Switzerland's

Greenhouse Gas Inventory

1990–2016

National Inventory Report

Including reporting elements under the Kyoto Protocol

Submission of April 2018
under the United Nations Framework Convention on Climate Change
and under the Kyoto Protocol

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

Publisher

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

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Bern, April 2018

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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
AAU	Assigned Amount Unit (under the Kyoto Protocol)
BCEF, BEF	Biomass conversion and expansion factor, biomass expansion factor
Carbura	Swiss organisation for the compulsory stockpiling of oil products
Cemsuisse	Association of the Swiss Cement Industry
CER	Certified Emission Reduction (under the Kyoto Protocol)
CC	Combination category
CDM	Clean Development Mechanism (under the Kyoto Protocol)
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
ERT	Expert review team (under the UNFCCC and the Kyoto Protocol)
ERU	Emission Reduction Unit (under the Kyoto Protocol)
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
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
IPPU	Industrial processes and product use
JI	Joint Implementation (under the Kyoto Protocol)
KCA	Key category analysis
kha	Kilo hectare
kt	Kilo tonne (1’000 tonnes)
L1, L2	Key category according to level assessment with approach 1, approach 2
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
NEU	Non-energy use of fuels
NF_3	Nitrogen trifluoride 2006 IPCC GWP: 17’200 (UNFCCC 2014a, Annex III)
NFI1, NFI2	First (1983–1985), Second (1993–1995), Third (2004–2006)
NFI3, NFI4	and Fourth (2009–2017) National Forest Inventory
NIR	National Inventory Report
NIS	National Inventory System
NFR	Nomenclature for Reporting (under the UNECE)
NMVOC	Non-methane volatile organic compounds
N_2O	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)
SEF	Standard electronic format (under the Kyoto Protocol)
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)
T1, T2	Key category according to trend assessment with approach 1, approach 2
tCER	Temporary Certified Emission Reduction (under the Kyoto Protocol)
QA/QC	Quality assurance/Quality control
QMS	Quality management system

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

In 2016 a comprehensive assessment of climate change and its impacts in Switzerland, both in the past and in the future, has been published by the Swiss Academies of Sciences (SCNAT 2016). Long-term measurements indicate a marked shift towards a warmer climate for Switzerland. Between 1864 and 2016, the average temperature in Switzerland has increased by +2.0 degrees Celsius compared to +0.9 degrees Celsius globally (FOEN 2018d). This corresponds to a linear increasing temperature trend of about 0.13 degrees Celsius per decade (CH2011 2011). Since 1961, the temperature increase has accelerated to 0.38 degrees Celsius per decade. In the course of the 21st century, Swiss climate is projected to depart significantly from present and past conditions. Mean temperature will very likely increase in all regions and seasons.

Summer mean precipitation will likely decrease by the end of the century all over Switzerland by 18–28 per cent depending on the emission scenario, while winter precipitation will likely increase in Southern Switzerland for the investigated emission scenarios. The expected trends in precipitation 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.

The retreat and massive loss of volume of glaciers in the Alps is the most apparent indicator of the recent increase in atmospheric temperature. In recent years a dramatic acceleration of glacial melting was observed. From the ca. 2’900 square kilometres of glacier area in the mid-1970s, only about 2’100 square kilometres remained in 2003 and an estimated 1’900 square kilometres in 2013 (FOEN 2018d).

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 will increase the vulnerability of forests and potentially impair their protective, productive, and social functions. Species distribution will shift upward to higher elevations, thermophile species will spread, new species from warmer areas will arrive, and phenological shifts will occur.

For agriculture, climate change is expected to entail a shift of suitable areas for agricultural production, and to involve both positive (e.g. a longer vegetation period) and negative (e.g. increasing incidence of pest infestations owing to milder winters) aspects. Changes in the nature of extreme weather events, in particular more frequent, intense and longer-lasting summer heat waves, could also challenge agriculture, e.g. by reducing the yields.

Various sectors of the Swiss economy are likely to be adversely affected by progressing climate change: in particular, winter tourism will suffer from increased scarcity of snow, hydroelectric power stations are confronted with altered runoff and sediment transport regimes, and insurance companies may face increased losses due to winter storms and floods. Natural hazards and extreme weather events potentially pose a growing risk to infrastructures and settlements. Heat waves in combination with elevated tropospheric ozone levels present a serious threat to human health. 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, FOEN 2017k).

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 the 2006 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 (KP) 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 2018 inventory submission under the UNFCCC and under the Kyoto Protocol includes the NIR, the greenhouse gas inventory 1990–2016 including also the Kyoto Protocol LULUCF tables 2008–2016 in the Common Reporting Format as well as the standard electronic format (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 some of the recommendations and encouragements of the “Report on the individual review of the annual submission of Switzerland submitted in 2017” (UNFCCC 2018). 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 the 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 (IDP).
- The inventory quality management system (QMS) 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 2016).
- 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 the impacts of climate change in Switzerland, on institutional, legal and procedural arrangements, QA/QC activities, inventory preparation, methodologies of emissions modelling, key categories, uncertainties and completeness of the inventory.

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

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

Chapter 10 justifies, explains and summarises the recalculations and improvements. 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. This cap is set at 3.5% of the 1990 emissions (excluding LULUCF).

Switzerland chooses to account for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol (FOEN 2016c, FOEN 2016d) over the entire second commitment period. In addition to the mandatory submission of the inventory years 2013–2016, data for the whole time series since 1990 are available and shown in Switzerland's NIR in chp. 11.

ES.2 Summary of national emissions and removals related trends, and emissions and removals from KP-LULUCF activities

ES.2.1 GHG Inventory 2016

In 2016, Switzerland emitted 48'199 kt CO_2 eq (kilo tonnes of CO_2 equivalent), corresponding to 5.7 t CO_2 eq per capita (CO_2: 4.7 t per capita), to the atmosphere, excluding emissions from international bunkers (aviation and marine), excluding indirect greenhouse gas emissions and excluding emissions and removals from Land use, land-use change, and forestry (LULUCF). For emissions that are relevant under the Kyoto Protocol see chapter ES.3.3.

Key category analysis (KCA)

Several key category analyses are carried out by level (years 1990 and 2016) and trend assessment (period 1990–2016), both including LULUCF categories (see details in chp. 1.5.1.2 and IPCC (2006)).

- Approach 1: For 2016, 30 categories among a total of 162 are identified as level key categories. About half of these categories are part of sector 1 Energy, accounting for the largest share of total national emissions.
- Approach 2: For 2016, 25 categories among a total of 162 are identified as level 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 2016. Total emissions excluding LULUCF reach a minimum in 2015, which is 10.1% below base year emissions in 1990.

Table E- 1 Switzerland's GHG emissions in CO_2 equivalent (kt) by gas. The column below on the far right indicates the percentage change in emissions in the latest year as compared to the base year 1990. HFCs increased by more than 5 million per cent when compared to 1990 levels (1990 = 0.025 kt CO_2 equivalent).

Greenhouse Gas Emissions	1990	1995	2000	2005
	CO_2 equivalent (kt)			
CO_2 emissions including net CO_2 from LULUCF	43'343	39'377	48'306	43'158
CO_2 emissions excluding net CO_2 from LULUCF	44'162	43'414	43'612	45'780
CH_4 emissions including CH_4 from LULUCF	6'035	5'708	5'302	5'197
CH_4 emissions excluding CH_4 from LULUCF	6'005	5'688	5'287	5'184
N_2O emissions including N_2O from LULUCF	2'834	2'675	2'519	2'414
N_2O emissions excluding N_2O from LULUCF	2'775	2'622	2'469	2'364
HFCs	0.02	242	634	1'049
PFCs	117	17	50	44
SF_6	137	93	144	203
NF_3	0	0	0	0
Total (including LULUCF)	**52'466**	**48'113**	**56'954**	**52'065**
Total (excluding LULUCF)	**53'196**	**52'077**	**52'195**	**54'624**

Greenhouse Gas Emissions	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2016 vs. 1990
	CO_2 equivalent (kt)										%
CO_2 emissions including net CO_2 from LULUCF	43'072	43'522	41'430	43'437	39'593	40'525	41'847	37'867	37'269	37'268	-14.0%
CO_2 emissions excluding net CO_2 from LULUCF	43'360	44'707	43'528	45'045	40'980	42'251	43'184	39'238	38'738	39'205	-11.2%
CH_4 emissions including CH_4 from LULUCF	5'191	5'264	5'171	5'142	5'090	5'060	4'998	4'996	4'969	4'923	-18.4%
CH_4 emissions excluding CH_4 from LULUCF	5'175	5'251	5'158	5'129	5'076	5'047	4'985	4'983	4'956	4'907	-18.3%
N_2O emissions including N_2O from LULUCF	2'447	2'467	2'426	2'475	2'421	2'405	2'365	2'379	2'334	2'351	-17.0%
N_2O emissions excluding N_2O from LULUCF	2'395	2'418	2'377	2'426	2'371	2'356	2'315	2'329	2'285	2'300	-17.1%
HFCs	1'229	1'250	1'247	1'316	1'426	1'502	1'494	1'507	1'523	1'523	see caption
PFCs	49	58	63	64.49	69.18	71.36	51.07	43.01	54.72	55.02	-52.8%
SF_6	172	222	180	148	160	209	252	259	256	207	51.2%
NF_3	0.0	0.1	5	8	6	0.4	0.1	0.4	0.5	0.5	-
Total (including LULUCF)	**52'159**	**52'785**	**50'523**	**52'591**	**48'765**	**49'773**	**51'008**	**47'051**	**46'406**	**46'328**	**-11.7%**
Total (excluding LULUCF)	**52'380**	**53'906**	**52'558**	**54'137**	**50'086**	**51'437**	**52'281**	**48'359**	**47'813**	**48'199**	**-9.4%**

With regard to the distribution of emissions by individual greenhouse gases, CO_2 is the largest single contributor accounting for 81.3% of total GHG emissions (excluding LULUCF) in 2016. The shares of CH_4 and N_2O are about 10. 2% and 4.8%, respectively. The shares of the three gases show slightly decreasing trends in the period 1990–2016, whereas aggregated F-gases, which contributed only 0.5% in 1990, increased to a share of 3.7% in 2016 (Table E- 2).

Table E- 2 Switzerland's total GHG emissions (excluding LULUCF) in CO_2 equivalent (kt) and shares of different GHG (%).

Greenhouse Gas Emissions	**1990**		**1995**		**2000**		**2005**		**2010**	
(excluding LULUCF)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	44'162	83.0%	43'414	83.4%	43'612	83.6%	45'780	83.8%	45'045	83.2%
CH_4	6'005	11.3%	5'688	10.9%	5'287	10.1%	5'184	9.5%	5'129	9.5%
N_2O	2'775	5.2%	2'622	5.0%	2'469	4.7%	2'364	4.3%	2'426	4.5%
HFCs	0	0.0%	242	0.5%	634	1.2%	1'049	1.9%	1'316	2.4%
PFCs	117	0.2%	17	0.0%	50	0.1%	44	0.1%	64	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)	**53'196**	**100%**	**52'077**	**100%**	**52'195**	**100%**	**54'624**	**100%**	**54'137**	**100%**

Greenhouse Gas Emissions	**2011**		**2012**		**2013**		**2014**		**2015**		**2016**	
(excluding LULUCF)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	40'980	81.8%	42'251	82.1%	43'184	82.6%	39'238	81.1%	38'738	81.0%	39'205	81.3%
CH_4	5'076	10.1%	5'047	9.8%	4'985	9.5%	4'983	10.3%	4'956	10.4%	4'907	10.2%
N_2O	2'371	4.7%	2'356	4.6%	2'315	4.4%	2'329	4.8%	2'285	4.8%	2'300	4.8%
HFCs	1'426	2.8%	1'502	2.9%	1'494	2.9%	1'507	3.1%	1'523	3.2%	1'523	3.2%
PFCs	69	0.1%	71	0.1%	51	0.1%	43	0.1%	55	0.1%	55	0.1%
SF_6	160	0.3%	209	0.4%	252	0.5%	259	0.5%	256	0.5%	207	0.4%
NF_3	6	0.0%	0.4	0.0%	0.1	0.0%	0.4	0.0%	0.5	0.0%	0.5	0.0%
Total (excluding LULUCF)	**50'086**	**100%**	**51'437**	**100%**	**52'281**	**100%**	**48'359**	**100%**	**47'813**	**100%**	**48'199**	**100%**

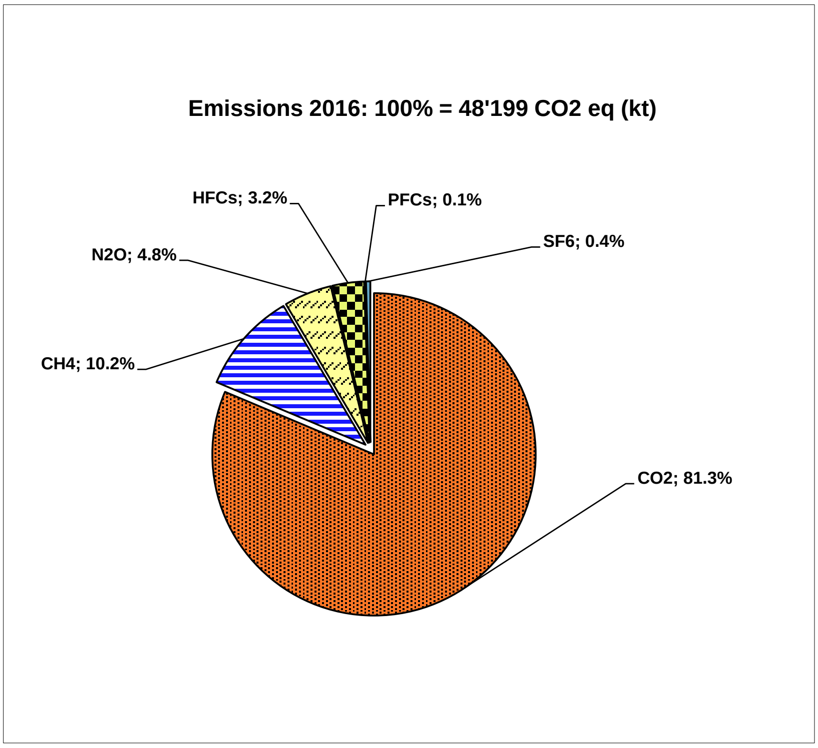

Figure E- 1 Contribution of individual gases to Switzerland's GHG emissions (excluding LULUCF) in 2016.

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 2016 (level) and for the period 1990–2016 (trend) (see details in chp. 1.6 and IPCC (2006)). The uncertainty results for Approach 2 are displayed in Table E- 3. When excluding LULUCF, Approach 2 level uncertainty amounts to 4.44% and trend uncertainty to 3.76%. Due to high uncertainties in sector 4 LULUCF, overall uncertainties are generally higher for the analyses including LULUCF categories (level: 6.36%, trend: 5.59%).

Table E- 3 Switzerland's relative uncertainties for national total GHG emissions excluding and including the LULUCF sector – Approach 2: Level uncertainties 2016 and trend uncertainties 1990–2016.

Approach 2 Uncertainty Analysis		
Inventory	**Level uncertainty 2016**	**Trend uncertainty 1990-2016**
excl. LULUCF	4.44%	3.76%
incl. LULUCF	6.36%	5.59%

Recalculations

For the latest recalculated year (2015), the total national emissions (excluding LULUCF) decreased from 48'038 kt CO_2 eq (FOEN 2017) to 47'813 kt CO_2 eq (current submission). 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 to the values of the KP reporting tables. All activities include emissions and removals of all GHG (i.e. CO_2, CH_4, N_2O) from Harvested wood products (HWP), biomass burning, drainage and N mineralization, where appropriate (see chp. 11.3).

Table E- 4 Net CO_2 eq emissions (positive sign) and removals (negative sign) for activities accounted for under Article 3, paragraph 3 and Forest management under Article 3, paragraph 4, of the Kyoto Protocol in kt CO_2 eq.

	1990	1995	2000	2005
	kt CO_2 equivalent			
A. Article 3.3 activities	89.26	107.01	121.30	120.36
B. Article 3.4 Forest managament	-1'743.32	-4'184.86	4'521.14	-3'197.64

	2008	2009	2010	2011	2012	2013	2014	2015	2016
	kt CO_2 equivalent								
A. Article 3.3 activities	82.40	118.07	134.56	137.13	138.52	137.48	121.70	104.30	131.84
B. Article 3.4 Forest managament	-1'578.72	-2'617.40	-2'551.05	-1'407.80	-2'671.16	-2'438.38	-1'278.96	-2'720.22	-2'433.61

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 (IPPU) 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 a net GHG sink.

Overall, Switzerland’s GHG emissions decreased in 2016 compared to 1990. This effect is mainly driven by decreases in the Energy and Agriculture sectors, which outweigh the increase in the Industrial processes and product use sector.

Table E- 5 Switzerland's total GHG emissions (excluding LULUCF) in CO_2 equivalent (kt) and the contribution of individual source (positive numbers) and sink (negative numbers) categories.

Source and Sink Categories	1990	1995	2000	2005
	CO_2 equivalent (kt)			
1. Energy	41'826	41'869	42'183	43'993
1A1 Energy industries	2'519	2'643	3'172	3'816
1A2 Manufacturing industries and construction	6'443	6'192	5'925	5'973
1A3 Transport	14'639	14'257	15'927	15'856
1A4 Other sectors	17'641	18'185	16'648	17'895
1A5 Other	220	163	151	139
1B Fugitive emissions from fuels	363	431	360	314
2. Industrial processes and product use	3'576	2'910	3'141	3'769
3. Agriculture	6'672	6'374	5'989	5'963
5. Waste	1'109	912	869	885
6. Other	12	12	13	14
Total (excluding LULUCF)	53'196	52'077	52'195	54'624
4. Land use, land-use change and forestry	-730	-3'964	4'759	-2'558
Total (including LULUCF)	52'466	48'113	56'954	52'065

Source and Sink Categories	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	*2016 vs. 1990*
	CO_2 equivalent (kt)										*%*
1. Energy	41'555	42'948	41'839	43'212	39'148	40'539	41'463	37'421	37'087	37'484	*-10.4%*
1A1 Energy industries	3'719	3'837	3'674	3'847	3'598	3'641	3'736	3'607	3'293	3'380	*34.2%*
1A2 Manufacturing industries and construction	5'946	6'018	5'701	5'817	5'378	5'390	5'484	5'089	4'973	4'982	*-22.7%*
1A3 Transport	16'295	16'646	16'440	16'329	16'147	16'262	16'170	16'061	15'324	15'155	*3.5%*
1A4 Other sectors	15'179	16'040	15'622	16'800	13'614	14'853	15'701	12'296	13'143	13'606	*-22.9%*
1A5 Other	136	131	133	138	125	133	134	139	135	140	*-36.5%*
1B Fugitive emissions from fuels	280	276	269	282	286	261	239	229	219	222	*-38.9%*
2. Industrial processes and product use	3'880	3'928	3'800	4'006	4'076	4'074	4'061	4'107	3'964	3'991	*11.6%*
3. Agriculture	6'061	6'164	6'075	6'089	6'045	6'029	5'968	6'055	5'992	5'963	*-10.6%*
5. Waste	869	852	831	818	803	780	774	764	758	748	*-32.6%*
6. Other	14	13	13	12	13	14	14	12	12	12	*-0.2%*
Total (excluding LULUCF)	52'380	53'906	52'558	54'137	50'086	51'437	52'281	48'359	47'813	48'199	*-9.4%*
4. Land use, land-use change and forestry	-220	-1'121	-2'035	-1'546	-1'322	-1'664	-1'273	-1'308	-1'407	-1'870	*156.2%*
Total (including LULUCF)	52'159	52'785	50'523	52'591	48'765	49'773	51'008	47'051	46'406	46'328	*-11.7%*

It becomes apparent in Figure E- 2 that GHG emissions in the period 1990–2016 are subject to fluctuations with a decreasing trend starting after 2005. The fluctuations derive from the year-to-year variability of the energy sector emissions caused by changing winter temperatures (and hence, changing heating demand). In addition, since 2006 a growing decoupling of fuel combustion emissions and winter temperature conditions is observed. That is, the emission reductions are not only caused by weather conditions, but are also the result of emission reduction measures.

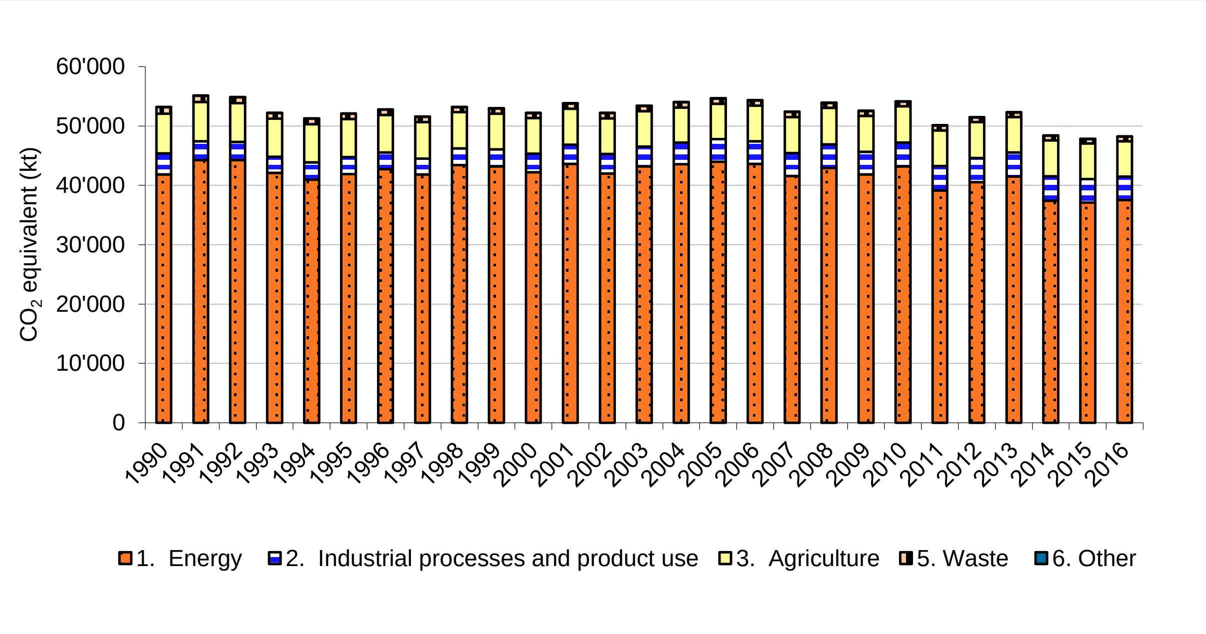

Figure E- 2 Switzerland's GHG emissions in CO_2 equivalent (kt) by sectors excluding LULUCF.

Table E- 6 provides more detailed information on 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 2016. When comparing the contributions in 2016 to 1990, the following development can be observed:

- Slightly lower relative contribution of sectors 1 Energy and 5 Waste.
- Larger relative contributions of sector 2 Industrial processes and product use.
- Similar relative contribution of sectors 3 Agriculture.

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

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	41'826	78.6%	41'869	80.4%	42'183	80.8%	43'993	80.5%	43'212	79.8%
1A1 Energy industries	*2'519*	*4.7%*	2'643	*5.1%*	3'172	*6.1%*	3'816	*7.0%*	3'847	7.1%
1A2 Manufacturing industries and construction	*6'443*	*12.1%*	6'192	*11.9%*	5'925	*11.4%*	5'973	*10.9%*	5'817	*10.7%*
1A3 Transport	*14'639*	*27.5%*	14'257	*27.4%*	15'927	*30.5%*	15'856	*29.0%*	16'329	*30.2%*
1A4 Other sectors	*17'641*	*33.2%*	18'185	*34.9%*	16'648	*31.9%*	17'895	*32.8%*	16'800	*31.0%*
1A5 Other	*220*	*0.4%*	163	*0.3%*	151	*0.3%*	139	*0.3%*	138	*0.3%*
1B Fugitive emissions from fuels	*363*	*0.7%*	431	*0.8%*	360	*0.7%*	314	*0.6%*	282	*0.5%*
2. Industrial processes and product use	3'576	6.7%	2'910	5.6%	3'141	6.0%	3'769	6.9%	4'006	7.4%
3. Agriculture	6'672	12.5%	6'374	12.2%	5'989	11.5%	5'963	10.9%	6'089	11.2%
5. Waste	1'109	2.1%	912	1.8%	869	1.7%	885	1.6%	818	1.5%
6. Other	12	0.0%	12	0.0%	13	0.0%	14	0.0%	12	0.0%
Total (excluding LULUCF)	53'196	100.0%	52'077	100.0%	52'195	100.0%	54'624	100.0%	54'137	100.0%

Source and Sink Categories	**2011**		**2012**		**2013**		**2014**		**2015**		**2016**	
	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
1. Energy	39'148	78.2%	40'539	78.8%	41'463	79.3%	37'421	77.4%	37'087	77.6%	37'484	77.8%
1A1 Energy industries	3'598	*7.2%*	3'641	*7.1%*	3'736	*7.1%*	3'607	*7.5%*	3'293	*6.9%*	3'380	*7.0%*
1A2 Manufacturing industries and construction	5'378	*10.7%*	5'390	*10.5%*	5'484	*10.5%*	5'089	*10.5%*	4'973	*10.4%*	4'982	*10.3%*
1A3 Transport	16'147	*32.2%*	16'262	*31.6%*	16'170	*30.9%*	16'061	*33.2%*	15'324	*32.1%*	15'155	*31.4%*
1A4 Other sectors	13'614	*27.2%*	14'853	*28.9%*	15'701	*30.0%*	12'296	*25.4%*	13'143	*27.5%*	13'606	*28.2%*
1A5 Other	125	*0.2%*	133	*0.3%*	134	*0.3%*	139	*0.3%*	135	*0.3%*	140	*0.3%*
1B Fugitive emissions from fuels	286	*0.6%*	261	*0.5%*	239	*0.5%*	229	*0.5%*	219	*0.5%*	222	*0.5%*
2. Industrial processes and product use	4'076	8.1%	4'074	7.9%	4'061	7.8%	4'107	8.5%	3'964	8.3%	3'991	8.3%
3. Agriculture	6'045	12.1%	6'029	11.7%	5'968	11.4%	6'055	12.5%	5'992	12.5%	5'963	12.4%
5. Waste	803	1.6%	780	1.5%	774	1.5%	764	1.6%	758	1.6%	748	1.6%
6. Other	13	0.0%	14	0.0%	14	0.0%	12	0.0%	12	0.0%	12	0.0%
Total (excluding LULUCF)	50'086	100.0%	51'437	100.0%	52'281	100.0%	48'359	100.0%	47'813	100.0%	48'199	100.0%

ES.3.2 KP-LULUCF activities

An overview of net CO_2 eq 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 Figure E- 3.

Detailed quantitative information for the years 1990–2016 is reported in chp. 11.4, chp. 11.5, and displayed in Table 11-1. Annual changes in the emissions from Afforestation and Deforestation can be directly attributed to the changes in their area (Table 11-2). The relative changes in the area of managed forest are comparatively small and fluctuations of the annual net carbon stock changes in Forest management can primarily be explained by changes in the losses from living biomass, dead wood and litter pools. The extraordinary high emissions of the Forest management sector in 2000 and the small removals in the following year 2001 originate from winter storm “Lothar” at the end of 1999, which caused large-scale damages in the forest stands and increased losses of living biomass due to salvage logging. Harvesting rates in Swiss forests gradually increased between 1991 and 2007, reaching peak values in 2006 and 2007, resulting in small removals from Forest management in those years. Because harvesting rates started to decline in 2008 (Table 6-16) due to the international and domestic economic framework conditions, removals from Forest management are increasing since 2008 with a large year-to-year variability. Fluctuations in the HWP pool are mainly caused by changes in the production of sawnwood and paper and paperboard (see chp. 6.11 and Table 6-35).

Table E- 7 Net CO_2 eq emissions (positive sign) and removals (negative sign) of activities accounted for under Article 3, paragraph 3 (Afforestation, Deforestation) and paragraph 4 (Forest management and Havested wood products HWP) of the Kyoto Protocol in kt CO_2 eq.

	1990	1995	2000	2005
	kt CO_2 equivalent			
A. Article 3.3 activities	89.26	107.01	121.30	120.36
Afforestation	-3.17	-15.66	-20.48	-24.53
Deforestation	92.43	122.67	141.78	144.89
B. Article 3.4 Forest Management	-1'743.32	-4'184.86	4'521.14	-3'197.64
Forest management excl. HWP	-438.52	-3'680.90	5'230.41	-2'457.68
HWP	-1'304.80	-503.96	-709.27	-739.96

	2008	2009	2010	2011	2012	2013	2014	2015	2016
	kt CO_2 equivalent								
A. Article 3.3 activities	82.40	118.07	134.56	137.13	138.52	137.48	121.70	104.30	131.84
Afforestation	-26.85	-27.61	-22.47	-20.47	-19.81	-18.88	-16.78	-18.23	-19.61
Deforestation	109.25	145.68	157.03	157.60	158.33	156.36	138.48	122.53	151.44
B. Article 3.4 Forest Management	-1'578.72	-2'617.40	-2'551.05	-1'407.80	-2'671.16	-2'438.38	-1'278.96	-2'720.22	-2'433.61
Forest management excl. HWP	-1'192.83	-2'207.30	-2'135.91	-948.99	-2'377.27	-2'348.71	-978.42	-2'492.92	-2'220.11
HWP	-385.88	-410.10	-415.14	-458.81	-293.89	-89.67	-300.54	-227.30	-213.50

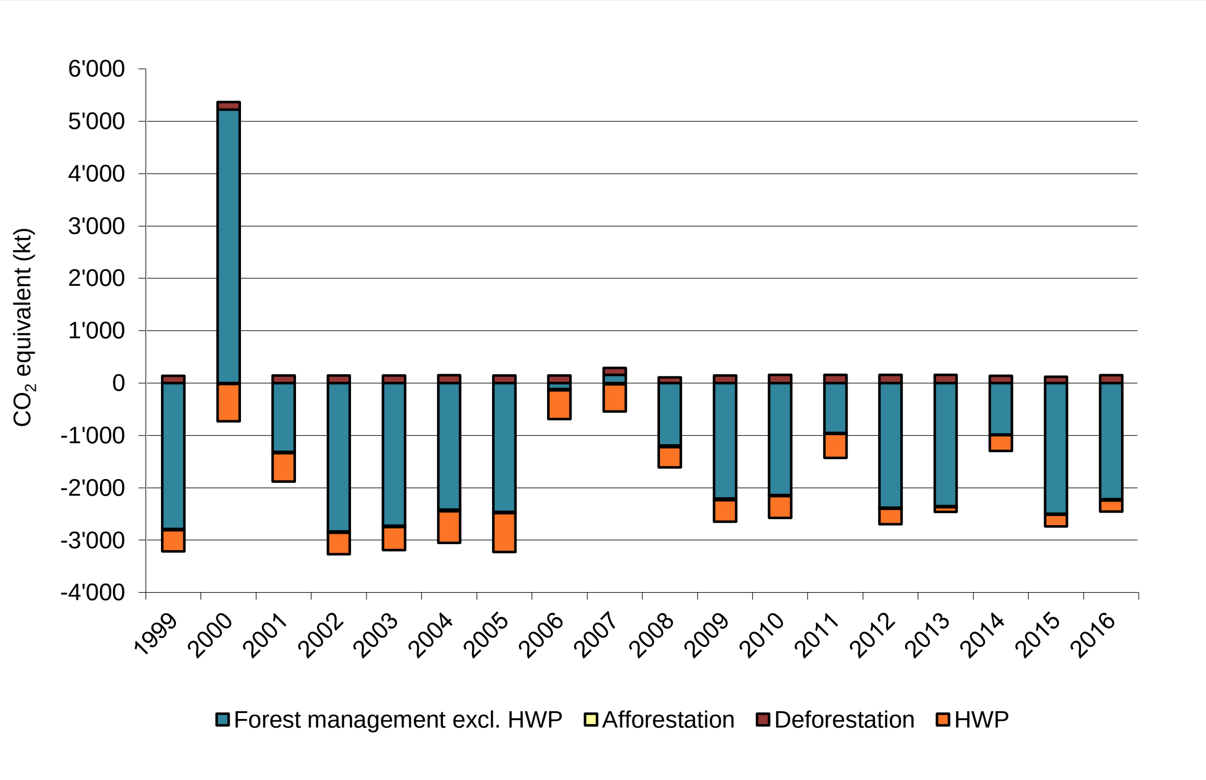

Figure E- 3 GHG emissions (positive sign) and removals (negative sign). Shown are data for Afforestation (too small to be distinguishable) and Deforestation under Article 3, paragraph 3, Forest management excluding HWP and HWP under Article 3, paragraph 4.

ES.3.3 GHG inventory (Kyoto Protocol)

Relevant emissions and removals under the Kyoto Protocol by sectors and GHG are shown in Table E- 8 and Table E- 9. Total emissions reported under the Kyoto Protocol differ from those reported under the UNFCCC because sectors 4 LULUCF and 6 Other and international bunkers are not accounted for under the Kyoto Protocol. However, activities under Article 3, paragraph 3 (Afforestation, Reforestation and Deforestation) and Article 3, paragraph 4 (Forest management, Cropland management, Grazing land management, and Revegetation) as well as indirect CO_2 emissions are included in the tables. Under the 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) are reported in Switzerland's Second Initial Report (FOEN 2016c) and the update to the report following the UNFCCC in-country review (FOEN 2016d).

Table E- 8 Summary of Switzerland's GHG emissions in CO_2 equivalent (kt) as well as emissions and removals under KP-LULUCF by sectors. Excluded are emissions and removals from sectors 4 LULUCF, 6 Other and from International bunkers.

		Sector	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		1 Energy + indirect CO_2 from this sector	41'881	41'870	44'260	44'297	42'121	41'003	41'897	42'768	41'848	43'418
		2 Industrial processes and product use + indirect CO_2 from this sector	3'887	3'932	3'531	3'340	3'001	3'176	3'145	2'997	2'893	2'990
		3 Agriculture	6'804	6'672	6'633	6'522	6'414	6'402	6'374	6'337	6'147	6'103
		5 Waste + indirect CO_2 from this sector	1'135	1'111	1'022	1'023	972	914	914	904	891	876
		Total (Annex A sources)	**53'707**	**53'585**	**55'445**	**55'182**	**52'508**	**51'494**	**52'329**	**53'006**	**51'780**	**53'388**

		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	43'209	42'200	43'615	42'012	43'205	43'571	44'006	43'617	41'568	42'961
		2 Industrial processes and product use + indirect CO_2 from this sector	3'049	3'301	3'393	3'423	3'491	3'751	3'874	3'902	3'983	4'031
		3 Agriculture	6'010	5'989	6'045	6'007	5'932	5'912	5'963	6'004	6'061	6'164
		5 Waste + indirect CO_2 from this sector	865	871	885	897	876	895	886	886	870	854
		Total (Annex A sources)	**53'132**	**52'361**	**53'939**	**52'339**	**53'504**	**54'129**	**54'730**	**54'409**	**52'482**	**54'009**
KP-LULUCF	Art.3.3	Afforestation & Reforestation										-27
		Deforestation										109
	Art.3.4	Forest management										-1'579
		Cropland management										NA
		Grazing land management										NA
		Revegetation										NA

		Sector	2009	2010	2011	2012	2013	2014	2015	2016	*2016 vs. 1990*
			CO_2 equivalent (kt)								*%*
Annex A sources		1 Energy + indirect CO_2 from this sector	41'851	43'223	39'159	40'549	41'474	37'432	37'096	37'493	*-10%*
		2 Industrial processes and product use + indirect CO_2 from this sector	3'903	4'109	4'178	4'175	4'161	4'206	4'063	4'088	*4%*
		3 Agriculture	6'075	6'089	6'045	6'029	5'968	6'055	5'992	5'963	*-11%*
		5 Waste + indirect CO_2 from this sector	832	820	805	781	776	766	759	749	*-33%*
		Total (Annex A sources)	**52'661**	**54'240**	**50'187**	**51'535**	**52'379**	**48'459**	**47'909**	**48'293**	***-10%***
KP-LULUCF	Art.3.3	Afforestation & Reforestation	-28	-22	-20	-20	-19	-17	-18	-20	
		Deforestation	146	157	158	158	156	138	123	151	
	Art.3.4	Forest management	-2'617	-2'551	-1'408	-2'671	-2'438	-1'279	-2'720	-2'434	
		Cropland management	NA	NA	NA	NA	NA	NA	NA	NA	
		Grazing land management	NA	NA	NA	NA	NA	NA	NA	NA	
		Revegetation	NA	NA	NA	NA	NA	NA	NA	NA	

Table E- 9 Switzerland's total GHG emissions (excluding 4 LULUCF, 6 Other and International bunkers) and the contribution of individual gases in CO_2 equivalent (kt), as well as emissions and removals under KP-LULUCF.

		GHG	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		CO_2 + indirect CO_2	44'516	44'553	46'505	46'352	43'908	42'953	43'667	44'331	43'249	44'806
		CH_4	6'086	6'005	5'937	5'854	5'746	5'696	5'688	5'645	5'503	5'435
		N_2O	2'852	2'774	2'764	2'738	2'666	2'638	2'622	2'626	2'524	2'517
		HFCs	0.0	0.0	1.5	15	32	79	242	294	358	454
		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)	**53'707**	**53'585**	**55'445**	**55'182**	**52'508**	**51'494**	**52'329**	**53'006**	**51'780**	**53'388**

		GHG	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO_2 equivalent (kt)									
Annex A sources		CO_2 + indirect CO_2	44'620	43'779	45'232	43'599	44'769	45'339	45'887	45'474	43'463	44'812
		CH_4	5'338	5'286	5'324	5'281	5'201	5'167	5'183	5'195	5'174	5'250
		N_2O	2'478	2'468	2'477	2'446	2'400	2'363	2'364	2'369	2'395	2'417
		HFCs	531	634	733	822	908	1'009	1'049	1'133	1'229	1'250
		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)	**53'132**	**52'361**	**53'939**	**52'339**	**53'504**	**54'129**	**54'730**	**54'409**	**52'482**	**54'009**
KP-LULUCF	Art.3.3	CO_2										80
		CH_4										NO
		N_2O										2.1
	Art.3.4	CO_2										-1'583
		CH_4										2.7
		N_2O										1.2

		GHG	2009	2010	2011	2012	2013	2014	2015	2016	*2016 vs.1990*
			CO_2 equivalent (kt)								*%*
Annex A sources		CO_2 + indirect CO_2	43'632	45'149	41'082	42'350	43'282	39'339	38'835	39'301	*-12%*
		CH_4	5'157	5'129	5'075	5'047	4'985	4'982	4'955	4'907	*-18%*
		N_2O	2'377	2'426	2'370	2'355	2'314	2'328	2'285	2'300	*-17%*
		HFCs	1'247	1'316	1'426	1'502	1'494	1'507	1'523	1'523	*see caption*
		PFCs	63	64	69	71	51	43	55	55	*-53%*
		SF_6	180	148	160	209	252	259	256	207	*51%*
		NF_3	5.1	8.5	6.2	0.4	0.1	0.4	0.5	0.5	*NA*
		Total (Annex A sources)	**52'661**	**54'240**	**50'187**	**51'535**	**52'379**	**48'459**	**47'909**	**48'293**	***-10%***
KP-LULUCF	Art.3.3	CO_2	116	132	135	136	135	119	102	130	
		CH_4	NO	NO	NO	NO	NO	NO	NO	NO	
		N_2O	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	
	Art.3.4	CO_2	-2'621	-2'554	-1'414	-2'674	-2'442	-1'282	-2'724	-2'441	
		CH_4	2.7	2.3	4.0	2.2	2.2	2.4	2.4	5.0	
		N_2O	1.2	1.0	2.2	1.0	1.0	1.1	1.1	2.8	

ES.4. Other information

Emissions from 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 by 56% (NO_x) up to 85% (SO_2) in the period 1990–2016 in emissions of precursor gases and SO_2. 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 within the industry sector (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.

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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). Long-term measurements indicate a marked shift towards a warmer climate for Switzerland, +2.0 degrees Celsius between 1864 and 2016 compared to +0.9 degrees Celsius globally (FOEN 2018d). This corresponds to a linear increasing temperature trend of about 0.13 degrees Celsius per decade, with a substantially accelerated warming in recent decades (CH2011 2011). In the course of the 21st century, Swiss climate is projected to depart significantly from present and past conditions. Mean temperature will very likely increase in all regions and seasons. Summer mean precipitation will likely decrease by the end of the century all over Switzerland (decrease by 21–28 per cent for the A2 scenario and 18–24 per cent for the A1B scenario), while winter precipitation will likely increase in Southern Switzerland for the investigated emission scenarios A2, A1B and RCP3PD. In other regions and seasons, models indicate that mean precipitation could either increase or decrease. For further information about projections of future temperature and precipitation see FOEN (2018d)[1].

The retreat and massive loss of volume of glaciers in the Alps is the best visible indicator of the recent increase in atmospheric temperature. The changes of the glaciers in the Swiss Alps are measured every year and compiled by the network GLAMOS. In recent years evidence of vigorous impacts on glaciers has been accumulated, including collapse structures on the glacier surface, disintegration into pieces, separation of glacier tongues from the main ice body at steep slopes, leaving dead ice in formerly covered areas. At various locations all over the Swiss Alps glacier lakes have formed or grown as a result of continuing glacier retreat. From the ca. 2’900 square kilometres of glacier area in the mid-1970s, only about 2’100 square kilometres remained in 2003 and an estimated 1’900 square kilometres in 2013. The first glacier-wide mass-balance records worldwide with a coverage of 100 years showed that mass balances were predominantly negative between 1920 and 1965, with accelerated mass loss in the 1940s. After a phase with moderate mass gains lasting until the late 1980s, persistently negative balances have been observed until the

[1] Please note that a couple of sentences about climate change are literally cited from Switzerland’s 7th National Communication (NC7, FOEN 2018d), but the original data sources are not referenced here. The reader is invited to look in NC7 for finding original references.
https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/klima-climatereporting/7th_national_communication_1st_biennial_report_2018.pdf.pdf.download.pdf/CHE_NC7_BR3_2018.pdf [28.02.2018]

present (FOEN 2018d). Several studies indicate that Alpine glaciers are far out of balance with the current climate. Due to delayed response effects, glaciers would continue to shrink even without any further increase in temperature. If temperatures are going to increase further as projected by climate models e.g. Swiss Climate Change Scenarios (CH2011 2011), the loss of glaciers will be much more dramatic. Modelling studies indicate a strong future area loss of 50–90 per cent (for a temperature increase between two and six degrees Celsius) by 2100 for Switzerland and the entire Alps (FOEN 2018d).

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 with indicators such as the phenological spring phases, flowering indices and animal specific indices (FOEN 2018g). They show significant changes in a wide range of ecosystems during the last decades. 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 raise the vulnerability of forests and impair their protective, productive and social functions. Species distribution shifts towards higher elevations, spread of thermophile species, colonisation by new species from warmer areas, and phenological shifts. In the driest areas, increasing droughts are affecting tree survival and fish species are suffering from warm temperatures in lowland regions. River ecosystems will be doubly affected by climate change, i.e. by both the higher air temperature and the seasonal redistribution of river flows. Higher air temperatures together with the associated higher water temper-atures and lower water levels in summer are likely to put pressure on river ecology and thereby also on fishing (FOEN 2018d).

In general, climate change in Switzerland is expected to entail a shift of suitable areas for agricultural production, and to involve both positive (e.g. a longer vegetation period) and negative (e.g. increasing incidence of pest infestations owing to milder winters) aspects. Changes in the nature of extreme weather events, in particular more frequent, intense and longer-lasting summer heat waves, could also challenge agriculture, e.g. by reducing the reliability of harvests. The extent to which climate change will affect agriculture will depend, however, on the regional settings, the overall political framework and the specific economic situation of the farms. Economic considerations are expected to play a crucial role for the adoption of adaptation measures (FOEN 2018d).

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 and 2015 (FOEN 2016l). 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).

In 2016 a comprehensive overview on Swiss climate – basics, consequences and perspectives – has been published by the Swiss Academies of Sciences (SCNAT 2016).

With the advancement of new higher-resolved regional climate model projections over Europe from the EURO-CORDEX initiative (http://www.euro-cordex.net/) and with an improved scientific understanding, it is desirable to update the national scenarios of 2011. The new generation of climate change scenarios for Switzerland ("CH2018 scenarios"), to be launched in 2018, is developed as a focus area of the National Centre for Climate Services. As in CH2011 (2011), this project involves several partners from academia and federal offices (http://www.ch2018.ch/).

1.1.2 Information on the greenhouse gas inventory

On 10 December 1993, Switzerland ratified the 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 28th November 2016 (ISO 9001:2008, Swiss-TS 2016). 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 UNFCCC. The Initial Report for the second commitment period (FOEN 2016c) was submitted simultaneously with the inventory 2016. An update following the in-country review by an expert review team was submitted on 7th November 2016 to the UNFCCC secretariat (FOEN 2016d).

The 2015 inventory submission under the UNFCCC 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 part of the submission included the NIR sumitted on 27 April 2015 and the standard electronic format (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 2018 inventory submission under the UNFCCC and under the Kyoto Protocol includes the NIR on hand, the Greenhouse gas inventory 1990 to 2016, the Kyoto Protocol LULUCF tables 2008 to 2016 in the CRF 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, FOEN 2016d). In addition to the mandatory submission of the inventory years 2013–2016, data for the years 1990–2012 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 of the FOEN, is fully operational ever since and ensures timely fulfilment of Switzerland’s reporting obligations.

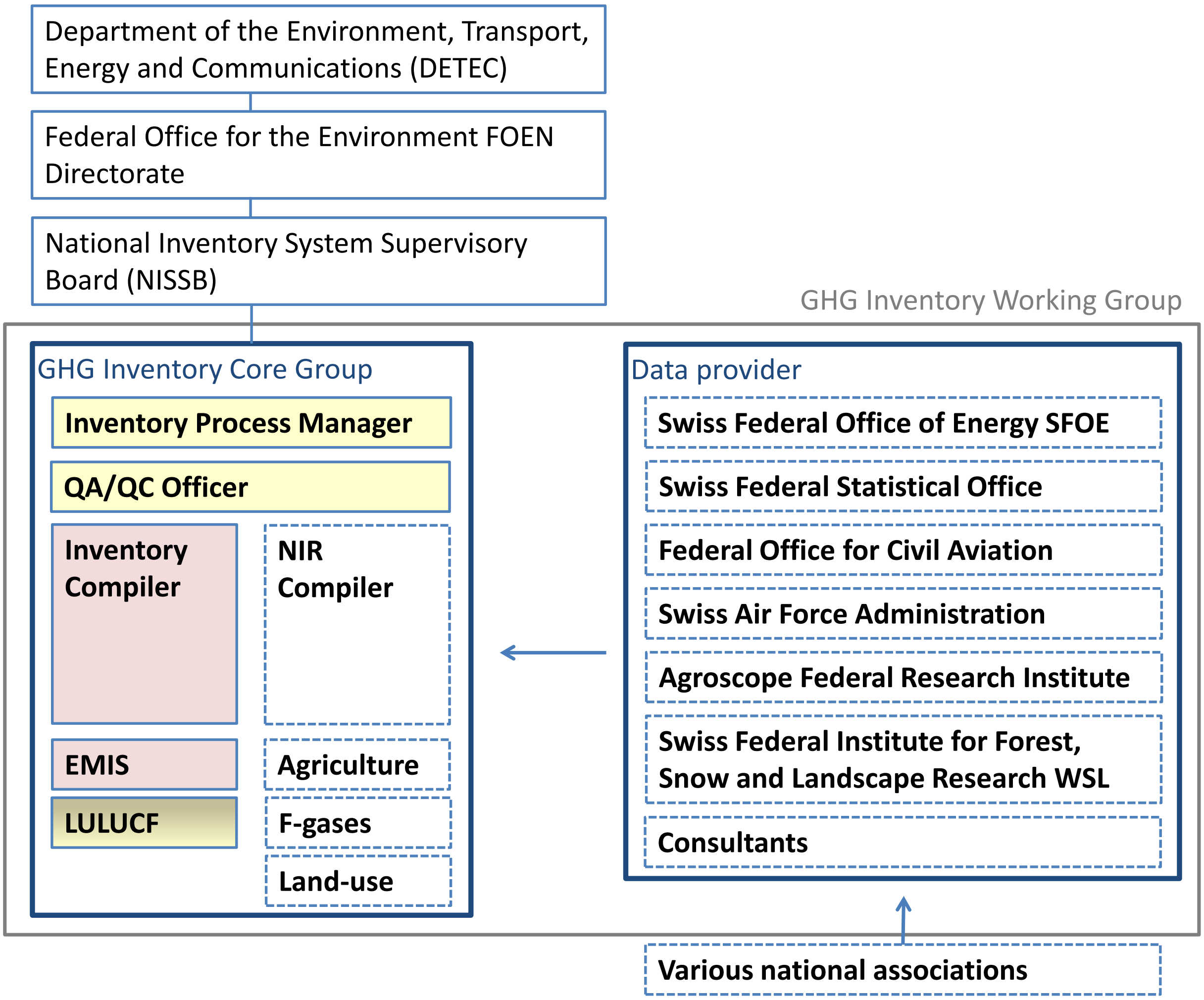

Figure 1-1 Institutional arrangements of the National Inventory System. Colours refer to divisions at FOEN. yellow: Climate division, red: Air Pollution Control and Chemicals division, beige: Forest division.

Legal arrangements

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

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

Institutional arrangements

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

The overall responsibility for the greenhouse gas inventory lies with the Climate division of the FOEN. The Air Pollution Control and Chemicals division of the FOEN maintains and updates the emissions database (greenhouse gases and air pollutants), named EMIS, 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:

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Climate Division, Climate Reporting and Adaptation Section
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www.climatereporting.ch

Table 1-1 Overview of the institutional arrangements and tasks

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). In 2014 the NISSB, which originally covered the National Inventory System as well as the National Registry, was formally split in two separate boards with separate mandates and responsibilities. Since then, the NISSB is overseeing all aspects related to reporting obligations under the UNFCCC (including reporting of the National Registry in the NIR), while the Emission Registry Supervisory Board (ERSB) deals with management issues related to the National Registry.

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 (IDP). 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 IDP 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-2016). 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 2018a) – as required by ISO 9001:2008 – contains all relevant information regarding the QMS. It is updated annually and available to all members of the GHG inventory core group. Currently, the QMS is in preparation to comply with the requirements of ISO 9001:2015. The re-certification is planned for June 2018.

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.

Recalculations are compiled in a document and made available to the data compilers and the members of the GHG inventory core group including the NIR authors. 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 the EMIS database experts. Then, after the required changes were implemented by the EMIS experts, also by the NIR authors.

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

Category-specific QC procedures

Whenever new emission factors are considered, they are compared to the IPCC default values and to the values used in previous years. If the values are based on better or more appropriate data and compare reasonably well with the IPCC default values (or if differences can be explained), the new values are presented to the core group for adoption in future inventories. Similarly, if new activity data have become available for a particular category, a comparison between existing and new activity data is made and if the new data provide a more consistent or more reliable basis for the inventory, they are again presented to the core group for inclusion in future inventories. Quite often, sectoral and/or EMIS experts commission research to look into a particular topic in more detail. Results from these mid- to long-term projects are presented to the inventory core group. The core group decides on how to best implement the results and documents the agreed procedure in the inventory development plan. The general procedures regarding category-specific QC is also described in the quality manual (FOEN 2018a), 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. In 2017, an expert peer review for Harvested wood products (HWP) has been conducted (Didion 2017). In 2017, an expert peer review for waste water treatment was initiated with experts by the Eawag (Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz). Previous expert peer reviews covered the Industrial Processes (CSD 2013), LULUCF (VTI 2011) and Waste sector (Rytec 2010).

Likewise, recommendations and encouragements from the UNFCCC expert review teams (ERT) are also added to the inventory development plan, discussed in the core group and implemented in future submissions. 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 Table1.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 CH_4 emissions in Switzerland based on atmospheric CH_4 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 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. In a next step, it will be investigated to what extent the approach could be applied to N_2O. The research project is therefore extended to also cover N_2O, and measurements of atmospheric N_2O concentrations commenced in March 2017.

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 refer to a single enterprise are 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, NF_3 and SF_6 from private companies or industry associations. In the National Inventory Report, the activity data underlying emission estimates of HFCs, PFCs, NF_3 and SF_6 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, reporting 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 and with contractors from private companies. The agreements regarding responsibilities and deliverables are maintained.

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

A member of the EMIS team left per 1. July 2017. His tasks concerning data import of the Agriculture sector have been taken over by another team member, who is part of the team since 2009. A new recruit will join the team in spring 2018.

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.):

No changes.

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 (see 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 (IPCC 2006) and the revised reporting tables (CRF). The software in use is called “Mesap”, Release 5.3.9 by Seven2one information systems (Seven2one 2014); it is running on commonly used laptops or desktop computers as client. The EMIS database is stored as SQL database on a server.

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 2018/NFR-Code” in this report.

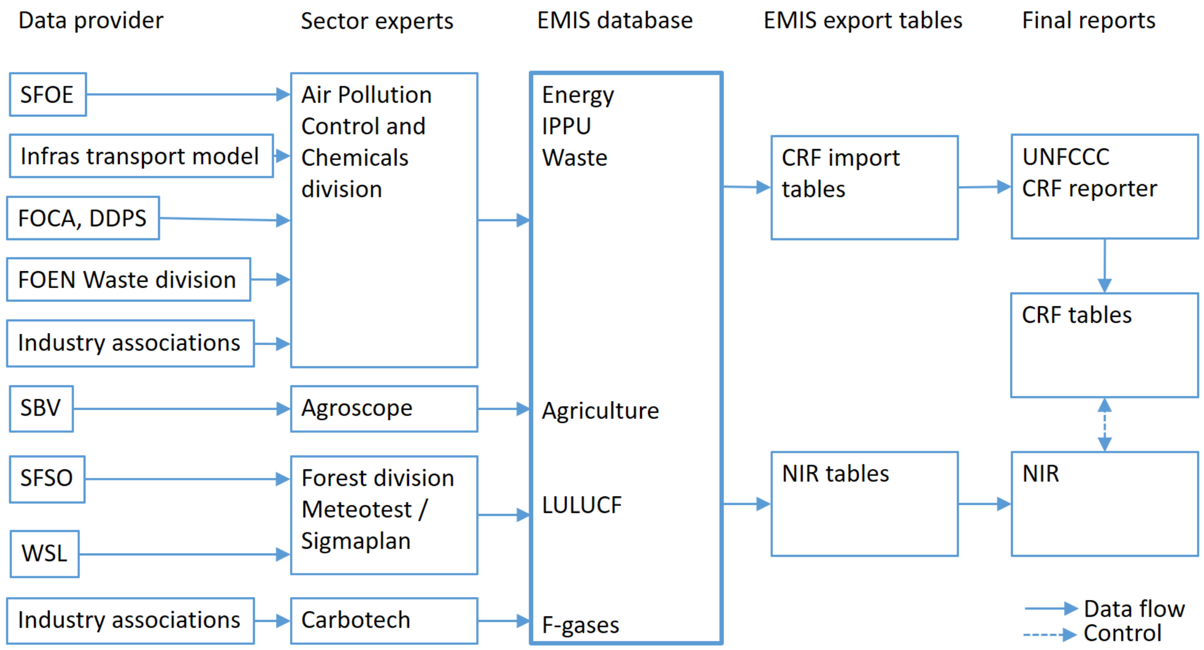

Figure 1-2 Schematic overview: Data collection and processing, compilation in EMIS database, import into CRF Reporter and National Inventory Report (NIR). Abbreviations: see glossary.

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 CRF Summary3s1 and CRF Summary3s2.

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 non-road emission models of INFRAS, the complete area survey by the SFSO as well as the national forest inventory by the WSL require large efforts and are therefore updated every couple of years. Coloured boxes mark those sectors to which each data provider contributes. Abbreviations: see glossary.

Institution	**Subject**	**Inventory category (numbering according to reporting tables)**											
		1A1	1A2	1A3	1A4	1A5	1B	2	3	4 / KP	5	6	indir. CO2/ N2O
FOEN, Air Pollution Control and Chemicals division	EMIS database	■	■		■	■	■	■	■		■	■	■
FOEN, Climate division	monitring data due to ordinance of reduction of CO2 (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

The aim of the key category analysis (KCA) is to identify relevant categories that have a strong influence on Switzerland's GHG inventory in terms of absolute emission and removal levels, trends and uncertainties (IPCC 2006, chp. 4). Data collection as well as quality assurance and control are prioritised for key categories during the inventory resource allocation.

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 (2016) including all GHG (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3). A total of 162 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. A table showing the key category analysis with all 162 categories is provided in the annex (Table A – 1).

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 N_2O emissions are not considered for the key category analysis. However, indirect CO_2 emissions are considered for the key category analysis in this submission.

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.

1.5.1.2 KCA (including LULUCF categories)

Approach 1

For 2016, among the total of 162 categories, 30 are identified as **level key categories** under Approach 1 (see Table 1-4).

Fifteen of the key categories belong to sector 1 Energy, accounting for the largest share of CO_2 equivalent emissions in 2016. The other key categories are more or less equally distributed between sectors 2 Industrial processes and product use (3 key categories), 3 Agriculture (5 key categories), 4 LULUCF (5 key categories) and 5 Waste (2 key categories).

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, CO_2
- 1A3b Fuel Combustion, Road Transportation, Diesel, CO_2
- 1A4b Fuel Combustion, Other Sectors, Residential, Liquid Fuels, CO_2

Within the ten most relevant key categories (level contribution), only 3A Enteric fermentation and 4A1 Forest land remaining forest land are not part of sector 1 Energy.

Table 1-4 Switzerland's Approach 1 level key categories for the year 2016 including LULUCF categories, sorted by emission contribution to the national total.

APPROACH 1 LEVEL ASSESSMENT FOR 2016						
A	B	C	D	E	F	G
Code	**IPCC Category**	**GHG**	**Ex,t (kt CO2 eq)**	**|Ex,t| (kt CO2 eq)**	**Lx,t**	**Cumula-tive Total**
1A3b	Road transportation: Gasoline	CO2	7426	7426	14.3%	14.3%
1A3b	Road transportation: Diesel	CO2	7281	7281	14.0%	28.3%
1A4b	Residential: Liquid fuels	CO2	6006	6006	11.5%	39.8%
3A	Enteric Fermentation	CH4	3325	3325	6.4%	46.2%
1A4a	Commercial: Liquid fuels	CO2	2789	2789	5.4%	51.6%
1A4b	Residential: Gaseous fuels	CO2	2754	2754	5.3%	56.8%
1A1	Energy industries: Other fuels	CO2	2454	2454	4.7%	61.6%
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	2234	2234	4.3%	65.9%
4A1	forest land remaining forest land	CO2	-2197	2197	4.2%	70.1%
1A2	Manufacturing industry and construction: Liquid fuels	CO2	1854	1854	3.6%	73.6%
2A1	Cement production	CO2	1769	1769	3.4%	77.0%
1A4a	Commercial: Gaseous fuels	CO2	1490	1490	2.9%	79.9%
2F1	Refrigeration and air conditioning	HFC	1287	1287	2.5%	82.4%
3Da	Direct emissions from managed soils	N2O	1080	1080	2.1%	84.5%
3B1-3B4	Manure management	CH4	753	753	1.4%	85.9%
1A1	Energy industries: Gaseous fuels	CO2	505	505	1.0%	86.9%
4A2	Land converted to forest	CO2	-442	442	0.8%	87.7%
1A2	Manufacturing industry and construction: Solid fuels	CO2	436	436	0.8%	88.6%
1A2	Manufacturing industry and construction: Other fuels	CO2	415	415	0.8%	89.4%
3Db	Indirect emissions from managed soils	N2O	412	412	0.8%	90.1%
1A4c	Agriculture and forestry: Liquid fuels	CO2	403	403	0.8%	90.9%
1A1	Energy industries: Liquid fuels	CO2	393	393	0.8%	91.7%
5A	Solid waste disposal	CH4	335	335	0.6%	92.3%
3B5	Indirect N2O emissions from manure management	N2O	271	271	0.5%	92.8%
4G	HWP harvest wood products	CO2 biog.	-213	213	0.4%	93.3%
4E2	Land converted to settlements	CO2	194	194	0.4%	93.6%
1B2	Oil and natural gas energy production	CH4	194	194	0.4%	94.0%
4C2	Land converted to grassland	CO2	189	189	0.4%	94.4%
2G	Other product manufacture and use	SF6	182	182	0.3%	94.7%
5D	Wastewater treatment and discharge	CH4	180	180	0.3%	95.1%

For the **base year 1990**, 31 categories are identified as **level key categories** under Approach 1 (see Table 1-5). The following categories are key according to level in the base year 1990, but not anymore in the current year 2016:

- 1A3a Civil Aviation, Liquid Fuels, CO_2
- 1A5 Other (Military), Liquid fuels, CO_2
- 2A4 Other process uses of carbonates, CO_2
- 2 Indirect CO_2 emissions, CO_2
- 4B1 Cropland remaining cropland, CO_2

On the other hand, the following categories are key according to level in the current year 2016, but not in the base year 1990:

- 2F1 Refrigeration and air conditioning, HFC
- 2G Other product manufacture and use, SF_6
- 4C2 Land converted to grassland, CO_2
- 5D Wastewater treatment and discharge, CH_4

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 LEVEL ASSESSMENT FOR BASE YEAR						
A	**B**	**C**	**D**	**E**	**F**	**G**
Code	**IPCC Category**	**GHG**	**Ex,0 (kt CO2 eq)**	**|Ex,0| (kt CO2 eq)**	**Lx,0**	**Cumula-tive Total of Column F**
1A3b	Road transportation: Gasoline	CO2	11334	11334	19.7%	19.7%
1A4b	Residential: Liquid fuels	CO2	10099	10099	17.5%	37.2%
1A4a	Commercial: Liquid fuels	CO2	4261	4261	7.4%	44.6%
1A2	Manufacturing industry and construction: Liquid fuels	CO2	3889	3889	6.8%	51.4%
3A	Enteric Fermentation	CH4	3585	3585	6.2%	57.6%
1A3b	Road transportation: Diesel	CO2	2633	2633	4.6%	62.2%
2A1	Cement production	CO2	2581	2581	4.5%	66.7%
1A1	Energy industries: Other fuels	CO2	1492	1492	2.6%	69.2%
1A4b	Residential: Gaseous fuels	CO2	1429	1429	2.5%	71.7%
4G	HWP harvest wood products	CO2 biog.	-1305	1305	2.3%	74.0%
1A2	Manufacturing industry and construction: Solid fuels	CO2	1275	1275	2.2%	76.2%
3Da	Direct emissions from managed soils	N2O	1247	1247	2.2%	78.4%
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	1050	1050	1.8%	80.2%
1A4a	Commercial: Gaseous fuels	CO2	1013	1013	1.8%	81.9%
4B1	Cropland remaining cropland	CO2	913	913	1.6%	83.5%
3B1-3B4	Manure management	CH4	869	869	1.5%	85.0%
5A	Solid waste disposal	CH4	763	763	1.3%	86.4%
1A1	Energy industries: Liquid fuels	CO2	686	686	1.2%	87.6%
3Db	Indirect emissions from managed soils	N2O	588	588	1.0%	88.6%
4A2	Land converted to forest	CO2	-581	581	1.0%	89.6%
1A4c	Agriculture and forestry: Liquid fuels	CO2	485	485	0.8%	90.4%
4A1	forest land remaining forest land	CO2	-425	425	0.7%	91.2%
2	Indirect CO2 emissions	CO2	356	356	0.6%	91.8%
1B2	Oil and natural gas energy production	CH4	336	336	0.6%	92.4%
4E2	Land converted to settlements	CO2	260	260	0.5%	92.8%
1A3a	Civil aviation: Liquid fuels	CO2	253	253	0.4%	93.3%
1A1	Energy industries: Gaseous fuels	CO2	243	243	0.4%	93.7%
3B5	Indirect N2O emissions from manure management	N2O	230	230	0.4%	94.1%
1A5	Other (military): Liquid fuels	CO2	218	218	0.4%	94.5%
1A2	Manufacturing industry and construction: Other fuels	CO2	192	192	0.3%	94.8%
2A4	Other process uses of carbonates	CO2	163	163	0.3%	95.1%

Regarding the **trend assessment** between the base year 1990 and the most recent year 2016, 33 categories are identified as trend key categories under Approach 1 (see Table 1-6).

Table 1-6 Switzerland's Approach 1 trend key categories between 1990 and 2016 including LULUCF categories, sorted by contribution to the trend assessment.

APPROACH 1 TREND ASSESSMENT FOR 2016							
A	B	C	D	E	F	G	H
Code	**IPCC Category**	**GHG**	**Ex,0 (kt CO2 eq)**	**Ex,t (kt CO2 eq)**	**Trend Assess-ment**	**Contri-bution to Trend**	**Cumula-tive Total of Column G**
1A3b	Road transportation: Diesel	CO2	2633	7281	0.086%	18.1%	18.1%
1A4b	Residential: Liquid fuels	CO2	10099	6006	0.049%	10.3%	28.4%
1A3b	Road transportation: Gasoline	CO2	11334	7426	0.044%	9.1%	37.5%
4A1	forest land remaining forest land	CO2	-425	-2197	0.030%	6.2%	43.7%
1A2	Manufacturing industry and construction: Liquid fuels	CO2	3889	1854	0.027%	5.6%	49.4%
1A4b	Residential: Gaseous fuels	CO2	1429	2754	0.026%	5.5%	54.8%
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	1050	2234	0.023%	4.8%	59.6%
2F1	Refrigeration and air conditioning	HFC	0	1287	0.022%	4.7%	64.3%
4G	HWP harvest wood products	CO2 biog.	-1305	-213	0.022%	4.5%	68.8%
1A1	Energy industries: Other fuels	CO2	1492	2454	0.020%	4.2%	73.0%
1A4a	Commercial: Liquid fuels	CO2	4261	2789	0.016%	3.4%	76.4%
1A2	Manufacturing industry and construction: Solid fuels	CO2	1275	436	0.012%	2.5%	78.9%
4B1	Cropland remaining cropland	CO2	913	156	0.011%	2.3%	81.2%
1A4a	Commercial: Gaseous fuels	CO2	1013	1490	0.010%	2.2%	83.4%
2A1	Cement production	CO2	2581	1769	0.009%	1.8%	85.2%
5A	Solid waste disposal	CH4	763	335	0.006%	1.2%	86.4%
1A1	Energy industries: Gaseous fuels	CO2	243	505	0.005%	1.1%	87.5%
1A2	Manufacturing industry and construction: Other fuels	CO2	192	415	0.004%	0.9%	88.4%
2	Indirect CO2 emissions	CO2	356	97	0.004%	0.8%	89.1%
4A2	Land converted to forest	CO2	-581	-442	0.004%	0.8%	89.9%
1A1	Energy industries: Liquid fuels	CO2	686	393	0.004%	0.8%	90.7%
3A	Enteric Fermentation	CH4	3585	3325	0.003%	0.7%	91.3%
4C2	Land converted to grassland	CO2	68	189	0.002%	0.5%	91.8%
2C3	Aluminium production	CO2	139	0	0.002%	0.4%	92.2%
3Db	Indirect emissions from managed soils	N2O	588	412	0.002%	0.4%	92.6%
2C3	Aluminium production	PFC	116	0	0.002%	0.4%	93.0%
1B2	Oil and natural gas energy production	CH4	336	194	0.002%	0.4%	93.3%
1A3b	Road transportation: Gasoline	N2O	134	20	0.002%	0.4%	93.7%
2G	Other product manufacture and use	HFC	0	85	0.001%	0.3%	94.0%
1A3a	Civil aviation: Liquid fuels	CO2	253	141	0.001%	0.3%	94.3%
1A3b	Road transportation: Gasoline	CH4	98	13	0.001%	0.3%	94.6%
1A4b	Residential: Biomass	CH4	110	26	0.001%	0.3%	94.8%
3B5	Indirect N2O emissions from manure management	N2O	230	271	0.001%	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 for both, level and trend assessment.

Concerning the **level assessment**, 25 out of 162 categories are identified as key categories for the current reporting year 2016 (see Table 1-7).

The most relevant sources in 2016 which contribute 10% or more to the level assessment are the following:

- 4A1 Forest land remaining forest land, CO_2

- 3Da Direct emissions from managed soils, N_2O
- 4C1 Grassland remaining grassland, CO_2

Table 1-7 Switzerland's Approach 2 level key categories for the year 2016 including LULUCF categories, sorted by contribution to the uncertainty of the level assessment.

APPROACH 2 LEVEL ASSESSMENT FOR 2016						
A	**B**	**C**	**D**	**E**	**F**	**G**
Code	**IPCC Category**	**GHG**	**Ex,t (kt CO2 eq)**	**|Ex,t| (kt CO2 eq)**	**Lx,t**	**Cumula-tive Total of Column F**
4A1	forest land remaining forest land	CO2	-2197	2197	18.3%	18.3%
3Da	Direct emissions from managed soils	N2O	1080	1080	11.4%	29.8%
4C1	Grassland remaining grassland	CO2	110	110	10.0%	39.8%
3Db	Indirect emissions from managed soils	N2O	412	412	7.6%	47.4%
3B5	Indirect N2O emissions from manure management	N2O	271	271	7.0%	54.4%
3A	Enteric Fermentation	CH4	3325	3325	6.1%	60.5%
3B1-3B4	Manure management	CH4	753	753	4.1%	64.6%
4A2	Land converted to forest	CO2	-442	442	3.9%	68.5%
1A1	Energy industries: Other fuels	CO2	2454	2454	2.6%	71.1%
4B1	Cropland remaining cropland	CO2	156	156	2.6%	73.7%
5D	Wastewater treatment and discharge	N2O	149	149	2.3%	76.0%
2F1	Refrigeration and air conditioning	HFC	1287	1287	1.9%	77.8%
2	Indirect CO2 emissions	CO2	97	97	1.5%	79.3%
1A4b	Residential: Gaseous fuels	CO2	2754	2754	1.4%	80.7%
4G	HWP harvest wood products	CO2 biog.	-213	213	1.2%	81.9%
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	2234	2234	1.2%	83.1%
5A	Solid waste disposal	CH4	335	335	1.0%	84.1%
4E2	Land converted to settlements	CO2	194	194	0.9%	85.1%
5D	Wastewater treatment and discharge	CH4	180	180	0.9%	86.0%
2A1	Cement production	CO2	1769	1769	0.8%	86.8%
4C2	Land converted to grassland	CO2	189	189	0.8%	87.6%
4D1	Wetland remaining wetland	CO2	68	68	0.8%	88.4%
1A4a	Commercial: Gaseous fuels	CO2	1490	1490	0.8%	89.2%
4III	Direct N2O from disturbance	N2O	39	39	0.7%	89.9%
1A3b	Road transportation: Diesel	CO2	7281	7281	0.7%	90.6%

Regarding the **trend assessment** between the base year 1990 and the most recent year 2016, 22 categories are identified as trend key categories under Approach 2 (see Table 1-8).

Table 1-8 Switzerland's Approach 2 trend key categories between 1990 and 2016 including LULUCF categories, sorted by contribution to the trend assessment.

APPROACH 2 TREND ASSESSMENT WITH UNCERTAINTIES FOR 2016							
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Code	**IPCC Category**	**GHG**	**Ex,0 (kt CO2 eq)**	**Ex,t (kt CO2 eq)**	**Trend Assess-ment**	**Contri-bution to Trend**	**Cumula-tive Total of Column G**
4A1	forest land remaining forest land	CO2	-405	-2189	2.550%	23.8%	23.8%
4B1	Cropland remaining cropland	CO2	908	152	1.915%	17.9%	41.7%
4G	HWP harvest wood products	CO2 biog.	-1299	-214	1.240%	11.6%	53.3%
4C1	Grassland remaining grassland	CO2	69	112	0.639%	6.0%	59.3%
2	Indirect CO2 emissions	CO2	362	97	0.573%	5.4%	64.6%
3Db	Indirect emissions from managed soils	N2O	575	407	0.342%	3.2%	67.8%
2F1	Refrigeration and air conditioning	HFC	0	1289	0.328%	3.1%	70.9%
4A2	Land converted to forest	CO2	-583	-447	0.327%	3.1%	73.9%
3B5	Indirect N2O emissions from manure management	N2O	229	265	0.319%	3.0%	76.9%
1A1	Energy industries: Other fuels	CO2	1490	2452	0.216%	2.0%	78.9%
5A	Solid waste disposal	CH4	770	336	0.180%	1.7%	80.6%
1A4b	Residential: Gaseous fuels	CO2	1428	2754	0.138%	1.3%	81.9%
5D	Wastewater treatment and discharge	N2O	122	144	0.129%	1.2%	83.1%
1A2	Manufacturing industry and construction: Solid fuels	CO2	1273	436	0.128%	1.2%	84.3%
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	1050	2232	0.123%	1.1%	85.5%
4C2	Land converted to grassland	CO2	68	189	0.096%	0.9%	86.4%
1A3b	Road transportation: Gasoline	N2O	133	20	0.089%	0.8%	87.2%
1A3b	Road transportation: Diesel	CO2	2633	7279	0.082%	0.8%	88.0%
2F2	Foam blowing agents	HFC	0	32	0.077%	0.7%	88.7%
2G	Other product manufacture and use	N2O	107	38	0.073%	0.7%	89.4%
5D	Wastewater treatment and discharge	CH4	131	181	0.060%	0.6%	89.9%
3A	Enteric Fermentation	CH4	3594	3327	0.059%	0.6%	90.5%

Comparison of the results of approaches 1 and 2

Due to large differences in the uncertainties of specific source categories, the key category analyses under Approach 1 and Approach 2 show different results. This is particularly the case for large source categories in the energy sector with relatively small uncertainties, which dominate the level assessment in Approach 1, and large source categories in the agriculture or LULUCF sector with large uncertainties, which dominate the level assessment in Approach 2.

Several categories being key categories under Approach 1 are not key anymore when assessed with Approach 2. Nevertheless, there are six categories only being key under Approach 2 (for year 2016):

- 2F2 Foam blowing agents, HFC (trend)
- 2G Other product manufacture and use, N_2O (trend)
- 4C1 Grassland remaining grassland, CO_2 (level and trend)
- 4D1 Wetlands remaining wetlands, CO_2 (level)
- 4 III Direct N_2O from disturbance, N_2O (level)
- 5D Wastewater treatment and discharge, N_2O (level and trend)

The categories listed above, which are only key under the Approach 2 assessments, are subject to rather high uncertainties (combined uncertainties according to uncertainty analysis Approach 1: 2F2 HFC: 113.8%; 2G N_2O: 80.0%; 4C1 CO_2: 915.9%; 4D1 CO_2: 95.1%; 4 III N_2O: 158.7%; 5D N_2O: 150.0%).

1.5.1.3 Summary of combined KCA including LULUCF categories

A summary of the key category analysis for 2016 is shown in Table 1-9, considering level and trend assessments for both, Approach 1 and Approach 2.

Table 1-9 Summary of Switzerland's combined KCA for the year 2016 including LULUCF categories, sorted by NFR code (first column). The abbreviations used in the last column indicate both, the approach and whether a certain category is identified as key because of the level or trend assessment (L1 = level according to Approach 1, T1 = trend according to Approach 1; L2 = level according to Approach 2, T2 = trend according to Approach 2).

SUMMARIES TO IDENTIFY KEY CATEGORIES			
A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1A1	Energy industries: Gaseous fuels	CO2	L1, T1
1A1	Energy industries: Liquid fuels	CO2	L1, T1
1A1	Energy industries: Other fuels	CO2	L1, T1, L2, T2
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	L1, T1, L2, T2
1A2	Manufacturing industry and construction: Liquid fuels	CO2	L1, T1
1A2	Manufacturing industry and construction: Other fuels	CO2	L1, T1
1A2	Manufacturing industry and construction: Solid fuels	CO2	L1, T1, T2
1A3a	Civil aviation: Liquid fuels	CO2	T1
1A3b	Road transportation: Diesel	CO2	L1, T1, L2, T2
1A3b	Road transportation: Gasoline	CH4	T1
1A3b	Road transportation: Gasoline	CO2	L1, T1
1A3b	Road transportation: Gasoline	N2O	T1, T2
1A4a	Commercial: Gaseous fuels	CO2	L1, T1, L2
1A4a	Commercial: Liquid fuels	CO2	L1, T1
1A4b	Residential: Biomass	CH4	T1
1A4b	Residential: Gaseous fuels	CO2	L1, T1, L2, T2
1A4b	Residential: Liquid fuels	CO2	L1, T1
1A4c	Agriculture and forestry: Liquid fuels	CO2	L1
1B2	Oil and natural gas energy production	CH4	L1, T1
2A1	Cement production	CO2	L1, T1, L2
2C3	Aluminium production	CO2	T1
2C3	Aluminium production	PFC	T1
2F1	Refrigeration and air conditioning	HFC	L1, T1, L2, T2
2F2	Foam blowing agents	HFC	T2
2G	Other product manufacture and use	HFC	T1
2G	Other product manufacture and use	N2O	T2
2G	Other product manufacture and use	SF6	L1
2	Indirect CO2 emissions	CO2	T1, L2, T2
3A	Enteric Fermentation	CH4	L1, T1, L2, T2
3B1-3B4	Manure management	CH4	L1, L2
3B5	Indirect N2O emissions from manure management	N2O	L1, T1, L2, T2
3Da	Direct emissions from managed soils	N2O	L1, L2
3Db	Indirect emissions from managed soils	N2O	L1, T1, L2, T2
4A1	forest land remaining forest land	CO2	L1, T1, L2, T2
4A2	Land converted to forest	CO2	L1, T1, L2, T2
4B1	Cropland remaining cropland	CO2	T1, L2, T2
4C1	Grassland remaining grassland	CO2	L2, T2
4C2	Land converted to grassland	CO2	L1, T1, L2, T2
4D1	Wetland remaining wetland	CO2	L2
4E2	Land converted to settlements	CO2	L1, L2
4G	HWP harvest wood products	CO2 biog.	L1, T1, L2, T2
4III	Direct N2O from disturbance	N2O	L2
5A	Solid waste disposal	CH4	L1, T1, L2, T2
5D	Wastewater treatment and discharge	CH4	L1, L2, T2
5D	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 2006 IPCC Guidelines (IPCC 2006/Chapter 3 Uncertainties). Concerning key assumptions and requirements for both approaches we refer to the guidelines, here we only recap the clues of both approaches:

- Approach 1: based on propagation of error, uncertainty in the emission level in 2016 and in the trend between the reporting year (2016) and the base year (1990) is estimated for the inventory total and for the single source categories and gases using uncertainty ranges of corresponding activity data and emission factors.
- Approach 2: is based on Monte Carlo analysis (IPCC 2006, UNFCCC 2014a). This approach provides a detailed category-by-category assessment of uncertainty, particularly where uncertainties are large, distribution is non-normal, the algorithms are complex functions and/or there are correlations between some of the activity data, emission factors or both. 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 100’000 times until an adequately stable result has been found, i.e. until the change of the simulated mean of the total GHG emissions is small. The results of all realisations yield the overall emission probability distribution.

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 2006 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 (chp. 3 to 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. Uncertainties are estimated for the reporting year only (except LULUCF). For some categories uncertainties in activity data and emission factors for 2016 are considerably lower as compared to 1990. For example, uncertainty of N_2O emissions in 2B2 Nitric acid production used to be much higher than in the current reporting year, for which emissions are derived from continuous N_2O measurements. Continuous N_2O measurements started in 2013. For the LULUCF sector uncertainties are assessed separately for 1990 and 2016 and uncertainties are differentiated in the uncertainty analysis according to approach 2.

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 2006 IPCC 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 (chp. 3 to 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 1-10). 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 from sectoral experts and authors.

Table 1-10 Semi-quantitative (combined) uncertainties (U) for the emission of categories with no quantitative uncertainty data available. Note that there is no source of NF_3, 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_2O	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 submission in 2016 (FOEN 2016). They are described in detail in chp. 3.2.4.7. Main result of the evaluation were a lowering of the uncertainty of CO_2 for this sector. Despite the investigation carried out previously it will be necessary to continously 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 1-11 gives a summary for the Approach 1 uncertainties for the national total emissions and removals.

Table 1-11 Switzerland’s relative uncertainties for national total GHG emission excluding and including the LULUCF sector – Approach 1: Level uncertainties 2016 and trend uncertainties 1990–2016. The uncertainty analysis is based on emissions including indirect CO_2 emissions.

Approach 1 Uncertainty Analysis		
Inventory	**Level uncertainty 2016**	**Trend uncertainty 1990-2016**
excl. LULUCF	4.65%	3.49%
incl. LULUCF	6.62%	5.72%

Uncertainty analysis results for the Switzerland’s GHG inventory 2016 and including indirect CO_2 emissions with Approach 1:

- The level uncertainty 2016 is **4.65%** excluding LULUCF and **6.62%** including LULUCF. Explanations are given below in the chapter on Approach 2 results.

- The trend uncertainty 1990–2016 is **3.49%** excluding LULUCF and **5.72%** including LULUCF.

Compared to the results of the previous inventory 2015 (which included indirect CO_2 emissions for the first time, see FOEN 2017):

- The level uncertainty in 2015 was **3.75%** excluding LULUCF and **6.36%** including LULUCF.
- The trend uncertainty 1990–2015 was **1.51%** excluding LULUCF and **4.03%** including LULUCF.

Changes in total level and trend uncertainty are on one hand due to changes in the uncertainties of the emission factors and activity data in the different source categories. On the other hand changes in the activity data and emission factors cause changes in the contribution to the total level and trend uncertainty of each source category. Contribution to level uncertainty and the uncertainty introduced to the trend in total national emissions of each source category are shown in Table A – 2.

The level uncertainty excluding LULUCF increased compared to the previous uncertainty analysis, mostly because of the higher contribution to level uncertainty of HFC emissions from source category 2F1. The level uncertainty when including LULUCF, has slightly increased in 2016 compared to 2015, mostly because of the higher contribution to level uncertainty of HFC emissions from source category 2F1 and a lower contribution to level uncertainty of CO_2 emissions from source category 4C1.

Trend uncertainties including LULUCF increased for the current submission, which can be explained by an increase in the contribution to trend uncertainty of CO_2 emissions from 4C1 and of HFC emissions from source category 2F1. Excluding LULUCF, there is also an increase in trend uncertainty due to an increase in the contribution to trend uncertainty of HFC emissions from source category 2F1.

Detailed results of the Approach 1 uncertainty analysis for GHG emissions 2016 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 neglected temporal variability when assuming constant parameters over time (e.g. emission factors).
- errors due to non-normal, asymmetric distribution of the uncertainties;
- errors due to methodological shortcomings, i.e. simplified approaches;
- 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)

In the present analysis, Monte Carlo simulations were performed to estimate uncertainties both in emissions 2016 and in emission trends 1990–2016, 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[2] (® Decisioneering, Release 11.1.2.4.400). 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 1-12 Switzerland's relative uncertainties for national total GHG emission excluding and including the LULUCF sector – Approach 2: Level uncertainties 2016 and trend uncertainties 1990–2016. The emission trend 1990–2016 is -10.07% excl. LULUCF and -12.33% incl. LULUCF. The emissions shown in this table include indirect CO_2 emissions.

Approach 2 (Monte Carlo) Uncertainty Analysis						
Version	**Level uncertainty 2016**			**Trend uncertainty 1990-2016**		
	2.5 percentile	97.5 percentile	**mean**	2.5 percentile	97.5 percentile	**mean**
excl. LULUCF	-4.34%	4.54%	**4.44%**	-13.85%	-6.33%	**3.76%**
incl. LULUCF	-6.31%	6.41%	**6.36%**	-17.92%	-6.75%	**5.59%**

Approach 2 uncertainties excluding LULUCF and including indirect CO_2 emissions:

- The total uncertainty level of Switzerland's 2016 national total GHG emissions excluding LULUCF is **4.44%** with a slightly asymmetric 95% confidence interval between 95.66% and 104.54%.
- The trend in national total emissions excluding LULUCF between 1990 and 2016 is -10.07%. With a probability of 95% the trend lies within the range of -13.85% to -6.33%, which corresponds to a **mean trend uncertainty of 3.76%**.

[2] https://docs.oracle.com/cd/E40248_01/epm.1112/cb_statistical/frameset.htm?index.html [01.03.2018]

Approach 2 uncertainties including LULUCF and including indirect CO_2 emissions:

- The total uncertainty level of Switzerland's 2016 national total GHG emissions including LULUCF is **6.36%** with a slightly asymmetric 95% confidence interval between 93.69% and 106.41%.
- The trend in national total emissions including LULUCF between 1990 and 2016 is -12.33%. With a probability of 95%, the trend lies within the range of -17.92% to -6.75%, which corresponds to a **mean trend uncertainty of 5.59%**.

That means that level and trend uncertainty are considerably higher if LULUCF categories are included in the uncertainty analysis, which is caused by a combination of large contributions, large uncertainties and strong trends (1990 to 2016) of several LULUCF categories.

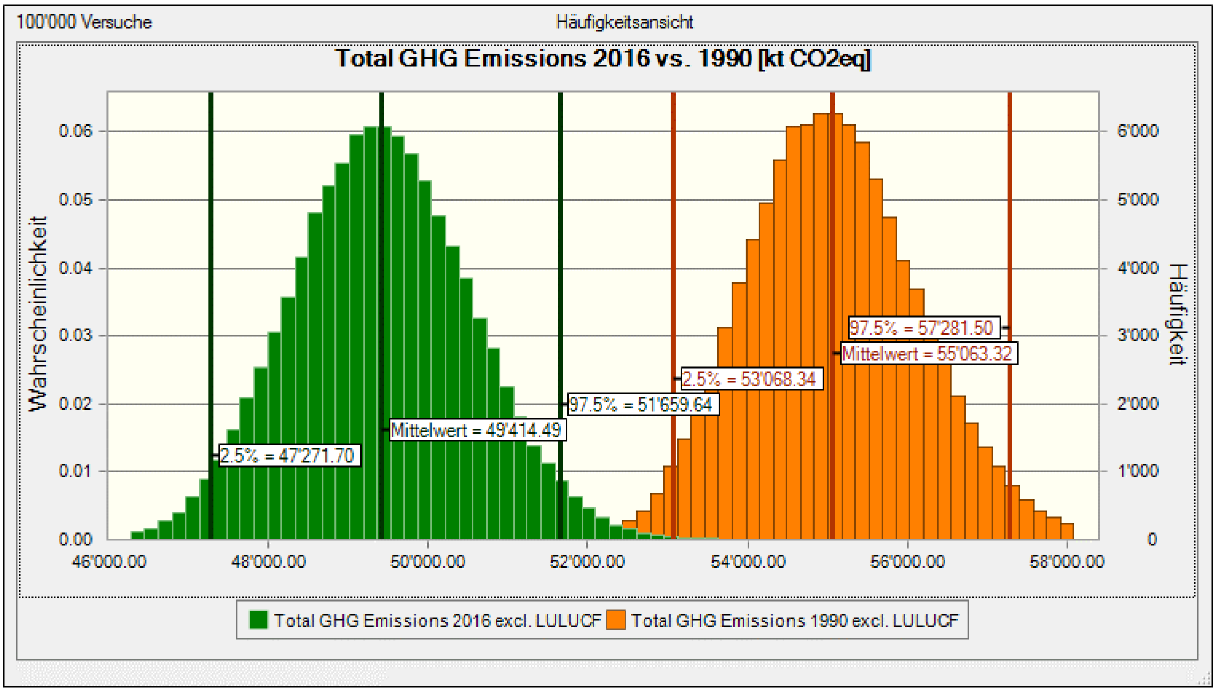

Figure 1-3 Probability distributions of the simulated total emissions excluding LULUCF and including indirect CO_2 emissions for the base year 1990 (in orange) and year 2016 (in green). The vertical lines show simulated mean and percentile values (black for 2016, red for 1990). The number of Monte Carlo runs is 100’000. X-axis: total emissions (excl. LULUCF) [kt CO_2 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 including indirect CO_2 emissions 2016 is 49’414 kt CO_2 eq, whereas the reported value is 48’306 kt CO_2 eq, 2.3% lower than the simulated value). The emissions shown in this figure include indirect CO_2 emissions.

In the course of Monte Carlo simulation, the uncertainties are also evaluated by gas (see Table 1-13). As expected, CO_2 emissions have the highest precision or the lowest uncertainties among the Kyoto gases.

Table 1-13 Approach 2 level uncertainties by gas for the total national emissions 2016 excluding LULUCF. The emissions shown in this table include indirect CO_2 emissions.

Gas	**Simulated Emissions 2016 (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	39'310	38'981	39'641	330	0.84%
CH_4	4'907	4'002	5'809	903	18.4%
N_2O	3'511	2'250	5'028	1'389	39.6%
HFC	1'424	34	2'810	1'388	97.4%
PFC	54	38	70	16	29.5%
SF_6	207	62	354	146	70.3%
NF_3	0.51	0.25	0.77	0.26	51%
Total	**49'414**	**47'272**	**51'660**	**2'194**	**4.44%**

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, highlighting the most important uncertainties (see Figure 1-4). These can either be emission factors, activity data or emissions. The bars illustrate the absolute 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 (latest) year 2016.

Categories 4A1 Forest land remaining forest land (CO_2), 2F1 Refrigeration and air conditioning (HFC) and 3Da Direct N_2O emissions from managed soils are the most important contributors to level uncertainty. The fact that the most important contributor stems from the LULUCF sector explains the result given above that the level uncertainty including LULUCF is higher than without LULUCF.

Based on the analysis of the predominant contributions to the uncertainty of the Swiss greenhouse gas inventory, the FOEN commissions and/or supports various projects. In line with UNFCCC (2017/ID#L.12) the soil carbon model Yasso07 will be further developed to improve the accuracy in the estimates of carbon changes in mineral soil, litter and dead wood in forest land (see chp. 6.4.6 for details). A Tier 3 methodological approach for the quantification of carbon stock changes in agricultural soils (cropland remaining cropland and grassland remaining grassland) is currently under development at Agroscope research station (see chp. 6.5.6 and chp. 6.6.6, respectively). In the agriculture sector, a research project run by Agroscope looks into CH_4 and N_2O emissions from current pasture practices using micrometeorological measurements and modelling approaches. With regard to HFC emissions, the FOEN supports a long-term monitoring initiative at Jungfraujoch to derive independent emission estimates from atmospheric concentrations (Annex 5.1). Another, more recent verification activity addresses national total CH_4 and N_2O emissions (Annex 5.2).

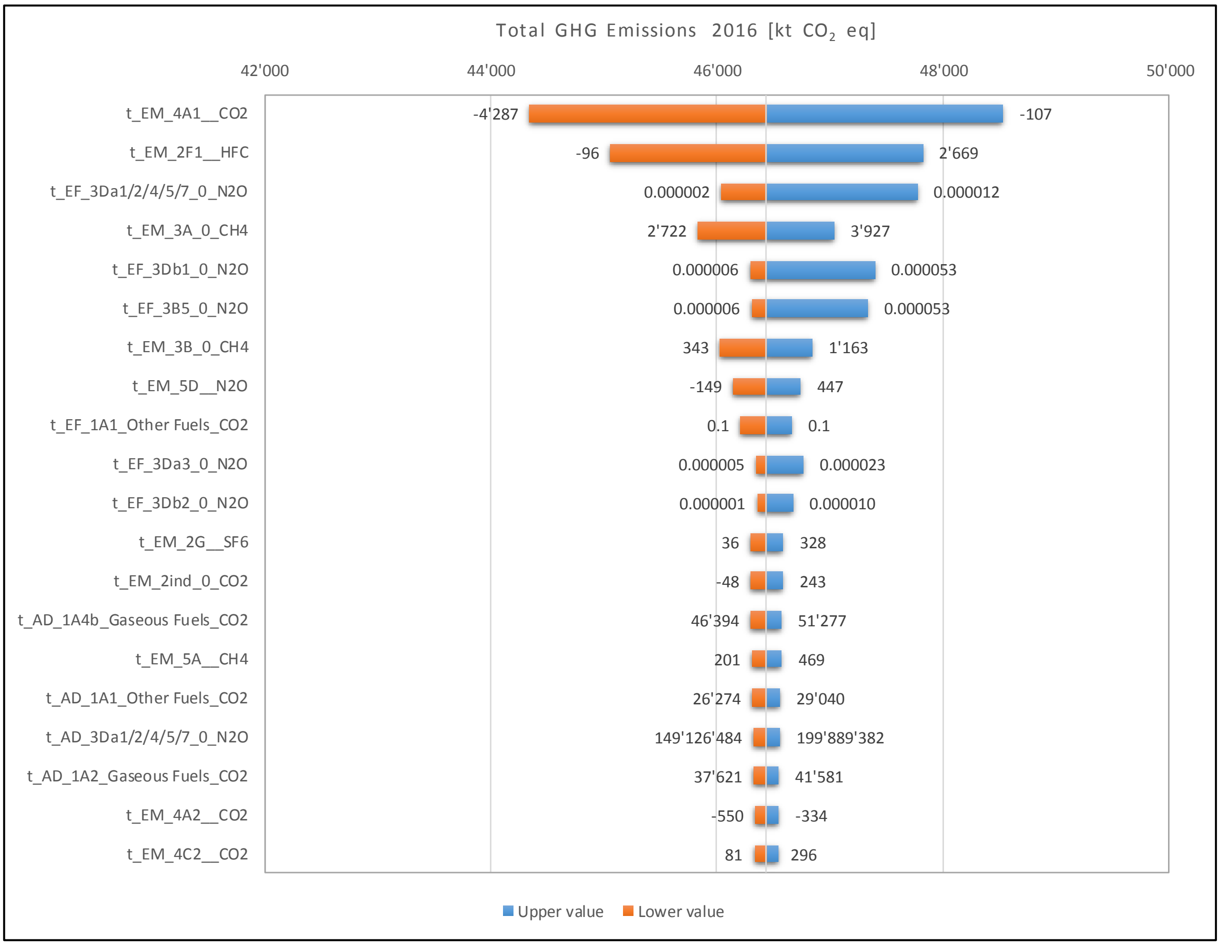

Figure 1-4 Tornado plot of the uncertainties by category. Abbrev.: “t” refers to 2016, “EF” emission factor, “AD” activity data, “EM” emissions. X-axis: Simulated national total of CO_2 eq emissions (in kt) including LULUCF in 2016 (the simulated values deviate from the reported inventory values, see Table A – 8 for details). The width of the bars show the uncertainty introduced in the national total GHG emissions by the uncertainty in the source categories that have the highest contribution to total uncertainty. Uncertainty analysis includes indirect CO_2 emissions. The values next to the bars indicate the range of variation in the input variables (activity data, emission factors, emissions) used in the simulation of the Tornado plot.

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

For a direct comparison of the methane inventory data with the independent verification of methane emissions (see Annex 5.2) the 1-σ uncertainty range of CH_4 emissions was calculated from the Monte Carlo simulations: it is ±18.41 kt CH_4 in absolute or 9.38 per cent in relative terms.

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 4.44%, which is slightly lower than the result of Approach 1 (4.65%). The correct treatment of large uncertainties, asymmetric distributions for agricultural sources and accounting for relevant correlations lead all together to a decrease in the level uncertainty.

The same holds for the level uncertainty incl. LULUCF. With Approach 2, an overall level uncertainty of 6.36% is computed, which is also slightly lower than the result of Approach 1 6.62%.

Trend uncertainty

In terms of trend uncertainty, the result of Approach 2 show lower uncertainties than the results of Approach 1, when LULUCF categories are excluded. In this case Approach 2 leads to an uncertainty of 3.76% and Approach 1 to 3.49%, whereas when LULUCF categories are included, the numbers are 5.59% and 5.72%, respectively. Positive correlations for activity data and emission factors between the base year and 2016 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 Table9.

For the following categories, for which reporting is “not mandatory”, the notation key “not estimated” is used

- CH_4 emissions from 4.A Forest Land/4(II), 4.B Cropland/4(II), 4.C Grassland/4(II)
- N_2O emissions from 4.D Wetlands/4(II).

For 1A1a Municipal and special waste incineration plants / Other Fossil Fuels, CH_4 emissions were negligible according to a study carried out in 2013. Therefore, the notation key NE is used (see chp. 3.2.5.2.1).

Notation key “included elsewhere” (IE) is used as follows:

- in category 1A2c for reasons of confidentiality,
- in categories 5B2a and 5B2b since the emissions from stationary motors / CHP at agricultural biogas plants are reported under 1A1a,
- in categories 1A2d and 1A2e (biomass) because a part of the biomass used in 1A2 could not be allocated to these categories and is therefore reported under category 1A2g viii, and
- in categories 1A3a / aviation gasoline, 2B1, 4(I)E (N_2O), 4(II)A (CO_2), 4(II)B (CO_2), 4(II)C (CO_2), 4(III)C1 (N_2O), 4(IV)1 (N_2O), 4(V)A (CO_2, CH_4, N_2O), 4(V)C (CO_2, CH_4, N_2O), 4D1.2 (CO_2), 5C1 and 5D2 because data for further disaggregation are not available or because the emissions in these categories are inherently covered by another category.

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. 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 2016 as well as trends for the period 1990–2016. 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 2016 (UNFCCC)

Table 2-1 shows the aggregated emissions of all greenhouse gases (GHG) 2016 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, CO_2 is the main contributor to total GHG emissions followed by CH_4, N_2O and 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 2016.

Table 2-1 Switzerland's GHG emissions in CO_2 equivalent (kt) by gas and sector in 2016.

Sectors	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**NF_3**	**Total**	**Share**
	CO_2 equivalent (kt)								
1 Energy	36'979	280	225					37'484	77.8%
2 IPPU	2'157	3	45	1'523	55	207	0.5	3'991	8.3%
3 Agriculture	47	4'078	1'838					5'963	12.4%
5 Waste	10	547	192					748	1.6%
6 Other	11	0.6	0.5					12	0.0%
Total (excluding LULUCF)	39'205	4'907	2'300	1'523	55	207	0.5	**48'199**	100.0%
4 LULUCF	-1'937	16	51					-1'870	-3.9%
Total (including LULUCF)	37'268	4'923	2'351	1'523	55	207	0.5	**46'328**	96.1%
International aviation bunkers	5'140	0.5	42					*5'182*	
International marine bunkers	25	0.01	0.24					*25*	

A breakdown of Switzerland's total emissions by gas (both excluding and including 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.

The national total of 48'199 kt of CO_2 equivalent (excluding LULUCF) corresponds to 5.7 tonnes of CO_2 equivalent per capita[3] (CO_2: 4.7 tonnes per capita) emitted to the atmosphere in 2016 (Table 2-1).

[3] Population statistics taken from SFSO 2017a.

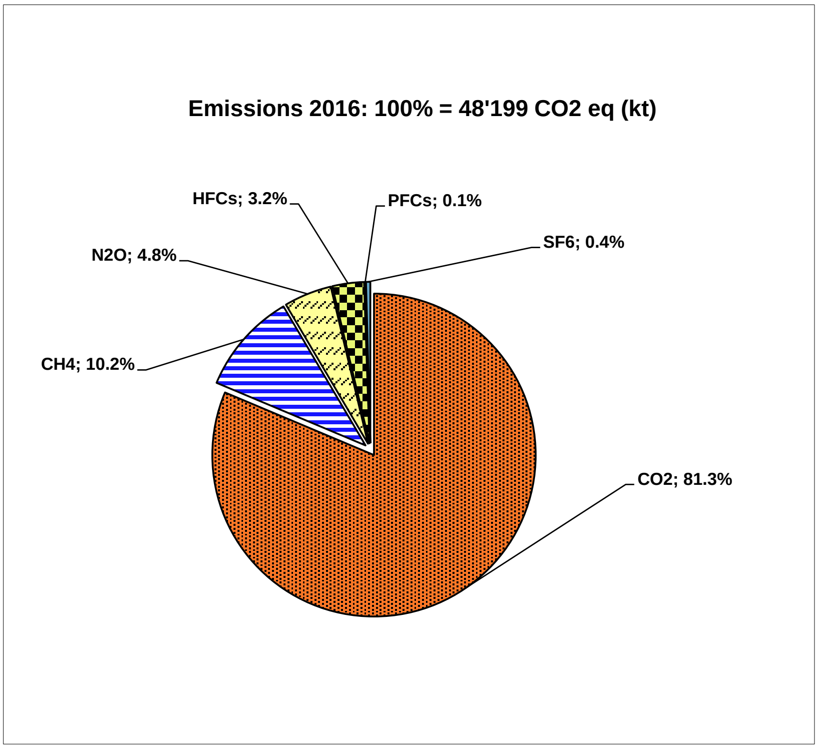

Figure 2-1 Contribution of individual gases to Switzerland's GHG emissions (excluding LULUCF) in 2016.

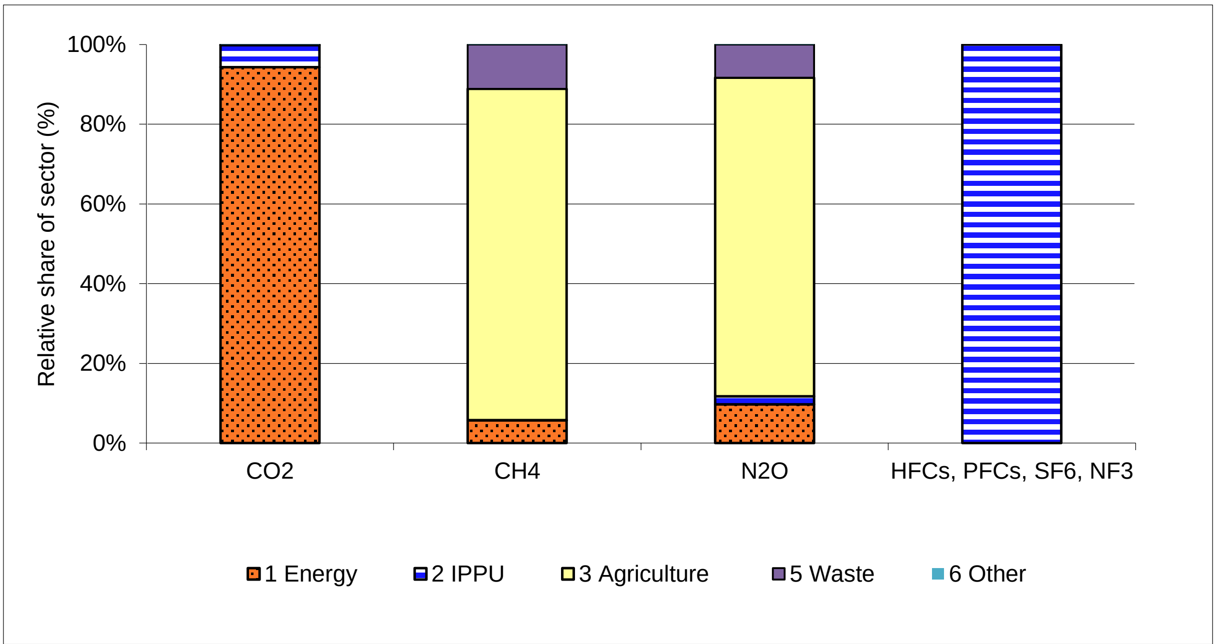

Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2016.

A clear dominance of CO_2 emissions in 2016 is related to source category 1A Fuel combustion within sector 1 Energy. CH_4 and N_2O emissions mainly originate from sector 3 Agriculture, while F-gas emissions by definition only stem from sector 2 Industrial processes and product use.

2.2 Emission trends by gas

Emission trends by gas for the period 1990–2016 are summarized in Table 2-2.

Table 2-2 Switzerland's GHG emissions in CO_2 equivalent (kt) by gas. The column below on the far right indicates the percentage change in emissions in the latest year as compared to the base year 1990. HFCs increased by 5'032'398% when compared to 1990 levels (1990 = 0.025 kt CO_2 equivalent).

Greenhouse Gas Emissions	1990	1995	2000	2005
	CO_2 equivalent (kt)			
CO_2 emissions including net CO_2 from LULUCF	43'343	39'377	48'306	43'158
CO_2 emissions excluding net CO_2 from LULUCF	44'162	43'414	43'612	45'780
CH_4 emissions including CH_4 from LULUCF	6'035	5'708	5'302	5'197
CH_4 emissions excluding CH_4 from LULUCF	6'005	5'688	5'287	5'184
N_2O emissions including N_2O from LULUCF	2'834	2'675	2'519	2'414
N_2O emissions excluding N_2O from LULUCF	2'775	2'622	2'469	2'364
HFCs	0.02	242	634	1'049
PFCs	117	17	50	44
SF_6	137	93	144	203
NF_3	0	0	0	0
Total (including LULUCF)	**52'466**	**48'113**	**56'954**	**52'065**
Total (excluding LULUCF)	**53'196**	**52'077**	**52'195**	**54'624**

Greenhouse Gas Emissions	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2016 vs. 1990
	CO_2 equivalent (kt)										%
CO_2 emissions including net CO_2 from LULUCF	43'072	43'522	41'430	43'437	39'593	40'525	41'847	37'867	37'269	37'268	-14.0%
CO_2 emissions excluding net CO_2 from LULUCF	43'360	44'707	43'528	45'045	40'980	42'251	43'184	39'238	38'738	39'205	-11.2%
CH_4 emissions including CH_4 from LULUCF	5'191	5'264	5'171	5'142	5'090	5'060	4'998	4'996	4'969	4'923	-18.4%
CH_4 emissions excluding CH_4 from LULUCF	5'175	5'251	5'158	5'129	5'076	5'047	4'985	4'983	4'956	4'907	-18.3%
N_2O emissions including N_2O from LULUCF	2'447	2'467	2'426	2'475	2'421	2'405	2'365	2'379	2'334	2'351	-17.0%
N_2O emissions excluding N_2O from LULUCF	2'395	2'418	2'377	2'426	2'371	2'356	2'315	2'329	2'285	2'300	-17.1%
HFCs	1'229	1'250	1'247	1'316	1'426	1'502	1'494	1'507	1'523	1'523	see caption
PFCs	49	58	63	64.49	69.18	71.36	51.07	43.01	54.72	55.02	-52.8%
SF_6	172	222	180	148	160	209	252	259	256	207	51.2%
NF_3	0.0	0.1	5	8	6	0.4	0.1	0.4	0.5	0.5	-
Total (including LULUCF)	**52'159**	**52'785**	**50'523**	**52'591**	**48'765**	**49'773**	**51'008**	**47'051**	**46'406**	**46'328**	**-11.7%**
Total (excluding LULUCF)	**52'380**	**53'906**	**52'558**	**54'137**	**50'086**	**51'437**	**52'281**	**48'359**	**47'813**	**48'199**	**-9.4%**

As shown in Table 2-2, Table 2-3, and Figure 2-3, total emissions excluding LULUCF in 2016 are 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. Compared to 2015, emissions have slightly increased in 2016 (0.8%). The emission maximum occurred in 1991. Also when including LULUCF categories, a decreasing trend is visible compared to the base year 1990, although the net CO_2 sink generated by LULUCF categories was generally smaller after 1997. Total emissions excluding LULUCF reached a minimum in 2015, which was 10.1% below base year emissions in 1990.

There is a strong correlation between CO_2 emissions and winter climatic conditions (number of heating degree days; see footnote 4, page 66 for further information) in the period 1990–2016. However, the relative developments of heating degree days and CO_2 emissions are clearly drifting apart in the years since 2003, which indicates that additional effects like reduction measures contribute to emission reductions (see Figure 2-7).

Between 1990 and 2016, CH_4 emissions (excluding LULUCF) decreased. One major reason for this decrease was a reduction of livestock in the years 1990 to 2004 that led to a reduction of emissions from enteric fermentation in the agricultural sector. 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, N_2O emissions that mainly stem from manure management and agricultural soils decrease between 1990 und 2016 as well.

HFC emissions increased significantly in 2016 compared to the base year due to their application as substitutes for CFCs, while PFC emissions declined. SF_6 emissions show relatively large fluctuations between 1990 and 2016. 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 SF_6 emissions in recent years is due the disposal of sound proof windows. NF_3 has been used only short-term in the photovoltaic industry.

Table 2-3 Switzerland’s total GHG emissions (excluding LULUCF) in CO_2 equivalent (kt) and the contribution of individual gases (as percentage values) for selected years.

Greenhouse Gas Emissions	**1990**		**1995**		**2000**		**2005**		**2010**	
(excluding LULUCF)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	44'162	83.0%	43'414	83.4%	43'612	83.6%	45'780	83.8%	45'045	83.2%
CH_4	6'005	11.3%	5'688	10.9%	5'287	10.1%	5'184	9.5%	5'129	9.5%
N_2O	2'775	5.2%	2'622	5.0%	2'469	4.7%	2'364	4.3%	2'426	4.5%
HFCs	0	0.0%	242	0.5%	634	1.2%	1'049	1.9%	1'316	2.4%
PFCs	117	0.2%	17	0.0%	50	0.1%	44	0.1%	64	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)	**53'196**	**100%**	**52'077**	**100%**	**52'195**	**100%**	**54'624**	**100%**	**54'137**	**100%**

Greenhouse Gas Emissions	**2011**		**2012**		**2013**		**2014**		**2015**		**2016**	
(excluding LULUCF)	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
CO_2	40'980	81.8%	42'251	82.1%	43'184	82.6%	39'238	81.1%	38'738	81.0%	39'205	81.3%
CH_4	5'076	10.1%	5'047	9.8%	4'985	9.5%	4'983	10.3%	4'956	10.4%	4'907	10.2%
N_2O	2'371	4.7%	2'356	4.6%	2'315	4.4%	2'329	4.8%	2'285	4.8%	2'300	4.8%
HFCs	1'426	2.8%	1'502	2.9%	1'494	2.9%	1'507	3.1%	1'523	3.2%	1'523	3.2%
PFCs	69	0.1%	71	0.1%	51	0.1%	43	0.1%	55	0.1%	55	0.1%
SF_6	160	0.3%	209	0.4%	252	0.5%	259	0.5%	256	0.5%	207	0.4%
NF_3	6	0.0%	0.4	0.0%	0.1	0.0%	0.4	0.0%	0.5	0.0%	0.5	0.0%
Total (excluding LULUCF)	**50'086**	**100%**	**51'437**	**100%**	**52'281**	**100%**	**48'359**	**100%**	**47'813**	**100%**	**48'199**	**100%**

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

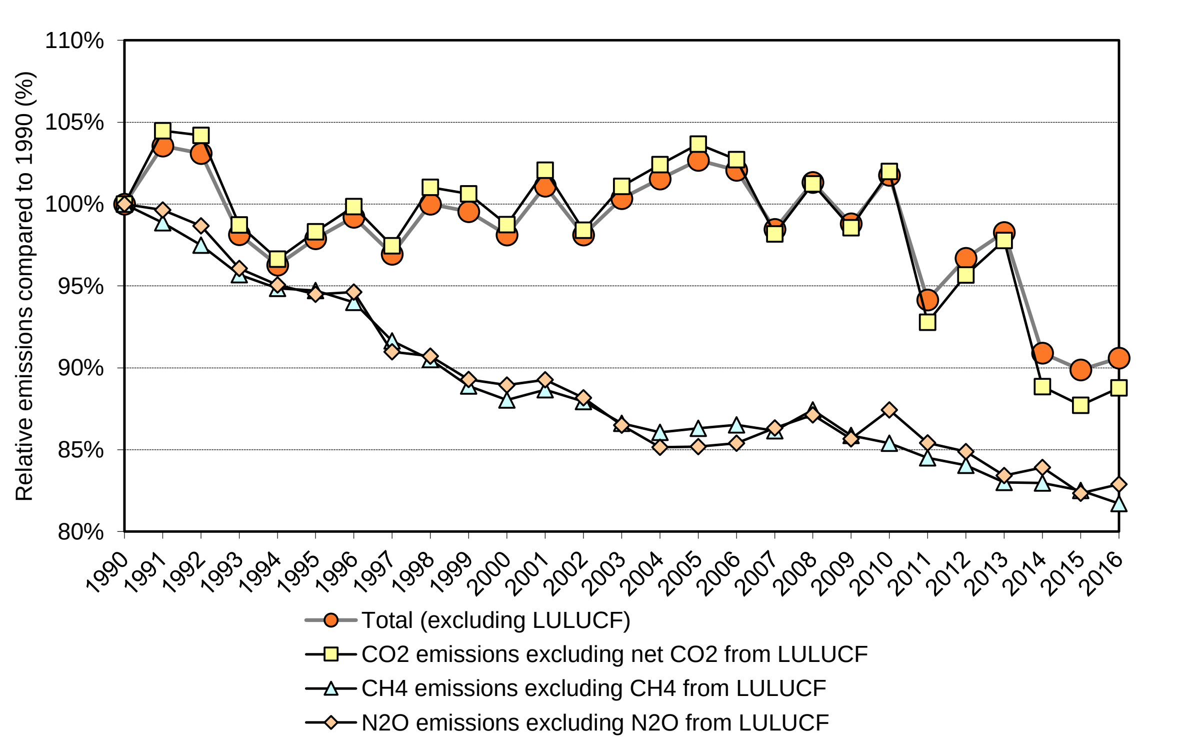

Figure 2-3 Relative trends of Switzerland's main greenhouse gas emissions (excluding LULUCF). The base year 1990 represents 100%. F-gases are not illustrated (see Figure 4-3).

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 chp. 2.3.2 and Figure 2-6 below).

In line with economic development, overall emissions in sector 2 Industrial processes and producte use (IPPU) show a decreasing trend in the early 1990s and a gradual increase between 1997 and 2016, 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 ozone-depleting substances (ODS), the second most important source in sector 2, increased by some orders of magnitude since 1990 due to the replacement of CFCs with HFCs. Source category 2G Other product manufacture and use with SF_6 and PFC emissions from electrical equipment and other product use, as well as N_2O emissions from the application in households and hospitals 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 by fertilizer use. Both factors have been declining, thus leading to a decrease in CH_4 and N_2O 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 2016, 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).

The total emissions from sector 6 Other (fire damages) show fluctuations on a very low level. Emissions from sector 6 Other are not accounted for under the Kyoto Protocol and are of minor importance.

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

Source and Sink Categories	**1990**	**1995**	**2000**	**2005**
	CO_2 equivalent (kt)			
1. Energy	41'826	41'869	42'183	43'993
1A1 Energy industries	2'519	2'643	3'172	3'816
1A2 Manufacturing industries and construction	6'443	6'192	5'925	5'973
1A3 Transport	14'639	14'257	15'927	15'856
1A4 Other sectors	17'641	18'185	16'648	17'895
1A5 Other	220	163	151	139
1B Fugitive emissions from fuels	363	431	360	314
2. Industrial processes and product use	3'576	2'910	3'141	3'769
3. Agriculture	6'672	6'374	5'989	5'963
5. Waste	1'109	912	869	885
6. Other	12	12	13	14
Total (excluding LULUCF)	53'196	52'077	52'195	54'624
4. Land use, land-use change and forestry	-730	-3'964	4'759	-2'558
Total (including LULUCF)	52'466	48'113	56'954	52'065

Source and Sink Categories	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	***2016 vs. 1990***
	CO_2 equivalent (kt)										%
1. Energy	41'555	42'948	41'839	43'212	39'148	40'539	41'463	37'421	37'087	37'484	*-10.4%*
1A1 Energy industries	3'719	3'837	3'674	3'847	3'598	3'641	3'736	3'607	3'293	3'380	*34.2%*
1A2 Manufacturing industries and construction	5'946	6'018	5'701	5'817	5'378	5'390	5'484	5'089	4'973	4'982	*-22.7%*
1A3 Transport	16'295	16'646	16'440	16'329	16'147	16'262	16'170	16'061	15'324	15'155	*3.5%*
1A4 Other sectors	15'179	16'040	15'622	16'800	13'614	14'853	15'701	12'296	13'143	13'606	*-22.9%*
1A5 Other	136	131	133	138	125	133	134	139	135	140	*-36.5%*
1B Fugitive emissions from fuels	280	276	269	282	286	261	239	229	219	222	*-38.9%*
2. Industrial processes and product use	3'880	3'928	3'800	4'006	4'076	4'074	4'061	4'107	3'964	3'991	*11.6%*
3. Agriculture	6'061	6'164	6'075	6'089	6'045	6'029	5'968	6'055	5'992	5'963	*-10.6%*
5. Waste	869	852	831	818	803	780	774	764	758	748	*-32.6%*
6. Other	14	13	13	12	13	14	14	12	12	12	*-0.2%*
Total (excluding LULUCF)	52'380	53'906	52'558	54'137	50'086	51'437	52'281	48'359	47'813	48'199	*-9.4%*
4. Land use, land-use change and forestry	-220	-1'121	-2'035	-1'546	-1'322	-1'664	-1'273	-1'308	-1'407	-1'870	*156.2%*
Total (including LULUCF)	52'159	52'785	50'523	52'591	48'765	49'773	51'008	47'051	46'406	46'328	*-11.7%*

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 CO_2 equivalent (kt) and the contribution of individual source categories (as percentage values) 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	41'826	78.6%	41'869	80.4%	42'183	80.8%	43'993	80.5%	43'212	79.8%
1A1 Energy industries	*2'519*	*4.7%*	2'643	*5.1%*	3'172	*6.1%*	3'816	*7.0%*	3'847	7.1%
1A2 Manufacturing industries and construction	*6'443*	*12.1%*	6'192	*11.9%*	5'925	*11.4%*	5'973	*10.9%*	5'817	*10.7%*
1A3 Transport	*14'639*	*27.5%*	14'257	*27.4%*	15'927	*30.5%*	15'856	*29.0%*	16'329	*30.2%*
1A4 Other sectors	*17'641*	*33.2%*	18'185	*34.9%*	16'648	*31.9%*	17'895	*32.8%*	16'800	*31.0%*
1A5 Other	*220*	*0.4%*	163	*0.3%*	151	*0.3%*	139	*0.3%*	138	*0.3%*
1B Fugitive emissions from fuels	*363*	*0.7%*	431	*0.8%*	360	*0.7%*	314	*0.6%*	282	*0.5%*
2. Industrial processes and product use	3'576	6.7%	2'910	5.6%	3'141	6.0%	3'769	6.9%	4'006	7.4%
3. Agriculture	6'672	12.5%	6'374	12.2%	5'989	11.5%	5'963	10.9%	6'089	11.2%
5. Waste	1'109	2.1%	912	1.8%	869	1.7%	885	1.6%	818	1.5%
6. Other	12	0.0%	12	0.0%	13	0.0%	14	0.0%	12	0.0%
Total (excluding LULUCF)	53'196	100.0%	52'077	100.0%	52'195	100.0%	54'624	100.0%	54'137	100.0%

Source and Sink Categories	**2011**		**2012**		**2013**		**2014**		**2015**		**2016**	
	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%	kt CO_2 eq	%
1. Energy	39'148	78.2%	40'539	78.8%	41'463	79.3%	37'421	77.4%	37'087	77.6%	37'484	77.8%
1A1 Energy industries	3'598	*7.2%*	3'641	*7.1%*	3'736	*7.1%*	3'607	*7.5%*	3'293	*6.9%*	3'380	*7.0%*
1A2 Manufacturing industries and construction	5'378	*10.7%*	5'390	*10.5%*	5'484	*10.5%*	5'089	*10.5%*	4'973	*10.4%*	4'982	*10.3%*
1A3 Transport	16'147	*32.2%*	16'262	*31.6%*	16'170	*30.9%*	16'061	*33.2%*	15'324	*32.1%*	15'155	*31.4%*
1A4 Other sectors	13'614	*27.2%*	14'853	*28.9%*	15'701	*30.0%*	12'296	*25.4%*	13'143	*27.5%*	13'606	*28.2%*
1A5 Other	125	*0.2%*	133	*0.3%*	134	*0.3%*	139	*0.3%*	135	*0.3%*	140	*0.3%*
1B Fugitive emissions from fuels	286	*0.6%*	261	*0.5%*	239	*0.5%*	229	*0.5%*	219	*0.5%*	222	*0.5%*
2. Industrial processes and product use	4'076	8.1%	4'074	7.9%	4'061	7.8%	4'107	8.5%	3'964	8.3%	3'991	8.3%
3. Agriculture	6'045	12.1%	6'029	11.7%	5'968	11.4%	6'055	12.5%	5'992	12.5%	5'963	12.4%
5. Waste	803	1.6%	780	1.5%	774	1.5%	764	1.6%	758	1.6%	748	1.6%
6. Other	13	0.0%	14	0.0%	14	0.0%	12	0.0%	12	0.0%	12	0.0%
Total (excluding LULUCF)	50'086	100.0%	51'437	100.0%	52'281	100.0%	48'359	100.0%	47'813	100.0%	48'199	100.0%

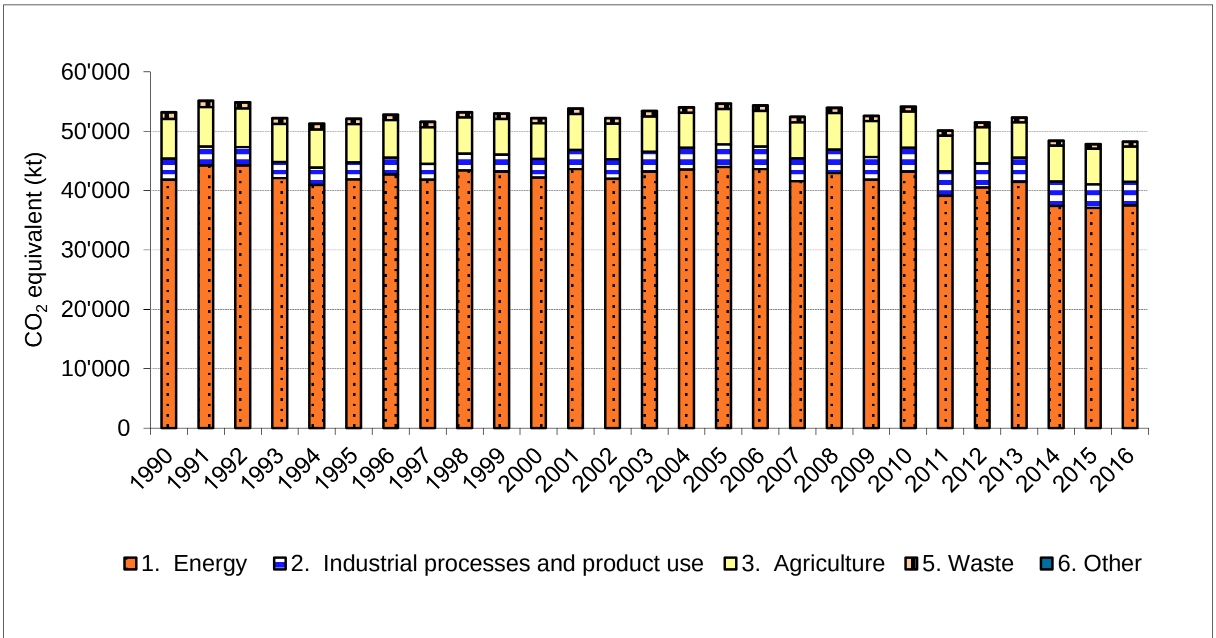

Figure 2-4 Switzerland's GHG emissions in CO_2 equivalent (kt) by sectors excluding LULUCF.

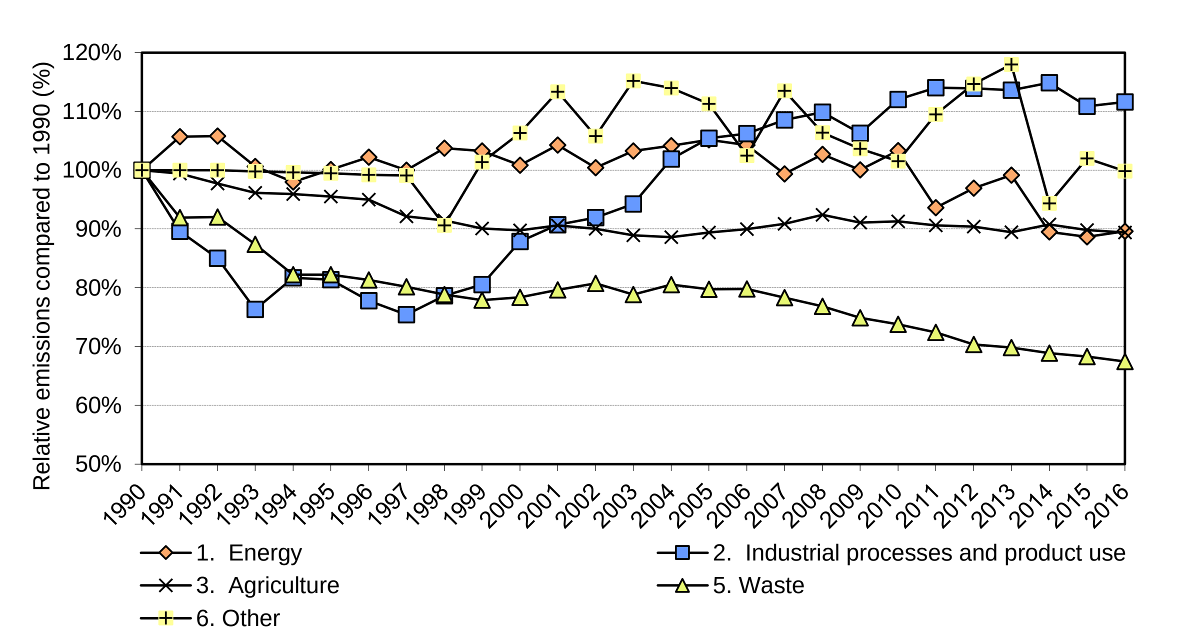

Figure 2-5 Relative emission trends (CO_2 eq) by main source categories (base year 1990 = 100%).

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 2016; see SFOE (2017), 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 2005–2016 the combination of effective reduction measures and warm winters (see Figure 2-7) led to a decreasing trend in emissions (see further details below under 1A4 Other sectors).
- Overall emissions from source category 1A1 Energy industry in 2016 are higher than in 1990. The time series shows an increase until 2006 and a decreasing trend from then on, fluctuations being caused by varying combustion activities in the petroleum refinery industry, waste-to-energy, new installations of district heating and weather related forcing of heating activities (see Figure 2-6 and values in Table 2-5).
- The trend for category 1A3 Transport is quite stable with minor fluctuations. They are representing the overall economic development in Switzerland fairly well (gross domestic product) (SFSO 2017g). The slight decrease of transport emissions since 2008 as well as the drop from 2014 to 2016 is largely caused by decreasing fuel tourism (EV 2015a) (see chp. 3.2.9.2.2).

- 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”[4] – used as an index of cold weather conditions – is apparent from Figure 2-7, which shows CO_2 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 2016 increased compared to 2015. CO_2 emissions caused by fuel combustion in source category 1A4 Other sectors – stationary sources increased as well (see Figure 2-7). In the period 1990–2016, the number of buildings and apartments increased as well as the average floor space per person and workplace. Both phenomena result 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.

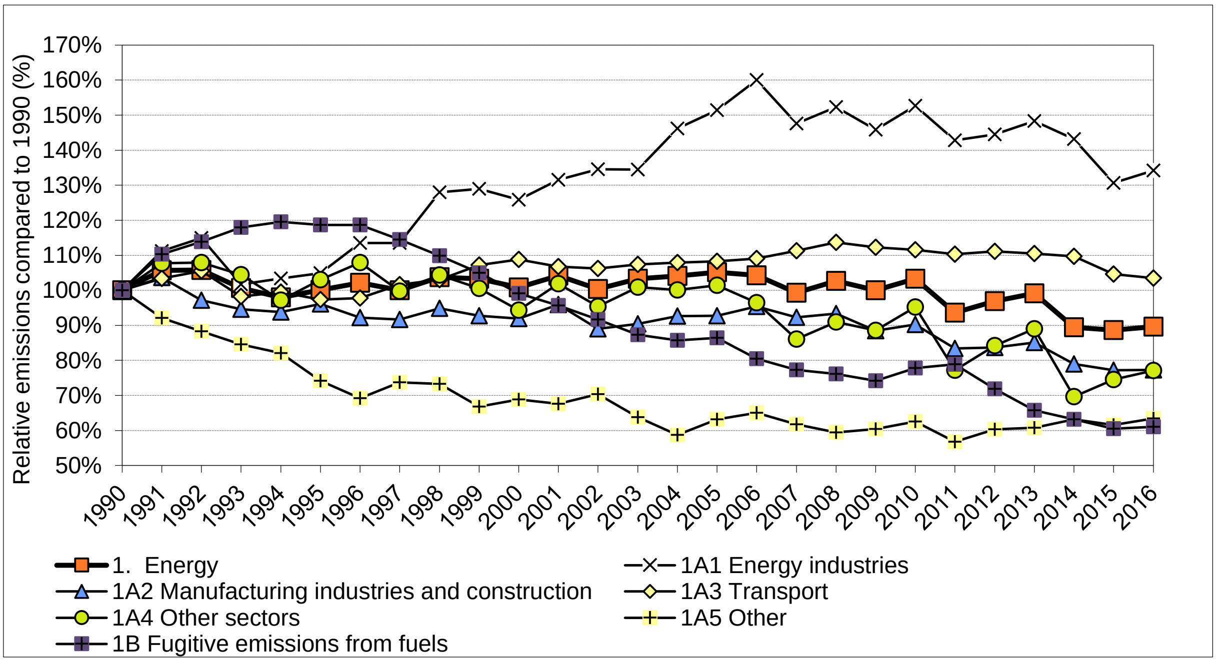

Figure 2-6 Emission trends (CO_2 eq) for the source categories in sector 1 Energy. The trend for the entire sector 1 Energy is represented by the bold line with orange squares.

[4] 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.

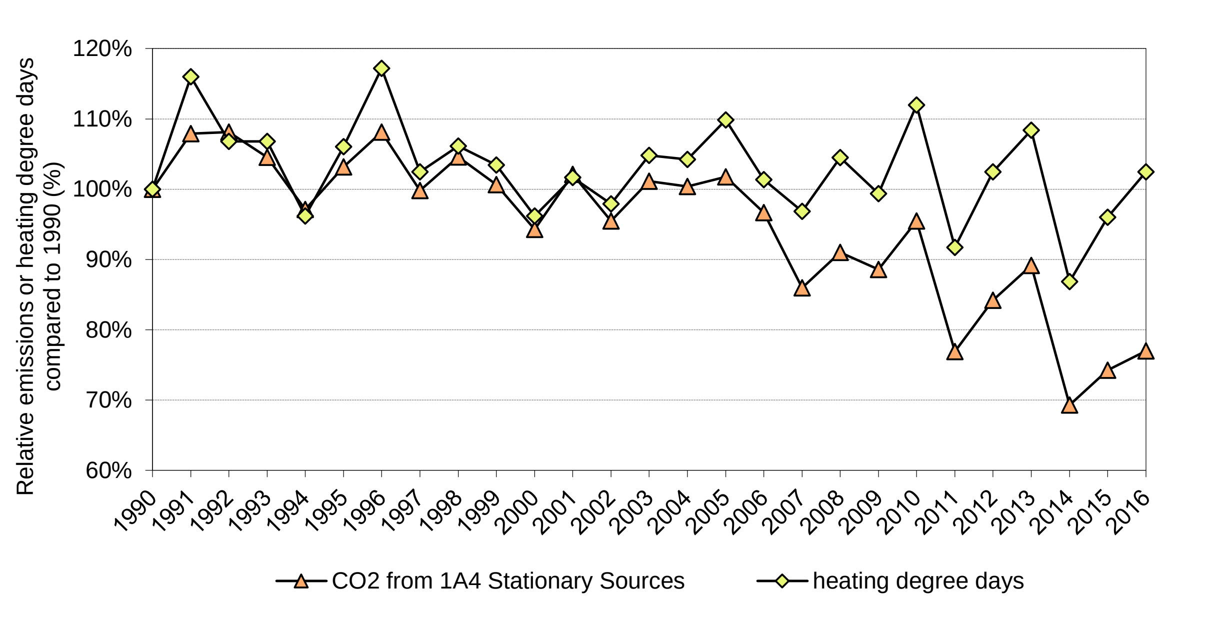

Figure 2-7 Relative trend for CO_2 emissions from 1A4 Fuel Combustion - Other Sectors (stationary sources only) compared with the number of heating degree days.

2.3.3 Emission trends in sector 4 LULUCF

Figure 2-8 illustrates the net emissions and removals of sector 4 LULUCF. Associated data are given in Table 2-4. LULUCF GHG emissions are dominated by biomass dynamics in forests. Except for the years 2000 and 2006, the removals in sector 4 LULUCF were higher than the emissions over the inventory period. A strong year-to-year variation is evident over the whole period. The reasons for the high net CO_2 eq emissions in 2000 (and the small removals in 1990 and 2001) are the storms Vivian (February 1990) and Lothar (December 1999), respectively, which caused great damages in the forest stands and markedly increased harvesting. In a medium-term perspective, harvesting rates in Swiss forests appeared to increase since 1991 and peaked in 2000 (storm Lothar, see above) and in 2006 and 2007 resulting in a net emission in 2006 and a minor removal in 2007. Primarily because harvesting rates started to decline in 2008 due to the international and domestic economic framework conditions, removals from LULUCF increased again since 2007 and showed a moderate year-to-year variation over the last inventory years. The annual contributions of CH_4 and N_2O emissions to LULUCF overall GHG net emissions over the inventory period was small compared to the CO_2fluxes.

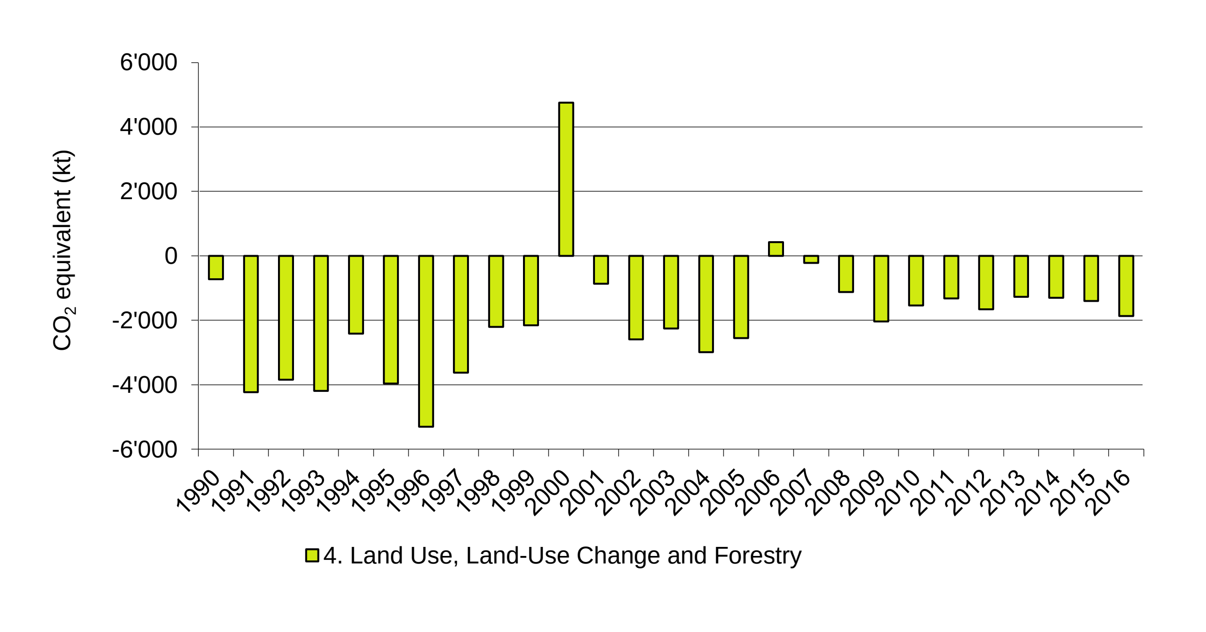

Figure 2-8 Net GHG emissions and removals of sector 4 Land use, land-use change and forestry (LULUCF), in kt CO_2 eq. Positive values refer to emissions, negative values refer to removals.

2.4 Emission trends for precursor gases and SO_2

Emission trends for precursor gases (IPCC 2006, Volume 1, Chapter 7) 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 decreasing emissions of precursor gases and SO_2 over the period 1990–2016. 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 within the industry sector (FOEN 2010i, Swiss Confederation 1985, 1997).

Table 2-6 Switzerland's precursor gases and SO_2 emissions (kt) (excluding NMVOC from LULUCF).

Precursor gases and SO_2	**1990**	**1995**	**2000**	**2005**
	kt			
NO_x	139	114	103	90
CO	733	492	385	303
NMVOC	287	189	135	94
SO_2	40	26	15	15

Precursor gases and SO_2	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	***2016 vs. 1990***
	kt										*%*
NO_x	85	83	78	76	71	71	71	67	63	62	*-56%*
CO	266	256	239	230	208	201	193	175	166	161	*-78%*
NMVOC	88	87	84	82	79	78	76	74	72	71	*-75%*
SO_2	11	12	10	10	8	9	8	8	6	6	*-85%*

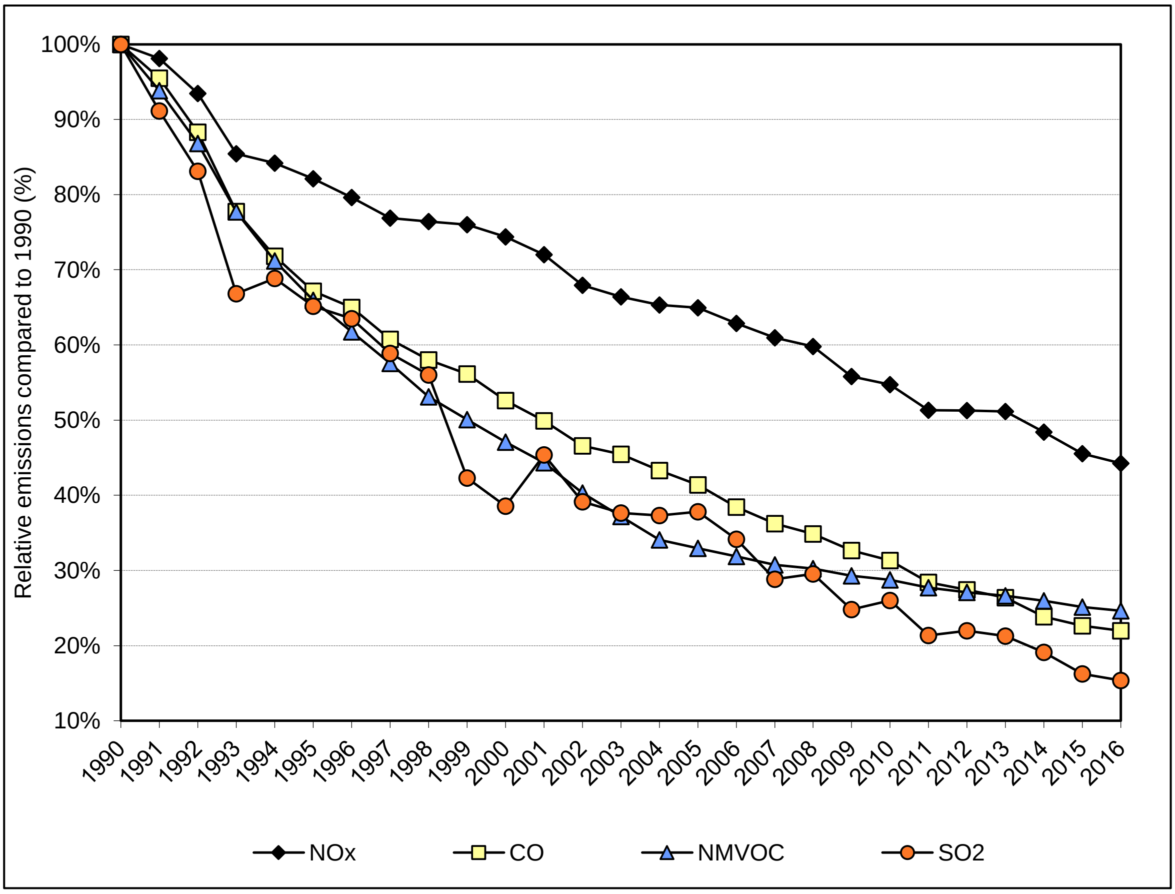

Figure 2-9 Relative trends for precursor and SO_2 emissions (excluding NMVOC from LULUCF; base year 1990 = 100%).

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 (see Figure 2-10). The total shown in Table 2-7 includes NMVOC emissions from LULUCF, which are estimated at almost 100 kt per year according to SAEFL (1996a).

Table 2-7 Precursor and SO_2 emissions (kt) by source in 2016. (NE = not estimated, NO = not occurring)

Sectors	**NO_x**		**CO**		**NMVOC**		**SO_2**	
	kt	%	kt	%	kt	%	kt	%
1 Energy	57.63	93.6%	156.22	96.3%	18.55	11.2%	5.21	85.8%
2 IPPU	0.26	0.4%	2.12	1.3%	46.75	28.1%	0.76	12.4%
3 Agriculture	3.18	5.2%	NO	NO	3.88	2.3%	NO	NO
4 LULUCF	0.05	0.1%	1.27	0.8%	95.52	57.5%	NE	NE
5 Waste	0.37	0.6%	1.93	1.2%	1.32	0.8%	0.10	1.6%
6 Other sources	0.08	0.1%	0.67	0.4%	0.11	0.1%	0.01	0.2%
Total	**61.58**	**100.0%**	**162.21**	**100.0%**	**166.14**	**100.0%**	**6.08**	**100.0%**

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

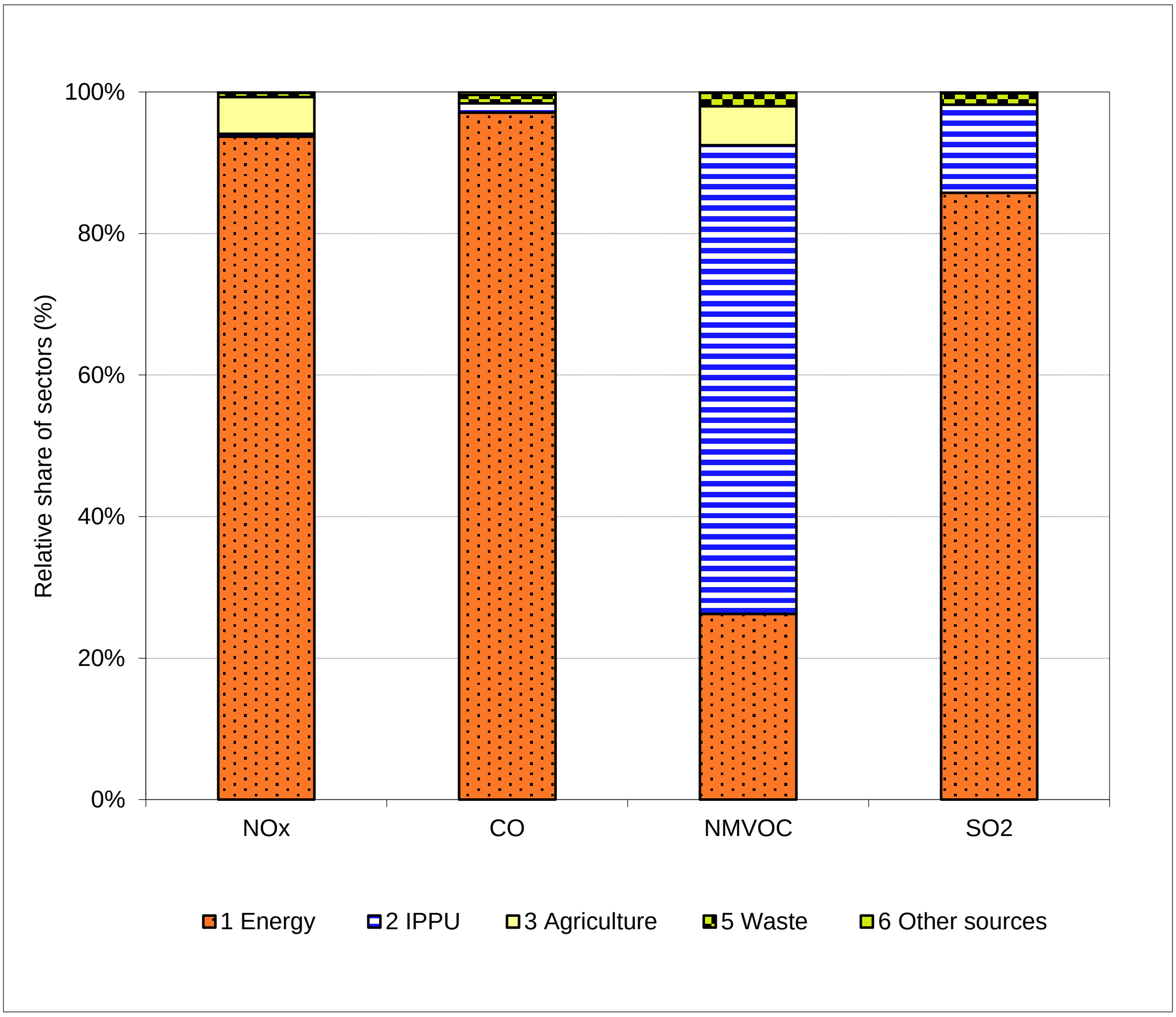

Figure 2-10 Relative contributions of individual sectors to precursor and SO_2 emissions in 2016 (excluding LULUCF).

2.5 Emission trends (Kyoto Protocol)

Relevant emissions and removals as accounted for under the Kyoto Protocol by sectors and GHG are shown in Table 2-8 and Table 2-9. Base year emissions for the second commitment period are reported in Switzerland's second Initial Report (FOEN 2016c) and the update to the report following the UNFCCC in-country review (FOEN 2016d).

Total emissions reported under the Kyoto Protocol differ from those reported under the UNFCCC because sectors 4 LULUCF and 6 Other and international bunkers are not accounted for under the Kyoto Protocol. However, activities under Article 3, paragraph 3 (Afforestation, Reforestation and Deforestation) and Article 3, paragraph 4 (Forest management, Cropland management, Grazing land management, and Revegetation) are taken into account. Under the activities of Article 3, paragraph 4 of the Kyoto Protocol, Switzerland only accounts for the mandatory activity Forest management.

Table 2-8 Summary of Switzerland's GHG emissions in CO_2 equivalent (kt) as well as emissions and removals under KP-LULUCF by sectors. Excluded are emissions and removals from sectors 4 LULUCF, 6 Other and from International bunkers.

		Sector	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		1 Energy + indirect CO_2 from this sector	41'881	41'870	44'260	44'297	42'121	41'003	41'897	42'768	41'848	43'418
		2 Industrial processes and product use + indirect CO_2 from this sector	3'887	3'932	3'531	3'340	3'001	3'176	3'145	2'997	2'893	2'990
		3 Agriculture	6'804	6'672	6'633	6'522	6'414	6'402	6'374	6'337	6'147	6'103
		5 Waste + indirect CO_2 from this sector	1'135	1'111	1'022	1'023	972	914	914	904	891	876
		Total (Annex A sources)	**53'707**	**53'585**	**55'445**	**55'182**	**52'508**	**51'494**	**52'329**	**53'006**	**51'780**	**53'388**

		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	43'209	42'200	43'615	42'012	43'205	43'571	44'006	43'617	41'568	42'961
		2 Industrial processes and product use + indirect CO_2 from this sector	3'049	3'301	3'393	3'423	3'491	3'751	3'874	3'902	3'983	4'031
		3 Agriculture	6'010	5'989	6'045	6'007	5'932	5'912	5'963	6'004	6'061	6'164
		5 Waste + indirect CO_2 from this sector	865	871	885	897	876	895	886	886	870	854
		Total (Annex A sources)	**53'132**	**52'361**	**53'939**	**52'339**	**53'504**	**54'129**	**54'730**	**54'409**	**52'482**	**54'009**
KP-LULUCF	Art.3.3	Afforestation & Reforestation										-27
		Deforestation										109
	Art.3.4	Forest management										-1'579
		Cropland management										NA
		Grazing land management										NA
		Revegetation										NA

		Sector	2009	2010	2011	2012	2013	2014	2015	2016	*2016 vs. 1990*
			CO_2 equivalent (kt)								%
Annex A sources		1 Energy + indirect CO_2 from this sector	41'851	43'223	39'159	40'549	41'474	37'432	37'096	37'493	*-10%*
		2 Industrial processes and product use + indirect CO_2 from this sector	3'903	4'109	4'178	4'175	4'161	4'206	4'063	4'088	*4%*
		3 Agriculture	6'075	6'089	6'045	6'029	5'968	6'055	5'992	5'963	*-11%*
		5 Waste + indirect CO_2 from this sector	832	820	805	781	776	766	759	749	*-33%*
		Total (Annex A sources)	**52'661**	**54'240**	**50'187**	**51'535**	**52'379**	**48'459**	**47'909**	**48'293**	***-10%***
KP-LULUCF	Art.3.3	Afforestation & Reforestation	-28	-22	-20	-20	-19	-17	-18	-20	
		Deforestation	146	157	158	158	156	138	123	151	
	Art.3.4	Forest management	-2'617	-2'551	-1'408	-2'671	-2'438	-1'279	-2'720	-2'434	
		Cropland management	NA	NA	NA	NA	NA	NA	NA	NA	
		Grazing land management	NA	NA	NA	NA	NA	NA	NA	NA	
		Revegetation	NA	NA	NA	NA	NA	NA	NA	NA	

Table 2-9 Switzerland's total GHG emissions (excluding 4 LULUCF, 6 Other and International bunkers) and the contribution of individual gases in CO_2 equivalent (kt), as well as emissions and removals under KP-LULUCF.

		GHG	Base year inital report	1990	1991	1992	1993	1994	1995	1996	1997	1998
			CO_2 equivalent (kt)									
Annex A sources		CO_2 + indirect CO_2	44'516	44'553	46'505	46'352	43'908	42'953	43'667	44'331	43'249	44'806
Annex A sources		CH_4	6'086	6'005	5'937	5'854	5'746	5'696	5'688	5'645	5'503	5'435
Annex A sources		N_2O	2'852	2'774	2'764	2'738	2'666	2'638	2'622	2'626	2'524	2'517
Annex A sources		HFCs	0.0	0.0	1.5	15	32	79	242	294	358	454
Annex A sources		PFCs	117	117	99	81	35	21	17	20	21	24
Annex A sources		SF_6	137	137	139	141	121	107	93	90	124	153
Annex A sources		NF_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Annex A sources		**Total (Annex A sources)**	**53'707**	**53'585**	**55'445**	**55'182**	**52'508**	**51'494**	**52'329**	**53'006**	**51'780**	**53'388**

		GHG	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			CO_2 equivalent (kt)									
Annex A sources		CO_2 + indirect CO_2	44'620	43'779	45'232	43'599	44'769	45'339	45'887	45'474	43'463	44'812
Annex A sources		CH_4	5'338	5'286	5'324	5'281	5'201	5'167	5'183	5'195	5'174	5'250
Annex A sources		N_2O	2'478	2'468	2'477	2'446	2'400	2'363	2'364	2'369	2'395	2'417
Annex A sources		HFCs	531	634	733	822	908	1'009	1'049	1'133	1'229	1'250
Annex A sources		PFCs	26	50	28	33	62	65	44	52	49	58
Annex A sources		SF_6	140	144	145	158	165	186	203	186	172	222
Annex A sources		NF_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Annex A sources		**Total (Annex A sources)**	**53'132**	**52'361**	**53'939**	**52'339**	**53'504**	**54'129**	**54'730**	**54'409**	**52'482**	**54'009**
KP-LULUCF	Art.3.3	CO_2										80
KP-LULUCF	Art.3.3	CH_4										NO
KP-LULUCF	Art.3.3	N_2O										2.1
KP-LULUCF	Art.3.4	CO_2										-1'583
KP-LULUCF	Art.3.4	CH_4										2.7
KP-LULUCF	Art.3.4	N_2O										1.2

		GHG	2009	2010	2011	2012	2013	2014	2015	2016	*2016 vs.1990*
			CO_2 equivalent (kt)								*%*
Annex A sources		CO_2 + indirect CO_2	43'632	45'149	41'082	42'350	43'282	39'339	38'835	39'301	*-12%*
Annex A sources		CH_4	5'157	5'129	5'075	5'047	4'985	4'982	4'955	4'907	*-18%*
Annex A sources		N_2O	2'377	2'426	2'370	2'355	2'314	2'328	2'285	2'300	*-17%*
Annex A sources		HFCs	1'247	1'316	1'426	1'502	1'494	1'507	1'523	1'523	*see caption*
Annex A sources		PFCs	63	64	69	71	51	43	55	55	*-53%*
Annex A sources		SF_6	180	148	160	209	252	259	256	207	*51%*
Annex A sources		NF_3	5.1	8.5	6.2	0.4	0.1	0.4	0.5	0.5	*NA*
Annex A sources		**Total (Annex A sources)**	**52'661**	**54'240**	**50'187**	**51'535**	**52'379**	**48'459**	**47'909**	**48'293**	***-10%***
KP-LULUCF	Art.3.3	CO_2	116	132	135	136	135	119	102	130	
KP-LULUCF	Art.3.3	CH_4	NO	NO	NO	NO	NO	NO	NO	NO	
KP-LULUCF	Art.3.3	N_2O	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	
KP-LULUCF	Art.3.4	CO_2	-2'621	-2'554	-1'414	-2'674	-2'442	-1'282	-2'724	-2'441	
KP-LULUCF	Art.3.4	CH_4	2.7	2.3	4.0	2.2	2.2	2.4	2.4	5.0	
KP-LULUCF	Art.3.4	N_2O	1.2	1.0	2.2	1.0	1.0	1.1	1.1	2.8	

3 Energy

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 1990–2016 are illustrated in Figure 3-1 and Table 3-1.

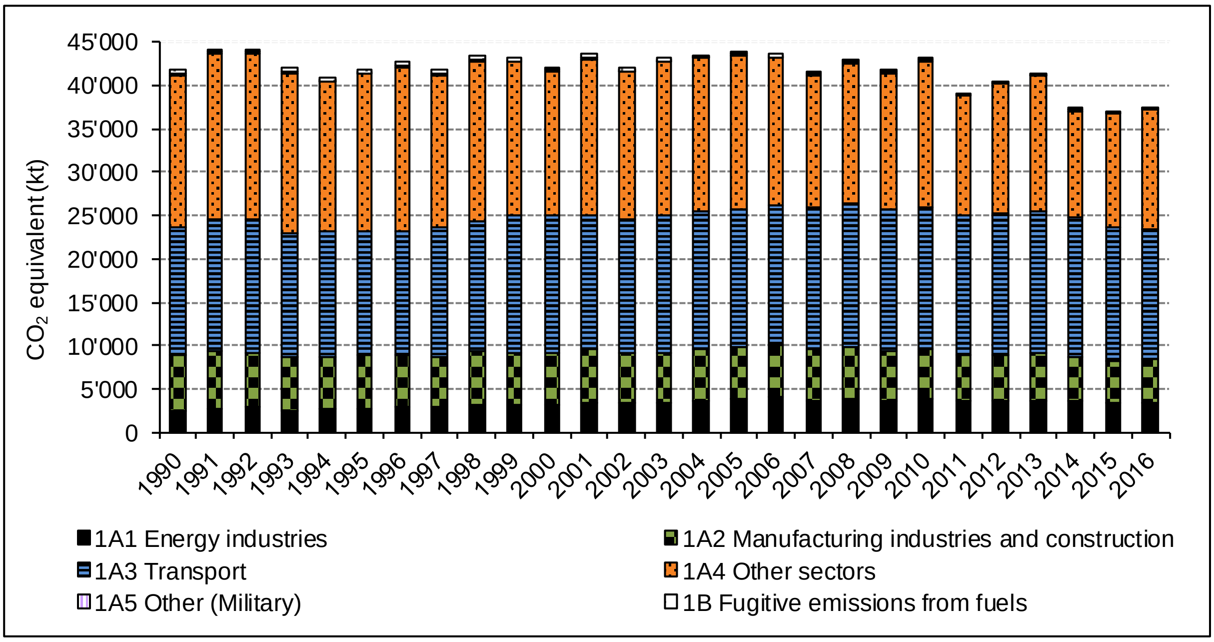

Figure 3-1 Switzerland's GHG emissions of sector 1 Energy in CO_2 equivalent (kt).

Considering total emissions of sector 1 Energy, fluctuations with no trend are observed in the period 1990–2005. From 2006 onwards, a decreasing trend can be identified, again superposed by fluctuations. The years 2014 – 2016 show the lowest values of the entire period 1990–2016. 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 CO_2. Fluctuations reflect inter alia the climatic variability in Switzerland (see Figure 2-7 and related comments).
- The decreasing trend of CH_4 emissions since 1990 is the result of improved gas transmission and distribution 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 N_2O emissions can mainly be explained by changes in the emission of road transportation due to changes in emission factors for diesel and gasoline combustion. The first generation of catalytic converters generated N_2O as an unintended by-product in the exhaust gases, leading to an increase in N_2O emissions until 1997. With new converter materials being used, the emission factors are decreasing since 2001 with strongest reduction during 2003 and 2004. For further details, see chp. 3.2.9.2.2.

Table 3-1 GHG emissions of source category 1 Energy by gas in CO_2 equivalent (kt)

Gas	**1990**	**1995**	**2000**	**2005**
	CO_2 equivalent (kt)			
CO_2	40'899	40'916	41'345	43'343
CH_4	634	635	515	419
N_2O	293	318	323	231
Sum	41'826	41'869	42'183	43'993

Gas	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2015 to 2016**	**1990 to 2016**
	CO_2 equivalent (kt)										%	
CO_2	40'963	42'353	41'259	42'614	38'595	39'992	40'922	36'921	36'591	36'980	1%	-10%
CH_4	373	366	352	364	334	319	307	281	278	280	1%	-56%
N_2O	220	229	227	234	219	228	234	219	219	225	3%	-23%
Sum	41'556	42'948	41'839	43'212	39'148	40'539	41'463	37'421	37'087	37'484	1%	-10%

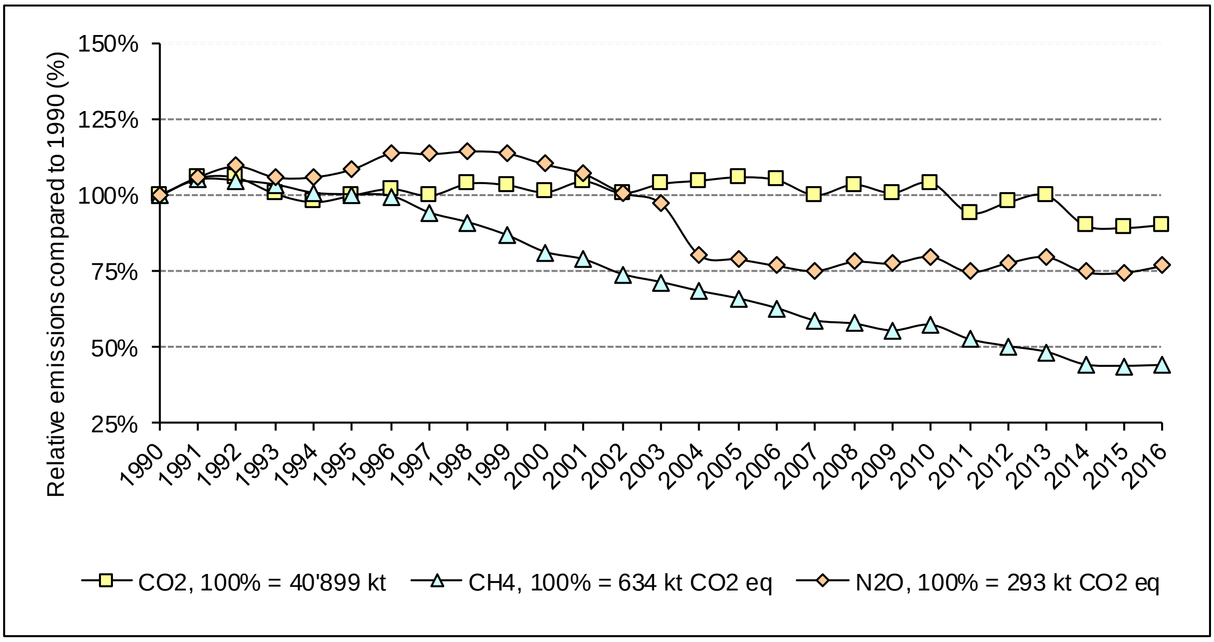

Figure 3-2 Relative trends of the greenhouse gas emissions of sector 1 Energy. The base year 1990 represents 100%.

The following table summarises the emissions of sector 1 Energy in 2016. The table also includes emissions from international bunkers (aviation and marine) as well as CO_2 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 2016 in kt CO_2 equivalent (Total: rounded values). For full biomass CO_2 emissions see Table 3-20. Note that in reporting table CRF Table10s2 biogene CO_2 emissions from 5C are missing (for an overview of errors of the CRF Reporter see Annex 6).

Sector Energy	**CO_2**	**CH_4**	**N_2O**	***Total***
	CO_2 equivalent (kt)			
1 Energy	36'980	279.9	224.8	*37'484*
1A Fuel combustion	36'951	86.3	224.8	*37'263*
1A1 Energy industries	3'352	0.7	27.3	*3'380*
1A2 Manufacturing industries and construction	4'942	5.0	35.0	*4'982*
1A3 Transport	15'042	13.7	98.6	*15'155*
1A4 Other sectors	13'477	66.8	62.6	*13'606*
1A5b Other (mobile)	138	0.2	1.2	*140*
1B Fugitive emissions from fuels	28	193.5	0.0	*222*

International bunkers	5'165	0.5	42.3	*5'208*
CO_2 emissions from biomass	7'463	-	-	*7'463*

In 2016, 45 key source categories are identified in the Swiss greenhouse gas inventory according to level or trend (Table 1-9). Amongst these, 19 belong to the sector 1 Energy. The key categories (according to level and trend) from sector 1 Energy are shown in Figure 3-3 (Approach 1) and Figure 3-4 (Approach 2).

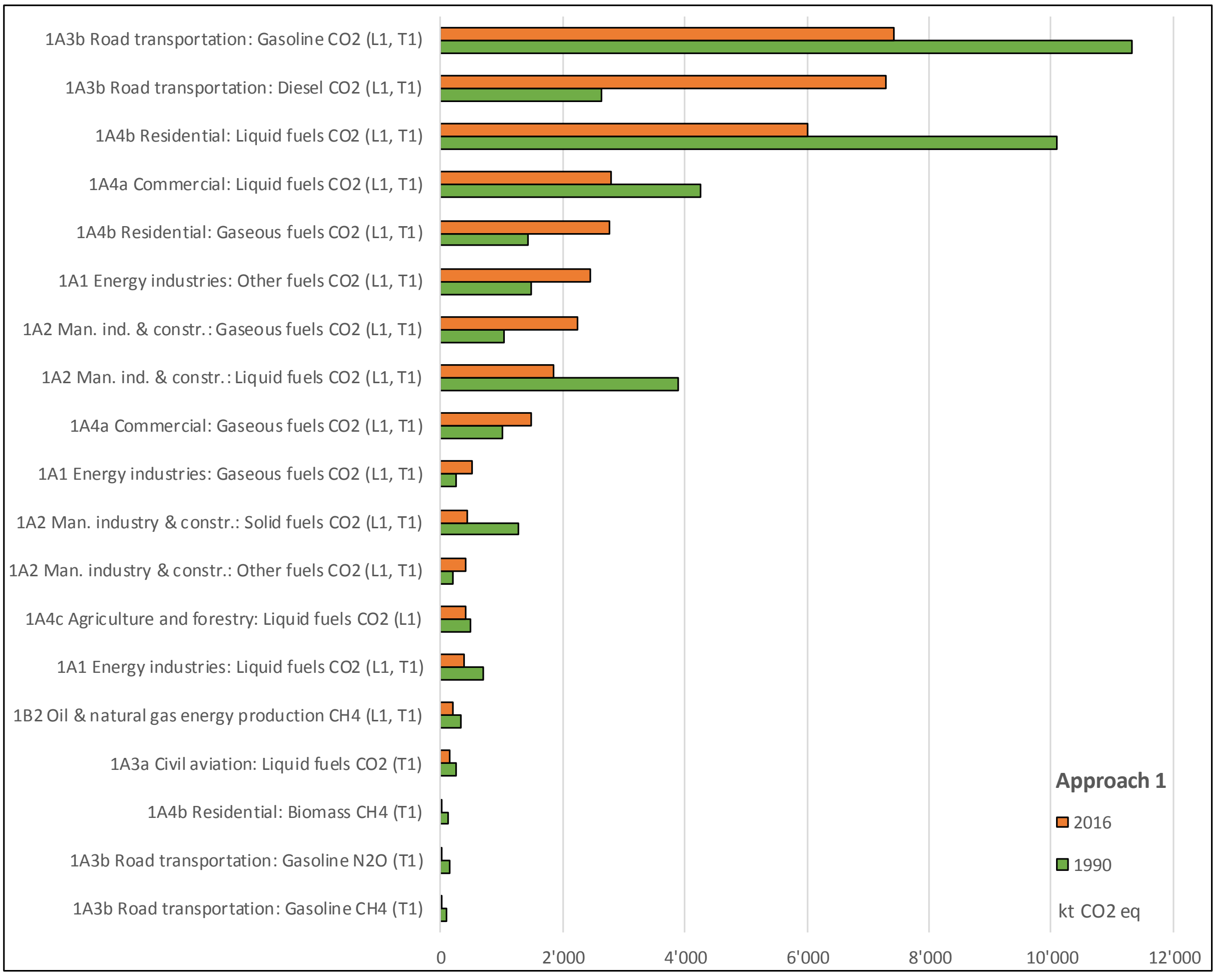

Figure 3-3 Key categories in the Swiss GHG inventory from sector 1 Energy determined by Approach 1 (L1 = key category according to Approach 1 level in 2016; T1 = key category according to Approach 1 trend 1990–2016).

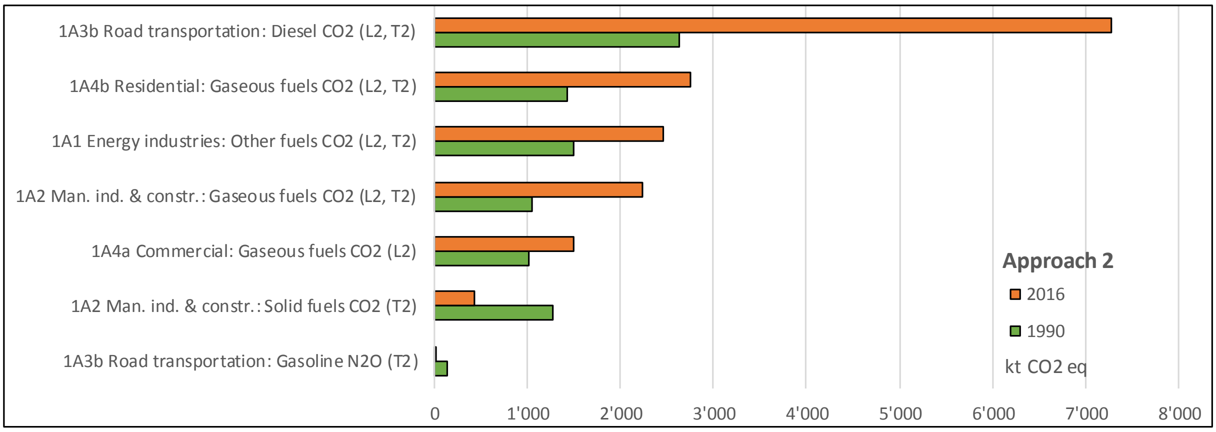

Figure 3-4 Key categories in the Swiss GHG inventory from sector 1 energy determined by Approach 2 (L2 = key category according to Approach 2 level in 2016; T2 = key category according to Approach 2 trend 1990–2016).

3.2 Source category 1A – Fuel combustion activities

3.2.1 Comparison of the Sectoral Approach with the Reference Approach

Two methods are applied for modelling CO_2 emissions from the 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 shows the two approaches, showing the input data used and the disaggregation of fuel types that ultimately allows for comparing the two approaches.

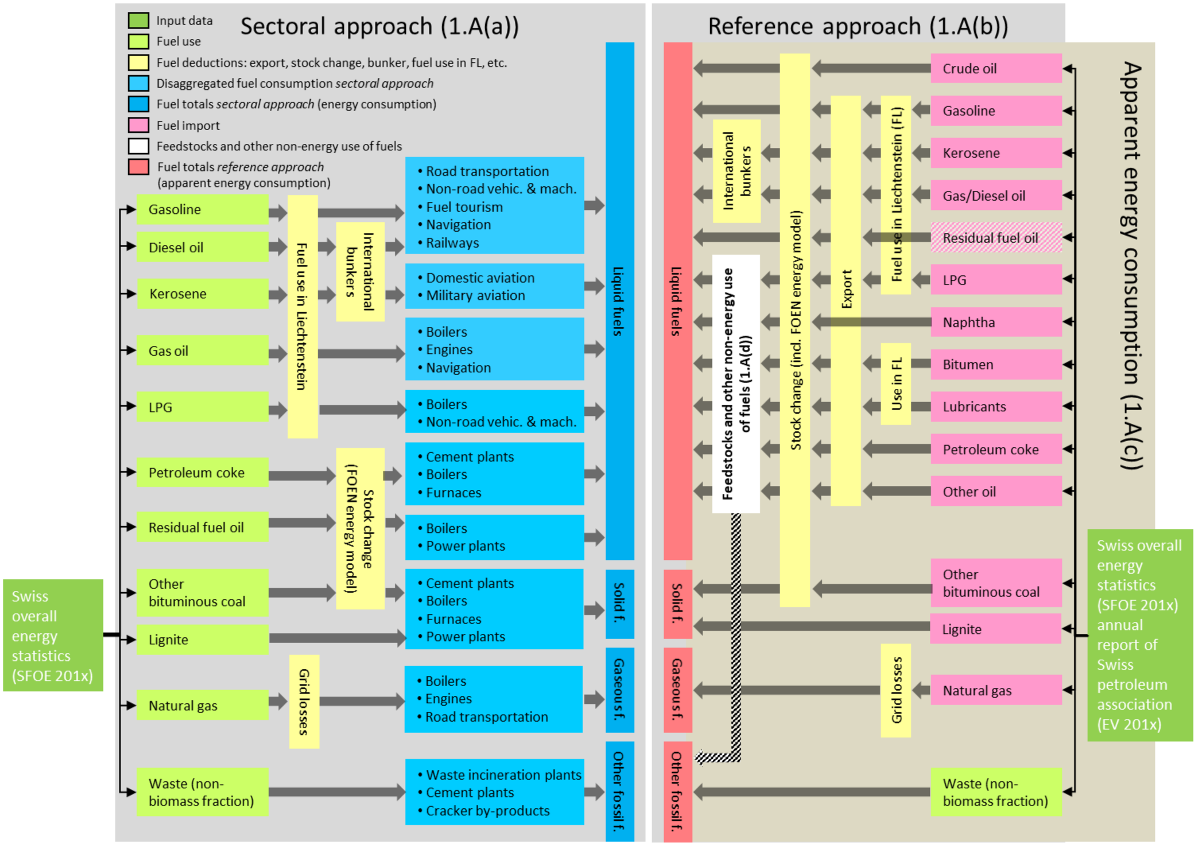

Figure 3-5 Calculation of Reference and Sectoral Approach. The input data for both approaches stem from the Swiss overall energy statistics (SFOE 2017). While the Reference Approach considers the net import/export balance, the Sectoral Approach considers the fuel consumption. The dark grey arrows represent fuel deductions where occurring. The dashed arrow from the Feedstock use to Other fossil fuels stands for the CO_2 emissions from cracker by-products (originating from feedstock use of LPG and naphtha) which are accounted for under Other fossil fuels. The graphic box of the import of Residual fuel oil is dashed since there is no more import of residual fuel oil.

The Sectoral Approach is based on sectoral energy consumption data from the Swiss overall energy statistics (SFOE 2017) 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 2017). Apparent consumption (in tonnes) is derived from imports and exports of primary fuels (crude oil, natural gas, coal[5]), secondary fuels (gasoline, diesel oil etc.) and stock changes. For crude oil, a constant value for carbon content and net calorific value is applied for the entire time period, 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 and Table 3-10, Table 3-12 and Table 3-13 in chp. 3.2.4.2). After the deduction of feedstocks and non-energy use of fuels (see chp. 3.2.3), the net carbon emissions and effective CO_2 emissions are calculated for the Reference Approach as shown in the reporting tables 1.A(b)–1.A(d). The oxidation factor is set to one (see chp. 3.2.4.4.1). The Reference Approach covers the CO_2 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. In 2015 after closing of one refinery, the share dropped down to 30% (EV 2016). In addition, the reporting tables 1.A(b) provide information of the Reference Approach of total biomass use as well as consumption of so-called other non-fossil fuels (biogenic waste) in Switzerland.

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 as of Table 3-9.
- Liechtenstein's liquid fossil fuel consumption is subtracted from the input figures in SFOE (2017), as the Swiss overall energy statistics includes Liechtenstein's liquid fuel consumption as well (customs union with Switzerland) (see also chp. 3.2.4). The same holds for the non-energy use of bitumen and lubricants.

The differences in energy consumption and CO_2 emissions between Reference and Sectoral Approach are calculated within the EMIS database. For the entire period, they are below 1% and in the range of about 1% for the energy consumption and the CO_2 emissions, respectively, as shown in Table 3-3 and in Figure 3-6. Various effects influence the difference between Reference and Sectoral Approach. 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.

[5] Coke oven coke and anthracite are included under other bituminous coal.

There are two mistakes in the petroleum balance of the petroleum association for 2016 regarding the energy-related use of petroleum coke in 2016 and regarding the amount of petroleum coke sold in 2015 (EV 2017a, Table 23).

- For 2016, the statistics reports the total domestic sales of petroleum coke as energy use – forgetting that its amount for feedstock use which is part of so-called other non-energy products should have been deducted (EV 2017). Therefore, the data provided in the reference approach, do not agree with the numbers published in EV 2017.
- In addition, there is a mistake in the amount of domestic sales of petroleum coke in 2015 published in EV 2017. Therefore, the amount of petroleum coke is taken from the statistics of the previous year (EV 2016).

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

	1990	1995	2000	2005
	%			
Energy consumption	0.6	0.8	0.4	0.5
CO_2 emissions	0.8	0.9	0.7	0.8

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	%									
Energy consumption	0.5	0.4	0.6	0.5	0.5	0.4	0.4	0.4	0.2	0.3
CO_2 emissions	0.8	0.8	1.1	1.0	1.0	0.8	0.9	0.9	0.6	0.8

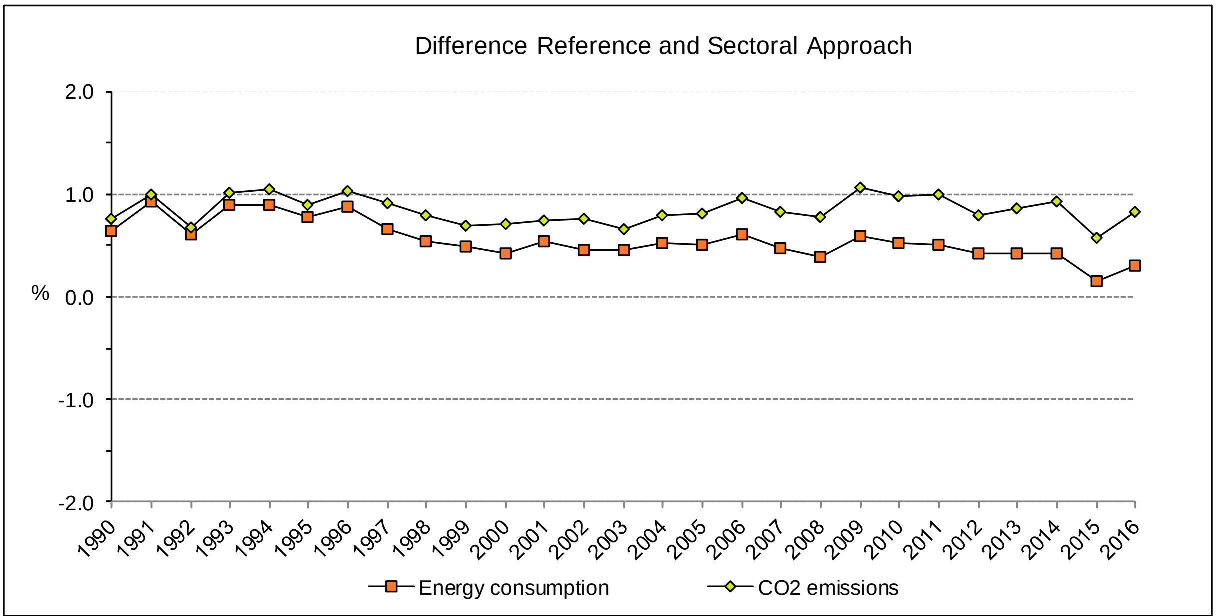

Figure 3-6 Time series for the differences between Reference and Sectoral Approach. Numbers are taken from Table 3-3. See caption there for further information.

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 Aviaton (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 3-74). 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 2017, FOCA 2017). 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 2016, the bunker fuel consumption and the emissions had to be expanded by the factor 1.045, the correction factor was 0.955 (FOCA 2017). For the more recent years, the modelled and actual total fuel sales are listed in Table 3-5. Subsequent Table 3-6 provides an overview of total fuel consumption of international aviation (bunker) in energy units.

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

Modelled and actual fuel sales	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
	Fuel consumption in t						
Modelled fuel sales domestic	39'252	42'047	43'414	42'064	44'462	43'680	44'716
Modelled fuel sales international	1'395'428	1'511'279	1'527'522	1'528'863	1'551'678	1'590'013	1'711'227
Actual fuel sales SFOE minus modelled fuel sales domestic	1'351'572	1'489'758	1'479'702	1'497'899	1'504'767	1'558'639	1'634'318
Correction factor for emission international	0.969	0.986	0.969	0.980	0.970	0.980	0.955
Overestimation emission international (modelled)	3.1%	1.4%	3.1%	2.0%	3.0%	2.0%	4.5%

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**	**2005**
	Fuel consumption in TJ			
1D1 International aviation	41'884	49'918	63'726	47'775
1990 = 100%	100%	119%	152%	114%

1D1 International aviation	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
	Fuel consumption in TJ									
1D1 International aviation	53'692	58'023	55'426	58'334	62'461	63'903	64'709	65'006	67'333	70'603
1990 = 100%	128%	139%	132%	139%	149%	153%	154%	155%	161%	169%

3.2.2.2.2 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 CO_2 (with country-specific carbon contents) and with a Tier 1 approach for CH_4 and N_2O 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 1997–2016 (SFOE 2017g).
- 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), data from 2013 onwards are constant on the 2012 level. 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 2015) this approach is justified. The emission factor for CO_2 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**	**2005**
	Fuel consumption in TJ			
1D2 International navigation	813	756	526	500
1990 = 100%	100%	93%	65%	62%

1D2 International navigation	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
	Fuel consumption in TJ									
1D2 International navigation	477	459	435	472	421	379	356	311	335	342
1990 = 100%	59%	57%	54%	58%	52%	47%	44%	38%	41%	42%

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 chp. 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in chp. 3.2.4.8.

3.2.2.5 Category-specific recalculations for 1D

- Recalculation of the total use of kerosene in the aviation model due to changed calorific value of kerosene since submission 2015. This changed calorific value of kerosene has not been considered in the aviation model for the years 1999-2012 yet. This recalculation results in 18 TJ more kerosene in the year 1999 and 276 TJ more in 2012. This results in higher emissions in 2012 of: 20.1 kt CO_2.

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 2017) 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 2017). To complement this source, bottom-up data from annual monitoring reports of the Swiss emissions trading scheme (ETS) and from surveys of individual companies are 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 under 4.3.2.1 and 4.3.2.4, respectively). Accordingly, activity data for liquefied petroleum gas and naphtha are confidential and included in fuel type Other oil in reporting table 1.A(d).

- 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 gasoline for 2-stroke engines. Two different ways of lubricant use are considered: lubricants used in 2-stroke engines are assumed to be 100% oxidised, whereas the use of all other lubricants are partly emissive. According to the 2006 IPCC guidelines (IPCC 2006), 20% of those lubricants are oxidized during use (ODU). All CO_2 emissions from use of lubricants are reported under source category 2D1, see chp. 4.5.2.1.
- Petroleum coke is used as a feedstock by two consumers only, i.e. for the production of silicium carbide and graphite as well as of anodes in primary aluminium production (up to 2006) in source categories 2B5 and 2C3, respectively (see chp. 4.3.2.3 and 4.4.2.2). Apart from bottom-up information from these two consumers, top-down information is provided by the Swiss petroleum association (EV 2017). Please note that there are two mistakes in the petroleum balance of the petroleum association for 2016 regarding the energy-related use of petroleum coke in 2016 and regarding the amount of petroleum coke sold in 2015 (EV 2017a, Table 23). For 2016, the statistics report the total domestic sales of petroleum coke as energy use – forgetting that its amount for feedstock use which is part of so-called other non-energy products should have been deducted (EV 2017). Therefore, the data provided for feedstock use, do not agree with the numbers published in EV 2017. In addition, there is a mistake in the amount of domestic sales of petroleum coke in 2015 published in EV 2017. Therefore, the amount of petroleum coke is taken from the statistics of the previous year (EV 2016). Activity data are confidential and included in fuel type Other oil in reporting table 1.A(d).
- Paraffin waxes for non-energy use are reported under Other oil, since there is no separate category for paraffin waxes in reporting table 1.A(d). The information used stems from the statistics of the Swiss petroleum association (EV 2017). 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. Please note that the net consumption of non-energy use of fuels reported in Swiss overall energy statistics includes sulphur produced by the refineries as well. This amount of sulphur is now subtracted resulting in lower fuel quantities for non-energy use of other oil for the entire time series.
- Anthracite is also used as feedstock in the Swiss production plant for silicium carbide and graphite in source category 2B5 (chp. 4.3.2.3). Accordingly, activity data for anthracite are confidential and thus denoted as “C” in reporting tables 1.A(d). After consulting the responsibles for the Swiss overall energy statistics, the feedstock use of anthracite has to be included in the stock changes of other bituminous coal.

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

Category-specific recalculations

- Non-energy use of fuels: The use of bitumen and lubricants of Liechtenstein (customs union with Switzerland) is now subtracted from the consumption reported by the Swiss petroleum association for the entire time series.

- The lubricant amount of gasoline used in two-stroke engines of motorcycles and non-road transportation is now reported as fully oxidized in source category 2D1 Lubricant use. This results in an increase in emissions of 1.5 and 0.5 kt CO_2 eq in 1990 and 2015, respectively.

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 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 2017, 2017b) and partly based on 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. For biogas, the NCV of natural gas is used.
- For liquid biofuels, the NCV are constant over the whole period 1990 to 2016. The values are taken from SFOE (2017). Note that the corresponding values have changed compared to previous sumbmissions: So far, the NCV of biodiesel and bioethanol were assumed to be the same as fossil diesel oil and gasoline. The entire time series have been recalculated.

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.

Net calorific values (NCV)		**1990-1998**	**2013-2016**
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 ga	SFOE (2017)	46.0	46.0
Petroleum coke	SFOE (2017), Cemsuisse (2010a)	35.0	31.8
Other bituminous coal	SFOE (2017), Cemsuisse (2010a)	28.1	25.5
Lignite	SFOE (2017), Cemsuisse (2010a)	20.1	23.6
Natural gas	SGWA	*see table below*	
Biofuel	**Data Sources**	**NCV [GJ/t]**	
Biodiesel	SFOE (2017)	38.0	38.0
Bioethanol	SFOE (2017)	26.5	26.5
Biogas	assumed equal to natural gas	*see table below*	
Wood	SFOE (2017b)	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 CO_2 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 2017)[6].

Petroleum coke, other bituminous coal, lignite

NCVs of petroleum coke, other bituminous coal and lignite are based on data from the SFOE for 1990 to 1998 and on measurements of samples taken from Switzerland’s cement plants from 2010 onwards. Cement plants are the largest consumers of these fuels in Switzerland. 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 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 1998 and 2010 the values are linearly interpolated (see SFOE 2017, p. 61).

[6] It is assumed that LPG consists of 50% propane and 50% butane.

Natural gas, biogas

The net calorific value of natural gas (and also the CO_2 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 (data source SGWA, latest report stems from SGWA 2017). Import shares are available for 1991, 1995, 2000, 2005, 2007 and from 2009 onwards on an annual basis. Estimated import shares for the years 1991, 1995 and 2000 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 (2017h). For biogas, the NCV is assumed to be equal to natural gas since the raw biogas is treated to become the same quality level including its energetic properties as natural gas.

Table 3-10 Net calorific values of natural gas and biogas for selected years. Years in-between are linearly interpolated. Data source annual reports of the Swiss Gas and Water Industry Association SGWA, latest report SGWA (2017). Spreadsheet to determine national averages: FOEN 2017h.

Year	Net calorific value [GJ/t] natural gas /biogas
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
2015	46.6
2016	47.1

Wood

The net calorific value of wood depends on the type of wood fuel (for e.g. log wood, wood chips, pellets) and are based on the Swiss wood energy statistics (SFOE 2017b). Table 3-9 illustrates the range of the NCV for all wood fuel types.

Bioethanol and biodiesel

The NCV of bioethanol and biodiesel are taken from the Swiss overall energy statistics SFOE (2017). They are kept constant over time.

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 2017). 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 2017), 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 2017). 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) and the Swiss petroleum association (EV) for data on import, export, sales, stocks of oil products and for processing of crude oil in refineries.
- Annual import data for natural gas from the Swiss gas industry association (VSG 2017).
- Annual import data for petroleum products and coal from the Federal Customs Administration (FCA).
- Data provided by industry associations (GVS, SGWA, Cemsuisse, VSG, VSTB etc.).
- Swiss renewable energy statistics (SFOE).
- Swiss wood energy statistics (SFOE)
- Swiss statistics on combined heat and power generation (SFOE)

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.

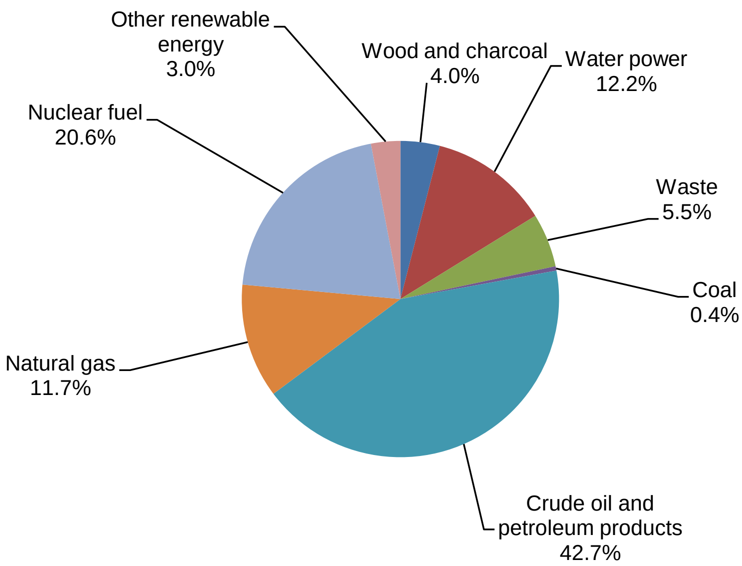

Figure 3-8 Switzerland's primary energy consumption in 2016 by fuels (see corresponding data in SFOE 2017).

Table 3-11 shows primary energy consumption excluding 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 1990–2016 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 as well as 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	23'342	8'890	1'400	14'901	68'599	19'160	46'646	652'857
1991	162'225	46'562	48'154	238'602	23'590	12'437	980	12'162	76'902	18'596	48'621	688'830
1992	168'100	49'099	46'706	236'809	24'170	11'492	315	8'758	80'808	19'009	47'518	692'784
1993	155'897	50'776	44'978	225'920	17'165	12'388	1'120	7'442	84'758	19'158	47'795	667'396
1994	156'087	52'109	47'748	207'141	17'860	13'455	1'470	7'632	83'587	19'154	45'783	652'026
1995	151'290	54'947	48'604	217'523	17'278	12'756	1'260	7'962	92'123	19'687	47'767	671'198
1996	155'209	56'753	45'597	226'289	15'097	13'939	1'015	5'456	99'710	20'584	51'236	690'884
1997	161'171	58'774	47'385	212'223	12'581	14'236	280	4'590	96'260	21'655	48'211	677'366
1998	162'477	61'268	49'209	222'407	15'882	15'259	455	3'960	99'065	23'803	49'754	703'538
1999	168'025	65'244	52'184	212'349	11'058	15'805	521	4'105	102'588	24'403	50'450	706'732
2000	168'165	68'060	55'677	196'137	7'923	13'649	551	6'120	101'970	26'536	50'122	694'911
2001	163'543	64'208	56'709	213'089	9'942	14'069	410	6'233	106'132	27'068	53'446	714'850
2002	160'375	59'406	58'721	196'655	6'446	15'584	679	5'565	104'170	27'877	53'043	688'522
2003	159'636	53'438	62'251	208'040	7'061	13'642	202	5'663	110'116	27'643	55'499	703'192
2004	156'812	50'441	66'893	203'370	7'561	16'429	1'819	5'420	113'615	28'845	56'415	707'620
2005	152'062	51'101	73'065	205'729	5'805	16'432	2'906	5'940	116'646	29'236	58'572	717'494
2006	147'436	53'571	79'063	195'926	6'419	18'578	3'324	6'467	113'412	31'233	61'297	716'727
2007	146'012	57'165	84'885	171'313	5'179	15'587	2'730	7'196	110'395	30'015	60'202	690'680
2008	142'801	61'151	93'143	178'833	4'606	16'288	3'616	6'562	117'589	30'854	63'848	719'290
2009	138'968	58'665	94'569	173'219	3'575	16'301	3'254	6'193	112'807	29'811	63'867	701'229
2010	134'043	61'620	98'247	182'305	3'027	15'463	3'498	6'208	126'013	31'185	68'393	730'002
2011	128'856	65'696	100'876	143'760	2'292	14'856	2'957	5'792	111'774	30'882	64'709	672'451
2012	124'301	67'306	106'996	154'448	2'780	12'247	3'148	5'269	122'521	31'145	70'572	700'733
2013	118'634	68'068	111'824	162'532	1'959	15'053	2'735	5'567	129'027	30'925	74'088	720'412
2014	113'875	68'541	114'688	122'704	1'651	14'473	3'148	5'704	111'770	31'320	69'770	657'645
2015	105'591	70'788	113'161	129'349	892	9'822	1'145	5'205	119'420	32'084	73'350	660'806
2016	102'297	74'161	114'400	132'335	378	9'136	890	4'795	125'456	33'583	79'168	676'599

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 2017). Activity data in sector 1 Energy are therefore calculated and disaggregated by the Swiss energy model, which is an intergral 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 2016), the Swiss renewable energy statistics (SFOE 2017a), the energy consumption statistics in the industry and services sectors (SFOE 2017d) as well as additional information from the industry and the Swiss wood energy statistics (SFOE 2017b).

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.

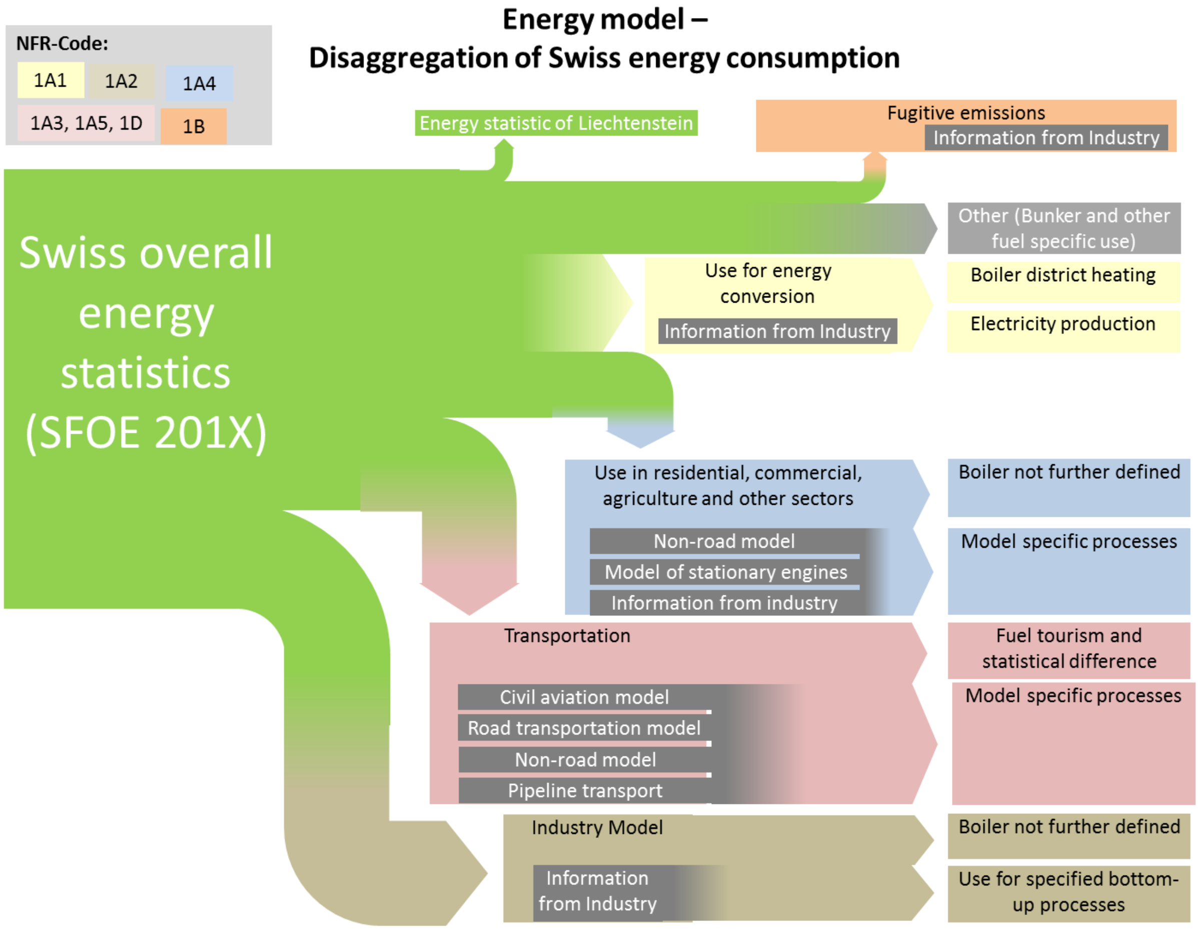

Figure 3-9 Overview of Switzerland's energy model. In the abbreviation SFOE 201X the "X" refers to the latest edition of the Swiss overall energy statistics.

Industry model (Details are given in chp. 3.2.6.2.1)
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 2017d), 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 differences.

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 military 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, ermission 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 2017b), 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 2017) 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.

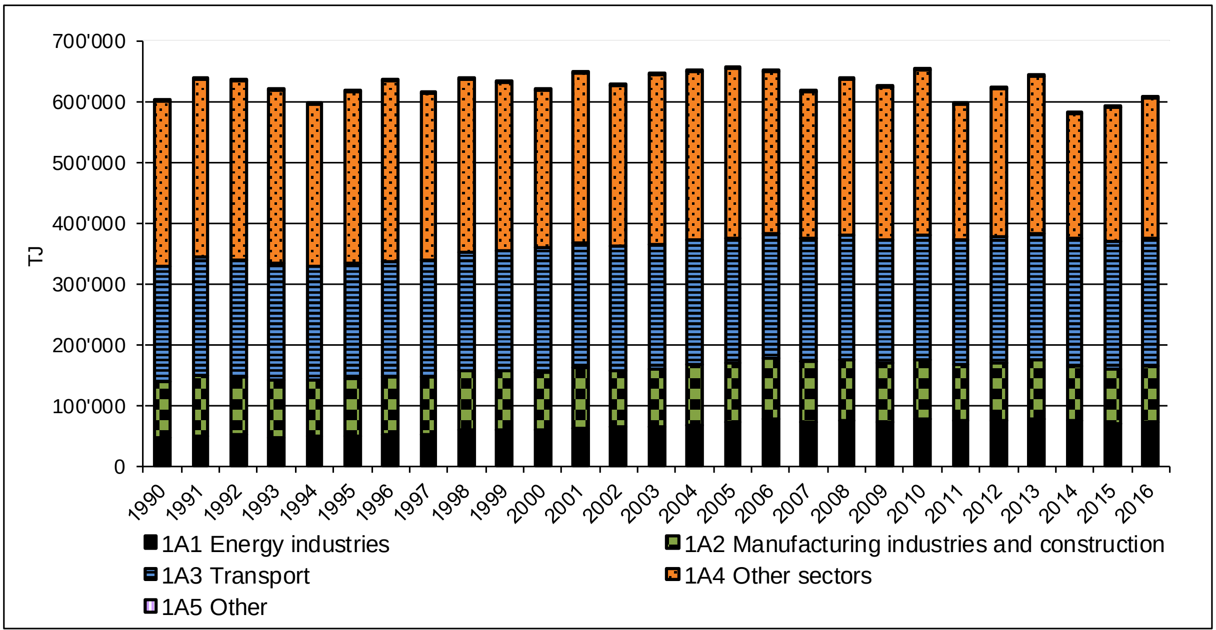

Figure 3-10 Switzerland's energy consumption by source categories 1A1-1A5 as based on the Swiss energy model. In the same period population increased by about 20%, industrial production by almost 70% and the motor vehicle fleet by 50% (SFOE 2017, table 43b).

Starting from the total energy consumption from the Swiss overall 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 2017c). 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 viii Fuel tourism and statistical differences.

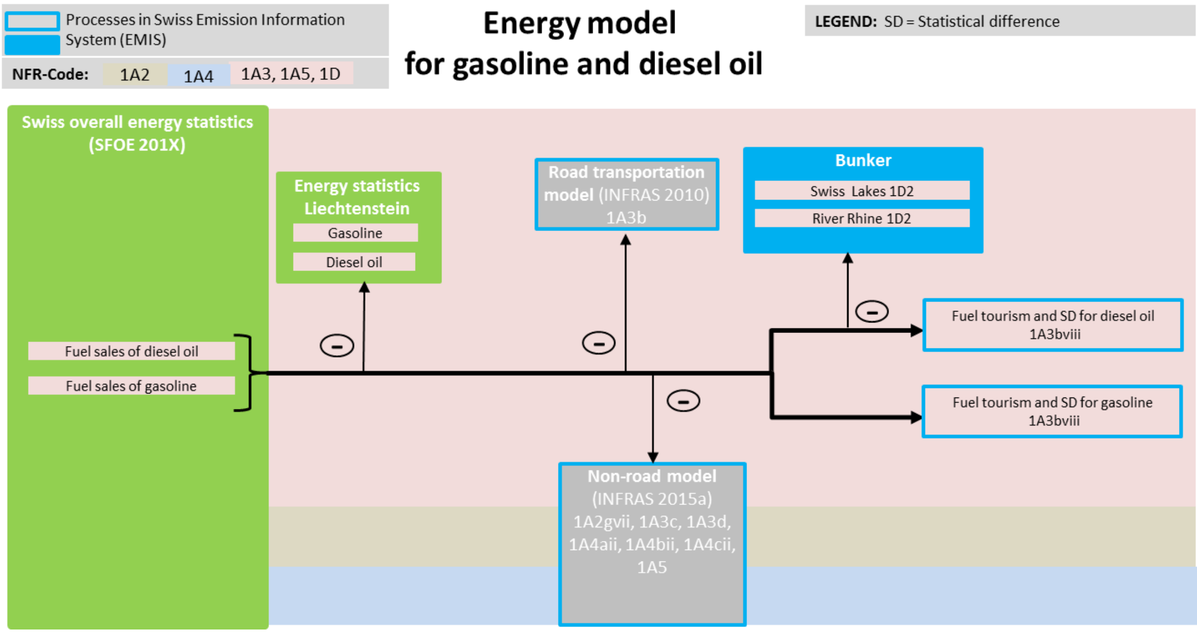

Figure 3-11 Schematic disaggregation of 1A Fuel consumption for gasoline and diesel oil. Marine bunker fuel consumption is based on the national customs statistics (see chp. 3.2.2.2.2 on memo items)

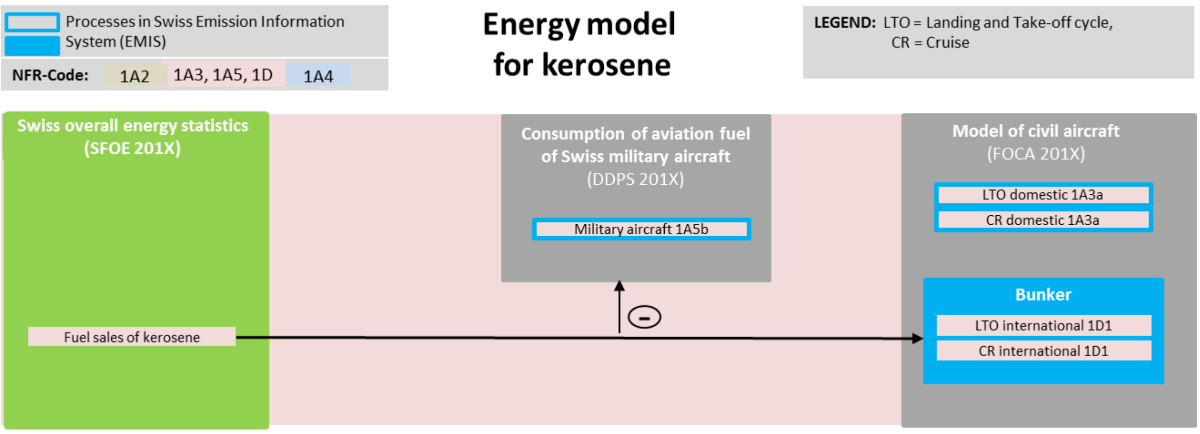

Figure 3-12 Schematic disaggregation of 1A Fuel consumption for kerosene. Fuel consumption for military aircraft is provided by the Federal Departement of Defence, Civil Protection and Sport. The differentiation between domestic and international aviation as well as between CR and LTO is provided by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

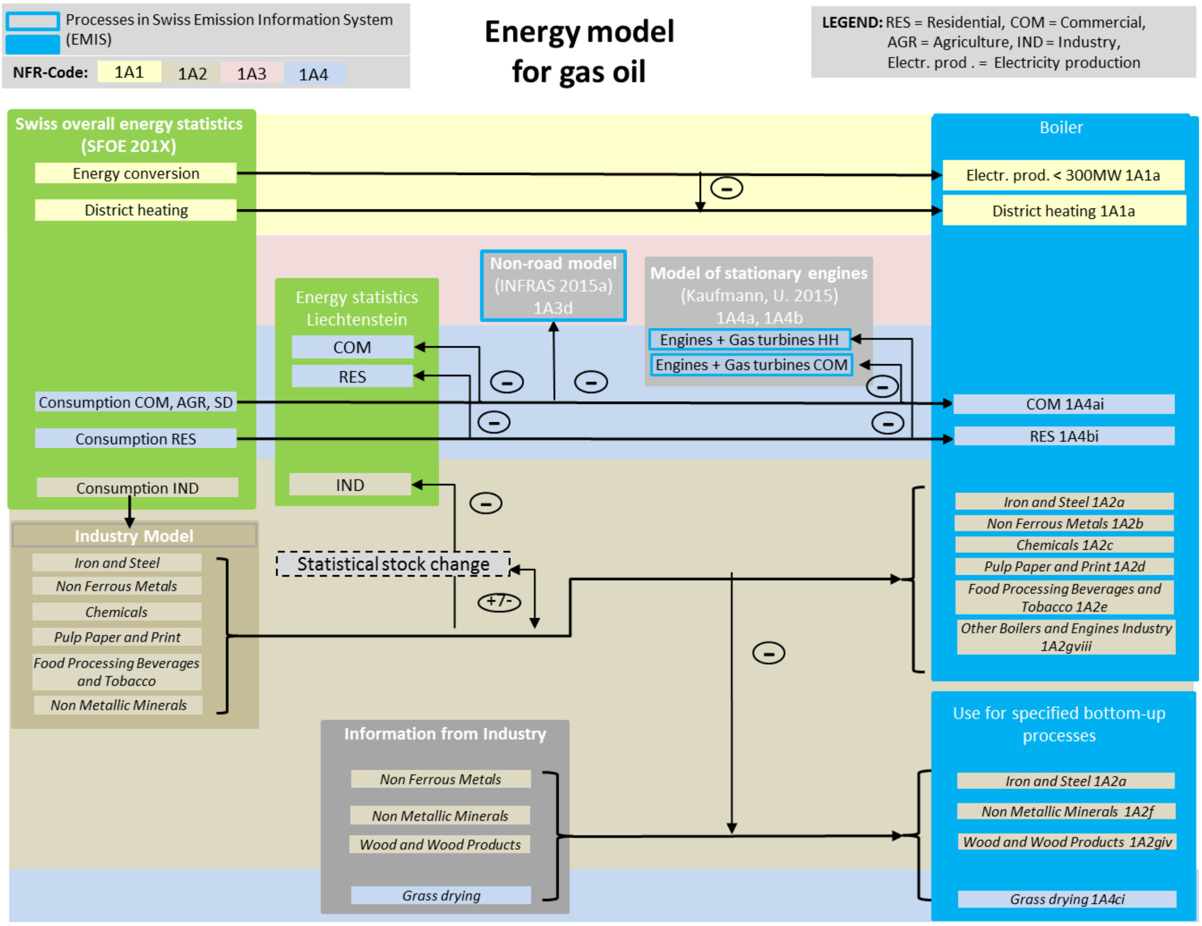

Figure 3-13 Schematic disaggregation of 1A Fuel consumption for gas oil. The Swiss overall energy statistics provide gas oil use for energy conversion and the amount thereof being used for district heating. Based on this information, gas oil use is split into 1A1a i Electricity generation and 1A1a iii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

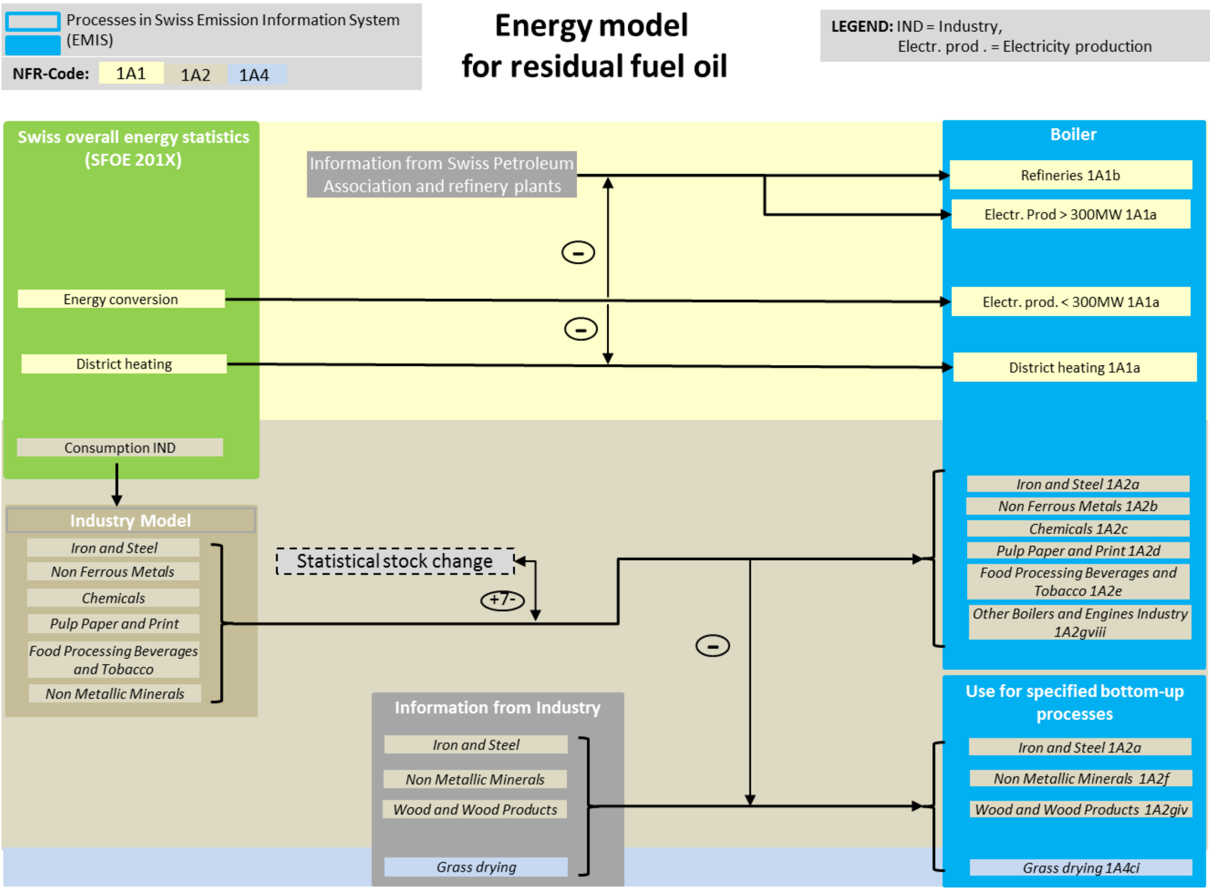

Figure 3-14 Schematic disaggregation of 1A Fuel consumption for residual fuel oil. The Swiss overall energy statistics report residual fuel oil use in energy conversion and the amount thereof consumed in electricity production (one single fossil fuel power station, operational from 1985 to 1994), district 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.

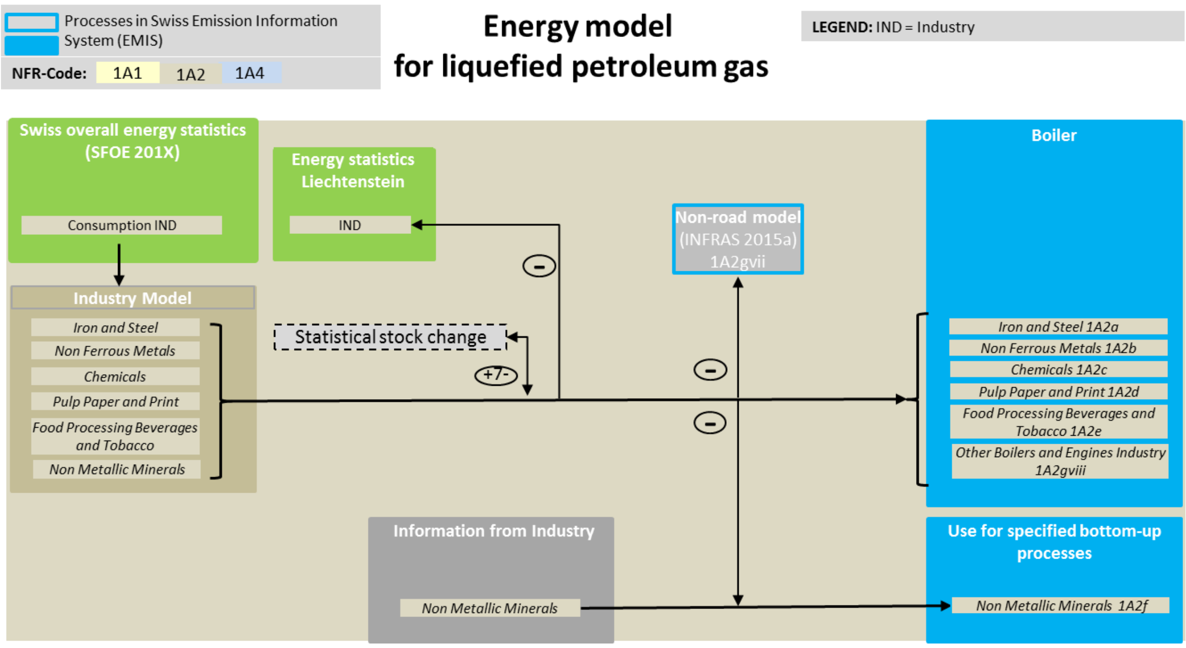

Figure 3-15 Schematic disaggregation of 1A Fuel consumption for liquefied petroleum gas (LPG).

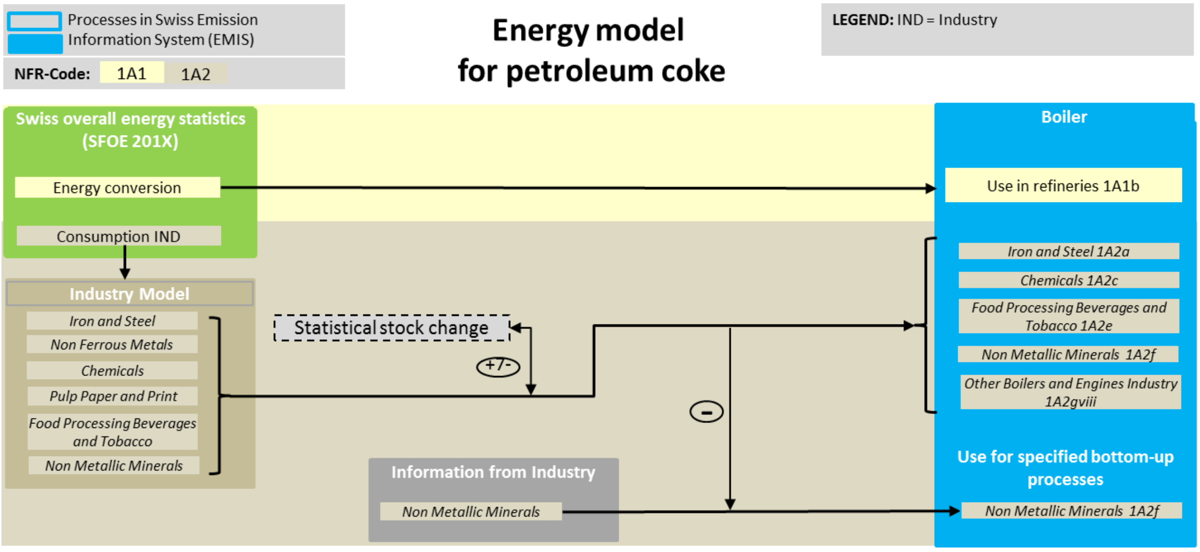

Figure 3-16 Schematic disaggregation of 1A Fuel consumption for petroleum coke.

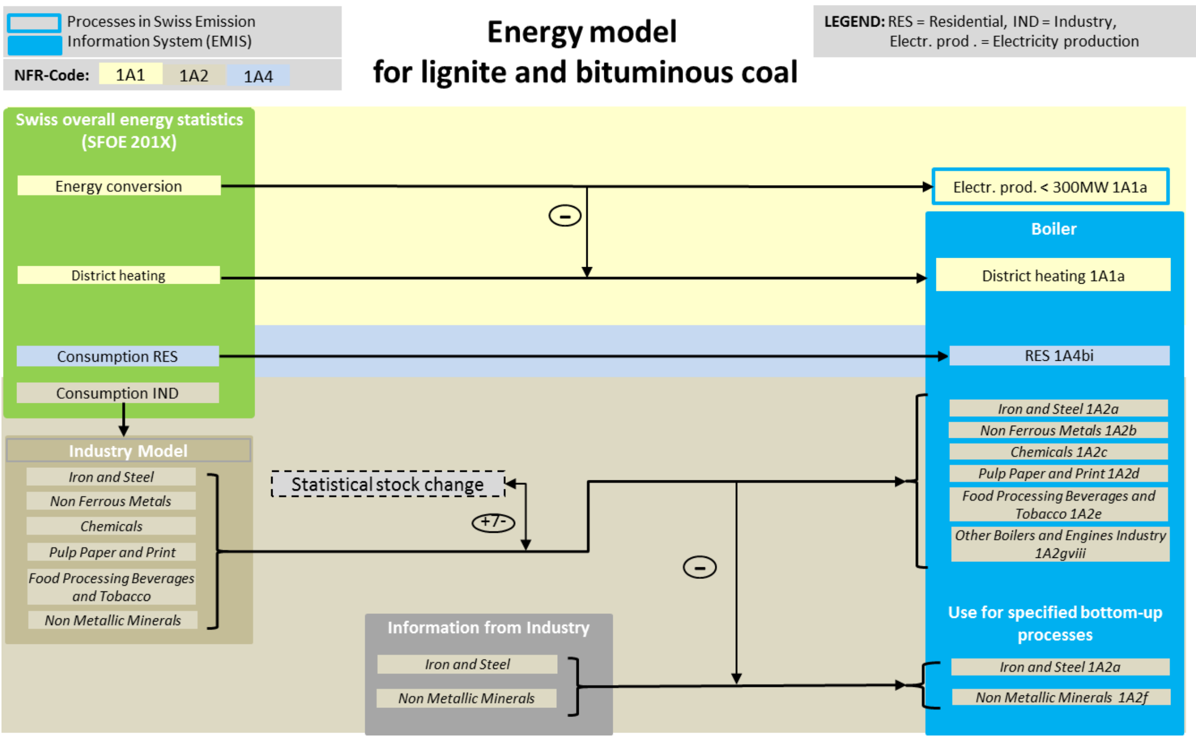

Figure 3-17 Schematic disaggregation of 1A Fuel consumption for lignite and bituminous coal. The Swiss overall energy statistics provide bituminous coal use for energy conversion and the amount thereof being used for district heating. Based on this information, use of bituminous coal in energy industries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

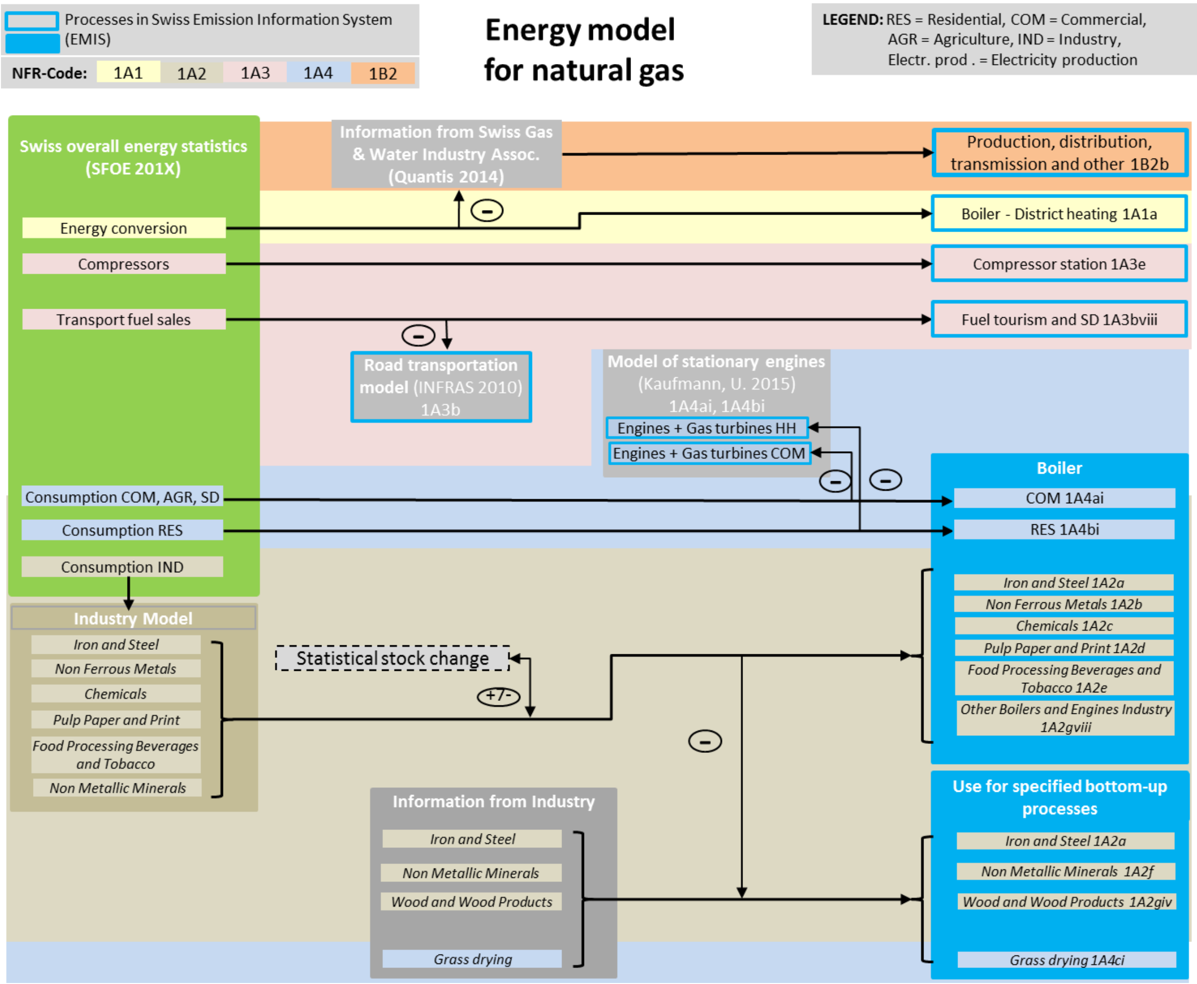

Figure 3-18 Schematic disaggregation of 1A Fuel consumption for natural gas. The Swiss overall energy statistics (SFOE 2017) provide gas use in the transformation sector (energy conversion and distribution losses). Distribution losses as estimated by the Swiss Gas and Water Industry Association SVGW 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.

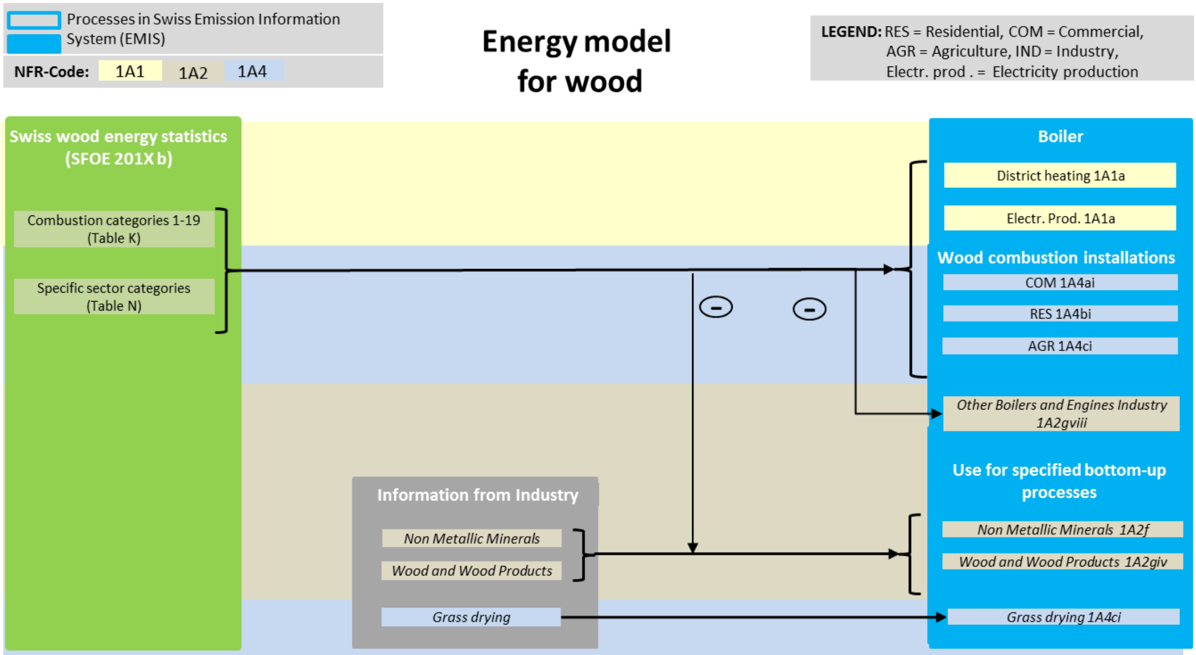

Figure 3-19 Schematic disaggregation of 1A Fuel consumption for wood. For a detailed description of the energy model for wood combustion see chp. 3.2.4.5.2.

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 the 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 CO_2 emissions from CO and NMVOC are implicitly reported as direct CO_2 emissions in sector 1A Energy and no indirect emissions are reported for sector 1A in chp. 9.

3.2.4.4.2 CO_2 Emission factors for 1A Fuel combustion

General CO_2 emission factors

The CO_2 emission factors applied for the time series 1990–2016 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 CO_2 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**	**2013-2016**
Fossil fuel	**CS/D**	**Data sources**	t CO_2 / TJ	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**		
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

CO_2 emission factors for natural gas and biogas

Table 3-13 Time series of CO_2 emission factors of natural gas and biogas. 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**	**2005**
Fuel	**CS/D**	**Data sources**	t CO_2 / TJ			
Natural gas/Biogas	CS	SGWA	56.1	55.7	56.2	56.4

CO_2 emission factors			**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Fuel	**CS/D**	**Data sources**	t CO_2 / TJ									
Natural gas/Biogas	CS	SGWA	56.5	56.5	56.5	56.5	56.6	56.5	56.4	56.5	56.4	56.4

Note that due to a consistency error, the CO_2 emission factors for biogas used in passenger cars and heavy duty vehicles slightly deviates from the values given in Table 3-13. The deviation varies from year to year with minimum -0.09% (2006: 56'450 t CO_2 /TJ) and maximum 0.5% (2016: 56'700 t CO_2 /TJ). The error affects the implied emission factors of 1A3b (see Table 3-75) and will be corrected for the next submission (planned improvement in chp. 3.2.9.6).

CO_2 emission factors for wood:

The CO_2 emission factor for wood combustion activities is taken from Cemsuisse (2010a).

3.2.4.4.3 CH_4 Emission factors for 1A Fuel combustion

General CH_4 emission factors

An overview of the general CH_4 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 combustion, country-specific factors are used. Details are given below in Table 3-15. CH_4 emission factors related to transport activities (aviation, road and non-road transportation) are category specific and given in the corresponding chapters.

Table 3-14 CH_4 emission factors for stationary combustion for the whole time period.

CH_4 emission factors			**1990-2016**
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)	1
Petroleum coke	D	IPCC (2006)	3
Other bituminous coal	D	IPCC (2006)	10
Lignite	D	IPCC (2006)	10
Natural gas	D	IPCC (2006)	1
Biofuel	**CS/D**	**Data Sources**	
Biogas	D	IPCC (2006)	1
Wood	CS	Nussbaumer and Hälg (2015)	1.2 - 240

CH_4 emission factors for wood

There are many different combustion installations in use which have very different CH_4 emission factors. A detailed overview of all applied wood related CH_4 emission factors for the entire time series is given in Table 3-15.

The CH_4 emission factor for each combustion type is modelled based on VOC measurements at wood combustion installations (Nussbaumer and Hälg 2015), assuming a CH_4 to VOC ratio of 0.4.

The EF for the different combustion installations varies 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 CH_4 emission factors for wood combustion installations.

1A Wood combustion	Unit	CH_4			
		1990	1995	2000	2005
Open fireplaces	g/GJ	160	149	138	127
Closed fireplaces, log wood stoves	g/GJ	160	149	138	127
Pellet stoves	g/GJ	16	15	14	13
Log wood hearths	g/GJ	240	229	218	207
Log wood boilers	g/GJ	200	161	122	83
Log wood dual chamber boilers	g/GJ	240	229	218	207
Automatic chip boilers < 50 kW	g/GJ	20	17	13	10
Automatic pellet boilers < 50 kW	g/GJ	6.7	5.6	4.5	3.4
Automatic chip boilers 50-500 kW w/o wood proc. companies	g/GJ	20	16	13	8.9
Automatic pellet boilers 50-500 kW	g/GJ	6.7	5.4	4.1	2.8
Automatic chip boilers 50-500 kW within wood proc. companies	g/GJ	20	16	13	8.9
Automatic chip boilers > 500 kW w/o wood proc. companies	g/GJ	13	11	8.1	5.6
Automatic pellet boilers > 500 kW	g/GJ	6.7	5.4	4.1	2.8
Automatic chip boilers > 500 kW within wood proc. companies	g/GJ	13	11	8.1	5.6
Combined chip heat and power plants	g/GJ	13	11	8.1	5.6
Plants for renewable waste from wood products	g/GJ	13	11	8.1	5.6

1A Wood combustion	Unit	CH_4									
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Open fireplaces	g/GJ	122	120	120	120	120	120	120	120	119	118
Closed fireplaces, log wood stoves	g/GJ	122	120	117	113	110	107	103	100	98	96
Pellet stoves	g/GJ	12	12	12	12	12	12	12	12	12	11
Log wood hearths	g/GJ	202	200	193	187	180	173	167	160	157	154
Log wood boilers	g/GJ	68	60	58	57	55	53	52	50	49	47
Log wood dual chamber boilers	g/GJ	202	200	193	187	180	173	167	160	154	149
Automatic chip boilers < 50 kW	g/GJ	8.7	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.7	7.5
Automatic pellet boilers < 50 kW	g/GJ	2.9	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.5
Automatic chip boilers 50-500 kW w/o wood proc. companies	g/GJ	7.4	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.5	6.3
Automatic pellet boilers 50-500 kW	g/GJ	2.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9
Automatic chip boilers 50-500 kW within wood proc. companies	g/GJ	7.4	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.5	6.3
Automatic chip boilers > 500 kW w/o wood proc. companies	g/GJ	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.7
Automatic pellet boilers > 500 kW	g/GJ	2.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.8
Automatic chip boilers > 500 kW within wood proc. companies	g/GJ	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.7
Combined chip heat and power plants	g/GJ	4.5	4.0	3.6	3.1	2.7	2.2	1.8	1.3	1.3	1.2
Plants for renewable waste from wood products	g/GJ	4.5	4.0	3.6	3.1	2.7	2.2	1.8	1.3	1.3	1.2

3.2.4.4.4 N_2O Emission factors for 1A Fuel combustion

Table 3-16 shows the general N_2O emission factors in source category 1A which are based on default values from the 2006 IPCC Guidelines (IPCC 2006) and kept constant over the whole period. N_2O emission factors related to transport activities (aviation, road and non-road transportation) are category specific and given in the corresponding chapters.

Table 3-16 N_2O emission factors. Default emission factors are used for all fuels for the whole time period.

N_2O emission factors			**1990-2016**
Fuel	**CS/D**	**Data sources**	g N_2O / GJ
Jet Kerosene	D	IPCC (2006)	2
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 CO_2, Fig. 3.4.1 in IPCC (2006)
- Tier 3 for railways CH_4, N_2O and precursors / SO_2, 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 SO_2. 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 Residental, 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

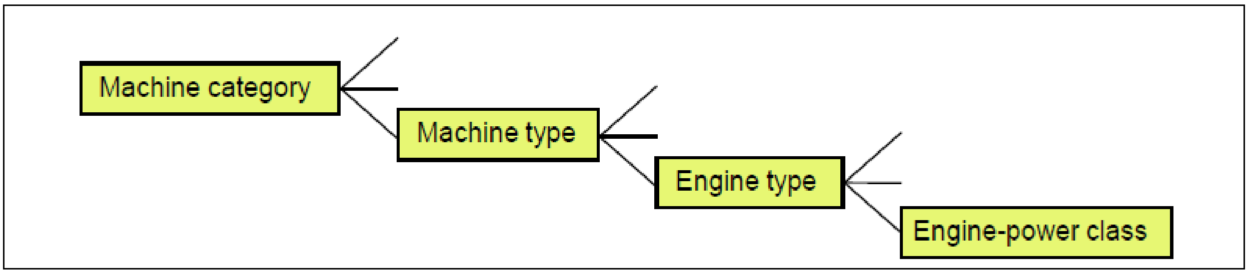

Figure 3-20 Each non-road vehicle is classified by its engine-power class, engine type, machine type and machine category (FOEN (2015j, INFRAS 2015a).

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: CH_4, N_2O
- 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:
  - CO_2 is calculated as product of fuel consumption and CO_2 emission factors (Table 3-12)
  - SO_2 is calculated as product of fuel consumption and SO_2 emission factors (Table A – 19)
  - NMVOC is calculated as the difference between VOC and CH_4
- CO_2 emissions from the use of lubricants as an additive in gasoline for 2-stroke engines are modelled separately and the corresponding CO_2 emissions from the lubricants are reported under 2D1 Lubricant use (chp. 4.5.2.1). Non-CO_2 emissions are reported in the energy sector (1A2g vii, 1A5b ii).

The total emission and consumption per non-road category is calculated by taking the sum 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.

- CO_2 and SO_2 emission factors are country-specific, see Table 3-12 and Table A – 19.
- For other gases, the main data sources are EPA (2010), IFEU (2010), EMEP/EEA (2016) 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)[7].

Until the previous submission, the use of gaseous fuels was treated as CNG. In fact, it is LPG, which has some different emission factors. See recalculations in the corresponding chapters of mobile sources.

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 FCA (2015c)
- 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).

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.

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[7] http://www.bafu.admin.ch/luft/00596/06906/offroad-daten/index.html?lang=en

For the current submission, some minor improvements for the activity data have been realised. The updated activity data deviate by 1% compared to the previous submission. See recalculations in the corresponding chapters of mobile sources.

3.2.4.5.2 Energy model for wood combustion

Choice of method

The emissions from wood combustion in 1A Fuel cocmbustion 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 2017b) provide 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 2018/1A Holzfeuerungen).

Table 3-18 Categories of wood combustion installations based on SFOE 2017b.

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 CO_2, 3.2.4.4.3 for CH_4, and 3.2.4.4.4 for N_2O.

Activity Data

Total activity data are based on the Swiss wood energy statistics (SFOE 2017b). 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 2018/1A 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	2005
Total	TJ	28'127	29'414	27'022	30'748
Open fireplaces	TJ	227	271	196	181
Closed fireplaces, log wood stoves	TJ	7'274	7'178	6'493	7'047
Pellet stoves	TJ	0	0	7	48
Log wood hearths	TJ	8'524	7'030	4'744	4'029
Log wood boilers	TJ	5'308	5'571	5'109	5'366
Log wood dual chamber boilers	TJ	1'964	1'779	978	481
Automatic chip boilers < 50 kW	TJ	239	434	550	754
Automatic pellet boilers < 50 kW	TJ	0	0	56	805
Automatic chip boilers 50-500 kW w/o wood proc. companies	TJ	686	1'325	1'779	2'681
Automatic pellet boilers 50-500 kW	TJ	0	0	2	95
Automatic chip boilers 50-500 kW within wood proc. companies	TJ	1'285	1'719	1'754	1'917
Automatic chip boilers > 500 kW w/o wood proc. companies	TJ	325	1'005	1'600	2'254
Automatic pellet boilers > 500 kW	TJ	0	0	0	9
Automatic chip boilers > 500 kW within wood proc. companies	TJ	1'316	2'039	2'223	2'516
Combined chip heat and power plants	TJ	0	3	186	127
Plants for renewable waste from wood products	TJ	979	1'060	1'345	2'439

1A Wood combustion	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total	TJ	29'794	33'798	35'190	37'563	33'197	37'498	41'232	35'314	36'744	40'042
Open fireplaces	TJ	150	150	137	123	87	84	83	62	64	68
Closed fireplaces, log wood stoves	TJ	6'282	6'827	7'011	7'913	6'586	7'468	8'333	6'738	7'451	7'741
Pellet stoves	TJ	72	93	109	140	127	156	184	157	182	193
Log wood hearths	TJ	2'914	2'838	2'491	2'267	1'576	1'485	1'351	900	918	889
Log wood boilers	TJ	4'586	4'893	4'751	4'904	3'692	3'826	3'884	2'822	2'972	3'034
Log wood dual chamber boilers	TJ	348	338	289	272	195	190	181	125	119	112
Automatic chip boilers < 50 kW	TJ	727	833	861	1'008	801	867	943	740	787	799
Automatic pellet boilers < 50 kW	TJ	1'248	1'562	1'731	2'104	1'814	2'153	2'499	2'102	2'378	2'566
Automatic chip boilers 50-500 kW w/o wood proc. companies	TJ	2'803	3'196	3'265	3'751	3'226	3'786	4'289	3'528	4'062	4'469
Automatic pellet boilers 50-500 kW	TJ	256	361	431	537	511	622	726	696	875	1'049
Automatic chip boilers 50-500 kW within wood proc. companies	TJ	1'751	1'870	1'872	2'010	1'740	1'881	2'020	1'671	1'825	1'944
Automatic chip boilers > 500 kW w/o wood proc. companies	TJ	2'519	3'127	3'397	3'960	3'627	4'348	5'032	4'422	5'188	5'826
Automatic pellet boilers > 500 kW	TJ	56	80	84	92	139	161	191	181	203	236
Automatic chip boilers > 500 kW within wood proc. companies	TJ	2'284	2'398	2'406	2'656	2'298	2'457	2'627	2'200	2'355	2'472
Combined chip heat and power plants	TJ	1'058	2'467	3'422	2'756	3'900	5'010	5'421	5'325	3'792	4'332
Plants for renewable waste from wood products	TJ	2'740	2'764	2'933	3'070	2'878	3'005	3'468	3'645	3'572	4'312

3.2.4.6 Emissions from Biomass (memo item)

CO_2 emissions from biomass do not count for the national total emissions and therefore are a memo item only. The CO_2 emissions from biomass as reported in the reporting tables are incomplete as the following CO_2 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 CO_2 emissions from biomass in 2016 and their reporting in the reporting tables (without land-use, land-use change and forestry). For further information on the biomass CO_2 emissions refer to the respective source category chapters.

Table 3-20 Effective biomass CO_2 emissions in 2016 and their representation in the reporting tables. Note that in reporting table CRF Table10s2 biogenic CO_2 emissions from 5C are missing (for an overview of errors of the CRF Reporter see Annex 6).

Biomass CO_2 emissions	Unit	2016	Note
1A1 Energy industries (without MSW incineration)	kt	544	Included in CRF
1A1 Energy generation from MSW Incineration	kt	2'279	Included in CRF
1A2 Manufacturing industry and construction	kt	1'400	Included in CRF
thereof use of waste derived fuels in cement production	kt	50	
thereof use of bio fuels (1A2gvii)	kt	12	
1A3 Transport	kt	219	Included in CRF
1A4 Other sectors (Commercial/institutional, residential)	kt	3'021	Included in CRF
1A5 Other	kt	0.38	Included in CRF
2H2 Food and beverages industry	kt	13	Not included in CRF
2G Other product use (Consumption of tabacco)	kt	11	Not included in CRF
5A Solid waste disposal on land	kt	44	Not included in CRF
5B Biological treatment of waste (composting and anaerobic digestion)	kt	176	Not included in CRF
5C Waste incineration (without MSW incineration)	kt	145	Included in CRF, see caption
5D Wastewater handling	kt	127	Not included in CRF
Total biomass combustion CO_2 emissions included in CRF	kt	7'607	
Total energy related biomass combustion CO_2 emissions included in CRF 1A	kt	7'463	See table "Summary 2" in CRF
Total biomass CO2 emissions in Switzerland in 2016	kt	7'978	

3.2.4.7 Uncertainty and time series consistency for source category 1A

Basic uncertainties of AD and EF CO_2 by fuel type

Table 3-21 Uncertainties of activity data and CO_2 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	0.99	5.10
other fuels	5.00	9.22	10.5
biomass	10.0	--	--

Liquid fuels

Uncertainty of the CO_2 emission factors: In 2013, a large measurement campaign was carried out to determine the CO_2 emission factors of the dominant liquid fuels (SFOE/FOEN 2014). From the standard deviation presented in this study, the 95% uncertainties are derived and shown in Table 3-22 as lower and upper values as well as relative uncertainties.

The uncertainties were updated for submission 2016. The new values are applied for the current submission. The former values were also based on measurements but were 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 CO_2 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 CO_2 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 CO_2 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.

Up to submission in 2015, 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 CO_2 emission factor*:** The composition of the imported gas is analysed in detail at the import stations. From this information, the FOEN annually calculates the CO_2 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 14 years within the period 1990 and 2016. The uncertainties fluctuate between 0.50% and 1.48% with a mean of 1.04%, which is used as the uncertainty of the CO_2 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 the 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 CO_2 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 the 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 (as for natural gas).

Other fuels (waste to energy)

Uncertainty of the CO_2 emission factor: There are two factors influencing the uncertainty of CO_2 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. (2011). A field application of the radio carbon (^{14}C) method was applied to calculate the ratio of biogenic versus fossil CO_2 emissions from five waste-to-energy plants. Gas samples for $^{14}CO_2$ analysis were taken at the plants during miscellaneous seasons. Six measuring campaigns of three weeks periods were carried our for three plants and three campaigns, again of three weeks periods, were carried out for two plants. That means that the measurements lasted 72 weeks in total. The 95% confidence interval of the campaigns result in a biogenic fraction of 52.3% ± 3.8% (Table 3-24), which corresponds to an uncertainty of 7.1%. The results fit well to a former measurement campaign on three plants which yield 52.0% ± 3.7% for the biogenic fraction (Mohn 2008). For the uncertainty analysis the latest result is used.

Table 3-24 Measures shares of fossil and biogenic share in five MSW plants campaign.

Plant	Shares		Uncertainty		Measurement campaigns
	fossil	**biogenic**	**absolute**	**relative**	(duration)
	%	%	%	%	weeks
Buchs	47.7	52.3	3.6	7.5	6 x 3 = 18
Winterthur	43.4	56.6	3.9	9.0	6 x 3 = 18
Linthgebiet	50.6	49.4	3.4	6.7	6 x 3 = 18
Fribourg	54.5	45.5	3.1	5.7	3 x 3 = 18
Zuchwil	45.9	54.1	3.7	8.1	3 x 3 = 18
Median / sum	47.7	52.3	1.8	3.8	72

- 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: $[(5.9\%)^2 + (3.8\%)^2]^{0.5} = 7.0\%$. (For the previous submission 9.2% had been applied based on the former results).

Uncertainty of activity data: There is no country-specific estimate of the uncertainty for the consumption of waste. It is taken from the 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 ±5% for most developed countries.” In accordance with that statement, the value of 5% is used.

Biomass

Uncertainty of the CO_2 emission factor: For CO_2 emissions of biomass burning, no uncertainty is estimated (memo item).

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 (without fireplaces) combustion and 20% from open and closed fireplaces (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 3-25).

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 (current version see INFRAS 2017a), the uncertainties for the CH_4 and N_2O emission factors have been determined (see lines 1A3b gasoline and diesel oil in Table 3-25). 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 1-10. For **1A1, 1A2, 1A3a, 1A3c, 1A3d, 1A3e,**

1A4a, 1A4b, 1A4c, 1A5 the uncertainties of CH_4 and N_2O emissions have similarly been estimated qualitatively (see Table 3-25).

Summary

Table 3-25 below provides a summary of the uncertainties of 1A Fuel combustion as derived in the preceeding sections. The uncertaintiy of the CO_2 emissions ("combined uncertainty") are calculated from the uncertainties of the activity data and the emission factors by Approach 1 error propagation.

Table 3-25 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 1-10. The emission factor uncertainty is calculated "backward"[8] from the combined and the activity data uncertainty). CH_4 and N_2O: semi-quantitave uncertainties (see Table 1-10).

1A Fuel Combustion Categories	Fuel type	Uncertainties				
		Activity data	CO_2 em. factors	CO_2 emissions	CH_4 emissions	N_2O 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	1.0	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	1.0	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	1.0	5.1	medium	medium
3c. Transport; Railways	diesel oil	0.9	0.1	0.9	medium	medium
3d. Transport; Domestic navigation	liquid fuels	0.7	0.1	0.7	medium	high
3e. Transport; Other transportation	gaseous fuels	5.0	1.0	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	1.0	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	1.0	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	1.0	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.

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

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 CO_2 emissions, a quality control consists in the comparison of emissions modelled using the sectoral approach with emissions calculated based directly on fuel consumption according to the Swiss overall energy statistics (SFOE 2017). The differences in total CO_2 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 2017) 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 CO_2 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 CO_2 emission factors compare well with the IPCC default values (see Table 3-26).

Table 3-26 Comparison of default CO_2 emission factors from IPCC 2006 with current country-specific values for selected fuels.

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

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

For natural gas, the CO_2 emission factor has been reassessed for submission 2018. A country-specific CO_2 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 CO_2 EF used by the countries from which gas is imported (Germany (IEF: 55.5–56.0 t CO_2/TJ), the Netherlands (IEF: 56.5–56.8 t CO_2/TJ), Norway (IEF: 56.1 t CO_2/TJ), France (IEF: 56.0–57.0 t CO_2/TJ), Italy (IEF: 55.3 to 56.9 t CO_2/TJ) and Denmark (IEF: 56.9–57.5 t CO_2/TJ). It lies within the range given by the IPCC (lower 54.3 t CO_2/TJ, upper 58.3 t CO_2/TJ, compared to the country-specific value of 56.4 t CO_2/TJ for 2015).

The CH_4 emission factors from combustion of wood have been scrutinized and revised based on Nussbaumer and Hälg (2015). The range of country-specific values is not entirely consistent with the upper and lower IPCC default values (Table 3-27). However, as the country-specific emission factors are based on an extensive measurement campaign, they are considered representative for Swiss circumstances.

Table 3-27 Comparison of default CH_4 emission factors from the 2006 IPCC Guidelines (IPCC 2006) with country-specific values

CH_4 Emisson 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

- Reference approach and non-energy use of fuels: The use of bitumen and lubricants of Liechtenstein (customs union with Switzerland) is now subtracted from the consumption reported by the Swiss petroleum association for the entire time series.
- 1A: Activity data of all wood combustion installations of 1A1a, 1A2g viii, 1A4ai, 1A4bi and 1A4ci have been revised due to recalculations in the Swiss wood energy statistics (SFOE 2017b) for the entire time series 1990 to 2015. Main changes were carried out for automatic boilers resulting in total recalculations between -4 and -178 TJ.
- 1A mobile sources (road and non-road transport):
  - NCV of biodiesel and bioethanol werde adapted to the values of SFOE (2017).
  - The lubricant amount of gasoline used in two-stroke engines of ronon-road and

transportation is now reported as fully oxidized in source category 2D1 Lubricant use, see chp. 4.5.5.

- 1A mobile sources of non-road categories have been updated:

  - In the non-road database since the 2008 version, the fuel natural gas was falsely deposited. This was corrected in the non-road publication FOEN (2015j), but not in the data itself. In fact, in the non-road sector partial liquefied petroleum gas and partly natural gas is used (mainly by fork-lift trucks), but liquefied petroleum gas is much more widespread. Therefore use of natural gas has been reallocated to liquefied petroleum gas. In consequence these machines have about 17% more CO_2 emissions and SO_2 has been eliminated.

  - Fuel mix (biofuel shares) corresponds to INFRAS 2017

  - SO_2 in general: Due to an error correction in the current export, the emissions are between 2.5% and 54% lower than in the last data delivery.

  - The special scheme for narrow track tractors, according to which they skip the Euro-4 emission level, was taken into account. As a result, NO_x emissions from the non-road sector will rise marginally by 2020 (about 0.3%).

3.2.4.10 Planned improvements for source category 1A in general

No improvements for 1A general are planned

3.2.5 Source category 1A1 - Energy industries (stationary)

3.2.5.1 Source category description for 1A1 (stationary)

Table 3-28 Key categories of 1A1 Energy industries. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1A1	Energy industries: Gaseous fuels	CO2	L1, T1
1A1	Energy industries: Liquid fuels	CO2	L1, T1
1A1	Energy industries: Other fuels	CO2	L1, T1, L2, T2

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 2017). Emissions from industries producing heat and/or electricity (CHP) for their own use are included in category 1A2 Manufacturing Industries and Construction.

Table 3-29 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. Emissions of SO2 from Claus units in refineries.
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 3-30) 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. There was a single fossil fuel power station operating with residual fuel oil in Vouvry. However, the power station closed down in 1999.

Table 3-30 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 CO_2 emissions in source category 1A1a Public electricity and heat production 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). For CH_4 emissions a Tier 1 method was applied (using IPCC default emission factors), except for biomass country specific as well as IPCC default emission factors are used, combining Tier 1 and Tier 3 method. For N_2O IPCC default values are used (Tier 1), except for municipal solid waste and special waste incineration plants where country specific emission factors as well as IPCC default emission factors were used, combining Tier 1 and Tier 3 methods.

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 chp. 3.2.4.4.

Table 3-31 Emission Factors for 1A1a Public Electricity and Heat Production in 2016.

1A1a Public electricity and heat production	CO_2	CO_2 bio.	CH_4	N_2O	NO_x	NMVOC	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	0.6	34	2	16	6.4
Residual fuel oil	NO	NA	NO	NO	NO	NO	NO	NO
Petroleum coke	NO	NA	NO	NO	NO	NO	NO	NO
Natural gas	56.4	NA	1.0	0.1	18	2	0.5	10
Other (waste-to-energy), fossil	88.7	NA	NE	1.5	32	2.4	3.6	8.4
Other (waste-to-energy), biogenic	NA	92.0	NE	1.4				
Biomass (wood, renewable waste)	NA	99.9	1.2	4.0	115	2	11	95
Biogas (co-generation from landfills, fermentation engines)	NA	100.7	2.1	0.1	47	3	15	63

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 digestion gas). The emission factors for CO_2, NO_x, CO, NMVOC and SO_2 are country-specific and based on measurements and expert estimates. Emission factors for CH_4 and N_2O are IPCC default values, with the exception of waste and biomass as fuel, where country specific emission factors are applied. Emission factors are documented in EMIS 2018/1A1a Kehrichtverbrennungsanlagen, EMIS 2018/1A1a Sondermüllverbrennungsanlagen, EMIS 2018/1A1a Vergärung IG, EMIS 2018/1A1a Vergärung LW und EMIS 2018/1A1a Kehrichtdeponien.

Source-specific CO_2 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, 2017). 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 assumption is based on measurements in two MSWIPs in Zurich (AWEL 2009) and on a study in Austria (Zeschmar-Lahl 2004), where the MSWIP have the same standards as in Switzerland. The measurements in Zurich showed transfer coefficients into air of 0.96–0.99 and the ones in Austria stated a transfer coefficient into clan air of 0.989.

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 radioactive isotope carbon-14 (^{14}C) in the flue gas for calibration (Mohn 2011). The CO_2 emission factor in MSWIPs fluctuates over the reporting period because of gradual changes in the net calorific values of the waste. Please refer to Table 3-32 for data.

Table 3-32 Emission factor CO_2 total, share of CO_2 fossil and net calorifc value (NCV) in municipal solid waste incineration plants (MSWIP).

1A1a Public electricity and heat production, Other fossil fuels	Unit	1990	1995	2000	2005
CO_2 total (MSWIP)	t/TJ	92.80	91.86	91.09	91.49
Share of CO_2 fossil (MSWIP)	1	0.497	0.505	0.513	0.505
NCV of waste (MSWIP)	TJ/t	0.0114	0.0119	0.0124	0.0121

1A1a Public electricity and heat production, Other fossil fuels	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CO2 total (MSWIP)	t/TJ	91.90	92.20	92.50	92.32	92.25	92.62	92.76	92.43	92.28	92.01
Share of CO_2 fossil (MSWIP)	1	0.497	0.493	0.489	0.486	0.482	0.478	0.478	0.478	0.478	0.478
NCV of waste (MSWIP)	TJ/t	0.0119	0.0117	0.0116	0.0117	0.0117	0.0115	0.0114	0.0116	0.0117	0.0118

Sodium bicarbonate and calcium carbonate are used in MSWIP for flue gas treatment. Sodium bicarbonate is used since 2013 and calcium carbonate was used between 1990 and 2005. According to IPCC 2006 the corresponding emission are reported in source category 2A4d.

Source-specific CO_2 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 CO_2/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 2018/1A1a Sondermüllverbrennungsanlagen.

Source-specific CH_4 emission factors in municipal and special waste incineration plants

Emissions of CH_4 are not occurring in waste incineration plants because of the high temperatures and the long dwell time in the combustion chamber as confirmed by Mohn (2013). In the year 2013 EMPA assessed the N_2O and CH_4 emission factors for MSWIP (Mohn 2013). In this study EMPA evaluated measurements that were performed in 2011 in five Swiss MSWIP with different Denox techniques (SCR, SNCR). For most of the measurements CH_4 concentrations were below the detection limit of 0.3 ppm. The study concluded that "CH_4 emission concentrations were very low and below the background concentration of 1.8 ppm". CH_4 emissions are considered to be negligible for municipal waste incineration and are therefore reported as not estimated because they are considered insignificant. The same fact applies for special waste incineration.

Source-specific N_2O emission factors for municipal solid waste incineration

In 2013, a study evaluated N_2O measurements that have been performed in the years 2010–2011 in the flue gas of five Swiss municipal waste incineration plants (Mohn 2013) and derived plant-specific emission factors for 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 N_2O emission factors have been calculated, based on the amounts of waste burnt in every plant. For the years in between, the N_2O emission factors were linearly interpolated. Since 2012 the emission factor is assumed to be constant (however the emission factor related to energy changes by reason of the conversion with the net calorific value of waste). It is planned to calculate a new value periodically, depending on data available. See documentation in EMIS 2018/1A1a Kehricht- und Sondermüllverbrennungsanlagen. The emission factor is therefore not constant over time.

Source-specific N_2O emission factors for special waste incineration

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

Table 3-33 N_2O emission factors of 1A1a Municipal solid and special waste incineration.

1A1a Public electricity and heat production, Other fossil fuels	Unit	1990	1995	2000	2005
N_2O (MSWIP)	kg/TJ	5.26	2.96	2.06	1.44
N_2O (SWIP)	kg/TJ	3.06	4.23	5.41	5.48

1A1a Public electricity and heat production, Other fossil fuels	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
N_2O (MSWIP)	kg/TJ	1.40	1.38	1.41	1.40	1.40	1.43	1.44	1.42	1.41	1.39
N_2O (SWIP)	kg/TJ	4.84	4.53	4.21	3.89	3.57	3.25	2.94	2.62	2.30	1.98

Activity data (1A1a)

Activity data for liquid, gaseous, solid fuels and wood are based on the Swiss overall energy statistics (SFOE 2017) 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 2017i, see Table 3-35). Activity data for combined heat and power generation in landfills and in biogas facilities are taken from the Swiss renewable energy statistics (SFOE 2017a).

Please note that waste-to-energy activities in CRF Table1.A(a)s1 are allocated to fuel types ‘Other fossil fuels’ and ‘Biomass’. ‘Other fossil fuels’ encompasses emissions from fossil share of MSWIP and from SWIP. Whereas ‘Biomass’ covers emissions from wood, waste wood, landfill gas use in co-generation, digestion gas and biogenic share from MSWIP.

Table 3-34 Activity data in 1A1a Public Electricity and Heat Production.

1A1a Public electricity and heat production	**Unit**	**1990**	**1995**	**2000**	**2005**
Total fuel consumption	TJ	40'414	39'216	50'018	57'230
Gas oil	TJ	980	554	790	1'300
Residual fuel oil	TJ	3'214	1'813	340	290
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	530	46	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	4'339	5'422	8'292	9'827
Other (waste-to-energy), fossil	TJ	16'605	16'870	22'482	24'711
Biomass	TJ	14'747	14'511	18'114	21'103
Other (waste-to-energy), biogenic	TJ	14'163	13'394	16'889	19'797
Biomass (wood, renewable waste)	TJ	301	466	547	844
Biogas (co-generation from landfills, fermentation engines)	TJ	282	651	679	462

1A1a Public electricity and heat production	**Unit**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Total fuel consumption	TJ	58'220	59'488	58'518	62'638	60'837	64'728	64'852	60'994	63'138	67'246
Gas oil	TJ	800	490	540	500	400	800	670	780	660	440
Residual fuel oil	TJ	220	180	130	40	10	NO	NO	NO	NO	NO
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	7'910	8'468	8'073	9'926	7'512	8'213	8'449	5'072	7'060	8'956
Other (waste-to-energy), fossil	TJ	25'791	25'880	24'853	26'002	25'575	26'262	25'738	26'049	26'832	27'657
Biomass	TJ	23'498	24'470	24'922	26'169	27'341	29'453	29'994	29'092	28'586	30'193
Other (waste-to-energy), biogenic	TJ	21'415	21'464	21'249	22'275	22'272	23'051	22'489	23'112	23'716	24'765
Biomass (wood, renewable waste)	TJ	1'458	2'312	2'877	2'958	3'983	5'032	5'949	4'323	3'072	3'444
Biogas (co-generation from landfills, fermentation engines)	TJ	625	695	796	937	1'086	1'370	1'556	1'657	1'798	1'984

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 power station located in Vouvry that has been operated with residual fuel oil in the 1990ies.

Municipal solid waste incineration and special 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 in kt reported in Table 3-35 is the total amount of waste burned (it includes fossil and biogenic shares). The fossil and biogenic share in TJ are given as well.

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.

Table 3-35 Activity data for 1A1a iv Other: Municipal solid waste and special waste incinerated with heat and/or power generation. The amount of municipal solid waste in kt is the total amount of waste burned.

1A1a iv Public electricity and heat production, Other	**Unit**	**1990**	**1995**	**2000**	**2005**
Total fuels	TJ	30'768	30'264	39'371	44'508
Municipal solid waste fossil	TJ	13'995	13'664	17'790	20'197
Municipal solid waste biogenic	TJ	14'163	13'394	16'889	19'797
Special waste	TJ	2'610	3'206	4'692	4'514
Total fuels	kt	2'603	2'433	3'040	3'527
Municipal solid waste (fossil and biogenic)	kt	2'470	2'270	2'801	3'297
Special waste	kt	133	163	239	230

1A1a iv Public electricity and heat production, Other	**Unit**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Total fuels	TJ	47'206	47'344	46'102	48'277	47'847	49'313	48'228	49'161	50'548	52'422
Municipal solid waste fossil	TJ	21'159	20'871	20'334	21'062	20'724	21'108	20'593	21'163	21'717	22'678
Municipal solid waste biogenic	TJ	21'415	21'464	21'249	22'275	22'272	23'051	22'489	23'112	23'716	24'765
Special waste	TJ	4'632	5'009	4'519	4'941	4'851	5'155	5'145	4'886	5'115	4'979
Total fuels	kt	3'816	3'865	3'827	3'968	3'924	4'104	4'035	4'066	4'150	4'264
Municipal solid waste (fossil and biogenic)	kt	3'580	3'610	3'597	3'717	3'676	3'841	3'773	3'817	3'889	4'010
Special waste	kt	236	255	230	252	247	263	262	249	261	254

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 since 2014. 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), Switzerland applies a Tier 3 approach with country-specific emission factors for CO_2 emissions. The calculations are based on measurements and data from the refining industry as documented in the EMIS database (EMIS 2018/1A1b Heizkessel Raffinerien).

Emission factors (1A1b)

CO_2 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 – 2016 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 – 2015). The CO_2 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 2013 the annual emission factor is derived from annual monitoring reports and the allocation report (2005-2011), which provide plant-specific data.

The resulting CO_2 emission factors are all within the given ranges in IPCC (2006).

Table 3-36 Emission factors for 1A1b Petroleum refining in 2016.

1A1b Petroleum refining	CO_2	CH_4	N_2O	NO_x	NMVOC	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	NO	NO	NO	NO	NO	NO	NO

Activity data (1A1b)

Activity data on fuel combustion for petroleum refining (1A1b) is provided by the Swiss overall energy statistics (SFOE 2017) 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 2017).

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 3-37 Activity data for 1A1b Petroleum refining.

1A1b Petroleum refining	Unit	1990	1995	2000	2005
Total fuel consumption	TJ	5'629	9'836	9'636	14'548
Residual fuel oil	TJ	1'259	1'786	1'908	902
Refinery gas	TJ	4'370	8'050	7'728	11'833
Petroleum coke	TJ	NO	NO	NO	1'813

1A1b Petroleum refining	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total fuel consumption	TJ	13'774	15'118	14'473	14'176	13'169	11'242	13'834	14'173	7'232	6'355
Residual fuel oil	TJ	1'182	692	733	891	764	1'212	1'094	C	C	C
Refinery gas	TJ	11'033	11'978	11'706	11'282	10'720	8'249	11'055	C	C	C
Petroleum coke	TJ	1'558	2'449	2'035	2'003	1'685	1'781	1'685	C	C	NO

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 CO_2 emission factor is based on literature (USEPA 1995) and CH_4, NO_x, CO and NMVOC emission factors are taken from the revised 1996 IPCC Guidelines (EMIS 2018/1A1c).

Table 3-38 Emission factors for 1A1c Manufacture of Solid Fuels and other energy industries in 2016. The CO_2 emission factor refers to CO_2 of biogenic origin.

1A1c Charcoal	Unit	CO_2 biog.	CH_4	NO_x	NMVOC	SO_2	CO
Charcoal production	kg/TJ	16'900	1'000	10	1'700	NA	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 2018/1A1c. 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 not used in the industry anymore but mainly for barbecues. Production has increased between 1990 and 2016 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 3-39 Activity data for 1A1c Manufacture of Solid Fuels and other energy industries.

1A1c Charcoal	Unit	1990	1995	2000	2005
Charcoal production	TJ	1.25	1.43	2.20	3.37

1A1c Charcoal	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Charcoal production	TJ	3.48	3.52	3.48	3.19	3.30	3.62	2.82	3.82	3.30	3.77

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

The uncertainty of CO_2 emission factors is described in chp. 1.6.1.2 and 3.2.4.7. The uncertainty in emissions of non-CO_2 gases are estimated to be medium, i.e. 30% for CH_4 and 80% for N_2O (see also chp. 1.6, Table 1-10).

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 chp. 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in chp. 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)

The following recalculations were implemented in submission 2018. Recalculations that cause a change in emission levels 1990 or 2015 of at least 1 kt CO_2 eq are quantified. All the other recalculations have an impact of less than 1 kt CO_2 eq in the years 1990 and 2015.

- 1A: AD of all wood combustion installations of 1A1a have been revised due to recalculations in the Swiss wood energy statistics (SFOE 2017b) for the entire time series 1990 to 2015. Main changes were carried out for automatic boilers resulting in total recalculations between -4 and -178 TJ.
- 1A: Recalculation in the Swiss overall energy statistics concerning use of gas oil for the year 2015. 190 TJ more use of gas oil for energy production. This leads to more emissions in 2015: 14kt CO_2, 0.1 kt N_2O, 0.57 kt CH_4.
- 1A: Recalculation in the Swiss overall energy statistics concerning use of natural gas for the years 1990-2015 due to recalculations in losses of natural gas transportation and distribution leads to insignificantly smaller emissions 1990-2015.
- 1A1a: The EF for N_2O for municipal solid waste incineration for the year 2016 has been calculated as a weighted average for all Swiss MSWIP according to the DeNOx-equipment and the amount of waste burnt in each plant. The EF for the years 2013-2015 have been interpolated using the value for 2012 and the new value for 2016. However this only leads to minor changes in the EF visible in the fourth decimal place in Table 3-33.
- 1A1a: Gas oil consumption for public electricity and heat production in 2015 has been revised according to the Swiss energy statistics (SFOE 2017)
- Gas oil consumption increased by 190 TJ compared to the previous submission, corresponding to approximately +14kt CO_2, 0.1 kt N_2O, 0.57 kt CH_4. (see Figure 10-1).

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

There are no category-specific planned improvements.

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

3.2.6.1 Source category description for 1A2 (stationary)

Table 3-40 Key categories of 1A2 Manufacturing industries and construction. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	L1, T1, L2, T2
1A2	Manufacturing industry and construction: Liquid fuels	CO2	L1, T1
1A2	Manufacturing industry and construction: Other fuels	CO2	L1, T1
1A2	Manufacturing industry and construction: Solid fuels	CO2	L1, T1, T2

[Source category 1A2 contains the sum of emissions of stationary and mobile sources – the statement on key categories holds for the aggregated emission only. The CO_2 emissions of 1A2 from Liquid Fuels are dominated by the stationary sources, however, 37% (2016) of the CO_2 emissions stem from mobile sources 1A2g vii.]

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 Table1.A(d) and described in chp. 3.2.3.

Table 3-41 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 electric arc furnaces 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
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) and Industry model

For CO_2 emissions from fuel combustion in source category 1A2 Manufacturing industries and construction, a Tier 2 method is applied (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1) using country-specific emission factors.

For all fuel combustion in 1A2f Cement production and for wood combustion in 1A2f Brick and tile production (2000-2012), 1A2giv and 1A2gviii, CH_4 emissions are calculated by a Tier 2 approach using country-specific emission factors. CH_4 emissions from all other fuel combustion processes in source category 1A2 Manufacturing industries and construction, a Tier 1 method is applied (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1) using default emission factors from the 2006 IPCC Guidelines.

For N_2O emissions from fuel combustion in source category 1A2 Manufacturing industries and construction, a Tier 1 method is applied (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1) using default emission factors from the 2006 IPCC Guidelines.

Overview Industry Model

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.

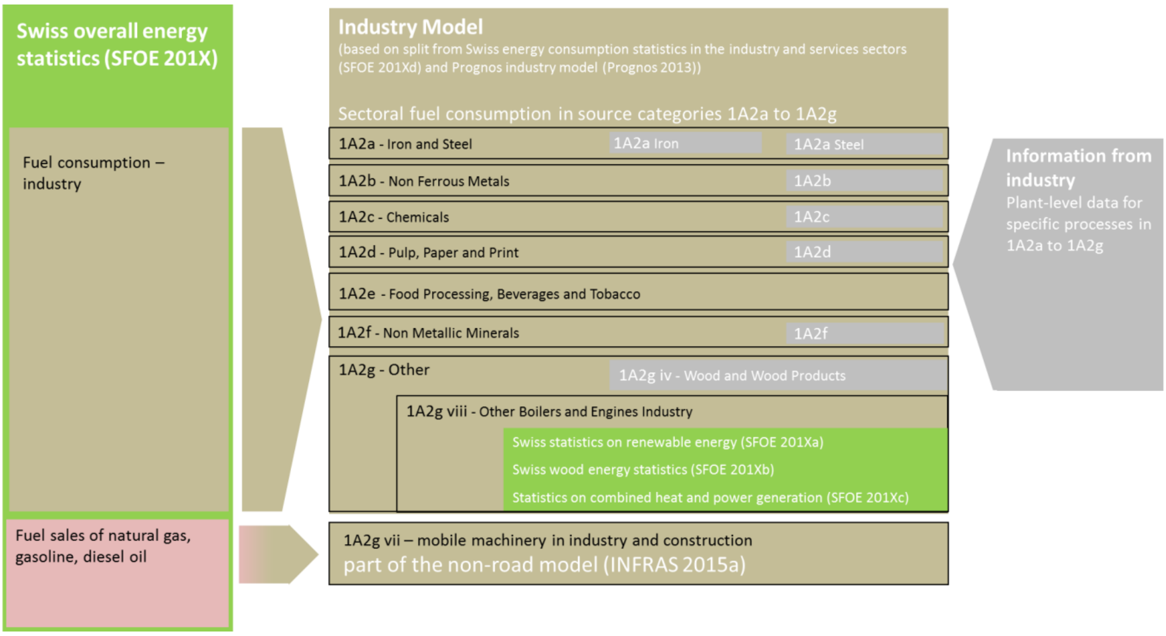

Figure 3-21 Schematic presentation of the data sources used for the industrial sectors 1A2a – 1A2g. The reference SFOE 201X refers to the 2017 edition of the corresponding energy statistics. For each fuel type, the Swiss overall energy statistics provide the total consumption for industry. The total consumption is then distributed to the different source categories based on information from industry surveys (SFOE 2017d) and the Prognos industry model. The grey boxes on the right show the specific bottom-up industry information.

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 2017d). These statistics are available since 1999 for gas oil and natural gas. For all 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 sub-section.

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 2017c).

Energy consumption statistics in the industry and services sectors

The energy consumption statistics in the industry and services sectors (SFOE 2017d) refers to representative surveys with about 12’000 workplaces in the industry and services sectors 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 surveys represents a census covering all fuel consumed. The surveys are available for all years since 1999 or 2002, depending on the fuel type.

In 2015, a change in the survey method of the energy consumption statistics in the industry and services sectors was implemented (SFOE 2015d). In brief, the business and enterprise register, which forms the basis for the samples of the surveys, was revised. While previously the business and enterprise register was based on direct surveys with work places, it is now based on annual investigations of registry data (e.g. from the old-age and survivors' insurance). In the course of this revision, a comparative assessment was conducted for the year 2013. This comparison shows that the energy consumption in the source categories of 1A2 stationary are modified by less than 1 percent, but also that the differences between the new and the old results for 2013 are not statistically significant (SFOE 2015d). As these statistics are only used for allocation of total energy consumption to different source categories, the impact on the different source categories consists only of a reallocation of the energy consumption and does not affect the total of the sector. Moreover, only consumption of gas oil and natural gas is affected. For all these reasons, the time series consisting of data based on the old (1990–2012) and new (2013–2016) survey method are therefore considered consistent.

Modelling of industry categories

The energy consumption statistics in the industry and services sectors (SFOE 2017d) are 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–1A2g 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 2018/1A2 Sektorgliederung Industrie).

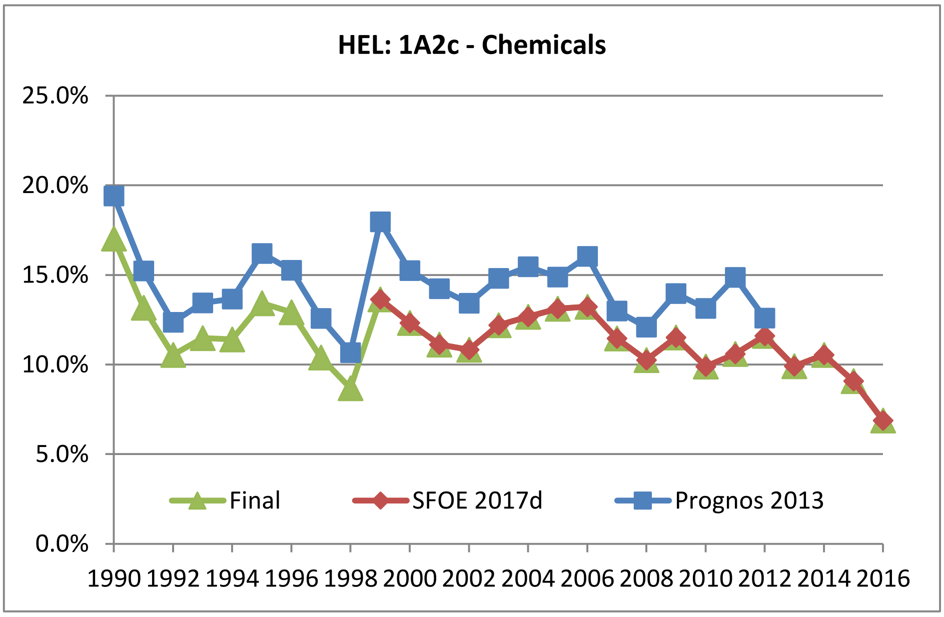

Figure 3-22 Illustrative example for combining time series with consistent overlap according to the 2006 IPCC Guidelines (IPCC 2006). The y-axis indicates the share of source category 1A2c of total gas oil consumption in the industry sector. The green line, which is based on the combination of the shares from the energy consumption statistics in the industry and services sectors (SFOE 2017d, red line from 1999 to 2016) 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 2018/1A2 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 validated and verified monitoring data from the Swiss emissions trading scheme implemented under the Ordinance for the Reduction of CO_2 Emissions (Swiss Confederation 2012) and are discussed in depth in the following chapters 3.2.6.2.2 to 3.2.6.2.8.

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 2017d).

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 2017b) as well as on data from the Swiss renewable energy statistics (SFOE 2017a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2017c), 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 3-42 Emission factors for 1A2 Manufacturing industries and construction in 2016. Values that are highlighted in green are described in chp. 3.2.4.4.

1A2 Emission factors (mix of bottom-up and top-down approach (modelling)) for GHG	**CO_2 fossil**	**CO_2 bio.**	**CH_4**	**N_2O**
	t/TJ	t/TJ	kg/TJ	kg/TJ
Gas oil	73.7		3	0.6
Residual fuel oil	77.0		<3 *(lower IEF than default emission factor)*	0.6
Liquefied petroleum gas	65.5		1	0.3
Petroleum coke	91.4		<3 *(lower IEF than default emission factor)*	0.6
Other bituminous coal	92.7		<10 *(lower IEF than default emission factor)*	1.5
Lignite	96.1		<10 *(lower IEF than default emission factor)*	1.5
Natural gas	56.4		1	0.1
Other fossil fuels (including solvents, plastics, waste tyres and rubber (see 1A2f))	72.0	3.5	2.4	3.4
Biomass (wood, biogas, biodiesel, bioethanol and other biogenic waste)		91.0	5.0	3.3

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 CO_2, CH_4 and N_2O are implied emission factors based on the fossil waste fuel mix. In addition the CH_4 emission factor includes the total CH_4 emissions of the cement industry based on direct exhaust measurements at the chimneys of the cement plants (see documentation in EMIS 2018/1A2f Zementwerke_Feuerung) based on industry data and emission declarations according to the Ordinance on Air Pollution Control (Swiss Confederation 1985). Implied CH_4 emission factors of source category 1A2 for residual fuel oil, petroleum coke, other bituminous coal and lignite are thus lower than the default emission factors of source category 1A documented in chp. 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 SO_2 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 SO_2 emission factors are country-specific and documented in SAEFL (2000).

In contrast to combustion in boilers, emission factors of precursors and SO_2 for fuel combustion in bottom-up industry processes are based on bottom-up industry data. Production-weighted emission factors based on various air pollution control measurements under the Ordinance on Air Pollution Control (Swiss Confederation 1985) are used to derive the corresponding process-specific emission factors.

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 2016, 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 2016. 1A2f Non-metallic minerals and 1A2c Chemicals are the second and third most important fuel consumers, respectively.

Table 3-43 Activity data fuel consumption in 1A2 Manufacturing industries and construction.

Source	Unit	1990	1995	2000	2005
1A2 Manufacturing industries and constr. (stationary sources)	TJ	87'982	88'877	87'699	91'275
Gas oil	TJ	21'754	23'529	25'145	24'711
Residual fuel oil	TJ	18'870	13'678	5'675	4'613
Liquefied petroleum gas	TJ	4'354	4'458	5'627	4'309
Petroleum coke	TJ	1'400	1'260	551	1'093
Other bituminous coal	TJ	13'476	7'303	5'866	4'799
Lignite	TJ	265	153	124	742
Natural gas	TJ	18'711	27'898	31'373	34'372
Other fossil fuels	TJ	2'555	2'817	4'054	4'525
Biomass	TJ	6'597	7'780	9'283	12'112

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2 Manufacturing industries and constr. (stationary sources)	TJ	91'837	93'307	87'622	90'382	84'008	85'329	87'235	81'916	80'417	81'322
Gas oil	TJ	21'602	21'386	21'005	20'686	16'771	17'157	17'902	12'340	12'636	12'726
Residual fuel oil	TJ	3'776	3'734	2'713	2'096	1'518	1'568	848	301	226	155
Liquefied petroleum gas	TJ	4'272	4'033	4'322	3'912	3'876	3'746	3'755	3'304	3'358	2'772
Petroleum coke	TJ	1'171	1'167	1'219	1'495	1'272	1'367	1'049	1'240	795	890
Other bituminous coal	TJ	4'859	4'445	4'263	4'348	3'868	3'794	3'910	2'403	1'946	1'517
Lignite	TJ	1'937	1'717	1'531	1'460	1'624	1'175	1'357	3'102	3'060	3'078
Natural gas	TJ	36'910	38'719	35'126	38'042	36'903	38'013	39'400	39'956	39'137	39'601
Other fossil fuels	TJ	4'224	4'975	4'958	5'183	5'307	4'883	5'186	5'270	5'252	5'926
Biomass	TJ	13'084	13'132	12'487	13'161	12'869	13'625	13'828	14'001	14'008	14'657

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 2018/1A2a-g).

3.2.6.2.2 *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 as fuel. Part of the other bituminous coal acts also as carburization material as well as reducing agent. Since other bituminous coal first of all acts as fuel in cupola furnaces it was decided to report its CO_2 emissions in source category 1A2a. Furthermore, this allows to be consistent with the fuel use of other bituminous coal provided by the Swiss overall energy statistics (SFOE 2017). Additionally, also limestone is used as flux in cupola furnaces yielding geogenic CO_2 emissions. These emissions are reported in source category 2A4d Other carbonate uses. 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. In these electric arc furnaces also so-called injection coal and petroleum coke for slag formation as well as natural gas are used. So far, the consumption of these fuels have been reported within the respective boilers of source categories 1A2gviii Other (petroleum coke, other bituminous coal) and 1A2a Iron and steel (natural gas). From now on these fuel consumptions are reported under source category 1A2a Electric arc furnaces of steel production based on plant-specific data from monitoring reports of the Swiss ETS for the years 2005-2011 and from 2013 onwards. For natural gas, this corresponds to a reallocation within 1A2a and for petroleum coke and other bituminous coal this corresponds to a reallocation from 1A2gviii to 1A2a. In addition, 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, other bituminous coal and gas oil and small amounts of petroleum coke are used.

Table 3-44 Activity data fuel consumption in 1A2a Iron and steel.

Source	Unit	1990	1995	2000	2005
1A2a Iron and steel	TJ	3'567	2'733	3'579	3'654
Gas oil	TJ	480	262	338	401
Residual fuel oil	TJ	346	131	20	39
Liquefied petroleum gas	TJ	408	193	286	217
Petroleum coke	TJ	85	46	56	72
Other bituminous coal	TJ	606	406	439	346
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	1'642	1'695	2'439	2'578

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2a Iron and steel	TJ	4'743	4'501	3'457	4'102	4'145	3'962	3'850	4'007	4'287	4'147
Gas oil	TJ	326	307	279	315	271	172	139	86	136	134
Residual fuel oil	TJ	36	51	39	51	2	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	295	246	214	219	226	438	438	388	393	327
Petroleum coke	TJ	86	40	21	47	37	42	53	81	69	78
Other bituminous coal	TJ	402	482	316	346	377	341	321	325	313	303
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	3'598	3'374	2'588	3'125	3'233	2'969	2'898	3'128	3'376	3'305

3.2.6.2.3 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 2016. Fuels consumed in 2016 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 3-45 Activity data fuel consumption in 1A2b Non-ferrous metals.

Source	Unit	1990	1995	2000	2005
1A2b Non-ferrous metals	TJ	2'378	1'969	1'560	977
Gas oil	TJ	587	347	236	125
Residual fuel oil	TJ	NO	NO	NO	NO
Liquefied petroleum gas	TJ	27	17	15	7
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	1'764	1'605	1'309	845

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2b Non-ferrous metals	TJ	1'022	1'042	1'006	1'218	1'177	1'746	1'593	1'917	1'792	1'672
Gas oil	TJ	94	112	167	112	76	153	128	90	78	76
Residual fuel oil	TJ	NO	0	0	0	0	1	23	NO	44	NO
Liquefied petroleum gas	TJ	8	7	7	8	8	11	11	10	10	8
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	920	924	833	1'098	1'093	1'581	1'430	1'817	1'660	1'587

3.2.6.2.4 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 chp. 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. Data are available to reviewers on request.

The CO_2 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 CH_4 and N_2O (see Table 3-42 and Table 3-14 (CH_4 EF of residual fuel oil)).

Table 3-46 Emission factors for 1A2c Chemicals are documented in the confidential NIR, which is available to reviewers on request.

The fuels consumed in 2016 include mainly natural gas as well as minor amounts of gas oil. Fuel consumption in this source category has slightly decreased between 1990 and 2016. Consumption of gas oil and residual fuel oil have decreased in that period, while natural gas consumption has increased.

Table 3-47 Activity data fuel consumption in 1A2c Chemicals.

Source	Unit	1990	1995	2000	2005
1A2c Chemicals	TJ	14'431	15'158	13'497	15'477
Gas oil	TJ	3'942	3'313	3'215	3'345
Residual fuel oil	TJ	1'434	693	252	36
Liquefied petroleum gas	TJ	15	13	12	10
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	9'039	11'138	10'017	12'086
Other fossil fuels	TJ	IE	IE	IE	IE

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2c Chemicals	TJ	14'810	14'610	12'611	11'814	12'167	13'909	14'125	12'131	12'528	14'359
Gas oil	TJ	2'556	2'261	2'498	2'103	1'847	2'055	1'797	1'321	1'167	888
Residual fuel oil	TJ	6	79	91	66	0.2	0.2	1	NO	NO	NO
Liquefied petroleum gas	TJ	10	9	9	8	7	10	10	9	9	8
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	12'239	12'261	10'014	9'637	10'312	11'845	12'317	10'800	11'352	13'463
Other fossil fuels	TJ	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

3.2.6.2.5 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. Emissions from use of carbonate in flue gas treatment in cellulose production is reported in 2A4d Other process use of carbonates.

Fuel consumption in 1A2d consists both of fuels used in boilers and specific industrial production processes. In this source category only biomass (biogenic waste) from cellulose production (until 2008) is included, based on data from the only production site. The GHG emissions were calculated using a country-specific CO_2 emission factor (EMIS 2018/1A2d Zellulose-Produktion) and default factors for CH_4 and N_2O (IPCC 2006, vol. 2, chp.2, table 2.3, sulphite lyes). Biomass (e.g. wood and wood waste) used in paper production is reported in source category 1A2gviii, because no comprehensive information (statistical data) exists to distribute biomass consumption to the specific industry sectors within 1A2 as explained in chapter 3.2.4.5.2. Therefore, from 2009 onwards GHG emissions from biomass are reported as ”IE” in the reporting tables Table1.A(a)s2.

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 2016 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 3-48 Activity data of fuel consumption in 1A2d Pulp, paper and print.

Source	Unit	1990	1995	2000	2005
1A2d Pulp, paper and print	TJ	11'760	13'700	11'577	11'379
Gas oil	TJ	1'188	1'751	1'403	1'456
Residual fuel oil	TJ	5'250	3'061	1'417	2'092
Liquefied petroleum gas	TJ	86	141	148	100
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	3'151	7'389	6'916	5'678
Biomass	TJ	2'085	1'358	1'694	2'053

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2d Pulp, paper and print	TJ	10'236	9'455	6'124	6'773	6'051	5'374	5'474	4'645	3'656	3'087
Gas oil	TJ	1'096	1'019	948	852	561	623	711	297	383	411
Residual fuel oil	TJ	1'885	1'887	1'084	279	4	3	0	22	19	9
Liquefied petroleum gas	TJ	71	60	62	61	62	67	67	60	60	50
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	5'085	5'164	4'030	5'581	5'424	4'681	4'696	4'266	3'194	2'617
Biomass	TJ	2'099	1'324	IE	IE	IE	IE	IE	IE	IE	IE

3.2.6.2.6 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 2017d) and Prognos (2013).

In 2016, the fuels used in this category were mainly natural gas as well as gas oil and small amounts of liquefied petroleum gas. There was a slight increase in fuel consumption between 1990 and 2016. 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.

Biomass (e.g. wood and wood waste) used in 1A2e Food processing, beverages and tobacco is reported in source category 1A2gviii, because no comprehensive information (statistical data) exists to distribute biomass consumption to the specific industry sectors within 1A2 as explained in chapter 3.2.4.5.2. Therefore, from 2009 onwards GHG emissions from biomass are reported as ”IE” in the CRF Table1.A(a)s2.

Table 3-49 Activity data fuel consumption in 1A2e Food processing, beverages and tobacco.

Source	Unit	1990	1995	2000	2005
1A2e Food processing, beverages and tobacco	TJ	9'858	8'784	10'437	10'239
Gas oil	TJ	7'410	5'511	5'515	4'070
Residual fuel oil	TJ	1'160	466	137	NO
Liquefied petroleum gas	TJ	204	308	535	534
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	1'085	2'500	4'250	5'635
Biomass	TJ	IE	IE	IE	IE

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2e Food processing, beverages and tobacco	TJ	11'221	10'975	12'558	13'161	11'374	11'310	13'079	12'442	11'574	10'919
Gas oil	TJ	3'500	3'376	3'687	3'778	3'197	3'237	3'681	2'395	2'522	2'512
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	596	535	736	659	675	935	935	828	838	699
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	7'126	7'064	8'135	8'723	7'502	7'138	8'463	9'220	8'214	7'708
Biomass	TJ	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

3.2.6.2.7 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). Except for brick and tile production (from 2013 onwards) bottom-up information is also available on the amount of biomass consumed in source category 1A2f. Therefore, all emissions from biomass used in these processes are reported in source category 1A2f. Fuel consumption in 2016 comprises mainly other fossil fuels, natural gas, lignite and biomass

Between 1990 and 2016 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 3-50 Activity data fuel consumption in 1A2f Non-metallic minerals.

Source	Unit	1990	1995	2000	2005
1A2f Non-metallic minerals	TJ	25'613	19'884	18'056	17'832
Gas oil	TJ	1'871	1'629	1'642	1'389
Residual fuel oil	TJ	5'382	5'578	3'649	2'420
Liquefied petroleum gas	TJ	523	498	468	324
Petroleum coke	TJ	550	300	480	638
Other bituminous coal	TJ	12'665	6'758	5'415	4'364
Lignite	TJ	265	153	124	737
Natural gas	TJ	1'769	1'566	1'496	1'861
Other fossil fuels	TJ	2'555	2'817	4'054	4'525
Biomass	TJ	33	585	728	1'575

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2f Non-metallic minerals	TJ	18'036	17'902	17'102	18'196	17'801	16'956	17'119	17'677	16'484	16'518
Gas oil	TJ	1'343	1'299	1'260	1'269	1'238	1'097	1'174	1'204	1'098	1'020
Residual fuel oil	TJ	1'744	1'598	1'374	1'519	1'403	1'456	801	209	130	139
Liquefied petroleum gas	TJ	181	160	95	102	127	108	113	45	52	44
Petroleum coke	TJ	912	1'036	994	1'130	1'081	920	815	1'052	622	658
Other bituminous coal	TJ	4'348	3'912	3'940	3'992	3'474	3'403	3'478	1'973	1'498	1'089
Lignite	TJ	1'790	1'596	1'379	1'348	1'493	1'081	1'283	2'912	2'856	2'881
Natural gas	TJ	2'017	1'919	1'731	2'048	1'938	2'085	2'506	3'111	3'121	2'952
Other fossil fuels	TJ	4'224	4'975	4'958	5'183	5'307	4'883	5'186	5'270	5'252	5'926
Biomass	TJ	1'476	1'406	1'371	1'604	1'739	1'923	1'764	1'901	1'856	1'809

Cement (1A2f)

Methododology

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

Emission factors

The CH_4 emission factor includes the overall CH_4 emissions of the cement industry based on direct exhaust measurements at the chimneys of the cement plants. Therefore, these CH_4 emissions are reported under the fuel type other fossil fuels in the reporting tables.

Table 3-51 Emission factors for cement industry in 2016. Emission factors for CO_2 and N_2O are fuel-specific (see Table 3-43).

Cement industry (part of 1A2f)	CO_2	N_2O	CH_4	NO_x	NMVOC	SO_2	CO
	t/TJ		g/t clinker				
Cement	fuel specific		6	930	59	270	1'900

The NCVs and CO_2 emission factors for waste oil, solvents and residues from destillation, 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 Mauschitz (2003). The biogenic fraction of waste tyres is based on an Austrian study and published by the German Ministry of Environment (UBA

2006). The emission factor of N_2O for all waste derived fuels is the same and is taken from 2006 IPCC guidelines (IPCC 2006, vol 2, chp.2 table 2.3 industrial wastes).

Table 3-52 NCV, CO_2 and N_2O emission factors as well as biomass fraction of waste derived fuels (Other fossil fuels and Biomass) used in the cement industry in 2016.

Cement industry (part of 1A2f) **Waste derived fuel**	**NCV**	**EF CO_2 Tot.**	**EF N_2O**	**Fraction biomass-C**
	MJ/kg	kg CO_2/GJ	g/GJ	%
Waste oil	32.48	74.35	4	0
Waste coke from coke filters	23.7	97	4	0
Mixed industrial waste	18.34	74	4	0
Other fossil waste fuels	20.85	97	4	0
Solvents and residues from distillation	23.63	73.99	4	0.9
Waste tyres and rubber	26.4	84	4	27
Plastics	25.24	84.66	4	27.7
Mix of special waste with saw dust (CSS)	9.22	102.4	4	78.5
Sewage sludge (dried)	9.39	94.52	4	100
Wood waste	16.26	99.9	4	100
Animal meal	16.81	86.66	4	100
Sawdust	16.26	99.9	4	100
Agricultural waste / other biomass	12.72	110	4	100

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 (EMIS 2018/1A2f Zementwerke Feuerung).

In 2016, the Swiss cement industry used about slightly more waste derived fuels than standard fossil 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 2016. 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.

In the reporting tables, the mainly biogenic waste derived fuels are reported under fuel type Biomass, whereas mainly fossil waste derived fuels are reported under fuel type Other fossil fuels (however, both fuel types also contain a fossil and a biogenic fraction, respectively, see Table 3-52).

Table 3-53 Activity data: Overview on fuel use in 1A2f cement industry.

Cement industry (part of 1A2f)	Unit	1990	1995	2000	2005
Cement, total incl. waste	TJ	17'193	12'772	11'018	11'623
Cement fossil without waste	TJ	15'319	9'993	7'332	6'208
Gas oil	TJ	NO	NO	NO	72
Residual fuel oil	TJ	1'907	2'825	1'530	637
Petroleum coke	TJ	550	300	480	638
Other bituminous coal	TJ	12'235	6'547	5'176	4'120
Lignite	TJ	265	153	124	737
Natural gas	TJ	362	168	22	4
Cement, waste derived fuel	TJ	1'874	2'780	3'686	5'415
Other fossil fuels	TJ	1'841	2'195	2'998	3'931
Waste oil	TJ	1'169	1'485	1'519	1'411
Waste coke from coke filters	TJ	59	59	59	58
Mixed industrial waste	TJ	NO	NO	NO	NO
Other fossil waste fuels	TJ	NO	NO	NO	NO
Solvents and residues from distillation	TJ	284	181	427	976
Waste tyres and rubber	TJ	330	415	421	645
Plastics	TJ	NO	55	572	841
Biomass	TJ	33	585	688	1'484
Mix of special waste with saw dust (CSS)	TJ	23	136	158	133
Sewage sludge (dried)	TJ	9	128	332	494
Wood waste	TJ	NO	321	NO	NO
Animal meal	TJ	NO	NO	198	856
Sawdust	TJ	NO	NO	NO	NO
Agricultural waste / other biomass	TJ	NO	NO	NO	NO

Cement industry (part of 1A2f)	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cement, total incl. waste	TJ	12'022	11'954	11'816	12'388	12'187	11'462	11'866	12'339	11'348	11'583
Cement fossil without waste	TJ	6'914	6'389	6'127	6'278	5'859	5'406	5'512	5'847	4'917	4'544
Gas oil	TJ	NO	NO	NO	5	1	0.1	88	75	87	50
Residual fuel oil	TJ	175	135	100	112	101	297	86	58	45	90
Petroleum coke	TJ	912	1'036	994	1'130	1'081	920	815	1'052	622	658
Other bituminous coal	TJ	4'033	3'618	3'650	3'662	3'167	3'097	3'203	1'713	1'267	826
Lignite	TJ	1'790	1'596	1'379	1'348	1'493	1'081	1'283	2'912	2'856	2'881
Natural gas	TJ	4	4	4	21	16	11	38	37	41	39
Cement, waste derived fuel	TJ	5'108	5'565	5'689	6'109	6'329	6'056	6'354	6'492	6'431	7'039
Other fossil fuels	TJ	3'727	4'237	4'394	4'580	4'685	4'225	4'599	4'596	4'582	5'234
Waste oil	TJ	844	866	1'278	1'253	1'170	839	876	923	1'142	1'567
Waste coke from coke filters	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Mixed industrial waste	TJ	2	1	1	NO	NO	NO	NO	NO	NO	NO
Other fossil waste fuels	TJ	48	105	137	45	55	36	25	19	12	11
Solvents and residues from distillation	TJ	1'295	1'476	1'032	1'189	1'264	1'294	1'414	1'273	1'292	1'534
Waste tyres and rubber	TJ	525	794	828	842	1'033	964	985	1'021	958	951
Plastics	TJ	1'013	995	1'119	1'252	1'163	1'092	1'299	1'360	1'177	1'171
Biomass	TJ	1'381	1'328	1'295	1'530	1'644	1'831	1'756	1'896	1'850	1'805
Mix of special waste with saw dust (CSS)	TJ	164	157	131	123	96	100	96	103	80	98
Sewage sludge (dried)	TJ	549	511	475	477	483	527	418	428	420	479
Wood waste	TJ	NO	NO	61	292	409	586	732	886	896	811
Animal meal	TJ	664	658	621	624	614	572	479	457	412	409
Sawdust	TJ	NO	NO	NO	6	24	17	32	21	42	8
Agricultural waste / other biomass	TJ	5	2	7	7	18	28	NO	NO	NO	NO

Lime (1A2f)

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 other bituminous coal is used anymore as it was replaced by residual fuel oil.

Container Glass (1A2f)

Today, there exists only one production plant for container glass in Switzerland. In 2014, fuel consumption for container glass production includes only natural gas. Since 1990, fuel consumption has drastically decreased due to reduction in production. Until 2003 only residual fuel oil was used and since 2004 the share of natural gas has increased to reach a stable share between 2006 and 2012. The large increase in natural gas between 2012 and 2013 is due to the fact that the plant has switched its glass kiln completely to natural gas in autumn 2013.

Tableware Glass (1A2f)

Today, there exists only one production plant for tableware glass in Switzerland. Fuel consumption for tableware glass currently includes only liquefied petroleum gas as residual fuel oil was eliminated in 1995. Since 1990, fuel consumption has strongly decreased because of the closure of one production plant in 2006.

Glass wool (1A2f)

In Switzerland, Glass wool is produced in two plants. 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 2016.

Fine ceramics (1A2f)

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 2016.

Brick and tile (1A2f)

Methodology

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.

Emission factors

The CO_2 emission factors for wood and animal grease are based on a study of Cemsuisse (Cemsuisse 2010a), see Table 3-52, 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 2018/1A2f Ziegeleien).

For CH_4 and N_2O 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 CH_4 and N_2O 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.

Activity data

Since 2013, plant-specific activity data – except for biomass – are available from monitoring reports of the Swiss ETS. Fuels used in the brick and tile production in 2016 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, a 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 (1A2f)

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 (1A2f)

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 2016 are gas oil and natural gas. Since 1990, there has been a fuel switch from gas oil to natural gas.

3.2.6.2.8 Other (1A2g stationary)

Methodology (1A2g stationary)

Source category 1A2g iv 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 1A2g viii 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 2016 of 1A2 Manufacturing industries and construction.

Methodologically, the fossil fuel consumption in boilers of 1A2g viii 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 CO_2 emission factors for wood waste and animal grease in 1A2g iv Fibreboard production are based on a study of Cemsuisse (Cemsuisse 2010a), see Table 3-52. For wood waste the respective CH_4 and N_2O 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 1A2g viii Other boilers and engines industry the same emission factors as for natural gas are assumed.

Activity data (1A2g stationary)

1A2g iv Fibreboard production

In source category fibreboard production, mainly wood waste as well as natural gas are used. Since 1990, the production of fibreboard and thus the fuel consumption have increased significantly. The fuel mix has strongly shifted between 1990 and 2016 from fossil fuels to biomass (wood waste). Between 2001 and 2013, also animal grease was used for fibreboard production. Since 2004, data on annual fuel consumption is taken from monitoring reports of the industry as documented in the EMIS database (EMIS 2018/1A2g iv).

1A2g viii Other boilers and engines industry

Activity data for wood combustion is based on Swiss wood energy statistics (SFOE 2017b) whereas sewage and biogas consumption is based on data from the Swiss renewable energy statistics (SFOE 2017a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2017c). 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 3-54 Activity data fuel consumption in 1A2g iv Wood and wood products and 1A2g viii Other (stationary).

Source	Unit	1990	1995	2000	2005
1A2g iv: Wood and wood products, 1A2g viii: Other (stationary)	TJ	20'374	26'649	28'993	31'717
Gas oil	TJ	6'276	10'716	12'796	13'925
Residual fuel oil	TJ	5'298	3'749	199	26
Liquefied petroleum gas	TJ	3'091	3'288	4'164	3'116
Petroleum coke	TJ	765	914	15	383
Other bituminous coal	TJ	205	140	12	88
Lignite	TJ	NO	NO	NO	5
Natural gas	TJ	261	2'005	4'946	5'689
Other fossil fuels	TJ	NO	NO	NO	NO
Biomass	TJ	4'479	5'838	6'861	8'485

Source	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2g iv: Wood and wood products, 1A2g viii: Other (stationary)	TJ	31'768	34'822	34'763	35'118	31'293	32'071	31'995	29'097	30'095	30'622
Gas oil	TJ	12'688	13'012	12'166	12'256	9'581	9'821	10'272	6'947	7'253	7'684
Residual fuel oil	TJ	105	119	124	182	109	109	22	70	33	8
Liquefied petroleum gas	TJ	3'111	3'016	3'200	2'855	2'771	2'176	2'180	1'965	1'995	1'635
Petroleum coke	TJ	174	91	203	318	154	405	181	108	104	155
Other bituminous coal	TJ	109	50	6	11	16	50	110	105	134	125
Lignite	TJ	147	121	152	111	131	95	75	189	204	197
Natural gas	TJ	5'926	8'012	7'796	7'828	7'400	7'713	7'090	7'614	8'220	7'970
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	9'509	10'402	11'116	11'557	11'131	11'702	12'064	12'100	12'152	12'848

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

The uncertainty of CO_2 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-CO_2 gases is estimated to be medium, i.e. 30% for CH_4 and 80% for N_2O (see Table 1-10).

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 chp. 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in chp. 3.2.4.8.

3.2.6.5 Category-specific recalculations for 1A2 (stationary)

- 1A2: So far the consumption of so-called injection coal and petroleum coke for slag formation as well as of natural gas in the electric arc furnaces of secondary steel production have been reported within the respective boilers of source categories 1A2gviii Other (petroleum coke, other bituminous coal) and 1A2a Iron and steel (natural gas). From now on these fuel consumptions are reported under source category 1A2a Electric arc furnaces of steel production based on plant-specific data from monitoring reports of the Swiss ETS for the years 2005-2011 and from 2013 onwards. In order to accommodate this, stock changes had to be adjusted for petroleum coke (2007 -100 TJ; 2008 +100 TJ) and bituminous coal (various amounts ranging from -500 TJ in 1991 to +240 TJ in 2002). Total coal consumption over the period 1990-2016 remained the same, only the distribution between the years has been adjusted. These changes are the main contributor to the large and fluctuating recalculations in CO_2 emissions in 1A2 as seen in Figure 10-1.

- 1A2a: The activity data (natural gas) of the reheating furnaces in 1A2a Steel production have been revised from 2003 onwards. These changes are balanced out by the natural gas consumption in boilers of 1A2a Iron and steel and therefore, do not influence the emissions from consumption of natural gas within 1A2a.
- 1A2f: The activity data (gas oil, natural gas) of 1A2f Production of mixed goods have been revised for 2014 and 2015 due to correction of a calculation error in last year's submission resulting in a decrease in emission of 8.1 kt CO_2 eq in 2015. These changes are balanced out by an increase in consumption of gas oil and natural gas in boilers of 1A2gviii Other and therefore, do not influence the net emissions within 1A2.
- 1A2f: The activity data (gas oil, liquefied petroleum gas, natural gas) of 1A2f Brick and tile production have been revised for 2014 and 2015 due to minor adjustements of the fuel consumption in one plant. These changes are balanced out by the consumption of gas oil, liquefied petroleum gas and natural gas in boilers of 1A2gviii Other and therefore, do not influence the net emissions within 1A2.
- 1A2g: Recalculation in the Swiss overall energy statistics concerning use of lignite for the year 2015. -0.378 TJ of lignite were less used in 2015, this results in less emissions for 2015: -0.36t CO_2.
- 1A2g: Small recalculation in use of sewage gas in the yeaers 2014-2015.
- 1A2g iv: The NO_x emission factor of animal meal has been corrected from 2000 onwards of 1A2giv Fibreboard production resulting in revised values from 1996 onwards.

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)

Table 3-55 Key categories of 1A4 Other sectors. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1A4a	Commercial: Gaseous fuels	CO2	L1, T1, L2
1A4a	Commercial: Liquid fuels	CO2	L1, T1
1A4b	Residential: Biomass	CH4	T1
1A4b	Residential: Gaseous fuels	CO2	L1, T1, L2, T2
1A4b	Residential: Liquid fuels	CO2	L1, T1
1A4c	Agriculture and forestry: Liquid fuels	CO2	L1

[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 CO_2 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. See chp. 3.2.10.1]

Table 3-56 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/forerstry/fishing	Emissions from stationary fuel combustion of agriculture and grass drying.

3.2.7.2 Methodological issues for 1A4 (stationary)

Methodology (1A4 stationary)

CO_2 emissions from stationary combustion in source categories 1A4ai, 1A4bi and 1A4ci are estimated based on country-specific emission factors 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) for liquid, solid, gaseous fuels, biogas, wood consumption in bonfires and animal grease. For wood biomass and other fossil fuels, a Tier 3 approach using country-specific emission factors is applied. For Direct emission measurements are not available.

A Tier 1 approach is applied with 2006 IPCC defaults EFs for CH_4 emissions of liquid fuels and gasoil for boilers and N_2O emissions of all fuels and technologies. CH_4 emissions of gasoil used in engines, gaseous fuels and biogas are calculated by a Tier 2 approach using country-specific emission factors. CH_4 emissions of wood biomass are calculated by a Tier 3 approach using country-specific emission factors.

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 3-57 Emission factors for stationary combustion in 1A4ai Other sectors commercial/institutional in 2016. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

Source/fuel	CO_2	CO_2 biog.	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	t/TJ		kg/TJ					
1A4a Other sectors: Commercial/institutional								
Gas oil (weighted average)	73.7		10	0.6	34	6.5	6	15.9
Gas oil (heat only boilers)	73.7		10	0.6	34	6.4	6	15.9
Gas oil (engines)	73.7		10	0.6	40	30.0	8	15.2
Natural gas (weighted average)	56.4		2.0	0.1	21.0	12.3	1.9	0.5
NG (heat only boilers)	56.4		1	0.1	17.2	9.8	2	0.5
NG (turbines)	56.4		2.0	0.1	60.0	15.0	0.1	0.5
NG (engines)	56.4		20	0.1	87.3	56.7	1	0.5
Other bituminous coal	NO		NO	NO	NO	NO	NO	NO
Lignite	NO		NO	NO	NO	NO	NO	NO
Biomass (weighted average)		84.7	17.8	3.0	90.5	570.4	26.8	7.5
Biomass (wood)		91.6	22.0	3.7	108.5	707.8	32.9	9.2
Biomass (biogas)		56.4	1	0.1	17.2	9.8	2.0	0.5

Table 3-58 Emission factors for stationary combustion in 1A4bi Other sectors residential in 2016. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

Source/fuel	CO_2	CO_2 biog.	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	t/TJ		kg/TJ					
1A4b Other sectors: Residential								
Gas oil (weighted average)	73.7		10	0.6	35.0	12	6	15.9
Gas oil (heat only boilers)	73.7		10	0.6	35.0	12	6	15.9
Gas oil (engines)	73.7		2	0.6	40	30	8	15.2
Natural gas (weighted average)	56.4		1.2	0.1	16.4	13.2	4	0.5
NG (heat only boilers)	56.4		1	0.1	16.2	13	4	0.5
NG (turbines)	56.4		2	0.1	60	15	0.1	0.5
NG (engines)	56.4		20	0.1	33.3	56.7	1	0.5
Other bituminous coal	92.7		300	1.5	65	1800	100	350
Lignite	NO		NO	NO	NO	NO	NO	NO
Biomass (Wood)		95.0	46.9	3.8	89.3	1261.0	70.3	9.5

Table 3-59 Emission factors for stationary combustion in 1A4ci Agriculture/forestry/fishing in 2016.

1A4c Agriculture/forestry/fishing	Unit	CO_2 fossil	CO_2 biog.	CH_4	N_2O
Grass drying (fossil, biogenic)	kg/TJ	61'275	98'159	6.2	1.0
Biomass	kg/TJ	NA	119'656	15	4.8

Charcoal and bonfires

Emission factors concerning CO_2, CH_4 and N_2O 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 CH_4 and N_2O emissions resulting from bonfires. The CO_2 emission factor for bonfires in the residential category (1A4bi) is based on literature (SAEFL 2000). Emission factors of precursors are taken from the EMEP/EEA Guidebook (2016).

Table 3-60 Emission factors for use of charcoal and bonfires in 1A4bi Other sectors residential in 2016.

1A4bi Other sectors: residential stationary combustion	Unit	CO_2 biog.	CH_4	N_2O	NO_X	NMVOC	SO_2	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 futher information). For other energy sources such as other bituminous coal, activity data is provided directly by the Swiss overall energy statistics (SFOE 2017). 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 2018/1A4ci Grastrocknung). Since submission 2015, the actual fuel consumption for grass drying is available and used for emission calculations.

Table 3-61 Activity data in 1A4a Commercial/Institutional (stationary).

Source/Fuel	Unit	1990	1995	2000	2005
1A4a Other sectors: Commercial/institutional	TJ	78'623	85'570	81'916	88'015
Gas oil	TJ	57'622	58'811	53'013	54'937
Gas oil heat only boilers	TJ	57'599	58'635	52'662	54'620
Gas oil engines	TJ	24	175	351	318
Natural gas	TJ	18'048	22'955	24'539	27'721
NG heat only boilers	TJ	17'772	21'784	22'802	25'688
NG turbines	TJ	85	78	NO	28
NG engines	TJ	192	1'093	1'737	2'004
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Biomass (total)	TJ	2'952	3'804	4'364	5'357
Biomass (wood)	TJ	2'929	3'781	4'306	5'219
Biomass (biogas)	TJ	24	23	58	138

Source/Fuel	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A4a Other sectors: Commercial/institutional	TJ	75'020	79'232	77'202	83'551	69'324	76'226	81'130	64'841	71'088	74'568
Gas oil	TJ	45'450	47'585	45'699	48'778	38'900	41'814	44'328	34'191	36'406	37'592
Gas oil heat only boilers	TJ	45'269	47'416	45'545	48'660	38'796	41'720	44'242	34'109	36'324	37'510
Gas oil engines	TJ	181	169	154	119	105	94	86	82	82	82
Natural gas	TJ	23'785	25'257	24'761	27'469	24'057	27'025	28'455	22'187	25'070	26'419
NG heat only boilers	TJ	21'859	23'399	22'948	25'764	22'476	25'472	26'957	20'751	23'634	24'983
NG turbines	TJ	28	29	26	23	17	5	7	7	7	7
NG engines	TJ	1'898	1'829	1'787	1'681	1'564	1'548	1'490	1'429	1'429	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	5'785	6'390	6'742	7'304	6'367	7'387	8'347	8'463	9'611	10'556
Biomass (wood)	TJ	5'480	5'984	6'297	6'716	5'620	6'490	7'192	6'941	7'838	8'479
Biomass (biogas)	TJ	305	406	444	587	747	897	1'155	1'522	1'773	2'078

Table 3-62 Activity data in 1A4b Residential (stationary).

Source/Fuel	Unit	1990	1995	2000	2005
1A4b Other sectors: Residential	TJ	184'901	189'259	170'411	185'916
Gas oil	TJ	136'887	133'548	116'295	124'024
Gas oil heat only boilers	TJ	136'887	133'544	116'242	123'961
Gas oil engines	TJ	1	4	53	63
Natural gas	TJ	25'464	34'088	36'261	42'633
NG heat only boilers	TJ	25'404	33'830	35'822	42'103
NG turbines	TJ	NO	NO	NO	NO
NG engines	TJ	60	258	439	530
Other bituminous coal	TJ	630	460	130	400
Lignite	TJ	NO	NO	NO	NO
Biomass	TJ	21'920	21'162	17'725	18'859

Source/Fuel	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A4b Other sectors: Residential	TJ	159'070	170'185	166'808	180'892	145'216	160'227	171'263	134'195	143'869	149'728
Gas oil	TJ	102'729	108'715	105'296	111'731	86'989	94'103	99'373	75'136	79'406	81'340
Gas oil heat only boilers	TJ	102'663	108'663	105'254	111'695	86'955	94'072	99'344	75'109	79'379	81'312
Gas oil engines	TJ	65	52	42	36	34	32	29	27	27	27
Natural gas	TJ	39'158	42'389	42'469	48'229	40'910	47'043	50'957	42'367	46'106	48'836
NG heat only boilers	TJ	38'613	41'848	41'931	47'723	40'440	46'577	50'509	41'937	45'676	48'406
NG turbines	TJ	3	3	NO	NO	NO	NO	NO	NO	NO	NO
NG engines	TJ	542	537	538	506	470	466	448	430	430	430
Other bituminous coal	TJ	400	400	400	400	300	300	300	200	200	200
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	16'783	18'681	18'643	20'531	17'017	18'781	20'633	16'492	18'157	19'353

Table 3-63 Activity data in 1A4ci Agriculture/forestry/fishing (stationary).

Source/Fuel	Unit	1990	1995	2000	2005
1A4c Agriculture/forestry/fishing	TJ	2'323	2'032	1'702	1'643
Grass drying (fossil, biogenic)	TJ	1'895	1'544	1'223	994
Biomass	TJ	428	488	479	648
1990=100%		100%	87%	73%	71%

Source/Fuel	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A4c Agriculture/forestry/fishing	TJ	1'506	1'444	1'486	1'434	1'460	1'397	1'038	1'149	1'150	1'506
Grass drying (fossil, biogenic)	TJ	948	822	856	739	891	685	458	524	431	492
Biomass	TJ	557	622	629	696	569	712	580	626	719	1'013
1990=100%		65%	62%	64%	62%	63%	60%	45%	49%	49%	65%

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 2017).

The total wood demand for bonfires is assumed to be constant over time (for further details see documentation in EMIS 2018/1A4bi Lagerfeuer).

Table 3-64 Activity data in 1A4bi Charcoal and bonfires.

1A4bi Other sectors: residential stationary combustion	Unit	1990	1995	2000	2005
Use of charcoal	TJ	311	291	292	313
Bonfires	TJ	160	160	160	160

1A4bi Other sectors: residential stationary combustion	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Use of charcoal	TJ	313	354	343	343	343	344	343	354	353	334
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 CO_2 emissions from fuel combustions is described in the uncertainty analysis in chp. 3.2.4.7. Uncertainty in emissions of other non-CO_2 gases is estimated to be medium: 30% for CH_4 and 80% for N_2O (see Table 1-10).

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 chp. 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in chp. 3.2.4.8.

3.2.7.5 Category-specific recalculations for 1A4 (stationary)

- 1A4a: Recalculation in the Swiss overall energy statistics concerning use of natural gas for the years 1990-2015 due to recalculations in losses of natural gas transportation and distribution leads to insignificantly smaller emissions 1990-2015.
- 1A4a: The correction of the allocation of natural gas to source category 1A2g vii (mobile) leads to higher natural gas consumption in source category 1A4a (see also 10.1.2.1.8). The resulting increase in CO_2 emissions compared to the previous submission ranges from approximately 10 kt CO_2 in 1990 to about 17 kt CO_2 around the year 2000 and decreases again afterwards to around 10 kt CO_2, as seen in Figure 10-1.
- 1A4b: Recalculation in the Swiss overall energy statistics (SFOE 2017) concerning use of bituminous coal in households for the years 2011-2015 Coal consumption was reduced by 100 TJ for the years 2011-2013, and by 200 TJ for the years since 2014, compared to the previous submission, leading to a reduction of -9 kt CO_2 for the period 2011-2013 and -18kt CO_2 for the period 2014-2015. This recalculation is responsible for the observed stepwise decrease in CO_2 emissions since 2010 in source category 1A4 as compared to the previous submission (Figure 10-1). This recalculation is also responsible for the observed decrease in CH_4 emissions in source category 1A4 as compared to the previous submission (Figure 10-2).
- 1A4b: Small recalculation (of the order of 10 TJ, corresponding to 0.5 kt CO_2) in the Swiss overall energy statistics concerning use of natural gas in housholds for some years.

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)

Note for Key categories 1A2:

See chp. 3.2.6 and note that source category 1A2 contains the sum of emissions of stationary and mobile sources – the statement on key categories holds for the aggregated emission only. The CO_2 emissions of 1A2 from Liquid Fuels are dominated by the stationary sources, however, 37% (2016) of the CO_2 emissions stem from mobile sources 1A2g vii.].

Table 3-65 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.

CO_2 emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO_2 emission factor for lubricants, 73.3 t/TJ (IPCC 2006). However, these emissions are reported under source category 2D1 Lubricant use (see chp. 4.5.2.1 and see also remark on a potential double-counting of the non-CO_2 emissions in chp. 3.2.9.2.2).

The mix of fossil and biofuels was recalculated for all of non-road vehicles (INFRAS 2018). This also affects industry and construction machinery (see chp. 3.2.8.5).

Emission factors (1A2g vii)

- The CO_2 emission factors applied for the time series 1990–2016 for diesel oil, gasoline, LPG and biofuels are country-specific and are given in Table 3-12.
- The CH_4 and N_2O emission factors are country-specific and are shown in Table 3-66 to Table 3-68 for diesel oil, gasoline and LPG engines for all emission standards.
- For SO_2 the emission factors are country-specific. See also Table A – 19 in Annex 3.1.5 for diesel oil, gasoline, gas oil and LPG.
- 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 CH_4 emissions.
- The implied emission factors 2016 are shown in Table 3-69.

All emission factors (GHG, precursors, SO_2) can be downloaded by query from the public part of the non-road database INFRAS (2015a)[9]. They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels.

[9] https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html [01.02.2018]

Table 3-66 Emission factors CH_4 and N_2O for industry and construction vehicles with diesel oil engines by emission standards including the year of inforcement.

Gas	Power class	PreEU-A	PreEU-B	EU-I	EU-II	EU-IIIA	EU-IIIB	EU-IV
		<1996	1996	2002/03	2002/04	2006/08	2011/12	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_2O	0–3000	0,035	0,035	0,035	0,035	0,035	0,035	0,035

Table 3-67 Emission factors CH_4 and N_2O for industry and construction vehicles with gasoline engines by emission standards including the year of inforcement.

Gas	Power class	PreEU-A	PreEU-B	PreEU-C	EU-I	EU-II
		<1996	1996	2000	2004	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_2O	0–3000	0,03	0,03	0,03	0,03	0,03

Table 3-68 Emission factors CH_4 and N_2O for industry and construction vehicles with LPG engines (for all years).

Gas	without catalyst	with catalyst
	g/kWh	
CH_4	0,552	0,035
N_2O	0,05	0,05

Table 3-69 Implied emission factors 2016 for industry and construction vehicles.

1A2gvii Non-road vehicles and other machinery	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**NMVOC**	**SO_2**	**CO**
	t/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Gasoline	73.8	39.7	1.1	106	722	0.38	19'542
Diesel oil	73.3	0.69	3.3	339	29	0.47	145
Liquefied petroleum gas	65.5	0.67	2.4	105	8.8	0.46	24
Biodiesel	73.3	0.59	2.8	290	24	0.40	124
Bioethanol	73.8	9.4	0.78	53	266	0.24	12'083

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 2017a). Activity data are shown in Table 3-70 and in Annex A3.1.4. Detailed data can be downloaded from the online database of INFRAS (2015a).

Table 3-70 Activity data for industry and construction vehicles.

Source/Fuel	Unit	1990	1995	2000	2005
1A2gvii Non-road vehicles and other machinery	TJ	5'721	6'852	7'636	8'169
Gasoline	TJ	196	224	227	225
Diesel oil	TJ	5'359	6'380	7'106	7'626
LPG	TJ	165	248	294	290
Biodiesel	TJ	NO	NO	9	28
Bioethanol	TJ	NO	NO	NO	NO

Source/Fuel	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A2gvii Non-road vehicles and other machinery	TJ	8'413	8'535	8'657	8'779	8'811	8'843	8'875	8'906	8'938	8'944
Gasoline	TJ	223	222	221	220	213	206	198	191	184	180
Diesel oil	TJ	7'877	8'003	8'129	8'254	8'283	8'312	8'341	8'370	8'399	8'380
LPG	TJ	282	277	273	269	260	252	243	235	226	215
Biodiesel	TJ	31	33	34	36	54	73	91	110	128	166
Bioethanol	TJ	0.002	0.003	0.004	0.005	0.26	0.51	0.76	1.02	1.27	1.96

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 9. 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 3-25.

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

The general QA/QC procedures are described in chp. 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)

- Until the previous submission, the use of gaseous fuels was treated as CNG. In fact, it is LPG, which has some different emission factors. Specifically, the CO_2 emission factor of LPG is 17% higher than that of CNG (LPG: 65.5 t/TJ CO_2, CNG: 56'100 t/TJ, see Table 3-12). That leads to a 17% increase of CO_2 emissions of all vehicles with LPG engines. Time series 1990-2015 have been corrected corredspondingly.
- The lubricant blended into gasoline used in two-stroke engines of non-road transportation is now assumed to be fully oxidized. The resulting CO_2 emissions of the oxidation of the lubricants are included in source category 2D1 Lubricant use, see chp. 4.5.5.
- Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017).
- SO_2 emissions are slightly reduced due to a correction of a calculation error in the interface between the non-road model and the EMIS database.

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

Table 3-71 Key categories of 1A3 Transport. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1A3a	Civil aviation: Liquid fuels	CO2	T1
1A3b	Road transportation: Diesel	CO2	L1, T1, L2, T2
1A3b	Road transportation: Gasoline	CH4	T1
1A3b	Road transportation: Gasoline	CO2	L1, T1
1A3b	Road transportation: Gasoline	N2O	T1, T2

Table 3-72 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 800 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) and updated in 2015 (FOCA 2015a).

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 2016), 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 emission factors are adjusted to cruise conditions by using the Boeing Fuel Flow Method 2. For N_2O, the IPCC default emission factor of 2 kg/TJ is used. For the methane split of unburned hydrocarbons, the 10% methane share for the LTO, given in IPCC 2006 is used. For cruise emissions, no methane is reported. Activity data are derived from a detailed movement statistics.

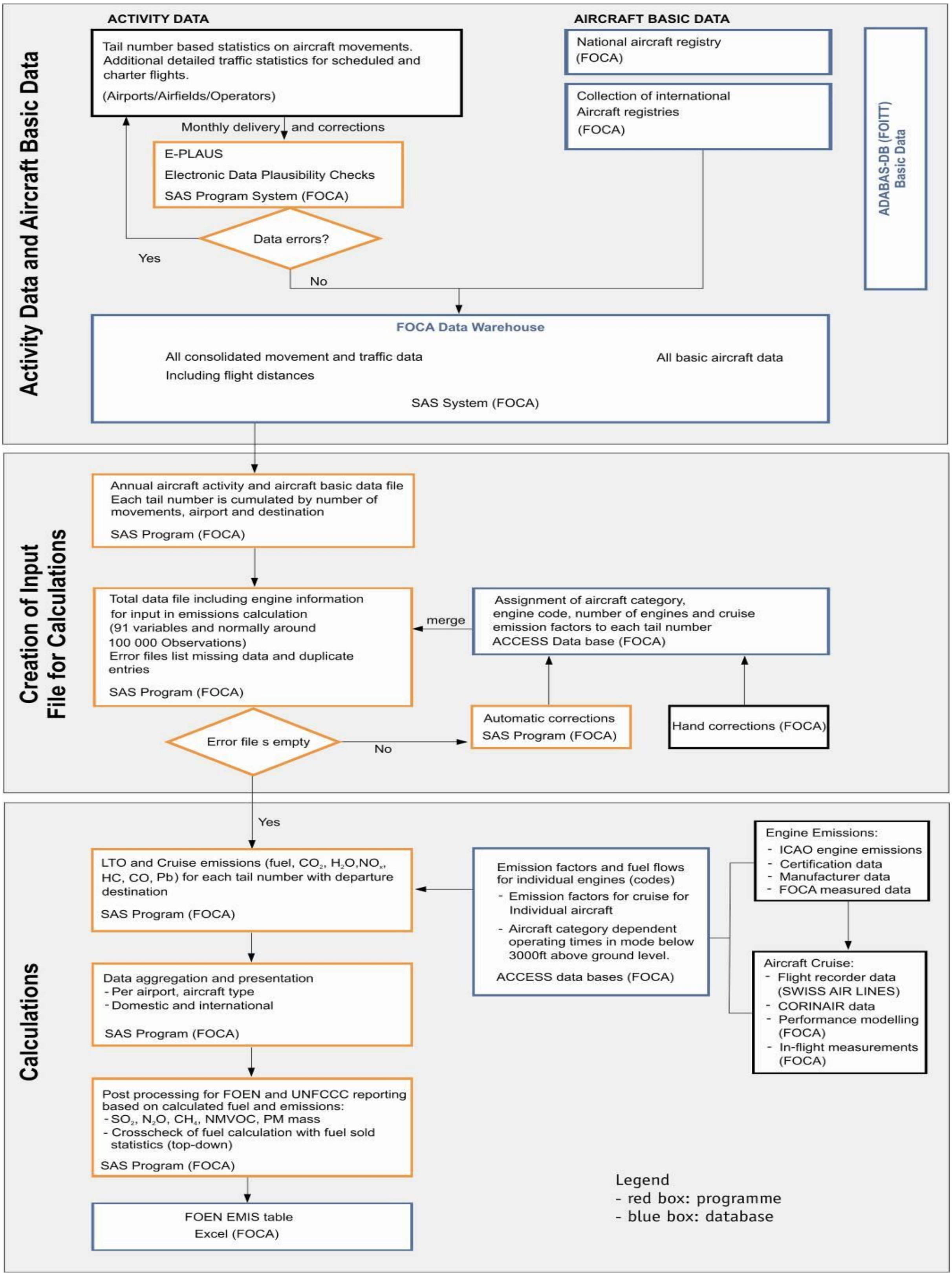

Figure 3-23 Modelling scheme (activity data, emission factors, emissions) for domestic aviation.

A complete emission modelling (LTO and cruise emissions for domestic and international flights) has been carried out by FOCA for 1990, 1995, 2000, 2002, 2004–2016. The results of the emission modelling have been transmitted from FOCA to FOEN in an aggregated form (FOCA 2006a, 2007-2017). 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 800 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 2016) 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, FOCA 2015a).

In 2015 and 2016, the FOCA Helicopter Emissions Calculation Guidance has been updated and implemented in the emissions calculation for the 2015 and 2016 emission inventory (FOCA 2015a, 2016a). FOCA now uses engine power specific emission factors for most helicopters, taking into account lower power requirement per engine, if engines are installed in a twin engine configuration. On top of the few non-public manufacturer data sources, FOCA introduced 80 individual helicopter engine models replacing most of the generic engine assignments.

Kyoto gases

- CO_2: the emission factor of 72.8 t/TJ is country-specific and is based on measurements and analyses of fuel samples (see Table 3-12 and Table 3-73)
- CH_4, NMVOC (country-specific; CORINAIR): VOC emissions (see Precursors below) are split into CH_4 and NMVOC by a constant share of 0.1 (CH_4) and 0.9 (NMVOC) for LTO. For cruise flights the VOC emissions do not consist of CH_4 emissions. The implied emission factor for CH_4 is shown in Table 3-73.
- The N_2O 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 constant over the entire time period 1990–2016 (see Table 3-73).

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 2016: 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 3-73.

Table 3-73 Implied emission factors of 1A3a in 2016. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3a Aviation	Unit	CO_2 fossil	CH_4	N_2O	NO_X	NMVOC	SO_2	CO
Kerosene, domestic, LTO	kg/TJ	72'800	10.8	2.0	247	96.9	21.1	2'371
Kerosene, domestic, CR	kg/TJ	72'800	NA	2.0	302	41.2	22.1	512
Kerosene, international, LTO	kg/TJ	72'800	3.3	2.0	300	29.9	23.2	302
Kerosene, international, CR	kg/TJ	72'800	NA	2.0	329	8.5	23.2	42

Activity data (1A3a)

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 are 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 468'226 aircraft movements in the total of scheduled and charter traffic in 2016 as provided by FOCA 2017).

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. 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). In this case, emissions are calculated based on operating hours of the helicopters, with emission factors taken from the helicopter study (see FOCA 2015a).
- Since 2007, the data of these helicopter statistics 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 helicopters a fix split of 87% for single engine helicopters and 13% for twin engine helicopters has been applied for the entire commitment period until 2014 based on investigations in 2004 (FOCA 2004). Since 2015, the statistics allowed to assign the individual helicopters to the helicopter companies. All emissions from helicopter flights without using an official airport or an official airfield are considered domestic emissions.

Fuel consumption: Table 3-74 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. In 2016, the modelled total fuel consumption in Switzerland was 4.5% 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 3-74 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, 2008–2017).

1A3a/1D1 Civil aviation	1990	1995	2000	2005
	Fuel consumption in TJ			
Kerosene, domestic, LTO	1'050	935	773	518
Kerosene, domestic, CR	2'401	2'139	1'768	1'184
Kerosene, international, LTO (not part of national total)	4'277	5'097	6'507	4'878
Kerosene, international, CR (not part of national total)	37'608	44'821	57'219	42'896
Total Civil aviation	45'334	52'993	66'267	49'477
1990 = 100%	100%	117%	146%	109%

1A3a/1D1 Civil aviation	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	Fuel consumption in TJ									
Kerosene, domestic, LTO	545	514	499	464	509	504	494	525	387	421
Kerosene, domestic, CR	1'350	1'109	1'211	1'230	1'306	1'371	1'323	1'396	1'500	1'511
Kerosene, international, LTO (not part of national total)	5'416	5'755	5'468	5'643	6'041	6'226	6'208	6'142	6'459	6'529
Kerosene, international, CR (not part of national total)	48'277	52'269	49'958	52'691	56'420	57'677	58'501	58'864	60'874	64'073
Total Civil aviation	55'588	59'646	57'136	60'028	64'277	65'778	66'526	66'927	69'220	72'534
1990 = 100%	123%	132%	126%	132%	142%	145%	147%	148%	153%	160%

3.2.9.2.2 Road transportation (1A3b)

Methodology (1A3b)

Choice of method

- The CO_2 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 CH_4 and the N_2O 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.
- CO_2 emissions from the use of lubricants as an additive in 2-stroke motorcyles are reported under 2D1 Non-energy products from fuels and solvent use / lubricant use. Non-CO_2 emissions are reported under 1A3b.

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), the general method is described in FOEN (2010i), Keller et al. (2017), Hausberger and Matzer (2017); for details see following paragraphs and Annex A3.1.3) and a model for non-road transportation (mobile sources in 1A2g vii, 1A3c, 1A3d, 1A4aii, 1A4bii, 1A4cii, 1A5b excl. military avaiation; (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 varying (due to fluctuations of fuel prices) amounts of fuels to foreign car owners. This amount of fuel is mainly consumed abroad, called **fuel tourism**, which is not captured by the territorial road model, but has to be included in the GHG inventory for the UNFCCC reporting. For modelling of fuel tourism and the results thereof see SFOE (2017e, 2017f) and Keller (2015). 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 the sum of 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 plus statistical differences[10]. 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:

- CO_2 emissions are calculated by using fuel sales and country-specific CO_2 emission factors.
- CH_4 and N_2O emissions are calculated in three steps:
  (i) From fuel used and country-specific CH_4 and N_2O emission factors, the territorial emissions are calculated. (ii) The differences between fuels sold and fuels used (territorial) are interpreted as fuel tourism plus and statistical differences. These amounts of gasoline and diesel oil are multiplied with implied CH_4 and N_2O emission factors, which are deduced from the territorial road transportation model (including weighted averages over all vehicle categories), to form the CH_4 and N_2O emissions resulting from fuel tourism plus statistical differences. (iii) CH_4 and N_2O emissions from the territorial model plus CH_4 and N_2O from fuel tourism and statistical differences are added to the total CH_4 and N_2O emissions reported to the UNFCCC.
- Precursor and SO_2 emissions are calculated in the same manner as CH_4 and N_2O using the specific emission factors.

Please note that the emissions resulting from fuel tourism are integrated in the reporting tables (CRF Table1.A(a)s3) as follows:

- Gasoline emissions are implemented in 1A3b i Cars/Gasoline,
- natural gas emissions are implemented in 1A3b i Cars/Gaseous fuels,
- diesel oil emissions are implemented in 1A3b iii Heavy duty trucks and buses.

[10] The amount of fuel tourism is regularly estimated in ex-post analysis, latest update by SFOE (2017e). The results for fuel tourism clearly show 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. Therefore, the difference between fuel sales and fuel used in the traffic model is indicated in the NIR as “fuel tourism and statistical differences”.

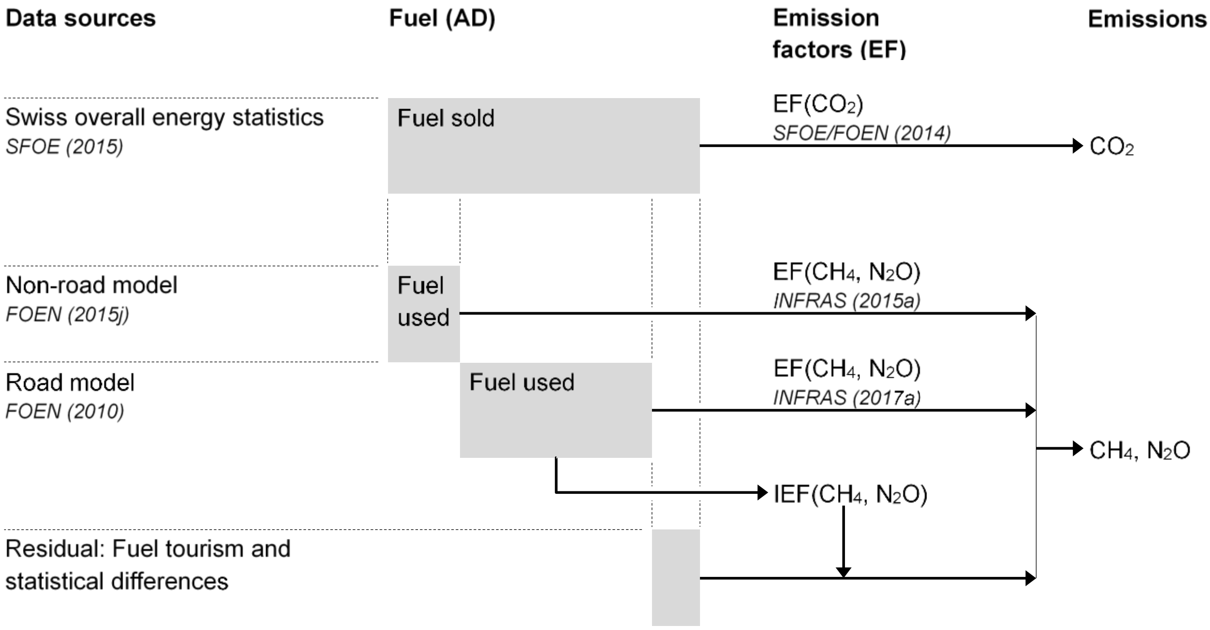

Figure 3-24 Connections between fuel sold and fuel used for road and non-road transportation. Fuel sold is provided by the Swiss overall energy statistics (minus Liechtenstein's gasoline and diesel oil consumption and bunker fuels for navigation). Fuel used results from the territorial road and non-road models. The residual fuel consists of fuel tourism and a statistical differences. 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:

- 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 from gasoline passenger cars and light duty vehicles only) 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

- $N_{evap,i}$: Number of stops (i= ”after stops”) or number of vehicles (i = ”running losses” and “diurnal losses”)
- *i* runs over three evaporiation categories: stops, running losses, diurnal losses
- Emissions factors are differentiated for all fuel types: Gasoline (4-stroke), gasoline (2-stroke), diesel oil, bioethanol, biodiesel, gas (CNG), biogas.

CO_2 emissions from lubricant use in 2-stroke engines are calculated from the gasoline consumption of 2-stroke motorcycles, assuming a lubricant content of 2% in the gasoline. Note that the road transportation model distinguishes 2-stroke (including 2% lubricant) and 4-stroke gasoline (without lubricant). It is assumed that the whole amount of lubricant is being oxidised. The resulting CO_2 emissions are included in source category 2D1 Lubricant use. CH_4 and N_2O emissions from lubricant use are included in the road transportation model, since the emission factors are deduced from measurements on motorcylces including 2-stroke engines. However, CH_4 and N_2O emissions are also calculated for the use of lubricants under source category 2D1. This might be a double-counting, which will be analysed for the next submission, see planned improvements chp. 3.2.9.6.

Note that cold start emissions for N_2O are not accounted for in the model described. During the in-country review in 2016, the ERT identified a potential underestimation. Switzerland therefore estimated N_2O cold start excess emissions for PC and LDV by means of emission factors of the Copert model, as recommended by the ERT. The corresponding emission factors per Euro class are documented in the EMEP/EEA air pollutant emission inventory guidebook - 2016 on p. 78 ff. (EMEP/EEA 2016). The procedure was repeated for the current submission by modelling the base year and the latest year (1990, 2016). For the years 1991–2015 the emissions were interpolated linearly between 1990 and 2016. The ERT confirmed that this approach complies with the 2006 IPCC Guidelines. In a forthcoming update of the road transport emission model, cold start emission factors for N_2O will be integrated.

A number of smaller modifications have been carried out for the modelling of road transportation since the last submssions (INFRAS 2018). The methodology remained unchanged, the modifications are related to the emission factors (e.g. NO_x, to account for realistic exhaust emission factors after manipulation in diesel cars became public in 2015) and activity data, see chp. 3.2.9.5).

Emission factors (1A3b)

CO_2

- The country-specific CO_2 emission factors are described in chp.3.2.4.4.2. Values are shown inTable 3-12 (gasoline, diesel oil, biofuels) and in Table 3-13 (natural gas, biogas). The values in 2014 are also shown in Table 3-75.
- The same emission factors are also applied for the calculation of the emissions resulting from fuel tourism and statistical differences.
- Emission factor for gasoline 2-stroke: For the gasoline part of the fuel, the CO_2 emission factor for gasoline according to Table 3-12 is applied. For the lubricant part of the fuel the IPCC default CO_2 emission factor for lubricants is applied, see Table 4-35 (IPCC 2006). The resulting emissions from the gasoline part are reported under 1A3b iv, the emissions

from the lubricant part, however, under source category 2D1 Lubricant use (see chp. 4.5.2.1).

CH_4

- Country-specific emission factors are applied. Details including data sources see below (“*Country-specific emission* factors*”).* Note that update emission factors are applied for the current submission.
- CH_4 emissions from fuel tourism: From the territorial model, implied emission factors for CH_4 are derived per fuel type corresponding to mean emission factors for Switzerland including all vehicle categories (see Figure 3-24). These factors are then applied to calculate the emissions resulting from fuel tourism. This approach has been verified by comparing implied emission factors with the neighbouring countries (see 3.2.9.4).
- For biofuels, no country-specific EFs for CH_4 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).

N_2O

- N_2O emissions from territorial traffic under warm operating condition: Country-specific emission factors are used, details see below (INFRAS 2017a).
- Cold start emission factors are not included in the Handbook of Emissions Factors and are therefore taken from the COPERT model for gasoline PC and for LDV for the base and the latest year 1990 and 2016 (EMEP/EEA 2016, chapter on 1A3b). Values in-between are linearly interpolated. Example 2016: 10 mg/start for PC and 18 mg/start for LDV. For the on-going update of the road transportation model, N_2O cold start emission will be implemented consistently with all other cold start emissions since it is planned to integrate N_2O cold start emission factors in the next version of the Handbook of Emission Factors (the update is on-going, the results will be available in submission 2019 or 2020, see planned improvements chp. 3.2.9.6)
- N_2O emissions from fuel tourism: The same approach as for CH_4 is applied (see paragraph above) by means of mean emission factors (country-specific).
- For biofuels no country-specific EFs for N_2O are available. Therefore, emissions have been estimated using the EFs for alternative fuel vehicles provided in table 3.2.4 on page 3.23 of Volume 2 of the 2006 IPCC Guidelines (IPCC 2006). The value of 101 mg/km from the 2006 IPCC Guidelines was used for urban buses running on CNG only. For the bi-fuel passenger cars, it is assumed that they use gasoline mainly during the start but otherwise run on CNG; therefore the respective CNG emission factor for light duty vehicles of 27 mg/km from the same source was applied.

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 a s 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, 2010 and latest in 2017. These emission factors are compiled in a “Handbook of Emission Factors for Road Transport”

(HBEFA, see INFRAS 2017a). The latest version 3.3 – which was used for an update of the emissions in the current submission resulting in a recalculation of the complete time series – is presented on the website http://www.hbefa.net/ and documented in Keller et al. (2017) and Hausberger and Matzer (2017), further descriptions can also be found in the former publication FOEN (2010i). The emission factors refer to the so-called “traffic situations”, which represents characteristic patterns of driving behaviour and further technical and topographic features. They serve as a key to the disaggregation of the activity data. The underlying database contains dynamic fleet compositions 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 SO_2

The following Table 3-75 presents mean emission factors for GHG, precursors and SO_2 in 2016. More or less pronounced decreases of the emission factors have occured 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 N_2O, leading to an emission increase until 1998. Recent converter technologies have overcome this problem resulting in a decrease of the (mean) emission factor. Note that CO_2 emission factors for gas/biogas shoud not differ by vehicle category. The difference occurs due to an unintended difference between gas and biogas. This is a consistency error, which will be corrected for the next submission (see also remark to Table 3-13).

Table 3-75 Implied emission factors in 2016 for road transportation. For more details see Annex A3.1.3.

1A3b Road Transportation Gasoline / Bioethanol	**CO_2**	**CH_4**	**N_2O**	**NO_X**	**NMVOC**	**SO_2**	**CO**
	kg/TJ						
Passenger cars	73'800	3.8	0.6	35	62	0.38	515
Light duty vehicles	73'800	8.3	2.1	124	132	0.38	1838
Heavy duty vehicles	NO	NO	NO	NO	NO	NO	NO
Motorcycles	73'800	45	1.4	147	305	0.38	4137
Fuel tourism and statistical differences	73'800	5.0	0.7	40	75	0.38	641

1A3b Road Transportation Diesel / Biodiesel	**CO_2**	**CH_4**	**N_2O**	**NO_X**	**NMVOC**	**SO_2**	**CO**
	kg/TJ						
Passenger cars	73'300	0.18	2.0	276	7.3	0.47	39
Light duty vehicles	73'300	0.16	1.9	302	6.4	0.47	41
Heavy duty vehicles	73'300	0.17	3.6	265	6.7	0.47	78
Motorcycles	NO	NO	NO	NO	NO	NO	NO
Fuel tourism and statistical differences	73'300	0.17	2.5	276	7.1	0.47	50

1A3b Road Transportation Gas / Biogas	**CO_2**	**CH_4**	**N_2O**	**NO_X**	**NMVOC**	**SO_2**	**CO**
	kg/TJ						
Passenger cars	56'516	6.5	6.7	53	0.6	NA	175
Light duty vehicles	56'400	4.53	11.9	14.1	0.39	NA	493
Heavy duty vehicles	56'534	11.9	4.8	175	1.0	NA	27
Motorcycles	NO	NO	NO	NO	NO	NO	NO
Fuel tourism and statistical differences	56'400	8.1	8.4	90	0.7	NA	142.2

Activity data (1A3b)

Energy-related activity data (basis for modelling the CO_2 emissions)

The amount of gasoline and diesel oil sold in Switzerland serves as the activity data for the calculation of the CO_2 emissions. The Swiss overall energy statistics provides the amount of liquid fuels sold in Switzerland and the Principality of Liechtenstein (SFOE 2017). From these numbers, Liechtenstein's sales, Switzerland's non-road consumption, bunker fuel emissions and fugitive emissions from transmission, storage and fuelling of gasoline (reported under 1B2av Distribution of oil products) are subtracted. The result gives the inventory-relevant consumption for estimating the CO_2 emissions. (It contains the fuel consumption 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 2017), the Swiss renewable energy statistics (SFOE 2017a) and the Federal Customs Administrations (FCA 2017). Note that the NCV of biogas used in 1A3b is kept constant for the whole period 1997-2016. The value is 45.7 GJ/t. It corresponds to the value of the years 1995, 2013, 2014, but deviates slightly (max. 3%) from the values of the other years (see NCV time series for natural gas and biogas in Table 3-10).

Table 3-76 shows the split of fuel sales into territorial road transportation model, the territorial non-road transportation model and fuel tourism including 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: CNG/passenger cars and urban buses running purely on CNG. Data source is FCA (2017).
- Consumption of biofuels for road transportation (biodiesel, bioethanol and biogas) starts in Switzerland in 1997.

Table 3-76 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	Source category	1990	1995	2000	2005
on-road and non-road categories		PJ			
Gasoline					
on-road consumption (model)	1A3b	144.2	141.1	148.4	134.8
fuel tourism and statistical differences	1A3b	9.2	7.8	17.5	15.2
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	2.4	2.4	2.3	2.1
Gasoline sold in Switzerland		155.8	151.3	168.2	152.1
Diesel oil					
on-road consumption (model)	1A3b	38.3	41.3	46.0	60.2
fuel tourism and statistical differences	1A3b	-2.5	-5.8	-4.4	-1.6
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	11.0	12.4	13.5	13.9
Diesel oil sold in Switzerland		46.7	47.8	55.2	72.6
Natural gas					
on-road consumption (model)	1A3b	NO	NO	NO	0.1
fuel tourism and statistical differences	1A3b	NO	NO	NO	0.1
non-road consumption (models)		NO	NO	NO	NO
Natural gas sold in on- and non-road categories in Switzerland		NO	NO	NO	0.2
Liquified petroleum gas					
on-road consumption (model)	1A3b	NO	NO	NO	NO
non-road consumption (models)	1A2gvii	0.2	0.2	0.3	0.3
LPG sold in on- and non-road categories in Switzerland		0.2	0.2	0.3	0.3
Biodiesel					
on-road consumption (model)	1A3b	NO	NO	0.1	0.4
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	NO	NO	0.02	0.05
Biodiesel sold in Switzerland		NO	NO	0.1	0.5
Bioethanol					
on-road consumption (model)	1A3b	NO	NO	NO	0.02
non-road consumption (models)	1A2gvii; 1A3dii; 1A4bii; cii; 1A5b	NO	NO	NO	NO
Bioethanol sold in Switzerland		NO	NO	NO	0.02
Biogas					
on-road consumption (model)	1A3b	NO	NO	NO	0.0
non-road consumption (models)		NO	NO	NO	NO
Biogas sold in Switzerland		NO	NO	NO	NO

Activity data for	Source category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
on-road and non-road categories		PJ									
Gasoline											
on-road consumption (model)	1A3b	125.7	122.3	118.9	115.3	111.6	107.8	104.0	100.7	97.1	93.9
fuel tourism and statistical differences	1A3b	18.3	18.6	18.1	16.8	15.4	14.7	12.9	11.4	6.8	6.7
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.7
Gasoline sold in Switzerland		146.0	142.8	139.0	134.0	128.9	124.3	118.6	113.9	105.6	102.3
Diesel oil											
on-road consumption (model)	1A3b	68.5	72.0	75.8	80.2	84.8	89.5	94.7	98.7	102.0	104.9
fuel tourism and statistical differences	1A3b	1.6	6.2	3.8	2.8	0.9	2.4	2.0	0.9	-4.0	-5.6
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	14.3	14.4	14.6	14.8	14.8	14.8	14.8	14.8	14.8	14.7
Diesel oil sold in Switzerland		84.4	92.7	94.1	97.8	100.5	106.6	111.5	114.4	112.8	114.1
Natural gas											
on-road consumption (model)	1A3b	0.31	0.47	0.60	0.71	0.70	0.68	0.70	0.67	0.63	0.60
fuel tourism and statistical differences	1A3b	0.16	0.25	0.21	0.27	0.35	0.32	0.33	0.34	0.28	0.27
non-road consumption (models)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas sold in on- and non-road categories in Switzerland		0.47	0.72	0.81	0.98	1.05	1.00	1.03	1.01	0.91	0.87
Liquified petroleum gas											
on-road consumption (model)	1A3b	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
non-road consumption (models)	1A2gvii	0.28	0.28	0.27	0.27	0.26	0.25	0.24	0.23	0.23	0.21
LPG sold in on- and non-road categories in Switzerland		0.28	0.28	0.27	0.27	0.26	0.25	0.24	0.23	0.23	0.21
Biodiesel											
on-road consumption (model)	1A3b	0.33	0.37	0.26	0.30	0.27	0.29	0.23	0.50	1.25	2.08
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	0.06	0.06	0.06	0.06	0.10	0.13	0.16	0.19	0.23	0.29
Biodiesel sold in Switzerland		0.39	0.42	0.32	0.37	0.37	0.42	0.39	0.70	1.47	2.37
Bioethanol											
on-road consumption (model)	1A3b	0.07	0.07	0.03	0.05	0.08	0.09	0.08	0.16	0.58	0.79
non-road consumption (models)	1A2gvii; 1A3dii; 1A4bii; cii; 1A5b	0.0000	0.0000	0.0000	0.0000	0.0022	0.0043	0.0065	0.0086	0.011	0.017
Bioethanol sold in Switzerland		0.07	0.07	0.03	0.05	0.09	0.10	0.08	0.17	0.59	0.80
Biogas											
on-road consumption (model)	1A3b	0.04	0.06	0.09	0.11	0.09	0.09	0.11	0.09	0.11	0.11
non-road consumption (models)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas sold in Switzerland		0.04	0.06	0.09	0.11	0.09	0.09	0.11	0.09	0.11	0.11

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

The activity data are 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 are not public, but the ordinary vehicle stock numbers are published by the Swiss Federal Statistical Office (SFSO 2017b). 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"]).
- The transport performance, i.e. the mileage per vehicle category is an input from Swiss Federal Statistical Office (SFSO 2017c, 2017d). It is based on periodical surveys/Mikrozensus (ARE 2002, ARE/SFSO 2005, ARE/SFSO 2012). By means of the vehicle stock data (see paragraph above), the specific mileage per vehicle category can be derived. Note that the mileage was updated for the current submission leading to modifications, e.g. in the share of gasoline and diesel oil vehicle kilometres (INFRAS 2017). Also, in the last submissions projected data for the years 2011-2015 were used, which have now been replaced by statistical data 2011-2015 and 2016.
- Numbers of starts/stops: Derived from vehicles stock, with data on trip length distributions and parking time distributions (ARE/SFSO 2005, ARE/SKSO 2012).

The transport performance is attributed to "traffic situations" (characteristic patterns of driving behaviour) which serve as a key to select the appropriate emission factor and 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, and top-down by the total of the mileage per vehicle category. The assignment of traffic situations to the modelled mileage is described in INFRAS (2017). 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 3-77 shows the time series of the mileage per vehicle category. The total mileage has constantly been growing by about 1.0 per cent per year. The major part of vehicle kilometres was driven by passenger cars over the whole period. In the same period, on-ro ad fuel consumption increased less strongly indicating improved fuel efficiency. This effect is also reflected in Table 3-78 that shows the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990–2016.

Table 3-77 Mileages in millions of vehicle kilometres. PC: passenger cars, LDV: light duty vehicles, HDV: heavy duty vehicles).

Veh. category	1990	1995	2000	2005
	million vehicle-km			
PC	42'649	41'324	45'613	48'040
LDV	2'600	2'746	2'957	3'228
HDV	1'992	2'107	2'273	2'120
Coaches	108	110	99	106
Urban Bus	174	192	200	229
2-Wheelers	2'025	1'563	1'700	1'785
Sum	49'548	48'042	52'841	55'507
(1990=100%)	100%	97%	107%	112%

Veh. category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	million vehicle-km									
PC	48'728	49'467	50'373	50'949	51'575	52'582	53'493	54'313	55'114	55'473
LDV	3'373	3'415	3'432	3'502	3'635	3'776	3'874	3'998	4'129	4'175
HDV	2'194	2'218	2'164	2'226	2'258	2'229	2'243	2'236	2'235	2'259
Coaches	120	114	116	118	122	124	125	128	131	132
Urban Bus	230	228	238	244	250	254	262	267	272	279
2-Wheelers	1'821	1'850	1'847	1'852	1'894	1'934	1'957	1'992	2'027	2'040
Sum	56'466	57'292	58'171	58'891	59'734	60'899	61'953	62'933	63'908	64'358
(1990=100%)	114%	116%	117%	119%	121%	123%	125%	127%	129%	130%

Table 3-78 Specific fuel consumption of road transport, not including fuel tourism and statistical differences. They include additional fuel consumption by cold starts.

Veh. cat.	Fuel	1990	1995	2000	2005
		MJ/veh-km			
PC	Gasoline	3.37	3.44	3.35	3.23
	Diesel	3.60	3.61	3.50	3.03
	CNG	---	---	---	---
LDV	Gasoline	3.32	3.30	3.29	3.31
	Diesel	3.93	3.92	3.81	3.54
HDV	Diesel	11.3	11.2	10.7	11.1
Coach	Diesel	12.4	12.2	11.8	11.7
Urban Bus	Diesel	15.8	15.9	15.5	15.1
	CNG	---	---	---	---
2-Wheeler	Gasoline	1.24	1.33	1.25	1.33
Average		**3.68**	**3.80**	**3.68**	**3.52**
		100%	**103%**	**100%**	**95%**

Veh. cat.	Fuel	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		MJ/veh-km									
PC	Gasoline	3.16	3.12	3.09	3.05	3.02	2.98	2.93	2.90	2.86	2.84
	Diesel	2.97	2.95	2.90	2.88	2.86	2.84	2.82	2.81	2.80	2.78
	CNG	---	2.67	2.65	2.64	2.62	2.61	2.59	2.58	2.58	2.57
LDV	Gasoline	3.33	3.33	3.33	3.32	3.30	3.29	3.26	3.22	3.18	3.13
	Diesel	3.49	3.47	3.45	3.45	3.46	3.44	3.41	3.38	3.35	3.30
HDV	Diesel	11.0	11.0	10.9	10.9	11.0	11.0	10.9	10.9	10.9	10.8
Coach	Diesel	11.7	11.7	11.7	11.6	11.6	11.8	10.9	10.9	10.9	10.8
Urban Bus	Diesel	15.0	15.0	14.8	14.7	14.5	14.4	14.4	14.4	14.4	14.3
	CNG	---	19.4	19.3	19.3	19.4	19.3	19.2	19.1	18.8	18.8
2-Wheeler	Gasoline	1.32	1.32	1.32	1.32	1.32	1.34	1.35	1.33	1.36	1.39
Average		**3.47**	**3.45**	**3.40**	**3.36**	**3.34**	**3.31**	**3.26**	**3.23**	**3.19**	**3.16**
		94%	**94%**	**92%**	**91%**	**91%**	**90%**	**89%**	**88%**	**87%**	**86%**

For modelling of evaporative emissions, the stock, the mileage and the number of stops of gasoline passenger cars and light duty vehicles are used. For modelling of cold start emissions, also start numbers of passenger cars and light duty vehicles are used for activity data. The corresponding numbers are summarised in Table 3-79. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific surveys (ARE/SFSO 2005, 2012).

Table 3-79 Vehicle stock numbers (gasoline vehicles only – relevant for diurnal evaporation) and average number of starts per vehicle per day (gasoline, diesel oil, and CNG vehicles).

Veh. Category	1990	1995	2000	2005
	stock in 1000 veh. (gasoline/bioeth.)			
PC	2'831	3'041	3'296	3'224
LDV	167	164	148	114
2-Wheelers	764	688	710	734
	starts per veh. per day			
PC	2.61	2.53	2.46	2.40
LDV	1.97	1.97	1.96	1.96

Veh. Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	stock in 1000 veh. (gasoline/bioeth.)									
PC	3'111	3'044	2'959	2'922	2'892	2'846	2'795	2'747	2'699	2'653
LDV	99	92	85	81	77	73	68	65	62	60
2-Wheelers	736	744	740	742	750	758	759	776	779	785
	starts per veh. per day									
PC	2.38	2.37	2.35	2.34	2.34	2.33	2.33	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

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 CO_2 (based on decision tree Fig. 3.4.1 in IPCC 2006)
- Tier 3 for CH_4, N_2O and precursors/SO_2 (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 2020 based on fuel used. For the years in-between, the emissions are interpolated linearly.

The mix of fossil and biofuels was recalculated for all of non-road vehicles (INFRAS 2018). This also affects railways (see chp. 3.2.9.5).

Emission factors (1A3c)

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

- The CO_2 emission factor applied for the time series 1990–2016 for diesel oil is country-specific and is given in Table 3-12.
- The CH_4 and N_2O emission factors of diesel locomotives are shown in Table 3-80.
- For SO_2 the emission factors are country-specific. See also Table A – 19 (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 CH_4 emissions.
- Implied emission factors 2016 are shown in Table 3-81.

All emission factors (GHG, precursos, SO_2) 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 9).

Table 3-80 CH_4 and N_2O 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_2O	all	0.035	0.035	0.035	0.035	0.035

Table 3-81 Implied emission factors 2016 for rail vehicles. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3c Railways	Unit	CO_2 fossil	CO_2 biogen	CH_4	N_2O	NO_X	NMVOC	SO_2	CO
Diesel oil	kg/TJ	73'300	NA	1.3	3.6	1'002	116	0.47	532
Biodiesel	kg/TJ	NA	73'300	1.1	3.0	856	99	0.40	454

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 2017a). Activity data are shown in Table 3-82 and in Annex A3.1.4.

Table 3-82 Activity data (diesel oil consumption) for railways.

1A3c Railways	Unit	1990	1995	2000	2005
Diesel oil	TJ	390	441	455	472
Biodiesel	TJ	NO	NO	0.6	1.7
Total Railways	TJ	390	441	456	474
1990 = 100%		100%	113%	117%	121%

1A3c Railways	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Diesel oil	TJ	480	484	488	492	471	451	431	410	390	388
Biodiesel	TJ	1.9	2.0	2.0	2.1	2.9	3.7	4.4	5.2	5.9	7.7
Total Railways	TJ	482	486	490	494	474	455	435	416	396	396
1990 = 100%		124%	125%	126%	127%	122%	117%	112%	107%	102%	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 9).

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 2020 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, chp. 3.2.2.)

The mix of fossil and biofuels was recalculated for all of mobile (road and non-road) sources (INFRAS 2017, 2018).

CO_2 emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO_2 emission factor for lubricants, 73.3 t/TJ (IPCC 2006). However, these emissions are reported under source category 2D1 Lubricant use (see chp. 4.5.2.1 and see also remark on a potential double-counting of the non-CO_2 emissions in chp. 3.2.9.2.2).

The mix of fossil and biofuels was recalculated for all of non-road vehicles (INFRAS 2018). This also affects navigation (see chp. 3.2.9.5).

Emission factors (1A3d)

- The CO_2 emission factor applied for the time series 1990–2016 for diesel oil, gasoline and gas oil are country-specific and are given in Table 3-12.

- The CH_4 and N_2O emission factors are country-specific and are shown below in the Table 3-83 to Table 3-85 for all fuel types and emission standards.
- For SO_2 the emission factors are country-specific. See also Table A – 19 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 CH_4 emissions.
- The implied emission factors 2016 are shown in Table 3-86.

All emission factors (GHG, precursos, SO_2) 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 9).

Table 3-83 CH_4 and N_2O emission factors for ships with diesel engines.

Gas	Power class	Ships with diesel oil engines				
		PreSAV	SAV	EU-I	EU-II	EU-IIIA
		(<1995)	1995	2003	2008	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_2O	all	0.035	0.035	0.035	0.035	0.035

Table 3-84 CH_4 and N_2O 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	SAV	SAV/EU	PreSAV	SAV	EU
		<1995	1995	2007	<1995	1995	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_2O	0–300	0.01	0.01	0.01	0.03	0.03	0.03

Table 3-85 CH_4 and N_2O 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_2O	0.035	0.035	0.035

Table 3-86 Implied emission factors 2016 for navigation. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3d Navigation	Unit	CO_2 fossil	CO_2 biog.	CH_4	N_2O	NO_X	NMVOC	SO_2	CO
Gasoline	kg/TJ	73'800	NA	20.4	1.9	540	375	0.38	7'688
Diesel oil	kg/TJ	73'300	NA	1.7	3.4	906	280	0.47	527
Gas oil	kg/TJ	73'700	NA	0.23	0.73	26	1.6	11	6.9
Biodiesel	kg/TJ	NA	73'300	1.5	2.9	774	239	0.40	451
Bioethanol	kg/TJ	NA	73'800	12.1	1.3	348	230	0.24	4'844

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 2017a). Activity data are shown in Table 3-87 and in Annex A3.1.4.

Table 3-87 Fuel consumption of (domestic) navigation.

1A3d Navigation	Unit	1990	1995	2000	2005
Gasoline	TJ	701	654	616	565
Diesel oil	TJ	738	724	792	800
Gas oil	TJ	110	139	147	150
Biodiesel	TJ	NO	NO	1.0	2.9
Bioethanol	TJ	NO	NO	NO	NO
Total Navigation	TJ	1'550	1'517	1'556	1'518
1990 = 100%		100%	98%	100%	98%

1A3d Navigation	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Gasoline	TJ	827	841	854	868	870	872	874	876	878	873
Diesel oil	TJ	553	547	541	535	530	526	522	518	514	512
Gas oil	TJ	154	155	157	159	157	156	154	153	151	150
Biodiesel	TJ	3.2	3.4	3.6	3.8	5.7	7.6	9.5	11.5	13.4	17.3
Bioethanol	TJ	0.005	0.008	0.010	0.013	0.79	1.6	2.3	3.1	3.9	6.3
Total Navigation	TJ	1'537	1'546	1'556	1'565	1'564	1'563	1'562	1'561	1'560	1'559
1990 = 100%		99%	100%	100%	101%	101%	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 9).

3.2.9.2.5 Other transportation (1A3e)

Methodology (1A3e)

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 CO_2, CH_4, N_2O, NO_x, CO, NMVOC and SO_2 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 CO_2 emission factor applied for the time series 1990–2016 for natural gas is country-specific and is given in Table 3-12.
- The CH_4 emission factor corresponds to the one used for gas turbines in Switzerland (SAEFL 2000) as suggested by expert judgement. The CH_4 EF is assumed to be 5 g/GJ up to 1995 and 2 g/GJ from 2000 onwards, with linear interpolation in between. This corresponds with the fact that a catalyst was fitted to the system, which reduced the CH_4 emissions of the gas turbine. For the value 2016 see Table 3-88.
- For N_2O emission factors the IPCC 2006 default value (Table 3-16) is used as displayed in Table 3-88.
- For SO_2 the emission factors are country-specific. The emission factor 2016 is shown in Table 3-88. See also See also Table A – 19 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 2018/1A3e “Gasturbinen; Erdgas”.

Table 3-88 Emission factors of 1A3e i Pipeline transportation / compressor station located in Ruswil in 2016. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3e Other transportation	Unit	CO_2 fossil	CH_4	N_2O	NO_X	NMVOC	SO_2	CO
Gas	kg/TJ	56'400	2.00	0.10	60	0.10	0.50	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 2017; Table 17).

Table 3-89 Activity data of 1A3e.

1A3ei Pipeline transport	Unit	1990	1995	2000	2005
Natural gas	TJ	560	310	340	1'070
1990=100%		100%	55%	61%	191%

1A3ei Pipeline transport	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Natural gas	TJ	1'430	1'460	950	830	840	810	410	830	760	340
1990=100%		255%	261%	170%	148%	150%	145%	73%	148%	136%	61%

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 3-25) 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 chp. 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 2016 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 aircraft of four Swiss airlines. The difference between the two methods was smaller than 1%.

Specific: Road transportation (1A3b)

Comparison between the 2006 IPCC Guideline's default and Switzerland's emission factors

- CO_2 (see also Table 3-26): IPCC default value for gasoline is 69.3 t/TJ and for diesel oil 74.1 t/TJ (IPCC 2006, Table 3.2.1). Switzerland's emission factors vary between 73.8 and 73.9 t/TJ for gasoline – 6% higher than IPCC – and between 73.3 and 73.6 t/TJ for diesel oil – about 1% below IPCC default value.
- CH_4: The IPCC default emission factor for gasoline motors with oxidation catalysts is 25 kg/TJ with an uncertainty range from 7.5 to 86 kg/TJ (IPCC 2006, Table 3.2.2). Switzerland's emission factor for gasoline passenger cars dropped from 26.6 kg/TJ (1990) to 3.8 kg/TJ (2016) 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 0.16-1.7 kg/TJ.
- N_2O: The IPCC default emission factor for gasoline motors with oxidation catalysts lies in the uncertainty range 2.6-24 kg/TJ (IPCC 2006, Table 3.2.2). Switzerland's emission factor for gasoline passenger cars dropped from 4.2 kg/TJ (1997) to 0.4 kg/TJ (2016) 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 between 0.5 kg/TJ (1990) and 2.3 kg/TJ (2016).

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 2015 and 2017, 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 CH_4 and N_2O used for the modelling of 1A3b Road Transportation are taken from the handbook of emission factors (INFRAS 2017b), which is also applied in Germany, Austria, Netherlands, and Sweden. The Swiss emission factors for CH_4 and N_2O used in 1A3b were additionally compared with those shown in the CRF from Germany and a good match was found. Possible small differences might result from a varying fleet composition.

Use of implied emission factors from territorial model to calculate emissions for fuel tourism: This approach has been verified by comparing implied emission factors with the neighbouring countries. The differences turned out to be small between Switzerland, Austria, and Germany because all three countries used the same emission factors (INFRAS 2010), whereas there were some differences when comparing with France and Italy that use other emission factors (COPERT[11])). Nevertheless, the use of the implied Swiss emission factors

[11] see Euopean Environment Agency http://www.eea.europa.eu/publications/TEC05 [25.01.2018]

seemed to be the consistent approach. It must be noted, that this comparison was carried out with version 3.1 of the “Handbook of Emission Factors for Road Transport”, whereas the current emissions are based on version 3.3. A similar verification with the updated emission factors of version 3.3 of the Handbook (INFRAS 2017a) is not yet possible since the modelling results for implied emission factors of the neighbouring countries are not yet available.

For gasoline, the activity data is easily verified due to the fact, that 98.3% of the gasoline sold 2016 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

- 1A3a: Recalculation of the total use of kerosene in the aviation model due to changed calorfic value of kerosene since submission 2015. This changed calorific value of kerosene has not been considered in the aviation model for the years 1999-2012 yet. This recalculation results in 0.8 TJ more kerosen in the year 1999 and 8.1 TJ more in 2012. This results in more emissions in 2012 of: 0.59 kt CO_2.
- 1A3b: The road transportation model has been revised (INFRAS 2017, 2017a, 2018, Keller et al. 2017, Hausberger and Matzer 2017); note that the corresponding recalculations dominate the behaviour of the time series shown in Figure 10-2 and Figure 10-3:
  - Update of share between gasoline and diesel oil PC. The increasing share of diesel oil is one of the main explanations in the reductions in the CH_4 emissions of 1A3 in Figure 10-2) in the period 2010-2015.
  - Update of the mileages per vehicle category. The modifications differ by vehicle category. The effects differ from year to year and are more pronounced for CH_4 in former years 1990-2000 (Figure 10-2). For N_2O emissions a substantial reduction of the diesel oil consumption of HDV (with simultaneous increase for diesel oil PC) between 2010-2015 is responsible for the reductions in those years (Figure 10-3). This effect also influences CH_4 realculations 2010-2014. The fluctuations of N_2O emissions between 1990 and 2009 can be explained by the update of the mileages because it affects the age-distribibution of the fleet and N_2O emission factors depend strongly on the age of the emission control system of the motors.

  The following recalculations have lower influence on the emissions:
  - Update of energy consumption by integrating time-dependent NCV (Table 3-9)
  - Update of consumption by adopting specific NCV vor bioethanol and biodiesel
  - Update of emission factors of N_2O, CH_4 and most pollutants (precursors) according to the latest version 3.3 of the Handbook of Emissions Factors of Road Transport
  - extended differentiation of the AD in the modelling tool.
- 1A3b The activity data for losses of gasoline in petrol stations and fuel depots were based on gasoline sold before subtraction of gasoline sold in Lichtenstein. This has been adjusted for the whole time series 1990-2015 such that the activity data bases on gasoline sold in Switzerland only. This leads to smaller sum of gasoline fuel tourism and statistical differences.
- 1A3b: Calculation of gasoline losses in fuel handling stations base on fugitive emissions in 1B2a. Change of units in calculation leads to small rounding differences in total gasoline losses and therefore to changes in total used gasoline in 1A3b. For 2015 1 TJ

less gasoline is used / more gasoline is lost in fugitive emissions. This results in very small changes in emissions for 1A3b fuel tourism of gasoline.

- 1A3b and 1A3d: The lubricant blended into gasoline used in two-stroke engines of road and non-road transportation is now assumed to be fully oxidized. Resulting CO_2 emissions of the oxidation of the lubricants are included in source category 2D1 Lubricant use, see chp. 4.5.2.1 and 4.5.5.
- 1A3c: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). 89 GJ more fuel use in 2015.
- 1A3d: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). 152 GJ more fuel use in 2015.

3.2.9.6 Category-specific planned improvements for 1A3

- 1A3b: A further update of the emission model is on-going. Details of modifications and extensions of the model are documented in Keller et al. (2016).The results will be presented in future submissions (2018 or 2019).
- 1A3b: The CO_2 emission factor of biogas for passenger cars and heavy duty vehicles will be corrected for 2001-2016.
- 1A3a, 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)

Key categories 1A4

See key categories mentioned in chp. 3.2.7.1, which are vastly dominated by the emissions of the stationary sources except CO_2 from the combustion of Liquid Fuels in 1A4c Agriculture/Forestry/Fishing (level approach 1).

Table 3-90 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	Emisions 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.

CO_2 emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO_2 emission factor for lubricants, 73.3 t/TJ (IPCC 2006). However, these emissions are reported under source category 2D1 Lubricant use (see chp. 4.5.2.1 and see also remark on a potential double-counting of the non-CO_2 emissions in chp. 3.2.9.2.2).

The mix of fossil and biofuels was recalculated for all of non-road vehicles (INFRAS 2018). This also affects gardening, forestry and agrultural machinery (see chp. 3.2.10.5).

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 (more than 80%, see Table 3-92) and only a small amount of gasoline e.g. chainsaws (less than 20%).

- The CO_2 emission factors applied for the time series 1990–2016 are country-specific and are given in Table 3-12.
- The CH_4 and N_2O emission factors are country-specific and are shown in Table 3-66 and Table 3-67 for diesel oil and gasoline engines for all emission standards.
- For SO_2 the emission factors are country-specific. See also Table A – 19 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 CH_4 emissions.
- Implied emission factors 2016 are shown in Table 3-91.

All emission factors (GHG, precursors, SO_2) 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 9).

Table 3-91 Implied emission factors 2016 for 1A4 Other sectors (1A4a ii – 1A4c ii mobile). Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A4 Non-road machinery	Unit	CO_2 fossil	CH_4	N_2O	NO_X	NMVOC	SO_2	CO
1A4a ii Gardening professional, gasoline	kg/TJ	73'800	89	1.1	184	1'436	0.38	26'421
1A4b ii Gardening, gasoline	kg/TJ	73'800	48	1.4	158	992	0.38	25'018
1A4c ii Forestry and agriculture, gasoline	kg/TJ	73'800	86	1.1	174	1'507	0.38	23'935
1A4c ii Forestry and agriculture, diesel oil	kg/TJ	73'300	1.5	3.0	490	57	0.47	288

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 3-92 and in Annex A3.1.4.

Table 3-92 Activity data for non-road vehicles and machinery in 1A4 Other sectors (mobile).

1A4 Non-road machinery	Unit	1990	1995	2000	2005
1A4a ii Gardening professional, gasoline	TJ	191	245	295	295
1A4b ii Gardening, gasoline	TJ	142	155	165	166
1A4c ii Forestry and agriculture, gasoline	TJ	1'160	1'070	963	824
1A4c ii Forestry and agriculture, diesel oil	TJ	4'269	4'604	4'920	4'802
Total 1A4 non-road machinery	TJ	5'761	6'073	6'343	6'086
1990=100%		100%	105%	110%	106%

1A4 Non-road machinery	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A4a ii Gardening professional, gasoline	TJ	292	290	289	287	280	273	266	260	253	251
1A4b ii Gardening, gasoline	TJ	164	164	163	163	162	160	159	158	156	155
1A4c ii Forestry and agriculture, gasoline	TJ	770	743	716	689	665	641	616	592	568	551
1A4c ii Forestry and agriculture, diesel oil	TJ	4'834	4'850	4'866	4'882	4'876	4'870	4'864	4'859	4'853	4'835
Total 1A4 non-road machinery	TJ	6'060	6'047	6'034	6'021	5'982	5'944	5'906	5'868	5'830	5'793
1990=100%		105%	105%	105%	104%	104%	103%	103%	102%	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 9).

3.2.10.3 Uncertainties and time-series consistency for 1A4 Other sectors, mobile

Uncertainties by fuel type are given in Table 3-25.

3.2.10.4 Category-specific QA/QC and verification for 1A4 Other sectors, mobile

The general QA/QC procedures are described in chp. 1.2.3. Furthermore QA/QC procedures conducted for all 1A source categories are listed in chp. 3.2.4.8.

3.2.10.5 Category-specific recalculations for 1A4 Other sectors, mobile

- The lubricant amount of gasoline used in two-stroke engines of non-road transportation is now reported as fully oxidized in source category 2D1 Lubricant use, see chp. 4.5.5.
- 1A4a ii: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). -20 GJ less fuel use in 2015.
- 1A4b ii: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). -19 GJ less fuel use in 2015.
- SO_2 emissions are slightly reduced due to a correction of a calculation error in the export utility that produces the reporting output format.

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)

Source category 1A5b – Other (mobile) is not a key category.

All of the Swiss source categories of 1A5 refer to mobile sources of military activities (1A5b). Stationary activities are not occurring.

Table 3-93 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 CO_2, CH_4, N_2O, NMVOC and SO_2 is also accomplished by FOEN.

- The CO_2 emission factor applied for the time series 1990–2016 for kerosene is country-specific and is given in Table 3-12.
- CH_4: The division of VOC into CH_4 and NMVOC is carried out as described for civil aviation (see chp. 3.2.9.2.1).
- N_2O: The emission factor is set equal to the emission factor of 1A3a Civil aviation (FOCA 2017), where the IPCC default value is used (IPCC 2006).
- 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 2001–2016, the values 2000 are used.

- SO_2: The emission factor is taken from the EMEP/EEA Guidebook (EMEP/EEA 2016, Table 3.11, row "Switzerland/CCD"[12]) and is assumed to be constant over the period 1990–2016.

Table 3-94 Implied emission factors 1A5b i military aviation in 2016. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A5bi Military aviation	Unit	CO_2 fossil	CH_4	N_2O	NO_X	NMVOC	SO_2	CO
Jet kerosene	kg/TJ	72'800	3.6	2.0	133	32	23	672

Activity data (1A5b i Other, military aviation)

The fuel consumption 1990–2016 is known on an annual basis (DDPS 2017). 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 3-95 Activity data (fuel consumption) for military aviation.

1A5 Other Military aviation	1990	1995	2000	2005
	fuel consumption in TJ			
Jet kerosene	2'733	1'955	1'794	1'624

1A5 Other Military aviation	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	fuel consumption in TJ									
Jet kerosene	1'577	1'505	1'529	1'592	1'420	1'527	1'542	1'615	1'567	1'627

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).

CO_2 emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO_2 emission factor for lubricants, 73.3 t/TJ (IPCC 2006). However, these emissions are reported under source category 2D1 Lubricant use (see chp. 4.5.2.1 and see also remark on a potential double-counting of the non-CO_2 emissions in chp. 3.2.9.2.2).

The mix of fossil and biofuels was recalculated for all of non-road vehicles (INFRAS 2018). This also affects military non-road vehicles (see chp. 3.2.11.5).

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[12] CCD: climb/cruise/descent

Emission factors (1A5b ii Other, military machinery)

- The CO_2 emission factors applied for the time series 1990–2016 for diesel oil, gasoline and biofuels are country-specific as shown in Table 3-12.
- The CH_4 and N_2O emission factors are country-specific and are shown in Table 3-66 to Table 3-68 for diesel oil and gasoline engines for all emission standards.
- For SO_2 the emission factors are country-specific. See also Table A – 19 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 CH_4 emissions.
- Implied emission factors are shown in Table 3-96.

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 9).

Table 3-96 Implied emission factors 1A5b ii military non-road vehicles 2016. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A5bii Military non-road	Unit	CO_2 fossil	CO_2 biog.	CH_4	N_2O	NO_X	NMVOC	SO_2	CO
Gasoline	kg/TJ	73'800	NA	43.2	1.5	133	793	0.38	24088
Diesel	kg/TJ	73'300	NA	0.86	3.0	434	35	0.47	183
Biodiesel	kg/TJ	NA	73'300	0.74	2.6	371	30	0.40	157
Bioethanol	kg/TJ	NA	73'800	11.0	1.0	73	305	0.24	15309

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 2017a). Activity data are shown in Table 3-97 and in Annex A3.1.4.

Table 3-97 Activity data (fuel consumption) for military non-road vehicles.

1A5bii Military non-road	1990	1995	2000	2005
	fuel consumption in TJ			
Military non-road	239	248	252	257
Gasoline	19	19	19	19
Diesel	220	228	233	238
Biodiesel	NO	NO	0.30	0.86
Bioethanol	NO	NO	NO	NO

1A5bii Military non-road	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	fuel consumption in TJ									
Military non-road	265	268	272	275	275	275	275	275	275	274
Gasoline	19	18	18	18	18	18	17	17	17	17
Diesel	245	249	252	256	256	255	255	254	254	252
Biodiesel	1.0	1.0	1.1	1.1	1.7	2.2	2.8	3.3	3.9	5.0
Bioethanol	0.000	0.000	0.000	0.000	0.023	0.046	0.069	0.092	0.11	0.18

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 9).

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 3-25) 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 chp. 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).

3.2.11.5 Category-specific recalculations for 1A5b Other (mobile)

- The lubricant amount of gasoline used in two-stroke engines of non-road transportation is now reported as fully oxidized in source category 2D1 Lubricant use, see chp. 4.5.5.
- Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). 62 GJ more fuel use in 2015.
- SO_2 emissions are slightly reduced due to a correction of a calculation error in the interface between the non-road model and the EMIS database.

3.2.11.6 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

Table 3-98 Key categories (KCA incl. LULUCF) of 1B Fugitive emissions from fuels.

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1B2	Oil and natural gas energy production	CH4	L1, T1

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 3-99 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 1 (1B2a iii) and a Tier 2 (1B2a iv, v) approach (IPCC 2006, Volume 2 Energy, chp. 4 Fugitive Emissions, Figure 4.2.3).

For source 1B2a fugitive emissions from oil, fugitive emissions of CH_4 are reported, which occur only in 1B2a iii Transport and 1B2a iv Refining/storage. Indirect CO_2 emissions resulting from NMVOC emissions in this source category are reported in chp. 9. For CO complete oxidatation is assumed and therefore there are no indirect CO_2 emissions from CO.

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 3-100 are converted using a crude oil density of 0.82 t/m^3.

For oil refining and storage (1B2a iv), country-specific emission factors for CH_4 and NMVOC are used. The emission factors for CH_4 are delineated from an emission estimation project in one of the refineries in 1992 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 2018/1B2a iv). The emission factors for SO_2 emissions from Claus units in refineries are country-specific and based on measurements and data from industry and expert estimates.

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 2018/1B2a v Benzinumschlag Tanklager and EMIS 2018/1B2a 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 3-100 Emission factors for fugitive emissions of source category 1B2a Oil in 2016.

Source/fuel	Unit	CO_2	CH_4	N_2O	NO_x	NMVOC	SO_2	CO
1B2a Oil								
Exploration	g/t	NO	NO	NO	NO	NO	NO	NO
Production	g/t	NO	NO	NO	NO	NO	NO	NO
Transport	g/t	NA	6.59	NA	NA	65.9	NA	NA
Refining/Storage	g/t	NA	45	NA	NA	430	38	NA
Distribution of oil products: Gasoline storage tank	g/GJ	NA	NA	NA	NA	7	NA	NA
Distribution of oil products: Gasoline station	g/GJ	NA	NA	NA	NA	9	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 2017). The annual amount of processed crude oil in Claus units is based on the Swiss overall energy statistics (SFOE 2017).

For oil distribution from storage tanks and gasoline stations (1B2a v), gasoline sales based on the Swiss overall energy statistics (SFOE 2017), 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 2017), losses of gasoline and of natural gas to source category 1B.

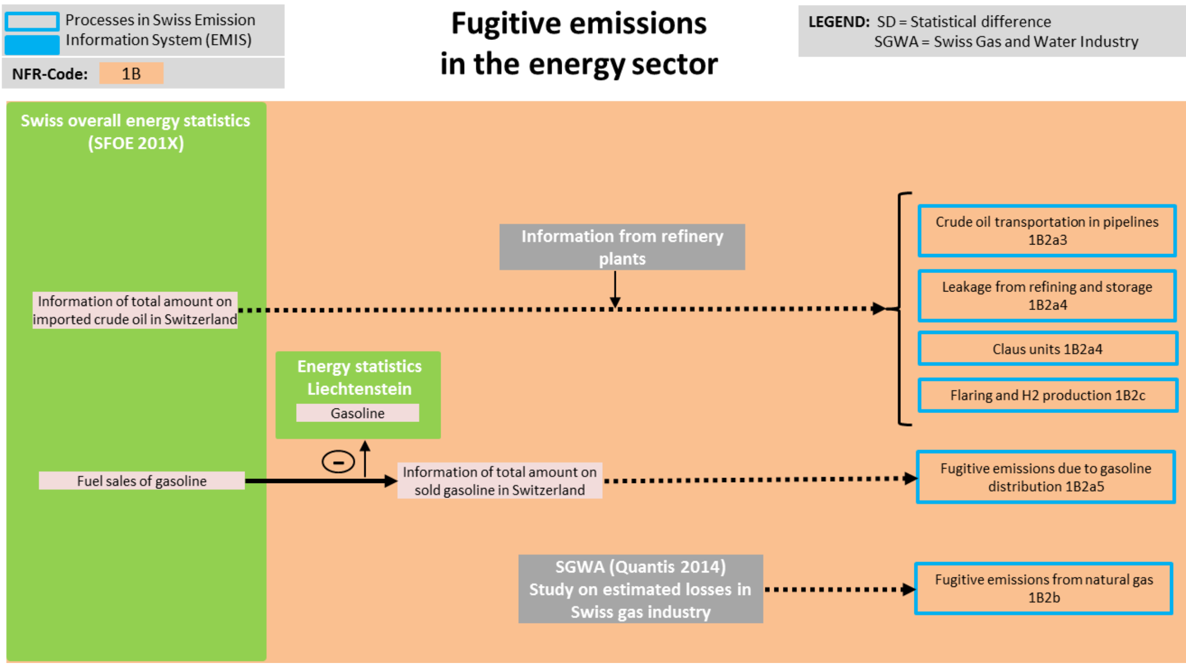


Figure 3-25 Attribution of fugitive emissions to source categories of 1B Fugitive emissions from fuels.

Table 3-101 Activity data for fugitive emissions from 1B2a Oil.

1B2a Oil products	Unit	1990	1995	2000	2005
Crude oil	kt	3'127	4'657	4'649	4'877
Gasoline transport	TJ	156'516	151'672	168'353	152'182

1B2a Oil products	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Crude oil	kt	4'720	5'133	4'833	4'546	4'452	3'455	4'935	4'975	2'836	3'006
Gasoline transport	TJ	146'120	142'904	139'067	134'129	128'941	124'386	118'717	113'954	105'664	102'367

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 1-10).

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 chp. 1.2.3 and partly also in chp. 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

The following recalculations were implemented in submission 2018. These recalculations cause a change in emission levels in 1990 or 2015 by less than 1 kt CO_2.

- 1B2a: The activity data for losses of gasoline in petrol stations and fuel depots were based on gasoline sold before subtraction of gasoline sold in Liechtenstein. This has been adjusted and now the activity data bases on gasoline sold in Switzerland only.

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 source category occur from natural gas transmission (1B2b iv) and distribution (1B2b v). Emissions from accidents in the gas pipeline system are reported under source category 1B2b vi Other Leakage.

Table 3-102 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 (IPCC 2006, Volume 2 Energy, chp. 4 Fugitive Emissions, Figure 4.2.1), Switzerland follows a Tier 1 approach for fugitive emissions concerning 1B2b ii Production and a Tier 2 approach for fugitive emissions attributed to 1B2b iv Transmission and storage as well as 1B2b v Distribution.

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. The emissions from source category 1B2b ii 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.

For emission calculations from source category 1B2b iv, 1B2b v and 1B2b vi country-specific emission factors and activity data are available. Emissions are calculated with a country-specific method which first assesses the losses of natural gas in the gas network including pipelines, fittings and gas devices, as these data represent the activity data. Based on the gas losses, CO_2, CH_4 and NMVOC emissions are calculated with country-specific emission factors which reflect the composition of the gas lost.

Emissions from gas transmission (source category 1B2b iv) include emissions from transport pipelines including the transit pipeline and the single compressor station. Emissions comprise leakages from gas pipelines, small-scale damages, maintenance work and leakages of pipeline fittings. Gas storages are considered as components of the distribution network and the respective emissions are included in source category 1B2b v.

Source category 1B2b v Distribution covers emissions from the gas distribution pipelines and network components (e.g. control units, fittings and gas meters) as well as fugitive emissions at the end users. Emission calculations for the gas distribution network are based on the length, material and pressure of the gas pipelines. Fugitive emissions at the end users arise from on-site and indoor pipelines and the permanent leakiness of the different gas appliances in households, industry and natural gas fuelling stations. In the calculations, the number and kind of end users and connected gas appliances are considered.

Indirect CO_2 emissions resulting from NMVOC emissions in this source category are reported in chp. 9. For CO complete oxidatation is assumed and therefore there are no indirect CO_2 emissions from CO.

Emission factors (1B2b)

For natural gas production, CO_2, CH_4 and NMVOC default emission factors are taken from the 2006 IPCC Guidelines (IPCC 2006) as documented in the internal emission database documentation (EMIS 2018/1B2b Diffuse Emissionen Erdgas).

Emission factors for transmission, distribution and other leakages (source category 1B2b iv 1B2b v and 1B2b vi) are calculated based on the average CO_2, CH_4, and NMVOC concentrations of natural gas and its average net calorific value in Switzerland as described in Quantis (2014) and EMIS 2018/1B2b Diffuse Emissionen Erdgas. Since 2012, the annual average CH_4 concentration and net calorific value of natural gas in Switzerland are provided by the Swiss Gas and Water Industry Association (SGWA).

Table 3-103- Emission factors for fugitive emissions of source category 1B2b Natural gas in 2016.

1B2b Natural gas	CO_2	CH_4	N_2O	NO_x	NMVOC	SO_2	CO
	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
1B2b ii Production	NO	NO	NO	NO	NO	NO	NO
1B2b iv Transmission	303	17'868	NA	NA	1'408	NA	NA
1B2b v Distribution	303	17'868	NA	NA	1'408	NA	NA
1B2b vi Other Leakage	NO	NO	NO	NO	NO	NO	NO

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 2017).

For gas transmission (1B2b iv), distribution (1B2v), and other leakage (1B2b vi), the activity data have been reassessed in a recent study by Quantis (2014) and updated in 2016 (EMIS

2018/1B2b Diffuse Emissionen Erdgas). The activity data represent the amount of natural gas lost from the gas network and are shown in Table 3-104.

For source categories 1B2b iv and 1B2b v, information regarding the gas transport and distribution network from the Swiss Gas and Water Industry Association (SGWA) is used to derive the activity data (see Quantis 2014 and EMIS 2018/1B2b Diffuse Emissionen Erdgas).

For transmission pipelines a constant emission factor per pipeline length is applied accounting for losses from purging and cleaning flows, pipeline damages and leaky fittings and mountings. For the one compressor station a constant emission rate based on the physical power of the turbines is employed including emissions due to shutting down and starting of the gas turbines, leakages at regulating valves and fittings, maintenance and gasometry work.

The calculation of losses from source category 1B2b v Distribution follows a detailed country-specific approach that considers losses from the pipeline network as well as losses at the end users.

The calculated gas losses from the pipeline network depend on the length, material and pressure of the pipelines. Gas losses due to permanent leakiness, small-scale damages, network maintenance and the network components are evaluated separately. As no applicable loss rates are available for the network compounds in Switzerland (installed control units, fittings, storage systems and gas meters), a fixed percentage is applied to the permanent gas losses.

Regarding the end users, gas losses from on-site and indoor pipelines as well as gas losses due to the permanent leakiness of gas appliances are evaluated. Pipeline loss rates apply to the number of households, industrial users and gas fuelling stations separately. Regarding the gas appliances, different loss rates are assigned to the number of gas heating systems, gas cooking stoves and gas fuelling stations.

For some (earlier) years in the time series, sufficient input data are not available to calculate the gas losses. For these years, polynomial interpolations are applied to assess the activity data.

For significant emission events due to accidents the Swiss Pollutant Release and Transfer Register is considered, and emissions are attributed to source category 1B2b vi Other Leakage. So far, two events have been reported by the transit pipeline operator, one in 2010 and one in 2011.

Fugitive emissions from pipelines are the major emission source in source category 1B2b. Fugitive emissions from damages and ruptures of the pipelines, maintenance of the pipelines and the components are very small (Quantis 2014). Total CH_4 emissions from gas transmission and distribution decreased due to gradual replacement of cast-iron pipes with polyethylene pipes.

Table 3-104 Activity data (amount of gas lost) for fugitive emissions from 1B2b Natural gas

1B2b Natural Gas	Unit	1990	1995	2000	2005
1B2b Natural gas	GJ	868'472	847'902	687'838	545'527
1B2b ii Production	GJ	130'000	NO	NO	NO
1B2b iv Transmission	GJ	28'226	30'874	32'571	33'491
1B2b v Distribution	GJ	710'246	817'028	655'267	512'036
1B2b vi Other Leakage	GJ	NO	NO	NO	NO

1B2b Natural Gas	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1B2b Natural Gas		521'517	506'306	493'784	484'014	476'427	470'194	434'845	424'435	423'719	424'582
1B2b ii Production	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2b iv Transmission	GJ	34'451	34'572	34'586	34'595	34'569	34'495	34'852	35'125	35'468	35'539
1B2b v Distribution	GJ	487'066	471'734	459'198	449'419	441'858	435'699	399'993	389'310	388'251	389'043
1B2b vi Other Leakage	GJ	NO	NO	NO	35'444	28'114	NO	NO	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 CH_4 emissions from natural gas pipelines in Switzerland.

A preliminary uncertainty assessment of all other sources in source category 1B2 based on expert judgement results in medium confidence in the emissions estimate (see Table 1-10).

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 chp. 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 in 2014 (Quantis 2014) and 2016 (EMIS 2018/1B2b Diffuse Emissionen Erdgas).

3.3.4.5 Category-specific recalculations for 1B2b

The following recalculations were implemented in submission 2017. Recalculations that cause a change in emission levels 1990 or 2015 of at least 1 kt CO_2 eq are quantified.

- 1B2b: A few corrections in the calculation file for natural gas losses in gas distribution and transportation led to recalculations in activity data (amount of gas lost) and emission factors. In particular, the CH_4 content, net calorific value and density of the natural gas slightly changed due to adjustments of the shares of different import stations by the Swiss Gas and Water Industry Association SVGW. Losses for the years 1990 to 2015 increased, while emission factors for the years 2012 to 2015 decreased. Overall, these corrections led to an increase of CH_4 emissions by 30t for 1990 and a decrease of CH_4 emission by 82t CH_4 for 2015.This recalculation is responsible for the observed decrease in CH_4 emissions between 2012 and 2015 in source category 1B as compared to the previous submission (Figure 10-2).
- 1B2b: Correction of CH_4 content of natural gas for the years 2012-2014 based on information from the Swiss Gas and Water Industry Association SVGW.

- 1B2b: Natural gas contains small amounts of CO_2. Fugitive emissions of natural gas therefore also lead to CO_2 emissions. They are now estimated and included in source category 1B2b Transmission and storage and 1B2b Distribution.

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 production is not occurring, and only one production site for natural gas production was operational from 1985 – 1994. Therefore, emissions from flaring result primarily from the torches, which were operational at the two refineries (1B2c i Flaring). Since 2015, there is only one refinery in operation. In addition, CO_2 emissions from H_2 production in one of the two refineries are also reported under 1B2c.

Table 3-105 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 Emissions from gas production (1990-1994 only)

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, Oil 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, Oil, emissions of CO_2 as well as CH_4, N_2O, NO_x, CO and NMVOC are considered. For source category 1B2c ii Flaring, Gas emissions of CO_2 as well as CH_4, N_2O and NMVOC are considered.

Emissions from gas production are calculated by a Tier 1 method according to 1B2c fugitive emissions from venting and flaring according to the decision tree for natural gas systems (IPCC 2006, Volume 2 Energy, chp. 4 Fugitive Emissions, Figure 4.2.1). For source category 1B2c ii Flaring, Gas, emissions of CO_2 as well as CH_4, N_2O and NMVOC are considered.

One of the refining plants produces H_2 from butane leading to process emissions of CO_2. Emissions are estimated based on plant-specific data.

Since the CO_2 emission factors assume an oxidation of 100%, no indirect emissions need to be accounted for. Therefore, from this source category no indirect emissions are reported in chp. 9.

Emission factors (1B2c)

Emission factors are based on data from the refining industry as documented in the internal emission database documentation (EMIS 2018/1B2c 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 CO_2 Emissions (Swiss Confederation 2011) based on daily measurements of CO_2 emission factors of the flared gases. From these data annual emission factors are derived. Since 2005, the evolution of the other emission factors (CH_4, N_2O, NO_x, CO and NMVOC) is assumed to vary proportionally to the CO_2 emission factor. Emission factors are considered confidential and are available to reviewers on request.

The emissions from flaring in the gas production facility are calculated based on default emission factors provided in the 2006 IPCC Guidelines.

Emission factors for butane production are confidential. Data are available to reviewers on request.

Table 3-106 Emission factors for 1B2c Venting and flaring in 2016.

Source/fuel	Unit	CO_2	CH_4	N_2O	NO_x	NMVOC	SO_2	CO
1B2ci Flaring Oil	g/t	C	C	C	C	C	C	C
1B2cii Flaring Gas	g/GJ	NO	NO	NO	NA	NO	NA	NA
1B2ci Flaring Oil: H2 production refinery (butane)	g/GJ	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 2017). 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 gas production, the amount flared is estimated based on the amount of gas produced.

For H_2 production in one of the refining plants, annual data on butane consumption are provided by the industry since 2005, when the H_2 production unit was installed. Data are confidential and they are available to reviewers on request.

Table 3-107 Activity data for 1B2c Venting/flaring.

1B2c Venting and flaring	Unit	1990	1995	2000	2005
1B2ci Flaring Oil: Crude oil used	kt	3'127	4'657	4'649	4'877
1B2cii Flaring Gas	GJ	130'000	NO	NO	NO
1B2ci Flaring Oil: H2 production refinery (butane)	GJ	NO	NO	NO	C

1B2c Venting and flaring	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1B2ci Flaring Oil: Crude oil used	kt	4'720	5'133	4'833	4'546	4'452	3'455	4'935	C	C	C
1B2cii Flaring Gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2ci Flaring Oil: 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 1-10).

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 chp. 1.2.3. No category-specific QA/QC activities were undertaken.

3.3.5.5 Category-specific recalculations for 1B2c

The following recalculations were implemented in submission 2018. Recalculations cause a change in emission levels in 1990 or 2015 by less than 1 kt CO_2.

- 1B2c: Flaring in refineries: new rounding of the 2012-2015 emission factors leads to recalculations of emissions.
- 1B2c: Reported emissions of H_2 production have changed negligibly due to rounding differences in the emission factor (9 kg CO_2).
- 1B2c: As reommended by the ERT, emissions from natural gas production from 1990-1994 were taken into account for the last submission, but unfortunately they were not included in the reporting tables. In this submission they are now included in the reporting tables.

3.3.5.6 Category-specific planned improvements for 1B2c

No category-specific improvements are planned.

3.4 Source category 1C – CO_2 transport and storage

CO_2 transport and CO_2 storage is not occurring in Switzerland.

4 Industrial processes and product use

4.1 Overview

This chapter provides information on the estimation of the 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. CO_2 emissions from solvent and partly from product use are due to post-combustion of NMVOC in order to reduce NMVOC in exhaust gases. The disposal of solvents is reported in the waste sector (chp. 7).

Indirect emissions of CO_2 from fossil CO and NMVOC as well as of N_2O from NO_x and NH_3 emissions are included in CRF Table6 and reported in chapter 9. Since the CO_2 emissions from the cracker reported in source category 2B8b Ethylene, from 2C1 Secondary steel production, electric arc furnace and from 2C3 Primary aluminium production are based on carbon mass balances their emissions of CO (from source categories 2C1 and 2C3) and NMVOC (from source categories 2C1 and 2B8) are not accounted for calculation of the indirect CO_2 emissions. Biogenic NMVOC and CO emissions occur in source category 2H2 Food and beverages and 2G4 tobacco consumption and are not reported as indirect CO_2 emissions.

For several industrial processes within source categories 2A Mineral industry, 2B Chemical industry and 2C Metal industry data and information on 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 GHG emissions in sector 2 between 1990 and 2016.

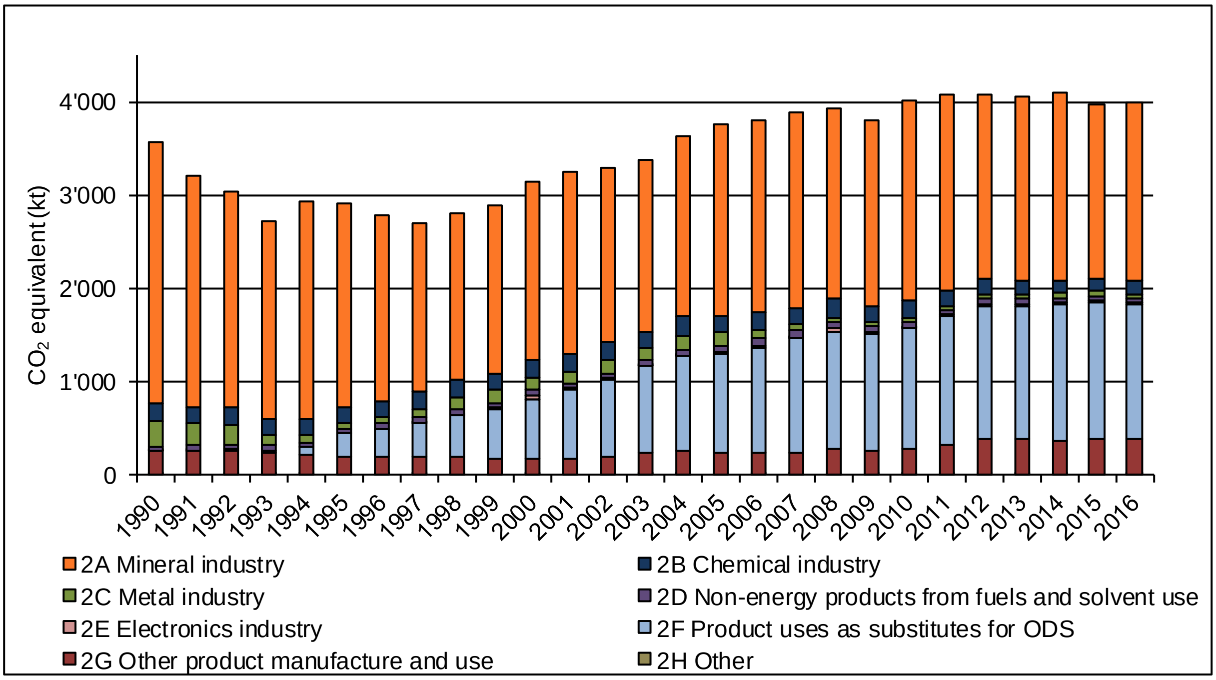


Figure 4-1 Switzerland's greenhouse gas emissions of sector 2 Industrial processes and product use.

2A Mineral industry remains the dominant source of sector 2 accounting for around half of the GHG emissions in 2016 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 2016. 2D Non-energy products also only have a minor contribution in 2016.

2F Product uses as substitutes for ozone depleting substances (ODSs) is of increasing importance: The emissions have increased since 1990 and account for almost half of total GHG emissions in sector 2 in 2016. This is primarily due to the replacement of CFCs and other ODSs 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 is given by gases. Dominant gases are CO_2 and F-gases in 2016 whereas N_2O and CH_4 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 CO_2 equivalent.

Gas	1990	1995	2000	2005
	CO_2 equivalent (kt)			
CO_2	3'149	2'415	2'197	2'370
CH_4	1.8	1.8	1.7	2.6
N_2O	171	140	115	100
F-gases	254	353	828	1'296
Sum	3'576	2'910	3'141	3'769

Gas	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	CO_2 equivalent (kt)									
CO_2	2'327	2'286	2'205	2'364	2'318	2'194	2'196	2'250	2'082	2'157
CH_4	2.6	2.9	1.9	2.7	2.8	2.8	2.1	2.1	2.2	2.7
N_2O	101	109	99	102	94	94	66	45	45	45
F-gases	1'450	1'531	1'495	1'537	1'661	1'783	1'797	1'810	1'834	1'786
Sum	3'880	3'928	3'800	4'006	4'076	4'074	4'061	4'107	3'964	3'991

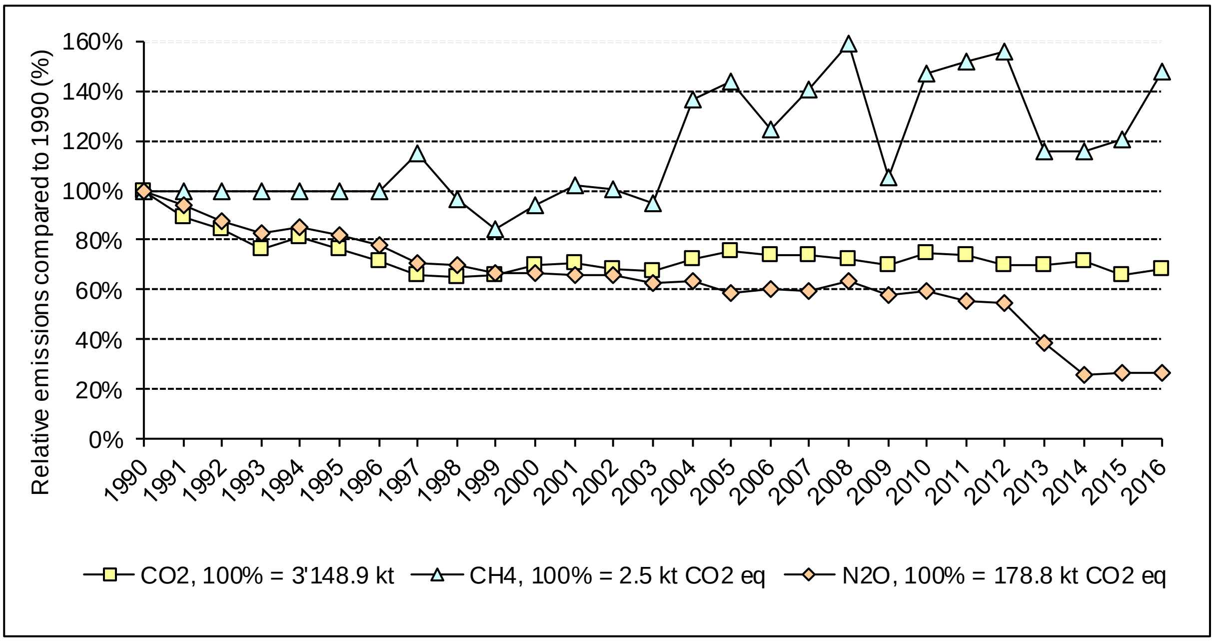


Figure 4-2 Relative trends of the greenhouse gas emissions (without F-gases, see Figure 4-3) of sector 2 Industrial processes and product use. The base year 1990 represents 100%.

Figure 4-2 shows that the emissions of CO_2 decreased between 1990 and 1998 and since then, they remain at a constant level. Emissions of N_2O from sector 2 Industrial processes and product use have also decreased since 1990 and remain at a constant level since 2014. . Emissions of CH_4 have increased in the same time period with considerable interannual fluctuation. However, absolute emissions are small compared to CO_2 and N_2O.

Figure 4-3 shows a large increase in emissions of F-gases compared to the year 1990. Main contributions in the inventory 1990 result from the PFC emissions in the smeltering process of aluminium production (chp. 4.4.2.2) and from the use of SF_6 in electrical equipment and sound proof windows (chp. 4.8.2.1 and chp. 4.8.2.2). The increase between 1995 and 2012is due to the increasing product uses of HFCs as substitutes for ODS (chp. 4.7) in refrigeration and air conditioning. Since 2012, emissions remain at a constant level. Most relevant and main source of F-gases emissions in 2016 is the use of HFC in refrigeration and air conditioning.

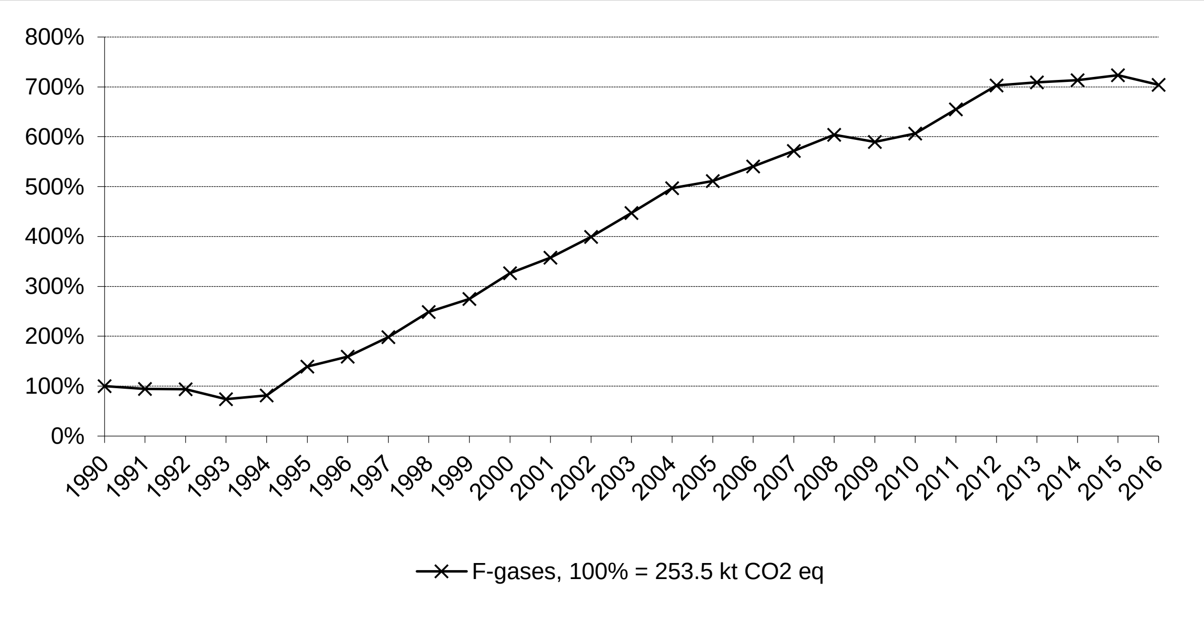


Figure 4-3 Relative trends of the F-gases of sector 2 Industrial processes and product use in the period 1990–2016. The base year 1990 represents 100%.

4.2 Source category 2A – Mineral industry

4.2.1 Source category description

Table 4-2 Key categories of 2A Mineral industries. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
2A1	Cement production	CO_2	L1, T1, L2

Table 4-3 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, NOx, 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, NOx, 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, NOx, CO, NMVOC and SO_2 from blasting operations in plaster production Geogenic CO_2 emissions from carbonate use for fluegas purification in cellulose production and waste incineration plants

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 CO_2 occur during the production of clinker, which is an intermediate component in the cement manufacturing process. During the production of clinker, limestone, which is mainly calcium carbonate ($CaCO_3$), is heated (calcined) to produce lime (CaO) and CO_2 as by-product. The CaO reacts subsequently with minerals in the raw materials and yields clinker. During this reaction step no further CO_2 is emitted. Clinker is then mixed with other components such as gypsum to make cement.

Blasting operations in the limestone quarries are another source of emissions for both CO_2 and precursor greenhouse gases such as NO_x, CO, NMVOC and SO_2.

Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

Methodology

Calcination process

The geogenic CO_2 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).

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.

Blasting operations

Emissions resulting from blasting operations during the digging of limestone are calculated by a Tier 2 method according to EMEP/EEA Guidebook 2016 (EMEP/EEA 2016, chp. 2A1, Fig. 3.1) using country-specific emission factors. The CO_2 emissions from "blasting" are related only to the usage of explosives in the quarries and not to the fuel consumption of construction machinery such as bulldozers etc. The amount of used explosives is reported to be 0.13 kg/t cement[13] (EMIS 2018/2A1 Zementwerke übriger Betrieb).

Total emissions reported for the production of cement are the sum of emissions from calcination process and blasting operations. The share of CO_2 emissions from blasting operations in limestone quarries is well below one tenth of a per cent of the geogenic CO_2 emissions from the calcination process.

Emission factors

Calcination process

The emission factor of CO_2 from calcination is provided per tonne of clinker. It accounts for geogenic emissions from the carbonate containing raw material, emissions from organic carbon content of the raw material and from cement kiln dust (CKD).

The base emission factor of 525 kg CO_2/t clinker used in the Swiss ETS corresponds to the value provided by the Cement Sustainability Initiative (CSI) in its report “CO_2 and Energy Accounting and Reporting Standard for the Cement Industry – The Cement CO_2 and Energy

[13] The CO_2 emission factor for the use of blasting agents amounts to 600 kg CO_2/t of blasting agent. For the average amount on blasting agent used per kg cement measurement data for the year 2002 were taken. Measurement data were available for four Swiss cement plants, covering more than 60% of the Swiss cement production. Therefore, this information is considered representative for cement plants in Switzerland.

Protocol”(see method B1, p. 9 in CSI 2011). Data from the Swiss cement industry for the years 2008-2011 showed that CaO contents in clinker typically varied between 63 – 66%, while MgO contents were around 2%. However, these contents already contained fractions deriving from non-carbonate sources. Therefore, it was decided in the ETS to define the base EF as described in the CSI Protocol and then add a share for non-carbonate C and CKD. In submission 2017 it was decided to revise the EF in order to establish a consistent time series from 1990 – 2015 and also achieve consistency between the Swiss ETS and the greenhouse gas inventory (CSI 2011).

The emissions from the organic carbon content of the raw material are assumed to be a constant share of 0.2% of the raw material (i.e. 11.37 kg CO_2/t clinker). The emission factor of CKD is estimated based on plant-specific data available for 2013 – 2016 that are provided by the cement industry association (cemsuisse). From this data, an average emission factor of CO_2 from CKD is calculated (0.35 kg CO_2/t clinker).

Based on these emission factors a total country-specific emission factor per ton of clinker is calculated. The emission factor is assumed constant for the entire time period.

Table 4-4 CO_2 emission factor for calcination in 2A1 Cement Production 1990 to 2016.

2A1 Cement production	**Unit**	**1990 - 2016**
Calcination, CO_2	kg/t clinker	536.7

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 the EMIS database (EMIS 2018/2A1 Zementwerke übriger Betrieb). They are assumed to be constant over the entire time period and are given per tonne of clinker.

Table 4-5 Emission factors for CO_2, NO_x, CO, NMVOC and SO_2 from blasting operations in g/t clinker from source category 2A1 Cement Production in 2016

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 (EMIS 2018/2A1_Zementwerke Rohmaterial). From 2008 onwards they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Table 4-6 Activity data of clinker production

2A1 Cement production	Unit	1990	1995	2000	2005
Clinker production	kt	4'808	3'706	3'214	3'442

2A1 Cement production	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Clinker production	kt	3'512	3'461	3'443	3'642	3'587	3'368	3'415	3'502	3'195	3'296

4.2.2.2 Lime production (2A2)

During the production of lime calcium carbonate ($CaCO_3$) is heated (calcined) yielding burnt lime (CaO) and CO_2 as by-product. In Switzerland, there is only one plant producing lime. There is no industry in Switzerland producing lime for its own requirements, except for sugar production. A request to both sugar producing plants confirmed that indeed they produce lime from limestone in own shaft kilns. However, the CO_2 is re-captured in the sugar production process and thus no CO_2 emissions occur.

Blasting operations in quarries are another source of emissions for both CO_2 and precursor emissions such as NO_x, CO, NMVOC and SO_2.

Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

Methodology

Calcination process

Since 2013, the geogenic CO_2 emissions from the calcination process in lime production are determined by a Tier 3 method using plant-specific emission factors according to the decision tree Fig. 2.2. of 2006 IPCC guidelines (vol. 3, chp. 2.2 Lime production). Between 1990 and 2012, a Tier 2 method is applied.

Blasting operations

Emissions resulting from blasting operations during the digging of limestone are calculated by a Tier 2 method according to EMEP/EEA Guidebook 2016 (EMEP/EEA 2016, chp. 2A2, Fig. 3.1) using country-specific emission factors. The CO_2 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. CO_2 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 CO_2 from calcination of limestone depends both on the purity of the limestone and the degree of calcination (i.e. amount of rest CO_2 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 2018/2A2 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).

Table 4-7 CO_2 emission factor for calcination process in lime production in kg/t lime for 1990–2016 are documented in the confidential NIR, which is available to reviewers on request.

Blasting operations

The emission factors are country-specific as documented in EMIS 2018/2A2 Kalkproduktion, übriger Betrieb. The values are confidential and they are available to reviewers on request.

Table 4-8 CO_2 emission factor for the calcination process in lime production in kg/t lime and emission factors for CO_2, NO_X, CO, NMVOC and SO_2 from blasting operations in g/t lime in 2016

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 2018/2A2 Kalkproduktion, Rohmaterial and EMIS 2018/2A2 Kalkproduktion übriger Betrieb). Since 2009 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 4-9 In the confidential NIR, the respective table with activity data on lime production are separately reported and available to reviewers.

4.2.2.3 Glass production (2A3)

Source category 2A3 Glass production comprises geogenic CO_2 emissions from the carbonate containing raw materials, i.e. soda ash, limestone and dolomite. In Switzerland, the following three glass types are produced: container glass, tableware glass and glass wool. Today, there is only one production plant 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 CO_2 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:

$$CO_2 \text{ Emissions} = M_{\text{Glass type}} \bullet EF_{\text{Glass type}} \bullet (1 - \text{cullet ratio})$$

The cullet ratio describes the share of recycled glass material which is used in the production. The melting of cullet causes no geogenic CO_2 emissions.

From 2005 onwards, the geogenic CO_2 emissions from 2A3 Container glass production is determined according to a Tier 3 method based on the amount of carbonate containing raw materials used, i.e. soda, dolomite and limestone and their effective carbonate content.

Emission factors

The emission factors for glass production in Switzerland are taken from IPCC 2006 (vol.3, chp. 2.4 Glass production, Table 2.6). For the production of container glass (1990-2004), tableware glass (1990-2016) and glass wool (1990-2016) 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 from ETS monitoring reports for the container glass production and thus the corresponding default CO_2 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 4-10 Geogenic CO_2 emission factor for glass production in g/t glass and g/t carbonate containing raw material (IPCC 2006).

2A3 Glass production	**Unit**	**CO_2 geogenic**	
Glass wool (fibre glass insulation)	g/t	250'000	
Glass (speciality tableware)	g/t	100'000	
		1990–2004	**2005–2016**
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

Table 4-11 In the confidential NIR, a comparison of implied CO_2 emission factors based on Tier 2 and Tier 3 approaches is provided for container glass production in g/t glass for the time period 2005-2011.

Activity data and cullet ratios

Source category 2A3 Glass production is dominated by the emissions from the production of container glass and glass wool.

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.

Activity data of tableware and container glass production are based on data from Swiss glass producers.

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 2018/2A3 Hohlglas Produktion, EMIS 2018/2A3 Glas übrige Produktion and EMIS 2018/2A3 Glaswolle Produktion Rohprodukt).

Table 4-12 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	2005
Container glass					
Production	kt	C	C	C	C
Cullet ratio	%	C	C	C	NA
Soda use	kt	NA	NA	NA	C
Dolomite use	kt	NA	NA	NA	C
Limestone use	kt	NA	NA	NA	C
Glass (speciality tableware)					
Production	kt	C	C	C	C
Cullet ratio	%	C	C	C	C
Glass wool					
Production	kt	24.3	24.2	31.1	37.5
Cullet ratio	%	21	45	69	65

2A3 Glass production	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
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	44.5	44.4	33.5	35.7	41.4	38.7	33.4	32.3	31.4	31.6
Cullet ratio	%	71	69	69	71	72	61	67	67	67	67

4.2.2.4 Other process uses of carbonates (2A4)

Source category 2A4 Other process uses of carbonates comprises geogenic CO_2 emissions from production of fine ceramics (2A4a), bricks and tiles (2A4a) and rockwool (2A4d), from use of carbonates for sulphur oxide removal in municipal solid waste incineration plants (2A4d) and cellulose production (ceased in 2008) (2A4d), from use of limestone in iron-foundries (cupola furnaces) (2A4d) and from use of sodium bicarbonate (2A4d) as well as emissions of CO_2, NO_x, CO, NMVOC and SO_2 from blasting operations in plaster production (2A4d).

Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

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 2018/2A4a Feinkeramik Produktion.

Methodology

The geogenic CO_2 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:

$$CO_2 \text{ Emissions} = (M_{Limestone} \bullet EF_{Limestone}) + (M_{Dolomite} \bullet EF_{Dolomite}) + (M_{Soda\ Ash} \bullet EF_{Soda\ Ash})$$

Emission factors

The CO_2 emission factors of limestone, dolomite and soda ash are taken from IPCC 2006 (vol. 3, chp. 2.1, Table 2.1). As these emission factors are material properties, they remain constant over time.

Table 4-13 Geogenic CO_2 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	CO_2 geogenic				
Fine ceramics		**1990–2016**				
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**	**2015**	**2016**
Brick and tile production	g/t	117'000	100'000	110'000	103'000	115'000

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 CO_2 emissions based on representative analyses of the carbonate content of the clay used for brick and tile production in a number of plants in Switzerland and the European Union are applied. This study was carried out by the Swiss association of brick and tile industry (Verband Schweizerische Ziegelindustrie, VSZ) in 2012 (see EMIS 2018/2A4a 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 CO_2 Emissions, Swiss Confederation 2011 and Ordinance for the Reduction of CO_2 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 CO_2 (variation range 5.4% - 24%) and roof tiles have a weighted average of 8.6% (variation range 5.6% - 13%). Based on the production shares of the largest Swiss brick producer, a production ratio for bricks to tiles of 2:1 was assumed for the whole period from 1990 to 2012. This resulted in an average geogenic CO_2 emission factor of 117 kg CO_2/t brick and tile, which was assumed 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 CO_2 emissions from the carbonate containing raw materials. For emission factors see Table 4-13.

Activity data

Activity data are based on production data from the Swiss association of brick and tile industry (VSZ). Since 2011 they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Table 4-14 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**	**2005**
Fine ceramics production	kt	C	C	C	C
Limestone use	kt	C	C	C	C
Dolomite use	kt	C	C	C	C
Soda use	kt	C	C	C	C
Brick and tile production	kt	1'271	1'115	959	1'086
2A4d Other					
Rock wool production	kt	C	C	C	C
Carbonate use in waste incineration plants	kt	0.7	0.8	0.8	0.6
Limestone use in cellulose	kt	8.5	9.4	9.3	8.3
Limestone use in iron foundries	kt	6.2	4.1	3.8	2.3
Other use of carbonates	kt	5.9	5.4	7.0	7.3
Plaster production	kt	319	304	288	327

2A4a Ceramics	**Unit**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
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	975	865	701	879	800	792	785	765	726	644
2A4d Other											
Rock wool production	kt	C	C	C	C	C	C	C	C	C	C
Carbonate use in waste incineration plants	kt	NO	NO	NO	NO	NO	NO	2.7	1.9	6.5	6.6
Limestone use in cellulose	kt	7.8	6.5	NO	NO	NO	NO	NO	NO	NO	NO
Limestone use in iron foundries	kt	2.4	2.7	1.1	1.0	1.1	0.9	0.9	0.8	0.7	0.7
Other use of carbonates	kt	7.0	7.4	6.6	6.9	6.4	7.6	6.1	7.5	6.7	6.8
Plaster production	kt	314	295	293	335	293	271	213	166	140	148

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 4-13).

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 2018/2A4d Steinwolle Produktion).

Methodology

Since 2013, rock wool manufacturers are legally obliged to report geogenic CO_2 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 CO_2 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). Before 2004, a Tier 2 method was applied.

Emission factors

For rock wool production in Switzerland, the CO_2 emission factor is based on measurements of the oxides (CaO, MgO, Na_2O, K_2O, MnO) of the carbonate containing raw materials and the product for the years 2005 to 2011 as well as since 2013. Based on the difference in the oxide content in the raw material and the products, the total geogenic CO_2 emissions are determined. Consequently, the emission factor is specified as g/t rock wool. Since data on the carbonate content are missing for the years 1990 to 2004 and 2012 the mean value of the years 2005-2011 and 2013 is applied for these years.

The CO_2 emission factors are confidential. They are available to reviewers on request.

Table 4-15 Geogenic CO_2 emission factors used for rock wool production and other carbonate uses, CO_2 fossil, NO_x, CO, NMVOC and SO_2 emission factors for plaster production in g/t carbonate containing raw material and g/t product, respectively for 2016.

2A4d Other	Unit	CO_2 geogenic	CO_2 fossil	NO_x	CO	NMVOC	SO_2
Rock wool production	g/t	C	NA	NA	NA	NA	NA
Carbonate use in waste incineration plants	g/t	523'880	NA	NA	NA	NA	NA
Limestone use in iron foundries	g/t	439'710	NA	NA	NA	NA	NA
Other carbonate uses	g/t	523'880	NA	NA	NA	NA	NA
Plaster production	g/t rocks	NA	144	5.6	33	14.4	0.24

Table 4-16 In the confidential NIR, the respective table with geogenic CO_2 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)

In 2014, an assessment was carried out in order to identify sources of CO_2 emissions from carbonate use for sulphur oxide removal and acid neutralization, which were not considered in the Swiss greenhouse gas inventory so far (INFRAS 2015). The survey among selected potentially relevant industrial plants, industry associations, Swiss cantons and the Swiss customs administration (EZV) comprised the following substances: limestone ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), sodium bicarbonate ($NaHCO_3$) and soda ash (Na_2CO_3).

Besides applications of calcium hydroxide and sodium hydroxide in flue gas treatment also a few applications of limestone and sodium bicarbonate for sulphur oxide removal could be identified in Switzerland. Limestone had been used in the cellulose production up to 2008, when the plant was closed, and in one municipal solid waste incineration plant up to 2005.

Since 2013, several waste incineration plants are using sodium bicarbonate.

In cupola furnaces of iron foundries limestone is also used as flux as documented in the EMIS database (EMIS 2018/1A2a 2A4d Eisengiessereien Kupolöfen). These geogenic emissions of CO_2 are also reported in 2A4d.

Limestone is also used to neutralize acid waste water in one chemical production plant. These emissions are reported in source category 2B10 Limestone pit.

Additionally, it is assumed, that all other applications of sodium bicarbonate result in a complete conversion to CO_2. Since there is no production of sodium bicarbonate in Switzerland, the annual emissions can be estimated based on the net import.

Methodology

The method for calculating the geogenic CO_2 emissions from the use of limestone and sodium bicarbonate in all the source categories mentioned above – except in waste incineration plants from 1994 onwards– 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).

The method for calculating the geogenic CO_2 emissions from the use of limestone and sodium bicarbonate in waste incineration plants from 1994 onwards 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).

Emission factors

The emission factors of limestone and sodium bicarbonate are based on the stoichiometry of $CaCO_3$ (2006 IPCC Guidelines, vol. 3 chp. 2.1, table 2.1, IPCC 2006) and $NaHCO_3$ (CRC 2004), respectively, see Table 4-15. A conversion factor of 100% is assumed for all apllications of both carbonates.

Activity data

Activity data on limestone use in flue gas treatment in cellulose production are based on expert estimates on the specific consumption of limestone per tonne of cellulose as documented in the EMIS database (EMIS 2018/1A2d Zellulose Produktion)

The activity data of limestone and sodium bicarbonate use in waste incineration plants are provided by the industry as documented in the EMIS database (EMIS 2018/1A1a Kehrichtverbrennungsanlagen).

The amount of limestone used as flux in iron foundries (cupola furnaces) is estimated by the Swiss foundry association to be in the range of 30 – 50% of the coal consumed. Therefore, an average share of 40% is assumed to calculate the activity data of limestone use (EMIS 2018/1A2a Eisengiessereien Kupolöfen).

The activity data of sodium bicarbonate correspond to the net import of sodium bicarbonate. These data are provided by the Swiss customs administration (EZV, FCA 2017b).

For activity data see Table 4-14.

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 2016 (EMEP/EEA 2016).

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 2018/2A4d Gips-Produktion übriger Betrieb. For emission factors see Table 4-15.

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 2018/2A4d Gips-Produktion übriger Betrieb (see Table 4-14).

4.2.3 Uncertainties and time-series consistency

The uncertainty for CO_2 emissions in 2A1 Cement production, which is a key category regarding level and trend, amounts to 4.5%. The uncertainty of CO_2 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). An uncertainty of 2% is assumed for activity data and 4% for the emission factor, which consists of an average emission factor per tonne of clinker for calcination of the carbonate containing raw material (FOEN 2013q, chp. G.7) and a correction for the content of organic carbon and cement kiln dust.

Combined uncertainty is estimated to be 3% for emissions from 2A2 Lime production and 4% for emissions from 2A3 Glass production (expert estimate).

For CO_2 emissions in source category 2A4 Other process uses of carbonates, an overall uncertainty of 3% is assumed. 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) and from the Swiss Federal Customs Administration.

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 2017, implied emission factors of 2A3 container glass production were assessed by both a Tier 2 and Tier 3 method for the years 2005 – 2011. This comparison provides an indication of the differences caused by the switch in the Tier level from Tier 2 (1990-2004) to Tier 3 (2005-2015).

4.2.5 Category-specific recalculations

The following recalculations were implemented in submission 2018. Recalculations that cause a change in emission levels 1990 and 2015 of at least 0.3 kt CO_2 eq are quantified. All the other recalculations have an impact of less than 0.3 kt CO_2 eq in the years 1990 and 2015.

Major recalculations which contribute significantly to the total differences in direct CO_2 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:

- 2A4d: The activity data of 2A4d Limestone use in iron foundries has been revised for the entire time series since the net calorific value of lignite instead of other bituminous coal was used so far. This results in a reduction of CO_2 emissions of 1.1 kt in 1990.

Further recalculations:

- 2A4d: The activity data of 2A4d Carbonate use in waste incineration plants have been updated from 2014 onwards based on industry data yielding revised activity data of 2A4d Other use of carbonates as well but no net change in CO_2 emissions.

4.2.6 Category-specific planned improvements

There are no category-specific planned improvements

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 4-17 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_2O and NOx 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 (NH_3) is produced in one single plant in Switzerland by catalytic reaction of nitrogen and synthetic hydrogen (see Figure 4-4). Ammonia is not produced in an isolated reaction plant but is part of an integrated production chain (see Figure 4-5).

The starting production process is the thermal cracking of liquefied petroleum gas (LPG) and light virgin naphtha yielding ethylene (ethene, C_2H_4), and a series of by-products such as e.g. synthetic hydrogen and methane, which are used as educts for further production steps. According to the Swiss ammonia producer it is not possible to split and allocate the emissions of the cracking process (CO_2 and NMVOC) to every single product such as, e.g., ethylene, acetylene (ethyne, C_2H_2), cyanic acid or ammonia. Therefore, all CO_2 and NMVOC emissions of the cracking process are allocated to the ethylene production and are reported under the category 2B8b Ethylene production. Thus, for source category 2B1 Ammonia production, CO_2 and NMVOC emissions are reported as included elsewhere (IE). All information on the ammonia production and the cracking process is documented in EMIS 2018/2B1 Ammoniak-Produktion and EMIS 2018/2B8b Ethen-Produktion, respectively.

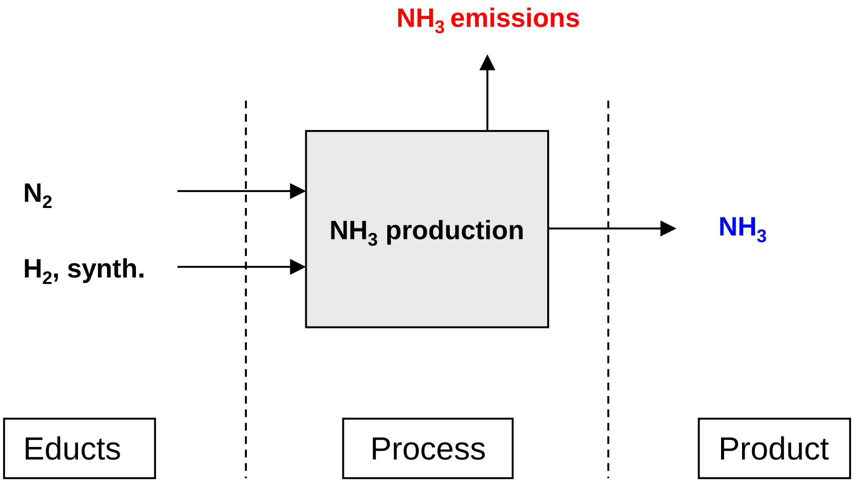


Figure 4-4 Process flow chart for the production of ammonia (NH_3) from nitrogen (N_2) and hydrogen (H_2, synth.). Hydrogen is derived from the thermal cracking process in the same plant (see Figure 4-5).

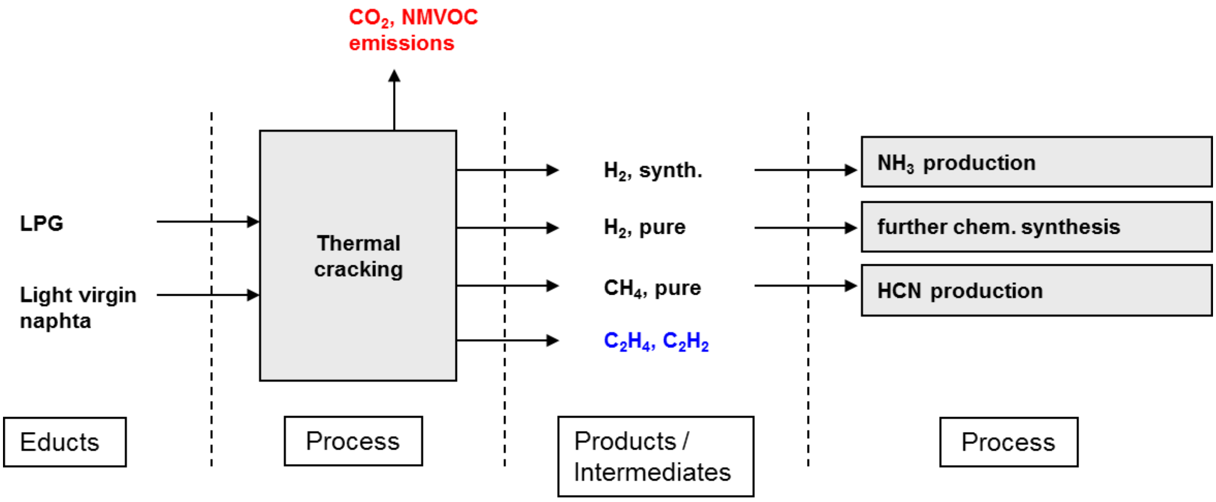


Figure 4-5 Process flow chart for the production of ethylene (C_2H_4) and acetylene (C_2H_2) by thermal cracking of liquefied petroleum gas (LPG) and light virgin naphtha. The intermediate product H_2, synth. is used as educt in the ammonia production in the same plant (see Figure 4-4).

Table 4-18 Activity data for ammonia production in Switzerland are documented in the confidential NIR, which is available to reviewers on request.

4.3.2.2 Nitric acid production (2B2)

In Switzerland, there is one single plant producing nitric acid (HNO_3). Nitric acid is produced by catalytic oxidation of ammonia (NH_3) with air. At temperatures of 800°C nitric monoxide (NO) is formed. During cooling, nitrogen monoxide reacts with excess oxygen to form nitrogen dioxide (NO_2). The nitrogen dioxide reacts with water to form 60% nitric acid (HNO_3). Today, two types of processes are used for nitric acid production: single pressure or dual pressure plants. In Switzerland a dual pressure plant is installed.

During this process, nitrous oxide (N_2O) 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 N_2 and O_2 (the SCR in this plant is also used for treatment of other flue gases and was not installed for the HNO_3 production specially). In 1990, an automatic control system for the dosing of ammonia to the SCR process was installed. A new catalyst installed in 2013 reduced the N_2O emissions.

No additional abatement technique is installed to destroy N_2O. A decomposition of N_2O 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 N_2O 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 (2016) (chp. 2B Chemical industry) using a plant-specific emission factor.

Emission factors

The N_2O 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 N_2O was carried out in 2009 according to the guideline VDI-Richtlinie 2469/Blatt 1 (Messen gasförmiger Emissionen - Messen von Distickstoffmonoxid - Manuelles gaschromatographisches Verfahren) and is the only plant-specific measurement of N_2O emissions. The test gas is sucked in via a heated titanium sensor and then treated with a solution of potassium permanganate and hydrogen peroxide in order to remove nitrogen oxides and further disturbing components. The N_2O concentration is then measured using a gas chromatograph with an electron capture detector. The measurement uncertainty is ±20% (minimum ± 0.5 mg/m^3). On repeated enquires the plant confirmed that since a denitrification system and an automatic control system for the ammonia addition was installed in 1988 and 1990, respectively, no modifications were made in the production line until 2012. Therefore, a constant N_2O-emission factor is assumed for this time period. A new catalyst installed in 2013 reduced the N_2O emissions, which are measured online by NDIR photometry from 2013 onwards.

The 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 2018/2B2 Salpetersäure Produktion.

Table 4-19 Emission factors for N_2O and NO_x for nitric acid production in Switzerland in kg/t nitric acid for 2015. Data refers to 100% nitric acid

2B2 Nitric acid production	Unit	N_2O	NO_x
	kg/t	C	C

Activity data

Activity data on annual production of nitric acid (100%) are provided annually by the Swiss production plant for the entire time period 1990-2016. 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 2018/2B2 Salpetersäure Produktion).

Table 4-20 Activity data for the production of nitric acid (100%) in Switzerland are documented in the confidential NIR, which is available to reviewers on request.

4.3.2.3 Carbide production (2B5)

In Switzerland, there is one single plant producing carbide. The plant produces silicon carbide, which is used in abrasives, refractories, metallurgy and anti-skid flooring. The Swiss silicon carbide is produced in an electric furnace at temperatures above 2000ºC using the Acheson process. The starting materials are quartz sand (SiO_2), petroleum coke and anthracite (C) which yield silicon carbide (SiC) and carbon monoxide (CO). The CO is converted to CO_2 in excess oxygen and released to the atmosphere. Petroleum coke and anthracite – although to a lower portion – may contain volatile organic compounds, which can form methane (CH_4) as an unintended by-product. There is no abatement techniques installed which could capture the CO_2 or CH_4 emissions.

Methodology

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 (2016) (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 2018/2B5 Graphit und Siliziumkarbid Produktion.

Table 4-21 In the confidential NIR, a respective table with emission factors of fossil CO_2 in kg/t silicon carbide are provided. Data are available to reviewers on request.

Table 4-22 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 2018/2B5 Graphit und Siliziumkarbid Produktion).

Table 4-23 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 2018/2B8b Ethen-Produktion). Therefore, CH_4 emissions are reported as NA for ethylene production and only CO_2 and NMVOC emissions are reported.

The CO_2 emissions from the cracker reported in source category 2B8b Ethylene production are based on a mass balance condisering all feedstocks, products and by-products.

Therefore, the NMVOC emissions are no longer included in the calculation of the indirect CO_2 emissions from sector 2 IPPU in order to avoid double counting.

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 (2016) (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 2018/2B8b Ethylene production).

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 4-24 Emission factors for CO_2 and NMVOC in ethylene production, NMVOC in acetic acid production, CO_2 in limestone pit and niacin production and SO_2 in sulphuric acid production for 2015 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

Table 4-25 CO_2 fossil emission factors in 2B8b Ethylene are documented in the confidential NIR, which is available to reviewers on request.

Activity data

Activity data on the annual production of ethylene are provided annually by the single ethylene production plant in Switzerland. Since 2013, activity data are taken from annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

The data are considered confidential but available to reviewers on request.

Table 4-26 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	2005
2B8 Petrochemical and carbon black production					
2B8b Ethylene	kt	C	C	C	C
2B10 Other					
Acetic acid production	kt	30	27	24	8
Limestone pit	kt	C	C	C	C
Niacin production	kt	C	C	C	C
PVC production	kt	43	43	NO	NO
Sulphuric acid production	kt	C	C	C	C

	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
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	9	18	28	20	18	12	C	C	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	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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 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.

Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

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 (2016) (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 2018/2B10 Essigsäure-Produktion.

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 4-27 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 2018/2B10 Essigsäure-Produktion (see Table 4-26).

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 CO_2 emissions from the limestone pit are determined by Tier 2 method using plant-specific emission factors..

Emission factors

The CO_2 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 2018/2B10 Kalksteingrube. For the years 2005-2011 and since 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 2015.

Activity data is considered confidential but available to reviewers on request.

Niacin production (2B10)

CO_2 emissions from niacin production of the single manufacturer in Switzerland are reported since submission 2014. CO_2 is released in the last reaction step of the niacin production.

Methodology

In order to determine emissions of CO_2 from niacin production, a country-specific method analogous to a Tier 2 method according to the IPCC 2006 guidelines (vol. 3) is used.

Emission factors

The CO_2 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 2018/2B10 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 2018/2B10 Niacin-Produktion. For the years 2005-2011 and since 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.

Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

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 (2016) (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 2018/2B10 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 2018/2B10 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 2018/2B10 Schwefelsäure-Produktion and EMIS 2018/2B10 PVC-Produktion (see Table 4-26). 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 in source category 2B are estimated to be medium, (see Table 1-11 Semi-quantitative uncertainties for non-key categories) resulting in a relative uncertainty of 10%. For CH_4 a combined uncertainty of 20% is estimated.

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 chp. 1.2.3.

4.3.5 Category-specific recalculations

The following recalculations were implemented in submission 2018. Recalculations that cause a change in emission levels 1990 and 2015 of at least 0.3 kt CO_2 eq are quantified. All the other recalculations have an impact of less than 0.3 kt CO_2 eq in the years 1990 and 2015.

Major recalculations which contribute significantly to the total differences in direct CO_2 and CH_4 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:

- 2B5: The last year's extrapolated activity data and emission factors from 2B5 Silicon carbide production have been revised based on industry data resulting in an increase in emissions of 0.5 kt CO_2 eq (CO_2: 0.4 kt, CH_4: 0.1 kt CO_2 eq).

Further recalculations:

- 2B8: The CO_2 emissions from the cracker reported in source category 2B8b Ethylene production are based on a mass balance considering all feedstocks, products and by-products. Therefore, the NMVOC emissions are no longer included in the calculation of the indirect CO_2 emissions from sector 2 IPPU in order to avoid double counting.

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

Table 4-28 Key categories of 2C Metal industry. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
2C3	Aluminium production	CO2	T1
2C3	Aluminium production	PFC	T1

Table 4-29 Specification of source category 2C Metal industry in Switzerland.

2C	Source	Specification
2C1	Iron and steel production	Emissions of CO_2, NOx, CO, NMVOC and SO_2 from the production of iron and steel
2C2	Ferroalloys production	Production is not occuring in Switzerland
2C3	Aluminium production	Emissions of PFC, CO_2, NOx, CO, NMVOC, and SO_2 from the production of primary aluminium (ceased in 2006). Emissions from use of SF_6 in aluminium foundries.
2C4	Magnesium production	Emissions from use of SF_6 in magnesium foundries
2C7	Other	Emissions of CO and NMVOC from non-ferrous metal foundries Emissions of CO_2, NOx, 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 CO_2 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 SO_2 occur as well.

In Switzerland, no production of pig iron occurs but iron is processed in foundries only. Today, there exist about 14 iron foundries in Switzerland. About 75% of the iron is processed in induction furnaces and 25% in cupola furnaces. From induction furnaces only precursors are emitted. In cupola furnaces also CO_2 emissions from other bituminous coal occur. Other bituminous coal acts first of all as fuel but also as carburization material and reductant. Therefore it was decided to report those CO_2 emissions in source category 1A2a. Geogenic CO_2 emissions from use of limestone in cupola furnaces are reported in 2A4d Other process uses of carbonates.

The CO_2 emissions from 2C1 Secondary steel production, electric arc furnace are based on a carbon mass balance considering all carbon sources and sinks of the process. Therefore, the emissions of CO and NMVOC are no longer included in the calculation of the indirect CO_2 emissions from sector 2 IPPU in order to avoid a double counting.

Methodology

For determination of CO_2 emission from iron and steel production a mixture of a Tier 2 (before 2005 and for 2012) and a Tier 3 method (2005-2011 and since 2013) 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 from 2013 onwards 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 CO_2 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 CH_4 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 (2016) using country-specific emission factors (EMIS 2018/2C1).

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 2018/2C1 Eisengiessereien Elektroschmelzofen/übriger Betrieb, EMIS

2018/2C1 Stahl-Produktion Elektroschmelzöfen and EMIS 2018/2C1 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 from 2013 onwards were taken into account. Based on these carbon mass balances, a mean plant-specific CO_2 emission factor results. The reported CO_2 emission factor for Swiss steel industry is the production-weighted average. Consequently, there are no indirect CO_2 emissions to be accounted for in chp. 9 Indirect CO_2 and N_2O emissions for source category 2C1.

The plant-specific data are confidential but available to reviewers on request.

Table 4-30 CO_2 emission factor of electric arc furnaces in 2C1 Steel production in kg/t.

2C1 Steel production	Unit	1990	1995	2000	2005
CO_2	kg/t	8.3	8.0	7.7	8.8

2C1 Steel production	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CO_2	kg/t	8.5	6.8	6.8	7.6	7.1	7.9	8.5	8.2	8.6	8.8

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, SO_2, 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 4-31 Emission factors for NO_x, CO and NMVOC in iron production, for CO_2, NO_x, CO, NMVOC and SO_2 in steel production, for CO and NMVOC in non-ferrous metal production and for CO_2, NO_x, CO and SO_2 in battery recycling for 2016.

2C Metal industry	Unit	CO_2	NO_x	CO	NMVOC	SO_2
2C1 Iron production	kg/t	IE	0.01	4.1	4	NA
2C1 Steel production	kg/t	8.8	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	C	C	C	C	C

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 4-32 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	2005
2C1 Iron production	kt	170	130	120	67
2C1 Steel production	kt	1'108	716	1'022	1'159
2C3 Aluminium production	kt	87	21	36	45
2C7a Non-ferrous metals	kt	55	60	70	33
2C7c Battery recycling	kt	C	C	C	C

2C Metal industry	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2C1 Iron production	kt	72	78	49	53	61	46	45	43	37	34
2C1 Steel production	kt	1'267	1'315	935	1'218	1'322	1'252	1'231	1'315	1'296	1'238
2C3 Aluminium production	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C7a Non-ferrous metals	kt	28	21	15	20	12	18	6.8	7.4	6.8	6.6
2C7c Battery recycling	kt	C	C	C	C	C	C	C	C	C	C

4.4.2.2 Aluminium production (2C3)

Methodology

The last production site for primary aluminium in Switzerland closed down in April 2006. According to the 2006 IPCC Guidelines (IPCC 2006, vol. 3, chp. 4.4, fig. 4.11), CO_2 emissions are 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 in the year 2003 part of the SF_6 imports to be related to the aluminium industry, referring to cleaning processes in foundries. The 2006 IPCC Guidelines mention use of SF_6 in aluminium production for magnesium alloys on a low scale but do not provide further information for evaluation. Accordingly, the same evaluation methodology as for magnesium foundries with an emission factor based on a Tier 2 method is applied.

Emission factors

The emission factor for CO_2 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 2018/2C3 Aluminium Produktion). CO_2 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. Therefore, there are no indirect CO_2 emissions to be accounted for in chp. 9 Indirect CO_2 and N_2O emissions from CO emissions of primary aluminium production. But as the NMVOC emissions originate solely from the production of the electrodes at the plants they have to be considered for the calculation of the indirect CO_2 emissions in chp. 9.

Before the close down of the only Swiss primary aluminium factory in 2006, PFC emission factors of operating smelters have been monitored periodically. Measurements made in 1990, 1999 and 2000 reported EFs in kg per tonne of 0.17, 0.06 and 0.04, respectively, for those three years (Alcan 2003). This was reported to be lower than the European averages, by factors of 3.9, 4.7 and 5.1, respectively. For other years no measurements have been made; thus, European Union (EU) average EFs have been used, multiplied by a factor of 0.25 (Alcan 2002). Figure 4-6 shows the resulting development of the EF for PFC over time. The European average has been decreasing over 60% from 0.68 kg PFC per t Aluminium to 0.16 kg PFC per t Aluminium between 1990 and 2000.

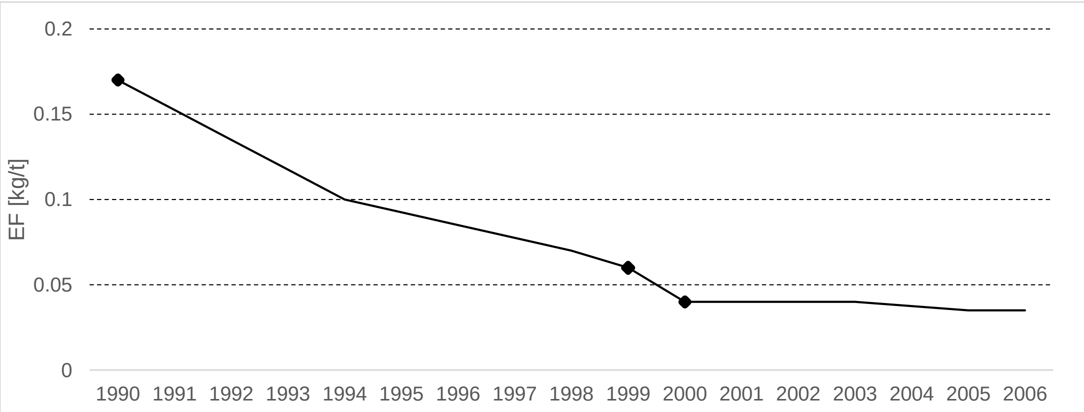


Figure 4-6 Extrapolation of PFC emission factor based on measurements in 1990, 1999 and 2000. The path for the reduction between measurements and the stagnation after the last measurements reflects the observed development in the European Union.

There is no documentation of the measurements. Due to the close down in 2006 it is not possible to redo any measurements or to collect any information about the process details retroactively. Measurement results and development of EFs are assumed to be plausible because the factory used point feed prebake (PFPB) technology which is known for the lowest emissions per tonne of aluminium. The resulting emission factors for Switzerland are within the uncertainty range according to the 2006 IPCC Guidelines (variations by a factor of 10 using same technologies). The comparison with data from IAI (2005) on global PFC emissions from aluminium production showed that the monitored emissions from the smelter in Switzerland were lower by a factor of about 4.

Table 4-33 PFC emission factors for aluminium production in Switzerland. Aluminium production in Switzerland ceased in 2006.

Gas	Unit	1990	1995	2000	2005
CF_4	kg/t	0.1530	0.0833	0.0360	0.0315
C_2F_6	kg/t	0.0170	0.0093	0.0040	0.0035

Gas	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CF_4	kg/t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C_2F_6	kg/t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

There are no measurements of SF_6 emissions available from aluminium foundries to identify the fraction of SF_6 destroyed or transformed in the cleaning process. For SF_6 used in aluminium foundries (2C3) it is therefore assumed that the total imported amount is emitted, in accordance with the default emission factor (1000 kg per tonne of imported substance) of the 2006 IPCC Guidelines (IPCC 2006).

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 4-32.

Activity data on SF_6 used in aluminium foundries (2C3) is derived from import data from FOEN statistics. Import companies indicated in the year 2003 a portion of SF_6 imports for foundries to be used for aluminium cleaning. 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 2004 the mean value of 2003 and 2004 import data are used). It is assumed that the total imported amount is emitted within one year. In 2011, a study was carried out among members of the Swiss Foundry Association (GVS), confirming that SF_6 is not used any more in aluminium foundries. As no details on the imported amount are available for the time period 2003–2011, a steady decrease of the import amount of SF_6 is assumed from 2003 until the final elimination of SF_6 for aluminium cleaning in 2011. This assumption is based on the above-mentioned survey and on information obtained on applications within the category ‘others’ from FOEN import statistics.

4.4.2.3 Magnesium production (2C4)

Use of SF_6 in magnesium foundries (2C4)

SF_6 is used in Swiss magnesium foundries since 1997. There have been two magnesium foundries known to be using SF_6. In 2007 one of them closed down. A survey carried out 2011 among members of the Swiss Foundry Association (GVS) confirmed that only one company is using SF_6.

A phase-out of SF_6 is excpected in 2016 due to existing regulations of F-Gas use.

Methodology

SF_6 is used in 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 SF_6 emissions available to identify the fraction of SF_6 destroyed or transformed in the process. For SF_6 used in magnesium foundries (2C4) it is therefore assumed that the total imported amount is emitted, in accordance with the default emission factor (1000 kg per tonne of imported substance) of the 2006 IPCC Guidelines (IPCC 2006).

Activity data

Activity data on SF_6 used in magnesium foundries (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 2016 the mean value of 2015 and 2016 import data are used). It is assumed that the total imported amount is emitted within one year. The import of SF_6 ceased in 2016. Part of the import of the preceding year were considered for the phase-out 2016.

The last magnesium foundry using SF_6 reported consumptions between 2008 to 2015 to the SWISSMEM statistics. The information is in accordance with import data from FOEN statistics.

4.4.2.4 Other (2C7)

Battery recycling and non-ferrous metal foundries (2C7)

There is one battery recycling plant in Switzerland. The recycling is done by applying the Sumitomo process. The batteries are first pyrolised at temperatures of 700°C in a reducing atmosphere in a shaft kiln. The gas with the carbonised components then goes to a post-combustion step where it is completely oxidised at temperatures of 1000°C. The flue gas is then 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.

Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

Methodology

To determine emissions of CO_2, NO_x, CO and SO_2 from battery recycling and of CO and NMVOC from non-ferrous metal foundries, Tier 2 methods according to EMEP/EEA Guidebook 2016 (EMEP/EEA 2016, chp. 2C7c and 2C7a) with country-specific emission factors are used.

Emission factors

The emission factors of CO_2, NO_x, SO_2, CO from battery recycling between 1990 and 2002 are based on measurements in 2003 as well as mass balances of the single recycling site and are assumed constant. Since 2003 they are based on air pollution control measurements from 2003 and 2012 and are assumed constant during this time period. Emission factors of NMVOC are also based on air pollution control measurements from 2003 and 2012 and are reported for the first time in submission 2017. They are assumed constant for the entire time period (EMIS 2018/2C7 Batterie-Recycling).

Emission factors 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 (2017/2C7 Buntmetallgiessereien Elektroöfen) (see Table 4-31). Emission factors are confidential. They are available to reviewers on request.

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 2018/2C7 Batterie-Recycling and 2017/2C7 Buntmetallgiessereien Elektroöfen). Activity data are confidential. They are available to reviewers on request.

4.4.3 Uncertainties and time-series consistency

The uncertainty of CO_2 emissions in 2C1 Iron and steel production amounts to 5.4%. Production data of the steel industry have a high confidence and its uncertainty is estimated at 2%. The uncertainty for the CO_2 emission factor is estimated at 5%.

For the emission of CO_2 and PFC from 2C3 Aluminium production, which is a key category for both gases, combined uncertainties of 20.6 % and 9%, respectively, are determined. The emission factor uncertainty for CO_2 and PFC are estimated to be 20% and 6.4%, respectively. The uncertainty in the activity data is estimated to be 5% for CO_2 emissions and 6.4% for PFC emissions.

For the emissions of SF_6 from the use in 2C4 Magnesium the combined uncertainty is estimated at 27.7%.

The uncertainty of CO_2 emissions from source category 2C7 Other is estimated to be 20% (expert estimate).

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 chp. 1.2.3.

4.4.5 Category-specific recalculations

The following recalculations were implemented in submission 2018. These recalculations cause a change in emission levels 1990 or 2015 by less than 0.3 kt CO_2 eq.

- 2C1: The activity data of the rolling mills in 2C1 Steel production have been revised from 2013 onwards.

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

Source category 2D – Non-energy products from fuels and solvent use is not a key category.

Table 4-34 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

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 of road and non-road vehicles are primarily used for their lubricating properties and associated GHG emissions are therefore considered as non-combustion emissions reported in 2D1 Lubricant use. Only lubricants blended into gasoline for 2-stroke engines are assumed to be fully oxidised.

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

Emissions from the use of lubricants in 2-stroke engines (road and non-road vehicles) are calculated by a Tier 1 method and default emissions factors according to the decision trees in IPCC 2006, vol 2, chp. 3, Figure 3.2.2 and Figure 3.2.3) assuming that the lubricants are fully oxidised (as described in chp. 3.2.9.2.2).

CO_2 emissions from oxidation of all other 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 for lubricants used in 2-stroke vehicles are based on the default emission factor and the net calorific value from 2006 IPCC Guidelines (vol. 2, chp. 2 Stationary combustion, Table 2.2 and chp.1, Table 1.2, respectively), see Table 4-35 and EMIS 2018/2 D 1_Schmiermittel-Verbrauch B2T.

The emission factors of CO_2 from all other lubricant and paraffin wax use in Switzerland are based on default IPCC values for NCV, carbon content and oxidation fraction documented in vol. 2, chp.1 and vol. 3, chp. 5.2 and 5.3, respectively, of IPCC 2006, see also EMIS 2018/2D1 Lubricant use and EMIS 2018/2D2 Paraffin wax use.

Table 4-35 CO_2 emission factor of 2D1 Lubricant use and 2D2 Paraffin wax use for 2016 in kg/t.

	Unit	CO_2	CH_4	N_2O
2D1 Lubricant use				
in two-stroke engines	kg/t	2'948	0.12	0.024
unspecified	kg/t	590	NA	NA
2D2 Paraffin wax use	kg/t	590	NA	NA

Note that by applying the emission CH_4 and N_2O factors for lubricant use in 2-stroke engines, a potential double-counting might occur. See remark in chp. 3.2.9.2.2, below paragraph “Methodology of the territorial road transportation model”: Non-CO_2 emissions from lubricant use are included in the road and the non-road transportation model, since the emission factors are deduced from measurements on motorcylces including 2-stroke engines. If a double-counting occurs or not will be analysed for the next submission (see planned improvements, chp. 4.5.6).

Activity data

The annual amount of lubricant and paraffin wax used in Switzerland is derived from the Swiss petroleum association (EV 2017). The consumption of lubricants of Liechtenstein, which forms a customs union with Switzerland, is subtracted from the consumption reported by the Swiss petroleum association. The resulting amount is further differentiated between application in two-stroke engines and unspecified use. The amount of lubricants corresponds to 2% of total gasoline consumption of all two-stroke engines based on the road and non-road transportation models (INFRAS 2017a, INFRAS 2015a).

Table 4-36 Use of lubricants in Switzerland.

	Unit	1990	1995	2000	2005
2D1 Lubricant use					
in two-stroke engines	kt	0.6	0.4	0.5	0.4
unspecified	kt	79	61	62	72
2D2 Paraffin wax use	kt	11	10	12	10

	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2D1 Lubricant use											
in two-stroke engines	kt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2
unspecified	kt	70	65	51	55	53	51	53	53	51	51
2D2 Paraffin wax use	kt	9	9	6	5	5	3	4	4	4	3

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 2016 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. 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 2016. Indirect CO_2 emissions resulting from NMVOC emissions in this source category are only included in CRF Table6 and reported in chp. 9.

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 CO_2 emissions from post-combustion of NMVOC are estimated based on industry data and expert estimates (Carbotech 2017a).

Post-combustion of NMVOC (2D3a)

Methodology

The CO_2 emissions from post combustion of NMVOC are calculated by a Tier 2 method using country-specific emission factors. Emissions are calculated based on the amount of NMVOC (and their carbon content) destroyed in the respective combustion facility of more than 100 industrial plants (Carbotech 2017a). Post combustion facilities are applied in source categories industrial paint applications (NFR code 2D3d), metal degreasing (NFR code 2D3e) and chemical products (NFR code 2D3g). These amounts of NMVOC eliminated by post-combustion are also declared in the respective VOC balances of the industrial plants and are thus, not included as NMVOC emissions. When deriving the NMVOC emission factors for these source categories, the amount of NMVOC destroyed in post-combustion facilities is taken into account, i.e. the NMVOC emission factor is reduced accordingly.

Emission factors

Emission factors are derived from the composition of solvents. For installation with no information on the solvent composition a default carbon content of 50% is assumed.

Activity data

Activity data are provided by the industry. For the ten most important installations, activity data are provided annually.

Coating applications (2D3d NFR)

Methodology

For the determination of NMVOC emissions from coating applications a Tier 2 method according to the EMEP/EEA Guidebook 2016 is used based on the consumption of paints, lacquers, thinners etc. and their solvent content. Switzerland's Informative Inventory Report 2018 contains a detailed description of the methods and country-specific data used for estimating the NMVOC emissions from 2D3d NFR Coating applications (FOEN 2018f).

Emission factors

Emission factors for NMVOC are based on data from VSLF and retailers as documented in the EMIS database (EMIS 2018/2D3d NFR). In recent years, values of all emission factors for coating applications declined as a result of both a reduction of the solvent content and replacing of solvent based paint by water based paint due to increasingly strict NMVOC regulations by the EU directive (EC 2004). In addition, powder coatings, which are far more efficient, replaced in this time period the conventional paint (rough estimate: 1 t of powder coating replaces 3 t of conventional paint).

For 2D3d NFR Paint application in construction the emission factor of NMVOC is based on a case study by VSLF in 2005 and expert estimates.

Table 4-37 NMVOC emission factors of coating applications, degreasing, dry cleaning, chemical products, manufacture and processing in 2D3a Solvent use for 2016.

2D3a Solvent use	Unit	NMVOC
Coating applications (2D3d NFR)		
Paint application, construction	kg/t paint	55
Paint application, households	kg/t paint	85
Paint application, industrial & non-industrial	kg/t paint	282
Paint application, wood	kg/t paint	289
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	3.5
Glue production	kg/t glue	0.8
Handling and storing of solvents	t/production index	1.8
Ink production	kg/t ink	8.4
Paint production	kg/t paint	3.4
Pharmaceutical production	kg/t pharmaceutical	7.6
Polyester processing	kg/t polyester	50
Polystyrene processing	kg/t polystyrene	16
Polyurethane processing	kg/t polyruethane	3.5
PVC processing	kg/t PVC	4.0
Rubber processing	kg/tyres	0.14
Tanning of leather	kg/employee	0.68

Activity data

The activity data correspond to the annual consumption of paints. The consumption and solvent content are estimated according to information from the Swiss association for coating and paint applications (VSLF) and in addition from relevant retailers for paint applications in households (EMIS 2018/2D3d NFR). Between 1990 and 1998, the total consumption of paint decreased considerably and increases continuously again since 2001. This trend results from the opposing trends in the different source categories:

- 2D3d NFR Paint application, construction: Activity data of paint application in construction show a substantial reduction compared to 1990 levels. The increasing tendency in paint application since 2000 can be explained by an increase in the construction activity in Switzerland. Since 2000, the expenditures on construction have increased and are thus contributing to an increase in paint application in construction. Before 2000, there was a decline in construction activity, which explains the decreasing tendency in paint application.
- 2D3d NFR Paint application, industrial & non industrial: Between 1990 and 2016, the activity of industrial and non-industrial paint application decreased significantly. There was a clear decrease between 2001 and 2004 due to structural changes in the industrial sectors and a widespread application of powder coatings from 2004 onwards. Since powder coatings are solvent-free their amounts are not included in the activity data.
- 2D3d NFR Paint application, households: Activity data of paint application in households has more than doubled between 1990 and 2016 due to an increase in demand. The

number of private households increased since 1990, thus leading to an increasing tendency in paint application in the household sector.

Table 4-38 Activity data of coating applications, degreasing, dry cleaning and chemical products, manufacture and processing in Switzerland.

2D3a Solvent use	Unit	1990	1995	2000	2005
Coating applications (2D3d NFR)					
Paint application, construction	kt	122	66	33	42
Paint application, households	kt	12	13	13	20
Paint application, industrial & non-industrial	kt	20	21	21	5.7
Paint application, wood	kt	6.0	6.3	6.5	7.7
Paint application, car repair	kt	2.7	2.2	2.0	1.9
Degreasing (2D3e NFR)					
Cleaning of electronic components	kt	0.90	0.56	0.35	0.64
Degreasing of metal	kt	16	10	5.9	2.6
Other industrial cleaning	kt	0.6	0.6	0.6	1.4
Dry cleaning (2D3f NFR)	kt	1.30	1.01	0.72	0.43
Chemical products, manufacture and processing (2D3g NFR)					
Fine chemicals production	prod. index	70	100	163	224
Glue production	kt	19	32	44	60
Handling and storing of solvents	prod. index	70	100	163	224
Ink production	kt	20	18	18	18
Paint production	kt	138	122	117	122
Pharmaceutical production	kt	16	21	20	28
Polyester processing	kt	11	7	6	7
Polystyrene processing	kt	20	19	19	24
Polyurethane processing	kt	17	35	45	54
Production of adhesive tape	kt	2	NO	NO	NO
PVC processing	kt	94	94	78	64
Rubber processing	tyres	120'000	119'375	103'667	67'000
Tanning of leather	employees	110	108	102	88

2D3a Solvent use	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Coating applications (2D3d NFR)											
Paint application, construction	kt	45	48	51	54	56	59	61	61	61	61
Paint application, households	kt	20	23	25	28	28	28	28	28	29	29
Paint application, industrial & non-industrial	kt	5.9	5.7	5.5	5.3	5.2	5.1	5.0	5.0	5.0	5.0
Paint application, wood	kt	8.0	8.7	9.3	10.0	10.0	10.0	10.0	10.1	10.3	10.4
Paint application, car repair	kt	1.8	1.8	1.7	1.7	1.5	1.4	1.2	1.2	1.3	1.3
Degreasing (2D3e NFR)											
Cleaning of electronic components	kt	0.57	0.60	0.63	0.67	0.70	0.73	0.73	0.73	0.73	0.73
Degreasing of metal	kt	2.4	2.3	2.2	2.1	2.0	1.9	1.9	1.9	1.9	1.9
Other industrial cleaning	kt	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Dry cleaning (2D3f NFR)	kt	0.32	0.26	0.20	0.14	0.09	0.03	0.03	0.03	0.03	0.03
Chemical products, manufacture and processing (2D3g NFR)											
Fine chemicals production	prod. index	283	280	295	314	299	302	305	307	310	313
Glue production	kt	64	64	64	63	63	63	62	62	62	61
Handling and storing of solvents	prod. index	283	280	295	314	299	302	305	307	310	313
Ink production	kt	19	19	19	19	21	24	26	26	26	25
Paint production	kt	125	125	126	126	126	126	126	125	124	123
Pharmaceutical production	kt	29	29	30	30	30	30	30	31	31	31
Polyester processing	kt	7.6	6.2	4.8	3.4	3.5	3.7	3.7	3.7	3.7	3.7
Polystyrene processing	kt	26	29	31	34	36	31	32	32	33	33
Polyurethane processing	kt	70	67	52	54	40	40	38	38	37	37
Production of adhesive tape	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PVC processing	kt	78	73	62	52	55	40	38	37	36	35
Rubber processing	tyres	70'000	72'500	75'000	77'500	80'000	80'000	81'000	82'000	83'000	84'000
Tanning of leather	employees	87	87	87	87	87	86	85	85	84	83

Degreasing and dry cleaning (2D3e NFR, 2D3f NFR)

Methodology

Source category 2D3e NFR comprises emissions from degreasing of electronic components, metal and other industrial cleaning. For the determination of NMVOC emissions from degreasing and dry cleaning a Tier 2 method according to the EMEP Guidebook (EMEP/EEA 2016) is used based on the consumption of solvents. Switzerland's Informative Inventory Report 2018 contains a detailed description of the methods and country-specific data used for estimating the NMVOC emissions from 2D3e NFR Degreasing and 2D3f NFR dry cleaning (FOEN 2018f).

Emission factors

Emission factors for NMVOC emissions from degreasing are based on data from the association of Swiss mechanical and electric engineering industries (swissmem) including VOC balance evaluations in 2004, 2007 and 2012 and expert estimates as documented in the EMIS database (EMIS 2018/2D3e NFR). For emission factors in 2015 see Table 4-37.

NMVOC emission factors for dry cleaning are estimated based on data and information from a survey of selected dry cleaning facilities that are representative for Swiss dry cleaning factilities and import statistics as documented in the EMIS database (EMIS 2018/2D3f NFR).

Activity data

Activity data of degreasing correspond to the annual consumption of solvents used for degreasing. Data are based on data from the association of Swiss mechanical and electric engineering industries (swissmem) in 2004, 2007 and 2012, VOC balances, import statistics and expert estimates, documented in the EMIS database (EMIS 2018/2D3e NFR)). A comparison between the surveys and the evaluations of VOC balances showed an underestimation of the survey data by about 6%. Thus, the emissions based on survey data from the industry association (swissmem) have been corrected by +10%. Activity data is provided in Table 4-38.

For dry cleaning, activity data is based on the amount of tetrachloroethylene (PER) and non-halogenated solvents imported and estimates of the share used for dry cleaning. Activity data for 2012 are based on the most recent survey at cantons and cleaning facilities as well as data from the Swiss supervising association of textile cleaning (VKTS). Activity data for 1990 are based on net imports of PER. For the years in between, data are interpolated linearly and after 2012, the activity data are assumed to remain constant, as documented in the EMIS database (EMIS 2018/2D3f NFR).

Chemical products, manufacture and processing (2D3g NFR)

Methodology

Based on the decision tree Fig. 3.1 in chapter 2D3g in EMEP/EEA (2016), for source category 2D3 Chemical products a Tier 2 method using country-specific emission factors is used for calculating the NMVOC emissions. Switzerland's Informative Inventory Report 2018 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 2018f).

Emission factors

Emission factors for NMVOC are mainly provided by industry associations, i.e. for

- fine chemicals production, pharmaceutical production and handling and storing of solvents: Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries)
- paint and ink production: Swiss association for coating and paint applications (VSLF) and the Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV)
- polyurethane processing: Swiss plastics association
- polyester processing: Swiss polyester association
- tanning of leather: Swiss leather tanning association.

For the other processes in source category 2D3 (2D3g NFR) data are based on information from the industry and expert estimates as documented in the EMIS database.(EMIS 2018/2D3g). For emission factors see Table 4-37.

Activity data

The activity data are mainly production or consumption data provided by industry associations and by the Swiss Federal Office of Statistics, i.e. for

- fine chemicals production and handling and storing of solvents: Swiss Federal Office of Statistics
- pharmaceutical production: Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries)
- paint and ink production: Swiss association for coating and paint applications (VSLF) and Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV)
- polyurethane processing: Swiss plastics association
- polyester processing: Swiss polyester association
- tanning of leather: Swiss leather tanning association.

For the other processes in source category 2D3 (2D3g NFR) data are based on information of from the industry and expert estimates as documented in the EMIS database. Since 1994 no production of adhesive tape is occurring in Switzerland anymore.

For activity data see Table 4-38.

Road paving with asphalt (2D3b)

Methodology

Asphalt road surfaces are composed of compacted aggregate and asphalt binder. From road surfacing operations only NMVOC emissions occur. Based on the decision tree Fig. 3.1 in chapter 2D3b in EMEP/EEA (2016), the NMVOC emissions from 2D3b Road paving with asphalt are determined by a Tier 2 method based on country-specific emission factors as documented in EMIS 2018/2D3b NFR.

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 4-39 Emission factors of 2D3b Road paving with asphalt and 2D3c Asphalt roofing for 2016.

	Unit	CO	NMVOC
2D3b Road paving	kg/t asphalt concrete	NA	0.54
2D3c Asphalt roofing	kg/t asphalt sealing sheeting	0.01	5.5

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 4-40 Activity data for road paving with asphalt, asphalt roofing and urea use in SCR catalysts.

	Unit	1990	1995	2000	2005
2D3b Road paving with asphalt					
Asphalt concrete	kt	5'500	4'800	5'170	4'780
2D3c Asphalt roofing					
Asphalt sealing sheeting	kt	54.0	55.9	57.7	50.7
2D3d Urea use in SCR catalysts					
AdBlue	kt	NO	NO	NO	0.3

	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2D3b Road paving with asphalt											
Asphalt concrete	kt	5'100	5'160	5'200	5'250	5'300	4'770	4'770	5'260	4'850	4'710
2D3c Asphalt roofing											
Asphalt sealing sheeting	kt	48.0	54.5	61.0	67.5	74.0	73.6	73.3	72.9	72.6	72.2
2D3d Urea use in SCR catalysts											
AdBlue	kt	5.7	10.0	14.4	17.7	20.0	21.6	23.1	24.2	25.6	28.1

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). Based on the decision tree Fig. 3.1 in chapter 2D3c in EMEP/EEA (2016), the emissions of NMVOC from Asphalt roofing are determined by a Tier 2 method based on country-specific emission factors as documented in the EMIS database (EMIS 2018/2D3c Dachpappen Produktion und Verlegung). Emissions of CO are determined based on a Tier 1 method using the default emission factor (EMEP/EEA 2016).

Indirect CO_2 emissions resulting from CO and NMVOC emissions in this source category are only included in CRF Table6 and reported in chp. 9.

Emission factors

The NMVOC emission factors from Asphalt roofing are based on information from the industry association, literature and expert estimates as documented in the EMIS database. Tier 1 emission factors of CO and PM10 are taken from the EMEP/EEA Guidebook 2016 (EMEP/EEA 2016) (see Table 4-39).

Activity data

Activity data is based on data from industry and expert estimates as documented in the EMIS database (see Table 4-40).

Urea use in SCR catalysts of diesel engines (2D3d)

This source category encompasses CO_2 emissions from the use of urea containing AdBlue in diesel engines with SCR-catalysts in road transportation (Euro V/VI and Euro 5/6).

Methodology

In accordance with the 2006 IPCC Guidelines the consumption of Ad Blue is reported in this submission following a methodology suggested in the EMEP/EEA guidebook 2016 (EMEP/EEA 2016; 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:

CO_2 Emissions = EF • FC • Share of SCR vehicles mileage • Specific urea share

"FC" relates to the fuel consumption in tonnes of the entire vehicle category. "Share of SCR vehicles mileage" implies the mileage share of SCR-vehicles in the entire vehicle category and "Specific urea share" comprises the percentage of fuel consumption, which relates to AdBlue (urea solution) consumption.

Emission factors

The emission factor for CO_2 emissions from urea use in SCR-catalysts in vehicles is a default value (EMEP/EEA 2016) considering the molecular mass conversion of urea into CO_2 during the reaction with water and the content of 32.5% of the aqueous AdBlue urea solution.

Activity data

Activity data on AdBlue consumption as well as annual mileage are provided by INFRAS (INFRAS 2017) on a yearly basis as documented in EMIS 2018/2D3d NFR Urea (AdBlue) Einsatz Strassenverkehr. For activity data see Table 4-40.

4.5.3 Uncertainties and time-series consistency

The uncertainty of total CO_2 emissions from the entire source category 2D – Non-energy products from fuels and solvent use is estimated to be 100% (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 chp. 1.2.3 and partly also in chp. 3.2.4.8.

4.5.5 Category-specific recalculations

The following recalculations were implemented in submission 2018. Recalculations that cause a change in emission levels 1990 and 2015 of at least 0.3 kt CO_2 eq are quantified.

Major recalculations which contribute significantly to the total differences in direct and indirect CO_2 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:

- 2D3: The double counting of CO_2 emissions from the cracking process at a chemical production plant has been corrected. Additionally to source category 2B8b Ethylene they were also reported erroneously under 2D3a Post-combustion of NMVOC from solvent use. This results in a reduction of CO_2 emissions of 10.3 and 10.1 kt in 1990 and 2015, respectively. This recalculation dominates the observed difference of CO_2 emissions shown in Figure 10-4.
- 2D3: AD from 2D3d Adblue use in road transportation was adapted to the new road-model. This leads to higher CO_2 emissions (4kt for the year 2015).

- 2D3: The survey on post-combustion of NMVOC from manufacture and processing of chemical products has been revised resulting in an increase of CO_2 emissions from 2D3a of NMVOC from solvent use of 0.7 and 0.6 kt in 1990 and 2015, respectively.
- 2D1: The lubricant blended into gasoline used in 2-stroke engines of motorcycles and non-road transportation is now assumed to be fully oxidized. Resulting CO_2 emissions of the oxidation of the lubricants are included in source category 2D1 Lubricant use. This results in an increase in emissions of 1.5 and 0.5 kt CO_2 eq in 1990 and 2015, respectively.
- 2D3: The so far four source categories of 2D3c Asphalt roofing covering the emissions from production and laying of shingles and primer have been merged to one source category. At the same time activity data and emission factors of NMVOC and CO have been revised for the entire time series.
- 2D3: The activity data and NMVOC emission factor of 2D3a Paint application, industrial and non-industrial have been revised from 2002 and 1999 onwards, respectively.

Further recalculations:

- 2D1: The activity data of 2D1 Lubricant use have been revised for the entire time series since the consumption of lubricants of Liechtenstein (customs union with Switzerland) is now subtracted from the consumption reported by the Swiss petroleum association. This results in a decrease in CO_2 emissions of 0.2 and 0.1 kt in 1990 and 2015, respectively.
- 2D3: The activity data of 2D3a Fine chemicals production, 2D3a Handling and storing of chemicals and 2D3a Pharmaceutical production have been changed for 2020 resulting in revised interpolated values for 2012-2015.
- 2D3: The activity data of 2D3a Ink production of has been changed for 2020 resulting in revised interpolated values for 2014-2015.
- 2D3: The activity data of 2D3c Asphalt roofing has been changed for 2020 resulting in revised interpolated values for 2012-2015.

4.5.6 Category-specific planned improvements

For 2D1 Lubricant use in 2-stroke-engines it will be analysed whether a double-counting occurs with CH_4 and N_2O emissions from 2-stroke engines of road and non-road vehicles reported in sector 1 Energy.

4.6 Source category 2E – Electronics industry

4.6.1 Source category description

Source category 2E Electronics industry is not a key category.

Source category 2E Electronics industry comprises HFC, PFC, NF_3 and SF_6 emissions from consumption of the applications listed below in Table 4-41.

Table 4-41 Specification of source category 2E Electronics industry in Switzerland.

2E	Source	Specification
2E1	Integrated circuit or semiconductur	Etching and cleaning processes in the production of IC and semiconductors (similar cleaning services for printed wiring boards included in the evaluation)
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 4-41 (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 and to obtain information on waste air treatment. Information was obtained on the type of substance used in different source categories, but no information on emission factors and type of efficiency of exhaust treatment. More information are available from Carbotech (2018).

Methodology

A Tier 2a approach with process gas-specific parameters is used for emission calculations. IPCC default values for the gas-specific transformation rate of different processes and general values for the 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 in Table 4-41 (Carbotech, 2018). As a result, the peak of NF_3 imports (and corresponding emissions) 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) and given limit of 5% for the emission factor in semiconductor use. 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 HFC, PFC, SF_6 and NF_3 in 2E Electronics industry is estimated at 51% (HFC), 63% (PFC), 62% (SF_6), 194% (NF_3) based on a Monte Carlo simulation.

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. The general QA/QC measures are described in chp. 1.2.3.

4.6.5 Category-specific recalculations

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

Table 4-42 Key categories of 2F Product uses as substitutes for ozone depleting substances. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
2F1	Refrigeration and air conditioning	HFC	L1, T1, L2, T2
2F2	Foam blowing agents	HFC	T2

Source category 2F Product uses as substitutes for ozone depleting substances comprises HFC and PFC emissions from consumption of the applications listed in Table 4-43.

Table 4-43 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. In 2016, stationary and mobile refrigeration and air conditioning equipment accounted by far for the highest emissions with a share of 97% of the total emissions in source category 2F. Further, emissions are dominated by HFCs and only a minor contribution comes from PFCs (generally less than 1%).

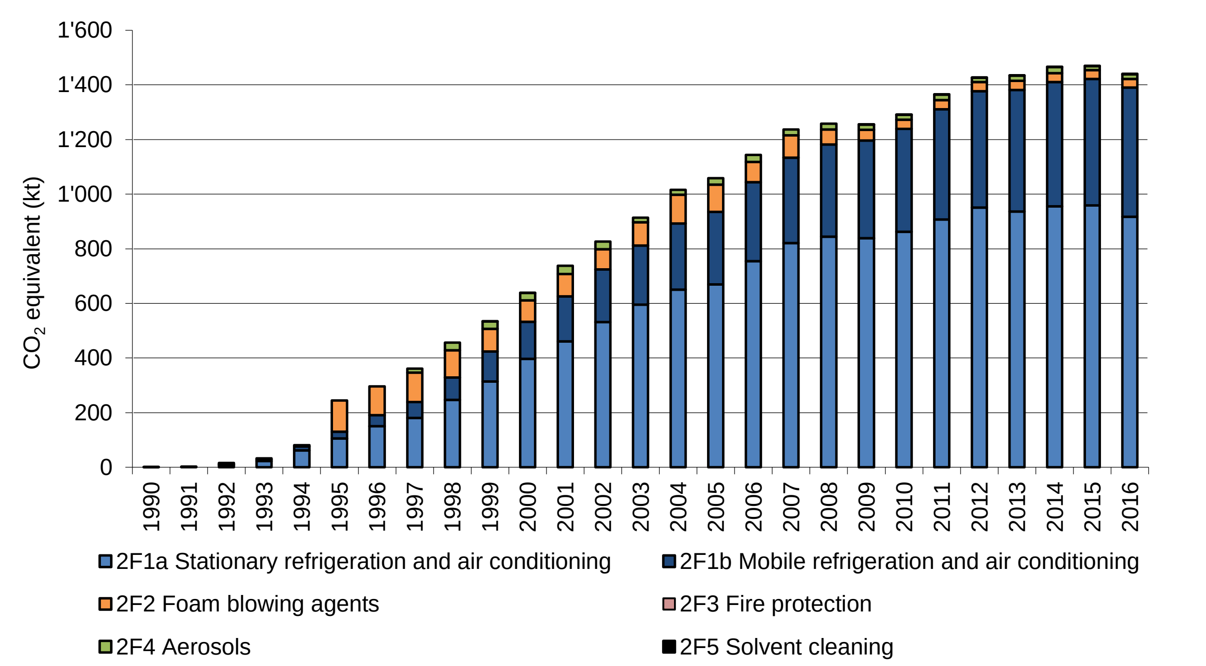


Figure 4-7 Development of emissions under source category 2F Product uses as substitutes for ozone depleting substances. HFC and small amounts of PFC are used as substitutes for ozone depleting substances. Most relevant today are emissions from the built up refrigerant stock in refrigeration and air conditioning equipment.

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. Most relevant is the contribution of 2F1 refrigeration and air conditioning. Calculations are carried out for different applications separately.

- 2F1a Stationary refrigeration and air conditioning
  - Domestic refrigeration
  - Commercial refrigeration
  - Industrial refrigeration
  - Stationary air conditioning, heat pumps and tumble dryers
- 2F1a Mobile refrigeration and air conditioning
  - Mobile air conditioning in different vehicle types
  - Transport refrigeration for different vehicle types

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 in Table 4-44. More information of the individual data and models is available from Carbotech (2018) 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 different applications and equipment types. For each individual emission, models are used for calculating actual emissions as per the 2006 IPCC Guideline's 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. For the following applications a 'bottom up' approach is applied relying on statistics, product informations and expert estimations:

- Domestic refrigeration
- Mobile air conditioning for different vehicle types
- Transport refrigeration for different vehicles types
- Stationary air conditioning (direct and indirect systems)
- Heat pumps
- Tumble dryers

On the other hand, a 'top down' approach is applied for the calculation of the stock in commercial and industrial equipment starting with the total imported amount of refrigerant. To determine the portion used for commercial and industrial refrigeration, the refrigerant consumption of other applications is subtracted from the import amount (consumption for the production and maintenance based on the bottom up calculations of stock as given in the example of mobile air conditioning in Annex A3.2).

Commercial and industrial refrigeration have been evaluated together so far. For the present submission calculations were carried out separately. To do so, the bulk refrigerant for commercial and industrial application was split for the entire time period of F-Gas use, considering typical use of refrigerant blends and information on commercial and industrial equipment provided to FOEN (Carbotech 2018). Parameters covering so far commercial and industrial applications were adapted accordingly (see Table 4-44).

The combination of 'bottom up' with 'top down' calculations leads to more comprehensive results than using just one approach. Noteworthy, in the hypothetical but possible case of incomplete 'bottom up' evaluations, remaining imported refrigerant would be attributed to the production and maintenance of industrial and commercial refrigeration equipment. This might be a reason why the resulting refrigerant stock of commercial and industrial refrigeration, which serves as the resuidual, tends to be higher than in neighbouring countries.

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. The split factor is based on the proportion of employees in the industrial and service sector (share of import for Liechtenstein <1%). The adjustment does not affect the bottom up calculations and leads to an adjustment of commercial and industrial refrigeration mainly.

Figure 4-8 shows the required data for the model calculation of refrigeration and air conditioning.

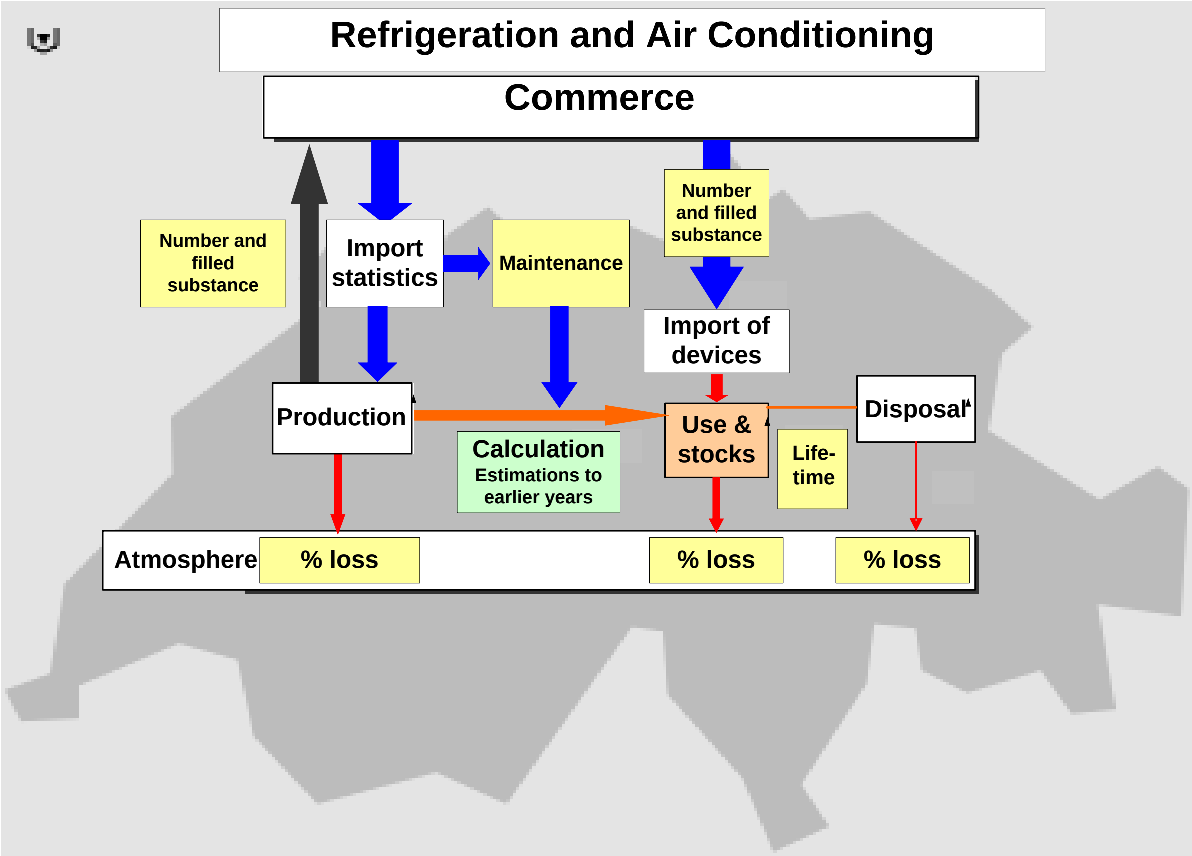


Figure 4-8 Required data for the model to calculate emissions from refrigeration and air conditioning in Switzerland.

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 to provide information to FOEN on the date of operation start, type of equipment, type and amount of refrigerant and date of disposal was introduced. This data source provides valuable information and has been used to improve the estimates used for modelling emissions under source category 2F and for the split of commercial and industrial equipment. However, it did not allow to directly draw the stock data or emission factors for the national inventory.

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 and has been used partly for the verification of quality (confidential data from retailers and other type of industry). The product life factors and further parameters (i.e. re-filling frequency, handling losses and reuse of refrigerant) are used to allocate imported F-gases to new products and maintenance activities.

Table 4-44 displays the detailed model parameters used for the present submission. Changes of model parameters within the period 1990 to 2016 are indicated with values in brackets. The parameters in brackets are applied for the inventory 2016. For product life emission factors of some equipment types, a dynamic model which implies that emission decrease linearly between 1995 and 2016 due to improved production technologies and the continuous sensibilisation of service technicians is applied. The start/end values are based on expert statements (UBA 2005, UBA 2007, Schwarz 2001, Schwarz and Wartmann 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 assumptions on the portion of broken equipment (100% loss) and on assumptions on disposal losses for professional recovery at site or waste treatment by specialized companies.

Table 4-44 Typical values of lifetime, charge and emission factors used in the model calculations for 1990 to 2016 for refrigeration and air conditioning equipment. Changes of model parameters within this time period are indicated with the new value 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 2016.

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	19 ****)
Commercial refrigeration	8	NR	0.5	Sinking from 12.5 in 1990 to 7.8 in 2015	80-90	NE	21
Industrial refrigeration	15	NR	0.5	Sinking from 10 in 1990 to 5 in 2015	75-90	NE	15
Transport refrigeration: trucks/vans	10	1.8-7.8	1.5	15	86	90	28
Transport refrigeration: wagons	16	NR	NO	10	100	NE	28
Stationary air conditioning: direct cooling systems	15	NR	3 (2005: 1)	Sinking from 10 in 1995 to 4 in 2010	74-89	NE	28
Stationary air conditioning: indirect cooling systems	15	NR	1	Sinking from 6 in 1995 to 4 in 2010	85-89	NE	19
Stationary air conditioning: heat pumps	15	4.7-7.5 (2000: 2.8-4.5)	3 (2005: 1)	2	86	NE	19
Stationary air conditioning: tumble dryers	15	0.4	0.5	2	74	NE	19
Mobile air conditioning: cars	15	Sinking from 0.84 1990 to 0.55 in 2014	NO	8.5	58	31-72 (2016: 48)	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	50	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 (export for reselling and secondhand use)

***) 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 8 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)

NE = Not estimated

Activity data

Activity data are taken from industry information and national statistics such as for admission of new cars, buses, vans 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 (CO_2 eq) of source category 2F1 Refrigeration and air conditioning in the inventory 2016.

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 with higher disposal values in model calculations compared to the FOEN disposal statistics. Some of the gap is explained by the onsite reuse and recycling of refrigerants, which is not reflected in the FOEN statistics and by other factors as e.g. the not accounted export of refrigeration equipment for secondhand use. Export rates used in model calculations are given in Table 4-44.

The registered refrigerant import is assumed to cover the consumption of Switzerland and Liechtenstein. To avoid double counting with the inventory data of Liechtenstein, the activity data for the equipment type commercial and industrial refrigeration is 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 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 4-45 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 imported. For PU rigid foams no HFCs are used as foam blowing agent (only pentane and CO_2). There has been no production of XPS in Switzerland with HFCs. XPS foams were 100% imported until 2010. In 2011 a new production facility was started which, however, does not use HFCs. The HFC import not related to the main applications above has been allocated to further unknown applications (possible use in the production of sandwich elements mentioned by an import company of foam blowing agents has not been confirmed).

Detailed activity data for this source category are available from Carbotech (2018) as well as related background documents 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 SF_6 in fire extinguishers is prohibited by law.

4.7.2.4 Aerosols (2F4)

Methodology

The Tier 2a emission model for Aerosol / MDI is based on a ‘top-down’ approach using import statistics for HFCs.

Emission factors

A manufacturing emission factor of 1% is applied. The model then assumes prompt emissions, i.e. 50% of the remaining substance is emitted in the first year and the rest in the second year, 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, but assumed to be in a similar range.

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 cover imported substances to be used in Switzerland and Liechtenstein, and are therefore split in proportion of inhabitants of the two countries to avoid double counting.

Emission factors

In line with the 2006 IPCC Guidelines prompt emissions are assumed, i.e. half of the initial amount is emitted in the first year, the other half in the second year.

Activity data

Activity data are based on import statistics. Imports before 2011 were included under solvents. Therefore, the model for allocation of imported PFC volumes was adjusted accordingly for substances related to the electronics industry. 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 2018). 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 4-46 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. Details on the distributions of parameters used (i.e. type of distribution, minimum, maximum, most likely value) are available from background documents at FOEN (Carbotech, 2018).

For the submission 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 1997–2015 led to the estimations of standard deviation and minimal and maximal values given in Table 4-46. A normal distribution is used in the Monte Carlo analysis and the standard deviation, minimal and maximal values applied to define the probability ranges.

Table 4-46 Estimated uncertainty for the data of the imported substances.

Year	Std. Dev.	Minimal	Maximal	Remarks
Up to 1999	20%	15%	50%	Assumed that the data is not complete
2000 – 2003	20%	20%	20%	Data can be incomplete or possible double declaration
2004 – 2016	10%	20%	20%	Data can be incomplete or possible double declaration

The probability range of parameters applied in the model calculation is defined based on the variation given in expert interviews and the literature. Table 4-47 illustrate the definition of ranges for the example of commercial refrigeration.

Table 4-47 Assumptions on probability ranges for the example of commercial refrigeration.

Parameter	appplied "likeliest"	Minimal	Maximal	Remarks
Initial charge of product	NR	NR	NR	Not relevant, calculated value
Manufacturing emission factor	0.5%	0.1%	3%	Triangular distribution
Prefilled import	25%	10%	40%	Normal distribution, StdDev5%
Product life emission factor 1990	12.5%	5%	20%	Normal distribution, StdDev5%
Product life emission factor 2016	7.8%	5%	15%	Lognormal distribution, StdDev2%
Recharge of product life emissions	80%	70%	100%	Triangular distribution
Product lifetime	8	7	15	Triangular distribution
Charge at end of life	NR	NR	NR	Not relevant, calcualted value
Disposal loss emission factor (professional disposal)	10%	1%	40%	Normal distribution, StdDev10%
Professional disposal	85%	45%	95%	Normal distribution, StdDev5%

Table 4-48 summarises the results for the application-specific emission models. The “value 2016” represents the reported emissions in kt CO_2 equivalent for the specific application for the year 2016. The uncertainty values stem from the Monte Carlo analysis. Detailed data are available from background documents at FOEN (Carbotech 2018).

The uncertainty of the resulting total emissions from source category 2F Product uses as substitutes for ODS is about 17%. Higher values result for the contributions of sub-categories and for single applications evaluated under 2F1. The calculated refrigerant amount for commercial and industrial refrigeration depends on the consumption of further refrigerant applications. Higher consumption for those applications lead to lower consumption in commercial and industrial applications and vice versa.

Relevant parameters for the building of stock in 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 uncertainty regarding the emission factor of the first year.

Table 4-48 Summary of results for model parameter “emissions” from Monte Carlo analysis for 2016 data on selected emission sources.

Application	Model para-meter	Value 2016 kt CO_2 eq.	Average kt CO_2 eq.	Median kt CO_2 eq.	min. kt CO_2 eq.	max. kt CO_2 eq.	Uncer-tainty %
2F1 Refrigeration and air conditioning	Emissions in kt CO_2 eq.	1'390	1'430	1'421	1'147	1'929	15
2F2 Foam blowing agents		31.6	43.3	40.3	10.1	211.2	114
2F4 Aerosols		16.8	17.4	17.3	6.9	29.5	41
2F5 Solvents		1.6	1.6	1.6	0.5	3.0	52
Total 2F Product use as substitutes for ODS		1'440	1'492	1'480	1'164	2'173	17

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 correspond to applied changes and improvements in model calculations.

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 and commercial and industrial refrigeration. 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 SF_6. Second, the decommissioning sector is well-organized by the SENS foundation and recycling is taxed in advance. Third, servicing staff is well-trained to proper handling and disposal of respective appliances. And fourth, the good economic conditions allow a higher renewal frequency and higher equipment standard (export of old vehicles and equipment for secondhand use).

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 observed differences.

4.7.5 Category-specific recalculations

Recalculations reported in submission 2018

- 2F1a: Split between commercial and industrial refrigeration 1990 till 2016 (industrial refrigeration previously included in commercial refrigeration).
- 2F1b: Adjusted portion and type of refrigerant used for stationary air conditioning and heat pumps 2014 and 2015.

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 and will be analysed in this area due to the revision of the Chemical Risk Reduction Ordinance and CO_2 compensation programms (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

Table 4-49 Key categories of 2G Other product manufacture and use. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
2G	Other product manufacture and use	HFC	T1
2G	Other product manufacture and use	N2O	T2
2G	Other product manufacture and use	SF6	L1

Table 4-50 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_2O from product uses	Emissions of N_2O from the use of N_2O in hospitals; Emissions of N_2O from the use of aerosol cans
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, NO_x, CO, NMVOC and SO_2 as well as CO from use of fireworks and tobacco, respectively; 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 SF_6 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 SF_6 for other applications (i.e. research, magnesium foundry). SWISSMEM is collecting data from its members and is crosschecking the reported SF_6 consumption data with data from importers of SF_6. Installations in operation with electrical equipment containing SF_6 are periodically inspected for leakage, and losses are refilled (topping up). The refilled quantities and any SF_6 charge required 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 SF_6 emissions.

Activity data

Activity data are based on industry information. The wide annual fluctuation of SF_6 emissions from electrical equipment is related to the annual fluctuation of market volumes for such equipment as well as variations in inspection intervals and equipment break-down requiring topping up of SF_6 charge in the equipment. 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 SF_6 and PFCs from other product use (2G2)

Methodology

The emissions reported under 2G2 are related to the use of SF_6 for industrial particle accelerators (2G2b), the use of SF_6 for soundproof windows (2G2c) and other PFC and SF_6 use (2G2e). 2G2e summarizes research/analytics and further applications (including the unallocated difference in SF_6 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 SF_6 from industrial particle accelerators on the basis of a mass-balance approach (Tier 3a).

For 2G2c soundproof windows and 2G2e Other a Tier 2 approach is applied. Therefore, the unallocated amount of SF_6 under 2G2e has been assigned as application of cables and electrical control systems. Further evaluations of applications under 2G2e are based on FOEN import statistics and industry data, including applications with direct emissions and applications with banks. No further details are provided due to confidentiality. Data are available from Carbotech (2018).

Emission factors

For the unallocated amount of SF_6 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 yet relevant for the results.

For soundproof windows an emission rate of 1% per year is assumed, including the portion of broken windows. For the manufacturing an emission factor of 33% is assumed. However, since 2008, there is no production of windows with SF_6 in Switzerland.

Activity data

Activity data are based on import statistics and industry information. For the unallocated amount of SF_6 assigned to cables and electrical control systems an export rate of 80% is assumed similar to electrical equipment 2G1. For the inventory report submitted in 2015 (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 N_2O from product uses (2G3)

Methodology

Emissions of N_2O from the source category 2G3 occur from the anaesthesia use in hospitals (2G3a Medical applications) and from the use of aerosol cans in households (2G3b Other). For both categories a Tier 2 method based on country-specific emission factors for the production/consumption of N_2O 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 N_2O sold for anaesthesia purpose in Switzerland divided by the number of inhabitants. The amount of N_2O sold is derived from annual sales data from the main suppliers from 2005 onwards (EMIS 2018/2G3a Lachgasanwendung Spitäler).

Source category 2G3b Other includes N_2O emissions from whipped-cream makers using gas capsules for private households and restaurants. The emission factor is calculated based on sales data and N_2O content of gas capsules sold in Switzerland divided by the number of inhabitants (EMIS 2018/2G3b Lachgasanwendung Haushalt).

Table 4-51 N_2O emission factors for the source categories 2G3a Medical applications and 2G3b Other in 2016.

2G3a Use of N_2O for anaesthesia	**Unit**	**1990**	**1995**	**2000**	**2005**
N_2O	g/inhabitant	43	29.8	16.6	12.0
2G3b N_2O from aerosol cans					
N_2O	g/inhabitant	9.3	9.6	9.8	10.5

2G3a Use of N_2O for anaesthesia	**Unit**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
N_2O	g/inhabitant	9.0	8.0	7.0	7.0	6.0	5.7	3.5	3.8	3.3	2.5
2G3b N_2O from aerosol cans											
N_2O	g/inhabitant	11.0	11.3	11.5	11.8	12.0	12.2	12.4	12.7	12.9	13.1

Activity data

For the source categories 2G3a Medical applications and 2G3b Other the activity data correspond to the Swiss population (SFSO 2017a) (EMIS 2018/2G3a Lachgasanwendung Spitäler and EMIS 2018/2G3b Lachgasanwendung Haushalt).

Table 4-52 Activity data for the source categories 2G3a Use of N_2O for anaesthesia and 2G3b N_2O from aerosol cans.

2G3 N_2O from product uses	**Unit**	**1990**	**1995**	**2000**	**2005**
2G3a, 2G3b	inhabitants	6'796'000	7'081'000	7'209'000	7'501'000

2G3 N_2O from product uses	**Unit**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2G3a, 2G3b	inhabitants	7'619'000	7'711'000	7'801'000	7'878'000	7'912'000	7'997'000	8'089'000	8'189'000	8'282'000	8'373'000

4.8.2.4 Other (2G4)

Since the 2006 IPCC Guidelines (vol. 3, chp. 5.5) refer to the EMEP/EEA Guidebook 2016 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 CO_2, NO_x, CO and SO_2 as well as CO from the use of fireworks and tobacco, respectively, are emitted. Switzerland's Informative Inventory Report 2018 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 2018f). Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

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 CO_2 emissions from post-combustion of NMVOC are estimated based on industry data and expert estimates (Carbotech 2017a).

Post-combustion of NMVOC (2G4)

Methodology

The CO_2 emissions from post combustion of NMVOC are calculated by a Tier 2 method using country-specific emission factors. Emissions are calculated based on the amount of NMVOC (and their carbon content) destroyed in the respective combustion facility of more than 100 industrial plants (Carbotech 2017a). Post combustion facilities are applied in source categories printing (NFR code 2D3h), other solvent use (NFR code 2D3i)) and other product use (NFR codes 2G). These amounts of NMVOC eliminated by post-combustion are also declared in the respective VOC balances of the industrial plants and are thus not included as NMVOC emissions. When deriving the NMVOC emission factors for these source categories, the amount of NMVOC destroyed in post-combustion facilities is taken into account, i.e. the NMVOC emission factor is reduced accordingly.

Emission factors

Emission factors are derived from the composition of solvents. For installation with no information on the solvent composition a default carbon content of 50% is assumed.

Activity data

Activity data are provided by the industry. For the ten most important installations, activity data are provided annually.

Domestic solvent use (2D3a NFR)

Methodology

The source category 2G4 Domestic solvent use (2D3a NFR) Domestic solvent use including fungicides comprises mainly the use of cleaning agents and solvents in private households for building and furniture cleaning and cosmetics and toiletries but also the use of spray cans and pharmaceuticals. These products contain solvents, which evaporate during use or after the application. Among the numerous NMVOC emission sources, the use of household cleaning agents is the largest single source in source category 2D3.

Based on the decision tree Fig. 3.1 in chapter 2D3a in EMEP/EEA (2016), the emissions are calculated by a Tier 2 method (EMIS 2018/2D3a) using country-specific emission factors. All emissions related to domestic solvent use are calculated proportional to the Swiss population.

Emission factors

- *Household cleaning agents:* The source category 2D3a Use of cleaning agents includes the use of cosmetics, toiletries, cleaning agents and care products. Its resulting emission factor bases thus on a multitude of products, their NMVOC contents, emission fractions and consumption numbers. About 80% of the NMVOC emissions stem from the use of cosmetics and toiletries whereas the rest arises from the use of cleaning agents and care products. Available data sources consist of surveys of the use of household cleaning agents, cosmetics and toiletries in Switzerland (1990) and information from the Swiss association of cosmetics and detergents (SKW 2010) as well as surveys from Germany (1998, 2005). 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 J. (2005). There were no significant improvements in the solvent compositions of the employed detergents. In a study conducted in 2013/2014 in Switzerland more accurate data of household cleaning agents, cosmetics and toiletries was collected based on comprehensive surveys at retailers, producers, industry associations and experts as well as analysis of import statistics (Hubschmid 2014). As a result of this study, the emission factor of household cleaning agents was adjusted in 2013. The study indicates again an increase in the NMVOC emission factor in 2013.
- *Domestic use of spray cans:* Emission factors of domestic use of spray cans are based on surveys in Switzerland (1990) and a Swiss study conducted in 2013/2014. This study provided more accurate data of domestic spray cans based on comprehensive surveys at retailers, producers, industry associations and experts as well as analysis of import statistics (Hubschmid 2014). As a result of this study, the emission factor of spray cans was adjusted. It is assumed constant for the time period since 1998.
- *Domestic use of pharmaceutical products:* Emission factors of domestic use of pharmaceutical products are available from surveys in Switzerland (1990) and Germany (1998) and from the Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries) for 2011, as documented in the EMIS database. For years with no survey data, emission factors are interpolated.

Table 4-53 Emission factors for NMVOC for source category 2G4 Other: domestic solvent use, printing, other solvent use, other product use in 2016.

2G4 Other	Unit	NMVOC
Domestic solvent use (2D3a NFR)		
Domestic use of spray cans	g/inhabitant	360
Domestic use of pharmaceuticals	g/inhabitant	30
Household cleaning agents	g/inhabitant	983
Printing (2D3h NFR)		
Printing	kg/t ink	280
Package printing	kg/t ink	177
Other solvent use (2D3i NFR)		
Production of cosmetics	kg/employee	63
Production of paper and paperboard	g/t	35
Production of perfume and flavour	kg/employee	38
Production of textiles	kg/employee	8
Production of tobacco	kg/employee	12
Removal of paint and lacquer	g/inhabitant	34
Scientific laboratories	kg/employee	15
Other product use (2G NFR)		
Application of glues and adhesives	kg/t solvent	733
Commercial & industrial use of cleaning agents	g/employee	443
Cosmetic institutions	kg/employee	28
De-icing of airplanes	kg/t de-icing agent	280
Glass wool enduction	g/t glass wool	190
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	477
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	33
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 2017a), see Table 4-54.

Table 4-54 Activity data for source category 2G4 domestic solvent use, printing, other solvent use, other product use.

2G4 Other	Unit	1990	1995	2000	2005
Domestic solvent use (2D3a NFR)	inhabitants	6'796'000	7'081'000	7'209'000	7'501'000
Printing (2D3h NFR)					
Printing	kt ink	13	13	14	5.5
Package printing	kt ink	5.9	5.9	5.5	9.1
Other solvent use (2D3i NFR)					
Fat, edible & non-edible oil extraction	kt	40	38	12	NO
Production of cosmetics	employees	2'200	2'200	2'267	2'100
Production of paper and paperboard	kt	1'510	1'560	1'780	1'750
Production of perfume and flavour	employees	2'200	2'325	2'567	3'200
Production of textiles	employees	25'200	26'763	24'300	17'067
Production of tobacco	employees	3'300	2'988	2'733	2'700
Removal of paint and lacquer	inhabitants	6'796'000	7'081'000	7'209'000	7'501'000
Scientific laboratories	employees	10'194	18'604	23'217	23'000
Vehicles dewaxing	vehicles	200'000	166'250	72'667	NO
Other product use (2G NFR)					
Application of glues and adhesives	kt	4.0	3.0	2.0	1.5
Commercial & industrial use of cleaning agents	employees	3'950'000	3'867'500	3'954'667	4'133'667
Cosmetic institutions	employees	2'600	3'100	3'533	3'800
De-icing of airplanes	kt	1.3	1.3	1.3	2.5
Fireworks	kt	0.8	1.0	1.5	1.4
Glass wool enduction	kt	24	24	31	37
Hairdressers	employees	20'553	22'826	23'530	22'200
Health care, other	employees	113'000	129'250	145'667	161'667
Medical practices	employees	27'625	42'047	50'833	55'357
Preservation of wood	kt paint	6.0	7.9	8.7	7.2
Rock wool enduction	kt	38	40	51	46
Underseal treatment & conservation of vehicles	kt	0.06	0.06	0.08	0.12
Use of concrete additives	kt	24	25	29	36
Use of cooling lubricants	kt	5.0	5.2	5.8	4.5
Use of lubricants	kt	1.3	1.3	1.3	3.7
Use of pesticides	kt	2.4	2.0	1.7	1.5
Use of tobacco	Mio cigarette eq.	16'192	15'774	15'381	13'369

2G4 Other	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Domestic solvent use (2D3a NFR)	inhabitants	7'619'000	7'711'000	7'801'000	7'878'000	7'912'000	7'997'000	8'089'000	8'189'000	8'282'000	8'373'000
Printing (2D3h NFR)											
Printing	kt ink	2.6	2.5	2.5	2.4	2.2	2.0	1.9	1.9	1.9	1.9
Package printing	kt ink	13	13	13	13	13	13	13	13	13	13
Other solvent use (2D3i NFR)											
Fat, edible & non-edible oil extraction	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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	kt	1'734	1'700	1'540	1'540	1'380	1'372	1'363	1'355	1'346	1'338
Production of perfume and flavour	employees	3'400	3'425	3'450	3'475	3'500	3'521	3'542	3'563	3'583	3'604
Production of textiles	employees	16'400	16'200	14'200	13'800	14'800	14'768	14'737	14'705	14'674	14'642
Production of tobacco	employees	3'033	3'200	3'200	3'200	3'200	3'200	3'200	3'200	3'200	3'200
Removal of paint and lacquer	inhabitants	7'619'000	7'711'000	7'801'000	7'878'000	7'912'000	7'997'000	8'089'000	8'189'000	8'282'000	8'373'000
Scientific laboratories	employees	23'000	23'000	23'000	23'000	23'000	23'083	23'167	23'250	23'333	23'417
Vehicles dewaxing	vehicles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other product use (2G NFR)											
Application of glues and adhesives	kt	1.3	1.2	1.2	1.1	1.0	1.9	1.0	1.0	1.0	1.0
Commercial & industrial use of cleaning agents	employees	4'283'000	4'323'333	4'363'667	4'404'000	4'333'333	4'262'667	4'192'000	4'236'000	4'280'000	4'324'000
Cosmetic institutions	employees	4'200	4'400	4'600	4'800	5'000	5'111	5'222	5'333	5'444	5'556
De-icing of airplanes	kt	1.7	2.4	3.1	3.7	4.4	5.1	5.1	5.1	5.1	5.1
Fireworks	kt	1.7	2.0	2.0	1.7	2.0	1.9	2.3	1.8	1.6	1.2
Glass wool enduction	kt	44	44	33	36	41	39	33	32	31	32
Hairdressers	employees	22'733	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000
Health care, other	employees	165'000	163'000	163'000	163'000	163'000	163'000	163'000	163'000	163'000	163'000
Medical practices	employees	57'586	58'700	58'700	58'700	58'700	58'700	58'700	58'700	58'700	58'700
Preservation of wood	kt paint	6.9	6.1	5.3	4.5	3.6	2.8	2.0	2.0	2.0	2.0
Rock wool enduction	kt	63	58	53	56	57	57	54	53	47	52
Underseal treatment & conservation of vehicles	kt	0.13	0.14	0.15	0.16	0.17	0.18	0.18	0.18	0.18	0.18
Use of concrete additives	kt	34	34	34	41	44	38	38	37	37	36
Use of cooling lubricants	kt	5.1	4.9	3.1	3.9	4.4	4.1	4.1	4.1	4.1	4.1
Use of lubricants	kt	1.5	0.4	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.4
Use of pesticides	kt	1.5	1.7	1.9	2.0	2.2	2.2	2.2	2.2	2.2	2.2
Use of tobacco	Mio cigarette eq.	13'072	13'310	13'667	12'443	11'856	12'705	12'162	10'628	10'284	10'709

Printing (2D3h NFR)

Methodology

The source category 2G4 Printing (2D3h NFR) has been split into 2G4 Other printing industry and 2G4 Package printing. A Tier 2 method according to the EMEP/EEA Guidebook 2016 is applied using country-specific emission factor for calculating the NMVOC emissions from ink applications.

Emission factors

Emission factors for NMVOC are based on data from industry associations (Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV)), VOC balances in the printing industry, German studies on NMVOC emissions from solvent use (Theloke 2005) and expert estimates, as documented in the EMIS database (EMIS 2018/2G4). For emission factors of 2016 see Table 4-53.

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 (SOLV), VOC balances in the printing industry and expert estimates, documented in the EMIS database (EMIS 2018/2G4). For activity data see Table 4-54.

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 (2016), a Tier 2 method using country-specific emission factors is applied for calculating the NMVOC emissions from the different solvent applications in source category 2D3i Other solvent use (EMIS 2018/2G4). 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, 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 2018/2G4). For emission factors see Table 4-53.

Activity data

For the majority of production processes and services – such as production of perfume and flavour and production of textiles – the activity data correspond to the respective number of employees (SFSO 2017h). The quantity of NMVOC emission per employee originates from the bottom-up approach in these industrial sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are referred to the number of employees in order to calculate the Swiss total.

For production of paper and paperboard and fat, edible and non-edible oil extraction, the activity data are based on production volumes. Annual production volumes of paper and paperboard are provided by the Swiss association of pulp, paper and paperboard industry

(ZPK). For the removal of paint and lacquer the activity data correspond to the number of inhabitants (SFSO 2017a).

For activity data see Table 4-54.

Other product use (2G NFR)

Methodology

Within source category 2G Other product use, the major NMVOC emission sources in 2016 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 (2016), for source category 2G Other product use Tier 2 methods using country-specific emission factors are applied for calculating the emissions from the different product applications and the use of fireworks and tobacco (EMIS 2018/2G).

For the source categories 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 CO_2 emissions from CO and NMVOC emissions from tobacco use are of biogenic origin and are therefore not reported in chp. 9 Indirect CO_2 and N_2O 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 2018/2G4). For emission factors see Table 4-53.

Emission factors of CO_2, NO_x, CO and SO_2 as well as CO from use of fireworks and tobacco (EMIS 2018/2G), respectively, are displayed in the following table. Emission factors of fireworks are documented in FOEN (2014p).

Table 4-55 Emission factors for CO_2, NO_x, CO, SO_2 for source category 2G4 Fireworks in 2016.

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

For the production processes, such as enduction of glass and rock wool and part of the applications in services, such as preservation of wood and application of glues and adhesives the activity data are based on production volume or employed agents. For the other part of applications in services, such as house cleaning in services, commerce and industry and medical practices the activity data correspond to the respective number of employees. The quantity of NMVOC emission per employee originates from the bottom-up approach in these service sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are refererenced to the number of employees in order to calculate the Swiss total.

The activity 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 and the annual firework sales are provided by the Swiss addiction prevention foundation (“Sucht Schweiz”) and the statistics of the Swiss federal office for police (FEDPOL 2017), respectively.

For activity data see Table 4-54.

A double counting of NMVOC emissions from de-icing of airplanes for the years 1990–2006 was identified in Submission 2017 (I.12 in UNFCCC 2018). The correct time series is shown in the following table.

Table 4-56 NMVOC emissions from de-icing of airplanes

2G4 De-icing of airplanes	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
NMVOC emissions	t	598	598	598	598	598	598	598	598	598	589

2G4 De-icing of airplanes	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
NMVOC emissions	t	581	572	709	784	797	676	557	442	628	820

2G4 De-icing of airplanes	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
NMVOC emissions	t	1'017	1'220	1'428	1'428	1'428	1'428	1'428

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 documented in a confidential/internal report (Carbotech 2018).

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 CO_2 emissions from the entire source category 2G is estimated at 40% (expert estimate).

The uncertainty of N_2O emissions from source category 2G3, which is a key category for this gas regarding trend according to Approach 2, is estimated at 80% (expert estimate, see Table 1-10).

The uncertainty of SF_6, HFC and PFC emissions in source category 2G is estimated at 32%, 12% and 16% respectively based on a Monte Carlo analysis. Further details are available from background documents, confidential/internal excel calculations and the respective report (Carbotech, 2018).

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 chp. 1.2.3.

4.8.5 Category-specific recalculations

The following recalculations were implemented in submission 2018. Recalculations that cause a change in emission levels 1990 and 2015 of at least 0.3 kt CO_2 eq are quantified.

Major recalculations which contribute significantly to the total differences in N_2O and indirect CO_2 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:2G3a: The N_2O emission factor of 2G3a N_2O use in in hospitals has been revised from 2012 onwards resulting in a decrease in emissions of 4.1 kt CO_2 eq in 2015. This recalculation is responsible for the observed difference in N_2O emissions from sector 2 IPPU.

- 2G4: The NMVOC emission factor of 2G4 Domestic use of spray cans has been revised for the years 1999–2012.
- 2G4: The double counting in the NMVOC emissions from 2G4 De-icing of airplanes for the years 1990-2006 in last year's submission has been corrected (Table 4-56).

Further recalculations:

- 2G4: The activity data of 2G4 Use of cooling lubricants have been updated from 2005 onwards. In addition, the emission factor of NMVOC for 2005 has been updated resulting in revised values for the years 2005-2011.
- 2G4: Activity data of 2G4 Hairdressers have been revised for 2004 and 2007 resulting in revised values for 2002-2004 and 2006-2007, respectively.
- 2G4: Activity data of 2G4 Cosmetic institutions has been revised for 2004 resulting in revised values for 2002-2004.

- 2G4: The activity data of 2G4 Use of concrete additives has been changed for 2020 resulting in revised interpolated values for 2013-2015.
- 2G4: Activity data for the consumption of tobacco has slightly changed for the years 1997-2004 due to the correction of errors in the calculation.
- 2D3: The activity data of 2G4 Tobacco production have been updated for 2001, 2004, 2005, 2007 and 2008 resulting in revised values for 1999-2015.
- 2G4: The activity data of 2G4 Package printing and 2G4 Printing have been changed for 2020 resulting in revised interpolated values for 2014-2015.
- 2G4: The activity data of 2G4 Production of paper and paperboard and 2G4 Production of textiles have been changed for 2020 resulting in revised interpolated values for 2012-2015.

4.8.6 Category-specific planned improvements

A portion of imported HFCs under 2G4 is for applications in France, the amount and related emissions will be determined as far as possible for the following submission. No further category-specific improvements are planned.

4.9 Source category 2H – Other

4.9.1 Source category description

Source category 2H Other is not a key category.

Table 4-57 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, NOx, CO, NMVOC and SO_2 from blasting and shooting;

4.9.2 Methodological Issues

4.9.2.1 Pulp and paper (2H1)

Methodology

In 2016, 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. The NMVOC emissions are calculated by a Tier 2 method according to EMEP/EEA (2016) using country-specific emission factors.

Indirect CO_2 emissions resulting from NMVOC emissions in this source category are only included in CRF Table6 and reported in chp. 9.

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 2018/2H1. The implied emission factor given in Table 4-48 is production-weighted and related to chipboard and fibreboard production.

Table 4-58 Emission factors for CO and NMVOC in pulp and paper production and food and beverages industry, CO_2, NO_x, CO, NMVOC and SO_2 from blasting and shooting for 2016.

2H Other	Unit	CO_2	NO_x	CO	NMVOC	SO_2
2H1 Pulp and paper	g/t	NA	NA	NA	540	NA
2H2 Food and beverage industry (exc. beer, wine, spirits)	g/t	NA	NA	250	3'180	NA
2H2 Food and beverage industry (beer, wine, spirits)	g/m^3	NA	NA	NA	340	NA
2H3 Blasting and shooting	kg/t	400	35	310	60	0.5

Activity data

The annual amount of pulp and paper produced in Switzerland is based on data from industry and expert estimates documented in EMIS 2018/2H1.

Table 4-59 Pulp and paper production, food and beverages production, amount of used explosives and processed crude oil in Switzerland.

2H Other	Unit	1990	1995	2000	2005
2H1 Pulp and paper	kt	604	593	641	693
2H2 Food and beverage industry (exc. beer, wine, spirits)	kt	2'254	2'116	2'301	2'138
2H2 Food and beverage industry (beer, wine, spirits)	m^3	560'972	516'519	492'208	452'877
2H3 Blasting and shooting; blasting agent and powder	kt	2.6	1.3	1.9	0.8

2H Other	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2H1 Pulp and paper	kt	790	765	544	602	564	533	510	516	519	503
2H2 Food and beverage industry (exc. beer, wine, spirits)	kt	2'343	2'428	2'437	2'400	2'531	2'470	2'446	2'508	2'484	2'400
2H2 Food and beverage industry (beer, wine, spirits)	m^3	462'141	479'293	465'753	467'699	461'453	454'903	449'070	446'567	447'709	439'556
2H3 Blasting and shooting; blasting agent and powder	kt	1.1	1.4	2.1	2.4	2.9	2.3	2.2	2.1	2.1	0.7

4.9.2.2 Food and beverages industry (2H2)

Methodology

In Switzerland, production of beverages comprises wine, beer and spirits and food industry comprises production of bread, sugar, smoked meat, roasting of coffee and the milling industry. The CO and NMVOC emissions from food and beverages industry are calculated by a Tier 2 method according to EMEP/EEA (2016) using country-specific emission factors. Since these CO and NMVOC emissions are of biogenic origin they are not considered for calculation of indirect CO_2 emissions.

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 2018/2H2). The implied emission factors are production-weighted (Table 4-58).

Indirect CO_2 emissions from CO and NMVOC emissions from food and beverages industry are of biogenic origin and are therefore, not reported in chp. 9 Indirect CO_2 and N_2O 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 2018/2H2 (Table 4-59).

4.9.2.3 Other (2H3)

Methodology

For determination of emissions of CO_2, NO_x, CO, NMVOC and SO_2 from blasting and shooting, an analogous Tier 2 method with country-specific emission factors is used as documented in the EMIS database (EMIS 2018/2H3 Sprengen und Schiessen).

Indirect CO_2 emissions resulting from NMVOC and CO emissions in this source category are only included in CRF Table6 and reported in chp. 9.

Emission factors

The emission factors for CO_2, NO_x, CO, NMVOC and SO_2 from blasting and shooting activities in Switzerland are country-specific and based on measurements and data from industry and expert estimates (see Table 4-58).

Activity data

The annual amount of used explosives is based on the Federal statistics on explosives (FEDPOL 2017) (Table 4-59).

4.9.3 Uncertainties and time-series consistency

The uncertainty for CO_2 emissions from 2H3 Other is estimated to be 8% (expert judgement) since activity data are taken from customs statistics.

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 chp. 1.2.3.

4.9.5 Category-specific recalculations

The following recalculations were implemented in submission 2017. These recalculations cause a change in emission levels 1990 and 2014 of less than 0.3 kt CO_2 eq.

- 2H1: The activity data of 2H1 Chipboard production has been corrected for 2004
- 2H2: Activity data for bread production for the years 2013-2015 has slightly changed. For the years 2013 and later the amount of bread produced is now estimated based on industry data for grinded grains and not on the per-capita consumption as before.
- 2H3: The activity data of 2H3 Blasting and shooting has been corrected for 2015. In addition, the activity data have been adjusted for 1995–2006 due to rounding differences resulting in minor recalculations between 1991 and 2006.

4.9.6 Category-specific planned improvements

No category-specific improvements are planned.

5 Agriculture

5.1 Overview

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

- 3A Enteric fermentation, CH_4 emissions from domestic livestock,
- 3B Manure management, emissions of CH_4, N_2O and NO_x,
- 3D Agricultural soils, emissions of N_2O, NO_x and NMVOC,
- 3G Liming, emissions of CO_2
- 3H Urea application; emissions of CO_2

No emissions are reported for 3C Rice cultivation as in Switzerland only a small area is cultivated with upland rice. The categories 3E Prescribed burning of savannahs and 3F Field burning of agricultural residues do not occur in Switzerland and are therefore not reported.

CO_2 emissions from soils are reported under Land use, land-use change and forestry. CO_2 emissions from energy use in agriculture are reported under 1A4c Agriculture/forestry/fishing.

Total greenhouse gas emissions from the agriculture sector in 2016 were 5'963 kt CO_2 equivalents which is a contribution of 12.4% to the total of Swiss greenhouse gas emissions (excluding indirect CO_2, excluding LULUCF, Table 2-5, Table 5-1). Main agricultural sources of greenhouse gases were 3A Enteric fermentation, emitting 56% of all agricultural greenhouse gases, followed by 3D Agricultural soils with 25% and 3B Manure management with 18% (Figure 5-1). 3G Liming and 3H Urea application contributed 0.6% and 0.2% respectively.

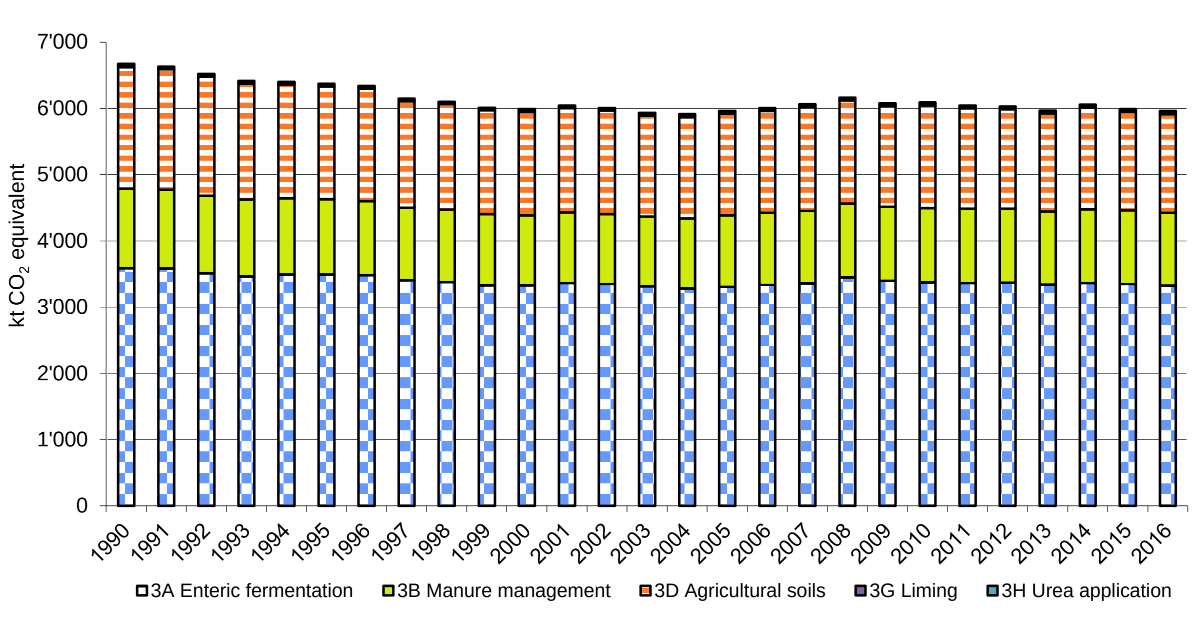


Figure 5-1 Greenhouse gas emissions of the agricultural sector in kt CO_2 equivalents.

Table 5-1 Greenhouse gas emissions of the agricultural sector in kt CO_2 equivalents.

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	4'453	4'441	4'356	4'301	4'322	4'313	4'282	4'186	4'153	4'092
N_2O	2'170	2'149	2'123	2'071	2'038	2'019	2'014	1'923	1'914	1'881
Sum	6'672	6'633	6'522	6'414	6'402	6'374	6'337	6'147	6'103	6'010

Gas	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	kt CO_2 equivalent									
CO_2	39	40	41	39	44	42	42	46	44	41
CH_4	4'072	4'108	4'083	4'045	4'014	4'051	4'087	4'110	4'213	4'157
N_2O	1'877	1'897	1'883	1'848	1'855	1'869	1'875	1'906	1'907	1'877
Sum	5'989	6'045	6'007	5'932	5'912	5'963	6'004	6'061	6'164	6'075

Gas	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
	kt CO_2 equivalent						
CO_2	44	43	42	42	46	44	47
CH_4	4'132	4'126	4'129	4'093	4'127	4'116	4'078
N_2O	1'912	1'876	1'859	1'833	1'882	1'832	1'838
Sum	6'089	6'045	6'029	5'968	6'055	5'992	5'963

CH_4 and N_2O emissions generally declined from 1990 until 2004 (Figure 5-2). Subsequently emissions increased slightly until 2008 and decreased again until 2016. 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. CO_2 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.

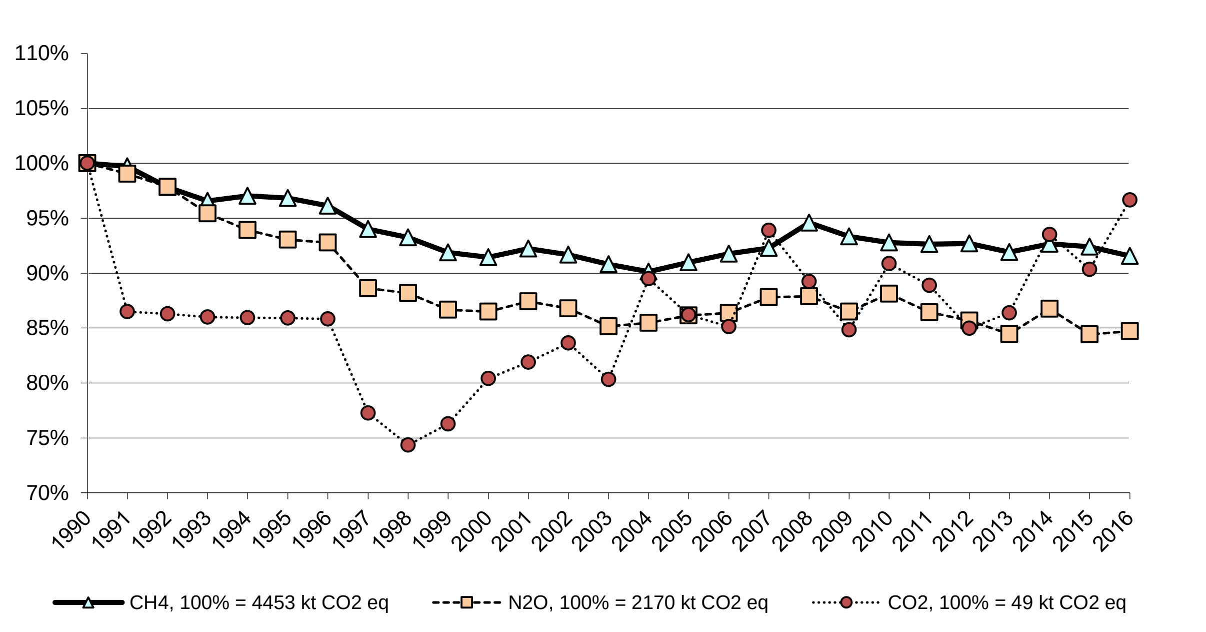


Figure 5-2 Relative trends of the greenhouse gas emissions of sector 5 Agriculture. The base year 1990 represents 100%.

Among the key categories of the Swiss inventory, five are from the agricultural sector (Figure 5-3).

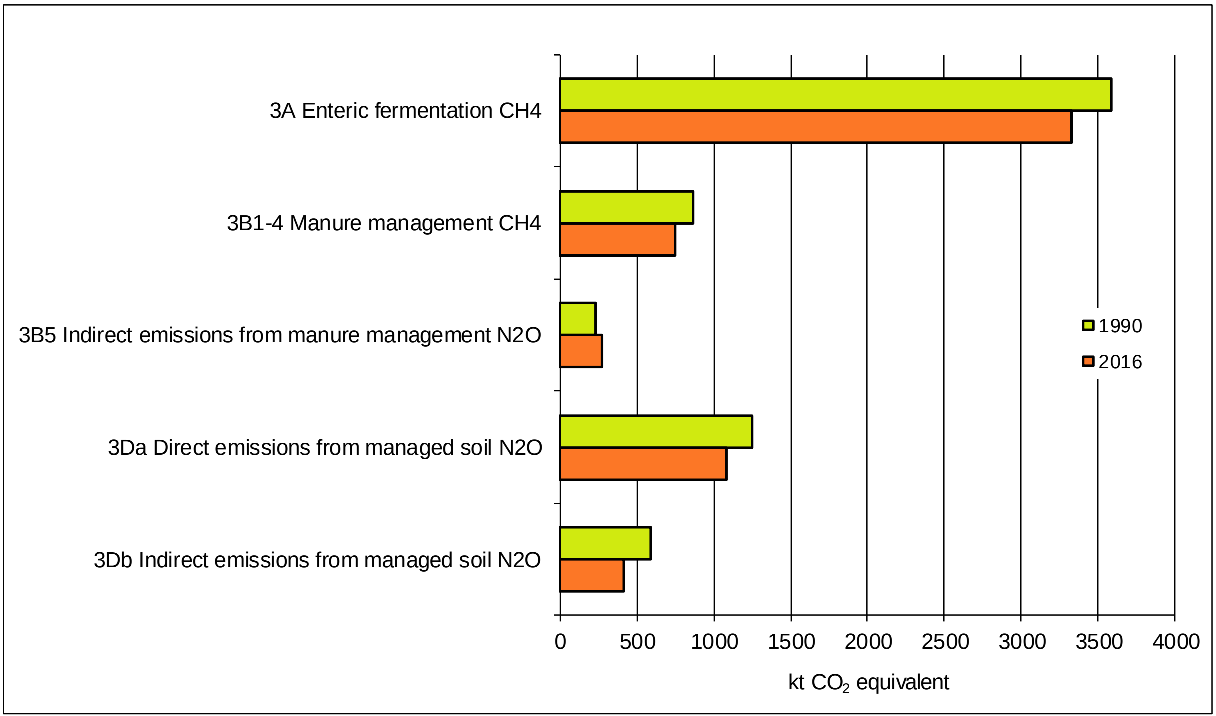


Figure 5-3 Key categories (Approach 1 and Approach 2) in the agricultural sector.

5.2 Source category 3A – Enteric fermentation

5.2.1 Source category description

Table 5-2 Key categories of 3A Enteric fermentation. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
3A	Enteric Fermentation	CH4	L1, T1, L2, T2

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 5-3).

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 CH_4 emissions increased, whereas since 2008 they were 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%.

Emissions from fur-bearing animals are not occurring in Switzerland as provisions for the husbandry of wild animals are very strict according to the Swiss animal protection law (Swiss

Confederation 2003). This is true for the whole inventory time period as the first version of the law dates back to 1978. Consequently, fur farming is not economically viable in Switzerland. In addition, fur animals (other than rabbits) are not included in national livestock data.

Table 5-3 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[1]
		Bisons > 3 years[1]
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

1) Bisons (Bos bison and/or Bos bonasus). Water buffalos (bubalus bubalis) are included under cattle. See chp. 5.2.2.3.

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 bio-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 done by Agroscope, the Swiss centre of excellence for agricultural research (Agroscope 2018).

5.2.2.2 Emission factors

All emission factors for 3A Enteric fermentation are country-specific, based on IPCC equation 10.21 (IPCC 2006):

$$EF = \frac{GE * (Y_m \div 100) * 365\, days / y}{55.65\, MJ / kg\, CH_4}$$

EF = annual CH_4 emission factor (kg/head/year)

GE = gross energy intake (MJ/head/day)

Y_m = methane conversion rate, which is the fraction of gross energy in feed converted to methane (%)

55.65 MJ/kg = energy content of methane.

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 5-4.

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.

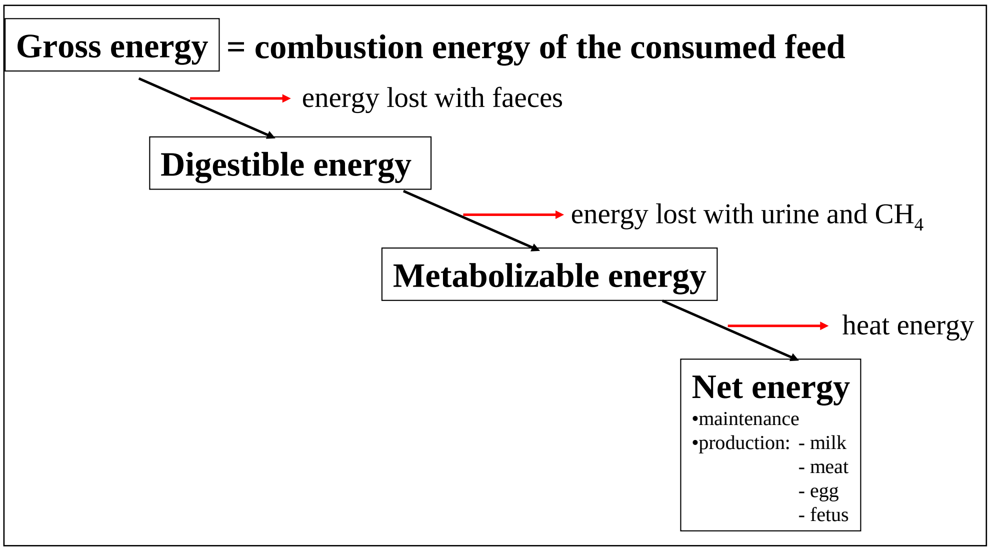


Figure 5-4 Levels of feed energy conversion (Soliva 2006).

Table 5-4 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 2016.

Livestock Category		**Conversion Factors**	
Mature Dairy Cattle		NEL to GE	0.341
Other Mature Cattle		NEL to GE	0.265
Growing Cattle	*Fattening Calves*	*ME to GE*	*0.939*
	Pre-Weaned Calves	*NEL to GE*	*0.299*
	Breeding Calves	*NEL to GE*	*0.358*
	Breeding Cattle (4-12 months)	*NEL to GE*	*0.319*
	Breeding Cattle (> 1 year)	*NEL to GE*	*0.313*
	Fattening Calves (0-4 months)	*NEV to GE*	*0.355*
	Fattening Cattle (4-12 months)	*NEV to GE*	*0.397*
Sheep	*Fattening Sheep*	*NEV to GE*	*0.350*
	Milksheep	*NEL to GE*	*0.287*
Swine		DE to GE	0.682
Buffalo		NA	NA
Camels and Llamas		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 2017, Table 5-5). Milk production includes marketed milk, milk consumed by calves on farms and milk sold outside the commercial industry (MISTA 2017). 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 bio-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 1990–2016.

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 5-6).

A more exhaustive model description is contained in Agroscope (2016b).

Table 5-5 Average daily milk production during 305 days of lactation in Switzerland.

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**	**2015**	**2016**
Population Size Mature Dairy Cattle	head	589'024	589'239	591'212	586'609	587'385	583'277	575'766
Lactation Period	day	305	305	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	22.46	22.63	22.57	22.27	22.87	23.10	22.98
Milk Yield Other Mature Cattle	kg/head/day	8.20	8.20	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. In general NE is subdivided into NE for lactation (NEL) and NE for growth (NEV)(Table 5-4). For some of the growing cattle categories NEL is used instead of NEV, even if NEV would seem appropriate. 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 5-6 Gross energy intake per head of different livestock groups. Sub-categories not contained in the reporting tables (CRF) are displayed in italic. The entire time series at a livestock sub-category level is provided in Annex 3.3.

Gross Energy Intake		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)		103.3	103.9	103.6	101.0	101.1	100.9	101.0	100.3	99.8	99.9
	Fattening Calves	*47.1*	*47.1*	*47.1*	*47.1*	*47.1*	*47.1*	*47.1*	*47.1*	*47.1*	*47.1*
	Pre-Weaned Calves	*60.1*	*60.1*	*60.1*	*60.1*	*60.1*	*60.1*	*60.1*	*60.1*	*60.1*	*60.1*
	Breeding Calves	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*
	Breeding Cattle (4-12 months)	*90.1*	*90.1*	*90.1*	*90.1*	*90.1*	*90.1*	*90.1*	*90.1*	*90.1*	*90.1*
	Breeding Cattle (> 1 year)	*143.6*	*143.6*	*143.6*	*143.6*	*143.6*	*143.6*	*143.6*	*143.6*	*143.6*	*143.6*
	Fattening Calves (0-4 months)	*56.9*	*56.9*	*56.9*	*56.9*	*56.9*	*56.9*	*56.9*	*56.9*	*56.9*	*56.9*
	Fattening Cattle (4-12 months)	*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	2013	2014	2015	2016
		MJ/head/day				
Cattle						
Mature Dairy Cattle		301.2	299.8	302.5	303.6	303.1
Other Mature Cattle		250.6	250.6	250.6	250.6	250.6
Growing Cattle (weighted average)		100.2	100.1	99.9	99.7	99.2
	Fattening Calves	*47.1*	*47.1*	*47.1*	*47.1*	*47.1*
	Pre-Weaned Calves	*60.1*	*60.1*	*60.1*	*60.1*	*60.1*
	Breeding Calves	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*
	Breeding Cattle (4-12 months)	*90.1*	*90.1*	*90.1*	*90.1*	*90.1*
	Breeding Cattle (> 1 year)	*143.6*	*143.6*	*143.6*	*143.6*	*143.6*
	Fattening Calves (0-4 months)	*56.9*	*56.9*	*56.9*	*56.9*	*56.9*
	Fattening Cattle (4-12 months)	*126.3*	*126.3*	*126.3*	*126.3*	*126.3*
Sheep		22.5	22.4	22.5	22.4	22.4
Swine		26.5	27.3	27.4	27.2	27.2
Buffalo (weighted average)		135.9	136.0	134.6	134.5	134.4
Camels (weighted average)		31.6	31.9	31.8	31.6	31.2
Deer (weighted average) [1)]		57.0	58.1	58.0	58.0	58.5
Goats		25.6	25.6	25.0	25.4	25.4
Horses (weighted average)		107.9	108.0	108.1	108.3	108.4
Mules and Asses (weighted average)		39.9	39.6	39.6	39.6	39.6
Poultry [2)]		1.1	1.1	1.1	1.1	1.1
Rabbits		1.2	1.2	1.2	1.2	1.2
Livestock NCAC (weighted average)		37.9	38.2	38.5	37.2	38.1

[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 5-6 (in italics) and subsequently averaged (weighted average). No methane is generated from milk. Energy intake from milk or milk products is still considered when estimating methane emission factors from enteric fermentation of calves. However, the methane conversion rate is adjusted accordingly as explained under chp. 5.2.2.2.2. The energy intake values for all 7 sub-categories are constant over time. Since the composition of the growing cattle category changed over time (e.g. more pre-weaned calves, fewer fattening calves, see Table 5-8), 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 5-6 and Table 5-8). Accordingly, the respective animals have two separate gross energy intake values, i.e. 44.0 MJ/head/day for the first 4 months and 90.1 MJ/head/day for the last 8 months. The same procedure is applied for fattening calves 0–4 months (56.9 MJ/head/day) and fattening cattle 4–12 months (126.3 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 2017, Giuliani 2017). These estimates are not officially published anymore in the statistical yearbooks (e.g. SBV 2017) but are still available from background data and are based on the same method as used for energy requirement statistics in earlier years (e.g. SBV 2007).

Gross energy intake for **horses**, **mules and asses** were estimated by Stricker (2012), mainly based on Meyer and Coenen (2002).

Table 5-7 Dry matter and gross energy requirements for buffalo, camels and deer according to Richner et al. (2017).

		DM Intake	GE Intake
		kg DM/head/day	MJ/head/day
Buffalo	Bisons < 3 years	4.93	90.99
	Bisons > 3 years	10.68	197.14
Camels	Llamas < 2 years	1.34	24.77
	Llamas > 2 years	2.33	42.97
	Alpacas < 2 years	0.82	15.16
	Alpacas > 2 years	1.51	27.80
Deer [1)]	Fallow Deer	2.74	50.55
	Red Deer	5.48	101.10

1) Requirements for deer are assessed per animal place i.e. mother with offspring.

For **buffalo**, **camels** and **deer**, energy intake was derived from data on dry matter intake provided in Richner et al. (2017) (Table 5-7). According to the 2006 IPCC Guidelines an energy density of 18.45 MJ*kg^{-1} was used to convert dry matter to gross energy.

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 (2018). Resulting estimates are provided in Table 5-6 (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 milk or milk products (i.e. calves) the methane conversion rate is weighted, assuming a Y_m of zero for milk energy and a Y_m of 6.5 for all other energy.

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 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 for 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 2017) and the Swiss Federal Statistical Office (SFSO 2017e)(Table 5-8). 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 livestock category growing cattle in the reporting tables 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 category growing cattle 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. The livestock category “buffalo” in the Swiss GHG Inventory contains only bisons (*Bos bison* and/or *Bos bonasus*). Water buffalos (bubalus bubalis) are included under cattle. The category “camels” contains only llamas and alpacas.

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 2017f).

Table 5-8 Activity data for calculating methane emissions from 3A Enteric fermentation (ART/SHL 2012, SBV 2017, SFSO 2017e, SFSO 2017f). The complete time series on a livestock sub-category level are provided in Annex 3 A3.3.

Population Size		**1990-2011**									
		1990	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
		1'000 head									
Cattle		1'855	1'748	1'588	1'555	1'567	1'572	1'604	1'597	1'591	1'577
Mature Dairy Cattle		783	740	669	621	618	615	629	599	589	589
Other Mature Cattle		12	23	45	78	87	94	98	108	111	111
Growing Cattle		1'060	986	874	856	862	863	877	890	891	877
	Fattening Calves	*112*	*102*	*103*	*106*	*101*	*100*	*95*	*107*	*114*	*111*
	Pre-Weaned Calves	*10*	*18*	*36*	*62*	*67*	*72*	*76*	*84*	*86*	*86*
	Breeding Cattle 1st Year										
	Breeding Calves	*214*	*166*	*76*	*75*	*77*	*76*	*80*	*76*	*75*	*73*
	Breeding Cattle (4-12 months)	*132*	*129*	*161*	*147*	*147*	*147*	*152*	*148*	*146*	*142*
	Breeding Cattle (> 1 year)										
	Breeding Cattle 2nd Year	*253*	*239*	*222*	*205*	*210*	*210*	*213*	*216*	*215*	*213*
	Breeding Cattle 3rd Year	*151*	*139*	*130*	*113*	*110*	*109*	*110*	*112*	*111*	*109*
	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*	*110*	*109*
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	9'667
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		**2012-2016**				
		2012	**2013**	**2014**	**2015**	**2016**
		1'000 head				
Cattle		1'565	1'557	1'563	1'554	1'555
Mature Dairy Cattle		591	587	587	583	576
Other Mature Cattle		114	117	118	118	121
Growing Cattle		859	854	857	853	859
	Fattening Calves	*103*	*102*	*102*	*103*	*107*
	Pre-Weaned Calves	*88*	*90*	*91*	*91*	*93*
	Breeding Cattle 1st Year					
	Breeding Calves	*72*	*71*	*71*	*71*	*72*
	Breeding Cattle (4-12 months)	*139*	*137*	*138*	*139*	*139*
	Breeding Cattle (> 1 year)					
	Breeding Cattle 2nd Year	*211*	*210*	*210*	*209*	*209*
	Breeding Cattle 3rd Year	*106*	*103*	*101*	*99*	*97*
	Fattening Cattle					
	Fattening Calves (0-4 months)	*33*	*34*	*34*	*34*	*33*
	Fattening Cattle (4-12 months)	*107*	*108*	*109*	*108*	*107*
Sheep		417	409	403	395	397
Swine		1'544	1'485	1'498	1'496	1'454
Buffalo		1	0	1	1	1
Camels		6	6	6	6	6
Deer [1)]		6	6	6	6	6
Goats		85	85	85	84	85
Horses		58	57	57	55	56
Mules and Asses		20	20	20	20	20
Poultry		10'353	10'684	11'584	11'918	12'085
Rabbits		28	28	27	25	25
Livestock NCAC		112	107	106	112	106

[1)] Deer: numbers correspond to animal places i.e. mother with offspring.

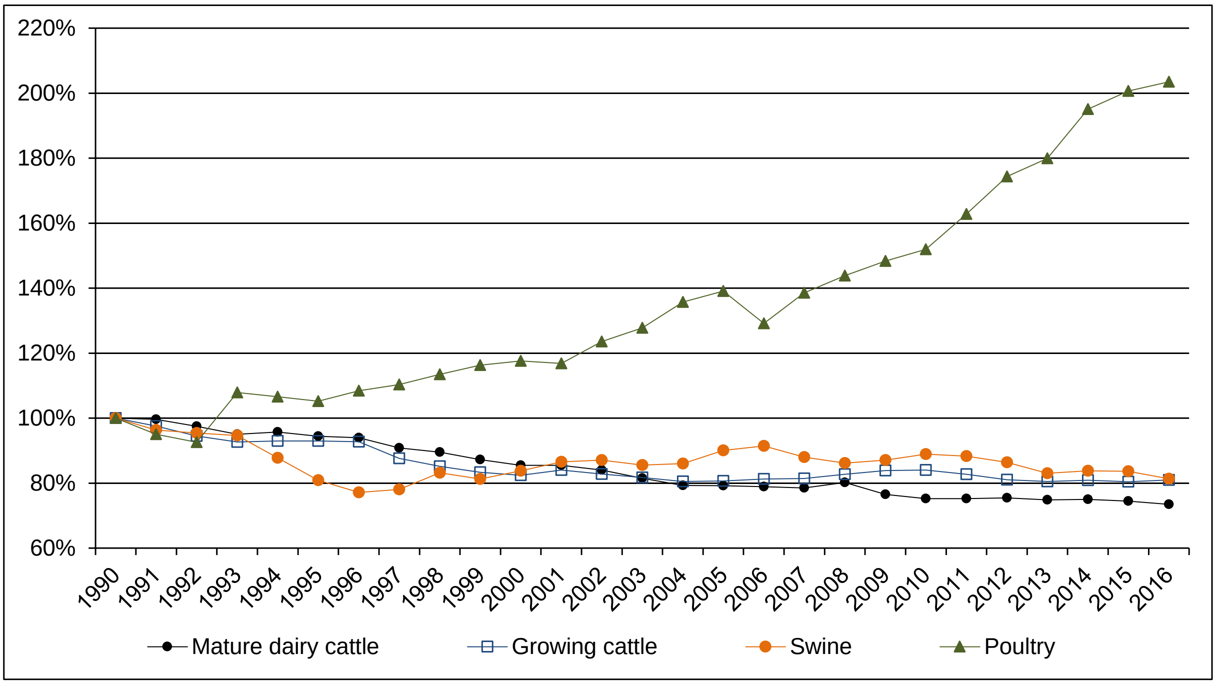


Figure 5-5 Relative development of the populations of main animal categories. The category with the strongest increase, i.e. other mature cattle, is not displayed, as it increases to over 1000% of the 1990 value by 2016.

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 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. During the most recent years a slight downward trend can be observed. The number of poultry shows a rapid increase between 1990 and 2016 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 (6.5%) 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 results and discussion of the uncertainties see chp. 1.6.1 and Annex A2.

The time series 1990–2016 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 5-5).
- 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 seven inventory years the population statistics of growing cattle were not available in the usual format. Data for 2009 to 2015 is based on the animal traffic database. Aggregation was adapted to the format necessary for the AGRAMMON-model and the GHG inventory by the School of Agricultural, Forest and Food Science (HAFL, Kupper et al. 2018). Data in the animal traffic database are considered more complete than the data from the survey of the SFSO because the animal traffic database includes also animals held outside agricultural enterprises.
- Since 2015 the census date for sheep and goats is the 1st of January instead of May as before. This is especially relevant for juveniles as they are usually only born in spring. Accordingly, a rupture in the official time series can be observed. This has been corrected in the GHG Inventory by extrapolating the ratio between adults and juveniles.

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 ± 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 ±3% with census data (April) always slightly above the annual mean. Data from the animal traffic database (i.e. cattle populations for the years 2009–2016) 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 approximatively 6.4% was found when comparing the overall GE-intake of the cattle population with the respective estimate of the Swiss Farmers Union (Giuliani 2017). 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 subject 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 might be underestimated by the inventory method when they measured atmospheric CH_4 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 by Hiller et al. (2014a) in their study. Stieger (2013) and Stieger et al. (2015) reported a very good agreement of bottom-up estimates and flux measurements with a tethered balloon system. Bamberger et al. (2014) conducted regional CH_4 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, 2016, 2017) found a very good agreement between inventory estimates of CH_4 emissions and independent atmospheric measurements over Switzerland (see Annex 5).

5.2.5 Category-specific recalculations

General information on recalculations is provided in chp. 10.

Recalculations with an overall impact of >0.5 kt CO_2 equivalents are assessed quantitatively. All other recalculations are only described qualitatively.

- Activity data for all growing cattle subcategories in the years 2009-2015 were revised due to a new model for the conversion of the categories in the animal traffic database to the categories needed for the GHG Inventory. The new model estimates less “breeding cattle 3rd year” and “fattening cattle” and more “fattening calves”. Accordingly, overall agricultural emissions decreased on average by approximately 10 kt CO_2 equivalent per year over the years 2009-2015.
- Livestock population data for sheep and goats in the year 2015 was recalculated due to the retrospective accounting of the change of the census date. The new values are approximately 15% higher and lead to an increase of overall emissions of 2.3 kt CO_2 equivalent. See also chp. 5.2.3.
- Livestock population data of “fattening pig over 25 kg” (part of the swine population) and “broilers” (part of the poultry population) was revised for the years 2010-2015 due to a new accounting system for the animal rotation cycles. The new system leads to higher numbers for these animals. Accordingly overall emissions increased by approximately 6 kt CO_2 equivalents per year over the years 2010-2015.
- Gross energy intake and methane conversion rates for all calve-categories (fattening calves, pre-weaned calves, breeding calves and fattening calves (0-4 months)) were revised due to a different accounting of milk energy. Emission factors and overall CH_4 emissions did not change since it was only a reallocation of calculation parameters.
- CH_4 emission factors for the year 2014 and 2015 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 2017). The effect of the recalculation on overall greenhouse gas emissions is negligible for 2014 and +1.0 kt CO_2 equivalent for 2015.

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).

5.3 Source category 3B – Manure management

5.3.1 Source category description

Table 5-9 Key categories of 3B Manure management. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
3B1-3B4	Manure management	CH4	L1, L2
3B5	Indirect N2O emissions from manure management	N2O	L1, T1, L2, T2

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 5-10). Six (CH_4) respectively five (N_2O) different manure management systems are considered as well as indirect N_2O emissions from 3B Manure management (Table 5-11). Additionally, NO_x emissions from manure management are estimated. In the reporting tables all NO_x emissions are reported under 3.D Agricultural soils.

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 CH_4 emissions from 3B Manure management are cattle with approximatively 74% and swine with approximatively 23% on average over the period 1990-2016. Cattle and sheep contribute significantly to direct N_2O emissions with 71% and 12% respectively on average over the period 1990-2016.

Leaching of NO_3^- from manure management systems is not occurring in Switzerland and is thus not included in the estimates. This assessment is principally based on expert judgement from Thomas Kupper from the “School for Agricultural, Forest and Food Sciences (HAFL)” (Kupper, 2014) and based on his personal expertise and on the following literature: Sagoo et al. (2007); Petersen et al. (1998); Webb (2001); Monteny et al. (2006); Oenema et al. (2007) and Chadwick (2005).

Emissions from fur-bearing animals are not occurring in Switzerland as provisions for the husbandry of wild animals are very strict according to the Swiss animal protection law (Swiss Confederation 2003). See also chp. 5.2.1.

Table 5-10 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 1st year (Breeding Calves + Breeding Cattle 4-12 months), Breeding Cattle > 1 year (Breeding Cattle 2nd year + Breeding Cattle 3rd year), Fattening Cattle (Fattening Calves 0-4 months + Fattening Cattle 4-12 months))
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 5-11 Specification of source category 3B Manure management by manure management systems.

3B	Source	Specification CH_4		Specification N_2O	
3B6a	Direct Emissions	Liquid systems		Liquid systems	
3B6b		Solid storage and dry lot		Solid storage and dry lot	
3B6c / 3D		Pasture, range and paddock		NA[1]	
3B6d		Digesters (anaerobic digestion)		Digesters (anaerobic digestion)	
3B6e		Other	Deep litter	Other	Deep litter
			Poultry system		Poultry system
3B5a	Indirect Emissions	NA		Atmospherical deposition	
3B5b		NA		Leaching and run-off	

1) Reported under 3D Agricultural Soils

5.3.2 Methodological issues

5.3.2.1 Methodology

The calculation is based on methods described in the 2006 IPCC Guidelines (CH_4: IPCC 2006 equation 10.23; N_2O: IPCC 2006 equation 10.25).

CH_4 emissions from 3B Manure management were generally estimated using a Tier 2 methodology. For cattle a more detailed Tier 3 method was applied, estimating volatile solids (VS) excretion based on gross energy intake estimates as used for enteric fermentation. VS excretion from buffalo, camels, horses 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, poultry manure), country-specific (deep litter) or were modelled according to Mangino et al. (2001) (liquid systems, anaerobic digesters).

N_2O emissions from 3B Manure management were estimated using a country-specific Tier 3 methodology. Activity data were adjusted to the particular situation of Switzerland in coordination with the Swiss ammonia model AGRAMMON (Kupper et al., 2013). Detailed country-specific data on nitrogen excretion rates, manure management system distribution and nitrogen volatilisation were applied. Emission factors for direct N_2O emissions (EF_3) 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).

The N_2O emissions from pasture, range and paddock are reported under 3D Agricultural soils, source category 3Da3 Urine and dung deposited by grazing animals.

For calculation of CH_4 and N_2O emissions, slightly different livestock sub-categories were used (Table 5-12). 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 categorisation for the estimation of CH_4 emissions had to be adapted to data availability for energy requirements, while the categorisation for the estimation of N_2O emissions is determined by the respective categorisation of the Swiss ammonia inventory (AGRAMMON, Kupper et al. 2013, Richner et al. 2017). Nevertheless, there is no inconsistency in the total number of animals as they are the same both for CH_4 and N_2O emissions. Note that although not growing cattle in the proper sense, bulls are contained in the categories breeding cattle >1 year, breeding cattle 3rd year and/or fattening cattle according to their purposes.

The calculation of CH_4 and N_2O emissions is done by Agroscope, the Swiss centre of excellence for agricultural research (Agroscope 2018).

Table 5-12 Livestock categories for estimating CH_4 and N_2O emissions from 3B Manure management.

3B	**CH_4**		**N_2O**	
Cattle	Mature Dairy Cattle		Mature Dairy Cattle	
	Other Mature Cattle		Other Mature Cattle	
	Growing Cattle	Fattening Calves Pre-Weaned Calves Breeding Cattle 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)	Growing Cattle	Fattening Calves Pre-Weaned Calves Breeding Cattle 1st year Breeding Cattle 2nd year Breeding Cattle 3rd year Fattening Cattle
Sheep	Lambs < 1 year Mature Sheep		Fattening Sheep Milk Sheep	
Swine	Swine		Piglets Fattening Pig over 25 kg Dry Sows Nursing Sows Boars	
Buffalo	Bisons < 3 years Bisons > 3 years		Bisons < 3 years Bisons > 3 years	
Camels	Llamas < 2 years Llamas > 2 years Alpacas < 2 years Alpacas > 2 years		Llamas < 2 years Llamas > 2 years Alpacas < 2 years Alpacas > 2 years	
Deer	Fallow Deer Red Deer		Fallow Deer Red Deer	
Goats	Goats		Goat places	
Horses	Horses < 3 years Horses > 3 years		Horses < 3 years Horses > 3 years	
Mules and Asses	Mules Asses		Mules Asses	
Poultry	Poultry		Growers Layers Broilers Turkey Other Poultry	
Rabbits	Rabbits		Rabbits	
Livestock NCAC	Sheep Goats Horses < 3 years Horses > 3 years Mules Asses		Sheep Goats Horses < 3 years Horses > 3 years Mules Asses	

5.3.2.2 Emission factors CH_4

Calculation of CH_4 emissions from 3B Manure management is based on methods described in the 2006 IPCC Guidelines (IPCC 2006, equation 10.23):

$$EF_T = VS_T \bullet 365 days/year \bullet B_{0T} \bullet 0.67 kg/m^3 \bullet \sum_S MCF_S \bullet MS_{TS}$$

EF_T = annual CH_4 emission factor for livestock category *T* (kg/head/year)

VS_T = daily volatile solids (VS) excreted for livestock category *T* (kg/head/day)

B_{0T} = maximum CH_4 producing capacity for manure produced by livestock category *T* (m^3/kg)

0.67 kg/m^3 = conversion factor of m^3 CH_4 to kilograms CH_4

MCF_S = CH_4 conversion factors for each manure management system *S* (%)

MS_{TS} = fraction of livestock category *T*'s manure handled using manure management system *S* (dimensionless)

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):

$$VS = \left[GE \bullet \left(1 - \frac{DE\%}{100} \right) + (UE \bullet GE) \right] \bullet \left[\frac{1 - ASH}{EDF} \right]$$

VS = volatile solids excretion per day on a dry-organic matter basis (kg/day)

GE = gross energy intake (MJ/head/day)

DE = digestibility of the feed (%)

(UE • GE) = urinary energy expressed as fraction of GE

ASH = ash content of manure calculated as a fraction of the dry matter feed intake

EDF = energy density of feed, conversion factor for dietary GE per kg of dry matter (MJ/kg)

Gross energy intake was calculated according to the method described in chp. 5.2.2.2.1. In the case of **mature dairy cattle** the same model was used as for the estimation of CH_4 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).

For **buffalo**, **camels, horses** 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, 60% for camels and deer (assuming similar feed composition as for sheep) and 70% for horses. The urinary energy as fraction of the gross energy was 0.04, the energy density of the feed (EDF) was 18.45 MJ/kg. The ash content of manure was 8.0% for buffalo, camels and deer and 4.0% for horses (IPCC 2006).

Finally for **livestock NCAC** the same VS excretion rates as for the respective animal categories in the official census were used.

5.3.2.2.2 Maximum CH_4 producing capacity (B_0)

For the methane producing capacity (B_o) 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 m^3/kg).

5.3.2.2.3 Methane conversion factor (MCF)

For estimating CH_4 emissions from manure management, six different manure management systems are distinguished. Switzerland has an average annual temperature below 15°C (MeteoSwiss 2014) and was therefore allocated to the cool climate region without differentiation.

In the case of **solid manure** and **pasture range and paddock** the default MCF values from table 10.17 of the 2006 IPCC Guidelines were used (Table 5-13).

Liquid/slurry systems are responsible for the major part of methane emissions from Manure management (89% 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 13.3% to 14.3%. 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 for liquid/slurry systems (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 (4.0% of all volatile solids in 2016). Emissions from the digestion plant itself are reported under source category 5B2 (Anaerobic digestion at biogas facilities) and described in chp. 7.3.2.2. However, emissions from manure storage before alimentation into the digester are reported in source category 3B Manure management. The amount of manure digested anaerobically was estimated based on total energy production (SFOE 2017a) 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 5-13 is reduced according to the duration of pre-storage before the manure is delivered to the digester:

$$MCF_{PSAD} = MCF_{LS} * \left(\frac{14.49 * \left(e^{-k*AI_j} - 1 \right)}{AI_j} + 1 \right)$$

MCF_{PSAD} = CH_4 conversion factor for pre-storage of liquid manure before delivery to biogas plants (%)

MCF_{LS} = CH_4 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 2.5% and 2.7%. 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 5-13 Manure management systems and methane conversion factors (MCFs). Blue: annually changing parameters, value for 2016.

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 5-14). The fractions are determined by the livestock husbandry system (e.g. tie stall or loose housing system) as defined in Richner et al. (2017). Estimation is conducted within the Swiss ammonium model AGRAMMON (Kupper et al. 2013, Kupper et al. 2018) based on expert judgement and values from the literature (1990, 1995) and on extensive farm surveys (2002, 2007, 2010 and 2015). 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.

Data for manure management system distribution for cattle is different for VS and nitrogen. This is because cattle stables usually have simultaneously both liquid and solid manure storage systems. As volatile solids are excreted mainly in dung and nitrogen maily in urine, the proportion of VS stored as solid manure is higher compared to the proportion of N. Data provided in Table 5-14 and in the CRF refers to the distribution of nitrogen.

The amount of manure digested anaerobically was estimated based on total energy production (SFOE 2017a) 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 CH_4

Activity data of all livestock categories covered by the official census was obtained from SBV (2017) and the SFSO (2017e). 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 2017f). For further details and additional data on a livestock sub-category level refer to chp. 5.2.2.3, Table 5-8 as well as Annex 3 A3.3.

Table 5-14 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	20.6	39.1	0.5	0.0
Growing Cattle (weighted average)	47.5	31.8	15.7	0.4	4.5	48.5	30.9	15.8	0.4	4.5	42.2	25.5	27.3	0.5	4.5
Fattening Calves	*14.6*	*0.0*	*0.0*	*0.4*	*85.0*	*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*	*41.3*	*21.0*	*37.3*	*0.5*	*0.0*
Breeding Cattle 1st Year	*36.9*	*48.6*	*14.1*	*0.4*	*0.0*	*38.0*	*47.5*	*14.2*	*0.4*	*0.0*	*33.8*	*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*	*23.3*	*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*	*42.3*	*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*	*67.4*	*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	38.2	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	86.8	7.3	0.0	5.9	0.0	38.4	26.9	0.0	34.7

MS Distribution	2007					2010					2015				
	%					%					%				
	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	67.5	13.5	17.7	1.3	0.0	67.1	14.3	16.9	1.7	0.0	70.0	10.6	16.1	3.3	0.0
Other Mature Cattle	49.7	20.1	29.0	1.3	0.0	48.0	17.8	32.4	1.7	0.0	50.7	14.6	31.4	3.3	0.0
Growing Cattle (weighted average)	45.6	23.8	24.7	1.3	4.7	45.0	24.8	22.7	1.7	5.7	47.0	21.8	22.5	3.3	5.4
Fattening Calves	*21.9*	*0.0*	*0.2*	*1.3*	*76.6*	*17.0*	*0.0*	*0.2*	*1.7*	*81.1*	*22.1*	*0.0*	*1.2*	*3.3*	*73.3*
Pre-Weaned Calves	*50.1*	*18.5*	*30.1*	*1.3*	*0.0*	*44.7*	*32.7*	*20.9*	*1.7*	*0.0*	*35.9*	*27.6*	*33.2*	*3.3*	*0.0*
Breeding Cattle 1st Year	*41.1*	*34.4*	*23.3*	*1.3*	*0.0*	*43.5*	*33.3*	*21.5*	*1.7*	*0.0*	*44.8*	*30.7*	*21.1*	*3.3*	*0.0*
Breeding Cattle 2nd Year	*41.5*	*20.7*	*36.5*	*1.3*	*0.0*	*43.3*	*20.7*	*34.3*	*1.7*	*0.0*	*42.4*	*19.4*	*34.8*	*3.3*	*0.0*
Breeding Cattle 3rd Year	*45.7*	*21.3*	*31.8*	*1.3*	*0.0*	*46.3*	*21.3*	*30.6*	*1.7*	*0.0*	*54.2*	*17.0*	*25.5*	*3.3*	*0.0*
Fattening Cattle	*62.4*	*28.9*	*4.3*	*1.3*	*3.1*	*57.8*	*32.7*	*4.0*	*1.7*	*3.9*	*61.5*	*27.0*	*4.8*	*3.3*	*3.4*
Sheep (weighted average)	0.0	0.0	39.3	0.0	60.7	0.0	0.0	33.7	0.0	66.3	0.0	0.0	33.6	0.0	66.4
Swine (weighted average)	94.5	0.1	1.2	4.1	0.0	94.0	0.3	0.1	5.6	0.0	89.2	0.0	0.0	10.8	0.0
Buffalo (weighted average)	42.4	21.1	36.5	0.0	0.0	44.5	21.2	34.3	0.0	0.0	44.8	20.4	34.8	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	0.0	0.0	33.0	0.0	67.0
Deer (weighted average)	0.0	0.0	40.2	0.0	59.8	0.0	0.0	34.5	0.0	65.5	0.0	0.0	33.0	0.0	67.0
Goats	0.0	0.0	7.1	0.0	92.9	0.0	0.0	10.0	0.0	90.0	0.0	0.0	11.6	0.0	88.4
Horses (weighted average)	0.0	78.7	21.3	0.0	0.0	0.0	74.4	25.6	0.0	0.0	0.0	80.5	19.5	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	0.0	77.5	22.5	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	0.0	0.0	3.1	0.0	96.9
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	34.6	28.6	0.0	36.9	0.0	39.5	27.4	0.0	33.1	0.0	41.4	24.0	0.0	34.5

5.3.2.4 Emission factors N_2O

Estimation of direct N_2O emissions from manure management relies basically on the same animal waste management systems as the estimation of CH_4 emissions (compare chp. 5.3.2.2). All emission factors are based on default values given in table 10.21 of the 2006 IPCC Guidelines (Table 5-15). For liquid/slurry systems a weighted emission factor was calculated based on the share of systems with and without natural crust cover. Data on occurrence of natural crusts on slurry tanks of Swiss farms was raised in the census conducted for the Swiss ammonia inventory AGRAMMON (Kupper et al. 2013). Results suggest that formation of thick and permanent natural crusts on slurry tanks is not widespread in Switzerland. The share of systems with crust formation ranges from 0.0 to 7.1% and leads to a N_2O emission factor that ranges from 0.0000 to 0.0004 kg N_2O-N/kg N, respectively.

Table 5-15 Emission factors for calculating N_2O emissions from manure management. Blue: annually changing parameters, value for 2016.

Animal waste management system	**Emission factor**
	kg N_2O-N / kg N
Liquid/Slurry: with natural crust cover	0.005
Liquid/Slurry: without natural crust cover	0.000
Solid storage	0.005
Anaerobic digester	0.000
Cattle and swine deep bedding: no mixing	0.010
Poultry manure	0.001
Indirect emissions due to volatilisation	0.026

The emission factor for indirect N_2O emissions after volatilisation of NH_3 and NO_x from manure management systems was reassessed during a literature review by Bühlmann et al. 2015 and Bühlmann 2014. Due to the fragmented land use in Switzerland, where agricultural land use alternates with natural and semi-natural ecosystems over short distances, the share of volatilised nitrogen that is re-deposited in (semi-)natural habitats is on average higher than 55%. Thus, the assumption made in the 2006 IPCC Guidelines that "a substantial fraction of the indirect emissions will in fact originate from managed land", cannot be applied to Switzerland. Accordingly, the overall emission factor for indirect emissions was estimated by calculating an area-weighted mean of the indirect emission factor for managed land (i.e. 0.01 based on IPCC 2006) and the indirect emission factor for (semi-)natural land (as provided in Bühlmann 2014). Due to slightly changing land use over the inventory time period, the resulting emission factor shows some small temporal variation around a mean value of 2.55%. Note that the emission factor in cell R37 of CRF Table3.B(b) refers to kg N_2O/kg N instead of kg N_2O-N/kg N.

5.3.2.5 Activity data N_2O

Activity data for N_2O emissions from 3B Manure management was estimated according to equation 10.25 of the 2006 IPCC Guidelines:

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

$N_2O_{D(mm)}$ = direct N_2O emissions from manure management (kg N_2O/year)

$N_{(T)}$ = number of head of livestock species/category *T* (head)

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* (kg N/head/year)

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S*

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system *S* (kg N_2O-N/kg N)

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

5.3.2.5.1 Livestock population

Activity data of all livestock categories covered by the official census was obtained from SBV (2017) and the SFSO (2017e). 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 2017f). For further details and additional data on a livestock sub-category level refer to chp. 5.2.2.3, Table 5-8 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 5-16). These values are based on the “Principles of Fertilisation in Arable and Forage Crop Production” (Richner et al. 2017). 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.; Kupper et al. (2013)). 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 CH_4 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 2015.

Sheep in Switzerland are fed mainly on roughage from extensive pasture and meadows (Richner et al. 2017) 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 5-16 Nitrogen excretion rates of Swiss livestock. 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		100.4	101.5	103.9	108.0	109.1	110.1	110.3	110.4	110.5	110.7
Other Mature Cattle		85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Growing Cattle (weighted average)		33.0	33.1	33.1	32.6	32.7	32.7	32.9	32.8	32.7	32.8
	Fattening Calves	*13.0*	*13.0*	*13.0*	*14.2*	*14.6*	*15.0*	*15.3*	*15.7*	*16.0*	*16.4*
	Pre-Weaned Calves	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*
	Fattening Cattle	*33.0*	*33.0*	*33.0*	*34.2*	*34.6*	*35.0*	*35.3*	*35.7*	*36.0*	*36.4*
Sheep (weighted average)		7.5	7.6	8.0	8.1	8.2	8.2	8.2	8.4	8.5	8.4
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		11.2	11.1	11.3	11.1	11.3	11.2	11.2	11.4	11.2	11.4
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)		16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Poultry (weighted average)		0.6	0.5	0.5	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	34.0	14.5	12.6	12.5	12.6	12.3	13.2	14.3	14.9

Nitrogen Excretion		**2012-2016**				
		2012	**2013**	**2014**	**2015**	**2016**
		kg N/head/year				
Mature Dairy Cattle		111.0	111.2	111.4	111.6	111.6
Other Mature Cattle		85.0	85.0	85.0	85.0	85.0
Growing Cattle (weighted average)		33.0	33.1	33.1	33.1	33.0
	Fattening Calves	*16.8*	*17.2*	*17.6*	*18.0*	*18.0*
	Pre-Weaned Calves	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*
	Fattening Cattle	*36.8*	*37.2*	*37.6*	*38.0*	*38.0*
Sheep (weighted average)		8.5	8.6	8.5	8.4	8.4
Swine (weighted average)		9.3	9.4	9.5	9.6	9.7
Buffalo (weighted average)		36.9	36.9	36.4	36.4	36.4
Camels (weighted average)		12.8	12.9	12.8	12.7	12.6
Deer (weighted average) [1)]		22.5	23.0	23.0	23.0	23.1
Goats		11.5	11.6	11.6	11.4	11.4
Horses (weighted average)		43.7	43.8	43.8	43.8	43.8
Mules and Asses (weighted average)		16.0	16.0	16.0	16.0	16.0
Poultry (weighted average)		0.5	0.5	0.5	0.5	0.5
Rabbits		1.0	1.0	1.0	1.0	1.0
Livestock NCAC (weighted average)		15.4	15.6	15.7	14.9	15.3

[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, Kupper et al. 2018) and on data provided in Richner et al. (2017). For cattle, the distribution of animal excreta to the various manure management systems is different with regard to estimating CH_4 emissions from 3B Manure management (for further information refer to chp. 5.3.2.2.4) compared to estimating N_2O emissions from 3B Manure management. This is because cattle stables usually have simultaneously both liquid and solid manure storage systems. As volatile soilds are excreted mainly in dung and nitrogen maily in urine, the proportion of VS stored as solid manure is higher compared to the proportion of N. Data provided in Table 5-14 and in the CRF refers to the distribution of nitrogen.

5.3.2.5.4 Volatilisation of NH_3 and NO_x from manure management systems

Indirect N_2O emissions from the deposition of NH_3 and NO_x volatilised from manure management are considered. 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 14.9 to 20.4%.

For the volatilisation of NO_x default values from the EMEP/EEA air pollutant emission inventory guidebook 2016 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 2016). 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 5-20.

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 5-17).

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 5-17 Uncertainties for 3B Manure management. (AD: Activity data; EF: Emission factor; CO: Combined).

Uncertainty 3B		Approach 1			Approach 2		
		AD	EF	CO	low	high	mean
		%			%		
CH_4		6.5	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	-76	89	83
N_2O indirect	Indirect emissions	46.5	240.0	244.5	-77	126	102

The time series 1990–2016 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, 2010 and 2015 (extensive surveys on approximately 3000 farms). Values in-between the assessment years were interpolated linearly. For 2016 the same values as in 2015 were applied.
- 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 assurance 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. A cross check of these estimates was conducted during the 2016 submission. 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. Using this approach, total VS excretion for the year 2014 was 4.1% higher than reported in the Swiss GHG 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 $\leq$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, Henne et al. 2016, Henne et al. 2017, Hiller et al. 2014, Hiller et al. 2014a, Stieger 2013, Stieger et al. 2015). For further information on these studies see chp. 5.2.4. and Annex 5.2.

5.3.4.2 QA/QC and verification – N_2O

N_2O estimation is based on the Swiss ammonium emission model AGRAMMON that is documented in Kupper et al. (2013, 2018).

All relevant data needed for the calculation of N_2O emissions such as nitrogen excretion rates, manure management system distribution and N_2O emission factors were checked for consistency and were compared to the corresponding values of other countries and to the IPCC default value if available (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 agreement 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 (see 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). There was good agreement (average discrepancy of ±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. 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. Differences were smaller than 3% for years after 2005. All QA/QC checks of the N_{ex} values are further elaborated in Agroscope (2016b).

5.3.5 Category-specific recalculations

General information on recalculations is provided in chp. 10.

Recalculations with an overall impact of >0.5 kt CO_2 equivalents are assessed quantitatively. All other recalculations are only described qualitatively.

- Recalculation of livestock population statistics and net energy intake is provided in chp. 5.2.5.
- All estimates based on AGRAMMON data were recalculated for all years due to the implementation of a new model version and revised estimates. This affects among others particularly nitrogen excretion rates. The impact on overall emissions in kt CO_2 equivalents is: 1990: -38.7; 2015: -28.8; mean 1990-2015: -45.2.
- Distribution of VS to the different manure management systems (MS) was recalculated for all years based on Richner et al. 2017. See chp. 5.3.2.2.4. As the amount of VS stored in liquid systems declined, overall emissions declined significantly. Effects on overall emissions in kt CO_2 equivalents are: 1990: -46.4; 2015: -34.7; mean 1990-2015: -38.5.
- The MCF for liquid/slurry systems was slightly revised for all years due to new model runs based on new AGRAMMON data and the new VS distribution to the different manure management systems. Effects on overall emissions in kt CO_2 equivalents are: 1990: -9.4; 2015: -9.6; mean 1990-2015: -10.5.
- N_2O emissions from manure management for the years 2011-2015 were recalculated due to a new value for the occurrence of natural crust covers in 2015 and the respective

interpolation. Effects on overall emissions in kt CO_2 equivalents are: 2013: -2.1; 2014: -2.8; 2015: -3.5.

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).

A release of a new version of the AGRAMMON model is planned for 2018. If possible the respective AGRAMMON projections will be included during the next GHG inventory submission.

NMVOC emissions will be revised and separately reported for 3B Manure management and 3D Agricultural soils.

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 2017). Only one farm in the south of Switzerland is cultivating upland rice. CH_4 emissions are assumed to be zero. 90 hectars of upland rice are reported from 1997 onward in CRF Table3.C.

5.5 Source category 3D – Agricultural soils

5.5.1 Source category description

Table 5-18 Key categories of 3D Agricultural soils. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
3Da	Direct emissions from managed soils	N2O	L1, L2
3Db	Indirect emissions from managed soils	N2O	L1, T1, L2, T2

The source category 3D includes direct and indirect N_2O emissions from managed soils (Table 5-19). 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 use of synthetic fertilisers). Indirect N_2O emissions are further subdivided in 1. Atmospheric deposition and 2. Nitrogen leaching and run-off. All indirect N_2O emissions after deposition of NO_x and NH_3 or after leaching of NO_3^- are reported under source category 3Db Indirect N_2O Emissions from managed soils. This includes indirect N_2O emissions after NO_3^- 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 N_2O emissions from managed soils or in CRF Table6 “Indirect emissions of N_2O and CO_2” (see also chp. 9).

Table 5-19 Specification of source category 3D Agricultural soils.

3D	Source	Specification
3Da	Direct N_2O emissions from managed soils	1. Inorganic N fertilisers 2. Organic N fertilisers (animal manure applied to soils, sewage sludge applied to soils, other organic fertilisers applied to soils) 3. Urine and dung deposited by grazing animals 4. Crop residues (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 use of synthetic fertilisers)
3Db	Indirect N_2O 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 N_2O emissions from managed soils have decreased since 1990 in almost all major sub-categories. Only N_2O emissions from 3Da3 (Urine and dung deposited by grazing animals) increased due to a higher share of manure excreted on pasture, range and paddock. NO_x emissions have declined by more than 21% 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 N_2O emission sources are animal manure applied to soils (27%, mean 1990-2016), nitrogen input from atmospheric deposition (20%, mean 1990-2016), inorganic nitrogen fertilisers (15%, mean 1990-2016) and urine and dung deposited by grazing animals (12%, mean 1990-2016).

5.5.2 Methodological issues

5.5.2.1 Methodology

For the calculation of most N_2O emissions from 3D Agricultural soils a Tier 1 method was applied that is based on the IULIA model from Schmid et al. (2000). IULIA is an IPCC-derived method for the calculation of N_2O emissions from agriculture that basically uses the default emission factors, but adjusts the activity data to the particular situation of Switzerland. For the estimation of N_2O emissions from animal manure applied to soils as well as for the estimation of indirect N_2O emissions a more detailed Tier 3 approach was used. 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, 2018). Furthermore, the updated version of the "Principles of Fertilisation in Arable and Forage Crop Production" (GRUD; Richner et al. 2017) was used instead of obsolete data from FAL/RAC (2001), Walther et al. (1994) and Flisch et al. (2009). Most recently, additional livestock categories, new emission factors for indirect N_2O emissions from atmospheric deposition, new estimates for nitrogen leaching and run-off as well as new NO_x emission factors were implemented. Emission factors for N_2O are all IPCC default with the exception of the emission factor for indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils (EF_4) which is country specific.

The modelling of the N_2O emissions is done by Agroscope, the Swiss centre of excellence for agricultural research (Agroscope 2018) and is consistent with source category 3B N_2O emissions from manure management. The model structure is displayed in Figure 5-6 and the corresponding amounts of nitrogen are given in Table 5-20.

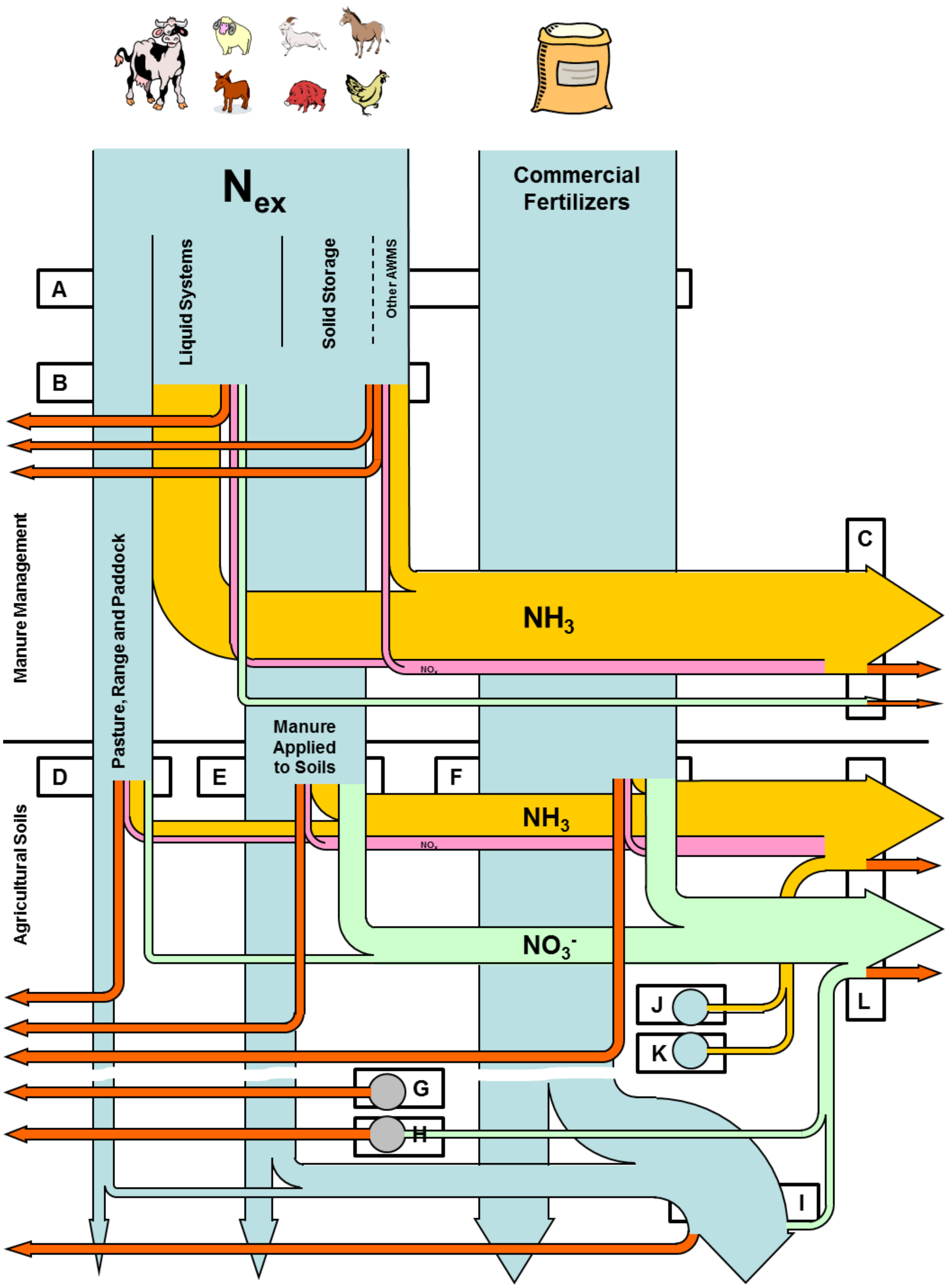


Figure 5-6 Diagram depicting the methodology of the approach to calculate the N_2O emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-20. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical nitrogen flows. Commercial fertilisers refer to the sum of urea, other mineral fertilisers, sewage sludge, other organic fertilisers and domestic use of fertilisers.

Table 5-20 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	2016		
		tN			
A	1 Pasture, range and paddock	13'424	22'386	= B	3.Da3
	2 Liquid/slurry systems	90'779	75'356		3.B(b)
	3 Solid storage	35'421	17'256		3.B(b)
	4 Other AWMS	8'455	16'601		3.B(b)
	5 Commercial fertiliser	75'016	52'781	= F	3.Da1,2bc,7
B	1 Pasture, range and paddock	13'424	22'386	= A1 + A2 + A3 + A4	3.Da3
	2 NH_3 volatilisation housing	10'887	14'853		3.B(b)5
	3 N_2O emission liquid/slurry	0	16		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	114'614	87'196		3.Da2a
	7 N_2O emission solid storage	177	86		3.B(b)
	8 N_2O emission other AWMS	46	59		3.B(b)
	9 NO_x volatilisation solid storage and deep litter	108	70		3.B(b)5
	10 NH_3 volatilisation storage	8'817	6'929		3.B(b)5
C	1 NH_3 deposition manure management	19'704	21'782	= B2+B10	3.B(b)5
	2 NO_x deposition manure management	112	74	= B4+B9	
	3 Leaching manure management	0	0	= B5	
D	1 Plant available N PR&P	9'703	16'741	= B1	
	2 N_2O emission PR&P	257	425		3.Da3
	3 NO_x volatilisation PR&P	74	123		
	4 NH_3 volatilisation PR&P	625	1'103		
	5 Leaching and run-off PR&P	2'767	3'993		
E	1 Plant available N animal manure	59'941	51'843	= B6	
	2 N_2O emission application animal manure	1'146	872		3.Da2a
	3 NO_x volatilisation application animal manure	630	480		
	4 NH_3 volatilisation application animal manure	29'277	18'446		
	5 Leaching and run-off application animal manure	23'620	15'555		
F	1 Plant available N com. fertiliser	53'753	39'660	= A5	
	2 N_2O emission application com. fertiliser	750	525		3.Da1,2bc,7
	3 NO_x volatilisation application com. fertiliser	413	290		
	4 NH_3 volatilisation application com. fertiliser	4'641	2'925		
	5 Leaching and run-off application com. fertiliser	15'460	9'381		
G	1 Cultivation of organic soils (ha)	*18'039*	*17'382*		3.Da6
H	1 Mineralisation/immobilisation soil organic matter	620	762		3.Da5
I	1 N in crop residues pasture, range and paddock	23'972	23'631		3.Da4
	2 N in crop residues arable crops	11'953	10'139		
J	1 NH_3 volatilisation agricultural area	NA	NA		
K	1 NH_3 volatilisation alpine area	NA	NA		
L	1 NH_3 deposition fertiliser appl. and PR&P	34'543	22'474	= D4+E4+F4	3.Db1
	2 NO_x deposition fertiliser appl. and PR&P	1'117	893	= D3+E3+F3	
	3 NH_3 deposition agricultural and alpine area	0	0	= J+K	
	4 Leaching and run-off fertiliser appl. and PR&P	41'846	28'930	= D5+E5+F5	3.Db2
	5 Leaching and run-off mineralisation SOM	128	136		
	6 Leaching and run-off crop residues	7'404	6'024		

5.5.2.2 Direct N_2O emissions from managed soils (3Da)

Calculation of Direct N_2O emissions from managed soils is based on IPCC 2006 equation 11.1 including six terms for activity data and three different emission factors:

$$N_2O_{Direct} - N = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_1 + F_{OS} \bullet EF_2 + F_{PRP} \bullet EF_3$$

N_2O_{Direct}-N = annual direct N_2O–N emissions produced from managed soils (kg N_2O–N/year)

F_{SN} = annual amount of synthetic fertiliser N applied to soils (kg N/year)

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (kg N/year)

F_{CR} = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

F_{OS} = annual area of managed/drained organic soils (ha)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (kg N/year)

EF_1 = emission factor for N_2O emissions from N inputs (kg N_2O–N/kg N input)

EF_2 = emission factor for N_2O emissions from drained/managed organic soils (kg N_2O–N/ha/year)

EF_3 = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (kg N_2O–N/kg N input)

5.5.2.2.1 Emission factors

Emission factors for calculating 3Da Direct N_2O emissions from managed soils are based on default values as provided in the 2006 IPCC Guidelines (Table 5-21). Since the year 2007 mineral fertilisers with nitrification inhibitors are used in Switzerland. The use of nitrification inhibitors reduces direct N_2O emissions from these fertilisers by 65% (Pfab et al. 2012). The applied amounts are still small and the weighted EF_1 reported is thus only slightly below 1.0%. Due to the lack of data no other fertiliser specific emission factors were applied for EF_1. The emission factor for urine and dung deposited by grazing animals was calculated as the weighted mean between the emission factor for cattle, poultry and pigs ($EF_{3PRP,CPP}$ = 0.02) and the emission factor for sheep and “other animals” ($EF_{3PRP,SO}$ = 0.01) according to the shares of nitrogen excreted by the respective animals.

Table 5-21 Emission factors for calculating direct N_2O emissions from managed soils (IPCC 2006). Blue: annually changing parameters, value for 2016.

Emission source	Emission factor
EF_1 Inorganic N fertilisers (kg N_2O-N/kg)	0.0099
EF_1 Organic N fertilisers (kg N_2O-N/kg)	0.0100
EF_1 Crop residue (kg N_2O-N/kg)	0.0100
EF_1 Mineralisation/immobilisation soil organic matter (kg N_2O-N/kg)	0.0100
EF_1 Other (domestic synthetic fertilisers) (kg N_2O-N/kg)	0.0100
EF_2 Cultivation of organic soils (kg N_2O-N/ha)	8.0000
EF_3 Urine and dung deposited by grazing animals (kg N_2O-N/kg)	0.0190

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 use of 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 (2016). 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 (i.e. domestic use of inorganic fertilisers; Kupper et al. 2013). These fertilisers are used in public green areas, sports grounds and home gardens. In the repoting 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 N_2O emissions from managed soils, the sum of urea, other mineral fertilisers, sewage sludge, other organic fertilisers and domestic use of fertilisers is referred to as “commercial fertilisers” (see also Figure 5-6 and Table 5-20).

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 the respective N-volatilisation during manure management see chp. 5.3.2.5, compare also Figure 5-6 and Table 5-23). $Frac_{GASM}$ in CRF Table3.D represents the amount of nitrogen volatilised as NH_3, NO_x and N_2O from housing and manure storage divided by the manure excreted in the stable (liquid/slurry, solid storage, digesters, deep litter and poultry manure). The nitrogen input from manure applied to soils under 3Da2a in CRF 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 applied 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). Additionally nitrogen input through co-substrats in agricultural biogas plants is accounted for under this sub-category.

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 5-14). For each livestock category the share of animals that have access to grazing, the number of days per year they are actually grazing as well as the number of hours per day grazing takes place was assessed. Estimates are based on values from the literature and expert judgement (1990, 1995) and on surveys on approximatively 3000 farms (2000, 2007, 2010, 2015).

N_2O emissions from **crop residues** are based on the amount of nitrogen in crop residues returned to soil. For **arable crops**, data on total annual crop yields were adopted from the statistical yearbooks of the Swiss Farmers Union (SBV 2017). Subsequently the relationship between nitrogen returned in crop residues and fresh matter crop yield was determined for each crop and hereafter the overall amount of nitrogen returned to soils was calculated as follows:

$$F_{CR,AC} = \sum_{T} \left(Y_T \bullet \frac{NR_T}{SY_T} \right)$$

$F_{CR,AC}$ = amount of nitrogen in crop residues from arable crops returned to soils (t N)

Y_T = amount of fresh matter crop yield for crop *T* (t)

NR_T = standard amount of nitrogen in crop residues for crop *T* (dt/ha)

SY_T = standard amount of fresh matter crop yield for crop *T* (dt/ha)

Standard values for fresh matter crop yields and nitrogen contained in crop residues are given in the “Principles of Fertilisation in Arable and Forage Crop Production” (FAL/RAC 2001 and Richner et al. 2017). For sugar beet and fodder beet it is assumed that 10% of the crop residues are removed from the fields for animal fodder. The use of crop residues for fuel or the (open) burning of crop residues are not common practice in Switzerland and are subject to strong regulations. These activities are therefore not considered to reduce the amount of N returned to soils.

Crop residues from **meadows and pastures** were also assessed. Two thirds of the agricultural land consists of grassland which underscores the importance of this source for Switzerland. According to the 2006 IPCC Guidelines (chp. 11.2.1.3) crop residues on pastures should be included in the estimation of N_2O emission from agricultural soils only for years when renewal of pastures happened. However, the area of meadows and pastures applied here refers to permanent grassland (in contrast to leys and intensive meadows). Renewal of these grasslands is not common practice in Switzerland. Crop residues from meadows and pasture therefore refer here only to field losses from feed not eaten by the animals and feed losses due to trampling effects.

$$F_{CR,MP} = \sum_{P} \left(A_P \bullet \frac{SY_{DM,P}}{10} \bullet N_{DM,P} \div 1000 \bullet R_P \right)$$

$F_{CR,MP}$ = amount of nitrogen in crop residues from meadows and pastures returned to soils (t N)

A_P = area of meadow and pasture of type *P* (ha)

$SY_{DM,P}$ = standard dry matter yield per area of meadow and pasture of type *P* (dt/ha)

$N_{DM,P}$ = dry matter nitrogen content of meadow and pasture of type *P* (kg/t)

R_P = ratio of residues to harvested yield for meadows and pasture of type *P* (kg/kg)

Areas of intensive meadows, natural meadows, pasture and alpine and Jurassic pasture were obtained from SBV (2017) and from the SFSO (2017e). 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) and on Richner et al. (2017).

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 based on land use changes on a sub-category level. Only land use changes that led to a net carbon stock loss were considered, excluding land use changes that led to a net carbon stock increase. Consequently, the carbon losses used for calculating N_2O emissions from nitrogen mineralisation are not identical with the net carbon stock changes reported in the reporting tables (CRF Table4.B and Table4.C). 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 Table4.B and 4.C (see also 6.2.2).

The relevant activity data for calculating N_2O emissions from soils is displayed in Table 5-22. Additional information is given in Annex 3 A3.3.

Table 5-22 Activity data for calculating 3Da Direct N_2O emissions from managed soils.

Activity Data		**1990-1999**									
		1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
		t N/yr									
1. Inorganic N fertilisers	Urea	16'284	11'966	11'650	11'335	11'021	10'707	10'391	7'555	6'405	6'690
	Other mineral fertilisers	50'391	54'913	55'035	50'646	47'326	47'652	45'899	41'086	42'511	44'461
2. Organic N fertilisers	a. Animal manure	114'614	112'913	110'339	108'193	107'210	104'906	102'746	98'161	95'696	91'406
	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	748	823	898	972	1'047	1'122	1'253	1'380	1'507	1'635
3. Urine and dung deposited by grazing animals		13'424	13'663	13'743	13'648	13'905	14'035	15'977	17'207	18'449	19'213
4. Crop residues	Arable crops	11'953	11'620	11'805	11'741	11'134	11'350	12'670	12'053	12'454	10'933
	Residues M&P	23'972	23'985	24'060	23'938	23'602	23'952	24'028	24'092	24'142	24'047
5. Min./imm. associated with loss/gain of SOM		620	615	616	595	676	661	684	669	743	749
6. Cultivation of organic soils (ha)		18'039	18'014	17'989	17'964	17'941	17'912	17'884	17'853	17'822	17'791
7. Other (domestic inorganic fertilisers)		2'778	2'787	2'779	2'583	2'431	2'432	2'345	2'027	2'038	2'131

Activity Data		**2000-2009**									
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
		t N/yr									
1. Inorganic N fertilisers	Urea	7'631	7'815	8'020	6'754	7'875	6'605	5'977	8'305	6'600	5'302
	Other mineral fertilisers	43'042	46'788	45'281	44'098	43'392	43'478	43'227	43'282	41'985	40'456
2. Organic N fertilisers	a. Animal manure	88'538	87'161	84'488	83'708	83'153	84'696	85'482	85'966	87'797	86'786
	b. Sewage sludge	3'356	2'596	1'836	1'542	1'248	1'054	859	573	286	0
	c. Other organic fertilisers	1'763	1'949	2'082	2'096	2'160	2'418	2'719	3'048	3'321	3'572
3. Urine and dung deposited by grazing animals		21'312	23'009	24'475	24'175	23'743	23'879	24'053	24'067	24'264	23'750
4. Crop residues	Arable crops	12'345	10'752	11'722	10'011	12'152	11'750	10'876	11'786	11'690	12'103
	Residues M&P	24'056	24'075	24'062	24'154	24'154	23'976	23'975	24'030	23'996	23'994
5. Min./imm. associated with loss/gain of SOM		749	749	749	749	749	779	733	682	571	759
6. Cultivation of organic soils (ha)		17'760	17'729	17'698	17'668	17'637	17'606	17'580	17'555	17'535	17'513
7. Other (domestic inorganic fertilisers)		2'111	2'275	2'221	2'119	2'136	2'087	2'050	2'149	2'024	1'907

Activity Data		**2010-2016**						
		2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
		t N/yr						
1. Inorganic N fertilisers	Urea	7'101	6'487	5'338	5'748	7'890	6'914	8'818
	Other mineral fertilisers	45'986	40'243	39'810	37'969	41'446	36'830	37'585
2. Organic N fertilisers	a. Animal manure	86'749	86'891	87'317	86'968	87'735	87'716	87'196
	b. Sewage sludge	0	0	0	0	0	0	0
	c. Other organic fertilisers	3'875	3'951	4'088	4'236	4'268	4'295	4'445
3. Urine and dung deposited by grazing animals		23'338	23'059	23'064	22'822	22'719	22'438	22'386
4. Crop residues	Arable crops	10'740	12'460	11'429	10'330	12'504	10'925	10'139
	Residues M&P	23'983	24'028	23'976	23'838	23'785	23'677	23'631
5. Min./imm. associated with loss/gain of SOM		779	779	779	775	625	602	762
6. Cultivation of organic soils (ha)		17'490	17'468	17'446	17'426	17'410	17'400	17'382
7. Other (domestic inorganic fertilisers)		2'212	1'947	1'881	1'822	2'056	1'823	1'933

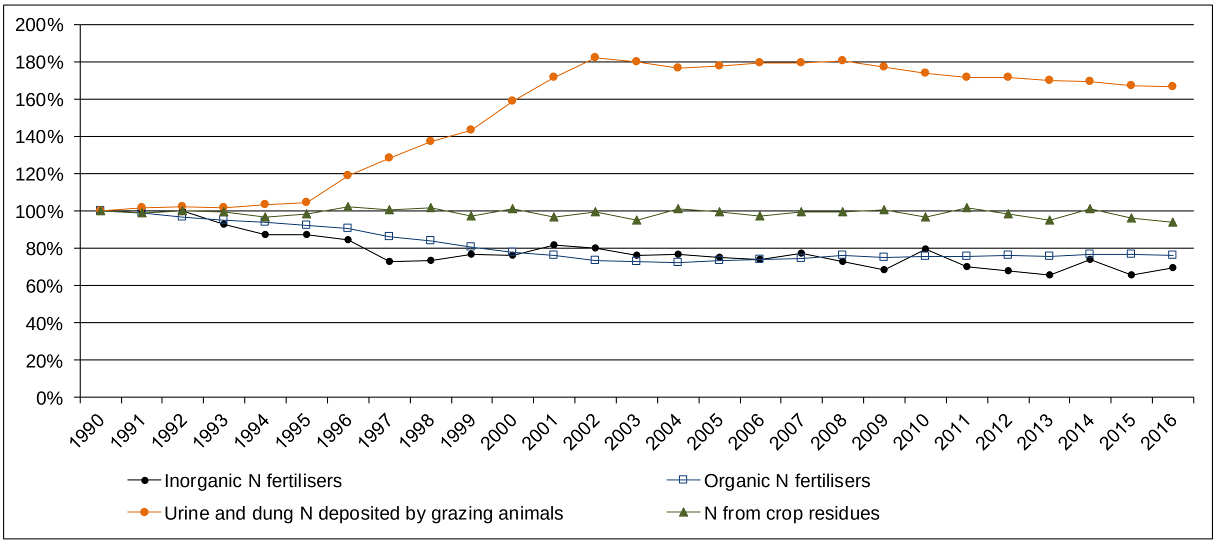


Figure 5-7 Relative development of the most important activity data for 3Da Direct N_2O emissions from managed soils.

Figure 5-7 represents the development of the most important activity data for 3Da Direct N_2O emissions from managed soils. The use of inorganic N-fertiliser declined mainly during the 1990s due to the agricultural policy reforms and the introduction of the "Proof of Ecological Performance (PEP)" that requires a balanced fertiliser management. Simultaneously, nitrogen input from animal manure declined due to declining livestock populations (mainly cattle). Urine and dung deposited by grazing animals increased substantially due to the shift to more animal-friendly livestock husbandry in the course of the agricultural policy reforms during the 1990s and the early 21[st] century (see also chp. 5.3.2.2.4). N inputs from crop residues remained more or less constant during the inventory time period due to more or less stable crop production.

5.5.2.3 Indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils (3Db1)

N_2O emissions from atmospheric deposition of N volatilised from managed soils 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:

$$N_2O_{(ATD)} - N = \left\{ \left[\sum_i \left(F_{CN_i} * Frac_{GASF_i} \right) + \sum_T \left(F_{AM_T} * Frac_{GASM_T} \right) + \sum_T \left(F_{PRP_T} * Frac_{GASP_T} \right) \right] + \left[\left(F_{CN} + F_{AM} \right) * Frac_{NOXA} + F_{PRP} * Frac_{NOXP} \right] \right\} * EF_4$$

$N_2O_{(ATD)}$-N = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils (kg N_2O–N/year)

F_{CNi} = annual amount of commercial fertiliser N of type *i* applied to soils (kg N/year)

$Frac_{GASFi}$ = fraction of commercial fertiliser N of type *i* that volatilises as NH_3 (kg N/kg N)

F_{AMT} = annual amount of managed animal manure N of livestock category *T* applied to soils (kg N/year)

$Frac_{GASMT}$ = fraction of applied animal manure N of livestock category *T* that volatilises as NH_3 (kg N/kg N)

F_{PRPT} = annual amount of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category *T* (kg N/year)

$Frac_{GASPT}$ = fraction of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category *T* that volatilises as NH_3 (kg N/kg of N)

F_{CN} = total amount of commercial fertiliser N applied to soils (kg N/year)

F_{AM} = total amount of managed animal manure N applied to soils (kg N/year)

$Frac_{NOXA}$ = fraction of applied N (commercial fertilisers and animal manure) that volatilises as NO_x (kg N/kg N)

F_{PRP} = total amount of urine and dung N deposited on pasture, range and paddock by grazing animals (kg N/year)

$Frac_{NOXP}$ = fraction of urine and dung N deposited on pasture, range and paddock that volatilises as NO_x (kg N/kg of N)

EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces (kg N_2O-N/ kg N volatilised).

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 2.55%. 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 5-23). Losses of commercial fertiliser nitrogen, animal manure N applied to soils, as well as urine and dung N deposited on pasture, range and paddock by grazing animals 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 (based on EMEP/EEA 2016), sewage sludge, and other organic fertilisers (compost, liquid and solid digestates from biogas plants). Ammonia volatilisation of nitrogen in synthetic fertilisers was assessed separately for individual fertiliser types based on

(EMEP/EEA 2016). The weighted mean value for synthetic fertilisers excluding urea is 2.8% (mean 1990-2016). Furthermore 13.1% of urea-nitrogen is lost as ammonia. 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 2001 until 2010 due to the increasing use of trailing hoses during field application.

Total $Frac_{GASF}$ (including NO_x emissions) as reported in CRF Table3.D declined considerably from 6.7% in 1990 to 5.1% in 2006 and then increased again to 6.1% in 2016 due to a change in the shares of the different commercial fertilisers.

Different ammonia loss factors were used for **animal manure N applied to soils** from different livestock categories according to the detailed approach of the AGRAMMON model (Kupper et al. 2013). Overall weighted $Frac_{GASMT}$ for animal manure applied to soils slightly declined from 26% in the early 1990s to 21% in 2016.

Ammonia volatilisation from **urine and dung N deposited on pasture, range and paddock by grazing animals** was also assessed individually for each livestock category. Weighted mean loss rates ($Frac_{GASPT}$) range from 4.7% to 4.9%.

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 5-24. Additional information is given in Annex 3 A3.3.

Table 5-23 Overview of NH_3 and NO_x emission factors used for the assessment of 3Db Indirect N_2O emissions from atmospheric deposition. 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 ($Frac_{GASFi}$)			6.19	6.05	5.45	4.71	4.51	4.93	4.84	4.77	4.89	4.96
	Urea		13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10
	Other Mineral Fertilisers		2.72	2.72	2.51	2.76	2.65	2.73	2.94	3.12	3.07	2.99
	Recycling Fertilisers (weighted average)		17.77	20.35	19.37	13.56	12.93	12.70	12.14	11.35	11.71	11.92
		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	26.06	25.05	24.04	23.03	22.01	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 ($Frac_{GASMT}$)			25.54	25.57	23.87	23.70	23.95	24.16	23.64	23.03	22.45	22.19
	Mature Dairy Cattle		27.95	28.00	26.52	26.34	26.50	26.65	26.03	25.40	24.78	24.43
	Other Mature Cattle		25.58	25.18	23.40	24.19	24.69	25.16	24.73	24.29	23.83	23.62
	Growing Cattle (weighted average)		25.90	25.96	24.18	24.38	24.74	25.10	24.56	24.04	23.51	23.30
	Sheep (weighted average)		8.81	9.36	9.34	10.48	10.90	11.32	11.19	11.07	10.96	10.86
	Swine (weighted average)		21.85	21.37	20.21	20.28	20.53	20.82	20.20	19.58	18.96	18.83
	Other Livestock (weighted average)		11.45	12.23	11.38	11.44	11.52	11.59	11.78	12.02	12.26	12.35
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)			4.65	4.69	4.78	4.89	4.91	4.95	4.90	4.87	4.84	4.85
	Mature Dairy Cattle		4.67	4.65	4.64	4.61	4.61	4.60	4.60	4.59	4.59	4.59
	Other Mature Cattle		4.57	4.57	4.56	4.57	4.57	4.57	4.57	4.56	4.56	4.56
	Growing Cattle (weighted average)		4.57	4.57	4.57	4.57	4.56	4.56	4.56	4.56	4.56	4.56
	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	6.93	7.81	9.40	9.66	10.11	9.48	8.89	8.39	8.61
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			2012-2016				
			2012	2013	2014	2015	2016
			%				
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)			4.93	5.13	5.30	5.66	5.54
	Urea		13.10	13.10	13.10	13.10	13.10
	Other Mineral Fertilisers		3.11	3.12	3.04	3.37	2.82
	Recycling Fertilisers (weighted average)		12.25	12.58	13.13	13.65	13.90
		Sewage Sludge	26.07	26.07	26.07	26.07	26.07
		Compost	3.43	3.43	3.43	3.43	3.43
		Digestate Liquid	21.00	21.00	21.00	21.00	21.00
		Digestate Solid	4.00	4.00	4.00	4.00	4.00
NH_3 from application of animal manure N ($Frac_{GASMT}$)			21.92	21.68	21.42	21.17	21.15
	Mature Dairy Cattle		24.09	23.75	23.41	23.07	23.07
	Other Mature Cattle		23.42	23.21	23.01	22.81	22.80
	Growing Cattle (weighted average)		23.10	22.88	22.66	22.46	22.45
	Sheep (weighted average)		10.75	10.63	10.52	10.41	10.41
	Swine (weighted average)		18.70	18.56	18.42	18.28	18.28
	Other Livestock (weighted average)		12.38	12.44	12.52	12.58	12.62
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)			4.86	4.87	4.88	4.90	4.93
	Mature Dairy Cattle		4.59	4.59	4.59	4.59	4.59
	Other Mature Cattle		4.57	4.57	4.57	4.57	4.57
	Growing Cattle (weighted average)		4.56	4.56	4.56	4.56	4.56
	Sheep (weighted average)		5.00	5.00	5.00	5.00	5.00
	Swine (weighted average)		14.00	14.00	14.00	14.00	14.00
	Other Livestock (weighted average)		8.67	9.01	9.34	9.79	10.18
NO_x from applied fertilisers ($Frac_{NOXA}$)			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

Table 5-24 Overview of N pools and flows for calculating 3Db Indirect N_2O emission from managed soils.

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	114'614	104'906	88'538	84'696	85'482	85'966	87'797	86'786	86'749	86'891
	Commercial fertiliser	75'016	66'854	57'903	55'642	54'832	57'357	54'217	51'236	59'175	52'628
	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)	538'676	499'774	496'667	487'956	484'816	486'686	485'812	485'330	486'382	483'414
Deposition	Sum volatised N (NH_3 and NO_x)	35'659	32'554	26'237	24'764	25'031	25'709	25'489	24'477	24'430	23'905
	NH_3 emissions from commercial fertilisers	4'641	4'048	3'158	2'621	2'471	2'826	2'626	2'442	2'893	2'609
	NH_3 emissions from applied animal manure	29'277	26'826	21'138	20'071	20'474	20'772	20'759	19'988	19'476	19'285
	NH_3 emissions from pasture, range and paddock	625	658	1'018	1'168	1'182	1'191	1'190	1'157	1'130	1'118
	NO_x emissions from commercial fertilisers	413	368	318	306	302	315	298	282	325	289
	NO_x emissions from applied animal manure	630	577	487	466	470	473	483	477	477	478
	NO_x emissions from PR&P	74	77	117	131	132	132	133	131	128	127
Leaching and run-off	Sum leaching and run-off	49'377	45'700	40'336	37'660	37'146	37'473	36'841	35'785	36'507	35'624
	Leaching and run-off from commercial fertilisers	15'460	13'777	11'398	10'440	10'187	10'521	9'835	9'219	10'535	9'362
	Leaching and run-off from applied animal manure	23'620	21'619	17'429	15'891	15'881	15'812	15'987	15'642	15'475	15'501
	Leaching and run-off from pasture, range and paddock	2'767	2'892	4'195	4'480	4'468	4'427	4'418	4'281	4'163	4'114
	Leaching and run-off from crop residues	7'404	7'275	7'166	6'703	6'474	6'588	6'498	6'506	6'194	6'509
	Leaching and run-off from mineralisation of SOM	128	136	147	146	136	125	104	137	139	139

Nitrogen pools and flows		2012-2016				
		2012	2013	2014	2015	2016
		t N/yr				
	Animals manure N applied to soils	87'317	86'968	87'735	87'716	87'196
	Commercial fertiliser	51'117	49'774	55'659	49'862	52'781
	Area of agricultural soils (ha)	1'051'063	1'049'923	1'051'183	1'049'478	1'049'072
	Alpine area (ha)	481'379	479'745	475'690	474'575	472'432
Deposition	Sum volatised N (NH_3 and NO_x)	23'667	23'394	23'763	23'369	23'367
	NH_3 emissions from commercial fertilisers	2'519	2'553	2'949	2'822	2'925
	NH_3 emissions from applied animal manure	19'140	18'852	18'791	18'567	18'446
	NH_3 emissions from pasture, range and paddock	1'120	1'111	1'109	1'100	1'103
	NO_x emissions from commercial fertilisers	281	274	306	274	290
	NO_x emissions from applied animal manure	480	478	483	482	480
	NO_x emissions from PR&P	127	126	125	123	123
Leaching and run-off	Sum leaching and run-off	35'237	34'671	36'194	34'798	35'090
	Leaching and run-off from commercial fertilisers	9'091	8'851	9'904	8'868	9'381
	Leaching and run-off from applied animal manure	15'577	15'514	15'651	15'648	15'555
	Leaching and run-off from pasture, range and paddock	4'114	4'071	4'053	4'003	3'993
	Leaching and run-off from crop residues	6'316	6'095	6'474	6'173	6'024
	Leaching and run-off from mineralisation of SOM	139	138	112	107	136

Figure 5-8 shows the development of the most important activity data for 3Db Indirect N_2O emissions from managed soils. Ammonia emissions from application of commercial fertilisers declined mainly due to reduced fertiliser use and partly also due to the decreasing share of fertilisers with high ammonia emission rates (i.e. urea and sewage sludge). Ammonia emissions from applied animal manure declined mainly due to declining livestock populations and hence due to the reductions of available manure N. The fraction of applied animal manure N that volatilises as NH_3 ($Frac_{GASMT}$) declined slightly and also contributed to the decreasing trend.

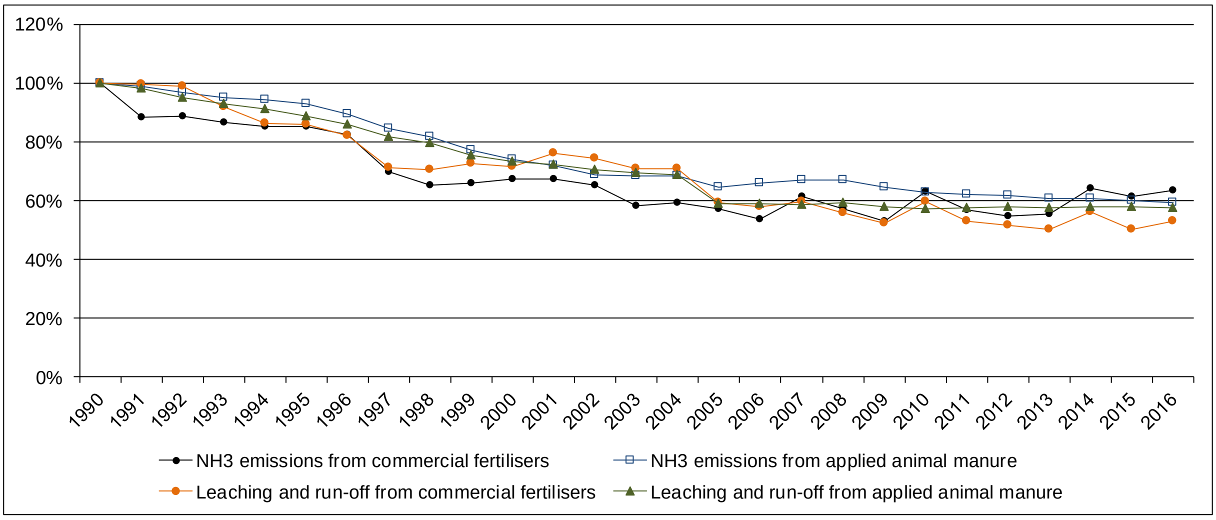


Figure 5-8 Relative development of the most important activity data for 3Db Indirect N_2O emissions from managed soils.

5.5.2.4 Indirect N_2O emissions from leaching and run-off from managed soils (3Db2)

N_2O emissions from leaching and run-off from managed soils are estimated based on equation 11.10 of the 2006 IPCC Guidelines:

$$N_2O_{(L)} - N = (F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

$N_2O_{(L)}$–N = annual amount of N_2O–N produced from leaching and run-off of N additions to managed soils (kg N_2O–N/year)

F_{CN} = annual amount of commercial fertiliser N applied to soils (kg N/year)

F_{AM} = annual amount of managed animal manure N applied to soils (kg N/year)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals (kg N/year)

F_{CR} = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes of land use or management (kg N/year)

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed soils that is lost through leaching and runoff (kg N/kg of N additions)

EF_5 = emission factor for N_2O emissions from N leaching and run-off (kg N_2O–N/kg N leached and run-off)

5.5.2.4.1 Emission factor

The emission factor for indirect N_2O emissions from leaching and run-off from managed soils is 0.0075 kg N_2O–N/kg N according to the 2006 IPCC Guidelines (IPCC 2006).

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 5-22.

$Frac_{LEACH}$ was estimated for the years 1990 and 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 Prasuhn 2016. The respective loss rates are 20.6% for 1990 and 17.8% for 2010. Spiess and Prasuhn (2006), confirm that the loss rates were somewhat higher in the early 1990s and then declined due to the agricultural policy reforms. Accordingly, the reduction in the nitrate loss rate was implemented between 1995 and 2010 with constant loss rates after 2010. The same loss rates were applied to all nitrogen pools independent of their origin and composition. An additional reduction of the nitrate loss rate originates from the application of fertilisers with nitrification inhibitors. The nitrogen loss rate is reduced by 23% for fertilisers with nitrification inhibitors (Weiske et al. 2001). Due to the limited application of nitrification inhibitors the respective effect is still small (see also chp. 5.5.2.2.1). The overall amount of nitrogen that is lost through leaching and run-off is given in Table 5-24.

Figure 5-8 illustrates the development of the most important activity data for 3Bb Indirect N_2O emissions from managed soils. Both leaching and run-off from commercial fertiliser and animal manure N declined during the inventory time period due to the reduced nitrogen inputs and the decreasing nitrate loss rates ($Frac_{LEACH}$).

5.5.2.5 NMVOC emissions

Estimation of NMVOC emissions of meadows and arable land is based on Spirig and Neftel (2002). VOC flows are estimated in Warneke et al. (2002) (for meadows) and König et al. (1995) (for arable land). Emissions were measured in a field trial in Austria (Karl et al. 2001).

5.5.3 Uncertainties and time-series consistency

For the uncertainty analysis the input data from ART (2008a) were used and were updated with current activity and emission data as well as with new default uncertainties of the 2006 IPCC Guidelines. The arithmetic mean of the lower and upper bound uncertainty is used for activity data and for emission factors, resulting in combined Approach 1 uncertainties as shown in Table 5-25. 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 5-25 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	14.5	135.0	135.8	-64	87	76
	Organic soils	32.2	137.5	141.2	-68	100	84
	Urine and dung deposited on PR&P	68.0	132.5	148.9	-68	114	91
Indirect soil emissions	Atmospheric deposition	42.0	240.0	243.6	-77	124	101
	Leaching and run-off	22.2	163.3	164.8	-77	102	90

The time series 1990–2016 are all considered consistent, although the following issues should be considered:

- For time series consistency of livestock population data see chp. 5.2.3.
- Input data from the AGRAMMON model is available for the years 1990 and 1995 (expert judgement and literature) as well as for 2002, 2007, 2010 and 2015 (extensive surveys on approximatively 3000 farms). Values in-between the assessment years were interpolated linearly.
- Estimates for sewage sludge and compost are not available for every year. Values for years without data were estimated by linear interpolation. For 2016 the same values as in 2015 were applied.
- $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{GASP}$ are fluctuating along the time series due to fluctuating shares of different fertiliser types and animal populations with different ammonia emission factors.
- The emission factor for indirect N_2O emissions following volatilisation of NH_3 and NO_x from applied fertilisers and urine and dung excreted on PR&P varies according to varying land use as described in 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, 2018) and Agrammon (2010). Generally the reporting of N_2O emissions in the Swiss national GHG inventory is consistent with the reporting of other nitrogen compounds (NH_3, 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. Nitrogen excretion, being one of the most important parameters, was analysed in more detail as described in chp. 5.3.4.2.

For quality assurance of livestock population data consult chp. 5.2.4.

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). The N_2O emission factor for cultivated organic soils was validated by a study from Leifeld (2018) that used a large data set of C/N ratios in Swiss organic soils to predict N_2O emissions. The study concluded that the current national GHG inventory neither systematically over- nor underestimates total emissions.

The estimate for the area of cultivated histosols in the agricultural sector is consistent with the estimates reported under cropland and grassland in the LULUCF sector. A literature study conducted by Leifeld et al. (2003) estimates 17'000 ± 5'000 ha which is close to the numbers reported in the LULUCF sector (17'700 ha on average).

The country-specific value of $Frac_{LEACH}$ is based on a very detailed model for the assessment of leaching and run-off in Switzerland (Hürdler et al. 2015, Prasuhn 2016) that takes into account regional parameters such as topography, different crop species as well as fertiliser application levels.

5.5.5 Category-specific recalculations

General information on recalculations is provided in chp. 10.

Recalculations with an overall impact of >0.5 kt CO_2 equivalents are assessed quantitatively. All other recalculations are only described qualitatively.

- Synthetic fertilisers applied in Liechtenstein were subtracted from the statistics provided by Agricura (2016). The recalculation affects direct and indirect N_2O emissions from agricultural soils as well as CO_2 emissions from urea application in all inventory years. The impact on overall emissions in kt CO_2 equivalents is: 1990: -1.5; 2015: -1.2; mean 1990-2015: -1.2.
- The EF for inorganic fertilisers was recalculated due to the use of nitrification inhibitors from 2007 onward. Overall emissions decreased by 1.26 kt CO_2 equivalent on average for the 2007-2015 time period.
- All estimates based on AGRAMMON data were recalculated due to the implementation of a new model version and revised estimates. This affects among others particularly nitrogen excretion rates. The impact on overall emissions in kt CO_2 equivalents is: 1990: -38.7; 2015: -28.8; mean 1990-2015: -45.2.
- AD for other organic fertilizers (liquid and solid digestate, compost) was recalculated for all years due to new data assessed and made available by the School of Agricultural, forest and Food Sciences (HAFL). For most years emissions in kt CO_2 equivalents are slightly lower after the recalculation (1990: -0.4 kt; 2015: -2.7 kt; mean: -2.0 kt).
- The AD for direct N_2O emissions from N in crop residues returned to soils was revised for the year 2014 and 2015 due to data updates by the Swiss Farmers Union and the Swiss Federal Statistical Office (harvested crop yields). Overall emissions increased negligibly for 2014 and by 1.0 kt CO_2 equivalent for 2015.
- The AD for direct N_2O emissions from N in crop residues returned to soils was revised for the whole time series due to new data on standard amounts of fresh matter crop yields and standard amounts of nitrogen in crop residues from Richner et al. (2017). The

recalculation affects direct and indirect emissions from agricultural soils. The impact on overall emissions in kt CO_2 equivalents is: 1990: +15.6; 2015: +12.3; mean: +13.4.

- The AD for direct N_2O emissions from N in mineral soils that is mineralized/immobilized in association with loss of soil C was revised due to revised estimates in the LULUCF sector for all inventory years. Overall emissions decreased by 0.6 and 0.8 kt CO_2 equivalent in 2014 and 2015. Effects on overall emissions were negligible for all other years (below 0.5 kt CO_2 equivalent).
- AD for N_2O emissions from the cultivation of organic soils was revised due to revised estimates in the LULUCF sector for all inventory years. Impact on overall emissions is negligible (below 0.2 kt CO_2 equivalents).
- Indirect N_2O emissions from atmospheric deposition was revised for all years due to new EF for ammonia volatilization for synthetic fertilisers based on EMEP/EEA (2016). The impact on overall emissions in kt CO_2 equivalents is: 1990: +0.7; 2015: +4.8; mean: +2.4.
- A re-assessment of information regarding volatilisation of ammonia from vegetation cover on agricultural and alpine soils led to the conclusion that such emissions could not be substantiated. Therefore, indirect N_2O emissions from atmospheric deposition were revised for all years. Overall emissions decreased by 28.4 kt CO_2 equivalents on average.

5.5.6 Category-specific planned improvements

A release of a new version of the AGRAMMON model is planned for 2018. If possible the revised estimates from AGRAMMON will be included during the next GHG inventory submission.

NMVOC emissions will be revised and separately reported for 3B Manure management and 3D Agricultural soils.

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, the respective emissions were moved to the LULUCF and the waste sector based on recommendations from the UNFCCC expert review teams (e.g. FCCC/ARR/2016/CHE W12 and W13). Respective information can be found under source category 4V “Biomass Burning” (see chp. 6.4.2.13) and source category 5C “Incineration and open burning of waste” (see chp. 7.4).

5.8 Source category 3G – Liming

5.8.1 Source category description

CO_2 emission from 3G Liming is not a key category.

Emissions from the application of lime ($Ca(CO_3)$) and dolomite ($CaMg(CO_3)_2$) to agricultural soils are reported.

The emissions due to liming of agricultural soils range from 22.2 to 32.9 kt CO_2 per year.

5.8.2 Methodological issues

A simple Tier 1 approach was adopted using estimated amounts of lime and dolomite applied and IPCC default emission factors.

5.8.2.1 Emission factor

The availability of country-specific emission factors for agricultural lime and dolomite application was investigated, but no domestic measurement data could be found. Consequently, the IPCC default carbon conversion factors for carbonate containing lime (0.12 t C per t $Ca(CO_3)$) and for dolomite (0.13 t C per t $CaMg(CO_3)_2$) were used (IPCC 2006).

5.8.2.2 Activity data

The total annual amount of lime and dolomite applied to agricultural soils is between 51’300 Mg (1990) and 74'050 Mg (2008–2015). It was estimated by Agroscope in 2009 for the period 1990–2008. For 2009–2015 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). The split of lime into calcium carbonate and dolomite is based on the following assumptions and data:

- $Ca(CO_3)$ contained in mixed compound fertilisers as reported by Agricura (2016)
- All material originating from nuclear power plants and from the sugar beet industry is $Ca(CO_3)$
- The remaining lime not covered under the points above was divided equally into $Ca(CO_3)$ and $CaMg(CO_3)_2$.

5.8.3 Uncertainties and time-series consistency

The amount of total lime applied in agriculture is mainly based on expert judgement; the resulting number is uncertain. A relative uncertainty of ± 40% was used as an approximation (Agroscope 2014a). For the emission factor of lime a lower uncertainty of ± 5% was chosen, because it is a simple chemical process. The combined Approach 1 uncertainty is thus ±40.3%. Approach 2 uncertainties do not differ significantly from Approach 1 uncertainties.

For further results also consult 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

General information on recalculations is provided in chp. 10.

No category-specific recalculations were carried out.

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

CO_2 emission from 3H Urea application is not a key category.

Adding urea to soils during fertilisation leads to a loss of CO_2 that was fixed during the industrial production process of the fertiliser. Emissions in Switzerland range from 8.7 to 26.7 kt CO_2 per year with a general decreasing trend from 1990 to 2016.

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 (2016). Fertiliser statistics are based on sales statistics by the compulsory stockpiler of fertilisers (Pflichtlagerhalter) and small importers. Agricura conducts plausibility checks with import-data received by the Directorate General of Customs (Oberzolldirektion).

5.9.3 Uncertainties and time-series consistency

An uncertainty of ±5% for the activity data was estimated according to ART (2008a). An uncertainty of ±5% was assumed for the emission factor since it is a simple chemical process. The combined Approach 1 uncertainty is hence ±7.1%. Approach 2 uncertainties do not differ significantly from Approach 1 uncertainties.

For further results also consult 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

General information on recalculations is provided in chp. 10.

Recalculations with an overall impact of >0.5 kt CO_2 equivalents are assessed quantitatively. All other recalculations are only described qualitatively.

- Synthetic fertilisers applied in Liechtenstein were subtracted from the statistics provided by Agricura (2016). The recalculation affects direct and indirect N_2O emissions from agricultural soils as well as CO_2 emissions from urea application in all inventory years. The impact on overall emissions in kt CO_2 equivalents is: 1990: -1.5; 2015: -1.2; mean 1990-2015: -1.2.

5.9.6 Category-specific planned improvements

No category-specific improvements are planned.

6 LULUCF

6.1 Overview of LULUCF

6.1.1 Methodology

Chapter 6 presents estimates of GHG 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 subcategories country-specific emission factors were used.

The land areas in the period 1990–2016 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 were completed in 2013 and the interpretation of the entire Swiss territory is available for three time slices. In this submission, results of the ongoing AREA4 survey for the western part of Switzerland 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 National Forest Inventories (NFI1, NFI2, NFI3, finalized in 1985, 1995, and 2006, respectively) and the first five annual tranches of the continuous NFI4 (2011–2015). The inventories comprised ca. 3'400 (5-years interval from NFI4), 6'500 (NFI2 and NFI3) and 11'000 (NFI1) terrestrial plots (see Table 6-12), where biomass stock, growth, cut and mortality were measured.

For the remaining land-use categories, carbon stocks and GHG emissions and removals were derived from domestic surveys, particular research activities, and measurements in the fields of agriculture (Cropland, Grassland) and nature conservation (Wetlands). Partially, also IPCC default values and expert estimates were used.

6.1.2 Emissions and removals

Table 6-1 and Figure 6-1 summarize the CO_2 emissions and removals as a result of carbon losses and gains for the years 1990–2016. The total net emissions and removals of CO_2 varied between -5'373 kt (1996) and 4'694 kt (2000).

Table 6-1 and Figure 6-1 show a breakdown of Switzerland's CO_2 balance in the LULUCF sector. Five components were differentiated:

- Gains in carbon stock of living biomass on all land uses and due to land-use changes; this component represents the largest sink of carbon.
- Losses in carbon stock of living biomass on all land uses and due to land-use changes; this componentrepresents the largest source of carbon. The highest losses were observed in the year 2000 after 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 land converted to or from Forest land. This component 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 (2) due to land-use changes. 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 occured in forests, where growth of biomass (gains) exceeded cut and mortality (losses), except for the years 2000 and 2006 (see also chp. 2.3.3). Overall, the LULUCF sector was a sink of on average -2'014 kt CO_2 yr^{-1} between 1990 and 2016 (see Table 6-1 and Figure 6-3).

Table 6-1 CO_2 emissions and removals in the LULUCF sector. See main text for the respective components. Positive values refer to emissions; negative values refer to removals. In this data set, emissions of CH_4 and N_2O are not included; GHG (i.e. CO_2, CH_4, N_2O) emissions and removals in the LULUCF sector (in CO_2 eq) are shown in Figure 6-3.

LULUCF	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt CO_2									
Gains of living biomass	-12'696	-12'712	-12'857	-12'815	-12'756	-13'003	-12'956	-12'944	-12'636	-12'647
Losses of living biomass	12'478	9'232	8'879	8'678	9'659	9'266	9'097	9'885	11'033	10'938
Net change in dead organic matter	219	-485	110	-131	487	-277	-1'715	-889	-921	-600
Net change in organic and mineral soils	486	486	485	481	484	482	486	481	496	497
LULUCF (excluding HWP)	486	-3479	-3383	-3786	-2127	-3533	-5087	-3467	-2027	-1813
Net change in Harvested wood products (HWP)	-1'305	-823	-531	-476	-363	-504	-286	-255	-251	-404
Total LULUCF	-818	-4302	-3913	-4262	-2490	-4037	-5373	-3722	-2278	-2216

LULUCF	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt CO_2									
Gains of living biomass	-13'060	-12'663	-12'717	-12'679	-13'371	-12'792	-13'256	-13'876	-13'469	-13'485
Losses of living biomass	18'346	12'373	10'098	11'308	11'085	11'417	14'157	13'724	12'728	12'018
Net change in dead organic matter	-379	-594	-134	-1'016	-655	-1'019	-520	-133	-557	-707
Net change in organic and mineral soils	496	495	495	494	493	513	519	515	499	486
LULUCF (excluding HWP)	5403	-388	-2258	-1893	-2448	-1882	900	229	-798	-1688
Net change in Harvested wood products (HWP)	-709	-543	-408	-441	-606	-740	-544	-517	-386	-410
Total LULUCF	4694	-931	-2666	-2333	-3054	-2622	356	-288	-1184	-2098

LULUCF	2010	2011	2012	2013	2014	2015	2016	Mean
	kt CO_2							
Gains of living biomass	-13'415	-14'034	-13'430	-13'440	-14'139	-13'428	-13'656	-13'146
Losses of living biomass	12'941	12'575	11'907	12'386	12'243	12'020	11'608	11'559
Net change in dead organic matter	-1'216	33	-408	-706	310	-363	-191	-461
Net change in organic and mineral soils	498	498	499	513	516	529	516	498
LULUCF (excluding HWP)	-1192	-928	-1432	-1247	-1070	-1242	-1724	-1'551
Net change in Harvested wood products (HWP)	-415	-459	-294	-90	-301	-227	-213	-463
Total LULUCF	-1608	-1387	-1726	-1337	-1371	-1469	-1937	-2'014

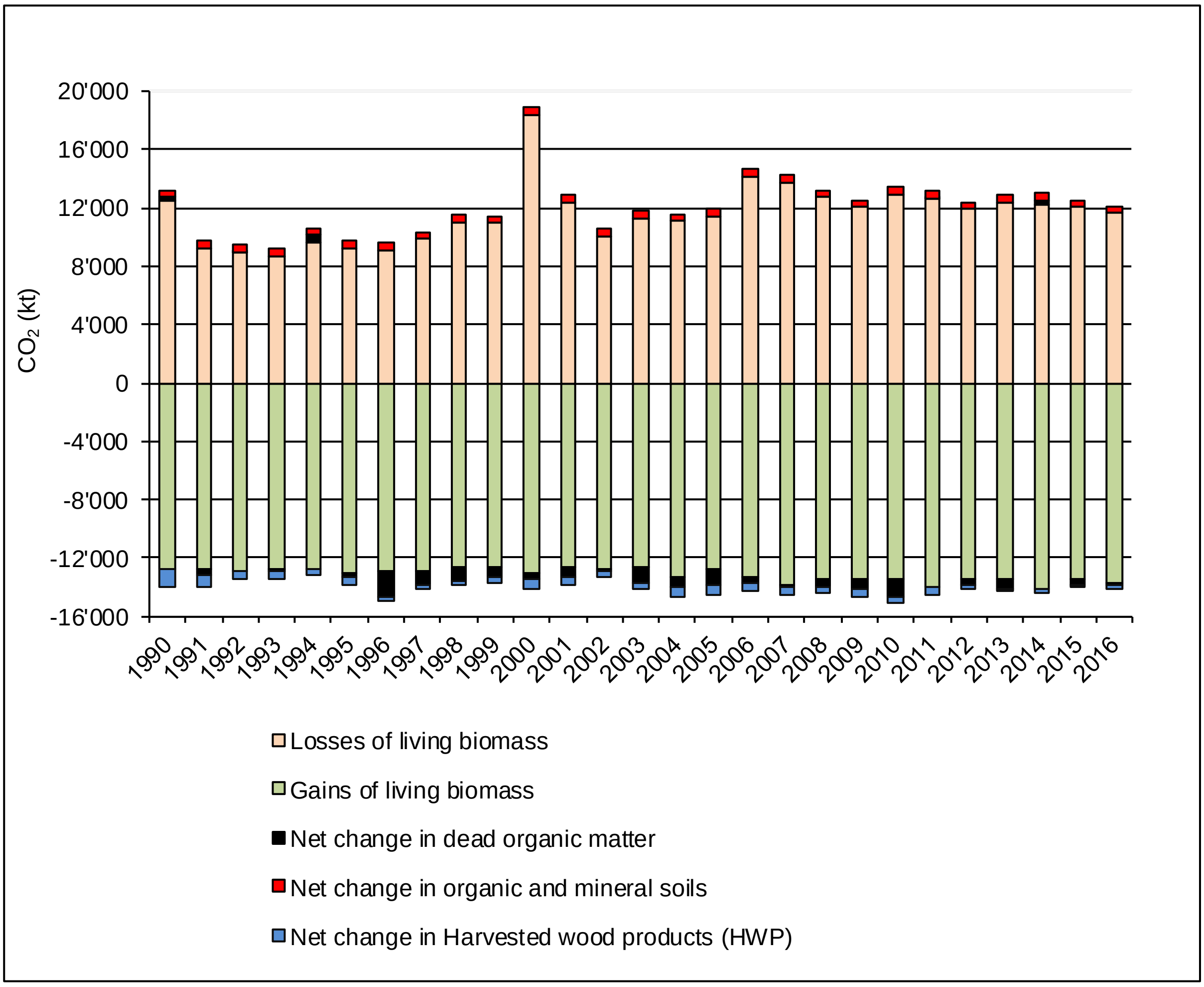


Figure 6-1 CO_2 emissions and removals in the LULUCF sector (in kt CO_2), broken down for: (i) CO_2 removals due to the gain (growth) of living biomass, (ii) CO_2 emissions due to the loss (cut and mortality) of living biomass, (iii) net CO_2 emissions and removals from dead organic matter, (iv) net CO_2 emissions from soils, and (v) net CO_2 removals from Harvested wood products. Positive values indicate emissions, negative values indicate removals.

The non-CO_2 emissions associated with land use, land-use change and forestry were relatively small. Between 1990 and 2016 maximum annual CH_4 emissions were 1.29 kt yr^{-1}, and maximum annual N_2O emissions were 0.21 kt yr^{-1} (32 kt CO_2 eq and 62 kt CO_2 eq, respectively; see year 1997 in Figure 6-2). The emissions arose from (1) drained organic soils (N_2O; CRF Table4(II)), (2) flooded lands/reservoirs (CH_4; CRF Table4(II)), (3) nitrogen mineralization associated with loss of soil organic matter resulting from land use on non-agricultural soils and land-use change (direct N_2O emissions; CRF Table4(III)), (4) nitrogen leaching and run-off on non-agricultural soils and land-use change (indirect N_2O emissions; CRF Table4(IV)), (5) wildfires on Forest land and Grassland (CH_4 and N_2O; CRF Table4(V)), and (6) controlled burning of residues from forestry (CH_4 and N_2O; CRF Table4(V)). The calculation methods are based on default procedures of IPCC (2006, Volume 4).

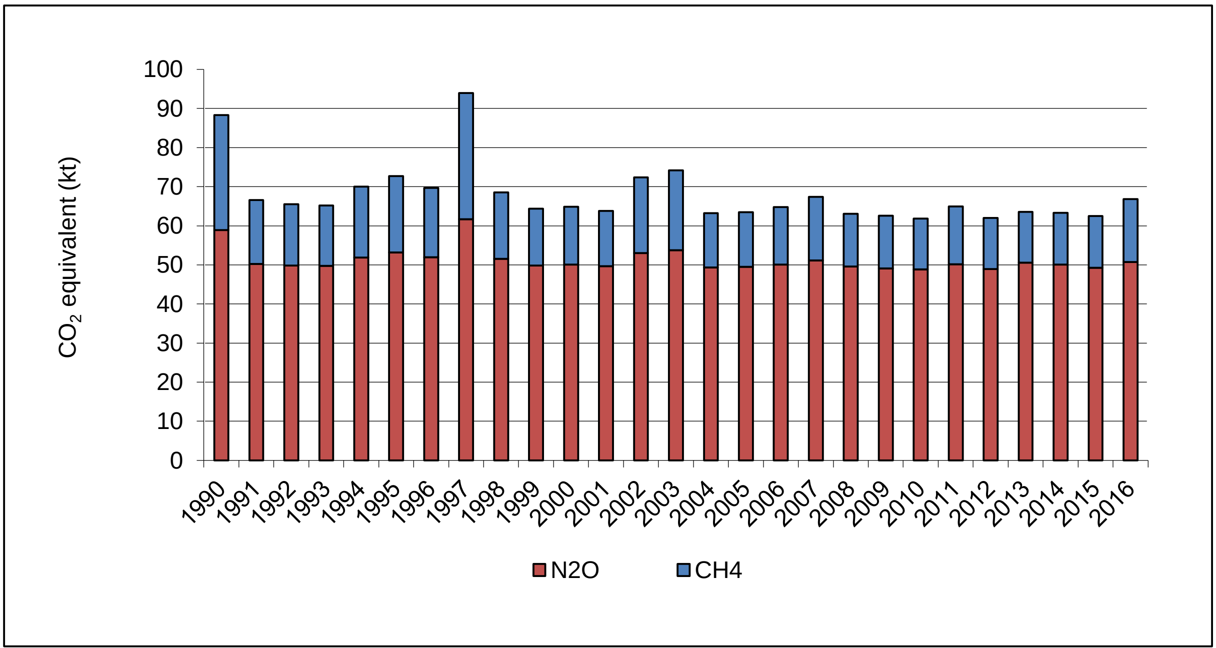


Figure 6-2 N_2O and CH_4 emissions in the LULUCF sector (in kt CO_2 eq).

Figure 6-3 shows the resulting net GHG emissions and removals in the LULUCF sector 1990–2016, including both CO_2 and non-CO_2 (i.e. CH_4, N_2O) fluxes. Further explanatory notes on LULUCF data can be found in chp. 2.3.3 “Emission trends in sector 4 LULUCF”.

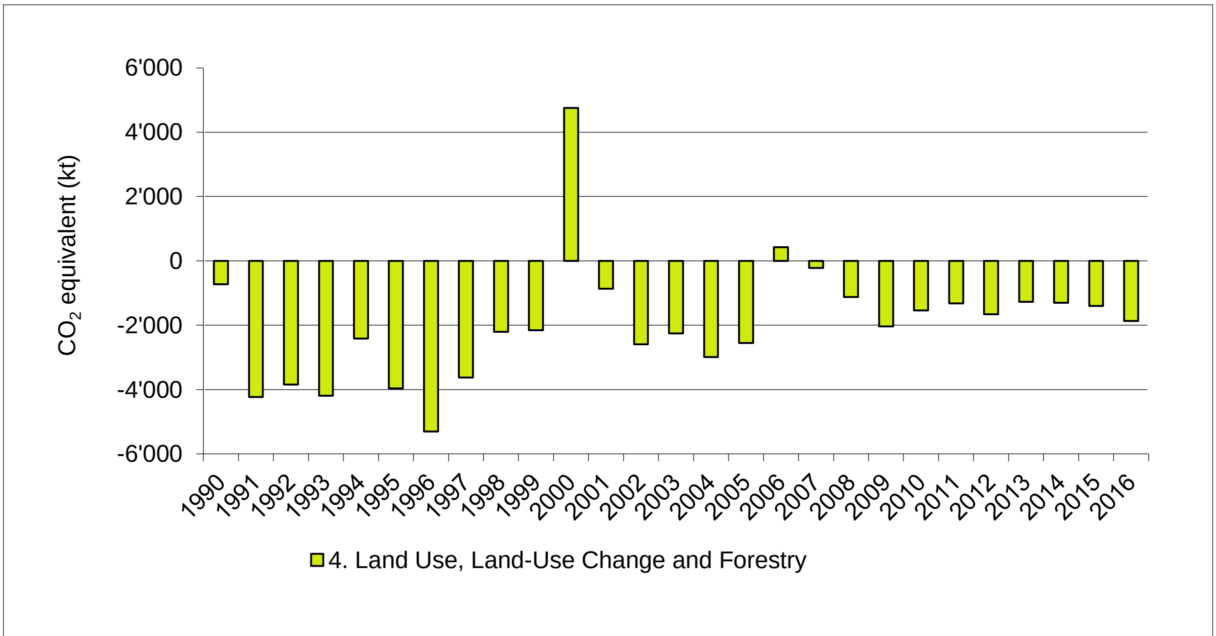


Figure 6-3 Net GHG emissions and removals in the LULUCF sector (in kt CO_2 eq). Positive values refer to emissions, negative values refer to removals.

6.1.3 Approach for calculating carbon emissions and removals

6.1.3.1 Work steps

The selected procedure for calculating carbon emissions and removals in the LULUCF sector corresponds to a Tier 2 approach as described in IPCC 2006 (Volume 4, chp. 3). It can be summarised as follows:

- Define managed and unmanaged land: In Switzerland, all land besides Other land is considered to be managed. Other land (CC61, see Table 6-2) is unmanaged. It is defined as the residual country's land area without any relevant human activities.
- 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.
- For Forest land: Measure or estimate the carbon stocks in living biomass ($stockC_l$), in dead wood ($stockC_d$), in litter ($stockC_h$), and in soil ($stockC_s$) for each spatial stratum of the combination categories (CC).
  For non-Forest land: Measure or estimate the carbon stocks in living biomass ($stockC_l$), in dead organic matter ($stockC_{dom}$), and in soil ($stockC_s$) for each spatial stratum of the combination categories (CC).
- For Forest land: Measure or estimate the gain of carbon in living biomass ($gainC_l$), the loss of carbon in living biomass ($lossC_l$), the net carbon stock change in dead wood ($changeC_d$), in litter ($changeC_h$), and in soil ($changeC_s$) for each spatial stratum of the combination categories (CC).
  For non-Forest land: Measure or estimate the gain of carbon in living biomass ($gainC_l$), the loss of carbon in living biomass ($lossC_l$), the net carbon stock change in dead organic matter ($changeC_{dom}$), and in soil ($changeC_s$) for each spatial stratum of the combination categories (CC).
- Calculate the land use and the land-use change matrix for each spatial stratum.
- For Forest land: Calculate the net carbon stock changes in living biomass ($deltaC_l$), in dead wood ($deltaC_d$), in litter ($deltaC_h$), and in soil ($deltaC_s$) for all cells of the land-use change matrix for each year under consideration.
  For non-Forest land: Calculate the net carbon stock changes in living biomass ($deltaC_l$), in dead organic matter ($deltaC_{dom}$), and in soil ($deltaC_s$) for all cells of the land-use change matrix for each year under consideration.
- Finally, aggregate the results by summarising the carbon stock changes over combination categories and spatial strata according to the level of disaggregation displayed in the reporting tables.
- Calculate emissions and removals of the carbon pool in Harvested wood products (HWP).

The combination category CC11 (see Table 6-2) refers a conversion from land to forest land that corresponds to the Swiss definition for afforestation activities under Article 3, paragraph 3, of the Kyoto Protocol as defined in the Initial Report for the first commitment period (FOEN 2006h). For the reporting under the UNFCCC, afforested areas were allocated to category 4A2 (Land converted to forest land), where they were reported in an individual subdivision afforestation (no capitalisation, first letter in lowercase; see chp. 6.4.1). The identical afforested areas were reported as Afforestations (with capitalisation, first letter in uppercase) under the Kyoto-Protocol (see chp. 11.1.3). In a nutshell, the diction Afforestation was consistently used to indicate the Kyoto Protocol Article 3, paragraph 3 activity.

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 reporting 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	afforestation	areas converted to forest by active measures, e.g. planting	afforestation	11
	productive forest	dense and open forest meeting the criteria of forest land	4A1: prod 4A2: productive	12
	unproductive forest	brush forest and forest on unproductive areas meeting the criteria of forest land	4A1: unprod 4A2: unproductive	13
B. Cropland		arable and tillage land (annual crops and leys in arable rotations)	cropland	21
C. Grassland	permanent grassland	meadows, pastures (low-land and alpine)	permanent	31
	shrub vegetation	agricultural and unproductive areas predominantly covered by shrubs	4C1: shrub 4C2: woody	32
	vineyard, low-stem orchard, tree nursery	perennial agricultural plants with woody biomass (no trees)	4C1: vine 4C2: woody	33
	copse	agricultural and unproductive areas covered by perennial woody biomass including trees	4C1: copse 4C2: woody	34
	orchard	permanent grassland with fruit trees	4C1: orchard 4C2: woody	35
	stony grassland	grass, herbs and shrubs on stony surfaces	4C1: stony 4C2: unproductive	36
	unproductive grassland	unproductive grass vegetation	unproductive	37
D. Wetlands	surface water	lakes and rivers	surface water	41
	unproductive wetland	reed, extensively managed wetland	unprod wetland	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		unmanaged 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 reporting tables on non-forest land under the UNFCCC (Table4.B to Table4.F), the carbon stocks and carbon stock changes of litter and dead wood are merged into "dead organic matter" (DOM):

$stockC_{dom,i,CC} = stockC_{d,i,CC} + stockC_{h,i,CC}$

$changeC_{dom,i,CC} = changeC_{d,i,CC} + changeC_{h,i,CC}$

On this basis, the total changes in carbon stocks (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 for each year under consideration. 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 gains and losses: (1) the gain-loss approach (Equation 2.4; IPCC 2006, Volume 4) and (2) the stock-difference approach (Equation 2.5; IPCC 2006, Volume 4).

The gain-loss approach is defined as:

$$deltaC_{l,i,ba} = (gainC_{l,i,a} - lossC_{l,i,a}) * A_{i,ba} \quad (6.1)$$

$$deltaC_{d,i,ba} = changeC_{d,i,a} * A_{i,ba} \quad (6.2)$$

$$deltaC_{h,i,ba} = changeC_{h,i,a} * A_{i,ba} \quad (6.3)$$

$$deltaC_{s,i,ba} = changeC_{s,i,a} * A_{i,ba} \quad (6.4)$$

The stock-difference approach is defined as:

$$deltaC_{l,i,ba} = [(stockC_{l,i,a} – stockC_{l,i,b}) / CT] * A_{i,ba} \quad (6.5)$$

$$deltaC_{d,i,ba} = [(stockC_{d,i,a} – stockC_{d,i,b}) / CT] * A_{i,ba} \quad (6.6)$$

$$deltaC_{h,i,ba} = [(stockC_{h,i,a} – stockC_{h,i,b}) / CT] * A_{i,ba} \quad (6.7)$$

$$deltaC_{s,i,ba} = [(stockC_{s,i,a} – stockC_{s,i,b}) / CT] * A_{i,ba} \quad (6.8)$$

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 (area converted in the inventory year if CT=1 year, or the sum of the areas converted within the last 20 years if CT=20 years)
CT	conversion time (yr), see chp. 6.1.3.3.

Table 6-3 pinpoints which approach was used for calculating the carbon stock changes for the various types of land-use conversion and carbon pools (living biomass, dead wood / litter, mineral soil and organic soil).

The gain-loss approach was used in cases of no land-use change and generally 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 for 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 of living biomass cannot be underestimated: e.g. for CC12 to CC13 stock-difference is used, and for CC13 to CC12 gain-loss is used, respectively (see Table 6-3).

In case of land-use changes to "Buildings and constructions" (CC51) a loss of 20% of the initial soil carbon stock was reported (for a detailed documentation see chp. 6.8.2.3). In case of land-use changes from CC51 to other categories the regular stock-difference approach or the gain-loss approach according to equations 6.4 and 6.8 and Table 6-3, respectively, were applied.

Table 6-3 Calculation approach (gain-loss or stock-difference with conversion time in years) applied for different land-use changes and carbon pools. KP = corresponding activity under the Kyoto Protocol; NF = non-forest combination categories. Combination categories CC11 to CC61 were introduced in Table 6-2.

Change in main land-use category or sub-division	**Living biomass**	**Dead wood, litter**	**Mineral soil**	**Organic soil**	**Remarks**
no change in category KP and UNFCCC	gain-loss	gain-loss	gain-loss	gain-loss	
CC13 to CC12 UNFCCC: 4A1 KP: Forest management	gain-loss	stock-diff., 20	stock-diff., 20	gain-loss	
CC12 to CC13 UNFCCC: 4A1 KP: Forest management	stock-diff., 20	stock-diff., 20	stock-diff., 20	gain-loss	
CC11 to CC12 UNFCCC: 4A1 KP: Afforestation >20 yr	gain-loss	gain-loss	gain-loss	gain-loss	
change to CC11 UNFCCC: 4A2 KP: Afforestation ≤20 yr	gain-loss	stock-diff., 20	stock-diff., 20	gain-loss	Dead organic matter is 0 in CC11 and in NF; direct human-induced
NF to CC12/CC13 UNFCCC: 4A2 KP: Forest management	gain-loss	stock-diff., 20	stock-diff., 20	gain-loss	
change to CC51 UNFCCC: 4E2 KP: Deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 20 (20%)	stock-diff., 20 (20%)	Soil carbon stock reduced by 20% (buildings and constructions; sealed areas)
change to CC52-54 UNFCCC: 4E2 KP: Deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	Unsealed settlement areas
change to CC21 UNFCCC: 4B2 KP: Deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	Cropland
change to CC31-37 UNFCCC: 4C2 KP: Deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	Grassland
change to CC41 UNFCCC: 4D2 KP: Deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 1	gain-loss	Surface water
change to CC42 UNFCCC: 4D2 KP: Deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	Unproductive wetland
change to CC61 UNFCCC: 4F2 KP: Deforestation	stock-diff., 1	stock-diff., 1	stock-diff., 20	stock-diff., 20	Other land

6.1.3.3 Conversion time (CT) in the stock-difference approach

Table 6-3 shows the conversion times applied in the stock-difference approach to carbon stock changes in living biomass, in dead organic matter (dead wood, litter), and in soils for different land-use changes.

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 ($stockC_{s,i,a}$ – $stockC_{s,i,b}$) 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 mineral soil carbon stock changes (except for land converted to surface water). Accordingly, the area of mineral soil of each category 2 in reporting tables Table4.A to Table4.F contains the cumulative area remaining in the respective category in the reporting year.

The combination category afforestations (CC11) is a transitional category by definition in the land-use survey. Areas converted to afforestations are reported in category 2 in CRF Table4.A with the same conversion time as for other forest subcategories (20 years). However, after 20 years afforestations remaining afforestations (according to the land-use survey) are reported in category 1 of CRF Table4.A and are merged with productive forests (CC12). Note: Under the Kyoto Protocol Afforestations are processed differently (see chp. 11.2.3).

There are no consistent data sources on land-use changes before 1990, but it is well known (ARE/FOEN 2007, FOEN 2017d) that the main trends of the Swiss land-use dynamics (e.g. increase of forests and settlements) did arise before 1972. 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 to 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 deltaC are accordingly summarised. Positive values of $deltaC_{l,i,ba}$ were inserted in the column "Gains" and negative values in the column "Losses", respectively. The values of $deltaC_{d,i,ba}$, $deltaC_{h,i,ba}$ 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 $deltaC_{dom,i,ba}$ were inserted into columns "Net carbon stock change in dead organic matter" in the reporting tables Table4.B to Table4.F. The values of $deltaC_{s,i,ba}$ were inserted into columns "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 CRF Table4.C 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.

The CRF Reporter generated errors or inconsistent content in several reporting tables related to the LULUCF sector (see Annex 6).

6.1.4 Carbon stocks and stock changes at a glance

Table 6-4 lists carbon stocks, gains, losses and net changes of carbon for the pools living biomass, dead wood, litter and soil stratified by combination category (CC) and spatial strata for the year 1990. These values remain constant during the inventory period 1990–2016 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, and net change in mineral soils of productive forest (CC12): Derivation of the data and the annual values are described in chp. 6.4.2.5, chp. 6.4.2.6 and chp. 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 chapters 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 zone, NFI production region, and soil type. The values are valid for the whole inventory period since 1990 with the exception of the values in the highlighted cells, which change annually (numbers given here are for the year 1990); cf. main text.

Combination category (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}]					
11 Afforestations	1	1	10.00	0	0	82.65	145.6	2.39	-0.21	0	0	0	-0.1
	1	2	10.00	0	0	102.03	145.6	2.39	-0.21	0	0	0	-0.078
	1	3	7.50	0	0	121.34	145.6	1.35	-0.1	0	0	0	-0.078
	2	1	10.00	0	0	55.40	145.6	2.39	-0.21	0	0	0	-0.078
	2	2	10.00	0	0	62.12	145.6	2.39	-0.21	0	0	0	-0.078
	2	3	7.50	0	0	122.00	145.6	1.35	-0.1	0	0	0	-0.078
	3	1	10.00	0	0	66.10	145.6	2.39	-0.21	0	0	0	-0.078
	3	2	10.00	0	0	75.91	145.6	2.39	-0.21	0	0	0	-0.078
	3	3	7.50	0	0	95.78	145.6	1.35	-0.1	0	0	0	-0.078
	4	1	10.00	0	0	66.47	145.6	2.39	-0.21	0	0	0	-0.078
	4	2	10.00	0	0	74.39	145.6	2.39	-0.21	0	0	0	-0.078
	4	3	7.50	0	0	69.48	145.6	1.35	-0.1	0	0	0	-0.078
	5	1	10.00	0	0	102.37	145.6	2.39	-0.21	0	0	0	-0.078
	5	2	10.00	0	0	108.99	145.6	2.39	-0.21	0	0	0	-0.078
	5	3	7.50	0	0	107.08	145.6	1.35	-0.1	0	0	0	-0.078
12 Productive forest	1	1	128.65	5.77	9.51	82.65	145.6	3.60	-2.38	-0.01	-0.13	0.00	-0.078
	1	2	125.27	6.05	7.53	102.03	145.6	3.21	-2.28	-0.03	-0.09	0.00	-0.078
	1	3	84.74	5.67	7.76	121.34	145.6	1.95	-1.36	-0.15	-0.18	0.00	-0.078
	2	1	134.51	9.18	8.70	55.40	145.6	4.63	-4.77	-0.04	-0.12	0.00	-0.078
	2	2	147.20	8.76	11.42	62.12	145.6	4.63	-4.61	-0.07	-0.09	0.00	-0.078
	2	3	102.11	8.76	11.42	122.00	145.6	1.60	-1.05	-0.07	-0.09	0.00	-0.078
	3	1	135.07	8.74	7.51	66.10	145.6	4.56	-3.35	-0.14	-0.10	0.00	-0.078
	3	2	147.49	9.36	16.29	75.91	145.6	4.15	-3.78	-0.01	-0.06	0.00	-0.078
	3	3	118.79	8.47	26.21	95.78	145.6	2.48	-2.75	-0.07	-0.12	0.00	-0.078
	4	1	92.97	7.45	3.15	66.47	145.6	3.24	-3.19	-0.01	-0.14	0.00	-0.078
	4	2	103.37	8.12	19.99	74.39	145.6	2.49	-2.59	-0.06	-0.15	0.00	-0.078
	4	3	94.98	7.80	33.37	69.48	145.6	1.81	-2.47	0.00	-0.06	0.00	-0.078
	5	1	72.68	2.34	8.22	102.37	145.6	2.74	-0.92	-0.10	-0.13	0.00	-0.078
	5	2	76.85	3.29	11.03	108.99	145.6	2.20	-0.61	0.08	-0.17	0.00	-0.078
	5	3	76.43	3.05	30.77	107.08	145.6	1.61	-0.30	-0.01	-0.02	0.00	-0.078
13 Unproductive forest	1	1	38.53	0	9.51	82.65	145.6	0	0	0	0	0	-0.078
	1	2	51.10	0	7.53	102.03	145.6	0	0	0	0	0	-0.078
	1	3	51.34	0	7.76	121.34	145.6	0	0	0	0	0	-0.078
	2	1	20.45	0	8.70	55.40	145.6	0	0	0	0	0	-0.078
	2	2	35.83	0	11.42	62.12	145.6	0	0	0	0	0	-0.078
	2	3	51.33	0	11.42	122.00	145.6	0	0	0	0	0	-0.078
	3	1	20.45	0	7.51	66.10	145.6	0	0	0	0	0	-0.078
	3	2	47.53	0	16.29	75.91	145.6	0	0	0	0	0	-0.078
	3	3	42.36	0	26.21	95.78	145.6	0	0	0	0	0	-0.078
	4	1	21.60	0	3.15	66.47	145.6	0	0	0	0	0	-0.078
	4	2	31.48	0	19.99	74.39	145.6	0	0	0	0	0	-0.078
	4	3	29.88	0	33.37	69.48	145.6	0	0	0	0	0	-0.078
	5	1	20.83	0	8.22	102.37	145.6	0	0	0	0	0	-0.078
	5	2	23.82	0	11.03	108.99	145.6	0	0	0	0	0	-0.078
	5	3	24.35	0	30.77	107.08	145.6	0	0	0	0	0	-0.078

(Table 6-4 continued)

Combination category (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	0.00	-0.34	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.	24.62	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.	7.87	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:
1 < 601 m
2 601 - 1200 m
3 > 1200 m

NFI regions:
1 Jura
2 Central Plateau
3 Pre-Alps
4 Alps
5 Southern Alps

n.s. = no stratification
Annual data

6.1.5 Uncertainty estimates

Table 6-5 gives an overview of uncertainty estimates of activity data (AD) and of emission factors (EF). For categories 4A–4F (highlighted in yellow), the uncertainties of AD mainly depend on the uncertainty of the AREA survey data (see chp. 6.3.3, Table 6-10). For categories 4D1, 4(II)–4(V) and 4G other data sources are relevant. They are presented in detail in the respective chapters (6.X.3) of the LULUCF categories, along with the uncertainty estimates for 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), 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 mainly on the uncertainty of the AREA survey.

IPCC category		Gas	Activity data uncertainty	EF uncertainty 1990	EF uncertainty 2016
			%	%	
4A1	Forest land remaining forest land	CO_2	1.1	88.6	88.6
4A2	Land converted to forest land	CO_2	1.6	88.6	88.6
4B1	Cropland remaining cropland	CO_2	4.9	32.3	164.3
4B2	Land converted to cropland	CO_2	5.1	34.6	32.4
4C1	Grassland remaining grassland	CO_2	5.2	1342.3	915.9
4C2	Land converted to grassland	CO_2	5.3	67.7	40.4
4D1	Wetlands remaining wetlands	CO_2	61.9	72.2	72.2
4D2	Land converted to wetlands	CO_2	4.0	25.6	24.1
4E1	Settlements remaining settlements	CO_2	4.4	50.0	50.0
4E2	Land converted to settlements	CO_2	4.6	50.0	50.0
4F1	Other land remaining other land	CO_2	NA	NA	NA
4F2	Land converted to other land	CO_2	3.2	50.0	50.0
4(II)	Drained organic soils	N_2O	34.1	66.9	66.9
4(II)D2	Flooded land	CH_4	10.0	70.0	70.0
4(III)	N mineralization	N_2O	83.5	135.0	135.0
4(IV)2	N leaching and runoff	N_2O	85.8	161.5	161.5
4(V)	Biomass burning	CH_4	30.0	70.0	70.0
4(V)	Biomass burning	CO_2	NA	NA	NA
4(V)	Biomass burning	N_2O	30.0	70.0	70.0
4G	Harvested wood products	CO_2	4.5	57.0	57.0

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) processed by the Swiss Federal Statistical Office (SFSO 2006a) is the basis for the land-use categories used for land area representation in the LULUCF sector. In the course of the AREA surveys (see chp. 6.3.1), every sample point on a hectare-mesh in Switzerland was assigned to a land-use category (NOLU04) and to a land-cover category (NOLC04) (SFSO nomenclature version 2004). The interpretation is backed by a large set of geodata (e.g. forest boundary layer from the NFI; for just a public subset of geodata available to the SFSO interpreters see https://map.geo.admin.ch; English version available) that can be superimposed if required. These geodata also include data sets indicating the legal status of land use (e.g. residential zones, crop rotation areas, nature reserves). Ambiguous sample points are visited by the AREA staff to verify the on-screen classification of land use (ground control).

The AREA survey is a highly sophisticated and well-established land use statistic (see visualization example in chp 6.3.1). It allows for the identification of country-specific categories that are more detailed than those defined in IPCC (2006) (see Table 6-2). Thus, the 46 NOLU04 categories and 27 NOLC04 categories of AREA were aggregated to 18 combination categories (CC) following the assignment shown in Table 6-6 (The first digit of the CC code represents the IPCC main land-use category, whereas the second digit stands for the respective sub-division). This approach enables more precise estimates of carbon stocks and carbon stock changes in the LULUCF sector than on the basis of the IPCC main categories alone because each CC can be fed with individual carbon data and distinctive carbon dynamics can be assumed (see below).

The CCs 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.

With regard to carbon content in living biomass, there is a strong relation to the vegetation type (i.e. to 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 changes in living biomass, dead organic matter, and in soils the CC definition was driven by the consideration that frequently individual vegetation units – like e.g. orchards – are subject to a similar management all over Switzerland leading to comparable carbon fluxes in biomass, dead organic matter, and in soils.

For individual CCs (especially for 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 stock changes and soil conditions as good as possible.

The underlying criteria to include land use sub-divisions 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, in contrast, there are no perennial crops, but annual crops and leys in arable rotations. All perennial crops are included in the Grassland sub-divisions.

All sub-divisions of Forest land, Grassland and Wetlands are defined as managed and reported under managed land in CRF Table4.1. Cropland and Settlements are regarded to be managed by default. Other land is regarded to be unmanaged by default. In a nutshell, the entire land area of Switzerland – except for 4F Other land – is reported to be managed.

Table 6-6 Derivation of 18 combination categories (CC) from AREA NOLU04 and NOLC04 categories.

Land Use (NOLU04) acc. to AREA — Settlement and urban areas

18 Combination Categories (CC) / Land Cover (NOLC04) acc. to AREA	101 Industrial and commercial areas > 1 ha	102 Industrial and commercial areas < 1 ha	103 Residential areas (one and two-family house	104 Residential areas (terraced houses)	105 Residential areas (blocks of flats)	106 Public buildings and surroundings	107 Agricultural buildings and surroundings	108 Unspecified buildings and surroundings	121 Motorways	122 Roads	123 Parking areas	124 Railway surface	125 Airports and airfields	141 Energy supply plants	142 Waste treatment plants	143 Other supply or waste treatment plants	144 Dumps	145 Quarries, mines	146 Construction sites	147 Unexploited urban areas	161 Public parks	162 Sport facilities	163 Golf courses	164 Camping areas	165 Garden allotments	166 Cemeteries
	Building areas								Transport surfaces					Special urban areas							Recreational areas and cemeteries					
10 Artificial areas																										
11 Sealed surfaces	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
12 Buildings	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
13 Greenhouses	52	52	52	52	52	52	52	52			52	52	52						52	52	52	52	52	52	52	52
14 Gardens with border and patch structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
15 Lawns	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
16 Trees in artificial areas	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54			54	54	54	54	54	54	54	54
17 Mix of small structures	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52			52	52	52	52	52	52	52	52
20 Grass and herb vegetation																										
21 Grass and herb vegetation	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
30 Brush vegetation																										
31 Shrub	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
32 Brush meadows	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
33 Short-stem fruit trees	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
34 Vines	53	53	53	53	53	53	53	53	53	53	53	53								53	53				53	53
35 Permanent garden plants and brush crops	52	52	52	52	52	52	52	52	52	52	52	52								52	52				52	52
40 Tree vegetation																										
41 Closed forest	54	54	54	54	54	54	54	54	54		54									54	54	54		54	54	54
42 Forest edges	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54	54	54	54	54
43 Forest strips	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
44 Open forest	54	54	54	54	54	54	54	54	54		54			54	54	54				54	54	54		54	54	54
45 Brush forest																					53			53		
46 Linear woods	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
47 Clusters of trees	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
50 Bare land																										
51 Solid rock	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
52 Granular soil	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
53 Rocky areas	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
60 Watery areas																										
61 Water	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
62 Glacier, perpetual snow																										
63 Wetlands	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
64 Reedy marshes	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42

Land Use (NOLU04) acc. to AREA — Agricultural areas, Forest areas, Unproductive areas

Land Cover (NOLC04) acc. to AREA	201 Orchards	202 Vineyards	203 Horticulture	221 Arable land, in general	222 Semi-natural grassland, in general	223 Farm pastures, in general	241 Alpine meadows, in general	242 Alpine pastures, in general	243 Alpine sheep grazing pastures, in general	301 Forest	302 Afforestation	303 Lumbering areas	304 Damaged forest	401 Lakes	402 Streams, rivers	403 Flood protection structures	421 Unused	422 Avalanche and rockfall protection structures	423 Alpine sports facilities	424 Landscape intervention
	Orchards, vineyards, horticulture			Arable and grassland			Alpine grazing areas			Forest (not used for agriculture)				Lakes and rivers			Unproductive land			
10 Artificial areas																				
11 Sealed surfaces		51	51											51	51	51		51	51	51
12 Buildings																				
13 Greenhouses			21																	
14 Gardens with border and patch structures		21	21	21	21		21			12										
15 Lawns		31	31																	
16 Trees in artificial areas																				
17 Mix of small structures		21	21																	
20 Grass and herb vegetation																				
21 Grass and herb vegetation	31	31	31	21	31	31	31	31	31		11	12	12	37	37	37	37	37	37	31
30 Brush vegetation																				
31 Shrub		32	32								11	12	12	32	32	32	32	32	32	32
32 Brush meadows		32	32		32	32	32	32			11	12	12	32	32	32	32	32	32	32
33 Short-stem fruit trees	33		33																	
34 Vines		33	33																	
35 Permanent garden plants and brush crops			33							12										
40 Tree vegetation																				
41 Closed forest	35									12	11					12		12		
42 Forest edges	35									12	11	12	12			12		12		
43 Forest strips	35									12	11					12		12		
44 Open forest	35				12	12	12	12	13	12	11	12	12			12		12	12	12
45 Brush forest										13						13		13		
46 Linear woods	34	34	34	34	34	34	34	34	34		11	12	12	34	34	34	34	34	34	34
47 Clusters of trees	34	34	34	34	13	13	34	13	34		11	12	12	34	34	34	34	34	34	34
50 Bare land																				
51 Solid rock												13	13	61	61	61	61	61	61	61
52 Granular soil		61	61									12	12	61	61	61	61	61	61	61
53 Rocky areas		36	36			36	36	36			11	13	13	36	36	36	36	36	36	36
60 Watery areas																				
61 Water														41	41	41				41
62 Glacier, perpetual snow																	61		61	
63 Wetlands					42	42	42	42	42			12	13	42	42	42	42	42	42	42
64 Reedy marshes				21	42	42	42	42	42					42	42	42	42			

Combination Categories (CC):

- 11 Afforestations
- 12 Productive forest
- 13 Unproductive forest
- 21 Cropland
- 31 Permanent grassland
- 32 Shrub vegetation
- 33 Vineyards, Low-stem Orchads, Tree nurseries
- 34 Copse
- 35 Orchards
- 36 Stony grassland
- 37 Unproductive grassland
- 41 Surface waters
- 42 Unproductive wetland
- 51 Buildings and constructions
- 52 Herbaceous biomass in settlements
- 53 Shrubs in settlements
- 54 Trees in settlements
- 61 Other land

6.2.2 Spatial stratification

In order to quantify carbon stocks and GHG emissions 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.

Soil Type

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, forest 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).

The definition of organic soils in the GHG inventory is as follows:

Intact or degraded peaty soils are considered organic soils. Where information on soil organic carbon (SOC) is known, the definition of organic soils from the IPCC (IPCC 2006, Volume 4, chp. 3, Annex 3A.5) was used to classify soils as mineral / organic (see Wüst-Galley et al. 2015: 11). Thus, this definition was used for the ground-truthing of forest habitat maps and fen inventories. This definition also formed the basis of the classification of soil types from the soils maps, as organic or mineral. Here however, two soils types ("anmoorig" and "antorfig" soils) could not be classified; these have a ranges of SOC and peat depth that are wider than those given in the IPCC definition, meaning they cannot be classified as either mineral or organic soils. Due to lack of information regarding their distribution, they were not explicitly considered in the estimate of organic soils (see Wüst-Galley et al. 2015: 14-15 and 61); including these additional soil types would lead to inconsistency of the definition of organic soils across the country, because their distribution is only known for a small area in Switzerland.

For the other data sets used in the construction of the organic soils map (geology maps, hydrogeology maps and other habitat maps), no information on SOC is available, and the presence of peat was used as evidence of organic soils. The carbon content of peat meets the IPCC definition of organic soils.

Consistency: A single map of organic soils is applied to all years (1990 to present), meaning the classifications used are consistent through time. The same definition of organic soils was used across the whole country.

Elevation

For Forest land (CC11-CC13) and permanent grassland (CC31), three elevation zones were differentiated: <601 m a.s.l. (meters above sea level), 601-1200 m a.s.l., and >1200 m a.s.l. (Figure 6-4). Elevation data from the Federal Office of Topography (swisstopo.ch) on a 25x25 m raster (product DHM25) were used to map the three zones.

Forest production region

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 production regions were adopted from EAFV/BFL (1988) as shown in Figure 6-4:

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.

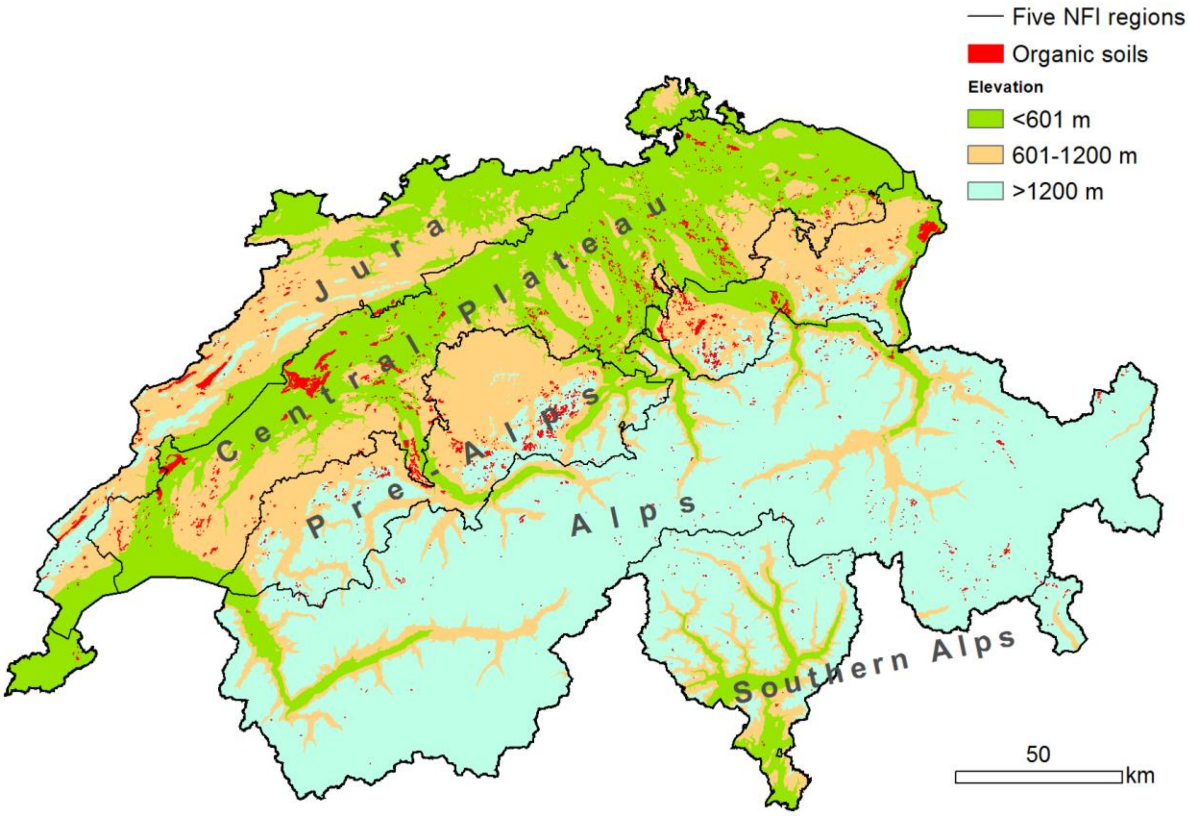


Figure 6-4 Map showing the spatial stratification according to NFI production region, elevation zone, and soil type.

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 the size of the individual spatial strata.

Table 6-7 Land use projection by the end of 1990 (in terms of combination categories CC), stratified separately for elevation (3 zones), soil type (mineral or organic) and NFI production region (1-5), in kha. The country's total area is 4'129'042 ha (SFSO 2017).

CC:	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
Altitude																			
<601 m	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 m	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 m	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	54.3	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 2016. For example, the area of afforestations (CC11) decreased by 81% during this period, while the area of unproductive forests (CC13) increased by 3%. The area of CC11 is decreasing because on the one hand afforestations activities slowed down over the inventory period (see Table 6-9) and because on the other hand most of the afforestations turn to productive forests after a certain time.

Table 6-8 Statistics of land use (in terms of combination categories CC) and relative change (%) between 1990 and 2016, in kha. The country's total area is 4'129'042 ha (SFSO 2017).

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	937.4	155.7	26.5	89.34	1.56	151.6	66.3	161.6	25.1	174.6	68.2	3.93	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	429.4	932.3	154.2	26.5	86.2	1.4	150.9	65.8	161.6	25.1	179.5	69.9	4.1	25.9	594.2	4129.0
1994	3.4	1115.4	105.1	428.0	931.6	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	426.1	931.5	153.1	26.5	84.3	1.3	150.6	65.5	161.6	25.1	182.7	71.2	4.2	26.2	593.5	4129.0
1996	3.0	1118.7	105.4	424.2	931.7	152.6	26.4	83.4	1.3	150.5	65.4	161.6	25.2	184.2	71.9	4.2	26.2	593.1	4129.0
1997	2.8	1120.2	105.6	422.2	932.0	152.2	26.3	82.5	1.2	150.4	65.3	161.7	25.2	185.8	72.7	4.2	26.1	592.8	4129.0
1998	2.6	1121.5	105.7	420.2	932.3	151.9	26.2	81.6	1.2	150.4	65.1	161.7	25.2	187.3	73.5	4.2	26.0	592.4	4129.0
1999	2.4	1122.8	105.8	418.2	932.6	151.7	26.1	80.6	1.2	150.5	65.0	161.8	25.2	188.8	74.4	4.2	25.9	592.1	4129.0
2000	2.2	1124.1	105.8	416.2	932.9	151.5	26.1	79.7	1.2	150.5	64.8	161.8	25.2	190.3	75.2	4.2	25.7	591.7	4129.0
2001	2.0	1125.4	105.9	414.1	933.2	151.3	26.0	78.8	1.1	150.5	64.7	161.8	25.2	191.9	76.0	4.2	25.6	591.4	4129.0
2002	1.7	1126.7	106.0	412.1	933.5	151.1	25.9	77.8	1.1	150.6	64.5	161.9	25.2	193.4	76.8	4.2	25.5	591.1	4129.0
2003	1.5	1127.9	106.1	410.1	933.7	150.9	25.8	76.9	1.1	150.6	64.3	161.9	25.3	194.9	77.7	4.2	25.4	590.7	4129.0
2004	1.3	1129.2	106.2	408.1	934.0	150.7	25.7	76.0	1.0	150.6	64.2	162.0	25.3	196.4	78.5	4.2	25.2	590.4	4129.0
2005	1.2	1130.7	106.2	406.5	933.9	150.4	25.6	75.0	1.0	150.7	64.0	162.0	25.3	198.0	79.3	4.2	25.1	590.1	4129.0
2006	1.0	1132.2	106.3	404.8	933.7	150.2	25.6	73.9	1.0	150.7	63.9	162.1	25.3	199.6	79.9	4.2	25.0	589.8	4129.0
2007	0.9	1133.7	106.4	403.1	933.6	150.0	25.5	72.9	1.0	150.8	63.7	162.1	25.3	201.1	80.4	4.1	25.0	589.5	4129.0
2008	0.9	1135.8	106.7	402.0	933.6	149.5	25.4	71.7	0.9	150.8	63.5	162.2	25.3	202.4	80.5	4.1	25.0	588.8	4129.0
2009	0.9	1137.4	106.8	400.3	933.1	149.2	25.3	71.0	0.9	150.9	63.3	162.3	25.3	204.1	81.0	4.1	25.1	588.3	4129.0
2010	0.8	1138.5	106.9	398.7	932.6	149.0	25.2	70.4	0.9	150.9	63.1	162.3	25.3	205.7	81.4	4.1	25.2	588.0	4129.0
2011	0.8	1139.7	107.0	397.0	932.0	148.9	25.2	69.9	0.9	150.9	63.0	162.4	25.3	207.3	81.8	4.1	25.3	587.7	4129.0
2012	0.8	1140.8	107.1	395.3	931.5	148.7	25.1	69.3	0.9	151.0	62.9	162.4	25.3	208.9	82.2	4.1	25.4	587.4	4129.0
2013	0.8	1142.2	107.3	394.3	930.5	148.5	25.0	68.6	0.9	151.0	62.7	162.4	25.3	210.6	82.5	4.1	25.3	587.1	4129.0
2014	0.8	1143.7	107.6	393.8	929.6	148.2	24.8	67.9	0.8	151.0	62.5	162.5	25.3	212.1	82.7	4.0	25.2	586.7	4129.0
2015	0.8	1145.2	107.8	394.2	928.2	147.8	24.7	67.1	0.8	151.1	62.4	162.5	25.2	213.3	82.9	4.0	24.9	586.3	4129.0
2016	0.7	1146.4	107.8	393.3	927.3	147.6	24.6	66.6	0.8	151.1	62.2	162.5	25.2	214.7	83.2	3.9	24.9	586.0	4129.0
Change:	-81	4	3	-9	-1	-5	-7	-25	-48	0	-6	1	0	23	22	0	0	-2	0

The annual land-use changes across the entire territory of Switzerland (change-matrices, see examples for 1990 and 2016 in Table 6-9) were obtained by adding up the annual changes on a hectare basis 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 2018). More aggregated change-matrices are reported in CRF Table4.1 for each year of the inventory period.

It is worth noting that in general the numbers given in the change-matrices (Table 6-9) cannot be directly compared with the figures of category 2 in CRF Table4.A, Table4.B, Table4.C, Table4.D, Table4.E, and Table4.F (Land converted to X), 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 land-use changes in 1990 and in 2016 (change matrices). Units: ha/year, rounded values. Empty cells indicate that no change occurred.

1990	change to CC																		
change from CC	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	decrease
11		369	1	0	0	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

2016	change to CC																		
change from CC	11	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	decrease
11		59	0			0								0					60
12			305	1	233	132	2	75		31	19	15	10	72	20	8	9	74	1006
13		707		2	402	77	2	74	0	6	2	1	2	29	14	1	8	11	1338
21	1	1	1		1677	3	112	22	1	3	6	4	5	339	173	6	4	10	2369
31	13	125	463	1240		801	77	251	2	83	32	8	10	710	390	15	11	73	4305
32	2	671	534	2	140		3	302		21	13	7	1	12	4	2	1	33	1748
33	0	3	2	124	94	4		20	1	1	0			29	23	2	1	3	308
34	1	510	65	39	574	56	10		5	10	22	6	0	76	43	1	15	16	1450
35				1	6		1	17						1	0				26
36	0	19	24	1	92	203	0	46			56	4		6	1			45	497
37	2	16	3	0	6	195		58		16		3	0	4	1			13	315
41	0	4	1	0	1	6		3		4	3		8	4	1	0	0	101	136
42		33	4	0	1	0		1		0	0	7		1	0		0	1	50
51	17	13	2	55	139	7	2	4		6	7	6	2		255	42	24	6	588
52	8	5	1	15	46	3	1	2		1	2	2	1	506		49	294	0	936
53	2	16	0	4	9	3	0	1		0	1		0	53	44		43		177
54	1	8	1	0	2	0		3			0	0	0	127	319	24			485
61	1	27	12	10	58	73	5	31		340	16	105	1	6	1				685
increase	48	2217	1418	1495	3481	1564	215	909	10	522	179	167	42	1975	1289	150	410	386	16479

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) processed by the Swiss Federal Statistical Office (SFSO 2017) form the basis of activity data. In the course of the AREA surveys, every hectare of Switzerland’s territory (4'129'042 ha) is 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 inventory period four datasets were used:

- Land Use Statistics “1979/85” (AREA1), status: completed
- Land Use Statistics “1992/97” (AREA2), status: completed
- Land Use Statistics “2004/09” (AREA3), status: completed
- Land Use Statistics "2013/18" (AREA4), status: 36% of territory processed.

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 taken 2012–2016 were included.

The website https://map.geo.admin.ch allows a visualization of the completed AREA surveys. See the example https://s.geo.admin.ch/7998813555 for the change in direct neighbourhood of a FOEN building in Bern-Ittigen (Legend: yellow cross represents sample point; circles represent land cover, squares represent land use, from left to right for AREA1, AREA2 and AREA3, respectively). Click circles and squares for object information. To get a clue on the situation prior to the construction of the FOEN building check the box “Journey through time – Maps” (preset 1986, but year is freely selectable) and look out for the former course of the stream nowadays bound to the south of the rail tracks. (Please note: The background aerial photograph is of recent age).

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 methodic 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 6-5: 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.

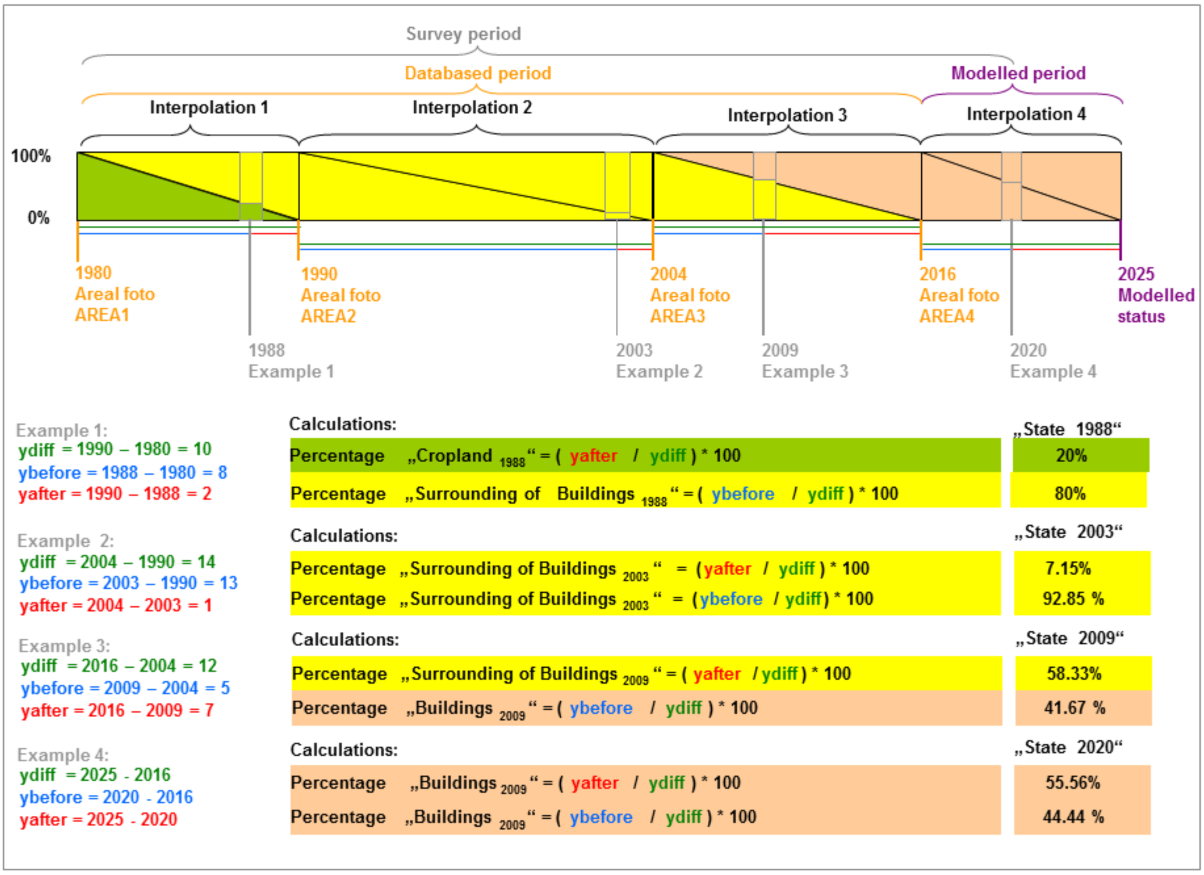


Figure 6-5 Hypothetical development of land use for a supposed survey period 1980–2020. The linear land-use changes between AREA1, AREA2, AREA3 and AREA4 considering as example a hectare changing from “Cropland” to “Surrounding of Buildings” and later from "Surrounding of Buildings" to "Buildings". For 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 (here exemplarily shown for the period 2004–2016, highlighting “state 2009”).

After completion, AREA4 will comprehend aerial photos from 2012–2018.

To obtain consistent and complete nationwide data for each year during the ongoing AREA4 survey two analyses are required:

1) For those hectares that currently have no data in AREA4, the land-use states after AREA3 were 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 2018).

2) For those hectares that were already covered by AREA4, the land-use states after the flight year of AREA4 were 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 2018). Therefore, the land-use changes occurring after the flight year of AREA4 (i.e. when it was covered) were calculated from the linear development detected between AREA4 and the virtual 5th survey AREA5v for this type of hectare (regarding CC and spatial strata) (see Figure 6-5: example “state 2020”).

The “virtual survey” approach used in 1) and 2) 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 2018).

The wall-to-wall land-use status within Switzerland for each individual year in the inventory period 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 consumption of Harvested wood products) and uncertainties of emission factors are presented in the respective LULUCF chapters (6.X.3).

In most cases, the uncertainty of AD for categories 4A–4F depends on the quality of the AREA survey data. For categories with relevant emissions from drained organic soils, also the uncertainty of the spatial allocation of organic soils (see chp. 6.2.2 and below) was considered.

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 2017) 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

$U_{sampling} = 100 * 1.96 * (\text{number of points})^{-0.5}$

The number of sampling points lies between 2'497 (for 4D2) and 1'358'528 (for 4C1) leading to values of Usampling between 3.9% and 0.2%.

The overall uncertainty was calculated as:

$U_{overall} = (U_{interpret}^2 + U_{sampling}^2)^{0.5}$

Table 6-10 Sources of AD uncertainty and overall uncertainties in the allocation of land-use categories, expressed as half of the 95% confidence intervals. Calculations are based on AREA data from SFSO (2017).

Category	Description	Interpretation uncertainty	Sampling uncertainty	Overall uncertainty
4A1	Forest land remaining forest land	1.1	0.2	1.1
4A2	Land converted to forest land	1.1	1.1	1.6
4B1	Cropland remaining cropland	4.9	0.3	4.9
4B2	Land converted to cropland	4.9	1.6	5.1
4C1	Grassland remaining grassland	5.2	0.2	5.2
4C2	Land converted to grassland	5.2	0.9	5.3
4D1	Wetlands remaining wetlands	0.9	0.5	1.0
4D2	Land converted to wetlands	0.9	3.9	4.0
4E1	Settlements remaining settlements	4.4	0.4	4.4
4E2	Land converted to settlements	4.4	1.2	4.6
4F1	Other land remaining other land	1.4	0.3	1.4
4F2	Land converted to other land	1.4	2.9	3.2

An analysis of the uncertainty of the spatial allocation of organic soils published by Wüst-Galley et al. (2015) resulted in: 27.4% for forest land, 37.8% for Cropland, 55.9% for Grassland and 61.9% for Wetlands. For Forest land (chp. 6.4.3) and Settlements (chp. 6.8.3), the CO_2 emission from organic soils were not considered in the calculation of the overall uncertainty (Meteotest 2018).

Activity data for wildfires were taken from the Swissfire database (see chapters 6.4.2.12 and 6.6.2.5). The uncertainty for areas affected by wildfires was estimated between 10% (NFI production region 5) and 30% (other NFI production regions) for forest land by expert judgment (Pezzatti 2017). For grassland the mean uncertainty is probably higher than for forest land. As a consequence, a value of 30% was agreed on for both land uses.

Consistency: Time series for activity data are all considered consistent; they were calculated based on consistent methods for interpolation and extrapolation and homogenous databases.

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 (2017) were checked for consistency (Sigmaplan 2018).

In former submissions also provisional, unverfied AREA data were used. Starting with this submission, only data verified by a second interpreter (where appropriate in the field) were processed.

The temporal interpolation and extrapolation of the AREA sample is quite a complex procedure, whose internal consistency was checked systematically as described in Sigmaplan (2018). 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 Forest land and under the Kyoto Protocol activity Forest management was carried out (see chp. 11.3.2.2).

It was checked and confirmed that the total country area remains constant over the inventory period.

6.3.5 Recalculations of activity data

The AD time series 1990–2015 was updated as a result of the following activities:

- The most recent land-use data from the fourth area survey (AREA4) were included (SFSO 2017). They are based on aerial photographs from 2012 and 2016. The interpolation and projection procedures were adapted accordingly (see chp. 6.3.2 and Sigmaplan 2018).
- Along with the AREA4 survey the SFSO continuously performs consistency checks and, where appropriate, corrections in the data of AREA3 (2004–2009).
- The total area of the country recorded by the AREA survey increased by 15 ha to 4'129'042 ha (SFSO 2017). This modification is due to the inclusion of the most recent land survey data elaborated at the Federal Office of Topography (changes caused e.g. by glacial melting), defining the country's frontiers.

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. Interpretation and further processing of AREA4 is expected to be completed in 2020.

6.4 Category 4A – Forest land

6.4.1 Description

Table 6-11 Key categories in category 4A. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
4A1	Forest land remaining forest land	CO2	L1, T1, L2, T2
4A2	Land converted to forest land	CO2	L1, T1, L2, T2

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).

According to the Federal Act on Forest, it is one objective to "conserve the forest in its area and spatial distribution" (Swiss Confederation 1991: Art. 1a). Any change of the forested area has to be authorized. Therefore, all forests in Switzerland are considered to be under management.

For reporting purposes, 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; Didion and Thürig 2013).

Note for afforested areas: The diction *afforestation* is consistently used for reporting under the UNFCCC, and the diction *Afforestation* for reporting the activity under the Kyoto Protocol (see chp. 6.1.3.1 and chp. 11.1.3).

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.

The four available Swiss National Forest Inventories (NFIs) are NFI1, NFI2, NFI3, and NFI4 (see Table 6-12). A description of NFI1 and NFI2 methodologies can be found in EAFV/BFL (1988) and in Brassel and Brändli (1999). Data and methodology of NFI3 are described in Brändli (2010). The inventories NFI1, NFI2 and NFI3 were based on full surveys that were repeated in intervals of approximately 10 years. The fourth inventory (NFI4, 2009–2017) is carried out as a continuous survey where annualy a nationally representative subsample of approximately 12% of the Swiss forests is surveyed and evaluated. Otherwise, the methodology remained identical to Brändli (2010).

Data for growing stock (in carbon mass of total living biomass) were estimated for a particular inventory. Gross growth (gain in carbon stock of total living biomass) and cut and mortality (loss in carbon stock of total living biomass) were based on the observed changes between two consecutive inventories (chp. 6.4.2.3 and 6.4.2.5).

For assembling the results for the GHG inventory 1990–2016, NFI4 data for the years 2011–2015 were available in addition to the data from NFI1, NFI2, and NFI3. Results of the 5-year subset of the NFI4 were summarised in the data release NFI4 (2011–2015) (Thürig et al. 2017; Rigling and Schaffer 2015).

Table 6-12 Characteristics of the National Forest Inventories NFI1, NFI2, NFI3 and NFI4 (2011–2015), accessible forest plots without brush forest.

	NFI1	NFI2	NFI3	NFI4 (2011-2015)
Inventory cycle	1983-1985	1993-1995	2004-2006	2011-2015
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	3'403
Measured single trees	128'441	76'394	77'959	39'955

Consequences following the use of NFI4 data (2011–2015; FOEN 2017 and this submission) instead of NFI4 data (2009–2013; FOEN 2016)

In response to UNFCCC (2018, ID#L.8 and ID#KP.10) this section provides information on the consequences for carbon stock changes due to the use of NFI4 data (2011–2015) instead of NFI4 data (2009–2013). To represent the reporting years to the most recent NFI, data from the years 2011 to 2015 were selected for this and the former submission FOEN (2017).

The use of the NFI4 data (2011–2015) in this and in the former submission (FOEN 2017) instead of the NFI4 data (2009–2013) resulted in a recalculated time series of carbon stock changes for living biomass since 2006. These changes were described in detail in Thürig et al. (2017). Carbon stock changes (gains and losses) were calculated based on the differences between two inventories, in this case NFI 3 and NFI 4, thereby affecting the values since 2006.

Thürig et al. (2017) showed that differences between data reported in FOEN (2016) and in FOEN (2017) and in this submission are caused by 1) recalculations of the NFI data years 2009–2013 following continuous plausibility and quality cheks of the database, and 2) selecting the five most recent data years 2011–2015.

- Recalculations of NFI data following continuous quality checks including plausibility checks of single tree measurements and consistency checks of data derivations and data deliveries resulted in no changes of the estimates of biomass in growing stock for national estimates and only very small changes of losses (cut and mortality: +0.2%) and gains in living biomass (gross growth: +0.2%).
- All other differences between the data for the period between NIF3 and NFI4 used in FOEN (2016) and in FOEN (2017; this submission) are caused by the change from NFI4 data (2009-2013) in FOEN (2016) to NFI4 data (2011-2015) in (FOEN 2017; this submission). Overall, estimations of living biomass were 1.84 t ± 4.9 t ha^{-1} higher in the NFI4 (2011–2015) than in the NFI4 (2009–2013). This is an increase of +0.75% ±2%. Cut and mortality increased by +0.45 ± 0.44 t ha^{-1} yr^{-1} mainly due to an increase of losses of conifers in the Pre-Alps and deciduous trees below 601 m on the Plateau. This is an increase of +8.8% ± 8.6%. Gross growth increased by +0.13 ± 0.13 t ha^{-1} yr^{-1} mainly caused by an increase of gross growth of deciduous trees in the Alps, Pre-Alps and Southern Alps and increase of growth of all trees in the Jura. This is an increase of +2.1% ± 2.1%. However, all changes are within two standard errors or slightly above and therefore have to be interpreted with caution.

The consequences of the use of NFI4 data (2011–2015) instead of NFI4 data (2009–2013) were a pronounced shift between 2005 and 2006. From 2006 onwards, differences are within two standard errors or slightly above.

6.4.2.2 Stratification

Spatial strata

Forests in Switzerland reveal a high heterogeneity in terms of elevation, growth conditions, tree species composition, and interannual 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 6-13).

Table 6-13 Analysis of variance of gross growth of data from NFI2 and NFI3. Explanatory variables: Tree species, NFI production region, and elevation.

	Gross growth	
	F-value	**p-value**
Coniferous / broadleaved	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 broadleaved 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.

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 ratios for the pooled emission factors correspond to the biomass ratios for the two regions, which were calculated for the three periods between NFI1 and NFI2, NFI2 and NFI3, and NFI3 and NFI4 (2011–2015) (Table 6-14).

Table 6-14 Ratio of biomass in the eastern and western Alps (NFI production region 4) for 1985–1994 (derived from NFI1 and NFI2; source: Brassel and Brändli 1999), for 1995–2005 (derived from NFI2 and NFI3 data; source: Brändli 2010) and for 2006–2015 (derived from NFI3 and NFI4 (2011–2015) data; source: Thürig et al. 2017). For NFI4 (2011–2015), NFI production region 4 <601 m and 601–1200 m were aggregated (Thürig et al. 2017).

	1985 - 1994		**1995 – 2005**		**2006-2015**	
Elevation [m]	**NFI1-2 Eastern**	**NFI1-2 Western**	**NFI2-3 Eastern**	**NFI2-3 Western**	**NFI3-4 Eastern**	**NFI3-4 Western**
<601	0.56	0.44	0.53	0.47	0.58	0.42
601-1200	0.62	0.38	0.61	0.39	0.58	0.42

Aggregation of strata

Since only the data for the years 2011 to 2015 of the continuously sampled NFI4 (see chp. 6.4.2.1) were used in this submission, several spatial strata were represented by a low number of plots (Thürig et al. 2017). 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 NFI4 (2011–2015), the following strata were aggregated and treated as single strata:

- NFI production region 2 Central Plateau 601-1200 m and >1200 m:
  new stratum NFI production region 2 Central Plateau >600 m (276 plots)
- NFI production region 3 Pre-Alps ≤600 m and 601-1200 m:
  new stratum NFI production region 3 Pre-Alps ≤1200 m (400 plots)
- NFI production region 4 Alps West ≤600 m and 601-1200 m:
  new stratum NFI production region 4 Alps West ≤1200 m (142 plots)
- NFI production region 4 Alps East ≤600 m and 601-1200 m:
  new stratum NFI production region 4 Alps East ≤1200 m (162 plots)

6.4.2.3 Estimation of growing stock in biomass

Growing stock in the Swiss GHGI is defined as the biomass of all tree compartments (stem-wood over bark including stump, coarse and small branches, needles/leaves, and roots). It was 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 stump, 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).

Stumps of standing and lying trees are included in total living biomass according to 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. stump	DBH, D7, height	12’000	Kaufmann 2001
Coarse branches (>= 7 cm)	DBH	40’000	Kaufmann 2001
Small branches (< 7 cm)	DBH	40’000	Kaufmann 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 total 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 of alive trees between subsequent NFIs (chp. 6.4.2.5; Thürig and Herold 2013).

6.4.2.4 Carbon content

A mean carbon content of 50% was used to convert the biomass of alive trees to carbon stocks. 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 Volume 4 of IPCC (2006), and on the fact that in Switzerland coniferous trees are more abundant than broadleaved trees (see 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 plots measured during NFI1 and NFI2 (Kaufmann 2001), 5’581 samples measured during NFI2 and NFI3 (Brändli 2010) and 3’280 samples measured during NFI3 and NFI4 (2011–2015) (Thürig et al. 2017). 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.

Annual gain of living giomass – gross growth

Annual values of gross growth were derived from the NFI1 and NFI2 datasets for the period 1985–1994, from the NFI2 and NFI3 datasets for the period 1995–2005 and from the NFI3 and NFI4 (2011–2015) datasets for the period 2006–2016. Annual values of gross growth were assumed to remain constant in the intersurvey periods of NFI1 to NFI2, NFI2 to NFI3 and of NFI3 to NFI4 (2011–2015), respectively (Table 6-17). The estimate for 2016 is based on an extrapolation of the NFI4 data; i.e. gross growth in 2016 equals gross growth calculated for the intersurvey period NFI3 to NFI4 (2011–2015).

Annual loss of living biomass – cut and mortality

An average value for cut and mortality (CM) was derived from the NFI1 and NFI2 dataset for the period 1985–1994, from the NFI2 and NFI3 datasets for the period 1995–2005 and from the NFI3 and NFI4 (2011–2015) datasets for the period 2006–2015. To calculate annual values of cut and mortality (CMy) for the years 1985 to 1994, 1995 to 2005 and 2006 to 2016, respectively, the average amount of cut and mortality from NFI was weighted by the percentage of the relative harvesting amounts taken from the forest statistics (Table 6-16; FOEN 2017d and former editions; Swiss Federal Statistical Office: Wood production in Switzerland 1975–2016, https://www.pxweb.bfs.admin.ch/). These relative harvesting amounts, used as weighting factors, were calculated for each year per NFI intersurvey period. The estimate for 2016 is based on an extrapolation of cut and mortality from the intersurvey period NFI3 to NFI4 (2011–2015) which is multiplied with the specific weigthing factor from the forest statistics for the year 2016.

Data from the forest statistics (Table 6-16) 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 6-16 Annual harvesting amount in m^3 merchantable timber specified for five NFI production region as well as for coniferous and broadleaved tree species (FOEN 2017d 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.	Broadl.	Conif.	Broadl.	Conif.	Broadl.	Conif.	Broadl.	Conif.	Broadl.	
	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[m^3]	[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	653049	359808	1810839	614845	1010979	180546	514905	70603	35462	33614	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
2015	528'202	505'431	916'020	766'645	753'783	244'149	625'555	96'230	62'233	53'649	4'551'897
2016	549'561	509'699	859'677	737'207	766'647	236'279	570'415	103'416	65'254	60'836	4'458'991

Growing stock: calculation of time series

In order to develop a consistent time series, annual growing stocks of living biomass ($stockC_l$) were calculated per spatial strata (i) for productive forests (CC12) backward or forward starting from the growing stock 2005, determined from NFI3 (abbreviations are explained in chp. 6.1.3.2):

$$stockC_{l,i,CC12,iy} = stockC_{l,i,CC12,2005} - \sum_{n=2005}^{iy} [gainC_{l,i,CC12,n}] + \sum_{n=2005}^{iy} [lossC_{l,i,CC12,n}] \quad \text{for iy < 2005}$$

$$stockC_{l,i,CC12,iy} = stockC_{l,i,CC12,2005} \quad \text{for iy = 2005}$$

$$stockC_{l,i,CC12,iy} = stockC_{l,i,CC12,2005} + \sum_{n=2006}^{iy} [gainC_{l,i,CC12,n}] - \sum_{n=2006}^{iy} [lossC_{l,i,CC12,n}] \quad \text{for iy > 2005}$$

where “iy” indicates the inventory year (here: 1985-2016), “n” the years between 2005 and the inventory year iy.

The backward calculation was used for the time period 1985–2004 (iy <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 ($gainC_{l,i,CC12,iy}$) and the losses due to the annual amounts of cut and mortality ($lossC_{l,i,CC12,iy}$).

The forward calculation was used for the time period after 2005 (iy >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 ($gainC_{l,i,CC12,iy}$) and the losses due the annual amounts of cut and mortality ($lossC_{l,i,CC12,iy}$).

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 stocks (carbon stocks in living biomass) for the period 1990 to 2016 specified for all spatial strata are displayed in Table 6-17.

All working steps and data required to reproduce the calculation of emission factors for productive forests (CC12) in the period 1990–2016 are summarized in FOEN (2018b).

Table 6-17 Annual carbon data of living biomass for productive forest (CC12) stratified for NFI production region (NFI) and elevation zone (Elev.) for stocks (stockCl), gains (gross growth, gainCl) and losses (cut and mortality, lossCl). 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	128.65	130.14	131.45	132.77	133.91	134.96	134.44	133.64	132.63	131.80
1	2	125.27	126.64	127.81	128.99	129.98	130.87	131.58	132.08	132.48	132.96
1	3	84.74	85.71	86.53	87.36	88.06	88.69	89.46	90.11	90.73	91.37
2	1	134.51	135.97	136.89	137.82	138.74	139.34	140.14	140.70	140.83	140.90
2	2	147.20	148.86	149.99	151.13	152.23	153.02	154.09	154.91	155.30	155.63
2	3	102.11	103.09	103.95	104.81	105.64	106.40	106.82	107.17	107.41	107.64
3	1	135.07	136.81	138.76	140.67	142.46	144.02	146.17	148.18	149.97	151.71
3	2	147.49	148.86	150.59	152.32	153.87	155.38	156.92	158.20	159.16	160.12
3	3	118.79	119.37	120.26	121.17	121.92	122.71	123.80	124.70	125.41	126.14
4	1	92.97	93.11	93.52	94.22	94.77	95.74	97.85	99.66	100.68	102.39
4	2	103.37	103.65	104.48	105.50	106.38	107.54	108.53	109.44	109.85	110.69
4	3	94.98	94.76	95.15	95.71	96.14	96.81	97.56	98.15	98.54	99.09
5	1	72.68	74.33	75.88	77.27	78.63	79.97	80.57	81.13	81.63	82.23
5	2	76.85	78.33	79.69	80.96	82.22	83.44	84.94	86.40	87.86	89.37
5	3	76.43	77.69	78.73	79.79	80.87	81.85	83.06	84.13	85.31	86.56

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	130.14	130.09	130.12	129.97	129.67	128.99	129.09	128.95	128.87	129.05
1	2	132.57	133.59	134.64	135.47	136.09	136.57	136.53	136.25	136.16	136.42
1	3	91.47	92.38	93.30	94.06	94.70	95.30	96.45	97.54	98.69	99.94
2	1	135.39	134.39	134.81	134.68	134.37	133.68	131.17	129.11	127.75	126.82
2	2	150.00	149.04	149.58	149.52	149.25	148.67	145.49	144.20	143.70	143.65
2	3	106.15	105.96	106.20	106.26	106.25	106.19	145.49	144.20	143.70	143.65
3	1	151.23	152.21	153.91	155.40	156.81	158.25	156.37	155.59	155.26	155.40
3	2	156.83	156.00	156.38	156.43	156.59	156.97	156.37	155.59	155.26	155.40
3	3	123.92	123.30	123.49	123.46	123.58	123.92	124.97	125.98	127.16	128.54
4	1	104.45	106.39	108.26	110.07	111.88	113.65	117.18	117.61	117.94	118.17
4	2	111.91	112.98	113.98	114.88	115.91	116.88	117.18	117.61	117.94	118.17
4	3	99.99	100.73	101.42	101.99	102.77	103.49	104.65	105.71	106.71	107.68
5	1	82.98	83.71	84.43	85.17	85.90	86.70	87.29	88.01	88.73	89.52
5	2	90.98	92.58	94.16	95.74	97.33	98.93	100.19	101.40	102.66	103.92
5	3	88.06	89.54	90.93	92.26	93.67	95.02	96.33	97.49	98.73	99.95

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016			
		CC12: carbon stock in living biomass (stockCl,i) [t C ha^{-1}]									
1	1	128.95	128.83	128.95	128.90	128.66	128.80	128.87			
1	2	136.43	136.50	136.79	136.96	136.95	137.33	137.62			
1	3	101.13	102.34	103.62	104.87	106.06	107.36	108.64			
2	1	125.96	125.11	124.58	124.04	123.36	122.80	122.49			
2	2	143.70	143.79	144.20	144.61	144.94	145.38	146.06			
2	3	143.70	143.79	144.20	144.61	144.94	145.38	146.06			
3	1	155.05	154.70	155.01	155.16	155.18	155.64	156.10			
3	2	155.05	154.70	155.01	155.16	155.18	155.64	156.10			
3	3	129.76	130.99	132.45	133.89	135.29	136.84	138.38			
4	1	118.23	118.34	118.56	118.56	118.66	118.96	119.31			
4	2	118.23	118.34	118.56	118.56	118.66	118.96	119.31			
4	3	108.57	109.52	110.51	111.48	112.48	113.54	114.68			
5	1	89.93	90.30	90.78	91.22	91.71	92.06	92.13			
5	2	105.03	106.12	107.30	108.40	109.36	110.44	111.40			
5	3	101.10	102.24	103.47	104.59	105.46	106.60	107.68			

(Table 6-17 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	3.76	3.76	3.76	3.76
1	2	3.04	3.04	3.04	3.04	3.04	3.04	3.36	3.36	3.36	3.36
1	3	1.80	1.80	1.80	1.80	1.80	1.80	2.11	2.11	2.11	2.11
2	1	4.54	4.54	4.54	4.54	4.54	4.54	4.51	4.51	4.51	4.51
2	2	4.56	4.56	4.56	4.56	4.56	4.56	4.89	4.89	4.89	4.89
2	3	1.28	1.28	1.28	1.28	1.28	1.28	4.89	4.89	4.89	4.89
3	1	4.23	4.23	4.23	4.23	4.23	4.23	4.11	4.11	4.11	4.11
3	2	4.15	4.15	4.15	4.15	4.15	4.15	4.11	4.11	4.11	4.11
3	3	2.50	2.50	2.50	2.50	2.50	2.50	2.67	2.67	2.67	2.67
4	1	3.44	3.44	3.44	3.44	3.44	3.44	2.30	2.53	2.53	2.53
4	2	2.50	2.50	2.50	2.50	2.50	2.50	2.30	2.53	2.53	2.53
4	3	1.90	1.90	1.90	1.90	1.90	1.90	2.16	2.16	2.16	2.16
5	1	2.04	2.04	2.04	2.04	2.04	2.04	2.52	2.52	2.52	2.52
5	2	2.18	2.18	2.18	2.18	2.18	2.18	2.17	2.17	2.17	2.17
5	3	1.79	1.79	1.79	1.79	1.79	1.79	1.85	1.85	1.85	1.85

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016			
		CC12: gain of living biomass (gainCl,i) [t C ha^{-1} yr^{-1}]									
1	1	3.76	3.76	3.76	3.76	3.76	3.76	3.76			
1	2	3.36	3.36	3.36	3.36	3.36	3.36	3.36			
1	3	2.11	2.11	2.11	2.11	2.11	2.11	2.11			
2	1	4.51	4.51	4.51	4.51	4.51	4.51	4.51			
2	2	4.89	4.89	4.89	4.89	4.89	4.89	4.89			
2	3	4.89	4.89	4.89	4.89	4.89	4.89	4.89			
3	1	4.11	4.11	4.11	4.11	4.11	4.11	4.11			
3	2	4.11	4.11	4.11	4.11	4.11	4.11	4.11			
3	3	2.67	2.67	2.67	2.67	2.67	2.67	2.67			
4	1	2.53	2.53	2.53	2.53	2.53	2.53	2.53			
4	2	2.53	2.53	2.53	2.53	2.53	2.53	2.53			
4	3	2.16	2.16	2.16	2.16	2.16	2.16	2.16			
5	1	2.52	2.52	2.52	2.52	2.52	2.52	2.52			
5	2	2.17	2.17	2.17	2.17	2.17	2.17	2.17			
5	3	1.85	1.85	1.85	1.85	1.85	1.85	1.85			

(Table 6-17 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	-3.66	-3.90	-3.84	-3.59
1	2	-3.43	-2.02	-1.99	-2.21	-2.41	-2.56	-3.41	-3.64	-3.45	-3.10
1	3	-1.70	-0.89	-0.88	-1.03	-1.16	-1.20	-0.95	-1.02	-0.95	-0.85
2	1	-10.04	-5.54	-4.12	-4.67	-4.85	-5.23	-7.03	-6.57	-5.88	-5.44
2	2	-10.20	-5.52	-4.03	-4.62	-4.83	-5.14	-6.69	-6.18	-5.38	-4.95
2	3	-2.77	-1.47	-1.05	-1.22	-1.29	-1.34	-6.69	-6.18	-5.38	-4.95
3	1	-4.72	-3.24	-2.54	-2.74	-2.82	-2.80	-4.80	-4.89	-4.44	-3.98
3	2	-7.44	-4.99	-3.77	-4.10	-4.00	-3.77	-4.80	-4.89	-4.44	-3.98
3	3	-4.72	-3.12	-2.31	-2.53	-2.38	-2.16	-1.63	-1.67	-1.49	-1.29
4	1	-1.37	-1.50	-1.57	-1.62	-1.63	-1.67	-2.01	-2.10	-2.20	-2.30
4	2	-1.28	-1.44	-1.50	-1.61	-1.48	-1.53	-2.01	-2.10	-2.20	-2.30
4	3	-1.00	-1.16	-1.20	-1.33	-1.12	-1.18	-1.00	-1.09	-1.16	-1.19
5	1	-1.29	-1.32	-1.32	-1.31	-1.31	-1.24	-1.93	-1.80	-1.79	-1.73
5	2	-0.56	-0.58	-0.59	-0.60	-0.59	-0.57	-0.91	-0.96	-0.91	-0.90
5	3	-0.29	-0.31	-0.40	-0.46	-0.38	-0.44	-0.54	-0.69	-0.60	-0.63

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016			
		CC12: loss of living biomass (lossCl,i) [t C ha^{-1} yr^{-1}]									
1	1	-3.86	-3.88	-3.64	-3.81	-4.00	-3.62	-3.69			
1	2	-3.35	-3.30	-3.07	-3.19	-3.37	-2.99	-4.13			
1	3	-0.92	-0.90	-0.83	-0.86	-0.91	-0.80	-3.07			
2	1	-5.37	-5.36	-5.05	-5.06	-5.19	-5.07	-1.85			
2	2	-4.83	-4.80	-4.49	-4.47	-4.56	-4.45	-0.88			
2	3	-4.83	-4.80	-4.49	-4.47	-4.56	-4.45	-0.88			
3	1	-4.47	-4.46	-3.80	-3.97	-4.09	-3.65	-5.08			
3	2	-4.47	-4.46	-3.80	-3.97	-4.09	-3.65	-5.08			
3	3	-1.46	-1.44	-1.21	-1.23	-1.28	-1.12	-4.34			
4	1	-2.48	-2.42	-2.31	-2.53	-2.43	-2.24	-0.63			
4	2	-2.48	-2.42	-2.31	-2.53	-2.43	-2.24	-0.63			
4	3	-1.26	-1.21	-1.17	-1.19	-1.16	-1.10	-0.92			
5	1	-2.10	-2.15	-2.03	-2.07	-2.03	-2.17	-2.45			
5	2	-1.05	-1.08	-0.98	-1.07	-1.21	-1.09	-4.19			
5	3	-0.69	-0.71	-0.61	-0.73	-0.98	-0.72	-3.73			

6.4.2.6 Productive forests (CC12): carbon stocks in dead wood, litter and in mineral soils

Carbon stocks in dead wood

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. Table 1 in Didion et al. 2014a). Carbon content varied very little (± 1.2–1.4%) 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 Bont 2015).

The total amount of carbon in the dead wood pool (henceforth dead wood) in Switzerland is estimated as the sum of carbon in

- Stemwood including stump of standing dead trees ≥12 cm DBH
- lying dead trees ≥7 cm DBH
- branchwood ≥7 cm in diameter
- coarse roots > ca. 5 mm in diameter of dead trees ≥12 cm DBH.

The biomass pools of dead trees were estimated according to Table 6-15.

A time series of carbon stocks in dead wood was simulated with the soil carbon model Yasso07 (Didion and Thürig 2017; see description in chp. 6.4.2.7). Stratified estimated dead wood stocks for 1990 are shown in Table 6-18. Annual values for dead wood stocks since 1990 are displayed in Table 6-19.

Carbon stocks in litter (organic soil horizons) and in mineral soils

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 6-18). The estimated national average carbon stocks in mineral forest soils calculated by Nussbaum et al. (2012) were 79.9 t C ha^{-1} (0–30 cm topsoil) and 125.8 t C ha^{-1} (0–100 cm), respectively, and 16.7 t C ha^{-1} in the organic soil horizons (litter) of mineral forest soils .

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. Hence, it is not possible to attribute the national estimates of carbon stocks in mineral forest soils and in litter to one single year. Consequently, a combination of these carbon stocks and the carbon stock changes derived from the Yasso07 model (Didion and Thürig 2017; see chp. 6.4.2.7) would not result in a consistent time series for litter and soilcarbon stocks. Thus, it was assumed that the values from Nussbaum et al. (2012, 2014) are representative for the period 1990 until the inventory year.

Table 6-18 Dead wood stocks ($stockC_d$) in Swiss productive forests (CC12) by spatial stratum in t C ha^{-1} for 1990 (Tables A-21 (means) and A-23 (SE) in Didion and Thürig 2017). Carbon stocks in organic soil horizons (litter; $stockC_h$; Table 3 in Nussbaum et al. 2012; used for CC12, CC13) and carbon stocks in mineral soil (0–30 cm; $stockC_s$; Table 5 in Nussbaum et al. 2012, Nussbaum et al. 2014; used for CC11, CC12, CC13) were assumed to be representative for 1990–2016. The data were stratified for NFI production regions and elevation zones. Dead wood and litter stocks in NFI production region 2, 601-1200 and >1200 m were 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 ($stockC_{d,i,CC12}$) [t C ha^{-1}]	Carbon stock in litter ($stockC_{h,i,CC12}$, $stockC_{h,i,CC13}$) [t C ha^{-1}]	Carbon stock in mineral topsoil 0-30 cm ($stockC_{s,i,CC11}$, $stockC_{s,i,CC12}$, $stockC_{s,i,CC13}$) [t C ha^{-1}]
1	<601	5.77 ± 0.09	9.51 ± 1.57	82.65 ± 3.34
1	601-1200	6.05 ± 0.06	7.53 ± 0.70	102.03 ± 3.56
1	>1200	5.67 ± 0.15	7.76 ± 1.74	121.34 ± 5.39
2	<601	9.18 ± 0.1	8.70 ± 0.68	55.40 ± 1.55
2	601-1200	8.76 ± 0.1	11.42 ± 1.45	62.12 ± 1.68
2	>1200	8.76 ± 0.1	11.42 ± 1.45	122.00 ± 7.07
3	<601	8.74 ± 0.33	7.51 ± 1.25	66.10 ± 2.06
3	601-1200	9.36 ± 0.09	16.29 ± 1.55	57.91 ± 2.00
3	>1200	8.47 ± 0.13	26.21 ± 4.77	95.78 ± 3.27
4	<601	7.45 ± 0.37	3.15 ± 0.47	66.47 ± 2.44
4	601-1200	8.12 ± 0.09	19.99 ± 2.64	74.39 ± 2.42
4	>1200	7.8 ± 0.07	33.37 ± 3.53	69.48 ± 1.85
5	<601	2.34 ± 0.05	8.22 ± 1.62	102.37 ± 4.07
5	601-1200	3.29 ± 0.08	11.03 ± 2.11	108.99 ± 4.09
5	>1200	3.05 ± 0.05	30.77 ± 5.43	107.08 ± 4.11
Switzerland		7.44 ± 0.03	16.73 ± 0.83	79.93 ± 1.52

Table 6-19 Carbon stock in dead wood for CC12 stratified for NFI production region (NFI) and elevation zone (Elev.). Highlighted data for 1990 are displayed in Table 6-4 and Table 6-18.

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	5.77	5.80	5.80	5.80	5.77	5.76	6.05	6.29	6.48	6.64
1	2	6.05	6.05	6.03	6.02	5.97	5.96	6.04	6.09	6.13	6.16
1	3	5.67	5.55	5.42	5.31	5.19	5.09	5.04	4.97	4.91	4.86
2	1	9.18	9.21	9.20	9.19	9.13	9.11	9.49	9.80	10.07	10.28
2	2	8.76	8.75	8.71	8.67	8.59	8.56	8.93	9.24	9.51	9.74
2	3	8.76	8.75	8.71	8.67	8.59	8.56	8.93	9.24	9.51	9.74
3	1	8.74	8.65	8.55	8.44	8.32	8.23	8.50	8.71	8.89	9.04
3	2	9.36	9.39	9.39	9.39	9.35	9.36	9.82	10.19	10.54	10.85
3	3	8.47	8.43	8.37	8.33	8.25	8.22	8.27	8.28	8.31	8.33
4	1	7.45	7.47	7.47	7.46	7.43	7.43	7.56	7.67	7.78	7.87
4	2	8.12	8.09	8.04	8.00	7.94	7.91	7.92	7.90	7.89	7.88
4	3	7.80	7.81	7.80	7.81	7.78	7.80	7.75	7.68	7.63	7.58
5	1	2.34	2.25	2.17	2.09	2.01	1.95	1.91	1.86	1.82	1.79
5	2	3.29	3.36	3.43	3.48	3.53	3.58	3.34	3.12	2.92	2.75
5	3	3.05	3.05	3.04	3.03	3.02	3.02	3.00	2.96	2.94	2.91

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	6.78	6.92	7.02	7.20	7.32	7.44	7.57	7.66	7.76	7.88
1	2	6.19	6.21	6.22	6.27	6.30	6.34	6.58	6.77	6.97	7.16
1	3	4.79	4.74	4.68	4.64	4.60	4.57	4.45	4.34	4.24	4.16
2	1	10.47	10.63	10.78	11.01	11.17	11.34	11.54	11.67	11.82	11.99
2	2	9.94	10.12	10.27	10.49	10.65	10.83	10.93	10.99	11.07	11.17
2	3	9.94	10.12	10.27	10.49	10.65	10.83	10.93	10.99	11.07	11.17
3	1	9.16	9.28	9.37	9.51	9.61	9.72	9.59	9.41	9.28	9.17
3	2	11.12	11.38	11.59	11.84	12.06	12.28	12.49	12.66	12.84	13.02
3	3	8.34	8.36	8.35	8.35	8.38	8.41	8.16	7.93	7.74	7.56
4	1	7.96	8.03	8.08	8.18	8.25	8.35	8.57	8.74	8.92	9.10
4	2	7.85	7.84	7.80	7.80	7.80	7.82	8.05	8.25	8.43	8.61
4	3	7.51	7.46	7.40	7.37	7.35	7.34	7.38	7.41	7.44	7.48
5	1	1.75	1.72	1.69	1.67	1.65	1.64	2.02	2.36	2.66	2.93
5	2	2.59	2.45	2.32	2.21	2.10	2.01	2.11	2.19	2.27	2.34
5	3	2.88	2.86	2.84	2.82	2.81	2.81	2.92	3.02	3.11	3.19

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016			
		CC12: carbon stock in dead wood (stockCd,i) [t C ha^{-1}]									
1	1	8.01	8.09	8.16	8.25	8.28	8.37	8.41			
1	2	7.36	7.49	7.63	7.77	7.85	7.96	8.04			
1	3	4.10	4.01	3.94	3.88	3.80	3.74	3.67			
2	1	12.17	12.29	12.41	12.54	12.57	12.69	12.74			
2	2	11.29	11.35	11.42	11.50	11.49	11.56	11.58			
2	3	11.29	11.35	11.42	11.50	11.49	11.56	11.58			
3	1	9.09	8.97	8.89	8.83	8.71	8.64	8.56			
3	2	13.23	13.33	13.47	13.62	13.66	13.74	13.81			
3	3	7.43	7.25	7.11	6.99	6.84	6.71	6.59			
4	1	9.30	9.43	9.56	9.70	9.76	9.87	9.96			
4	2	8.81	8.93	9.07	9.21	9.29	9.38	9.47			
4	3	7.54	7.55	7.57	7.60	7.60	7.61	7.63			
5	1	3.19	3.41	3.61	3.80	3.96	4.11	4.26			
5	2	2.42	2.47	2.53	2.58	2.62	2.67	2.71			
5	3	3.29	3.35	3.42	3.49	3.54	3.59	3.65			

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 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) and, for the current submission, in Didion and Thürig (2017). 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 (annual monthly temperature 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. Table 6-18 shows the carbon stocks in Swiss forests by stratum for the pools mineral soil, litter (both based on Nussbaum et al 2012, 2014) and dead wood (based on Didion and Thürig 2017). Annual stratified values of carbon stock changes for dead wood, litter and mineral soils are given in Table 6-20. Carbon stocks and carbon stock changes were validated as described in Didion and Thürig (2017).

Table 6-20 Net carbon stock change in dead wood, in litter and in mineral soils for productive forest (CC12) stratified for NFI production region (NFI) and elevation zone (Elev.). 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	-0.01	0.03	0.00	0.00	-0.03	-0.01	0.28	0.24	0.19	0.16
1	2	-0.03	0.00	-0.02	-0.01	-0.04	-0.02	0.08	0.05	0.04	0.03
1	3	-0.15	-0.12	-0.13	-0.11	-0.13	-0.09	-0.05	-0.07	-0.06	-0.06
2	1	-0.04	0.03	-0.01	-0.01	-0.06	-0.02	0.37	0.32	0.26	0.21
2	2	-0.07	-0.01	-0.04	-0.04	-0.08	-0.03	0.37	0.31	0.27	0.23
2	3	-0.07	-0.01	-0.04	-0.04	-0.08	-0.03	0.37	0.31	0.27	0.23
3	1	-0.14	-0.09	-0.11	-0.10	-0.13	-0.08	0.26	0.22	0.17	0.15
3	2	-0.01	0.03	0.00	0.00	-0.04	0.01	0.46	0.37	0.35	0.31
3	3	-0.07	-0.04	-0.06	-0.04	-0.08	-0.03	0.06	0.01	0.03	0.02
4	1	-0.01	0.02	-0.01	0.00	-0.03	0.00	0.14	0.11	0.11	0.09
4	2	-0.06	-0.03	-0.05	-0.04	-0.06	-0.03	0.01	-0.02	-0.01	-0.02
4	3	0.00	0.02	-0.01	0.01	-0.02	0.01	-0.04	-0.07	-0.05	-0.06
5	1	-0.10	-0.09	-0.09	-0.08	-0.08	-0.06	-0.04	-0.04	-0.04	-0.04
5	2	0.08	0.08	0.06	0.06	0.04	0.05	-0.24	-0.22	-0.19	-0.17
5	3	-0.01	0.00	-0.01	0.00	-0.01	0.00	-0.02	-0.04	-0.03	-0.03

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	0.15	0.13	0.11	0.18	0.11	0.12	0.13	0.09	0.11	0.11
1	2	0.02	0.03	0.01	0.05	0.03	0.04	0.24	0.19	0.20	0.19
1	3	-0.06	-0.05	-0.06	-0.04	-0.04	-0.03	-0.12	-0.12	-0.10	-0.08
2	1	0.19	0.17	0.14	0.24	0.15	0.17	0.20	0.13	0.15	0.16
2	2	0.20	0.19	0.15	0.22	0.16	0.18	0.11	0.05	0.08	0.10
2	3	0.20	0.19	0.15	0.22	0.16	0.18	0.11	0.05	0.08	0.10
3	1	0.12	0.12	0.09	0.14	0.10	0.11	-0.13	-0.17	-0.14	-0.11
3	2	0.27	0.27	0.21	0.24	0.22	0.23	0.21	0.16	0.18	0.18
3	3	0.00	0.02	-0.01	0.01	0.02	0.04	-0.25	-0.23	-0.19	-0.18
4	1	0.09	0.07	0.05	0.09	0.08	0.10	0.22	0.17	0.18	0.18
4	2	-0.03	-0.01	-0.04	0.00	0.00	0.02	0.23	0.19	0.18	0.18
4	3	-0.07	-0.05	-0.07	-0.03	-0.02	0.00	0.04	0.02	0.03	0.04
5	1	-0.04	-0.03	-0.03	-0.02	-0.02	-0.01	0.39	0.34	0.30	0.27
5	2	-0.16	-0.14	-0.13	-0.11	-0.11	-0.09	0.10	0.08	0.08	0.07
5	3	-0.03	-0.02	-0.03	-0.01	-0.01	0.00	0.11	0.10	0.09	0.09

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016			
		CC12: net change in dead wood (changeCd,i) [t C ha^{-1} yr^{-1}]									
1	1	0.13	0.08	0.07	0.09	0.02	0.09	0.04			
1	2	0.20	0.13	0.14	0.14	0.08	0.11	0.08			
1	3	-0.06	-0.09	-0.07	-0.06	-0.08	-0.07	-0.06			
2	1	0.19	0.12	0.12	0.13	0.03	0.12	0.05			
2	2	0.13	0.06	0.07	0.08	-0.01	0.07	0.02			
2	3	0.13	0.06	0.07	0.08	-0.01	0.07	0.02			
3	1	-0.08	-0.12	-0.08	-0.06	-0.13	-0.07	-0.08			
3	2	0.21	0.10	0.14	0.15	0.04	0.08	0.07			
3	3	-0.13	-0.18	-0.14	-0.12	-0.15	-0.13	-0.12			
4	1	0.20	0.13	0.13	0.14	0.06	0.10	0.09			
4	2	0.20	0.12	0.14	0.15	0.08	0.09	0.09			
4	3	0.06	0.01	0.02	0.04	0.00	0.01	0.02			
5	1	0.26	0.22	0.20	0.19	0.16	0.16	0.14			
5	2	0.08	0.06	0.06	0.06	0.04	0.04	0.04			
5	3	0.09	0.07	0.07	0.07	0.05	0.05	0.05			

(Table 6-20 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	-0.13	0.07	-0.07	-0.03	-0.16	-0.04	0.29	0.16	0.04	-0.02
1	2	-0.09	0.07	-0.05	-0.02	-0.13	-0.01	0.25	0.09	0.07	0.02
1	3	-0.18	-0.06	-0.12	-0.07	-0.15	-0.02	0.18	0.02	0.07	0.04
2	1	-0.12	0.10	-0.05	-0.04	-0.16	-0.02	0.18	0.09	0.01	-0.06
2	2	-0.09	0.09	-0.04	-0.02	-0.15	0.00	0.18	0.06	0.03	-0.02
2	3	-0.09	0.09	-0.04	-0.02	-0.15	0.00	0.18	0.06	0.03	-0.02
3	1	-0.10	0.05	-0.05	-0.05	-0.16	0.00	0.05	-0.03	-0.06	-0.05
3	2	-0.06	0.09	-0.05	-0.01	-0.15	0.03	0.23	0.02	0.07	0.04
3	3	-0.12	0.01	-0.11	-0.03	-0.16	0.03	0.15	-0.07	0.06	0.03
4	1	-0.14	0.00	-0.10	-0.06	-0.14	-0.02	0.24	0.12	0.13	0.05
4	2	-0.15	-0.02	-0.13	-0.06	-0.16	0.00	0.19	0.02	0.08	0.01
4	3	-0.06	0.06	-0.10	0.02	-0.15	0.06	0.24	0.04	0.13	0.01
5	1	-0.13	-0.07	-0.10	-0.08	-0.09	0.00	0.38	0.22	0.21	0.15
5	2	-0.17	-0.10	-0.13	-0.09	-0.12	-0.01	0.29	0.13	0.14	0.11
5	3	-0.02	0.06	-0.06	0.01	-0.10	0.09	0.45	0.17	0.20	0.17

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	0.00	-0.05	0.24	0.00	0.08	-0.12	-0.19	-0.06	0.00
1	2	0.00	0.02	-0.05	0.15	0.02	0.10	0.00	-0.08	0.03	0.06
1	3	-0.01	0.03	-0.04	0.04	0.03	0.08	0.04	0.00	0.06	0.06
2	1	-0.05	-0.04	-0.06	0.20	-0.01	0.08	-0.20	-0.26	-0.12	-0.05
2	2	-0.04	-0.01	-0.06	0.15	0.01	0.09	-0.11	-0.18	-0.05	-0.01
2	3	-0.04	-0.01	-0.06	0.15	0.01	0.09	-0.11	-0.18	-0.05	-0.01
3	1	-0.09	-0.03	-0.09	0.10	0.00	0.05	0.07	-0.08	0.00	0.04
3	2	-0.02	0.04	-0.07	0.07	0.05	0.09	-0.12	-0.16	-0.04	-0.02
3	3	-0.03	0.04	-0.07	-0.01	0.06	0.10	-0.20	-0.16	-0.06	-0.05
4	1	0.05	0.03	-0.04	0.11	0.05	0.11	-0.07	-0.13	-0.03	0.00
4	2	-0.03	0.04	-0.08	0.09	0.08	0.14	-0.04	-0.10	-0.03	0.02
4	3	-0.05	0.06	-0.09	0.12	0.13	0.19	0.04	-0.04	0.01	0.09
5	1	0.08	0.12	0.04	0.14	0.04	0.17	0.11	-0.01	0.00	0.02
5	2	0.05	0.09	0.02	0.10	0.03	0.15	0.15	0.04	0.06	0.05
5	3	0.07	0.13	0.01	0.14	0.09	0.28	0.15	0.04	0.08	0.07

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016			
		CC12: net change in litter (changeCh,i) [t C ha^{-1} yr^{-1}]									
1	1	0.07	-0.06	-0.05	0.02	-0.16	0.08	-0.07			
1	2	0.15	-0.08	0.00	0.05	-0.15	0.02	-0.05			
1	3	0.15	-0.08	0.03	0.07	-0.11	-0.03	-0.03			
2	1	0.04	-0.08	-0.05	0.00	-0.17	0.05	-0.08			
2	2	0.09	-0.09	-0.01	0.03	-0.18	0.03	-0.07			
2	3	0.09	-0.09	-0.01	0.03	-0.18	0.03	-0.07			
3	1	0.10	-0.09	0.03	0.07	-0.17	0.02	-0.04			
3	2	0.10	-0.16	0.00	0.05	-0.20	-0.05	-0.06			
3	3	0.10	-0.21	-0.02	0.04	-0.17	-0.10	-0.04			
4	1	0.10	-0.08	-0.01	0.03	-0.16	0.00	-0.04			
4	2	0.13	-0.13	-0.01	0.06	-0.14	-0.04	-0.03			
4	3	0.22	-0.14	-0.04	0.08	-0.13	-0.07	0.01			
5	1	0.10	-0.03	0.01	0.02	-0.09	0.02	-0.01			
5	2	0.14	-0.03	0.02	0.04	-0.06	-0.01	0.00			
5	3	0.22	-0.09	0.00	0.07	-0.07	-0.04	0.01			

(Table 6-20 continued)

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC12: net change in mineral soil (changeCs,i) [t C ha^{-1} yr^{-1}]									
1	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
1	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
1	3	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
2	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
2	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
2	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
3	1	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
3	2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002
3	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	2	0.000	0.000	0.000	0.000	-0.001	-0.001	0.000	0.000	0.000	0.000
4	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002
5	1	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001
5	2	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	-0.001
5	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC12: net change in mineral soil (changeCs,i) [t C ha^{-1} yr^{-1}]									
1	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1	3	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
2	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2	2	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
2	3	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
3	1	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.000	-0.001	-0.001	-0.001
3	2	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
3	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001
4	1	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	3	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002
5	1	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000
5	2	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
5	3	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016			
		CC12: net change in mineral soil (changeCs,i) [t C ha^{-1} yr^{-1}]									
1	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
1	2	0.002	0.002	0.002	0.002	0.002	0.002	0.002			
1	3	-0.001	-0.002	-0.002	-0.001	-0.002	-0.002	-0.002			
2	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
2	2	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
2	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
3	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001			
3	2	0.002	0.002	0.002	0.002	0.002	0.002	0.002			
3	3	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002			
4	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
4	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
4	3	0.002	0.002	0.002	0.002	0.002	0.002	0.002			
5	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
5	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
5	3	0.003	0.004	0.004	0.004	0.004	0.004	0.004			

Carbon stock changes in the soil pool are small (Table 6-20). 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 (Figure 6-6). 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 extend driven by the increase in the dead wood stocks following the hurricane Lothar (1999). As Lothar occurred between the NFI2 (1993–1995) and NFI3 (2004–2006), it strongly affects the results of the change analysis for dead wood volume in the period NFI2 to NFI3. 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 NFI3 (Table 6-16) 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 NFI4 (Brändli and Speich 2011).

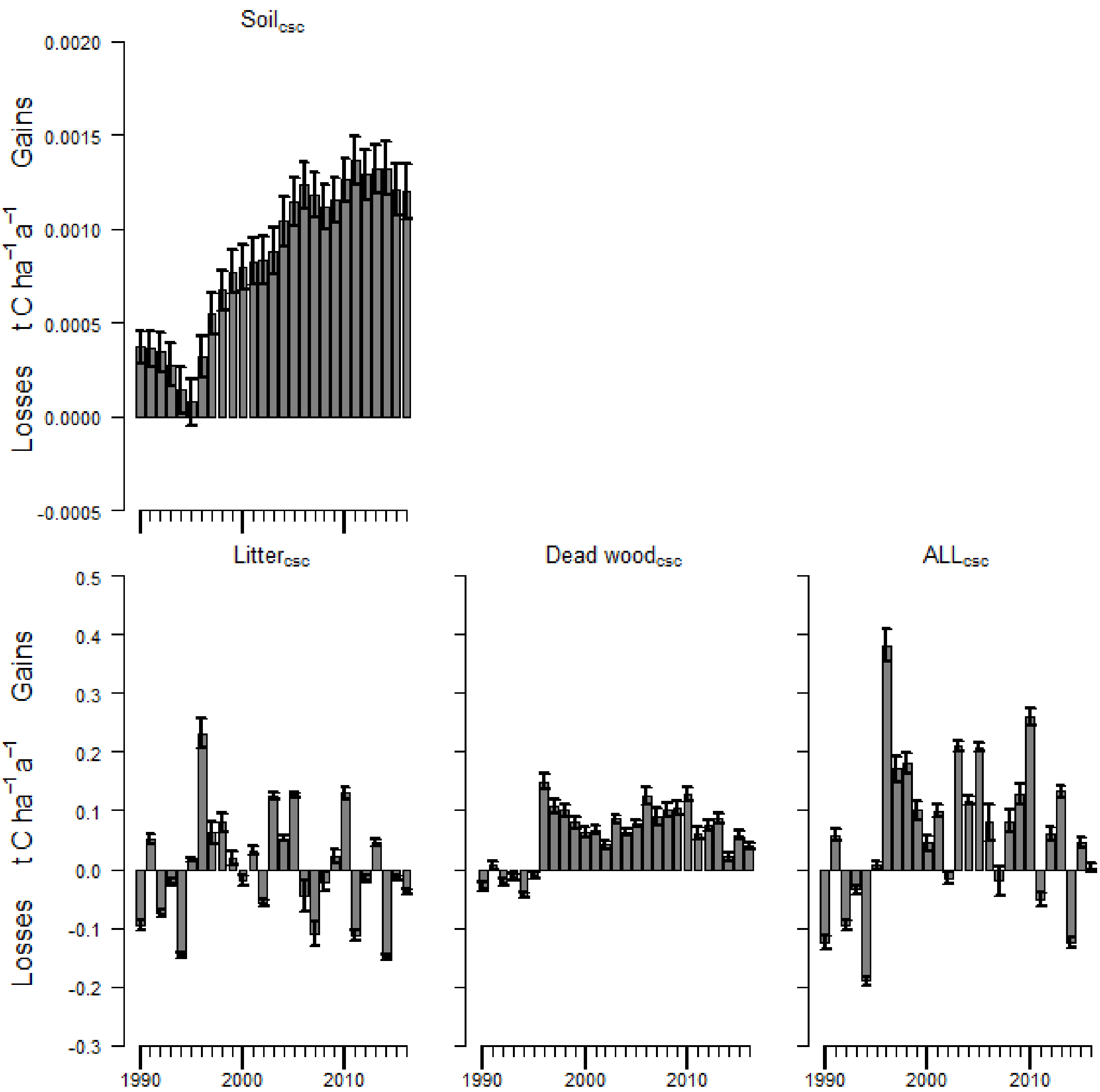


Figure 6-6 Mean carbon stock change (CSC) for three pools soil (0–100 cm), litter, dead wood and their sum (ALL) in t C ha^{-1} a^{-1}. Note the difference of the y-axis scale between $Soil_{csc}$ and $Litter_{csc}$, $Dead\ wood_{csc}$ and ALL_{csc}, respectively. Negative values indicate losses in carbon stock, positive values gains in carbon stock. The error bars indicate the double standard error.

6.4.2.8 Unproductive forests (CC13)

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 2017d) are distributed over the productive forests, total harvesting in Swiss forests was accounted for under productive forests (CC12), 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 NFI3, 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: 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 the Kyoto Protocol 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 definition of 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 clusters of trees" (NOLC04 47/NOLU04 222, NOLC04 47/NOLU04 223, NOLC04 47/NOLU04 242) and "alpine sheep grazing pastures, in general with open forest" with "clusters of trees") NOLC04 44/NOLU04 243; cf. Table 6-6).

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 (Table 1 in Düggelin and Abegg 2011). Following the NFI definition, brush forests are dominated by more than two thirds by shrubs. For brush forests, no NFI data are available to derive their growing stock. In a case study, Düggelin and Abegg (2011) analysed the carbon stock of total living biomass in Swiss brush forests and found an average value of 20.45 t C ha^{-1}.
- Inaccessible stands: Inaccessible stands are considered similar to brush forest regarding biomass and carbon stock. Their area is determined based on land cover "tree vegetation" in typically remote and high-elevation land uses such as avalanche chutes (NOLU04 403 and 422; Table 6-6).
- Unproductive forests not covered by NFI: These forests are mainly associated with extensively pastured land where sparse tree vegetation (NOLC04 44 and 47; Table 6-6) is found. As those forests are assumed to grow preferably on bad site conditions, an average growing stock (>7 cm diameter) of 150 m^3 ha^{-1} was assumed. Multiplied by the mean BCEF of 0.69 (i.e. weighted mean based on the quotient of stemwood volume and total tree biomass of coniferous and broadleaved trees as described in Thürig and Herold 2013), an average biomass for these forests of 102.75 t ha^{-1} was estimated, which corresponds to 51.38 t C ha^{-1} (using a carbon content of 50%; see chp. 6.4.2.4).

The carbon stock of living biomass (C_l) in unproductive forest (CC13) was calculated as a weighted average of brush forest, inaccessible stands and unproductive forest not covered by NFI per spatial stratum:

$$stockC_{l,i,CC13} = F_i * stockC_{l,i,CC13bi} + (1- F_i) * stockC_{l,i,CC13u}$$

where F_i is the fraction of the brush and inaccessible forest per spatial stratum i,

$stockC_{l,i,CC13bi}$ is the carbon stock of brush and inaccessible forest (20.45 t C ha^{-1}),

$stockC_{l,i,CC13u}$ is the carbon stock of forest on unproductive areas (51.38 t C ha^{-1}).

Table 6-21 shows the resulting carbon stocks in living biomass of unproductive forest per spatial stratum in t C ha^{-1}.

Table 6-21 Area of brush forest, inacessesibble forest and unproductive forest not covered by NFI, their areal fractions (F_i: fraction of brush and inaccessible forest per stratum i) and the resulting weighted carbon stocks in living biomass in t C ha^{-1} of unproductive forests (CC13) specified for all spatial strata ($stockC_{l,i,CC13}$).

NFI region	Altitude [m]	Brush forest [ha]	Inacessessible forest [ha]	Forest not covered by NFI [ha]	Fraction of brush and inaccessible forest (F_i)	Fraction of forest not covered by NFI ($1-F_i$)	Carbon stock in living biomass ($stockC_{l,i,CC13}$) [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

Carbon stocks in dead wood, litter, and mineral soil

As stated above, CC13 consists of different types of forests and data are hardly available. So far, there are no data available for carbon stocks in dead wood in unproductive forests (CC13). Dead wood on CC13 forest stands was assumed to be zero.

Carbon stocks in litter and in mineral soil under unproductive forests reveal a high spatial heterogeneity, and specific data are not available. Both carbon stocks of soil carbon and litter were assumed to be the same as for productive forests, which were derived from Nussbaum et al. (2012, 2014) (see Table 6-18).

Values for carbon stocks in dead wood, litter, and in mineral soil for CC13 are listed in Table 6-4.

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 equilibrium. This approach is confirmed by three studies in which basal area and crown cover were used as a proxy for the stock of living biomass (Huber and Thürig 2014; Ginzler 2014; Huber and Frehner 2013). 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 inventories NFI3 and NFI4 (2009–2012). The authors found that the number of trees had increased over the approximately 6 year period between the two inventories. 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 m^2 ha^{-1} in 2006 to 5.47 m^2 ha^{-1} in 2012.
- Ginzler (2014) analysed the crown cover density of 135 aerial photographs between 2006 (NFI3) and 2011 (NFI4) and found no statistical change in crown cover density of well-established, existing brush forests. The terrestrial NFI data, however, showed a slight increase in the basal area of trees in brush forests.
- Huber and Frehner (2013) showed that the expansion of Green Alder (*Alnus viridis*) 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 Swiss brush forests, it was concluded that living biomass in unproductive forests was not a net source of carbon over the last decades. Applying a Tier 1 approach, living biomass is reported to be in equilibrium. In Table 6-4 and in CRF Table4.A, this approach is transcribed into “gains ($gainC_{l,i,13}$) = losses ($lossC_{l,i,13}$) = 0”.

Changes in carbon stocks of dead wood, litter, and mineral soil

There are no repeated measurements of carbon stocks in dead wood, in litter, and in mineral soil.

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 dead wood production and in litter, which in turn can lead to an accumulation in soil carbon. Based on these conceptional considerations, it was concluded that dead wood, litter, and mineral soil in uproductive forests were not a net source of carbon over the last decades. Applying a Tier 1 approach, thus, dead wood, litter, and mineral soil are reported to be in equilibrium. In Table 6-4 and in CRF Table4.A, this approach is transcribed into “$changeC_{d,i,11}$= $changeC_{h,i,11}$ = $changeC_{s,I,13}$ = 0”. The Tier 1 approach is supported by the following evidences:

- Unproductive forest stands 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 2012). By stabilizing soils, brush forests act as a good protection against soil erosion (Richard 1995; Stangl 2004).
- Green Alder has an ameliorative effect on the soil with its nitrogen-fixing root nodules (Huber and Frehner 2012). 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 an application of the Tier 1 approach are considered to be 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 mineral soil are the same for CC12 and CC13.

With the exception of brush forests, it is very likely that carbon stocks in litter and in mineral soil are smaller under unproductive forests than under productive forests. As the area changing from CC13 to CC12 is larger than from CC12 to CC13 (see Table 6-9), by applying the stock-difference method (see Table 6-3) with the same carbon stocks for litter and mineral soil under productive and unproductive forest, the resulting emissions are not underestimated.

6.4.2.9 Afforestations (CC11)

Carbon stock and changes in carbon stocks of living biomass

Thürig and Traub (2015: Table 6) estimated the average carbon stock and gains and losses in living biomass of afforestations and young stands 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 generally characterized by a large number of trees in small DBH classes and 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 to forest 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.

Carbon stock and changes in carbon stocks of dead wood and litter

On afforestations, carbon stocks in litter and dead wood were assumed to be zero (IPCC 2006, Volume 4, chp. 4.3.2). Applying the stock-difference calculation approach (Table 6-3), calculated changes in the litter and dead wood pool after a afforestation were rather small since the major part of afforestations (CC11) in Switzerland occur on grasslands and in settlements (see Table 6-9) where there is no litter and no dead wood (Table 6-4).

Carbon stock and changes in carbon stocks of mineral soil

The estimates for soil carbon stocks from Nussbaum et al. (2012, 2014) were used for afforestations (see Table 6-4 and Table 6-18). Carbon stock changes of afforestations (≤20 years) were calculated with the stock-difference method (see Table 6-3).

6.4.2.10 Organic soils

Carbon stock in organic soils

The mean soil organic carbon stock (0–30 cm) for organic soils under forest land is 145.6 ± 24.1 t C ha^{-1} (Wüst-Galley et al. 2016). This value was used for CC11, CC12, and CC13 (cf. Table 6-4).

Changes in carbon stocks of organic soils

Drainage of forests is not a permitted practice in Switzerland (Swiss Confederation 1991). However, it is possible that parts of the Swiss forest were drained before 1990 or were established on drained areas. Abegg (2017) estimated the amount of drained organic soils by intersecting information on drainage from NFI plots with the shapefile of organic soils in Switzerland produced by Wüst-Galley et al. (2015). 3% of organic soils in forest land appeared to be subject to drainage.

For the calculation of changes in carbon stocks of organic soils, the default emission factor of 2.6 t C ha^{-1} yr^{-1} was applied for all forest stands (CC11, CC12, and CC13; cf. Table 6-4) according to the Wetlands Supplement (IPCC 2014a: Table 2.1).

6.4.2.11 N_2O emissions from Forest land

Fertilization of forests is prohibited by the Federal Act on Forest and the adherent ordinance (Swiss Confederation 1991, 1992). The Federal Act on Forest (Art. 18) states: “The use of environmentally hazardous substances in the forest is prohibited” with a direct reference to the Federal Act on the Protection of the Environment (Swiss Confederation 1983). Details of the Federal Act on Forest Art. 18 had initially been regulated in the Ordinance on Forest (Art.

27). Since 2005, the Ordinance on Chemical Risk Reduction (Swiss Confederation 2005: Art. 4) prohibits the application of fertilizers, including liming, in forests. Hence, the application of fertilizers, including liming in forests was prohibited since 1991 in Switzerland. 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) (notation key “NO”).

N_2O emissions from drainage of organic soils was calculated for Forest land with an emission factor of 2.8 kg N_2O-N ha^{-1} for 3% of the area of organic soils (see chp. 6.4.2.10) and reported in category A in CRF Table4(II). The emission factor used is the default value given in the Wetlands Supplement (IPCC 2014a, Table 2.5) for temperate forest land.

The calculation of emissons reported in CRF Table4(III) and CRF Table4(IV), i.e. direct N_2O emissions from nitrogen mineralization in mineral soils and indirect N_2O emissions from managed soils, 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). Table 6-22 shows the time series 1990 to 2016 of the area affected and associated emissions.

As controlled burning of forest stands is not allowed in Switzerland all fires in forests were considered “wildfires”. All fires were assigned to productive forests. In this way, emissions are not underestimated, 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-Forest land to Forest land (or Afforestations under the Kyoto Protocol 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.

CO_2 emissions from wildfires were encompassed (“IE”) in the data in CRF Table4.A. Losses in living biomass are reflected in the NFI dataset. Carbon 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. 2.3.3 in Didion and Thürig 2017).

CH_4 and N_2O emissions from wildfires (Table 6-22) were calculated using equation 2.27 in Volume 4 of IPCC (2006) with the following parameters:

- For CH_4 the default emission factor of 4.7 g kg^{-1} dry matter burned and for N_2O, 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 stocks of living biomass, dead wood, and litter. 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 NFI1, NFI2, NFI3 and NFI4 2009–2013 (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 occure in the southern Alps, 15% in the Central Alps). The average amount of litter in Swiss forests was 16.73 t C ha^{-1} (see Table 6-18) or 33.46 t biomass ha^{-1} and average stocks of dead wood were calculated per NFI period based on data from Didion and Thürig 2017 (see Table 6-19).

- The fraction of the biomass combusted was 0.45 (IPCC 2006, Volume 4, Table 2.6).

CH_4 and and N_2O emissions caused by wildfires were reported in CRF Table4(V). CH_4 and N_2O emissions from wildfires of all types of forests 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, category 4(V)A2 has the notation key "IE".

Table 6-22 Forest land affected by wildfires (WSL, Swissfire database) and resulting CH_4 and N_2O emissions.

Forest land	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Area burnt	ha	1'060.6	70.5	26.9	17.7	233.2	362.8	232.0	1'389.5	197.7	11.2
CH_4	t	529.4	35.2	13.4	8.8	116.4	181.1	115.8	693.6	98.7	5.6
N_2O	t	29.3	1.9	0.7	0.5	6.4	10.0	6.4	38.4	5.5	0.3

Forest land	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Area burnt	ha	47.4	12.9	418.0	527.0	24.6	40.6	112.0	238.1	37.4	48.5
CH_4	t	23.7	6.5	208.7	263.1	12.3	20.3	55.9	118.8	18.7	24.2
N_2O	t	1.3	0.4	11.5	14.6	0.7	1.1	3.1	6.6	1.0	1.3

Forest land	Unit	2010	2011	2012	2013	2014	2015	2016
Area burnt	ha	26.0	168.7	23.7	24.2	43.2	42.3	255.7
CH_4	t	13.0	84.2	11.8	12.1	21.6	21.1	127.6
N_2O	t	0.7	4.7	0.7	0.7	1.2	1.2	7.1

6.4.2.13 Emissions from controlled burning

Emissions from controlled burning covers the burning of residues in forestry; controlled burning of forest stands is not allowed in Switzerland.

Emissions were calculated by a Tier 2b approach based on chp. 5.2. in Volume 5 of IPCC (2006). The emissions of burning of residues in forestry are calculated by multiplying the annual estimate of branches burnt (in kt) by emission factors (IPCC default values).

The amount of natural residues burnt openly was estimated by INFRAS (2014). Open burning of such residues is regulated in the Ordinance on Air Pollution Control OAPC, (Swiss Confederation 1985: Art. 26b). In Switzerland cantonal authorities are responsible for the enforcement of the OAPC regulations. For INFRAS (2014) an inquiry of some cantonal authorities has been performed in order to assess the activity data for these processes.

CO_2 emissions from wildfires were encompassed ("IE") in the data in CRF Table4.A since losses in living biomass are reflected in the NFI dataset.

The emission factors of CH_4 und N_2O of burning of branches in forestry were calculated based on EMEP/CORINAIR (EMEP/EEA 2002), see also documentation in EMIS (2018/5C2 *Abfallverbrennung in der Land- und Forstwirtschaft*).

6.4.2.14 NMVOC emissions

Estimates for annual biogenic emissions of NMVOC in Switzerland for forests (and natural grassland) are available in SAEFL (1996a): The values are 92.0 kt yr^{-1} for coniferous forests, 2.4 kt yr^{-1} for broadleaved forests and 0.61 kt yr^{-1} 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

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. The relative uncertainty of the total carbon stock change for Forest land was calculated as follows.

For living biomass, the uncertainty was estimated based on the following information:

- Stem wood of growth (gains of living biomass) and cut & mortality (losses of living biomass) in NFI4 2009–2013 and differences between NFI3 and NFI4 2009–2013 (Abegg et al. 2014):
  - mean gain 8.95 m^3 ha^{-1} yr^{-1}, mean loss -7.64 m^3 ha^{-1} yr^{-1}, resulting mean net change in stem volume 1.31 m^3 ha^{-1} yr^{-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 Lamlom and Savidge (2003) (4-8% RSD).
- Biomass expansion function (for Forest land in the Swiss GHG inventory, allometric functions for individual trees were 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 (2016) including 21.2% (2SE) sampling uncertainty and 22.2% (2SE) model uncertainty.

Thus, the total uncertainty of net carbon stock change in living biomass ($U_{liv.biom}$) in terms of carbon per unit area can be calculated following equation 3.1 in chp. "'Quantifying Uncertainties" (Volume 1 of IPCC 2006):

$$U_{liv.biom} = \sqrt{54^2+2^2+21.2^2+22.2^2} = 62.15\%$$

The uncertainty in the estimates of annual carbon stock changes derived with the Yasso07 model originates from the following sources:

- carbon input estimates obtained from the NFI (measurement errors, allometries, etc.) (chp. 2.3.3 in Didion and Thürig 2017);

- decomposition parameters used in the Yasso07 model (chp. 2.3.1 in Didion and Thürig 2017).

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 and Thürig (2017).

Based on this approach, the absolute uncertainty (double standard error) of the estimates of C stock changes are:

- $U_{Soil.abs}$ = 0.00014 t C ha^{-1} yr^{-1}
- $U_{Litter.abs}$ = 0.00371 t C ha^{-1} yr^{-1}
- $U_{Deadwood.abs}$ = 0.00708 t C ha^{-1} yr^{-1}

which correspond to the relative uncertainties (2SE) of

- U_{Soil} = 13.18%
- U_{Litter} = 2.31%
- $U_{Deadwood}$ = 679.46%.

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):

$$U_{tot} = \frac{\sqrt{(U_{\mathrm{liv.biom}} * X_{\mathrm{liv.biom}})^2 + (U_{soil} * X_{soil})^2 + (U_{Litter} * X_{Litter})^2 + (U_{Deadwood} * X_{Deadwd})^2}}{|X_{\mathrm{liv.biom}} + X_{soil} + X_{Litter} + X_{Deadwood}|}$$

With mean carbon stock changes in 2014 in

living biomass ($X_{liv.biom}$): 0.53 t C ha^{-1} yr^{-1},

soil (X_{Soil}): 0.001 t C ha^{-1} yr^{-1},

litter (X_{Litter}): -0.160 t C ha^{-1} yr^{-1}, and

dead wood ($X_{Deadwood}$): 0.001 t C ha^{-1} yr^{-1}, where positive values refer to gains in carbon stock; negative values refer to losses in carbon stock. Thus,

$$U_{tot} = \frac{\sqrt{(62.15 * -0.53)^2 + (13.18 * -0.001)^2 + (2.31 * 0.160)^2 + (679.46 * -0.001)^2}}{|(-0.53) + (-0.001) + 0.160 + (-0.001)|}$$

Thus, the resulting relative uncertainty of the total carbon stock change for Forest land is 88.6%. This value is used for the whole inventory period, i.e. explicitly for 1990 and 2016 (see Table 6-5). It should be noted that this value is an overestimation. Responsible for the high value is the high uncertainty estimate for the mean net change in volume of living biomass (54%) which is the result of the calculation of the relative uncertainty for a small net change in volume of living biomass of 1.31 m^3 ha^{-1} yr^{-1}. In fact, the uncertainties of mean gains and losses in living biomass from which the net change is calculated are only ±2% and ±4%, respectively. For the combined stock change from soil, litter and dead wood the uncertainty is 5%.

The CO_2 emissions from drained organic forest soils are very small (<0.5% of category 4A total) and was neglected in the uncertainty calculation.

The contribution of forest land to N_2O emissions from drained organic soils (category 4(II)A) is small (around 5%). Its uncertainty was included in the uncertainty calculation for wetlands (see chp. 6.7.3).

The emission factor uncertainty for category 4(V) (biomass burning, wildfires) is 70%. This is the default value given for non-CO_2 emissions in IPCC (2003, chp. 3.2.1.4.2.4) and also corresponds to the uncertainty of the combustion factor from IPCC 2006 (Volume 4, Table 2.6, mean = 0.45, 2SE = 0.32). The activity data uncertainty for wildfires is 30% (see chp. 6.3.3).

Time-series consistency

Consistent time series of annual carbon stocks of living biomass were calculated backward or forward starting from the growing stock 2005, as derived from NFI3 (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 2017 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.

Suitability of the soil carbon model Yasso07 for application for forests in Switzerland

The validity of the Yasso07 model in Swiss forests was examined by Didion et al. (2014a). The study analyzed, among other, the accuracy of Yasso07 for reproducing observed carbon decomposition in litter and dead wood in Swiss forests. The authors found that no significant differences existed between simulated and observed remaining carbon in foliage and fine root litter after 10 years and in lying dead trees after 14 to 21 years.

Afforestation – Growing stock and changes in growing stock

A comparison of Swiss carbon data for living biomass in afforestations 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 t C ha^{-1} a^{-1} in the first 20 years following an afforestation.

Afforestation – Litter

In an experiment by Zimmermann and Hiltbrunner (2012; COST E639-project “Turnover and stabilization of soil organic matter: effect of land-use change in alpine regions”), litter accumulation in a 40 year old afforestation with Norway Spruce was determined. The authors found accumalation rates of 0.17-0.20 t C ha^{-1} yr^{-1}. Further relevant studies are discussed in 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 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.ch; NABO) is to assess soil quality in the long term and to validate appropriate soil protection measures. NABO operates about 110 long-term monitoring sites throughout Switzerland. Most of them were sampled for the first time between 1985 and 1989 and resampled every five years ever since. 28 sites are located in forests (SAEFL 1993).

The long-term soil monitoring sites are resampled every 5 years. At each site, four replicate bulked soil samples from the upper soil layer 0–20 cm are taken within an area of 10m*10m. Each bulked sample consists of 25 single cores taken according to a stratified random sampling scheme. Further details are provided by SAEFL (2000a) and FOEN (2015p). Currently, results of sampling campaigns 1 to 5 are available for Forest land. For Cropland and Grassland, additionally the results of sampling campaign 6 were already processed.

The spatial variation of bulk density was included in calculating the carbon pools. Bulk density and soil skeleton (>2 mm) were measured repeatedly for all monitoring sites at the occasion of sampling campaigns 4 to 6 (2000–2014), but not in the previous campaigns. The mass of fine earth (<2 mm; M_{FE}) per total soil volume (V_{tot}, including skeleton and pores) was determined for four volumetric samples 0–20 cm per site and campaign to derive the so-called apparent density of fine earth ($D = M_{FE} / V_{tot}$). Subsequently, SOC pools 0–20 cm [t/ha] were calculated by D [g/cm^3] * SOC [% w./w.] * 20 [cm]. For each site, the site-specific apparent density was used; repeated apparent density measurements per site were used to account for the variability of the bulk density.

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 6-7 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 third resampling campaign.

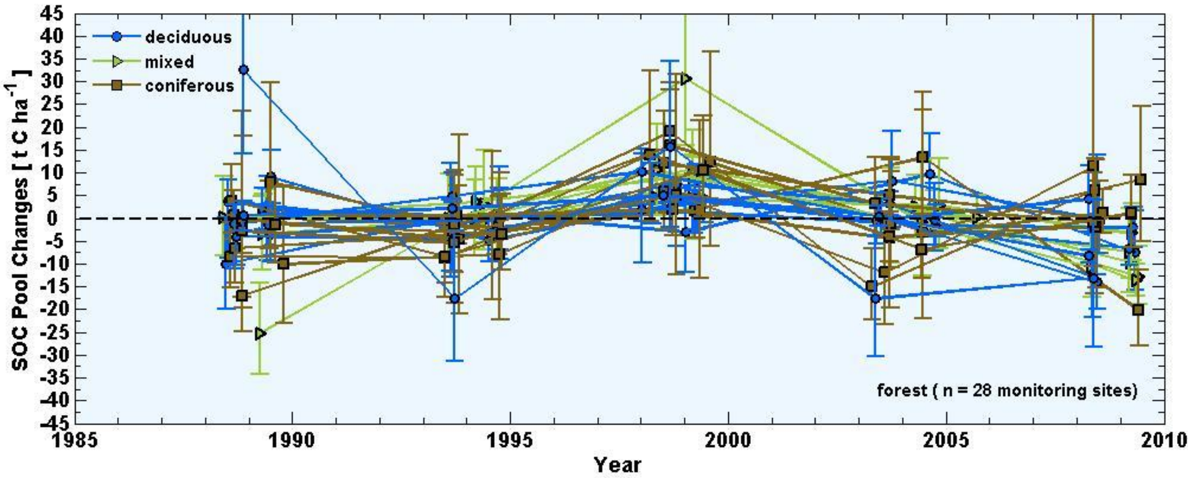


Figure 6-7 Time series of measured SOC pool changes in the top soil (0–20 cm) at the 28 NABO forest sites from the 1st to the 5th resampling campaigns. SOC pools were centred by the median SOC pool of all resamplings of the monitoring site. Each pool value presents the median of four bulked soil samples 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 ± 1.8% and ± 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 hypotheses is also supported by the fact that the soil samples in the third resampling campaign were taken earlier in spring time as in the other sampling campaigns and hence, soil moisture content of the samples was higher on average. This might explain the large temporal variation, in particular at coniferous forest sites with a pronounced organic layer. Using a robust linear regression approach for the SOC pool data of the forest soils, the 95% confidence interval for the SOC pool was ± 1.5 t C ha^{-1}. In order to capture as good as possible the natural variation of these site-specific characteristics, standard operation procedures and quality assurance were implemented since the 4th soil campaign. Further work will focus on the correction of the measured carbon pools to equivalent mass of the fine earth <2 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 -0.00075 ± 0.00053 t C ha^{-1} yr^{-1} (2SE; based on data in Didion and Thürig 2017). This value would correspond to -0.015 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 for carbon stock changes in dead wood, litter and soil organic matter reported by Finland, where the Yasso07 model is also applied, was 31.5% for the year 2015 (Statistics Finland 2017: chp. 6.4.3.2). For the total uncertainty in the change of living biomass, Finland reported 20% (Statistics Finland 2017: chp. 6.4.3.1).

6.4.5 Category-specific recalculations

Activitiy data 1990–2015 were updated (see chp. 6.3.5).

To ensure a consistent time series of annual carbon stocks of living biomass an error was corrected in the backward calculation of the stocks of living biomass for the period 1990-2004: $gainC_{l,i,CC12,n}$ and $lossC_{l,i,CC12,n}$ was shifted one year (see chp. 6.4.2.5).

The time series of losses of living biomasse was recalculated from 2006 onwards since periodic values of cut and mortality from the NFI were recalibrated with relative harvesting amounts taken from the forest statistics (see chp. 6.4.2.5) over a different time span (2006-2016 instead of 2006-2015 in FOEN (2017).

Modelling carbon stock changes in dead wood, litter and mineral soil with Yasso07 for productive forests: More accurate elevation data from a digital elevation model for the NFI plots available for this submission were used (Didion and Thürig 2017), which resulted in a redistribution of a few individual NFI plots between elevation zones (chp. 6.2.2) and consequently also of their estimated carbon stocks and carbon stock changes. The overall total, however, was not affected (see chp. 6.4.2.6 and Table 6-18). Further, a correction was made in the post-processing of the values of carbon stock changes in dead wood. In FOEN (2017) there was an error in the attribution to the strata in the input file for the reporting tables.

In response to UNFCCC (2018, ID#KL.2) the assumption that 50% of the difference between the soil carbon stocks before and after the change was reported as a source or sink, respectively, for conversions from CC51 (buildings and constructions) to other land-use categories, was revised. Instead, the regular stock-difference approach was applied for land-use changes from CC51 to other land-use categories as described in chp. 6.1.3.2. This led to higher gains in soil carbon stocks on areas converted from CC51 to CC11, CC12 und CC13 in comparison to the last submission.

In response to UNFCCC (2018, ID#L.6 and ID#KL.3) estimates on the share of organic soils affected by past drainage under Forest land were recalculated. In former submissions it was assumed that all organic soils under Forest land had been drained. For this submission the amount of drained organic soils was estimated from the shapefile of organic soils in Switzerland (Wüst-Galley et al. 2015) by using additional descriptive information from the NFI surveys (Abegg 2017). Based on this study the share of drained organic soils under Forest land was reduced from 100% to 3% (see chp. 6.4.2.10).

The area affected by wildfires in the Swissfire database was updated for the years 2005–2007.

CH_4 and N_2O emissions from open burning of residues from forestry (category 4(V)A1, controlled burning in Forest land remaining forest land) were recalculated for the years 2011-

2015, since an error was corrected in the interpolation of the data between the reference values 2010 and 2020 provided by INFRAS (2014).

6.4.6 Category-specific planned improvements

The implementation of the soil model Yasso07 to improve the accuracy in the estimates of temporal changes in soil carbon, litter and dead wood will be further developed. Depending on the availability of relevant data and studies, planned improvements include:

- Investigating the validity of the further development of Yasso07 for application in Switzerland. The new model version Yasso15 includes, among other, a new parameter set that improves the sensitivity of the simulated decomposition to temperature and precipitation. Preliminary results from Switzerland using a beta-version of Yasso15 indicate improvements over Yasso07, particularly with regards to soil carbon stocks. Status of the project: ongoing.
- Evaluating available data to improve the completeness of the litter inputs by accounting for the contribution of (a) fine-woody litter <7 cm and (b) litter from the herb- and shrub layer. A field study was recently completed which will provide estimates on biomass turnover of plants in the herb- and shrub layer of NFI plots. These activities may also further improve the accuracy of the simulated estimates. Status of the project: ongoing.

Projects in the national research programme "Sustainable Use of Soil as a Resource" ("SOM control") aimed at identifying the drivers of soil organic matter storage in Swiss forest soils. The objectives were 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. In a follow-up project financed by FOEN, the implications for carbon stabilization in mineral forest soils is investigated and the application to further development of the Yasso model is examined (Gosheva et al. 2018).

6.5 Category 4B – Cropland

6.5.1 Description

Table 6-23 Key categories in category 4B. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
4B1	Cropland remaining cropland	CO2	T1, L2, T2

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 were 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 2016, category 4B1 Cropland remaining cropland was a net source of 155.84 kt CO_2 due to emissions from organic soils. Average living biomass was increasing slightly over the period 1990–2016. However, annual fluctutations in carbon stocks of biomass are considerable (see Table 6-24). Carbon stocks in mineral soils were assumed to be in equilibrium (i.e. no carbon stock changes occur in mineral soils). Thus, all soil emissions in category 4B1 are considered to originate from carbon mineralization in organic soils, mainly in the lowest elevation zone (z1: 86%). Overall, organic soils accounted for 2.7% of cropland area in Switzerland (Table 6-7).

Category 4B2 Land converted to cropland was a small net source of 48.01 kt CO_2 in 2016 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 6-24. 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:

$$\text{Biomass cropland} = \Sigma f\ (Af / At) * Cf$$

where Af = Area of crop type f, At = total cropping area and Cf = yield (annual crops, leys) for the particular crop (t C ha^{-1}). Annual values 1990-2015 for Af, At and Cf were published by the Swiss Farmers Union (SBV 2016). For the year 2016 provisional values were calculated (mean 2006-2015).

The resulting mean biomass stock for Swiss cropland over the inventory time period was 4.76 ± 0.36 (1 SD) t C ha^{-1}.

Table 6-24 Annual values for arable crop yields (SBV 2016), resulting area-weighted carbon stock means (t C ha^{-1}) and carbon stock changes (gain/loss) (t C ha^{-1} yr^{-1}), assuming a carbon fraction of 0.5. Highlighted data for 1990 are displayed in Table 6-4.

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	CC21: yield (stock) [t C ha^{-1}] and gain/loss [t C ha^{-1} yr^{-1}] in living biomass									
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 yield	4.34	4.30	4.39	4.44	4.11	4.28	4.51	4.72	4.67	4.43
Gain/loss	-0.34	-0.03	0.09	0.05	-0.32	0.17	0.23	0.21	-0.05	-0.24

Crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	CC21: yield (stock) [t C ha^{-1}] and gain/loss [t C ha^{-1} yr^{-1}] in living biomass									
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	7.29	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
Gain/loss	0.28	-0.21	0.03	-0.13	0.49	0.08	-0.27	0.37	0.06	0.06

Crop	2010	2011	2012	2013	2014	2015	2016	mean 1990-2016	
	CC21: yield (stock) [t C ha^{-1}] and gain/loss [t C ha^{-1} yr^{-1}] in living biomass								
Barley	2.56	2.75	2.75	2.45	3.19	3.00	2.72	2.60	
Wheat	2.48	2.72	2.49	2.32	2.73	2.65	2.56	2.51	
Maize	3.61	4.13	3.85	3.12	3.75	2.65	3.73	3.69	
Silage maize	7.47	8.42	8.06	7.79	8.46	7.20	7.81	7.04	
Sugar beet	8.03	10.38	9.58	7.61	10.06	7.55	8.70	8.05	
Fodder beet	6.49	6.65	5.58	4.67	5.52	4.95	5.94	6.08	
Potatoes	4.26	5.04	4.52	3.59	4.89	3.69	4.40	4.39	
Leys	6.11	6.11	6.11	6.11	6.11	6.09	6.11	6.11	
Mean	4.99	5.44	5.23	4.93	5.46	4.96	5.11	4.76	
Gain/loss	-0.20	0.45	-0.21	-0.30	0.52	-0.49	0.15	0.02	

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 ± 5 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 ± 48 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 5.11 t C ha^{-1} in 2016 (Table 6-24; SBV 2016). The difference in biomass stock between a specific year and the preceding year was reported as gain or loss of carbon (see Table 6-24). The resulting values are in the range between -0.49 and 0.52 t C ha^{-1} yr^{-1} with an average of 0.02 t C ha^{-1} yr^{-1} for the inventory time period.

Applying a Tier 1 approach, changes in carbon stocks, in dead organic matter, and in mineral soils were assumed to be in equilibrium for Cropland remaining cropland.

The annual net carbon stock change in organic soils was estimated to -9.52 t C ha^{-1} according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and verified by ART (2009b) and Paul (2018).

In the case of land-use change, the net carbon changes in biomass and soil were calculated as described in chp. 6.1.3.

6.5.2.4 N_2O emissions from cropland

N_2O emissions from drainage of organic soils (category 4(II)) on cropland are reported in the agriculture sector (CRF Table3.D).

The calculation of emissons for categories 4(III) and 4(IV) (direct N_2O emissions from nitrogen mineralization in mineral soils and indirect N_2O emissions from managed soils) is described in chp. 6.10.

6.5.3 Uncertainties and time-series consistency

Uncertainties of activity data of category 4B Cropland are described in chp. 6.3.3. For calculating the overall uncertainty of category 4B, the relevant emissions from living biomass, mineral soils and organic soils were considered (Meteotest 2018).

- Living biomass: 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 absolute uncertainties per hectare, calculated with the implied emission factors of 2016, are 0.019 t C ha^{-1} yr^{-1} for 4B1 and 0.011 t C ha^{-1} yr^{-1} for 4B2.
- Mineral soils: A range of possible carbon stock changes in mineral cropland 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 ± 0.15 t C ha^{-1} yr^{-1} (see chp. 6.5.4). 0.15 t C ha^{-1} yr^{-1} was used as absolute uncertainty for 4B1 and 4B2.

- Organic soils: The uncertainty of the carbon stock change (emission factor) in organic soils is 23% as reported by Leifeld et al. (2003: 56) and the uncertainty of the activity data (area of organic soil) is 37.8% (see chp. 6.3.3), resulting in a combined uncertainty of 44.2%. Thus, the absolute uncertainties of the total organic soil emissions in 2016 are 42.54 kt C for 4B1 and 1.10 kt C for 4B2. By dividing those uncertainties with the total area of 4B1 and 4B2, respectively, the absolute uncertainties per hectare result in 0.116 t C ha^{-1} yr^{-1} for 4B1 and 0.040 t C ha^{-1} yr^{-1} for 4B2.

The root sum squares of the above-mentioned three absolute uncertainties are 0.191 t C ha^{-1} yr^{-1} for 4B1 and 0.156 t C ha^{-1} yr^{-1} for 4B2. These absolute uncertainties were used to calculate relative emission factor uncertainties for 4B1 and 4B2 by dividing with the mean net carbon stock change per hectare of 4B1 and 4B2, respectively. In 2016, the mean net carbon stock changes were -0.116 t C ha^{-1} for 4B1 and -0.480 t C ha^{-1} for 4B2 (calculated from CRF Table4.B). The resulting relative uncertainties are 164.3% for 4B1 and 32.4% for 4B2, respectively (see Table 6-5).

In the same way the uncertainties for the year 1990 were calculated. They are 32.3% (4B1) and 34.6% (4B2) (Table 6-5).

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 soil carbon stocks

The Tier 1 assumption that changes of carbon stocks in mineral soils are zero for Cropland remaining cropland was 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 pools measured at 29 cropland monitoring sites of the Swiss Soil Monitoring Network (NABO; see chp. 6.4.4) featuring mineral soils indicate no significant changes from 1990 to 2014 (Figure 6-8). The decline from the first to the second sampling campaign was identified as artefact introduced by the date of sampling; in the first campaign, samplings were conducted substantially later in the year compared with the remaining campaigns, which induced higher SOC contents and thus SOC pools. The range of the calculated SOC pools was large (20.6–88.4 t C ha^{-1}) with a mean of 46.7 t C ha^{-1}.

The monitoring scheme applied by NABO is able to detect relative changes in SOC stocks of roughly 3.3% per 10 years for mineral cropland soils (minimum detectable change for about 30 monitoring sites including three or more sampling campaigns). Regarding the measured SOC pools (mean ≈ 47 t ha^{-1}) this corresponds to a minimum detectable change of roughly 0.15 t C ha^{-1} yr^{-1} for SOC pools.

In conclusion, NABO data provide evidence that Swiss cropland mineral soils did not act as a net carbon source or sink over the last 30 years.

The SOC pools for three additional cropland sites featuring organic soils ranged from 205 to 269 t C ha^{-1} in the first and from 141 to 236 t C ha^{-1} for the sixth sampling campaing (not included in Figure 6-8). Thus, SOC pools 0–20 cm of these sites declined by 14–63 t C ha^{-1} over a period of 30 years (however, the effective losses over the whole soil profiles are even higher due to decreasing depths of soil layers).

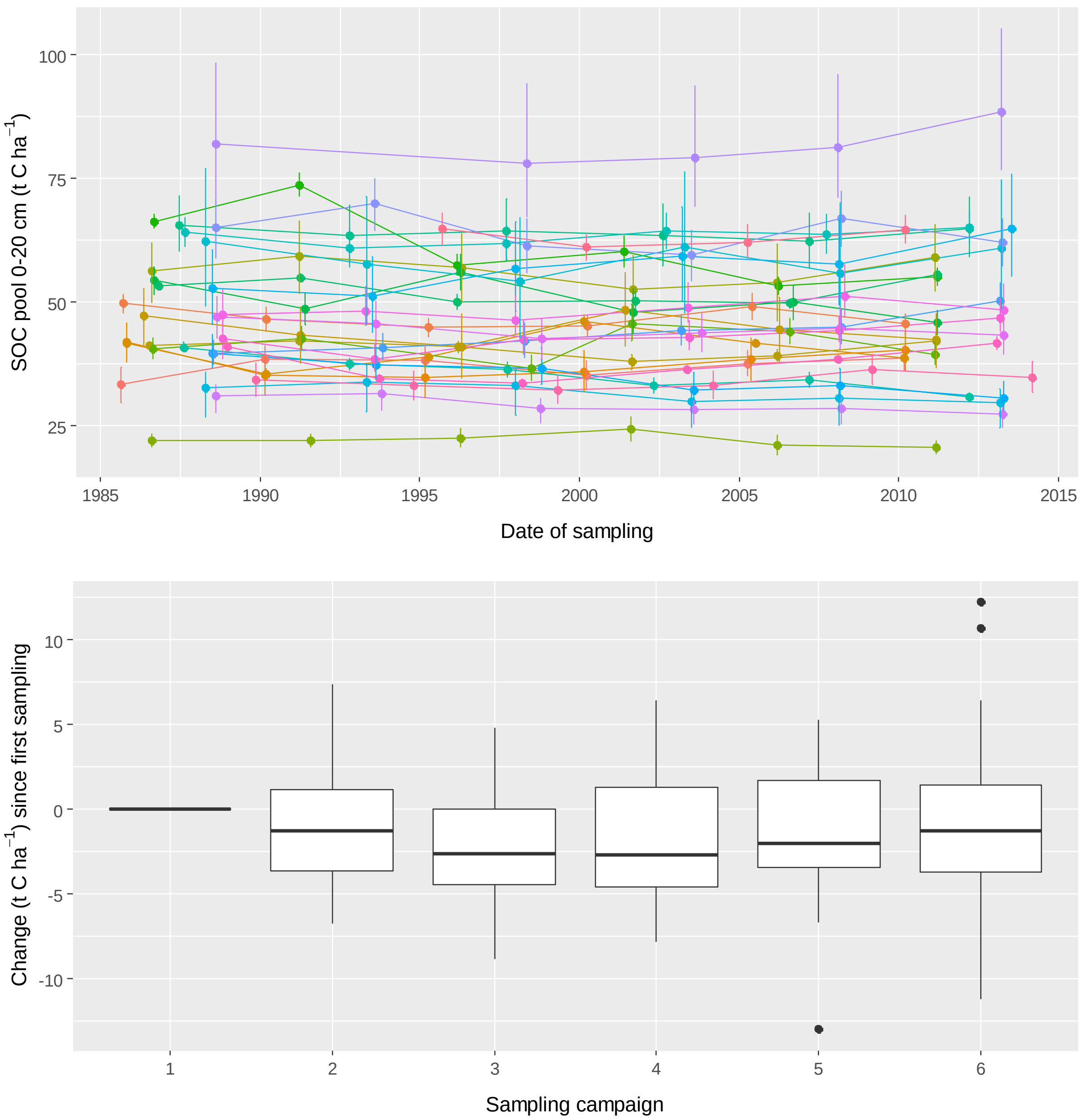


Figure 6-8 Measured SOC pools for topsoils (0–20 cm) and their changes for 29 NABO long-term monitoring sites featuring mineral soils and used as cropland during the time period 1985–2014. The elevation of the sites ranges from 324 to 945 m a.s.l. Top panel: SOC pools 0–20 cm per site and sampling; the dots indicate the mean and the bars the range of 5% and 95% percentiles of bootstrap samples taking into account the variability in SOC contents of the individual replicates per site and sampling as well as the variations of the bulk density. Bottom panel: boxplot of changes in SOC pools since first sampling (boxes indicate the lower und the upper quartiles with the median indicated; lines include all observations inside the range of 1.5 times the interquartile distance, observations beyond that range are indicated as dots).

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

Activitiy data 1990–2015 were updated (see chp. 6.3.5).

Provisional carbon stocks and carbon stock changes in living biomass for the year 2015 were replaced by definitive values from SBV (2016).

In response to UNFCCC (2018, ID#KL.2) the assumption that 50% of the difference between the soil carbon stocks before and after the change was reported as a source or sink, respectively, for conversions from CC51 (buildings and constructions) to other land-use categories, was revised. Instead, the regular stock-difference approach was applied for land-use changes from CC51 to other land-use categories as described in chp. 6.1.3.2. This led to higher gains in soil carbon stocks on areas converted from CC51 to CC21 in comparison to the last submission.

6.5.6 Category-specific planned improvements

Price et al. (2017) created a nationwide model for tree biomass in Switzerland (both inside and outside of forest), using structural information available from airborne laser scanning. The model offers significant opportunity for improved estimates of carbon stocks in living biomass on land use combination categories where tree biomass has either not been included or only roughly estimated until now. The suitability of the obtained data for reporting in category 4B is subject to evaluation.

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 was finalized by the end of 2017. The implementation of the model is projected for the inventory cycle 2019-2020.

Projects in the national research programme "Sustainable Use of Soil as a Resource" 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. The thematic syntheses as well as the results of the research projects phase II (2016-2017), the FACCE-JPI and several focus studies will be published in 2018. Thematic synthesis 2 “Soil and Environment” embraces inter alia soil organic matter and soil-borne GHG fluxes (Hagedorn et al. 2018).

The calculation of carbon stock changes in living biomass and the estimate of their uncertainties will be improved with respect to consistency in the next submission: In this submission only provisional values for the carbon stock in living biomass for 2016 were available.

6.6 Category 4C – Grassland

6.6.1 Description

Table 6-25 Key categories in category 4C. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
4C1	Grassland remaining grassland	CO2	L2, T2
4C2	Land converted to grassland	CO2	L1, T1, L2, T2

Swiss grasslands belong to the cold temperate wet climatic zone.

Carbon stocks in living biomass and carbon stocks in mineral and organic soils were considered.

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).

In category 2 in CRF Table4.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 2016, category 4C1 Grassland remaining grassland was a net source of 110.05 kt CO_2. Carbon stocks in living biomass and carbon stocks in mineral soils are assumed to be in balance (i.e. no carbon stock changes occur). The highest contribution to the CO_2 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 (Table 6-7). Contributions of other Grassland remaining grassland categories (CC32-CC37) were of minor importance.

Category 4C2 Land converted to grassland was a net source of 188.51 kt CO_2 in 2016. The highest individual contribution came from subcategory 4C2.1 Forest land converted to grassland being responsible for a net source of 397.62 kt CO_2. Most of this source was due to net changes in living biomass from deforestation. Subcategories 4C2.2 to 4C2.5 were net sinks due to sequestration of CO_2 in mineral soils and biomass in the course of the conversion to grassland.

6.6.2 Methodological issues

6.6.2.1 Carbon in living biomass

Permanent grassland (CC31)

Permanent grasslands range in 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 6-26), assuming a carbon fraction of 0.5. Mean standing above-ground biomass stocks were taken for each of the altitudinal zones (see Table 6-27) because the spatial distribution of grassland management types is not known.

Table 6-26 Annual yields of different types of managed permanent grassland (CC31). Each value represents the mean of two fertilization levels (based on FAL/RAC 2001).

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 elevation. Root biomass was added to above-ground biomass to derive the total living biomass for CC31. Table 6-27 shows the living biomass of permanent grassland for the three elevation zones as the the sum of cumulated annual yield (above-ground biomass) and roots.

Table 6-27 Root biomass (Croot), above ground biomass (Cyield) and total living biomass Cl of permanent grassland (CC31).

Elevation [m]	Croot	Cyield	Cl
	[t C ha^{-1}]		
<601	1.82	5.26	7.08
601-1200	2.04	3.96	6.00
>1200	5.70	2.25	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 (Cl) for CC33 was therefore calculated as:

Cl = [(Cl vineyards * area vineyards) + (Cl low-stem orchards * area low-stem orchards)] / (area vineyards + area low-stem orchards)

Cl of vineyards is 3.61 t C ha^{-1}, calculated based on the mean stand density (5’556 vines ha^{-1}) and 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.

Stem wood volume = $r^2 * \pi *$ 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, Volume 4, chp. 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:

C low-stem = stem wood volume * BEF * wood density * carbon content

= 7.75 dm^3 * 2.3 * 0.55 kg/dm^3 * 0.5 = 4.9 kg C

The mean stand density of low-stem orchards 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 biomass = (carbon per fruit tree [t C] * number of fruit trees / area orchards [ha]) + carbon in grass [t C ha^{-1}]

The carbon content of a large fruit tree with a DBH of 25–35 cm was calculated as follows:

C (Hochstamm) = Stem wood volume * KE-Factor = 225 kg C

where:

- Stem wood volume of an apple tree assuming a cylindrical stem with mean DBH of 30 cm and a stem height of 7 m amounts to 0.5 m^3, 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. The biomass of CC31 (cf. Table 6-27) was weighted with the area of CC35 in the three elevation zones (i.e. 6.84 t C ha^{-1}) and added to the woody biomass to obtain a total biomass stock of 24.62 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; Düggelin 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 area-weighted mean of permanent grasslands biomass in the three elevation zones (cf. Table 6-27), 7.87 t C ha^{-1}, 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 6-28. 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 6-28 Mean carbon stocks and their uncertainties 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 between 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 6-28) 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 6-28) 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 6-28) 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 6-28, the carbon stock of CC36 was calculated as:

Cs of CC36 = 0.35 * Cs permanent grassland >1200 m = 26.31 t C ha^{-1} (0–30 cm)

The mean soil organic carbon stock (0–30 cm) for organic soils is 240 t C ha^{-1}. It was assumed that the small area covered by organic soils in CC36 (cf. category 1 in CRF Table4.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 corrrespond to the mean value of carbon stocks under permanent grassland on mineral soils for all elevation zones (Table 6-28). 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

Applying a Tier 1 approach, changes in carbon stocks in biomass, in dead organic matter, and in mineral soils were assumed to be in equilibrium for Grassland remaing grassland.

The annual net carbon stock change in organic soils on managed grassland (CC31, CC33 and CC35) was estimated as -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) and Paul (2018). For extensively managed grasslands (CC32, CC34, CC36 and CC37) the emission from organic soils was estimated as 5.30 t C ha^{-1} yr^{-1} according to available domestic data (ART 2011b; Paul 2018).

In the case of land-use change, the net carbon 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 N_2O emissions from grassland

N_2O emissions from drainage of organic soils (category 4(II)) on grassland were reported in the agriculture sector (CRF Table3.D).

The calculation of emissons for categories 4(III) and 4(IV) (direct N_2O emissions from nitrogen mineralization in mineral soils and indirect N_2O emissions from managed soils) is described in chp. 6.10.

6.6.2.5 Emissions from wildfires

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 6-29 shows the annual burnt area from 1990 to 2016. 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 CH_4 and N_2O emissions were calculated using equation 2.27 in Volume 4 of IPCC (2006) with the following parameters:

- For CH_4 the default emission factor of 2.3 g (kg combusted biomass)$^{-1}$ and for N_2O, 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 carbon stock of living biomass (litter and dead wood carbon stocks were assumed to be zero for grassland). On average, the amount of living biomass amounted to 18.26 t biomass ha^{-1} or, assuming a carbon fraction of 0.5, to a carbon stock of 9.13 t C ha^{-1}. This value was derived from the carbon stocks of all grassland categories (CC31 to CC37) as an area-weighted mean using the geographical extensions in 2015.
- The fraction of the biomass combusted was 0.74 (IPCC 2006 Volume 4, Table 2.6, Savanna and Grassland).

The resulting annual CH_4 and N_2O emissions 1990–2016 on burnt areas in category 4C Grassland are shown in Table 6-29 and are reported in CRF Table4(V).

Table 6-29 Area of 4C Grassland affected by wildfires (WSL, Swissfire database) and resulting CH_4 and N_2O emissions.

Grassland	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Area burnt	ha	637.1	22.3	6.0	18.9	174.5	82.0	42.8	371.8	72.0	18.9
CH_4	t	19.8	0.7	0.2	0.6	5.4	2.5	1.3	11.6	2.2	0.6
N_2O	t	1.8	0.1	0.0	0.1	0.5	0.2	0.1	1.1	0.2	0.1

Grassland	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Area burnt	ha	21.8	7.5	257.2	137.9	4.3	4.4	14.3	97.6	29.2	2.7
CH_4	t	0.7	0.2	8.0	4.3	0.1	0.1	0.4	3.0	0.9	0.1
N_2O	t	0.1	0.0	0.7	0.4	0.0	0.0	0.0	0.3	0.1	0.0

Grassland	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Area burnt	ha	1.3	56.3	4.4	3.4	2.3	3.3	207.3
CH_4	t	0.0	1.7	0.1	0.1	0.1	0.1	6.4
N_2O	t	0.0	0.2	0.0	0.0	0.0	0.0	0.6

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 yr^{-1}.

6.6.3 Uncertainties and time-series consistency

Uncertainties of activity data of category 4C Grassland are described in chp. 6.3.3. For calculating the overall uncertainty of category 4C, the relevant emissions from living biomass, mineral soils and organic soils were considered (Meteotest 2018).

- Living biomass: The relative uncertainty in yield determination was 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) were based on many agricultural field experiments and have a high reliability. The absolute uncertainties per hectare, calculated with the implied emission factors of 2016, are 0.001 t C ha^{-1} yr^{-1} for 4C1 and 0.099 t C ha^{-1} yr^{-1} for 4C2.
- Mineral soils: A range of possible carbon stock changes in mineral grassland soils was determined by the Swiss Soil Monitoring Network (NABO). The monitoring scheme applied by NABO is able to detect carbon stock changes of ± 0.21 t C ha^{-1} yr^{-1} (see chp. 6.6.4). Therefore, 0.21 t C ha^{-1} yr^{-1} was used as absolute uncertainty for 4C1 and 4C2.
- Organic soils: The uncertainty of the carbon stock change (emission factor) in organic soils is 23% as reported by Leifeld et al. (2003: 56) and the uncertainty of the activity data (area of organic soil) is 55.9% (see chp. 6.3.3), resulting in a combined uncertainty of 60.4%. Thus, the absolute uncertainties of the total organic soil emissions in 2016 are 32.31 kt C for 4C1 and 6.01 kt C for 4C2. By dividing those uncertainties with the total area of 4C1 and 4C2, respectively, the absolute uncertainties per hectare result in 0.023 t C ha^{-1} yr^{-1} for 4C1 and 0.121 t C ha^{-1} yr^{-1} for 4C2.

The root sum squares of the above-mentioned three absolute uncertainties are 0.211 t C ha^{-1} yr^{-1} for 4C1 and 0.262 t C ha^{-1} yr^{-1} for 4C2. These absolute uncertainties were used to calculate relative emission factor uncertainties for 4C1 and 4C2 by dividing with the mean net carbon stock change per hectare of 4C1 and 4C2, respectively. In 2016, the mean net carbon stock changes were -0.023 t C ha^{-1} for 4C1 and -0.648 t C ha^{-1} for 4C2 (calculated from CRF Table4.C). The resulting relative uncertainties are 915.9% for 4C1 and 40.4% for 4C2, respectively (see Table 6-5).

In the same way the uncertainties for the year 1990 were calculated. They are 1342.3% (4C1) and 67.7% (4C2) (Table 6-5).

For wildfires, the emission factor uncertainties of CH_4 and N_2O were set to 70% (identical to forest land, see chp. 6.4.3). The activity data uncertainty is 30% (see chp. 6.3.3).

Consistency: Time series for category 4C Grassland are all considered consistent; they were calculated based on consistent methods and homogenous databases.

6.6.4 Category-specific QA/QC and verification

The general QA/QC measures are described in 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 was 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 soil carbon stocks

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 Swiss Soil Monitoring Network (NABO; see chp. 6.4.4) provided data from 31 monitoring sites identified as grassland according to the land-use definitions used for LULUCF (see chp. 6.2); thus, the selected sites included –in addition to meadows and pastures– also vineyards, orchards, and urban parks. SOC pools for the top 20 cm of these soils ranged from 25.3 to 142.1 t C ha^{-1} with a mean of 73.5 t C ha^{-1} (Figure 6-9). The highest pools were found for alpine pastures at high elevation. On average, a slight increase during the period 1985 to 2000 (sampling campaigns 1 to 3) and a slight decrease thereafter (campaigns 3 to 4) were observed for SOC. However, these minor changes were statistically non-significant. In addition, previous studies showed that the elevated SOC pools for the third sampling campaign must be considered as artefact induced by sub-optimal conditions during field work. From sampling campaigns 4 to 6, SOC pools remained stable. The monitoring scheme applied by NABO is able to detect relative changes in SOC contents of roughly 2.5% per 10 years for mineral grassland soils (minimum detectable change for about 30 monitoring sites including three or more sampling campaigns). Regarding the measured SOC pools (mean ≈ 74 t ha^{-1}) this corresponds to a minimum detectable change of roughly 0.19 t C ha^{-1} yr^{-1} for SOC pools (or 0.21 t C ha^{-1} yr^{-1} if vineyards are excluded).

In conclusion, NABO data provide evidence that Swiss grassland mineral soils did not act as a net source or sink of carbon over the last 30 years.

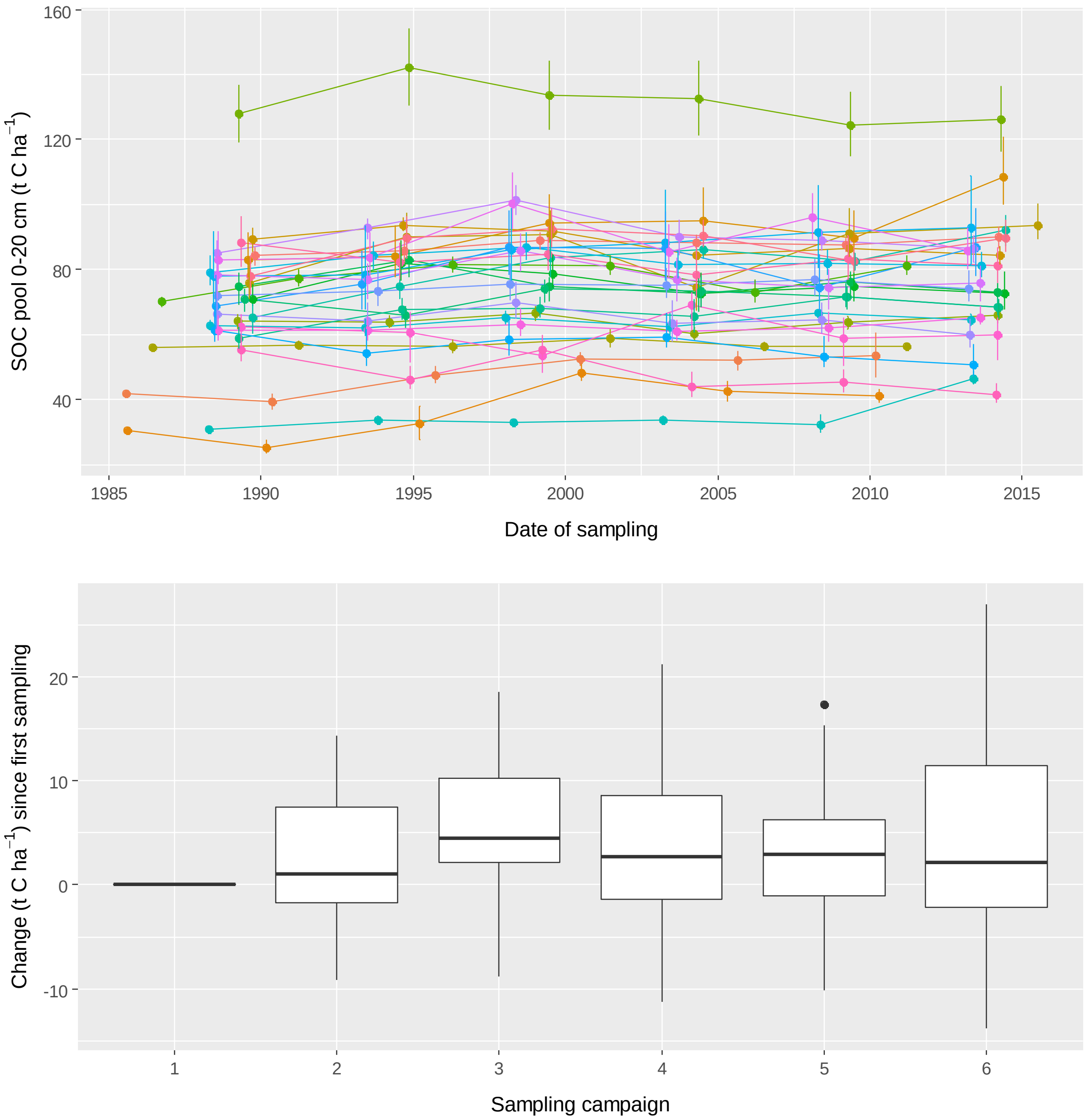


Figure 6-9 Measured SOC pools for topsoils (0–20 cm) and their changes for 31 NABO long-term monitoring sites used as grassland during the time period 1985–2014. The elevation of the sites ranges from 265 to 2400 m a.s.l. Top panel: SOC pools 0–20 cm per site and sampling; the dots indicate the mean and the bars the range of 5% and 95% percentiles of bootstrap samples taking into account the variability in SOC contents of the individual replicates per site and sampling as well as the variations of the bulk density. Bottom panel: boxplot of changes in SOC pools since first sampling (boxes indicate the lower und the upper quartiles with the median indicated; lines include all observations inside the range of 1.5 times the interquartile distance, observations beyond that range are indicated as dots).

Short-term land-use changes between Grassland and Cropland

See chp. 6.5.4.

6.6.5 Category-specific recalculations

Activitiy data 1990–2015 were updated (see chp. 6.3.5).

The area affected by wildfires in the Swissfire database was updated for 2005–2007.

In response to UNFCCC (2018, ID#KL.2) the assumption that 50% of the difference between the soil carbon stocks before and after the change was reported as a source or sink, respectively, for conversions from CC51 (buildings and constructions) to other land-use categories, was revised. Instead, the regular stock-difference approach was applied for land-use changes from CC51 to other land-use categories as described in chp. 6.1.3.2. This led to higher gains in soil carbon stocks on areas converted from CC51 to CC31, CC32, CC33, CC45, CC35, CC36, and CC37 in comparison to the last submission.

6.6.6 Category-specific planned improvements

Price et al. (2017) created a nationwide model for tree biomass in Switzerland (both inside and outside of forest), using structural information available from airborne laser scanning. The model offers significant opportunity for improved estimates of carbon stocks in living biomass on land use combination categories where tree biomass has either not been included or only roughly estimated until now. The suitability of the obtained data for reporting in category 4C is subject to evaluation.

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 was finalized by the end of 2017. The implementation of the model is projected for the inventory cycle 2019-2020.

A study on GHG emissions from an intensively used fen under grassland management (Agroscope in collaboration with the University of Basel, 2017–2020, financed by FOEN) will improve the robustness of country-specific emission factor estimates for grassland soils rich in organic matter in the medium term. A further objective of the study is to estimate potential emission reductions from coverage of managed organic soils with mineral soil material.

Projects in the national research programme "Sustainable Use of Soil as a Resource" 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. The thematic syntheses as well as the results of the research projects phase II (2016-2017), the FACCE-JPI and several focus studies will be published in 2018. Thematic synthesis 2 “Soil and Environment” embraces inter alia soil organic matter and soil-borne GHG fluxes (Hagedorn et al. 2018).

6.7 Category 4D – Wetlands

6.7.1 Description

Table 6-30 Key categories in category 4D. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
4D1	Wetland remaining wetland	CO2	L2

Carbon stocks in living biomass and carbon stocks in mineral and organic soils were considered.

Wetlands were subdivided into surface waters (CC41) and unproductive wetlands 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 (very) 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 wetlands are located on organic soils (cf. Table 6-7). 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 (68.23 t C ha^{-1}; 0–30 cm).

6.7.2.3 Changes in carbon stocks

Applying a Tier 1 approach, changes in carbon stocks in biomass, in dead organic matter, and in mineral soils were assumed to be in equilibrium 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 t C ha^{-1} yr^{-1} according to domestic data (ART 2011b; Paul 2018). This value was used for weakly managed ecosystems such as fens and (very) extensively managed ecosystems such as raised bogs. Bogs and fens are protected to a large part by Federal Ordinances (Swiss Confederation 1991a, 1994) and drainage is not allowed any more. However, the impact of old drainages constructed before 1990 probably still triggers certain emissions.

In the case of land-use change, the net carbon 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 reconsidered as recommened 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 wetland soils the conversion time is 20 years.

6.7.2.4 Non-CO_2 emissions from wetlands

No emissions were reported in category D in CRF Table4(I) (notation key “NO”). Input of nitrogen fertilizers to unproductive wetlands (CC42) is very unlikely as these areas represent mostly nature conservation areas (raised bogs, fens) protected by legislation (Swiss Confederation 1991a, 1994), where fertilizing is prohibited.

An estimate of 0.43 kt CH_4 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 D.2 in CRF Table4(II).

N_2O emissions from drainage of organic soils was calculated for unproductive wetlands (CC42) and reported in category D.3 in CRF Table4(II) (labelled as “WL drained”). The emission factor of 1.6 kg N_2O-N ha^{-1} used is the default value given in the IPCC Wetlands Supplement (IPCC 2014a, Table 2.5) for shallow drained, nutrient-rich grassland.

The calculation of emissons for categories 4(III) and 4(IV) (direct N_2O emissions from nitrogen mineralization in mineral soils and indirect N_2O emissions from managed soils) is described in chp. 6.10.

6.7.3 Uncertainties and time-series consistency

Uncertainties of activity data of category 4D Wetlands are described in chp. 6.3.3.

For calculating the overall uncertainty of 4D1, only the relevant emissions from organic soils were considered (Meteotest 2018).

- Organic soils: The uncertainty of the carbon stock change (emission factor) in organic soils is 72.2% calculated on the basis of measurement data compiled by ART (2011b). The uncertainty of the activity data (area of organic soil) is 61.9% (see chp. 6.3.3).

For calculating the overall uncertainty of 4D2, the relevant emissions from living biomass, mineral soils and organic soils were considered (Meteotest 2018).

- Living biomass: The relative uncertainty in yield determination was 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) were based on many agricultural field experiments and have a high reliability. The absolute uncertainty per hectare, calculated with the implied emission factors of 2016, is 0.107 t C ha^{-1} yr^{-1} for 4D2.
- Mineral soils: Based on expert judgement, a value of 50% was chosen for the emission factor uncertainty in 4D2. The absolute uncertainty per hectare, calculated with the implied emission factor of 2016, is 0.399 t C ha^{-1} yr^{-1} for 4D2.
- Organic soils: The uncertainty of the carbon stock change (emission factor) in organic soils is 72.2% calculated on the basis of measurement data compiled in ART (2011b) and the uncertainty of the activity data (area of organic soil) is 61.9% (see chp. 6.3.3), resulting in a combined uncertainty of 95.1%. Thus, the absolute uncertainties of the total organic soil emissions in 2016 are 0.781 kt C for 4D2. By dividing this uncertainty with the total area of 4D2, the absolute uncertainty per hectare results in 0.212 t C ha^{-1} yr^{-1} for 4D2.

The root sum squares of the above-mentioned three absolute uncertainties is 0.464 t C ha^{-1} yr^{-1} for 4D2. This absolute uncertainty was used to calculate the relative emission factor uncertainty for 4D2 by dividing with the mean net carbon stock change per hectare of 4D2. In 2016, the mean net carbon stock change was -1.925 t C ha^{-1} for 4D2 (calculated from CRF Table4.D). The resulting relative uncertainties is 24.1% for 4D2 (see Table 6-5).

In the same way the uncertainties for the year 1990 were calculated. They are 72.2% (4D1) and 25.6% (4D2) (Table 6-5).

The emission factor uncertainty for CH_4 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 CH_4 emission factor of 4(II)D2 (Table 6-5). The activity data uncertainty of flooded lands was set to 10% based on an expert judgment considering the methods used by Hiller et al. (2014) for estimating the area of reservoirs/flooded land.

For N_2O emissions from drainage of organic soils (category 4(II)), the emission factor uncertainty for shallow-drained, nutrient-rich grassland given in the Wetlands Supplement Guidelines (IPCC 2014a, Table 2.5) was used. It was calculated as arithmetic mean of the lower and upper bound uncertainty (66.9%) (see also chp. 5.5.3). The respecitve activity data uncertainty is 34.1% (Meteotest 2018); it was calculated by combining the uncertainties of the area of organic soils (see chp. 6.3.3) for forest land (27.4%) and for wetlands (61.9%).

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

Activitiy data 1990–2015 were updated (see chp. 6.3.5).

In response to UNFCCC (2018, ID#KL.2) the assumption that 50% of the difference between the soil carbon stocks before and after the change was reported as a source or sink, respectively, for conversions from CC51 (buildings and constructions) to other land-use categories, was revised. Instead, the regular stock-difference approach was applied for land-use changes from CC51 to other land-use categories as described in chp. 6.1.3.2. This led to higher gains in soil carbon stocks on areas converted from CC51 to CC41 (in the case of organic soil) and CC42 in comparison to the last submission. Because both CC51 and CC41 do not have carbon stocks in mineral soils, calculation results of land-use changes from CC51 to CC41 in this pool were actually not modified by the methodological revision.

6.7.6 Category-specific planned improvements

Price et al. (2017) created a nationwide model for tree biomass in Switzerland (both inside and outside of forest), using structural information available from airborne laser scanning. The model offers significant opportunity for improved estimates of carbon stocks in living biomass on land use combination categories where tree biomass has either not been included or only roughly estimated until now. The suitability of the obtained data for reporting in category 4D is subject to evaluation.

6.8 Category 4E – Settlements

6.8.1 Description

Table 6-31 Key categories in category 4E. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
4E2	Land converted to settlements	CO2	L1, L2

Carbon stocks in living biomass and carbon stocks in mineral and organic soils were considered.

Settlements were subdivided into buildings/constructions (CC51), herbaceous biomass in settlements (CC52), shrubs in settlements (CC53), and trees in settlements (CC54) (see Table 6-2 and Table 6-6).

GHG emissions by biomass burning in settlements (category 4(V)E) do not occur.

6.8.2 Methodological issues

6.8.2.1 Carbon in living biomass

Buildings and constructions (CC51)

By default, buildings/constructions have no carbon stocks.

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 in organic soils for CC51 (buildings and constructions) were assumed to be zero.

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

Applying a Tier 1 approach, changes in carbon stocks in biomass, in dead organic matter, and in mineral soils were assumed to be in equilibrium 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 and Paul 2018).
- 5.30 t C ha^{-1} yr^{-1} for CC53 and CC54. This corresponds to the value used for extensively managed grasslands (ART 2011b; Paul 2018).

Land-use changes concerning CC51

In case of land-use changes from non-CC51 to CC51 on mineral or on organic soils a loss of 20% of the initial carbon stock was reported following IPCC 2006 (Volume 4, chp. 8.3.3.2). The reason for this is that 20% the soil organic matter is assumed to be lost as a result of disturbance, removal or relocation on these areas being sealed. This assumption is supported by paragraph 7 of the federal "Ordinance against deterioration of soils" (Swiss Confederation 1998) stating that 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 CC51.

Thus, equation 6.8 presented in chp. 6.1.3.2 was adjusted as follows if a=CC51:

$$deltaC_{s,i,b51} = [\ 0.2 * (0 - stockC_{s,i,b}\ ) / CT\ ] * A_{i,b51}$$

where:

$stockC_{s,i,b}$	carbon stock in soil (t C ha^{-1})
b	land-use category before conversion (CC = b ≠ 51)
b51	land use conversion from b to CC51
i	spatial stratum
$A_{i,b51}$	area of land (ha) converted from b to CC51 in the spatial stratum i (the sum of the areas converted within the last 20 years)
CT	conversion time (20 years; see Table 6-3).

In case of land-use changes from CC51 to non-CC51 categories, the regular stock-difference approach and gain-loss approach, respectively, according to chp. 6.1.3.2 and Table 6-3 was applied.

Land-use changes concerning CC52, CC53, and CC54

In the case of land-use change from or to CC52, CC53, and CC54, the net carbon changes in biomass and soil of CC52, CC53, and CC54 were calculated as described in chp. 6.1.3.2.

6.8.2.4 N_2O emissions from settlements

N_2O emissions associated with inputs from N in Settlements (category 4(I)E) were included in the Agriculture sector (category 3Da7 Other “Domestic use of inorganic fertilizers”; see chp. 5.5).

The calculation of emissons for categories 4(III) and 4(IV) (direct N_2O emissions from nitrogen mineralization in mineral soils and indirect N_2O 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 category 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

Activitiy data 1990–2015 were updated (see chp. 6.3.5)

In response to UNFCCC (2018, ID#KL.2) the assumption that 50% of the difference between the soil carbon stocks before and after the change was reported as a source or sink, respectively, for conversions from CC51 (buildings and constructions) to other land-use categories and for conversions from other land-use categories to CC51, was revised. Instead, the following approaches were used:

- A loss of 20% in soil carbon stocks was assumed on areas sealed (i.e. following a conversion from other land-use categories to CC51) according to the guidelines (IPCC 2006 Volume 4, chp. 8.3.3.2; see chp. 6.8.2.3). This led to lower losses in soil carbon stocks on areas converted to CC51 in comparison to the last submission.
- The regular stock-difference approach was applied for land-use changes from CC51 to other land-use categories as described in chp. 6.1.3.2.

6.8.6 Category-specific planned improvements

Price et al. (2017) created a nationwide model for tree biomass in Switzerland (both inside and outside of forest), using structural information available from airborne laser scanning. The model offers significant opportunity for improved estimates of carbon stocks in living biomass on land use combination categories where tree biomass has either not been included or only roughly estimated until now. The suitability of the obtained data for reporting in category 4E is subject to evaluation.

6.9 Category 4F – Other land

6.9.1 Description

Category 4F – Other land is not a key category.

As shown in Table 6-2 and in Table 6-6 Other land (CC61) covers unmanaged, non-vegetated areas such as glaciers, rocks and shores.

6.9.2 Methodological issues

By definition, Other land has no carbon stocks. Coherently, changes in carbon stock in biomass, in dead organic matter, and in soils were assumed to be zero for Other land remaining other land.

In the case of land converted to other land, the net carbon changes in biomass and soil were calculated as described in chp. 6.1.3.

The calculation of emissons on land converted to other land for categories 4(III) and 4(IV) (direct N_2O emissions from nitrogen mineralization in mineral soils and indirect N_2O 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 subcategory 4F2 (Table 6-5).

Uncertainties of activity data of category 4F Other Land are described in chp. 6.3.3.

Consistency: Time series for category 4F 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

Activitiy data 1990–2015 were updated (see chp. 6.3.5).

In response to UNFCCC (2018, ID#KL.2) the assumption that 50% of the difference between the soil carbon stocks before and after the change was reported as a source or sink, respectively, for conversions from CC51 (buildings and constructions) to other land-use categories, was revised. Instead, the regular stock-difference approach was applied for land-use changes from CC51 to other land-use categories as described in chp. 6.1.3.2. Because both CC51 and CC61 do not have carbon stocks in soils, calculation results of land-use changes from CC51 to CC61 were actually not modified by the methodological revision.

6.9.6 Category-specific planned improvements

No category-specific improvements are planned.

6.10 Categories 4(III) and 4(IV) – N_2O emissions

6.10.1 Description

Table 6-32 Key categories in categories 4(III) and 4(IV). Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
4III	Direct N2O from disturbance	N2O	L2

This chapter presents the methods for calculating direct (category 4(III)) and indirect (category 4(IV)) N_2O emissions from nitrogen (N) mineralization in mineral soils. The source of nitrogen is N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils. As the approaches applied were not Tier 3, no N_2O immobilization is reported.

- In category 4(III), direct N_2O emissions from nitrogen mineralization associated with loss of soil organic matter are reported.
- In category 4(IV)2, indirect emissions of N_2O due to nitrogen leaching and run-off after mineralization of soil organic matter are reported.

The following N_2O emissions were included in the Agriculture sector:

- Direct N_2O emissions on Cropland remaining cropland (no category registered in CRF Table4(III); see chp. 5.5) and on Grassland remaining grassland (category 4(III)C1; see chp. 5.5). In Switzerland, grassland is considered to be under agricultural management.
- Indirect N_2O emissions due to atmospheric deposition (category 4(IV)1; all land uses) and leaching and run-off on agricultural land (category 4(IV)2; Cropland remaining cropland and Grassland remaining grassland) (see chp. 5.3).

6.10.2 Methodological issues

Direct N_2O emissions

Direct N_2O emissions (category 4(III)) as a result of the disturbance of mineral soils associated with change of land use or management of mineral soils were calculated according to IPCC (2006, vol. 4, chp. 11):

$$\text{Emission}(N_2O) = -\text{deltaCs} * 1 / (C{:}N) * EF1 * 44/28, \text{ if deltaCs} < 0 \qquad [kt\ N_2O]$$

where:

- deltaCs: soil carbon change induced by land-use change [kt C]
- C:N: C to N ratio of the soil before the land-use change
- EF1: default emission factor = 0.01 kg N_2O-N $(kg\ N)^{-1}$, IPCC 2006 (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 N_2O emissions provoked by the specific 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 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, Volume 4, equation 11.8).

Indirect N_2O emissions

The indirect N_2O emissions (category 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, Volume 4, Table 11.3):

Emission(N_2O) = – deltaCs * $Frac_{LEACH}$ / (C:N) * EF5 * 44/28, if deltaCs <0 [kt N_2O]

where:

- $Frac_{LEACH}$: fraction of mineralized N lost by leaching or run-off, see Table 6-33.
- C:N ratio as above for direct N_2O emissions
- EF5: default emission factor = 0.0075 kg N_2O-N (kg N)$^{-1}$, IPCC 2006 (Volume 4, Table 11.3)

If deltaCs is zero or positive (carbon gain) there are no N_2O emissions provoked by the specific land-use change.

For calculating deltaCs, all land-use changes and conversions between land-use subcategories were taken into account.

On productive forest land (CC12), small annual changes in carbon contents of mineral soils are reported that were calculated with the Yasso07 model (chp. 6.4.2.7). These changes were deliberately not considered for the calculation of N_2O emissions in categories 4(III) and 4(IV) as they are not associated with a land-use change or any change in management.

Table 6-33 Fractions of mineralized N lost by leaching or run-off ($Frac_{LEACH}$), see also chp. 5.5.2.4.2.

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
$Frac_{LEACH}$	--	0.206	0.206	0.206	0.206	0.206	0.206	0.204	0.202	0.201	0.199

	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
$Frac_{LEACH}$	--	0.197	0.195	0.193	0.191	0.189	0.188	0.186	0.184	0.182	0.180

	Unit	2010	2011	2012	2013	2014	2015	2016
$Frac_{LEACH}$	--	0.178	0.178	0.178	0.178	0.178	0.178	0.178

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 (Table 6-5):

- Uncertainty 4(III) (EF1): 135.0%
- Uncertainty 4(IV) (EF5): 161.5%

The uncertainty of the activity data for category 4(III) corresponds to the uncertainty of the amount of mineralized N. It was calculated as the combined uncertainty of:

- Uncertainty of the carbon stock losses in mineral soils: Land converted to settlements (4E2) is the main source in category 4(III). Therefore, the uncertainty of the area converted to settlements (4.6%; Table 6-5) and the uncertainty of the CO_2 emission factor (50.0%) were combined to estimate the uncertainty of the carbon stock loss: 50.2%.
- Uncertaintiy of the C:N ratio: The dominant process in category 4(III) is the change from Forest land to other land-use categories. Therefore, the uncertainty of the C:N ratio for Forest land is used here. With a value of 15 and a 95%-range between 10 and 30 (IPCC 2006, Volume 4, equation 11.8) the mean uncertainty results in 66.7%.

The resulting uncertainty for AD of category 4(III) is 83.5%, calculated as $(50.2^2+66.7^2)^{0.5}$.

The uncertainty of the activity data for category 4(IV)2 is 85.8%. It is the combined uncertainty of the amount of leached N, which is calculated from the amount of mineralized N (uncertainty 83.5%, see category 4(III)) and $Frac_{LEACH}$ (uncertainty 20%, adopted from ART 2008a).

Consistency: Time series for categories 4(III) and 4(IV) N_2O 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

Activitiy data 1990–2015 were updated (see chp. 6.3.5).

The values for $Frac_{LEACH}$ 1990–2015 were updated. Annual values were adopted from the agriculture sector (chp. 5.5.2.4.2). They are in the range 0.178–0.206 (see Table 6-33). In previous submissions a constant value (0.218) had been used.

The amount of mineralized N in category 4(III) was affected by the methodic changes for calculating carbon stock changes in soils on sealed areas (see chp. 6.8.5).

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

Table 6-34 Key categories in category 4G. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
4G	HWP Harvested wood products	CO2 biog.	L1, T1, L2, T2

The data presented in this chapter are estimates of net emissions (outflow) and removals (inflow) from HWP due to annual changes in the HWP carbon pool.

The approach to calculate carbon stock changes in HWP can 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. The estimate covers all wood products originating from trees harvested in Switzerland (sawnwood, wood based panels and paper and paperboard) and that are produced in Switzerland and that are used for material (i.e. not for energetic) purposes.

The Harvested wood products pool also includes products made from domestic harvest that were exported and are 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 Kyoto Protocol for HWPs in Switzerland consistent with paragraph 29 in the Annex to Decision 2/CMP.7, which states 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”. 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).

For the estimation of carbon stocks and carbon stock change, the equations described in IPCC (2014: chpt. 2.8) were used. A Tier 2 approach, first order decay, was applied for the product categories sawnwood, wood based panels,and paper and paperboard 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.
- Emissons from the HWP pool accounted for in the first commitment period on the basis of instantaneous oxidation were excluded from the accounting for the second commitment period (FOEN 2016j).
- Emissons from HWP in solid waste disposals and from wood harvested from energy purposes were accounted on the basis of instantaneous oxidation (FOEN 2018h).
- Exported HWP were included in the calculation (notation key “IE” in CRF 4(KP-I)C).
- The feedstock from domestic harvest was calculated according to equation 2.8.1 in IPCC (2014). Exported round wood was not included in the calculation of HWP.
- Based on the available datasets it was not possible to differentiate between HWP from Afforestation and HWP from Forest management. Since Afforestation in Switzerland typically serves purposes other than timber production such as recreation, ground water protection, noise control, improvement of microclimate and air quality, biomass is not removed to enter the HWP pool. In case there is some wood of first thinings in Afforestations since 1990, it is a neglible amount which is mostly left on the site or sometimes collected for energy purposes. Therefore, the amount of HWP from Afforestation was reported as not occurring (“NO”) and all carbon stock changes in HWPs were reported under Forest management.
- The change in carbon stocks of HWPs was estimated separately for each product category and differentiating HWPs from Deforestation and from Forest management including HWP from Afforestations by applying equation 2.8.4 in IPCC (2014). Applying instantaneous oxidation to HWPs originating from Deforestation, the same results were obtained for changes in carbon stocks of HWP reported under the UNFCCC (CRF Table4.Gs1) and under the Kyoto Protocol (CRF 4(KP-I)C).

6.11.2.1 Activity data

The time series are shown in the CRF Table4.Gs2. The activity data are described in detail in FOEN (2018h):

- Data for the product categories sawnwood and wood panels are retrieved from FAOSTAT (2017; data before 1990) and national statistics (FOEN 2017d; from 1990 onwards).
- Data for the product category paper and paperboard were based on FAOSTAT (2017; Forestry Production and Trade).
- 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.

In order to estimate carbon amounts in each HWP category and subcategory, 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, 35 years for sawnwood and 2 years for paper products (IPCC 2014; equation 2.8.5).

6.11.2.3 Results

Emissions and removals per product category are listed in Table 6-35. Figure 6-10 shows the resulting CO_2 emissions and removals.

Table 6-35 CO_2 emissions and removals from Harvested wood products (HWP) derived from sawnwood ($changeC_{HWP\text{-}sawnwood}$), panels ($changeC_{HWP\text{-}panels}$) and paper and paperboard ($changeC_{HWP\text{-}paper\ and\ paperboard}$), originating from Forest management, in kt CO_2 yr^{-1} (positive values refer to emissions, negative values refer to removals). HWPs originating from Deforestation were calculated using instantaneous oxidation; there are no HWPs from Afforestation (see main text).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt CO_2									
HWP	-1'304.8	-823.0	-530.6	-475.6	-363.1	-504.0	-286.3	-255.3	-251.1	-403.8
$changeC_{HWP\text{-}sawnwood}$	-738.3	-466.6	-275.7	-184.7	-121.6	-298.1	-174.1	-123.6	-213.6	-272.4
$changeC_{HWP\text{-}panels}$	-465.7	-376.3	-400.7	-370.5	-294.5	-237.1	-194.0	-165.9	-181.3	-166.0
$changeC_{HWP\text{-}paper\ and\ paperboard}$	-100.8	19.9	145.8	79.6	53.0	31.2	81.8	34.2	143.8	34.5

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt CO_2									
HWP	-709.3	-542.8	-408.0	-440.5	-606.3	-740.0	-543.8	-517.0	-385.9	-410.1
$changeC_{HWP\text{-}sawnwood}$	-408.6	-146.5	-79.0	-86.4	-255.5	-344.8	-335.0	-125.0	-230.2	-192.7
$changeC_{HWP\text{-}panels}$	-387.5	-306.2	-241.2	-272.3	-347.6	-418.0	-291.5	-254.8	-278.3	-301.5
$changeC_{HWP\text{-}paper\ and\ paperboard}$	86.8	-90.1	-87.8	-81.9	-3.2	22.8	82.7	-137.2	122.6	84.1

	2010	2011	2012	2013	2014	2015	2016
	kt CO_2						
HWP	-415.1	-458.8	-293.9	-89.7	-300.5	-227.3	-213.5
$changeC_{HWP\text{-}sawnwood}$	-175.8	-77.4	34.4	130.2	23.0	-0.5	3.6
$changeC_{HWP\text{-}panels}$	-332.2	-297.5	-188.3	-123.9	-146.8	-126.6	-110.2
$changeC_{HWP\text{-}paper\ and\ paperboard}$	92.8	-83.9	-140.1	-96.0	-176.7	-100.2	-106.9

Fluctuations in the HWP pool are mainly caused by changes in the production of sawnwood and paper and paperboard (see Table 6-35). The production of sawnwood strongly correlates with the domestic harvesting rate. The contribution of paper and paperboard to changes in HWP fluctuates over the years. Because of the strong reduction in the production of sawnwood over the last 5 years, the relative contribution of paper and paperboard to the HWP pool considerably increased.

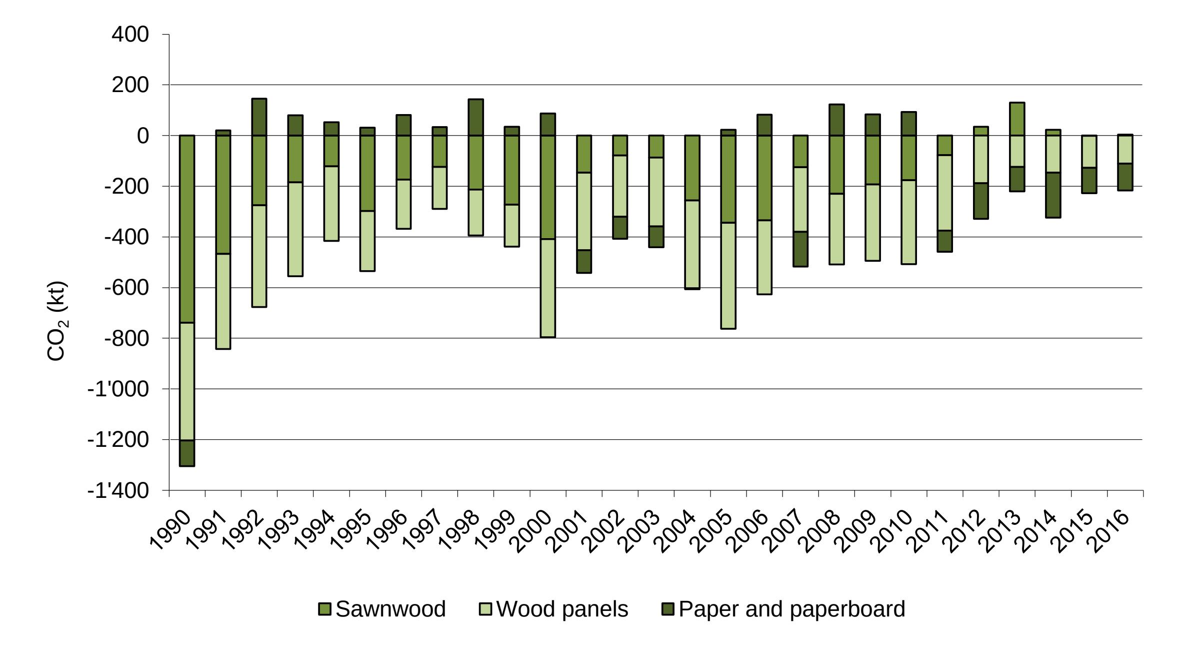


Figure 6-10 CO_2 emissions and removals from category 4G Harvested wood products originating from Forest management (KP) (in kt CO_2; positive values refer to emissions, negative values refer to removals).

6.11.3 Uncertainties and time-series consistency

For category 4G HWP, the following information on relative uncertainty was used:

Activity data: A mean AD uncertainty of 4.5% (Table 6-5) was estimated based on the following sources:

- Roundwood harvest: 5% (national activity data from the Swiss Forestry Statistics, annual complete survey)
- 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 2017d)
- 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 2017d)
- Paper and Paperboard: 5% (activity data from FAOSTAT 2017).

Conversion factors:

- Wood density: 25% (default from IPCC 2006, Volume 4, Table 12.6)
- Carbon contents in wood products: 10% (Lamlom and Savidge 2003, assessment of carbon content in wood); IPCC 2006, Volume 4, Table 12.6)
- Emission factors (half-life estimates): 50% (default from IPCC 2006, Volume 4, Table 12.6).

The relative uncertainty of the emission factors for HWP amounts to 57% (Table 6-5):

$$U_{HWP}EF = \sqrt{25^2 + 10^2 + 50^2} = 57\%$$

The overall relative uncertainty of carbon losses and gains in HWP was thus calculated as:

$$U_{HWP}Sawnwood = \sqrt{5^2 + 5^2 + 25^2 + 10^2 + 50^2} = 57\%$$

$$U_{HWP}Panels = \sqrt{5^2 + 4^2 + 25^2 + 10^2 + 50^2} = 57\%$$

$$U_{HWP}Paper = \sqrt{5^2 + 5^2 + 25^2 + 10^2 + 50^2} = 57\%$$

Consistency: Time series for category 4G Harvested wood products are all considered consistent; they were calculated based on consistent methods and homogenous databases (FOEN 2018h).

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 were carried out.

6.11.5 Category-specific recalculations

The activity data were updated for the whole time series according to the most recent data in the FAOSTAT database (FAOSTAT 2017).

In response to UNFCCC (2018, ID#KL.7) the contribution of paper and paperboard to the HWP pool was calculated using data from the FAOSTAT database and applying the first order decay function (see Table 10-1).

6.11.6 Category-specific planned improvements

For the calculation of paper and paperboard there are still some methodological challenges, such as how to determine the amount of domestic pulp wood contained in recycled products (see UNFCCC 2018, ID#KL.7). Therefore, a study will be carried out to obtain additional national activity data on paper and paperboard to improve the calculation of the contribution of this pool.

7 Waste

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 direct GHG emissions, but indirect GHG emissions reported in chp. 9)

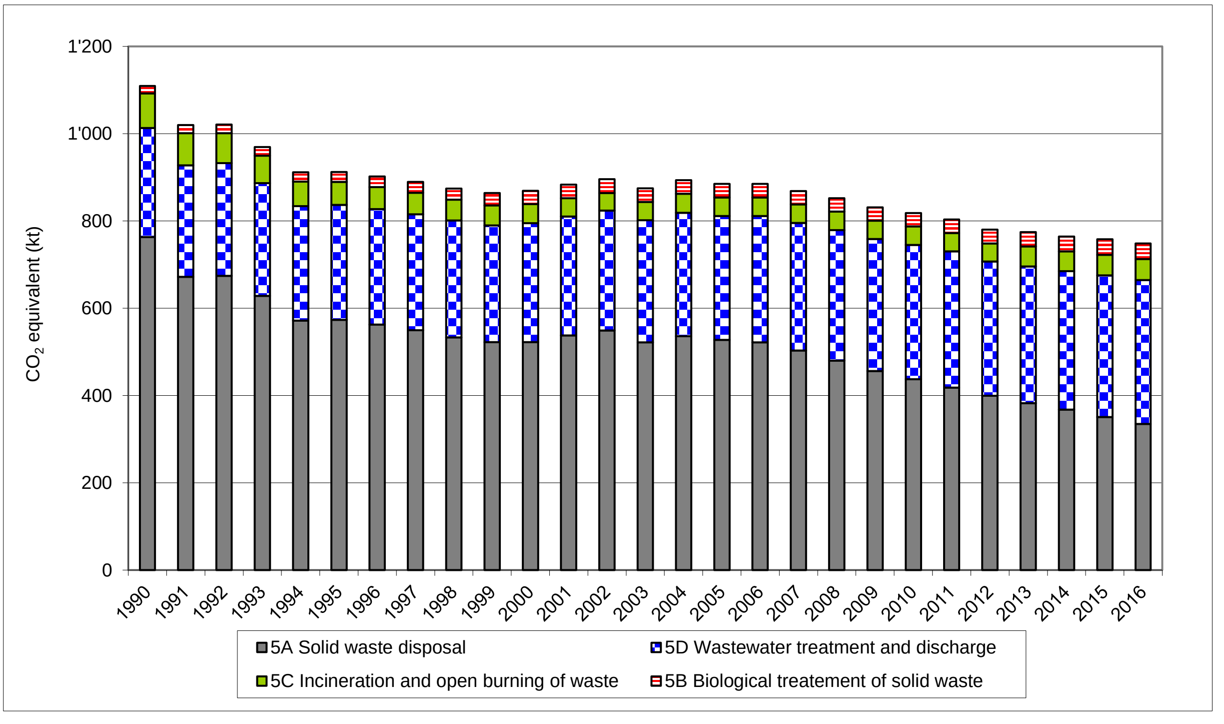


Figure 7-1 Switzerland's greenhouse gas emissions from sector 5 Waste. There are no direct greenhouse gas emissions from sector 5 E Other.

The total greenhouse gas emissions from sector 5 Waste show a decrease within the reporting period. 5A Solid waste disposal and 5D Wastewater treatment and discharge are the two dominant source categories. The former shows decreasing emissions, while the latter shows an increase in greenhouse gas emissions.

Table 7-1 Trend of total GHG emissions from sector 5 Waste in Switzerland.

Gas	1990	1995	2000	2005
	CO_2 equivalent (kt)			
CO_2	54	30	19	12
CH_4	915	738	697	710
N_2O	141	144	153	163
Sum	1109	912	869	885

Gas	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	CO_2 equivalent (kt)									
CO_2	12	12	11	11	11	10	10	10	10	10
CH_4	689	668	646	630	612	596	582	572	559	547
N_2O	168	172	174	177	181	174	182	182	189	192
Sum	869	852	831	818	803	780	774	764	758	748

CH_4 is the most important greenhouse gas in sector 5 Waste over the whole reporting period. Nevertheless, CH_4 emissions have decreased. Two processes determine the trend in sector 5 Waste: a decreasing trend from 5A Solid waste disposal and an increasing trend from 5D Wastewater treatment and discharge.

The relative trends of the gases are shown in Figure 7-2.

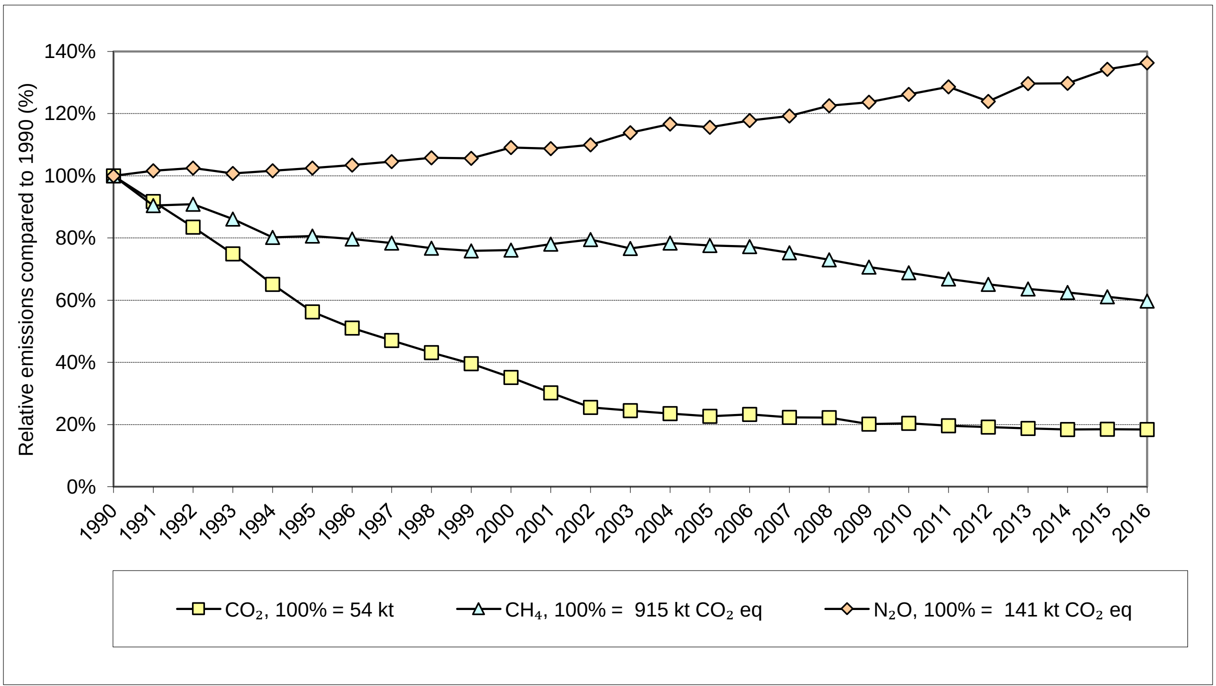


Figure 7-2 Relative trends of greenhouse gas emissions of sector 5 Waste. The base year 1990 represents 100%.

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).

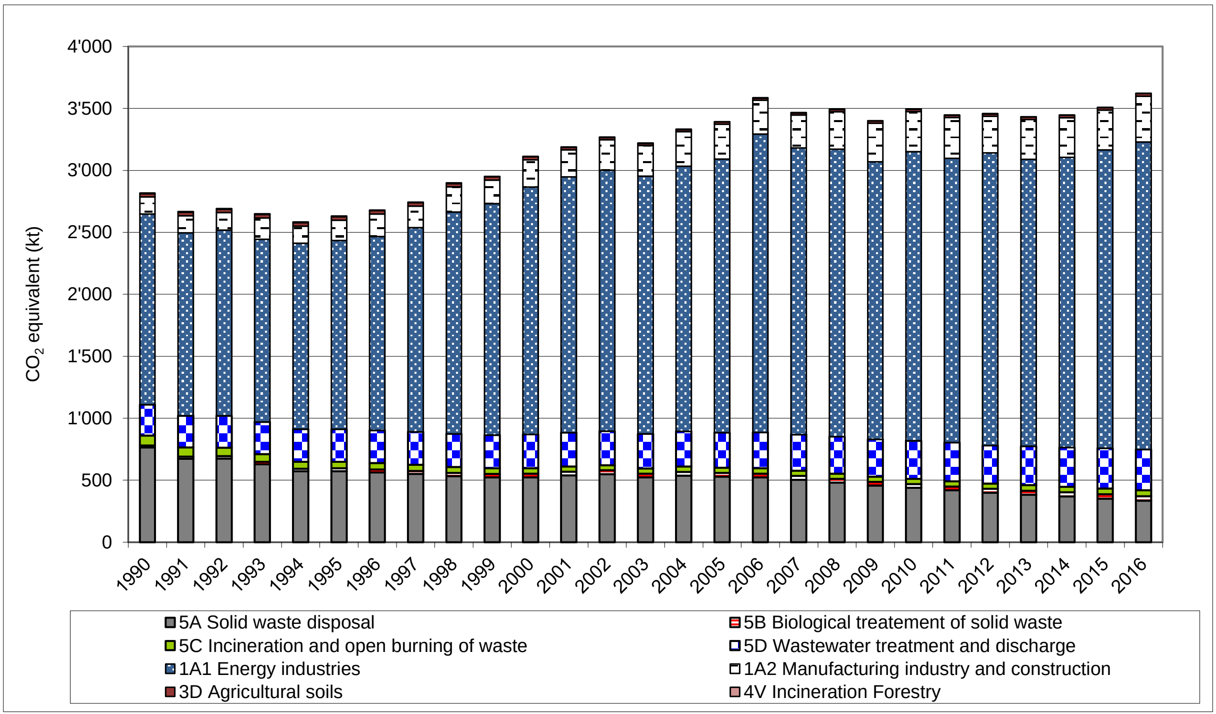


Figure 7-3 Total waste-related GHG emissions, reported in different sectors.

7.1.2 Overview of waste management in Switzerland

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 waste imports and waste exports. Only waste fractions that are relevant for emissions 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 (1A1a). MSWIP treat burnable municipal solid waste as well as sewage sludge, burnable construction waste and some special wastes. Cement industry uses conventional fossil fuels but also alternative fuels, which are special waste, dried sewage sludge, biomass as well as plastics collected separately or segregated from solid waste streams (1A2fi). 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 and 1A4ci.
- **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 relevant for emissions (N_2O emissions as described in chp. 5.5.2.2, Table 5-22).
- **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 mandatory for disposal of 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 private households as well as cremations. Special waste incineration without energy recovery, such as cable incineration or hospital waste incineration plants, no longer takes place in Switzerland and is thus crossed out in the figure. These waste fractions are nowadays incinerated in MSWIP and are therefore reported under sector 1 Energy. Emissions related to wastewater treatment are reported under 5D.

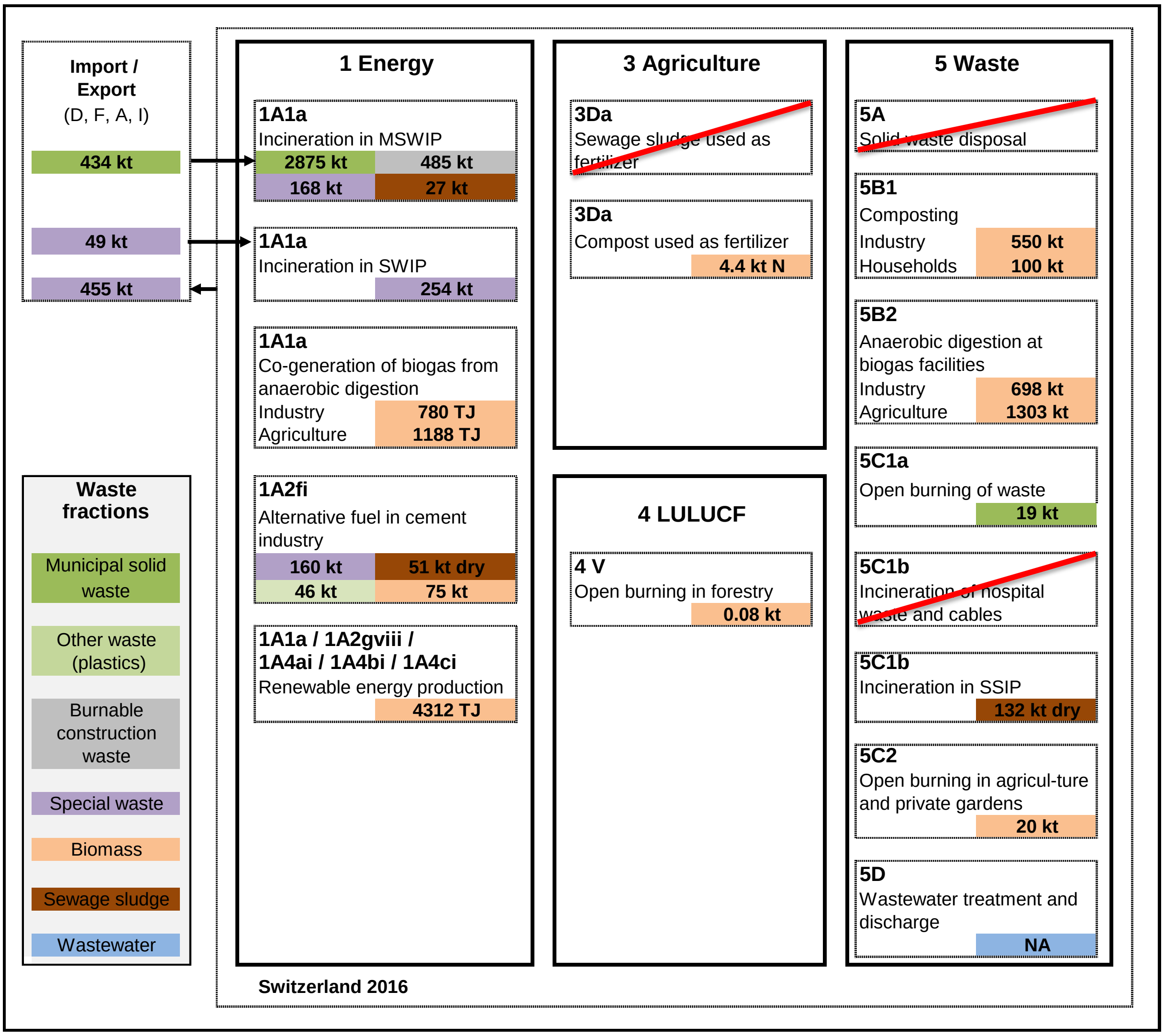


Figure 7-4 Overview on the type of treatment and amounts of waste treated in the respective sectors in Switzerland in 2016. Abbreviations: MSWIP: Municipal Solid Waste Incineration Plant, SWIP: Special Waste Incineration Plant, SSIP: Sewage Sludge Incineration Plant, D: Germany, F: France, A: Austria, I: Italy.

Regarding the treatment and amounts of relevant waste types the following details can be provided (state in 2016, recycled amounts are not shown in Figure 7-4 because they are not relevant for emissions):

- **Municipal solid waste:** In Switzerland more than 50% of the municipal solid waste is collected separately and recycled (FOEN 2017i). 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 50% 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. A minor amount of combustible construction waste is incinerated in MSWIP. The remaining, inert

construction waste is disposed of in landfills for inert waste (ERM 2016; Wüest & Partner 2015).

- **Special waste:** Special waste refers to a highly diverse waste fraction encompassing hospital wastes, batteries, electronic waste, hazardous industrial sludge, contaminated soils, solvents, chemicals etc. Special waste is either recycled, biologically treated, landfilled, burnt or exported for landfilling in foreign countries (FOEN 2017i). Only the amount of incinerated special waste is relevant for emissions (EMIS 2018/1A1a Kehrichtverbrennungsanlagen and EMIS 2018/1A1a Sondermüllverbrennungsanlagen). Some special waste is also used as an alternative fuel in the cement production (EMIS 2018/1A2f 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). Dried sewage sludge is also used as an alternative fuel in the cement industry (EMIS 2018/1A2fi 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 2018/5C2 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 2018/1A2fi Zementwerke Feuerung). Compost is used as a fertilizer (see Table 5-22 “Other organic fertilisers”).

7.2 Source category 5A – Solid waste disposal

7.2.1 Source category description

Table 7-2 Key categories of 5A Solid waste disposal. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
5A	Solid waste disposal	CH4	L1, T1, L2, T2

Source category 5A1 Managed waste disposal sites comprises all emissions from managed solid waste landfill sites. As incineration is mandatory for combustible waste since 2000, inputs into managed solid waste landfill sites have dropped to zero. Remaining 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, three managed biogenic active landfill sites were equipped to recover landfill gas in 2016 (SFOE 2017a). 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 7-3 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 2 method based on the decision tree in the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 3, Fig. 3.1). The spreadsheet for the First Order Decay (FOD) model provided by IPCC (2006) has been applied and parametrised for Swiss conditions (FOEN 2017g).

The values for the parameter degradable organic carbon (DOC) are provided for each waste fraction (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, as most of the industrial waste deposited in Switzerland is assumed to be wood waste.

Table 7-4 Degradable organic carbon (DOC) values for fractions of different waste compositions (weight fraction, wet basis).

Waste composition	IPCC default value		Country-specific parameters	
(weight fraction, wet basis)	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 7-5). 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 7-5 Methane generation rate [1/yr] according to waste by composition for wet temperature conditions.

Waste composition	**IPCC default value**		**Country-specific parameters**	
(weight fraction, wet basis)	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:

- DOCf (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 CH_4 = 1.33 (IPCC default value)
- Oxidation factor (OX) = 0.1

The oxidation factor OX has been set to 0.1 according to the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 3), since it is standard practice in Switzerland to cover the landfills, e.g. with soil.

For the methane correction factors (MCF) for the different solid waste disposal site types IPCC default values are used. Between 1990 and 2015 (the IPCC spreadsheet has to be parametrised from 1950 to 2030/2050) 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 deposited has changed during the last 60 years (see Table 7-6).

Table 7-6 Composition of MSW going to solid waste disposal sites (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 CH_4 generated in landfills is calculated. The amount of CH_4 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 CH_4 burnt (Table 7-7).

Emission factors (5A)

Emission factors for CO_2, CH_4, CO, NMVOC and SO_2 are country-specific based on measurements and expert estimates, as documented in EMIS 2018/1A1 & 5A Kehrichtdeponien. CO_2 emissions from non-biogenic waste are included, while CO_2 emissions from biogenic waste are excluded from total emissions. Table 7-7 presents the emission factors used in 5A1.

Table 7-7 Emission factors for 5A1 Managed waste disposal sites in 2016.

5A1 Managed waste disposal sites	Unit	CO_2 biogen	CO_2 fossil	CH_4	NO_x	CO	NMVOC	SO_2
Direct emissions from landfill	t / t CH_4 produced	3.0	NA	1.0	NA	NA	NA	NA
Flaring	kg / t CH_4 burned	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 CH_4 emissions and CH_4 flared.

For the calculation of these three kinds of activity data the amounts of MSW, IW and SS deposited on SWDS are relevant.

Table 7-8 Activity data in 5A1: Waste disposed on managed waste disposal sites (documented in EMIS 2018/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1950	1960	1970	1980	1990	1995	2000	2005
Municipal solid waste (MSW)	kt	570.2	675.4	864.0	532.4	650.0	540.0	291.7	13.7
Construction waste (CW)	kt	9.9	10.5	36.0	84.8	150.0	60.0	53.9	1.4
Sewage sludge (SS)	kt (dry)	NO	NO	3.2	29.6	60.0	28.1	4.2	1.0
Open burned waste	kt	298.9	293.9	225.8	96.7	NO	NO	NO	NO
Total waste quantity	kt	879.0	979.8	1129.0	743.5	860.0	628.1	349.7	16.1

5A1 Managed waste disposal sites	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Municipal solid waste (MSW)	kt	1.5	1.2	NO	NO	NO	NO	NO	NO	NO	NO
Construction waste (CW)	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge (SS)	kt (dry)	NO	NO	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	1.5	1.2	NO	NO	NO	NO	NO	NO	NO	NO

Table 7-8 documents the amounts of municipal solid waste, construction waste and sewage sludge disposed of on managed waste disposal sites since 1950 (as documented in EMIS 2018/1A1a & 5A Kehrichtdeponien). An increase of waste landfilled until 1970 can be observed. The decline of waste amounts landfilled afterwards is due to changes in the legislative framework, making incineration mandatory for disposal of combustible waste and banning the disposal of combustible waste 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. By reason of legal requirements and regulations it is assumed that open burning did not take place after 1990 anymore (Consaba 2016) and is therefore NO in Table 7-8.

With these primary activity data total CH_4 emissions generated are calculated using the spreadsheet FOD model provided by IPCC (2006). For the calculation of direct CH_4 emissions, CH_4 flared and used in co-generation units is determined and subtracted from total CH_4 emissions (Table 7-9). 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 Table5.A.

The amount of CH_4 used in co-generation stems from the Swiss statistics of renewable energies (SFOE 2017a). The amount of landfill gas flared has been assessed in a separate investigation (Consaba 2016). The CH_4 flared has been estimated as follows:

1. A list of all managed SWDS that are still operated or have been closed since 1990 was compiled.
2. Their technical equipment was assessed and deduced (motors, torches, gas drainage, etc.).
3. Four types of managed landfill sites according to their equipment and CH_4 management were distinguished:
    a) landfills with gas recovery in combined heat and power generation, boiler and torch
    b) landfills with gas recovery or thermal treatment (boiler, torch, non-catalytic oxidation, flameless oxidation)
    c) landfill gas recovery without methane elimination (biofilter, aerobiosation)
    d) landfills without gas treatment (direct release)

4. A survey was conducted in 14 managed SWDS and data on their operation mode has been collected.
5. With these data the amounts flared in SWDS category a) and b) were estimated.
6. The amount flared on all managed SWDS has been extrapolated considering the waste amounts deposited.
7. A time series for the amount of methane torched relative to the total amount of CH_4 estimated with the Swiss FOD IPCC 2006 model (managed and unmanaged sites) has been calculated.

The amount flared is expressed as a percentage of CH_4 produced in all SWDS in Switzerland. The percentage flared varies between 5 and 15% since 1990.

Table 7-9 Activity data in 5A1: Direct CH_4 emissions, CH_4 flared and CH_4 used in combined heat and power (CHP) units (as documented in EMIS 2018/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1990	1995	2000	2005
CH_4 direct emissions	kt	30.5	22.9	20.9	21.1
CH_4 flared	kt	1.8	5.2	5.6	3.4
CH_4 used in co-generation units (reported under 1A1a)	kt	4.9	12.1	11.3	4.1

5A1 Managed waste disposal sites	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CH_4 direct emissions	kt	20.1	19.2	18.3	17.5	16.7	16.0	15.3	14.7	14.0	13.4
CH_4 flared	kt	2.9	2.6	2.4	2.4	2.1	1.8	1.6	1.4	1.4	1.4
CH_4 used in co-generation units (reported under 1A1a)	kt	2.1	1.8	1.5	1.0	0.9	0.9	0.8	0.6	0.4	0.2

The CH_4 generated in landfill sites decreased since 1990 because waste quantities disposed of in landfills have been decreasing. Together with the relative increase of CH_4 recovery from 1990 until 2016 this is the reason for CH_4 emissions from the source category 5A being a key source regarding trend.

7.2.3 Uncertainties and time-series consistency

Uncertainty in CH_4 and CO_2 emissions from 5A Solid waste disposal

For lack of a detailed uncertainty analysis with the new FOD model, a combined uncertainty of 30% is assumed for the CH_4 emissions (EMIS 2018/1A1a & 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 chp. 1.2.3.

7.2.5 Category-specific recalculations

No category-specific recalculations were carried out.

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

Source category 5B – Biological treatment of solid waste is not a key category.

Source category 5B Biological treatment of solid waste comprises the process-related GHG emissions from composting and from digesting of organic waste.

Within 5B1 Composting two kinds of composting are distinguished, i.e. industrial composting and backyard composting. Industrial composting covers the emissions from centralized composting activities with a capacity of more than 100 tonnes of organic matter per year as well as the composting of organic material at the border of agricultural fields. Backyard composting in private households or communities is also common practice in Switzerland and therefore considered.

In 5B2 Anaerobic digestion at biogas facilities emissions occur from gas leakages as well as from digested matter (solid leftovers after completion of anaerobic microbial degradation of organic matter) which 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 CH_4 losses from biogas facilities and emerging from biogas upgrading are included. Emissions related to the use of biogas for combined heat and power generation as well as emissions from biogas upgrading are reported in sector 1 Energy.

Table 7-10 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

7.3.2.1 Composting (5B1)

Methodology (5B1)

Emissions are calculated by a Tier 2 method based on the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 4.1.1 Biological treatment of solid waste).

Activity data and emission factors for industrial and backyard composting have been thoroughly reassessed in 2017 (Schleiss 2017). New data were gained and EMIS 2018/5B1

Kompostierung, which serves as basis for greenhouse gas emission estimates, has been revised accordingly.

Emission factors (5B1)

Emission factors used for source category 5B1 Composting are summarized in Table 7-11 and documented in detail in EMIS 2018/5B1 Kompostierung. Emission factors are country-specific and encompass CH_4, N_2O and NMVOC based on measured or estimated values reported in the literature.

Activity data (5B1)

Activity data for source category 5B1 Composting are shown in Table 7-12 and documented in detail in EMIS 2018/5B1 Kompostierung.

Activity data for industrial composting are based on waste surveys (Schleiss 2017). For 2013 reliable data on waste quantities are available (FOEN 2016m). All cantons were addressed and data on the amounts of organic waste quantities, according to their respective treatment option, have been collected. Data on waste quantities are also available from surveys in 1989, 1993 and 2000. Activity data between these years were interpolated. The time series were validated with further data sets from the years 2002 and 2010. After 1993 digesting of organic waste was also becoming a relevant treatment option and therefore respective amounts were subtracted. In addition, also waste wood quantities were subtracted, in order to get the amount of organic waste treated in industrial composting plants.

Activity data for backyard composting were reassessed in 2017 (Schleiss 2017). Basically, amounts of organic waste composted in backyards are based on expert assessments as well as on data from a small number of cities and villages. The experts took into account different parameters affecting the waste amounts composted in backyards over the time, i.e. urban, rural situation, communication and incentive programs, and separate door-to-door collection of organic wastes.

7.3.2.2 Anaerobic digestion at biogas facilities (5B2)

Methodology (5B2)

In source category 5B2 Anaerobic digestion at industrial and agricultural biogas facilities are considered. The produced biogas is used for combined heat and power generation or upgraded to natural gas quality. Accordingly, biogas upgrading is considered as a separate process in 5B2. However, emissions from the use of biogas as fuel for combined heat and power generation are reported under sector 1 Energy, in accordance with the 2006 IPCC Guidelines (IPCC 2006).

For the emissions from 5B2 Anaerobic digestion at biogas facilities, a Tier 2 method is used. While industrial and agricultural biogas facilities are separately considered, the same emission factors are used (see below). As mentioned above, emissions from biogas upgrading are estimated separately, based on the amount of biogas upgraded.

Emissions of greenhouse gases from industrial and agricultural biogas facilities are estimated to be a constant emission factor for each biogas facility. This is based on an evaluation of measurement data for methane losses that has shown that those losses are not dependent on the amount of substrate processed in a particular facility. Therefore, CH_4 emissions are calculated based on an emission factor per plant multiplied by the number of industrial and agricultural biogas facilities, respectively.

In contrast, emissions of air pollutants are calculated based on estimates from up to seven different process steps (such as pre-storage, primary and secondary digester, interim storage, maturing, handling of biogas etc.), as documented in EMIS 2018/1A1a & 5 B 2 Vergärung LW and EMIS 2018/1A1a & 5 B 2 Vergärung IG. However, as NMVOC and CO emissions from source category 5B are of biogenic origin, they are not considered for the calculation of indirect CO_2 emissions in chp. 9 Indirect CO_2 and N_2O emissions.

N_2O emissions from source category 5B2 are considered to be negligible according to the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 4.1.3), and are therefore set to zero.

Emission factors (5B2)

Table 7-11 presents the emission factors used in 5B2 Anaerobic digestion at biogas facilities. As documented in FOEN (2015n), the emission factor for CH_4 for anaerobic digestion at industrial and agricultural biogas facilities is based on investigations performed in the framework of the GHG emission compensation projects. Field measurements indicate that there is no correlation between the produced amount of biogas and the amount of biogas lost to the atmosphere. The investigated data show that on average each biogas facility loses 1.23 t CH_4 per year to the atmosphere. This value is used to estimate the emissions from industrial and agricultural biogas facilities in Switzerland.

The emission factor for losses of CH_4 from biogas upgrading is based on official regulations regarding maximal CH_4 leakage, as well as studies focussing on CH_4 emissions from biogas upgrading. Accordingly, regulations by the Swiss Gas and Water Association (SGWA 2016a) set an emission limit value (ELV) for CH_4 losses from biogas upgrading. In 1990, such losses were allowed to be 5% of the upgraded amount, in 2014 the limit was lowered to 2.5%. Measurements in a few biogas upgrade installations in 2007, 2013 and 2014 showed the following losses: 2007 one plant: 2.6%, 2013 one plant: 1%, 2014 three plants: 1.3%, 1.8%, and 3.5%. The measurements showed that the emission limits were respected (with the exception of one plant in 2014) and therefore Switzerland decided to set the losses from biogas upgrading to the ELV with the assumption of a linear improvement between the 1990 and the 2014 value. The continuous improvement seems plausible, as newer plants show fewer losses and values of less than 1%–2.5% are state of the art.

Activity data (5B2)

Activity data for 5B2 Anaerobic digestion at biogas facilities, as shown in Table 7-12, are based on data from the Swiss renewable energy statistics (SFOE 2017a). Relevant are the number of industrial and agricultural biogas facilities, as well as the total amount of biogas upgraded.

Table 7-11 Emission factors for 5B Biological treatment of solid waste in 2016.

5B Biological treatment of solide waste	Unit	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Composting (industrial)	g/t composted waste	1'000	50	NA	NA	300	NA
Composting (backyard)	g/t composted waste	1'000	50	NA	NA	300	NA
Digestion (industrial biogas facilities)	t/facility	1.23	NA	NA	NA	NA	NA
Digestion (agricultural biogas facilities)	t/facility	1.23	NA	NA	NA	NA	NA
Biogas up-grade	g/GJ	500	NA	NA	NA	NA	NA

Table 7-12 Activity data in 5B Biological treatment of solid waste.

5B Biological treatment of solide waste	Unit	1990	1995	2000	2005
Composting (industrial)	kt wet	240	360	519	526
Composting (backyard)	kt wet	110	155	180	170
Digestion (industrial biogas facilities)	number	NO	4	11	14
Digestion (agricultural biogas facilities)	number	102	76	68	72
Biogas up-grade	GJ	NO	NO	19'866	40'637

5B Biological treatment of solide waste	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Composting (industrial)	kt wet	529	530	532	530	532	534	536	540	545	550
Composting (backyard)	kt wet	150	140	130	120	110	100	100	100	100	100
Digestion (industrial biogas facilities)	number	16	16	21	22	28	26	26	25	26	27
Digestion (agricultural biogas facilities)	number	77	75	75	72	80	89	97	98	99	98
Biogas up-grade	GJ	50'966	71'721	85'008	121'627	168'170	236'074	283'503	368'862	447'877	483'323

To improve transparency the CH_4 and N_2O emissions of source category 5B Biological treatment of solid waste are shown on a completely disaggregated level in Table 7-13.

Table 7-13 CH_4 and N_2O emissions of 5B Biological treatment of solid waste.

5B Biological treatment of solide waste	Gas	Unit	1990	1995	2000	2005
Composting (industrial)	CH_4	t	240.2	360.3	519.3	526.2
	N_2O	t	12.0	18.0	26.0	26.3
Composting (backyard)	CH_4	t	110.0	120	130	140
	N_2O	t	5.5	6.0	6.5	7.0
Digestion (industrial)	CH_4	t	NO	4.9	13.6	17.2
Digestion (agricultural)	CH_4	t	125.5	93.5	83.6	88.6
Biogas up-grade	CH_4	t	NO	NO	15.7	28.0

5B Biological treatment of solide waste	Gas	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Composting (industrial)	CH_4	t	529.0	530.4	531.8	529.7	531.7	533.6	535.6	540.5	545.3	550.2
	N_2O	t	26.5	26.5	26.6	26.5	26.6	26.7	26.8	27.0	27.3	27.5
Composting (backyard)	CH_4	t	150.0	140.0	130.0	120.0	110.0	100.0	100.0	100.0	100.0	100.0
	N_2O	t	7.5	7.0	6.5	6.0	5.5	5.0	5.0	5.0	5.0	5.0
Digestion (industrial)	CH_4	t	19.7	19.7	25.9	27.1	34.5	32.0	32.0	30.8	32.0	33.3
Digestion (agricultural)	CH_4	t	94.7	92.3	92.3	88.6	98.4	109.5	119.4	120.6	121.8	120.6
Biogas up-grade	CH_4	t	32.9	44.8	51.3	70.9	94.7	128.0	147.7	184.4	223.9	241.7

7.3.3 Uncertainties and time-series consistency

Uncertainty in CH_4 emissions from composting and digestion

The uncertainty of all emission factors in source category 5B1 Composting is estimated at 30% for industrial composting and at 100% for backyard composting. The uncertainty of the related activity data is estimated at 30% for industrial composting and at 100% for backyard composting (EMIS 2018/5B1 Kompostierung).

For 5B2 Anaerobic digestion at biogas facilities the uncertainty takes into account the different process steps on one hand and emission factors on the other hand (EMIS 2018/1A1a & 5 B 2 Vergärung LW and EMIS 2018/1A1a & 5 B 2 Vergärung IG).

The overall uncertainty for 5B Biological treatment of solid waste for activity data as well as for emission factor is 30%.

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 chp. 1.2.3.

7.3.5 Category-specific recalculations

The following recalculations were implemented in submission 2018:

- The number of agricultural digestion facilities for the years 1990 and 1991 has been swapped. This has been corrected and leads to slightly different methane emissions for the years 1990 and 1991.
- The time series for industrial composting has been completely revised, affecting activity data for all years since 1990. Emission factors for CH_4, N_2O, CO_2 biogenic and NMVOC have been reestimated. Changes in emissions are (kt CO_2 eq): CH_4 1990: -26, CH_4 2015: -87; N_2O 1990: -2, N_2O 2015: -9 $CO_{2\ biog.}$ 1990: -57, CO_2 biog. 2015: -228.
- The time series for backyard composting has been completely revised, affecting activity data for all years since 1990. Emission factors for CH_4, N_2O, CO_2 biogenic and NMVOC have been introduced. Changes in emissions are (kt CO_2 eq): CH_4 1990: +3 CH_4 2015: +3; N_2O 1990: +2, N_2O 2015: +1; $CO_{2\ biog.}$ 1990: +29, $CO_{2\ biog.}$ 2015: +26.

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 – Incineration and open burning of waste 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 material from cables, of sewage sludge and in crematoria.

5C2 consists of emissions from open burning of branches in agriculture and gardening. Natural agricultural and gardening residues consist of fallen fruit trees, part of diseased residue which are cut up, collected and burned off-site. Field burning of agricultural residues does not occur in Switzerland. Emissions from open burning of natural residues in forestry are reported in LULUCF sector 4 V (chp. 6.4.2.13).

Table 7-14 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 and gardening.

7.4.2 Methodological issues

Methodology (5C)

Emissions are calculated using Tier 2 methods based on the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 5.2). 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 emission factors 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.

Emissions from burning of residues in agriculture and gardening are calculated using a Tier 1 method based on the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 5.2). Emission factors are taken from EMEP/CORINAIR (EMEP/EEA 2013).

Indirect CO_2 emissions from fossil CO and NMVOC emissions from illegal waste incineration, insulation material from cables and hospital waste incinerations are documented in chp. 9 Indirect CO_2 and N_2O emissions.

Emission factors (5C)

Table 7-15 presents an overview of the emission factors for 5C for the most recent inventory year.

Table 7-15 Emission factors for 5C Waste incineration and open burning of waste in 2016.
Documentation/sources: EMIS 2018/5C1 and EMIS 2018/5C2 (details see Table 7-14), EMEP/EEA (2013).

5C Waste incineration and open burning of waste	CO_2 t/t	CH_4 kg/t	N_2O g/t	NO_x kg/t	CO kg/t	NMVOC kg/t	SO_2 kg/t
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 private households	NA	6.8	180	1.4	49	1.5	0.03
	CO_2 t/crem.	CH_4 kg/crem.	N_2O g/crem.	NO_x kg/crem.	CO kg/crem.	NMVOC kg/crem.	SO_2 kg/crem.
Cremation	NA	NA	NA	0.21	0.05	0.007	NA

Comments on CO_2 emission factors:

- For all waste incineration categories, only CO_2 emissions from non-biogenic waste are taken into account.
- Hospital waste incineration: The waste is mainly of fossil origin. The default value for the CO_2 emission factor is taken from SAEFL (2000). Since 2002, no emissions from hospital waste incineration occur, as all 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 CO_2 emission factor is estimated by using the same assumption as in case of MSW incineration: The C-content is based on the study by FOEN (2014l) and the fossil carbon fraction was determined by Rytec (2014). See also chp. 3.2.5.2 and detailed information in EMIS 2018/1A1a Kehrichtverbrennungsanlagen (pp. 5–7).
- Industrial waste (consists of cable insulation materials): The CO_2 emission factor is based on measurements of the flue gas treatment of a cable disassembling site where O_2 was measured in the flue gas. Assuming that the ratio of CO_2/O_2 is the same as in municipal solid waste incineration plants, a fraction of 7% of CO_2 results. Based on these assumptions, an emission factor 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 CO_2 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-CO_2) gases:

- Hospital waste incineration: All emission factors are taken from SAEFL (2000).
- Illegal waste incineration: The emission factor for N_2O is taken from the 2006 IPCC Guidelines (IPCC 2006, vol. 5), the emission factors for CH_4, SO_2, 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 emission 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. Emission factors for NMVOC, CO, SO_2 and CH_4 decrease due to gradual technical improvements.
- Crematoria: NMVOC and CO emissions were reduced by technical improvements. A large number of measurements were 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 2018/5C1 Krematorien).
- The emission factors of burning of branches in agriculture and gardening are calculated based on EMEP/EEA (2013) except for CH_4 und N_2O for which emission factors are based on EMEP/CORINAIR (EMEP/EEA 2002), see also documentation in EMIS 2018/5C2 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 CO_2 emissions from fossil CO and NMVOC emissions are reported in chp. 9 Indirect CO_2 and N_2O emissions.

Activity data (5C)

The activity data for 5C Waste incineration are the quantities of waste incinerated, see Table 7-16. Activity data for open burning are split into open burning of natural residues in agriculture as well as into open burning of natural residues in private households, while respective activity data in CRF Table5.C are aggregated.

Table 7-16 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	2005
Hospital waste incineration	kt	30.0	17.5	5.0	NO
Municipal waste incineration (illegal)	kt	32.3	26.2	24.9	21.7
Industrial waste incineration	kt	7.5	NO	NO	NO
Sewage sludge incineration	kt dry	57.0	50.2	64.3	94.9
Open burning of natural residues in agriculture	kt	16.5	15.2	14.0	12.8
Open burning of natural residues in private households	kt	6.1	4.9	3.6	2.4
Total	kt	149.3	114.0	111.8	131.7
Cremation	Numb.	37'513	40'968	44'821	48'169

5C Incineration and open burning of waste	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Hospital waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Municipal waste incineration (illegal)	kt	22.1	22.4	20.7	21.0	20.3	20.3	19.9	19.3	19.3	19.0
Industrial waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge incineration	kt dry	95.2	97.7	100.1	102.6	102.4	100.8	120.9	121.0	127.6	131.9
Open burning of natural residues in agriculture	kt	12.3	12.0	11.8	11.5	11.4	11.3	11.2	11.1	11.0	10.8
Open burning of natural residues in private households	kt	1.9	1.7	1.5	1.2	1.2	1.2	1.2	1.2	1.2	1.1
Total	kt	131.5	133.8	134.1	136.4	135.3	133.5	153.1	152.5	159.0	162.9
Cremation	Numb.	49'413	51'116	52'402	52'813	52'530	50'567	53'205	55'616	59'664	54'634

Hospital waste incineration: Does not occur anymore in specific hospital waste incineration plants since 2002. The amount of hospital waste burnt in 1990 stems from BUS (1988).

Illegal municipal waste incineration: As waste incineration outside incineration plants is forbidden in Switzerland, no data is available. Illegal incineration of waste e.g. in wood stoves, garden fires, construction sites etc. is decreasing due to surveillance by authorities but also by citizens that would report open burning. However, there still are cases of illegal waste incineration. It is assumed that 1% of all waste in Switzerland has been burnt illegally in 1990 and that this value decreases to 0.25% in 2030 and then remains constant.

Industrial waste incineration (cable insulation): Does not occur anymore since 1995. The amount burnt in 1990 is estimated by the amount reported by a company that was supposed to burn approx. 1/3 of all insulation material in Switzerland.

Sewage sludge incineration: Activity data for sewage sludge incineration is calculated as follows: Total amount of sewage sludge (according to waste statistics) minus sewage sludge burnt in MSWIP minus sewage sludge used as alternative fuel in cement industry.

Open burning of natural residues: The amount of natural residues burnt openly has been estimated in a study (INFRAS 2014) as briefly described in the following. Open burning of such residues is regulated in the Ordinance on Air Pollution Control OAPC, Article 26b. In Switzerland, cantonal authorities are responsible for the implementation of the regulations of the OAPC. Since there is no nationwide data available for the activity data of open burning of natural residues, cantonal authorities have been interviewed. Based on the available statistics in many cantons on the number of permitted fires and sanctions due to non-permitted fires, the amount of burnt material in those cantons has been quantified. Since there also is a significant number of unreported cases, it has been assumed that the actual amount of material burnt is three times as large as the amount that has been approved by the authorities. Based on the numbers from the evaluated cantons an extrapolation to the amount burnt in Switzerland has been made. For the extrapolation the statistics on the usage of wood has been used (FOEN 2012i). For the determination of a time series of natural residues burnt, elder experts with historical knowledge in agriculture and forestry have been interviewed. Furthermore, statistical data on agricultural and forestry activities has been used to estimate the potential of material available for burning at a certain time. With this approach a time series since 1900 has been compiled. Emissions from open burning of natural residues in forestry (5 C 2 ii) are reported in LULUCF sector 4 V (chp. 6.4.2.13).

Cremations: Activity data is reported by the Swiss Cremation Association. These statistics are updated every year.

7.4.3 Uncertainties and time-series consistency

The uncertainty assessment, based on expert judgment, results in high uncertainties for CO_2 and CH_4 of 40% and 60% of emission estimates, respectively, and for N_2O in low uncertainty of 40% of emission estimates (see Table 1-10 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 chp. 1.2.3.

7.4.5 Category-specific recalculations

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

Table 7-17 Key categories of 5D Wastewater treatment and discharge. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
5D	Wastewater treatment and discharge	CH4	L1, L2, T2
5D	Wastewater treatment and discharge	N2O	L2, T2

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 and 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 industrial and commercial effluents are also handled for final treatment in municipal WWT plants (see below). Concerning wastewater streams, there is no difference between the terms “industrial” and “commercial” (see Figure 7-5). Switzerland’s wastewater management infrastructure – comprising about 850 WWT plants and 40’000–50’000 km of public sewers – is now practically complete (FOEN 2017l). 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. See also EMIS 2018/5D1 Wastewater Treatment Plants.

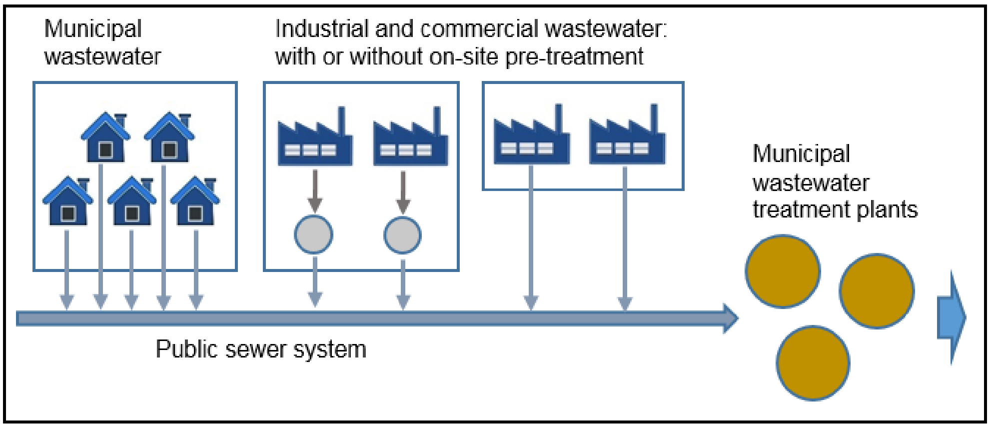


Figure 7-5 Graphical representation of municipal and industrial or commercial wastewater streams.

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 (see Figure 7-5 and Figure 7-6). Due to this strong connection with domestic wastewater treatment, industrial wastewater is not identified as separate wastewater stream for the calculation of GHG emissions, but joined to the domestic wastewater treatment. For the calculation of emissions of other gases (NO_x, CO, NMVOC, SO_2), domestic and industrial wastewater streams are distinguished (i.e. different emission factors relative to population, see below). See also EMIS 2018/5D2 Pre-treatment of industrial wastewater.

Table 7-18 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_2O 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), 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 further emissions reported in other categories, as illustrated in Figure 7-6 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 7-6. 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).

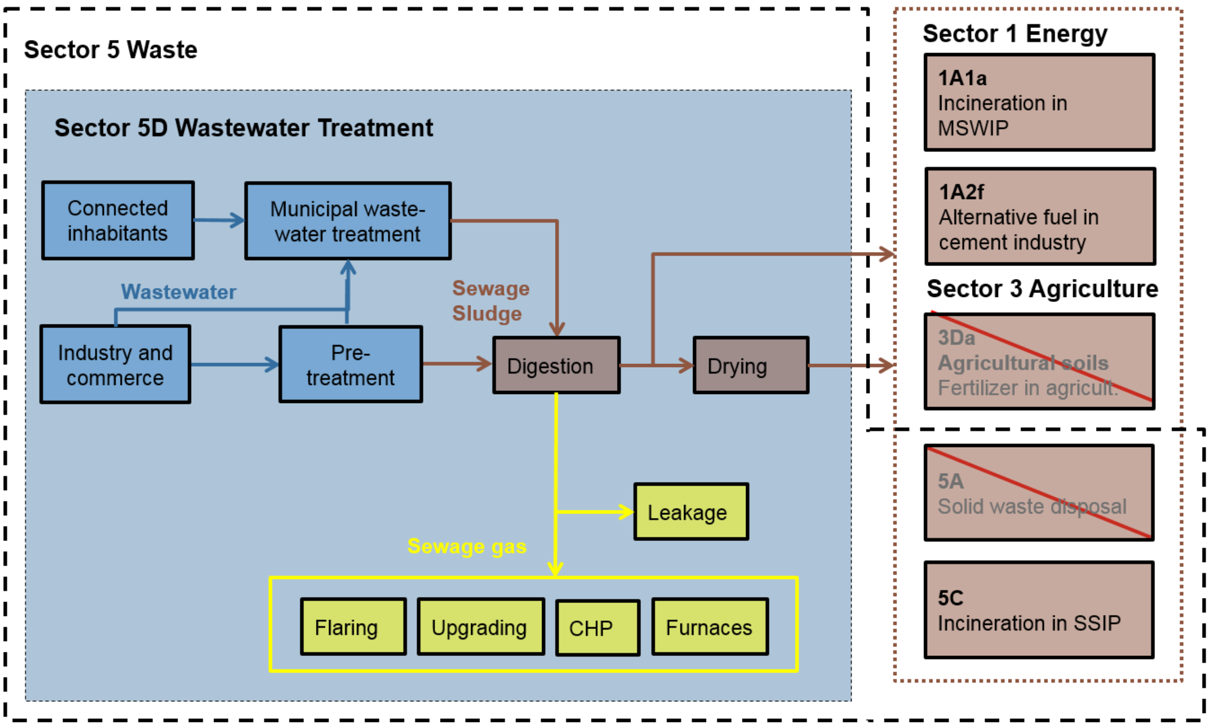


Figure 7-6 System boundaries of processes related to wastewater treatment. CHP= Combined heat and power generation. MSWIP = Municipal solid waste incineration plant. SSIP = Sewage sludge incineration plant.

7.5.2 Methodological issues

CH_4 emissions are calculated by a Tier 2 method based on the decision tree of the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 6, Fig. 6.2 and Fig. 6.3).

N_2O emissions are calculated using a country-specific method according to IPCC (2006).

Details regarding the calculation of CH_4 and N_2O emissions are provided in the following.

7.5.2.1 CH_4 emissions

Methodology (5D, CH_4)

CH_4 emissions from wastewater treatment and discharge take into account emissions stemming from organically degradable material in wastewater and emissions related to sewage gas production (and recovery) from sewage sludge (in domestic as well as industrial installations). As noted above industrial and commercial wastewater is treated together with domestic wastewater in municipal WWT plants. Accordingly, the contribution of industrial and commercial wastewater is taken into account in the calculation of CH_4 emissions from domestic wastewater by means of a correction factor for additional industrial and commercial biochemical oxygen demand (BOD) discharged into the domestic sewer system. 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 and commercial pre-treatment of wastewater are also taken into account in the calculation of emissions from municipal WWT plants, because the underlying Swiss renewable energy statistics in Switzerland (see below) does not differentiate between sewage gas production in domestic and industrial WWT plants.

Accordingly, total CH_4 emissions from domestic, industrial and commercial 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 sewered to WWT plants is determined by:

$$CH_{4,wastewater} = EF_{wastewater} * T_{Plant} * TOW$$

$EF_{wastewater}$ corresponds to the emission factor (see below), T_{Plant} to the fraction of population connected to municipal WWT plants in each year and TOW to the total organically degradable material in the wastewater per year.

From all inhabitants (urban and rural) 90% were connected to WWT plants in 1990, and this percentage reached 97% in 2006, remaining constant thereafter. Switzerland reports emissions only from wastewater discharged to the public sewer system, without taking into account potential emissions from wastewater of unconnected inhabitants. However, emissions from the small fraction of wastewater not treated in WWT plants (since 2006 the wastewater from 3% of the population) are negligible. Federal law only permits alternative treatment systems in remote and sparsely populated regions. Some of such alternative systems treat wastewater very similar to centralized WWT plants, often under aerobic conditions. The sewage sludge from these small scale treatment installations is either dealt with by centralized WWT plants or MWIP (municipal waste incineration plants). Simpler systems are e.g. septic tanks with at least three chambers. However, the production of CH_4 in an anaerobic environment is strongly temperature dependent and significant CH_4 production is unlikely below 15°C due to the inactivity of methanogens (IPCC 2006). As in Switzerland alternative systems are typically buried, the wastewater reaches the rather constant temperature of the surrounding soil, approximately corresponding to the mean annual air temperature. At Grono, the warmest place in Switzerland, the mean annual temperature is 12.4°C. Accordingly, in alternative treatment systems the temperature of the wastewater is too low to produce substantial CH_4 emissions. CH_4 emissions from wastewater produced by inhabitants not connected to municipal WWT plants are thus considered insignificant and set to zero in the Swiss greenhouse gas inventory.

ii) Sewage gas

The CH_4 emissions resulting from sewage gas treatment (aiming at stabilizing the sewage sludge and producing sewage gas) are calculated based on a country-specific implied emission factor ($EF_{sewage\ gas}$, see below), which is normalized with population (P):

$$CH_{4,sewage\ gas} = EF_{sewage\ gas} * P$$

Emission factors (5D, CH_4)

(i) Wastewater

The wastewater of all connected inhabitants, i.e. virtually all wastewater generated in Switzerland, is sewered to WWT plants using closed sewer systems. The emission factor according to the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 6, Equation 6.2) is represented by the product of the maximum CH_4 producing potential (B_o, default value 0.60 $kgCH_4/kgBOD$) and the methane correction factor (MCF) for the wastewater treatment and discharge system. For the wastewater sewered to centralized WWT plants, the 2006 IPCC Guidelines (IPCC 2006) propose that the MCF is zero (range 0.0–0.1) for well managed aerobic WWT plants. While WWT plants are generally well managed in Switzerland and mostly operated aerobically (with the exception of sewage sludge treatment, which is considered separately, see below), some CH_4 emissions may still occur. Therefore, the MCF is set to 0.05 (corresponding to the mid-value of the range of well managed aerobic WWT plants), which also brings total CH_4 emissions from WWT in Switzerland to similar values as estimated by Hiller et al. (2014) in their peer-reviewed study. This leads to the following constant emission factor:

$$EF_{wastewater} = B_0 * MCF = 0.60 \frac{kgCH_4}{kgBOD} * 0.05 = 0.03 \frac{kgCH_4}{kgBOD}$$

As mentioned above the maximum CH_4 producing capacity of the wastewater not treated in WWT plants is zero, as the wastewater has a temperature most likely too low to produce significant amounts of CH_4. Accordingly, the emission factor 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 $EF_{sewage\ gas}$ for CH_4 emissions from sewage gas treatment the total sewage gas production (in domestic and industrial systems) is taken into account based on detailed Swiss renewable energy statistics in Switzerland (SFOE 2017a). 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. 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 the leakage of upgraded gas linearly decreases from 5% in 1990 to 2.5% in 2014, remaining constant thereafter. The emission factor is adapted on a yearly basis due to the respective annual changes in population and the total production of sewage gas.

(iii) Values of emission factors referred to the number of inhabitants

The CH_4 emission factors for 5D Wastewater treatment and discharge are summarized in Table 7-19.

Table 7-19 Country-specific CH_4 emission factors for source category 5D Wastewater treatment and discharge in 2016 referred to the number of inhabitants. Detailed information is given in EMIS 2018/5D1 5D2 Kläranlagen GHG (Wastewater Handling - Emissions of Nitrous Oxide (N_2O) and Methane (CH_4), Update to the 2006 IPCC Guidelines).

5D Wastewater treatment and discharge	**Unit**	**2016**
Population	in 1000	8'373
Emissions from WW sewered to WWT plants	kg CH_4/person/a	0.80
Emissions from WW not sewered to WWT plants	kg CH_4/person/a	NA
Emissons from losses during sludge treatment	kg CH_4/person/a	0.07

Activity data (5D, CH_4)

(i) Wastewater

In correspondence with the emission factor $EF_{wastewater}$ given above, the activity data is the fraction of population connected to municipal WWT plants (T_{plant}), as well as the total organically degradable material (*TOW*) in domestic, industrial and 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 7-20). 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 and 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 7-20.

(ii) Sewage gas

As elaborated above, a per capita CH_4 emission factor ($EF_{sewage\ gas}$) is calculated for CH_4 emissions from separate sewage sludge treatment, and the respective activity data is population (Table 7-20).

7.5.2.2 N_2O emissions

Methodology (5D, N_2O)

Direct N_2O emissions from centralized WWT plants and N_2O emissions from wastewater effluent are calculated in accordance with the 2006 IPCC Guidelines (IPCC 2006).

(i) N_2O emissions from WWT plants

Direct N_2O emissions from WWT plants are determined with equation 6.9 of the 2006 IPCC Guidelines (IPCC 2006):

$$N_2O_{PLANTS} = EF_{PLANT} * P * T_{PLANT} * F_{IND-COM}$$

N_2O_{PLANTS} corresponds to the total N_2O emissions from WWT plants in kg N_2O/yr, P to the population, T_{PLANT} to the degree of utilization of modern, centralized WWT plants (%), $F_{IND-COM}$ to the correction factor for industrial and commercial co-discharged protein, and EF_{PLANT} to the emission factor from the plants.

(ii) N_2O emissions from wastewater effluents

The following equation from the 2006 IPCC Guidelines (IPCC 2006) for the N_2O emissions from wastewater effluent is used:

$$N_2O_{EFFLUENT} = EF_{EFFLUENT} * N_{EFFLUENT} * 44/28$$

$N_2O_{Effluent}$ corresponds to the total N_2O emissions from effluents (kg N_2O/yr), $N_{EFFLUENT}$ to the total amount of nitrogen discharged to the aquatic environment (kg N/yr), and $EF_{EFFLUENT}$ to the emission factor for N_2O emissions from discharged wastewater (kg N-N_2O/kg N). The following equation allows for the calculation of the total amount of nitrogen in the wastewater ($N_{EFFLUENT}$, kg N/yr, IPCC 2006):

$$N_{EFFLUENT} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{SLUDGE} - N_{WWT}$$

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, N_2O)

(i) N_2O emissions from WWT plants

The IPCC default emission factor is applied: EF_{PLANT} = 3.2 g N_2O/inhabitant/yr (IPCC 2006).

(ii) N_2O emissions from wastewater effluents

The IPCC default emission factor is applied: $EF_{EFFLUENT}$ = 0.005 kg N_2O/kg N (IPCC 2006).

Activity Data (5D, N_2O)

(i) N_2O emissions from WWT plants

The needed time-dependent and country-specific activity data are summarized in Table 7-20:

- Population (P)
- Degree of utilization of modern, centralized WWT plants (T_{PLANT})
- In addition, the following constant factor is used:
- Industrial and commercial co-discharged protein, IPCC default value: $F_{IND\text{-}COM}$ = 1.25 (IPCC 2006)

(ii) N_2O emissions from wastewater effluents

The time-dependent and country-specific activity data are also summarized in Table 7-20:

- 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: FNPR = 0.16 kg N/kg protein (IPCC 2006).
- Factor accounting for non-consumed protein added to the wastewater, IPCC default value: $F_{NON\text{-}CON}$ = 1.1 (IPCC 2006). 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 and commercial co-discharged protein, IPCC default value: $F_{IND\text{-}COM}$ = 1.25 (IPCC 2006).

Table 7-20 Activity data for source category 5D Wastewater treatment and discharge (source EMIS 2018/5D1 Wastewater Treatment Plants and EMIS 2018/5D2 Pre-treatment of industrial wastewater).

5D Wastewater treatment and discharge	Unit	1990	1995	2000	2005
Population	persons in 1000	6'796	7'081	7'209	7'501
Fraction of population connected to wastewater treatment plants	%	90.0	93.5	95.4	96.8
Connected persons	persons in 1000	6'116	6'621	6'877	7'261
Protein consumption	kg/inhab./a	38	37	37	36
N removed with sludge (N_{sludge})	N in t/a	9'465	9'009	8'831	9'026
N directly emitted (N_{WWT})	N in t/a	15.6	16.9	17.5	18.5
Total org. degr. material (TOW)	t/a	186'041	193'842	197'346	205'340

5D Wastewater treatment and discharge	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Population	persons in 1000	7'619	7'711	7'801	7'878	7'912	7'997	8'089	8'189	8'282	8'373
Fraction of population connected to wastewater treatment plants	%	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0	97.0
Connected persons	persons in 1000	7'390	7'480	7'567	7'642	7'675	7'757	7'846	7'943	8'034	8'122
Protein consumption	kg/inhab./a	37	38	38	38	39	37	37	37	37	37
N removed with sludge (N_{sludge})	N in t/a	9'135	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	18.8	19.0	19.3	19.5	19.5	19.7	20.0	20.2	20.4	20.7
Total org. degr. material (TOW)	t/a	208'570	211'089	213'552	215'660	216'591	218'918	221'436	224'174	226'720	229'211

7.5.2.3 Other gases

The sewage gas production generates emissions of further gases from flaring: CO_2 (biogenic), NO_x, CO, NMVOC, and SO_2. The emissions are calculated by multiplying population (as activity data, see Table 7-20) with country-specific emission factors based on measurements and expert estimates, documented in EMIS 2018/5D1 Wastewater Treatment Plants and EMIS 2018/5D2 Pre-treatment of industrial wastewater. The emission factors used are summarized in Table 7-21.

Table 7-21 Emission factors of CO_2 (biogenic), CH_4, N_2O, NO_x, CO, NMVOC and SO_2 for 5D Wastewater treatment and discharge in 2016.

5D Wastewater treatment and discharge	CO_2 biog.	N_2O	CH_4	NO_x	CO	NMVOC	SO_2
	kg/person	g/person					
5D1 Domestic wastewater	13.1	60	862	21	36	0.5	2.3
5D2 Industrial wastewater	2.1	IE	IE	2.8	4.6	0.1	0.3

7.5.3 Uncertainties and time-series consistency

Uncertainty in CH_4 and N_2O emissions from 5D

7.5.3.1 CH_4 emissions

The default values of the 2006 IPCC Guidelines (IPCC 2006) are adopted to estimate the uncertainty of CH_4 emissions. The following specifications are given:

- Activity data: Uncertainties of the single factors U(population) = 5%, U(BOD) = 30%, U(I) = 20% lead to an aggregated uncertainty of U(AD) = 36%.
- CH_4 emission factor: Uncertainties of the single factors U(B_0) = 30%, U(MCF) = 10% (well managed plants) lead to an aggregated uncertainty of U(EF) = 32%.
- Combined uncertainty U(Em CH_4) = 48%.

7.5.3.2 N_2O emissions

By applying the default uncertainties of the 2006 IPCC Guidelines (IPCC 2006, vol. 5, 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 1-10 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 chp. 1.2.3.

7.5.5 Category-specific recalculations

The following recalculations were implemented in submission 2018:

- 5D1: The emission factor for N_2O for domestic wastewater treatment has been slightly adjusted for the years 1990-2015 for different reasons: Protein consumption in the year 2008 has been corrected in the statistics provided by the Swiss farmers association. This influences the whole time series from 1990-2006 as there is a break in the time series in 2007 which has been corrected using values from 2007-2010. Furthermore protein consumption for the year 2015 has been adjusted, as well as the number of digits used for the EF.

- 5D1: The value for sewage gas used in CHP installations has been corrected in the underlying statistics be the SFOE for the year 2000. This slightly diminishes the amount of CH_4 recovered (see CRF Table5.D).

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 7-22 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 1 method is used.

Indirect CO_2 emissions from fossil CO and NMVOC emissions are described in chp. 9 Indirect CO_2 and N_2O 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 four plants in the years from 2002 to 2008 (EMIS 2018/5E Shredder Anlagen). For CO a constant emission factor is applied over the whole reporting period.

Table 7-23 CO and NMVOC emission factors for 5E Other (car shredding) in 2016.

5E Other waste	Unit	CH_4	N_2O	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 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 2018/5E Shredder Anlagen).

Table 7-24 Activity data 5E Other (car shredding).

5E Other waste	Unit	1990	1995	2000	2005
Shredding	kt	280	300	300	300

5E Other waste	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
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 chp. 1.2.3.

7.6.5 Category-specific recalculations

No category-specific recalculations were carried out.

7.6.6 Category-specific planned improvements

No category-specific improvements are planned.

8 Other

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

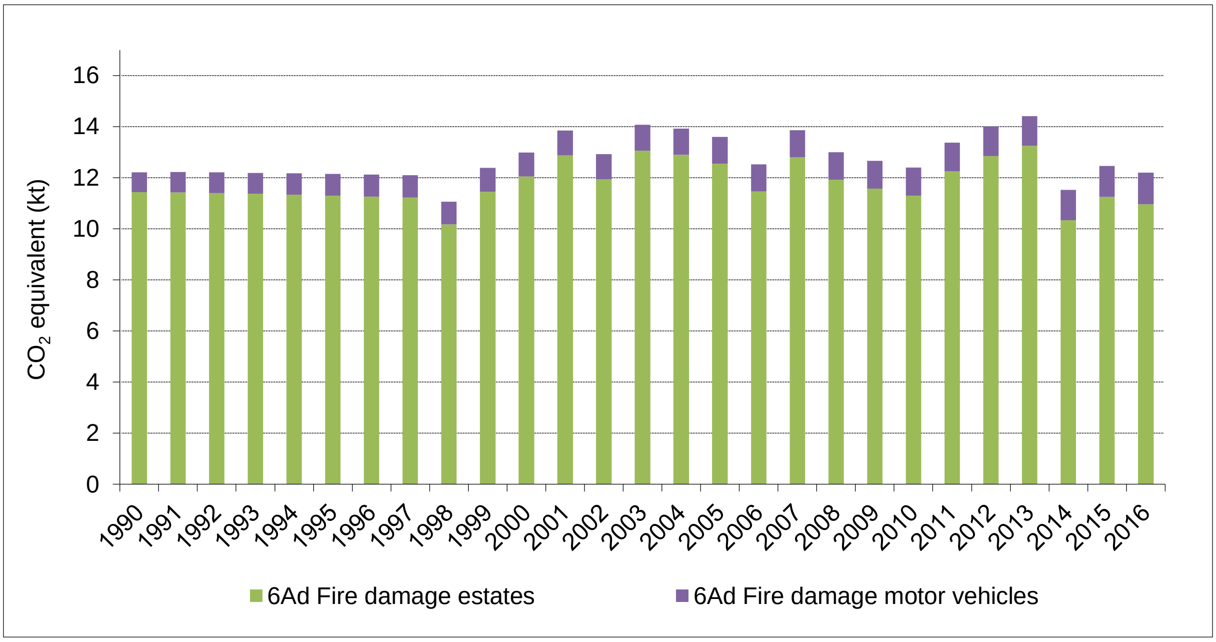


Figure 8-1 Switzerland's greenhouse gas emissions in the sector 6 Other.

Table 8-1 Trend of total GHG emissions from sector 6 Other in Switzerland.

Gas	1990	1995	2000	2005
	CO_2 equivalent (kt)			
CO_2	11.0	11.0	11.8	12.4
CH_4	0.7	0.6	0.6	0.7
N_2O	0.6	0.5	0.5	0.6
Sum	12.2	12.1	13.0	13.6

Gas	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	CO_2 equivalent (kt)									
CO_2	12.6	11.8	11.5	11.3	12.2	12.8	13.1	10.5	11.3	11.1
CH_4	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.6	0.6	0.6
N_2O	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5
Sum	13.9	13.0	12.7	12.4	13.4	14.0	14.4	11.5	12.5	12.2

In 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 variations around 12 kt CO_2 eq during the reporting period. Consequently, 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

Source category 6 - Other is not a key category.

The sources reported in source category 6 Other are shown 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)

CO_2 emissions are calculated by a Tier 1 method based on the decision tree of the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 5, Fig. 5.1). Emission factors are country specific.

CH_4 emissions are calculated by a Tier 1 method based on the decision tree of the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 5, Fig. 5.2). Emission factors are country specific (fire damage estates) and from EPA (fire damage motor vehicles).

N_2O emissions are calculated by a country specific Tier 1 method based on the decision tree of the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 5, Fig. 5.2). Emission factors are country specific. N_2O emissions from fire damages of motor vehicles have not been estimated.

The estimation of GHG emissions are based on damage sums and fires reported from insurance companies.

Emission factors (6 Other)

a) Fire damage estates

Emission factors for CO_2, CO, NO_x and SO_2 are country-specific based on measurements and expert estimates originally completed for illegal waste incineration. It is assumed that for fire damage in estates emissions are similar (EMIS 2018/6Ad Brand- und Feuerschäden Immobilien).

The fraction between fossil and biogenic CO_2 emissions is assumed to remain constant since 2000 with 80% being fossil and 20% biogenic CO_2 emissions. Before 2000, it is assumed that the fraction of fossil CO_2 emissions from burnt goods has been increasing linearly from 20% in 1950 to 80% in 2000.

Indirect CO_2 emissions from fossil CO and NMVOC emissions are documented in chp. 9 Indirect CO_2 and N_2O emissions.

b) Fire damage motor vehicles

Emission factors for CO_2, CO, NO_x and SO_2 are country-specific based on measurements and expert estimates originally gained from the combustion of cable insulation materials, documented in EMIS 2018/6Ad Brand- und Feuerschäden Motorfahrzeuge.

The emission factor for CH_4 from fire damage in motor vehicles is based on EPA (1992), while N_2O emissions have not been estimated for this source category.

Indirect CO_2 emissions from fossil CO and NMVOC emissions are documented in chp. 9 Indirect CO_2 and N_2O emissions.

Table 8-3 Emission factors for fire damages in 2016 (EMIS 2018/6Ad).

6A Other	Unit	CO_2 biogenic	CO_2 fossil	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
6Ad Fire damage estates	t / kt burned good	400	1'500	3	0.25	2	100	16	1
6Ad Fire damage motor vehicles	t / kt burned good	NO	1'500	5	NE	1.3	2	2	5

Activity data (6 Other)

a) Fire damage estates

Activity data are estimated yearly based on annually published information by the fire insurance association of the cantons (Vereinigung kantonaler Feuerversicherungen, VKF). VKF publishes the number of fire incidents in buildings each year and the total sum of monetary damage.

Data from 1992 to 2001 shows that the average damage sum per fire incident in buildings amounts to approx. CHF 20’000. It is assumed that this corresponds to 780 kg of flammable material per case. It is further assumed that in average 50% of the material actually burns down during an incident because of the intervention of the fire brigade. Thus, an average amount of 400 kg of burnt material per fire case is estimated and held constant throughout the time series. With these assumptions, the amount of burnt material for each year can be estimated using the total sum of monetary damage published by VKF (EMIS 2018/6Ad Brand- und Feuerschäden Immobilien), divided by the average damage sum (CHF 20’000) and multiplied by the burnt material per fire incident (400 kg).

b) Fire damage motor vehicles

Activity data are estimated yearly based on vehicle numbers published annually by the Swiss Federal Statistical Office SFSO (EMIS 2018/6Ad Brand- und Feuerschäden Motorfahrzeuge).

Based on data from a Swiss insurance company with 25% market share in 2002, the number of reported cases of fire damage to vehicles was extrapolated to the total vehicle number in Switzerland. It was estimated that one fire case per 790 vehicles occurs per year, remaining constant within the reporting period. Applying this ratio to the actual vehicle number, the total number of fire incidents with vehicles in Switzerland can be calculated.

During a car fire incident, a car burns down only partially. It is assumed that approx. 100 kg of material burns down during a car fire. With these assumptions, the total number of material burnt can be calculated from the total number of cars in Switzerland.

Table 8-4 Activity data of burnt goods (documented in EMIS 2018/6Ad).

6A	Unit	1990	1995	2000	2005
6Ad Fire damage estates	kt	8.0	7.3	7.3	7.6
6Ad Fire damage motor vehicles	kt	0.48	0.52	0.58	0.64

6A	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
6Ad Fire damage estates	kt	7.8	7.2	7.0	6.8	7.4	7.8	8.0	6.3	6.8	6.6
6Ad Fire damage motor vehicles	kt	0.66	0.66	0.67	0.68	0.69	0.71	0.72	0.73	0.75	0.76

8.2.3 Uncertainties and time series consistency

Uncertainties of CO_2, CH_4 and N_2O emissions are estimated to be high (according to Table 1-10).

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 chp. 1.2.3.

8.2.5 Category-specific recalculations

- 6Ad: An error in the calculation of the activity data for fire damages estates has been corrected. This leads to slightly changed values for the years 1996-2014.

8.2.6 Category-specific planned improvements

No category-specific improvements are planned.

9 Indirect CO_2 and N_2O emissions

9.1 Overview

In this chapter, indirect CO_2 emissions that result from the atmospheric oxidation of NMVOC and CO as well as indirect N_2O emissions that are induced by the deposition of NO_x and NH_3 are documented. While indirect CO_2 emissions reported in this chapter are accounted for in the national total, indirect N_2O emissions are not.

Indirect emissions of CO_2 and N_2O are shown in CRF Table6, together with the emissions of the precursor gases CH_4, CO, NMVOC, NO_x and NH_3. While all emissions of precursor gases are shown in both CRF Table6 and in the respective sectors, the indirect emissions of CO_2 and N_2O shown in CRF Table6 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 CO_2 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 Table6, they are not included for the calculation of indirect CO_2 emissions. Consequently, the implied emission factors may vary from sector to sector and also from year to year. Indirect CO_2 emissions resulting from the atmospheric oxidation of CH_4 are generally not considered.

Chapter 9.2 explains in detail the methodological issues to derive indirect CO_2 and N_2O emissions based on the emissions of the precursor gases NMVOC and CO, as well as NO_x and NH_3 from the different sectors. As an overview, the resulting indirect CO_2 emissions are shown in Table 9-1, as well as in Figure 9-1 and Figure 9-2. The resulting indirect N_2O emissions are shown in Table 9-2, as well as in Figure 9-3 and Figure 9-4.

Indirect CO_2 emissions are considered for both the uncertainty analysis (see chp. 1.6) and the key category analysis (see chp. 1.5).

Indirect N_2O emissions are not considered for the uncertainty analysis (see chp. 1.6), nor for the key category analysis (see chp. 1.5).

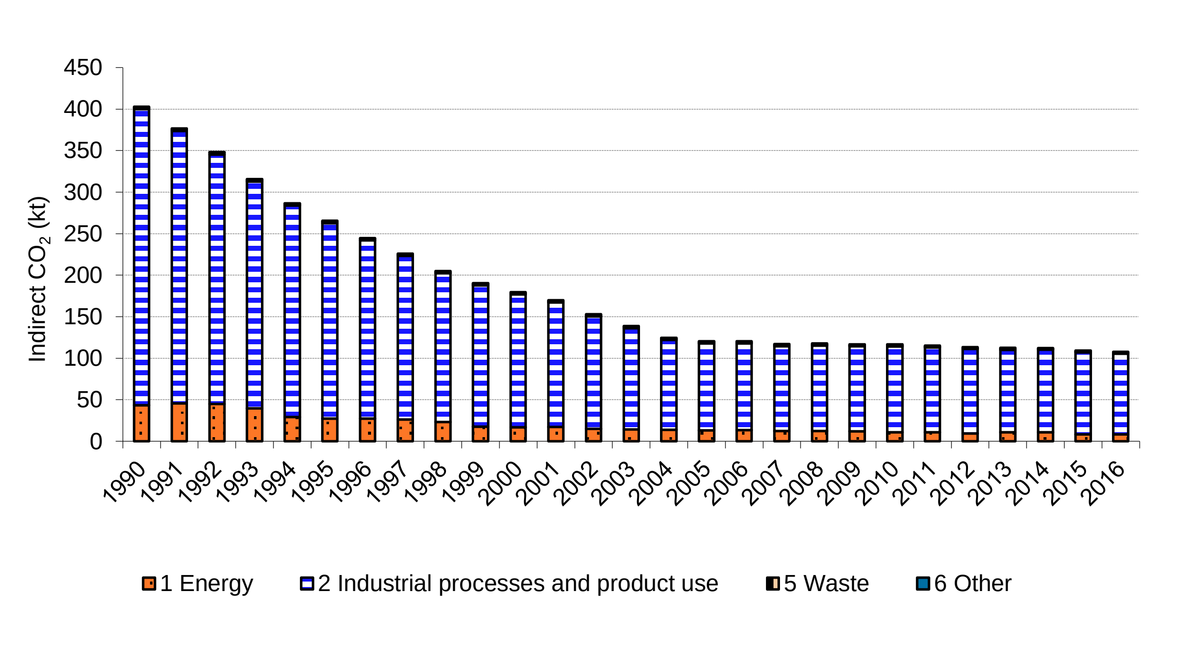


Figure 9-1 Switzerland's indirect fossil CO_2 emissions.

Table 9-1 Indirect fossil CO_2 emissions.

Indirect fossil CO_2 emissions by source category	1990	1995	2000	2005
	(kt CO_2)			
1 Energy	**43.55**	**27.52**	**16.99**	**13.22**
1B Fugitive emissions from fuels	43.55	27.52	16.99	13.22
2 Industrial processes and product use	**356.11**	**235.22**	**159.95**	**104.82**
2A Mineral industry	0.15	0.12	0.11	0.11
2B Chemical industry	1.30	0.35	0.02	0.01
2C Metal industry	3.36	2.41	2.21	1.26
2D Non-energy products from fuels and solvent use	224.26	132.77	86.35	46.00
2G Other product manufacture and use	124.21	97.54	69.36	56.14
2H Other	2.83	2.02	1.91	1.29
5 Waste	**2.01**	**1.66**	**1.60**	**1.38**
5A Solid waste disposal	NO	NO	NO	NO
5C Waste incineration and open burning of waste	1.95	1.56	1.47	1.25
5E Other	0.06	0.10	0.13	0.13
6 Other	**1.04**	**1.04**	**1.11**	**1.16**
6Ad Fire damages	1.04	1.04	1.11	1.16
Total	**402.71**	**265.44**	**179.65**	**120.58**

Indirect fossil CO_2 emissions by source category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	(kt CO_2)									
1 Energy	**12.36**	**12.52**	**11.96**	**11.04**	**10.80**	**9.59**	**11.01**	**10.81**	**8.20**	**8.23**
1B Fugitive emissions from fuels	12.36	12.52	11.96	11.04	10.80	9.59	11.01	10.81	8.20	8.23
2 Industrial processes and product use	**102.27**	**102.78**	**102.55**	**103.22**	**102.23**	**101.46**	**99.16**	**99.48**	**98.69**	**97.36**
2A Mineral industry	0.12	0.11	0.11	0.12	0.12	0.11	0.10	0.10	0.09	0.09
2B Chemical industry	0.01	0.02	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.00
2C Metal industry	1.26	1.35	0.85	0.93	1.05	0.81	0.80	0.77	0.67	0.63
2D Non-energy products from fuels and solvent use	44.81	45.19	45.50	45.88	44.73	43.24	42.91	43.33	42.67	42.33
2G Other product manufacture and use	54.44	54.29	54.07	53.99	53.80	55.21	53.31	53.32	53.31	53.29
2H Other	1.62	1.81	2.01	2.27	2.51	2.09	2.02	1.95	1.94	1.01
5 Waste	**1.38**	**1.39**	**1.29**	**1.30**	**1.25**	**1.24**	**1.22**	**1.18**	**1.18**	**1.17**
5A Solid waste disposal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5C Waste incineration and open burning of waste	1.25	1.26	1.15	1.16	1.11	1.10	1.08	1.05	1.05	1.03
5E Other	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
6 Other	**1.18**	**1.10**	**1.07**	**1.04**	**1.13**	**1.19**	**1.22**	**0.96**	**1.04**	**1.01**
6Ad Fire damages	1.18	1.10	1.07	1.04	1.13	1.19	1.22	0.96	1.04	1.01
Total	**117.19**	**117.78**	**116.86**	**116.60**	**115.41**	**113.48**	**112.61**	**112.43**	**109.11**	**107.77**

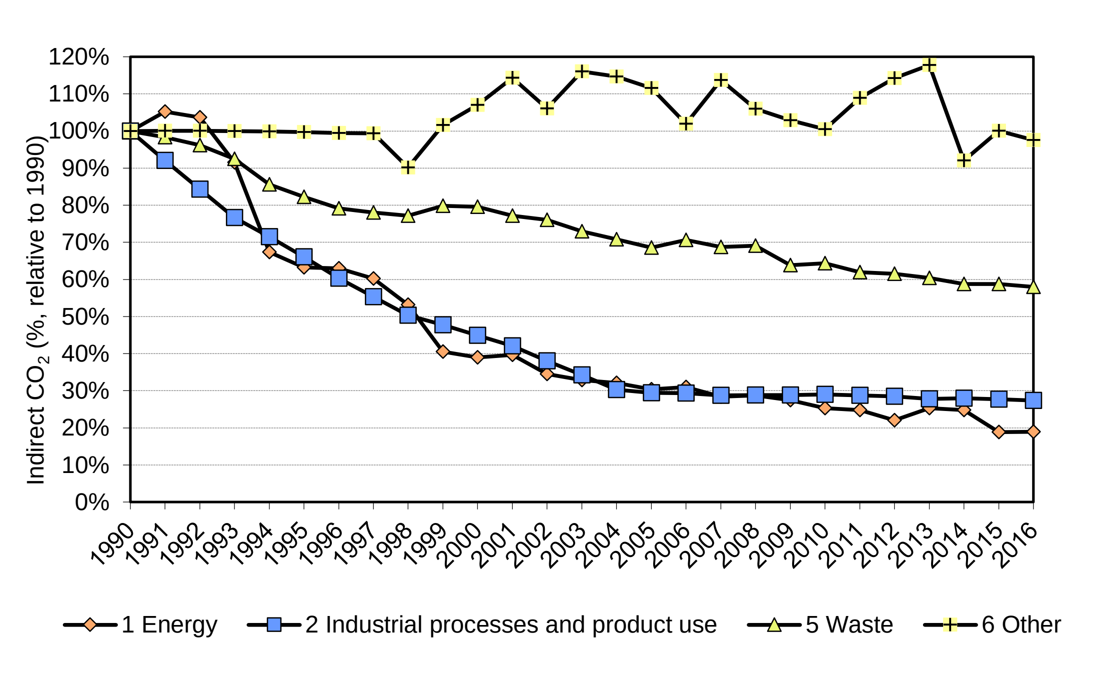


Figure 9-2 Relative trends of the indirect fossil CO_2 emissions by sector. The base year 1990 represents 100%.

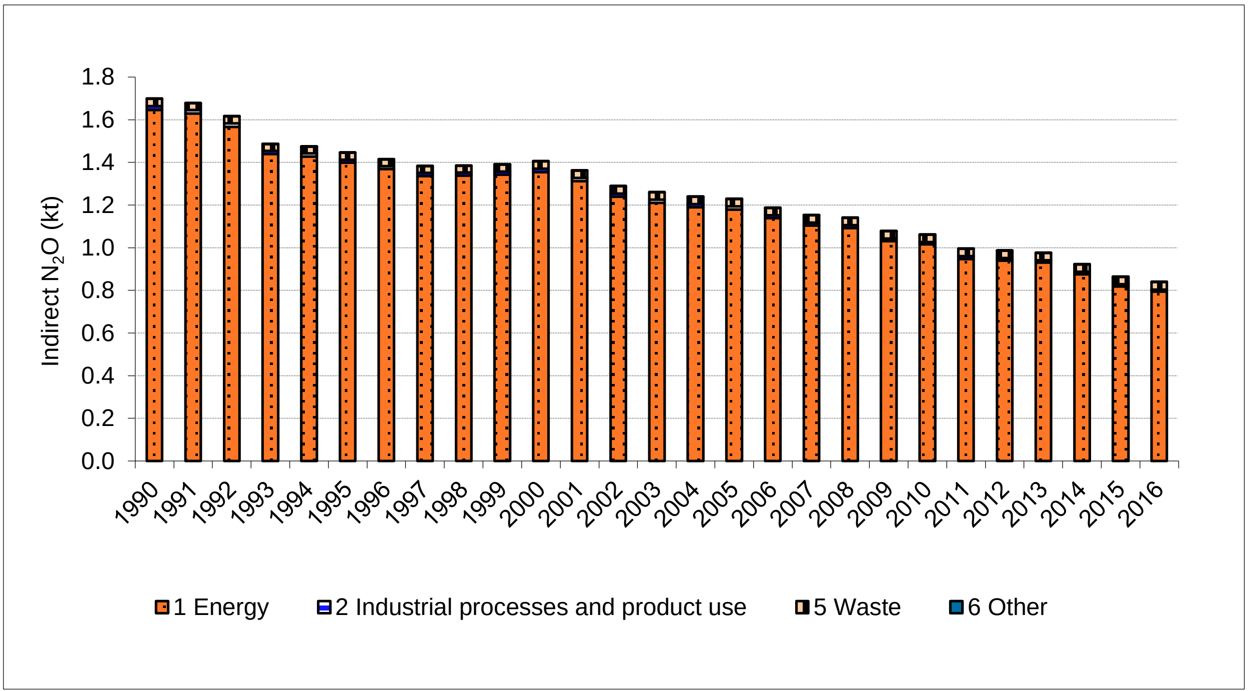


Figure 9-3 Switzerland's indirect N_2O emissions.

Table 9-2 Indirect N_2O emissions.

Indirect N_2O emissions by source category	1990	1995	2000	2005
	(kt)			
1 Energy	**1.65**	**1.40**	**1.35**	**1.18**
1A Fuel combustion activities	1.64	1.40	1.35	1.18
1B Fugitive emissions from fuels	0.00	0.00	0.00	0.00
2 Industrial processes and product use	**0.02**	**0.01**	**0.02**	**0.01**
2A Mineral industry	0.00	0.00	0.00	0.00
2B Chemical industry	0.00	0.00	0.00	0.00
2C Metal industry	0.00	0.00	0.00	0.00
2G Other product manufacture and use	0.01	0.01	0.01	0.01
2H Other	0.01	0.00	0.01	0.00
5 Waste	**0.03**	**0.03**	**0.03**	**0.03**
5A Solid waste disposal	0.02	0.01	0.01	0.01
5B Biological treatement of solid waste	0.01	0.01	0.01	0.01
5C Waste incineration and open burning of waste	0.00	0.00	0.00	0.00
5D Wastewater handling and discharge	0.00	0.01	0.01	0.01
6 Other	**0.00**	**0.00**	**0.00**	**0.00**
6Ad Fire damages	0.00	0.00	0.00	0.00
Total	**1.70**	**1.44**	**1.40**	**1.23**

Indirect N_2O emissions by source category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	(kt)									
1 Energy	**1.10**	**1.09**	**1.03**	**1.02**	**0.95**	**0.94**	**0.93**	**0.88**	**0.82**	**0.79**
1A Fuel combustion activities	1.10	1.09	1.03	1.01	0.95	0.94	0.93	0.87	0.82	0.79
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2H Other	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00
5 Waste	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.04**	**0.04**
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 treatement of solid waste	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
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	**1.15**	**1.14**	**1.08**	**1.06**	**0.99**	**0.99**	**0.98**	**0.92**	**0.86**	**0.84**

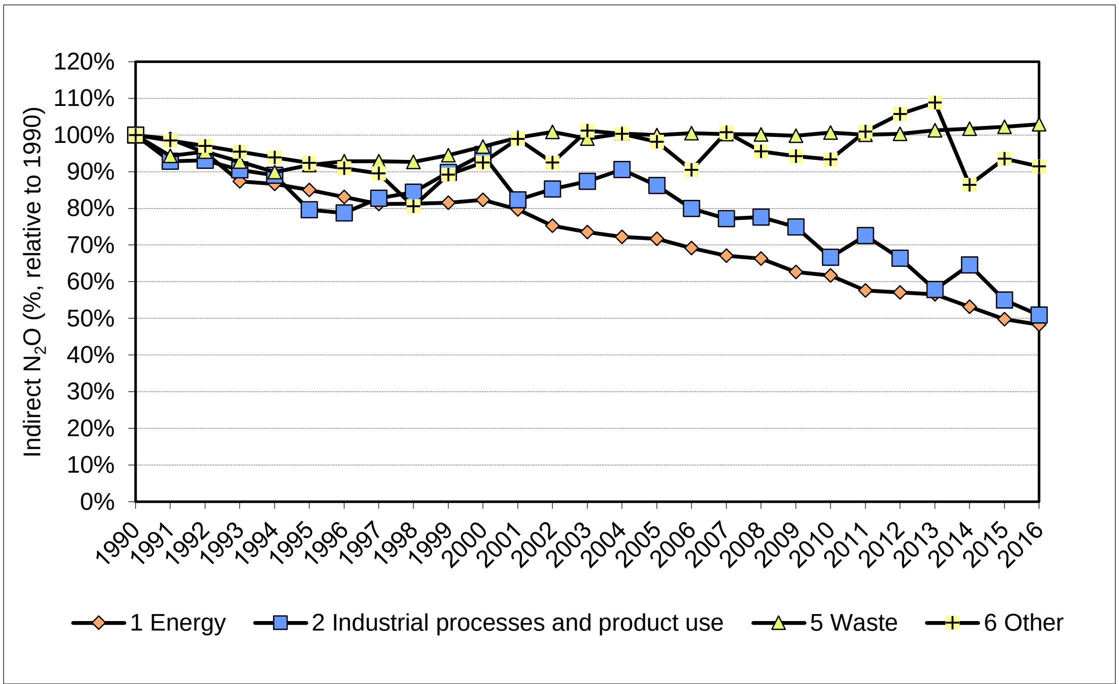


Figure 9-4 Relative trends of the indirect N_2O emissions by sector. The base year 1990 represents 100%.

9.2 Methodological issues

9.2.1 Methodological issues to derive indirect CO_2 emissions

Table 9-3 Key categories of indirect CO_2 emissions. Combined KCA results, level for 2016 and trend for 1990-2016, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

A	B	C	D
Code	**IPCC Category**	**GHG**	**Identification Criteria**
2	Indirect CO2 emissions	CO2	T1, L2, T2

Indirect CO_2 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 CO_2 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 CO_2 emissions (Em) result from the following equations:

$$Em_{CO2,\ indirect\ from\ NMVOC} = Em_{NMVOC,\ fossil} * 0.6 * 44/12$$

$$Em_{CO2,\ indirect\ from\ CO} = Em_{CO,\ fossil} * 44/28$$

Activity data for the calculation of indirect CO_2 emissions

Activity data to calculate indirect CO_2 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 (CO_2) 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%), CO_2 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 CO_2 emissions. The respective emissions are thus implicitly reported as direct CO_2 emissions in 1A and no indirect CO_2 emissions from 1A Energy are reported (see chp. 3.2.4.4.1).

1B Fugitive emissions from fuels: CO_2 resulting from the atmospheric oxidation of NMVOC and CO emitted from source category 1B is reported as indirect CO_2 emissions unless it is already accounted for implicitly as direct CO_2 emissions in 1B (chp. 3.3). For 1B, Table 9-4 illustrates in which processes CO and NMVOC emissions occur, and whether the related CO_2 emissions are reported as indirect CO_2 emissions or implicitly as direct CO_2 emissions. In summary, all CO_2 resulting from the atmospheric oxidation of CO emitted from 1B is implicitly included in 1B as direct CO_2 and is therefore not reported as indirect CO_2.

CO_2 resulting from the atmospheric oxidation of NMVOC emitted from 1B is reported as indirect CO_2, except for CO_2 from source category 1B2c, where an oxidation factor of 100% is applied to calculate direct CO_2 emissions.

Table 9-4 Sources of indirect CO_2 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:	*Leakage:* -	*Leakage:* Indirect CO_2 emissions reported in chp. 9
	Crude oil: -	*Crude oil:* -
1B2a v, Oil - Distribution of oil products:	*Gasoline storage tank:* -	*Gasoline storage tank:* Indirect CO_2 emissions reported in chp. 9
	Gasoline station: -	*Gasoline station:* 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	*Distribution:* -	*Distribution:* -
	Leakage gas pipeline: -	*Leakage gas pipeline:* Indirect CO_2 emissions reported in chp. 9
	Other leakage: -	*Other leakage:* Indirect CO_2 emissions reported in chp. 9
1B2b vi, Other (losses due to major accidents)	-	Indirect CO_2 emissions reported in chp. 9 (Emissions occur only in 2010 and 2011)
1B2c Venting and flaring	*Flaring:* CO_2 emissions from CO are reported in 1B2c a as direct CO_2 emissions (CO_2 EF assumes an oxidation of 100%)	*Flaring:* CO_2 emissions from NMVOC are reported in 1B2c a as direct CO_2 emissions (CO_2 EF assumes an oxidation of 100%)
	H_2 Production: -	*H_2 Production:* -

2 Industrial processes and product use: Except for NMVOC emissions from the cracker reported in source category 2B8b Ethylene, CO and NMVOC emissions from 2C1 Secondary steel production, electric arc furnaces and CO emissions from anodes in source category 2C3 Primary aluminium production, none of the CO_2 emissions resulting from the atmospheric oxidation of NMVOC and CO emitted from sector 2 are already considered under the direct CO_2 emissions of this sector. The CO_2 emissions from 2C1 Secondary steel production, electric arc furnace are based on a carbon mass balance considering all carbon sources and sinks of the process. Therefore, the emissions of both CO and NMVOC are not accounted for as indirect CO_2 emissions from sector 2 IPPU. Also CO_2 emissions from the cracker reported in source category 2B8b Ethylene are based on a carbon mass balance considering all carbon sources and sinks of the process. Therefore, these NMVOC emissions are not accounted for as indirect CO_2 emissions from sector 2 IPPU. For CO emissions from 2C3 Primary aluminium production full oxidation of the anodes is assumed and these emissions are therefore not included in the indirect emissions (see chp. 4.4.2.2). On the other hand the NMVOC emissions from 2C3 Primary aluminium production originate solely from the production of the electrodes at the plants. Therefore, they have to be considered for the calculation of indirect CO_2 emissions.

In addition, before indirect CO_2 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.

In source categories 2D3a and 2G4 both direct CO_2 emissions from post-combustion of NMVOC and indirect CO_2 emissions from oxidation of NMVOC in the atmosphere occur. The amount of NMVOC that is destroyed in post-combustion facilities is assessed separately and the resulting CO_2 emissions are reported in the respective source categories 2D3a and 2G4. This amount of NMVOC is not part of the reported NMVOC emissions of source categories 2D3a and 2G4 which are used to calculate indirect CO_2 emissions that are reported in CRF Table6.

3 Agriculture and 4 LULUCF: NMVOC and CO emissions from the sectors 3 Agriculture and 4 LULUCF are of biogenic origin. Accordingly, no indirect CO_2 emissions are reported for these sectors.

5 Waste: NMVOC and CO emissions from sector 5 Waste contain fossil and biogenic shares. Only CO_2 resulting from the atmospheric oxidation of fossil NMVOC and CO is reported as indirect CO_2. 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 CO_2 resulting from the atmospheric oxidation of fossil NMVOC and CO is reported as indirect CO_2. Emissions of fossil NMVOC and CO stem from the following processes:

- Fire damage estate: The share of fossil CO and NMVOC emission is assumed to be equal to the share of fossil CO_2 emissions, see chp. 8.2 (6Ad).
- Fire damage motor vehicles: The share of fossil CO and NMVOC emission is assumed to be 100%, see chp. 8.2 (6Ad).

9.2.2 Methodological issues to derive indirect N_2O emissions

Indirect N_2O emissions are estimated using a country-specific method according to a study of indirect N_2O emissions induced by nitrogen deposition in Switzerland (Bühlmann 2014, Bühlmann et al. 2015). In this study, ecosystem-specific emission factors for indirect N_2O 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 N_2O 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 N_2O-N per N-deposition (deposited in form of NO_x or NH_3, 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 N_2O 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 N_2O emissions induced by the deposition of NO_x and NH_3 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 NO_2 equivalents) and NH_3 emissions using the stoichiometric conversion according to the following equation:

$$\text{Mass-N} = \text{Mass-NO}_{2,eq} * 14/46 + \text{Mass-NH}_3 * 14/17$$

Activity data for the calculation of indirect N_2O emissions

The activity data to calculate indirect N_2O emissions from a specific sector corresponds to the NO_x and NH_3 emissions reported in the respective source categories. However, the following exceptions need to be considered:

- Indirect N_2O emissions from sector 3 Agriculture are reported in the respective sector together with direct N_2O emissions (chp. 5.3.2.5.4 Volatilisation of NH_3 and NO_x from manure management systems, chp. 5.5.2.3 Indirect N_2O emissions from atmospheric deposition of N volatilised from managed soils (3Db1) and chp. 5.5.2.4 Indirect N_2O emissions from leaching and run-off from managed soils (3Db2)).
- For sector 6, the only indirect N_2O emissions to be considered are those resulting from NO_x emissions in source category 6Ad Fire damages. All other indirect N_2O emissions are included in sector 3 Agriculture together with direct N_2O emissions.

9.2.3 Uncertainties and time series consistency

Indirect CO_2 emissions are included in the uncertainty analysis, but indirect N_2O emissions are not included.

Uncertainties of indirect CO_2 emissions are based on respective uncertainties of NMVOC and CO emissions. Uncertainties of NMVOC emissions are estimated based on AD and EF uncertainties as documented in Switzerland's Informative Inventory Report 2018 (FOEN 2018f). The estimated uncertainties distinguish between fossil and biogenic shares. Uncertainties of CO emissions are estimated based on AD uncertainties documented in Switzerland's Informative Inventory Report 2018 (FOEN 2018f) and EF uncertainties are based on expert judgements and uncertainties provided by the EMEP/EEA Guidebook.

Combined uncertainties of indirect CO_2 emissions amount to 23% for indirect CO_2 emissions from sector 1 Energy, 150% for indirect CO_2 emissions from sector 2 IPPU, 48% for indirect CO_2 emissions from sector 5 Waste and 60% for indirect CO_2 emissions from sector 6 Other.

Consistency: Time series for indirect CO_2 and N_2O 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 NH_3 related source categories in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.

9.2.5 Category-specific recalculations

- 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 NH_3 related recalculations reported in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.

9.2.6 Category-specific planned improvements

No category-specific improvements are planned.

10 Recalculations and improvements

10.1 Explanations and justifications for recalculations, including in response to 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 2018), 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).

For the current submission, reporting tables CRF Summary3s1 and Summary3s2 were updated for all sectors.

Table 10-1 Recommendations from the ERT based on the Review Report FCCC/ARR/2017/CHE (UNFCCC 2018) and explanations for implementation 2018.

ID	classification	recommendations from ARR 2017	Answer including ref to chapter in NIR
General			
G.4	Recalculations	Switzerland described in the NIR (section 10.3) the implications of recalculations for the emission trends. It provided data for the years 1990 and 2014 showing the change of the emission trend owing to recalculations between the previous and the current inventory submissions. More information was provided within the sectoral chapters of the NIR, and an extensive list with all detailed recalculations and specifics of the recalculations compiled by EMIS experts was made available to the ERT during the review week. The ERT concludes that the impact of recalculations on the emission trend for 1990–2014 cannot be assessed with the information provided in the NIR on the base year and the inventory year only. If this information is confidential, the Party could provide the consistency of the recalculated trends for 1990–2014, in the form of indices for instance. The ERT recommends that the Party provide in the NIR information on recalculations for the whole time series.	Figures showing implications of recalculations by gas and by source category, as well as the aggregated impact of recalculations on total emissions including and excluding LULUCF for the entire time series were added in chp. 10. The figures show the difference in terms of absolute values between the latest and the previous submission.
G.5	Commitment period reserve	The ERT noted that Switzerland reported the commitment period reserve in NIR (section 12.5 p.515) as 325,591.674 kt CO2 eq calculated as 90 per cent of the assigned amount. However, according to the review report of the report to facilitate the calculation of the assigned amount for the second period of the Kyoto Protocol (FCCC/IRR/2016/CHE) the correct value calculated as 90 per cent of the assigned amount is 325,591.672 kt CO2 eq. The ERT further noted that a similar situation occurs for the assigned amounted, the correct value of which is 361,768.524 kt CO2 eq. The ERT recommends that Switzerland report the correct value of the commitment period reserve in future annual submissions.	Chapter 12 has been revised accordingly.
Energy			
E.3	1.A.1.a Public electricity and heat production – other fuels – CH4 Transparency	Addressing. The Party claimed in the NIR (section 3.2.5.2.1) as well as during the review that emissions of CH4 do not occur in waste incineration plants according to a study conducted by EMPA in 2013. In the study EMPA evaluated measurements that were performed in 2011 at five Swiss MSW incineration plants with different nitrogen oxides reduction techniques (e.g. selective catalytic reduction and selective non-catalytic reduction). The study showed that CH4 emissions from waste incineration were mostly below the detection limit of 0.3 ppm, and the study concluded that CH4 emission concentrations were very low and below the background concentration of 1.8 ppm. Switzerland report these emissions as "NA", but the ERT considers that CH4 emissions from waste incineration should be reported as "NE" together with the explanation that these emissions are insignificant.	notation key changed from NA to NE in Table 1A(a)s1 and explanation included in Table 9
E.7	1.A.2.f Non-metallic minerals – biomass – CH4 Adherence to the UNFCCC Annex I inventory reporting guidelines	Addressing. The notation key has been changed as recommended. The NIR (section 3.2.6.2.7) explains that all CH4 emissions from biomass used as fuel in non-metallic minerals (cement production) are reported under "other fossil fuels". However, still missing is explanatory information in CRF table 9.	notation key changed from NO to IE in Table 1A(a)s2 and explanation included in Table 9
E.8	1.A.3.b Road transportation – biomass – CO2, CH4 and N2O Accuracy	Addressing. The Party explained in the NIR (sections 3.2.9.6 and 10.4) as well as during the review that a general update of the parameters, EFs and AD is ongoing for the road transportation model, whereby the error will be corrected and the updated results will be presented in the 2018 or, latest, 2019 annual submission.	The NCV of biodiesel and bioethanol have been changed to their specific values (differing from diesel and gasoline). See chp. 3.2.4.2 Net calorific values (NCV)
E.12	1.B.2.c Venting and flaring – natural gas – CO2, CH4 and N2O Completeness	Not resolved. During the review the Party informed the ERT that CO2, CH4 and N2O emissions for category 1.B.2.c.ii (flaring of natural gas) were estimated for the period 1990–1994 using default EFs from the 2006 IPCC Guidelines (only one production plant was in operation through 1994), and a short description was provided in the NIR (section 3.3.5.2). However, the emissions have not yet been included in the CRF tables (the Party still reported "NE" in CRF table 1.B.2). The Party confirmed that this will be corrected in the next annual submission.	Emissions from flaring during gas production (1990-1994) are now included in CRF table 1.B.2.
E.15	1.B.2.b Natural gas – natural gas – CH4	Switzerland reported in the NIR (section 3.3.4.5, p.189) that for categories 1.B.2.b.4 (transmission and storage) and 1.B.2.b.5 (distribution) the recalculations for CH4 emissions for the period 1990–2014 were carried out due to the update of the employed calculation tool, with minor corrections of individual natural gas loss rates, minor corrections of AD from the Swiss gas network as well as minor changes to the polynomial interpolations for years with insufficient data from the gas network available. The ERT noted that these recalculations resulted in a change for the period 1990–2013 that exceeds the threshold (2 per cent). In addition, the NIR (p.188) stated that, for some (earlier) years in the time series, sufficient input data were not available to calculate the gas losses. For those years, polynomial interpolations were applied to assess the AD. However, the Party has not provided in the NIR a detailed description of the updates, minor corrections to the employed calculation tool or minor changes to the polynomial interpolations, nor of how those minor corrections resulted in a recalculation change that exceeds the 2 per cent threshold. The ERT recommends that the Party ensure that the next recalculations for the energy sector are reported in a comprehensive and transparent manner.	The calculation of gas transmission and distribution losses is done in a calculation tool. It is therefore difficult to document recalculations in the NIR without direct reference to the tool. Switzerland made great efforts to document the changes to input parameters and the resulting changes to emissions. Should this be considered insufficiently transparent, the tool will be made available to reviewers.
E.16	1. General (energy sector) – solid fuels – CO2	Table A-33 (NIR, p.565) indicates that there are some imports and consumption of anthracite and coke oven coke in Switzerland (e.g. 7 Gg anthracite and 18 Gg coke oven coke in 2010). The NIR (p.83) also states that other bituminous coal (anthracite) is used as feedstock in the Swiss production plant for silicon carbide and graphite in category 2.B.5 (carbide production). However, the ERT noted that the notation key "NO" was used for reporting anthracite and coke oven coke in CRF tables 1.A(b) and 1.A(d). During the review, the Party informed the ERT that the Swiss overall energy statistics distinguish only between other bituminous coal and lignite, without further disaggregation. "NO" was chosen for the reporting of anthracite and coke oven coke in CRF tables 1.A(b) and 1.A(d) as they are not listed in the data files that the inventory team receives from the Swiss Federal Office of Energy. The Party also notified that, as shown in annex 4 to the NIR, the coal consumption reported to IEA and in the reference approach agree at an aggregated level. Therefore, in view of the apparent disaggregation in the reporting to IEA, the Party agreed that it could use "IE" instead. The ERT recommends that the Party make efforts to acquire statistical data to allow disaggregating AD and GHG emissions for anthracite and coke oven coke use, or, if this is not possible, change the reported notation key for anthracite and coke oven coke in CRF tables 1.A(b) and 1.A(d) from "NO" to "IE" for the years 1990–2015, with a description in the NIR and CRF table 9 that anthracite and coke oven coke have been aggregated under other bituminous coal.	In CRF table 1.A(b), the notation keys of import and stock change of anthracite and coke oven coke have been changed from "NO" to "IE" for the years 1990–2015 whereas the indication of the feedstock use of anthracite for silicon carbide production has been relocated from other bituminous coal to anthracite (notation key "C"). Table 9 does not allow to include explanations for notation keys of Table 1.A(b) and 1.A(d).

Table 10-1 continued.

ID	classification	recommendations from ARR 2017	Answer including ref to chapter in NIR
E.17	Fuel combustion – reference approach – gaseous fuels – CO2	The NIR (p.186) states that there was a single natural gas production plant operating in Switzerland during the years 1985–1994 (see ID#s E.11 and E.12 in table 3). The ERT notes that CRF table 1.B.2 reported a numerical value for natural gas production for the years 1990–1994, for example 0.13 PJ for 1990. Nevertheless, "NO" was reported for natural gas production in CRF table 1.A(b) for the years 1990–1994. During the review, the Party confirmed that in the reference approach (CRF table 1.A.b) all natural gas was reported as imported, including the natural gas from domestic production. Therefore, natural gas production in Switzerland in the period 1990–1994 was included in both the sectoral and the reference approach; however, it was reported in the wrong column for the reference approach (under import instead of production). The ERT recommends that the Party report the amount of natural gas production under the column "production" instead of under "import" for the years 1990–1994 in CRF table 1.A(b).	In CRF table 1.A(b), the amount of natural gas production in Switzerland (1990-1994) is now reported explicitly in the column "production" instead of "import".
E.18	1.A.2 Manufacturing industries and construction – biomass – CO2, CH4 and N2O	Switzerland explained in the NIR (p.133) that, because no comprehensive information exists to distribute biomass consumption to the specific industries within category 1.A.2 (manufacturing industries and construction), biomass is reported under category 1.A.2.g.viii (other). However, the ERT noted that in CRF table1.A(a)s2 values for biomass consumption were reported for category 1.A.2.d (pulp, paper and print) for 1990–2008, and for 2009 onward the notation key "NO" was reported. The ERT also noted that consumption of biomass was reported for categories 1.A.2.f (non-metallic minerals) and 1.A.2.g.iv (wood and wood products). During the review, the Party informed the ERT that biomass consumption data were available for category 1.A.2.d between 1990 and 2008 and are related to the biomass used in the cellulose production plant, which closed in 2008. According to the Party, currently there is no comprehensive information available to distribute biomass consumption to specific industries, except for biomass used in cement production and fireboard production, which has already been reported under categories 1.A.2.f and 1.A.2.g.iv, respectively. Therefore, biomass used in category 1.A.2 that could not be allocated to any other specific source category was reported under category 1.A.2.g.viii. In addition, the Party explained that the amount of biomass that could not be allocated was most probably used in categories 1.A.2.d (pulp, paper and print), 1.A.2.e (food processing, beverages and tobacco), 1.A.2.f (non-metallic minerals) and 1.A.2.g.iv (wood and wood products). The ERT recommends that the Party make efforts to acquire statistical data to allow the reporting of GHG emissions from biomass split between categories 1.A.2.d, 1.A.2.e, 1.A.2.f and 1.A.2.g.iv. Where this is not possible, report the appropriate notation key "IE" instead of "NO" and indicate in the CRF table 9 (completeness table) that emissions for the relevant categories are reported under category 1.A.2.g.viii.	No statistical data are available to allow the reporting of GHG emissions from biomass split between categories 1.A.2.d, 1.A.2.e, 1.A.2.f and 1.A.2.g.iv but for source categories 1.A.2.f and 1.A.2.g.iv bottom-up information for a number of manufacturing industries is provided mainly based on monitoring reports of the Swiss Emissions Trading System. Therefore, the notation keys "IE" instead of "NO" are reported for GHG emissions from biomass use in source categories 1.A.2.d and 1.A.2.e where no information of biomass use is available at all. Corresponding information was added in the description of the activity data for 1.A.2.d, 1.A.2.e, 1.A.2.f and 1.A.2.g.iv in chp. 3.2.6.2.5 - 3.2.6.2.8.
E.19	1.A.3.b Road transportation – liquid and gaseous fuels – CO2, CH4 and N2O	The Party reported in the NIR (pp.83, 84, 92 and 159) that fuel sold in Switzerland but consumed abroad ('fuel tourism') is accounted for in Switzerland's GHG inventory and reported under category 1.A.3.b.viii. However, the ERT could not find category 1.A.3.b.viii in CRF table 1.A(a)s3, nor find fuel tourism reported under category 1.A.3.b.v (other). During the review the Party informed the ERT that the description in the NIR is incorrect, that fuel tourism is treated as a separate category in the EMIS database (1.A.3.b.viii) and that, when data are exported to the CRF Reporter, the data for fuel tourism are added to category 1.A.3.b.i (cars) if the fuel is gasoline, and to category 1.A.3.b.iii (heavy-duty trucks and buses) if the fuel is diesel. The ERT recommends that the Party correct the description of the allocation of fuel tourism and associated emissions in the NIR to explain that data for fuel tourism are added to category 1.A.3.b.i (cars) if the fuel is gasoline and to category 1.A.3.b.iii (heavy-duty trucks and buses) if the fuel is diesel.	Fuel tourism emissions for gasoline and gas consumption are included in 1A3b i Cars, diesel oil emissions are included in 1A3b iii Heavy duty trucks and buses. See corresponding description in chp. 3.2.9.2.2 Road Transportation.
E.20	1.A.3.b Road transportation – liquid and gaseous fuels – N2O	Switzerland reported in the NIR (p.162) that the cold-start N2O EFs for 2015 are 0.011 kg/TJ (for passenger cars –gasoline) and 0.025 kg/TJ (for light-duty vehicles). However, in the NIR (p.160) the Party also provided the equation for estimating start emissions with the number of starts as AD. During the review, the Party explained that cold-start emissions for air pollutants and GHGs (except N2O) were calculated by means of an EF in g/cold start, as stated in the NIR (p.160). Cold-start excess emissions of N2O were previously not calculated because they were considered not to be relevant. However, owing to a recommendation made by the ERT during the review in 2016 (see E.9 in table 3), Switzerland provided estimations for N2O cold-start emissions for the 2017 annual submission applying the latest version of the COPERT model, as suggested by the previous ERT. The COPERT method deviates from the Swiss method: it connects the cold-start excess emissions to the fuel consumption and not to the number of starts. Therefore, the EFs in the NIR (p.162) are given in kg/TJ. The ERT notes that, in the NIR (p.160), a corresponding reference to the exception for the N2O modelling was not provided. The Party informed the ERT that, for the next submission, the cold-start excess emissions for each air pollutant or GHG will be integrated into the Swiss road transportation model. The ERT welcomes Switzerland's efforts and recommends that the Party estimate cold-start excess emissions of N2O using the Swiss road transportation model and describe in NIR the method and assumptions used.	The Copert method has been applied for the current submission again. A consistent modelling of the cold start excess emissions with the approach according to the Handbook of Emission Factors will be implemented in future submissions, after the next update of the road transportation model.
E.21	1.A.3.b.ii Light-duty trucks – gaseous fuels –CO2, CH4 and N2O	Switzerland reported in the NIR (p.162) that an inconsistency in the attribution of natural gas to the vehicle categories led to an error in the IEFs for gas-driven light-duty vehicles, and that the error will be corrected for the next submission. No further information was provided in the NIR. During the review, the Party explained that the consumption of natural gas (as compressed natural gas) in road transportation started in 2005 but the road transportation model at that time did not contain any other fuel types than gasoline and diesel oil. The model was only extended in 2010, and the first reporting of natural gas consumption in category 1.A.3.b happened in the 2011 NIR (section 3.2.9, p.139). Because the penetration of bifuel (compressed natural gas/gasoline) light-duty vehicles in the Swiss vehicle fleet happened slowly and only very few bifuel light-duty vehicles were in operation in 2010, an error in the dynamical fleet model that affects the accuracy of the AD for bifuel light-duty vehicles was not detected. The error was only detected when the IEF for compressed natural gas of light-duty vehicles was reported for the first time in the 2015 NIR. The Party also stated that a full update of the road transportation model is ongoing and the error will be corrected. The ERT welcomes Switzerland's efforts and recommends that the Party correct the error related to the AD for bifuel light-duty vehicles during the ongoing full update of the road transportation model and report the results in the NIR.	The error is corrected. See Table 3-75 in chp. 3.2.9.2.2.

Table 10-1 continued.

ID	classification	recommendations from ARR 2017	Answer including ref to chapter in NIR
E.22	1.A.3.b.iv Motorcycles – lubricant oil – CO_2, CH_4 and N_2O	Switzerland reported in the NIR (pp.82 and 228) that lubricants are used in a variety of processes, including blending with motorcycle fuel; and that lubricants in engines are primarily used for their lubricating properties, and the associated CO_2 emissions are therefore reported as non-combustion emissions under source category 2.D.1 (lubricant use). The Party also reported (p.82) that 20 per cent of lubricants are oxidized during use. According to the 2006 IPCC Guidelines (volume 2, chapter 3.2.1.4), lubricants intentionally mixed with fuel and combusted in road vehicles should be reported as energy and the associated emissions calculated using mobile source guidelines. During the review, the Party informed the ERT that, after further enquiries with the Swiss Federal Office for Energy regarding the allocation of lubricants in two-stroke gasoline engines in the Swiss overall energy statistics, only the gasoline part of two-stroke oil is allocated to gasoline, while the lubricants are listed under non-energy use of oil products. Therefore, in the Swiss inventory, emissions of CO_2, CH_4 and N_2O from the oxidation of lubricants used in two-stroke engines are not fully estimated owing to the allocation under non-energy use (with the value for oxidation during use of 0.2, i.e. 80 per cent of CO_2 and 100 per cent of CH_4 and N_2O are reported as "NE"). In response to a follow-up question, the Party estimated that the range of total lubricant use in two-stroke engines is 200–500 t in road transportation and 140–250 t in non-road application. However, the emissions not estimated are well below the significance threshold (on the basis of CRF table summary 2, this threshold is 24.08 kt CO_2 eq for Switzerland) in accordance with decision 24/CP.19, annex, paragraph 37(b). The ERT recommends that the Party either provide additional information to justify that the CH_4 and N_2O emissions not estimated due to their current allocation under category 2.D.1 are below the significance threshold as contained in decision 24/CP.19, annex, paragraph 37(b) or estimate the full emissions of CO_2, CH_4 and N_2O for lubricants blended with motorcycle fuel, reporting them under category 1.A.3.b.iv.	Emissons from use of lubricant in 2-stroke engines are modelled and reported. See recalculations in 3.2.8.5, 3.2.9.5, 3.2.10.5, 3.2.11.5, 4.5.5
E.23	1.A.4.b Residential – biomass – CO_2, CH_4 and N_2O	Switzerland indicated in the NIR (p.147) that the total wood demand for bonfires is assumed to be constant (160 TJ) over time, without providing further information to justify this assumption. However, the ERT noted that the population of Switzerland increased by almost 16 per cent from 1990 to 2015. During the review, the Party explained that the assumption is based on the per capita consumption of wood for bonfires decreasing from 2 kg/capita to 1.5 kg/capita between 1990 and 2015, owing mainly to an increase in the use of gas barbecue grills. However, in response to a follow-up question, the Party informed the ERT that the assumption is based on the judgment of the inventory team, and there are no supporting materials for the assumption and no figures available on the use of gas barbecue grills. According to the ERT, a 16 per cent increase in the population (between 1990 and 2015) would have increased the total wood demand, approximately, from 160 TJ to 186 TJ of biomass, resulting in a very small increase in CH_4 emissions and an even smaller increase in N_2O emissions that is below the threshold of significance according to paragraph 37(b) of the UNFCCC reporting guidelines. As the underestimate is below the threshold of significance, it would also be below the threshold for commencement of an adjustment procedure in accordance with paragraph 80(b) of the annex to decision 22/CMP.1, and therefore was not listed as a potential problem. The ERT recommends that the Party justify that the per capita consumption of wood for bonfires decreased from 2 kg/capita to 1.5 kg/capita between 1990 and 2015 (owing mainly to an increase in the use of gas barbecue grills), or revise the estimates of CH_4 and N_2O emissions assuming constant per capita consumptions between 1990 and 2015.	In view of the insignificant emission level of this source category, no further investigations are planned to corroborate this assumption. Total wood demand for bonfires is assumed to be constant over time.
IPPU			
I.1	2. General (IPPU) – CO_2 Transparency	Addressing. The Party improved the description of the methodology used to estimate indirect CO_2 emissions in the NIR (see sections 4.4.2.1, 4.4.2.2 and 9.2.1). However, the description is still insufficient to understand thoroughly the methodology used by the Party.	The description of the methodology used to estimate indirect emissions was improved. For each source category in the IPPU sector it is indicated in the methodology chapter, if precursor emissions are accounted for as indirect emissions and that indirect emissions are exclusively reported in CRF table 6.
I.5	2.C.3 Aluminium production – PFCs Transparency	Not resolved. Switzerland explained that the aluminium production company closed in 2007 and that no additional information was found in the archives. However, the ERT is of the view that the Party could improve the information in the NIR (section 4.4.2.2) without providing any new assessment; for example, by simply including more information on the analysis of the measurements, including the comparison between measured values and the values for the European and global averages.	The text in chapter 4.4.2.2 has been revised to clarify the issue as much as possible and development of EF is illustrated. Given that the company closed down in 2006 and that no additional information was found in the archives, it will not be possible to provide any additional information regarding this issue.
I.9	2.F.1 Refrigeration and air conditioning – HFCs and PFCs Comparability	Addressing. The Party informed the ERT that efforts are ongoing to acquire additional statistical data, but so far the data quality is insufficient. In CRF table 2(II)B-Hs2, information is provided in the documentation box that "2.F.1 industrial refrigeration is included under commercial refrigeration"; however, the notation key "IE" has not been reported for the gases HFC and PFC under industrial refrigeration (row 25 of the CRF table).	Chp 4.7.2.1 describes the introduced split between industrial and commercial refrigeration for submission 2018.
I.12	2.G.4 Other (other product manufacture and use) – CO_2	For this category, no recalculations changed the emission/removal estimate for a category by more than 2 per cent and/or national total emissions by more than 0.5 per cent. However, according to the Party (NIR, section 4.8.5, p.263), during the recalculations, a double counting of NMVOC emissions from de-icing of aeroplanes for the years 1990–2006 was identified, which will be corrected for the 2018 annual submission. Since the NMVOC emissions are used to calculate indirect CO_2 emissions, the ERT recommends that, in the next submission, the Party provide a correct time series for NMVOC emissions from de-icing of aeroplanes and update the respective indirect CO_2 emissions reported in CRF table 6 and in the national totals.	A correct time series for NMVOC emissions from de-icing of aeroplanes is provided in chp. 4.8.2.4 - Other product use.
I.13	2.A.1 Cement production – CO_2	Switzerland reported in the NIR (section 4.2.2, p.199) that data on annual clinker production were provided by the industry association cemsuisse for the period 1990–2007 and that the data for 2008 onward were based on plant-specific annual monitoring reports from the Swiss ETS. However, the ERT noted that the composition of the raw material used for clinker production was not provided in the NIR, and not even in the guidelines of the Swiss ETS (provided to the ERT during the review), which would be needed to assess the correctness of the indicated value (525 kg CO_2/t clinker). During the review, Switzerland explained that the EF of 525 kg CO_2/t clinker used in the Swiss ETS corresponds to the value provided by the report from Cement Sustainability Initiative (2011) (see method B1, p.9). The Party also explained that data from the Swiss cement industry for the years 2008–2011 showed that the CaO content of clinker typically varied between 63 and 66 per cent, while MgO content was around 2 per cent. The Party also explained that, as these contents already contained fractions deriving from non-carbonate sources, it was decided to add a share for non-carbonate carbon and CKD (as described in the above-mentioned report). The Party further explained that for the current submission it was decided to revise the EF in order to establish a consistent time series from 1990 to 2015 and also to achieve consistency between the Swiss ETS and the GHG inventory. In order to facilitate the assessment by the ERT of the correctness of the CO_2 EF for the calcination process, the ERT recommends that the Party summarize in the NIR the information concerning the composition of the raw material and the methodology used to derive the country-specific EF.	Information on the methodology for calculating the emission factor for clinker was added in chp. 4.2.2.1

Table 10-1 continued.

ID	classification	recommendations from ARR 2017	Answer including ref to chapter in NIR
I.14	2.C.1 Iron and steel production	Switzerland reported CO2 emission from cupola furnaces in the energy sector under category 1.A.2.a (iron and steel). The Party explained that bituminous coal first of all acts as fuel in cupola furnaces, and because it was not possible to split the part that acts as fuel and as carburization material and reductant, it was decided to report the CO2 emissions under category 1.A.2.a. However, the ERT noted that according to 2006 IPCC Guidelines (volume 3, chapter 1, box 1.1): "combustion emissions from fuels obtained directly or indirectly from the feedstock for an IPPU process will normally be allocated to the part of the source category in which the process occurs. These source categories are normally 2B and 2C. However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of the Energy Sector source categories (normally 1A1 or 1A2)". In addition, the ERT noted that Switzerland reported CO2 emissions from limestone used in cupola furnaces under category 2.A.4.d (other uses of carbonates). However, according to the 2006 IPCC Guidelines (volume 3, chapter 2, p.2.6), it is good practice to allocate emissions from the use of limestone, dolomite and other carbonates to the industrial source category where they are emitted (e.g. iron and steel production). The ERT recommends that Switzerland, in accordance with the 2006 IPCC Guidelines, allocate CO2 emissions from bituminous coal and limestone used in cupola furnaces under category 2.C.1.	This recommendation is not implemented, since bituminous coal used in cupola furnaces primarily acts as fuel, but also as carburization material and reductant. Therefore, emissions are accounted for in source category 1A2a. This allows to be consistent with the allocation of bituminous coal in the Swiss overall energy statistics (SFOE 2017). A corresponding explanation was added in chp 3.2.6.2.2.
I.15	2.E.1 Integrated circuit or semi-conductor – HFCs, PFCs, SF6 and NF3	Switzerland reported in the NIR (section 4.6.2, p.238) the methodology used to estimate emissions from the electronics industry and stated that a survey within the electronics industry was carried out for the 2015 annual submission in order to distribute the imported substances to the different categories of electronic industry and to obtain information on waste air treatment. However, the ERT noted that no explanation was provided in the NIR on the approach used to select EFs. The ERT recommends that Switzerland describe in the NIR: the results of the survey carried out among users of the substances about the presence of exhaust treatments; the criteria used to characterize emission abatement at smaller installations for which no information was provided by the survey; and the reason why default EFs were used instead of the consumption and abatement data made available through the survey.	Chp 4.6.2 explains the information obtained in the survey. Only type of substances applied was reported and no information given on EFs
Agriculture			
A.1	3. General (agriculture) – N2O Adherence to the UNFCCC Annex I inventory reporting guidelines	Addressing. Switzerland updated CRF table summary 3s2 to include use of country-specific EFs, but some inconsistencies remain. The entries in CRF table summary 3s2 for reporting the tier method used for estimating N2O for categories 3.B and 3.D should be further amended to be consistent with the text in the NIR (sections 5.3.2.1 and 5.5.2.1). Therefore, the method in CRF table summary 3s2 for N2O for category 3.B should be reported as tier 2, and the method for N2O for category 3.D should be reported as country-specific tier 2.	CRF table Summary3s2 has been updated accordingly.
A.7	3. General (agriculture) – CH4 and N2O	The ERT noted that the livestock characterization for category 3.A (enteric fermentation) and 3.B (manure management) provided in NIR tables 5-3 and 5-10 (pp.270 and 284) includes "bison <3 years" and "bison> 3 years" under categories 3.A.4.a and 3.B.4.a (buffalo). However, it was not clear to the ERT whether the term "bison" does refer to bison (bison bonasus or bison bison) or if these livestock classes should be "buffalo". During the review, Switzerland confirmed that the term "bison" is correctly applied and that these animals are not buffalo. In addition, Switzerland provided data that supported the emission estimation for bison, and informed the ERT that it will report emission estimates for bison under categories 3.A.4 and 3.B.4 (other livestock/other (please specify)) in the future in order to prevent any confusion. However, in response to the draft report, Switzerland informed the ERT that the CRF Reporter does not allow a new category of livestock to be added beyond those already existing and that will continue to report "bisons" under categories 3.A.4.a and 3.B.4.a (buffalo). The ERT recommends that Switzerland provide a clear definition and description of the animal species reported under 3.A.4.a and 3.B.4.a (buffalo) and include some additional information in the NIR to give a short explanation of the data and assumptions that are used for the corresponding emission calculations.	Some additional clarification is provided in 5.2.2.3
A.8	3. General (agriculture) – CH4 and N2O	Switzerland provided emission estimates for rabbits under categories 3.A and 3.B. However, the ERT noted that there was no mention in the NIR of fur animals (except for rabbits) and whether emissions from other animal types are "NE" or confirmed as "NO". During the review, Switzerland provided documentation and a reference to a list of national legislation regarding the standards relating to farming fur animals such as mink and foxes, and explained that these prohibit commercial fur-farming. In particular, Switzerland confirmed that this is true for all years from 1990 onward, because provisions for the husbandry of wild animals were already very strict in the first Swiss animal protection law from 1978 and therefore standards were already prohibitive for commercial fur-farming before 1990. In addition, fur animals (other than rabbits) are not included in national livestock data. The ERT recommends that Switzerland explain in the NIR why fur animals (other than rabbits) are not included in the emission estimates under categories 3.A and 3.B and include references to the relevant documentation and national legislation.	Some additional clarification is provided in 5.2.1 and 5.3.1
A.9	3.B.5 Indirect – N2O emissions	Switzerland reported in the NIR (section 5.3.2.1, p.285) that N2O emissions from category 3.B (manure management) were estimated using a tier 2 methodology, that AD were adjusted to the particular situation of Switzerland in coordination with the Swiss ammonia model AGRAMMON, and that detailed country-specific data on nitrogen excretion rates, manure management system distribution and nitrogen volatilization were applied. The Party also reported that N lost and the resulting indirect N2O emissions from leaching and run-off from manure management systems under category 3.B.5 (indirect N2O emissions) were considered negligible and reported as "NO" in CRF table 3.B(b); however, no justification to support this assumption was provided in the NIR. During the review, Switzerland explained that the information provided in the NIR is principally based on the judgment of an expert (Thomas Kupper, from the School of Agricultural, Forest and Food Sciences) who is responsible for the Swiss ammonia model AGRAMMON, and it provided a list of technical articles that justify the expert judgment (that N leaching from animal waste management systems is negligible). However, in response to the draft report the Party informed the ERT that in fact the expert judgment is stating that leaching from manure management is not occurring although the wording "negligible" was used. The ERT recommends that Switzerland provide information in the NIR that supports the expert judgment, clarifying whether N leaching from animal waste management systems is negligible or not occurring, in line with the 2006 IPCC Guidelines (e.g. through the provision of expert judgment protocols, minutes of panels or meetings, reports, peer-reviewed articles).	Some additional clarification is provided in 5.3.1

Table 10-1 continued.

ID	classification	recommendations from ARR 2017	Answer including ref to chapter in NIR
A.10	3.C.4 Other (rice cultivation) – CH4	Switzerland reported "NO" for harvested area of upland rice in CRF table 3.C for the whole time series. However, the ERT noted that this is inconsistent with the information provided in the NIR. In the NIR (section 5.1, p.267) the Party reported that "Category 3.C (rice cultivation) does not occur in Switzerland", and in (section 5.4, p.302) the Party reported that "there is only some insignificant upland rice cultivation in the southern part of Switzerland and CH4 emissions are assumed to be zero". While the ERT recognizes that zero emissions may arise from upland rice, it considers that there is inconsistency in the current reporting and no explanation as to why "NO" was reported for the area of upland rice in CRF table 3.C. During the review, Switzerland explained that the notation key "NO" was reported incorrectly in CRF table 3.C and that although rice cultivation is occurring (approximately 80 ha) there are no associated emissions. The ERT recommends that Switzerland report the harvested area for upland rice in CRF table 3.C instead of the notation key "NO".	Area for upland rice production is included in CRF table 3.C
A.11	3.D.a.4 Crop residues – N2O	Switzerland reported in the NIR (p.308) the equation used for estimating N2O emissions from crop residues. The Party stated in the NIR that "standard values for fresh matter crop yields and N contained in crop residues are given in Flisch et al. (2009) and that for sugar beet and fodder beet it is assumed that 10 per cent of the crop residues are removed from the fields for animal fodder". However, the ERT noted that no comment was included in the NIR on other possible removal terms for crop residues that would reduce the amount of N that is eventually returned to the soil, such as removal of residue material for use as fuel or burned as waste. During the review, Switzerland explained that the use of crop residues for fuel or the (open) burning of crop residues are not common practice in the country and are subject to strong regulations. The ERT recommends that Switzerland explain in the NIR that the use of crop residues for fuel or the (open) burning of crop residues are not common practice in the country and are subject to strong regulations, and therefore not considered to be an activity that reduces the amount of N returned to soil in the country.	Some additional clarification is provided in 5.5.2.2.2
LULUCF			
L.1	Land representation – Transparency	Addressing. Switzerland included in the NIR (section 6.2.1, p.338) a clear definition of managed land, which states that all land except other land is considered managed. However, the NIR (section 6.1.3.1, p.329) also contains a statement that is ambiguous in relation to this issue: "In Switzerland, all land is considered to be managed". Switzerland clarified during the review that only other land is considered unmanaged. The Party indicated that it will clarify this issue in the next NIR.	L.1 was addressed in chp. 6.1.3.1, in chp. 6.2.1, and in chp. 6.4.1.
L.2	Land representation – Transparency	Not resolved. Switzerland stated in the NIR (section 6.3.6, p.349) that the description of the identification of the country-specific combination categories and subdivisions will be improved, but did not give an indication of when this improvement will be made.	L.2 was addressed in chp. 6.2.1.
L.6	4.A Forest land – CO2	Not resolved. Switzerland has indicated in the NIR (section 6.4.6, p.382) that data on the share of organic soils affected by past draining activities under forest land will be collected for the next annual submission, using additional descriptive information from the NFI surveys.	L.6 was addressed in chp. 6.4.2.10
L.8	4.A.1 Forest land remaining forest land – CO2	The ERT noted that Switzerland has recalculated its data for CO2 emissions/removals from forest land remaining forest land. The recalculations resulted in a considerable decrease in the removals of CO2. In the 2017 submission the values for CO2 (net emissions and removals) in 2014 for the category were lower by 749.35 kt (–44.75 per cent) compared with in the 2016 submission, which represents a change of 1.4 per cent of the national total emissions for Switzerland. The recalculation affects the years from 2006 onward, resulting in a pronounced shift in the time series between 2005 and 2006 and remaining more or less quantitatively constant for all years thereafter. During the review, Switzerland explained that the recalculation was due to the inclusion of the most recent NFI data (NFI4) for the period 2011–2015 (see NIR, sections 6.4.2.1 and 6.4.5). Switzerland further explained that changes in gains and losses of living biomass are calculated based on the differences between two NFIs, in this case NFI 3 and NFI 4, thereby affecting the values since 2005. The fact that the difference remains more or less constant for the years after 2006 shows that the calculation is internally consistent. During the review, Switzerland also referred to the background document Thürig et al. (2017) which shows and explains in a very detailed way all changes occurring as a result of using NFI 4 (2011–2015). The Party also clarified that the publication year for Thürig et al. (2015) in the reference list to the NIR (p.618) should be 2017 and informed the ERT that it will be corrected in the next submission. The ERT is of the view that the quantity of the change and its effect on the time series, described above, raises questions regarding time-series consistency for the category. The ERT recommends that Switzerland ensure that the time series is consistent in accordance with the 2006 IPCC Guidelines, or justify the validity of the reason behind the substantial inter-annual change in the time series for CO2 emissions/removals from forest land remaining forest land between 2005 and 2006; and explain why this introduction of data from NFI4 only affects the time period from 2006 onward by, for example adding to the NIR the information giving during the review and provided in Thürig et al. (2017).	L.8 was addressed in chp. 6.4.2.1
L.9	4.A Forest land – CO2	Chapter 4 of the 2006 IPCC Guidelines includes stumps as part of the biomass and dead organic matter pools. The ERT noted that stumps were not specifically mentioned in the NIR in relation to the methodological description on the quantification of living biomass and dead organic matter. Looking at the methodological reference contained in the NIR (Kaufmann, 2001), it is difficult to understand how stumps are partitioned from the rest of the biomass. Stumps makes up a sizeable portion of trees' biomass. It is important that the methodology for quantification of the stump portion is transparently described, especially since that part of the tree remains after harvest and needs to be transferred to the dead organic matter pool and included, in Switzerland's case, as input in the simulations with the Yasso07 model to determine changes in the soil organic matter pool. During the review Switzerland clarified that stumps were included and referred to as "stock" in table 6-15 of the NIR (p.353). The ERT recommends that Switzerland, in its NIR, improve its description of the quantification of stump biomass and how stumps after cutting are included in the dead organic matter pool and subsequently transferred as input to the Yasso07 model.	L.9 was addressed in chp. 6.4.2.3 and in chp. 6.4.2.6

Table 10-1 continued.

ID	classification	recommendations from ARR 2017	Answer including ref to chapter in NIR
Waste			
W.1	5.A Solid waste disposal on land – CH4 Transparency	Addressing. Switzerland has good-quality country-specific AD and well-documented historical data, and estimates emissions using the IPCC first order decay method with default parameters. The Party has updated the NIR (section 7.2.2, p.421), indicating the use of a tier 2 method as per the previous recommendation, but it has not updated CRF table summary 3s2 accordingly.	CRF table Summary3s2 has been updated accordingly.
W.3	5.B.1 Composting – CH4 Accuracy	Not resolved. Switzerland included this recommendation in its planned improvements in the NIR (section 7.3.6). The new AD will be fed into the 2018 annual submission.	AD and EF for Composting have been revised. Detailed explanations are given in chp 7.3.
W.8	5.C.2 Open burning of waste (biogenic) Transparency	Addressing. Switzerland corrected the AD in NIR table 7-17 (p.434) and CRF table 5.C. However, the values in NIR table 7-17 are split into agriculture and private households while those in the CRF table 5.C are aggregated. The ERT is of the view that the Party could include a footnote to NIR table 7-17 explaining the differences between the values in the NIR and the CRF table 5.C.	Amended text in chp. 7.4.2
W.11	5.C.2 Open burning of waste – CH4 and N2O	Switzerland reported in the NIR (section 7.4.1, p.430) that emission estimates for category 5.C.2 cover open burning of branches and garden waste. However, the ERT noted that the estimation methodology and how the data on branches burned were obtained were not clearly explained in the NIR. During the review, the Party explained that the data were obtained from cantonal authority statistics on the number of permitted fires and sanctions due to non- permitted fires, with the amount of burned material in those cantons quantified; and given that there are a significant number of unreported cases, it was assumed that the actual amount of material burned was three times greater than the amount that has been approved by the authorities. On the basis of the numbers from the evaluated cantons, an extrapolation of the amount burned in Switzerland was made. The ERT recommends that Switzerland describe in the NIR how AD were obtained and which assumptions were made for estimating CH4 and N2O emissions from open burning of branches and garden waste.	More detailed explanations are given in chapter 7.4.2.
W.12	5.D Wastewater treatment and discharge –	The ERT noted that Switzerland estimated CH4 emissions from industrial and commercial wastewater together, but no explanation or description of the sources of AD was included in the NIR (section 7.5). The ERT noted that the AD were expressed as the total organically degradable material in domestic and industrial/commercial wastewater. The use of "/" between industrial and commercial makes it ambiguous as to whether industrial and commercial wastewater were treated as the same or emissions from the two were added up. During the review the Party explained that, in general, wastewater from industrial or commercial companies is discharged into the connected public sewer system. Concerning wastewater streams, there is no difference between the terms "industrial" and "commercial". In order to be allowed to discharge wastewater into the public system, companies have to meet legal requirements (maximum allowed load factors for critical pollutants). If the wastewater is heavily polluted, there is the option of an on-site pretreatment, in order to lower the load and to meet the legal requirements of the discharged wastewater or in order to pay a lower discharge fee. The pretreated wastewater is then discharged into the public sewer system. The ERT recommends that Switzerland include in the NIR the explanation of the sources of AD for commercial and industrial wastewater.	More detailed explanations are given in chapter 7.5.1.
Other			
O.1	Sector 6 (other) – all fuels – CO2, CH4 and N2O	The ERT noted that in CRF table 8s3, recalculations for sector 6 (other) for the year 2014 resulted in a change of –18.7 per cent for CO2 emissions, –17.0 per cent for CH4 and –21.7 per cent for N2O. However, the explanation in the NIR did not reveal the underlying cause for such vast differences owing to the recalculations. During the review, the Party informed the ERT that: (a) for fire-damaged motor vehicles, AD for motor vehicles in the 2016 submission were assessed for the years 1990–2002 and then left constant at the value for 2002 (i.e. 610 t) for 2003 onward, and for the 2017 submission the time series has been updated with vehicle data up to 2015 and AD increased to a value of 750 t, which resulted in a significant change; and (b) for fire-damaged estates, for the 2016 submission, the amount of material burned for the respective process was estimated using statistical insurance data for the years 1992–2001. The resulting value of 8 kt was used for the whole time series and not estimated on a year-to-year basis. For the 2017 submission Switzerland decided to update the time series with statistical data from the insurance association, which are now available for the years 1996–2015. As a result, the AD now vary on a year-to-year basis (between 6.3 kt and 8 kt) over that time period. This resulted in a large percentage change and led, in sum with fire-damaged motor vehicles, to the detected decreases in emissions. The ERT welcomes the Party's efforts in estimating and reporting emissions from fire-damaged estates and motor vehicles under sector 6 (other) and recommends that the Party ensure that any recalculations are reported transparently in the NIR.	Text in chp. 8.2.2. has been updated accordingly.

Table 10-1 continued.

ID	classification	recommendations from ARR 2017	Answer including ref to chapter in NIR
KP-LULUCF			
KL.1	General (KP-LULUCF) – Gen Transparency	Addressing. For Switzerland's response to this recommendation, see the ERT assessment and rationale under IDs# L.1, L.2, L.4 and L.5 above. (L.12 (2016/2015) refers to an encouragement and is not included in this table 3). For the two resolved issues from the previous review (see IDs# L.4 and L.5 above), the necessary information in relation to KP-LULUCF was indicated by referencing in section 11 of the NIR the relevant parts of section 6, and the ERT found this sufficient.	L.1 was addressed in chp. 6.1.3.1, in chp. 6.2.1, and in chp. 6.4.1. L.2 was addressed in chp. 6.2.1. L.4 and L.5 were resolved.
KL.2	Afforestation and reforestation, and deforestation – CO_2 Accuracy	Not resolved. Switzerland reported in the NIR (sections 6.8.6, p.406, and 11.5.2.3, p.508) that "a revision of the assumption that only 50% of the difference between the carbon stocks before and after the change is reported as a source or sink" is included as a category-specific planned improvement.	KL.2 was addressed in chp. 6.1.3.2, in Tab. 6-3 and in chp. 11.3.1.4
KL.3	Deforestation – CO_2 Accuracy Forest management – CH_4 and N_2O	Not resolved. The Party has not resolved the previous recommendation to identify the areas of drained organic soils in forests accurately by collecting data on areas of organic soils under forest land affected by past draining activities. See the ERT assessment and rationale under ID# L.6 above.	L.6 and KL.3 were addressed in chp. 6.4.2.10
KL.4	Forest management – CH_4 and N_2O Transparency	Addressing. Switzerland provided an explanation for the reallocation of CH_4 and N_2O emissions from category 5.C.2 to category 4(V).A.1 in the NIR (section 6.4.2.13, p.374) in response to ID# L.7 above. The Party provided a short explanation about this reallocation under the section "technical correction forest management reference level" in its NIR (section 11.5.2.3, p.509) but without including any cross reference to NIR section 6.4.2.13 where the calculations and methods applied were reported.	KL.4 was addressed in chp. 11.5.2.3
KL.7	Harvested wood products – CO_2 Accuracy	Not resolved. Switzerland has added the issue to the list of planned improvements in the NIR (section 6.11.6, p.414). A study on how to determine domestic pulp in production of recycled paper will be carried out.	KL.7 was addressed in chp. 6.11.5: estimates of paper and paperboard were included as a subcategory of HWP. Further work on the determination of domestic pulp is planned (chp. 6.11.6).
KL.10	Forest management – CO_2	The ERT noted that the recalculation issue described in ID# L.8 above affects the KP-LULUCF reporting. The ERT recommends that Switzerland report the recalculations in relation to KP-LULUCF activities at the same time as the Party clarifies in the NIR the reason behind the substantial inter-annual change in the time series for CO_2 emissions/removals from forest land remaining forest land between 2005 and 2006 and explains why the introduction of data from NFI4 is only affecting the time period from 2006 onward (see ID# L.8 above).	KL.10 was addressed in chp. 6.4.2.1

Table 10-2 Encouragements from the ERT based on the Review Report FCCC/ARR/2017/CHE (UNFCCC 2018) and explanations for implementation 2018.

ID	classification	encouragements from ARR 2017	Details (This column can be used for NIR later)
General			
G.7	Uncertainty analysis	The Party included indirect CO2 emissions in the key category and uncertainty analyses for the first time for the 2017 inventory submission. According to the NIR (section 9.2.3), uncertainties of indirect CO2 emissions are taken from the Party's informative inventory report (FOEN, 2017) for CO and NMVOCs. The indirect emissions of CO2 from CO and NMVOCs are calculated according to the 2006 IPCC Guidelines (volume 1, chapter 7.2.1.5, box 7.2). This calculation assumes that CO and NMVOCs will be oxidized to CO2. The ERT noted that the uncertainty related to this assumption is not accounted for in the uncertainty analysis. During the review, the Party confirmed that the uncertainty of this estimation is not included in the analysis owing to a lack of reliable data on the uncertainty of the oxidation factors. The ERT encourages the Party to estimate the uncertainty of indirect CO2 emissions by taking into account the oxidation of atmospheric pollutants in order to increase the accuracy of its estimates.	Uncertainties were revised such that only the fossil shares are accounted for in the uncertainty analysis.
G.8	Key category analysis	The ERT noted that the key category analysis performed by the Party using approach 1 and 2 results in different categories contributing more than 10 per cent to the level assessment (NIR, p.40 for approach 1 and p.45 for approach 2). For example, under approach 1 (table 1-4) categories 1.A.3.b (CO2) – gasoline, 1.A.3.b (CO2) – diesel and 1.A.4.b (CO2) – liquid fuels each contribute more than 10 per cent to the level assessment, whereas under approach 2 (table 1-7) categories 4.A.1 (CO2) and 3.D.a (N2O) are the two categories contributing more than 10 per cent to the level assessment. However, the reasons for the differences are not transparently detailed in the NIR. During the review the Party informed the ERT that the uncertainty of each category is provided in the NIR (annex A2.1, table A2). The ERT encourages the Party to include in its NIR an explanation of any differences in the results of the key category analysis using approach 1 and approach 2, and how such a comparison contributes to prioritizing efforts for the continuous improvement of the inventory..	A short explanation of the differences (particularly of categories that are key under Approach 2, but not under Approach 1) has been included in Switzerland's NIR 2018 under chp. 1.5.1.2
Agriculture			
A.12	3.D.b.1 Atmospheric deposition – N2O	Switzerland reported in the NIR (section 5.5.3.2, p.313) that 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, and that an additional source, "volatilization of ammonia from the vegetation cover on agricultural soils and from alpine areas", was accounted for, assuming that 2.0 kg NH3-N/ha and 0.5 kg NH3-N/ha are emitted from agricultural land and the alpine area, respectively. However, the ERT noted that the latest version of the EMEP/EEA guidebook (EEA, 2016) (chapter 3.D, section 2.1.1, p.8) does not present a methodology for estimating NH3 emissions from standing crops and states that it has not yet been possible to develop a robust and usable methodology to calculate these emissions. During the review, Switzerland explained that, irrespective of the information provided in the latest (2016) version of the EMEP/EEA guidebook, it has extensive information from the literature that supports the estimation of NH3 directly volatilized from vegetation. Switzerland also indicated that a decision on the relevance and correctness of this emission source will be taken when the national agriculture expert group next meet with the GHG inventory group. The ERT encourages Switzerland to review the most up-to-date guidance material in the EMEP/EEA guidebook (currently the 2016 version) and the literature in general, and then review the inclusion of this emission source of NH3 when estimating N2O emissions for category 3.D.b.1.	A re-assessment of information regarding volatilisation of ammonia from vegetation cover on agricultural and alpine soils led to the conclusion that such emissions could not be substantiated. Therefore, indirect N_2O emissions from atmospheric deposition were revised for all years. Overall emissions decreased by 28.4 kt CO_2 equivalents on average
Waste			
W.10	5.B.1 Composting – CH4 and N2O	Switzerland reported in the NIR (section 7.3.3, p.429) that the uncertainty for category 5.B.1 of the CH4 EF was estimated at 40 per cent and is unknown for the N2O EF and therefore a combined uncertainty of 80 per cent was attributed. In response to a question raised by the ERT on why Switzerland did not include in its inventory improvement plan a provision to reduce the uncertainty of CH4 and N2O emissions from composting, the Party explained that efforts are under way to assess and improve AD, EFs and their uncertainties for both industrial and private composting, and that it is planned to include a new time series in the 2018 annual submission. The ERT encourages Switzerland to continue its efforts to improve AD and EFs for composting.	Results from recent re-assessment were used to recalculate emissions from composting (see 7.3.5).

10.1.2 Recalculations and improvements implemented in the current submission

10.1.2.1 Energy

Recalculations for sector 1 Energy are expressed quantitatively for changes of 1 kt CO_2 eq or larger, whereas smaller changes are described qualitatively. The description of recalculations in the following chapters follows the structure in chp. 3, i.e. all stationary sources are described first (chp. 10.1.2.1.5–10.1.2.1.7), followed by mobile sources (chp. 10.1.2.1.8-10.1.2.1.11).

10.1.2.1.1 Reference Approach

Reference approach (and non-energy use of fuels): The use of bitumen and lubricants of Liechtenstein (customs union with Switzerland) is now subtracted from the consumption reported by the Swiss petroleum association for the entire time series. See also 10.1.2.1.3.

10.1.2.1.2 International aviation / aviation bunkers

- Recalculation of the total use of kerosene in the aviation model due to changed calorific value of kerosene since submission 2015. This changed calorific value of kerosene has not been considered in the aviation model for the years 1999-2012 yet. This recalculation results in 18 TJ more kerosene in the year 1999 and 276 TJ more in 2012. This results in higher emissions in 2012 of: 20.1 kt CO_2.

10.1.2.1.3 Feedstocks and non-energy use of fuels

- Non-energy use of fuels: The use of bitumen and lubricants of Liechtenstein (customs union with Switzerland) is now subtracted from the consumption reported by the Swiss petroleum association for the entire time series. See also 10.1.2.1.1
- The lubricant amount of gasoline used in two-stroke engines of motorcycles and non-road transportation is now reported as fully oxidized in source category 2D1 Lubricant use. This results in an increase in emissions in 2D1 of 1.5 and 0.5 kt CO_2 eq in 1990 and 2015, respectively, and reduces the amount of carbon stored accordingly.

10.1.2.1.4 Category-specific recalculations for 1A and 1B in general

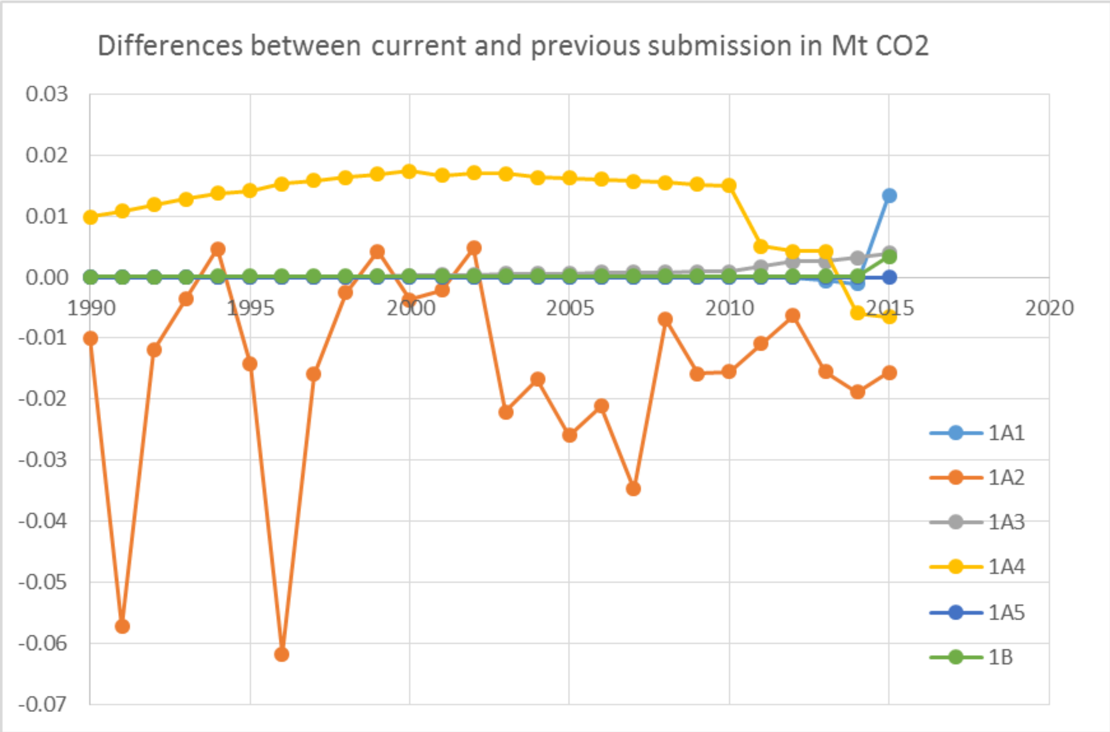


Figure 10-1 Differences in CO_2 emissions (in Mt CO_2) between the current and the previous submission for various source categories in the energy sector. Positive values refer to higher emissions and negative values to lower emissions in the current compared to the previous submission.

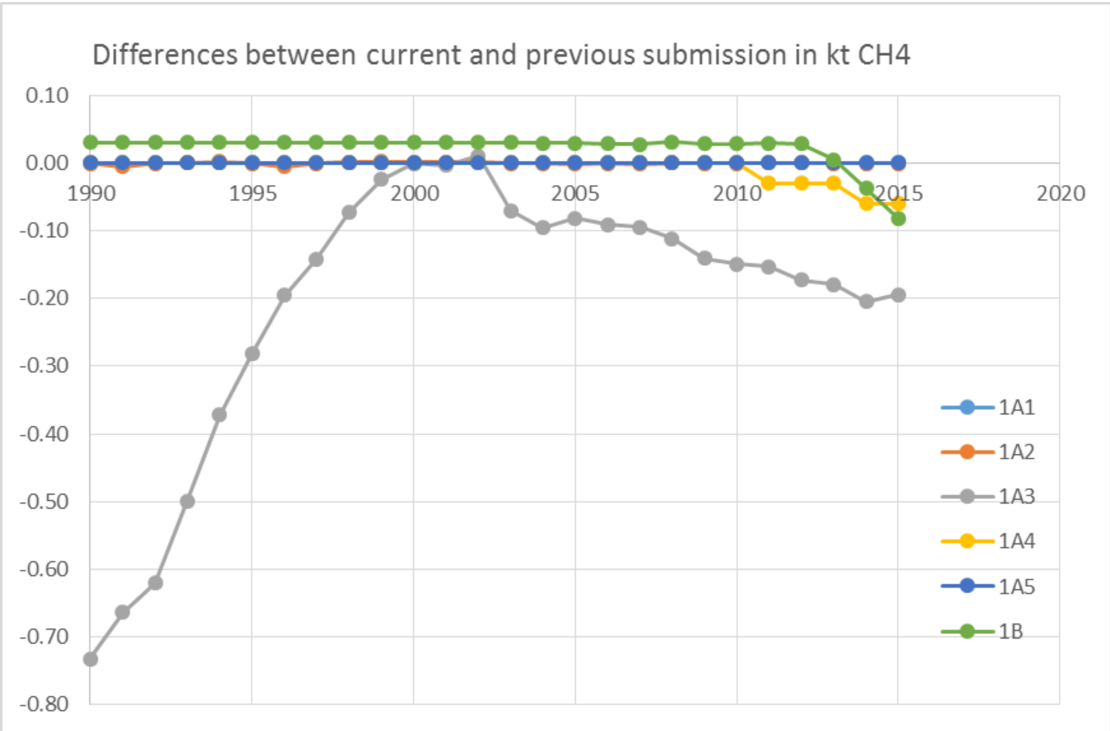


Figure 10-2 Differences in CH_4 emissions (in kt CH_4) between the current and the previous submission for various source categories in the energy sector. Positive values refer to higher emissions and negative values to lower emissions in the current compared to the previous submission.

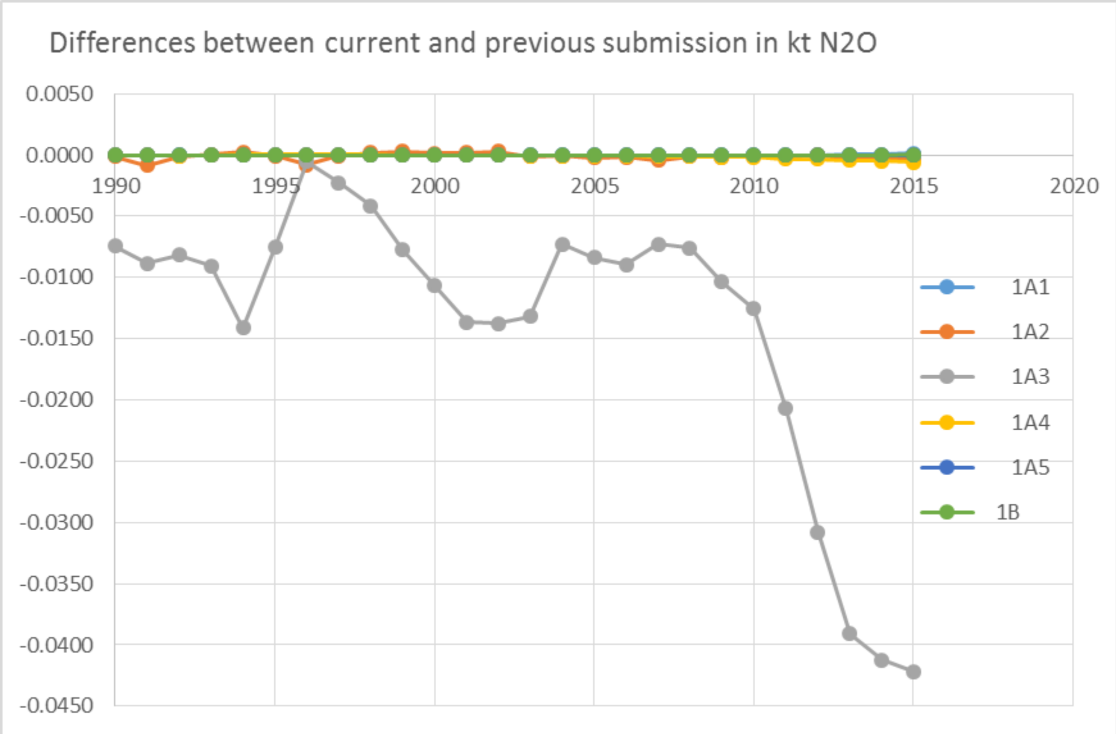


Figure 10-3 Differences in N_2O emissions (in kt N_2O) between the current and the previous submission for various source categories in the energy sector. Positive values refer to higher emissions and negative values to lower emissions in the current compared to the previous submission.

- 1A: Activity data of all wood combustion installations of 1A1a, 1A2g viii, 1A4ai, 1A4bi and 1A4ci have been revised due to recalculations in the Swiss wood energy statistics (SFOE 2017b) for the entire time series 1990 to 2015. Main changes were carried out for automatic boilers resulting in total recalculations between -4 and -178 TJ.
- 1A mobile sources (road and non-road transport):
  - NCV of biodiesel and bioethanol were adapted to the values of SFOE (2017)
  - The lubricant blended into gasoline used in two-stroke engines of road and non-road transportation is now assumed to be fully oxidized. Resulting CO_2 emissions of the oxidation of the lubricants are included in source category 2D1 Lubricant use, see chp. 4.5.2.1 and 4.5.5.
- 1A non-road categories (1A2g vii, 1A3c, 1A3d, 1A4aii/bii/cii, 1A5b) have been updated:

  - Fuel mix (biofuel shares) corresponds to INFRAS (2017), INFRAS (2018)

  - In the non-road database, natural gas instead of liquefied petroleum gas was allocated to a couple of vehicle categories. This was corrected in the publication FOEN (2015j), but not in the data itself. In fact, in the non-road sector the predominant gas used as fuel is liquefied petroleum gas (which is reported under liquid fuels), not natural gas. Therefore, NCV and emission factors have changed accordingly to those of liquefied petroleum gas (LPG) instead of natural gas (CNG). As a consequence, CO_2 emissions of these machines increased by about 17% and SO_2 emissions have been eliminated (1990-2015) since the EF for SO_2 are assumed to be zero for LPG. Moreover, the recalculation led to a reallocation of natural gas from non-road categories to 1A4a (also apparent in Figure 10-1).

  - SO_2 emissions are slightly reduced due to a correction of a calculation error in the interface between the non-road model and the EMIS database. The resulting emissions are between 2.5% and 54% lower than in the last data delivery.

- The special scheme for narrow track tractors, according to which they skip the Euro-4 emission level, was taken into account. As a result, NO_x emissions from the non-road sector will rise marginally by 2020 (about 0.3%).

10.1.2.1.5 Category-specific recalculations for 1A1 (stationary)

- 1A1a: The EF for N_2O for municipal solid waste incineration for the year 2016 has been calculated as a weighted average for all Swiss MSWIP according to the DeNOx-equipment and the amount of waste burnt in each plant. The EF for the years 2013-2015 have been interpolated using the value for 2012 and the new value for 2016. However this only leads to minor changes in the EF visible in the fourth decimal place in Table 3-33.
- 1A1a: Gas oil consumption for public electricity and heat production in 2015 has been revised according to the Swiss energy statistics (SFOE 2017). Gas oil consumption increased by 190 TJ compared to the previous submission, corresponding to approximately +14kt CO_2, +0.1 kt N_2O, +0.57 kt CH_4. (see Figure 10-1).

10.1.2.1.6 Category-specific recalculations for 1A2 (stationary)

- 1A2: So far the consumption of so-called injection coal and petroleum coke for slag formation as well as of natural gas in the electric arc furnaces of secondary steel production have been reported within the respective boilers of source categories 1A2gviii Other (petroleum coke, other bituminous coal) and 1A2a Iron and steel (natural gas). From now on these fuel consumptions are reported under source category 1A2a Electric arc furnaces of steel production based on plant-specific data from monitoring reports of the Swiss ETS for the years 2005-2011 and from 2013 onwards. In order to accommodate this, stock changes had to be adjusted for petroleum coke (2007 -100 TJ; 2008 +100 TJ) and bituminous coal (various amounts ranging from -500 TJ in 1991 to +240 TJ in 2002). Total coal consumption over the period 1990-2016 remained the same, only the distribution between the years has been adjusted. These changes are the main contributor to the large and fluctuating recalculations in CO_2 emissions in 1A2 as seen in Figure 10-1.
- 1A2a: The activity data (natural gas) of the reheating furnaces in 1A2a Steel production have been revised from 2003 onwards. These changes are balanced out by the natural gas consumption in boilers of 1A2a Iron and steel and therefore, do not influence the emissions from consumption of natural gas within 1A2a.
- 1A2f: The activity data (gas oil, natural gas) of 1A2f Production of mixed goods have been revised for 2014 and 2015 due to correction of a calculation error in last year's submission resulting in a decrease in emission of 8.1 kt CO_2 eq in 2015. These changes are balanced out by an increase in consumption of gas oil and natural gas in boilers of 1A2gviii Other and therefore, do not influence the net emissions within 1A2.
- 1A2f: The activity data (gas oil, liquefied petroleum gas, natural gas) of 1A2f Brick and tile production have been revised for 2014 and 2015 due to minor adjustements of the fuel consumption in one plant. These changes are balanced out by the consumption of gas oil, liquefied petroleum gas and natural gas in boilers of 1A2gviii Other and therefore, do not influence the net emissions within 1A2.
- 1A2g: Recalculation in the Swiss overall energy statistics concerning use of lignite for the year 2015. -0.378 TJ of lignite were less used in 2015, this results in less emissions for 2015: -0.36t CO_2.

- 1A2g: Small recalculation in use of sewage gas in the years 2014-2015.
- 1A2giv: The NO_x emission factor of animal meal has been corrected from 2000 onwards of 1A2g iv Fibreboard production resulting in revised values from 1996 onwards.

10.1.2.1.7 Category-specific recalculations for 1A4 (stationary)

- 1A4a: Recalculation in the Swiss overall energy statistics concerning use of natural gas for the years 1990-2015 due to recalculations in losses of natural gas transportation and distribution leads to insignificantly smaller emissions 1990-2015.
- 1A4a: The correction of the allocation of natural gas to source category 1A2g vii (mobile) leads to higher natural gas consumption in source category 1A4a (see also 10.1.2.1.8). The resulting increase in CO_2 emissions compared to the previous submission ranges from approximately 10 kt CO_2 in 1990 to about 17 kt CO_2 around the year 2000 and decreases again afterwards to around 10 kt CO_2, as seen in Figure 10-1.
- 1A4b: Recalculation in the Swiss overall energy statistics (SFOE 2017) concerning use of bituminous coal in households for the years 2011-2015. Coal consumption was reduced by 100 TJ for the years 2011-2013, and by 200 TJ for the years since 2014, compared to the previous submission, leading to a reduction of -9 kt CO_2 for the period 2011-2013 and -18kt CO_2 for the period 2014-2015. This recalculation is responsible for the observed stepwise decrease in CO_2 emissions since 2010 in source category 1A4 as compared to the previous submission (Figure 10-1). This recalculation is also responsible for the observed decrease in CH_4 emissions in source category 1A4 as compared to the previous submission (Figure 10-2).
- 1A4b: Small recalculation (of the order of 10 TJ, corresponding to 0.5 kt CO_2) in the Swiss overall energy statistics concerning use of natural gas in housholds for some years.

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

- Until the previous submission, the use of gaseous fuels in 1A2g vii (mobile) was treated as CNG. It has now been changed to LPG, which has some different emission factors. Specifically, the CO_2 emission factor of LPG is 17% higher than that of CNG (LPG: 65.5 t/TJ CO_2, CNG: 56.4 t/TJ, see Table 3-12 and Table 3-13). That leads to a 17% increase of CO_2 emissions of all vehicles with LPG engines. Time series 1990-2015 have been corrected corredspondingly. This recalculation also has implications for emissions of 1A4a: As 1A2g vii is now not consuming natural gas, the energy balance for natural gas has to be compensated elsewhere in the inventory. 1A4a is the source category that also includes the residual of total national gas consumption. Therefore, gas consumption increased accordingly in source category 1A4a (see also 10.1.2.1.7). On the other hand, CO_2 emissions of 1A2 decreased by the same amount as 1A4a increased (partly responsible for reductions in CO_2 emissions by 10 to 17 kt CO_2 in 1A2 as seen in Figure 10-1) The LPG consumption of 1A2g vii (mobile) is taken from the LPG previously allocated to 1A2g viii.
- Further recalculations concering all non-road categories, see recalculations above for 1A in general.

10.1.2.1.9 Category-specific recalculations for 1A3

- 1A3a: Recalculation of the total use of kerosene in the aviation model due to changed calorfic value of kerosene since submission 2015. This changed calorific value of kerosene has not been considered in the aviation model for the years 1999-2012 yet. This recalculation results in 0.8 TJ more kerosen in the year 1999 and 8.1 TJ more in 2012. This results in more emissions in 2012 of: 0.59 kt CO_2.
- 1A3b: The road transportation model has been revised (INFRAS 2017, 2017a, 2018, Keller et al. 2017, Hausberger and Matzer 2017); the corresponding recalculations dominate the behaviour of the time series shown in Figure 10-2 and Figure 10-3:
  - Update of share between gasoline and diesel oil PC. The increasing share of diesel oil is one of the main explanation in the reductions in the CH_4 emissions of 1A3 in Figure 10-2 in the period 2010-2015.
  - Update of the mileages per vehicle category. The modifications differ by vehicle category. The effects differ from year to year and are more pronounced for CH_4 in former years 1990-2000 (Figure 10-2). For N_2O emissions a substantial reduction of the diesel oil consumption of HDV (with simultaneous increase for diesel oil PC) between 2010-2015 is responsible for the reductions in those years (Figure 10-3). This effect also influences CH_4 recalculations 2010-2014. The fluctuations of N_2O emissions between 1990 and 2009 can be explained by the update of the mileages because it affects the age-distribution of the fleet and N_2O emission factors depend strongly on the age of the emission control system of the motors.
  The corresponding recalculations are the second main explanation for the effects shown in Figure 10-2 and Figure 10-3.

  The following recalculations have lower influence on the emissions:
  - Update of energy consumption by integrating time-dependent NCV (Table 3-9)
  - Update of consumption by adopting specific NCV for bioethanol and biodiesel
  - Update of emission factors of N_2O, CH_4 and most pollutants (precursors) according to the latest version 3.3 of the Handbook of Emissions Factors of Road Transport
  - extended differentiation of the AD in the modelling tool.
- 1A3b The activity data for losses of gasoline in petrol stations and fuel depots were based on gasoline sold before subtraction of gasoline sold in Liechtenstein. This has been adjusted for the whole time series 1990-2015 such that the activity data bases on gasoline sold in Switzerland only. This leads to smaller sum of gasoline fuel tourism and statistical differences.
- 1A3b: Calculation of gasoline losses in fuel handling stations base on fugitive emissions in 1B2a. Change of units in calculation leads to small rounding differences in total gasoline losses and therefore to changes in total used gasoline in 1A3b. For 2015 1 TJ less gasoline is used / more gasoline is lost in fugitive emissions. This results in very small changes in emissions for 1A3b fuel tourism of gasoline.
- 1A3c: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). 89 GJ more biofuel use in 2015.
- 1A3d: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). 152 GJ more biofuel use in 2015.
- Further recalculations concerning all non-road categories, see recalculations above for 1A in general.

10.1.2.1.10 Category-specific recalculations for 1A4 aii/bii/cii mobile

- 1A4a ii: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). -20 GJ less biofuel use in 2015.
- 1A4b ii: Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). -19 GJ less biofuel use in 2015.
- Further recalculations concering all non-road categories, see recalculations above for 1A in general.

10.1.2.1.11 Category-specific recalculations for 1A5b (mobile)

- Recalculation concerning the mix of fossil and biofuels (INFRAS 2018). It is now in line with the fuel mix in road transportation (INFRAS 2017). 62 GJ more biofuel use in 2015.
- Further recalculations concering all non-road categories, see recalculations above for 1A in general.

10.1.2.1.12 Category-specific recalculations for 1B2a

1B2a: The activity data for losses of gasoline in petrol stations and fuel depots were based on gasoline sold before subtraction of gasoline sold in Liechtenstein. This has been adjusted and now the activity data bases on gasoline sold in Switzerland only.

10.1.2.1.13 Category-specific recalculations for 1B2b

- 1B2b: A few corrections in the calculation file for natural gas losses in gas distribution and transportation led to recalculations in activity data (amount of gas lost) and emission factors. In particular, the CH_4 content, net calorific value and density of the natural gas slightly changed due to adjustments of the shares of different import stations by the Swiss Gas and Water Industry Association SVGW. Losses for the years 1990 to 2015 increased, while emission factors for the years 2012 to 2015 decreased. Overall, these corrections led to an increase of CH_4 emissions by 30 t for 1990 and a decrease of CH_4 emission by 82 t CH_4 for 2015. This recalculation is responsible for the observed decrease in CH_4 emissions between 2012 and 2015 in source category 1B as compared to the previous submission (Figure 10-2).
- 1B2b: Correction of CH_4 content of natural gas for the years 2012-2014 based on information from the swiss gas and water association.
- 1B2b: Natural gas contains small amounts of CO_2. Fugitive emissions of natural gas therefore also lead to CO_2 emissions. They are now estimated and included in source category 1B2b Transmission and storage and 1B2b Distribution, leading to an increase of 0.1 to 0.3 kt CO_2.

10.1.2.1.14 Category-specific recalculations for 1B2c

- 1B2c: Flaring in refineries: new rounding of the 2012-2015 emission factors leads to recalculations of emissions.

- 1B2c: Reported emissions of H_2 production have changed negligibly due to rounding differences in the emission factor (9 kg CO_2).
- 1B2c: As reommended by the ERT, emissions from natural gas production from 1990-1994 were taken into account for the last submission, but unfortunately they were not included in the reporting tables. In this submission they are now included in the reporting tables.

10.1.2.2 Industrial processes and other product use

Recalculations for sector 2 Industrial processes and other product use are expressed quantitatively for changes amounting to 0.3 kt CO_2 eq or larger, whereas smaller changes are described qualitatively.

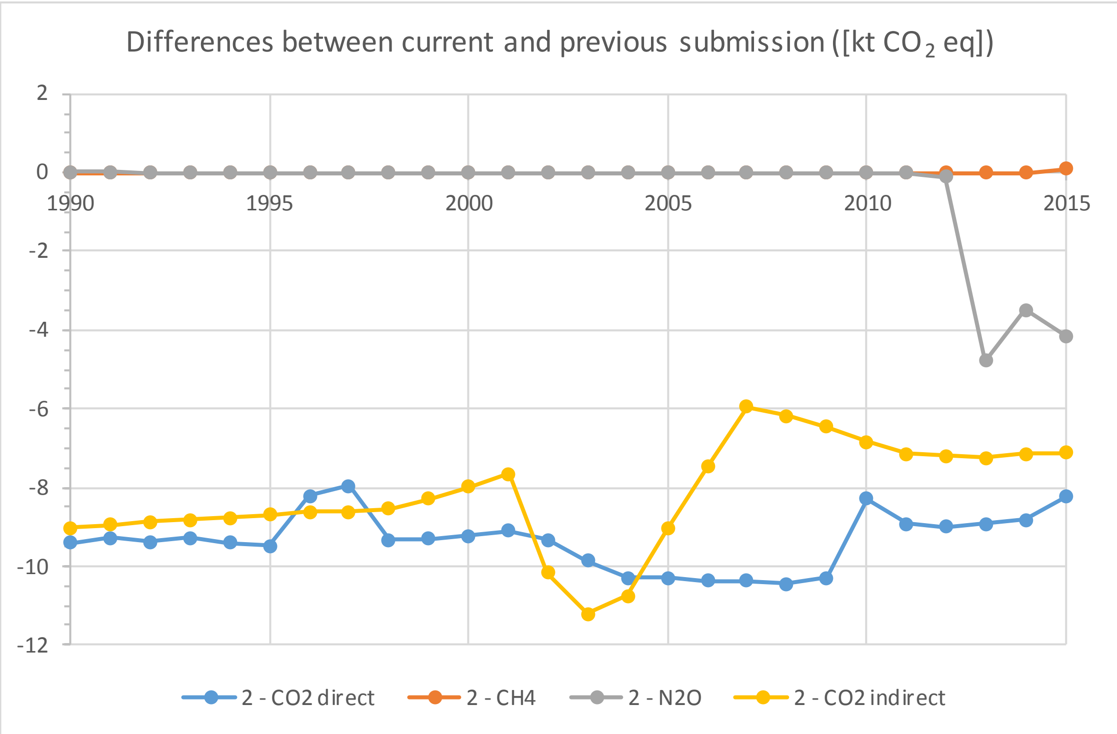


Figure 10-4 Differences in GHG emissions (in kt CO_2 eq) between the current and the previous submission for sector IPPU. Positive values refer to higher emissions and negative values to lower emissions in the current compared to the previous submission. The differences in indirect CO_2 emissions are the result of the sum of all recalculations affecting NMVOC and CO emissions. They cannot be attributed to a particular recalculation. They are mostly due to changes in CO and NMVOC emissions from 2D3c Asphalt roofing and changes in NMVOC emissions from 2D3a Paint application, industrial and non-industrial, 2G Domestic use of spray cans and correction of double counting in 2G4 De-icing of airplanes.

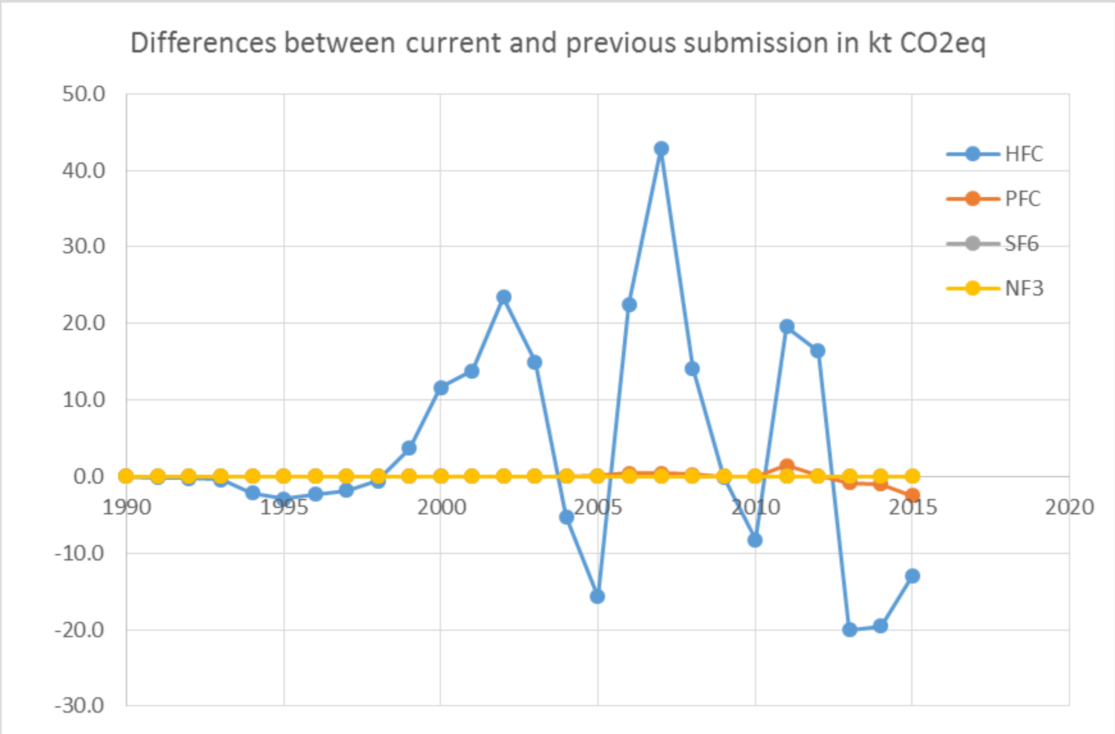


Figure 10-5 Differences in F-gas emissions (in kt CO_2 eq) between the current and the previous submission for sector IPPU. Positive values refer to higher emissions and negative values to lower emissions in the current compared to the previous submission.

10.1.2.2.1 Category-specific recalculations for 2A

Major recalculations which contribute significantly to the total differences in direct CO_2 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:

- 2A4d: The activity data of 2A4d Limestone use in iron foundries has been revised for the entire time series since the net calorific value of lignite instead of other bituminous coal was used so far. This results in a reduction of CO_2 emissions of 1.1 kt in 1990.

Further recalculations:

- 2A4d: The activity data of 2A4d Carbonate use in waste incineration plants have been updated from 2014 onwards based on industry data yielding revised activity data of 2A4d Other use of carbonates as well but no net change in CO_2 emissions.

10.1.2.2.2 Category-specific recalculations for 2B

Major recalculations which contribute significantly to the total differences in direct CO_2 and CH_4 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:

- 2B5: The last year's extrapolated activity data and emission factors from 2B5 Silicon carbide production have been revised based on industry data resulting in an increase in emissions of 0.5 kt CO_2 eq (CO_2: 0.4 kt, CH_4: 0.1 kt CO_2 eq).

Further recalculations:

- 2B8: The CO_2 emissions from the cracker reported in source category 2B8b Ethylene production are based on a mass balance considering all feedstocks, products and by-products. Therefore, the NMVOC emissions are no longer included in the calculation of the indirect CO_2 emissions from sector 2 IPPU in order to avoid double counting.

10.1.2.2.3 Category-specific recalculations for 2C

Further recalculations:

- 2C1: The activity data of the rolling mills in 2C1 Steel production have been revised from 2013 onwards.

10.1.2.2.4 Category-specific recalculations for 2D

Major recalculations which contribute significantly to the total differences in direct and indirect CO_2 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:

- 2D3: The double counting of CO_2 emissions from the cracking process at a chemical production plant has been corrected. Additionally to source category 2B8b Ethylene they were also reported erroneously under 2D3a Post-combustion of NMVOC from solvent use. This results in a reduction of CO_2 emissions of 10.3 and 10.1 kt in 1990 and 2015, respectively. This recalculation dominates the observed difference of CO_2 emissions shown in Figure 10-4.
- 2D3: AD from 2D3d Adblue use in road transportation was adapted to the new road-model. This leads to higher CO_2 emissions (4kt for the year 2015).
- 2D3: The survey on post-combustion of NMVOC from manufacture and processing of chemical products has been revised resulting in an increase of CO_2 emissions from 2D3a of NMVOC from solvent use of 0.7 and 0.6 kt in 1990 and 2015, respectively.
- 2D1: The lubricant blended into gasoline used in 2-stroke engines of motorcycles and non-road transportation is now assumed to be fully oxidized. Resulting CO_2 emissions of the oxidation of the lubricants are included in source category 2D1 Lubricant use. This results in an increase in emissions of 1.5 and 0.5 kt CO_2 eq in 1990 and 2015, respectively.
- 2D3: The so far four source categories of 2D3c Asphalt roofing covering the emissions from production and laying of shingles and primer have been merged to one source category. At the same time activity data and emission factors of NMVOC and CO have been revised for the entire time series.
- 2D3: The activity data and NMVOC emission factor of 2D3a Paint application, industrial and non-industrial have been revised from 2002 and 1999 onwards, respectively.

Further recalculations:

- 2D1: The activity data of 2D1 Lubricant use have been revised for the entire time series since the consumption of lubricants of Liechtenstein (customs union with Switzerland) is now subtracted from the consumption reported by the Swiss petroleum association. This results in a decrease in CO_2 emissions of 0.2 and 0.1 kt in 1990 and 2015, respectively.
- 2D3: The activity data of 2D3a Fine chemicals production, 2D3a Handling and storing of chemicals and 2D3a Pharmaceutical production have been changed for 2020 resulting in revised interpolated values for 2012-2015.
- 2D3: The activity data of 2D3a Ink production of has been changed for 2020 resulting in revised interpolated values for 2014-2015.

- 2D3: The activity data of 2D3c Asphalt roofing has been changed for 2020 resulting in revised interpolated values for 2012-2015.

10.1.2.2.5 Category-specific recalculations for 2E

No category-specific recalculations were carried out

10.1.2.2.6 Category-specific recalculations for 2F

- 2F1a: Split between commercial and industrial refrigeration 1990 till 2016 has been introduced (industrial refrigeration was previously included in commercial refrigeration).
- 2F1b: Adjusted portion and type of refrigerant used for stationary air conditioning and heat pumps 2014 and 2015.

10.1.2.2.7 Category-specific recalculations for 2G

- Major recalculations which contribute significantly to the total differences in N_2O and indirect CO_2 emissions of sector 2 IPPU between latest and previous submission, see Figure 10-4:2G3a: The N_2O emission factor of 2G3a N_2O use in in hospitals has been revised from 2012 onwards resulting in a decrease in emissions of 4.1 kt CO_2 eq in 2015. This recalculation is responsible for the observed difference in N_2O emissions from sector 2 IPPU.
- 2G4: The NMVOC emission factor of 2G4 Domestic use of spray cans has been revised for the years 1999–2012.
- 2G4: The double counting in the NMVOC emissions from 2G4 De-icing of airplanes for the years 1990-2006 in last year's submission has been corrected (Table 4-56).

Further recalculations:

- 2G4: The activity data of 2G4 Use of cooling lubricants have been updated from 2005 onwards. In addition, the emission factor of NMVOC for 2005 has been updated resulting in revised values for the years 2005-2011.
- 2G4: Activity data of 2G4 Hairdressers have been revised for 2004 and 2007 resulting in revised values for 2002-2004 and 2006-2007, respectively.
- 2G4: Activity data of 2G4 Cosmetic institutions has been revised for 2004 resulting in revised values for 2002-2004.
- 2G4: The activity data of 2G4 Use of concrete additives has been changed for 2020 resulting in revised interpolated values for 2013-2015.
- 2G4: Activity data for the consumption of tobacco has slightly changed for the years 1997-2004 due to the correction of errors in the calculation.
- 2D3: The activity data of 2G4 Tobacco production have been updated for 2001, 2004, 2005, 2007 and 2008 resulting in revised values for 1999-2015.
- 2G4: The activity data of 2G4 Package printing and 2G4 Printing have been changed for 2020 resulting in revised interpolated values for 2014-2015.
- 2G4: The activity data of 2G4 Production of paper and paperboard and 2G4 Production of textiles have been changed for 2020 resulting in revised interpolated values for 2012-2015.

10.1.2.2.8 Category-specific recalculations for 2H

Further recalculations:

- 2H1: The activity data of 2H1 Chipboard production has been corrected for 2004
- 2H2: Activity data for bread production for the years 2013-2015 has slightly changed. For the years 2013 and later the amount of bread produced is now estimated based on industry data for grinded grains and not on the per-capita consumption as before.
- 2H3: The activity data of 2H3 Blasting and shooting has been corrected for 2015. In addition, the activity data have been adjusted for 1995–2006 due to rounding differences resulting in minor recalculations between 1991 and 2006.

10.1.2.3 Agriculture

Recalculations with an overall impact of >0.5 kt CO_2 equivalents are assessed quantitatively. All other recalculations are only described qualitatively.

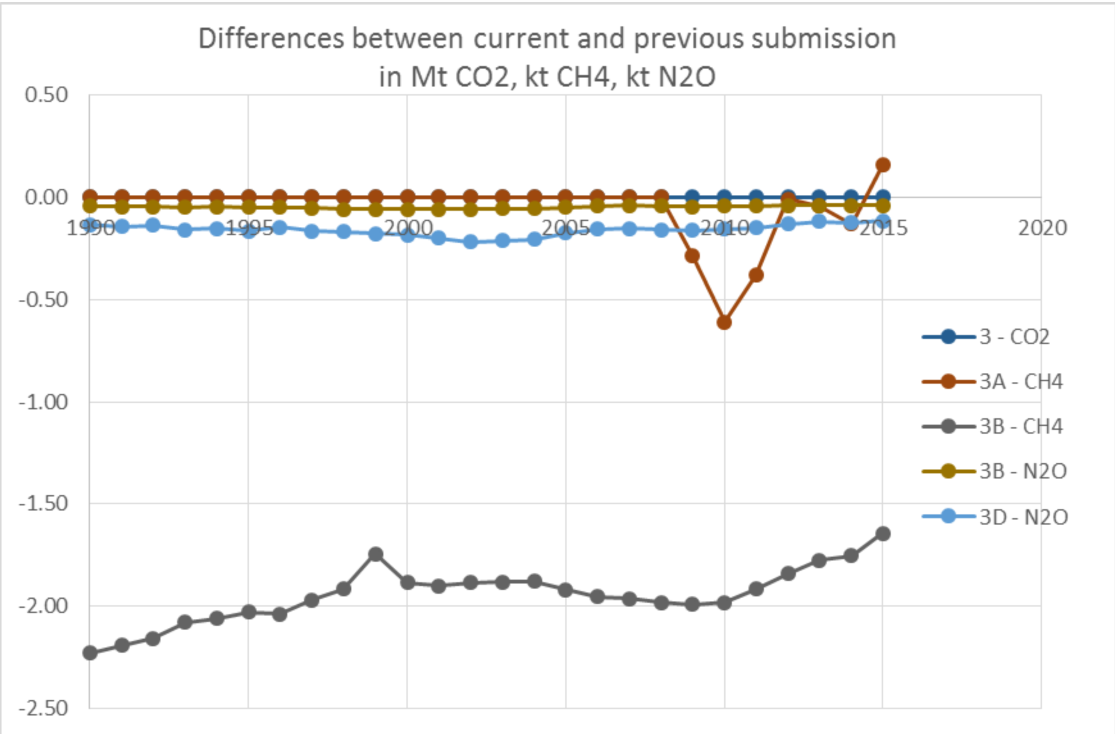


Figure 10-6 Differences in GHG emissions (in Mt CO_2, kt CH_4 and in kt N_2O) between the current and the previous submission for sector Agriculture. Positive values refer to higher emissions and negative values to lower emissions in this submission compared to the previous submission.

10.1.2.3.1 Category-specific recalculations for 3A

- Activity data for all growing cattle subcategories in the years 2009-2015 was revised due to a new model for the conversion of the categories in the animal traffic database to the categories needed for the GHG Inventory. The new model estimates less “breeding cattle

3rd year" and "fattening cattle" and more "fattening calves". Accordingly, overall agricultural emissions decreased on average by approximately 10 kt CO_2 equivalent per year over the years 2009-2015.

- Livestock population data for sheep and goats in the year 2015 was recalculated due to the retrospective accounting of the change of the census date. The new values are approximately 15% higher and lead to an increase of overall emissions of 2.3 kt CO_2 equivalent. See also chp. 5.2.3.
- Livestock population data of "fattening pig over 25 kg" (part of the swine population) and "broilers" (part of the poultry population) was revised for the years 2010-2015 due to a new accounting system for the animal rotation cycles. The new system leads to higher numbers for these animals. Accordingly overall emissions increased by approximately 6 kt CO_2 equivalents per year over the years 2010-2015.
- Gross energy intake and methane conversion rates for all calve-categories (fattening calves, pre-weaned calves, breeding calves and fattening calves (0-4 months)) were revised due to a different accounting of milk energy. Emission factors and overall CH_4 emissions did not change since it was only a reallocation of calculation parameters.
- CH_4 emission factors for the year 2014 and 2015 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 2017). The effect of the recalculation on overall greenhouse gas emissions is negligible for 2014 and +1.0 kt CO_2 equivalent for 2015.

10.1.2.3.2 Category-specific recalculations for 3B

- Recalculation of livestock population statistics and net energy intake is provided in chp. 5.2.5.
- All estimates based on AGRAMMON data were recalculated for all years due to the implementation of a new model version and revised estimates. This affects among others particularly nitrogen excretion rates. The impact on overall emissions in kt CO_2 equivalents is: 1990: -38.7; 2015: -28.8; mean 1990-2015: -45.2.
- Distribution of VS to the different manure management systems (MS) was recalculated for all years based on Richner et al. 2017. See chp. 5.3.2.2.4. As the amount of VS stored in liquid systems declined, overall emissions declined significantly. Effects on overall emissions in kt CO_2 equivalents are: 1990: -46.4; 2015: -34.7; mean 1990-2015: -38.5.
- The MCF for liquid/slurry systems was slightly revised for all years due to new model runs based on new AGRAMMON data and the new VS distribution to the different manure management systems. Effects on overall emissions in kt CO_2 equivalents are: 1990: -9.4; 2015: -9.6; mean 1990-2015: -10.5.
- N_2O emissions from manure management for the years 2011-2015 were recalculated due to a new value for the occurrence of natural crust covers in 2015 and the respective interpolation. Effects on overall emissions in kt CO_2 equivalents are: 2013: -2.1; 2014: -2.8; 2015: -3.5.

10.1.2.3.3 Category-specific recalculations for 3D

- Synthetic fertilizers applied in Liechtenstein were subtracted from the statistics provided by Agricura (2016). The recalculation affects direct and indirect N_2O emissions from agricultural soils as well as CO_2 emissions from urea application in all inventory years. The impact on overall emissions in kt CO_2 equivalents is: 1990: -1.5; 2015: -1.2; mean 1990-2015: -1.2.

- The EF for inorganic fertilizers was recalculated due to the use of nitrification inhibitors from 2007 onward. Overall emissios decreased by 1.26 kt CO_2 equivalent on average for the 2007-2015 time period.
- All estimates based on AGRAMMON data were recalculated due to the implementation of a new model version and revised estimates. This affects among others particularly nitrogen excretion rates. The impact on overall emissions in kt CO_2 equivalents is: 1990: -38.7; 2015: -28.8; mean 1990-2015: -45.2.
- AD for other organic fertilizers (liquid and solid digestate, compost) was recalculated for all years due to new data assessed and made available by the School of Agricultural, forest and Food Sciences (HAFL). For most years emissions in kt CO_2 equivalents are slightly lower after the recalculation (1990: -0.4 kt; 2015: -2.7 kt; mean: -2.0 kt).
- The AD for direct N_2O emissions from N in crop residues returned to soils was revised for the year 2014 and 2015 due to data updates by the Swiss Farmers Union and the Swiss Federal Statistical Office (harvested crop yields). Overall emissions increased negligibly for 2014 and by 1.0 kt CO_2 equivalent for 2015.
- The AD for direct N_2O emissions from N in crop residues returned to soils was revised for the whole time series due to new data on standard amounts of fresh matter crop yields and standard amounts of nitrogen in crop residues from Richner et al. (2017). The recalculation affects direct and indirect emissions from agricultural soils. The impact on overall emissions in kt CO_2 equivalents is: 1990: +15.6; 2015: +12.3; mean: +13.4.
- The AD for direct N_2O emissions from N in mineral soils that is mineralized/immobilized in association with loss of soil C was revised due to new projections in the LULUCF sector for all inventory years. Overall emissions decreased by 0.6 and 0.8 kt CO_2 equivalent in 2014 and 2015. Effects on overall emissions were negligible for all other years (below 0.5 kt CO_2 equivalent).
- AD for N_2O emissions from the cultivation of organic soils was revised due to new AREA-projections in the LULUCF sector for all inventory years. Impact on overall emissions is negligible (below 0.2 kt CO_2 equivalents).
- Indirect N_2O emissions from atmospheric deposition was revised for all years due to new EF for ammonia volatilization for synthetic fertilizers based on EMEP/EEA (2016). The impact on overall emissions in kt CO_2 equivalents is: 1990: +0.7; 2015: +4.8; mean: +2.4.
- Indirect N_2O emissions from atmospheric deposition was revised for all years due to the abolition of the reporting of volatilisation of ammonia from the vegetation cover on agricultural and alpine soils. Overall emissions decreased by 28.4 kt CO_2 equivalents on average.

10.1.2.3.4 Category-specific recalculations for 3G

No category-specific recalculations were carried out.

10.1.2.3.5 Category-specific recalculations for 3H

- Synthetic fertilizers applied in Liechtenstein were subtracted from the statistics provided by Agricura (2016). The recalculation affects direct and indirect N_2O emissions from agricultural soils as well as CO_2 emissions from urea application in all inventory years.

The impact on overall emissions in kt CO_2 equivalents is: 1990: -1.5; 2015: -1.2; mean 1990-2015: -1.2.

10.1.2.4 Land Use, Land-Use change and Forestry

Recalculations with an overall impact of >100 kt CO_2 equivalents are assessed quantitatively. The remaining recalculations are described qualitatively in the respective chp. 6.X.5.

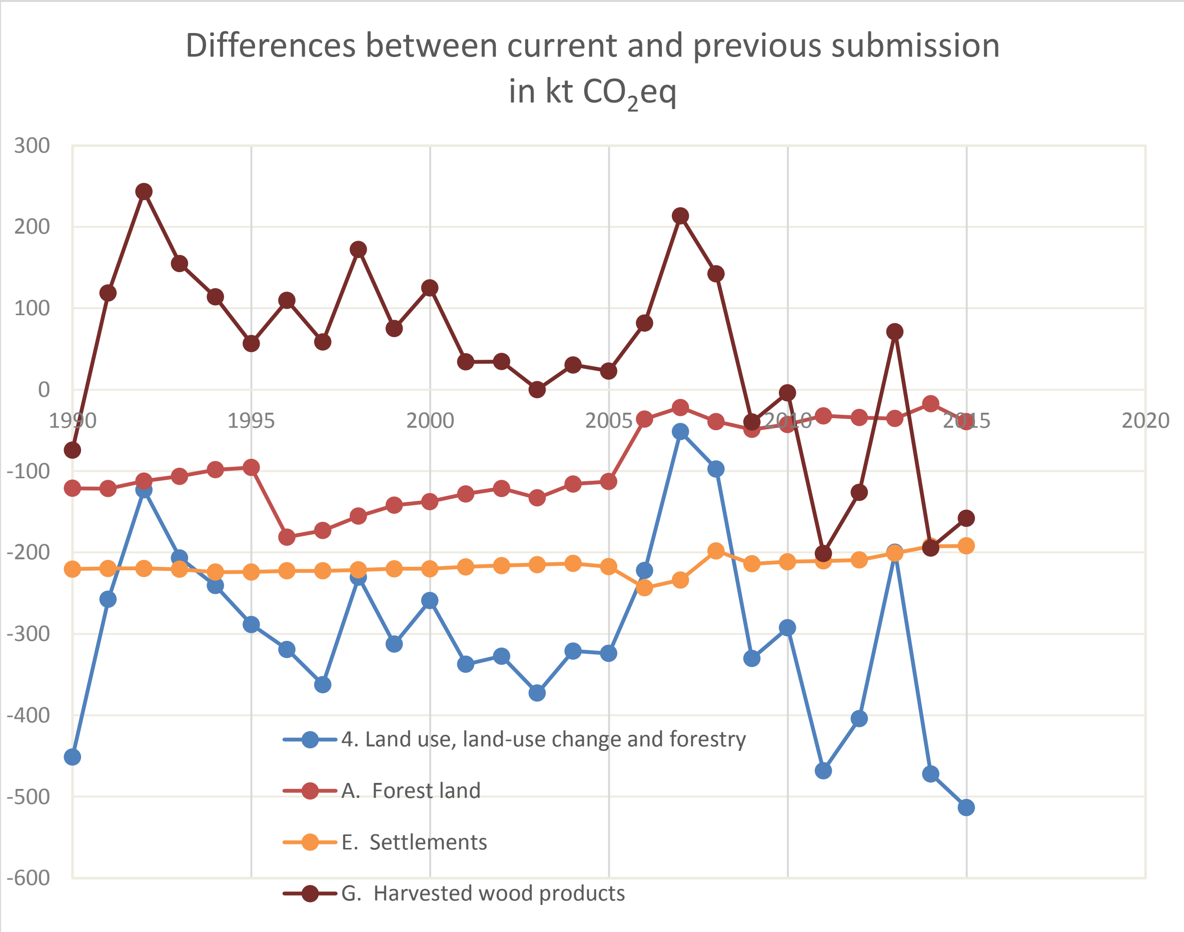


Figure 10-7 Differences due to recalculations in the LULUCF sector with an overall net impact of >100 kt CO_2 eq. Positive values refer to higher emissions and negative values to lower emissions in this submission compared to the previous submission (FOEN 2017).

The seesaw pattern of the deviation of CO_2 eq emissions and removals in the LULUCF sector between FOEN (2017) and this submission (less emissions of 51.5 kt CO_2 eq (2007) to 513.4 kt CO_2 eq (2015); blue line in Figure 10-7) is directly controlled by recalculations in 4G Harvested wood products (brown line). Recalculated HWP data fluctuate between +243.7 kt CO_2 (1992) and -201.1 kt CO_2 (2011) and result from (1) the first-time inclusion of the paper and paperboard carbon pool (UNFCCC 2018, ID#KL.7) and (2) an update of raw activity data for the whole time series in the FAOSTAT database (FAOSTAT 2017) (chp. 6.11.5 and Table 6-35). Recalculations in 4E Settlements (orange line) are primarily due to UNFCCC (2018, ID#KL.2; chp. 6.8.5). The replacement of the linear factor (0.2 instead of 0.5) in equation 6.8 as introduced in chp. 6.8.2.3 causes quite stable net emission reductions in the range of 191.9 kt CO_2 eq (2015) to 243.4 kt CO_2 eq (2006). The reductions are made up of CO_2 emissions in category 4E (mainly 4E2) (around 90%) and N_2O emissions in category 4(III) (around 10%). In 4A Forest land several recalculations cut overall net emissions by an amount of between 17.2 kt CO_2 eq (2014) and 181.0 kt CO_2 eq (1996) (red line) (see chp. 6.4.5 for a comprehensive description). The biggest impact is caused by recalculated Yasso07 data following a correction of input data of changes in carbon stocks of dead wood in the reporting tables (wrong allocation). This modifiaction of net carbon changes in dead wood reduced emissions between 48.4 kt CO_2 eq (1995) and 144.2 kt CO_2 eq (2006). The time series of losses of living biomass was recalculated for 2006–2015 since NFI data were recalibrated with relative harvesting amounts taken from the forest statistics (Table 6-16) over the period 2006–2016 instead of 2006–2015. This results in higher removals between 85.2 kt CO_2 (2015) and 151.4 kt CO_2 (2006). The adjustment of the share of drained organic soil in response to UNFCCC (2018, ID#L.6 and ID#KL.3; chp. 6.4.2.10) shortened annual CO_2 emissions by approximately 35 kt and annual N_2O emissions by approximately 5 kt CO_2 eq, respectively (equivalent to a drop of 97%). The remaining recalculations in category 4A listed in chp. 6.4.5 are marginal and add up to an amount of less than 20 kt CO_2 eq per year.

10.1.2.5 Waste

Recalculations for sector 5 Waste are expressed quantitatively for changes amounting to 0.2 kt CO_2 eq or larger, whereas smaller changes are described qualitatively.

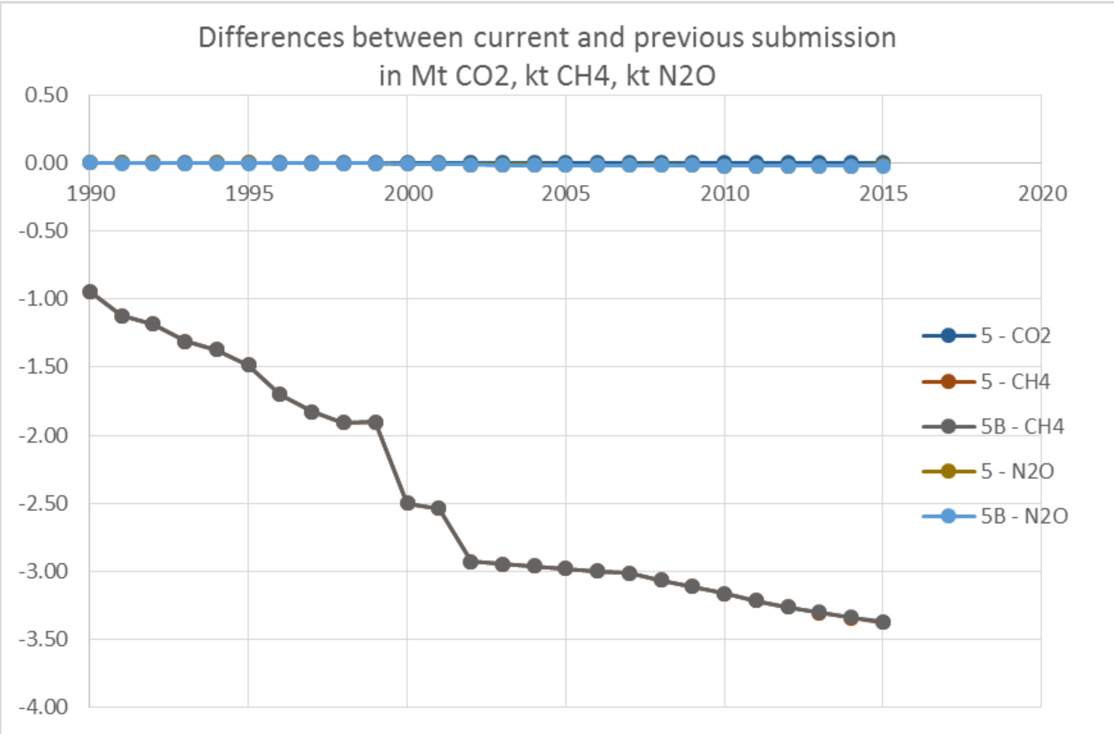


Figure 10-8 Differences in GHG emissions (in Mt CO_2, kt CH_4 and in kt N_2O) between the current and the previous submission for sector Waste. Positive values refer to higher emissions and negative values to lower emissions in the current compared to the previous submission.

10.1.2.5.1 Category-specific recalculations for 5A

No category-specific recalculations were carried out.

10.1.2.5.2 Category-specific recalculations for 5B

- The number of agricultural digestion facilities for the years 1990 and 1991 has been swapped. This has been corrected and leads to slightly different methane emissions for the years 1990 and 1991.
- The time series for industrial composting has been completely revised and activity data has changed for all years since 1990. Emission factors for CH_4, N_2O, CO_2 biogenic and NMVOC have been reestimated. Changes in emissions are (kt CO_2 eq): CH_4 1990: -26, CH_4 2015: -87; N_2O 1990: -2, N_2O 2015: -9 CO_2 biog. 1990: -57, CO_2 biog. 2015: -228. The recalculations for CH_4 for industrial composting are responsible for the most apparent differences in Figure 10-8.
- The time series for backyard composting has been completely revised and activity data has changed for all years since 1990. Emission factors for CH_4, N_2O, CO_2 biogenic and NMVOC have been introduced. Changes in emissions are (kt CO_2 eq): CH_4 1990: +3 CH_4 2015: +3; N_2O 1990: +2, N_2O 2015: +1; CO_2 biog. 1990: +29, CO_2 biog. 2015: +26.

10.1.2.5.3 Category-specific recalculations for 5C

No category-specific recalculations were carried out.

10.1.2.5.4 Category-specific recalculations for 5D

- 5D1: The emission factor for N_2O for domestic wastewater treatment has been slightly adjusted for the years 1990-2015 for different reasons: Protein consumption in the year 2008 has been corrected in the statistics provided by the Swiss farmers association. This influences the whole time series from 1990-2006 as there is a break in the time series in 2007 which has been corrected using values from 2007-2010. Furthermore protein consumption for the year 2015 has been adjusted, as well as the number of digits used for the EF.
- 5D1: The value for sewage gas used in CHP installations has been corrected in the underlying statistics be the SFOE for the year 2000. This slightly diminishes the amount of CH_4 recovered in CRF Table5.D.

10.1.2.5.5 Category-specific recalculations for 5E

- No category-specific recalculations were carried out.

10.1.2.6 Other

- 6Ad: An error in the calculation of the activity data for fire damages estates has been corrected. This leads to slightly changed values for the years 1996-2014.

10.1.2.7 Indirect CO_2 and N_2O Emissions

- 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 NH_3 related recalculations reported in chp. 3 Energy, 4 Industrial processes and product use, 7 Waste and 8 Other.

10.1.2.8 KP- LULUCF Inventory

- All category-specific recalculations for 4A (chp. 6.4.5) and 4G (chp.6.11.5) are relevant for the KP-LULUCF inventory.
- Activitiy data 1990–2015 were updated (see chp. 6.3.5), resulting in a pronounced change in the area of Deforestations in 2015.
- Changes in soil carbon stocks for land-use changes from or to "Buildings and Constructions" (CC51) were recalculated in response to UNFCCC (2018, ID#KL.2). In case of Deforestations to CC51, a loss of 20% of the initial soil carbon stock was reported as a source (see chp. 6.8.2.3 and Table 11-4). In case of Afforestations on CC51, the soil carbon stock change was calculated with the regular stock-difference approach or gain-loss approach as shown in Table 6-3. Thus, there is no longer a differentiation depending on the land-use before the Afforestations (see Table 11-4 and chp. 6.1.3.2). This led to higher soil carbon stock gains on Afforestations in comparison with the last submission.

10.2 Implications for emission levels

Table 10-3 shows the effect of the recalculations on the results for the base year 1990. The recalculations resulted in an decrease of the total emissions in CO_2 equivalents (excluding CO_2 eq emissions and removals from LULUCF) of 160.7 kt CO_2 eq (-0.3%) in submission 2018 as compared to submission 2017. If the LULUCF sector is included, there is a decrease of 612.1 kt kt CO_2 eq (-1.15%) for submission 2018 as compared to submission 2017.

Table 10-3 Overview of implications of recalculations on 1990 data. Emissions are shown before the recalculation according to the previous submission 2017 "Prev." (FOEN 2017) and after the recalculation according to the present submission 2018 "Latest". The difference refers to the absolute values (Latest - Previous).

Recalculation	CO_2			CH_4			N_2O			Sum (CO_2, CH_4 and N_2O)		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
1. Energy	40'899	40'899	0.14	651.9	634.4	-17.57	294.8	292.6	-2.26	41'846	41'826	-19.69
2. IPPU	3'158	3'149	-9.41	1.8	1.8	0.00	171.4	171.4	0.00	3'331	3'322	-9.41
3. Agriculture	49	49	-0.06	4'509.2	4'453.5	-55.71	2'222.2	2'169.9	-52.30	6'780	6'672	-108.07
4 LULUCF	-395	-818	-423.5	29.4	29.4	0.00	86.9	58.9	-27.96	-279	-730	-451.45
5. Waste	54	54	0.00	938.7	915.1	-23.62	140.5	140.6	0.14	1'133	1'109	-23.48
6 Other	11	11	0.00	0.7	0.7	0.00	0.6	0.6	0.00	12	12	0.00
Sum (without F-gases)	43'776	43'343	-432.8	6'132	6'035	-96.90	2'916	2'834	-82.38	52'824	52'212	-612.10

Recalculation	**HFC**			**PFC**			**SF6**			**Sum (synthetic gases)**		
Emissions for 1990	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)									CO_2 equivalent (kt)		
2 Ind. Processes (only syn. gases)	0.02	0.02	0.00	116.5	116.5	0.00	137.0	137.0	0.00	253.55	253.55	0.00

Recalculation		**Sum (all gases)**		
Emissions for 1990		Prev.	Latest	Differ.
Source and Sink Categories		CO_2 equivalent (kt)		
Total CO_2 eq Em. incl. LULUCF		**53'078**	**52'466**	**-612.10**
		100%	98.85%	-1.15%
Total CO_2 eq Em. excl. LULUCF		**53'357**	**53'196**	**-160.65**
		100%	99.70%	-0.30%

Table 10-4 shows the effect of the recalculations on the results for the year 2015. The recalculations resulted in a decrease of the total emissions in CO_2 equivalents (excluding CO_2 eq emissions and removals from LULUCF) of 224.8 kt CO_2 eq (-0.47%) in submission 2018 compared to submission 2017. If the LULUCF sector is included, there is a decrease of 738.2 kt CO_2 eq (-1.57%) in submission 2018.

Table 10-4 Overview of implications of recalculations on 2015 data. Emissions are shown before the recalculation according to the previous submission 2017 “Prev.” (FOEN 2017) and after the recalculation according to the present submission 2018 “Latest”. The difference refers to the absolute values (Latest - Previous).

Recalculation	**CO_2**			**CH_4**			**N_2O**				**Sum (CO_2, CH_4 and N_2O)**		
Emissions for 2015	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.		Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)										CO_2 equivalent (kt)		
1. Energy	36'595	36'591	-4.54	286.5	278.1	-8.42	231.3	218.5	-12.81		37'113	37'087	-25.77
2. IPPU	2'091	2'082	-8.24	2.1	2.2	0.10	49.5	45.3	-4.14		2'142	2'130	-12.28
3. Agriculture	44	44	-0.05	4'152.9	4'115.7	-37.20	1'877.3	1'831.9	-45.39		6'074	5'992	-82.64
4 LULUCF	-981	-1'469	-488.77	13.3	13.1	-0.14	73.6	49.2	-24.46		-894	-1'407	-513.37
5. Waste	10	10	0.00	643.4	559.0	-84.40	193.1	188.9	-4.25		846	758	-88.65
6 Other	11	11.3	0.00	0.6	0.6	0.00	0.5	0.5	0.00		12	12	0.00
Sum (without F-gases)	37'771	37'269	-501.6	5'099	4'969	-130.06	2'425	2'334	-91.05		45'295	44'572	-722.71

Recalculation	**HFC**			**PFC**			**SF6**			**NF3**			**Sum (synthetic gases)**		
Emissions for 2015	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.	Prev.	Latest	Differ.
Source and Sink Categories	CO_2 equivalent (kt)												CO_2 equivalent (kt)		
2 Ind. Processes (only syn. gases)	1'535.99	1'522.97	-13.02	57.2	54.7	-2.48	255.8	255.8	0.00	0.49	0.49	0.00	1'849.45	1'833.94	-15.50

Recalculation		**Sum (all gases)**		
Emissions for 2015		Prev.	Latest	Differ.
Source and Sink Categories		CO_2 equivalent (kt)		
Total CO_2 eq Em. incl. LULUCF		**47'144**	**46'406**	**-738.21**
		100%	98.43%	-1.57%
Total CO_2 eq Em. excl. LULUCF		**48'038**	**47'813**	**-224.84**
		100%	99.53%	-0.47%

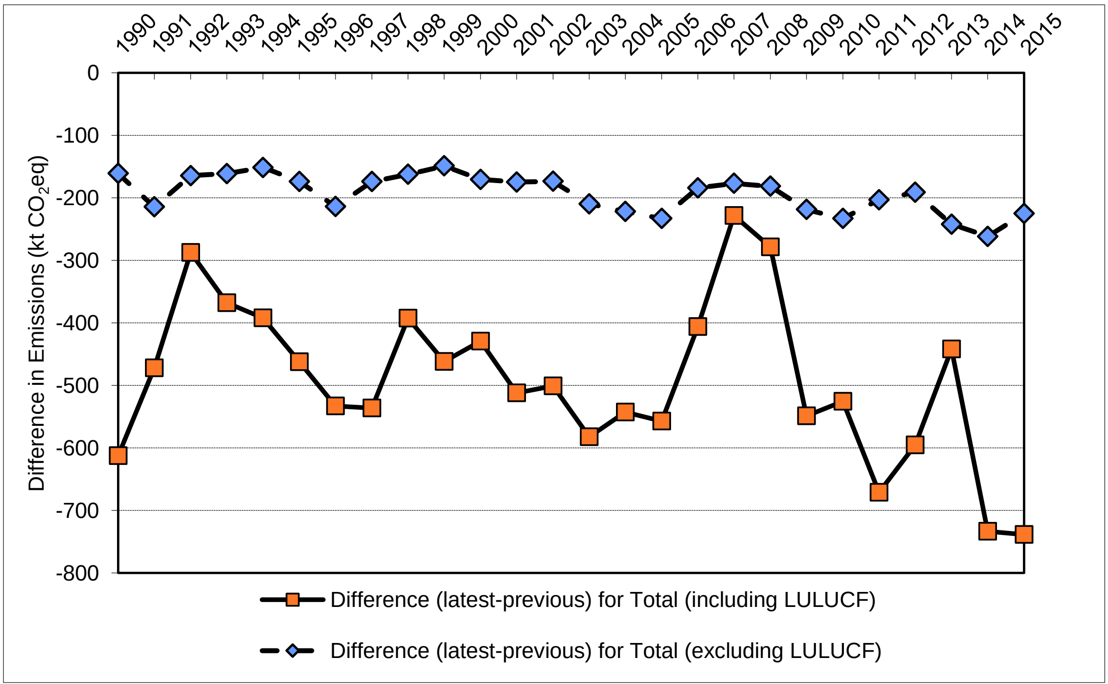


Figure 10-9 Implications of recalculations on the national total emissions including and excluding LULUCF. The difference refers to the absolute values in CO_2 equivalent (latest - previous).

Figure 10-9 shows the aggregated effect of all the recalculations carried out for the current submission. Each point of the blue curve indicates the difference between the national totals (excluding LULUCF) of the latest with the previous year. Negative values mean that the recalculated emissions are lower in the latest year than in the previous year. The orange points show the corresponding numbers for the nationl totals incl. LULUCF. The most important contribution to the decreasing effect of the recalculations stem from

- 5B Biological treatment of solid waste (2015: -91 kt CO_2 eq due to revision of the activity data of industrial composting),
- 3B Manure management and 3D Agricultural soils (2015: -52 kt CO_2 eq and -34 kt CO_2 eq, both due to recalculated nitrogen excretion rates).

The seesaw pattern of the deviation including the LULUCF sector in Figure 10-9 (less emissions of 51.5 kt CO_2 eq (2007) to 513.4 kt CO_2 eq (2015)) is directly controlled by recalculations in category 4G Harvested wood products. Further major contributions stem from recalculations in categories 4E Settlements and 4A Forest land. See chp. 10.1.2.4 for a quantitative breakdown of the category-specific contributions.

10.3 Implications for emissions trends, including time series consistency

Due to recalculations, the emission trend 1990–2015 reported in the present 2018 submission has slightly changed. Compared to 1990, 2015 emissions (national total excl. LULUCF) showed a decrease of 9.97% before recalculation (Submission 2017). After recalculation in 2018, the decrease is slightly larger with a decrease 1990–2015 of 10.12%.

Table 10-5 Change of the emission trend 1990–2015 due to recalculations.

Recalculation	**1990**		**2015**		**change 2015/1990**	
Submission	previous	latest	previous	latest	previous	latest
Unit	CO_2 eq (kt)				%	
Total excl. LULUCF	53'357	53'196	48'038	47'813	-9.97%	-10.12%

All time series in the present submission are consistent.

10.4 Planned improvements, including in response to the review process

- 1A3b Road Transportation: A further update of the emission model is on-going. Details of modifications and extensions of the model are documented in Keller et al. (2016).The results will be presented in future submissions (2019).
- 1A3b: The CO_2 emission factor of biogas for passenger cars and heavy duty vehicles will be corrected for 2001-2016.
- 2F1: Improvements of HFC emission calculations from refrigeration and air conditioning equipment.
- 2F1: Changes are expected and will be analysed in this area due to the revision of the Chemical Risk Reduction Ordinance and CO_2 compensation programms (share of products with HFC, recycling of HFC, early replacement of HFC).
- 3A: Planned improvements for future submissions are the further development, adaptation and verification of the dairy cattle feeding model (GE, Ym).

- 3B: Planned improvements for future submissions are the further development, adaptation and verification of the dairy cow feeding model (GE, DE, VS-excretion, N-excretion (Nex)).
- 3B, 3D: A release of a new version of the AGRAMMON model is planned for 2018. If possible the revised estimates from AGRAMMON will be included during the next GHG inventory submission.
- 3B, 3D: NMVOC emissions will be revised and separately reported for 3B Manure management and 3D Agricultural soils.
- 4A: The implementation of the soil model Yasso07 to improve the accuracy in the estimates of temporal changes in soil carbon, litter and dead wood will be further developed.
- 4A: Projects in a new national research programme ("SOM control") aimed at identifying the drivers of soil organic matter storage in Swiss forest soils. In a follow-up project financed by FOEN, the implications for carbon stabilization in mineral forest soils are investigated and the application to further development of the Yasso model is examined.
- 4B, 4C: Country-specific estimates of changes in carbon stocks in cropland and grassland mineral soils will be elaborated in the course of severals research projects in the medium term.
- 4B, 4C, 4D, 4E: Price et al. (2017) created a nationwide model for tree biomass in Switzerland (both inside and outside of forest), using structural information available from airborne laser scanning. The model offers significant opportunity for improved estimates of carbon stocks in living biomass on land use combination categories where tree biomass has either not been included or only roughly estimated until now. The suitability of the obtained data for reporting in categories 4B, 4C, 4D, and 4E, respectively, is subject to evaluation.
- 4C: A study on GHG emissions from an intensively used fen under grassland management (Agroscope in collaboration with the University of Basel, 2017–2020, financed by FOEN) will improve the robustness of country-specific emission factor estimates for grassland soils rich in organic matter in the medium term. A further objective of the study is to estimate potential emission reductions from coverage of managed organic soils with mineral soil material.
- 4G: For the calculation of paper and paperboard there are still some methodological challenges, such as how to determine the amount of domestic pulp wood contained in recycled products (see UNFCCC 2018, ID#KL.7). Therefore, a study will be carried out to obtain additional national activity data on paper and paperboard to improve the calculation of the contribution of this pool.

For further planned improvements please refer to respective chp. “planned improvements” for each category.

PART 2

11 KP-LULUCF

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, FOEN 2016d). In addition to the mandatory submission of the inventory years 2013, 2014, 2015 and 2016, data for the years 1990–2012 are available. 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). CRF NIR-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 chp. 11.3.1.2. The areas and change in areas between the previous and the current inventory year are shown in CRF NIR-2. CRF NIR-3 summarizes the results of the KCA for LULUCF activities under the Kyoto Protocol.

An overview of net annual CO_2 eq emissions and removals of activities under Article 3, paragraph 3 and Forest management under Article 3, paragraph 4, of the Kyoto Protocol is shown in Figure 11-1 and Table 11-1. Annual removals from Afforestation and Deforestation fluctuate (Figure 11-2), which can mainly be attributed to the changes in their respective areas (Table 11-2). The relative changes in the area of managed forest are comparatively low and fluctuations in the annual net changes in Forest management can primarily be explained by changes in the losses from the living biomass, dead wood and litter pools (Table 11-1). The reason for the high CO_2 eq net emissions in 2000 and the small CO_2 eq net removals in the following year 2001 for Forest management is the winter storm “Lothar” by the end of 1999, which caused great damages in the forest stands and increased losses of living biomass due to salvage logging. Harvesting rates in Swiss forests gradually increased since 1991 until 2007, reaching peak values in 2000 (storm Lothar, see above), 2006 and 2007 and thus also resulting in small removals from Forest management in the two latter years. Because harvesting rates started to decline in 2008 (Table 6-16) due to the international and domestic economic framework conditions, removals from Forest management increased since 2008, still showing high year-to-year variability. Fluctuations in the Harvested wood products (HWP) pool are mainly caused by changes in the production of sawnwood and paper and paperboard (see chp. 6.11 and Table 6-35). The production of sawnwood strongly correlates with the domestic harvesting rate. The contribution of paper and paperboard to changes in HWP fluctuates over the years. The relative contribution of paper and paperboard to the HWP pool considerably increased in the last 5 years. In 2015 and 2016 this category contributed to half of the carbon stock changes in HWP.

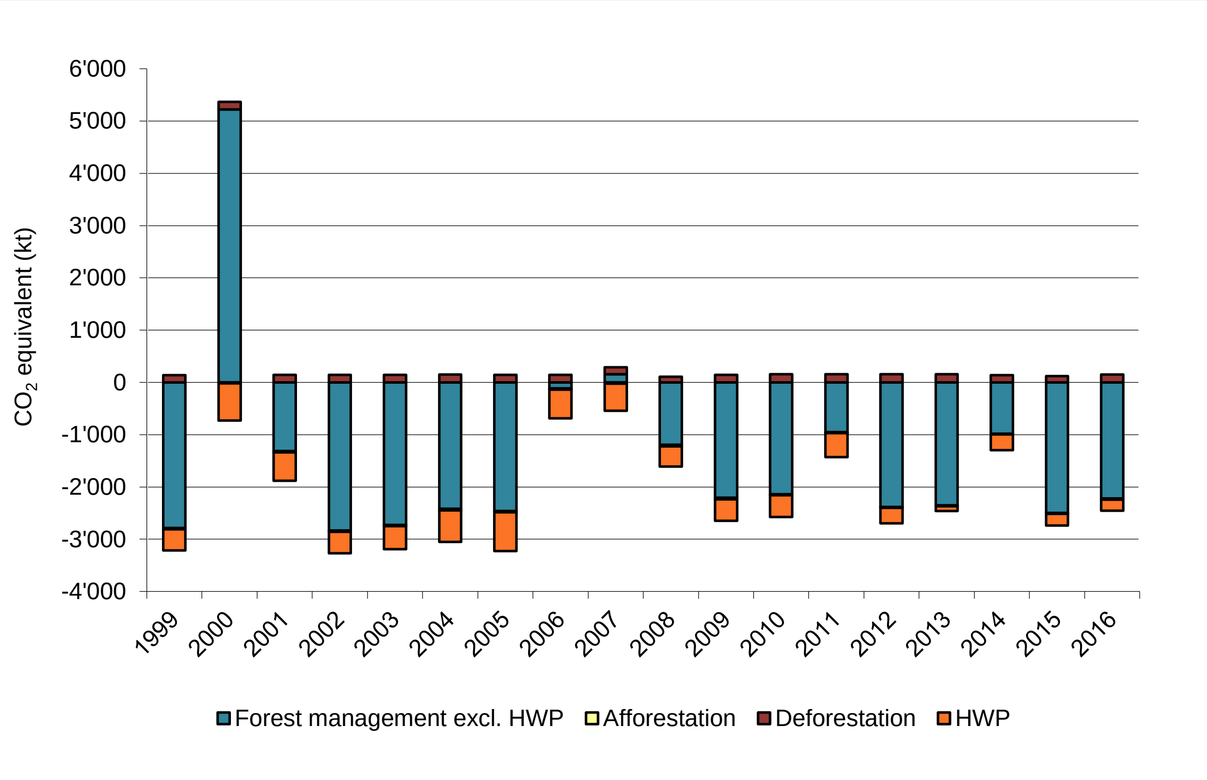


Figure 11-1 GHG emissions (positive sign) and removals (negative sign). Shown are data for Afforestation (too small to be distinguishable) and Deforestation under Article 3, paragraph 3, Forest management excluding HWP and HWP under Article 3, paragraph 4.

Table 11-1 Net CO_2 eq emissions (positive sign) and removals (negative sign) for activities accounted for under Article 3, paragraph 3 and Forest management under Article 3, paragraph 4, of the Kyoto Protocol, selected years. Abreveations are explained in chp. 6.1.3.2 except for $loss_{drainage\ and\ LUC}$ (N_2O), $loss_{LUC}$ (N_2O), $loss_{drainage}$ (N_2O): N_2O emissions associated with drainage and/or land-use change (LUC); C_{l_ag}: carbon in above-ground living biomass; C_{l_bg}: carbon in below-ground living biomass; C_{s_m}: carbon in mineral soil; C_{s_o}: carbon in organic soil; C_{HWP}: carbon in HWP; $loss_{biomburn}$: CH_4 and N_2O emissions from biomass burning. Figures correspond with CRF 4(KP) and CRF 4(KP-I)B.1.

Greenhouse gas source and sink activities	1990	1995	2000	2005
	kt CO_2 equivalent			
A. Article 3.3 activities	**89.26**	**107.01**	**121.30**	**120.36**
A.1. Afforestation and Reforestation incl. N_2O; 4(KP)	-3.17	-15.66	-20.48	-24.53
Afforestation <= 20 yr	-2.75	-13.60	-17.81	-21.40
Afforestation > 20 yr	-0.43	-2.11	-2.73	-3.21
$loss_{drainage\ and\ LUC}$ (N_2O)	0.01	0.05	0.07	0.08
A.2. Deforestation incl. N_2O; 4(KP)	92.43	122.67	141.78	144.89
Deforestation excl. N_2O	92.33	122.08	140.65	143.21
$loss_{LUC}$ (N_2O)	0.09	0.59	1.13	1.68
B. Article 3.4 activities	**-1'743.32**	**-4'184.86**	**4'521.14**	**-3'197.64**
B.1. Forest management; 4(KP)	-1'743.32	-4'184.86	4'521.14	-3'197.64
$gainC_{l\_ag}$	-9'759.91	-9'698.13	-9'729.03	-9'764.13
$gainC_{l\_bg}$	-2'749.42	-2'751.11	-2'763.44	-2'776.70
$lossC_{l\_ag}$	8'870.61	6'792.34	13'984.43	8'467.96
$lossC_{l\_bg}$	2'682.91	2'006.17	3'901.49	2'460.87
$changeC_h$	386.81	-69.16	74.77	-533.77
$changeC_d$	102.28	25.02	-241.41	-312.98
$changeC_{s\_m}$	-1.43	-0.26	-3.15	-4.57
$changeC_{s\_o}$	1.08	1.09	1.09	1.10
$changeC_{HWP}$	-1'304.80	-503.96	-709.27	-739.96
Forest management excl. CH_4 and N_2O; 4(KP-I)B.1	-1'771.87	-4'198.00	4'515.50	-3'202.18
$loss_{biomburn}$ (CH_4 and N_2O)	28.41	12.99	5.49	4.39
$loss_{drainage}$ (N_2O)	0.15	0.15	0.15	0.15
B.2. Cropland management	NA	NA	NA	NA
B.3. Grazing land management	NA	NA	NA	NA
B.4. Revegetation	NA	NA	NA	NA

Greenhouse gas source and sink activities	2008	2009	2010	2011	2012	2013	2014	2015	2016
	kt CO_2 equivalent								
A. Article 3.3 activities	**82.40**	**118.07**	**134.56**	**137.13**	**138.52**	**137.48**	**121.70**	**104.30**	**131.84**
A.1. Afforestation and Reforestation incl. N_2O; 4(KP)	-26.85	-27.61	-22.47	-20.47	-19.81	-18.88	-16.78	-18.23	-19.61
Afforestation <= 20 yr	-23.45	-24.12	-22.00	-19.99	-17.99	-16.55	-15.51	-14.96	-14.43
Afforestation > 20 yr	-3.48	-3.58	-0.55	-0.55	-1.88	-2.38	-1.31	-3.32	-5.21
$loss_{drainage\ and\ LUC}$ (N_2O)	0.08	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.04
A.2. Deforestation incl. N_2O; 4(KP)	109.25	145.68	157.03	157.60	158.33	156.36	138.48	122.53	151.44
Deforestation excl. N_2O	107.28	143.60	154.93	155.47	156.18	154.19	136.31	120.39	149.29
$loss_{LUC}$ (N_2O)	1.98	2.08	2.11	2.13	2.15	2.17	2.17	2.15	2.16
B. Article 3.4 activities	**-1'578.72**	**-2'617.40**	**-2'551.05**	**-1'407.80**	**-2'671.16**	**-2'438.38**	**-1'278.96**	**-2'720.22**	**-2'433.61**
B.1. Forest management; 4(KP)	-1'578.72	-2'617.40	-2'551.05	-1'407.80	-2'671.16	-2'438.38	-1'278.96	-2'720.22	-2'433.61
$gainC_{l\_ag}$	-10'294.04	-10'305.98	-10'311.31	-10'317.04	-10'322.77	-10'329.84	-10'338.20	-10'344.79	-10'354.92
$gainC_{l\_bg}$	-2'947.54	-2'951.80	-2'954.10	-2'956.38	-2'958.66	-2'961.38	-2'964.42	-2'966.90	-2'970.41
$lossC_{l\_ag}$	9'589.72	8'947.43	9'417.58	9'344.84	8'597.38	8'860.09	9'110.59	8'473.20	8'390.48
$lossC_{l\_bg}$	2'793.13	2'626.44	2'780.14	2'759.02	2'546.70	2'631.49	2'705.57	2'513.94	2'734.90
$changeC_h$	76.37	-97.02	-547.43	468.73	67.58	-193.37	605.13	71.30	146.05
$changeC_d$	-410.95	-426.76	-520.05	-249.92	-306.53	-354.58	-96.36	-239.33	-170.31
$changeC_{s\_m}$	-4.53	-4.68	-5.13	-5.56	-5.26	-5.39	-5.40	-4.95	-4.91
$changeC_{s\_o}$	1.11	1.12	1.12	1.12	1.12	1.13	1.13	1.13	1.14
$changeC_{HWP}$	-385.88	-410.10	-415.14	-458.81	-293.89	-89.67	-300.54	-227.30	-213.50
Forest management excl. CH_4 and N_2O; 4(KP-I)B.1	-1'582.61	-2'621.33	-2'554.32	-1'414.00	-2'674.33	-2'441.53	-1'282.49	-2'723.70	-2'441.48
$loss_{biomburn}$ (CH_4 and N_2O)	3.74	3.78	3.12	6.05	3.02	3.00	3.37	3.33	7.72
$loss_{drainage}$ (N_2O)	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16
B.2. Cropland management	NA	NA	NA	NA	NA	NA	NA	NA	NA
B.3. Grazing land management	NA	NA	NA	NA	NA	NA	NA	NA	NA
B.4. Revegetation	NA	NA	NA	NA	NA	NA	NA	NA	NA

CRF accounting ("Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol") gives an overview of the CO_2 eq emissions and removals from Afforestation and Deforestation under Article 3, paragraph 3 and Forest management under Article 3, paragraph 4.

In 2016, Forest management in Switzerland caused removals of -2433.61 kt CO_2 eq. The debit incurred from activities under Article 3.3 is 131.84 kt CO_2 eq.

11.1 General information

The inventory datasets on which the calculations are based (Swiss Land Use Statistics AREA and National Forest Inventory NFI) are described in 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 CRF NIR1.

Some source categories were explicitely excluded from the land-use 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), additions to the assigned amount resulting from Forest management under Article 3, paragraph 4, are capped. This cap for the second commitment period amounts to 15'037'884 t CO_2 eq for the entire commitment period 2013–2020 (FOEN 2016d).

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 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).

For the notation of activities under article 3.3 and article 3.4 of the Kyoto Protocol, the first character is capitalised (see chp. 6.1.3.1): Afforestation, Deforestation and Forest management.

Afforestation

Afforestation is the conversion to forest of an area not fulfilling the definition of forest for a period of at least 50 years if the definition of forest in terms of minimum area (625 m^2) is fulfilled, and the conversion is a direct human-induced activity (FOEN 2006h).

Natural forest regeneration following the abandonment of subalpine pastures is not considered to be a direct human-induced activity. Only conversions to forest land which can clearly be attributed as direct human-induced from aerial photographs (SFSO 2017; see also chp. 6.3.1) are considered as Afforestation under the Kyoto Protocol. Examples of direct human-induced conversions to forest land (Afforestations) are shown in FOEN (2010h).

Deforestation

Deforestation is the permanent conversion of areas fulfilling the definition of forest in terms of minimum forest area (625 m^2) to areas not fulfilling the definition of forest as a consequence of direct human influence (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 the Kyoto Protocol 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 4(KP-I)A.2 for Deforestations and CRF 4(KP-I)B.1 for Forest management). The area of the current land-use after Deforestation is given as information item in CRF 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.

11.2 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. 4'129.042 kha (see chp. 6.3.5; Table 6-8).

All activity data for reporting the activities under the Kyoto Protocol are retrieved from the Swiss Land Use Statistics (SFSO 2017; 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 and/or 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 Afforestation: “Total for Activity A.1” in CRF 4(KP-I)A.1 equals the cumulated afforestated areas since 1990 as shown in Table 11-2 and CRF NIR-2. The area of deforestations displayed under “Total for activity A.2” in CRF 4(KP-I)A.2 encompasses the cumulated area of deforestations since 1990 (see also Table 11-2 and CRF NIR-2). However, only the cumulated area of deforestations of the last 20 years are relevant to calculate changes in carbon stocks (Table 6-3).

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 CRF NIR-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 6-4). 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 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

Land Use Statistics (AREA) data allow to clearly separate between the land areas subject to a specific activity. Absolute and cumulated activity data since 1990 of Afforestations, Deforestations and Forest management are listed in Table 11-2. The total country area amounts to 4'129'042 ha (Table 6-8).

Table 11-2 Activity data for activities under Article 3, paragraphs 3 and 4, selected years. Data for Afforestation and Deforestation and values representing the area under Forest management were derived from the Swiss Land Use Statistics (AREA) (SFSO 2006a, 2017). See also CRF NIR-2.

	Unit	1990	1995	2000	2005
Afforestation area	kha	0.26	0.12	0.06	0.05
Cumulated area of Afforestation since 1990	kha	0.26	1.28	1.66	1.95
Deforestation area	kha	0.30	0.35	0.37	0.36
Cumulated area of Deforestation since 1990	kha	0.30	1.91	3.72	5.57
Forest management area	kha	1'210.66	1'221.61	1'229.10	1'236.07

	Unit	2008	2009	2010	2011	2012	2013	2014	2015	2016
Afforestation area	kha	0.06	0.06	0.05	0.05	0.05	0.07	0.07	0.06	0.05
Cumulated area of Afforestation since 1990	kha	2.12	2.18	2.23	2.28	2.33	2.40	2.46	2.52	2.57
Deforestation area	kha	0.25	0.34	0.37	0.37	0.37	0.36	0.31	0.28	0.35
Cumulated area of Deforestation since 1990	kha	6.49	6.83	7.20	7.57	7.94	8.31	8.62	8.90	9.25
Forest management area	kha	1'241.64	1'243.81	1'245.08	1'246.26	1'247.44	1'248.89	1'250.44	1'251.98	1'253.42

Afforestation

Activity data for Afforestations are derived from the Swiss Land Use Statistics (AREA; SFSO 2006a, 2017; 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, 2017; 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 Sigmaplan (2010a).

Not all changes from a forest combination category (afforestation CC11, productive forest CC12 and unproductive forest CC13) to a non-forest combination category correspond to the definition of Deforestation according to the Kyoto Protocol Art. 3.3. The following criteria 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 Sigmaplan (2012a) showed that, although the aspect of "temporal limitiation" was considered when classifying Deforestations, at the end still 14% of these Kyoto Deforestations were in fact "short-term reduction of crown coverage" and should be classified as "management interventions" rather than as real land-use changes (see chp. 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 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 (NOLU04 2XX) and forest area (NOLU04 3XX; cf. Table 6-6). Land cover on these points is in general open forest (NOLC04 44), linear woods (NOLC04 46) or cluster of trees (NOLC04 47; cf. 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 NOLU04 3XX to agricultural area NOLU04 2XX), 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 m^2.

- Areas with a reduction in forest cover on the grid point but still fulfilling the Kyoto definition of forest, i.e. having the potential to reach 3 m at maturity in situ.

3. No change in land use took place: reduction of tree cover without land-use change; former land use was mainly pasture

4. Tree loss is not direct human-induced: Conversion due to natural hazards and dynamics.

The four criteria were applied to the the land-use change data of the AREA survey (see chp. 6.2.2) for calculating annual values of the respective area (e.g. 0.980 kha in 2016, see Table 11-6).

It was ensured that the criteria and the application to identify conversions which do not correspond to Deforestations under the Kyoto Protocol 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. The classification under Forest management implies that carbon stocks on these areas are based on NFI data (see chp. 6.4.2.1). Thus, carbon stock changes are reflected in the Implied Emission Factors in the reporting tables and are 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, 2017; 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 (Table 11-2). 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, for example, 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 11-4. Annual values for carbon stocks and carbon stock changes in the pools of living biomass, dead wood, litter and soil carbon of Afforestations (CC11), productive forests (CC12) and unproductive forests (CC13) are displayed in Table 6-4, Table 6-17, and Table 6-20. All working steps and data required to reproduce the calculation of emission factors the reporting tables are summarized in FOEN (2018c).

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 11-3. Under the UNFCCC aggregated pools were reported, under the Kyoto Protocol the pools were reported separately. For Forest management the stratified ratios shown in Table 11-3 were used. For Afforestation and Deforestation the domestic mean value (0.30) was used.

Table 11-3 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

Table 11-4 Application of the methodolgy 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, and Forest management appearing in four types as defined by land use and land-use change, respectively (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 to buildings and constructions (i.e. a land-use change from C1X to CC51), changes in carbon stock of mineral soils and of organic soils are accounted for by reducing the carbon stock by 20% (see chp. 6.8.2.3). A conversion time (CT) of 20 years was 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_m = mineral soil, s_o = organic 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	Mineral Soil	Organic Soil
Afforestation CC11 ≤ 20 yr	gain-loss $\text{gainC}_{l,i,CC11} - \text{lossC}_{l,i,CC11}$	stock-difference, CT=20 $(\text{stockC}_{h,i,CC11} - \text{stockC}_{h,i,b})/CT = 0$	stock-difference, CT=20 $(\text{stockC}_{d,i,CC11} - \text{stockC}_{d,i,b})/CT = 0$	stock-difference, CT=20 $(\text{stockC}_{s\_m,i,CC11} - \text{stockC}_{s\_m,i,b})/CT$	gain-loss $\text{changeC}_{s\_o,i,CC11}$
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 $\text{changeC}_{s\_m,i,CC12}$	gain-loss $\text{changeC}_{s\_o,i,CC12}$
Deforestation	stock-difference, CT=1 $(\text{stockC}_{l,i,a} - \text{stockC}_{l,i,CC12})/CT$	stock-difference, CT=1 $(\text{stockC}_{h,i,a} - \text{stockC}_{h,i,CC12})/CT$	stock-difference, CT=1 $(\text{stockC}_{d,i,a} - \text{stockC}_{d,i,CC12})/CT$	stock-difference, CT=20 C1X to CC51: $0.2 * (\text{stockC}_{s\_m,i,CC51} - \text{stockC}_{s\_m,i,CC1X})/CT =$ $0.2 * (0 - \text{stockC}_{s\_m,i,CC1X})/CT$ C1X to other: $(\text{stockC}_{s\_m,i,a} - \text{stockC}_{s\_m,i,CC1X})/CT$	stock-difference, CT=20 C1X to CC51: $0.2 * (\text{stockC}_{s\_o,i,CC51} - \text{stockC}_{s\_o,i,CC1X})/CT =$ $0.2 * (0 - \text{stockC}_{s\_o,i,CC1X})/CT$ C1X to other: gain-loss; $\text{changeC}_{s\_o,i,CCXX}$
Forest management 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 $\text{changeC}_{s\_m,i,CC12}$	gain-loss $\text{changeC}_{s\_o,i,CC12}$
Forest management 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 $\text{changeC}_{s\_m,i,CC13} = 0$	gain-loss $\text{changeC}_{s\_o,i,CC13}$
Forest management CC12 to CC13	stock-difference, CT=20 $(\text{stockC}_{l,i,CC13} - \text{stockC}_{l,i,CC12})/CT$	stock-difference, CT=20 $(\text{stockC}_{h,i,CC13} - \text{stockC}_{h,i,CC12})/CT = 0$	stock-difference, CT=20 $(\text{stockC}_{d,i,CC13} - \text{stockC}_{d,i,CC12})/CT$ $= (0 - \text{stockC}_{d,i,CC12})/20$	stock-difference, CT=20 $(\text{stockC}_{s\_m,i,CC13} - \text{stockC}_{s\_m,i,CC12})/CT$ $= 0$	gain-loss $\text{changeC}_{s\_o,i,CC13}$
Forest management CC13 to CC12	gain-loss $\text{gainC}_{l,i,CC12} - \text{lossC}_{l,i,CC12}$	stock-difference, CT=20 $(\text{stockC}_{h,i,CC12} - \text{stockC}_{h,i,CC13})/CT = 0$	stock-difference, CT=20 $(\text{stockC}_{d,i,CC12} - \text{stockC}_{d,i,CC13})/CT$ $= \text{stockC}_{d,i,CC12}/20$	stock-difference, CT=20 $(\text{stockC}_{s\_m,i,CC12} - \text{stockC}_{s\_m,i,CC13})/CT$ $= 0$	gain-loss $\text{changeC}_{s\_o,i,CC12}$

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

Living biomass

- Gain and loss in living biomass of Afforestations (gross growth and cut and mortality) was taken from the study by Thürig and Traub (2015). Values are available for two elevation levels (Table 6-4).

Litter and dead wood

- On Afforestations, carbon stocks in litter and dead wood were assumed to be zero (IPCC 2006, chp. 4.3.2; see chp. 11.3.1.2 for details). Applying the stock-difference calculation approach (conversion time = 20 years; Table 11-4), calculated changes in the litter and dead wood pool on Afforestations are zero since there is no litter and no dead wood neither on Afforestations (land-use after conversion) nor on any other land-use types outside of forests (land-use before conversion; Table 6-4).

Soil carbon

- Mineral soils: In the case of a land-use change to Afforestations, the difference in soil carbon stocks between land use before and after the conversion was calculated. A conversion time of 20 years was applied.
- For organic soils, emissions due to drainage were calculated as described in chp. 6.4.2.10 and chp. 11.3.1.2.

Afforestation >20 years: units of land harvested since the beginning of the commitment period

After 20 years, afforestated areas are subject to common forest management practices and the first thinnings and treatments are conducted. These afforestated areas are, however, not reclassified to the activity Forest management: all afforestations after 1990 are consistently reported under Afforestation under Article 3.3 (CRF 4(KP-I)A.1; see chp. 11.2.3). Emissions and removals for the carbon pools of Afforestations older than 20 years were calculated using the carbon stock changes of productive forests (CC12) (see methodological description under Forest management) since nearly all of the afforestations (99.9%) develop into 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 was immediately accounted for after Deforestation (conversion time = 1 year). Losses in – both mineral and organic – soil carbon stocks due to disturbance caused by Deforestation and conversion to CC51 (buildings and constructions) were accounted for by reducing the carbon stock by 20% of the orginial carbon stock following the proposal of IPCC 2006 (Volume 4, chp. 8.3.3.2) over a conversion period of 20 years (see Table 11-4 and chp. 6.8.2.2). The reason for this is that 20% of the soil organic matter is assumed to be lost as a result of disturbance, removal or relocation on these sealed areas. A conversion time of 20 years was applied.

Forest management

Living biomass

- Gain in living biomass (gross growth) of productive forests was used for “CC12 remaining” (Table 6-17). Gain of unproductive forests was used for “CC13 remaining” and is assumed to be 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 6-17). Unproductive forests are not systematically harvested (see description in chp. 6.4.2.8; Table 6-4). Thus losses of unproductive forests “CC13 remaining” are assumed to be zero. Moreover, since yearly harvesting amounts from forest statistics (FOEN 2017d) are distributed over the productive forests, total harvesting in forests was accounted for under “CC12 remaining”.
- For the conversions between different forest combination categories (“CC13 to CC12” and “CC12 to CC13”) the method is chosen in such a way that no potential carbon losses could be 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 was applied, since applying a stock-difference approach would lead to a considerable sink in carbon stock of living biomass in this type of Forest management.

Litter, dead wood and soil

- For productive forests “CC12 remaining”, yearly values for changes in carbon stocks of litter, dead wood and soil were used (Table 6-20). The estimates 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 were assumed to be zero (chp. 6.4.2.8).
- For the conversions between different forest combination categories (“CC13 to CC12” and “CC12 to CC13”) the difference in carbon stock of dead wood, litter and soil carbon was taken into account. 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). Calculated carbon stock changes in the litter and dead wood pool were zero.
- For organic soils, emissions due to drainage were calculated as described in chp. 6.4.2.10.

Differences in accounting for “Forest categories 4A1 and 4A2” under the UNFCCC and Forest management under the Kyoto Protocol Art. 3.4

Under the Kyoto Protocol Art. 3.4, natural forest regeneration is reported under Forest management as productive forest (CC12) or unproductive forest (CC13) as soon as the KP definition of forest is fulfilled (CRF NIR-1). Changes within the activity Forest management are reported under the Kyoto Protocol in the combination 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 (area budget) 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

CRF NIR-1 summarizes the activity coverage and the carbon pools reported. When using the 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, no changes are reported.

Changes in carbon pools not reported – Afforestation ≤ 20 years: litter and dead wood

Applying the stock-difference calculation approach (cf. Table 11-4), calculated changes in the litter and dead wood pools after Afforestation under 20 years are zero (see chp. 6.4.2.9), since carbon stock in litter and dead wood is assumed to be zero on Afforestations (land-use after conversion; IPCC 2006, Volume 4, chp. 4.3.2) and also on all other land-use types outside of forests (land-use before conversion; Table 6-4).

A Tier 1 approach for these pools for Afforestations under 20 years was applied because a) Afforestation is not a key category (see chp. 11.6.1) and b) because the in comparison negligibly small carbon stock changes in these pools do not justify the (financial) effort to collect higher quality data without jeopardizing the resources for key categories (see Figure 4.1 in Volume 1 of IPCC 2006). 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 were not reported. In an experiment by Zimmermann and Hiltbrunner (2012) litter accumulation of an afforestation with Norway Spruce was determined 40 years after afforestation. The authors found accumalation rates of 0.17-0.20 t C ha^{-1} yr^{-1}. Other studies show even higher accumlation rates, e.g., 0.24-0.34 t C ha^{-1} yr^{-1} for afforestations with Norway spruce in the Southern Alps (Thuille and Schulze 2006), 0.24 t C ha^{-1} yr^{-1} for afforestation with ash and maple (Alberti et al. 2008) and 0.36 t C ha^{-1} yr^{-1} for Scotch pine (Vesterdal et al. 2002). In Finnish forests, Karhu et al. (2011) found that over 18 years the mean annual rate of carbon accumulation in the litter was 0.28 Mg ha^{-1} for Scots pine and 0.15 Mg ha^{-1} for birch.
- Based on a literature overview, Jandl et al. (2007) argued that the accumulation of a forest floor layer in, e.g., a conifer forest, results in a carbon sink. The authors concluded that after afforestation, forest floors accumulate carbon quickly. A long-term consequence of afforestation is the gradual incorporation of carbon in the carbon pool of the mineral soil. Guidi et al. (2014) found that the carbon stocks in the organic layers were affected by land-use change, with more carbon stored under early-stage forest compared with grassland abandoned 10 years ago, and highest carbon stocks were found under the old forest dominated by *Fagus sylvatica* and *Picea abies*.
- Changes in dead wood after afforestation: no changes in the dead wood pool after afforestations were 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 carbon stored in the dead wood of 0.26 t C ha^{-1} 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) was provided: At stand level, the pools dead wood and litter of afforestation on cropland and grassland cannot be a source, especially if the previous land use did not have perennial woody biomass. On afforestations, tree growth is assumed to follow 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 were reported.

Changes in carbon pools not reported – Unproductive forests

A description of unproductive forests and the reasoning why the living biomass, litter, dead wood and soil pools were reported to be 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 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 note 4 in IPCC (2006), Volume 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 reported no changes in the carbon pools of living biomass, litter, dead wood and mineral soil of unproductive forest areas.

Greenhouse gas sources reported

- Drainage of forests is not a permitted practice in Switzerland (Swiss Confederation 1991). However, it is possible that parts of the Swiss forest were drained before 1990 or had been established on drained areas. Abegg (2017) found that 3% of organic soils in forest land is or has been subject to drainage. CO_2 emissions due to drainage are calculated as described in chp. 6.4.2.10. N_2O emissions from drainage of organic soils were calculated as described in chp. 6.4.2.11.

Greenhouse gas sources reported as “included elsewhere (IE)”

- Biomass burning: emissions of CO_2 were given the notation “IE”; emissions of CH_4 and N_2O were reported. The calculation of these emissions is described in chp. 6.4.2.12.
- Emissions from biomass burning on Afforestations and unproductive forests were reported under Forest management of productive forests. In this way, emissions were not underestimated, since the carbon stock ("available fuel") in 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 (see chp. 6.4.2.12).
- Biomass burning on areas under Forest management: CO_2 emissions were reported as “IE”. The reported losses of living biomass and dead wood are covered by NFI data and thus the values reported in the reporting tables Table4.A and 4(KP-I)B.1 include these losses. Emissions of CH_4 and N_2O were reported. The calculation of these emissions is described in chp. 6.4.2.12.

Greenhouse gas sources reported as “not occurring (NO)”

- 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 on Afforestations and Forest management were reported as “not occurring”.
- HWP from Afforestation: Since Afforestation in Switzerland typically serves purposes other than timber production, biomass is not removed for products entering the HWP pool. In case there is some wood of first thinings in Afforestations since 1990, it is mostly left on the site or sometimes collected for energy purposes (i.e. it could be assessed as instantaneous oxidation). Therefore, the amount of HWP from Afforestation was reported as not occurring (“NO”) and all carbon stock changes in HWPs were reported under Forest management (see chp. 6.11.2). HWP from Deforestation was accounted for on the basis of instantaneous oxidation “IO”.

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals were factored out

No anthropogenic GHG emissions and removals from elevated CO_2 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 were factored out.

The IPCC does not give specific methods for factoring out these effects. Besides this, there are no reliable country-specific data available. Investigations on elevated CO_2 concentrations on growth showed complex relationships in the mid-term. Some species showed an increase others a decrease and some no change in growth (Bader el al. 2013). Opposing patterns are also reported regarding the effect of nitrogen deposition: A positve 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)

Table 10-1 (recommendations) and Table 10-2 (encouragements) list the improvements made since the last submission (FOEN 2017) in response to the questions, recommendations and ecouragements of the UNFCCC Expert Review Team.

Methodological improvements for Forest land in the LULUCF and the KP-LULUCF sectors are listed in chp. 6.4.5, 6.11.5, and 10.1.2.4. No Kyoto-specific methodological modification was made.

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.

A detailed description of the determination of the emission factor uncertainty for Forest land, which is also assigned to the activity Forest management, can be found in chp. 6.4.3. Uncertainty estimates of LULUCF emission factors are shown in Table 6-5, and deduced overall uncertainties for the reported activities under the Kyoto Protocol are composed in Table 11-5: 88.6% for Afforestations (associated UNFCCC category: 4A2), 50.2% for Deforestations (associated UNFCCC category: mainly 4E2) and 88.6% for Forest management (associated UNFCCC category: 4A1).

Lands fulfilling the definition of forest (see chp. 11.1.1) were accounted for under Forest management. Accordingly, the area under Forest management resulting from natural regeneration is attributed the uncertainty of Forest management.

Table 11-5 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 (chp. 6.3)**	**Activity data uncertainty**	**Emission factor uncertainty [%]**	**Combined uncertainty**
		%	**%**	**%**
Afforestation	4A2 Land converted to forest land	1.6	88.6	88.6
Deforestation	mainly 4E2 Land converted to settlements	4.6	50.0	50.2
Forest management	4A1 Forest land remaining forest land	1.1	88.6	88.6

11.3.1.6 Information on other methodological issues

N_2O emissions as a result of the disturbance associated with land-use conversion (Deforestation) were reported in CRF 4(KP-II)3. The emissions were 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 was derived (Table 11-2).

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 chp. 1.2.3.

11.3.2.1 Changes in soil carbon stock under Afforestation

The assumption 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 Table4.A) and under Forest management under the Kyoto Protocol (CRF 4(KP-I)B.1) is not possible due to the different structure of these reporting tables and due to different reporting requirements:

- Conversions to Forest land which are not human-induced (natural regneration) were not accounted for as Afforestations under the Kyoto Protocol. These areas were reported under KP Art. 3.4 Forest management in CRF 4(KP-I)B.1 as soon as the definition of Forest was fulfilled. Under the Convention, these afforestations were reported under land-use category 4A2 with a conversion time of 20 years.
- Afforestations under the Kyoto Protocol which are older than 20 years were consistently reported under Art. 3.3 (sub-division >20 years in CRF 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, afforestations older than 20 years were reallocated 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 chp. 11.2.3). These areas remained under the Kyoto Protocol Art. 3.4 activity Forest management and were included in the areas as reported in CRF 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 were not

reported seperately, but were reported as CC12 or CC13 as soon as the KP definition of forest was fulfilled. Only conversions within the activity Forest management were reported under the Kyoto Protocol, i.e. CC12 to CC13 and CC13 to CC12. Under the UNFCCC, land-use change to forest land were reported in category 4A2.

In Meteotest (2018) the reported activity data for the inventory year 2016 were examined and compared (Table 11-6). The differences in the reporting tables Table4.A, 4(KP-I)A.1 and 4(KP-I)B.1 can be explained and the resulting budget of areas reported under the Convention and the Kyoto Protocol is identical.

Table 11-6 Area budget (in kha) of KP-LULUCF and LULUCF under the UNFCCC in the year 2016 for forest land (Meteotest 2018).

activity	Table, Cells	area UNFCCC 2015 kha	area KP 2015 kha	Check Difference kha	remarks
All Forest Land					
Forest Management	4(KP-I)B.1, D11		1'253.423		a)
Afforestations <= 20 years	4(KP-I)A.1, C29		1.170		b)
Afforestations > 20 years	4(KP-I)A.1, C13		1.397		c)
Total area KP			1'255.989		
Non-Kyoto loss of forest cover			-0.980		d)
Forest Land UNFCCC	4.A, C10	1'255.010			e)
Total		1'255.010	1'255.010	0.000	
Afforestation, CC11					
UNFCCC	4.A, C32+C36+C40 +C44+C48	1.170			f)
KP (<= 20 years)	4(KP-I)A.1, C29		1.170	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) comprise 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 the UNFCCC) not fulfilling the definition of Deforestations according to the Kyoto Protocol (see chp. 11.2.3). For the comparison this area must be subtracted from the KP forest area. It is an annual value (not cumulated) calculated on the basis of the AREA survey data (chp. 6.2.2).

e) The total Forest land in CRF Table4.A 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 (chp. 6.2.2).

f) The CC11 area under the UNFCCC can be derived from CRF Table4.A.2 by summing up the afforestation 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 (Didion et al. 2012, Didion and Thürig 2017; 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 (annual monthly temperature and precipitation). The carbon inputs are obtained for each plot in the NFI that is simulated with Yasso07. The NFI plots were 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 were 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 were fully accounted for in the GHG inventory (Didion et al. 2014a).

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.

Net CO_2 eq removals from Afforestation and CO_2 eq emissions from Deforestation under Article 3, paragraph 3 differ by one order of magnitude (Figure 11-2, Figure 11-3). Since carbon from living biomass is immediately removed after clear-cutting, deforestation can be seen as a process where carbon is lost over a very short time. In contrast, afforestation is a slow process where carbon is sequestered and accumulated over decades. CO_2 emissions on organic soils under Afforestation are due to former drainage (see chp. 11.3.1.2). Figure 11-2 shows net CO_2 eq removals and emissions from Afforestation and CO_2 eq emissions from Deforestation for the years 1999–2016. Associated data for selected years are listed in Table 11-1.

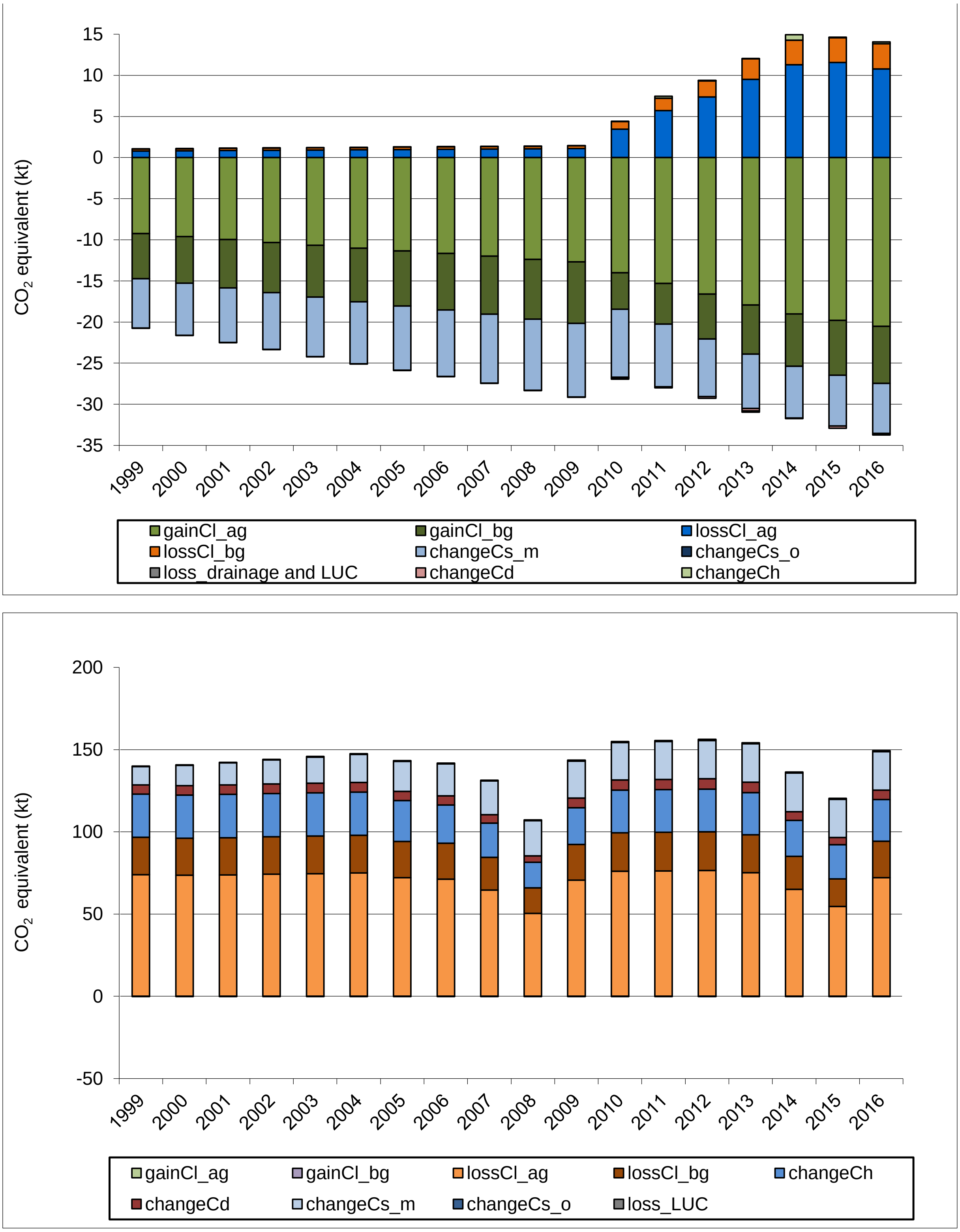


Figure 11-2 Net CO_2 eq removals (negative sign) and CO_2 eq emissions (positive sign) from Afforestation under Article 3, paragraph 3 (upper panel) and emissions from Deforestation under Article 3, paragraph 3 (lower panel) shown per carbon pool. For abbreviations see Table 11-1. Note the different scale of the y-axis in both graphs.

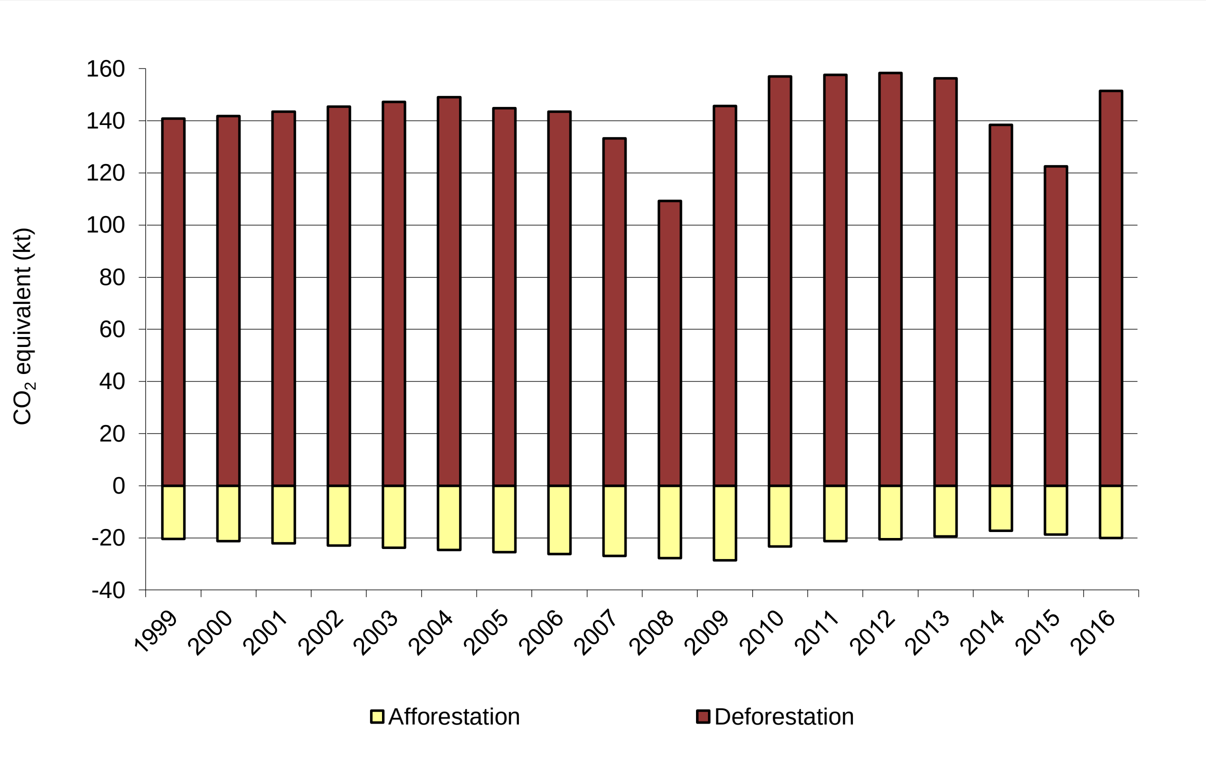


Figure 11-3 Net CO_2 eq removals (negative sign) of Afforestations under Article 3, paragraph 3 and CO_2 eq emissions (positive sign) of Deforestations under Article 3, paragraph 3.

11.4.1 Information that demonstrates that activities under Article 3.3. began on or after 01 January 1990 and before December 2020 and are direct human-induced.

The Swiss definitions of Afforestation and Deforestation only consider direct 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 forests under Afforestation (see chp. 11.1.3; FOEN 2010h).

The annual rate of all afforested areas since 1990 is assessed based on AREA data (chp. 6.3; chp. 11.1.3; FOEN 2010h). For reporting under the Kyoto Protocol, afforested areas since 1990 always remain in the Afforestation category. Therefore, the area in this activity has been increasing since 1990 (see Table 11-2).

Afforestations older than 20 years are subject to common forest management practices including harvesting (see chp. 11.3.1.1). These areas are reported as a subcategory in CRF 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 deforestation events 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 in this category has been increasing since 1990 (see Table 11-2). 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 to 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 followed by forest re-establishment. 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 combination category to a non-forest combination category. However, not all changes from Afforestation CC11, productive forest CC12, or 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 distrubances 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).

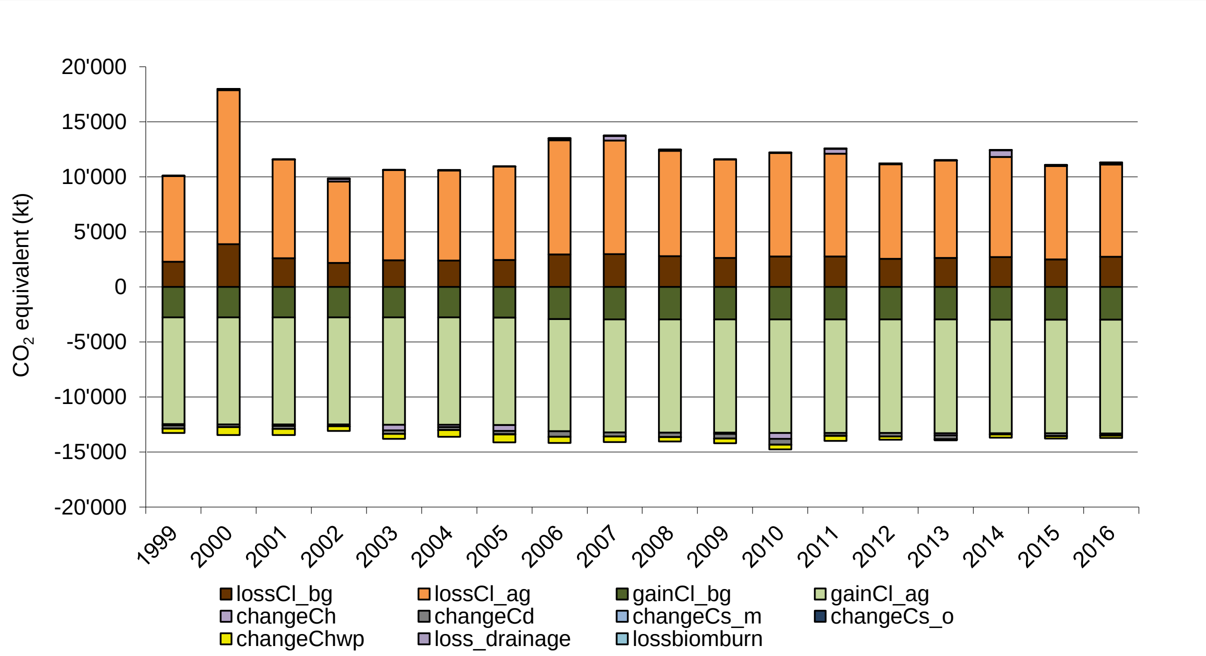
11.4.5 Information on Harvested wood products under Article 3.3

The calculation of carbon stock changes in Harvested wood products (HWP) is described in chp. 6.11. The change in carbon stocks was estimated differentiating HWPs originating from Deforestation and from Forest management. Based on the available datasets it was not possible to differentiate between HWP from Afforestation (if available, it is a negligible amount) and HWP from Forest management. Thus, HWP from Forest management also covers HWP from Afforestation.

Applying instantaneous oxidation to HWP originating from Deforestations, identical results are obtained for changes in carbon stocks of HWP reported under the UNFCCC (CRF Table4.Gs1) and under the Kyoto Protocol (CRF 4(KP-I)C) as shown in Table 6-35.

11.5 Article 3.4

CO_2 eq emissions and removals differentiated for the reported carbon pools and net CO_2 eq emissions and removals of KP Article 3, paragraph 4 activity Forest management for the years 1999–2016 are shown in Figure 11-4. Associated data for selected years are listed in Table 11-1. The annual fluctuations of the CO_2 eq emissions and removals from Forest management are described in the text accompanying Figure 11-1.



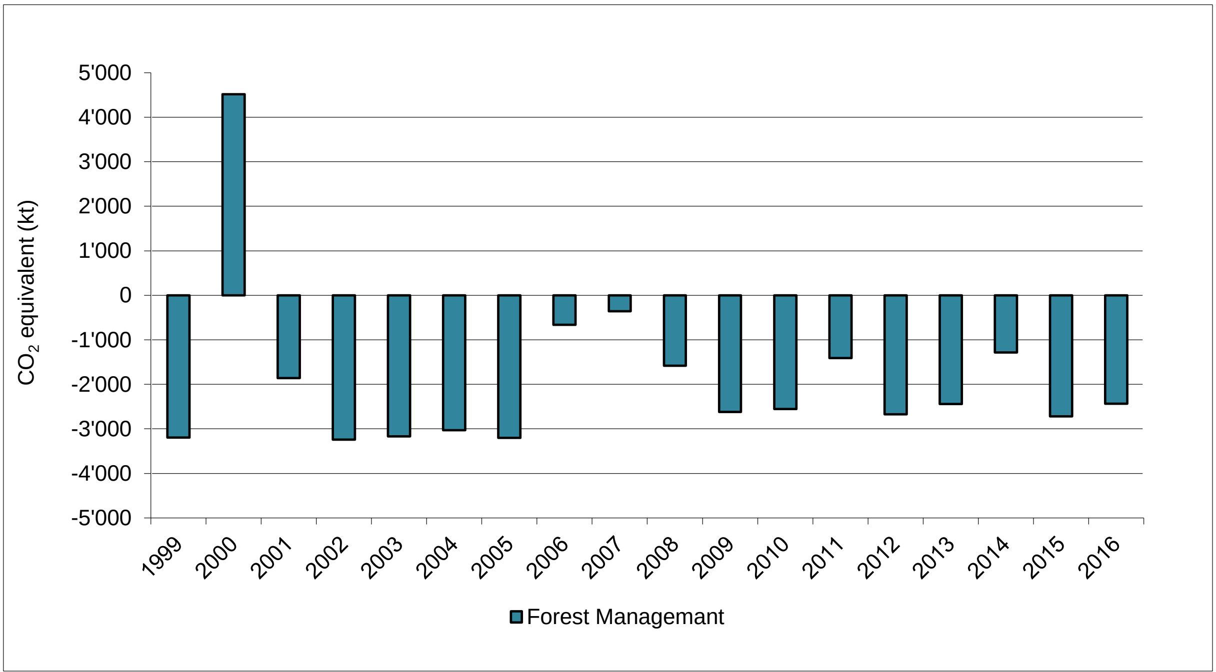


Figure 11-4 CO_2 eq emissions (positive sign) and CO_2 eq removals (negative sign) broken down for the reported carbon pools under Forest management (upper panel) and net CO_2 eq emissions and removals from Forest management (lower panel). For abreviations see Table 11-1. Note the different scale of the y-axis in both graphs.

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 Federal Act on Forest, 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 aimed 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% compared to the mid-19th century (Figure 11-5). Also the growing stock increased significantly due to changes in forest management practices. The revised 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.

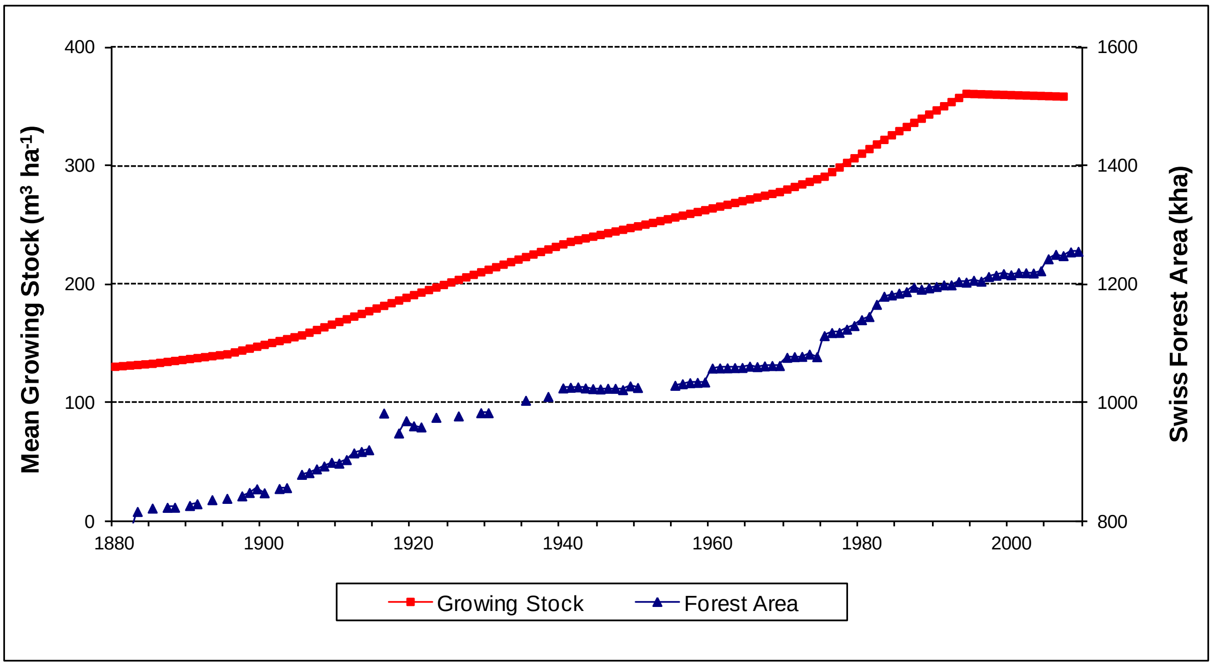


Figure 11-5 Historical mean growing stock ($m^3 ha^{-1}$) and forest area (kha) in Switzerland.

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 forests' protective function is guaranteed, (2) the economic viability of the forestry sector is improved, (3) the value-added chain for wood is strengthened, (4) biodiversity is conserved and (5) forest soils, trees and drinking water are not threatened. These objectives encompass that CO_2 removals by sinks and emissions by sources in the forests shall be recognized in terms of compliance with the Kyoto Protocol while making better use of the potential of forests for timber production and fuel wood through economic incentives and implementing new technologies.

In November 2006, the Swiss government communicated in its Initial Report to the UNFCCC that Switzerland will account for Forest management under Article 3.4 of the Kyoto Protocol (FOEN 2006h). In the second commitment period of the Kyoto Protocol, the accounting of Forest management is mandatory for all Parties.

To implement the objectives of the National Forest Programme (SAEFL 2004b), FOEN has formulated its Wood Resource Policy first initiated in 2008 (FOEN 2008h), updated in 2014 and 2017 (FOEN 2017j). With this Wood Resource Policy the Swiss Confederation formulated a separate Wood Action Plan, which is coordinated with the Forest Policy 2020 (FOEN 2013l), climate policy, energy policy and regional policy. As the lead agency in this process, the FOEN actively promotes the cooperation between these sectoral policy areas, the Swiss forestry and timber sector, and the cantons. The aim of the Wood Resource Policy is to ensure that wood from Swiss forests is supplied, processed and used in a way that is sustainable and resource-efficient. By this means, it makes a major contribution to forest, climate and energy policy. With its three priority areas of ‘optimised cascade use’, ‘climate-appropriate building and refurbishment’ and ‘communication, knowledge transfer and cooperation’, the Wood Action Plan supports the implementation of the Wood Resource Policy (FOEN 2017j). Upon evaluation of the first (2009–2012) and second phase (2013–2016), the Wood Resource Policy has been updated and the Wood Action Plan extended until 2020. In 2017, a new programme phase of the Wood Action Plan started (2017–2020). Its focus and relationship to other policy instruments are described above.

11.5.2.1 Conversion of natural forest to planted forest

Not applicable. Switzerland did not choose to apply the concept of carbon equivalent forests (see CRF 4(KP-I)B.1.2).

11.5.2.2 Forest management reference level (FMRL)

Switzerland’s Forest management reference level (FMRL) is documented in FOEN (2011l). The Swiss FMRL is inscribed in the appendix to the annex to Decision 2/CMP.7 and amounts to +0.220 Mt CO_2 eq. yr^{-1}. The FMRL was subject to a technical assessment. Based on the technical assessment report (UNFCCC 2011a) and applying guidance of IPCC (2014), a technical correction of Switzerland’s FMRL was implemented in FOEN (2015) as described in detail in FOEN (2016: chp. 11.5.2.3).

11.5.2.3 Technical correction Forest management reference level

For this submission 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. In order to reflect the most recent scientific knowledge, data availability and model versions and to ensure methodological consistency between the reference level and reporting for Forest management, the next technical correction of the FMRL will be reported in Switzerland’s submission in 2019. Corrections originating from recalculations in this submission (listed in chp. 10.1.2.4) and former submissions (since FOEN 2015) include the following elements:

Modelling carbon stock changes in living biomass with MASSIMO

To ensure methodological consistency between the reference level and reporting for Forest management, the most recent time series of NFI data (chp. 6.4.5).will be used.

For the Massimo model, 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:

- Representation of natural mortality to more accurately reflect the background level for natural disturbances (see chp. 11.5.2.4.2).
- Verification of allometries used to obtain estimates of whole tree volume and biomass, incl. branches, foliage, and roots.

Modelling carbon stock changes in dead wood, litter and mineral soil with Yasso07

- Application of the most recent time series of NFI data (chp. 6.4.5) to calculate input data to Yasso07.
- Attributing Yasso07 results since 1990 to the three elevation classes, which shifted slightly due to more accurate elevation data from a digital elevation model for the NFI plots.
- Further, the validity of the further development of Yasso07 for application in Switzerland will be investigated.

Harvested wood products

- Use the most recent time series since 1990 of the activity data (FAOSTAT database). These data have been updated: the share of domestic to total HWP has been revised (chp.6.11.5).
- HWP from paper and paperboard have to be included in the FMRL according to chp. 6.11.5 and in response to UNFCCC (2018, ID#KL.7).

Other emissions and removals to be recalculated for the FMRL

- Emissions from drainage from organic soils: based on the results of Abegg (2017) the share of drained organic soils under Forest land was reduced from 100% to 3%. This correction was made in response to UNFCCC (2018, ID#L.6 and ID#KL.3; see chp.6.4.2.10).
- Changes in soil carbon stocks for land-use changes from or to "Buildings and Constructions" (CC51) were recalculated in response to UNFCCC (2018, ID#KL.2; see chp. 6.8.5). In case of Deforestations to CC51, a loss of 20% of the soil carbon stock was reported as a source (see chp. 6.8.2.2 and Table 11-4). In case of Afforestations on CC51, the complete carbon stock change was reported (see Table 11-4 and chp.6.1.3.2).

Pools or emissions and removals to be removed from the FMRL

- CH_4 and N_2O emissions from wildfires were considered for the calculation of the background level and the margin with respect to the application of excluding natural disturbances from the accounting (see UNFCC2018, D#KL.5; FOEN 2016d). By moving these emissions to the background level, CH_4 and N_2O emissions from wildfires must be excluded from the contributing pools of the FMRL accordingly (see Table 11-14 in FOEN 2016).

Pools or emissions and removals not included in the FMRL so far

- Emissions from controlled burning cover the emissions from burning of residues in forestry (addressing UNFCCC 2018, ID#KL.4). Since the submission 2017 these emissions are reported in the category Forest land within the LULUCF sector (see chp. 6.4.2.13 in FOEN 2017 and in this submission). The emissions from controlled burning should be added as a pool to the FMRL (UNFCCC 2018, ID#KL.5; see FOEN 2017, chp. 6.4.5).

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 Second Initial Report (FOEN 2016c, FOEN 2016d), 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 technical effort would be justified to exclude them.

In the inventory years 2013, 2014, 2015 and 2016, no natural disturbances causing emissions exceeding the upper confidence interval (background level plus margin) occurred. Thus, no emissions from natural disturbances were excluded for 2013, 2014, 2015 and 2016.

11.5.2.4.2 Technical correction of the background level and margin

The background level and margin have been reviewed and are reported in the update of Switzerland's Second Initial Report under the Kyoto Protocol (FOEN 2016d).

There is no technical correction of the background level and margin so far.

11.5.2.5 Information on Harvested wood products under Article 3.4

Methodology, estimates and uncertainties of carbon stock changes in the HWP pool are described in chp. 6.11. The same methodology was applied for reporting HWP from Forest land under the UNFCCC and accounting for HWP from Forest management under the Kyoto Protocol. A time series for changes in the HWP pool is shown in Table 6-35 and Figure 6-10. An overview of emissions and removals resulting from the HWP pool from Forest management is presented in Table 11-1 and Figure 11-1.

New in this submission is that carbon stock changes in HWP comprise also paper and paperboard (see chp. 6.11.5).

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 accounted for based on emission factors of mature forests under Forest management. These units of lands are reported in CRF 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 extend removals from Forest management offset the debit incurred under Article 3, Paragraph 3

This information will only be 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 for the year 2016 are shown in Table 1-4 (by emissions) and summarized in Table 1-9. The method is explained in chp. 1.5. The smallest UNFCCC category, considered key based on an Approach 1 level assessment is “5D Wastewater treatment and discharge, CH_4” with a contribution of 180.33 kt CO_2 eq.

The following LULUCF activities under the Kyoto Protocol are listed in CRF NIR-3 because their associated LULUCF categories in the UNFCCC inventory are key categories under the level or trend assessment:

- Forest management (-2227.98 kt CO_2) encompasses net CO_2 removals from Forest management excluding HWP, biomass burning and drainage (see Table 11-1) and 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 activity under the Kyoto Protocol and the UNFCCC category. According to Table 1-9 the UNFCCC category ”Forest land remaining forest land“ is both level and trend key category under Approaches 1 and 2 assessments in 2016.
- Afforestation and Reforestation (-19.64 kt CO_2; encompasses net CO_2 removals; CRF 4(KP)) 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 2016 (Table 1-9).

- Deforestation (149.29 kt CO_2; encompasses CO_2 emissions; CRF 4(KP)) 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 in 2016 (Table 1-9).
- Harvested wood products (-213.50 kt CO_2; CRF 4(KP-I)C) is a level key category because its contribution is higher than the smallest UNFCCC category considered key. The same method is used for the calculation of HWP under the UNFCCC and the KP. According to Table 1-9 the UNFCCC category ”HWP“ is both level and trend key category under Approaches 1 and 2 assessments in 2016.

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 4 December 2007.

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 cooperates with Monaco regarding registry issues.

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 2017, have been submitted to the UNFCCC Secretariat electronically.

Overview of CP1 units

By the end of 2017, 241,826,246 AAUs were held in the Swiss Emissions Trading Registry (Table 12-1). In addition, 4,210,465 Emission Reduction Units (ERUs), 9,280,880 RMUs, 23,935,068 Certified Emission Reductions (CERs), and 114,793 Temporary Certified Emission Reductions (tCERs) were held in the Swiss Emissions Trading Registry. All remaining CP1 units in Party and Entity holding accounts have been carried over.

Table 12-1 Total quantities of CP1 Kyoto Protocol units by account type at the end of 2017 (SEF table 4)

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	NO	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	7'896'871	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	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	241'826'246	4'210'465	9'280'880	23'935'068	114'793	NO

Overview of CP2 units

By the end of the reporting year 2017, a total balance of 5,794,523 AAUs and 21,656,533 CERs were held in the Swiss Emissions Trading Registry, of which 1,821,654 CERs have been carried over from CP1(Table 12-2).

Table 12-2 Total quantities of CP2 Kyoto Protocol units by account type at the end of 2017 (SEF table 4)

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	1'723'552	NO	NO
Entity holding accounts	NO	NO	NO	17'944'551	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	5'794'523					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	1'988'430	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	5'794'523	NO	NO	21'656'533	NO	NO

12.3 Discrepancies and notifications

Switzerland's reports on discrepancies (R-2), Clean development mechanism (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 2017, 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 Public Information 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)) 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 Joint Implementation (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)* (FOEN 2016c), and the update to the report following the review (FOEN 2016d). According to the final review report (UNFCCC 2018), Switzerland's assigned amount for the second commitment period is 361'768.524 kt CO_2 equivalent. The commitment period reserve is 325'591.672 kt CO_2 equivalent.

12.6 KP-LULUCF Accounting

Switzerland chose to account over the entire commitment period for emissions and removals from activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol.

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	No change of cooperation arrangement occurred during the reported period.
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 2017, a new version of 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. The new software version was successfully deployed in October 2017 to the PROD environment. A more detailed documentation is not provide here, because the respective information is regarded as confidential. However, it may 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	The new registry software version that went live on the PROD environment in October 2017 included several additional security features further hardening the registry infrastructure. No futher details are provided for confidentiality reasons. However, it may be made available to the ERT upon approval of a specific request.
15/CMP.1 annex II.E paragraph 32.(g): Change of list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
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): Change of test results	No change of test results occurred during the reporting period.

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 minimise also potential adverse impacts on concerned actors (including developing countries). Given Switzerland's size and share in international trade (mainly with the European Union), it is not assumed that Swiss climate change policies have any significant adverse economic, social or 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 legal reform projects in Switzerland have to be accompanied by impact assessments, inter alia including evaluation of trade-related issues. This approach strives for 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 World Trade Organisation.

Impact assessments of legal reform projects are accompanied by a broad internal and external consultation process, inter alia inviting competent and potentially affected actors to provide advice on 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 domestic and foreign stakeholders can raise concerns and issues related to new policy initiatives, 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, is guided by the polluter pays principle, as enshrined in the Federal Act on the Protection of the Environment (Swiss Confederation, 1983). Accordingly, the internalisation 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 e.g. the Swiss emissions trading scheme, the supplemental use of international carbon credits from the Clean Development Mechanism or the CO_2 levy on heating and process fuels are important measures to put a price on emissions of greenhouse gases (see Seventh National Communication (FOEN 2018d) for more details), that are then reflected in market prices and thus internalizing externalities.

Fiscal incentives, tay and duty exemptions and subsidies

Price-based measures are recognised as essential instruments for promoting the efficient use of resources and to reduce market imperfections. In 2001, Switzerland introduced a heavy vehicle charge. It is applied to passenger and freight transport vehicles of more than 3.5 tonnes gross weight. The impact of the heavy vehicle charge 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, i.e. fewer trucks transporting more goods. Two thirds of the revenues are used to finance major railway infrastructure projects (such as the base tunnels through the Alps), and one third is transferred to the cantons.

In 2008, Switzerland introduced the CO_2 levy on heating and process fuel to set an incentive for a more efficient use of fossil fuels, promote investment in energy-efficient technologies and the use of low-carbon or carbon-free energy sources. Companies, especially those with substantial CO_2 emissions from use of heating and process fuels, may apply for exemption from the CO_2 levy, provided the company commits to emission reductions. The company has to elaborate an emission reduction target based on the technological potential and economic viability of various measures within the company. While the proceeds from the CO_2 levy on heating and process fuels were initially to be fully refunded to the Swiss population (on a per capita basis) and to the Swiss economy (in proportion to wages paid), a parliamentary decision of June 2009 earmarked a third of the revenues from the CO_2 levy for CO_2 relevant measures in the buildings sector. As of 1 January 2018, the funds for the national buildings refurbishment programme are limited to a maximum of 450 million Swiss francs per year (previously 300 million Swiss francs per year).

As analysed in detail in two studies, the overall economic impact of the Swiss climate policy is considered to be very small[14]. In general, Switzerland does not subsidise fossil fuels. However, depending on the definition, there are some policies in place that may be regarded as fossil fuel subsidies, although these policies are only applicable to small amounts of fossil fuels consumed in Switzerland. At the federal level, a few tax exemptions and reductions provide limited 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. These mineral oil tax exemptions in the specific sectors are listed in appendix 3 of the Swiss Federal Council's subsidy report[15]. Moreover, the mineral oil tax refunds in the agriculture sector are currently subject to an examination by the Swiss Federal Audit Office. Some vehicles are also exempt from the performance-related heavy vehicle charge, 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.

Worldwide subsidies for fossil fuels are estimated at 300 billion to 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 also poses a major obstacle for enhanced investments in energy efficiency measures and renewable energies.

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[14] Ecoplan (2009): Volkswirtschaftliche Auswirkungen der Schweizer Post-Kyoto-Politik, im Auftrag des BAFU. BAFU (2010): Synthesebericht zur Volkswirtschaftlichen Beurteilung der Schweizer Klimapolitik nach 2012.

[15] Swiss Federal Council (2008): Subventionsbericht des Bundesrates vom 30.05.2008.

Switzerland as a founding member of the Friends of Fossil Fuels Subsidy Reform supports the gradual and sustained phasing out of fossil fuel subsidies and the reduction of unnecessary market distortions. Furthermore, Switzerland contributes to World Bank development project ESMAP (Energy Sector Management Assistance Program). The 2016 Annual Report of ESMAP is also supported by Switzerland and provides the analytical basis for the implementation of such reforms.

Removing subsidies associated with the use of environmentally unsound and unsafe technologies

Switzerland does not subsidize the use of environmentally unsound and unsafe technologies.

Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end

Switzerland does not support any activities linked to the technological development of non-energy uses of fossil fuels in developing countries.

Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort

Switzerland is an active participant in the negotiations for a plurilateral Environmental Goods Agreement (EGA) at the World Trade Organisation with the aim to liberalise environmental goods, including the diffusion and transfer of less-greenhouse-gas-emitting advanced fossil fuel technologies.

Furthermore, Switzerland is supporting the improvement and refit of inefficient gas-fired power plants in developing countries and advocates the use of the most efficient technologies available. Several Swiss universities conduct research in the field of carbon capture and storage and cooperate with other research institutions, companies and universities primarily in Europe and northern America to further develop the technology. Currently, Switzerland is not supporting any least developed countries and other developing countries in the development of fossil fuel-fired power plants with carbon capture and storage technology, because Switzerland is of the view that the technology is not sufficiently mature and cost effective yet.

Strengthening the capacity of developing country Parties for improving efficiency in upstream and down-stream 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 technological 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 agri-cultural commodities), e.g. through the creation of sustainability standards, financial incentives and favourable framework conditions in developing countries. Further information is contained in chp. 7 of Switzerland's Seventh National Communication (FOEN 2018d).

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 international trade agreements. The Swiss State Secretariat for Economic Affairs 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 the Swiss State Secretariat for Economic Affairs are aimed at creating the necessary conditions for earning additional income in the beneficiary countries and thereby contribute directly to the alleviation of poverty. The Swiss State Secretariat for Economic Affairs is focusing on three areas of intervention along the value chain: (i) enabling framework conditions for trade (ii) international competitiveness, and (iii) improving market access.

Regarding market access, trade between developing and industrial countries is often insuf-ficiently developed respectively not diversified enough. On one hand, in some developing countries there is still a lack of necessary production capacities, quality standards, 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, the Swiss State Secretariat for Economic Affairs runs programmes for promoting imports to Switzerland and the rest of Europe. Easing 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:

- Generalised system of preferences;
- Swiss Import Promotion Program (www.sippo.ch);
- Promotion and strengthening of private voluntary social and environmental standards based on international multi-stakeholder approaches, such as Better Cotton, 4C (Common Code for the Coffee Community), Roundtable for Sustainable Biofuels, etc.

Finally, Switzerland is a strong supporter of the Extractive Industries Transparency Ini-tiative. Switzerland acts based on the firm conviction that an efficient use of natural resources is an important driving force for sustainable economic growth, contributing to sustainable development and poverty reduction. The sustainable management of natural resources – as supported by the Extractive Industries Transparency Initiative principle and criteria including regular publication and audit of revenues – is key to mobilise the funds for diversification strategies.

Changes compared to the previous submission

There are no fundamtental changes compared to the previous submission.

Annexes

Annex 1: Key category analysis (KCA)

Table A – 1 Overview over all categories included in the KCA (level of disaggregation) and summary of Switzerland’s combined KCA for the year 2016 including LULUCF categories, sorted by NFR code (first column). L1 = level, approach 1, T1 = trend, approach 1; L2 = level, approach 2, T2 = trend, approach 2.

SUMMARIES TO IDENTIFY KEY CATEGORIES			
A	**B**	**C**	**D**
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1	Indirect CO2 emissions	CO2	
1A1	Energy industries: Other fuels	CO2	L1, T1, L2, T2
1A1	Energy industries: Gaseous fuels	CO2	L1, T1
1A1	Energy industries: Liquid fuels	CO2	L1, T1
1A1	Energy industries: biomass	N2O	
1A1	Energy industries: Other fuels	N2O	
1A1	Energy industries: biomass	CH4	
1A1	Energy industries: Liquid fuels	N2O	
1A1	Energy industries: Gaseous fuels	N2O	
1A1	Energy industries: Gaseous fuels	CH4	
1A1	Energy industries: Liquid fuels	CH4	
1A1	Energy industries: Solid fuels	CH4	
1A1	Energy industries: Solid fuels	CO2	
1A1	Energy industries: Solid fuels	N2O	
1A2	Manufacturing industry and construction: Gaseous fuels	CO2	L1, T1, L2, T2
1A2	Manufacturing industry and construction: Liquid fuels	CO2	L1, T1
1A2	Manufacturing industry and construction: Solid fuels	CO2	L1, T1, T2
1A2	Manufacturing industry and construction: Other fuels	CO2	L1, T1
1A2	Manufacturing industry and construction: Biomass	N2O	
1A2	Manufacturing industry and construction: Liquid fuels	N2O	
1A2	Manufacturing industry and construction: Other fuels	N2O	
1A2	Manufacturing industry and construction: Solid fuels	N2O	
1A2	Manufacturing industry and construction: Biomass	CH4	
1A2	Manufacturing industry and construction: Liquid fuels	CH4	
1A2	Manufacturing industry and construction: Gaseous fuels	N2O	
1A2	Manufacturing industry and construction: Gaseous fuels	CH4	
1A2	Manufacturing industry and construction: Other fuels	CH4	
1A2	Manufacturing industry and construction: Solid fuels	CH4	
1A3a	Civil aviation: Liquid fuels	CO2	T1
1A3a	Civil aviation: Liquid fuels	N2O	
1A3a	Civil aviation: Liquid fuels	CH4	
1A3b	Road transportation: Gasoline	CO2	L1, T1
1A3b	Road transportation: Diesel	CO2	L1, T1, L2, T2
1A3b	Road transportation: Diesel	N2O	
1A3b	Road transportation: Gaseous fuels	CO2	
1A3b	Road transportation: Gasoline	N2O	T1, T2
1A3b	Road transportation: Gasoline	CH4	T1
1A3b	Road transportation: Biomass	N2O	
1A3b	Road transportation: Gaseous fuels	N2O	
1A3b	Road transportation: Diesel	CH4	
1A3b	Road transportation: Gaseous fuels	CH4	
1A3b	Road transportation: Biomass	CH4	
1A3c	Railways: Liquid fuels	CO2	
1A3c	Railways: Liquid fuels	N2O	
1A3c	Railways: Liquid fuels	CH4	
1A3c	Railways: Biomass	N2O	
1A3c	Railways: Biomass	CH4	
1A3d	Domestic navigation: Liquid fuels	CO2	
1A3d	Domestic navigation: Liquid fuels	N2O	
1A3d	Domestic navigation: Liquid fuels	CH4	
1A3d	Domestic navigation: Biomass	N2O	
1A3d	Domestic navigation: Biomass	CH4	
1A3e	Other transportation: Gaseous fuels	CO2	

Table A – 1 (continued)

SUMMARIES TO IDENTIFY KEY CATEGORIES			
A	**B**	**C**	**D**
Code	**IPCC Category**	**GHG**	**Identification Criteria**
1A3e	Other transportation: Gaseous fuels	CH4	
1A3e	Other transportation: Gaseous fuels	N2O	
1A4a	Commercial: Liquid fuels	CO2	L1, T1
1A4a	Commercial: Gaseous fuels	CO2	L1, T1, L2
1A4a	Commercial: Biomass	N2O	
1A4a	Commercial: Liquid fuels	CH4	
1A4a	Commercial: Liquid fuels	N2O	
1A4a	Commercial: Biomass	CH4	
1A4a	Commercial: Gaseous fuels	CH4	
1A4a	Commercial: Gaseous fuels	N2O	
1A4b	Residential: Liquid fuels	CO2	L1, T1
1A4b	Residential: Gaseous fuels	CO2	L1, T1, L2, T2
1A4b	Residential: Biomass	CH4	T1
1A4b	Residential: Biomass	N2O	
1A4b	Residential: Liquid fuels	CH4	
1A4b	Residential: Solid fuels	CO2	
1A4b	Residential: Liquid fuels	N2O	
1A4b	Residential: Solid fuels	CH4	
1A4b	Residential: Gaseous fuels	N2O	
1A4b	Residential: Gaseous fuels	CH4	
1A4b	Residential: Solid fuels	N2O	
1A4c	Agriculture and forestry: Liquid fuels	CO2	L1
1A4c	Agriculture and forestry: Gaseous fuels	CO2	
1A4c	Agriculture and forestry: Liquid fuels	N2O	
1A4c	Agriculture and forestry: Biomass	N2O	
1A4c	Agriculture and forestry: Liquid fuels	CH4	
1A4c	Agriculture and forestry: Biomass	CH4	
1A4c	Agriculture and forestry: Gaseous fuels	N2O	
1A4c	Agriculture and forestry: Gaseous fuels	CH4	
1A5	Other (military): Liquid fuels	CO2	
1A5	Other (military): Liquid fuels	N2O	
1A5	Other (military): Liquid fuels	CH4	
1A5	Other (military): Biomass	N2O	
1A5	Other (military): Biomass	CH4	
1B2	Oil and natural gas energy production	CH4	L1, T1
1B2	Oil and natural gas energy production	CO2	
1B2	Oil and natural gas energy production	N2O	
2	Indirect CO2 emissions	CO2	T1, L2, T2
2A1	Cement production	CO2	L1, T1, L2
2A2	Lime production	CO2	
2A3	Glass production	CO2	
2A4	Other process uses of carbonates	CO2	
2B10	Chemical industry other	CO2	
2B2	Nitric acid production	N2O	
2B5	Carbide production	CO2	
2B5	Carbide production	CH4	
2B8	Petrochemical and carbon black production	CO2	
2C1	Iron and steel production	CO2	
2C3	Aluminium production	CO2	T1
2C3	Aluminium production	PFC	T1
2C4	Magnesium production	SF6	
2C7	Other	CO2	

Table A – 1 (continued)

SUMMARIES TO IDENTIFY KEY CATEGORIES			
A	**B**	**C**	**D**
Code	**IPCC Category**	**GHG**	**Identification Criteria**
2D	Non-energy products from fuels and solvent use	CO2	
2E1	Semiconductor	SF6	
2E1	Semiconductor	PFC	
2E1	Semiconductor	HFC	
2E3	Photovoltaics	NF3	
2E4	Other electronic	PFC	
2F1	Refrigeration and air conditioning	HFC	L1, T1, L2, T2
2F1	Refrigeration and air conditioning	PFC	
2F2	Foam blowing agents	HFC	T2
2F4	Aerosols	HFC	
2F5	Solvents	HFC	
2G	Other product manufacture and use	SF6	L1
2G	Other product manufacture and use	HFC	T1
2G	Other product manufacture and use	PFC	
2G	Other product manufacture and use	N2O	T2
2G	Other product manufacture and use	CO2	
2H	Other	CO2	
3A	Enteric Fermentation	CH4	L1, T1, L2, T2
3B1-3B4	Manure management	CH4	L1, L2
3B1-3B4	Manure management	N2O	
3B5	Indirect N2O emissions from manure management	N2O	L1, T1, L2, T2
3Da	Direct emissions from managed soils	N2O	L1, L2
3Db	Indirect emissions from managed soils	N2O	L1, T1, L2, T2
3G	Liming	CO2	
3H	Urea application	CO2	
4A1	forest land remaining forest land	CO2	L1, T1, L2, T2
4A2	Land converted to forest	CO2	L1, T1, L2, T2
4B1	Cropland remaining cropland	CO2	T1, L2, T2
4B2	Land converted to cropland	CO2	
4C1	Grassland remaining grassland	CO2	L2, T2
4C2	Land converted to grassland	CO2	L1, T1, L2, T2
4D1	Wetland remaining wetland	CO2	L2
4D2	Land converted to wetland	CO2	
4E1	Settlements remaining settlements	CO2	
4E2	Land converted to settlements	CO2	L1, L2
4F2	Land converted to other land	CO2	
4G	HWP harvest wood products	CO2 biog.	L1, T1, L2, T2
4II	Drainage and rewetting	CH4	
4II	Drainage and rewetting	N2O	
4III	Direct N2O from disturbance	N2O	L2
4IV	Indirect N2O	N2O	
4V	Biomass burning	CH4	
4V	Biomass burning	N2O	
5	Indirect CO2 emissions	CO2	
5A	Solid waste disposal	CH4	L1, T1, L2, T2
5A	Solid waste disposal	CO2	
5B	Biological treatment of solid waste	CH4	
5B	Biological treatment of solid waste	N2O	
5C	Incineration and open burning of waste	N2O	
5C	Incineration and open burning of waste	CO2	
5C	Incineration and open burning of waste	CH4	
5D	Wastewater treatment and discharge	CH4	L1, L2, T2
5D	Wastewater treatment and discharge	N2O	L2, T2
6	Other sources	CO2	
6	Indirect CO2 emissions	CO2	
6	Other sources	CH4	
6	Other sources	N2O	

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 the 2006 IPCC Guidelines (IPCC 2006, vol. 1, chp. 3). For explanations to the columns see pp. 3.30–3.31 in vol. 1 of IPCC (2006).

The uncertainty analyses according to Approach 1 are not based on the final set of emission data but a previous version, which shows slight differences. Therefore, the total emissions provided in the following table differs slightly from the data provided in the reporting tables (CRF).

Table A – 2 Results of Approach 1 uncertainty analysis, overall results are presented at the bottom of the last part of the table (Table 3.2 of IPCC 2006 Guidelines). The uncertainty analysis includes indirect CO_2 emissions.

IPCC Source category					Gas	Base year emissions or removals	Year 2016 emissions or removals	AD uncer-tainty	EF uncer-tainty	Combined uncer-tainty	Contribution to variance by Category in 2016	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
						kt CO2 eq	kt CO2 eq	%	%	%	-	%	%	%	%	%
1A1	1. Energy	A. Fuel combustion activities	1. Energy industries	Biomass	CH4	0.45	0.31	10.0	28.3	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CH4	0.11	0.22	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	CH4	0.52	0.20	0.7	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Solid F.	CH4	0.13	-	5.0	29.6	30.0	-	0.0000	-	0.00	-	0.00
				Gaseous F.	CO2	243.40	505.14	5.0	1.0	5.1	0.003	0.0055	0.0095	0.01	0.07	0.00
				Liquid F.	CO2	685.81	392.72	0.7	0.1	0.7	0.000	0.0039	0.0074	0.00	0.01	0.00
				Other F.	CO2	1'491.55	2'454.47	5.0	9.2	10.5	0.307	0.0216	0.0463	0.20	0.33	0.15
				Solid F.	CO2	49.13	-	5.0	5.1	7.1	-	0.0008	-	0.00	-	0.00
				Biomass	N2O	22.58	14.43	10.0	79.4	80.0	0.001	0.0001	0.0003	0.01	0.00	0.00
				Gaseous F.	N2O	0.13	0.27	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	1.11	0.30	0.7	80.0	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Other F.	N2O	24.33	12.34	5.0	79.8	80.0	0.000	0.0002	0.0002	0.01	0.00	0.00
				Solid F.	N2O	0.24	-	5.0	79.8	80.0	-	0.0000	-	0.00	-	0.00
1A2			2. Manufacturing industries and construction	Biomass	CH4	4.27	1.84	10.0	28.3	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CH4	0.46	0.99	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	CH4	4.50	1.37	0.7	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Other F.	CH4	0.77	0.55	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Solid F.	CH4	0.31	0.22	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CO2	1'049.69	2'233.51	5.0	1.0	5.1	0.060	0.0248	0.0422	0.02	0.30	0.09
				Liquid F.	CO2	3'889.15	1'854.46	0.7	0.1	0.7	0.001	0.0293	0.0350	0.00	0.03	0.00
				Other F.	CO2	191.77	415.36	5.0	9.2	10.5	0.009	0.0047	0.0078	0.04	0.06	0.00
				Solid F.	CO2	1'274.70	436.41	5.0	5.1	7.1	0.004	0.0129	0.0082	0.07	0.06	0.01
				Biomass	N2O	5.11	14.47	10.0	79.4	80.0	0.001	0.0002	0.0003	0.01	0.00	0.00
				Gaseous F.	N2O	0.56	1.18	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	13.14	10.96	0.7	80.0	80.0	0.000	0.0000	0.0002	0.00	0.00	0.00
				Other F.	N2O	2.32	6.36	5.0	79.8	80.0	0.000	0.0001	0.0001	0.01	0.00	0.00
				Solid F.	N2O	6.14	2.05	5.0	79.8	80.0	0.000	0.0001	0.0000	0.01	0.00	0.00
1A3a			3. Transport; Domestic aviation	kerosene	CH4	0.17	0.11	1.0	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				kerosene	CO2	252.55	140.63	1.0	0.2	1.0	0.000	0.0015	0.0027	0.00	0.00	0.00
				kerosene	N2O	2.06	1.15	1.0	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category					Gas	Base year emissions or removals	Year 2016 emissions or removals	AD uncer-tainty	EF uncer-tainty	Combined uncer-tainty	Contribution to variance by Category in 2016	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
						kt CO2 eq	kt CO2 eq	%	%	%	-	%	%	%	%	%
1A3b	1. Energy	A. Fuel combustion activities	3. Transport; Road transportation	Biomass	CH4	-	0.11	10.0	59.2	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Diesel	CH4	1.58	0.43	0.9	20.0	20.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CH4	-	0.12	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gasoline	CH4	97.84	12.60	0.7	37.0	37.0	0.000	0.0014	0.0002	0.05	0.00	0.00
				Diesel	CO2	2'632.59	7'280.86	0.9	0.1	0.9	0.019	0.0938	0.1375	0.01	0.17	0.03
				Gaseous F.	CO2	-	33.84	5.0	1.0	5.1	0.000	0.0006	0.0006	0.00	0.00	0.00
				Gasoline	CO2	11'334.49	7'426.45	0.7	0.1	0.7	0.012	0.0473	0.1402	0.01	0.14	0.02
				Biomass	N2O	-	1.67	10.0	149.7	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Diesel	N2O	5.93	73.03	0.9	22.0	22.0	0.001	0.0013	0.0014	0.03	0.00	0.00
				Gaseous F.	N2O	-	1.49	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gasoline	N2O	134.37	19.75	0.7	50.0	50.0	0.000	0.0019	0.0004	0.09	0.00	0.01
1A3c			3. Transport; Railways	Biomass	CH4	-	0.00	10.0	59.2	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Diesel	CH4	0.03	0.01	0.9	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Diesel	CO2	28.69	28.46	0.9	0.1	0.9	0.000	0.0001	0.0005	0.00	0.00	0.00
				Biomass	N2O	-	0.01	10.0	149.7	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Diesel	N2O	0.43	0.41	0.7	80.0	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Biomass	CH4	-	0.00	10.0	59.2	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3d			3. Transport; Domestic navigation	Liquid F.	CH4	1.68	0.30	0.7	30.0	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	CO2	114.27	112.85	0.7	0.1	0.7	0.000	0.0002	0.0021	0.00	0.00	0.00
				Biomass	N2O	-	0.02	10.0	149.7	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	1.16	1.22	0.7	150.0	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A3e			3. Transport; Other transportation	Gaseous F.	CH4	0.07	0.02	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CO2	31.42	19.18	5.0	1.0	5.1	0.000	0.0002	0.0004	0.00	0.00	0.00
				Gaseous F.	N2O	0.02	0.01	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A4a			4. Other sectors; Commercial/instit utional	Biomass	CH4	9.22	4.73	10.0	28.3	30.0	0.000	0.0001	0.0001	0.00	0.00	0.00
				Gaseous F.	CH4	0.72	1.34	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	CH4	16.34	9.94	0.7	30.0	30.0	0.000	0.0001	0.0002	0.00	0.00	0.00
				Gaseous F.	CO2	1'012.50	1'490.05	5.0	1.0	5.1	0.027	0.0114	0.0281	0.01	0.20	0.04
				Liquid F.	CO2	4'260.86	2'789.09	0.7	0.1	0.7	0.002	0.0179	0.0527	0.00	0.05	0.00
				Biomass	N2O	3.49	10.17	10.0	79.4	80.0	0.000	0.0001	0.0002	0.01	0.00	0.00
				Gaseous F.	N2O	0.54	0.79	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	10.35	6.81	0.7	80.0	80.0	0.000	0.0000	0.0001	0.00	0.00	0.00
1A4b			4. Other sectors; Residential	Biomass	CH4	109.96	25.56	10.0	28.3	30.0	0.000	0.0013	0.0005	0.04	0.01	0.00
				Gaseous F.	CH4	0.69	1.43	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
			4. Other sectors; Residential	Liquid F.	CH4	34.83	20.52	0.7	30.0	30.0	0.000	0.0002	0.0004	0.01	0.00	0.00
				Solid F.	CH4	4.73	1.50	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CO2	1'428.53	2'754.33	5.0	1.0	5.1	0.091	0.0283	0.0520	0.03	0.37	0.14
				Liquid F.	CO2	10'099.07	6'006.20	0.7	0.1	0.7	0.008	0.0537	0.1134	0.00	0.11	0.01
				Solid F.	CO2	58.40	18.54	5.0	5.1	7.1	0.000	0.0006	0.0004	0.00	0.00	0.00
				Biomass	N2O	25.85	22.77	10.0	79.4	80.0	0.002	0.0000	0.0004	0.00	0.01	0.00
				Gaseous F.	N2O	0.76	1.46	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	24.53	14.61	0.7	80.0	80.0	0.001	0.0001	0.0003	0.01	0.00	0.00
				Solid F.	N2O	0.28	0.09	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category					Gas	Base year emissions or removals	Year 2016 emissions or removals	AD uncer-tainty	EF uncer-tainty	Combined uncer-tainty	Contribution to variance by Category in 2016	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
						kt CO2 eq	kt CO2 eq	%	%	%	-	%	%	%	%	%
1A4c	1. Energy	A. Fuel combustion activities	4. Other sectors; Agriculture / forestry / fishing	Biomass	CH4	1.97	0.38	10.0	28.3	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	CH4	0.02	0.01	5.0	29.6	30.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	CH4	6.45	1.36	0.7	30.0	30.0	0.000	0.0001	0.0000	0.00	0.00	0.00
				Gaseous F.	CO2	41.45	15.72	5.0	1.0	5.1	0.000	0.0004	0.0003	0.00	0.00	0.00
				Liquid F.	CO2	485.09	402.88	0.7	0.1	0.7	0.000	0.0004	0.0076	0.00	0.01	0.00
				Biomass	N2O	0.51	1.40	10.0	79.4	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Gaseous F.	N2O	0.02	0.01	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	4.20	4.54	0.7	80.0	80.0	0.000	0.0000	0.0001	0.00	0.00	0.00
				Biomass	CH4	-	0.00	10.0	59.2	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1A5			5. Other	Liquid F.	CH4	0.27	0.17	0.7	60.0	60.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	CO2	217.65	138.14	0.7	0.1	0.7	0.000	0.0010	0.0026	0.00	0.00	0.00
1A6				Biomass	N2O	-	0.00	106.1	106.1	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
				Liquid F.	N2O	1.84	1.20	106.1	106.1	150.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1B2		B. Fugitive emissions from fuels	2. Oil and natural gas and other emissions from energy production		CH4	336.27	193.54	5.0	29.6	30.0	0.016	0.0019	0.0037	0.06	0.03	0.00
					CO2	26.19	28.14	5.0	8.7	10.0	0.000	0.0001	0.0005	0.00	0.00	0.00
					N2O	0.60	0.01	5.0	79.8	80.0	0.000	0.0000	0.0000	0.00	0.00	0.00
1ind		Indirect emissions			CO2	43.55	8.23	16.2	16.2	22.9	0.000	0.0006	0.0002	0.01	0.00	0.00
2A1	2. Industrial processes and product use	A. Mineral industry	1. Cement production		CO2	2'580.79	1'768.99	2.0	2.0	2.8	0.012	0.0093	0.0334	0.02	0.09	0.01
2A2			2. Lime production		CO2	53.35	41.44	2.0	3.0	3.6	0.000	0.0001	0.0008	0.00	0.00	0.00
2A3			3. Glass production		CO2	15.25	6.47	2.0	2.0	2.8	0.000	0.0001	0.0001	0.00	0.00	0.00
2A4			4. Other process uses of carbonates		CO2	162.87	84.10	2.0	20.0	20.1	0.001	0.0011	0.0016	0.02	0.00	0.00
2B2		B. Chemical industry	2. Nitric acid production		N2O	65.49	6.11	2.0	5.0	5.4	0.000	0.0010	0.0001	0.00	0.00	0.00
2B5			5. Carbide production		CO2	15.72	31.30	2.0	10.0	10.2	0.000	0.0003	0.0006	0.00	0.00	0.00
			5. Carbide production		CH4	1.74	2.70	2.0	10.0	10.2	0.000	0.0000	0.0001	0.00	0.00	0.00
2B8			8. Petrochemical and carbon black production		CO2	94.08	111.48	2.0	10.0	10.2	0.001	0.0005	0.0021	0.01	0.01	0.00
2B10			10. Other (Niacin, Limestone pit)		CO2	11.87	12.49	2.0	7.2	7.5	0.000	0.0000	0.0002	0.00	0.00	0.00
2C1		C. Metal industry	1. Iron and steel production		CO2	9.20	10.89	5.0	20.0	20.6	0.000	0.0001	0.0002	0.00	0.00	0.00
2C3			3. Aluminium production		CO2	139.26	-	6.4	6.4	9.0	-	0.0023	-	0.01	-	0.00
			3. Aluminium production		PFC	116.46	-	19.6	19.6	27.7	-	0.0019	-	0.04	-	0.00
2C4			4. Magnesium production		SF6	-	18.38	2.0	20.0	20.1	0.000	0.0003	0.0003	0.01	0.00	0.00
2C7			7. Other		CO2	1.65	1.44	35.4	35.4	50.0	0.000	0.0000	0.0000	0.00	0.00	0.00
2D		D. Non-energy products from fuels and solvent use			CO2	57.19	52.03	36.0	36.0	50.9	0.003	0.0000	0.0010	0.00	0.05	0.00
					HFC	-	0.18	44.6	44.6	63.1	0.000	0.0000	0.0000	0.00	0.00	0.00
2E1		E. Electronics industry	1. Integrated circuit or semiconductor		PFC	-	4.33	43.7	43.7	61.9	0.000	0.0001	0.0001	0.00	0.01	0.00
					SF6	-	6.79	137.1	137.1	194.0	0.001	0.0001	0.0001	0.02	0.02	0.00
2E3			3. Photovoltaics		NF3	-	0.51	51.3	72.5	88.8	0.000	0.0000	0.0000	0.00	0.00	0.00
2E4			4. Heat transfer fluid		PFC	-	0.00	10.4	10.4	14.8	0.000	0.0000	0.0000	0.00	0.00	0.00
2F1		F. Product uses as substitutes for ODS	1. Refrigeration and air conditioning		HFC	0.02	1'286.65	76.0	76.0	107.5	8.863	0.0243	0.0243	1.85	2.61	10.22
					PFC	0.05	1.29	80.4	80.4	113.8	0.000	0.0000	0.0000	0.00	0.00	0.00
2F2			2. Foam blowing agents		HFC	-	31.58	29.0	29.0	41.0	0.001	0.0006	0.0006	0.02	0.02	0.00
2F4			4. Aerosols		HFC	-	16.81	38.2	38.2	54.1	0.000	0.0003	0.0003	0.01	0.02	0.00
2F5			5. Solvents		HFC	-	1.55	28.3	28.3	40.0	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category				Gas	Base year emissions or removals	Year 2016 emissions or removals	AD uncer-tainty	EF uncer-tainty	Combined uncer-tainty	Contribution to variance by Category in 2016	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
					kt CO2 eq	kt CO2 eq	%	%	%	-	%	%	%	%	%
2G	2. Ind. Processes	G. Other product manufacture and use		CO2	6.60	36.14	8.8	8.8	12.5	0.000	0.0006	0.0007	0.01	0.01	0.00
2G	2. Ind. Processes	G. Other product manufacture and use		HFC	-	85.39	11.1	11.1	15.7	0.001	0.0016	0.0016	0.02	0.03	0.00
2G	2. Ind. Processes	G. Other product manufacture and use		PFC	-	48.33	22.9	22.9	32.4	0.001	0.0009	0.0009	0.02	0.03	0.00
2G	2. Ind. Processes	G. Other product manufacture and use		SF6	137.01	181.95	1.0	80.0	80.0	0.098	0.0012	0.0034	0.09	0.00	0.01
2G	2. Ind. Processes	G. Other product manufacture and use		N2O	105.87	38.95	3.0	7.1	7.7	0.000	0.0010	0.0007	0.01	0.00	0.00
2H	2. Ind. Processes	H. Other		CO2	1.04	0.27	6.4	16.9	18.1	0.000	0.0000	0.0000	0.00	0.00	0.00
2ind	2. Ind. Processes	Indirect emissions		CO2	356.11	97.36	13.7	148.5	149.1	0.098	0.0041	0.0018	0.60	0.04	0.36
3A	3. Agriculture	A. Enteric fermentation		CH4	3'584.87	3'324.59	6.5	16.9	18.1	1.682	0.0034	0.0628	0.06	0.57	0.33
3B	3. Agriculture	B. Manure Management		CH4	868.63	753.02	6.5	54.0	54.4	0.779	0.0002	0.0142	0.01	0.13	0.02
3B	3. Agriculture	B. Manure Management	liquid	N2O	-	7.26	32.0	75.0	81.5	0.000	0.0001	0.0001	0.01	0.01	0.00
3B	3. Agriculture	B. Manure Management	solid	N2O	104.65	68.02	32.0	75.0	81.5	0.014	0.0004	0.0013	0.03	0.06	0.00
3B	3. Agriculture	B. Manure Management	indirect	N2O	230.33	270.51	46.5	240.0	244.5	2.028	0.0013	0.0051	0.31	0.34	0.21
3D	3. Agriculture	D. Agricultural Soils; Direct Soil Emissions	fertilizer	N2O	1'059.15	815.68	14.5	135.0	135.8	5.688	0.0021	0.0154	0.29	0.32	0.18
3D	3. Agriculture	D. Agricultural Soils; Direct Soil Emissions	organic soils	N2O	67.58	65.12	32.2	137.5	141.2	0.039	0.0001	0.0012	0.02	0.06	0.00
3D	3. Agriculture	D. Agricultural Soils; Pasture, Range and Paddock Manure		N2O	120.31	199.18	68.0	132.5	148.9	0.408	0.0018	0.0038	0.23	0.36	0.19
3D	3. Agriculture	D. Agricultural Soils; Indirect Emissions	deposition	N2O	414.48	289.20	42.0	240.0	243.6	2.302	0.0014	0.0055	0.34	0.32	0.22
3D	3. Agriculture	D. Agricultural Soils; Indirect Emissions	leaching and runoff	N2O	173.42	123.24	22.2	163.3	164.8	0.191	0.0005	0.0023	0.09	0.07	0.01
3G	3. Agriculture	G. Limestone		CO2	22.25	32.84	40.0	5.0	40.3	0.001	0.0003	0.0006	0.00	0.04	0.00
3H	3. Agriculture	H. Urea application		CO2	26.66	14.43	5.0	5.0	7.1	0.000	0.0002	0.0003	0.00	0.00	0.00
5A	5. Waste	A. Solid waste disposal		CH4	763.39	334.95	10.0	38.7	40.0	0.083	0.0063	0.0063	0.24	0.09	0.07
5A	5. Waste	A. Solid waste disposal		CO2	-	-	32.0	36.0	48.2	-	-	-	-	-	-
5B	5. Waste	B. Biological treatment of solid waste		CH4	11.89	26.14	32.0	146.5	150.0	0.007	0.0003	0.0005	0.04	0.02	0.00
5B	5. Waste	B. Biological treatment of solid waste		N2O	5.22	9.69	42.4	42.4	60.0	0.000	0.0001	0.0002	0.00	0.01	0.00
5C	5. Waste	C. Incineration and open burning of waste		CH4	8.89	5.20	28.3	28.3	40.0	0.000	0.0000	0.0001	0.00	0.00	0.00
5C	5. Waste	C. Incineration and open burning of waste		CO2	53.73	9.89	106.1	106.1	150.0	0.001	0.0007	0.0002	0.07	0.03	0.01
5C	5. Waste	C. Incineration and open burning of waste		N2O	16.78	32.94	16.2	16.2	22.9	0.000	0.0003	0.0006	0.01	0.01	0.00
5D	5. Waste	D. Wastewater treatment and discharge		CH4	130.92	180.33	2.0	50.0	50.0	0.038	0.0012	0.0034	0.06	0.01	0.00
5D	5. Waste	D. Wastewater treatment and discharge		N2O	118.62	149.16	2.0	200.0	200.0	0.413	0.0009	0.0028	0.17	0.01	0.03
5ind	5. Waste	Indirect emissions		CO2	2.01	1.17	33.6	33.6	47.5	0.000	0.0000	0.0000	0.00	0.00	0.00
6	6. Other			CH4	0.66	0.59	2.0	40.0	40.0	0.000	0.0000	0.0000	0.00	0.00	0.00
6	6. Other			CO2	10.96	11.11	2.0	20.0	20.1	0.000	0.0000	0.0002	0.00	0.00	0.00
6	6. Other			N2O	0.60	0.50	2.0	100.0	100.0	0.000	0.0000	0.0000	0.00	0.00	0.00
6ind	6. Other	Indirect emissions		CO2	1.04	1.01	17.2	57.8	60.3	0.000	0.0000	0.0000	0.00	0.00	0.00

IPCC Source category				Gas	Base year emissions or removals	Year 2016 emissions or removals	AD uncer-tainty	EF uncer-tainty	Combined uncer-tainty	Contribution to variance by Category in 2016	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
					kt CO2 eq	kt CO2 eq	%	%	%	-	%	%	%	%	%
4 II	4. LULUCF	Drainage, rewetting and other management of organic and mineral soils		CH4	10.75	10.75	30.0	70.0	76.2	0.000	0.0000	0.0002	0.00	0.01	0.00
				N2O	2.95	2.94	1.1	88.6	88.6	0.000	0.0000	0.0001	0.00	0.00	0.00
4 III		N mineralization		N2O	38.73	39.15	1.6	88.6	88.6	0.006	0.0001	0.0007	0.01	0.00	0.00
4 IV		Indirect emissions		N2O	6.44	5.72	4.9	164.3	164.3	0.000	0.0000	0.0001	0.00	0.00	0.00
4 V		Biomass burning		CH4	18.63	5.19	5.1	32.4	32.8	0.000	0.0002	0.0001	0.01	0.00	0.00
				CO2	-	-	5.2	915.9	915.9	-	-	-	-	-	-
				N2O	10.81	2.86	5.3	40.4	40.8	0.000	0.0001	0.0001	0.01	0.00	0.00
4A1		A. Forest land	1. Forest land remaining forest land	CO2	-425.45	-2'197.15	61.9	72.2	95.1	20.258	0.0344	0.0415	2.49	3.63	19.38
4A2			2. Land converted to forest land	CO2	-580.59	-441.71	4.0	24.1	24.5	0.054	0.0013	0.0083	0.03	0.05	0.00
4B1		B. Cropland	1. Cropland remaining cropland	CO2	912.56	155.84	4.4	50.0	50.2	0.028	0.0122	0.0029	0.61	0.02	0.37
4B2			2. Land converted to cropland	CO2	37.92	48.01	4.6	50.0	50.2	0.003	0.0003	0.0009	0.01	0.01	0.00
4C1		C. Grassland	1. Grassland remaining grassland	CO2	79.57	110.05	3.2	50.0	50.1	0.014	0.0008	0.0021	0.04	0.01	0.00
4C2			2. Land converted to grassland	CO2	67.85	188.51	4.5	57.0	57.2	0.054	0.0024	0.0036	0.14	0.02	0.02
4D1		D. Wetlands	1. Wetlands remaining wetlands	CO2	67.56	68.43	21.2	21.2	30.0	0.002	0.0002	0.0013	0.00	0.04	0.00
4D2			2. Land converted to wetlands	CO2	21.32	31.24	7.1	7.1	10.0	0.000	0.0002	0.0006	0.00	0.01	0.00
4E1		E. Settlements	1. Settlements remaining settlements	CO2	-48.65	-0.46	30.0	30.0	42.4	0.000	0.0008	0.0000	0.02	0.00	0.00
4E2			2. Land converted to settlements	CO2	259.92	193.92	30.0	30.0	42.4	0.031	0.0006	0.0037	0.02	0.16	0.02
4F2		F. Other land	2. Land converted to other land	CO2	94.28	119.80	10.0	59.2	60.0	0.024	0.0007	0.0023	0.04	0.03	0.00
4G		G. Harvested wood products		CO2	-1'204.03	-106.60	10.0	38.7	40.0	0.008	0.0179	0.0020	0.69	0.03	0.48
Total Uncertainty including LULUCF					**52'969**	**46'439**				**43.81**					**32.68**
Percentage uncertainty in total inventory:										**6.62**				Trend uncertainty:	**5.72**

A2.2 Detailed description of Approach 2 uncertainty analysis by Monte Carlo simulation

A2.2.1 Work steps

As a first step, the probability distributions need to be selected and their parameters need to be defined for the activity data and emission factors, based on measured data, literature or expert judgement. The most probable values of the probability distributions are set equal to the values of the GHG inventory. In most cases, normal distributions are assumed. For some agricultural categories, triangular distributions are applied (see below).

In a second step, correlation coefficients for activity data, CO_2 emission factors and emission levels are chosen. Correlations may have a significant effect on the overall inventory uncertainty. Depending on whether correlations are negative or positive, they can lead to a decrease or increase in level uncertainty, respectively. Regrading trend uncertainty, positive correlations lead to a decrease and negative correlations to an increase in the trend uncertainty. Correlations were defined only for categories with relevant contributions to total uncertainty. If a large set of parameters is correlated with each other, the resulting correlation matrix might be mathematically inconsistent. In this case, the software Crystal Ball adjusts correlation coefficients iteratively such that the resulting correlation matrix is mathematically consistent. On average, such a modification of the correlation coefficients amounts to 0.10.

In the third step, Monte Carlo simulations are carried out to produce simulated emissions and hence uncertainty results (see below). Two sets of simulations were performed to study the sensitivity to the choice of correlation strengths. Without considering any correlations the level uncertainty is slightly lower (-3%) and the trend uncertainty is slightly higher (+2.8%) compared to the run which did consider correlations.

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. For triangular distributions the values shown in Table A – 7 indicate the minimum and maximum value of the distribution rather than the 95% uncertainty range.

Table A – 3 Probability distribution assigned to activity data and emission factors (1990 and the reporting year 2016) of categories that are not considered 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 correlation coefficients available, only the following values have been used (if any are assumed):

- “strong” positive correlations are set to r = 1.0 (like perfect correlations),
- “medium” correlations are set to r = ±0. 5.
- “weak” correlations are set to r = ±0.25.

The following assumptions are made for the **level uncertainty**:

- Activity data of liquid and gaseous fuels from the categories 1A2, 1A4a and 1A4b are negatively correlated (r = -0.5), since the total amount is well known but the partitioning into the different categories is less precisely known. By 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 correlated between 1990 and 2016. A medium positive correlation is assumed (r = 0.5).
- 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 correlated between 1990 and 2016. A medium positive correlation is assumed (r = 0.5).
- The emission factors of agricultural categories are correlated between 1990 and 2016. A strong positive correlation is assumed .

Table A – 4 Correlation coefficients for correlated activity data.

	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_1A2_Gaseous Fuels_CO2	1.0					
b_AD_1A4a_Gaseous Fuels_CO2	-0.5	1.0				
b_AD_1A4b_Gaseous Fuels_CO2	-0.5	-0.5	1.0			
t_AD_1A2_Gaseous Fuels_CO2	0.5			1.0		
t_AD_1A4a_Gaseous Fuels_CO2		0.5		-0.5	1.0	
t_AD_1A4b_Gaseous Fuels_CO2			0.5	-0.5	-0.5	1.0

	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_1A2_Liquid Fuels_CO2	1.0					
b_AD_1A4a_Liquid Fuels_CO2	-0.5	1.0				
b_AD_1A4b_Liquid Fuels_CO2	-0.5	-0.5	1.0			
t_AD_1A2_Liquid Fuels_CO2	0.5			1.0		
t_AD_1A4a_Liquid Fuels_CO2		0.5		-0.5	1.0	
t_AD_1A4b_Liquid Fuels_CO2			0.5	-0.5	-0.5	1.0

	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_liquid_N2O	1.0				
t_AD_3B_solid_N2O	-0.4	1.0			
t_AD_3B5_indirect_N2O			1.0		
t_AD_3Db1_deposition_N2O	0.4	0.4	0.5	1.0	
t_AD_3Db2_leaching and runoff_N2O	0.4	0.4	0.5		1.0

	b_AD_3B_solid_N2O	b_AD_3B5_indirect_N2O	b_AD_3Db1_deposition_N2O	b_AD_3Db2_leaching and runoff_N2O
b_AD_3B_solid_N2O	1.0			
b_AD_3B5_indirect_N2O		1.0		
b_AD_3Db1_deposition_N2O	0.5	0.5	1.0	
b_AD_3Db2_leaching and runoff_N2O	0.5	0.5		1.0

	b_AD_1A3b_Gasoline_CO2	t_AD_1A3b_Gasoline_CO2
b_AD_1A3b_Gasoline_CO2	1.0	
t_AD_1A3b_Gasoline_CO2	0.5	1.0

	b_AD_1A3b_Diesel_CO2	t_AD_1A3b_Diesel_CO2
b_AD_1A3b_Diesel_CO2	1.0	
t_AD_1A3b_Diesel_CO2	0.5	1.0

Table A – 5 Correlation coefficients for correlated CO_2 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

The uncertainty analyses according to Approach 2 are not based on the final set of emission data but a previous version, which shows slight differences. Therefore, the total emissions provided in the following table differs slightly from the data provided in the reporting tables (CRF).

Table A – 7 Results of Approach 2 uncertainty analysis, Monte Carlo simulation (Table 3.3 of the 2006 IPCC Guidelines, see also explanations therein on pp. 3.42-3.43 for each column). The uncertainty analysis includes indirect CO_2 emissions. If year 2016 emissions are zero, combined uncertainties are indicated as NO.

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2016 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2016	Inventory trend in national emissions 1990-2016	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO2 eq	kt CO2 eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
1A1 Biomass CH4	0.45	0.31	-10	10	-28	28	-29	31	0.0000	-32	-36	36
1A1 Gaseous Fuels	0.11	0.22	-5	5	-30	30	-30	30	0.0000	106	-69	69
1A1 Liquid Fuels CH4	0.52	0.20	-1	1	-30	30	-30	30	0.0000	-61	-32	32
1A1 Solid Fuels CH4	0.13	-	-5	5	-30	30	NO	NO	-	-100	-30	30
1A1 Gaseous Fuels	243.40	505.14	-5	5	-1	1	-5	5	0.0001	108	-12	12
1A1 Liquid Fuels CO2	685.81	392.72	-1	1	-0	0	-1	1	0.0000	-43	-1	1
1A1 Other Fuels CO2	1'491.55	2'454.47	-5	5	-9	9	-10	11	0.0072	65	-16	16
1A1 Solid Fuels CO2	49.13	-	-5	5	-5	5	NO	NO	-	-100	-7	7
1A1 Biomass N2O	22.58	14.43	-10	10	-79	79	-79	81	0.0000	-36	-96	95
1A1 Gaseous Fuels	0.13	0.27	-5	5	-80	80	-80	80	0.0000	107	-185	184
1A1 Liquid Fuels N2O	1.11	0.30	-1	1	-80	80	-79	80	0.0000	-73	-83	83
1A1 Other Fuels N2O	24.33	12.34	-5	5	-80	80	-80	80	0.0000	-49	-89	90
1A1 Solid Fuels N2O	0.24	-	-5	5	-80	80	NO	NO	-	-100	-80	80
1A2 Biomass CH4	4.27	1.84	-10	10	-28	28	-29	31	0.0000	-57	-33	32
1A2 Gaseous Fuels	0.46	0.99	-5	5	-30	30	-30	30	0.0000	112	-70	70
1A2 Liquid Fuels CH4	4.50	1.37	-1	1	-30	30	-30	30	0.0000	-70	-31	31
1A2 Other Fuels CH4	0.77	0.55	-5	5	-30	30	-30	30	0.0000	-30	-37	37
1A2 Solid Fuels CH4	0.31	0.22	-5	5	-30	30	-30	30	0.0000	-29	-37	37
1A2 Gaseous Fuels	1'049.69	2'233.51	-5	5	-1	1	-5	5	0.0014	113	-9	10
1A2 Liquid Fuels CO2	3'889.15	1'854.46	-1	1	-0	0	-1	1	0.0000	-52	-1	1
1A2 Other Fuels CO2	191.77	415.36	-5	5	-9	9	-10	11	0.0002	117	-25	25
1A2 Solid Fuels CO2	1'274.70	436.41	-5	5	-5	5	-7	7	0.0001	-66	-8	7
1A2 Biomass N2O	5.11	14.47	-10	10	-79	79	-79	81	0.0000	183	-238	242
1A2 Gaseous Fuels	0.56	1.18	-5	5	-80	80	-80	80	0.0000	112	-186	188
1A2 Liquid Fuels N2O	13.14	10.96	-1	1	-80	80	-80	80	0.0000	-16	-105	105
1A2 Other Fuels N2O	2.32	6.36	-5	5	-80	80	-80	80	0.0000	174	-234	235
1A2 Solid Fuels N2O	6.14	2.05	-5	5	-80	80	-80	80	0.0000	-67	-84	84
1A3a kerosene CH4	0.17	0.11	-1	1	-30	30	-30	30	0.0000	-34	-36	36
1A3a kerosene CO2	252.55	140.63	-1	1	-0	0	-1	1	0.0000	-44	-1	1
1A3a kerosene N2O	2.06	1.15	-1	1	-150	150	-150	151	0.0000	-44	-172	172
1A3b Biomass CH4	-	0.11	-10	10	-59	59	-59	61	0.0000	-	-	-
1A3b Diesel CH4	1.58	0.43	-1	1	-20	20	-25	25	0.0000	-78	-21	21
1A3b Gaseous Fuels	-	0.12	-5	5	-30	30	-30	30	0.0000	-	-	-
1A3b Gasoline CH4	97.84	12.60	-1	1	-37	37	-37	37	0.0000	-87	-37	37
1A3b Diesel CO2	2'632.59	7'280.86	-1	1	-0	0	-1	1	0.0005	177	-2	2
1A3b Gaseous Fuels	-	33.84	-5	5	-1	1	-5	5	0.0000	-	-	-
1A3b Gasoline CO2	11'334.49	7'426.45	-1	1	-0	0	-1	1	0.0003	-34	-1	1
1A3b Biomass N2O	-	1.67	-10	10	-150	150	-150	152	0.0000	-	-	-
1A3b Diesel N2O	5.93	73.03	-1	1	-22	22	-22	22	0.0000	1'131	-270	272
1A3b Gaseous Fuels	-	1.49	-5	5	-80	80	-80	81	0.0000	-	-	-
1A3b Gasoline N2O	134.37	19.75	-1	1	-50	50	-50	50	0.0000	-85	-51	51
1A3c Biomass CH4	-	0.00	-10	10	-59	59	-59	61	0.0000	-	-	-
1A3c Diesel CH4	0.03	0.01	-1	1	-30	30	-30	30	0.0000	-57	-33	33
1A3c Diesel CO2	28.69	28.46	-1	1	-0	0	-1	1	0.0000	-1	-1	1
1A3c Biomass N2O	-	0.01	-10	10	-150	150	-150	151	0.0000	-	-	-
1A3c Diesel N2O	0.43	0.41	-1	1	-80	80	-80	79	0.0000	-3	-111	111
1A3d Biomass CH4	-	0.00	-10	10	-59	59	-60	61	0.0000	-	-	-
1A3d Liquid Fuels CH4	1.68	0.30	-1	1	-30	30	-30	30	0.0000	-82	-30	30
1A3d Liquid Fuels CO2	114.27	112.85	-1	1	-0	0	-1	1	0.0000	-1	-1	1
1A3d Biomass N2O	-	0.02	-10	10	-150	150	-149	151	0.0000	-	-	-
1A3d Liquid Fuels N2O	1.16	1.22	-1	1	-150	150	-149	150	0.0000	6	-218	217
1A3e Gaseous Fuels	0.07	0.02	-5	5	-30	30	-30	30	0.0000	-76	-31	31
1A3e Gaseous Fuels	31.42	19.18	-5	5	-1	1	-5	5	0.0000	-39	-6	6
1A3e Gaseous Fuels	0.02	0.01	-5	5	-80	80	-80	80	0.0000	-39	-94	93
1A4a Biomass CH4	9.22	4.73	-10	10	-28	28	-29	30	0.0000	-49	-34	33
1A4a Gaseous Fuels	0.72	1.34	-5	5	-30	30	-30	30	0.0000	87	-63	63
1A4a Liquid Fuels CH4	16.34	9.94	-1	1	-30	30	-30	30	0.0000	-39	-35	35
1A4a Gaseous Fuels	1'012.50	1'490.05	-5	5	-1	1	-5	5	0.0006	47	-7	7
1A4a Liquid Fuels CO2	4'260.86	2'789.09	-1	1	-0	0	-1	1	0.0000	-35	-1	1
1A4a Biomass N2O	3.49	10.17	-10	10	-79	79	-79	81	0.0000	191	-244	248
1A4a Gaseous Fuels	0.54	0.79	-5	5	-80	80	-80	80	0.0000	46	-141	141
1A4a Liquid Fuels N2O	10.35	6.81	-1	1	-80	80	-80	80	0.0000	-34	-96	96

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2016 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2016	Inventory trend in national emissions 1990-2016	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO2 eq	kt CO2 eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
1A4b Biomass CH4	109.96	25.56	-10	10	-28	28	-29	31	0.0000	-77	-32	30
1A4b Gaseous Fuels	0.69	1.43	-5	5	-30	30	-30	30	0.0000	104	-68	68
1A4b Liquid Fuels CH4	34.83	20.52	-1	1	-30	30	-30	30	0.0000	-41	-35	35
1A4b Solid Fuels CH4	4.73	1.50	-5	5	-30	30	-30	30	0.0000	-68	-31	31
1A4b Gaseous Fuels	1'428.53	2'754.33	-5	5	-1	1	-5	5	0.0021	93	-9	9
1A4b Liquid Fuels CO2	10'099.07	6'006.20	-1	1	-0	0	-1	1	0.0002	-41	-1	1
1A4b Solid Fuels CO2	58.40	18.54	-5	5	-5	5	-7	7	0.0000	-68	-8	7
1A4b Biomass N2O	25.85	22.77	-10	10	-79	79	-79	81	0.0000	-12	-107	106
1A4b Gaseous Fuels	0.76	1.46	-5	5	-80	80	-80	81	0.0000	92	-175	175
1A4b Liquid Fuels N2O	24.53	14.61	-1	1	-80	80	-80	80	0.0000	-40	-93	93
1A4b Solid Fuels N2O	0.28	0.09	-5	5	-80	80	-80	80	0.0000	-68	-85	84
1A4c Biomass CH4	1.97	0.38	-10	10	-28	28	-29	31	0.0000	-81	-31	30
1A4c Gaseous Fuels	0.02	0.01	-5	5	-30	30	-30	30	0.0000	-62	-32	32
1A4c Liquid Fuels CH4	6.45	1.36	-1	1	-30	30	-30	30	0.0000	-79	-31	31
1A4c Gaseous Fuels	41.45	15.72	-5	5	-1	1	-5	5	0.0000	-62	-5	5
1A4c Liquid Fuels CO2	485.09	402.88	-1	1	-0	0	-1	1	0.0000	-17	-1	1
1A4c Biomass N2O	0.51	1.40	-10	10	-79	79	-79	81	0.0000	173	-231	236
1A4c Gaseous Fuels	0.02	0.01	-5	5	-80	80	-80	80	0.0000	-62	-86	85
1A4c Liquid Fuels N2O	4.20	4.54	-1	1	-80	80	-80	81	0.0000	8	-118	118
1A5 Biomass CH4	-	0.00	-10	10	-59	59	-59	61	0.0000	-	-	-
1A5 Liquid Fuels CH4	0.27	0.17	-1	1	-60	60	-60	60	0.0000	-38	-71	71
1A5 Liquid Fuels CO2	217.65	138.14	-1	1	-0	0	-1	1	0.0000	-37	-1	1
1A5 Biomass N2O	-	0.00	-106	106	-106	106	-119	194	0.0000	-	-	-
1A5 Liquid Fuels N2O	1.84	1.20	-106	106	-106	106	-118	195	0.0000	-34	-214	181
1B2 CH4	336.27	193.54	-5	5	-30	30	-30	30	0.0004	-42	-35	35
1B2 CO2	26.19	28.14	-5	5	-9	9	-10	10	0.0000	7	-15	15
1B2 N2O	0.60	0.01	-5	5	-80	80	-80	80	0.0000	-99	-80	80
1ind CO2	43.55	8.23	-16	16	-16	16	-23	23	0.0000	-81	-23	23
2A1 CO2	2'580.79	1'768.99	-2	2	-2	2	-3	3	0.0003	-31	-3	3
2A2 CO2	53.35	41.44	-2	2	-3	3	-4	4	0.0000	-22	-5	5
2A3 CO2	15.25	6.47	-2	2	-2	2	-3	3	0.0000	-58	-3	3
2A4 CO2	162.87	84.10	-2	2	-20	20	-20	20	0.0000	-48	-23	22
2B2 N2O	65.49	6.11	-2	2	-5	5	-5	5	0.0000	-91	-5	5
2B5 CO2	15.72	31.30	-2	2	-10	10	-10	10	0.0000	99	-23	23
2B5 CH4	1.74	2.70	-2	2	-10	10	-10	10	0.0000	55	-19	19
2B8 CO2	94.08	111.48	-2	2	-10	10	-10	10	0.0000	18	-16	16
2B10 CO2	11.87	12.49	-2	2	-7	7	-7	7	0.0000	5	-11	11
2C1 CO2	9.20	10.89	-5	5	-20	20	-21	21	0.0000	19	-32	32
2C3 CO2	139.26	-	-6	6	-6	6	NO	NO	-	-100	-9	9
2C3 PFC	116.46	-	-20	20	-20	20	NO	NO	-	-100	-28	28
2C4 SF6	-	18.38	-2	2	-20	20	-20	20	0.0000	-	-	-
2C7 CO2	1.65	1.44	-35	35	-35	35	-100	99	0.0000	-12	-133	132
2D CO2	57.19	52.03	-36	36	-36	36	-51	51	0.0001	-9	-69	69
2E1 HFC	-	0.18	-45	45	-45	45	-63	63	0.0000	-	-	-
2E1 PFC	-	4.33	-44	44	-44	44	-62	62	0.0000	-	-	-
2E1 SF6	-	6.79	-137	137	-137	137	-194	194	0.0000	-	-	-
2E3 NF3	-	0.51	-51	51	-73	73	-51	51	0.0000	-	-	-
2E4 PFC	-	0.00	-10	10	-10	10	-0	-0	-	-	-	-
2F1 HFC	0.02	1'286.65	-76	76	-76	76	-108	108	0.2096	5'197'495	-5'609'381	5'591'453
2F1 PFC	0.05	1.29	-80	80	-80	80	-114	113	0.0000	2'306	-2'733	2'732
2F2 HFC	-	31.58	-29	29	-29	29	-41	41	0.0000	-	-	-
2F4 HFC	-	16.81	-38	38	-38	38	-54	54	0.0000	-	-	-
2F5 HFC	-	1.55	-28	28	-28	28	-40	40	0.0000	-	-	-
2G CO2	6.60	36.14	-9	9	-9	9	-12	12	0.0000	448	-69	69
2G HFC	-	85.39	-11	11	-11	11	-16	16	0.0000	-	-	-
2G PFC	-	48.33	-23	23	-23	23	-32	32	0.0000	-	-	-
2G SF6	137.01	181.95	-1	1	-80	80	-79	80	0.0023	33	-133	133
2G N2O	105.87	38.95	-3	3	-7	7	-8	8	0.0000	-63	-8	8
2H CO2	1.04	0.27	-6	6	-17	17	-18	18	0.0000	-74	-19	19
2ind CO2	356.11	97.36	-14	14	-149	149	-149	149	0.0023	-73	-155	155
3A CH4	3'584.87	3'324.59	-6	6	-17	17	-18.1	18.1	0.0393	-7	-17	17
3B CH4	868.63	753.02	-6	6	-54	54	-54	54	0.0181	-13	-50	50
3B N2O	-	7.26	-34	30	-50	100	-76	89	0.0000	-	-	-
3B N2O	104.65	68.02	-34	30	-50	100	-76	89	0.0003	-35	-57	38
3B5 N2O	230.33	270.51	-38	55	-80	400	-77	126	0.0438	11	-58	72

Categories (NFR, fuel, gas)	Base year (1990) emissions/ removals	Year 2016 emissions/ removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Contribution to variance in year 2016	Inventory trend in national emissions 1990-2016	Uncertainty introduced into the trend in total national emissions with respect to base year	
	kt CO2 eq	kt CO2 eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %
3Da1/2/4/5/7 N2O	1'059.15	815.68	-16	13	-70	200	-64	87	0.0939	-23	-32	19
3Da6 N2O	67.58	65.12	-18	46	-75	200	-68	100	0.0007	-4	-53	50
3Da3 N2O	120.31	199.18	-53	83	-65	200	-68	114	0.0096	72	-91	148
3Db1 N2O	414.48	289.20	-35	49	-80	400	-77	124	0.0477	-34	-71	36
3Db2 N2O	173.42	123.24	-22	22	-93	233	-77	102	0.0031	-29	-45	25
3G CO2	22.25	32.84	-40	40	-5	5	-40	40	0.0000	48	-52	52
3H CO2	26.66	14.43	-5	5	-5	5	-7	7	0.0000	-46	-6	6
5A CH4	763.39	334.95	-10	10	-39	39	-40	40	0.0020	-56	-44	43
5A CO2	-	-	-32	32	-36	36	NO	NO	-	-	-	-
5B CH4	11.89	26.14	-32	32	-147	147	-151	152	0.0002	119	-362	362
5B N2O	5.22	9.69	-42	42	-42	42	-60	60	0.0000	86	-127	126
5C CH4	8.89	5.20	-28	28	-28	28	-40	40	0.0000	-41	-46	46
5C CO2	53.73	9.89	-106	106	-106	106	-149	149	0.0000	-82	-153	152
5C N2O	16.78	32.94	-16	16	-16	16	-23	23	0.0000	96	-50	51
5D CH4	130.92	180.33	-2	2	-50	50	-50	50	0.0009	38	-85	85
5D N2O	118.62	149.16	-2	2	-200	200	-202	201	0.0097	25	-324	322
5ind CO2	2.01	1.17	-34	34	-34	34	-47	48	0.0000	-42	-55	55
6 CH4	0.66	0.59	-2	2	-40	40	-40	40	0.0000	-10	-53	53
6 CO2	10.96	11.11	-2	2	-20	20	-20	20	0.0000	1	-29	28
6 N2O	0.60	0.50	-2	2	-100	100	-150	150	0.0000	0	-214	212
6ind CO2	1.04	1.01	-17	17	-58	58	-60	61	0.0000	-2	-84	85
4 II CH4	10.75	10.75	-30	30	-70	70	-76	75	0.0000	0	-107	107
4 II N2O	2.95	2.94	-1	1	-89	89	-89	89	0.0000	0	-126	125
4 III N2O	38.73	39.15	-2	2	-89	89	-88	88	0.0001	1	-126	126
4 IV N2O	6.44	5.72	-5	5	-164	164	-163	163	0.0000	-11	-149	149
4 V CH4	18.63	5.19	-5	5	-32	32	-33	33	0.0000	-72	-36	36
4 V CO2	-	-	-5	5	-916	916	NO	NO	-	-	-	-
4 V N2O	10.81	2.86	-5	5	-40	40	-41	41	0.0000	-74	-69	69
4A1 CO2	-425.45	-2'197.15	-62	62	-72	72	95	-95	0.4774	416	500	-500
4A2 CO2	-580.59	-441.71	-4	4	-24	24	25	-25	0.0013	-24	32	-32
4B1 CO2	912.56	155.84	-4	4	-50	50	-51	50	0.0007	-83	-51	50
4B2 CO2	37.92	48.01	-5	5	-50	50	-51	50	0.0001	27	-82	81
4C1 CO2	79.57	110.05	-3	3	-50	50	-50	50	0.0003	38	-86	85
4C2 CO2	67.85	188.51	-5	5	-57	57	-57	58	0.0013	179	-169	170
4D1 CO2	67.56	68.43	-21	21	-21	21	-30	30	0.0000	1	-43	43
4D2 CO2	21.32	31.24	-7	7	-7	7	-10	10	0.0000	46	-18	18
4E1 CO2	-48.65	-0.46	-30	30	-30	30	42	-42	0.0000	-99	42	-42
4E2 CO2	259.92	193.92	-30	30	-30	30	-42	42	0.0007	-25	-53	53
4F2 CO2	94.28	119.80	-10	10	-59	59	-60	60	0.0006	27	-97	98
4G CO2	-1'204.03	-106.60	-10	10	-39	39	40	-40	0.0002	-91	40	-40
incl LULUCF	**52'969**	**46'439**					**-6.31**	**6.41**		**-12.33%**	**-5.59**	**5.58**
excl. LULUCF	**53'598**	**48'202**					**-4.34**	**4.54**		**-10.07%**	**-3.78**	**3.74**

A2.2.5 Relation between simulated and inventory values

The Monte Carlo method provides a probability distribution of the Swiss greenhouse gas emissions from which all relevant statistical parameters can be derived (standard deviation and percentiles). Since for skewed triangular distributions the most probable value rather than the mean value of the probability distribution is set equal to the values of the GHG inventory, the simulated average emissions deviate from the reported emissions.

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). The uncertainty analysis includes indirect CO_2 emissions.

Year	Parmeters	Unit	Emission (excl. LULUCF)	Lower bound 2.5 percentile	Upper bound 97.5 percentile	Lower uncertainty	Upper uncertainty
2016	**simulated values**						
	absolute	kt CO_2 eq	49'414	47'272	51'660	-2'143	2'245
	relative	%	100.00%	95.66%	104.54%	-4.34%	4.54%
	reported values						
	absolute	kt CO_2 eq	48'202	46'112	50'392	-2'090	2'190
	relative	%	100.00%	95.66%	104.54%	-4.34%	4.54%
1990	**simulated values**						
	absolute	kt CO_2 eq	55'063	53'068	57'281	-1'995	2'218
	relative	%	100.00%	96.38%	104.03%	-3.62%	4.03%
	reported values						
	absolute	kt CO_2 eq	53'598	51'656	55'757	-1'942	2'159
	relative	%	100.00%	96.38%	104.03%	-3.62%	4.03%

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. Further and more detailed emission factors can be found in Switzerland's Informative Inventory Report (FOEN 2018f).

Emission factors for greenhouse gases are given in 3.2.6.2.

Table A – 9 Emission factors 2016 of precursors from boiler in 1A2 Manufacturing industries and construction.

1A2 Boiler	**NO_x**	**NMVOC**	**SO_2**	**CO**
	g/GJ			
Boiler gas oil	32	2	16	7
Boiler residual fuel oil	125	4	291	10
Boiler liquefied petroleum gas	19	2	0.5	8
Boiler petroleum coke	125	4	291	10
Boiler other bituminous coal	200	10	500	100
Boiler lignite	207	10	500	100
Boiler natural gas	19	2	0.5	8

A3.1.2 Civil aviation

This paragraph contains further information on the emission modelling. More complete information is provided in FOCA (2006, 2006a, 2007–2017) 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, HP = Helicopter with Piston Engine, B = Business jet, SJ = Supersonic Jet, E = Electric Aircraft. 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	Time_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	3	5.5	5
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	3	5.5	5
4SJ	1.2	2	2.3	20
3H	0	3	5.5	5
4H	0	3	5.5	5
4B	0.4	0.5	1.6	13
1HP	0	4	5.5	5
2HP	0	4	5.5	5
3HP	0	4	5.5	5
4HP	0	4	5.5	5
1B	0.4	0.5	1.6	13
1E	0.7	10	5	13
4E	0.3	10	5	13
6J	0.7	2.2	4	20

Table A – 12 Aircraft-Engine Combinations and associated codes for SWISS FOCA emissions database. (Extract from list of more than 40'000 individual aircraft)

Aircraft Engine Combinations							
Engine Name	Aircraft Name	Aircraft Registr.	No. Eng.	Code	Type	Aircr. ICAO	Source
V2527-A5	AIRBUS A320-232	ECHXA	2	J220	2J	A320	1IA003
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHXM	2	J090	2J	CRJ2	1GE034
CFM56-3C1	BOEING 737-4K5	ECHXT	2	J022	2J	B734	1CM007
TPE331-11U-611G	FAIRCHILD (SWEARIN-GEN) SA227AC METR	ECHXY	2	T310	2T	SW4	FOI
CFM56-5B4/P	AIRBUS A320-214	ECHYC	2	J067	2J	A320	3CM026
CFM56-5B4/P	AIRBUS A320-214	ECHYD	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHYG	2	J090	2J	CRJ2	1GE034
CFEC-FE738-1-1B	DASSAULT FALCON 2000	ECHYI	2	B130	2B	F2TH	FOI-Ho-neywell
GA TPE331-11U-612G		ECHZH	2	T310	2T	FA3	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHZR	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-86Q (WINGLETS)	ECHZS	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECHZU	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIAA	2	J090	2J	CRJ2	1GE034
FJ44-1A	CESSNA 525 CITATIONJET	ECIAB	2	B001	2B	C525	FOCA
CFM56-5B4/P	AIRBUS A320-214	ECIAG	2	J067	2J	A320	3CM026
V2527-A5	AIRBUS A320-232	ECIAZ	2	J220	2J	A320	1IA003
BRBR700-710A2-20	BOMBARDIER BD-700-1A10 GLOBAL EX-PRE	ECIBD	2	J854	2J	GLEX	4BR009
PT6A-60A	BEECH-CRAFT KING AIR 350 (RAYTHEON B	ECIBK	2	T738	2T	B350	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIBM	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-81Q (WINGLETS)	ECICD	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECICK	2	J067	2J	A320	3CM026

Emissions (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_2O	SO_2	NO_x	VOC	CO
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	5673.492	17871.5	6978.395	5.673	26.04	139	359.2
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	47470.5	149532.1	58388.72	47.47	554.91	0	361.47
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	6164.2728	19417.46	7582.056	6.164	87.539	40.59	185.53
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	5668.542	17855.91	6972.307	5.669	46.937	28.13	163.44
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	4725.108	14884.09	5811.883	4.725	31.31	53.62	169.01
LSGG	112510.267	Taxi	100	2B	F2TH	CFE738-1-1B	5223.96	16455.47	6425.471	5.224	74.186	34.4	157.23
LSGG	107945.477	Taxi	96	2B	C560	JT15D-5D	3795.3216	11955.26	4668.246	3.795	16.959	271.6	287.98
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	307732.68	969357.9	378511.2	307.7	4513	29.43	274.71
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	673698.47	2122150	828649.1	673.7	7986.4	647.8	1038.2
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	225781.85	711212.8	277711.7	225.8	3311.2	21.59	201.55
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	298139.18	939138.4	366711.2	298.1	4372.3	28.52	266.14
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	193723.81	610230	238280.3	193.7	2841	18.53	172.93
LSGG	106761.289	Taxi	100	2B	F2TH	CFE738-1-1B	181011.75	570187	222644.4	181	2654.6	17.31	161.58
LSGG	103217.159	Taxi	96	2B	C560	JT15D-5D	175002.74	551258.6	215253.4	175	2566.5	16.74	156.22

A3.1.3 Road transportation

Emission factors (1A3b)

The derivation of the emission factors for road vehicles is described in detail in TUG (2009), Keller et al. (2017), Hausberger and Matzer (2017). The emission factors are contained in the “The Handbook Emission Factors for Road Transport (HBEFA)” (version 3.3), which is available as a database (INFRAS 2017a). 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 2017a).

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 are classified by “traffic situations”. The scheme (see table below) distinguishes the traffic situations along 4 dimensions: urban/rural areas, 10 road types, speed limits and 4 levels of service. This leads to the definition of 276 different traffic situations in total. A traffic situation is characterised by these four parameters which induce 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 INFRAS 2015b).

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. They represent weighted averages over all traffic situations but separate emission factors for warm operating state of the running engine in g/vehicle-km from cold start excess emissions in g per start per vehicle.

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. Cold start excess emissions are given in g/start.

Pollutant	Year	PC	LDV	HDV	Coach	Bus	MC	PC	LDV
		Emission factors in gramme per vehicle kilometre						**Cold starts in** gramme per start	
CH_4	1990	0.026	0.038	0.019	0.019	0.059	0.281	0.67	0.72
CH_4	1995	0.016	0.027	0.017	0.018	0.052	0.311	0.42	0.50
CH_4	2000	0.010	0.017	0.013	0.017	0.038	0.313	0.28	0.29
CH_4	2005	0.006	0.008	0.009	0.013	0.020	0.271	0.18	0.15
CH_4	2010	0.003	0.003	0.004	0.008	0.018	0.185	0.12	0.08
CH_4	2015	0.001	0.001	0.002	0.005	0.016	0.118	0.09	0.05
CO	1990	6.21	15.75	2.29	2.33	6.58	14.05	41.0	60.8
CO	1995	2.96	11.02	2.12	2.26	6.24	13.17	29.3	46.9
CO	2000	1.76	6.55	1.72	2.06	5.12	12.43	21.8	31.3
CO	2005	1.21	3.06	1.61	1.91	3.23	10.56	15.4	17.7
CO	2010	0.74	1.34	1.36	1.87	1.33	7.36	10.7	9.4
CO	2015	0.47	0.66	0.99	1.70	1.01	5.17	8.0	5.9
CO_2 (fossil)	1990	243	244	796	927	1'274	83	109	141
CO_2 (fossil)	1995	246	247	797	920	1'279	92	103	135
CO_2 (fossil)	2000	238	250	758	891	1'236	94	100	128
CO_2 (fossil)	2005	223	242	794	880	1'196	97	101	116
CO_2 (fossil)	2010	204	236	778	871	1'134	104	106	107
CO_2 (fossil)	2015	186	229	767	876	1'115	106	107	103
VOC	1990	0.72	1.14	0.81	0.81	2.48	3.71	7.12	6.84
VOC	1995	0.33	0.73	0.72	0.77	2.17	2.68	5.72	5.59
VOC	2000	0.16	0.37	0.54	0.70	1.59	2.13	4.63	4.14
VOC	2005	0.08	0.16	0.38	0.55	0.82	1.67	3.27	2.53
VOC	2010	0.04	0.07	0.16	0.32	0.25	1.14	2.29	1.39
VOC	2015	0.02	0.03	0.07	0.19	0.15	0.75	1.69	0.89
N_2O	1990	0.009	0.005	0.008	0.008	0.012	0.002	-0.000	0.002
N_2O	1995	0.013	0.007	0.009	0.008	0.012	0.002	0.002	0.005
N_2O	2000	0.011	0.008	0.009	0.008	0.011	0.002	0.004	0.008
N_2O	2005	0.005	0.007	0.008	0.007	0.009	0.002	0.006	0.011
N_2O	2010	0.003	0.006	0.031	0.014	0.017	0.002	0.008	0.015
N_2O	2015	0.003	0.005	0.042	0.022	0.029	0.002	0.009	0.018
NMVOC	1990	0.69	1.10	0.79	0.79	2.42	3.43	6.45	6.11
NMVOC	1995	0.31	0.70	0.70	0.75	2.11	2.37	5.30	5.10
NMVOC	2000	0.15	0.35	0.53	0.68	1.55	1.82	4.35	3.86
NMVOC	2005	0.07	0.15	0.37	0.53	0.80	1.40	3.09	2.38
NMVOC	2010	0.03	0.06	0.16	0.31	0.24	0.96	2.16	1.31
NMVOC	2015	0.02	0.03	0.07	0.19	0.13	0.63	1.60	0.84
NO_x	1990	1.04	2.13	11.12	12.00	17.87	0.11	0.56	0.03
NO_x	1995	0.71	1.74	10.29	11.39	17.32	0.14	1.19	0.53
NO_x	2000	0.56	1.52	9.06	10.56	15.84	0.15	1.19	0.57
NO_x	2005	0.43	1.30	7.53	9.32	13.16	0.16	0.74	0.24
NO_x	2010	0.34	1.08	4.84	7.50	9.69	0.14	0.37	0.02
NO_x	2015	0.35	0.94	2.98	5.99	7.25	0.13	0.17	-0.11
SO_2	1990	0.041	0.092	0.708	0.824	1.133	0.011	0.018	0.044
SO_2	1995	0.033	0.040	0.173	0.199	0.277	0.012	0.014	0.021
SO_2	2000	0.023	0.033	0.131	0.154	0.214	0.008	0.010	0.016
SO_2	2005	0.001	0.001	0.005	0.006	0.008	0.000	0.001	0.001
SO_2	2010	0.001	0.001	0.005	0.006	0.007	0.001	0.001	0.001
SO_2	2015	0.001	0.001	0.005	0.006	0.007	0.001	0.001	0.001

Table A – 17 Emisson factors N_2O from COPERT for passenger cars (PC) and light duty vehicles (LDV) by Euro class (EMEP/EEA 2016). Start excess is the difference between cold and hot EF.

veh. category	fuel	Euro class	EF(N_2O) hot	EF(N_2O) cold	start excess
			mg/km	mg/km	mg/km
PC	gasoline	EURO0	10.00	10.00	0.00
PC	gasoline	EURO1	21.34	16.38	-4.96
PC	gasoline	EURO2	10.68	11.25	0.57
PC	gasoline	EURO3	1.08	7.51	6.43
PC	gasoline	EURO4	1.77	5.18	3.42
PC	gasoline	EURO5	2.07	1.57	-0.50
PC	gasoline	EURO6	2.07	1.57	-0.50
PC	diesel oil	EURO0	0.00	0.00	0.00
PC	diesel oil	EURO1	2.00	0.00	-2.00
PC	diesel oil	EURO2	4.00	3.00	-1.00
PC	diesel oil	EURO3	9.00	15.00	6.00
PC	diesel oil	EURO4	9.00	15.00	6.00
PC	diesel oil	EURO5	9.00	15.00	6.00
PC	diesel oil	EURO6	11.00	9.00	-2.00
LCV	gasoline	EURO0	10.00	10.00	0.00
LCV	gasoline	EURO1	22.85	43.38	20.54
LCV	gasoline	EURO2	16.25	54.97	38.72
LCV	gasoline	EURO3	4.74	16.08	11.34
LCV	gasoline	EURO4	1.11	11.92	10.81
LCV	gasoline	EURO5	2.07	1.57	-0.50
LCV	gasoline	EURO6	2.07	1.57	-0.50
LCV	diesel oil	EURO0	0.00	0.00	0.00
LCV	diesel oil	EURO1	2.00	0.00	-2.00
LCV	diesel oil	EURO2	4.00	3.00	-1.00
LCV	diesel oil	EURO3	9.00	15.00	6.00
LCV	diesel oil	EURO4	9.00	15.00	6.00
LCV	diesel oil	EURO5	9.00	15.00	6.00
LCV	diesel oil	EURO6	11.00	9.00	-2.00

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 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 (Euro classes) in all vehicle categories, see also following Figure A-1 (INFRAS 2017).

2. The total mileage is an input data by Swiss Federal Statistical Office (SFSO 2017c/d).

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.

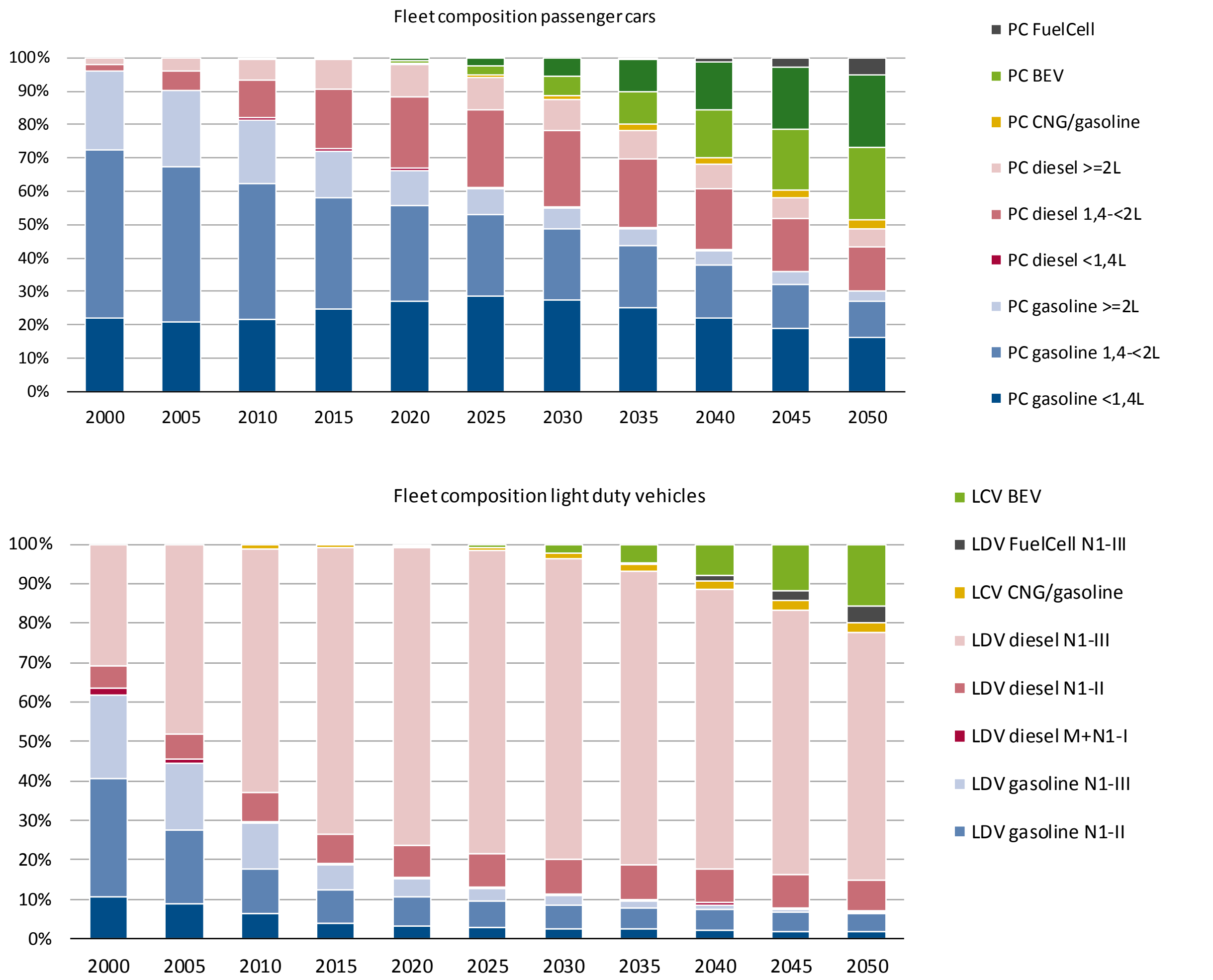


Figure A – 1 Fleet composition for passenger cars (above) and light duty vehicles (below). The specifications refer to fuel type (diesel oil, gasoline etc.) and engine size (PC: L = litres, LDV N1-I etc.) Data source INFRAS (2017).

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 chp. 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 (averaged over vehicle categories).

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). Note that there are cold start excess emissions available for motor cycles.

Results show that for CO_2 the hot exhaust emissions contribute to 97% of the total in 2016. Only 3% stem from cold start excess emissions. For CH_4, however, the picture is different. Only about 40% of the emission total is hot exhaust. More than 59% are cold start excess emissions, the rest results from evaporative emissions. For N_2O, no cold start emission factors are available in INFRAS (2017a) due to lack of measurement data. However, the missing N_2O emissions have been estimated by means of emission factors provided by the COPERT model and which are provided in the EMEP Guidebook (EMEP/EEA 2016). For details see chp. 3.2.9.2.2.

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):
https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html

Table A – 18 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	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**
	number of vehicles					
Construction machinery	63'364	58'816	52'729	57'102	60'384	62,726
Industrial machinery	26'714	43'244	70'671	69'786	69'757	70,083
Agricultural machinery	292'773	324'567	337'869	318'876	309'825	305,235
Forestry machinery	11'815	13'844	13'055	11'857	10'831	10,170
Garden-care / hobby appliances	1'198'841	1'539'624	1'944'373	2'322'737	2'464'323	2,499,627
Navigation machinery	94'866	103'383	93'912	95'055	97'522	99,104
Railway machinery	529	1'300	1'255	697	640	640
Military machinery	13'092	13'373	14'272	13'083	12'853	12,856

Category	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**
	Specific operating hours per year					
Construction machinery	247	322	406	417	424	429
Industrial machinery	666	670	684	680	675	671
Agricultural machinery	136	119	112	103	99	95
Forestry machinery	203	199	203	193	188	182
Garden-care / hobby appliances	12	17	20	64	77	81
Navigation machinery	39	38	38	36	35	35
Railway machinery	877	613	617	783	719	719

Category	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**
	million operating hours per year					
Construction machinery	15.7	19.0	21.4	23.8	25.6	26.9
Industrial machinery	17.8	29.0	48.4	47.5	47.1	47.0
Agricultural machinery	39.9	38.8	37.7	33.0	30.6	29.0
Forestry machinery	2.4	2.8	2.6	2.3	2.0	1.9
Garden-care / hobby appliances	14.6	25.7	39.3	149.7	190.8	201.3
Navigation machinery	3.7	3.9	3.5	3.4	3.4	3.4
Railway machinery	0.5	0.8	0.8	0.5	0.5	0.5
Military machinery	0.8	0.9	0.9	0.9	0.9	0.9
Total	**95**	**121**	**155**	**261**	**301**	**311**

A3.1.5 Sulphur dioxide (SO_2)

Table A – 19 shows sulphur contents and SO_2 emission factors per fuel type. Explanations:

- For liquid and solid fuels the SO_2 emission factors are determined by the sulphur content. The upmost lines in Table A – 19 “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 – 19 contain the effective sulphur contents. They are based on measurements: Summary and annual reports of the Swiss Petroleum Association (EV), reports by the Federal Customs Administration (FCA) since 2000.
- The lines at the bottom part of Table A – 19 give the emission factors in kg/TJ. They are calculated from the sulphur content S, the net calorific value NCV and the quotient of the molar masses of S and SO_2

$$EF_{SO2} = \frac{M_{SO2}}{M_S} \cdot \frac{S}{NCV} = 2 \cdot \frac{S}{NCV}$$

- Coal: The legal limit of sulphur content depends on the size of the heat capacity of the combustion system. The value shown in the table above (1%, 350 kg/TJ SO_2) holds for heat capacity below 1 MW; see OAPC Annex 4, §513 (Swiss Confederation 1985). For larger capacities the value is 3% (OAPC Annex 5, §2, Swiss Confederation 1985). For industrial combustion plants, the limit for the exhaust emissions actually sets the corresponding maximum sulphur content to 1.4% (500 kg/TJ).
- Residual fuel oil: OAPC Annex 5, §11, lit.2 sets 2.8% for the legal limit. Simultaneously, OAPC dispenses from emission control measurements if residual fuel oil is used with sulphur content of maximum 1% (see OAPC Annex 3, §421, lit. 2, Swiss Confederation 1985), which holds for most combustion plants.

Table A – 19 Sulphur content and SO_2 emission factors.

maximum legal limit of sulphur content					
Diesel oil	Gasoline	Gas oil	Natural gas	Res. fuel oil	Coal
ppm	ppm	ppm	ppm	%	%
1400	200	2000	190	1.0	1.0
1300	200	2000	190	1.0	1.0
1200	200	2000	190	1.0	1.0
1000	200	2000	190	1.0	1.0
500	200	2000	190	1.0	1.0
350	150	2000	190	1.0	1.0
50	50	2000	190	1.0	1.0
50	50	1000	190	1.0	1.0
10	50	1000	190	1.0	1.0
10	10	1000	190	1.0	1.0

Effective sulphur content		
Diesel oil	Gasoline	Gas oil
ppm	ppm	ppm
1400	200	1600
1300	200	1300
1200	200	1200
1000	200	1000
434	200	1350
341	200	1170
372	200	1160
353	200	1250
402	200	926
443	200	650
272	142	680
250	121	830
235	101	798
200	81	700
10	8.0	700
10	8.0	799
10	8.0	699
10	8.0	630
10	8.0	641
7.2	5.2	603
8.6	5.8	548
5.1	7.8	116
6.6	5.7	617
7.8	5.3	253
6.5	3.4	385
7.3	3.4	384
6.7	5.3	246

SO_2 emission factor used for Switzerland's emission inventory							
Diesel oil (average in 1A3b road transportation)	Gasoline (average in 1A3b road transportatio n)	Gas oil (boiler in 1A1, 1A2, 1A4)	Natural gas (boiler in 1A1, 1A2, 1A4, gas pipeline transport	Res. fuel oil (boiler in 1A1, 1A2)	Lignite (boiler in 1A2)	Bituminous coal (boiler in 1A1, 1A2, 1A4)	Kerosene (average)
kg/TJ							
65	9.4	75.1	0.5	473	500	350	25.8
61	9.4	61.0	0.5	432	500	500/350	25.3
56	9.4	56.3	0.5	417	500	500/350	25.4
47	9.4	46.9	0.5	422	500	500/350	25.4
20	9.4	63.4	0.5	374	500	500/350	25.3
16	9.4	54.9	0.5	377	500	500/350	25.5
17	9.4	54.5	0.5	379	500	500/350	25.4
16	9.4	58.7	0.5	340	500	500/350	25.2
19	9.4	43.5	0.5	403	500	500/350	25.1
21	9.4	30.5	0.5	301	500	500/350	25.2
13	6.7	31.9	0.5	320	500	500/350	25.0
12	5.7	39.0	0.5	398	500	500/350	24.4
11	4.8	37.5	0.5	398	500	500/350	23.6
9.3	3.8	32.9	0.5	383	500	500/350	23.2
0.47	0.38	32.9	0.5	369	500	500/350	23.1
0.47	0.38	37.5	0.5	379	500	500/350	22.8
0.47	0.38	32.8	0.5	361	500	500/350	21.2
0.47	0.38	29.6	0.5	344	500	500/350	21.5
0.47	0.38	30.1	0.5	326	500	500/350	21.3
0.47	0.38	25.3	0.5	309	500	500/350	21.2
0.47	0.38	25.7	0.5	291	500	500/350	21.2
0.47	0.38	24.1	0.5	291	500	500/350	21.2
0.47	0.38	22.4	0.5	291	500	500/350	21.4
0.47	0.38	20.8	0.5	291	500	500/350	21.5
0.47	0.38	19.2	0.5	291	500	500/350	21.5
0.47	0.38	17.6	0.5	291	500	500/350	21.3
0.47	0.38	15.9	0.5	291	500	500/350	21.1

A3.2 Industrial processes and product use (illustrative example of mobile air conditioning)

The use of HFCs as substitutes of ODSs in 2F1 refrigeration and air conditioning is the main factor for the increase of HFC emissions from 1990 to 2015. Refrigerants contained in installed equipment lead to a considerable stock with annual losses depending from equipment type between 0.5% to 20% (see Table 4-44). 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 – 20 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	%

Since 1991 HFC 134a has been used to replace ODS in the mobile air conditioning sector leading to a considerable stock of about 2’126 t of HFC in registered cars at present. A phase-out of HFC 134a is excpected in the near future due to regulations in the European Union. AC-refrigerant exceeding a GWP of 150 ist not allowed for new car models since 2011. After 2017 no new car with AC refrigerant exceeding GWP 150 will be allowed. Due to safesty concerns with alternative use of HFO-1234yf (GWP 4), there is a delay in the replacement of HFC 134a.

Interviews were carried out 2014 and 2017 with garages in Switzerland to follow the development of HFC 134a replacement The interviews showed that part of the imported brands switched to HFO-1234yf (GWP 4). In 2014 garages confirmed a minor portion below 5% of equipment with HFO, in 2017 feedback of garages varied widely depending on the models sold and origin of cars. About 30% HFO was assumed for import of new vehicles in 2016.

Table A – 21 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
2015	327'143	4'458'069	253'564	96	77	241'510	90	3'991'753	242'856	0.55
2016	319'331	4'524'029	253'371	96	69	211'525	87	3'933'720	269'557	0.55

Table A – 22 Results and structure of emission calculations of HFC-134a from mobile air conditioning of cars for the inventories 1990 to 2016.

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
2015	133	2'181	82	NO	200	22	222	107	42
2016	117	2'126	111	NO	195	28	223	104	57

A3.3 Agriculture

Additional data for estimating CH_4 emission from 3A Enteric fermentation

Table A – 23 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		16.1-23.1 [c]	0	305 days of lactation	72	6.90	117.3 - 137.4
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 supplementary milk 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	4.13	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	4.12	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	5.72	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 (MISTA 2015).

[d] data source: IPCC 2006 and Zeitz et al. 2012.

[e] For better comparability emission factors of young cattle were converted to kg/head/year although the time span of most of the individual categories is less than 365 days.

Table A – 24 Gross energy intake of Swiss livestock.

Gross Energy Intake		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		MJ/head/day																										
Cattle																												
Mature Dairy Cattle		259.3	261.6	261.9	265.0	264.7	267.4	266.4	270.4	274.2	277.4	280.1	281.8	284.5	287.7	291.5	291.6	292.2	295.2	297.2	299.8	300.7	301.4	301.2	299.8	302.5	303.6	303.1
Other Mature Cattle		250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6
Growing Cattle (weighted average)		103.3	103.4	103.6	103.3	103.7	103.9	103.6	104.1	103.1	101.4	103.6	102.5	102.3	102.0	101.6	101.0	101.1	100.9	101.0	100.3	99.8	99.9	100.2	100.1	99.9	99.7	99.2
	Fattening Calves	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1
	Pre-Weaned Calves	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1
	Breeding Calves	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
	Breeding Cattle (4-12 months)	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1
	Breeding Cattle (> 1 year)	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6
	Fattening Calves (0-4 months)	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9
	Fattening Cattle (4-12 months)	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3
Sheep		21.2	21.7	22.2	22.4	23.8	24.0	22.0	22.1	21.5	22.9	22.4	22.9	22.8	22.7	23.3	22.8	22.6	22.2	22.0	22.7	22.6	22.6	22.5	22.4	22.5	22.4	22.4
Swine		28.3	28.9	29.0	29.1	28.5	31.9	29.8	29.9	27.9	29.0	28.0	27.7	27.1	27.0	27.2	26.6	26.3	26.9	26.7	27.0	27.2	26.9	26.5	27.3	27.4	27.2	27.2
Buffalo (weighted average)		NA	NA	134.7	138.2	137.5	136.6	137.0	136.5	137.0	130.6	146.9	137.5	140.8	137.2	140.0	140.6	138.9	130.4	129.1	134.8	136.9	139.8	135.9	136.0	134.6	134.5	134.4
	Bisons < 3 years	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0
	Bisons > 3 years	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1	197.1
Camels (weighted average)		NA	NA	NA	NA	NA	NA	37.9	37.9	37.9	34.6	34.8	32.2	33.0	34.0	32.8	31.7	31.7	31.7	31.6	31.5	31.0	31.4	31.6	31.9	31.8	31.6	31.2
	Llamas < 2 years	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
	Llamas > 2 years	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
	Alpacas < 2 years	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
	Alpacas > 2 years	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8
Deer (weighted average)		50.5	51.6	53.6	54.5	55.0	55.3	59.7	55.4	54.8	55.5	56.4	55.8	56.7	55.2	55.6	55.4	55.8	55.9	56.5	56.8	56.5	56.7	57.0	58.1	58.0	58.0	58.5
	Fallow Deer [1)]	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5	50.5
	Red Deer [1)]	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1	101.1
Goats		25.0	24.6	25.0	25.4	25.5	27.9	25.3	25.6	26.9	25.8	25.7	26.0	25.2	25.4	25.2	25.4	25.3	25.0	25.0	25.3	25.1	25.6	25.6	25.6	25.0	25.4	25.4
Horses (weighted average)		107.3	107.3	107.3	107.3	107.1	106.9	107.1	107.3	107.3	107.2	107.4	107.5	107.6	107.6	107.6	107.7	107.7	107.7	107.7	107.8	107.9	107.9	107.9	108.0	108.1	108.3	108.4
	Horses <3 years	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4
	Horses >3 years	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0
Mules and Asses (weighted average)		39.2	39.2	39.2	39.2	39.5	39.7	39.7	39.8	39.6	39.8	39.5	39.6	39.6	39.6	39.5	39.4	39.5	39.3	39.2	40.0	40.2	39.9	39.9	39.6	39.6	39.6	39.6
	Mules	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0
	Asses	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9
Poultry [2)]		1.5	1.5	1.6	1.3	1.4	1.3	1.4	1.4	1.3	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.2	1.3	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.1	1.1
Rabbits		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Livestock NCAC (weighted average)		95.6	95.6	95.6	95.6	96.1	83.4	43.2	40.1	38.6	38.6	37.7	36.5	35.7	34.6	34.6	33.3	33.2	32.9	31.7	34.3	36.9	37.2	37.9	38.2	38.5	37.2	38.1
	Sheep Non-Agr.	21.2	21.7	22.2	22.4	23.8	24.0	22.0	22.1	21.5	22.9	22.4	22.9	22.8	22.7	23.3	22.8	22.6	22.2	22.0	22.7	22.6	22.6	22.5	22.4	22.5	22.4	22.4
	Goats Non-Agr.	25.0	24.6	25.0	25.4	25.5	27.9	25.3	25.6	26.9	25.8	25.7	26.0	25.2	25.4	25.2	25.4	25.3	25.0	25.0	25.3	25.1	25.6	25.6	25.6	25.0	25.4	25.4
	Horses <3 years Non-Agr.	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4
	Horses >3 years Non-Agr.	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0
	Mules Non-Agr.	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0
	Asses Non-Agr.	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9

1) Deer: Gross energy intake per animal place (mother with offspring)

2) Poultry data is not Gross Energy intake (GE) but Metabolizable Energy intake (ME)

Table A – 25 Livestock population. For some categories the numbers of the total population is not equal to the sum of the numbers of the subcategories because the latter refer to animal places instead of head. See also ART/SHL 2012.

Population Size	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	1000 head																										
Cattle	1855.2	1828.9	1782.6	1745.1	1755.4	1748.3	1747.1	1672.9	1640.9	1608.7	1588.0	1611.4	1593.7	1570.2	1544.5	1554.7	1566.9	1571.8	1604.3	1597.5	1591.2	1577.4	1564.6	1557.5	1562.8	1554.3	1555.4
Mature Dairy Cattle	783.1	780.5	763.5	744.5	749.7	739.6	736.0	711.6	701.3	683.5	669.4	669.4	657.9	638.3	621.0	620.7	618.1	614.8	628.5	599.4	589.0	589.2	591.2	586.6	587.4	583.3	575.8
Other Mature Cattle	12.0	14.0	17.0	18.0	20.0	23.0	28.0	32.0	36.0	41.2	44.9	50.6	58.1	65.1	70.0	78.5	87.3	93.5	98.4	108.4	111.3	110.7	114.4	116.9	118.0	117.9	120.8
Growing Cattle	1060.1	1034.4	1002.1	982.6	985.7	985.6	983.0	929.3	903.5	884.0	873.7	891.3	877.7	866.7	853.6	855.5	861.5	863.4	877.4	889.7	890.9	877.5	859.0	854.0	857.4	853.1	858.8
Fattening Calves	112.3	111.4	109.5	111.1	101.4	101.7	112.0	106.0	108.1	116.4	103.3	114.7	114.4	113.9	111.3	105.6	101.2	100.5	95.0	107.3	113.5	111.1	103.1	101.9	102.5	102.6	107.0
Pre-Weaned Calves	9.6	11.2	13.6	14.4	16.0	18.4	22.4	25.6	28.8	33.2	35.7	40.4	46.9	52.3	56.6	62.5	67.3	72.2	76.1	83.9	86.3	85.8	88.4	90.3	91.1	91.1	93.5
Breeding Cattle 1st Year	346.4	336.7	324.0	308.2	306.2	294.7	286.1	260.1	253.5	218.7	236.0	238.1	229.5	219.8	214.7	222.0	223.3	223.3	232.4	224.5	221.6	215.7	210.4	207.7	209.5	210.2	211.3
Breeding Cattle 2nd Year	253.3	251.9	250.5	238.7	237.2	238.6	243.0	232.9	217.4	187.5	221.9	219.3	219.1	212.7	205.4	204.7	210.2	210.5	212.7	215.9	214.9	212.7	210.7	209.5	210.4	209.0	209.2
Breeding Cattle 3rd Year	150.7	148.4	146.7	142.3	141.3	139.4	139.9	139.3	132.7	117.9	129.8	130.4	126.0	124.0	120.9	113.3	110.1	109.1	109.6	111.7	110.8	108.9	106.3	103.0	101.3	98.5	97.1
Fattening Cattle	187.8	174.8	157.8	168.0	183.5	192.9	179.6	165.4	163.1	210.2	147.1	148.5	141.7	144.1	144.7	147.5	149.3	148.0	151.6	146.5	143.8	143.2	140.0	141.5	142.7	141.7	140.8
Sheep	395.2	409.4	414.7	424.0	405.4	386.7	418.6	420.4	422.3	423.5	420.7	420.0	429.5	444.8	440.5	446.4	447.5	443.6	446.2	431.9	434.1	424.0	417.3	409.5	402.8	395.3	396.8
Fattening Sheep	190.6	200.8	201.0	211.1	201.2	191.4	207.6	208.0	208.7	221.7	216.6	216.6	219.9	228.6	227.5	229.4	230.6	230.0	229.4	227.3	228.2	221.8	219.3	216.2	209.5	204.0	205.0
Milksheep	4.3	4.0	3.8	3.5	3.3	3.0	2.8	3.1	4.4	5.8	6.7	7.0	7.2	8.0	8.1	8.9	9.5	10.2	10.7	11.7	12.4	12.4	12.8	13.3	13.7	13.6	12.9
Swine	1787.0	1722.6	1705.7	1691.8	1568.7	1445.6	1379.4	1394.9	1487.0	1453.3	1498.2	1547.7	1556.7	1528.9	1537.5	1609.5	1634.8	1573.1	1540.1	1557.2	1589.0	1578.7	1544.0	1484.7	1498.3	1495.7	1453.6
Piglets	299.4	282.5	290.8	299.6	287.2	274.8	240.9	252.2	261.8	281.0	296.6	318.8	326.6	322.8	327.8	337.6	366.5	344.8	336.1	338.4	350.9	352.7	344.7	333.3	339.2	330.0	314.4
Fattening Pig over 25 kg	1024.6	989.6	972.8	943.0	855.5	767.9	778.7	779.6	837.4	734.4	750.9	762.5	767.9	751.7	753.2	796.7	786.1	766.9	763.2	779.5	788.1	797.0	794.9	776.1	797.8	825.8	810.0
Dry Sows	129.3	126.0	124.9	125.3	117.1	108.9	98.8	104.3	110.9	101.2	104.8	108.0	108.6	105.3	107.9	112.7	115.2	105.7	105.4	104.7	106.1	103.4	97.4	95.8	94.2	93.3	90.9
Nursing Sows	37.4	36.8	36.8	37.3	35.1	33.0	30.2	29.9	31.4	35.0	36.7	37.5	36.5	35.8	35.3	36.0	36.5	34.9	32.6	33.1	33.5	32.3	31.0	29.4	29.4	29.4	28.7
Boars	8.4	8.1	8.0	8.2	7.7	7.1	6.3	6.4	6.4	6.2	6.2	6.1	5.8	5.3	5.2	5.1	4.9	4.2	4.0	3.8	3.7	3.3	3.0	3.2	2.9	2.7	2.6
Buffalo	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
Bisons < 3 years	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Bisons > 3 years	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Camels	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4	1.0	1.0	1.6	1.6	1.7	2.2	3.1	3.3	3.9	4.4	4.7	6.1	6.0	5.8	5.9	6.1	6.4	6.5
Llamas < 2 years	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.6
Llamas > 2 years	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.5	0.5	0.7	0.7	0.9	1.0	1.1	1.3	1.5	1.8	1.9	2.1	2.2	2.3	2.4	2.3	2.4	2.3
Alpacas < 2 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.7	0.8	0.8	0.7	0.9	0.9
Alpacas > 2 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.5	0.5	0.4	0.6	1.2	1.1	1.2	1.3	1.4	2.3	2.3	2.0	2.1	2.4	2.6	2.6
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	6.0	6.0
Fallow Deer	0.2	0.4	0.6	0.8	1.1	1.3	1.6	1.8	2.0	2.4	2.5	2.6	2.7	2.9	3.2	3.5	3.7	4.0	4.3	4.4	4.9	5.0	5.0	4.8	4.9	5.1	5.1
Red Deer	0.0	0.0	0.0	0.1	0.1	0.1	0.4	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9
Goats	68.3	65.2	58.2	56.7	54.9	53.2	56.8	58.0	60.1	61.6	62.5	63.0	66.0	67.4	70.6	74.0	76.3	79.1	81.4	81.2	82.8	83.0	84.7	84.5	84.7	83.7	84.9
Goat Places	44.8	43.1	38.4	37.3	35.9	34.6	37.1	37.7	39.8	40.8	41.4	42.1	43.0	44.9	46.2	48.5	50.5	51.9	53.4	54.3	54.7	55.9	57.4	57.4	57.9	56.1	56.9
Horses	28.2	30.2	32.3	34.5	37.9	41.4	43.0	45.8	46.3	48.5	50.3	50.1	51.2	52.7	53.7	55.1	56.4	57.7	59.0	60.2	62.1	57.2	58.0	57.2	57.2	55.5	55.7
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	4.7	4.3
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	50.8	51.4
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	19.7	20.2
Mules	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	1.0	0.8	0.9	0.7	0.7	0.7	0.7
Asses	5.7	6.1	6.6	7.0	7.1	7.3	8.1	9.0	9.6	10.9	11.4	12.0	12.8	13.6	14.4	15.5	15.9	16.7	17.3	18.4	19.4	18.2	19.3	18.9	18.9	19.0	19.5
Poultry 1)	5938.2	5646.8	5501.6	6409.8	6330.3	6250.7	6440.5	6552.5	6739.6	6907.5	6983.0	6939.5	7338.6	7587.3	8060.7	8260.4	7670.2	8228.5	8542.8	8809.4	9024.9	9667.4	10353.0	10684.0	11583.8	11918.3	12084.7
Growers	718.9	664.2	709.6	719.2	716.8	714.4	732.1	732.9	793.5	760.9	831.7	745.3	753.9	809.0	853.1	867.7	888.4	901.8	919.0	966.7	925.5	969.7	1075.6	1054.5	1195.6	1033.0	959.3
Layers	3083.0	2645.4	2535.8	2517.6	2317.9	2118.2	2226.0	2277.5	2270.1	2222.8	2150.3	2069.5	2154.1	2117.2	2088.8	2188.5	2147.3	2197.7	2254.9	2318.3	2438.1	2437.0	2520.6	2588.6	2665.1	2821.9	3055.9
Broilers	2019.9	2198.6	2095.5	2990.2	3110.6	3231.0	3293.2	3342.0	3502.3	3747.4	3807.8	3993.2	4298.2	4518.4	4970.8	5060.4	4481.3	5002.4	5300.4	5456.2	5580.1	6173.9	6680.5	6965.4	7644.2	7991.4	7968.8
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	49.3	70.9
Other Poultry	21.8	21.2	20.6	20.0	18.4	16.9	15.3	15.8	15.9	21.9	20.7	8.6	8.5	8.8	9.3	11.5	16.1	14.2	14.7	15.9	23.2	29.0	25.1	20.4	21.7	22.6	29.8
Rabbits	60.9	56.8	52.7	48.7	44.6	40.5	36.5	37.4	32.8	31.3	27.9	25.1	33.4	31.1	20.5	25.4	24.5	27.2	24.9	27.8	35.0	34.3	27.9	27.5	27.0	25.3	24.7
Livestock NCAC	27.9	26.6	25.3	23.9	24.0	29.6	82.1	94.9	93.8	95.6	93.8	94.8	91.7	91.8	86.1	85.7	82.4	79.8	85.5	90.0	91.4	99.2	111.7	107.3	105.6	112.4	106.3
Total Sheep	0.0	0.0	0.0	0.0	0.0	0.0	53.4	66.9	67.1	67.3	66.9	69.3	66.7	68.7	63.4	62.4	60.3	58.8	63.4	65.5	62.5	65.0	73.5	69.5	67.9	73.8	68.7
Fattening Sheep	0.0	0.0	0.0	0.0	0.0	0.0	26.7	33.3	33.1	34.8	34.0	34.9	33.5	34.8	32.1	31.4	30.1	30.0	33.1	34.6	33.2	36.5	43.4	40.7	39.7	42.2	39.1
Milksheep	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.6	0.8	0.9	0.9	0.9	0.9	0.9	0.7	0.6	0.5	0.6	0.6	0.7	0.6	0.4	0.5	0.4	0.3	0.4
Total Goats	0.0	0.0	0.0	0.0	0.0	5.7	5.5	5.2	5.4	7.6	7.4	7.7	8.5	7.9	8.9	10.8	9.9	9.1	10.6	9.7	10.1	13.6	13.6	13.6	13.4	14.8	13.6
Goat Places	0.0	0.0	0.0	0.0	0.0	4.0	3.7	3.3	3.5	5.3	4.9	5.2	5.6	5.2	5.9	7.3	6.5	5.8	6.9	6.2	6.3	9.4	9.5	9.5	9.4	10.0	9.1
Horses <3 years Non-Agr.	5.0	4.7	4.5	4.3	4.9	5.4	4.8	4.1	3.8	3.8	3.2	2.8	2.4	2.1	1.9	1.7	1.6	1.5	1.4	1.7	2.0	2.2	2.5	2.2	2.0	1.5	1.4
Horses >3 years Non-Agr.	18.1	17.3	16.4	15.5	15.2	14.8	14.6	14.8	13.8	13.0	12.6	11.5	10.7	9.9	8.9	8.1	7.8	7.6	7.4	9.6	12.1	13.2	15.8	15.8	16.0	16.0	16.2
Mules Non-Agr.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2
Asses Non-Agr.	4.7	4.5	4.2	4.0	3.8	3.6	3.7	3.7	3.6	3.8	3.6	3.4	3.3	3.1	2.9	2.7	2.7	2.6	2.6	3.4	4.4	4.9	6.1	6.0	6.0	6.0	6.2

1) Other Poultry: Geese, Ducks, Ostriches, Quails

Additional data for estimating CH_4 and N_2O emission from 3B Manure management

Table A – 26 Data for estimating manure management CH_4 emission factors (Table according to outline in IPCC 1997c, Tables B-1 to B-7).

Type	Weight kg [a]	Digestibility of Feed % [b]	Energy Intake MJ/day	Feed Intake kg/day	% Ash Dry Basis [b]	VS kg/head/day	B_0 m^3 CH_4/kg VS [b]
Mature Dairy Cattle	650	72	259 - 304	15.34 [c]	8.8 - 9.1	4.08 - 4.82	0.24
Other Mature Cattle	650	60	251	13.70 [c]	8	5.50	0.18
Fattening Calves	124	65	47	2.02 [a]	8	0.92	0.18
Pre-Weaned Calves	195	65	60	2.99 [a]	8	0.74	0.18
Breeding Calves	85	65	44	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	57	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	NA	60	21 - 24	1.08-1.39 [c]	8	0.40 [b]	0.19
Swine	NA	75	26 - 32	NA	2	0.31 [b]	0.45
Buffalo	NA	55	129 - 147	7.00-7.96 [c]	8	3.28	0.10
Camels	NA	60	31 - 38	1.68-2.05 [c]	8	0.68	0.26
Deer	NA	60	51 - 60	2.74-3.24 [c]	8	1.28	0.19
Goats	NA	60	25 - 28	1.34-1.62 [c]	8	0.30 [b]	0.18
Horses	NA	70	107 - 108	7.73-7.88 [c]	4	1.9	0.33
Mules and Asses	NA	70	39 - 40	2.79-2.83 [c]	4	0.94 [b]	0.33
Poultry	NA	NA	1.1 - 1.6 [d]	NA	NA	0.01 [b]	0.37
Rabbits	NA	NA	1.2	NA	NA	0.1 [b]	0.32
Livestock NCAC	NA	NA	NA	NA	NA	0.67	0.27

[a] RAP 1999

[b] IPCC 1997c and IPCC 2006

[c] Richner et al. 2017

[d] metabolizable energy (ME)

Table A – 27 Manure management system distribution in Switzerland.

MS Distribution	1990 Liquid / Slurry %	1990 Solid manure %	1990 Pasture range and paddock %	1990 Digesters %	1990 Other (Deep litter, Poultry manure) %	1995 Liquid / Slurry %	1995 Solid manure %	1995 Pasture range and paddock %	1995 Digesters %	1995 Other (Deep litter, Poultry manure) %	2002 Liquid / Slurry %	2002 Solid manure %	2002 Pasture range and paddock %	2002 Digesters %	2002 Other (Deep litter, Poultry manure) %	2007 Liquid / Slurry %	2007 Solid manure %	2007 Pasture range and paddock %	2007 Digesters %	2007 Other (Deep litter, Poultry manure) %	2010 Liquid / Slurry %	2010 Solid manure %	2010 Pasture range and paddock %	2010 Digesters %	2010 Other (Deep litter, Poultry manure) %	2015 Liquid / Slurry %	2015 Solid manure %	2015 Pasture range and paddock %	2015 Digesters %	2015 Other (Deep litter, Poultry manure) %
Mature Dairy Cattle	63.7	27.6	8.3	0.4	0.0	65.7	24.4	9.5	0.4	0.0	65.3	16.2	18.0	0.5	0.0	67.5	13.5	17.7	1.3	0.0	67.1	14.3	16.9	1.7	0.0	70.0	10.6	16.1	3.3	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	20.6	39.1	0.5	0.0	49.7	20.1	29.0	1.3	0.0	48.0	17.8	32.4	1.7	0.0	50.7	14.6	31.4	3.3	0.0
Growing Cattle (weighted average)	47.5	31.8	15.7	0.4	4.5	48.5	30.9	15.8	0.4	4.5	42.2	25.5	27.3	0.5	4.5	45.6	23.8	24.7	1.3	4.7	45.0	24.8	22.7	1.7	5.7	47.0	21.8	22.5	3.3	5.4
Fattening Calves	*14.6*	*0.0*	*0.0*	*0.4*	*85.0*	*15.0*	*0.0*	*0.0*	*0.4*	*84.6*	*21.6*	*0.0*	*0.3*	*0.5*	*77.6*	*21.9*	*0.0*	*0.2*	*1.3*	*76.6*	*17.0*	*0.0*	*0.2*	*1.7*	*81.1*	*22.1*	*0.0*	*1.2*	*3.3*	*73.3*
Pre-Weaned Calves	*41.2*	*32.1*	*26.3*	*0.4*	*0.0*	*39.3*	*34.1*	*26.2*	*0.4*	*0.0*	*41.3*	*21.0*	*37.3*	*0.5*	*0.0*	*50.1*	*18.5*	*30.1*	*1.3*	*0.0*	*44.7*	*32.7*	*20.9*	*1.7*	*0.0*	*35.9*	*27.6*	*33.2*	*3.3*	*0.0*
Breeding Cattle 1st Year	*36.9*	*48.6*	*14.1*	*0.4*	*0.0*	*38.0*	*47.5*	*14.2*	*0.4*	*0.0*	*33.8*	*38.8*	*27.0*	*0.5*	*0.0*	*41.1*	*34.4*	*23.3*	*1.3*	*0.0*	*43.5*	*33.3*	*21.5*	*1.7*	*0.0*	*44.8*	*30.7*	*21.1*	*3.3*	*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*	*23.3*	*38.4*	*0.5*	*0.0*	*41.5*	*20.7*	*36.5*	*1.3*	*0.0*	*43.3*	*20.7*	*34.3*	*1.7*	*0.0*	*42.4*	*19.4*	*34.8*	*3.3*	*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*	*42.3*	*22.5*	*34.8*	*0.5*	*0.0*	*45.7*	*21.3*	*31.8*	*1.3*	*0.0*	*46.3*	*21.3*	*30.6*	*1.7*	*0.0*	*54.2*	*17.0*	*25.5*	*3.3*	*0.0*
Fattening Cattle	*70.1*	*24.1*	*0.0*	*0.4*	*5.5*	*66.4*	*27.7*	*0.0*	*0.4*	*5.6*	*67.4*	*26.8*	*2.2*	*0.5*	*3.2*	*62.4*	*28.9*	*4.3*	*1.3*	*3.1*	*57.8*	*32.7*	*4.0*	*1.7*	*3.9*	*61.5*	*27.0*	*4.8*	*3.3*	*3.4*
Sheep (weighted average)	0.0	0.0	30.1	0.0	69.9	0.0	0.0	30.3	0.0	69.7	0.0	0.0	33.2	0.0	66.8	0.0	0.0	39.3	0.0	60.7	0.0	0.0	33.7	0.0	66.3	0.0	0.0	33.6	0.0	66.4
Fattening Sheep	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Milksheep	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*26.1*	*0.0*	*73.9*	*0.0*	*0.0*	*24.1*	*0.0*	*75.9*	*0.0*	*0.0*	*22.8*	*0.0*	*77.2*	*0.0*	*0.0*	*40.9*	*0.0*	*59.1*
Swine (weighted average)	98.8	0.0	0.0	1.2	0.0	98.7	0.0	0.0	1.3	0.0	98.0	0.3	0.1	1.5	0.0	94.5	0.1	1.2	4.1	0.0	94.0	0.3	0.1	5.6	0.0	89.2	0.0	0.0	10.8	0.0
Piglets	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*97.6*	*0.8*	*0.0*	*1.5*	*0.0*	*94.8*	*0.7*	*0.4*	*4.1*	*0.0*	*92.0*	*2.4*	*0.0*	*5.6*	*0.0*	*89.2*	*0.0*	*0.0*	*10.8*	*0.0*
Fattening Pig over 25 kg	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*98.1*	*0.3*	*0.2*	*1.5*	*0.0*	*94.4*	*0.0*	*1.5*	*4.1*	*0.0*	*94.2*	*0.0*	*0.2*	*5.6*	*0.0*	*89.2*	*0.0*	*0.0*	*10.8*	*0.0*
Dry Sows	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*98.4*	*0.0*	*0.1*	*1.5*	*0.0*	*94.8*	*0.1*	*1.0*	*4.1*	*0.0*	*94.2*	*0.0*	*0.2*	*5.6*	*0.0*	*89.1*	*0.0*	*0.1*	*10.8*	*0.0*
Nursing Sows	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*97.8*	*0.7*	*0.0*	*1.5*	*0.0*	*95.0*	*0.5*	*0.3*	*4.1*	*0.0*	*94.2*	*0.2*	*0.0*	*5.6*	*0.0*	*89.2*	*0.0*	*0.0*	*10.8*	*0.0*
Boars	*98.8*	*0.0*	*0.0*	*1.2*	*0.0*	*98.7*	*0.0*	*0.0*	*1.3*	*0.0*	*97.7*	*0.5*	*0.2*	*1.5*	*0.0*	*94.7*	*0.0*	*1.2*	*4.1*	*0.0*	*92.5*	*1.2*	*0.6*	*5.6*	*0.0*	*88.9*	*0.0*	*0.2*	*10.8*	*0.0*
Buffalo (weighted average)	NA	NA	NA	NA	NA	47.5	26.8	25.6	0.0	0.0	38.2	23.5	38.4	0.0	0.0	42.4	21.1	36.5	0.0	0.0	44.5	21.2	34.3	0.0	0.0	44.8	20.4	34.8	0.0	0.0
Bisons < 3 years	*45.6*	*29.0*	*25.4*	*0.0*	*0.0*	*47.5*	*26.8*	*25.6*	*0.0*	*0.0*	*38.2*	*23.5*	*38.4*	*0.0*	*0.0*	*42.4*	*21.1*	*36.5*	*0.0*	*0.0*	*44.5*	*21.2*	*34.3*	*0.0*	*0.0*	*44.8*	*20.4*	*34.8*	*0.0*	*0.0*
Bisons > 3 years	*45.6*	*29.0*	*25.4*	*0.0*	*0.0*	*47.5*	*26.8*	*25.6*	*0.0*	*0.0*	*38.2*	*23.5*	*38.4*	*0.0*	*0.0*	*42.4*	*21.1*	*36.5*	*0.0*	*0.0*	*44.5*	*21.2*	*34.3*	*0.0*	*0.0*	*44.8*	*20.4*	*34.8*	*0.0*	*0.0*
Camels (weighted average)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.0	33.5	0.0	66.5	0.0	0.0	40.2	0.0	59.8	0.0	0.0	34.5	0.0	65.5	0.0	0.0	33.0	0.0	67.0
Llamas < 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Llamas > 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Alpacas < 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Alpacas > 2 years	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Deer (weighted average)	0.0	0.0	30.7	0.0	69.3	0.0	0.0	30.7	0.0	69.3	0.0	0.0	33.5	0.0	66.5	0.0	0.0	40.2	0.0	59.8	0.0	0.0	34.5	0.0	65.5	0.0	0.0	33.0	0.0	67.0
Fallow Deer	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Red Deer	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Goats	0.0	0.0	13.6	0.0	86.4	0.0	0.0	13.6	0.0	86.4	0.0	0.0	12.2	0.0	87.8	0.0	0.0	7.1	0.0	92.9	0.0	0.0	10.0	0.0	90.0	0.0	0.0	11.6	0.0	88.4
Goat Places	*0.0*	*0.0*	*13.6*	*0.0*	*86.4*	*0.0*	*0.0*	*13.6*	*0.0*	*86.4*	*0.0*	*0.0*	*12.2*	*0.0*	*87.8*	*0.0*	*0.0*	*7.1*	*0.0*	*92.9*	*0.0*	*0.0*	*10.0*	*0.0*	*90.0*	*0.0*	*0.0*	*11.6*	*0.0*	*88.4*
Horses (weighted average)	0.0	93.2	6.8	0.0	0.0	0.0	93.2	6.8	0.0	0.0	0.0	76.1	23.9	0.0	0.0	0.0	78.7	21.3	0.0	0.0	0.0	74.4	25.6	0.0	0.0	0.0	80.5	19.5	0.0	0.0
Horses <3 years	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*61.8*	*38.2*	*0.0*	*0.0*	*0.0*	*61.7*	*38.3*	*0.0*	*0.0*	*0.0*	*66.4*	*33.6*	*0.0*	*0.0*	*0.0*	*70.8*	*29.2*	*0.0*	*0.0*
Horses >3 years	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*81.9*	*18.1*	*0.0*	*0.0*	*0.0*	*75.6*	*24.4*	*0.0*	*0.0*	*0.0*	*81.3*	*18.7*	*0.0*	*0.0*
Mules and Asses (weighted average)	0.0	93.2	6.8	0.0	0.0	0.0	93.2	6.8	0.0	0.0	0.0	76.9	23.1	0.0	0.0	0.0	75.2	24.8	0.0	0.0	0.0	79.3	20.7	0.0	0.0	0.0	77.5	22.5	0.0	0.0
Mules	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*77.5*	*22.5*	*0.0*	*0.0*
Asses	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*77.5*	*22.5*	*0.0*	*0.0*
Poultry (weighted average)	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.5	0.0	99.5	0.0	0.0	2.6	0.0	97.4	0.0	0.0	3.7	0.0	96.3	0.0	0.0	2.7	0.0	97.3	0.0	0.0	3.1	0.0	96.9
Growers	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.6*	*0.0*	*99.4*	*0.0*	*0.0*	*0.2*	*0.0*	*99.8*	*0.0*	*0.0*	*1.5*	*0.0*	*98.5*	*0.0*	*0.0*	*1.2*	*0.0*	*98.8*	*0.0*	*0.0*	*0.4*	*0.0*	*99.6*
Layers	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.6*	*0.0*	*99.4*	*0.0*	*0.0*	*5.1*	*0.0*	*94.9*	*0.0*	*0.0*	*7.3*	*0.0*	*92.7*	*0.0*	*0.0*	*6.1*	*0.0*	*93.9*	*0.0*	*0.0*	*7.0*	*0.0*	*93.0*
Broilers	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.4*	*0.0*	*99.6*	*0.0*	*0.0*	*0.6*	*0.0*	*99.4*	*0.0*	*0.0*	*1.2*	*0.0*	*98.8*	*0.0*	*0.0*	*0.3*	*0.0*	*99.7*	*0.0*	*0.0*	*0.2*	*0.0*	*99.8*
Turkey	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.4*	*0.0*	*99.6*	*0.0*	*0.0*	*3.1*	*0.0*	*96.9*	*0.0*	*0.0*	*3.1*	*0.0*	*96.9*	*0.0*	*0.0*	*1.9*	*0.0*	*98.1*	*0.0*	*0.0*	*3.1*	*0.0*	*96.9*
Other Poultry [a]	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*	*0.0*	*0.0*	*3.1*	*0.0*	*96.9*	*0.0*	*0.0*	*3.1*	*0.0*	*96.9*	*0.0*	*0.0*	*1.2*	*0.0*	*98.8*	*0.0*	*0.0*	*2.4*	*0.0*	*97.6*
Rabbits	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	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	86.8	7.3	0.0	5.9	0.0	38.4	26.9	0.0	34.7	0.0	34.6	28.6	0.0	36.9	0.0	39.5	27.4	0.0	33.1	0.0	41.4	24.0	0.0	34.5
Fattening Sheep Non-Agr.	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*30.7*	*0.0*	*69.3*	*0.0*	*0.0*	*33.5*	*0.0*	*66.5*	*0.0*	*0.0*	*40.2*	*0.0*	*59.8*	*0.0*	*0.0*	*34.5*	*0.0*	*65.5*	*0.0*	*0.0*	*33.0*	*0.0*	*67.0*
Milksheep Non-Agr.	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*11.4*	*0.0*	*88.6*	*0.0*	*0.0*	*26.1*	*0.0*	*73.9*	*0.0*	*0.0*	*24.1*	*0.0*	*75.9*	*0.0*	*0.0*	*22.8*	*0.0*	*77.2*	*0.0*	*0.0*	*40.9*	*0.0*	*59.1*
Total Goats Non-Agr.	*NA*	*NA*	*NA*	*NA*	*NA*	*0.0*	*0.0*	*13.6*	*0.0*	*86.4*	*0.0*	*0.0*	*12.2*	*0.0*	*87.8*	*0.0*	*0.0*	*7.1*	*0.0*	*92.9*	*0.0*	*0.0*	*10.0*	*0.0*	*90.0*	*0.0*	*0.0*	*11.6*	*0.0*	*88.4*
Horses <3 years Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*61.8*	*38.2*	*0.0*	*0.0*	*0.0*	*61.7*	*38.3*	*0.0*	*0.0*	*0.0*	*66.4*	*33.6*	*0.0*	*0.0*	*0.0*	*70.8*	*29.2*	*0.0*	*0.0*
Horses >3 years Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*81.9*	*18.1*	*0.0*	*0.0*	*0.0*	*75.6*	*24.4*	*0.0*	*0.0*	*0.0*	*81.3*	*18.7*	*0.0*	*0.0*
Mules Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*77.5*	*22.5*	*0.0*	*0.0*
Asses Non-Agr.	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*93.2*	*6.8*	*0.0*	*0.0*	*0.0*	*76.9*	*23.1*	*0.0*	*0.0*	*0.0*	*75.2*	*24.8*	*0.0*	*0.0*	*0.0*	*79.3*	*20.7*	*0.0*	*0.0*	*0.0*	*77.5*	*22.5*	*0.0*	*0.0*

[a] Other Poultry: Geese, Ducks, Ostriches, Quails

Table A – 28 Nitrogen excretion of livestock in Switzerland.

Nitrogen Excretion		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		kg N/head or place/year																										
Mature Dairy Cattle		100.4	100.7	100.9	101.1	101.3	101.5	102.0	102.5	103.0	103.4	103.9	104.4	104.8	105.9	106.9	108.0	109.1	110.1	110.3	110.4	110.5	110.7	111.0	111.2	111.4	111.6	111.6
Other Mature Cattle		85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Growing Cattle (weighted average)		33.0	33.0	33.0	33.0	33.1	33.1	33.0	33.2	32.9	32.4	33.1	32.7	32.6	32.7	32.7	32.6	32.7	32.7	32.9	32.8	32.7	32.8	33.0	33.1	33.1	33.1	33.0
	Fattening Calves	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.0*	*13.4*	*13.8*	*14.2*	*14.6*	*15.0*	*15.3*	*15.7*	*16.0*	*16.4*	*16.8*	*17.2*	*17.6*	*18.0*	*18.0*
	Pre-Weaned Calves	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*	*22.0*
	Breeding Cattle 1st Year	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*	*25.0*
	Breeding Cattle 2nd Year	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
	Breeding Cattle 3rd Year	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*	*55.0*
	Fattening Cattle	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.0*	*33.4*	*33.8*	*34.2*	*34.6*	*35.0*	*35.3*	*35.7*	*36.0*	*36.4*	*36.8*	*37.2*	*37.6*	*38.0*	*38.0*
Sheep (weighted average)		7.5	7.6	7.5	7.6	7.6	7.6	7.6	7.6	7.6	8.1	8.0	8.1	8.0	8.1	8.1	8.1	8.2	8.2	8.2	8.4	8.5	8.4	8.5	8.6	8.5	8.4	8.4
	Fattening Sheep	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*
	Milksheep	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Swine (weighted average)		13.4	13.4	13.3	13.1	13.0	12.8	12.7	12.3	12.0	10.9	10.5	10.1	9.8	9.6	9.5	9.4	9.2	9.1	9.2	9.2	9.2	9.2	9.3	9.4	9.5	9.6	9.7
	Piglets	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.6*	*4.5*	*4.5*	*4.4*	*4.4*	*4.4*	*4.4*	*4.3*	*4.3*	*4.2*	*4.1*	*4.0*	*3.9*	*3.9*
	Fattening Pig over 25 kg	*17.0*	*16.9*	*16.9*	*16.8*	*16.7*	*16.7*	*16.2*	*15.6*	*15.1*	*14.6*	*14.1*	*13.5*	*13.0*	*12.8*	*12.6*	*12.3*	*12.1*	*11.9*	*12.0*	*12.0*	*12.1*	*11.9*	*11.8*	*11.7*	*11.5*	*11.4*	*11.4*
	Dry Sows	*24.3*	*24.3*	*24.3*	*24.3*	*24.3*	*24.3*	*23.5*	*22.8*	*22.0*	*21.3*	*20.5*	*19.8*	*19.0*	*19.1*	*19.2*	*19.2*	*19.3*	*19.4*	*19.5*	*19.6*	*19.7*	*20.7*	*21.7*	*22.6*	*23.6*	*24.6*	*24.6*
	Nursing Sows	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*47.6*	*46.8*	*46.0*	*45.2*	*44.4*	*43.6*	*42.8*	*42.0*	*42.4*	*42.9*	*43.3*	*43.7*	*44.2*	*43.2*	*42.2*	*41.2*	*42.1*	*43.0*	*44.0*	*44.9*	*45.8*	*45.8*
	Boars	*20.5*	*20.5*	*20.5*	*20.5*	*20.5*	*20.5*	*20.0*	*19.5*	*19.0*	*18.6*	*18.1*	*17.6*	*17.1*	*17.2*	*17.3*	*17.3*	*17.4*	*17.5*	*17.7*	*17.9*	*18.2*	*18.1*	*18.1*	*18.1*	*18.1*	*18.0*	*18.0*
Buffalo (weighted average)		NA	NA	36.5	37.8	37.5	37.2	37.3	37.1	37.3	34.9	41.1	37.5	38.8	37.4	38.5	38.7	38.0	34.9	34.4	36.5	37.3	38.4	36.9	36.9	36.4	36.4	36.4
	Bisons < 3 years	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
	Bisons > 3 years	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*	*60.0*
Camels (weighted average)		NA	NA	NA	NA	NA	NA	15.3	15.3	15.3	14.0	14.1	13.0	13.3	13.7	13.3	12.8	12.8	12.8	12.8	12.8	12.6	12.7	12.8	12.9	12.8	12.7	12.6
	Llamas < 2 years	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*
	Llamas > 2 years	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*
	Alpacas < 2 years	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*
	Alpacas > 2 years	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*
Deer (weighted average)		20.0	20.4	21.2	21.6	21.8	21.9	23.6	21.9	21.7	22.0	22.3	22.1	22.4	21.8	22.0	21.9	22.1	22.1	22.4	22.5	22.4	22.4	22.5	23.0	23.0	23.0	23.1
	Fallow Deer	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
	Red Deer	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
Goats		11.2	11.2	11.2	11.2	11.1	11.1	11.1	11.1	11.2	11.3	11.3	11.4	11.1	11.3	11.1	11.1	11.3	11.2	11.2	11.4	11.2	11.4	11.5	11.6	11.6	11.4	11.4
	Goat Places	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*	*17.0*
Horses (weighted average)		43.6	43.6	43.6	43.6	43.5	43.5	43.5	43.6	43.6	43.5	43.6	43.6	43.6	43.6	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.8	43.8	43.8	43.8
	Horses <3 years	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*
	Horses >3 years	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*
Mules and Asses (weighted average)		16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
	Mules	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*
	Asses	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*
Poultry (weighted average)		0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Growers	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*
	Layers	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
	Broilers	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.5*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
	Turkey	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*
	Other Poultry [a]	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*
Rabbits		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Livestock NCAC (weighted average)		38.8	38.8	38.8	38.8	39.0	34.0	16.8	15.3	14.8	14.9	14.5	13.8	13.5	13.1	13.0	12.6	12.5	12.6	12.3	13.2	14.3	14.9	15.4	15.6	15.7	14.9	15.3
	Fattening Sheep Non-Agr.	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*
	Milksheep Non-Agr.	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
	Total Goats Non-Agr.	*NA*	*NA*	*NA*	*NA*	*NA*	*12.0*	*11.2*	*11.0*	*11.1*	*11.8*	*11.2*	*11.4*	*11.2*	*11.1*	*11.2*	*11.6*	*11.2*	*10.9*	*11.1*	*10.8*	*10.7*	*11.8*	*11.9*	*11.9*	*12.0*	*11.5*	*11.4*
	Horses <3 years Non-Agr.	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*	*42.0*
	Horses >3 years Non-Agr.	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*	*44.0*
	Mules Non-Agr.	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*
	Asses Non-Agr.	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*	*16.0*

[a] Other Poultry: Geese, Ducks, Ostriches, Quails

Additional data for estimating N_2O emissions from 3D Agricultural soils

Table A – 29 Additional data for estimating N_2O emission from crop residues.

2016		Total crop production kg DM	Nitrogen incorporated with crop residues $F_{(CR)}$ t N	N_2O emissions from crop residues t N_2O
1. Cereals	Wheat	316'388'700	1'325	20.83
	Barley	135'169'550	689	10.83
	Maize	122'745'100	1'155	18.15
	Oats	6'040'100	37	0.59
	Rye	7'149'350	30	0.47
	Other:			
	Triticale	30'751'300	151	2.37
	Spelt	11'892'350	109	1.71
	Mix of Fodder Cereals	794'750	4	0.06
	Mix of Bread Cereals	86'700	0	0.01
	Millet	146'867	4	0.06
2. Pulse	Dry Beans	1'437'350	57	0.90
	Peas (Eiweisserbsen)	7'667'850	226	3.54
	Soybeans	3'825'000	158	2.48
	Leguminous Vegetables	2'782'570	290	4.56
	Lupines	197'120	8	0.12
3. Tuber and Root	Potatoes	77'612'800	283	4.45
	Other:			
	Fodder Beet	7'632'000	55	0.86
	Sugar Beet	281'029'540	2'006	31.52
5. Other	Fruit	48'678'310	455	7.14
	Grass	7'000'525'095	23'631	371.34
	Green Corn	112'371'598	107	1.68
	Non-Leguminous Vegetables	55'386'393	655	10.29
	Rape	64'710'000	1'109	17.43
	Renewable Energy Crops	1'026'000	18	0.28
	Silage Corn	661'009'402	389	6.12
	Sunflowers	11'050'000	234	3.68
	Tobacco	1'013'000	26	0.42
	Berries	2'626'400	46	0.72
	Vine	27'270'600	477	7.50
	Oil Squash	5'867	0	0.00
	Oil Hemp	23'400	1	0.02
	Oil Flax	257'400	2	0.03
	Hops	31'000	0	0.00
	Medicinal Plants and Herbs	390'000	32	0.51
Total Non-leguminous		1'983'288'477	9'401	147.73
Total Leguminous		15'909'890	738	11.60
Total excluding Grass		1'999'198'367	10'139	159.32
Total including Grass		8'999'723'462	33'769	530.66

Table A – 30 Additional data for estimating N_2O emission from crop residues (fractions).

2016		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	1.10	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	1.15	0.85	0.0037
	Millet	1.29	0.85	0.0196
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	0.37	0.15	0.0233
	Sugar Beet	0.53	0.15	0.0220
5. Other	Fruit	NA	0.17	0.0040
	Grass	0.22	NA	0.0210
	Green Corn	0.05	0.32	0.0190
	Non-Leguminous Vegetables	0.46	0.13	0.0230
	Rape	2.57	0.85	0.0071
	Renewable Energy Crops	2.57	0.85	0.0071
	Silage Corn	0.05	0.32	0.0118
	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	2.50	NA	0.0330

Table A – 31 NH_3 and NO_x emission factors for 3Db Indirect N_2O emissions from managed soils.

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	2015	2016
														%													
NH_3 from application of animal manure N ($Frac_{GASMT}$)	25.54	25.55	25.53	25.46	25.54	25.57	25.24	24.90	24.55	24.20	23.87	23.55	23.16	23.33	23.51	23.70	23.95	24.16	23.64	23.03	22.45	22.19	21.92	21.68	21.42	21.17	21.15
Mature Dairy Cattle	27.95	27.96	27.97	27.98	27.99	28.00	27.72	27.43	27.13	26.83	26.52	26.19	25.86	26.02	26.18	26.34	26.50	26.65	26.03	25.40	24.78	24.43	24.09	23.75	23.41	23.07	23.07
Other Mature Cattle	25.58	25.50	25.42	25.34	25.26	25.18	24.87	24.54	24.18	23.80	23.40	22.96	22.49	23.09	23.66	24.19	24.69	25.16	24.73	24.29	23.83	23.62	23.42	23.21	23.01	22.81	22.80
Growing Cattle (weighted average)	25.90	25.89	25.88	25.90	25.94	25.96	25.61	25.30	24.91	24.46	24.18	23.72	23.29	23.66	24.03	24.38	24.74	25.10	24.56	24.04	23.51	23.30	23.10	22.88	22.66	22.46	22.45
Sheep (weighted average)	8.81	8.92	9.03	9.14	9.25	9.36	9.36	9.37	9.37	9.36	9.34	9.33	9.33	9.70	10.09	10.48	10.90	11.32	11.19	11.07	10.96	10.86	10.75	10.63	10.52	10.41	10.41
Swine (weighted average)	21.85	21.75	21.66	21.57	21.47	21.37	21.18	20.97	20.75	20.49	20.21	19.89	19.53	19.77	20.02	20.28	20.53	20.82	20.20	19.58	18.96	18.83	18.70	18.56	18.42	18.28	18.28
Buffalo (weighted average)	NA	NA	26.62	26.66	26.70	26.74	26.49	26.23	25.94	25.64	25.31	24.96	24.59	24.92	25.25	25.58	25.90	26.23	25.53	24.84	24.17	23.94	23.71	23.48	23.25	23.02	23.02
Camels (weighted average)	NA	NA	NA	NA	NA	NA	9.36	9.37	9.39	9.40	9.42	9.43	9.44	9.82	10.20	10.60	11.01	11.44	11.28	11.13	10.98	10.89	10.79	10.70	10.61	10.52	10.52
Deer (weighted average)	8.79	8.90	9.01	9.13	9.24	9.35	9.36	9.37	9.39	9.40	9.42	9.43	9.44	9.82	10.20	10.60	11.01	11.44	11.28	11.13	10.98	10.89	10.79	10.70	10.61	10.52	10.52
Goats	9.05	9.17	9.28	9.40	9.51	9.62	9.45	9.28	9.11	8.93	8.76	8.59	8.42	9.42	10.37	11.28	12.15	12.98	11.68	10.30	8.85	9.09	9.33	9.57	9.82	10.06	10.06
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	9.88	10.04	10.21	10.37	10.53	10.54
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	11.55	11.24	10.92	10.60	10.27	10.27
Poultry (weighted average)	13.76	14.00	14.25	14.48	14.72	14.96	14.79	14.63	14.46	14.28	14.08	13.91	13.74	13.41	13.09	12.83	12.64	12.30	12.91	13.64	14.38	14.37	14.36	14.34	14.31	14.30	14.31
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	8.89	8.89	8.89
Livestock NCAC (weighted average)	9.23	9.35	9.47	9.58	9.70	9.80	9.56	9.41	9.27	9.13	8.97	8.84	8.68	9.12	9.54	10.04	10.46	10.88	10.72	10.44	10.21	10.21	10.29	10.34	10.39	10.45	10.46
NH_3 from urine and dung N deposited on PR&P ($Frac_{GASPT}$)	4.65	4.66	4.67	4.68	4.69	4.69	4.72	4.74	4.76	4.78	4.78	4.78	4.79	4.82	4.85	4.89	4.91	4.95	4.90	4.87	4.84	4.85	4.86	4.87	4.88	4.90	4.93
Mature Dairy Cattle	4.67	4.67	4.66	4.66	4.66	4.65	4.65	4.64	4.64	4.64	4.64	4.63	4.63	4.63	4.62	4.61	4.61	4.60	4.60	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
Other Mature Cattle	4.57	4.57	4.57	4.57	4.57	4.57	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.57	4.57	4.57	4.57	4.57	4.56	4.56	4.56	4.57	4.57	4.57	4.57	4.57
Growing Cattle (weighted average)	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56
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	5.00	5.00	5.00
Swine (weighted average)	NA	NA	NA	NA	NA	NA	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Buffalo (weighted average)	NA	NA	4.57	4.57	4.57	4.57	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.57	4.57	4.57	4.57	4.57	4.57	4.57
Camels (weighted average)	NA	NA	NA	NA	NA	NA	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Deer (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Goats	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Horses (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Mules and Asses (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Poultry (weighted average)	NA	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00
Rabbits	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Livestock NCAC (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
NH_3 from commercial fertiliser N ($Frac_{GASFi}$)	6.19	5.61	5.63	5.85	6.04	6.05	6.06	5.83	5.41	5.42	5.45	5.01	5.03	4.70	4.84	4.71	4.51	4.93	4.84	4.77	4.89	4.96	4.93	5.13	5.30	5.66	5.54
Urea	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10	13.10
Other Mineral Fertilisers	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.59	2.44	2.62	2.51	2.44	2.66	2.58	2.62	2.76	2.65	2.73	2.94	3.12	3.07	2.99	3.11	3.12	3.04	3.37	2.82
Recycling Fertilisers (weighted average)	17.77	18.31	18.84	19.35	19.86	20.35	20.28	20.15	19.95	19.70	19.37	18.13	16.26	15.27	14.30	13.56	12.93	12.70	12.14	11.35	11.71	11.92	12.25	12.58	13.13	13.65	13.90
Sewage Sludge	20.00	20.79	21.58	22.37	23.15	23.94	24.37	24.79	25.22	25.64	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07	26.07
Compost	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
Digestate Liquid	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	29.10	28.09	27.08	26.06	25.05	24.04	23.03	22.01	21.00	21.00	21.00	21.00	21.00	21.00	21.00
Digestate Solid	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NO_x from applied fertilisers ($Frac_{NOXA}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
NO_x from urine and dung N deposited on PR&P ($Frac_{NOXP}$)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	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 2016 as published by the Swiss Federal Office of Energy (SFOE 2017). Diagram languages are German and French. The energy balance is also provided in tabular form in Table A – 32.

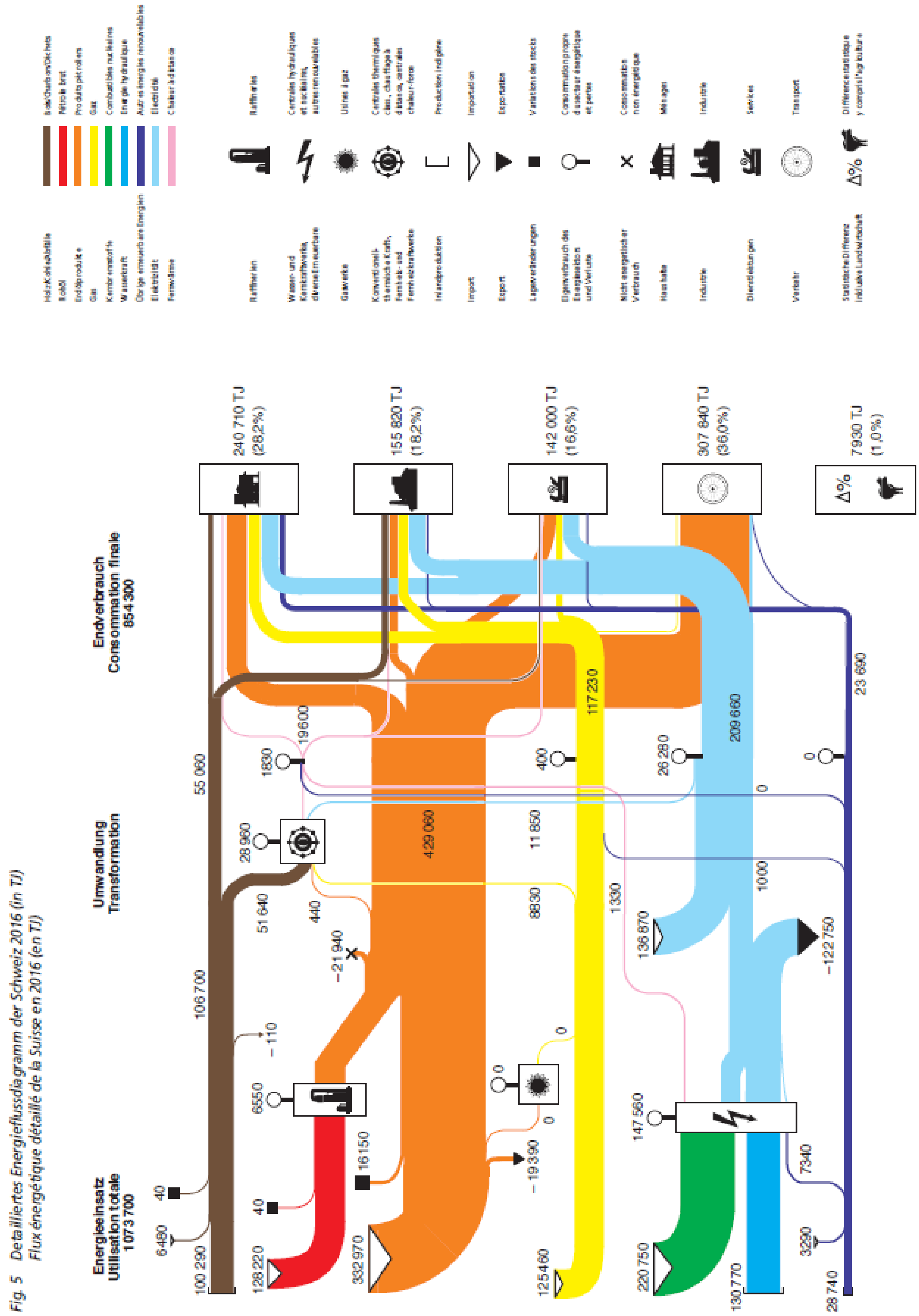


Figure A – 2 Energy flow in Switzerland 2016 in TJ (SFOE 2017)

Table A – 32 Switzerland's energy balance 2016 (SFOE 2017) in TJ[16].

Energiebilanz der Schweiz für das Jahr 2016 (in TJ)
Bilan énergétique de la Suisse pour 2016 (en TJ)

Tabelle 4
Tableau 4

			Holzenergie	Kohle	Müll und Industrieabfälle	Rohöl	Erdölprodukte	Gas	Wasserkraft	Kernbrennstoffe	Übrige erneuerbare Energien	Elektrizität	Fernwärme	Total
			Energie du bois	Charbon	Ord. mén. et déchets ind.	Pétrole brut	Produits pétroliers	Gaz	Energie hydraulique	Combustibles nucléaires	Autres énergies renouvelables	Electricité	Chaleur à distance	Total
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Inlandproduktion	Production indigène	(a)	41 350		58 940	–	–	0	130 770	–	28 740	–	–	259 800
+ Import	Importation	(b)	1 720	4 760	–	128 220	332 970	125 460	–	220 750	3 290	136 870	–	954 040
+ Export	Exportation	(c)	– 100	– 10	–	–	– 19 390	–	–	–	–	– 122 750	–	– 142 250
+ Lagerveränderung[1]	Variation de stock[1]	(d)	–	40	–	40	16 150	–	–	–	–	–	–	16 230
= Bruttoverbrauch	Consommation brute	(e)	42 970	4 790	58 940	128 260	329 730	125 460	130 770	220 750	32 030	14 120	0	1 087 820
+ Energieumwandlung:	Transformation d'énergie:													
• Wasserkraftwerke	• Centrales hydrauliques	(f)	–	–	–	–	–	–	– 130 770	–	–	130 770	–	0
• Kernkraftwerke	• Centrales nucléaires	(g)	–	–	–	–	–	–	–	–220 750	–	72 850	1 330	–146 570
• konventionell-thermische Kraft-, Fernheiz- und Fernheizkraftwerke	• Centrales thermiques class., chauffage à distance, centrales chaleur-force	(h)	–2 270	0	–48 150	–	–440	–8 830	–	–	–	11 060	20 100	–28 530
• Gaswerke	• Usines à gaz	(i)	–	–	–	–	–	0	–	–	–	–	–	0
• Raffinerien	• Raffineries	(j)	–	–	–	–128 260	128 260							0
• Diverse Erneuerbare	• Renouvelables div.	(k)	– 1 220	–	–	–	–	1 000	–	–	–8 340	7 140	0	– 1 420
+ Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherungen	Consommation propre du secteur énergétique, pertes de réseau, pompage d'accumulation	(l)	–	–	–	–	–6 550	– 400	–	–	–	– 26 280	–1 830	–35 060
+ Nichtenergetischer Verbrauch	Consommation non énergétique	(m)	–	–	–	–	– 21 940	–	–	–	–	–	–	–21 940
= Endverbrauch	Consommation finale	(n)	39 480	4 790	10 790	0	429 060	117 230	0	0	23 690	209 660	19 600	854 300
Haushalte	Ménages	(o)	19 060	200	–	–	81 430	48 990	–	–	14 810	68 680	7 540	240 710
Industrie	Industrie	(p)	11 120	4 590	10 790	–	16 800	39 880	–	–	1 700	63 940	7 000	155 820
Dienstleistungen	Services	(q)	8 660	0	–	–	35 850	27 060	–	–	3 360	62 010	5 060	142 000
Verkehr	Transport	(r)	–	–	–	–	291 820	940	–	–	3 560	11 520	–	307 840
Statistische Differenz inkl. Landwirtschaft	Différence statistique, y compris l'agriculture	(s)	640	0	–	–	3 160	360	–	–	260	3 510	0	7 930

[1] + Lagerabnahme
– Lagerzunahme

[1] + diminution de stock
– augmentation de stock

[16] 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 differences.

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 – 33 below are:

- Switzerland’s greenhouse gas inventory 1990–2011, submission of 15. April 2013, CRF Table1.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 – 33. 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 differences 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 overall energy statistics. 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 – 33 Comparison of the IEA energy statistic with the Reference Approach for the year 2010. Numbers in italics are fuels that are reported in a finer disaggregation in the IEA energy statistic than in the Reference Approach. Numbers in bold aggregate the data to the level of disaggregation used in the Reference Approach.

CRF vs. IEA (2010)	Import		Export		Bunker		Stock change		Stat.diff.	LIE	Consumption	
Gg	IEA	CRF	IEA	CRF	IEA	CRF	IEA	CRF	IEA	CRF	IEA	CRF
Crude oil	*4'488*	*4'546*					*0*	*1*	*0*		*4'488*	*4'547*
Refinery feedstocks	*3*						*1*		*2*		*6*	
Additives/blending components	*51*						*-1*		*2*		*52*	
											4'546	**4'547**
Motor gasoline	1'850	1'838					-9	-6	4	15	**1'830**	**1'832**
Aviation gasoline	*7*						*-2*		*-1*		*4*	
Kerosene type jet fuel	*1'354*	*1'362*			*-1'367*	*-1'352*		*2*	*6*		*-7*	*12*
Other Kerosene	*3*										*3*	
											0	**12**
Gas/diesel oil	3'510	3'485	-21	-39	-10	-11	38	1'072	1'020	27	**4'510**	**4'507**
Fuel oil	33	34	-323	-316			-17	-17	7		**-300**	**-299**
Liquefied petroleum gases (LPG)	*50*	*54*	*-24*	*-25*						*0.1*	*26*	*29*
White spirit & SBP	*7*								*-1*		*6*	
											32	**29**
Bitumen	317	318	-2	-2							**315**	**317**
Lubricants	86	72	-38	-16					7		**55**	**56**
Petroleum coke	73	47									**73**	**47**
Naphtha	*1*						*5*		*-1*		*5*	
Paraffin waxes	*1*										*1*	
Non-specified oil products / other oil	*4*	*63*	-	*-23*			-	*-6*			*4*	*33*
											10	**33**
Liquid fuels											**11'039**	**11'052**
Anthracite	*7*										*7*	
Other bituminous coal	*123*	*152*					*36*	*32*			*159*	*184*
Lignite	*66*	*62*					*-4*				*62*	*62*
Coke oven coke	*18*										*18*	
Solid fuels											**246**	**246**
Natural gas (TJ, NCV)	126'014	125'627									126'014	125'627
Fugitive emissions (TJ, NCV)		389										389
Gaseous fuels											**126'014**	**126'016**

Additional information regarding reporting of waste-derived fuels

During the in-country review in 2016, the ERT identified that the apparent consumption of non-biomass fraction of waste in the CRF Table1.A(b) was systematically smaller than the consumption reported to IEA. The difference stems from the assumptions made with regard to the fossil and renewable fractions. The SFOE, which is responsible for reporting to the IEA, allocates total wastes to 50% fossil and 50% renewable. For the greenhouse gas inventory, a more sophisticated method based on a detailed analysis of waste composition and measurements in the flue gas of waste incineration plants is used to estimate fossil and renewable fractions (see chp. 3.2.5.2.1).

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 estimating emissions of fluorinated greenhouse gases (HFCs, SF_6) from Switzerland and neighbouring countries. This information can be used for an independent assessment of Swiss inventory data of these greenhouse gases. The independent emission estimate is not used directly for deriving data for the inventory. Data is used, however, to identify discrepancies, which in turn lead to a reassessment of the corresponding part of the inventory and to evaluate options for further improvements of the inventory.

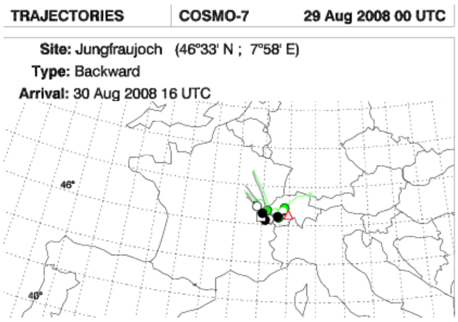
For this independent assessment the so-called tracer-ratio method is applied, where Swiss pollution events of HFC and SF_6, arriving at Jungfraujoch, are scaled to concurrent pollution events of carbon monoxide (CO) and then multiplied by the Swiss CO emission inventory (see Figure A – 3 for a graphical description of the method). Other methods that rely on the combination of atmospheric observations with atmospheric transport models are also being developed at Empa for future usage. Similar approaches are also used for Iindependent verification of greenhouse gas emissions is also performed in the United Kingdom (UK MetOffice – using atmospheric observations from Mace Head (Ireland) with atmospheric transport models measurements from Mace Head, Ireland) and in Australia (CSIRO – using measurements the tracer-ratio method with measurements from Cape Grim, Tasmania).

Method description

For yearly estimates of Swiss emissions of HFCs and SF_6 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 SF_6 are compared with those of CO. Periods which show a concurrent increase for both groups of compounds are selected for the independent assessment of Swiss emissions, as this is taken as an indication of thorough mixing of Swiss emissions during the transport to the height of Jungfraujoch. 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 centered over a 3-year period (e.g. the estimate for the 2015 emissions is calculated by using data from 2014–2016). Since 2009 the error of the estimates for HFCs has been assessed by using the range of the 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. For SF_6, with comparably low emissions and a higher degree of uncertainty, a general uncertainty of 50% is estimated, based on the long-term average of the 25%-75% percentiles. An additional absolute error could occur if the Swiss emissions of CO are over/underestimated by the inventory. This would linearly be transmitted to the emissions of the fluorinated greenhouse gases.

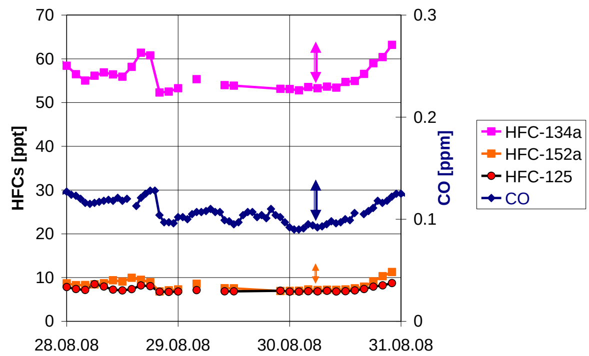
1st step:

Selection of periods with Swiss influence 2 days prior to the measurements by using COSMO trajectories from MeteoSwiss



2nd step:

Confine selected periods by using only periods with concurrent enhancement of CO and HFCs



$$E_H = E_{CO} \times \frac{\Delta H}{\Delta CO}$$

E_H = Swiss emission HFC

E_{CO} = Swiss Emission of CO (e.g. in 2014: 168 kt)

ΔH = HFC concentration increase

ΔCO = CO concentration increase

Swiss-emission estimation:

Median of all cases per year

3-year average

Figure A – 3 Description of the procedure to estimate annual emissions of HFCs from Switzerland by using continuous measurements of HFCs at Jungfraujoch (Switzerland).

Results and discussion:

In the following, Swiss emissions of five HFCs (HFC-134a, HFC-125, HFC-152a, HFC-143a, HFC-32) and of SF_6 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, as tracer gas in research and in cooling mixtures in the industrial and commercial refrigeration as well as 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 after 2007 is related to the decreasing HFCs used in propellants and to optimizations in the industrial and commercial refrigeration. Increasing tendencies are found again afterwards until around 2013 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). In most recent years emissions are stable in both the inventory and in the measurement-based estimates. 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%. Since then, the gap increased but in recent years the relative difference fluctuated around a constant value.

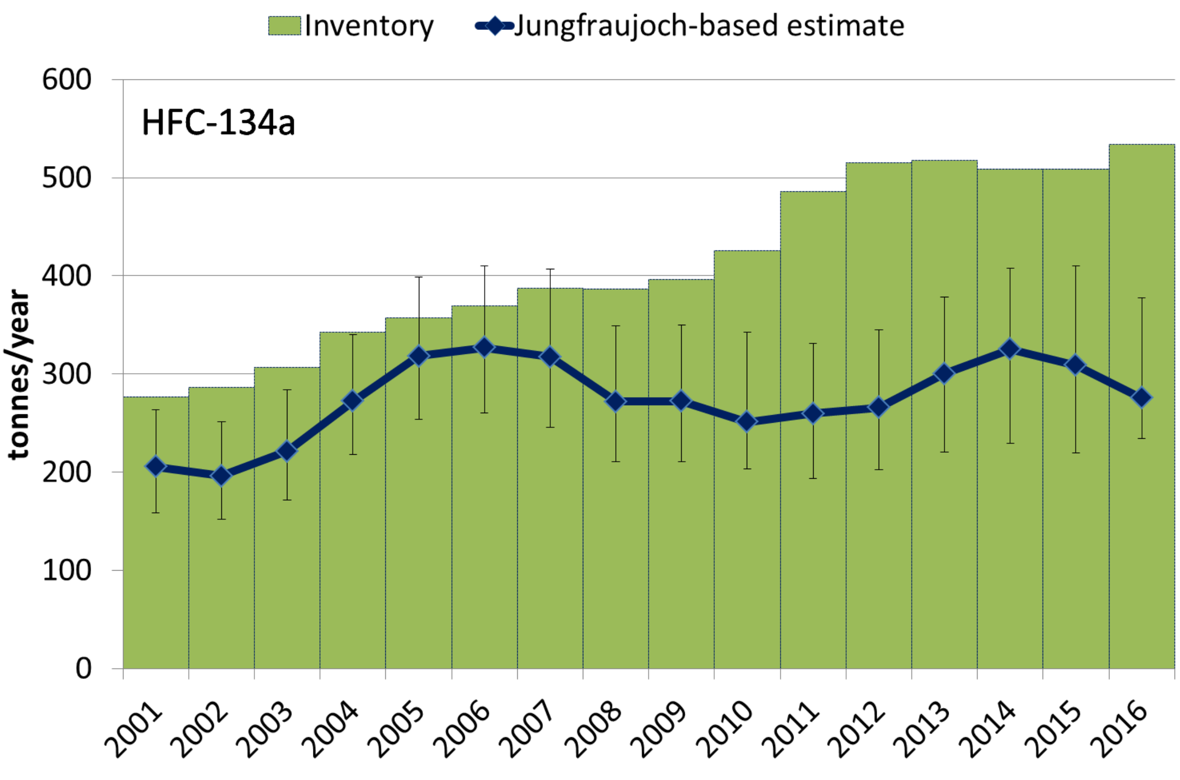


Figure A – 4 Comparison of HFC-134a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

HFC-125

HFC-125 is mainly used in cooling mixtures 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 consistently exceeded emissions based on measurements. However, since 2014 estimated emissions from the measurement-based method approach the emissions from the inventory.

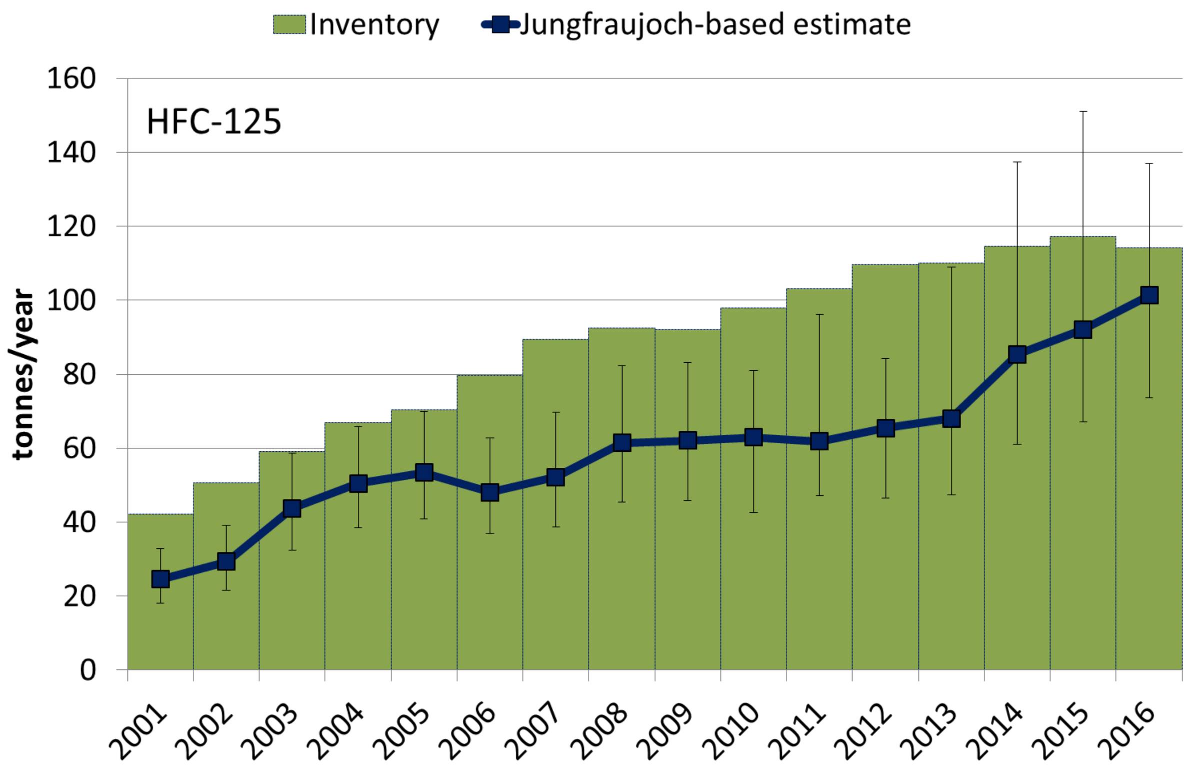


Figure A – 5 Comparison of HFC-125 emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

HFC-152a

HFC-152a is mainly used as a blowing agent 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 and 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 lifetime of the foam 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 the source category 2F2 (Foam Blowing).

HFC-152a emissions from foams in the inventory are mainly related to the production and consumption of PU spray. Most of other foam products are imported and consequently these emissions are allocated to the country of origin. The reported decrease in the inventory since 2003 reflects the replacement of HFC-152a in PU spray.

Up to the year 2002 estimated emissions from Jungfraujoch measurement data are lower than reported in the inventory and from then onwards they are higher. This can be explained by the UNFCCC practice to allocate HFC-152a emissions of the first year to the country of production of foams (which is except for PU spray mainly outside Switzerland). However, in reality a fraction of these first year emissions actually occur during usage of the products (e.g. for insulation) in Switzerland and therefore are reflected in the measurements but are not reflected by definition in the inventory[17]. Emissions estimated from Jungfraujoch show a consistent negative trend related to the partial phase-out of HFC-152a from the foam-blowing applications.

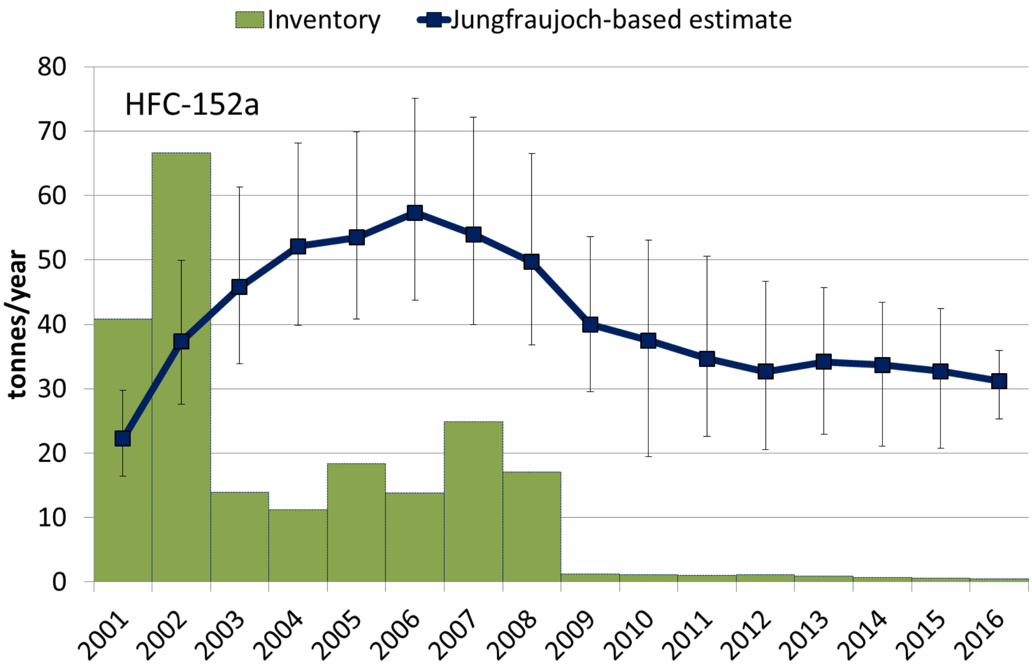


Figure A – 6 Comparison of HFC-152a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

HFC-143a and HFC-32

HFC-143a and HFC-32 are mainly used in cooling agent mixtures in commercial refrigeration and stationary air conditioners (together with HFC-134a and/or HFC-125). Until 2013 HFC-143a emissions estimated from Jungfraujoch measurement data were consistently slightly lower than emissions provided by the inventory. However, since 2014 they agree well with the inventory data, due to a rise in emissions estimated by the measurement-based method. A similar development can also be seen in estimated HFC-125 emissions (see Figure A – 5).

Measurement-based estimates of HFC-32 are consistently lower then the data from the inventory but show a parallel constant increase in emissions.

[17] Nonetheless it is important to apply the UNFCCC approach in the inventory as otherwise double counting may occur when allocating the total emissions to the country of origin and the country of product use.

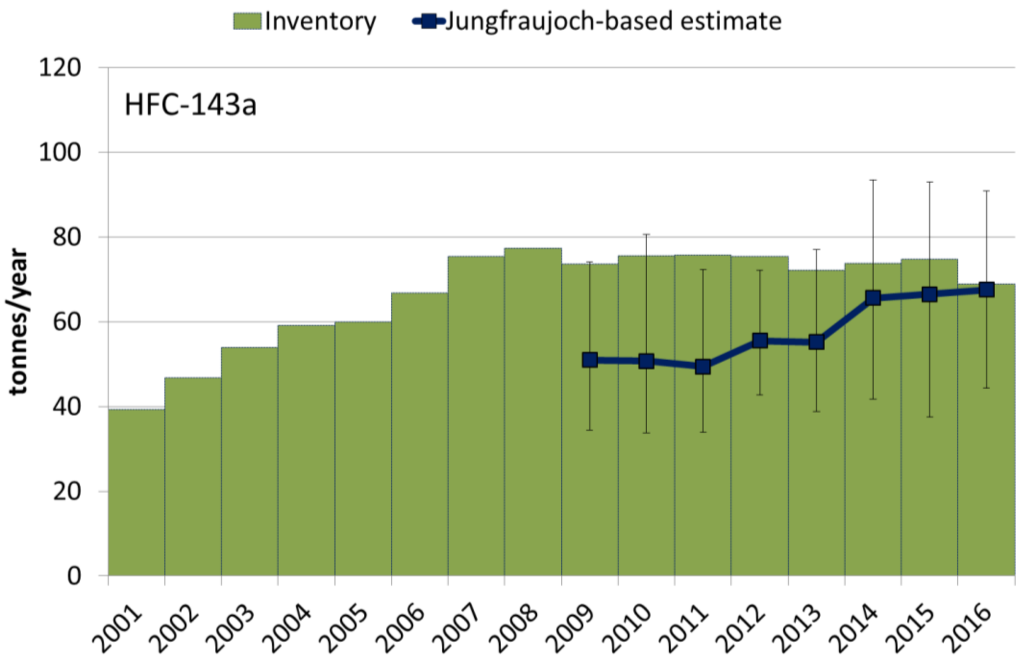


Figure A – 7 Comparison of HFC-143a emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

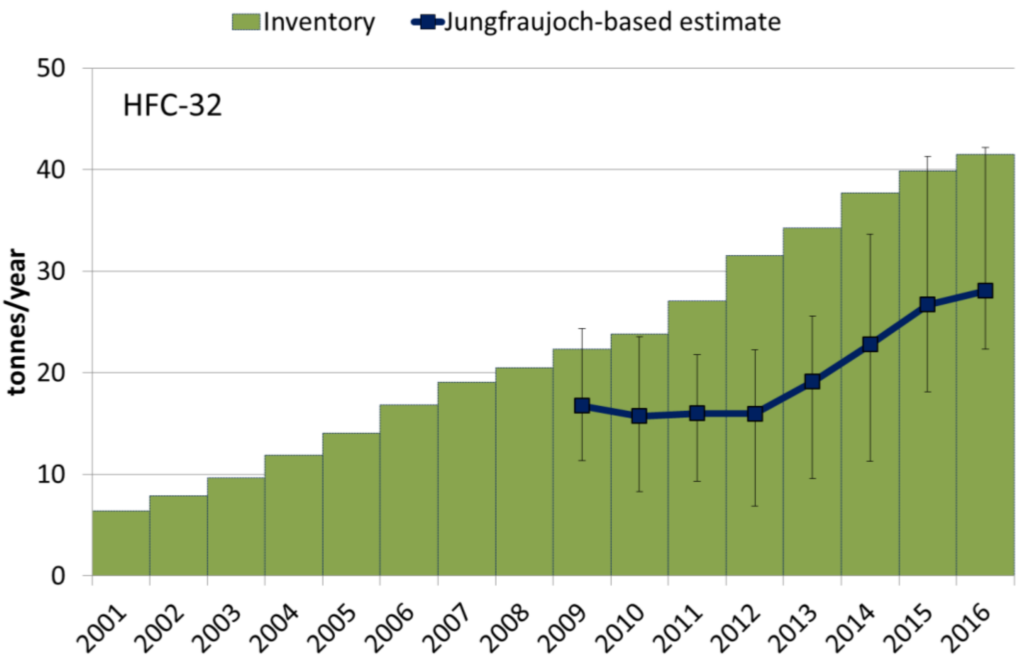


Figure A – 8 Comparison of HFC-32 emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

Sulfur hexafluoride (SF_6)
Until 2010 emissions of SF_6 in Switzerland were mainly due to its use as an insulator of electrical equipment, as for example in gas insulated switchgears and in gas circuit breakers. Since then emissions from insulating windows are dominant. Additional minor emissions arise from magnesium smelters, industrial particle accelerators and various other applications. Emission estimates for both methods show a remarkable similarity in the trend, except for the period of 2001–2003, when slightly higher emissions were estimated from the measurement-based method. Since 2003, a mass balance approach based on industry data is applied for the use of SF_6 in electrical equipment. Increasing SF_6 emissions 2010–2015 result in the inventory from the disposal of insulating windows (all SF_6 released).

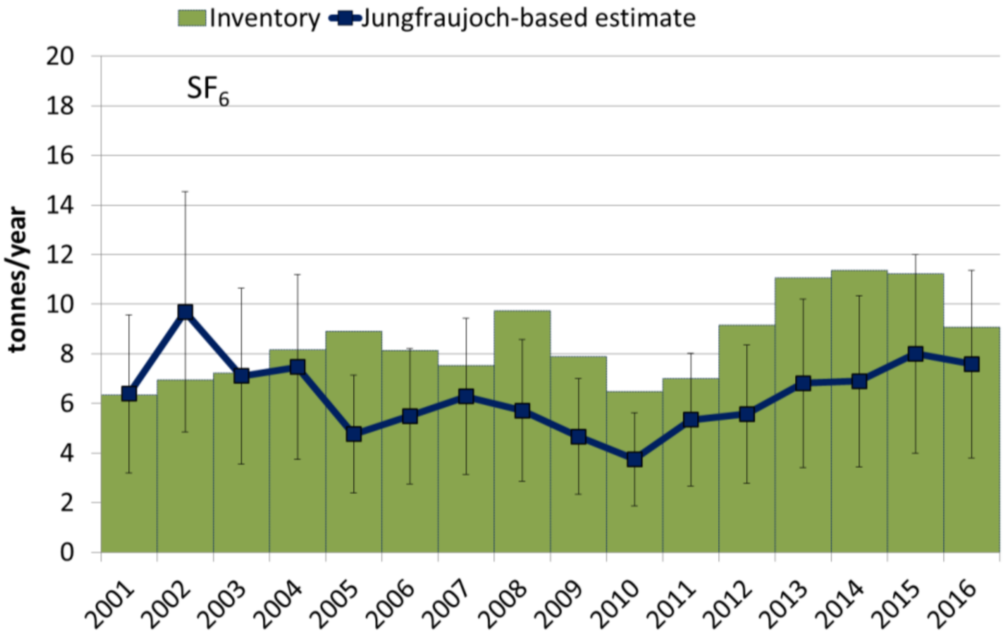


Figure A – 9 Comparison of SF_6 emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

A 5.2 Independent verification of methane emissions

Introduction
In 2013 the Swiss Federal Laboratories for Material Science and Technology (Empa), ETH Zürich and the University of Bern established a greenhouse gas (GHG) observing network in Switzerland as part of the CarboCount-CH SNF-Sinergia project (www.carbocount.ch). The network consists of four sites that continuously measure the atmospheric concentration of carbon dioxide (CO_2) and methane (CH_4). 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 anthropogenic emissions and biosphere-atmosphere exchange of the abovementioned GHGs by inverse modelling. Currently (January 2018), 3 of the 4 sites (Beromünster, Lägern-Hochwacht, Gimmiz) are still operational, whereas the measurements at Früuehbüehl were closed down in 2016. Additional GHG measurements were carried out in the summer of 2017 in north-eastern Switzerland (Gäbris, GBR, Appenzell) as part of this validation study to analyze the sensitivity of the results to additional

measurements in an area poorly covered by the network. Further continuous GHG observations with sensitivity to emissions over Switzerland are available from the high altitude site Jungfraujoch (see above) and Schauinsland (Germany, UBA, mountain top).

Here, the results of inverse modelling to validate total Swiss CH_4 emissions are reported. A previous 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, which showed good agreement between the NIR reporting and the top-down inverse modelling (Henne et al., 2016). That study also raised some questions regarding the spatial and temporal distribution of the emissions and the sensitivity to boundary conditions (i.e. CH_4 baseline concentrations) required for the regional inversion. Here, the previously reported results are extended to the four-year period 2013 to 2016 and by additional sensitivity tests concerning the use of additional measurements in north-eastern Switzerland and the use of baseline concentrations from global scale models.

Furthermore, high precision measurements of N_2O commenced in March 2017 at the tall tower site Beromünster and will be used in future inverse modelling studies to validate Swiss national emissions.

Methods

The inversion approach applied here was described in detail in Henne et al. (2016). It is based on so called source sensitivities that were calculated for each of the mentioned measurement sites with the Lagrangian atmospheric transport model FLEXPART. Source sensitivities give the sensitivity of an atmospheric concentration observation to the emissions released at a distant source and as such can be given as concentration units divided by a mass flux (e.g. ppb kg^{-1} s). FLEXPART was 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 surface 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. In addition to the emission distribution, the applied inversion system also optimizes a baseline concentration for each site which is required to subtract the non-regional contribution to the total concentration. Additional tests including this baseline concentration from global-scale CH_4 models are discussed at the end of this annex.

In contrast to the previously reported approach (Henne et al., 2016), which contained a large number of sensitivity inversions to investigate the structural uncertainty of the inversion system, only a reduced set of sensitivity inversions was used in this study, varying some key aspects of the transport model and the inversion system (particle release height, absolute *a priori* emissions, and seasonality).

As *a priori* emissions for Switzerland the MAIOLICA CH_4 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 kt yr^{-1} , which corresponds to the Swiss CH_4 emissions in 2012 as reported by the NIR in 2014. The MAIOLICA inventory also includes a small contribution from natural sources of 3 kt yr^{-1} (<2%). For the application to more recent years the Swiss national total emissions were scaled to those included in the NIR in 2016.

Two additional sensitivity tests were carried out. One for the year 2013 that used baseline concentrations from two different global-scale CH_4 models: TM5 (Bergamaschi et al., 2013) and FLEXPART-CTM (Henne et al., 2013). Both models used different kinds of data assimilation (TM5: 4DVAR, FLEXPART-CTM: observation nudging) of CH_4 surface observations to provide global CH_4 distributions. These fields were sampled at the end points of the particle trajectories from the regional-scale FLEXPART-COSMO simulations, thereby providing the required baseline concentrations. A second set of sensitivity inversions was run for the year 2016 using the additional CH_4 observations from the site Gäbris in Appenzell, a region for which large *a posteriori* emissions were previously estimated

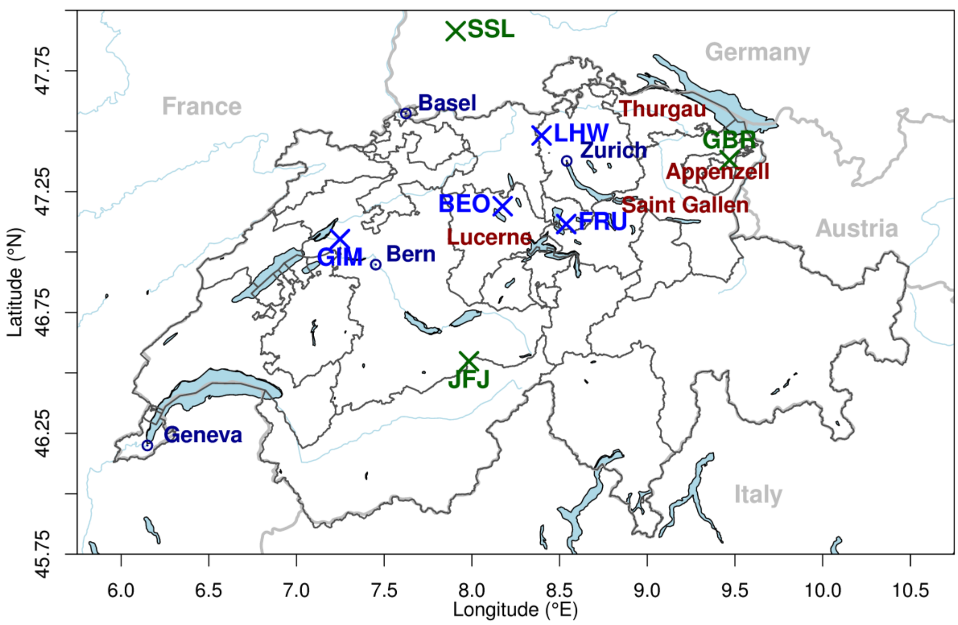


Figure A – 10: Map of Switzerland illustrating the location of CarboCount-CH sites (blue), supplementary sites (green), cantonal borders (gray), major cities (dark blue), and selected canton names (red). The sites are: Beromünster (tall tower, BEO), Lägern Hochwacht (mountain top, tower, LHW), Gimmiz (flat, tower, GIM), Früehbüehl (mountain, near surface, FRU), Gäbris (mountain top, GBR), Schauinsland (mountain top, SSL), and Jungfraujoch (high Alpine, JFJ).

Results and Discussion

The inversion results are presented in the following 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 and temporal information the results can provide qualitative insights into the contribution from specific source categories that dominate in a given region or period. Further details and discussion on the inversion performance and results can be found in Henne et al. (2017).

National Totals

The overall mean inverse estimate of total Swiss CH_4 emissions for the period 2013 to 2016 was 202±17 kt yr^{-1} (1-σ confidence interval around the mean). This number represents the average and standard deviation over the reference and all sensitivity inversions for all years. It is in very close agreement with the NIR values reported in submission 2018 for the same period, which decrease from 200 to 197 kt yr^{-1} (CRF Table10s3) with a 1-σ uncertainty range of ±18 kt yr^{-1} for the reporting year 2016.

For the mentioned period, the NIR suggests a minor CH_4 emission reduction of 3 kt, whereas the inversion estimates showed larger inter-annual variability: 199±17, 204±11, 213±14.4, and 191±21.2 kt yr^{-1} for the years 2013 to 2016 (Figure A – 12). This variability may mostly reflect the uncertainty of the inverse modelling system itself rather than a real temporal variability in the emissions. Due to this variability it is currently not possible to determine or validate the reported tendency. Additional years of observations and inverse modelling are required for this purpose.

Spatial and Temporal Distribution and Source Processes

In Figure A – 11 the spatial distribution of the *a priori* emissions is shown, whereas the absolute differences between *a posteriori* minus *a priori* emissions for individual years are shown in Figure A – 12. 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/Appenzell is clearly seen. In contrast, the densely populated areas of Zurich, Basel and Geneva do not show up as emission hot-spots, consistent with the small contribution of emissions from natural gas distribution and waste water treatment reported in the NIR.

The *a posteriori* results for the four analyzed years in terms of annual totals and spatial distribution were rather similar providing evidence for the robustness of the method. The *a posteriori* emissions were smaller than *a priori* emissions in the agricultural areas of Canton Lucerne, but were increased in the north-eastern part of Switzerland (Cantons Appenzell and Saint Gallen). Smaller differences were seen in other parts of the country. The possible reasons for this emission maximum are discussed below along with the use of additional observations from this area.

Previously, an alternative sensitivity inversion was performed that used *a priori* emissions from the EDGAR inventory (v4.2 FT2010, EC JRC 2009). In EDGAR, the Swiss country total amounts to 228 kt yr^{1}, mostly due to about 25 kt 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. From this Henne et al. (2016) concluded that the natural gas emissions as given in the NIR (8 kt yr^{-1}) are in much better agreement with our atmospheric observations than the emissions in the EDGAR inventory (32 kt yr^{-1}).

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 for all years (Figure A – 13). This is in line with the temperature dependent seasonality expected from manure handling and storage (fewer emissions at lower temperatures) and the productivity-dependent seasonality of milk cows (spring maximum in productivity and calving date).

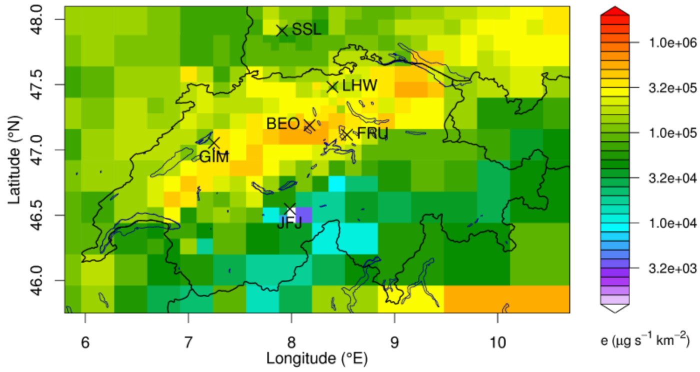


Figure A – 11: Spatial distribution of *a priori* emissions. Within Switzerland the distribution follows that derived by Hiller et al. (2014), scaled to the bottom-up estimates of the NIR (2016), outside Switzerland the bottom-up inventory of TNO/MACC (Kuenen et al., 2014) was used.

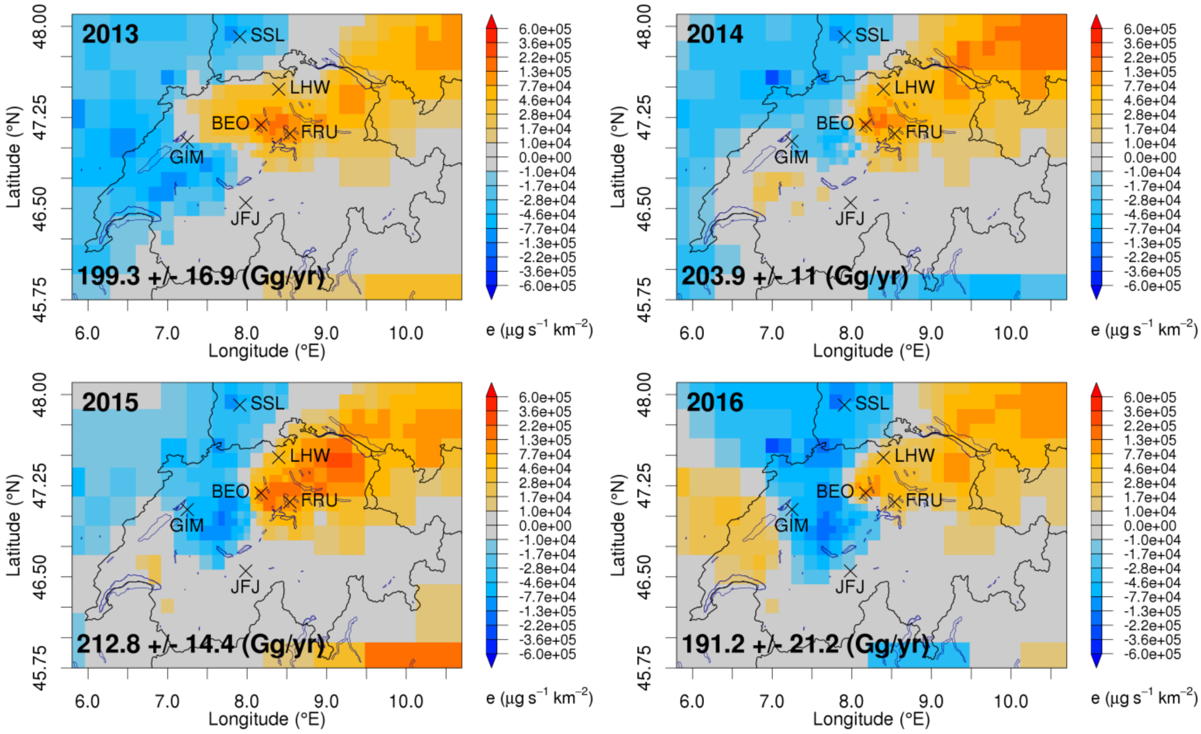


Figure A – 12: Absolute difference between *a posteriori* and *a priori* mean annual emissions (mean over 8 sensitivity runs). The numbers given in the plots refer to the total *a posteriori* Swiss emissions and their uncertainty (1σ level) for the given year.

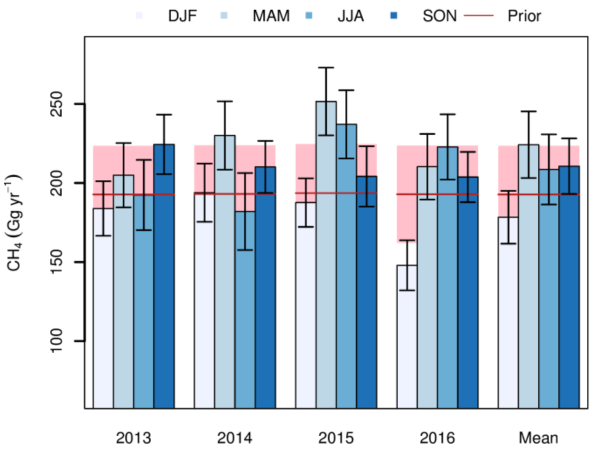


Figure A – 13: Seasonality of Swiss CH_4 emissions. *A priori* values and their uncertainties are given as red lines and red shaded areas. *A posteriori* emissions are given as blue bars and uncertainty bars for different seasons (DJF: December, January, February; MAM: March, April, May; JJA: June, July, August; SON: September, October, November). All uncertainties refer to 1-σ confidence intervals.

Additional sensitivity inversions

Two additional sets of inversions were run to further explore the uncertainties attached to the Swiss-scale inversion. First, analyzing the effect of additional measurements and, second, using additional model-based baseline concentrations in the inversion.

For all years and most sensitivity inversions a similar spatial distribution of the *a posteriori* emissions was obtained. This robust pattern suggests that the increased emissions estimated for north-eastern Switzerland are a true feature, but it remained unclear what source is responsible for this result. One possible candidate was 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 considered were waste water handling, composting and anaerobic digestion in biogas production and fugitive emissions from the natural gas distribution network, but there was no indication that these processes occur disproportionately in north-eastern Switzerland. Natural emissions, e.g. from the “Alter Rhein” wetland area were also suspected to contribute to the unexpectedly high emissions from this area. Additional observations at a new site established on a mountain top in Appenzell were therefore conducted from May to November 2016 to better characterize this source. These supplementary observations and their use in the inverse modelling for the year 2016 could not confirm the emission maximum at the same location. Including this site in the inversion did not affect the estimate of the Swiss total emissions, but the area of enhanced *a posteriori* emissions was shifted farther north-eastwards to southern Germany. Therefore, we conclude that the emission maximum in north-eastern Switzerland obtained in the default inversion setup is likely to be artificial, but has little influence on the validation of national total emissions.

The use of global methane simulations providing larger scale boundary conditions for the regional inversion system was implemented as an alternative to the previously used observation-based approach. The methane concentrations provided by the global-scale models were used as boundary conditions for the European domain, which was covered by FLEXPART-COSMO. Two different global simulations were available for the year 2013. Using either of these data sets as fixed boundary conditions resulted in considerably larger Swiss emissions. However, if the boundary conditions were optimized as part of the inversion (as done previously for the observation-based approach) similar results as in the base inversion were obtained, both with respect to the spatial distribution as well as the Swiss emission total. Since the global models are potentially biased as well as limited in resolution, including the optimization of boundary conditions in the inversion seems justified and is required to obtain unbiased regional emission estimates.

Annex 6: Information on the CRF Reporter

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 Table A – 34. In some instances where numbers are not identical in the reporting tables (CRF) and in the NIR, a remark was added in the NIR. This aspect should be taken into consideration when comparing information in the NIR with the reporting tables.

Table A – 34: Identified errors in the output of some reporting tables (CRF).

Reporting table CRF	**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.
Table2(I)s1-s2	In all empty cells should be written „NO“, but the effort would be very big to generate in the navigation tree of the CRF web application for every cell a new nod and then to adapt all the import files to these changes.	Because the effort would be quite big, and there is no real benefit, we passed on it.
Table2(II)	In all empty cells should be written „NO“, but the effort would be very big to generate in the navigation tree of the CRF web application for every cell a new nod and then to adapt all the import files to these changes..	Because the effort would be quite big, and there is no real benefit, we indicate in the documentation box: „2.B.9, 2.C, 2.E, 2.F.1-2.F6: "NO" for all empty cells“.
Table3.B(a)s2	NFR codes 3B4g and 3B4hi: cells I55 and L103 are still empty despite of correctly imported values.	Problem in the CRF web application.
Table3.B(b)	The IEF for "indirect emissions from atmospheric deposition" (cell R37): Wrong molecular weight. The IEF is displayed in kg N_2O per kg N handled instead of kg N_2O-N per kg N handled.	Problem in the CRF web application.
Table3s1; Table3.As1; Table3.As2; Table3.B(a)s1; Table3.B(a)s2; Table3.B(b)	All cells for “Cattle, Option A” should be filled with “IE” but this Option A cannot be selected together with Option B.	Problem in the CRF web application. Solved with comment in documentation box.
Table4	N_2O from 4(IV) (indirect emissions) 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.
Table4	There are empty cells in the CH_4 and N_2O columns; numbers and/or notation keys are not inserted	Problem in the CRF Reporter.
4.A	All the different documentation-box texts are in the same cell.	Inaccuracy in the CRF web application.
4.B	All the different documentation-box texts are in the same cell.	Inaccuracy in the CRF web application.
Table4(V)	“Values” and “IEF” in lines 9 and 10 are missing.	Problem in the CRF Reporter.
Summary3s1 Summary3s2	Wrong information in “Method applied” and “Emission factor” for several sectors and gases: There should be indicated “NO” instead of empty	Inaccuracy in the CRF web application. „NO“ is not imported and

	cells.	there is no possibility to change it, because „NO“ or „NA“ are not in the drop-down menu.
Table 9	Problems with entries in the CRF web application	Problem in the CRF web application
Table10s2	CO_2 emissions from biomass (row 60) are wrong. Biogenic CO_2 emissions from 5C are missing.	Problem in the CRF web application.
Table10s4	For N_2O in sector 4 LULUCF the sum is not just the displayed sum of N_2O emissions from the categories 4A+4B+4C+4D+4E+4F (rows 39 to 46) but including indirect N_2O from 4(IV). The sum is correct (with indirect emissions).	Inaccuracy in the CRF web application.
KP-CRF-Tables	Text in documentation boxes is (partly) right-aligned.	Problem in the CRF Reporter.
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 and sub-category is shown twice under „identification code“ and „subdivison“. This is not wrong but not necessary.	Problem in the CRF web application.

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References to EMIS database comments

Table A – 35 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. green cell: NEW comment for the submission at hand.

NFR Code CRF [UNECE]	EMIS Title	NFR Code CRF [UNECE]	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 & 2 A 4 d	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	Dachpappe**
1 A 2 c & 2 B 8 b [2 B 10 a]	Ethen-Produktion*	2 D 3 d	Urea (AdBlue) Einsatz Strassenverkehr
1 A 2 d & 2 A 4 d	Zellulose-Produktion Feuerung*	2 G 3 a	Lachgasanwendung Spitäler**
1 A 2 f	Kalkproduktion, Feuerung*	2 G 3 b	Lachgasanwendung Haushalt**
1 A 2 f	Mischgut Produktion	2 G 4 [2 D 3 a]	Pharma-Produkte im Haushalt
1 A 2 f	Zementwerke Feuerung	2 G 4 [2 D 3 a]	Reinigungs- und Lösemittel; Haushalte
1 A 2 f & 2 A 3	Glas übrige Produktion*	2 G 4 [2 D 3 a]	Spraydosen Haushalte**
1 A 2 f & 2 A 3	Glaswolle Produktion Rohprodukt*	2 G 4 [2 D 3 h]	Verpackungsdruckereien**
1 A 2 f & 2 A 3	Hohlglas Produktion*	2 G 4 [2 D 3 h]	Druckereien uebrige
1 A 2 f & 2 A 4 a	Feinkeramik Produktion*	2 G 4 [2 D 3 i]	Entfernung von Farben und Lacken
1 A 2 f & 2 A 4 a	Ziegeleien**	2 G 4 [2 D 3 i]	Entwachsung von Fahrzeugen
1 A 2 f & 2 A 4 d	Steinwolle Produktion*	2 G 4 [2 D 3 i]	Kosmetika-Produktion**
1 A 2 g iv	Faserplatten Produktion**	2 G 4 [2 D 3 i]	Lösungsmittel-Emissionen IG nicht zugeordnet
1 A 3 a & 1 A 5	Flugverkehr	2 G 4 [2 D 3 i]	Öl- und Fettgewinnung
1 A 3 b i-viii	Strassenverkehr	2 G 4 [2 D 3 i]	Papier- und Karton-Produktion**
1 A 3 c	Schienenverkehr	2 G 4 [2 D 3 i]	Parfum- und Aromen-Produktion**
1 A 3 e	Gastransport Kompressorstation	2 G 4 [2 D 3 i]	Tabakwaren Produktion**
1 A 4 b i	Holzkohle-Verbrauch	2 G 4 [2 D 3 i]	Textilien-Produktion
1 A 4 b i	Lagerfeuer	2 G 4 [2 D 3 i]	Wissenschaftliche Laboratorien
1 A 4 c i	Grastrocknung**	2 G 4 [2 G]	Korrosionsschutz im Freien
1 B 2 a iv	Raffinerie, Leckverluste	2 G 4 [2 G]	Betonzusatzmittel-Anwendung
1 B 2 a v	Benzinumschlag Tanklager	2 G 4 [2 G]	Coiffeursalons
1 B 2 a v	Benzinumschlag Tankstellen	2 G 4 [2 G]	Fahrzeug-Unterbodenschutz**
1 B 2 b ii & 1 B 2 c ii	Gasproduktion und Flaring	2 G 4 [2 G]	Feuerwerke
1 B 2 b iv-vi	Netzverluste Erdgas	2 G 4 [2 G]	Flugzeug-Enteisung
1 B 2 c	Raffinerie, Abfackelung	2 G 4 [2 G]	Gas-Anwendung
1 Energy Model***	Energie New	2 G 4 [2 G]	Gesundheitswesen, übrige**
1A	Holzfeuerungen	2 G 4 [2 G]	Glaswolle Imprägnierung*
1A2g vii, 1A3c, 1A3e, 1A5b (Without military aviation)	Off-Road	2 G 4 [2 G]	Holzschutzmittel-Anwendung
2 A 1	Zementwerke Rohmaterial	2 G 4 [2 G]	Klebstoff-Anwendung
2 A 1	Zementwerke übriger Betrieb	2 G 4 [2 G]	Kosmetik-Institute
2 A 2	Kalkproduktion, Rohmaterial*	2 G 4 [2 G]	Kühlschmiermittel-Verwendung
2 A 2	Kalkproduktion, übriger Betrieb*	2 G 4 [2 G]	Medizinische Praxen**
2 A 4 d	Kehrichtverbrennungsanlagen Karbonat**	2 G 4 [2 G]	Pflanzenschutzmittel-Verwendung
2 A 4 d	Karbonatanwendung weitere	2 G 4 [2 G]	Reinigung Gebäude IGD**
2 A 5 a	Gips-Produktion übriger Betrieb**	2 G 4 [2 G]	Schmierstoff-Verwendung
2 A 5 a	Kieswerke	2 G 4 [2 G]	Spraydosen IndustrieGewerbe
2 B 1	Ammoniak-Produktion*	2 G 4 [2 G]	Tabakwaren Konsum
2 B 10 [2 B 10 a]	Ammoniumnitrat-Produktion*	2 G 4 [2 G]	Steinwolle-Imprägnierung*
2 B 10 [2 B 10 a]	Chlorgas-Produktion*	2 H 1	Faserplatten Produktion**
2 B 10 [2 B 10 a]	Essigsäure-Produktion*	2 H 1	Zellulose Produktion übriger Betrieb*
2 B 10 [2 B 10 a]	*Formaldehyd-Produktion*	2 H 1	Spanplatten Produktion*
2 B 10 [2 B 10 a]	PVC-Produktion	2 H 2	Bierbrauereien
2 B 10 [2 B 10 a]	*Salzsäure-Produktion**	2 H 2	Branntwein Produktion
2 B 10 [2 B 10 a]	Schwefelsäure-Produktion*	2 H 2	Brot Produktion
2 B 10	Kalksteingrube*	2 H 2	Fleischräuchereien
2 B 10	Niacin-Produktion*	2 H 2	Kaffeeröstereien
2 B 2	Salpetersäure Produktion*	2 H 2	Müllereien
2 B 5	Graphit und Siliziumkarbid Produktion*	2 H 2	Wein Produktion
2 C - 2 G	Synthetische Gase	2 H 2	Zucker Produktion
2 C 1	Eisengiessereien Elektroschmelzöfen	2 H 3	Sprengen und Schiessen
2 C 1	Eisengiessereien übriger Betrieb	2 I	Holzbearbeitung
2 C 1 & 1 A 2 a	Stahl-Produktion Elektroschmelzöfen**	2 L	NH3 aus Kühlanlagen
2 C 1	Stahl-Produktion übriger Betrieb**	3	Landwirtschaft
2 C 1	Stahl-Produktion Walzwerke**	3 C	Reisanbau
2 C 7 a	Buntmetallgiessereien Elektroöfen**	3 D c	Landwirtschaftsflächen, PM-Emissionen
2 C 7 c	Verzinkereien	5 B 1	Kompostierung
2 C 7 c	Batterie-Recycling*	5 B 2	Biogasaufbereitung (Methanverlust)
2 D 1	Schmiermittel-Anwendung	5 C 1 [5 C 1 a]	Abfallverbrennung illegal
2 D 1	Schmiermittel-Verbrauch B2T	5 C 1 [5 C 1 b i]	Kabelabbrand
2 D 2	Paraffinwachs-Anwendung	5 C 1 [5 C 1 b iii]	Spitalabfallverbrennung
2 D 3 a [2 D 3 d]	Farben-Anwendung Bau	5 C 1 [5 C 1 b iv]	Klärschlammverbrennung
2 D 3 a [2 D 3 d]	Farben-Anwendung andere	5 C 1 [5 C 1 b v]	Krematorien
2 D 3 a [2 D 3 d]	Farben-Anwendung Haushalte**	5 C 2 / 4 V A 1 (Forstw.)	Abfallverbrennung Land-/Forstwirtschaft und Private
2 D 3 a [2 D 3 d]	Farben-Anwendung Holz	5 D 1 [5 D]	Kläranlagen kommunal (Luftschadstoffe)
2 D 3 a [2 D 3 d]	Farben-Anwendung Autoreparatur	5 D 2 [5 D]	Kläranlagen industriell (Luftschadstoffe)
2 D 3 a [2 D 3 e]	Elektronik-Reinigung	5 D 1 / 5 D 2 [5 D]	Kläranlagen GHG
2 D 3 a [2 D 3 e]	Metallreinigung	5 E	Shredder Anlagen
2 D 3 a [2 D 3 e]	Reinigung Industrie übrige	6 A d	Brand- und Feuerschäden Immobilien
2 D 3 a [2 D 3 f]	Chemische Reinigung**	6 A d	Brand- und Feuerschäden Motorfahrzeuge
2 D 3 a [2 D 3 g]	Druckfarben Produktion	6 A d	Brand- und Feuerschäden Motorfahrzeuge
2 D 3 a [2 D 3 g]	Farben-Produktion		
2 D 3 a [2 D 3 g]	Feinchemikalien-Produktion**		
2 D 3 a [2 D 3 g]	Gummi-Verarbeitung**		
2 D 3 a [2 D 3 g]	Klebband-Produktion		

* confidential process
** confidential EMIS comment
*** work in progress
Prozess nicht relevant für Inventar ab 1990
Neue Kommentare