 11-7 Application of the methodology described in equations 6.1–6.8 in chp. 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, CC12 to CC13, i.e. conversions from CC12 to CC13, and CC13 to CC12, i.e. conversions from CC13 to CC12). 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 chp. 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 $\text{gainC}_{l,i,CC11} - \text{lossC}_{l,i,CC11}$ $= \text{gainC}_{l,i,CC11} - 0$ $= \text{gainC}_{l,i,CC11}$	stock-difference, CT=20 $(\text{stockC}_{h,i,CC11} - \text{stockC}_{h,i,b})/\text{CT}$ $= (0 - 0)/20 = 0$	stock-difference, CT=20 $(\text{stockC}_{d,i,CC11} - \text{stockC}_{d,i,b})/\text{CT}$ $= (0 - 0)/20 = 0$	stock-difference, CT=20 $(\text{stockC}_{s,i,CC11} - \text{stockC}_{s,i,b})/\text{CT}$
Afforestation CC11 > 20 yr	gain-loss $\text{gainC}_{l,i,CC12} - \text{lossC}_{l,i,CC12}$	gain-loss $\text{changeC}_{h,i,CC12}$	gain-loss $\text{changeC}_{d,i,CC12}$	gain-loss $\text{changeC}_{s,i,CC12}$
Deforestation DEF	stock-difference, CT=1 $(\text{stockC}_{l,i,a} - \text{stockC}_{l,i,CC12})/\text{CT}$	stock-difference, CT=1 $(\text{stockC}_{h,i,a} - \text{stockC}_{h,i,CC12})/\text{CT}$	stock-difference, CT=1 $(\text{stockC}_{d,i,a} - \text{stockC}_{d,i,CC12})/\text{CT}$	stock-difference, CT=20 C1X to CC51: $0.5(\text{stockC}_{s,i,CC51} - \text{stockC}_{s,i,CC12})/\text{CT}$ C1X to other: $(\text{stockC}_{s,i,a} - \text{stockC}_{s,i,CC12})/\text{CT}$
CC12 remaining	gain-loss $\text{gainC}_{l,i,CC12} - \text{lossC}_{l,i,CC12}$	gain-loss $\text{changeC}_{h,i,CC12}$	gain-loss $\text{changeC}_{d,i,CC12}$	gain-loss $\text{changeC}_{s,i,CC12}$
CC13 remaining	gain-loss $\text{gainC}_{l,i,CC13} - \text{lossC}_{l,i,CC13}$ $= 0$	gain-loss $\text{changeC}_{h,i,CC13} = 0$	gain-loss $\text{changeC}_{d,i,CC13} = 0$	gain-loss $\text{changeC}_{s,i,CC13} = 0$
CC12 to CC13	stock-difference, CT=20 $(\text{stockC}_{l,i,CC13} - \text{stockC}_{l,i,CC12})/\text{CT}$	stock-difference, CT=20 $(\text{stockC}_{h,i,CC13} - \text{stockC}_{h,i,CC12})/\text{CT} = 0$	stock-difference, CT=20 $(\text{stockC}_{d,i,CC13} - \text{stockC}_{d,i,CC12})/\text{CT}$ $= (0 - \text{stockC}_{d,i,CC12})/20$	stock-difference, CT=20 $(\text{stockC}_{s,i,CC13} - \text{stockC}_{s,i,CC12})/\text{CT} = 0$
CC13 to CC12	gain-loss $\text{gainC}_{l,i,CC12} - \text{lossC}_{l,i,CC12}$	stock-difference, CT=20 $(\text{stockC}_{h,i,CC12} - \text{stockC}_{h,i,CC13})/\text{CT} = 0$	stock-difference, CT=20 $(\text{stockC}_{d,i,CC12} - \text{stockC}_{d,i,CC13})/\text{CT}$ $= \text{stockC}_{d,i,CC12}/20$	stock-difference, CT=20 $(\text{stockC}_{s,i,CC12} - \text{stockC}_{s,i,CC13})/\text{CT} = 0$

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 CC5X (see Table 6-9).

Living biomass

- Gain and loss in living biomass of Afforestations (gross growth and cut and mortality) is taken from the study by Thürig and Traub (2015). Values are available for two elevation levels (Table 6-4).

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 that neither dead wood nor litter is present 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,

Volume 4, chp. 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 chp. 11.3.1.2).

Soil carbon

- Organic soils: In the case of organic soils, emissions due to drainage are calculated as described in chp. 6.4.2.10 and chp. 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 common forest management practices and the first thinnings and treatments are conducted. These afforested areas are, however, not reclassified to the activity Forest management: all Afforestations after 1990 are reported under Article 3.3 (see chp. 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 chp. 6.1.3.2) over a conversion period of 20 years (see Table 6-3; chp. 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 chp. 6.4.2.8; 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 chp. 6.4.2.8; Table 6-4). Thus losses of unproductive forests “CC13 remaining” are zero. Moreover, since yearly harvesting amounts from forest statistics (FOEN 2015I) 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 chp. 6.4.2.7). For unproductive forests “CC13 remaining”, yearly changes in litter and dead wood and soil carbon stock are assumed to be zero (chp. 6.4.2.8).
- 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 chp. 6.4.2.10.

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 chp. 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-CRF 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, chp. 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.

11.3.1.2.1 Change in carbon pool not reported **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 chp. 6.4.2.9; Table 11-7) , since on

Afforestations carbon stock in litter and dead wood is conservatively assumed to be zero (IPCC 2006, Volume 4, chp. 4.3.2).

Figure 4.1 in Volume 1 chp. 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 chp. 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 estimate). 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 accumulation rates of $0.17\text{--}0.20 \text{ t C ha}^{-1} \text{ yr}^{-1}$. Other studies show even higher accumulation rates, e.g., $0.24\text{--}0.34 \text{ t C ha}^{-1} \text{ yr}^{-1}$ for Afforestations with Norway spruce in the Southern Alps (Thuille and Schulze 2006), $0.24 \text{ t C ha}^{-1} \text{ yr}^{-1}$ for Afforestation with ash and maple (Alberti et al. 2008) and $0.36 \text{ t C ha}^{-1} \text{ yr}^{-1}$ for Scotch pine (Vesterdal et al. 2002). Karhu et al. (2011) determined for Finnish 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: following a conservative approach, no changes in the dead wood pool after Afforestations are 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} . This corresponds to an annual increase of C stored in the dead wood of $0.26 \text{ t C ha}^{-1} \text{ yr}^{-1}$ for Afforestations with Norway Spruce.
- 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.

Unproductive forests CC13

A description of unproductive forests and the reasoning why the living biomass, litter, dead wood and soil pools are in equilibrium and thus not a source is given in detail in chp. 6.4.2.8.

Based on the fact that unproductive forest land only covers 8–9% of the area under Forest management (CRF-KP Table 4(KP.I)B) and based on the description of these stands in chp.

6.4.2.8, 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. Because of limited financial resources (IPCC 2006 Volume 1 chp. 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. CO₂ emissions due to drainage are calculated as described in chp. 6.4.2.10. N₂O emissions from drainage of organic soils was calculated as described in chp. 6.4.2.11.
- Biomass burning: emissions of CO₂ are “included elsewhere”; emissions of CH₄ and N₂O are reported. The calculation of these emissions is described in chp. 6.4.2.12.

Greenhouse gas sources “included elsewhere”

- Emissions from Biomass burning on Afforestation and reforestation are reported under Forest management (see chpt. 6.4.2.12). The number and area of the fires were assigned to productive forests. This is a conservative estimate, since the “available fuel” of productive forests is higher than the carbon stocks of Afforestations.
- Biomass burning on Forest management: CO₂ emissions are “included elsewhere”. The reported losses of living biomass and dead wood are covered by NFI data and thus the values reported in the reporting tables CRF Table 4.A and KP-CRF Table 4(KP-I)B.1 include these losses. Emissions of CH₄ and N₂O are reported. The calculation of these emissions is described in chp. 6.4.2.12.

Greenhouse gas sources “not occurring”

- HWP from Afforestation and reforestation: all HWP from Afforestations and Forest management are reported under Forest management (see chpt. 6.11.2). HWP from deforestation is reported separately and accounted for on the basis of instantaneous oxidation.

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 CO₂ 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 et al. 2013). Opposing patterns are also reported regarding the effect of nitrogen deposition: A positive 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 cause a reduction in growth. Such acidification processes are widely detected in Swiss forest soils (Braun and Flückiger 2012).

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

This is the first complete 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 the last submission 2014 based on the questions, recommendations and encouragements of the UNFCCC Expert Review Team.

Methodological improvements for the forest sector valid for the LULUCF and KP-LULUCF sector are listed in chp.6.4.5. The following Kyoto-specific methodological modifications were made.

Recalculations reported in submission 2015

- 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 chp. 11.3.1.1).
- Net CO₂ emissions and removals from harvested wood products (HWP) are reported for the first time using the methodology from the KP-Supplement (IPCC 2014).
- N₂O emissions from mineralisation of organic matter in mineral forest soils due to land-use changes are reported for the first time.

Recalculations reported in submission 2016

- The activity data for the calculation of HWP have been updated for the whole time-series (see chp. 6.11.5).

11.3.1.5 Uncertainty estimates

Uncertainty estimates of activity data are discussed in detail in chp. 6.1.5 and are 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 11-8.

A detailed description of the determination of the emission factor uncertainty of Forest management can be found in chp. 6.4.3. Table 6-5 lists the relative uncertainties in the LULUCF sector: an uncertainty of 48% was calculated for Afforestations, 50% for Deforestations and 48% for Forest management.

Lands fulfilling the definition of Forest (see chp. 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 11-8 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	48	48
Deforestation	mainly 5E2 Land converted to Settlements	5	50	50
Forest management	5A1 Forest Land remaining Forest Land	2	48	48

11.3.1.6 Information on other methodological Issues

The methodology used for reporting under the Kyoto Protocol is described in detail in previous sections.

N₂O emissions as a result of the disturbance associated with land-use conversion (Deforestation) are reported in KP-CRF Table 4(KP-II)3. The emissions are calculated according to the methodology described in chp. 6.10.

11.3.1.7 The year of the onset of an activity, if after 2013

The starting year of the activities reported can directly be derived from the land-use change matrix (Table 6-9), from which a continuous time series is derived (Table 11-6).

11.3.2 Category-specific QA/QC and verification

In chp. 6.4.4 category-specific QA/QC and verification items for forest land are described. 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 reporting tables

A direct comparison of the areas reported in the reporting tables under the Convention "Forest Land remaining Forest Land" (CRF Table 4.A) 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 regeneration) 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 examined and compared (Table 11-9). The study showed 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 reporting tables were not available by the editorial deadline.

Table 11-9 Area budget (in kha) of KP-LULUCF and LULUCF under the UNFCCC in the year 2012 for the forest sector. The references in the table are valid for the reporting 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 reporting 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 chp. 11.2.3). For the comparison this area must be subtracted from the area under Forest management.
- 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 chp. 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 and Thürig 2015; Didion et al. 2012, 2013, 2014; chp. 6.4.2.7). 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 (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 practices. 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 practices: effects of common forest management 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.

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. CO₂ emissions on organic soils under Afforestations and Deforestations are due to former drainage (see chp. 11.3.1.2).

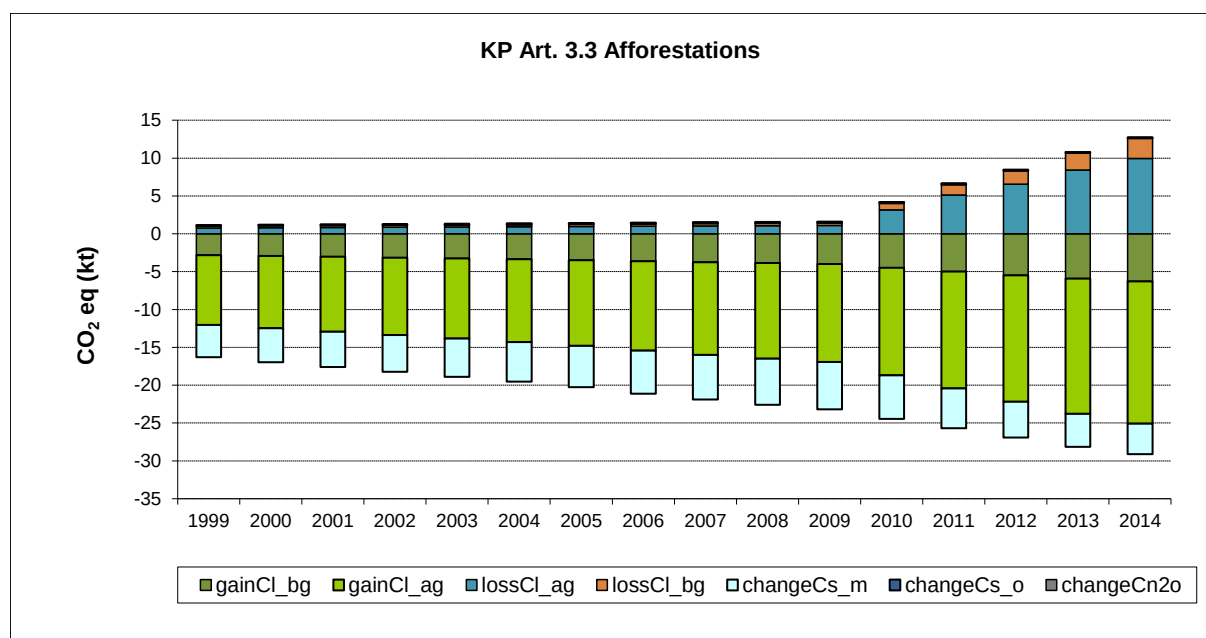


Figure 11-2 shows removals of CO₂ eq from Afforestations and emissions of CO₂ eq from Deforestations for the years 1999–2014. The corresponding values are listed in Table 11-4.

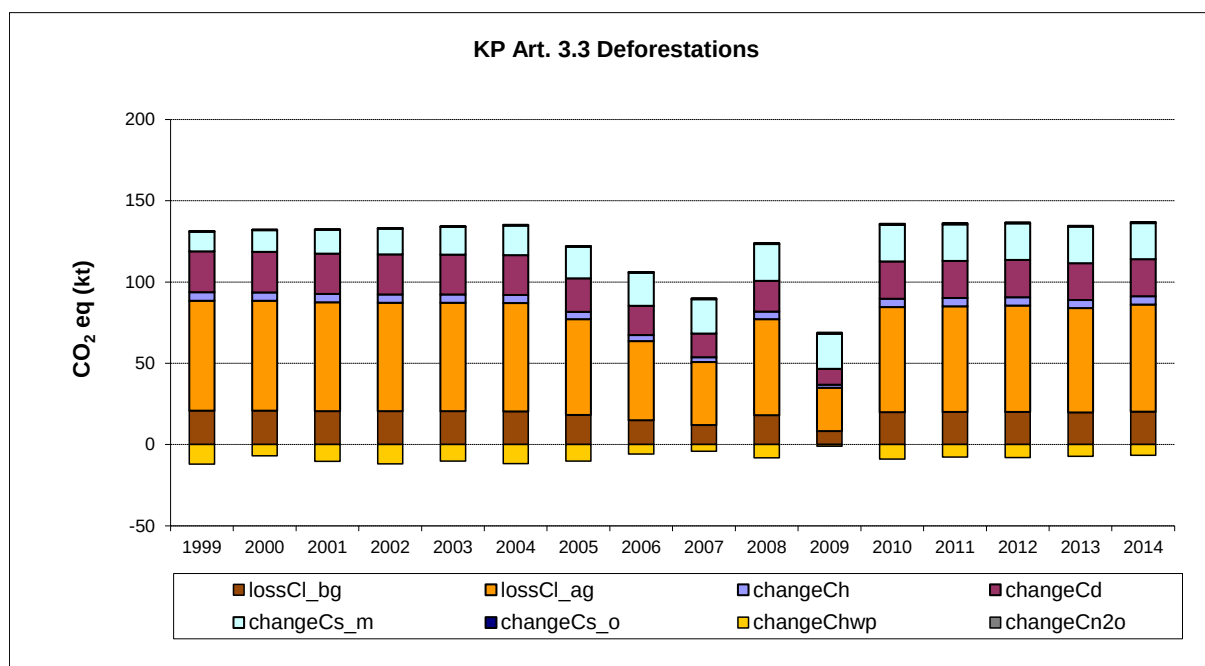


Figure 11-2 Removals (negative sign) and emissions (positive sign) of CO₂ eq from Afforestations (upper panel) and from Deforestations (lower panel) shown per carbon pool, 1999–2014. Below-ground and above-ground living biomass are reported separately. Abbreviations are: C_{l_ag}: C above-ground living 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 (cf. chp. 6.1.3.2), C_{hwp}: C in HWP, C_{n2o}: N₂O-emissions from mineralization in CO₂ equivalents. In this figure, HWP from deforestations after land-use change is shown, should however not be accounted for (see chp. 11.1.5).

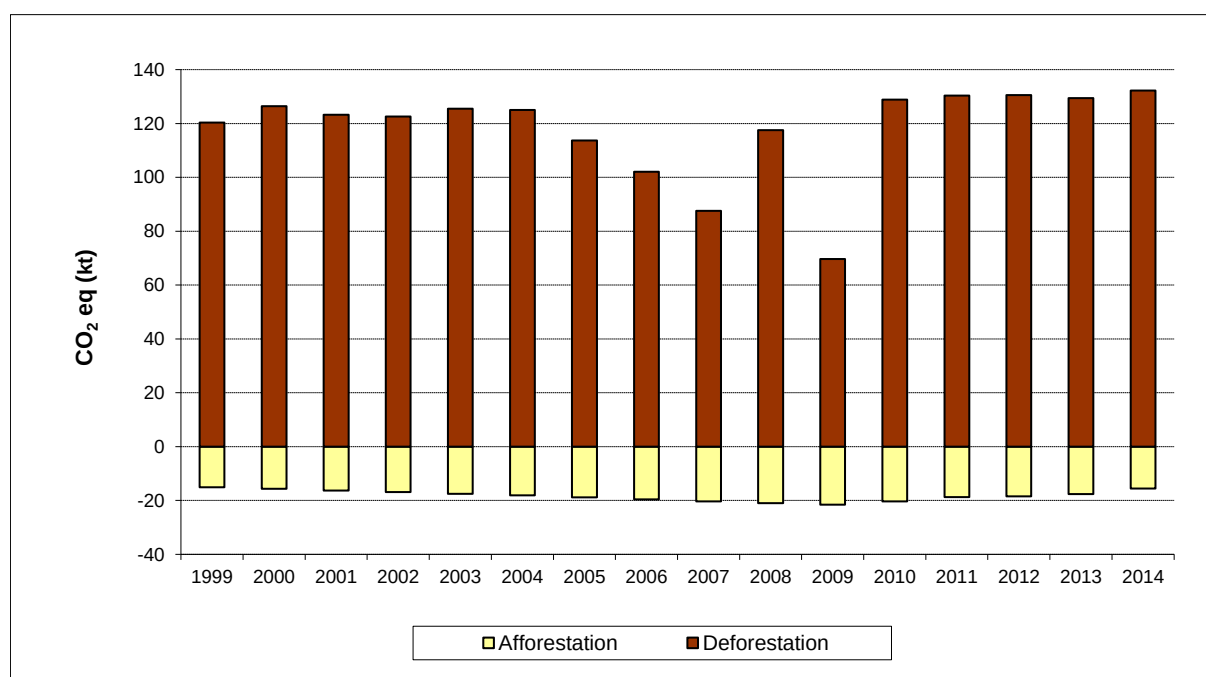


Figure 11-3 Removals (negative sign) and emissions (positive sign) of CO₂ eq of Afforestations and Deforestations, 1999–2014.

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 chp. 11.5.2). 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 chp. 11.1.3; FOEN 2010h).

The annual rate of Afforestation since 1990 is assessed based on AREA data (chp. 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 11-6).

Afforestations older than 20 years are subject to common forest management practices including harvesting (see chp. 11.3.1.1). These areas are reported in CRF Table 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 chp. 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 11-6). Since Switzerland only accounts for KP Art. 3.4 activity "Forest management", these deforested areas are not accounted for under 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. In the process of the interpretation of land conversions based on AREA data (chp. 11.2.3), the definition is implemented by applying the criteria discussed in chp. 11.2.3. This approach was verified by Sigmaplan (2012a).

The criteria 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 chp. 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 chp. 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. However, 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. Explicit criteria were developed (cf. FOEN 2010d and chp. 11.2.3) to identify which conversions from a forest combination category to a non-forest combination category do not correspond to Kyoto Deforestation under the Kyoto Protocol.

11.4.4 Information related to the natural disturbances provision under Article 3.3

Switzerland does not apply the provision of exclusion of natural disturbances for afforestation and reforestation under Article 3, paragraph 3, of the Kyoto Protocol (FOEN 2016c).

11.4.5 Information on Harvested wood products under Article 3.3

The calculation of carbon stock changes in Harvested Wood Products HWP is described in detail in chp. 6.11. The change in carbon stocks was estimated differentiating HWPs originating from Afforestation, Deforestation and from Forest management.

Applying instantaneous oxidation to HWPs originating from Deforestations, the same results are obtained for changes in carbon stocks of HWP reported under the UNFCCC (CRF Table 4.Gs1; Table 6-32) and under the KP (KP-CRF Table 4(KP-I)C). However, in this submission HWP from Deforestation was accidentally reported and accounted for under the KP. Furthermore, there was a problem with data input (some decimal places have not been correctly imported in the CRF Reporter; see chp. 11.1.5) resulting in slightly different values in the reporting tables (Table 11-5). A time series of carbon stock changes in the HWP pool reported under the Kyoto Protokoll is given in Table 11-10

Table 11-10: Changes in carbon stocks (positive values refer to emissions, negative values refer to removals) from Harvested Wood Products derived from sawnwood ($\text{changeC}_{\text{HWP-sawnwood}}$) and panels ($\text{changeC}_{\text{HWP-panels}}$) between 1999 and 2014 originating from Forest management, in kt CO₂. HWPs originating from Deforestation are not included in this table since they should be accounted for using instantaneous oxidation.

Greenhouse gas emissions and removals	1999	2000	2001	2002	2003	2004	2005	2006
Net CO ₂ emissions/removals (kt CO ₂)								
HWP: Article 3.4 (KP)	-479.50	-834.82	-577.53	-443.52	-441.45	-637.80	-764.70	-627.73
$\text{changeC}_{\text{HWP-sawnwood}}$	-298.36	-427.82	-213.79	-149.45	-133.45	-272.96	-343.40	-328.89
$\text{changeC}_{\text{HWP-panels}}$	-181.13	-407.00	-363.73	-294.07	-308.00	-364.83	-421.30	-298.83

Greenhouse gas emissions and removals	2007	2008	2009	2010	2011	2012	2013	2014
Net CO ₂ emissions/removals (kt CO ₂)								
HWP: Article 3.4 (KP)	-732.61	-522.86	-377.32	-410.86	-257.14	-167.51	-160.46	-105.76
$\text{changeC}_{\text{HWP-sawnwood}}$	-288.21	-230.63	-183.72	-170.69	-69.78	45.16	141.31	36.50
$\text{changeC}_{\text{HWP-panels}}$	-444.40	-292.23	-193.60	-240.17	-187.37	-212.67	-301.77	-142.27

11.5 Article 3.4

CO₂ eq emissions and removals from the reported pools and total CO₂ eq emissions and removals of the Kyoto Protocol activity Forest management for the years 1999 until 2014 are shown in Figure 11-4. The corresponding values are listed in Table 11-4.

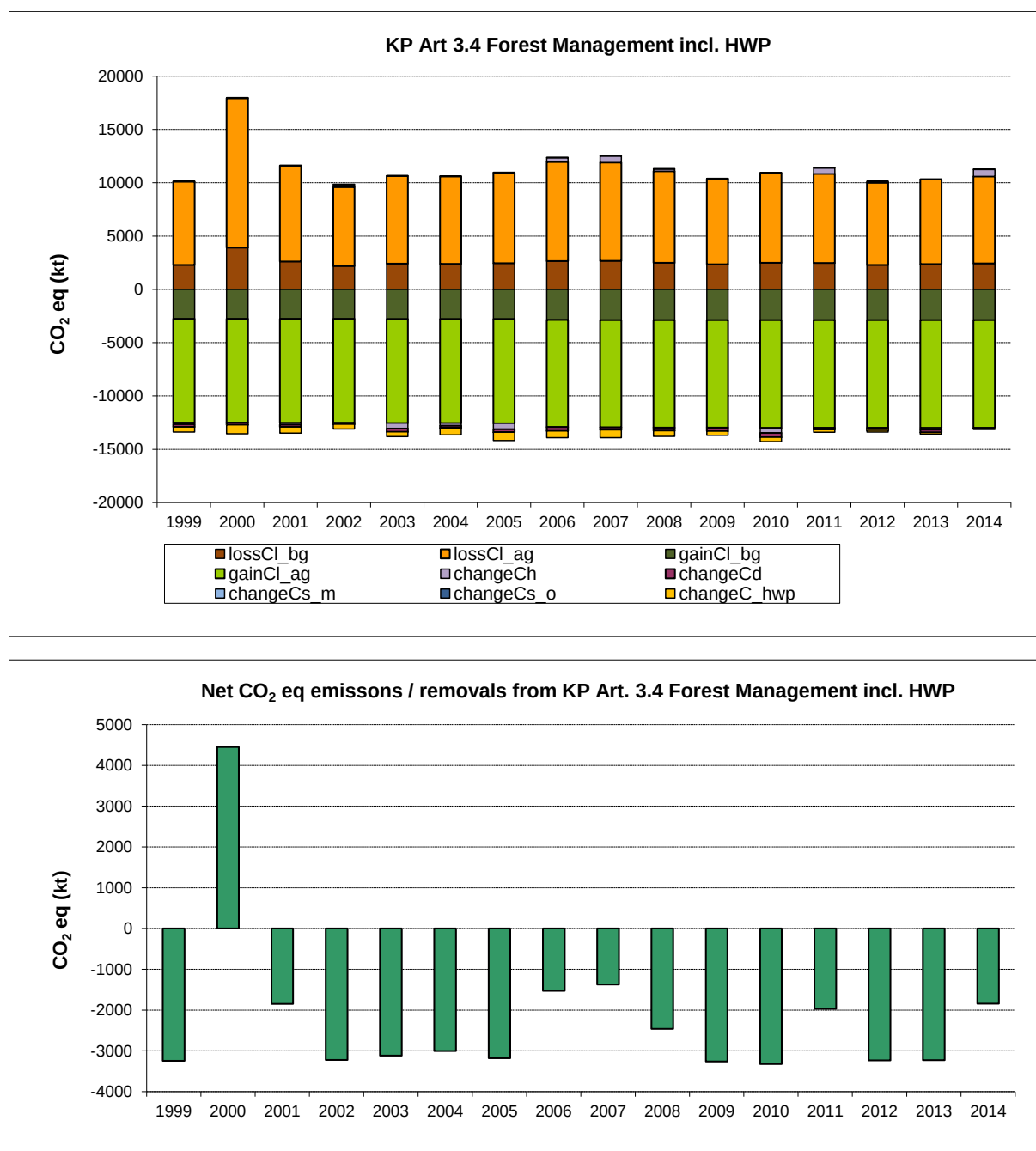


Figure 11-4 CO₂ eq emissions (positive sign) and removals (negative sign) from the reported carbon pools under Forest management with HWP (upper panel) and the total CO₂ eq emissions and removals from Forest Management with HWP (lower panel), 1999–2014. Below-ground and above-ground living biomass are reported separately. Used abbreviations explained in chp. 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 under Forest management are relatively small. In 2000, Forest management was a net source of CO₂ eq. due to high losses in living biomass after the storm Lothar, which caused large-scale damaged in Swiss forests in December 1999. Harvesting rates in Swiss forests gradually increased since 1991 until 2007; in 2008 harvesting rates started to decline due to the international and domestic economic framework conditions (Table 6-18). Fluctuations in the HWP-pool can mainly be attributed to changes in

the production of sawnwood (see chp. 6.11 and Table 6-35), which is strongly linked to the domestic harvesting rate.

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 and reported under Forest management under Article 3, paragraph 4 of the Kyoto Protocol (FOEN 2006h, Sect. F).

11.5.2 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 regions. Its aims were 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 increasing 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 the growing stock increased significantly due to changes in forest management practices. The Forest Act (Swiss Confederation 1991) that came into force in 1993 reaffirmed 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.

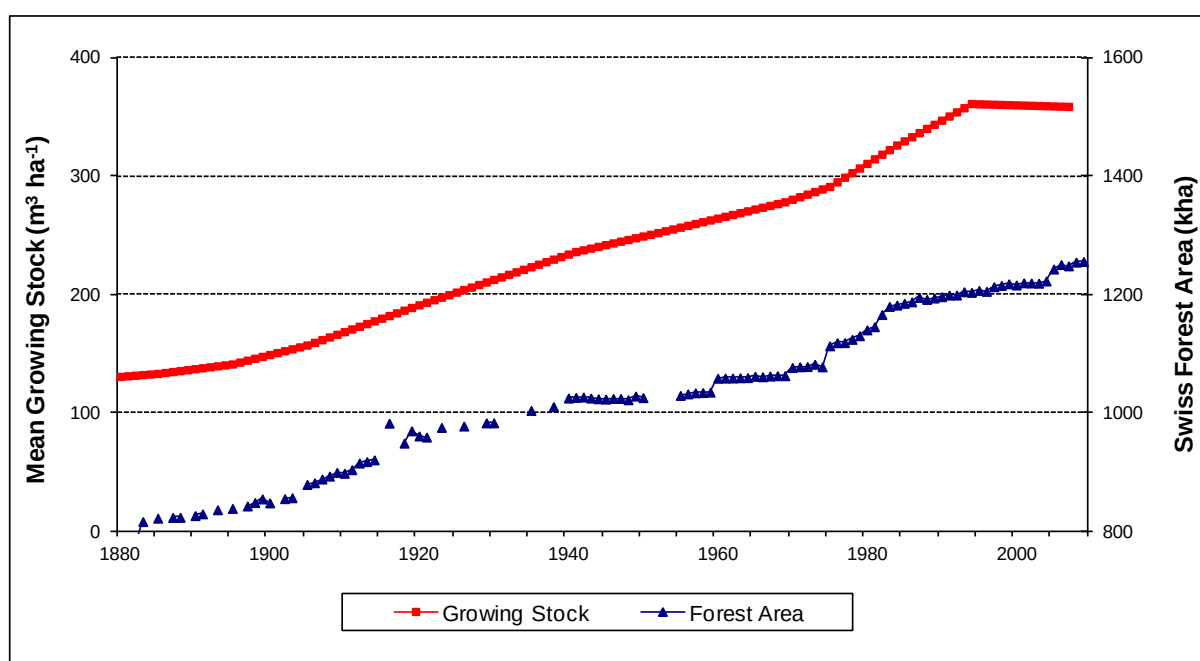


Figure 11-5 Historical mean growing stock and forest area in Switzerland since 1880.

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 CO₂ 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 finalized 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.

11.5.2.1 Conversion of natural forest to planted forest

Not applicable.

11.5.2.2 Forest management reference level (FMRL)

Switzerland's Forest management reference level (FMRL) is documented in FOEN (2011). The Swiss FMRL is inscribed in the appendix to the annex to Decision 2/CMP.7 and amounts to +0.220 Mt CO₂ eq. yr⁻¹. The FMRL 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 chp. 6.11).
- Emissions from forest fires and from organic soils have been incorporated into the FMRL (§16 of UNFCCC 2011a).

- The area under Forest management for 2013–2020 has been calculated using a linear extrapolation (§15 of UNFCCC 2011a), based on updated activity data for 1990–2009 (as used for FOEN 2014).

11.5.2.3 Technical correction Forest management reference level

The technical corrections described in this chapter were implemented for the submission 2015 (FOEN 2015). For the submission in 2016, no improvements leading to a technical correction of the FMRL were implemented. Switzerland decided not to provide technical corrections of the FMRL on an annual basis, but to correct the FMRL periodically.

11.5.2.3.1 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, which increases the accuracy of the FMRL-based accounting. 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 suitable to simulate short-term development of Swiss forests based on predefined management scenarios (Didion et al. 2014b).

11.5.2.3.2 Correction of implementation of the business-as-usual harvesting scenario (BAU)

11.5.2.3.2.1 Description of the BAU harvesting Scenario

The determination of BAU in FOEN (2011I) was 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 and Thees 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 2011I).

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 (2011I) 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 11-11.

- Extrapolation of historical data: no corrections have been made compared to FOEN (2011I). 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 underestimation 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 NFI (see chp. 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 previous study (Hofer and Altwegg, 2008), has also been adopted in the Swiss Forest Policy 2020 (FOEN 2013I) and in the official description of Switzerland's Wood Policy (FOEN/SFOE/EAER 2014). The recalculated value for the Swiss PSWS amounts to 8.23 Mio m³, which corresponds to the harvested volume to be exhausted in 2020. For the period 2013–2020 compared to 1990–2007, this corresponds to 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 Altwegg (2008) and Pauli et al. 2009 were based on modelling work with MASSIMO. This model has been updated (see chp. 11.5.2.3.1) leading to correction of the values. Using a modelling interval in this studies of 10 years, the starting year is 2006 (in FOEN 2011I it was 2005) and the harvesting value for 2006 is fixed at 6.7 Mio m³. 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. 2014b). From this point, the same scenarios (scenario basic, scenario increase energy cost, scenario constant carbon stocks) as in FOEN 2011I are modeled with Massimo (Table 11-11), but different results are obtained due to the update of the model.

Table 11-11: 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 m³).

	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 11-11 shows that, considering the corrected values from the updated studies, the harvesting amount to be reached in 2020 differs from FOEN (2011I).

- In FOEN 2011I, the 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 (2011I), the pathway of reaching the target value was not defined. For calculation of Switzerland's FMRL, an exponential pathway has been used, 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 for calculating the FMRL results in a more conservative accounting of Forest management than a linear pathway. In case of a linear pathway, harvesting values would be higher on average (see Table 11-11) 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 (2011I). To reach this target, the increase in harvest follows an exponential pathway.

11.5.2.3.2.2 Implementation of a stepwise pathway

Since the model uses a 5-year time step, the business-as-usual harvesting scenario has to be translated from a continuous into a stepwise pathway.

For the submission FOEN (2011I), 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.

11.5.2.3.3 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). Among others, both models were linked to ensure consistency between simulated forest development with Massimo and litter inputs used by 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).

11.5.2.3.4 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, eq. 2.8.5) which is different from the methodology applied in FOEN (2011). For the recalculation 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).

11.5.2.3.5 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 6-31). For an average area of 281.05 ha affected by wildfires, emissions of 13.98 kt CO₂ eq. were calculated.

11.5.2.3.6 Emissions from organic soils

Drainage of forests is reported as described in chp. 6.4.2.10.

- In order to calculate CO₂ emissions due to drainage, the default emission factor of 2.6 t C ha⁻¹ yr⁻¹ according to the Wetland Supplement (IPCC 2014a, Table 2.1) has been applied.
- N₂O emissions from drainage of organic soils was calculated for forest land with an emission factor of 2.8 kg N₂O-N ha⁻¹, default value in the Wetlands Supplement (IPCC 2014a, Table 2.5) for temperate forest land.

11.5.2.3.7 Calculation of the area under Forest management in CP2

The area under Forest management for the period 2013–2020 is calculated by linear extrapolation of the trend from the historical activity data 1990–2009. The area under Forest management 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 11-12).

Table 11-12: Mean area under Forest management for the period 2013–2020 derived from linear extrapolation of historical data 1990–2009 stratified per soil type. 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 chp. 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 then applied for the areas under Forest management (Table 11-12) in order to calculate total emissions and removals from living biomass, dead wood, litter and soil carbon in Swiss Forests (Table 11-13). Further, emissions from drainage of organic soils and emissions from forest fires were considered to calculate the corrected FMRL.

Table 11-13: Mean carbon stock changes (changeC) over the period 2013–2020 for the total area under Forest management. For the Forest management reference level carbon stock changes in living biomass (changeC_l), litter (changeC_h), dead wood (changeC_d) and soil (changeC_s; including emissions due to former drainage) are considered plus emissions from forest fires. Positive values indicate a source, negative values indicate a sink of carbon.

	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 on C stock changes in living biomass, dead wood, litter and soil carbon in Swiss Forests is summarized in Table 11-14. The technical correction equals the difference between the FMRL submitted in February 2011 (FOEN 2011I) and the corrected values for the FMRL and amounts to -1.90 Mt CO₂ eq. yr⁻¹.

Table 11-14: Summary of the technical correction of the FMRL. Values from FMRL as defined in FOEN (2011I) and corrected values (this chp.) are listed per pool or source. Abbreviations as used in chp. 6.1.3.2.

Mt CO ₂ eq yr ⁻¹	FMRL Subm. 2011	FMRL corrected April 2015	Explanation 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	

11.5.2.3.8 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 (cf. chp. 11.5.2.3.1).
- Improved representation of natural mortality to more accurately reflect the background level for natural disturbances (see chp. 11.5.2.4).
- Verification of allometries used to obtain estimates of whole tree volume and biomass, incl. branches, foliage, and roots.

Planned improvements for Yasso07 include:

- Implementing experience gained in the further development of the model at the Finnish Environment Institute and at Tampere University of Technology. This includes evaluating the validity of the forthcoming new model version Yasso15 (Järvenpää et al. in prep.) and the new model parameters for application in Swiss forests.
- Quantifying the effect of uncertainty associated with the spatially interpolated temperature and precipitation data on carbon stock changes estimates.
- Including the contribution of forest understory vegetation to the litter pool.

11.5.2.4 Information related to the natural disturbance provision under Article 3.4

11.5.2.4.1 Application of the provision of natural disturbances

As indicated in Switzerland's Initial Report (FOEN 2016c), 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 in which 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 years 2013 and 2014, 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 and 2014.

11.5.2.4.2 Technical correction of the background level and margin

There is no technical correction of the background level and margin for the inventory year 2013.

11.5.2.5 Information on Harvested wood products under Article 3.4

Methodology, estimates and uncertainties of carbon stock changes in the HWP pools are described in chp. 6.11. The same methodology is applied for reporting HWP from forest land under the UNFCCC and accounting for HWP from Forest management under the KP. A time series for changes in the HWP-pool is shown in Table 6-32 and Figure 6-9. HWPs originating from wood harvested on land converted from forest land to non forest land (UNFCCC) or from Deforestations (KP) should not be taken into account; however in this submission they are accidentally accounted for.

An overview of emissions and removals resulting from the HWP pool is presented in Table 11-4 and Figure 11-1.

Improvements leading to recalculation of the time series (see chp. 6.11.5), will also be implemented for the technical correction of the Forest management reference level in the following years.

11.5.3 Information relating to Cropland management, Grazing Land management, Revegetation and Wetland drainage and rewetting if elected, for the Base Year

Not applicable.

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 CRF 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.

11.5.5 Information that indicates to what extent removals from Forest management offsets the debit incurred under Article 3, Paragraph 3

This information will be first available at the end of the commitment period.

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 chp. 1.5 and are displayed in Table 1-4, and Table 1-10 for the year 2014. The

smallest UNFCCC category, considered key based on an Approach 1 level assessment is “5D Wastewater treatment and discharge, CH₄” with a contribution of 174.59 kt CO₂ 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 (-1743.77 kt CO₂; encompasses CO₂ emissions; Forest management excluding HWP, biomass burning and drainage; KP-CRF Table 4(KP-I)B.1) 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“. 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 both level and trend key category under Approaches 1 and 2 assessments in 2014.
- Afforestation and Reforestation (-15.66 kt CO₂; encompasses CO₂ emissions; KP-CRF Table 4(KP-I)A.1) 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 associated UNFCCC category “Land converted to Forest Land” 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 Approaches 1 and 2 assessments in 2014 (Table 1-10).
- Deforestation (136.83 kt CO₂; Deforestation excluding HWP encompasses CO₂ emissions; KP-CRF Table 4(KP-I)A.2) is not a key category under the Kyoto Protocol because its contribution is lower than the smallest UNFCCC category considered key. The associated UNFCCC category is „Land converted to Settlements“, but only a part of this UNFCCC category represents the activity Deforestation under the Kyoto Protocol (see chp. 11.2.3). The UNFCCC category “Land converted to Settlements” is level key category under Approaches 1 and 2 assessments and trend key category under Approach 2 assessment in 2014 (Table 1-10).
- Harvested Wood Products (-105.76 kt CO₂; KP-CRF Table 4(KP-I)C) is not a level key category under the Approach 1 assessment because its contribution is lower than the smallest UNFCCC category considered key. However, using the Approach 2, HWP is a level key category. The same method is used for calculation of HWP under the UNFCCC and the KP. Using Approach 2, the UNFCCC category HWP is a level key category. It is also trend key category under Approaches 1 and 2 assessments in 2014 (Table 1-10).

11.7 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. Switzerland continues to cooperate with Monaco, but no longer hosts the registry of Monaco on Swiss servers.

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), and with applicable commitment period 2 (CP2) for 2015, have been submitted to the UNFCCC Secretariat electronically.

Overview of CP1 units

By the end of the reporting year 2015 a total balance of 247,620,769 Assigned Amount Units (AAUs) were held in the Swiss Emissions Trading Registry (Table 12-1), which represents an increase of over 6 million units compared to 2014. 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.

Only 4,210,465 Emission Reduction Units (ERUs) were held in the Swiss Emissions Trading Registry, a significant reduction of approximately 23.4 Mio. units compared to the previous reporting year. The amount of Certified Emission Reductions (CERs) has also decreased significantly by roughly 10 Mio units. The amount of tCERs has remained constant. A total of 4,796,312 AAUs, 3,651,820 ERUs, 7,883,826 CERs, and all of the 114,793 tCERs have been voluntarily cancelled in the period from 2008 to 2015.

Table 12-1 Total quantities of CP1 Kyoto Protocol units by account type at the end of 2015 (SEF table 4)

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
Party holding accounts	5'794'523	NO	NO	1'640'531	NO	NO
Entity holding accounts	NO	NO	NO	194'168	NO	NO
Article 3.3/3.4 net source cancellation accounts	172'587	NO	1'013'340	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Other cancellation accounts	4'796'312	3'651'820	NO	7'883'826	114'793	NO
Retirement account	236'857'347	558'645	8'267'540	16'038'197	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	247'620'769	4'210'465	9'280'880	25'756'722	114'793	NO

Overview of CP2 units

By the end of the reporting year 2015 a total balance of 9,472,614 CERs were held in the Swiss Emissions Trading Registry, of which 550,261 CERs have been voluntarily cancelled (Table 12-2).

Table 12-2 Total quantities of CP2 Kyoto Protocol units by account type at the end of 2015 (SEF table 4)

	Account type	Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	ICERs
1	Party holding accounts	NO	NO	NO	NO	NO	NO
2	Entity holding accounts	NO	NO	NO	8'922'353	NO	NO
3	Retirement account	NO	NO	NO	NO	NO	NO
4	Previous period surplus reserve account	NO					
5	Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
6	Non-compliance cancellation account	NO	NO	NO	NO		
7	Voluntary cancellation account	NO	NO	NO	550'261	NO	NO
8	Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
9	Article 3.1 ter and quater ambition increase cancellation account	NO					
10	Article 3.7 ter cancellation account	NO					
11	tCER cancellation account for expiry					NO	
12	ICER cancellation account for expiry						NO
13	ICER cancellation account for reversal of storage						NO
14	ICER cancellation account for non-submission of certification report						NO
15	tCER replacement account for expiry	NO	NO	NO	NO	NO	
16	ICER replacement account for expiry	NO	NO	NO	NO		
17	ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
18	ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
19	Total	NO	NO	NO	9'472'614	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 2015, the Swiss Emissions Trading Registry had no discrepancies, no CDM notifications, no non-replacements including reversal of storage and failure of certification and no invalid units. Therefore the SIAR tables R-2, R-3, R-4 and R-5 are empty and no actions and changes have been taken to address discrepancies.

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. The Representative identifier (13/CMP.1 Annex paragraph 45 (d)), as well as all information according to 13/CMP.1 Annex paragraph 45 (e) are also considered as confidential. Therefore this information is not publicly available. 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 is 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 is part of the current submission (FOEN 2016c).

12.6 KP-LULUCF Accounting

According to the 'Report of the individual review of the annual submission of Switzerland submitted in 2014' (UNFCCC 2014c), Switzerland cancelled 4,479 Removal Units (RMUs) for the activity Afforestation and reforestation under Article 3, paragraph 3 of the Kyoto Protocol, 155,604 RMUs for the activity Deforestation under Article 3, paragraph 3 of the Kyoto Protocol, and 224,390 RMUs for Forest management under Article 3, paragraph 4 of the Kyoto Protocol into the Net Source Cancellation account (in its Emissions Trading Registry). The transactions took place on 3 February 2015.

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.E paragraph 32.(a): Change of name or contact	No change in the name or contact information of the registry administrator occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(b): Change of cooperation arrangement	Switzerland continues to cooperate with Monaco, but no longer hosts the registry of Monaco on Swiss servers.
15/CMP.1 annex II.E paragraph 32.(c): Change of the database or the capacity of National Registry	No change to the database or to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d): Change of conformance to technical standards	In September 2015, the registry software successfully passed the CP2 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 2.0.1. A more detailed documentation is not provided 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.E paragraph 32.(e): Change of discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f): Change of Security	No change of security measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(g): Change of list of publicly available information	The Representative identifier (13/CMP.1 Annex paragraph 45 (d)), as well as all information according to 13/CMP.1 Annex paragraph 45 (e) are considered as confidential. The confidentiality statement on the registry homepage (https://www.emissionsregistry.admin.ch) has been updated accordingly.
15/CMP.1 annex II.E paragraph 32.(h): Change of Internet address	No change of the registry Internet address occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(i): Change of data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j):	Based on the test reports and supporting documentation already submitted, Switzerland has successfully passed the CP2 Annex H test in September 2015. The test results are not provided here, because the information is regarded as confidential. However, it can be made available to the ERT upon approval of a specific request.

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 CO₂ 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 CO₂ act (Swiss Confederation 2012) still encompasses the imposition of a CO₂ levy on heating and process fuel. Companies, especially those industries with substantial CO₂ emissions from use of heating fuels, may apply for exemption from the CO₂ 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 CO₂ 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 CO₂ levy to CO₂ relevant measures in the building sector (Building refurbishment programme). The partial earmarking of revenues from the CO₂ tax is limited in the revised CO₂ act to a maximum of 300 million Swiss francs per year.

The economic impact of the Swiss climate policy was analysed in two studies¹⁰. 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 (HVF), 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.

¹⁰ 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 chp. 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.

Annexes

Annex 1: Key category analysis (KCA)

Table A – 1 displays all 157 categories used for the KCA of Switzerland's GHG inventory 2014.

Table A – 1 Key category analysis Approach 1 and 2 2014 including LULUCF (L1 = level according to Approach 1, L2 = level according to Approach 2, T1 = trend according to Approach 1, T2 = trend according to Approach 2).

Approach 1 and Approach 2 key category analysis - Level and Trend Assessment for the year 2014 with all categories shown (ordered by category code)									
No.	IPCC source categories and fuels if applicable					GHG	Year 1990 estimate	Year 2014 estimate	Result KCA assessment
							[Gg CO ₂ eq]	[Gg CO ₂ eq]	
1	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Biomass	CH ₄	0.45	0.33	
2	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CH ₄	0.11	0.13	
3	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CH ₄	0.52	0.58	
4	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Solid Fuels	CH ₄	0.13	0.00	
5	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	CO ₂	243.40	288.18	L1, T1
6	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	CO ₂	687.24	965.17	L1, T1
7	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	CO ₂	1491.86	2318.49	L1, L2, T1, T2
8	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Solid Fuels	CO ₂	49.13	0.00	
9	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Biomass	N ₂ O	22.58	14.95	
10	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Gaseous Fuels	N ₂ O	0.13	0.15	
11	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Liquid Fuels	N ₂ O	1.11	1.05	
12	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Other Fuels	N ₂ O	24.33	12.76	
13	1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Solid Fuels	N ₂ O	0.24	0.00	
14	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Biomass	CH ₄	4.12	1.83	
15	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CH ₄	0.49	1.00	
16	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CH ₄	4.48	1.43	
17	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CH ₄	0.77	0.58	
18	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CH ₄	0.31	0.27	
19	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	CO ₂	1059.63	2278.18	L1, L2, T1, T2
20	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	CO ₂	3890.57	1912.91	L1, T1
21	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	CO ₂	196.02	366.03	L1, T1, T2
22	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	CO ₂	1274.70	521.18	L1, T1, T2
23	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Biomass	N ₂ O	3.90	13.52	
24	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Gaseous Fuels	N ₂ O	0.68	1.36	
25	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Liquid Fuels	N ₂ O	13.03	10.86	
26	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Other Fuels	N ₂ O	2.32	5.60	
27	1A2	1. Energy	A. Fuel combustion activities	2. Manufacturing industries and construction	Solid Fuels	N ₂ O	6.14	2.46	
28	1A3a	1. Energy	A. Fuel combustion activities	3. Transport: Domestic aviation	Kerosene	CH ₄	0.29	0.28	
29	1A3a	1. Energy	A. Fuel combustion activities	3. Transport: Domestic aviation	Kerosene	CO ₂	252.55	139.83	T1
30	1A3a	1. Energy	A. Fuel combustion activities	3. Transport: Domestic aviation	Kerosene	N ₂ O	2.39	1.33	
31	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Biomass	CH ₄	0.00	0.05	
32	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Diesel	CH ₄	1.67	0.64	
33	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Gaseous Fuels	CH ₄	0.00	0.05	
34	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Gasoline	CH ₄	116.04	19.86	T1, T2
35	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Diesel	CO ₂	2632.66	7297.02	L1, L2, T1, T2
36	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Gaseous Fuels	CO ₂	0.00	37.99	
37	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Gasoline	CO ₂	11334.49	8276.97	L1, L2, T1
38	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Biomass	N ₂ O	0.00	1.20	
39	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Diesel	N ₂ O	5.61	73.08	T1
40	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Gaseous Fuels	N ₂ O	0.00	0.78	
41	1A3b	1. Energy	A. Fuel combustion activities	3. Transport: Road transportation	Gasoline	N ₂ O	136.88	19.81	T1, T2
42	1A3c	1. Energy	A. Fuel combustion activities	3. Transport: Railways	Biomass	CH ₄	0.00	0.00	
43	1A3c	1. Energy	A. Fuel combustion activities	3. Transport: Railways	Liquid Fuels	CH ₄	0.03	0.01	
44	1A3c	1. Energy	A. Fuel combustion activities	3. Transport: Railways	Liquid Fuels	CO ₂	28.69	30.19	
45	1A3c	1. Energy	A. Fuel combustion activities	3. Transport: Railways	Biomass	N ₂ O	0.00	0.00	
46	1A3c	1. Energy	A. Fuel combustion activities	3. Transport: Railways	Liquid Fuels	N ₂ O	0.43	0.44	
47	1A3d	1. Energy	A. Fuel combustion activities	3. Transport: Domestic navigation	Biomass	CH ₄	0.00	0.00	
48	1A3d	1. Energy	A. Fuel combustion activities	3. Transport: Domestic navigation	Liquid Fuels	CH ₄	1.68	0.29	
49	1A3d	1. Energy	A. Fuel combustion activities	3. Transport: Domestic navigation	Liquid Fuels	CO ₂	114.27	113.59	
50	1A3d	1. Energy	A. Fuel combustion activities	3. Transport: Domestic navigation	Biomass	N ₂ O	0.00	0.01	
51	1A3d	1. Energy	A. Fuel combustion activities	3. Transport: Domestic navigation	Liquid Fuels	N ₂ O	1.16	1.23	
52	1A3e	1. Energy	A. Fuel combustion activities	3. Transport: Other transportation	Gaseous Fuels	CH ₄	0.07	0.04	
53	1A3e	1. Energy	A. Fuel combustion activities	3. Transport: Other transportation	Gaseous Fuels	CO ₂	31.42	47.06	
54	1A3e	1. Energy	A. Fuel combustion activities	3. Transport: Other transportation	Gaseous Fuels	N ₂ O	0.02	0.02	
55	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Biomass	CH ₄	9.22	4.35	
56	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CH ₄	0.70	1.23	
57	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CH ₄	16.33	9.23	
58	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	CO ₂	981.49	1244.62	L1, L2, T1, T2
59	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	CO ₂	4259.54	2538.93	L1, T1
60	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Biomass	N ₂ O	3.50	8.36	
61	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Gaseous Fuels	N ₂ O	0.52	0.65	
62	1A4a	1. Energy	A. Fuel combustion activities	4. Other sectors; Commercial/institutional	Liquid Fuels	N ₂ O	10.34	6.20	
63	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	CH ₄	109.97	24.66	T1, T2
64	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CH ₄	0.70	1.26	
65	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CH ₄	34.83	19.00	
66	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Solid Fuels	CH ₄	4.73	3.00	
67	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	CO ₂	1451.63	2402.23	L1, L2, T1, T2
68	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	CO ₂	10098.96	5549.06	L1, T1, T2
69	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Solid Fuels	CO ₂	58.40	37.08	
70	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Biomass	N ₂ O	25.86	19.49	
71	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Gaseous Fuels	N ₂ O	0.77	1.26	
72	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Liquid Fuels	N ₂ O	24.53	13.50	
73	1A4b	1. Energy	A. Fuel combustion activities	4. Other sectors; Residential	Solid Fuels	N ₂ O	0.28	0.18	
74	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Biomass	CH ₄	1.97	0.35	
75	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Gaseous Fuels	CH ₄	0.02	0.01	
76	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CH ₄	6.45	1.63	
77	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Gaseous Fuels	CO ₂	41.45	14.99	
78	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	CO ₂	485.09	410.12	L1

Table A – 1 Continued: Key category analysis Approach 1 and 2 2014 including LULUCF (L1 = level according to Approach 1, L2 = level according to Approach 2, T1 = trend according to Approach 1, T2 = trend according to Approach 2).

Approach 1 and Approach 2 key category analysis - Level and Trend Assessment for the year 2014 with all categories shown (ordered by category code)									
No.	IPCC source categories and fuels if applicable					GHG	Year 1990 estimate	Year 2014 estimate	Result KCA assessment
							[Gg CO ₂ eq]	[Gg CO ₂ eq]	
79	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Biomass	N ₂ O	0.51	0.90	
80	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Gaseous Fuels	N ₂ O	0.02	0.01	
81	1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Liquid Fuels	N ₂ O	4.20	4.61	
82	1A5	1. Energy	A. Fuel combustion activities	5. Other	Biomass	CH ₄	0.00	0.00	
83	1A5	1. Energy	A. Fuel combustion activities	5. Other	Liquid Fuels	CH ₄	0.27	0.17	
84	1A5	1. Energy	A. Fuel combustion activities	5. Other	Liquid Fuels	CO ₂	217.65	137.51	
85	1A5	1. Energy	A. Fuel combustion activities	5. Other	Biomass	N ₂ O	0.00	0.00	
86	1A5	1. Energy	A. Fuel combustion activities	5. Other	Liquid Fuels	N ₂ O	2.11	1.36	
87	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		CH ₄	319.77	196.87	L1, L2, T1, T2
88	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		CO ₂	25.95	33.10	
89	1B2	1. Energy	B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from ener		N ₂ O	0.60	0.25	
90	2A1	2. Industrial processes	A. Mineral industry	1. Cement production		CO ₂	2524.45	1858.10	L1, T1
91	2A2	2. Industrial processes	A. Mineral industry	2. Lime production		CO ₂	53.35	51.66	
92	2A3	2. Industrial processes	A. Mineral industry	3. Glass production		CO ₂	15.25	6.36	
93	2A4	2. Industrial processes	A. Mineral industry	4. Other process uses of carbonates		CO ₂	156.11	93.08	
94	2B	2. Industrial processes	B. Chemical industry			CH ₄	1.83	2.12	
95	2B	2. Industrial processes	B. Chemical industry			CO ₂	121.59	114.95	
96	2B	2. Industrial processes	B. Chemical industry			N ₂ O	65.49	4.35	
97	2C1	2. Industrial processes	C. Metal industry	1. Iron and steel production		CO ₂	9.20	10.78	
98	2C3	2. Industrial processes	C. Metal industry	3. Aluminium production		CO ₂	139.26	0.00	T1
99	2C3	2. Industrial processes	C. Metal industry	3. Aluminium production		PFC	116.46	0.00	T1
100	2C4	2. Industrial processes	C. Metal industry	4. Magnesium production		SF ₆	0.00	45.99	
101	2C7	2. Industrial processes	C. Metal industry	7. Other		CO ₂	1.65	1.47	
102	2D	2. Industrial processes	D. Non-energy products from fuels and so			CO ₂	66.24	62.30	
103	2E1	2. Industrial processes	E. Electronics industry	1. Integrated circuit or semiconductor		HFC	0.00	0.17	
104	2E1	2. Industrial processes	E. Electronics industry	1. Integrated circuit or semiconductor		PFC	0.00	6.20	
105	2E1	2. Industrial processes	E. Electronics industry	1. Integrated circuit or semiconductor		SF ₆	0.00	8.59	
106	2E3	2. Industrial processes	E. Electronics industry	3. Photovoltaics		NF ₃	0.00	0.40	
107	2E4	2. Industrial processes	F. Product uses as substitutes for ODS	4. Heat transfer fluid		PFC	0.00	0.00	
108	2F1	2. Industrial processes	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	0.02	1398.55	L1, L2, T1, T2
109	2F1	2. Industrial processes	F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		PFC	0.05	6.11	
110	2F2	2. Industrial processes	F. Product uses as substitutes for ODS	2. Foam blowing agents		HFC	0.00	32.89	
111	2F4	2. Industrial processes	F. Product uses as substitutes for ODS	4. Aerosols		HFC	0.00	22.39	
112	2F5	2. Industrial processes	F. Product uses as substitutes for ODS	5. Solvents		HFC	0.00	0.73	
113	2G	2. Industrial processes	G. Other product manufacture and use			CO ₂	6.59	36.71	
114	2G	2. Industrial processes	G. Other product manufacture and use			HFC	0.00	46.25	
115	2G	2. Industrial processes	G. Other product manufacture and use			PFC	0.00	31.57	
116	2G	2. Industrial processes	G. Other product manufacture and use			SF ₆	137.01	204.26	L1, T1, T2
117	2G	2. Industrial processes	G. Other product manufacture and use			N ₂ O	105.87	43.93	T2
118	2H	2. Industrial processes	H. Other			CO ₂	1.04	0.84	
119	3A	3. Agriculture	A. Enteric fermentation			CH ₄	3584.87	3365.33	L1, L2, T1, T2
120	3B	3. Agriculture	B. Manure management			CH ₄	923.97	782.15	L1, L2, T2
121	3B1-3B4	3. Agriculture	B. Manure management	1. Cattle, 2. Sheep, 3. Swine, 4. Other livestock		N ₂ O	105.65	86.09	L2
122	3B5	3. Agriculture	B. Manure management	5. Indirect N ₂ O emissions		N ₂ O	242.32	283.54	L1, L2, T1, T2
123	3Da	3. Agriculture	D. Agricultural soils; Direct emissions from			N ₂ O	1239.22	1111.39	L1, L2, T2
124	3Db	3. Agriculture	D. Agricultural soils; Indirect emissions from			N ₂ O	658.57	499.67	L1, L2, T1, T2
125	3G	3. Agriculture	G. Liming			CO ₂	22.57	32.58	
126	3H	3. Agriculture	H. Urea application			CO ₂	26.71	12.96	
127	4 II	4. LULUCF	Drainage, rewetting and other managemen			CH ₄	10.75	10.75	
128	4 II	4. LULUCF	Drainage, rewetting and other managemen			N ₂ O	7.77	7.94	
129	4 III	4. LULUCF	N mineralization			N ₂ O	58.71	52.01	L2
130	4 IV	4. LULUCF	Indirect emissions			N ₂ O	9.60	8.50	
131	4 V	4. LULUCF	Biomass burning			CH ₄	13.73	0.54	
132	4 V	4. LULUCF	Biomass burning			CO ₂	0.00	0.00	
133	4 V	4. LULUCF	Biomass burning			N ₂ O	9.26	0.36	
134	4A1	4. LULUCF	A. Forest land	1. Forest land remaining forest land		CO ₂	-369.23	-1674.57	L1, L2, T1, T2
135	4A2	4. LULUCF	A. Forest land	2. Land converted to forest land		CO ₂	-570.45	-503.37	L1, L2, T1, T2
136	4B1	4. LULUCF	B. Cropland	1. Cropland remaining cropland		CO ₂	364.91	332.11	L1, L2
137	4B2	4. LULUCF	B. Cropland	2. Land converted to cropland		CO ₂	46.57	28.66	
138	4C1	4. LULUCF	C. Grassland	1. Grassland remaining grassland		CO ₂	79.05	115.70	L2, T2
139	4C2	4. LULUCF	C. Grassland	2. Land converted to grassland		CO ₂	91.50	183.10	L1, T1, T2
140	4D1	4. LULUCF	D. Wetlands	1. Wetlands remaining wetlands		CO ₂	67.56	70.77	L2
141	4D2	4. LULUCF	D. Wetlands	2. Land converted to wetlands		CO ₂	21.87	33.99	
142	4E1	4. LULUCF	E. Settlements	1. Settlements remaining settlements		CO ₂	17.27	54.32	T2
143	4E2	4. LULUCF	E. Settlements	2. Land converted to settlements		CO ₂	394.54	318.25	L1, L2, T2
144	4F2	4. LULUCF	F. Other land	2. Land converted to other land		CO ₂	94.34	117.35	L2
145	4G	4. LULUCF	G. Harvested wood products			CO ₂	-1231.92	-105.80	L2, T1, T2
146	5A	5. Waste	A. Solid waste disposal			CH ₄	763.39	367.74	L1, L2, T1, T2
147	5A	5. Waste	A. Solid waste disposal			CO ₂	0.00	0.00	
148	5B	5. Waste	B. Biological treatment of solid waste			CH ₄	35.64	107.96	T1, T2
149	5B	5. Waste	B. Biological treatment of solid waste			N ₂ O	5.42	16.56	
150	5C	5. Waste	C. Incineration and open burning of waste			CH ₄	13.79	7.37	
151	5C	5. Waste	C. Incineration and open burning of waste			CO ₂	53.73	9.89	
152	5C	5. Waste	C. Incineration and open burning of waste			N ₂ O	18.32	31.03	
153	5D	5. Waste	D. Wastewater treatment and discharge			CH ₄	130.92	174.59	L1, L2, T2
154	5D	5. Waste	D. Wastewater treatment and discharge			N ₂ O	118.27	144.47	L2, T2
155	6	6. Other				CH ₄	0.66	0.68	
156	6	6. Other				CO ₂	10.96	12.92	
157	6	6. Other				N ₂ O	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, find overall result at the bottom of the last part of the table (Table 3.2 of IPCC 2006 Guidelines).

IPCC Source category	Gas	Base year emissions or removals	Year 2014 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2014	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
1A1	1. Energy	Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
1A2	2. Manufacturing industries and construction	Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
1A3a	3. Transport; Domestic aviation	Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%

IPCC Source category	Gas	Base year emissions or removals	Year 2014 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2014	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
1A3b	3. Transport; Road transportation	Biomass	CH4	Gg CO2 eq	10.0	59.2	60.0	0.0000	0.0000	0.00	0.00	0.00
		Diesel	CH4	1.67	0.64	20.0	20.0	0.0000	0.0000	0.00	0.00	0.00
		Gaseous F.	CH4	-	0.05	29.6	30.0	0.0000	0.0000	0.00	0.00	0.00
		Gasoline	CH4	116.04	19.86	0.7	37.0	0.0016	0.0004	0.06	0.00	0.00
		Diesel	CO2	2'632.66	7'297.02	0.9	0.1	0.0935	0.1392	0.01	0.17	0.03
		Gaseous F.	CO2	-	37.99	5.0	1.1	0.0007	0.0007	0.00	0.01	0.00
		Gasoline	CO2	11'334.49	8'276.97	0.7	0.1	0.0386	0.1579	0.00	0.15	0.02
		Biomass	N2O	-	1.20	10.0	149.7	0.0000	0.0000	0.00	0.00	0.00
		Diesel	N2O	5.61	73.08	0.9	22.0	0.0013	0.0014	0.03	0.00	0.00
		Gaseous F.	N2O	-	0.78	5.0	79.8	0.0000	0.0000	0.00	0.00	0.00
		Gasoline	N2O	136.88	19.81	0.7	50.0	0.0020	0.0004	0.10	0.00	0.01
		Biomass	CH4	-	0.00	10.0	59.2	0.0000	0.0000	0.00	0.00	0.00
1A3c	3. Transport; Railways	Liquid F.	CH4	0.03	0.01	0.7	30.0	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	CO2	28.69	30.19	0.7	0.1	0.0001	0.0006	0.00	0.00	0.00
		Biomass	N2O	-	0.00	10.0	149.7	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	N2O	0.43	0.00	10.0	80.0	0.0000	0.0000	0.00	0.00	0.00
		Biomass	CH4	-	0.00	10.0	59.2	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	CH4	1.68	0.29	0.7	30.0	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	CO2	114.27	113.59	0.7	0.1	0.0002	0.0022	0.00	0.00	0.00
		Biomass	N2O	-	0.01	10.0	149.7	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	N2O	1.16	1.23	0.7	150.0	0.0000	0.0000	0.00	0.00	0.00
		Gaseous F.	CH4	0.07	0.04	5.0	29.6	0.0000	0.0000	0.00	0.00	0.00
		Gaseous F.	CO2	31.42	47.06	5.0	1.1	0.0004	0.0009	0.00	0.01	0.00
		Gaseous F.	N2O	0.02	0.02	5.0	79.8	0.0000	0.0000	0.00	0.00	0.00
1A3d	3. Transport; Domestic navigation	Biomass	CH4	9.22	4.35	10.0	28.3	0.0000	0.0001	0.00	0.00	0.00
		Gaseous F.	CH4	0.70	1.23	5.0	29.6	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	CH4	16.33	9.23	0.7	30.0	0.0001	0.0002	0.00	0.00	0.00
		Gaseous F.	CO2	981.49	1'244.62	5.0	1.1	0.0067	0.0237	0.01	0.17	0.03
		Liquid F.	CO2	4'259.54	2'538.93	0.7	0.1	0.0001	0.0002	0.00	0.05	0.00
		Biomass	N2O	3.50	8.36	10.0	79.4	0.0000	0.0002	0.01	0.00	0.00
		Gaseous F.	N2O	0.52	0.65	5.0	79.8	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	N2O	10.34	6.20	0.7	80.0	0.0001	0.0001	0.00	0.00	0.00
		Biomass	CH4	109.97	24.66	10.0	28.3	0.0000	0.0005	0.04	0.01	0.00
		Gaseous F.	CH4	0.70	1.26	5.0	29.6	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	CH4	34.83	19.00	0.7	30.0	0.0002	0.0004	0.01	0.00	0.00
		Solid F.	CH4	4.73	3.00	5.0	29.6	0.0000	0.0001	0.00	0.00	0.00
1A4a	4. Other sectors; Commercial/Industrial	Gaseous F.	CO2	1'451.63	2'402.23	5.0	1.1	0.067	0.0458	0.02	0.32	0.11
		Liquid F.	CO2	10'098.96	5'549.06	0.7	0.1	0.0006	0.1058	0.01	0.10	0.01
		Solid F.	CO2	58.40	37.08	5.0	5.1	0.0003	0.0007	0.00	0.01	0.00
		Biomass	N2O	25.86	19.49	10.0	79.4	0.0001	0.0004	0.01	0.01	0.00
		Gaseous F.	N2O	0.77	1.26	5.0	79.8	0.0000	0.0000	0.00	0.00	0.00
		Liquid F.	N2O	24.53	13.50	0.7	80.0	0.0002	0.0003	0.01	0.00	0.00
		Solid F.	N2O	0.28	0.18	5.0	79.8	0.0000	0.0000	0.00	0.00	0.00
1A4b	4. Other sectors; Residential	Biomass	CH4	-	0.05	10.0	59.2	0.0000	0.0000	0.00	0.00	0.00
		Diesel	CH4	1.67	0.64	0.9	20.0	0.0000	0.0000	0.00	0.00	0.00
		Gaseous F.	CH4	-	0.05	5.0	29.6	0.0000	0.0000	0.00	0.00	0.00
		Gasoline	CH4	116.04	19.86	0.7	37.0	0.0016	0.0004	0.06	0.00	0.00
		Diesel	CO2	2'632.66	7'297.02	0.9	0.1	0.0935	0.1392	0.01	0.17	0.03
		Gaseous F.	CO2	-	37.99	5.0	1.1	0.0007	0.0007	0.00	0.01	0.00
		Gasoline	CO2	11'334.49	8'276.97	0.7	0.1	0.0386	0.1579	0.00	0.15	0.02
		Biomass	N2O	-	1.20	10.0	149.7	0.0000	0.0000	0.00	0.00	0.00
		Diesel	N2O	5.61	73.08	0.9	22.0	0.0013	0.0014	0.03	0.00	0.00
		Gaseous F.	N2O	-	0.78	5.0	79.8	0.0000	0.0000	0.00	0.00	0.00
		Gasoline	N2O	136.88	19.81	0.7	50.0	0.0020	0.0004	0.10	0.00	0.01
		Biomass	CH4	-	0.00	10.0	59.2	0.0000	0.0000	0.00	0.00	0.00

	IPCC Source category			Gas	Base year emissions or removals	Year 2014 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2014	Type A sensitivity	Type B sensitivity	Uncertainty in trend in nat. emissions introduced by EF uncertainty	Uncertainty in trend introduced by AD uncertainty	Uncertainty introduced into the trend in total national emissions	
1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture/forestry/fishing	Biomass	CH4	Gg CO2 eq	1.97	0.35	10.0	28.3	%	%	%	0.0000	0.0000	0.00	0.00
			Gaseous F.	CH4	0.02	0.01	5.0	29.6	30.0	0.0000	0.0000	0.00	0.00	0.00	0.00	
			Liquid F.	CH4	6.45	1.63	0.7	30.0	30.0	0.0001	0.0000	0.00	0.00	0.00	0.00	
			Gaseous F.	CO2	41.45	14.99	5.0	1.1	5.1	0.0000	0.0004	0.0003	0.0000	0.00	0.00	
			Liquid F.	CO2	485.09	410.12	0.7	0.1	0.7	0.0000	0.0006	0.00078	0.0000	0.01	0.00	
			Biomass	N2O	0.51	0.90	10.0	79.4	80.0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	
			Gaseous F.	N2O	0.02	0.01	5.0	79.8	80.0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	
			Liquid F.	N2O	4.20	4.61	0.7	80.0	80.0	0.0000	0.0000	0.0001	0.0000	0.00	0.00	
			Biomass	CH4	-	0.00	10.0	59.2	60.0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	
			Liquid F.	CH4	0.27	0.17	0.7	60.0	60.0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	
5. Other	Liquid F.	CO2	217.65	137.51	0.7	0.1	0.7	0.0000	0.0012	0.0026	0.0000	0.00	0.00	0.00	0.00	
	Biomass	N2O	-	0.00	106.1	106.1	150.0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	
2. Oil and natural gas and other emissions from energy production	Liquid F.	N2O	2.11	1.36	106.1	106.1	150.0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	
	CO2	319.77	196.87	5.0	29.6	30.0	0.015	0.0018	0.0038	0.05	0.03	0.00	0.00	0.00	0.00	
B. Fugitive emissions from fuels	CO2	29.95	33.10	5.0	8.7	10.0	0.0000	0.0002	0.0008	0.00	0.01	0.00	0.00	0.00	0.00	
	N2O	0.60	0.25	5.0	79.8	80.0	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	
2. Industrial processes and product use	A. Mineral industry	1. Cement production	CO2	2524.45	1858.10	2.0	2.0	2.8	0.012	0.0083	0.0354	0.02	0.10	0.00	0.01	
		2. Lime production	CO2	53.35	51.66	1.4	1.4	2.0	0.0000	0.0001	0.0010	0.00	0.00	0.00	0.00	
		3. Glass production	CO2	15.25	6.36	1.4	1.4	2.0	0.0000	0.0001	0.0001	0.00	0.00	0.00	0.00	
		4. Other process uses of carbonates	CO2	156.11	93.08	1.4	4.8	5.0	0.0000	0.0009	0.0018	0.00	0.00	0.00	0.00	
	B. Chemical industry	CO2	1. Iron and steel production	CO2	9.20	10.78	5.0	40.0	40.3	0.0000	0.0000	0.0002	0.00	0.00	0.00	0.00
			3. Aluminium production	CO2	139.26	-	7.1	7.1	10.0	-	0.0024	-	0.0024	0.02	-	0.00
	C. Metal industry	SF6	4. Magnesium production	CO2	116.46	-	6.4	6.4	9.0	-	0.0020	-	0.01	-	0.00	0.00
			7. Other	CO2	1.65	45.99	17.7	17.7	25.0	0.001	0.0009	0.0009	0.02	0.02	0.00	0.00
	D. Non-energy products from fuels and solvent use	CO2	1. Integrated circuit or semiconductor	CO2	66.24	62.30	35.4	35.4	50.0	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
			3. Photovoltaics	CO2	-	0.17	33.6	33.6	47.5	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
E. Electronics industry	SF6	4. Heat transfer fluid	CO2	-	6.20	52.3	52.3	74.0	0.0000	0.0001	0.0001	0.01	0.01	0.00	0.00	0.00
		3. Photovoltaics	CO2	-	8.59	41.7	41.7	59.0	0.0000	0.0002	0.0002	0.01	0.01	0.00	0.00	0.00
F. Product uses as substitutes for ODS	HFC	1. Refrigeration and air conditioning	CO2	0.02	1398.55	10.6	10.6	15.0	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00
		2. Foam blowing agents	CO2	0.05	6.11	23.3	23.3	33.0	0.0000	0.0001	0.0001	0.0267	0.0267	0.28	0.40	0.24
2F1	HFC	4. Aerosols	1. Refrigeration and air conditioning	CO2	0.05	6.11	23.3	33.0	0.0000	0.0001	0.0001	0.00	0.00	0.00	0.00	0.00
			2. Foam blowing agents	CO2	-	32.89	15.6	15.6	22.0	0.0000	0.0006	0.0006	0.01	0.01	0.00	0.00
2F2	HFC	4. Aerosols	1. Refrigeration and air conditioning	CO2	0.05	6.11	23.3	33.0	0.0000	0.0001	0.0001	0.00	0.00	0.00	0.00	0.00
			2. Foam blowing agents	CO2	-	32.89	15.6	15.6	22.0	0.0000	0.0006	0.0006	0.01	0.01	0.00	0.00
2F4	HFC	4. Aerosols	1. Refrigeration and air conditioning	CO2	0.05	6.11	23.3	33.0	0.0000	0.0001	0.0001	0.00	0.00	0.00	0.00	0.00
			2. Foam blowing agents	CO2	-	32.89	15.6	15.6	22.0	0.0000	0.0006	0.0006	0.01	0.01	0.00	0.00
2F5	HFC	4. Aerosols	1. Refrigeration and air conditioning	CO2	0.05	6.11	23.3	33.0	0.0000	0.0001	0.0001	0.00	0.00	0.00	0.00	0.00
			2. Foam blowing agents	CO2	-	32.89	15.6	15.6	22.0	0.0000	0.0006	0.0006	0.01	0.01	0.00	0.00

IPCC Source category				Gas	Base year emissions or removals	Year 2014 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2014	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 CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	
2G				CO ₂	6.59	36.71	35.4	35.4	50.0	0.001	0.0006	0.0007	0.02	0.04	0.00
				HFC	-	46.25	6.7	6.7	9.5	0.000	0.0009	0.0009	0.01	0.01	0.00
				PFC	-	31.57	6.0	6.0	8.5	0.000	0.0006	0.0006	0.00	0.01	0.00
				SF ₆	137.01	204.26	14.5	14.5	20.5	0.008	0.0015	0.0039	0.02	0.08	0.01
2H				N ₂ O	105.87	43.93	35.4	71.8	80.0	0.005	0.0010	0.0008	0.07	0.04	0.01
				CO ₂	1.04	0.84	7.1	7.1	10.0	0.000	0.0000	0.0000	0.00	0.00	0.00
3A				CH ₄	3'584.87	3'365.33	6.4	16.9	18.1	1.638	0.0020	0.0642	0.03	0.58	0.34
				CH ₄	923.97	782.15	6.4	54.0	54.4	0.797	0.0011	0.0149	0.06	0.14	0.02
3B				N ₂ O	-	10.59	32.0	75.0	81.5	0.000	0.0002	0.0002	0.02	0.01	0.00
				N ₂ O	-	75.49	32.0	75.0	81.5	0.017	0.0004	0.0014	0.03	0.07	0.01
				N ₂ O	242.32	283.54	46.5	240.0	244.5	2.115	0.0012	0.0054	0.29	0.36	0.21
				N ₂ O	1'049.85	835.38	15.0	135.0	135.8	5.667	0.0023	0.0159	0.31	0.34	0.21
3D				N ₂ O	67.58	65.21	29.4	137.5	140.6	0.037	0.0001	0.0012	0.01	0.05	0.00
3D				N ₂ O	121.78	210.80	68.3	132.5	149.1	0.435	0.0019	0.0040	0.25	0.39	0.21
				N ₂ O	462.94	345.02	39.6	240.0	243.2	3.100	0.0014	0.0066	0.35	0.37	0.26
				N ₂ O	195.62	154.66	22.4	163.3	164.9	0.286	0.0004	0.0029	0.07	0.09	0.01
				CO ₂	22.57	32.58	40.0	5.0	40.3	0.001	0.0002	0.0006	0.00	0.04	0.00
3G				CO ₂	26.71	12.96	5.0	5.0	7.1	0.000	0.0002	0.0002	0.00	0.00	0.00
3H				CH ₄	763.39	367.74	21.2	21.2	30.0	0.054	0.0062	0.0070	0.13	0.21	0.06
5A				CO ₂	-	-	7.1	7.1	10.0	-	-	-	-	-	-
5B				CH ₄	35.64	107.96	10.0	40.0	41.2	0.009	0.0014	0.0021	0.06	0.03	0.00
5C				N ₂ O	5.42	16.56	10.0	79.4	80.0	0.001	0.0002	0.0003	0.02	0.00	0.00
				CH ₄	13.79	7.37	10.0	59.2	60.0	0.000	0.0001	0.0001	0.01	0.00	0.00
5D				CO ₂	53.73	9.89	10.0	38.7	40.0	0.000	0.0007	0.0002	0.03	0.00	0.00
				N ₂ O	18.32	31.03	10.0	38.7	40.0	0.001	0.0003	0.0006	0.01	0.01	0.00
6				CH ₄	130.92	174.59	32.0	36.0	48.2	0.031	0.0011	0.0033	0.04	0.15	0.02
				N ₂ O	118.27	144.47	32.0	146.5	150.0	0.207	0.0007	0.0028	0.10	0.12	0.03
6				CH ₄	0.66	0.68	42.4	42.4	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				CO ₂	10.96	12.92	28.3	28.3	40.0	0.000	0.0001	0.0002	0.00	0.01	0.00
				N ₂ O	0.60	0.60	106.1	106.1	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category		Gas	Base year emissions or removals	Year 2014 emissions or removals	AD uncertainty	EF uncertainty	Combined uncertainty	Contribution to variance by Category in 2014	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 CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	
4 LULUCF	4 II	Drainage, rewetting and other management of organic and mineral soils	CH ₄	10.75	10.75	10.0	70.0	0.000	0.0000	0.0002	0.00	0.00	0.00
	4 III	N mineralization	N ₂ O	7.77	7.94	30.0	137.5	0.001	0.0000	0.0002	0.00	0.01	0.00
	4 IV	Indirect emissions	N ₂ O	58.71	52.01	6.0	135.0	0.022	0.0000	0.0010	0.00	0.01	0.00
	4 V	Biomass burning	N ₂ O	9.60	8.50	20.0	161.5	0.001	0.0000	0.0002	0.00	0.00	0.00
			CH ₄	13.73	0.54	10.0	70.0	0.000	0.0002	0.0000	0.02	0.00	0.00
	4A1	1. Forest land remaining forest land	CO ₂	-	-	10.0	70.0	-	-	-	-	-	-
			N ₂ O	9.26	0.36	10.0	70.0	0.000	0.0002	0.0000	0.01	0.00	0.00
	4A2	2. Land converted to forest land	CO ₂	-369.23	-1'674.57	2.0	47.9	2.834	0.0255	0.0319	1.22	0.09	1.50
	4B1	1. Cropland remaining cropland	CO ₂	-570.45	-503.37	2.0	47.9	0.256	0.0003	0.0096	0.01	0.03	0.00
	4B2	2. Land converted to cropland	CO ₂	364.91	332.11	5.0	37.5	0.069	0.0000	0.0063	0.00	0.04	0.00
	4C1	1. Grassland remaining grassland	CO ₂	46.57	28.66	6.0	21.0	0.000	0.0003	0.0005	0.01	0.00	0.00
	4C2	2. Land converted to grassland	CO ₂	79.05	115.70	6.0	839.4	4.152	0.0008	0.0022	0.70	0.02	0.49
	4D1	1. Wetlands remaining wetlands	CO ₂	91.50	183.10	6.0	27.0	0.011	0.0019	0.0035	0.05	0.03	0.00
	4D2	2. Land converted to wetlands	CO ₂	67.56	70.77	30.0	100.0	0.024	0.0002	0.0013	0.02	0.06	0.00
	4E1	1. Settlements remaining settlements	CO ₂	21.87	33.99	5.0	50.0	0.001	0.0003	0.0006	0.01	0.00	0.00
	4E2	2. Land converted to settlements	CO ₂	17.27	54.32	5.0	50.0	0.003	0.0007	0.0010	0.04	0.01	0.00
	4F2	2. Land converted to other land	CO ₂	394.54	318.25	5.0	50.0	0.113	0.0008	0.0061	0.04	0.04	0.00
	4G	G. Harvested wood products	CO ₂	94.34	117.35	4.0	50.0	0.015	0.0006	0.0022	0.03	0.01	0.00
Total Uncertainty including LULUCF			52'430	47'656		57.0	57.1	0.016	0.0193	0.0020	1.10	0.01	1.22
			Percentage uncertainty in total inventory:					22.62					5.35
								4.76	Trend uncertainty:				2.31

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, where triangular distributions are applied.

Table A – 3 Probability distribution assigned to activity data and emission factors (1990 and 2014) of categories that are not normally distributed. For all other categories normal probability distributions have been assigned.

IPCC Source Category				Gas	Probability distribution	
					AD	EF
3B5	Agriculture	B. Manure Management	indirect	N2O	triangular	triangular
3Da1/2/4/5/7	Agriculture	D. Agricultural Soils; Direct Soil Emissions	fertilizer	N2O	normal	triangular
3Da6	Agriculture	D. Agricultural Soils; Direct Soil Emissions	organic soils	N2O	normal	triangular
3Da3	Agriculture	D. Agricultural Soils; Pasture, Range and Paddock Manure		N2O	triangular	triangular
3Db1	Agriculture	D. Agricultural Soils; Indirect Emissions	deposition	N2O	triangular	triangular
3Db2	Agriculture	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 $r = \pm 0.5$.
- “weak” correlations are set to $r = \pm 0.25$.

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 choosing 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 2014.
- 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 2014 ($r = 0.5$).
- The emission factors of agricultural categories are strongly and positively correlated between 1990 and 2014.

Table A – 4 Correlation coefficients for correlated activity data.

b_AD_1A2_Gaseous_Fuels_CO2	b_AD_1A2_Gaseous_Fuels_CO2	b_AD_1A4a_Gaseous_Fuels_CO2	b_AD_1A4b_Gaseous_Fuels_CO2	t_AD_1A2_Gaseous_Fuels_CO2	t_AD_1A4a_Gaseous_Fuels_CO2	t_AD_1A4b_Gaseous_Fuels_CO2
b_AD_1A4a_Gaseous_Fuels_CO2	1.0					
b_AD_1A4b_Gaseous_Fuels_CO2	-0.5	1.0				
b_AD_1A2_Gaseous_Fuels_CO2	-0.5	-0.5	1.0	1.0		
t_AD_1A2_Gaseous_Fuels_CO2	0.5			-0.5	1.0	
t_AD_1A4a_Gaseous_Fuels_CO2		0.5		-0.5	-0.5	1.0
t_AD_1A4b_Gaseous_Fuels_CO2			0.5	-0.5	-0.5	-0.5

b_AD_1A2_Liquid_Fuels_CO2	b_AD_1A2_Liquid_Fuels_CO2	b_AD_1A4a_Liquid_Fuels_CO2	b_AD_1A4b_Liquid_Fuels_CO2	t_AD_1A2_Liquid_Fuels_CO2	t_AD_1A4a_Liquid_Fuels_CO2	t_AD_1A4b_Liquid_Fuels_CO2
b_AD_1A4a_Liquid_Fuels_CO2	1.0					
b_AD_1A4b_Liquid_Fuels_CO2	-0.5	1.0				
b_AD_1A2_Liquid_Fuels_CO2	-0.5	-0.5	1.0	1.0		
t_AD_1A2_Liquid_Fuels_CO2	0.5			-0.5	1.0	
t_AD_1A4a_Liquid_Fuels_CO2		0.5		-0.5	-0.5	1.0
t_AD_1A4b_Liquid_Fuels_CO2			0.5	-0.5	-0.5	-0.5

t_AD_3B_liquid_N2O	t_AD_3B_liquid_N2O	t_AD_3B_solid_N2O	t_AD_3B5_indirect_N2O	t_AD_3Db1_deposition_N2O	t_AD_3Db2_leaching and runoff_N2O
t_AD_3B_solid_N2O	1.0				
t_AD_3B5_indirect_N2O	-0.4	1.0			
t_AD_3Db1_deposition_N2O	0.4	0.4	1.0	1.0	
t_AD_3Db2_leaching and runoff_N2O	0.4	0.4	0.5	0.5	1.0

b_AD_3B_solid_N2O	b_AD_3B_solid_N2O	b_AD_3B5_indirect_N2O	b_AD_3Db1_deposition_N2O	b_AD_3Db2_leaching and runoff_N2O
b_AD_3B5_indirect_N2O	1.0			
b_AD_3Db1_deposition_N2O	0.5	1.0		
b_AD_3Db2_leaching and runoff_N2O	0.5	0.5	1.0	1.0

b_AD_1A3b_Gasoline_CO2	t_AD_1A3b_Gasoline_CO2
t_AD_1A3b_Gasoline_CO2	1.0

b_AD_1A3b_Diesel_CO2	t_AD_1A3b_Diesel_CO2
t_AD_1A3b_Diesel_CO2	1.0

Table A – 5 Correlation coefficients for correlated CO₂ emission factors.

	b_EF_1A1_Other_Fuels_CO2	t_EF_1A1_Other_Fuels_CO2
b_EF_1A1_Other_Fuels_CO2	1.0	
t_EF_1A1_Other_Fuels_CO2	0.5	1.0
	b_EF_3B_solid_N2O	t_EF_3B_solid_N2O
b_EF_3B_solid_N2O	1.0	
t_EF_3B_solid_N2O	1.0	1.0
	b_EF_3Da1/2/4/5/7_fertilizer_N2O	t_EF_3Da1/2/4/5/7_fertilizer_N2O
b_EF_3Da1/2/4/5/7_fertilizer_N2O	1.0	
t_EF_3Da1/2/4/5/7_fertilizer_N2O	1.0	1.0
	b_EF_3Da3_0_N2O	t_EF_3Da3_N2O
b_EF_3Da3_0_N2O	1.0	
t_EF_3Da3_N2O	1.0	1.0
	b_EF_3Da6_organic_soils_N2O	t_EF_3Da6_organic_soils_N2O
b_EF_3Da6_organic_soils_N2O	1.0	
t_EF_3Da6_organic_soils_N2O	1.0	1.0
	b_EF_3Db2_leaching_and_runoff_N2O	t_EF_3Db2_leaching_and_runoff_N2O
b_EF_3Db2_leaching_and_runoff_N2O	1.0	
t_EF_3Db2_leaching_and_runoff_N2O	1.0	1.0
	b_EF_3Db1_deposition_N2O	t_EF_3Db1_deposition_N2O
b_EF_3Db1_deposition_N2O	1.0	
t_EF_3Db1_deposition_N2O	1.0	1.0
	b_EF_3B5_indirect_N2O	t_EF_3B5_indirect_N2O
b_EF_3B5_indirect_N2O	1.0	
t_EF_3B5_indirect_N2O	1.0	1.0

Table A – 6 Correlation coefficients for correlated emission levels.

	b_EM_2F1_HFC	t_EM_2F1_HFC
b_EM_2F1_HFC	1.0	
t_EM_2F1_HFC	0.5	1.0

	b_EM_3A_CH4	b_EM_3B_CH4	t_EM_3A_CH4	t_EM_3B_CH4
b_EM_3A_CH4	1.0			
b_EM_3B_CH4	0.5	1.0		
t_EM_3A_CH4	0.5		1.0	
t_EM_3B_CH4		0.5	0.5	1.0

	b_EM_3G_CO2	b_EM_3H_CO2	t_EM_3G_CO2	t_EM_3H_CO2
b_EM_3G_CO2	1.0			
b_EM_3H_CO2		1.0		
t_EM_3G_CO2	0.5		1.0	
t_EM_3H_CO2		0.5		1.0

A2.2.4 Detailed results of Monte Carlo simulations

Table A – 7 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 2014 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2014	Inventory trend in national emissions 1990-2014	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO ₂ eq	kt CO ₂ eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
1A1 Biomass CH ₄	0.45	0.33	-10	10	-28	28	-29	31	0.0000	-27	-37	37
1A1 Gaseous Fuels CH ₄	0.11	0.13	-5	5	-30	30	-30	30	0.0000	17	-46	46
1A1 Liquid Fuels CH ₄	0.52	0.58	-1	1	-30	30	-30	30	0.0000	11	-45	45
1A1 Solid Fuels CH ₄	0.13	-	-5	5	-30	30	NO	NO	-	-100	-30	30
1A1 Gaseous Fuels CO ₂	243.40	288.18	-5	5	-1	1	-5	5	0.0000	18	-8	8
1A1 Liquid Fuels CO ₂	687.24	965.17	-1	1	-0	0	-1	1	0.0000	40	-1	1
1A1 Other Fuels CO ₂	1'491.86	2'318.49	-5	5	-9	9	-10	11	0.0121	55	-15	16
1A1 Solid Fuels CO ₂	49.13	-	-5	5	-5	5	NO	NO	-	-100	-7	7
1A1 Biomass N ₂ O	22.58	14.95	-10	10	-79	79	-79	81	0.0000	-34	-96	96
1A1 Gaseous Fuels N ₂ O	0.13	0.15	-5	5	-150	150	-149	149	0.0000	17	-231	232
1A1 Liquid Fuels N ₂ O	1.11	1.05	-1	1	-80	80	-81	80	0.0000	-5	-110	110
1A1 Other Fuels N ₂ O	24.33	12.76	-5	5	-80	80	-80	81	0.0000	-48	-90	90
1A1 Solid Fuels N ₂ O	0.24	-	-5	5	-80	80	NO	NO	-	-100	-80	80
1A2 Biomass CH ₄	4.12	1.83	-10	10	-28	28	-29	31	0.0000	-56	-33	32
1A2 Gaseous Fuels CH ₄	0.49	1.00	-5	5	-30	30	-30	30	0.0000	106	-69	69
1A2 Liquid Fuels CH ₄	4.48	1.43	-1	1	-30	30	-30	30	0.0000	-68	-32	32
1A2 Other Fuels CH ₄	0.77	0.58	-5	5	-30	30	-30	30	0.0000	-26	-38	37
1A2 Solid Fuels CH ₄	0.31	0.27	-5	5	-30	30	-30	30	0.0000	-13	-40	40
1A2 Gaseous Fuels CO ₂	1'059.63	2'278.18	-5	5	-1	1	-5	5	0.0028	115	-10	10
1A2 Liquid Fuels CO ₂	3'890.57	1'912.91	-1	1	-0	0	-1	1	0.0000	-51	-1	1
1A2 Other Fuels CO ₂	196.02	366.03	-5	5	-9	9	-10	11	0.0003	87	-22	22
1A2 Solid Fuels CO ₂	1'274.70	521.18	-5	5	-5	5	-7	7	0.0003	-59	-8	8
1A2 Biomass N ₂ O	3.90	13.52	-10	10	-79	79	-81	81	0.0000	246	-290	291
1A2 Gaseous Fuels N ₂ O	0.68	1.36	-5	5	-150	150	-149	150	0.0000	101	-334	337
1A2 Liquid Fuels N ₂ O	13.03	10.86	-1	1	-80	80	-80	80	0.0000	-17	-104	105
1A2 Other Fuels N ₂ O	2.32	5.60	-5	5	-80	80	-80	80	0.0000	141	-207	209
1A2 Solid Fuels N ₂ O	6.14	2.46	-5	5	-80	80	-80	79	0.0000	-60	-87	86
1A3a kerosene CH ₄	0.29	0.28	-1	1	-30	30	-30	30	0.0000	-2	-42	42
1A3a kerosene CO ₂	252.55	139.83	-1	1	-0	0	-1	1	0.0000	-45	-1	1
1A3a kerosene N ₂ O	2.39	1.33	-1	1	-150	150	-151	150	0.0000	-45	-171	171
1A3b Biomass CH ₄	-	0.05	-10	10	-59	59	-60	61	0.0000	-	-	-
1A3b Diesel CH ₄	1.67	0.64	-1	1	-20	20	-20	20	0.0000	-62	-21	21
1A3b Gaseous Fuels CH ₄	-	0.05	-5	5	-30	30	-30	30	0.0000	-	-	-
1A3b Gasoline CH ₄	116.04	19.86	-1	1	-37	37	-37	37	0.0000	-83	-37	37
1A3b Diesel CO ₂	2'632.66	7'297.02	-1	1	-0	0	-1	1	0.0008	177	-2	2
1A3b Gaseous Fuels CO ₂	-	37.99	-5	5	-1	1	-5	5	0.0000	-	-	-
1A3b Gasoline CO ₂	11'334.49	8'276.97	-1	1	-0	0	-1	1	0.0007	-27	-1	1
1A3b Biomass N ₂ O	-	1.20	-10	10	-150	150	-150	153	0.0000	-	-	-
1A3b Diesel N ₂ O	5.61	73.08	-1	1	-22	22	-22	22	0.0001	1'202	-287	288
1A3b Gaseous Fuels N ₂ O	-	0.78	-5	5	-80	80	-80	80	0.0000	-	-	-
1A3b Gasoline N ₂ O	136.88	19.81	-1	1	-50	50	-50	50	0.0000	-86	-50	51
1A3c Liquid Fuels CH ₄	0.03	0.01	-1	1	-30	30	-30	30	0.0000	-54	-33	33
1A3c Liquid Fuels CO ₂	28.69	30.19	-1	1	-0	0	-1	1	0.0000	5	-1	1
1A3c Liquid Fuels N ₂ O	0.43	0.44	-1	1	-80	80	-80	81	0.0000	2	-114	114
1A3d Liquid Fuels CH ₄	1.68	0.29	-1	1	-30	30	-30	30	0.0000	-83	-30	31
1A3d Liquid Fuels CO ₂	114.27	113.59	-1	1	-0	0	-1	1	0.0000	-1	-1	1
1A3d Liquid Fuels N ₂ O	1.16	1.23	-1	1	-150	150	-150	150	0.0000	7	-219	219
1A3e Gaseous Fuels CH ₄	0.07	0.04	-5	5	-30	30	-30	30	0.0000	-41	-35	35
1A3e Gaseous Fuels CO ₂	31.42	47.06	-5	5	-1	1	-5	5	0.0000	50	-9	9
1A3e Gaseous Fuels N ₂ O	0.02	0.02	-5	5	-80	80	-80	80	0.0000	48	-143	142
1A4a Biomass CH ₄	9.22	4.35	-10	10	-28	28	-30	31	0.0000	-53	-34	33
1A4a Gaseous Fuels CH ₄	0.70	1.23	-5	5	-30	30	-30	30	0.0000	74	-60	60
1A4a Liquid Fuels CH ₄	16.33	9.23	-1	1	-30	30	-30	30	0.0000	-43	-35	34
1A4a Gaseous Fuels CO ₂	981.49	1'244.62	-5	5	-1	1	-5	5	0.0008	27	-6	6
1A4a Liquid Fuels CO ₂	4'259.54	2'538.93	-1	1	-0	0	-1	1	0.0001	-40	-1	1
1A4a Biomass N ₂ O	3.50	8.36	-10	10	-79	79	-80	81	0.0000	139	-206	210
1A4a Gaseous Fuels N ₂ O	0.52	0.65	-5	5	-80	80	-79	80	0.0000	26	-129	128
1A4a Liquid Fuels N ₂ O	10.34	6.20	-1	1	-80	80	-80	80	0.0000	-40	-94	93

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2014 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2014	Inventory trend in national emissions 1990-2014	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	109.97	24.66	-10	10	-28	28	-29	31	0.0000	-78	-32	30
1A4b Gaseous Fuels CH4	0.70	1.26	-5	5	-30	30	-30	30	0.0000	81	-62	62
1A4b Liquid Fuels CH4	34.83	19.00	-1	1	-30	30	-30	30	0.0000	-45	-34	34
1A4b Solid Fuels CH4	4.73	3.00	-5	5	-30	30	-30	30	0.0000	-37	-36	35
1A4b Gaseous Fuels CO2	1'451.63	2'402.23	-5	5	-1	1	-5	5	0.0031	66	-7	8
1A4b Liquid Fuels CO2	10'098.96	5'549.06	-1	1	-0	0	-1	1	0.0003	-45	-1	1
1A4b Solid Fuels CO2	58.40	37.08	-5	5	-5	5	-7	7	0.0000	-37	-8	8
1A4b Biomass N2O	25.86	19.49	-10	10	-79	79	-80	81	0.0000	-25	-101	100
1A4b Gaseous Fuels N2O	0.77	1.26	-5	5	-80	80	-80	80	0.0000	64	-154	154
1A4b Liquid Fuels N2O	24.53	13.50	-1	1	-80	80	-80	80	0.0000	-45	-91	91
1A4b Solid Fuels N2O	0.28	0.18	-5	5	-80	80	-80	81	0.0000	-37	-95	95
1A4c Biomass CH4	1.97	0.35	-10	10	-28	28	-29	31	0.0000	-82	-31	30
1A4c Gaseous Fuels CH4	0.02	0.01	-5	5	-30	30	-30	30	0.0000	-64	-32	32
1A4c Liquid Fuels CH4	6.45	1.63	-1	1	-30	30	-30	30	0.0000	-75	-31	31
1A4c Gaseous Fuels CO2	41.45	14.99	-5	5	-1	1	-5	5	0.0000	-64	-5	5
1A4c Liquid Fuels CO2	485.09	410.12	-1	1	-0	0	-1	1	0.0000	-15	-1	1
1A4c Biomass N2O	0.51	0.90	-10	10	-79	79	-79	81	0.0000	77	-162	163
1A4c Gaseous Fuels N2O	0.02	0.01	-5	5	-80	80	-79	80	0.0000	-64	-85	85
1A4c Liquid Fuels N2O	4.20	4.61	-1	1	-80	80	-80	80	0.0000	10	-119	119
1A5 Liquid Fuels CH4	0.27	0.17	-1	1	-60	60	-60	60	0.0000	-37	-71	71
1A5 Liquid Fuels CO2	217.65	137.51	-1	1	-0	0	-1	1	0.0000	-37	-1	1
1A5 Liquid Fuels N2O	2.11	1.36	-106	106	-106	106	-151	150	0.0000	-36	-177	178
1B2 CH4	319.77	196.87	-5	5	-30	30	-30	30	0.0007	-38	-35	35
1B2 CO2	29.95	33.10	-5	5	-9	9	-10	10	0.0000	31	-17	16
1B2 N2O	0.60	0.25	-5	5	-80	80	-80	80	0.0000	-58	-87	87
2A1 CO2	2'524.45	1'858.10	-2	2	-2	2	-3	3	0.0006	-26	-4	4
2A2 CO2	53.35	51.66	-1	1	-1	1	-2	2	0.0000	-3	-3	3
2A3 CO2	15.25	6.36	-1	1	-1	1	-2	2	0.0000	-58	-2	2
2A4 CO2	156.11	93.08	-1	1	-5	5	-5	5	0.0000	-40	-6	6
2B CH4	1.83	2.12	-7	7	-29	29	-30	30	0.0000	16	-46	46
2B CO2	121.59	114.95	-7	7	-7	7	-10	10	0.0000	-5	-14	14
2B N2O	65.49	4.35	-7	7	-3	3	-8	8	0.0000	-93	-8	7
2C1 CO2	9.20	10.78	-5	5	-40	40	-40	40	0.0000	17	-62	62
2C3 CO2	139.26	-	-7	7	-7	7	NO	NO	-	-100	-10	10
2C3 PFC	116.46	-	-6	6	-6	6	NO	NO	-	-100	-9	9
2C4 SF6	-	45.99	-18	18	-18	18	-25	25	0.0000	-	-	-
2C7 CO2	1.65	1.47	-7	7	-7	7	-10	10	0.0000	-11	-13	13
2D CO2	66.24	62.30	-35	35	-35	35	-50	50	0.0002	-6	-69	69
2E1 PFC	-	6.20	-52	52	-52	52	-74	74	0.0000	-	-	-
2E1 SF6	-	8.59	-42	42	-42	42	-59	59	0.0000	-	-	-
2E3 NF3	-	0.40	-134	134	-134	134	-189	189	0.0000	-	-	-
2E4 PFC	-	0.00	-51	51	-51	51	-72	73	0.0000	-	-	-
2F1 HFC	0.02	1'398.55	-11	11	-11	11	-15	15	0.0089	5'645'559	-837'788	846'332
2F1 PFC	0.05	6.11	-23	23	-23	23	-33	33	0.0000	11'295	-3'759	3'745
2F2 HFC	-	32.89	-16	16	-16	16	-22	22	0.0000	-	-	-
2F4 HFC	-	22.39	-28	28	-28	28	-40	40	0.0000	-	-	-
2F5 HFC	-	0.73	-39	39	-39	39	-56	56	0.0000	-	-	-
2G CO2	6.59	36.71	-35	35	-35	35	-50	50	0.0001	457	-283	283
2G HFC	-	46.25	-7	7	-7	7	-9	9	0.0000	-	-	-
2G PFC	-	31.57	-6	6	-6	6	-9	8	0.0000	-	-	-
2G SF6	137.01	204.26	-14	14	-14	14	-20	21	0.0004	49	-37	37
2G N2O	105.87	43.93	-35	35	-72	72	-80	80	0.0003	-59	-86	87
2H CO2	1.04	0.84	-7	7	-7	7	-10	10	0.0000	-19	-13	13
3A CH4	3'584.87	3'365.33	-6	6	-17	17	-18.1	18.1	0.0759	-6	-17	17
3B CH4	923.97	782.15	-6	6	-54	54	-54	54	0.0369	-15	-50	50
3B N2O	-	10.59	-32	32	-75	75	-76	89	0.0000	-	-	-
3B N2O	105.65	75.49	-32	32	-75	75	-76	88	0.0008	-27	-56	39
3B5 N2O	242.32	283.54	-47	47	-240	240	-77	126	0.0899	10	-59	71

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2014 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2014	Inventory trend in national emissions 1990-2014	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO ₂ eq	kt CO ₂ eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
3Da1/2/4/5/7 N ₂ O	1'049.85	835.38	-15	15	-135	135	-64	87	0.1863	-20	-32	20
3Da6 N ₂ O	67.58	65.21	-29	29	-138	138	-68	98	0.0013	-4	-49	45
3Da3 N ₂ O	121.78	210.80	-68	68	-133	133	-68	114	0.0201	80	-95	157
3Db1 N ₂ O	462.94	345.02	-40	40	-240	240	-76	122	0.1247	-30	-66	35
3Db2 N ₂ O	195.62	154.66	-22	22	-163	163	-77	102	0.0093	-21	-39	22
3G CO ₂	22.57	32.58	-40	40	-5	5	-40	41	0.0000	44	-51	51
3H CO ₂	26.71	12.96	-5	5	-5	5	-7	7	0.0000	-51	-6	6
5A CH ₄	763.39	367.74	-21	21	-21	21	-30	30	0.0025	-52	-33	33
5A CO ₂	-	-	-7	7	-7	7	NO	NO	-	-	-	-
5B CH ₄	35.64	107.96	-10	10	-40	40	-41	41	0.0004	203	-131	131
5B N ₂ O	5.42	16.56	-10	10	-79	79	-80	80	0.0000	205	-257	257
5C CH ₄	13.79	7.37	-10	10	-59	59	-60	60	0.0000	-47	-68	68
5C CO ₂	53.73	9.89	-10	10	-39	39	-40	40	0.0000	-82	-41	41
5C N ₂ O	18.32	31.03	-10	10	-39	39	-40	40	0.0000	69	-79	79
5D CH ₄	130.92	174.59	-32	32	-36	36	-48	48	0.0014	33	-80	81
5D N ₂ O	118.27	144.47	-32	32	-147	147	-150	150	0.0096	22	-236	237
6 CH ₄	0.66	0.68	-42	42	-42	42	-60	60	0.0000	2	-86	86
6 CO ₂	10.96	12.92	-28	28	-28	28	-40	40	0.0000	18	-62	62
6 N ₂ O	0.60	0.60	-106	106	-106	106	-150	150	0.0000	0	-214	212
4 II CH ₄	10.75	10.75	-10	10	-70	70	-71	70	0.0000	0	-100	100
4 II N ₂ O	7.77	7.94	-30	30	-138	138	-141	141	0.0000	2	-202	200
4 III N ₂ O	58.71	52.01	-6	6	-135	135	-136	136	0.0010	-11	-182	182
4 IV N ₂ O	9.60	8.50	-20	20	-162	162	-163	163	0.0000	-12	-216	217
4 V CH ₄	13.73	0.54	-10	10	-70	70	-71	71	0.0000	-96	-71	71
4 V CO ₂	-	-	-10	10	-70	70	NO	NO	-	-	-	-
4 V N ₂ O	9.26	0.36	-10	10	-70	70	-70	71	0.0000	-96	-70	71
4A1 CO ₂	-369.23	-1'674.57	-2	2	-48	48	48	-48	0.1310	353	221	-221
4A2 CO ₂	-570.45	-503.37	-2	2	-48	48	48	-48	0.0118	-12	64	-64
4B1 CO ₂	364.91	332.11	-5	5	-37	37	-38	38	0.0032	-9	-51	51
4B2 CO ₂	46.57	28.66	-6	6	-21	21	-22	22	0.0000	-38	-26	26
4C1 CO ₂	79.05	115.70	-6	6	-839	839	-837	837	0.1931	51	-1'524	1'529
4C2 CO ₂	91.50	183.10	-6	6	-27	27	-28	28	0.0005	100	-62	62
4D1 CO ₂	67.56	70.77	-30	30	-100	100	-105	105	0.0011	5	-153	153
4D2 CO ₂	21.87	33.99	-5	5	-50	50	-50	50	0.0001	55	-93	93
4E1 CO ₂	17.27	54.32	-5	5	-50	50	-50	50	0.0002	214	-167	166
4E2 CO ₂	394.54	318.25	-5	5	-50	50	-50	50	0.0052	-19	-65	64
4F2 CO ₂	94.34	117.35	-4	4	-50	50	-50	50	0.0007	24	-80	80
4G CO ₂	-1'231.92	-105.80	-3	3	-57	57	57	-57	0.0007	-91	58	-58
incl LULUCF	52'435	47'663					-4.40	4.64		-9.26	-4.12	4.06
excl. LULUCF	53'319	48'612					-3.38	3.79		-9.00	-2.68	2.55

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. 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 – 8.

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 – 8 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	Parameters	Unit	Emission (excl. LULUCF)	Lower bound 2.5 percentile	Upper bound 97.5 percentile	Lower uncertainty	Upper uncertainty
2014	simulated values						
	absolute	kt CO ₂ eq	49'936	48'248	51'827	-1'688	1'891
	relative	%	100.00%	96.62%	103.79%	-3.38%	3.79%
	reported values						
	absolute	kt CO ₂ eq	48'612	46'969	50'453	-1'643	1'841
	relative	%	100.00%	96.62%	103.79%	-3.38%	3.79%
1990	simulated values						
	absolute	kt CO ₂ eq	54'872	52'919	57'087	-1'953	2'215
	relative	%	100.00%	96.44%	104.04%	-3.56%	4.04%
	reported values						
	absolute	kt CO ₂ eq	53'319	51'421	55'471	-1'898	2'152
	relative	%	100.00%	96.44%	104.04%	-3.56%	4.04%

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 – 9 Emission factors of precursors from manufacturing industries and construction

1A2 Emission factors (mix of bottom-up and top-down approach (modelling))	NO _x kg/TJ	CO kg/TJ	NM VOC kg/TJ	SO ₂ 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 (1A3a)

Table A – 10 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 (1A3a)

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 – 11 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 – 12 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-Honeywell
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 (1A3a)

The output of the FOCA emission modelling consists of tables with the following structure:

Table A – 13 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 tonnes.

Airport	Distance	Type Traffic	Move-ments	Type	Aircraft ICAO	Engine Name	Fuel (LTO) tons	Emissions (LTO) in tons					
	Km		No.					CO ₂	H ₂ O	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 (1A3b)

The derivation of the emission factors for road vehicles is described in detail in TUG (2009). 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 following 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 – 14 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 – 15 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 – 16 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). CO₂ (rep.) refers to the fossil part, CO₂ (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 ₂ O	1990	0.009	0.005	0.008	0.008	0.003	0.002
N ₂ O	1995	0.012	0.007	0.009	0.008	0.003	0.002
N ₂ O	2000	0.011	0.009	0.009	0.008	0.003	0.002
N ₂ O	2005	0.005	0.007	0.008	0.007	0.002	0.002
N ₂ O	2010	0.003	0.006	0.030	0.014	0.001	0.002
N ₂ O	2015	0.002	0.005	0.041	0.023	0.002	0.002
N ₂ O	2020	0.002	0.005	0.043	0.029	0.005	0.002
N ₂ O	2025	0.002	0.005	0.043	0.032	0.008	0.002
N ₂ O	2030	0.002	0.004	0.042	0.033	0.009	0.002
N ₂ O	2035	0.002	0.004	0.042	0.033	0.010	0.002
N ₂ O	2040	0.002	0.004	0.041	0.033	0.010	0.002
N ₂ O	2045	0.002	0.004	0.041	0.033	0.010	0.002
N ₂ O	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 (1A3b)

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.

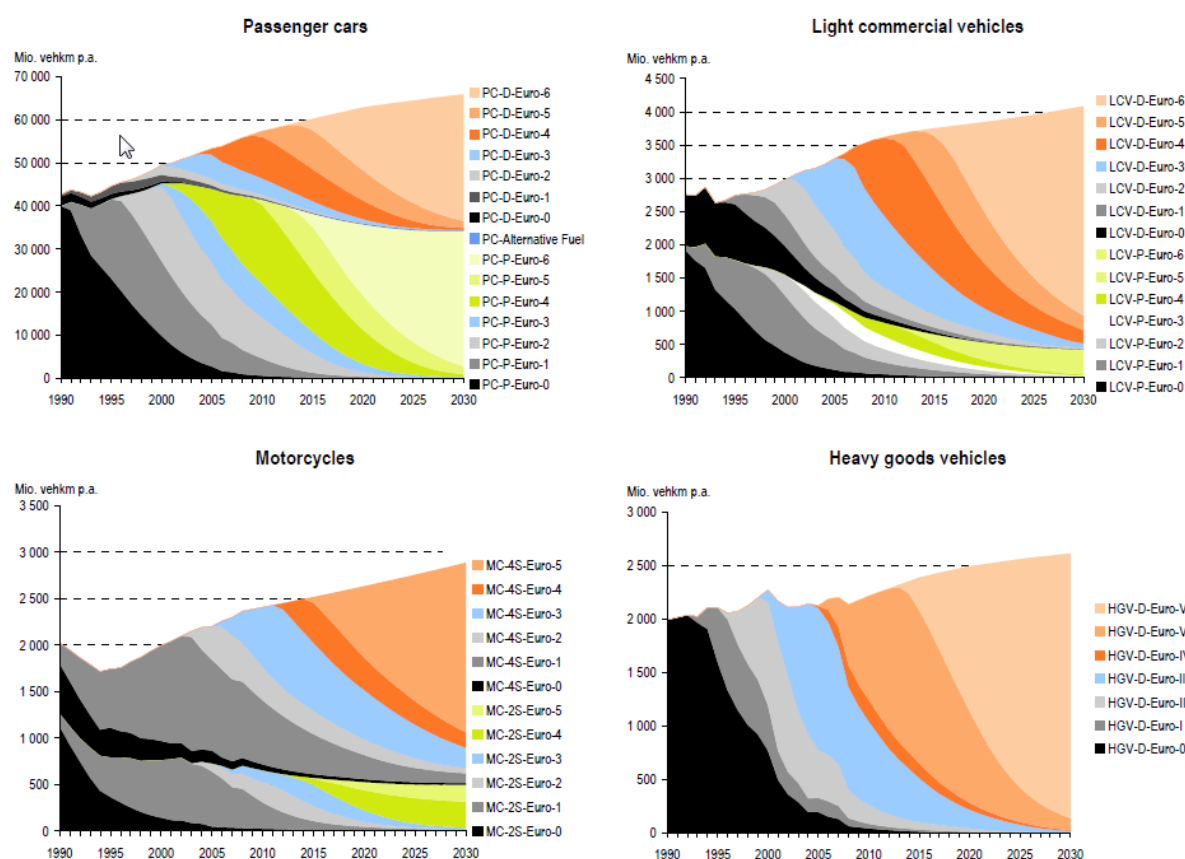


Figure A – 1 Mileage composition by emission concept (in million vehicle kilometres per year) for passenger cars, light duty trucks ("light commercial vehicles"), motorcycles and heavy duty trucks ("heavy goods vehicles"), FOEN 2010i.

Modelling hot exhaust emissions (1A3b)

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 3.2.9.2.2), 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 (1A3b)

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 TUG (2009).

Results show that for CO₂ the hot exhaust emissions contribute to 97% of the total. Only 3% stem from cold start excess emissions. For CH₄, 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 N₂O, no cold start emissions or evaporative emissions are taken into account due to lack of data.

A3.1.4 Non-road vehicles: supplementary activity data

The following table shows some aggregated information on stock numbers and annual operation hours of non-road vehicles. Detailed information is available in the report FOEN (2015j) and most disaggregated information is available by query from the online non-road database INFRAS (2015a):

<http://www.bafu.admin.ch/luft/00596/06906/offroad-daten/index.html?lang=en>

Table A – 17 Overview over stock and operating hours of non-road vehicles (FOEN 2015j):

Upper table: Number of vehicles,

middle table Specific operating hours per year

lower table: Total operating hours per year (in million hours)

Category	1990	2000	2010	2020
	number of vehicles			
Construction machines	58'816	52'729	57'102	60'384
Industrial machinery	43'244	70'671	69'786	69'757
Agricultural machinery	324'567	337'869	318'876	309'825
Forestry machinery	13'844	13'055	11'857	10'831
Garden-care/hobby appliances	1'539'624	1'944'373	2'322'737	2'464'323
Navigation machinery	103'383	93'912	95'055	97'522
Railway machinery	1'300	1'255	697	640
Military machinery	13'373	14'272	13'083	12'853

Category	1990	2000	2010	2020
	Specific operating hours (in hrs p.a.)			
Construction machines	322.0	406.0	417.0	424.0
Industrial machinery	670.0	684.0	680.0	675.0
Agricultural machinery	119.0	112.0	103.0	99.0
Forestry machinery	199.0	203.0	193.0	188.0
Garden-care/hobby appliances	17.0	20.0	64.0	77.0
Navigation machinery	38.0	38.0	36.0	35.0
Railway machinery	613.0	617.0	783.0	719.0

Category	1990	2000	2010	2020
	Total operating hours (in million hrs p.a.)			
Construction machines	19.0	21.4	23.8	25.6
Industrial machinery	29.0	48.4	47.5	47.1
Agricultural machinery	38.8	37.7	33.0	30.6
Forestry machinery	2.8	2.6	2.3	2.0
Garden-care/hobby appliances	25.7	39.3	149.7	190.8
Navigation machinery	3.9	3.5	3.4	3.4
Railway machinery	0.8	0.8	0.5	0.5
Military machinery	0.9	0.9	0.9	0.9
Total	121.0	155.0	261.0	301.0

A3.1.5 Sulphur dioxide (SO₂)

Table A – 18 shows sulphur contents and SO₂ emission factors per fuel type. Explanations:

- For liquid and solid fuels the SO₂ emission factors are determined by the sulphur content. The upmost lines in Table A – 18 “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 – 18 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 – 18 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 SO₂
- $$EF_{SO_2} = \frac{M_{SO_2}}{M_S} \cdot \frac{S}{NCV} = 2 \cdot \frac{S}{NCV}$$
- Coal: 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 SO₂) 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.

Table A – 18 Sulphur content and SO₂ 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
2014	10	10	1000	190	1.0	1.0

year	Effective sulphur content		
	Diesel oil ppm	Gasoline ppm	Gas oil ppm
1990	1400	200	1600
1991	1300	200	1300
1992	1200	200	1200
1993	1000	200	1000
1994	434	200	1350
1995	341	200	1170
1996	372	200	1160
1997	353	200	1250
1998	402	200	926
1999	443	200	650
2000	272	142	680
2001	250	121	830
2002	235	101	798
2003	200	81	700
2004	10	8.0	700
2005	10	8.0	799
2006	10	8.0	699
2007	10	8.0	630
2008	10	8.0	641
2009	7.2	5.2	603
2010	9	6	548
2011	5	8	116
2012	7	6	617
2013	8	5	253
2014	7	3	385

year	Effective SO ₂ emission factor							
	Diesel oil (average road transp.)	Gasoline	Gas oil	Natural gas	Res. fuel oil	Lignite	Bituminous coal Boiler 1A1, 1A2, 1A3 / Boiler 1A4	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
2014	0.5	0.4	20.8	0.50	291	500	500/350	22

A3.2 Industrial processes and product use (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 2014. Refrigerants contained in installed equipment lead to a considerable stock with annual losses depending from equipment type between 0.5% to 20% (see Table 4-36). 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 – 19 Applied model parameters and assumption for mobile air conditioning of cars

Characteristic values			
Initial charge in kg HFC per unit AC	1994	0.8	kg
	2002	0.7	kg
	2014	0.6	kg
	Extrapolation of other years		
Lifetime		15	years
Production			
Import of precharged equipment		100	%
Operation			
Annual losses		8.5	%
Recharge of losses (6.8% of 8.5%)		70	%
Additional service losses over lifetime		10	%
Disposal			
Export rate		31-72	%
Share with total loss of refrigerant		40	%
Disposal loss of professional recovery		15	%
Assumed reuse of recovered chemical		80	%

Table A – 20 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 [units]	Portion of vehicles with HFC-134a [%]	AC units with HFC-134 [units]	Units AC with HFC-134a [units]	Filled in amount [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	2'581'839	2'204	0.65
2007	284'674	3'955'787	228'804	96	100	273'287	72	2'847'133	7'992	0.64
2008	288'525	4'030'965	213'347	96	100	276'984	77	3'099'833	24'284	0.63
2009	266'018	4'051'569	245'414	96	100	255'377	82	3'309'039	46'172	0.61
2010	294'239	4'119'370	226'438	96	100	282'469	86	3'526'013	65'495	0.60
2011	327'896	4'209'300	237'966	96	100	314'780	90	3'738'372	102'421	0.59
2012	328'139	4'254'725	282'714	96	100	315'013	92	3'911'717	141'669	0.58
2013	310'154	4'320'885	243'994	96	92	273'928	92	3'983'456	202'188	0.56
2014	304'083	4'384'490	240'478	96	85	248'132	91	3'993'099	238'489	0.55

Table A – 21 Results and structure of emission calculations of HFC-134a from mobile air conditioning of cars for the inventories 1990 to 2014. Changes of parameters were found in a request carried out for the inventory 2013 (further reduction of charge since last request 2002).

HFC-134a	Activity			Emissions				Recharge	
	Input with vehicles	Stock	Disposed	Production	Stock incl. Recharge	Disposal	Total	import in bulk	recovered and reused
	[t]	[t]	[t]	[t]	[t]	[t]	[t]	[t]	[t]
1990	0	0	0	NO	0	0	0	0	0
1991	2	2	0	NO	0	0	0	0	0
1992	7	8	0	NO	1	0	1	0	0
1993	20	28	0	NO	3	0	3	1	0
1994	37	65	0	NO	6	0	6	2	0
1995	51	114	0	NO	10	0	10	4	0
1996	79	190	0	NO	17	0	17	7	0
1997	107	292	0	NO	27	0	27	12	0
1998	151	434	0	NO	40	0	40	19	0
1999	175	597	0	NO	55	0	55	28	0
2000	175	756	0	NO	69	0	69	38	0
2001	191	927	0	NO	85	0	85	49	0
2002	180	1'081	0	NO	99	0	99	59	0
2003	166	1'217	0	NO	112	0	112	69	0
2004	165	1'349	0	NO	124	0	124	78	0
2005	158	1'470	0	NO	135	0	135	87	0
2006	168	1'597	1	NO	146	0	147	94	0
2007	174	1'724	3	NO	158	0	158	101	2
2008	173	1'841	9	NO	169	3	171	107	5
2009	156	1'927	20	NO	177	6	183	110	10
2010	169	2'019	25	NO	185	7	192	114	13
2011	185	2'108	40	NO	193	11	205	113	21
2012	181	2'167	64	NO	199	15	213	109	33
2013	155	2'190	72	NO	201	19	220	110	36
2014	136	2'189	77	NO	201	21	222	109	39

A3.3 Agriculture

Additional data for estimating CH₄ emission from 3A Enteric fermentation

Table A – 22 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 Specification ^a	Milk ^b 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		16.1-22.9 ^c	0	305 days of lactation	72	6.90	117.3 - 136.9
Other Mature Cattle	NA	650	0		8.2	0		60	6.50	106.8
Fattening Calves	0-98 days	124	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	0.0
Pre-Weaned Calves	0-300 days	195	0.88	"Natura beef" production, milk from mother cow and additional feed.	0	0	0	65	6.50	16.3
Breeding Calves	0-105 days	85	0.67	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	30.0
Breeding Cattle (4-12 months)	4-12 month	210	0.80	Premature race (Milk-race)	0	0	0	60	6.50	
Breeding Cattle (> 1 year)	12-28/30 month	450	0.80	Premature race (Milk-race)	0	0	0	60	6.50	61.2
Fattening Calves (0-4 months)	0-132 days	115	0.83	Diet based on milk or milk-powder and feed concentrate, hay and/or silage	0	0	0	65	6.50	43.2
Fattening Cattle (4-12 months)	4-12 month	361	1.37	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 (MSTA 2015).

^d data source: IPCC 2006 and Zeltz 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 – 24 Livestock population 1990–2014.

Population Size		1000 head																								
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cattle	Mature Dairy 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	1562.8
	Other Mature 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	587.4
	Growing 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	118.0
	Fattening Calves	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	857.4
Sheep	Pre-Weaned Calves	112.3	111.4	109.5	111.1	101.7	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	96.7
	Breeding Cattle 1st Year	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	93.4
	Breeding Cattle 2nd Year	346.4	336.7	324.0	308.2	294.7	286.1	260.1	260.1	253.5	241.9	236.0	238.1	229.5	218.8	214.7	222.0	223.3	223.3	232.4	225.7	226.4	220.7	212.3	210.3	211.3
	Breeding Cattle 3rd Year	253.3	251.9	250.5	238.7	237.2	236.6	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	198.6
Swine	Fattening Cattle	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	111.2
	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	148.3	148.0	151.6	146.6	145.1	145.0	146.2	145.7	146.1
	Fattening 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	447.5	443.6	446.2	431.9	434.1	424.0	417.3	409.5	402.8	402.8
	Milksteep	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	209.5
Pigs	Milksteep	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	13.7
	Piglets	1787.0	1722.6	1705.7	1691.8	1568.7	1445.6	1379.4	1394.9	1487.0	1453.3	1488.2	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	1488.3
	Fattening Pig over 25 kg	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	339.2
	Dry Sows	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	759.8
Goats	Nursing 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	94.2
	Boars	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	36.3	34.9	32.6	33.1	33.5	32.3	31.0	29.4	29.4
	Bisons < 3 years	8.4	8.1	8.0	8.2	7.7	7.1	6.3	6.4	6.4	6.2	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	2.9
	Bisons > 3 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deer	Bisons < 3 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Bisons > 3 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Llamas < 2 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Llamas > 2 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Goats	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Fallow 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	5.7
	Red Deer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Horses	Goat Places	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	84.7
	Horses	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	57.9
	Horses < 3 years	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	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	6.5
Mules and Asses	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	50.7
	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	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	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	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	18.9
Poultry ¹⁾	Asses	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	8285.6	8542.8	8809.4	9024.9	9477.7	9954.6	10079.0	10723.4	
	Growners	718.9	664.2	709.6	719.2	716.8	714.4	732.1	732.9	735.5	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	1195.6
	Layers	3083.0	2645.4	2535.8	2517.6	2317.9	2118.2	2226.0	2277.5	2270.1	2222.8	2150.3	2095.3	2154.1	2117.2	2088.8	2188.5	2147.3	2197.7	2284.9	2318.3	2438.1	2437.0	2520.6	2588.6	2665.1
	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	5090.4	5002.4	5300.4	5456.2	5580.1	5984.1	6282.1	6380.3	6783.7	6783.7
Rabbits	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	57.2
	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	9.5	11.5	16.1	14.2	14.7	15.9	23.2	29.0	25.1	20.4	21.7
	Fattening Sheep	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	<											

Additional data for estimating CH₄ and N₂O emission from 3B Manure management

Table A – 25 Data for estimating manure management CH₄ 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 - 303	15.89 ^c	8.8 - 9.1	4.08 - 4.8	0.24
Other Mature Cattle	650	60	251	10.96 ^c	8	5.50	0.18
Fattening Calves	124	65	47	2.02 ^a	8	0.92	0.18
Pre-Weaned Calves	195	65	38	2.99 ^a	8	0.74	0.18
Breeding Calves	85	65	28	2.19 ^a	8	0.54	0.18
Breeding Cattle (4-12 months)	210	60	90	4.88 ^a	8	1.98	0.18
Breeding Cattle (> 1 year)	450	60	144	7.78 ^a	8	3.15	0.18
Fattening Calves (0-4 months)	115	65	50	3.00 ^a	8	0.97	0.18
Fattening Cattle (4-12 months)	361	60	126	6.84 ^a	8	2.77	0.18
Sheep	NE	60	21 - 24	1.09-1.25 ^c	8	0.40 ^b	0.19
Swine	NE	75	26 - 32	NE	2	0.31 ^b	0.45
Buffalo	NE	55	129 - 147	7.00-7.96 ^c	8	3.29	0.10
Camels	NE	60	31 - 38	1.68-2.05 ^c	8	0.70	0.26
Deer	NE	60	51 - 60	2.74-3.24 ^c	8	1.27	0.19
Goats	NE	60	25 - 28	1.21-1.27 ^c	8	0.30 ^b	0.18
Horses	NE	70	107 - 108	7.73-7.85 ^c	4	1.72 ^b	0.33
Mules and Asses	NE	70	39 - 40	NE	4	0.94 ^b	0.33
Poultry	NE	NE	1.1 - 1.6 ^d	NE	NE	0.01 ^b	0.37
Rabbits	NE	NE	1.2	NE	NE	0.10	0.32
Livestock NCAC	NE	NE	NE	NE	NE	0.64	0.27

a RAP 1999

b IPCC 1997c and IPCC 2006

c Flisch et al. 2009

d metabolizable energy (ME)

Table A – 26 Manure management system distribution in Switzerland 1990–2014.

MS Distribution	1990				1995				2002				2007				2010			
	%				%				%				%				%			
	Liquid / Slurry	Solid manure	Pasture range and padlock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid manure	Pasture range and padlock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid manure	Pasture range and padlock	Digesters	Other (Deep litter, Poultry manure)	Liquid / Slurry	Solid manure	Pasture range and padlock	Digesters	Other (Deep litter, Poultry manure)
Mature Dairy Cattle	63.7	27.6	8.3	0.4	0.0	66.7	24.4	9.5	0.4	0.0	65.3	26.2	18.0	0.5	0.0	67.5	13.6	17.7	1.3	0.0
Other Mature Cattle	41.2	32.1	26.3	0.4	0.0	38.3	34.1	26.2	0.4	0.0	39.8	20.7	39.1	0.5	0.0	49.5	20.2	29.0	1.3	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	41.6	21.6	0.3	0.5	77.6	21.8	25.3	0.2	1.3	76.7
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	0.0	0.3	0.5	50.0	18.6	30.1	1.3	0.0
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	50.0	18.6	30.1	1.3	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	41.4	20.8	36.5	1.3	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
Breeding Cattle 3rd Year	50.5	29.1	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
Fattening Cattle	70.1	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
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	68.8	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
Milk Sheep	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
Pigs (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
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	97.6	0.8	0.0	1.5	0.0	94.8	0.7	0.4	4.1	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
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
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
Bears	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
Buffalo (weighted average)	NA	NA	NA	NA	NA	NA	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
Elsons < 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
Elsons > 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
Camels (weighted average)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.0	33.5	0.0	33.5	0.0	40.2	59.8
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
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
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
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
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
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
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
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
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
Horses (weighted average)	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Horses < 3 years	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Horses > 3 years	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Mules and Asses (weighted average)	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Mules	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Asses	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Poultry (weighted average)	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	99.5	0.0	0.0	2.6	0.0	97.4	0.0	0.0	3.7	0.0	96.3
Groovers	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	99.4	0.0	0.0	0.2	0.0	99.4	0.0	0.0	1.5	0.0	98.2
Layers	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	99.6	0.0	0.0	5.1	0.0	98.4	0.0	0.0	7.3	0.0	98.8
Broilers	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	99.6	0.0	0.0	0.6	0.0	96.9	0.0	0.0	1.2	0.0	96.9
Turkey	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	99.4	0.0	0.0	3.1	0.0	95.8	0.0	0.0	3.1	0.0	95.8
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
Rabbits	0.0	100.0	0.0	0.0	0.0	100.0	0.0	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	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
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
Milk Sheep 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
Total Goats Non-Agr.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.0	12.2	0.0	87.8	0.0	7.1	92.9
Horses < 3 years Non-Agr.	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Horses > 3 years Non-Agr.	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Mules Non-Agr.	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8
Asses Non-Agr.	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8	0.0	93.2	6.8

1) Other Poultry: Geese, Ducks, Goslings, Quails

Annex 3: Other detailed methodological descriptions for individual source or sink categories

[illegible]

) Other Poultry: Geese, Ducks, Ostriches, Quails

Additional data for estimating N₂O emissions from 3D Agricultural soils

Table A – 28 Additional data for estimating N₂O emission from crop residues (2014).

2014		Total crop production kg DM	Nitrogen incorporated with crop residues F _(CR) t N	N ₂ O emissions from crop residues t N ₂ O
1. Cereals	Wheat	455'076'400	1'906	29.96
	Barley	170'954'550	872	13.70
	Maize	117'702'900	1'122	17.64
	Oats	7'443'450	46	0.73
	Rye	10'984'550	46	0.73
	Other:			
	Triticale	42'957'300	211	3.31
	Spelt	13'447'850	123	1.93
	Mix of Fodder Cereals	991'950	5	0.08
	Mix of Bread Cereals	135'150	1	0.01
	Millet	114'300	0	0.00
2. Pulse	Dry Beans	1'215'500	48	0.76
	Peas (Eiweisserbsen)	11'962'900	352	5.53
	Soybeans	3'299'700	136	2.14
	Leguminous Vegetables	2'880'920	418	6.57
	Lupines	215'600	9	0.13
3. Tuber and Root	Potatoes	107'843'200	394	6.19
	Other:			
	Fodder Beet	9'232'000	74	1.16
	Sugar Beet	423'337'200	3'810	59.87
5. Other	Fruit	48'568'320	194	3.05
	Grass	6'100'784'047	21'724	341.38
	Green Corn	114'110'248	52	0.82
	Non-Leguminous Vegetables	57'344'027	534	8.39
	Rape	84'550'500	1'235	19.40
	Renewable Energy Crops	1'539'000	22	0.35
	Silage Corn	671'236'752	385	6.06
	Sunflowers	8'270'500	175	2.75
	Tobacco	997'000	26	0.41
	Berries	2'963'200	18	0.28
	Vine	23'657'200	142	2.23
	Oil Squash	4'547	0	0.00
	Oil Hemp	6'300	0	0.00
	Oil Flax	316'800	3	0.04
	Hops	34'000	0	0.00
	Medicinal Plants and Herbs	346'000	9	0.14
Total Non-leguminous		2'374'165'193	11'406	179.24
Total Leguminous		19'574'620	963	15.13
Total excluding Grass		2'393'739'813	12'369	194.37
Total including Grass		8'494'523'861	34'093	535.75

Table A – 29 Additional data for estimating N₂O emission from crop residues (fractions)(2014).

2014		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
	Berries	NA	0.20	0.0060
	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	1.00	NA
	Medicinal Plants and Herbs	1.18	NA	0.0221

Table A – 30 NH₃ and NO_x emission factors for 3Db Indirect N₂O emissions from managed soils 1990–2014.

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	2014	
%																									
NH ₃ from application of animal manure N (Frac _{CASMN})	Mature Dairy Cattle	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	24.40	23.80	23.79	23.76	23.75
	Other Mature 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
	Growing Cattle (weighted average)	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	
	Sheep (weighted average)	27.67	27.67	27.68	27.77	27.77	27.81	27.47	27.16	26.78	26.33	26.04	25.62	25.20	25.63	26.05	26.45	26.88	27.30	26.75	26.27	25.76	25.72	25.72	
	Swine (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	
	Mules and Asses (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	20.55	20.79	20.98	21.06	20.41	19.77	19.12	19.13	19.14	19.15
	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
	Carnivores (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	11.28	11.13	10.98	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	11.28	11.13	10.98	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	10.20	10.60	11.01	11.28	11.13	10.98	10.98	10.98	10.98	10.98
NH ₃ from urine and dung N deposited on PR&P (Frac _{CASPR})	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	9.74
	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	14.37	14.37
	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)	4.96	4.97	4.98	4.99	4.99	4.99	5.00	5.02	5.05	5.06	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	5.13
	Mature Dairy Cattle	4.95	4.94	4.94	4.94	4.94	4.93	4.93	4.91	4.90	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	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NH ₃ from commercial fertiliser N (Frac _{CASF})	Buffalo (weighted average)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Carnivores (weighted average)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	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	
	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	
	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	
	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	
	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	
	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
	Urea	6.10	5.37	5.38	5.62	5.82	5.83	5.85	5.65	5.30	5.17	5.35	5.04	5.01	4.69	4.81	4.41	4.30	4.76	4.48	4.21	4.26	4.40	4.21	4.43
	Other Mineral Fertilisers	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
NH ₃ from Agricultural Soils (kg/ha/year)	Recycling Fertilisers (weighted average)	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
	Sewage Sludge	17.58	18.04	18.48	18.91	19.33	19.74	19.92	20.07	20.18	20.26	20.29	19.35	18.20	16.91	15.64	14.14	13.91	13.86	13.35	12.31	11.00	11.10	11.33	11.57
	Compost	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
	Digestate Liquid	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 Solid	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	30.00	30.00	30.00	30.00	30.00	30.00
NH ₃ from Alpine Area (kg/ha/year)	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
	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 applied fertilisers (Frac _{CASW})	NH ₃ from Agricultural Soils (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
	NH ₃ from Alpine Area (kg/ha/year)	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 _{CASPR})	NH ₃ from applied fertilisers (Frac _{CASW})	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
	NH ₃ from urine and dung N deposited on PR&P (Frac _{CASPR})	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 2014 as published by the Swiss Federal Office of Energy (SFOE 2015). Diagram languages are German and French. The energy balance is also provided in tabular form in Table A – 2.

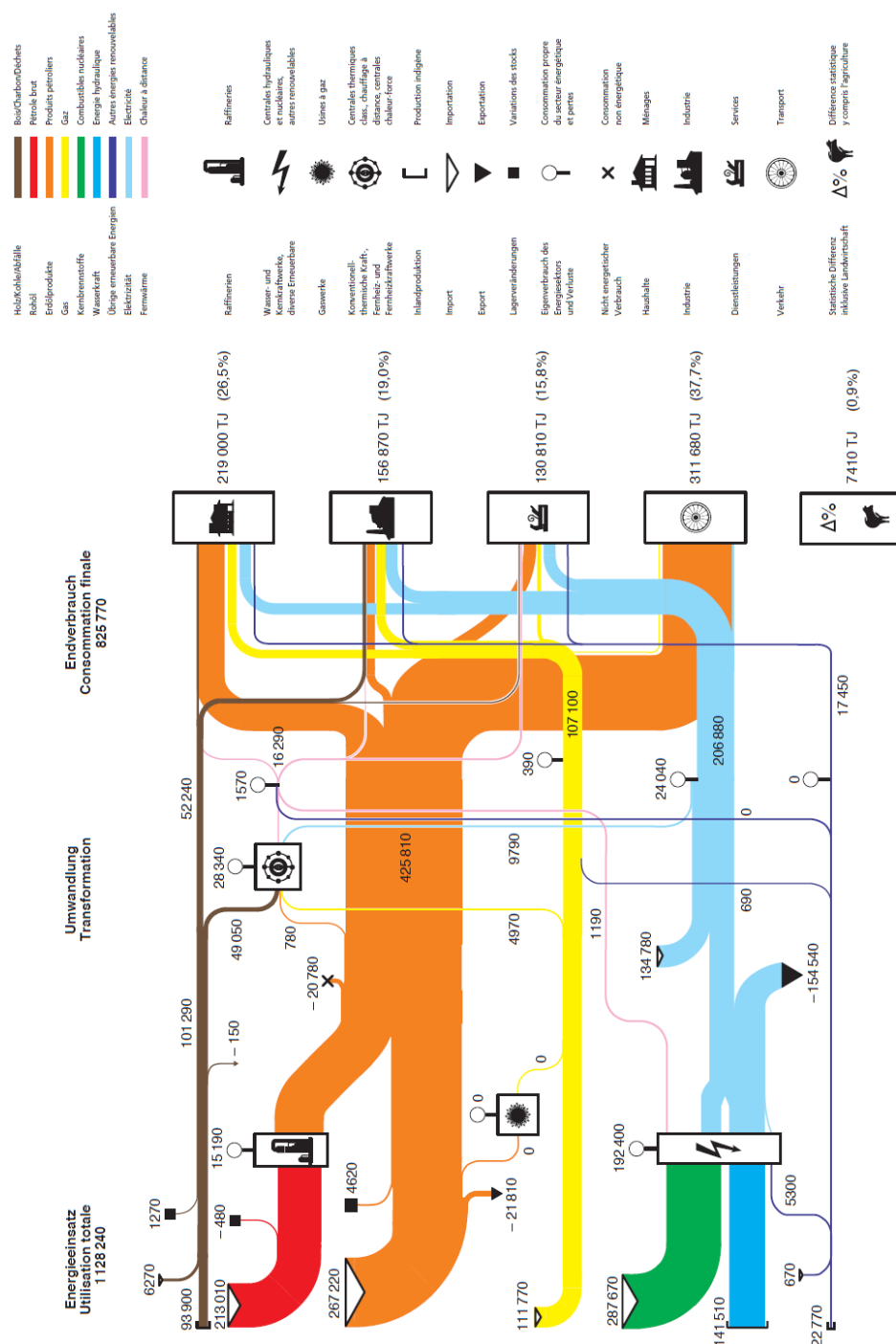


Figure A – 2 Energy flow in Switzerland 2014 in TJ (SFOE 2015)

Table A – 31 Switzerland's energy balance 2014 (SFOE 2015) in TJ¹¹.

	Holzenergie	Kohle	Müll und unver- abfälle	Roßöl	Erdöl- produkte	Gas	Wasserkraft	Kern- brennstoffe	Übrige Energie- träger	Elektrizität	Fernwärme	Total
	Energie du bois	Charbon	Ord. mûls 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 + Import + Export + Lagerveränderung ¹	(a) (b) (c) (d)	37 020 4 640 1 630 - 150 1 270	56 880 - - - -	- 213 010 - - 480	- 267 220 - 21 810 4 620	- 111 770 - -	0 141 510 - -	- 287 670 - -	22 770 670 - -	- 134 780 - 154 540 -	- -	258 180 1 021 390 - 176 500 5 410
= Bruttoverbrauch	(e)	38 500	56 880	212 530	250 030	111 770	141 510	287 670	23 440	- 19 760	0	1 108 480
+ Energieumwandlung: • Wasserkraftwerke • Kernkraftwerke • konventionell-ther- mische Kraft-, Fern- heiz- und Fernheiz- kraftwerke • Gaswerke • Raffinerien • Diverse Erneuerbare	(f) (g) (h) (i) (j) (k)	- - - 2 000 - - - 2 000	- - - 45 050 - - -	- - - - 212 530 -	- - - 780 211 540 -	- - - 4 970 0 690	- - 141 510 - -	- - 287 670 - -	- - - - 5 990 -	141 510 94 930 8 810 - 5 430	- 1 190 16 670 - 0	0 - 191 550 - 27 320 - 990 - 1 870
+ Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherungen	(l)	-	-	-	- 14 200	- 390	-	-	-	- 24 040	- 1 570	- 40 200
+ Nichtenergetischer Verbrauch	(m)	-	-	-	- 20 780	-	-	-	-	-	-	- 20 780
= Endverbrauch	(n)	34 500	11 830	0	425 810	107 100	0	0	17 450	206 880	16 290	825 770
Haushalte	(o)	16 600	400	-	75 230	42 520	-	-	11 940	65 830	6 480	219 000
Industrie	(p)	10 290	5 510	11 830	16 510	40 210	-	-	1 440	64 870	6 210	156 870
Dienstleistungen	(q)	7 040	0	-	32 920	22 630	-	-	2 990	61 630	3 600	130 810
Verkehr	(r)	-	-	-	298 260	1 500	-	-	870	11 050	-	311 680
Statistische Differenz inkl. Landwirtschaft	(s)	570	0	-	2 890	240	-	-	210	3 500	0	7 410

1 + Lagerzunahme
- Lagerabnahme

1 + diminution de stock
- augmentation de stock

¹¹ Liechtenstein's consumption of liquid fuels is included in the numbers (see chapter below on Final Swiss energy consumption).

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 – 32 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 – 32. 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 overall energy statistics (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 – 32 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.		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, SF₆) 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 SF₆ 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 SF₆ 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 (mostly in the summer). 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 SF₆ 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). Since 2009 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. 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.

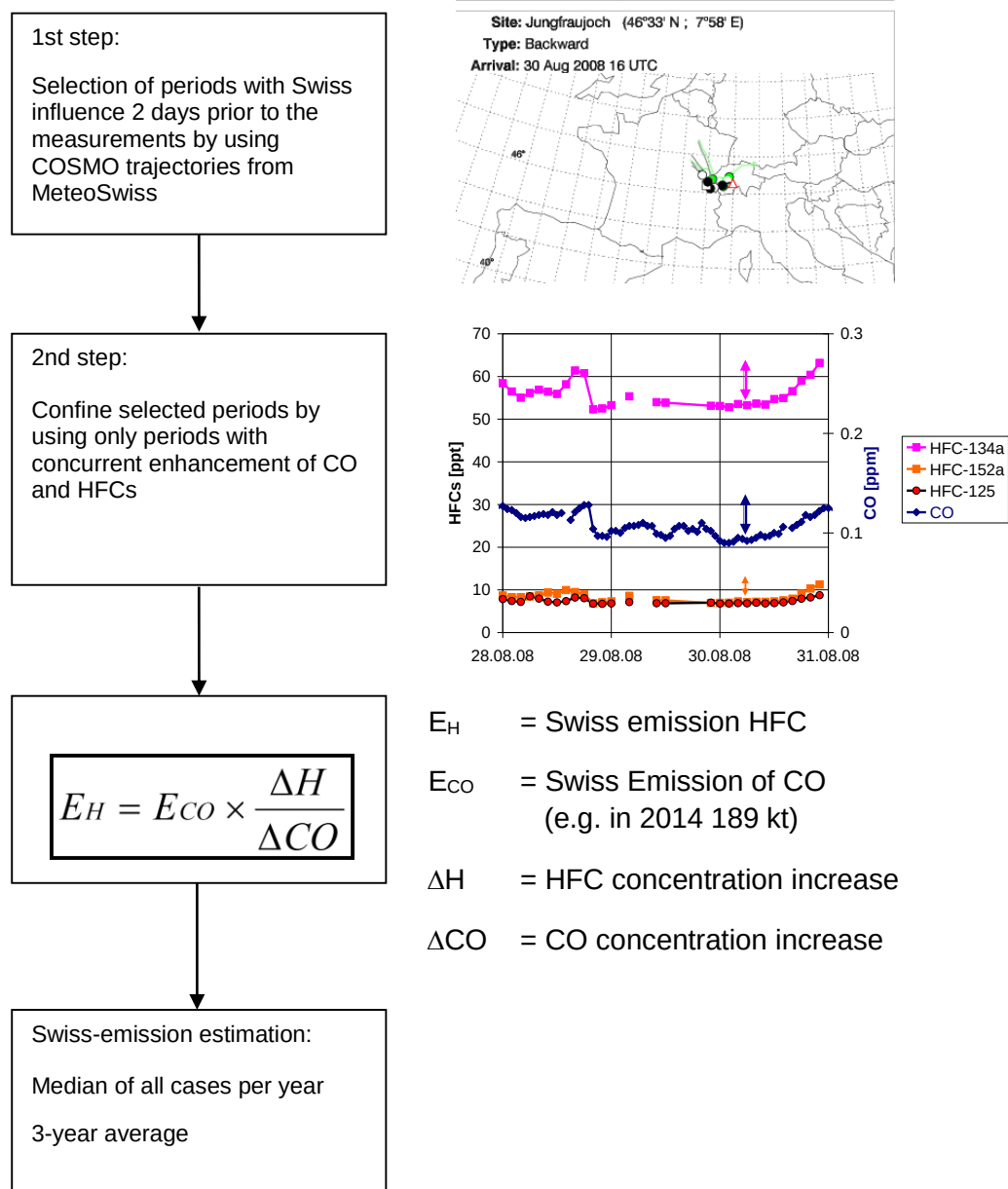


Figure A – 3 Description of the procedure to estimate annual emissions of HFCs from Switzerland by using continuous measurements of HFCs at Jungfraujoch (Switzerland).

Results and discussion:

In the following, Swiss emissions of five HFCs (HFC-134a, HFC-125, HFC-152a, HFC-143a, HFC-32) and SF₆ 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 fluorinated greenhouse gases 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 after 2010 in the inventory and to a lesser degree in the measurement-based estimates 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. Until 2007 the emissions according to the inventory were slightly higher than the ones based on measurements although data for both methods often agreed within the estimated uncertainty of 25%. Afterwards, the gap got larger but in recent years a concurrent increasing trend was seen with a tendency of smaller differences.

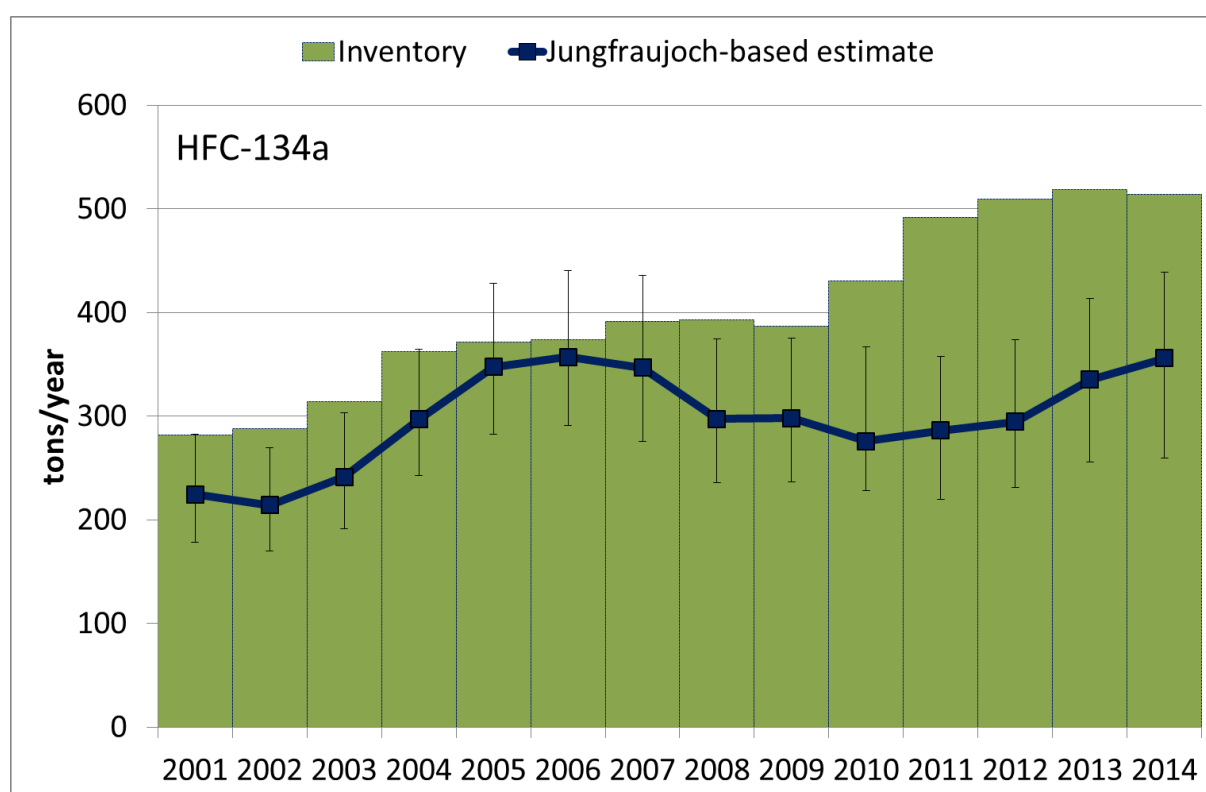


Figure A – 4 Comparison of HFC-134a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

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. Until 2013, emissions from the inventory slightly exceeded emissions based on measurements. However, in 2014 estimated emissions from the measurement-based method approached the emissions from the inventory.

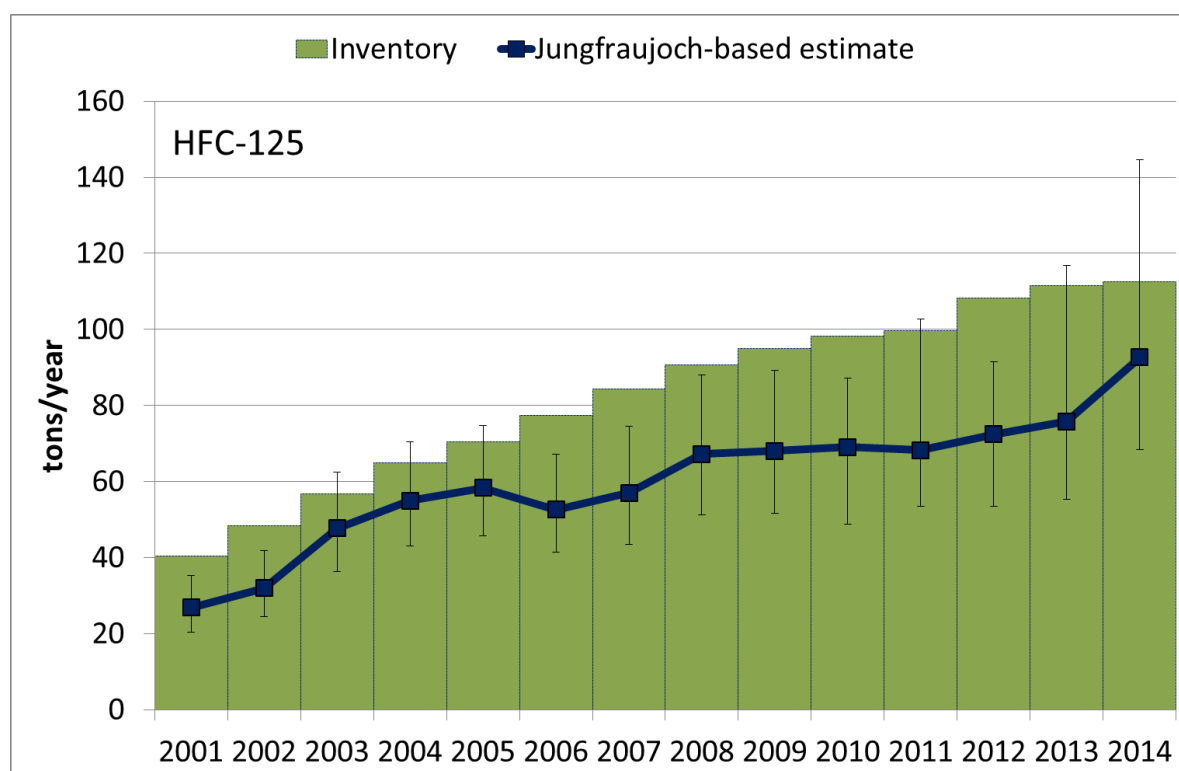


Figure A – 5 Comparison of HFC-125 emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

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 inventory¹². Emissions estimated from Jungfraujoch show a consistent negative trend related to the partial phase-out of HFC-152a from the foam-blowing applications.

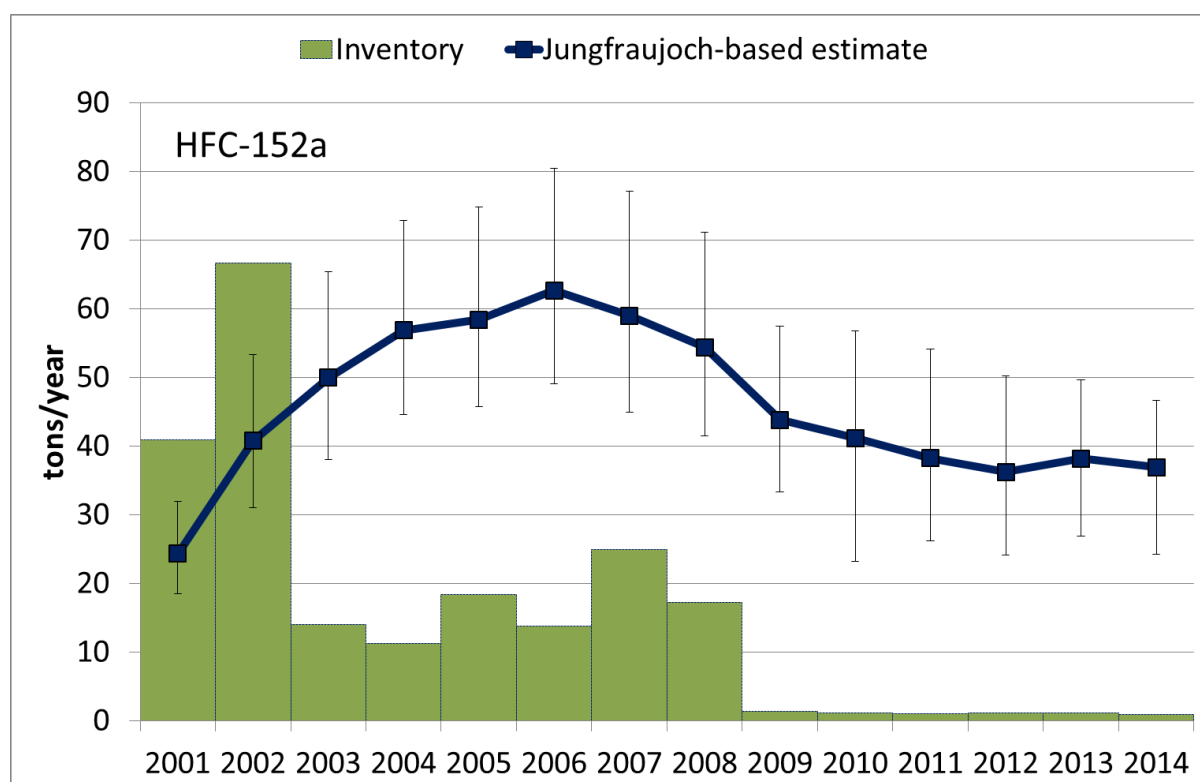


Figure A – 6 Comparison of HFC-152a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

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. In 2014, HFC-143a emissions from both methods agree exceptionally well due to a rise in emissions estimated by the measurement-based method, which is also seen in estimated HFC-125 emissions (see above).

¹² 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.

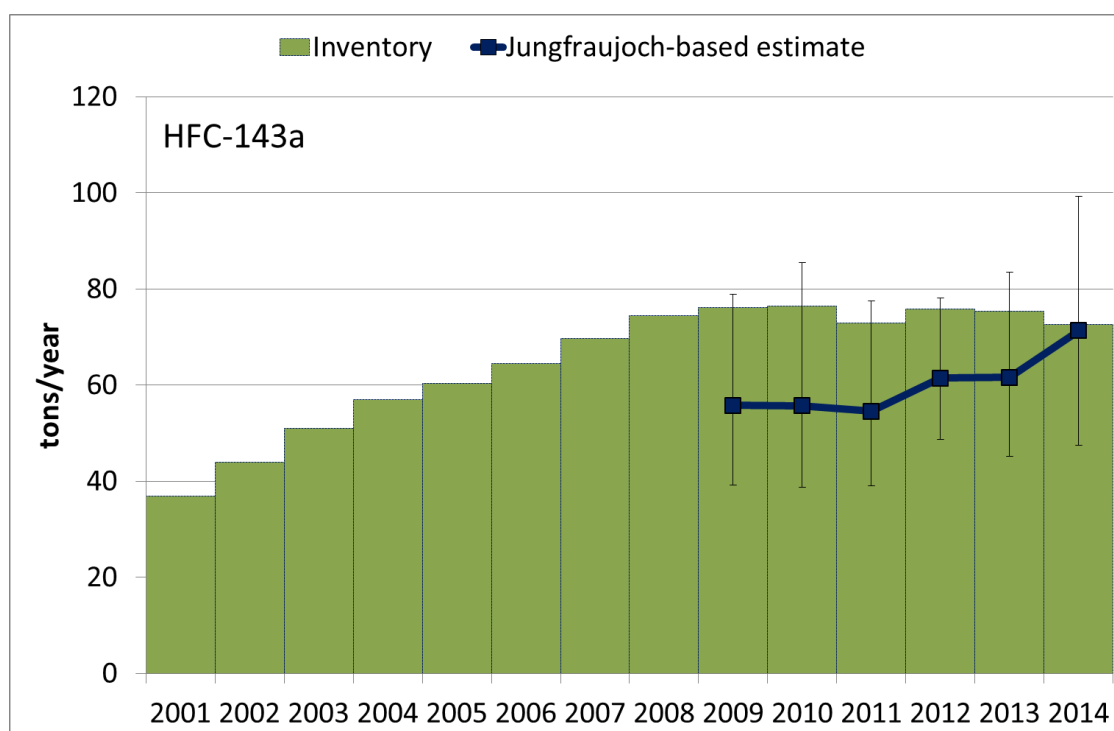


Figure A – 7 Comparison of HFC-143a emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

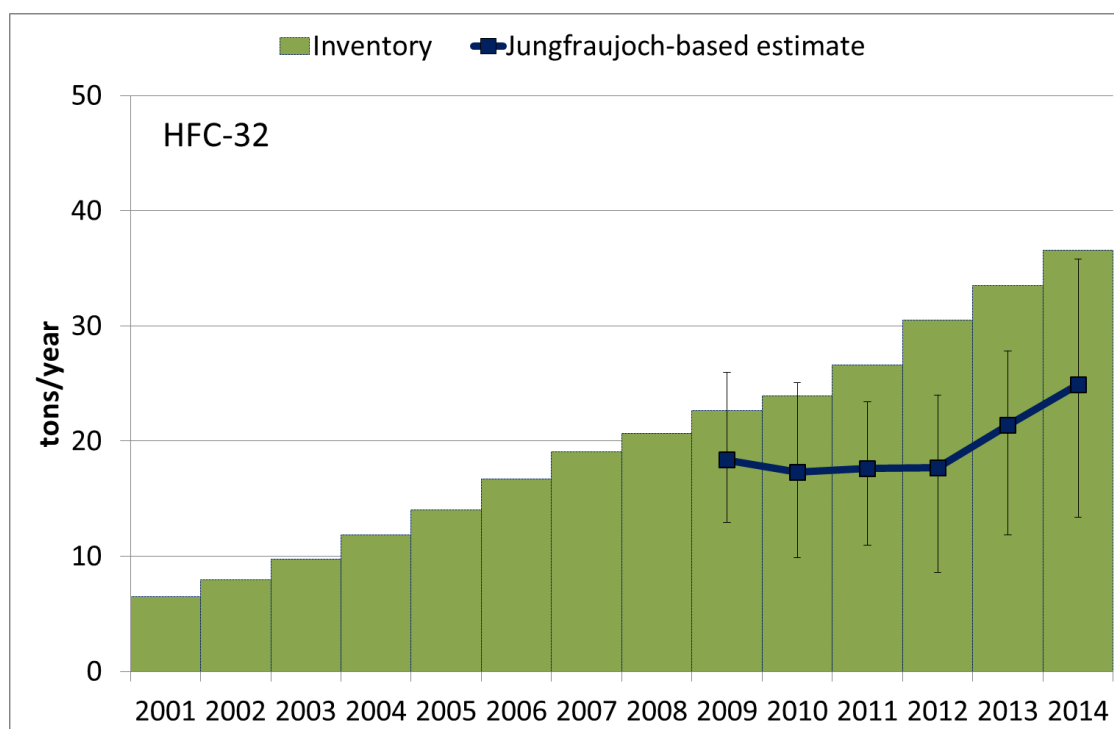


Figure A – 8 Comparison of HFC-32 emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

Sulfur hexafluoride (SF₆)

Emissions of SF₆ 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 period. Since 2003, a mass balance approach based on industry data is applied for the use of SF₆ in electrical equipment. Increasing SF₆ emissions 2012–2014 result in the inventory from the disposal of insulating windows (all SF₆ released).

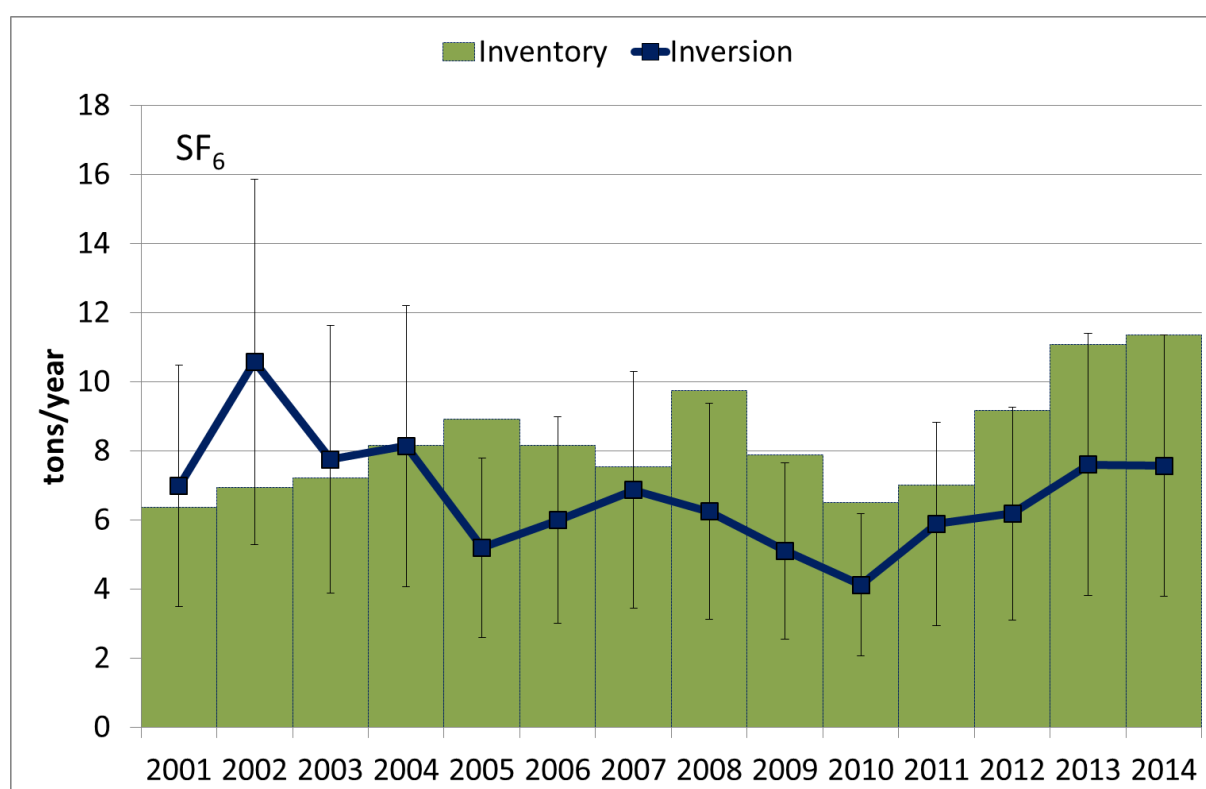


Figure A – 9 Comparison of SF₆ emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

A 5.2 Independent verification of methane emissions

Introduction

In 2013 the Swiss Federal Laboratories for Material Science and Technology (Empa), ETH Zürich and University of Bern established a greenhouse gas (GHG) observing network in Switzerland as part of the CarboCount-CH project (www.carbocount.ch). The network consists of four sites that continuously measure the atmospheric concentration of carbon dioxide (CO₂) and methane (CH₄). The sites were chosen to cover most of the densely populated and agriculturally used Swiss Plateau (see Figure A – 10). Atmospheric transport simulations confirm that the measurements at these sites are sensitive to emissions from a large part of Switzerland (Oney et al., 2015). The aim of CarboCount-CH was to better understand and quantify the exchange of the abovementioned GHGs between the atmosphere and the land surface by inverse modelling. Here, the results of such an inverse modelling approach to validate total Swiss CH₄ emissions are reported. The analysis was carried out for the measurement period March 2013 to February 2014, the first year with data available from all four CarboCount-CH sites. In addition, CH₄ observations from the high altitude site Jungfraujoch (Empa) and the mountaintop site Schauinsland (Germany, Umweltbundesamt) were used to further constrain the emission estimates. The results summarized here are excerpts from the publication by Henne et al. (2015).

Methods

The applied approach is based on source sensitivities calculated for each measurement site with the Lagrangian atmospheric transport model FLEXPART. FLEXPART is driven with high resolution meteorological input data from the numerical weather prediction model COSMO (7 km by 7 km horizontal resolution) provided by the Swiss national weather service (MeteoSwiss). For each site 3-hourly source sensitivities were calculated by running the model in time-inverted mode, releasing in each 3-hour time interval 50'000 air parcels and following them 4 days backward in time.

When combining source sensitivities with a map of emission fluxes, atmospheric concentrations at the location of the observations can be obtained. These simulated concentrations can be compared with the measurements, and through “inverse modeling” an optimized (*a posteriori*) emission distribution within and around Switzerland can be estimated that minimizes the differences between simulated and observed concentrations while also considering the uncertainties of the initial (*a priori*) emission distribution.

Two different inverse methods were applied: a Bayesian approach and an extended Kalman filter. Technical details of these approaches can be found in Henne et al. (2015) and Brunner et al. (2012), respectively.

As a *priori* emissions for Switzerland the MAIOLICA CH₄ inventory was used (Hiller et al., 2014), which disaggregates the emissions reported by the Swiss National Inventory Report (NIR) onto a regular spatial grid. For emissions outside of Switzerland the European TNO/MACC-2 inventory was employed (Kuenen et al., 2014). The total anthropogenic emissions of the MAIOLICA inventory was 176 Gg yr⁻¹, which corresponds to the Swiss CH₄ emissions in 2012 as reported by the NIR in 2014. The MAIOLICA inventory also includes a small contribution from natural sources of 3 Gg yr⁻¹ (<2%).

Next to a reference inversion a number of sensitivity inversions (30) were set up by systematically varying different aspects of the inversion system (inverse algorithm, transport

model, particle release height, *a priori* emissions, boundary conditions, uncertainty covariance, selection of observational data). In our reference case the measurements at the two CarboCount-CH sites Beromünster and Lägern-Hochwacht were used together with measurements at Schauinsland and Jungfraujoch. The CarboCount-CH sites Gimmiz and Fruebuel, which were more difficult to simulate due to their proximity to local CH₄ sources, were only treated as validation sites.

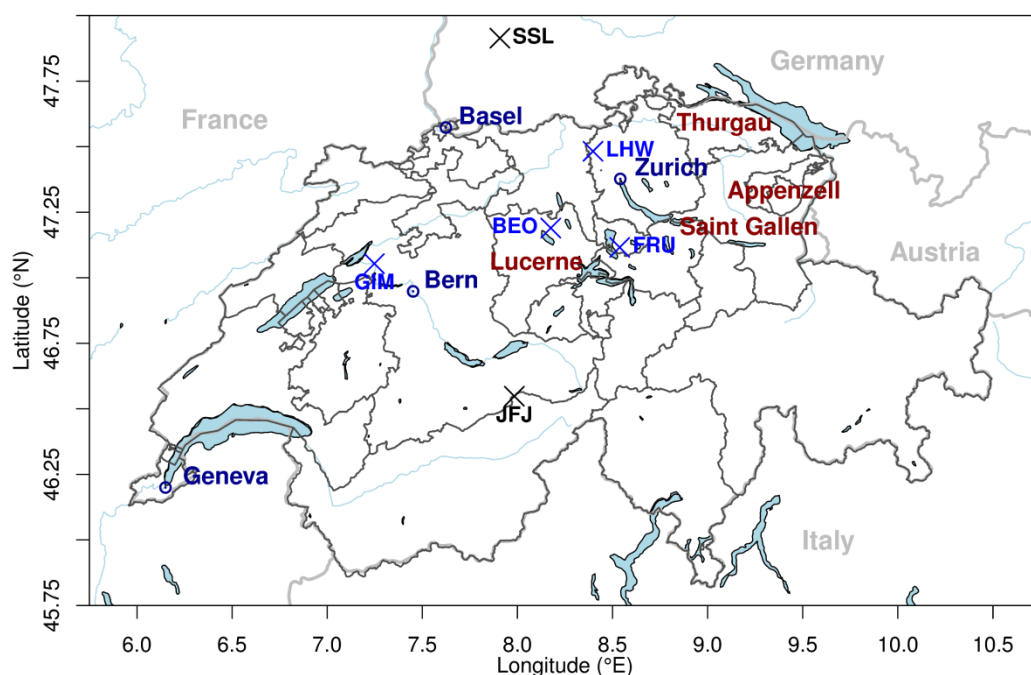


Figure A – 10 : Map of Switzerland illustrating the location of CarboCount-CH sites (blue), supplementary sites (black), cantonal borders (gray), major cities (dark blue), and selected canton names (red). The sites are: Beromünster (tall tower, BEO), Lägern-Hochwacht (mountain top, tower, LHW), Gimmiz (flat, tower, GIM), Fruebuel (mountain, near surface, FRU), Schauinsland (mountain top, SSL), and Jungfraujoch (high Alpine, JFJ).

Results and Discussion

The inversion results are presented in terms of national total emissions and spatial distribution. The inversion system was not set-up to optimize emissions by category separately, but to estimate the spatial distribution of total emissions. Nevertheless, through the spatial information the results can provide qualitative insights into the contribution from specific source categories that dominate in a given region. Further details and discussion on the inversion performance and results can be found in Henne et al. (2015).

National Totals

The best inverse estimate of total Swiss CH₄ emissions for the observation period March 2013 to February 2014 is 196 ± 18^{13} Gg yr⁻¹. This number represents the average and standard deviation over the reference and all sensitivity inversions (Figure A – 11). This is in close agreement with the NIR value reported in 2015 for the years 2012 and 2013 of 206 ± 33 Gg yr⁻¹. The uncertainty given in the NIR amounts to 16% of the national total and was also used as the uncertainty of our *a priori* emissions. The inversion results suggest a reduced uncertainty of 9%.

In conclusion, the independent atmospheric observations of the CarboCount-CH network largely confirm the estimate of the NIR and further suggest a reduced uncertainty on the reported value.

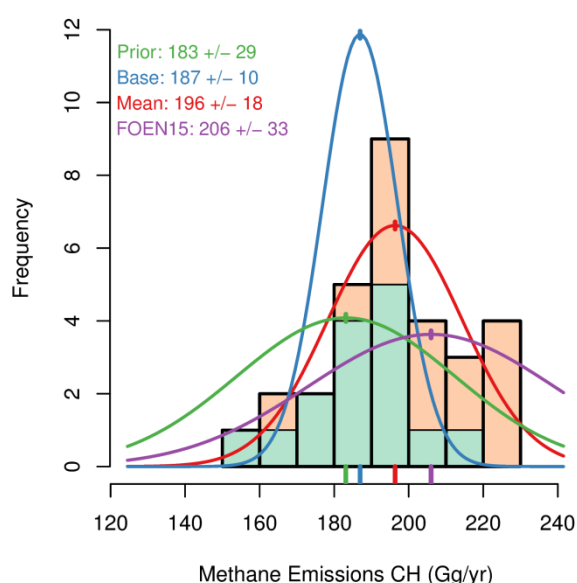


Figure A – 11: Histogram of total Swiss CH₄ emissions taken from all individual sensitivity inversions: low (light green) and high (light orange) particle releases. The base inversion prior (green) and posterior (blue) estimate as well as the average over all sensitivity inversions (red) and the NIR 2015 estimate (purple) are indicated by their Gaussian probability density functions. Taken from Henne et al. (2015).

Spatial and Temporal Distribution and Source Processes

In Figure A – 12 the spatial distribution of the *a priori* emissions (a), the *a posteriori* emissions (b), their absolute (c) and relative (d) difference (*a posteriori* minus *a priori*) is shown. An irregular inversion grid was used that exhibits high spatial resolution close to the observations and gets coarser with distance to these. In the *a priori* emissions the dominating role of agricultural emissions in the rural areas of the Cantons Lucerne and Thurgau/Appenzel is clearly seen. In contrast, the densely populated areas of Zurich, Basel and Geneva do not show up as emission hot-spots, as expected from the small contribution of emissions from natural gas distribution and waste water treatment reported in the NIR.

A posteriori emissions estimated by the inversion were smaller than *a priori* emissions in the agricultural areas of Canton Lucerne and Canton Thurgau, but were increased in the north-

¹³ All uncertainties given here represent 1- σ confidence levels (66% confidence interval around the mean).

eastern part of Switzerland (Cantons Appenzell and Saint Gallen). Smaller differences were seen in other parts of the country. When allowing the inversion to derive seasonal mean instead of annual mean emissions, a clear seasonal cycle with reduced winter time and increased spring to summer emissions was detected. This is in line with the temperature dependent seasonality expected from manure handling and storage and the productivity-dependent seasonality of milk cows. We conclude that the emission reductions as estimated by the inversion are largely due to an overestimation in agricultural emissions in the *a priori* estimate by 10% to 20% that can mainly be attributed to the winter season. A strong seasonality can be expected for emissions from manure handling and storage (lower winter temperatures). Hence, the observed overestimation in the *a priori* may be attributed to this emission process.

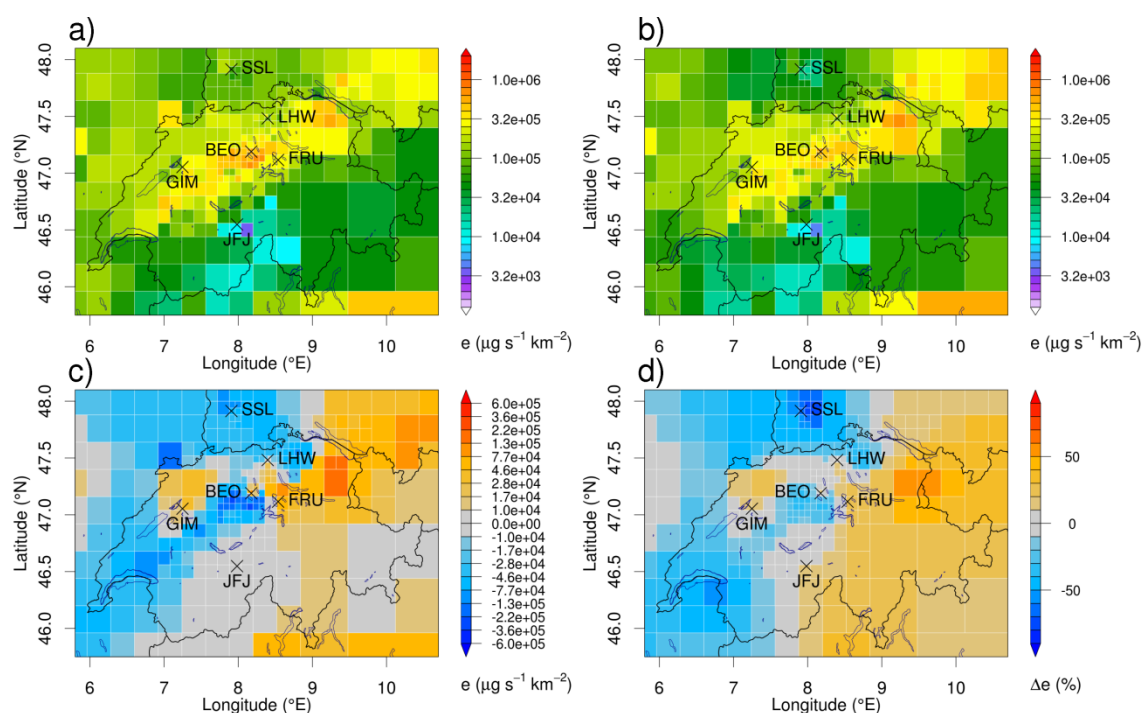


Figure A – 12: (a) *a priori* (MAIOLICA) and (b) *a posteriori* surface fluxes of CH₄ in the base inversion with low particle release heights. (c) absolute and (d) relative (to *a priori*) difference between *a posteriori* and *a priori* fluxes. For panels c and d red (blue) colors indicate higher (lower) *a posteriori* than *a priori* emissions. Taken from Henne et al. (2015).

An alternative sensitivity inversion used *a priori* emissions from the EDGAR inventory (v4.2 FT2010, EC JRC 2009). In EDGAR, the Swiss country total amounts to 228 Gg yr⁻¹, mostly due to about 25 Gg yr⁻¹ larger emissions from the natural gas distribution network (IPCC category 1B2: fugitive emissions from oil and gas). *A posteriori* emissions in this sensitivity inversion were very similar to those of the reference inversion, which in turn required large reductions from the *a priori* distribution especially in densely populated areas (see Figure A – 13). From this we conclude, that the natural gas emissions as given in the NIR (8 Gg yr⁻¹) are in much better agreement with our atmospheric observations than the emission in the EDGAR inventory (32 Gg yr⁻¹).

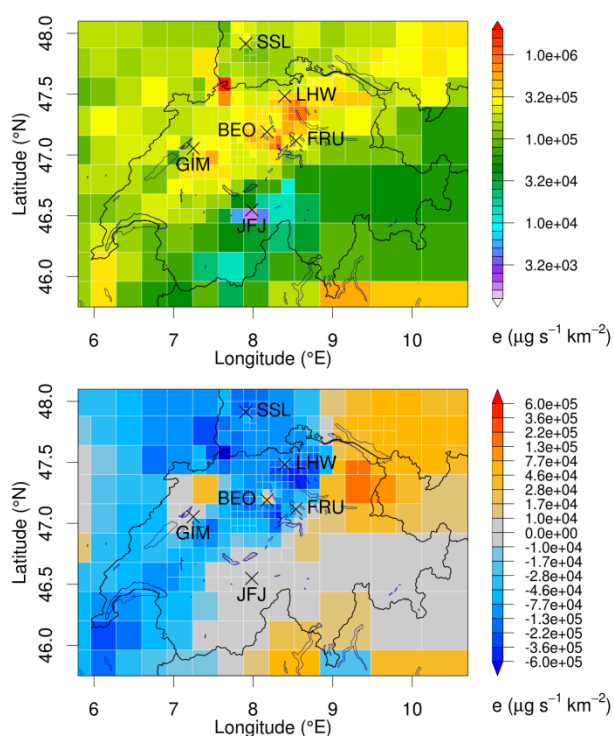


Figure A – 13: Annual average (left) *a priori* CH₄ fluxes and (right) absolute difference between *a posteriori* and *a priori* fluxes when using EDGAR *a priori* information

Most sensitivity inversions yielded a similar spatial distribution of the *a posteriori* emissions as the reference inversion. This robust pattern suggests that the increased emissions estimated for north-eastern Switzerland are a true feature, but it remains unclear what source is responsible for this result. A possible candidate is differences in farming practices between this area and the rest of the country, resulting in different per head emissions from livestock. Other potential anthropogenic sources are waste water handling, composting and anaerobic digestion in biogas production and fugitive emissions from the natural gas distribution network. However, there is no indication that these processes occur disproportionately in north-eastern Switzerland. Natural emissions, e.g. from the “Alter Rhein” wetland area, may also contribute to the unexpectedly high emissions from this area. Further observations will be needed to verify and better characterize this source.

Annex 6: Information on the CRF Reporter

As mentioned in chp. 1.2.4 the CRF Reporter still seems to generate errors in the numerical output of some reporting tables. A non-exhaustive list of issues and errors identified so far is provided in the table below. As noted at the beginning of the chapters 3 to 11 this aspect should be taken into consideration when comparing information in the NIR with the reporting tables (CRF).

Table A – 33 Identified errors in the numerical output of some reporting tables (CRF).

CRF Table	Problem	Solution
Table1A(d)	The column "Reported under ..." should include the NFR code in the Text.	Actually there is no possibility to change it, because a drop-down-menu determines the text.
Table1.A(a)s1	Solid fuels activity data and emissions (row 12) shows NO instead of the summarized values.	Problem in the CRF web application.
Table1.A(a)s1	Sum of biomass activity data (cell B16) is wrong (too low).	Problem in the CRF web application.
Table1.A(b)	Unit in Mg instead of Gg, despite data input in Gg. Values are correct (Mg).	Problem in the CRF web application.
Table2(l)s1-s2	In all empty cells should be written „NO“. However, it would be very time-consuming (especially given the long waiting times of the CRF web application) to generate for every cell a new nod in the navigation tree of the CRF web application and then to adapt all the import files to these changes.	The benefit would be marginal, given the effort required to fill all the cells. As soon as the CRF web application becomes more user friendly and operation is more efficient, we will reconsider filling all the cells.
Table2(lI)	In all empty cells should be written „NO“. However, it would be very time-consuming (especially given the long waiting times of the CRF web application) to generate for every cell a new nod in the navigation tree of the CRF web application and then to adapt all the import files to these changes.	Information is provided in the documentation box: „2.B.9, 2.C, 2.E, 2.F.1-2.F.6: "NO" for all empty cells." The benefit would be marginal, given the effort required to fill all the cells. As soon as the CRF web application becomes more user friendly and operation is more efficient, we will reconsider filling all the cells.
Table2(lI)B-Hs1	In all empty cells should be written „NO“. However, it would be very time-consuming (especially given the long waiting times of the CRF web application) to generate for every cell a new nod in the navigation tree of the CRF web application and then to adapt all the import files to these changes.	The benefit would be marginal, given the effort required to fill all the cells. As soon as the CRF web application becomes more user friendly and operation is more efficient, we will reconsider filling all the cells.
Table3.As1	Missing information for "Rabbit" for "Average gross energy intake" and "Average CH ₄ conversion rate". Correct numbers are provided in NIR chp. 5.2.2.2.1.	Problem in the CRF web application. The information is correctly imported, but not written in the reporting tables.
Table3.As2	Table is completely chaotic ("Other" and "Rabbits" at the top of the table...).	Problem in the CRF web application. Display problem only.
Table3.B(a)s2	The values for the cattle categories seem to be correct. For all other animal categories the rows are in a chaotic order. Accordingly quality control was hardly possible. For "Sheep" 4 rows seem to be missing. All correct values are provided in NIR chp. 5.3.2.2.	Problem in the CRF web application.
Table3.B(b)	IEF's for direct N ₂ O (kg N ₂ O-N/kg N handled) (row 39): Wrong molecular weight. The IEF's are displayed in kg N ₂ O per kg N handled instead of kg N ₂ O-N per kg N handled.	Problem in the CRF web application.
Table3.B(b)	IEF for "indirect emissions from atmospheric deposition" (cell R37): Wrong molecular weight. The IEF is displayed in kg N ₂ O per kg N handled instead of kg N ₂ O-N per kg N handled.	Problem in the CRF web application.
Table4	N ₂ O from 4(IV) (indirect emissios) are not separated in the categories 4A/B/C/D/E/F and just shown in table 4(IV). But are summarized in the total sum in table 4 without been displayed in this table 4. The sum is correct (with indirect emissions)	Inaccuracy in the CRF web application.
Table10s4	For N ₂ O in sector 4 LULUCF the sum is not just the displayed sum of N ₂ O emissions from the categories 4A+4B+4C+4D+4E+4F (rows 39 to 46) but including indirect N ₂ O from 4(IV). The sum is correct (with indirect emissions).	Inaccuracy in the CRF web application.
4 KP et al.	All the documentation boxes are not properly imported and displayed.	Problem in the CRF web application.
4(KP-I)A.2	Information items: every row is shown twice. This is not necessary.	Problem in the CRF web application.
4(KP-I)B.1	Description of category an sub-category is shown twice under „identification code" and „subdivision". This is not wrong but not necessary.	Problem in the CRF web application.
Summary3s1	Wrong information in Method applied and emission factor for sector 1B and 1C. There should be indicated „NO" instead of „NA".	Problem in the CRF web application. „NO" is not imported and there is no possibility to change it, because „NO" or „NA" are not in the drop-down menu.
Summary3s1	Wrong information in Method applied and emission factor for sector 2C: Method of SF6 should be „T2". Emission factor information of SF6 should be „D".	Problem with the CRF web application. Some information is not imported.
Summary3s2	Wrong information in Method applied and emission factor for sector 4 (LULUCF): 1) Method of CO2 should be „T2, T3" for 4A and "T2" for 4B-F. Emission factor information of CO2 for 4B-4F should be „CS". 2) Method of CH4 should be „NA" for 4B-F. Emission factor information of CH4 for 4A should be „CS" and "NA" for 4B-F. 3) Method of N2O should be „T1" for 4B-F. Emission factor information of N2O for 4B-F should be „D". 3B-3F: D	Problem in the CRF web application. Some information is not imported.
Table10s2	CO ₂ emissions from biomass (row 60) are wrong. Biogenic CO ₂ emissions from 5C are missing.	Problem in the CRF web application.
Table10s5	Total HFC (row 8) and total PFC (row 30) in the year 2014 are 1000 times too high.	Problem in the CRF web application.
Table10s5	Total SF ₆ (row 45) and total NF ₃ (row 48) are not converted to CO ₂ equivalent in the year 2014.	Problem in the CRF web application.

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References to EMIS database comments

Table A – 34 Assignments of NFR Codes to titles of EMIS (Swiss Emission Information System) database comments. These internal documents will be made available to reviewers on request.

NFR Code CRF [UNECE]	EMIS Title	NFR Code CRF [UNFCCC]	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	Kalksteigrube*	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