

# Switzerland's Greenhouse Gas Inventory 1990–2023

## National Inventory Document

Submission of 2025  
under the United Nations Framework Convention on Climate Change  
and under the Paris Agreement



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Bern, 2025

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### 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.

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## Glossary

°C	degree Celsius
AD	Activity data
AFOLU	Agriculture, Forestry and Other Land Use
Agroscope	Swiss centre of excellence for agricultural research, affiliated with the Federal Office for Agriculture (FOAG)
AREA1	Swiss Land Use Statistics, first survey 1979/85
AREA2	Swiss Land Use Statistics, second survey 1992/97
AREA3	Swiss Land Use Statistics, third survey 2004/09
AREA4	Swiss Land Use Statistics, fourth survey 2013/18
AREA5	Swiss Land Use Statistics, fifth survey 2020/25
ART	Agroscope Reckenholz-Tänikon Research Station (formerly FAL) since 2014 Agroscope
Avenergy	Avenergy Suisse (Swiss Petroleum Association) formerly Erdöl-Vereinigung (EV)
Base year	1990
BCEF, BEF	Biomass conversion and expansion factor, biomass expansion factor
CAEP	Committee on Aviation Environmental Protection
Carbura	Swiss organisation for the compulsory stockpiling of oil products
CC	Combination category
CCGT	Combined cycle gas turbine
CCSoils	Competence Center for Soils
Cemsuisse	Association of the Swiss Cement Industry
CFC	Chlorofluorocarbon (organic compound: refrigerant, propellant)
CH <sub>4</sub>	Methane, GWP: 28 (UNFCCC 2019; Myhre et al. 2013)
CHP	Combined heat and power
chp.	Chapter
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
CNG	Compressed natural gas
CO	Carbon monoxide
CO <sub>2</sub> , CO <sub>2</sub> eq	Carbon dioxide, carbon dioxide equivalent (GWP = 1 by definition)
COD	Chemical oxygen demand
CORINAIR	CORe INventory of AIR emissions (under the European Topic Centre on Air Emissions and under the European Environment Agency)
COVID-19	Coronavirus disease 2019 is a contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)
CRF	Common Reporting Format
CRT	Common Reporting Tables ( <a href="https://unfccc.int/documents/311076">https://unfccc.int/documents/311076</a> )
CRT reporter	ETF GHG inventory reporting tool ( <a href="https://myapps.unfccc.int/myapps">https://myapps.unfccc.int/myapps</a> )

CSC	Carbon stock change
CSCF	Carbon stock change factor
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
DOM	dead organic matter
dt	decitonne (100 kg)
EF	Emission factor
EMEP	European Monitoring and Evaluation Programme (under the Convention on Long-range Transboundary Air Pollution)
EMIS	Swiss Emission Information System (German: Emissions Informations System Schweiz)
Empa	Swiss Federal Laboratories for Materials Science and Technology
EnAW	Energy Agency of the Swiss Private Sector
ERT	Expert review team (under the UNFCCC)
ETF	Enhanced Transparency Framework
ETS	Emission Trading System
EU	European Union
EV	Erdöl-Vereinigung (Swiss Petroleum Association), since 1 July 2019 Avenenergy Suisse
FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2006: ART; since 2014 Agroscope)
FAO	Food and Agriculture Organization of the United Nations
FC	Fuel consumption
FCA	Federal Customs Administration, since 03.01.2022: Federal Office for Customs and Border Security (FOCBS)
FDFA	Federal Department of Foreign Affairs
FEDRO	Swiss Federal Roads Office
FOAG	Federal Office for Agriculture
FOCA	Federal Office of Civil Aviation
FOCBS	Federal Office for Customs and Border Security, formerly FCA
FOD	First order decay (model)
FOEN	Federal Office for the Environment (former name SAEFL until 2005)
FSO	Federal Statistical Office (formerly SFSO)
GHG	Greenhouse gas
GL	Guidelines
g	gram
GVS	Swiss Foundry Association
GWP	Global Warming Potential
ha	hectare

HAFL	School for Agricultural, Forest and Food Sciences
HFC	Hydrofluorocarbons (e.g. HFC-32 difluoromethane)
HWP	Harvested wood products
ICAO	International Civil Aviation Organization
IDP	Inventory Development Plan
IEA	International Energy Agency
IFR	Instrument Flight Rules
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial processes and product use
IVZ	Information system for traffic admission (Informationssystem Verkehrszulassung IVZ) run by FEDRO, formerly MOFIS
KCA	Key category analysis
kha	kilo hectare
kt	kiloton (1'000 tons)
L1, L2	Key category according to level assessment with approach 1, approach 2
LiDAR	Light Detection And Ranging
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 run by FEDRO (since 2022: IVZ)
MSW	Municipal solid waste
MSWIP	Municipal solid waste incineration plant
NABO	Swiss Soil Monitoring Network
NABODAT	National soil information system
NCAC	(livestock) not covered by agricultural census
NCV	Net calorific value
NF <sub>3</sub>	Nitrogen trifluoride, GWP: 16'100 (UNFCCC 2019; Myhre et al. 2013)
NFI1, NFI2, NFI3, NFI4, NFI5	First (1983–1985), Second (1993–1995), Third (2004–2006), Fourth (2009–2017) and Fifth (ongoing) National Forest Inventory
NFR	Nomenclature for Reporting (under the UNECE)
NID	National Inventory Document (formerly known as NIR)
NIR	National Inventory Report (NIR = NID + CRT)
NIS	National Inventory System
NMVOC	Non-methane volatile organic compounds
N <sub>2</sub> O	Nitrous oxide, GWP: 265 (UNFCCC 2019; Myhre et al. 2013)
NO <sub>x</sub>	Nitrogen oxides
ODS	Ozone-depleting substances (CFCs, halons etc.)
PFC	Perfluorinated carbon compounds (e.g. Tetrafluoromethane)

PSD	Prosperity and Sustainability Division (of the FDFA)
QA/QC	Quality assurance/Quality control
QMS	Quality management system
RY	Latest reporting year; i.e. the latest reported inventory year: 2023
SAEFL	Swiss Agency for the Environment, Forests and Landscape (since 2006: Federal Office for the Environment FOEN)
SAF	Sustainable aviation fuels
SBV	Schweizerischer Bauernverband; Swiss Farmers Union
SCGT	Simple cycle gas turbine
SCR	Selective catalytic reduction
SD	Standard deviation
SDC	Swiss Agency for Development and Cooperation (of the FDFA), (German: DEZA)
SECO	State Secretariat for Economic Affairs
SF <sub>6</sub>	Sulphur hexafluoride, GWP:23'500 (UNFCCC 2019; Myhre et al. 2013)
SFOE	Swiss Federal Office of Energy
SFSO	Swiss Federal Statistical Office, now: Federal Statistical Office (FSO)
SGWA	Swiss Gas and Water Industry Association (see SVGW/SSIGE)
SO <sub>2</sub>	Sulphur dioxide
SO <sub>x</sub>	Sulphur oxides (sum of SO <sub>2</sub> and SO <sub>3</sub> , expressed as SO <sub>2</sub> equivalents)
SOC	Soil organic carbon
SOLV	Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector
SSIP	Sewage sludge incineration plant
SVGW/SSIGE	Schweizerischer Verein des Gas- und Wasserfaches / Société Suisse de l'Industrie du Gaz et des Eaux (Swiss Gas and Water Industry Association)
SWIP	Special waste incineration plant
Swissmem	Swiss Mechanical and Electrical Engineering Industries (Schweizer Maschinen-, Elektro- und Metallindustrie)
swisstopo	Federal Office of Topography
TOW	Total degradable organic material in wastewater
T1, T2	Key category according to trend assessment with approach 1, approach 2
UBA	Umweltbundesamt (Federal Environment Agency in Germany)
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VFR	Visual Flight Rules
VOC	Volatile organic compounds
VSG	Verband der Schweizerischen Gasindustrie / Association Suisse de l'Industrie Gazière (ASIG) (Swiss Gas Industry Association)

VSLF	Swiss association for coating and paint applications
VSTB	Swiss Association of Grass Drying Plants
VSZ	Verband Schweizerische Ziegelindustrie (Swiss association of brick and tile industry)
VTG	Swiss Armed Forces – Defense
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
WWT(P)	Wastewater treatment (plant)
ZPK	Verband der Schweizerischen Zellstoff-, Papier- und Kartonindustrie



## Executive summary

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### ES.1 Background information on greenhouse gas inventories and climate change

Long-term measurements indicate a marked shift towards a warmer climate in Switzerland. Compared to the preindustrial average (reference period 1871–1900), the average temperature in Switzerland over the last ten years (2015–2024) has increased by +2.8°C (<https://www.meteoswiss.admin.ch/climate/climate-change.html>), about twice as much as observed on global average. In the course of the 21<sup>st</sup> century, Switzerland's climate is projected to further depart from present and past conditions. Mean temperature will very likely increase in all regions and seasons (CH2018 2018). Summer mean precipitation will likely decrease by the end of the century all over Switzerland by up to 40 %, while winter precipitation will likely increase, particularly in Southern Switzerland. This will have consequences for all regions and sectors (FOEN et al. 2020). Based on a decision of the Federal Council, Switzerland has established its National Centre for Climate Services, which coordinates the development and dissemination of climate services (<https://www.nccs.admin.ch/nccs/en/home.html>).

The Federal Office for the Environment (FOEN) is the designated national authority for climate policy and environmental monitoring. The FOEN bears overall responsibility for Switzerland's national greenhouse gas inventory and the national registry and is in charge of compiling the emission data. In addition to the FOEN, the Swiss Federal Office of Energy (SFOE), Agroscope (i.e. the Swiss centre of excellence for agricultural research, affiliated with the Federal Office for Agriculture (FOAG)) 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 takes recommendations and encouragements of the review process under the UNFCCC into account. The improvements made in response to the review process are documented in chp. 10.1.1.

### ES.2 Summary of trends related to national emissions and removals

In 2023, Switzerland's national emissions and removals sum up to 42'146 kt of CO<sub>2</sub> eq (kilo tonnes of CO<sub>2</sub> equivalent). When excluding LULUCF, total territorial emissions are 40'847 kt CO<sub>2</sub> eq, corresponding to 4.6 t CO<sub>2</sub> eq per capita for 2023. These numbers include indirect CO<sub>2</sub> emissions (94 kt CO<sub>2</sub> eq) but exclude emissions from international aviation and marine bunkers (5'066 kt CO<sub>2</sub> eq). Mean uncertainty of the emission level in 2023 is 6.7 % including LULUCF, and 3.2 % excluding LULUCF. The uncertainty of the emission trend between 1990 and 2023 is 6.28 % including LULUCF and 3.5 % excluding LULUCF (based on approach 2, see chp. 1.6 for details).

Compared to 1990, Switzerland's total emissions (including LULUCF) are 19.8 % lower in 2023. When excluding LULUCF a reduction of 26.1 % was achieved from 1990 to 2023. The

latter is shown in Figure E-1, which displays relative trends of Switzerland's annual GHG emissions by individual gases from 1990 to 2023 (excluding LULUCF).

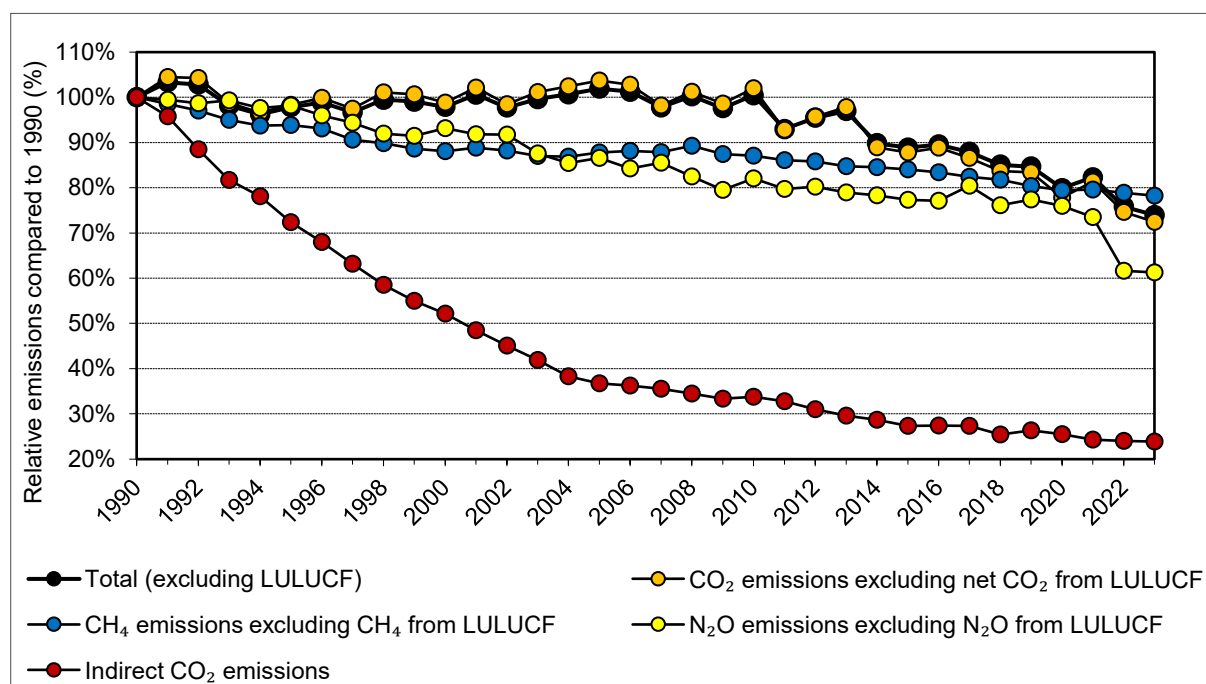


Figure E-1 Relative trends of Switzerland's greenhouse gas emissions (excluding LULUCF). The base year 1990 represents 100 %. F-gases are not illustrated separately here but included in the total.

### ES.3 Overview of source and sink category emission estimates and trends

Figure E-2 shows the GHG emissions and removals by the main source and sink categories. Sector 1 Energy clearly dominates national emissions, accounting for three quarters of the total GHG emissions (excluding LULUCF). 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. The total includes indirect CO<sub>2</sub> emissions; however, those too are of minor importance. Sector 4 LULUCF is mostly a net GHG sink over the inventory period except for the years 2000, 2015, 2018 and 2023 (see Figure E-3).

Overall, Switzerland's GHG emissions in 2023 are lower than in 1990. This is mainly due to the decrease in the energy sector, but other sectors have also contributed to the decreasing trend. The decrease in the energy sector is dominated by a substantial decrease in 1A4 Other sectors and 1A2 Manufacturing industries and construction (see Figure 2-6 and Table 2-4).

As shown in Figure E-2 GHG emissions in the period 1990–2023 are subject to fluctuations with a decreasing trend starting after 2005. The fluctuations derive from the year-to-year variability of emissions in the energy sector caused by changes in heating demand (related to meteorological conditions such as temperature and insolation) and hence in the use of heating fuels. Since around 2006, there has been a growing decoupling of winter temperatures and emissions from fuel combustion, reflecting the impact of emission reduction measures in the building sector.

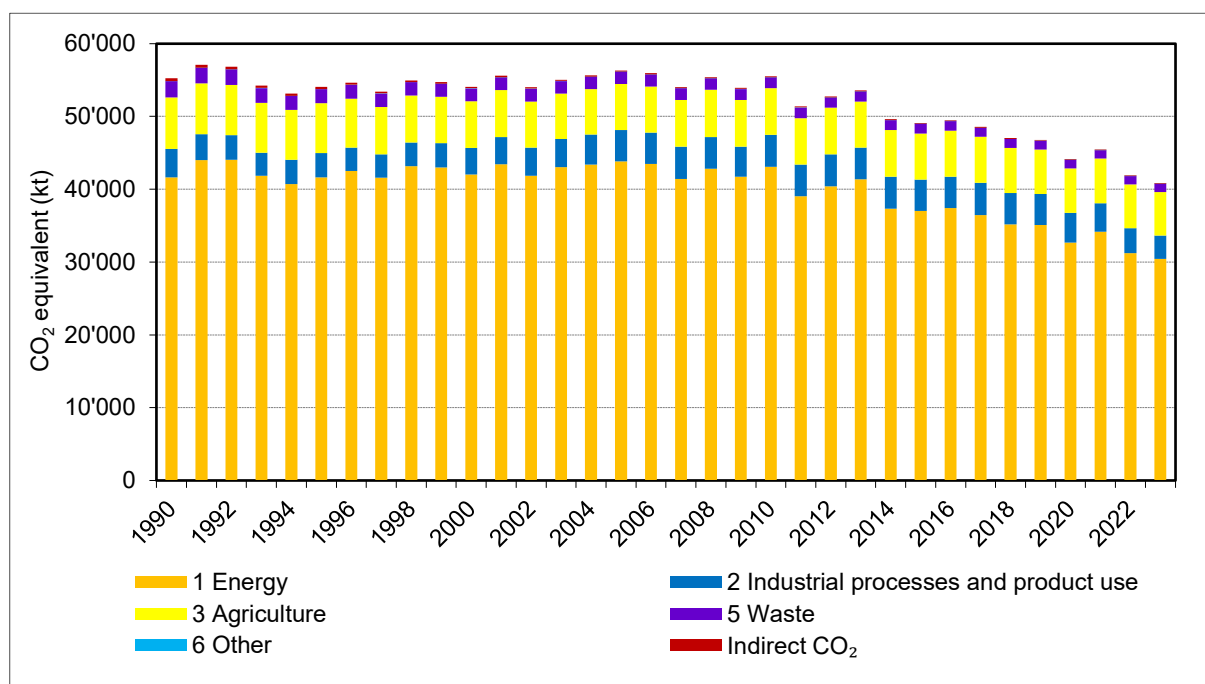


Figure E-2 Greenhouse gas emissions in CO<sub>2</sub> equivalent (kt) by sectors (excluding LULUCF).

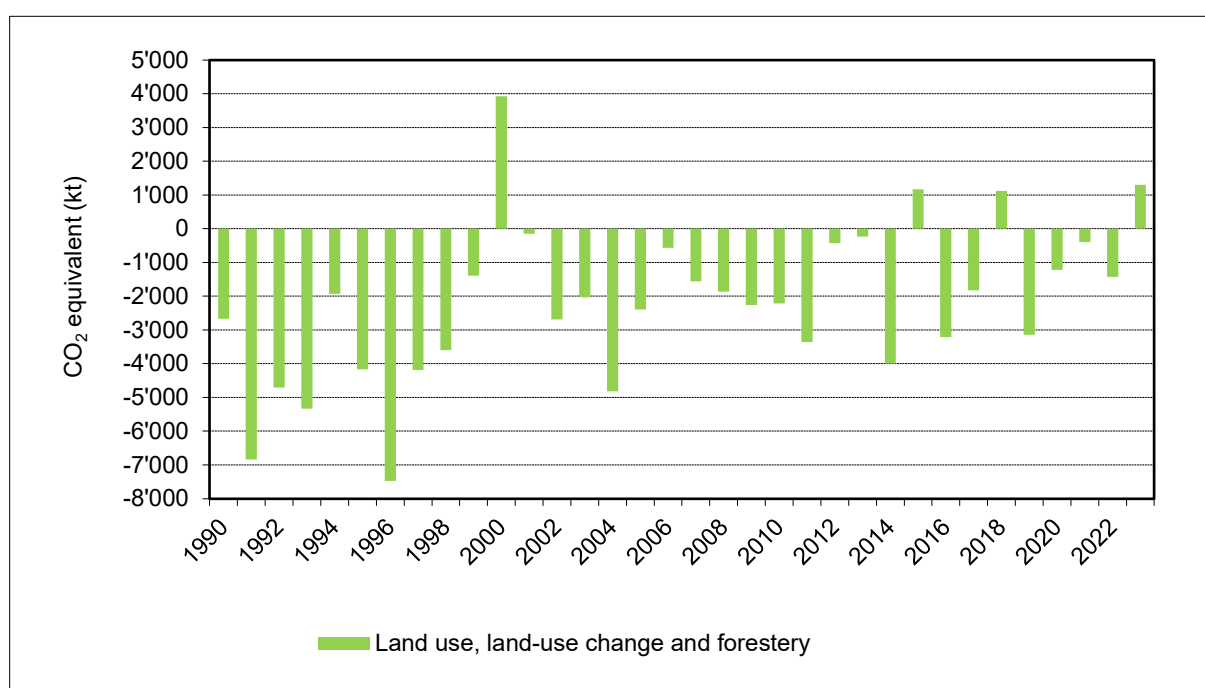


Figure E-3 Net GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) emissions and removals of sector 4 Land use, land-use change and forestry (LULUCF), in CO<sub>2</sub> equivalent (kt). Positive values refer to net emissions, negative values refer to net removals.

## ES.4 Other information

Emissions from precursor gases show a very pronounced decline (see Table 2-6 and Figure 2-10). A strict air pollution control policy led to strong decreases in emissions of precursor gases over the period 1990–2023. An overview concerning precursors is given in chp. 2.2.3 and details are provided in Switzerland's Informative Inventory Report (FOEN 2025b).

## ES.5 Key category analysis (KCA)

Key category analyses were conducted according to approaches 1 and 2 (see details in chp. 1.4.2 and IPCC (2006)). For both approaches, level assessments were conducted for the years 2023 and 1990 and a trend assessment for 1990–2023, including LULUCF categories and indirect CO<sub>2</sub> emissions. A total of 44 key categories were identified out of the 192 categories considered:

- Approach 1: For the year 2023, 31 out of 192 categories were identified as level key categories. About half of these categories are part of sector 1 Energy, accounting for the largest share of total emissions.
- Approach 2: For the year 2023, 24 out of 192 categories were identified as level key categories. Under approach 2, the most important categories originate from the sectors 3 Agriculture and 4 LULUCF.

## ES.6 Improvements introduced

Only major improvements are mentioned here. A quantitative description of large recalculations is provided in chapter 10.1.2. Further, smaller recalculations are described in the sector chapters.

### *General*

- The uncertainty analysis approach 2, using Monte Carlo simulations, was used in an additional analysis to estimate the uncertainty associated with each specific F-gas. These specific uncertainties are used in Annex A6.1 to compare the emission inventory with the top-down approach.

### *Energy*

- Switzerland assessed the origin of biofuels in order to identify and separate fossil from biogenic feedstocks (e.g. in case fossil-fuel derived methanol is used for biodiesel production).

### *Industrial processes and product use (IPPU)*

- None

### *Agriculture*

- 3.D.1.d: N<sub>2</sub>O emissions due to nitrogen in crop residues returned to soils was recalculated for 1990–2022. The whole methodology for assessing nitrogen inputs (AD) was revised and adjusted to the respective methodology for carbon inputs to soils in the LULUCF-sector. New estimates are considerably higher mainly due to the consideration of nitrogen inputs from roots and higher nitrogen inputs from intensive meadows and summering pasture.

### *LULUCF*

- 4 Methodology: A geo-referenced approach was implemented for calculating carbon stock changes in the LULUCF sector.
- 4 Activity data: The update of the dataset defining the geographical distribution of organic soil was finalised.
- 4C-4E: Adoption of mineral soil carbon stocks for several land-use categories from a digital soil carbon map.

### *Waste*

- None.

# 1. National circumstances, institutional arrangements and cross-cutting information

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## 1.1. Background information on Swiss greenhouse gas inventories and climate change

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On 10 December 1993, Switzerland ratified the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC 1992). Since 1996, the submission of its national greenhouse gas inventory has been based on IPCC Guidelines. In 2004, Switzerland started submitting annually its National Inventory Report (NIR) under the UNFCCC.

After ratifying the Kyoto Protocol under the UNFCCC (UNFCCC 1998) in July 2003, Switzerland submitted its Initial Report under Article 7, paragraph 4 of the Kyoto Protocol in 2006 (FOEN 2006h), including the description of the Swiss National Inventory System (NIS) according to Article 5.1 of the Kyoto Protocol. On 6 December 2007, the NIS quality management system (QMS) was certified to comply with ISO 9001. The QMS has been audited annually and recertified according to the ISO 9001 requirements ever since.

## 1.2. National circumstances and institutional arrangements

### 1.2.1. National entity

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). The FOEN established a process led by the Sector Climate, which covers maintaining the National Inventory System and fulfilling reporting obligations under the UNFCCC.

### National entity with overall responsibility for the inventory

Federal Office for the Environment (FOEN)

Climate Division, Climate Reporting and Adaptation Section

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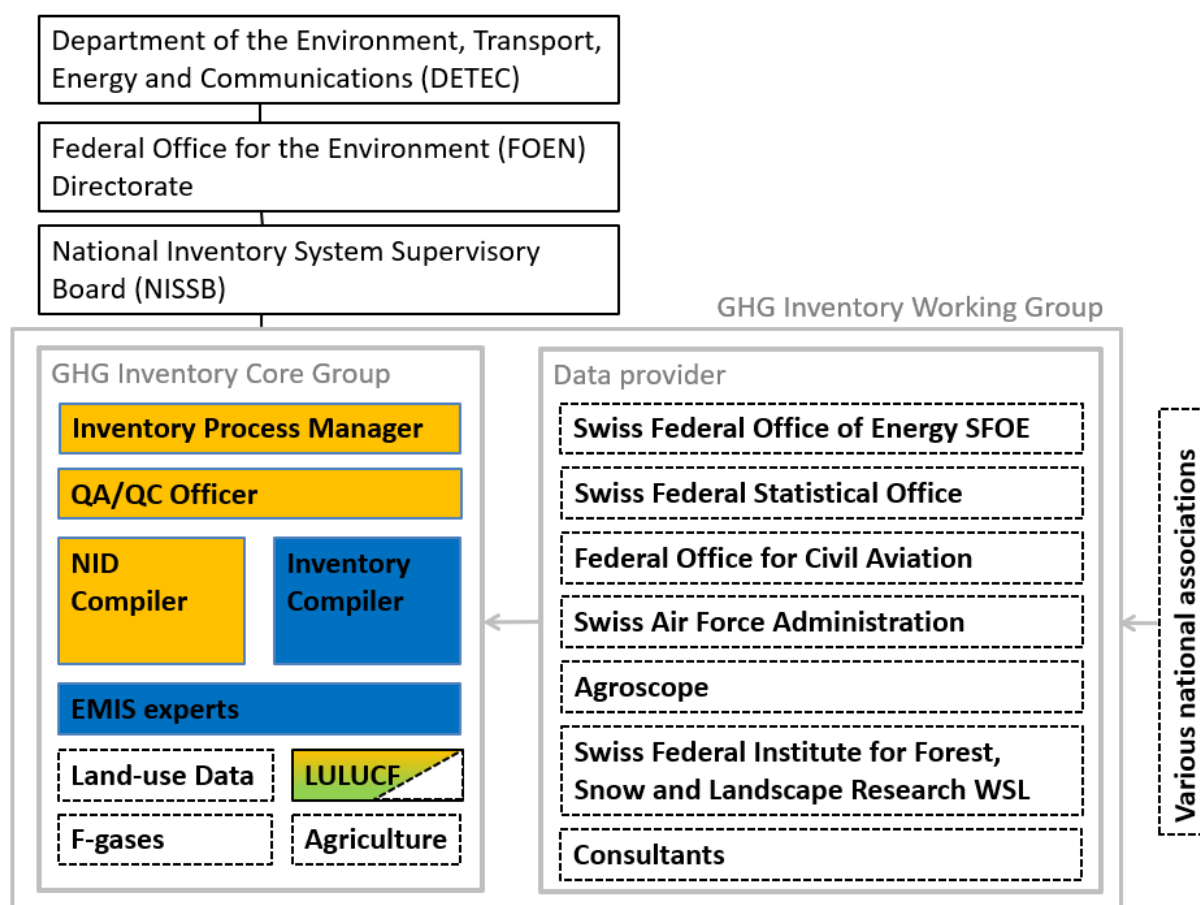


Figure 1-1 The National Inventory System. Colours correspond to FOEN structure: orange: Sector Climate; blue: Department Air Pollution Control and Chemicals; green: Department Forest. Boxes with dashed lines refer to external mandates.



### 1.2.2. Inventory preparation process

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 (Sector Climate) and FOEN department heads of the other relevant departments (Forest, Air Pollution Control and Chemicals, International Affairs).

At the operational level, the process of planning, preparation and management of the greenhouse gas inventory is led by the process manager. The QA/QC officer oversees design, development, and operation of the quality management system and is the primary contact point during the UN review process. The greenhouse gas (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 NID 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 2019, 2022a), 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.

The overall responsibility for the greenhouse gas inventory lies with the Sector Climate of the FOEN. The Air Pollution Control and Chemicals Department of the FOEN maintains and updates the emissions database (greenhouse gases and air pollutants), named EMIS, in close collaboration with the Sector Climate. 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 Agroscope. For LULUCF, detailed land use survey data are provided by the Federal Statistical Office (FSO). The Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) is in charge of the National Forest Inventory and forestry-related modelling. The WSL provides the input for the FOEN Department Forest, which compiles emissions and removals data for Forest land. Soil carbon modelling for Cropland and Grassland is carried out at Agroscope. Two consultancies (Sigmaplan, Meteotest) are mandated to process the land use survey and carbon stock change data to derive land-use change matrices and associated emissions and removals. The LULUCF sector is coordinated by a member of the Sector Climate of the FOEN. A collaboration between two consultancies (Meteotest, Infraso) is mandated to support data handling in the Swiss Emission Information System (EMIS), the reporting tables (CRT) and updating the National Inventory Document (NID).

### 1.2.3. Archiving of information

Archiving of inventory material is performed during preparation and after submission by the EMIS and sectoral experts, by the contributing authors and by the QA/QC officer.

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 2025/NFR-Code” in this report.

Nearly all of the data necessary to compile the Swiss GHG inventory are publicly available. There are exceptions for emission data that refer to a single enterprise, for the most disaggregated level of F-gases, and for land use statistics raw data as long as they have not yet been published the Federal Statistical Office (FSO). However, 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 2019).

FOEN operates a website ([www.climatereporting.ch](http://www.climatereporting.ch)) where the Swiss GHG inventories (NID, reporting tables, UNFCCC review reports), the Swiss National Communications and other reports submitted to the UNFCCC may be downloaded. On this website, most papers, 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. Processes for official consideration and approval of inventory**

The NIS supervisory board (NISSB) normally meets twice a year. At its spring meeting, the inventory is presented for official consideration. Based on that, the NISSB submits the inventory to the FOEN directorate for official approval. Submission is coordinated by the process manager and carried out by the national inventory compiler and the QA/QC officer.

#### **1.2.5. Changes in the national inventory arrangements since previous submission**

No changes.

### **1.3. General description of methodologies and data sources used**

According to the revised reporting guidelines under the UNFCCC and the Paris Agreement (UNFCCC 2019), emissions are calculated based on standard methods and procedures provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) its 2019 Refinement (IPCC 2019), 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 NID and compiled in CRT Summary<sup>3</sup>.

Various data suppliers contribute to the greenhouse gas inventory. 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 NID.

<sup>1</sup> National circumstances, institutional arrangements and cross-cutting information

## 1.4. 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). The KCA is performed based on two assessments and two approaches. In approach 1 of the KCA, categories are set out in decreasing order of contribution to the inventory emissions ("level assessment") or in decreasing order of deviation from the inventory trend ("trend assessment"). The level assessment highlights categories which are the main contributors to the inventory emissions. Since the inventory trend is negative for Switzerland, the trend assessment highlights categories with a positive category trend or a pronounced negative category trend. In approach 2, this ranking is weighted by the uncertainty assigned to each category. Approach 2 therefore identifies categories mostly contributing to the inventory uncertainty. Data collection as well as quality assurance and control are prioritised for key categories during the inventory resource allocation (see also the planned improvements in chp. 10.4).

### 1.4.1. Methodology

The key category analysis is performed according to the 2006 IPCC Guidelines (IPCC 2006, chp. 4) and Decision 18/CMA.1 (UNFCCC 2019, paragraph 25) for 1990 and the latest reporting year including all GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, NF<sub>3</sub> and indirect CO<sub>2</sub>). A total of 192 categories (including categories from the LULUCF sector) are used to disaggregate Switzerland's total GHG emissions for the purpose of this key category analysis (see Annex 1). 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.

Both approach 1 (with a threshold set at 95 %) and approach 2 (with a threshold set at 90 %) level and trend assessments are applied, including emissions from sector 4 LULUCF. For approach 2 of the KCA, uncertainties for emissions of each category are taken from the results of the Monte Carlo simulations (approach 2 uncertainty analysis, see details in chp. 1.6.2.2). Indirect CO<sub>2</sub> emissions are included in the key category analysis, indirect N<sub>2</sub>O emissions are not.

### 1.4.2. Results of the key category analysis (including LULUCF categories)

For the latest reporting year 2023, there are 44 identified key categories among the 192 categories taken into account (see overview in Table 1-6). The large majority of the key categories are sources of direct CO<sub>2</sub> (see also Table 2-3 and discussion in chp. 2.2), a few of CH<sub>4</sub> and N<sub>2</sub>O, two of HFCs, one of PFCs and one of indirect CO<sub>2</sub>. There are no key categories for SF<sub>6</sub> and NF<sub>3</sub>.

The detailed results of the key category analyses, approaches 1 and 2, level and trend assessments, are reported in Table 1-1 to Table 1-5. For level assessments, columns are labelled A to G according to Table 4-2 in the IPCC Guidelines (IPCC 2006, chp. 4) and for trend assessments, columns are labelled A to H according to Table 4-3 in the same guidelines. The following abbreviations are used:

- $E_{x,0}$ : base year emission/removal estimate.
- $E_{x,t}$ : latest reporting year emission/removal estimate.
- $L_{x,0}$ ,  $L_{x,t}$ : level assessment for the base year and the reporting year, respectively.
- $T_{x,t}$ : trend assessment for the trend between base year and latest reporting year.

### Approach 1

For the reporting year 2023, 31 out of 192 categories are identified as level key categories under approach 1 (see Table 1-1).

Fifteen of these key categories belong to sector 1 Energy, accounting for the largest share of CO<sub>2</sub> equivalent emissions in 2023 (see Table 2-1 for emission share per sector). Sector 2 Industrial processes and product use (2 key categories) and sector 3 Agriculture (5 key categories) are also significant contributors to the emissions for the year 2023 (Table 2-1), while sector 5 Waste (3 key categories) and sector 6 Other (no key category) have only marginal contributions. Sector 4 LULUCF (7 key categories) has a net positive contribution to the total emissions for the year 2023.

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

For the base year 1990, 34 categories are identified as level key categories under approach 1 (see Table 1-2). The following categories are key according to level in the base year 1990, but not anymore in the reporting year:

- 1A3a Domestic aviation, kerosene fossil, CO<sub>2</sub>
- 2B10 Chemical industry other, N<sub>2</sub>O
- 2D Non-energy products from fuels and solvent use, indirect CO<sub>2</sub> from NMVOCs
- 4G HWP Harvested wood products, CO<sub>2</sub>

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

- 2F1 Refrigeration and air conditioning, HFCs

Regarding the trend assessment between the base year 1990 and the latest reporting year, 34 categories are identified as trend key categories under approach 1 (see Table 1-3). Among these, 14 have an increasing trend and 20 a decreasing trend. See chp. 2.2 Emission trends by gas and chp. 2.2.2 Emission trends by sources and sinks for a further discussion.

Table 1-1 Switzerland's key categories according to approach 1 level assessment for the year 2023, including LULUCF categories and indirect CO<sub>2</sub> emissions, sorted by decreasing contribution. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 2023						
A	B	C	D	E	F	G
Code	IPCC category	Gas	Ex, t (kt CO <sub>2</sub> eq.)	Ex, t  (kt CO <sub>2</sub> eq.)	Lx, t (%)	Cumulative Total (%)
1.A.3.b	Road transportation; Diesel oil	CO <sub>2</sub>	6'860	6'860	15.7	15.7
1.A.3.b	Road transportation; Gasoline	CO <sub>2</sub>	6'366	6'366	14.5	30.2
1.A.4.b	Residential; Liquid fuels	CO <sub>2</sub>	3'682	3'682	8.4	38.6
3.A	Enteric fermentation	CH <sub>4</sub>	3'604	3'604	8.2	46.8
1.A.1	Energy industries; Other fossil fuels	CO <sub>2</sub>	2'431	2'431	5.5	52.4
1.A.4.b	Residential; Gaseous fuels	CO <sub>2</sub>	2'410	2'410	5.5	57.8
1.A.4.a	Commercial/institutional; Liquid fuels	CO <sub>2</sub>	1'892	1'892	4.3	62.2
1.A.2	Manufacturing industries and construction; Gaseous fuels	CO <sub>2</sub>	1'668	1'668	3.8	66.0
2.A.1	Cement production	CO <sub>2</sub>	1'506	1'506	3.4	69.4
1.A.2	Manufacturing industries and construction; Liquid fuels	CO <sub>2</sub>	1'465	1'465	3.3	72.8
2.F.1	Refrigeration and air-conditioning	HFCs	1'110	1'110	2.5	75.3
3.D.1	Direct N <sub>2</sub> O emissions from managed soils	N <sub>2</sub> O	990	990	2.3	77.5
1.A.4.a	Commercial/institutional; Gaseous fuels	CO <sub>2</sub>	960	960	2.2	79.7
4.A.2	Land converted to forest land	CO <sub>2</sub>	-786	786	1.8	81.5
3.B.1-4	Manure management	CH <sub>4</sub>	602	602	1.4	82.9
5.D	Wastewater treatment and discharge	N <sub>2</sub> O	517	517	1.2	84.1
4.B.1	Cropland remaining cropland	CO <sub>2</sub>	471	471	1.1	85.2
1.A.4.c	Agriculture/forestry/fishing; Liquid fuels	CO <sub>2</sub>	445	445	1.0	86.2
3.D.2	Indirect N <sub>2</sub> O Emissions from managed soils	N <sub>2</sub> O	423	423	1.0	87.1
1.A.2	Manufacturing industries and construction; Other fossil fuels	CO <sub>2</sub>	408	408	0.9	88.1
4.A.1	Forest land remaining forest land	CO <sub>2</sub>	393	393	0.9	89.0
4.C.1	Grassland remaining grassland	CO <sub>2</sub>	387	387	0.9	89.8
1.A.1	Energy industries; Liquid fuels	CO <sub>2</sub>	357	357	0.8	90.7
4.C.2	Land converted to grassland	CO <sub>2</sub>	352	352	0.8	91.5
1.A.1	Energy industries; Gaseous fuels	CO <sub>2</sub>	346	346	0.8	92.3
1.A.2	Manufacturing industries and construction; Solid fuels	CO <sub>2</sub>	286	286	0.7	92.9
5.A	Solid waste disposal	CH <sub>4</sub>	261	261	0.6	93.5
3.B.5	Indirect N <sub>2</sub> O emissions	N <sub>2</sub> O	230	230	0.5	94.0
5.D	Wastewater treatment and discharge	CH <sub>4</sub>	230	230	0.5	94.6
4.E.2	Land converted to settlements	CO <sub>2</sub>	155	155	0.4	94.9
1.A.5	Other; Liquid fuels	CO <sub>2</sub>	123	123	0.3	95.2
4.D.1	Wetlands remaining wetlands	CO <sub>2</sub>	112	112	0.3	95.4
1.A.3.d	Domestic navigation; Liquid fuels	CO <sub>2</sub>	110	110	0.3	95.7
3.B.1-4	Manure management	N <sub>2</sub> O	107	107	0.2	95.9
2.B.8	Petrochemical and carbon black production	CO <sub>2</sub>	107	107	0.2	96.2
1.A.4.c	Agriculture/forestry/fishing; Gaseous fuels	CO <sub>2</sub>	91	91	0.2	96.4
4.F.2	Land converted to other land	CO <sub>2</sub>	91	91	0.2	96.6
1.A.3.b	Road transportation; Diesel oil	N <sub>2</sub> O	90	90	0.2	96.8
1.A.3.a	Domestic aviation; Kerosene fossil	CO <sub>2</sub>	65	65	0.1	96.9
2.A.4	Other process uses of carbonates	CO <sub>2</sub>	63	63	0.1	97.1
Total number of key categories			31			

Table 1-2 Switzerland's key categories according to approach 1 level assessment for the year 1990, including LULUCF categories and indirect CO<sub>2</sub> emissions, sorted by decreasing contribution. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 1990						
A	B	C	D	E	F	G
Code	IPCC category	Gas	Ex, 0 (kt CO <sub>2</sub> eq.)	Ex, 0  (kt CO <sub>2</sub> eq.)	Lx, 0 (%)	Cumulative Total (%)
1.A.3.b	Road transportation; Gasoline	CO <sub>2</sub>	11'328	11'328	18.8	18.8
1.A.4.b	Residential; Liquid fuels	CO <sub>2</sub>	10'099	10'099	16.7	35.5
1.A.2	Manufacturing industries and construction; Liquid fuels	CO <sub>2</sub>	3'974	3'974	6.6	42.1
3.A	Enteric fermentation	CH <sub>4</sub>	3'930	3'930	6.5	48.6
1.A.4.a	Commercial/institutional; Liquid fuels	CO <sub>2</sub>	3'918	3'918	6.5	55.1
1.A.3.b	Road transportation; Diesel oil	CO <sub>2</sub>	2'632	2'632	4.4	59.4
2.A.1	Cement production	CO <sub>2</sub>	2'550	2'550	4.2	63.6
1.A.1	Energy industries; Other fossil fuels	CO <sub>2</sub>	1'492	1'492	2.5	66.1
1.A.4.b	Residential; Gaseous fuels	CO <sub>2</sub>	1'465	1'465	2.4	68.5
4.A.1	Forest land remaining forest land	CO <sub>2</sub>	-1'286	1'286	2.1	70.7
1.A.2	Manufacturing industries and construction; Solid fuels	CO <sub>2</sub>	1'275	1'275	2.1	72.8
3.D.1	Direct N <sub>2</sub> O emissions from managed soils	N <sub>2</sub> O	1'271	1'271	2.1	74.9
4.G	Harvested wood products	CO <sub>2</sub>	-1'149	1'149	1.9	76.8
1.A.2	Manufacturing industries and construction; Gaseous fuels	CO <sub>2</sub>	1'100	1'100	1.8	78.6
5.D	Wastewater treatment and discharge	N <sub>2</sub> O	1'056	1'056	1.7	80.4
1.A.4.a	Commercial/institutional; Gaseous fuels	CO <sub>2</sub>	928	928	1.5	81.9
5.A	Solid waste disposal	CH <sub>4</sub>	862	862	1.4	83.3
3.B.1-4	Manure management	CH <sub>4</sub>	777	777	1.3	84.6
4.A.2	Land converted to forest land	CO <sub>2</sub>	-767	767	1.3	85.9
1.A.4.c	Agriculture/forestry/fishing; Liquid fuels	CO <sub>2</sub>	742	742	1.2	87.1
1.A.1	Energy industries; Liquid fuels	CO <sub>2</sub>	686	686	1.1	88.3
4.C.1	Grassland remaining grassland	CO <sub>2</sub>	-645	645	1.1	89.3
3.D.2	Indirect N <sub>2</sub> O Emissions from managed soils	N <sub>2</sub> O	638	638	1.1	90.4
4.B.1	Cropland remaining cropland	CO <sub>2</sub>	523	523	0.9	91.2
2.B.10	Other	N <sub>2</sub> O	384	384	0.6	91.9
1.A.3.a	Domestic aviation; Kerosene fossil	CO <sub>2</sub>	253	253	0.4	92.3
1.A.1	Energy industries; Gaseous fuels	CO <sub>2</sub>	243	243	0.4	92.7
1.A.5	Other; Liquid fuels	CO <sub>2</sub>	218	218	0.4	93.1
4.E.2	Land converted to settlements	CO <sub>2</sub>	212	212	0.4	93.4
3.B.5	Indirect N <sub>2</sub> O emissions	N <sub>2</sub> O	209	209	0.3	93.8
5.D	Wastewater treatment and discharge	CH <sub>4</sub>	198	198	0.3	94.1
2.D	Non-energy products from fuels and solvent use	Ind. CO <sub>2</sub> (NMVOC)	194	194	0.3	94.4
1.A.2	Manufacturing industries and construction; Other fossil fuels	CO <sub>2</sub>	192	192	0.3	94.7
4.C.2	Land converted to grassland	CO <sub>2</sub>	191	191	0.3	95.0
3.B.1-4	Manure management	N <sub>2</sub> O	168	168	0.3	95.3
2.A.4	Other process uses of carbonates	CO <sub>2</sub>	160	160	0.3	95.6
1.A.3.b	Road transportation; Gasoline	N <sub>2</sub> O	143	143	0.2	95.8
2.G	Other product manufacture and use	SF <sub>6</sub>	141	141	0.2	96.1
2.C.3	Aluminium production	CO <sub>2</sub>	139	139	0.2	96.3
1.A.3.b	Road transportation; Gasoline	CH <sub>4</sub>	127	127	0.2	96.5
2.G	Other product manufacture and use	Ind. CO <sub>2</sub> (NMVOC)	125	125	0.2	96.7
4.D.1	Wetlands remaining wetlands	CO <sub>2</sub>	115	115	0.2	96.9
1.A.3.d	Domestic navigation; Liquid fuels	CO <sub>2</sub>	114	114	0.2	97.1
Total number of key categories						34

Table 1-3 Switzerland's key categories according to approach 1 trend assessment for 1990–2023, including LULUCF categories and indirect CO<sub>2</sub> emissions, sorted by decreasing contribution. Categories in orange have increased emissions in 2023 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 1 TREND ASSESSMENT 1990 - 2023							
A	B	C	D	E	F	G	H
Code	IPCC category	Gas	Ex, 0 (kt CO <sub>2</sub> eq.)	Ex, t (kt CO <sub>2</sub> eq.)	Trend Assessment	Contribution to trend assess. (%)	Cumulative Total (%)
1.A.3.b	Road transportation; Diesel oil	CO <sub>2</sub>	2'632	6'860	0.079	15.7	15.7
1.A.4.b	Residential; Liquid fuels	CO <sub>2</sub>	10'099	3'682	0.073	14.6	30.3
1.A.3.b	Road transportation; Gasoline	CO <sub>2</sub>	11'328	6'366	0.045	9.0	39.3
4.A.1	Forest land remaining forest land	CO <sub>2</sub>	-1'286	393	0.032	6.4	45.7
1.A.2	Manufacturing industries and construction; Liquid fuels	CO <sub>2</sub>	3'974	1'465	0.028	5.7	51.4
4.G	Harvested wood products	CO <sub>2</sub>	-1'149	42	0.024	4.7	56.1
1.A.4.a	Commercial/institutional; Liquid fuels	CO <sub>2</sub>	3'918	1'892	0.021	4.1	60.3
1.A.1	Energy industries; Other fossil fuels	CO <sub>2</sub>	1'492	2'431	0.020	4.1	64.4
1.A.4.b	Residential; Gaseous fuels	CO <sub>2</sub>	1'465	2'410	0.020	4.1	68.5
4.C.1	Grassland remaining grassland	CO <sub>2</sub>	-645	387	0.019	3.8	72.3
2.F.1	Refrigeration and air-conditioning	HFCs	0	1'110	0.018	3.7	76.0
1.A.2	Manufacturing industries and construction; Gaseous fuels	CO <sub>2</sub>	1'100	1'668	0.013	2.6	78.6
1.A.2	Manufacturing industries and construction; Solid fuels	CO <sub>2</sub>	1'275	286	0.012	2.4	81.0
2.A.1	Cement production	CO <sub>2</sub>	2'550	1'506	0.009	1.8	82.8
3.A	Enteric fermentation	CH <sub>4</sub>	3'930	3'604	0.008	1.5	84.3
5.A	Solid waste disposal	CH <sub>4</sub>	862	261	0.007	1.4	85.7
5.D	Wastewater treatment and discharge	N <sub>2</sub> O	1'056	517	0.005	1.1	86.8
2.B.10	Other	N <sub>2</sub> O	384	1	0.005	1.0	87.8
1.A.2	Manufacturing industries and construction; Other fossil fuels	CO <sub>2</sub>	192	408	0.004	0.8	88.7
1.A.4.a	Commercial/institutional; Gaseous fuels	CO <sub>2</sub>	928	960	0.004	0.7	89.4
4.C.2	Land converted to grassland	CO <sub>2</sub>	191	352	0.003	0.7	90.0
1.A.1	Energy industries; Liquid fuels	CO <sub>2</sub>	686	357	0.003	0.6	90.7
1.A.1	Energy industries; Gaseous fuels	CO <sub>2</sub>	243	346	0.002	0.5	91.2
1.A.4.c	Agriculture/forestry/fishing; Liquid fuels	CO <sub>2</sub>	742	445	0.002	0.5	91.7
1.A.3.a	Domestic aviation; Kerosene fossil	CO <sub>2</sub>	253	65	0.002	0.5	92.1
4.A.2	Land converted to forest land	CO <sub>2</sub>	-767	-786	0.002	0.4	92.6
2.D	Non-energy products from fuels and solvent use	Ind. CO <sub>2</sub> (NMVOC)	194	36	0.002	0.4	93.0
2.C.3	Aluminium production	CO <sub>2</sub>	139	0	0.002	0.4	93.3
1.A.3.b	Road transportation; Gasoline	N <sub>2</sub> O	143	13	0.002	0.3	93.7
1.A.3.b	Road transportation; Gasoline	CH <sub>4</sub>	127	13	0.001	0.3	94.0
3.D.2	Indirect N <sub>2</sub> O Emissions from managed soils	N <sub>2</sub> O	638	423	0.001	0.3	94.3
1.A.3.b	Road transportation; Diesel oil	N <sub>2</sub> O	5	90	0.001	0.3	94.5
2.C.3	Aluminium production	PFCs	105	0	0.001	0.3	94.8
5.D	Wastewater treatment and discharge	CH <sub>4</sub>	198	230	0.001	0.2	95.1
2.A.4	Other process uses of carbonates	CO <sub>2</sub>	160	63	0.001	0.2	95.3
3.B.5	Indirect N <sub>2</sub> O emissions	N <sub>2</sub> O	209	230	0.001	0.2	95.5
2.F.2	Foam blowing agents	HFCs	0	61	0.001	0.2	95.7
1.A.4.b	Residential; Biomass	CH <sub>4</sub>	104	22	0.001	0.2	95.9
2.G	Other product manufacture and use	Ind. CO <sub>2</sub> (NMVOC)	125	40	0.001	0.2	96.1
2.G	Other product manufacture and use	SF <sub>6</sub>	141	55	0.001	0.2	96.3
4.B.1	Cropland remaining cropland	CO <sub>2</sub>	523	471	0.001	0.2	96.5
1.A.5	Other; Liquid fuels	CO <sub>2</sub>	218	123	0.001	0.2	96.6
2.B.2	Nitric acid production	N <sub>2</sub> O	58	0	0.001	0.2	96.8
2.G.3	N <sub>2</sub> O from product uses	N <sub>2</sub> O	92	29	0.001	0.2	96.9
1.A.4.b	Residential; Solid fuels	CO <sub>2</sub>	58	5	0.001	0.1	97.1
Total number of key categories							34

## 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 assessments.

Concerning the level assessment, 24 out of 192 categories are identified as key categories for the latest reporting year (see Table 1-4). Regarding the trend assessment between the base year 1990 and the reporting year, 13 categories are identified as trend key categories under approach 2 (see Table 1-5).

Contrary to approach 1 of the KCA, highlighting significant emission contributions from the energy sector, approach 2 is dominated by contributions from categories having a large uncertainty, mostly from sector 3 Agriculture and sector 4 LULUCF, and to a lesser extent from sector 5 Waste and sector 2 IPPU.

Table 1-4 Switzerland's key categories according to approach 2 level assessment for the year 2023, including LULUCF categories and indirect CO<sub>2</sub> emissions, sorted by uncertainty-weighted emission contribution (column F). Categories in grey are not key and are given for information only. Compare also with results of the sensitivity study for the year 2023, see bottom panel of Figure 1-3.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, LEVEL ASSESSMENT FOR 2023						
A	B	C	D	E	F	G
Code	IPCC category	Gas	Ex, t (kt CO <sub>2</sub> eq.)	Ex, t  (kt CO <sub>2</sub> eq.)	Lx, t (%)	Cumulative Total (%)
4.C.1	Grassland remaining grassland	CO <sub>2</sub>	387	387	29.1	29.1
3.D.1	Direct N <sub>2</sub> O emissions from managed soils	N <sub>2</sub> O	990	990	8.8	37.9
3.A	Enteric fermentation	CH <sub>4</sub>	3'604	3'604	8.8	46.7
4.B.1	Cropland remaining cropland	CO <sub>2</sub>	471	471	5.2	51.9
1.A.1	Energy industries; Other fossil fuels	CO <sub>2</sub>	2'431	2'431	5.2	57.1
3.B.1-4	Manure management	CH <sub>4</sub>	602	602	4.0	61.1
3.D.2	Indirect N <sub>2</sub> O Emissions from managed soils	N <sub>2</sub> O	423	423	3.4	64.6
4.A.2	Land converted to forest land	CO <sub>2</sub>	-786	786	3.3	67.9
5.D	Wastewater treatment and discharge	N <sub>2</sub> O	517	517	3.1	71.0
5.D	Wastewater treatment and discharge	CH <sub>4</sub>	230	230	2.6	73.5
3.B.5	Indirect N <sub>2</sub> O emissions	N <sub>2</sub> O	230	230	2.5	76.0
2.F.1	Refrigeration and air-conditioning	HFCs	1'110	1'110	1.7	77.7
4.A.1	Forest land remaining forest land	CO <sub>2</sub>	393	393	1.7	79.4
4.D.1	Wetlands remaining wetlands	CO <sub>2</sub>	112	112	1.6	80.9
1.A.4.b	Residential; Gaseous fuels	CO <sub>2</sub>	2'410	2'410	1.5	82.4
2.F.2	Foam blowing agents	HFCs	61	61	1.0	83.4
1.A.2	Manufacturing industries and construction; Gaseous fuels	CO <sub>2</sub>	1'668	1'668	1.0	84.5
5.A	Solid waste disposal	CH <sub>4</sub>	261	261	1.0	85.4
4.E.2	Land converted to settlements	CO <sub>2</sub>	155	155	0.9	86.4
3.B.1-4	Manure management	N <sub>2</sub> O	107	107	0.9	87.3
2.A.1	Cement production	CO <sub>2</sub>	1'506	1'506	0.8	88.1
5.C	Incineration and open burning of waste	N <sub>2</sub> O	53	53	0.8	88.9
1.A.3.b	Road transportation; Diesel oil	CO <sub>2</sub>	6'860	6'860	0.7	89.7
4.C.2	Land converted to grassland	CO <sub>2</sub>	352	352	0.7	90.4
1.A.4.a	Commercial/institutional; Gaseous fuels	CO <sub>2</sub>	960	960	0.6	91.0
4.F.2	Land converted to other land	CO <sub>2</sub>	91	91	0.6	91.5
1.A.3.b	Road transportation; Gasoline	CO <sub>2</sub>	6'366	6'366	0.5	92.0
Total number of key categories			24			

Table 1-5 Switzerland's key categories according to approach 2 trend assessment for 1990–2023, including LULUCF categories and indirect CO<sub>2</sub> emissions, sorted by decreasing uncertainty-weighted contribution to the trend assessment (column G). Categories in orange have an increased emission in 2023 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, TREND ASSESSMENT 1990 - 2023							
A	B	C	D	E	F	G	H
Code	IPCC category	Gas	Ex, 0 (kt CO <sub>2</sub> eq.)	Ex, t (kt CO <sub>2</sub> eq.)	Trend Assessment	Contribution to trend assess. (%)	Cumulative Total (%)
4.C.1	Grassland remaining grassland	CO <sub>2</sub>	-645	387	23.751	65.9	65.9
4.G	Harvested wood products	CO <sub>2</sub>	-1'149	42	2.638	7.3	73.2
4.A.1	Forest land remaining forest land	CO <sub>2</sub>	-1'286	393	2.225	6.2	79.4
1.A.1	Energy industries; Other fossil fuels	CO <sub>2</sub>	1'492	2'431	0.720	2.0	81.4
2.B.10	Other	N <sub>2</sub> O	384	1	0.608	1.7	83.1
5.D	Wastewater treatment and discharge	N <sub>2</sub> O	1'056	517	0.534	1.5	84.6
2.F.1	Refrigeration and air-conditioning	HFCs	0	1'110	0.453	1.3	85.8
5.A	Solid waste disposal	CH <sub>4</sub>	862	261	0.427	1.2	87.0
3.A	Enteric fermentation	CH <sub>4</sub>	3'930	3'604	0.301	0.8	87.8
2.F.2	Foam blowing agents	HFCs	0	61	0.283	0.8	88.6
5.D	Wastewater treatment and discharge	CH <sub>4</sub>	198	230	0.216	0.6	89.2
1.A.4.b	Residential; Gaseous fuels	CO <sub>2</sub>	1'465	2'410	0.205	0.6	89.8
3.D.2	Indirect N <sub>2</sub> O Emissions from managed soils	N <sub>2</sub> O	638	423	0.195	0.5	90.3
3.B.5	Indirect N <sub>2</sub> O emissions	N <sub>2</sub> O	209	230	0.186	0.5	90.8
1.A.2	Manufacturing industries and construction; Solid fuels	CO <sub>2</sub>	1'275	286	0.173	0.5	91.3
1.A.3.b	Road transportation; Gasoline	N <sub>2</sub> O	143	13	0.167	0.5	91.8
4.B.1	Cropland remaining cropland	CO <sub>2</sub>	523	471	0.157	0.4	92.2
Total number of key categories			13				

### 1.4.3. Summary of combined KCA including LULUCF categories

A summary of the key category analysis including LULUCF categories and indirect CO<sub>2</sub> emissions is shown in Table 1-6, considering the level assessment for 2023 and the trend assessment for 1990–2023, for both approach 1 and approach 2. A category is counted multiple times as key category if it is a key category for multiple gases.



Table 1-6 Summary of Switzerland key category analysis, including LULUCF categories and indirect CO<sub>2</sub> emissions. L: Level assessment (2023); T: Trend assessment (1990–2023); 1: KCA approach 1; 2: KCA approach 2. SF<sub>6</sub> and NF<sub>3</sub> are not emitted from any key category. Results of the level assessment for the base year are not reported in this table.

SUMMARIES TO IDENTIFY KEY CATEGORIES							
A	B	C & D					
Code	IPCC category	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFCs	PFCs	Ind. CO <sub>2</sub> (NMVOC)
1.A.1	Energy industries; Gaseous fuels	L1, T1			NA	NA	NA
1.A.1	Energy industries; Liquid fuels	L1, T1			NA	NA	NA
1.A.1	Energy industries; Other fossil fuels	L1, L2, T1, T2	NA		NA	NA	NA
1.A.2	Manufacturing industries and construction; Gaseous fuels	L1, L2, T1			NA	NA	NA
1.A.2	Manufacturing industries and construction; Liquid fuels	L1, T1			NA	NA	NA
1.A.2	Manufacturing industries and construction; Solid fuels	L1, T1			NA	NA	NA
1.A.2	Manufacturing industries and construction; Other fossil fuels	L1, T1			NA	NA	NA
1.A.3.a	Domestic aviation; Kerosene fossil	T1			NA	NA	NA
1.A.3.b	Road transportation; Diesel oil	L1, L2, T1		T1	NA	NA	NA
1.A.3.b	Road transportation; Gasoline	L1, T1	T1	T1	NA	NA	NA
1.A.4.a	Commercial/institutional; Gaseous fuels	L1, T1			NA	NA	NA
1.A.4.a	Commercial/institutional; Liquid fuels	L1, T1			NA	NA	NA
1.A.4.b	Residential; Gaseous fuels	L1, L2, T1, T2			NA	NA	NA
1.A.4.b	Residential; Liquid fuels	L1, T1			NA	NA	NA
1.A.4.c	Agriculture/forestry/fishing; Liquid fuels	L1, T1			NA	NA	NA
1.A.5	Other; Liquid fuels	L1			NA	NA	NA
2.A.1	Cement production	L1, L2, T1	NA	NA	NA	NA	NA
2.B.10	Other			T1, T2	NA	NA	NA
2.C.3	Aluminium production	T1	NA	NA	NA	T1	NA
2.D	Non-energy products from fuels and solvent use	NA	NA	NA	NA	NA	T1
2.F.1	Refrigeration and air-conditioning	NA	NA	NA	L1, L2, T1, T2		NA
2.F.2	Foam blowing agents	NA	NA	NA	L2, T2	NA	NA
3.A	Enteric fermentation	NA	L1, L2, T1, T2	NA		NA	NA
3.B.1-4	Manure management	NA	L1, L2	L2	NA	NA	NA
3.B.5	Indirect N <sub>2</sub> O emissions	NA	NA	L1, L2	NA	NA	NA
3.D.1	Direct N <sub>2</sub> O emissions from managed soils	NA	NA	L1, L2	NA	NA	NA
3.D.2	Indirect N <sub>2</sub> O Emissions from managed soils	NA	NA	L1, L2, T1, T2	NA	NA	NA
4.A.1	Forest land remaining forest land	L1, L2, T1, T2	NA	NA	NA	NA	NA
4.A.2	Land converted to forest land	L1, L2, T1	NA	NA	NA	NA	NA
4.B.1	Cropland remaining cropland	L1, L2	NA	NA	NA	NA	NA
4.C.1	Grassland remaining grassland	L1, L2, T1, T2	NA	NA	NA	NA	NA
4.C.2	Land converted to grassland	L1, L2, T1	NA	NA	NA	NA	NA
4.D.1	Wetlands remaining wetlands	L2	NA	NA	NA	NA	NA
4.E.2	Land converted to settlements	L1, L2	NA	NA	NA	NA	NA
4.G	Harvested wood products	T1, T2	NA	NA	NA	NA	NA
5.A	Solid waste disposal		L1, L2, T1, T2	NA	NA	NA	NA
5.C	Incineration and open burning of waste		L2	NA	NA	NA	NA
5.D	Wastewater treatment and discharge	NA	L1, L2, T1, T2	L1, L2, T1, T2	NA	NA	NA
Total number of key categories		26	5	9	2	1	1

## 1.5. General description of QA/QC plan and implementation

The national inventory system has an established and certified quality management system (QMS) that complies with the requirements of ISO 9001:2015 and the UNFCCC reporting guidelines (UNFCCC 2019, 2022a) to ensure and continuously improve transparency, consistency, comparability, completeness, accuracy, and confidence in national GHG emission and removal estimates. The quality manual (FOEN 2025a) contains all relevant information regarding the QMS. It is updated annually and made available to everyone contributing to the GHG inventory.

### 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 1-7). 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.

The National Inventory Report (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.



Table 1-7 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												
CRT Tables												
QC CRT Tables												
Uncertainties / KCA												
NID												
Internal review NID and CRT 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	

### Category-specific QC procedures

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, particularly with regard to whether the new data provide a better estimate given the country-specific circumstances and whether a consistent time-series can be derived from the new data. The core group then decides if and how to best implement the results and documents the agreed procedure in the inventory development plan. The general procedures regarding category-specific QC are also described in the quality manual (FOEN 2025a), 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.

Likewise, recommendations and encouragements from the UNFCCC expert review teams (ERT, TERT) 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 NID and CRT Table1.A(b).

As suggested by IPCC (2019, vol. 1, chp. 6.10) verification activities are carried out. 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 (3'580 m a.s.l.), 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 summarised in Annex A6.1.

Furthermore, an ongoing project is developing an independent estimate of CH<sub>4</sub> and N<sub>2</sub>O emissions in Switzerland based on atmospheric measurements and inverse modelling of atmospheric transport. The results show a very good agreement between modelled emissions and emission estimates according to the greenhouse gas inventory for CH<sub>4</sub> and reasonable agreement within the uncertainties for N<sub>2</sub>O. A summary of the current state of these verification activities is provided in Annex A6.2.

## 1.6. General uncertainty assessment

The input uncertainty estimates for the greenhouse gas inventory under the UNFCCC and the obtained results as required by UNFCCC (2019, paragraph 29) are presented hereafter.

### 1.6.1. Data used

Input uncertainty values are mostly given for activity data and emissions factors. For categories concerning indirect CO<sub>2</sub> emissions and F-gases, uncertainty values are available for emissions only.

Input uncertainty values are selected and/or computed based on available data and according to the following order of preference:

- As a first choice, specific uncertainty information from studies or from data suppliers is used, if available. This is the case for most key categories.
- As a second choice, authors of the NID chapters, FOEN experts involved and several data suppliers derived estimates of uncertainties based on the IPCC Guidelines` (IPCC 2006, 2019) 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.
- As a last choice, for categories with no quantitative uncertainty data available, the NID 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 relevant gases and three uncertainty levels: low, medium and high (see Table 1-8). 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 2<sup>nd</sup> International Workshop on Uncertainty in Greenhouse Gas Inventories (Vienna 27–28 September 2007), and by expert judgement from sectoral experts and authors.

The following sources of uncertainties are not taken into account:

- Uncertainties in the GWP values.
- Uncertainty due to unknown bias.
- Uncertainty due to neglected temporal variability when assuming constant parameters over time (e.g. emission factors).

Several uncertainty values have been changed compared to the previous submission (see detailed input values in Annex A2.1):

- The uncertainty for the emission factor of category 1A Gaseous fuels CO<sub>2</sub> was updated (yearly update).
- The uncertainties assigned to emissions of HFCs, PFCs, SF<sub>6</sub> and NF<sub>3</sub> in sector 2 IPPU were updated (yearly update).
- The uncertainties assigned to emission factors for source categories 2B10 (CO<sub>2</sub>) were reassessed (see Chapter 4 for more details).
- The uncertainties assigned to activity data and emission factors in sector 3 Agriculture for CH<sub>4</sub> and N<sub>2</sub>O emissions were updated (yearly update).
- The uncertainties for the emissions for all indirect CO<sub>2</sub> emissions were updated (yearly update).

The detailed data sources can be found in the relevant chapters on “Uncertainties and time-series consistency” in each of the sectoral chapters (chp. 3 to 9) below.

Table 1-8 Semi-quantitative (combined) uncertainties (U) for the emission of categories with no quantitative uncertainty data available. Note that there is no source of HFCs, PFCs, SF<sub>6</sub> or NF<sub>3</sub> for which a semi-quantitative uncertainty value is required.

Gas	Uncertainty category	Combined uncertainty
CO <sub>2</sub>	low	2%
	medium	10%
	high	40%
CH <sub>4</sub>	low	15%
	medium	30%
	high	60%
N <sub>2</sub> O	low	40%
	medium	80%
	high	150%

### 1.6.2. Methodology

The uncertainty aggregation for the greenhouse gases is carried out for the latest submission according to approach 1 (uncertainty propagation) and approach 2 (Monte Carlo simulations).

Input uncertainty values for activity data and emission factors at the same aggregation level as required for the key category analysis are used for the computation. A total of 192 categories were considered, including LULUCF and indirect CO<sub>2</sub> emissions. Indirect N<sub>2</sub>O emissions are not included in the uncertainty analysis.

Uncertainties are assessed in accordance with the IPCC Guidelines 2006 (IPCC 2006). The Monte Carlo simulations follow the recommendations by JCGM (2008, Supplement 1).

The following assumptions were applied to both approaches:

- Full correlation or no correlation can be set between the base year and the latest reporting year for the same input variable.
- The following statistical distributions may be used: normal, triangular, gamma. If a variable cannot physically have negative values and has an uncertainty >100 %, a gamma distribution is preferred in order to not generate negative values during Monte Carlo simulations. This is particularly relevant for emission factors.
- Asymmetric distribution: in approach 1, this is taken into account by computing the uncertainty propagation separately for each side of the mean. In approach 2, each distribution can be simulated, and asymmetric distributions are not an issue.

The following factors are not accounted for:

- Partial correlation between the base year and the latest reporting year for the same input variable.
- Correlations between categories (for different input variables).

For both approaches, all uncertainty results represent a 95 % confidence interval. For a symmetrical distribution, this interval is centred on the mean, from 2.5 % up to 97.5 % of the distribution. For non-symmetrical distributions obtained by Monte Carlo simulations, the reported uncertainties represent the narrowest 95 % interval, in agreement with JCGM (2008, S1). This has consequences in particular for combined uncertainties strongly influenced by input gamma distributions, with the narrowest interval having the tendency to be shifted towards the lower end of the distribution (for example, from 1 % up to 96 % of the distribution). Uncertainties are given for the lower range (from the lower edge to the mean) and the upper range (from the mean to the upper edge), expressed as a percentage of the mean.

#### **1.6.2.1. Aggregation of uncertainties using approach 1: uncertainty propagation**

The uncertainty propagation is computed using the open-source software Python (version 3.6.1, <https://www.python.org/>), in which the equations given in the guidelines (IPCC 2006) are programmed. Results of approach 1 for the latest reporting year and for the trend are summarised in Table 1-9.

#### **1.6.2.2. Aggregation of uncertainties using approach 2: Monte Carlo simulations**

The Monte Carlo simulations were performed for the base year 1990, the reporting year 2023 and the trend at the aggregation level required for the KCA (chp. 1.4). All input variables can be found in Annex A2.1. Results for each gas are summarised in Table 1-11.

The main strategy in Monte Carlo analysis is to simulate a probability distribution for each input variable (distribution type, mean and standard deviation) and propagate these

probability distributions to the final value of the model, in order to obtain a realistic uncertainty envelope for the final quantity. In practice, this is achieved by generating a large set of random numbers for each input quantity according to its distribution probability and by computing the intermediate (if any) and final values according to the equations of the model. The strength of this method is to propagate uncertainties accurately even if the equations of the model are non-linear and even if the final uncertainty envelope is non-symmetric. Another advantage is that a distribution is produced to represent the final quantity, while this information is not available from approach 1.

With these chosen settings, each input quantity is, for each year, an activity data value associated with an emission factor or if applicable, a direct emission. The final quantity is the emission at the inventory level and the mathematical model is the sum of emissions from each process.

### Modelling framework

The Monte Carlo simulations are programmed using the open-source software Python (version 3.6.1, <https://www.python.org/>). Python is run through the Anaconda installation (<https://www.anaconda.com/>, version 4.4.0 (64 bit)) on a Windows PC.

To generate random numbers corresponding to the selected distributions, mean and variances, the Python function `random` is used. In practice, for each input emission factor and activity data value (or direct emission, if applicable), random numbers are generated according to the input parameters. The final uncertainty envelope is obtained by computing the emissions as the product of simulated activity data and emission factors and by then adding up all simulated emissions. Intermediate sums can also be obtained, for example the sum for a given sector.

For each input quantity, 100'000 random values were generated resulting in equal numbers of values for the base year, the latest reporting year and the trend.

The average offset between the simulated mean for each process and the input mean is less than 0.15 %. This reflects the uncertainty introduced by the Monte Carlo method itself. This computational uncertainty remains small compared to the uncertainty introduced by activity data and emission factors.

### Correlation

If two variables representing the base year (BY) and the latest reporting year (RY) for the same process are fully correlated, a random number is generated for the base year only, written  $BY_{\text{random}}$ . The random value for the reporting year  $RY_{\text{random}}$  is then computed as:

$$RY_{\text{random}} = BY_{\text{random}} * RY_{\text{input, mean}} / BY_{\text{input, mean}}$$

where  $RY_{\text{input, mean}}$  and  $BY_{\text{input, mean}}$  are the input mean values for the variables in the latest reporting year and the base year, respectively.

This method implicitly assumes that the uncertainty for the base year and the latest reporting year, expressed in percentage of the mean value, stays the same.

No correlation between activity data (or emission factors) resulting from different processes for the same year is programmed.

## Sensitivity analysis

The sensitivity analysis investigates how sensitive the total emission is to each input emission. This analysis was conducted for the base year and the latest reporting year.

The sensitivity of a total value (total base year emission, total latest reporting year emission) to the variability of input quantities is computed as the correlation coefficient between total and input values, using in Python the function `corrcoef` from the `numpy` package. Each sensitivity value is computed on 100'000 pairs of points.

The sensitivity therefore has a value between -1 and +1, where a negative value indicates a negative correlation, and a positive value a positive correlation. For emissions, since the total values are a sum of input values, only positive correlations are expected.

Intuitively, the variability in the total value will be very sensitive to a process with also a high variability, compared to other processes with a smaller variability. In other words, the inventory total is expected to be mostly sensitive to processes with a high uncertainty (expressed in absolute values or in the same unit as the emissions).

## Source code availability

The Python source code is available on the Github public repository with the repository name <inventory\_uncertainty\_UNFCCC\_CLRTAP>.

### 1.6.3. Results of approaches 1 and 2 uncertainty evaluation

In Table 1-9 the results of the uncertainty evaluations for the previous and latest submissions are summarised, using approaches 1 and 2 for the base year, the respective latest reporting year and the trend, excluding and including the LULUCF sector.

Table 1-9 Relative uncertainties for Switzerland's national total greenhouse gas emissions and removals excluding and including the LULUCF sector for the latest and previous submissions. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. Uncertainties are obtained by approach 1 (uncertainty propagation) and 2 (Monte Carlo simulations) for emission levels in 1990, 2023 and for the trend (1990–2023) and are detailed by lower range, upper range and mean uncertainty for submission 2025 as displayed in the upper panel. The uncertainty analyses are based on emissions and removals including indirect CO<sub>2</sub> emissions. For comparison purposes, the corresponding values from the previous submission are reported as well in the lower panel labelled submission 2024.

Submission 2025												
Source category	Emissions 1990				Emissions 2023				Trend 1990-2023			
	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	U mean %	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	U mean %	Value %	U(-)%	U(+)%	U mean %
Uncertainty propagation (approach 1)												
Total incl. LULUCF	52'577	3.9	4.7	4.3	42'146	6.5	6.8	6.7	-19.8	7.4	7.7	7.5
Total excl. LULUCF	55'244	2.9	3.8	3.3	40'847	2.9	3.6	3.2	-27.4	3.0	3.7	3.4
Monte Carlo simulations (approach 2)												
Total incl. LULUCF	52'577	4.2	4.4	4.3	42'146	6.8	6.6	6.7	-19.8	6.3	6.2	6.2
Total excl. LULUCF	55'244	3.2	3.4	3.3	40'847	3.2	3.3	3.2	-27.4	3.6	3.5	3.5
Submission 2024												
Source category	Emissions 1990				Emissions 2022				Trend 1990-2022			
	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	U mean %	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	U mean %	Value %	U(-)%	U(+)%	U mean %
Uncertainty propagation (approach 1)												
Total incl. LULUCF	52'099	4.2	4.9	4.6	42'064	4.1	4.5	4.3	-19.3	4.5	5.0	4.8
Total excl. LULUCF	55'058	2.8	3.6	3.2	41'630	2.8	3.3	3.1	-25.8	2.9	3.6	3.2
Monte Carlo simulations (approach 2)												
Total incl. LULUCF	52'099	4.5	4.7	4.6	42'064	4.3	4.4	4.3	-19.3	4.9	4.8	4.8
Total excl. LULUCF	55'058	3.1	3.3	3.2	41'630	3.0	3.1	3.1	-25.8	3.5	3.5	3.5

In general, mean uncertainties resulting from approaches 1 and 2 are in concordance. For the lower range uncertainty, approach 1 may result in a smaller estimate in cases where the inventory probability distribution is asymmetric. Therefore, it is recommended to take into consideration the uncertainty estimate provided by approach 2 (Monte Carlo simulations). Uncertainties including the LULUCF sector are in each case larger than excluding the LULUCF sector, as processes in the LULUCF sector have comparatively large uncertainties.

The overall level uncertainty for the latest reporting year 2023 and the trend uncertainty are larger for the latest submission compared to the previous one, by approx. 2.5 percentage points. This significant increase can be attributed to a noticeably larger uncertainty contribution from sector 4 LULUCF.

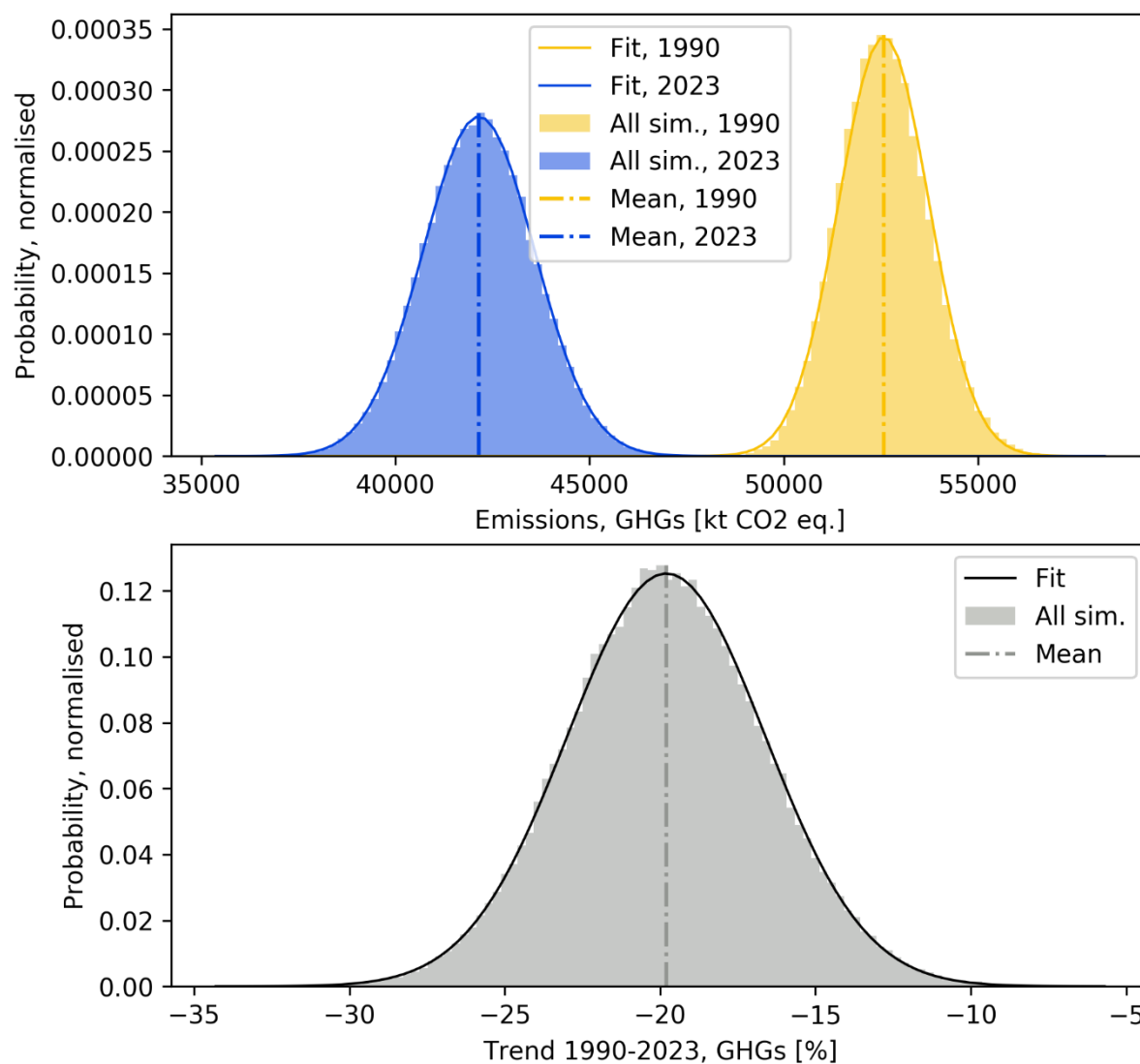


Figure 1-2 Results of Monte Carlo simulations: Distributions obtained for the inventory mean emission for all greenhouse gases, for the base year 1990 (top panel, yellow), the reporting year 2023 (top panel, blue) and the trend 1990–2023 (bottom panel, grey). All sim.: all simulations (100'000 values for each distribution). Fit: fit of the distribution using a normal distribution. By definition, the integral of the fit (or area) has an exact numeric value of one. Mean: mean inventory emission obtained from the simulations.



Table 1-10 Overview of sector contributions to inventory uncertainties for the base year and the latest reporting year emissions and removals and for the trend, including indirect CO<sub>2</sub> emissions. Uncertainties are computed using approach 1 (uncertainty propagation) and approach 2 (Monte Carlo simulations).

IPCC category	Emissions 1990				Emissions 2023				Contribution to trend 1990-2023			
	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	Contrib. fraction	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	Contrib. fraction	Value %	U(-)%	U(+)%	Contrib. fraction
Uncertainty propagation (approach 1)												
1 Energy	41'689	0.81	0.81	0.022	30'435	1.5	1.5	0.028	-21.4	0.72	0.72	0.0092
2 Industrial processes and product use	4'247	7.1	7.4	0.018	3'286	5.1	6.8	0.0049	-1.83	0.42	0.58	0.0045
3 Agriculture	7'043	18	23	0.42	6'001	17	22	0.17	-1.98	2.8	3.4	0.17
4 Land use land use change and forestry	-2'666	50	50	0.34	1'299	191	191	0.78	7.54	6.7	6.7	0.80
5 Waste	2'250	35	53	0.20	1'115	27	38	0.017	-2.16	0.80	1.1	0.017
6 Other sources	15	77	123	0.000049	9.7	69	111	0.000010	-0.0110	0.012	0.014	0.000003
<b>Total, inventory</b>	<b>52'577</b>	<b>3.9</b>	<b>4.7</b>	<b>1.0</b>	<b>42'146</b>	<b>6.5</b>	<b>6.8</b>	<b>1.00</b>	<b>-20</b>	<b>6.3</b>	<b>6.2</b>	<b>1.00</b>
Monte Carlo simulations (approach 2)												
1 Energy	41'689	0.82	0.80	0.022	30'435	1.5	1.5	0.028	-21.4	1.1	1.1	0.027
2 Industrial processes and product use	4'247	7.2	7.4	0.019	3'286	5.8	6.0	0.0048	-1.83	0.64	0.65	0.0090
3 Agriculture	7'043	21	21	0.42	6'001	19	19	0.17	-1.98	3.6	3.4	0.26
4 Land use land use change and forestry	-2'666	49	50	0.34	1'299	187	192	0.78	7.54	5.4	5.3	0.62
5 Waste	2'250	40	46	0.19	1'115	30	34	0.017	-2.16	2.0	1.8	0.080
6 Other sources	15	77	107	0.000051	9.7	72	97	0.000011	-0.0110	0.024	0.018	0.000010
<b>Total, inventory</b>	<b>52'577</b>	<b>4.2</b>	<b>4.4</b>	<b>1.00</b>	<b>42'146</b>	<b>6.8</b>	<b>6.6</b>	<b>1.0</b>	<b>-20</b>	<b>6.3</b>	<b>6.2</b>	<b>1.0</b>

Table 1-11 For each gas, net emission levels for 1990 and 2023, contribution to the inventory trend (1990–2023), and associated uncertainties obtained from Monte Carlo simulations and from uncertainty propagation, including indirect CO<sub>2</sub> emissions and LULUCF categories. Note that the contribution to the trend and its associated uncertainty are expressed in the same unit, in percent. As an example, for a trend contribution of -10 % with uncertainties of 2 %, the trend contribution is comprised between -12 % and -8 %.

Gas	Emissions 1990				Emissions 2023				Contribution to trend 1990-2023			
	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	Contrib. fraction	Value kt CO <sub>2</sub> eq.	U(-)%	U(+)%	Contrib. fraction	Value %	U(-)%	U(+)%	Contrib. fraction
Uncertainty propagation (approach 1)												
CO <sub>2</sub>	41'399	3.3	3.3	0.36	33'217	7.6	7.6	0.80	-15.6	6.8	6.8	0.81
CH <sub>4</sub>	6'256	15	16	0.19	4'884	16	18	0.089	-2.61	2.1	2.4	0.091
N <sub>2</sub> O	4'285	28	42	0.45	2'639	28	39	0.10	-3.13	1.9	2.7	0.098
HFCs	0.023	23	23	0.000000	1'226	12	17	0.0041	2.33	0.40	0.56	0.0041
PFCs	105	8.6	8.6	0.000016	28	9.6	13	0.000001	-0.146	0.0073	0.010	0.000001
SF <sub>6</sub>	141	25	25	0.000025	58	26	26	0.000029	-0.159	0.041	0.041	0.000029
NF <sub>3</sub>	NO	NO	NO	NO	0.62	70	111	0.000000	0.00117	0.0012	0.0018	0.000000
Indirect CO <sub>2</sub> total	392	29	38	0.0034	94	29	40	0.00014	-0.568	0.074	0.10	0.00014
<b>Total, inventory</b>	<b>52'577</b>	<b>3.9</b>	<b>4.7</b>	<b>1.0</b>	<b>42'146</b>	<b>6.5</b>	<b>6.8</b>	<b>1.0</b>	<b>-20</b>	<b>6.3</b>	<b>6.2</b>	<b>1.0</b>
Monte Carlo simulations (approach 2)												
CO <sub>2</sub>	41'399	3.3	3.3	0.36	33'217	7.5	7.6	0.81	-15.6	5.2	5.2	0.62
CH <sub>4</sub>	6'256	15	16	0.19	4'884	17	17	0.089	-2.61	2.3	2.4	0.13
N <sub>2</sub> O	4'285	34	36	0.45	2'639	31	35	0.10	-3.13	3.3	3.2	0.24
HFCs	0.023	23	24	0.000000	1'226	14	15	0.0039	2.33	0.34	0.36	0.0028
PFCs	105	8.6	8.5	0.000016	28	11	12	0.000001	-0.146	0.019	0.019	0.000009
SF <sub>6</sub>	141	25	25	0.000024	58	26	26	0.000029	-0.159	0.073	0.074	0.00013
NF <sub>3</sub>	NO	NO	NO	NO	0.62	80	92	0.000000	0.00117	0.00093	0.0011	0.000000
Indirect CO <sub>2</sub> total	392	33	34	0.0033	94	32	37	0.00014	-0.568	0.27	0.25	0.0015
<b>Total, inventory</b>	<b>52'577</b>	<b>4.2</b>	<b>4.4</b>	<b>1.00</b>	<b>42'146</b>	<b>6.8</b>	<b>6.6</b>	<b>1.0</b>	<b>-20</b>	<b>6.3</b>	<b>6.2</b>	<b>1.0</b>

Table 1-12 Uncertainties for individual F-gases obtained by Monte Carlo simulations, for the years 1990 and 2023. Monte Carlo simulations were run 100'000 times. The reported uncertainties correspond to the borders of the narrowest 95 % confidence interval.

Gas	Emissions 1990			Emissions 2023		
	Value kt CO <sub>2</sub> eq.	(-)%	(+)%	Value kt CO <sub>2</sub> eq.	(-)%	(+)%
Monte Carlo simulations (approach 2)						
HFC-125	NO	NO	NO	345	17	17
HFC-134a	0.023	23	24	582	25	28
HFC-143a	NO	NO	NO	238	23	23
HFC-152a	NO	NO	NO	0.034	100	52
HFC-227ea	NO	NO	NO	1.7	90	114
HFC-23	NO	NO	NO	4.1	49	53
HFC-236fa	NO	NO	NO	0.69	100	191
HFC-245fa	NO	NO	NO	0.18	8	8
HFC-32	NO	NO	NO	46	17	18
HFC-365mfc	NO	NO	NO	8.4	83	108
PFCs	105	9	9	28	11	12
SF <sub>6</sub>	141	25	25	58	27	26
NF <sub>3</sub>	NO	NO	NO	0.62	80	92

Changes in total level and trend uncertainties are on one hand due to changes in uncertainties assigned to emission factors and activity data in the different categories. On the other hand, changes in activity data and emission factor values cause changes in the contribution to the total level and trend uncertainty of each category.

Contribution to level uncertainty and the uncertainty introduced to the trend in total national emissions of each category are shown in Annex A2.2 for approach 1 (uncertainty propagation) and in Annex A2.3 for approach 2 (Monte Carlo simulations).

The Monte Carlo simulations provide data to conduct a sensitivity analysis between emissions from each category and the inventory (total) emission. This analysis quantifies the influence of a change in the emission of a given category on the inventory total. The results of the sensitivity analysis for the base year and the latest reporting year are shown in Figure 1-3. The processes ranked in descending order of importance according to the sensitivity analysis follow almost the same order as the processes ranked according to approach 2 of the key category analysis. In both cases, results are dominated by categories from sectors 3 Agriculture and 4 LULUCF. Both methods highlight categories with large uncertainties, expressed in absolute values. The sensitivity analysis therefore confirms the results obtained by approach 2 of the KCA.

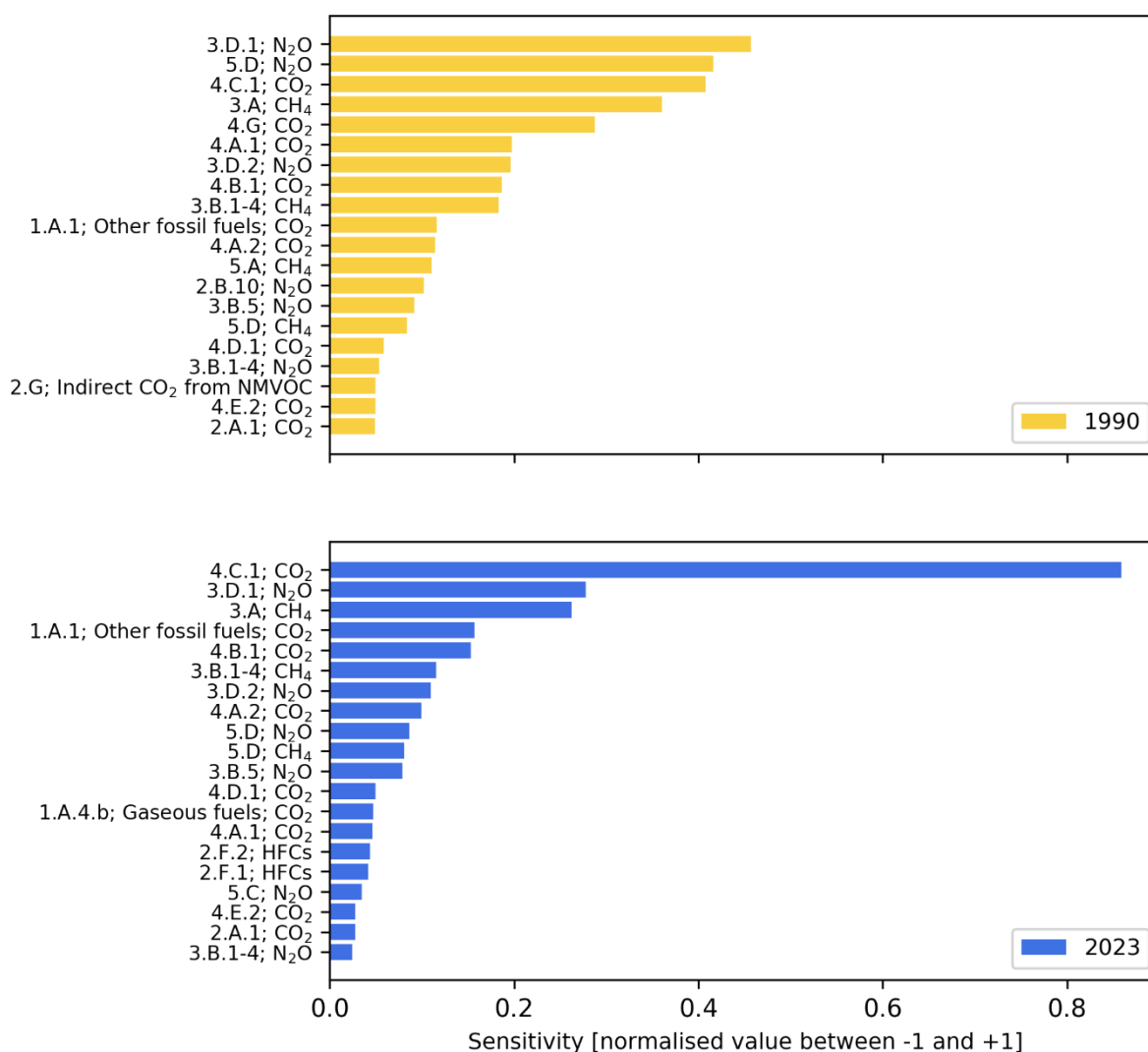


Figure 1-3 Results of the sensitivity analysis between emissions and removals from each category and inventory emissions and removals for all greenhouse gases, for the base year 1990 and the reporting year 2023. Only the twenty categories ranked first are listed. See chp. 1.6.2.2 for details and compare also with Table 1-4 (results for the key category analysis approach 2, i.e. using uncertainties).

Based on the analysis of the predominant contributions to the uncertainty of the national GHG inventory, the FOEN commissions and/or supports various projects. Planned improvements are given in the sectoral chapters and an overview list is reported in chp. 10.4.

## 1.7. General assessment of completeness

### 1.7.1. Information on completeness

The inventory is compiled using notation keys in the reporting tables as appropriate, according to the modalities, procedures and guidelines for the transparency framework under the Paris Agreement (UNFCCC 2019). Explanations for using the notation keys “NE” and “IE” are provided in CRT Table9.

Until Submission 2024, the CRF reporter did not transfer the use of notation keys in tables 1.A(b) Reference approach and 1.A(d) Feedstock, reductants and other non-energy use of

fuels into CRF Table9. Therefore, information on the use of notation key “IE” in tables 1.A(b) and 1.A(d) is provided here for completeness:

- 1.A(b) Reference approach, liquid fuels: Imports of refinery feedstocks are included in crude oil.
- 1.A(b) Reference approach, liquid fuels: Imports of other kerosene are included in jet kerosene.
- 1.A(b) Reference approach, liquid fuels: Carbon stored of liquefied petroleum gas, naphtha and petroleum coke are included in other oil.
- 1.A(b) Reference approach, solid fuels: Import and stock change of anthracite and coke oven/gas coke are included in other bituminous coal.
- 1.A(d) Feedstock, reductants and other non-energy use of fuels, liquid fuels: fuel quantity, C excluded from reference approach and CO<sub>2</sub> emissions for liquefied petroleum gas, naphtha and petroleum coke are included in other oil.

### 1.7.2. Description of insignificant categories

- A study commissioned by FOEN measuring greenhouse gas emissions from waste incineration plants came to the conclusion that "CH<sub>4</sub> emission concentrations were very low and below the background concentration of 1.8 ppm" (Mohn 2013). These measurements showed that CH<sub>4</sub> concentration in the exhaust air was below the CH<sub>4</sub> concentration in ambient air, which would indicate CH<sub>4</sub> removal rather than emissions. Therefore, CH<sub>4</sub> emissions from municipal waste incineration are reported as not estimated because they are considered insignificant (see chp. 3.2.5.2.1).
- Use of soda ash is reported for glass production (2A3) and ceramics (2A4a). A study investigating carbonate use in industry (INFRAS 2015) could not identify any other uses of soda ash. However, the amounts of soda ash used and reported in 2A3 and 2A4a are slightly smaller than net imports of soda ash. Assuming that the amount of soda ash unaccounted for in 2A3 and 2A4a caused additional CO<sub>2</sub> emissions in category 2A4b Other uses of soda ash, this would result in roughly 5 kt CO<sub>2</sub> in recent years (see chp. 4.2.2.4).

### 1.7.3. Total aggregate emissions considered insignificant

Here, Swiss emissions considered insignificant are discussed. Switzerland's national emissions and removals sum up to 42'146 kt of CO<sub>2</sub> equivalent in 2023. Therefore, the significance threshold for aggregated emissions equals 42.1 kt CO<sub>2</sub> equivalent. In the following some details are presented.

Exhaust gas measurements indicate that waste incineration plants are more likely to destroy ambient CH<sub>4</sub> rather than produce CH<sub>4</sub> itself (see chapter 3.2.5.2.1). Accordingly, CH<sub>4</sub> emissions from waste incineration are considered insignificant and reported as not estimated, with no contribution to total aggregate emissions.

Potential other uses of soda ash not already accounted for in Switzerland might produce 5 kt CO<sub>2</sub> (see chapter 4.2.2.4).

## **1.8. Metrics**

The inventory is prepared using the 100-year time-horizon global warming potential (GWP) values from the IPCC Fifth Assessment Report (Myhre et al. 2013) as required by the modalities, procedures and guidelines for the transparency framework under the Paris Agreement (UNFCCC 2019).

## **1.9. Summary of any flexibility applied**

Not applicable.

## 2. Trends in greenhouse gas emissions and removals

Responsibilities for Trends in greenhouse gas emissions and removals	
Authors	Michael Bock (FOEN), Nele Rogiers (FOEN; LULUCF), Andreas Schellenberger (FOEN; LULUCF), Adrian Schilt (FOEN; Energy, Indirect emissions)
Annual updates (NID text, tables, figures)	Beat Rihm (Meteotest; LULUCF), Nele Rogiers (FOEN), Felix Weber (INFRAS)
Quality control NID (annual updates)	Dominik Eggli (Meteotest), Beat Rihm (Meteotest), Andreas Schellenberger (FOEN; LULUCF)
Internal review	Michael Bock (FOEN), Anita Bertiler (Sigmaplan), Daniel Bretscher (Agroscope), Nele Rogiers (FOEN), Andreas Schellenberger (FOEN), Adrian Schilt (FOEN)

This chapter provides an overview of Switzerland's GHG emissions and removals in 2023 as well as trends for the period 1990–2023.

### 2.1. Aggregated greenhouse gas emissions and removals

Switzerland's national emissions and removals sum up to 42'146 kt of CO<sub>2</sub> equivalent including LULUCF in 2023; when excluding LULUCF, total territorial emissions are 40'847 kt CO<sub>2</sub> eq. Table 2-1 shows the aggregated emissions of all greenhouse gases (GHG) 2023 for each sector (including indirect CO<sub>2</sub>) and the relative shares of the sectors. Furthermore, emission data on international aviation and marine bunkers are provided. As the table indicates, CO<sub>2</sub> is the main contributor to total GHG emissions followed by CH<sub>4</sub>, N<sub>2</sub>O and F-gases. Sector 1 Energy is the main source concerning climate-related emissions followed by sectors 3 Agriculture and 2 IPPU. In the years 2000, 2015, 2018 and the latest reported year 2023, sector 4 LULUCF acts as a net source rather than a net sink regarding GHG net emissions and removals. In 2023, emissions of sector 5 Waste are smaller than LULUCF net emissions.

Table 2-1 Switzerland's GHG emissions in CO<sub>2</sub> equivalent (kt) by gas and sector in 2023. The last two columns show the share of the total for each sector including indirect CO<sub>2</sub> emissions excluding and including LULUCF.

Sectors	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFCs	PFCs	SF <sub>6</sub>	NF <sub>3</sub>	Indirect CO <sub>2</sub>	Total excl. ind.	Total incl. ind.	Share wrt Total excl. LULUCF	Share wrt Total incl. LULUCF
CO <sub>2</sub> equivalent (kt)												
1 Energy	30'066	128	232					9.4	30'425	30'435	75%	72%
2 Industrial processes and product use	1'849	5.1	37	1'226	28	58	0.62	82	3'204	3'286	8.0%	7.8%
3 Agriculture	46	4'206	1'749						6'001	6'001	15%	14%
5 Waste	8.3	528	578					1.1	1'114	1'115	2.7%	2.6%
6 Other	8.2	0.46	0.27					0.75	8.9	9.7	0.024%	0.023%
<b>Total (excluding LULUCF)</b>	<b>31'977</b>	<b>4'867</b>	<b>2'596</b>	<b>1'226</b>	<b>28</b>	<b>58</b>	<b>0.62</b>	<b>94</b>	<b>40'753</b>	<b>40'847</b>	<b>100%</b>	<b>97%</b>
4. Land use, land-use change and forestry	1'240	16	43						1'299	1'299	3.2%	3.1%
<b>Total (including LULUCF)</b>	<b>31'977</b>	<b>4'884</b>	<b>2'639</b>	<b>1'226</b>	<b>28</b>	<b>58</b>	<b>0.62</b>	<b>94</b>	<b>42'053</b>	<b>42'146</b>	<b>103%</b>	<b>100%</b>
International aviation bunkers	5'015	0.40	37						5'051	5'051		
International marine bunkers	15	0.0034	0.12						15	15		

A breakdown of Switzerland's total emissions by gas (excluding LULUCF) is given in Figure 2-1. Figure 2-2 charts the relative contributions of the individual sectors (excluding LULUCF) to the emissions of each GHG. Trends in GHG emissions per gas and per sector are given in chp. 2.2. The national total of 40'847 kt of CO<sub>2</sub> equivalent excluding LULUCF (see Table 2-1) corresponds to 4.6 tonnes of CO<sub>2</sub> equivalent per capita (CO<sub>2</sub>: 3.6 tonnes per capita) emitted

to the atmosphere in 2023. Emissions per capita are calculated based on population statistics from the Federal Statistical Office (FSO 2024c).

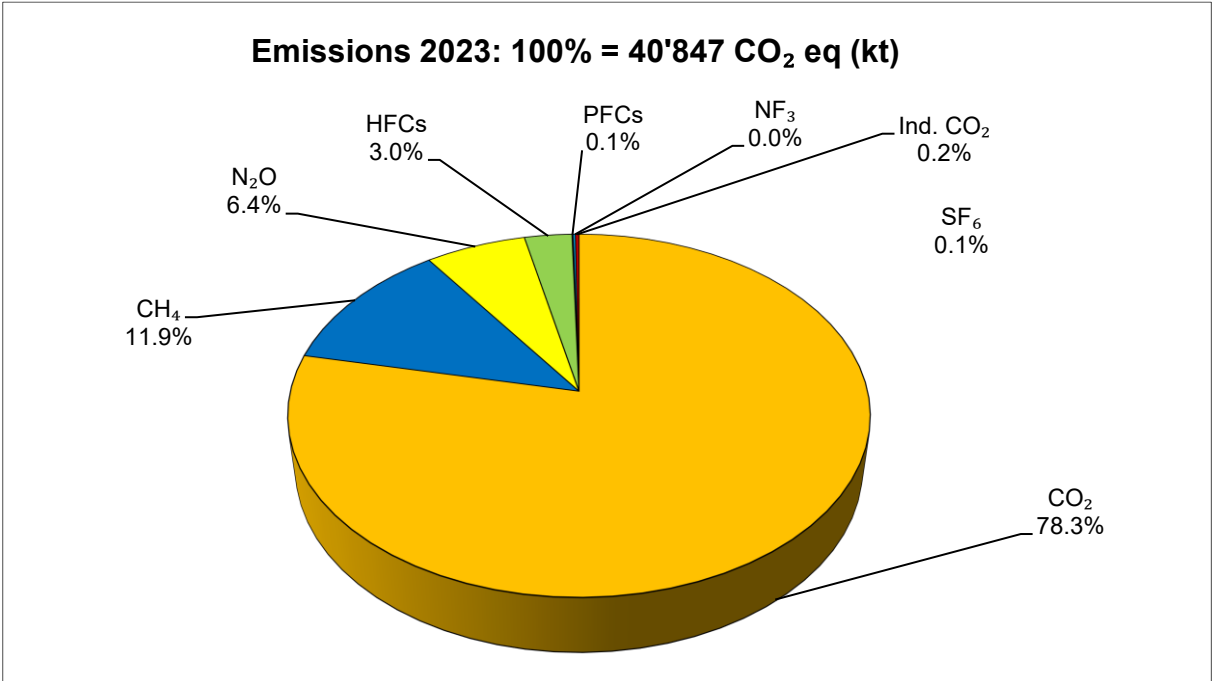


Figure 2-1 Contribution of individual gases to total greenhouse gas emissions in 2023 (excluding LULUCF).

A clear dominance of CO<sub>2</sub> emissions in 2023 is related to source category 1A Fuel combustion within sector 1 Energy. CH<sub>4</sub> and N<sub>2</sub>O emissions mainly originate from sector 3 Agriculture, while F-gas emissions by definition only originate from sector 2 Industrial processes and product use.

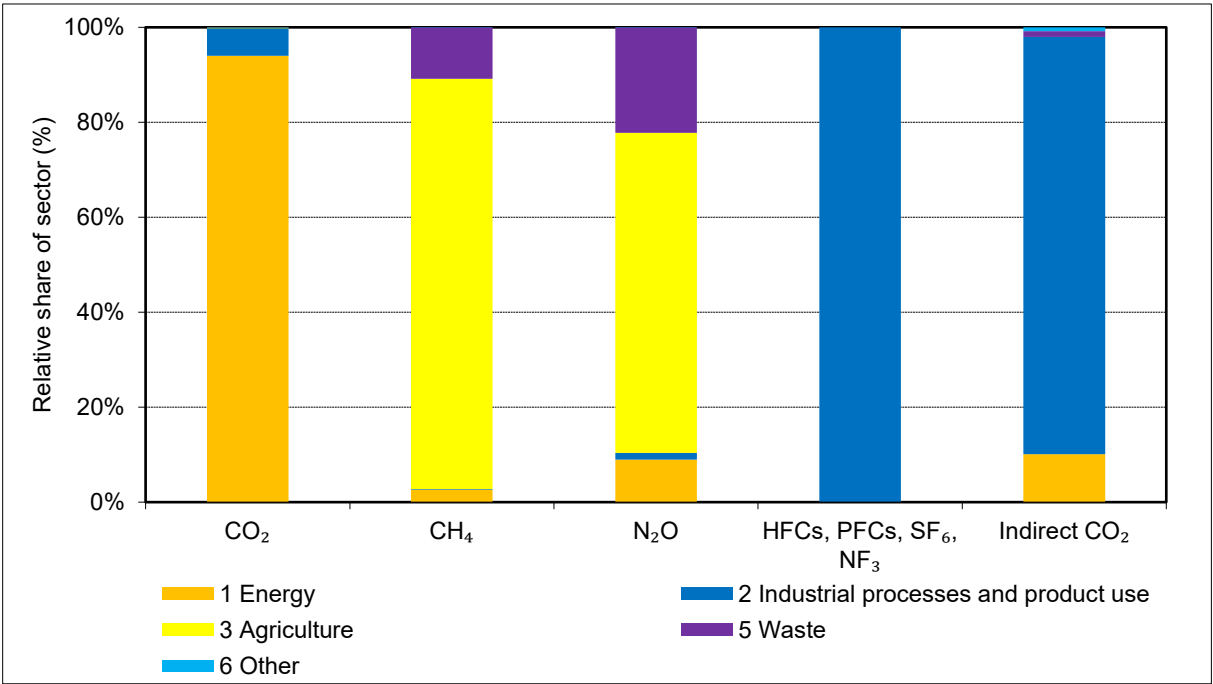


Figure 2-2 Relative contributions of the individual sectors (excluding LULUCF) to GHG emissions in 2023.

## 2.2. Emission and removal trends by gas and by sector

### 2.2.1. Emission and removal trends by gas

Emission trends by gas for the period 1990–2023 are summarised in Table 2-2.

Table 2-2 Greenhouse gas emissions in CO<sub>2</sub> equivalent (kt) by gas. The last column of the lower panel indicates the percentage change in emissions for the reporting year 2023 compared to the base year 1990. HFC emissions increased by more than 5 million percent when compared to 1990 levels. No NF<sub>3</sub> was emitted in 1990.

Greenhouse Gas Emissions	1990	1995	2000	2005	2010
CO <sub>2</sub> equivalent (kt)					
CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF	41'399	39'175	47'489	43'324	42'767
CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF	44'149	43'414	43'621	45'776	45'034
CH <sub>4</sub> emissions including CH <sub>4</sub> from LULUCF	6'256	5'863	5'493	5'475	5'432
CH <sub>4</sub> emissions excluding CH <sub>4</sub> from LULUCF	6'220	5'840	5'477	5'460	5'418
N <sub>2</sub> O emissions including N <sub>2</sub> O from LULUCF	4'285	4'205	3'989	3'709	3'518
N <sub>2</sub> O emissions excluding N <sub>2</sub> O from LULUCF	4'237	4'159	3'947	3'669	3'476
HFCs	0.023	227	605	997	1'245
PFCs	105	16	54	46	36
SF <sub>6</sub>	141	96	157	210	155
NF <sub>3</sub>	NO	NO	NO	NO	12
Indirect CO <sub>2</sub>	392	284	205	144	133
<b>Total (including LULUCF)</b>	<b>52'577</b>	<b>49'866</b>	<b>57'993</b>	<b>53'905</b>	<b>53'296</b>
<b>Total (excluding LULUCF)</b>	<b>55'244</b>	<b>54'036</b>	<b>54'065</b>	<b>56'303</b>	<b>55'507</b>

Greenhouse Gas Emissions	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs. 1990
CO <sub>2</sub> equivalent (kt)											%
CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF	35'191	39'874	35'956	36'353	38'009	33'622	33'065	35'456	31'458	33'217	-19.8%
CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF	39'244	38'756	39'225	38'234	36'945	36'822	34'343	35'902	32'951	31'977	-27.6%
CH <sub>4</sub> emissions including CH <sub>4</sub> from LULUCF	5'274	5'243	5'204	5'143	5'102	5'011	4'955	4'964	4'925	4'884	-21.9%
CH <sub>4</sub> emissions excluding CH <sub>4</sub> from LULUCF	5'260	5'229	5'186	5'128	5'088	4'998	4'942	4'951	4'907	4'867	-21.7%
N <sub>2</sub> O emissions including N <sub>2</sub> O from LULUCF	3'360	3'316	3'313	3'453	3'267	3'321	3'260	3'155	2'656	2'639	-38.4%
N <sub>2</sub> O emissions excluding N <sub>2</sub> O from LULUCF	3'318	3'275	3'267	3'409	3'224	3'279	3'218	3'113	2'611	2'596	-38.7%
HFCs	1'389	1'430	1'399	1'415	1'436	1'358	1'347	1'235	1'247	1'226	see caption
PFCs	21	24	18	29	33	29	34	28	28	28	-73.2%
SF <sub>6</sub>	270	281	254	239	184	178	156	131	56	58	-59.1%
NF <sub>3</sub>	0.57	0.68	0.72	0.75	0.47	0.51	0.39	0.37	0.31	0.62	see caption
Indirect CO <sub>2</sub>	112	107	108	107	100	103	100	95	94	94	-76.2%
<b>Total (including LULUCF)</b>	<b>45'618</b>	<b>50'276</b>	<b>46'253</b>	<b>46'741</b>	<b>48'130</b>	<b>43'622</b>	<b>42'917</b>	<b>45'064</b>	<b>40'465</b>	<b>42'146</b>	-19.8%
<b>Total (excluding LULUCF)</b>	<b>49'615</b>	<b>49'102</b>	<b>49'457</b>	<b>48'562</b>	<b>47'010</b>	<b>46'767</b>	<b>44'140</b>	<b>45'455</b>	<b>41'895</b>	<b>40'847</b>	-26.1%

As shown in Table 2-2, Table 2-3, and Figure 2-3, total emissions excluding LULUCF in 2023 are clearly below base year emissions. There is no discernible trend of overall emissions in the period 1990–2005. Only from 2005 onwards, a decreasing trend starts to develop. Also when including LULUCF categories, a decreasing trend is visible compared to the base year 1990, although the net CO<sub>2</sub> eq removals generated by LULUCF categories were generally smaller after 1997 and LULUCF was a net source in 2023 and three earlier years (see Figure 2-8, Figure 2-9 and Figure 6-4). The overall emission reduction between 1990 and 2023 amounts to 26.1 % when LULUCF categories are excluded and 19.8 % when including LULUCF. The emission maximum occurred in 1991. Compared to 2022, emissions have decreased in 2023 when excluding LULUCF (by 2.5 %) and increased when including LULUCF (by 4.1 %). The reduction of emissions from 1 Energy is mainly due to reduced emissions from heating fuels, mainly oil and gas. The main reasons for the decrease are the improved energy efficiency of buildings and the increasing use of renewable energies for heating. Heating demand (related to meteorological conditions such as temperature and insolation) play a similar role for the two years 2022 and 2023 (see Figure 2-7). As a result, CO<sub>2</sub> emissions from source category 1A4 Other sectors declined only modestly in 2023 compared to 2022.



The decrease of emissions between 2019 and 2020 can partially be interpreted as a consequence of the lockdown and subsequent measures associated with the COVID-19 pandemic that affected Switzerland from March 2020 onwards.

The trends of the different greenhouse gases can be described as follows:

- There is a strong correlation between **CO<sub>2</sub>** emissions and meteorological conditions (number of heating degree days; see box 1 on page FOEN); Starke, Michael (BFH-HAFL); Stettler, Cornelia (Carbotech); Stumpf, Felix (Competence Center for Soils); Thürig, Esther (WSL); Weber, Dominique (WSL); Weber, Felix (INFRAS); Wöhrnschimmel, Henry (FOEN); Wollmann, Iris (Agroscope3. However, the relative developments of heating degree days and CO<sub>2</sub> emissions are clearly drifting apart in the years since 2002, which indicates that additional effects like reduction measures contribute to domestic emission reductions (see Figure 2-7).
- Between 1990 and 2023, **CH<sub>4</sub>** emissions (excluding LULUCF) decreased. An important driver for this reduction is sector 5 Waste, where CH<sub>4</sub> emissions declined throughout the whole time series – in particular in source category 5A Solid waste disposal, where a change in waste legislation banning the disposal of municipal solid waste in landfills reinforced the trend since 2000. Furthermore, the development of livestock in sector 3 Agriculture is relevant for the overall reduction of CH<sub>4</sub> emissions, in particular cattle, where a reduction in the years 1990–2004 and 2012–2022 led to a reduction of emissions from source category 3A Enteric fermentation in the agricultural sector (see Table 5-8).
- A continuous decrease in **N<sub>2</sub>O** emissions was achieved between 1990 and 2023 due to progress in nitrogen removal in centralised wastewater treatment plants (sector 5 Waste). In addition, N<sub>2</sub>O emissions of sector 2 IPPU were considerably reduced due to the installation of a catalytic converter in a niacin production plant late in the year 2021. Furthermore, as a consequence of the declining livestock population and reduced input of synthetic fertilisers, N<sub>2</sub>O emissions that mainly stem from manure management and agricultural soils decreased between 1990 and 2023 as well.
- **HFC** emissions are significantly higher in 2023 compared to the base year due to their application as substitutes for CFCs. In contrast, **PFC** emissions declined mainly due to the decrease and stop of aluminium production in Switzerland. Decreasing tendencies are found for HFC emissions since 2018 due to restrictions of HFC use in mobile air-conditioning and stationary refrigeration. **SF<sub>6</sub>** emissions show relatively large fluctuations between 1990 and 2023. This effect bases on annual fluctuations of the market volumes in the production of electrical equipment as well as on changes in other applications. The temporary increase of SF<sub>6</sub> emissions between 2010 and 2018 is mainly due the disposal of soundproof windows. Although soundproof windows containing SF<sub>6</sub> are not produced or installed in Switzerland anymore, the disposal of old windows still leads to emissions. On the other hand, the SF<sub>6</sub> emissions from electrical equipment (2G1) are decreasing due to the agreement of Swissmem and FOEN on the reduction of SF<sub>6</sub> emissions since 2008. Further reductions are the result of the prohibition of the import of SF<sub>6</sub> for magnesium foundries (2C4) since 2017 and improved waste air treatment and recovery of SF<sub>6</sub> in further applications. **NF<sub>3</sub>** has been used only short-term in the photovoltaic industry (around the year 2010).

Table 2-3 Contribution of individual gases to total emissions (excluding LULUCF) in CO<sub>2</sub> equivalent (kt) and (%).

Greenhouse Gas Emissions (excluding LULUCF)	1990		1995		2000		2005		2010	
	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%
CO <sub>2</sub>	44'149	79.9%	43'414	80.3%	43'621	80.7%	45'776	81.3%	45'034	81.1%
CH <sub>4</sub>	6'220	11.3%	5'840	10.8%	5'477	10.1%	5'460	9.7%	5'418	9.8%
N <sub>2</sub> O	4'237	7.7%	4'159	7.7%	3'947	7.3%	3'669	6.5%	3'476	6.3%
HFCs	0.023	0.0%	227	0.4%	605	1.1%	997	1.8%	1'245	2.2%
PFCs	105	0.2%	16	0.0%	54	0.1%	46	0.1%	36	0.1%
SF <sub>6</sub>	141	0.3%	96	0.2%	157	0.3%	210	0.4%	155	0.3%
NF <sub>3</sub>	NO	-	NO	-	NO	-	NO	-	12	0.0%
Indirect CO <sub>2</sub>	392	0.7%	284	0.5%	205	0.4%	144	0.3%	133	0.2%
<b>Total (excluding LULUCF)</b>	<b>55'244</b>	<b>100%</b>	<b>54'036</b>	<b>100%</b>	<b>54'065</b>	<b>100%</b>	<b>56'303</b>	<b>100%</b>	<b>55'507</b>	<b>100%</b>

Greenhouse Gas Emissions (excluding LULUCF)	2019		2020		2021		2022		2023	
	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%
CO <sub>2</sub>	36'822	78.7%	34'343	77.8%	35'902	79.0%	32'951	78.7%	31'977	78.3%
CH <sub>4</sub>	4'998	10.7%	4'942	11.2%	4'951	10.9%	4'907	11.7%	4'867	11.9%
N <sub>2</sub> O	3'279	7.0%	3'218	7.3%	3'113	6.8%	2'611	6.2%	2'596	6.4%
HFCs	1'358	2.9%	1'347	3.1%	1'235	2.7%	1'247	3.0%	1'226	3.0%
PFCs	29	0.1%	34	0.1%	28	0.1%	28	0.1%	28	0.1%
SF <sub>6</sub>	178	0.4%	156	0.4%	131	0.3%	56	0.1%	58	0.1%
NF <sub>3</sub>	0.51	0.0%	0.39	0.0%	0.37	0.0%	0.31	0.0%	0.62	0.0%
Indirect CO <sub>2</sub>	103	0.2%	100	0.2%	95	0.2%	94	0.2%	94	0.2%
<b>Total (excluding LULUCF)</b>	<b>46'767</b>	<b>100%</b>	<b>44'140</b>	<b>100%</b>	<b>45'455</b>	<b>100%</b>	<b>41'895</b>	<b>100%</b>	<b>40'847</b>	<b>100%</b>

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

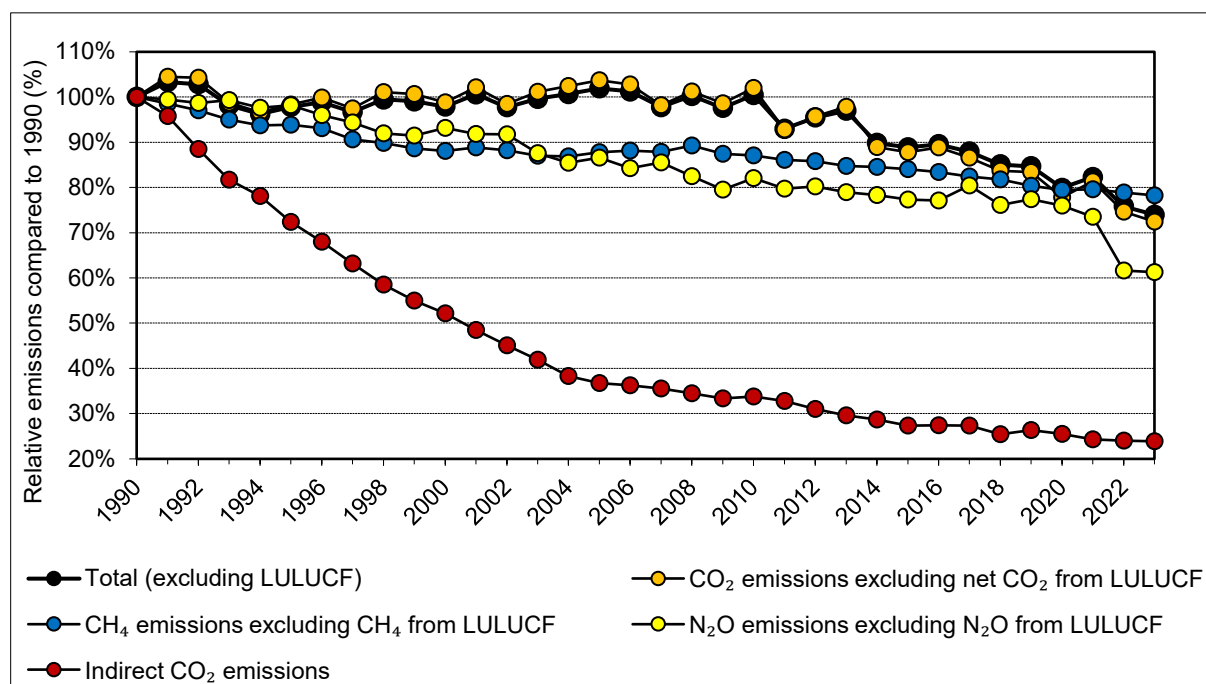


Figure 2-3 Relative trends of Switzerland's main greenhouse gas emissions (excluding LULUCF). The base year 1990 represents 100 %. F-gases are not illustrated here but included in the total (see Figure 4-3).

## 2.2.2. Emission and removal trends by sector

Table 2-4 shows the emission trends for all major source 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.

### 2.2.2.1. Overview

In order to understand trends within the sector **1 Energy**, the individual source categories are considered separately (see chp. 2.2.2.2 and Figure 2-6 below). The sector **4 LULUCF** is also presented in its own chp. 2.2.2.3.

In line with economic development, overall emissions in sector **2 Industrial processes and product use (IPPU)** show a decreasing trend in the early 1990s and a gradual increase between 1997 and 2011, except for the economically difficult year 2009. After 2011, emissions from the sector remained on a similar level until 2019. Since 2019, emissions show a decreasing tendency due to a reduction of HFC emissions in category 2F Product uses as substitutes for ozone-depleting substances (ODS). The Chemical Risk Reduction Ordinance (Swiss Confederation 2005) was put in place in 2005 and regulates the use of F-gases since then. The dominant source category of sector 2 is 2A Mineral industry although the emissions decreased by approximately one third since 1990. If sources are analysed in more detail, 2A1 Cement production is the most relevant emitter in this category. Until 2021, 2B Chemical industry was an important source category, however it is less relevant since the installation of a catalytic converter in a niacin production plant late in the year 2021 that reduced N<sub>2</sub>O emissions strongly. 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, the third-most important source category, contains in particular SF<sub>6</sub> and PFC emissions from electrical equipment and other product use, as well as N<sub>2</sub>O emissions from the application in households and hospitals. 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 fertiliser use. All three factors have generally been declining (see Table 5-8 and Table 5-25, respectively). However, the development is not linear which is also visible in the emission trend. CH<sub>4</sub> and N<sub>2</sub>O emissions decreased until 2004. Subsequently, CH<sub>4</sub> emissions increased slightly until 2008 and decreased again afterwards. N<sub>2</sub>O emissions remained near a constant level since 2004 with a decreasing trend in the last years.

Total emissions from the source category **5 Waste** continuously decrease between 1990 and 2023. The main driver of the decreasing trend is the emission reduction in solid waste disposal (sector 5A), 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 category 1A1 Energy industries rather than sector 5 Waste. A similar reduction was achieved in sector 5D Wastewater treatment mainly due to improvements concerning nitrogen removal in centralised wastewater treatment plants. Altogether, “waste-related” emissions (including emissions from all waste management activities reported in sectors 1 Energy, 3 Agriculture, and 5 Waste) are increasing from 1994 onwards, show a stagnation since 2006 and slightly declined since 2019 (see Figure 7-3 in chp. 7.1).

The total emissions from sector **6 Other** (fire damages) show a generally decreasing trend since 2003, mostly due to a gradually decreasing number of building fires per year. The total greenhouse gas emissions of this sector show emissions of less than 20 kt CO<sub>2</sub> eq in each year during the reporting period and is of minor importance for the national total.

Table 2-4 Greenhouse gas emissions in CO<sub>2</sub> equivalent (kt) by individual source (positive numbers) and sink (negative numbers) categories.

Source and Sink Categories	1990	1995	2000	2005	2010
CO <sub>2</sub> equivalent (kt)					
1 Energy	41'634	41'631	42'005	43'838	43'086
1A1 Energy industries	2'514	2'640	3'171	3'817	3'852
1A2 Manufacturing industries and construction	6'576	6'300	6'003	6'036	5'855
1A3 Transport	14'671	14'276	15'949	15'846	16'319
1A4 Other sectors	17'535	18'112	16'601	17'863	16'793
1A5 Other	219	163	151	139	137
1B Fugitive emissions from fuels	119	141	130	138	130
2 Industrial processes and product use	3'913	3'318	3'656	4'277	4'373
3 Agriculture	7'043	6'860	6'421	6'344	6'421
5 Waste	2'248	1'929	1'763	1'684	1'483
6 Other	14	15	16	15	11
Indirect CO <sub>2</sub>	392	284	205	144	133
Total (excluding LULUCF)	55'244	54'036	54'065	56'303	55'507
4. Land use, land-use change and forestry	-2'666	-4'170	3'927	-2'397	-2'211
Total (including LULUCF)	52'577	49'866	57'993	53'905	53'296

Source and Sink Categories	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs. 1990
CO <sub>2</sub> equivalent (kt)											%
1 Energy	37'328	37'012	37'424	36'458	35'177	35'072	32'653	34'145	31'226	30'425	-26.9%
1A1 Energy industries	3'634	3'334	3'432	3'361	3'437	3'459	3'378	3'336	3'290	3'172	26.2%
1A2 Manufacturing industries and construction	5'092	4'973	4'975	4'945	4'786	4'701	4'495	4'593	4'219	3'863	-41.3%
1A3 Transport	16'062	15'328	15'172	14'918	14'932	14'894	13'595	13'775	13'599	13'616	-7.2%
1A4 Other sectors	12'311	13'160	13'626	13'022	11'820	11'825	10'994	12'264	9'930	9'594	-45.3%
1A5 Other	139	135	139	127	126	115	119	115	123	124	-43.4%
1B Fugitive emissions from fuels	91	82	79	85	76	79	71	63	64	56	-53.2%
2 Industrial processes and product use	4'367	4'324	4'285	4'409	4'281	4'265	4'090	3'907	3'405	3'204	-18.1%
3 Agriculture	6'417	6'311	6'332	6'322	6'218	6'119	6'113	6'147	6'035	6'001	-14.8%
5 Waste	1'380	1'338	1'300	1'256	1'224	1'199	1'176	1'152	1'125	1'114	-50.5%
6 Other	11	9.8	9.7	11	9.8	8.5	8.3	9.2	9.1	8.9	-37.2%
Indirect CO <sub>2</sub>	112	107	108	107	100	103	100	95	94	94	-76.2%
Total (excluding LULUCF)	49'615	49'102	49'457	48'562	47'010	46'767	44'140	45'455	41'895	40'847	-26.1%
4. Land use, land-use change and forestry	-3'997	1'174	-3'205	-1'822	1'120	-3'145	-1'223	-391	-1'429	1'299	NA
Total (including LULUCF)	45'618	50'276	46'253	46'741	48'130	43'622	42'917	45'064	40'465	42'146	-19.8%

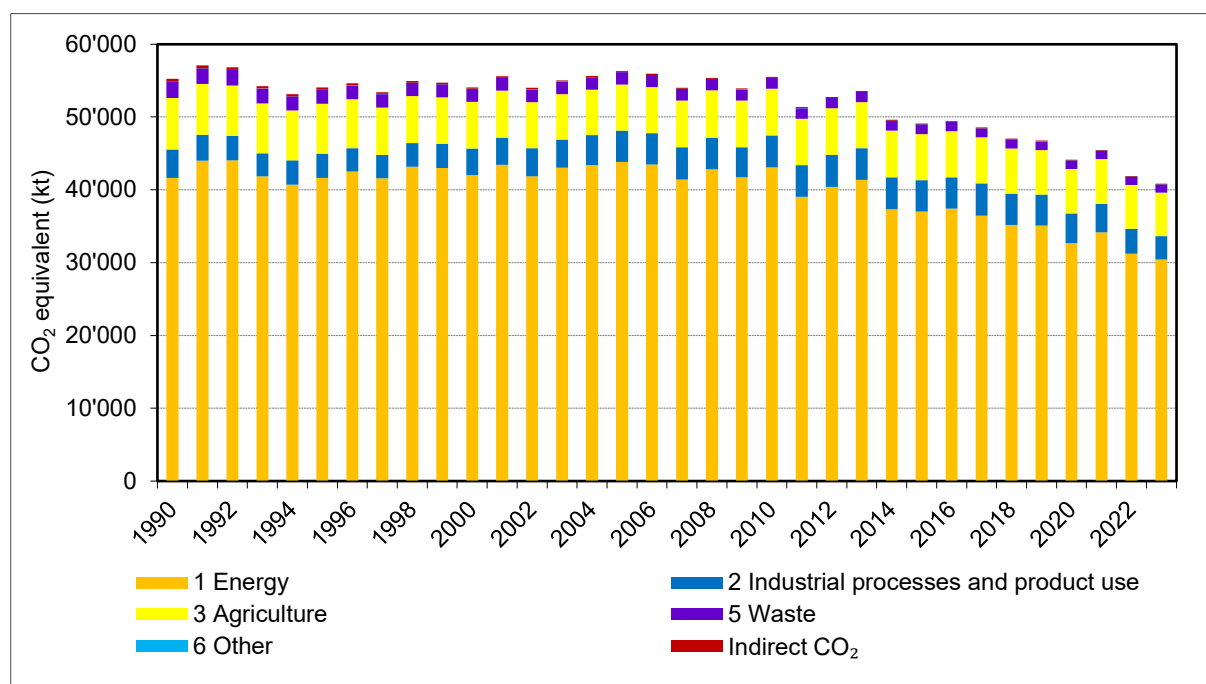
The percentage shares of source categories are shown for selected years in Table 2-5 whereas Figure 2-4 to Figure 2-6 are graphical representations of the data in Table 2-4. For the time series of the source categories of sector 1 Energy see chp. 3.

Table 2-5 Greenhouse gas emissions (excluding LULUCF) in CO<sub>2</sub> equivalent (kt) and the relative contribution (%) of individual source categories.

Source and Sink Categories	1990		1995		2000		2005		2010	
	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%
1 Energy	41'634	75.4%	41'631	77.0%	42'005	77.7%	43'838	77.9%	43'086	77.6%
1A1 Energy industries	2'514	4.6%	2'640	4.9%	3'171	5.9%	3'817	6.8%	3'852	6.9%
1A2 Manufacturing industries and construction	6'576	11.9%	6'300	11.7%	6'003	11.1%	6'036	10.7%	5'855	10.5%
1A3 Transport	14'671	26.6%	14'276	26.4%	15'949	29.5%	15'846	28.1%	16'319	29.4%
1A4 Other sectors	17'535	31.7%	18'112	33.5%	16'601	30.7%	17'863	31.7%	16'793	30.3%
1A5 Other	219	0.4%	163	0.3%	151	0.3%	139	0.2%	137	0.2%
1B Fugitive emissions from fuels	119	0.2%	141	0.3%	130	0.2%	138	0.2%	130	0.2%
2 Industrial processes and product use	3'913	7.1%	3'318	6.1%	3'656	6.8%	4'277	7.6%	4'373	7.9%
3 Agriculture	7'043	12.7%	6'860	12.7%	6'421	11.9%	6'344	11.3%	6'421	11.6%
5 Waste	2'248	4.1%	1'929	3.6%	1'763	3.3%	1'684	3.0%	1'483	2.7%
6 Other	14	0.0%	15	0.0%	16	0.0%	15	0.0%	11	0.0%
Indirect CO <sub>2</sub>	392	0.7%	284	0.5%	205	0.4%	144	0.3%	133	0.2%
Total (excluding LULUCF)	55'244	100%	54'036	100%	54'065	100%	56'303	100%	55'507	100%

Source and Sink Categories	2019		2020		2021		2022		2023	
	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%	kt CO <sub>2</sub> eq	%
1 Energy	35'072	75.0%	32'653	74.0%	34'145	75.1%	31'226	74.5%	30'425	74.5%
1A1 Energy industries	3'459	7.4%	3'378	7.7%	3'336	7.3%	3'290	7.9%	3'172	7.8%
1A2 Manufacturing industries and construction	4'701	10.1%	4'495	10.2%	4'593	10.1%	4'219	10.1%	3'863	9.5%
1A3 Transport	14'894	31.8%	13'595	30.8%	13'775	30.3%	13'599	32.5%	13'616	33.3%
1A4 Other sectors	11'825	25.3%	10'994	24.9%	12'264	27.0%	9'930	23.7%	9'594	23.5%
1A5 Other	115	0.2%	119	0.3%	115	0.3%	123	0.3%	124	0.3%
1B Fugitive emissions from fuels	79	0.2%	71	0.2%	63	0.1%	64	0.2%	56	0.1%
2 Industrial processes and product use	4'265	9.1%	4'090	9.3%	3'907	8.6%	3'405	8.1%	3'204	7.8%
3 Agriculture	6'119	13.1%	6'113	13.8%	6'147	13.5%	6'035	14.4%	6'001	14.7%
5 Waste	1'199	2.6%	1'176	2.7%	1'152	2.5%	1'125	2.7%	1'114	2.7%
6 Other	8.5	0.0%	8.3	0.0%	9.2	0.0%	9.1	0.0%	8.9	0.0%
Indirect CO <sub>2</sub>	103	0.2%	100	0.2%	95	0.2%	94	0.2%	94	0.2%
Total (excluding LULUCF)	46'767	100%	44'140	100%	45'455	100%	41'895	100%	40'847	100%

Figure 2-4 Greenhouse gas emissions in CO<sub>2</sub> equivalent (kt) by sectors (excluding LULUCF).

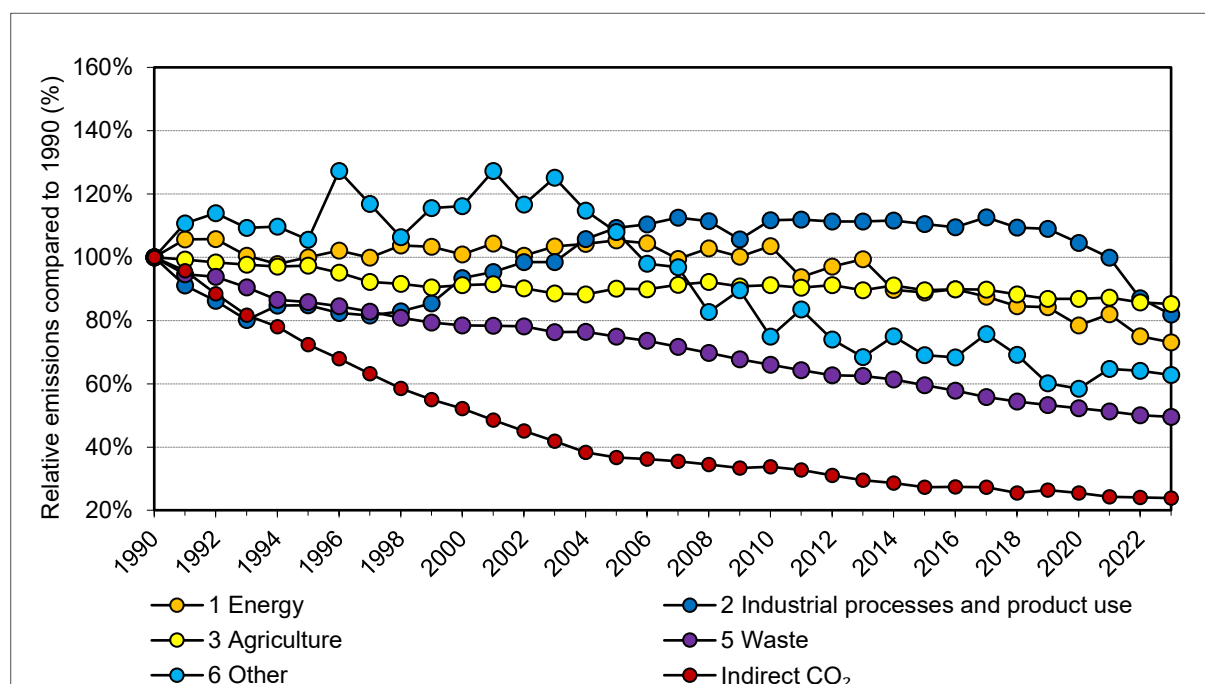


Figure 2-5 Relative emission trends (CO<sub>2</sub> eq) by main source categories (base year 1990 = 100 %).

### 2.2.2.2. 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 and Table 2-5.

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 1990–2006. Afterwards, the trend is determined by a combination of effective reduction measures and a decreasing trend of heating degree days (see Figure 2-7; see further details below under 1A1 Energy industries and 1A4 Other sectors).
- It is noteworthy that due to Switzerland’s electricity production structure (mainly hydroelectric and nuclear power; see SFOE (2024), Table 24), source 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 increase in waste incineration is the reason why overall emissions from source category 1A1 Energy industries are higher in 2023 than in 1990. The time series shows an increase until 2006 and a decrease thereafter. Fluctuations are caused by varying combustion activities for district heating. The emission reduction in 2015 was due to the closure of one of two refineries (see Figure 2-6 and values in Table 2-4).
- Emissions from 1A2 Manufacturing industries and construction show a decreasing trend since 1990, mainly due to continuous changes in the use of fuel types for stationary combustion (see Table 3-55). In addition, various companies from energy-intensive industries have relocated abroad since 1990.
- The increasing trend of emissions in source category 1A3 Transport between 1990 and 2008 is based on increasing traffic volumes (in all different types of transport). The effect of increasing energy efficiency of vehicles was unable to counterbalance the substantial growth in transport. Also after 2008, energy efficiency gains of passenger vehicles were largely neutralised by increasing traffic volumes as well as increasing average weight of vehicles. The decrease of transport emissions between 2014 to 2015 is largely caused by decreasing “fuel tourism” due to the increasing strength of the Swiss franc (EV 2015a)

(see chp. 3.2.9.2.2). The strong decrease between 2019 and 2020 can be attributed to the COVID-19 pandemic, when a lockdown and further measures reduced traffic volumes, in particular of passenger cars.

- The trend for source category 1A4 Other sectors reflects the impact of climatic variations on energy demand for heating in stationary source categories (1A4ai/bi/ci). The strong correlation with the number of “heating degree days” (see box 1 on page 3) – used as an index of meteorological conditions over the year – is apparent from Figure 2-7, which shows CO<sub>2</sub> emissions from source category 1A4 Other sectors (only stationary sources) and the number of heating degree days. Since 2002, heating degree days and CO<sub>2</sub> emissions are clearly drifting apart, which indicates that additional effects like reduction measures contribute to domestic emission reductions (see Figure 2-7). In the period 1990–2023, 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 around 45 % (FOEN 2024I). Over the same period, however, higher standards were specified for insulation and for combustion equipment efficiency for both new and renovated buildings and fossil fuels were partially replaced by renewable alternatives, compensating for the emissions from the additional area heated.
- CO<sub>2</sub> emissions from 1A5 Other mainly stem from military aircraft and therefore show almost the same decreasing trend as the use of jet kerosene within this source category (see Table 3-106).
- The development of CO<sub>2</sub> equivalent emissions in 1B are dominated by the trend of the CH<sub>4</sub> emissions from leakage in the natural gas distribution network. From 1990 to 1994, emissions increased due to network expansion. Thereafter, emissions decreased substantially due to gradual replacement of old pipelines.

#### **Box 1: Heating degree days**

Heating degree days: a standardized measure for linking heating demand and meteorological conditions. 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  $t$ .

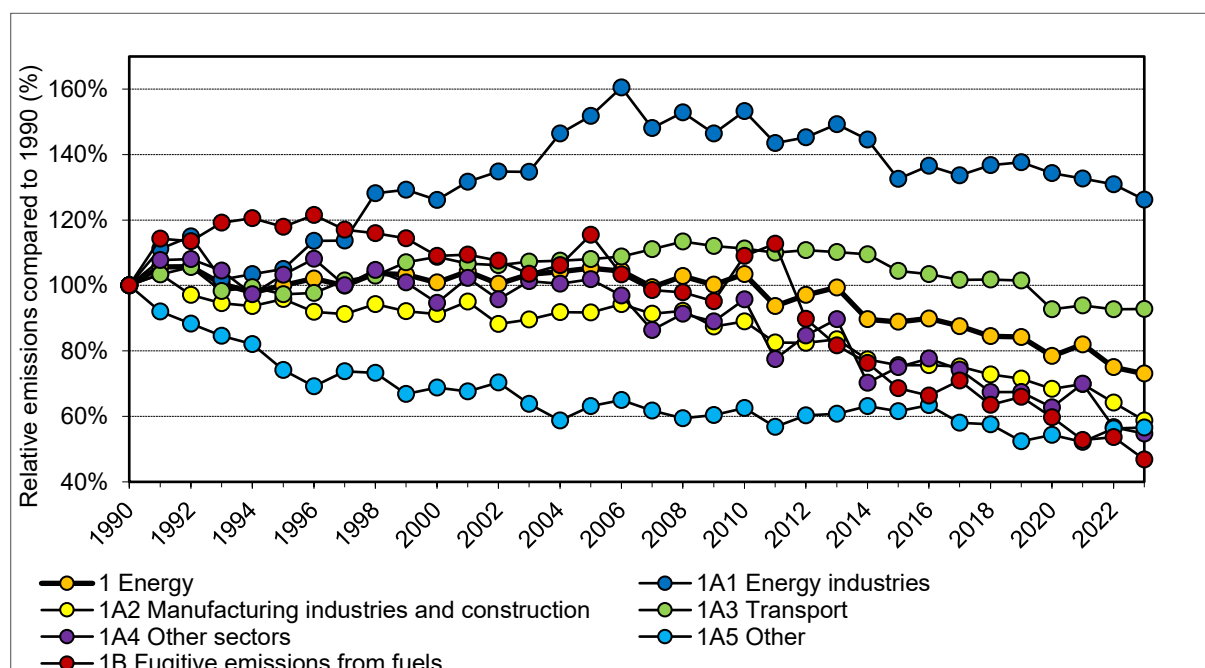


Figure 2-6 Emission trends (CO<sub>2</sub> eq) for the source categories in sector 1 Energy. The trend for the entire sector 1 Energy is represented by the bold line with orange bullets.

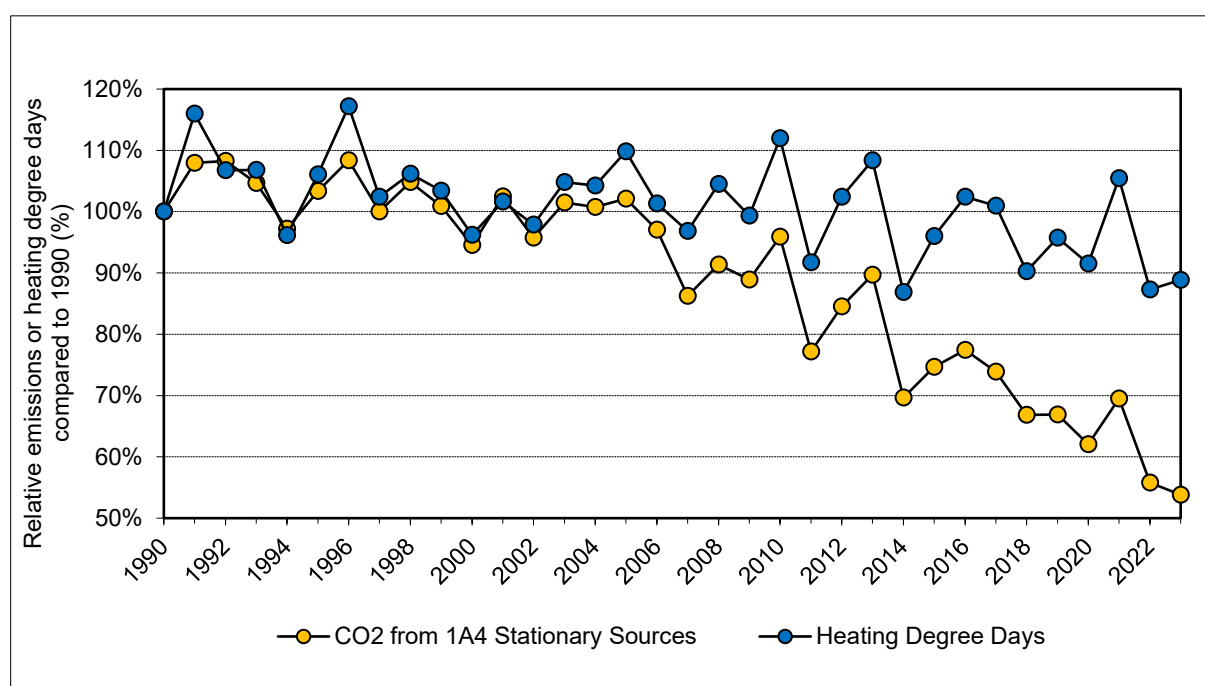


Figure 2-7 Relative trend for CO<sub>2</sub> emissions from 1A4 Fuel Combustion – Other Sectors (stationary sources only) compared with the number of heating degree days.

### 2.2.2.3. Emission and removal trends in sector 4 LULUCF

Figure 2-8 illustrates the net CO<sub>2</sub> eq emissions and removals in sector 4 LULUCF over the inventory period. Associated data are given in Table 2-4.

The GHG fluxes are reported for the six main land-use categories 4A Forest land, 4B Cropland, 4C Grassland, 4D Wetlands, 4E Settlements and 4F Other land (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) as well as in category 4G Harvested wood products (CO<sub>2</sub>). CO<sub>2</sub> is the most important



greenhouse gas by far in the LULUCF sector. CH<sub>4</sub> and N<sub>2</sub>O from fires, soil organic matter decomposition, reservoirs and drained organic soil make a minor contribution to the emissions (compare Figure 6-1 and Figure 6-3). With the exception of 2000, 2015, 2018 and the latest reporting year 2023, land use in Switzerland resulted in more CO<sub>2</sub> eq being removed from the atmosphere than being emitted (Figure 2-8, see also Figure 2-9, Figure 6-1 and Figure 6-4). The time series shows that land use has tended to absorb and store less CO<sub>2</sub> eq since the 1990s, when the highest net CO<sub>2</sub> eq removals were achieved, as illustrated by the Gaussian low-pass filter in Figure 2-8.

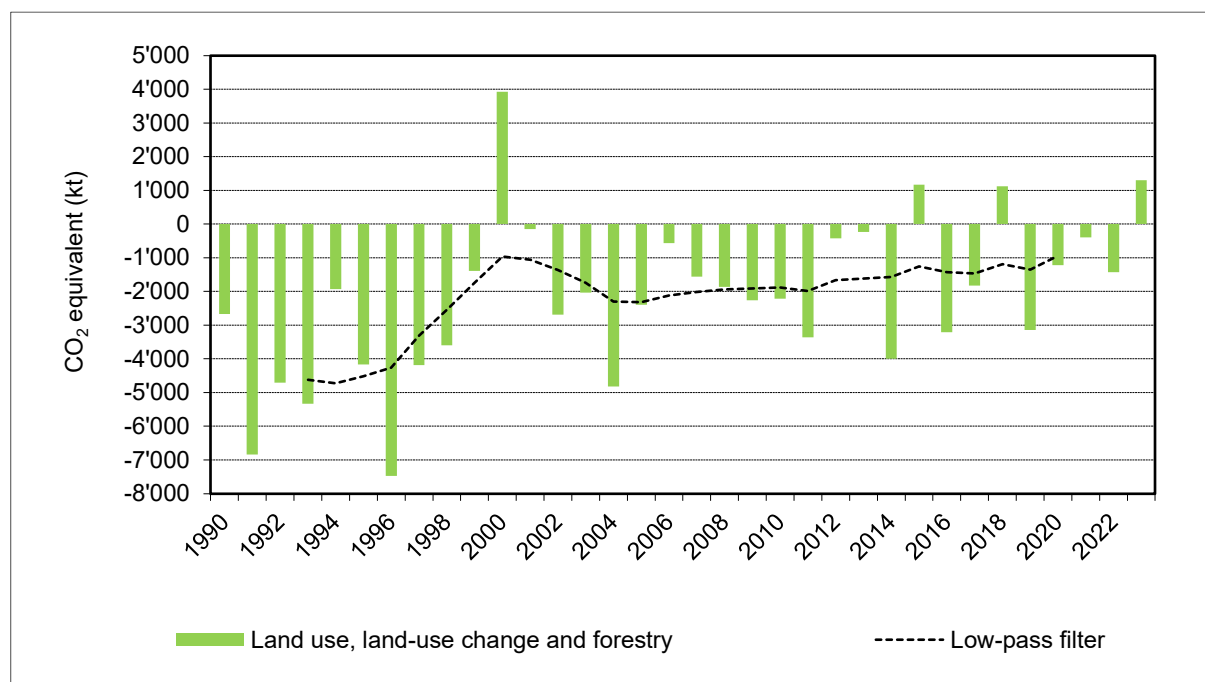


Figure 2-8 Net GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) emissions and removals of sector 4 Land use, land-use change and forestry (LULUCF), in kt CO<sub>2</sub> eq. Positive values refer to net emissions, negative values refer to net removals. The black dashed line shows a Gaussian low-pass filter (SD=2.5, window size = 7 years).

4A: Forest land dominates the GHG balance of Switzerland's land use sector. Forest land (encompassing the carbon pools living biomass, dead wood, litter and soil) consistently acted as a sink (i.e. a net removal of CO<sub>2</sub> from the atmosphere) with the exception of 2000 (Figure 2-9). The exceptionally high net CO<sub>2</sub> eq emissions in 2000 and the small net removals in the following year 2001 originate from winter storm Lothar (December 1999, see <https://s.geo.admin.ch/hh3tdskqvzq1>), which caused large-scale damages in forest stands and increased losses of living biomass due to salvage logging (Table 6-15). This also applies to a somewhat lesser extent to the storm Vivian in February 1990. The interplay between natural dynamics (growth, mortality and decomposition) and harvesting rates (including salvage logging) is reflected in the year-to-year variability of net CO<sub>2</sub> eq removals and emissions (Figure 2-9). Similarly to the situation for the entire LULUCF sector, the net CO<sub>2</sub> eq removal by Forest land has tended to decrease over the last decades. It is still unclear how much the series of hot and dry summers in the past decade, which caused drastic forest damage in many European countries, will affect the figures of the Swiss National Forest Inventory in the future (and thus the GHG inventory).

4G: In terms of climate policy, sustainable forest management can be achieved by using the wood grown in a cascade, firstly for long-lived harvested wood products (HWP) and

subsequently for energy purposes. In almost all years since 1990, more carbon has been incorporated into new wood products (such as construction timber or wood panels) than has been released from old ones. However, the amount of the annual net CO<sub>2</sub> removals from harvested wood products has decreased clearly since 2011. In 2013, 2016, 2019 and 2023 HWP fluxes resulted in small net CO<sub>2</sub> emissions (see Figure 2-9 and Figure 6-22 for details).

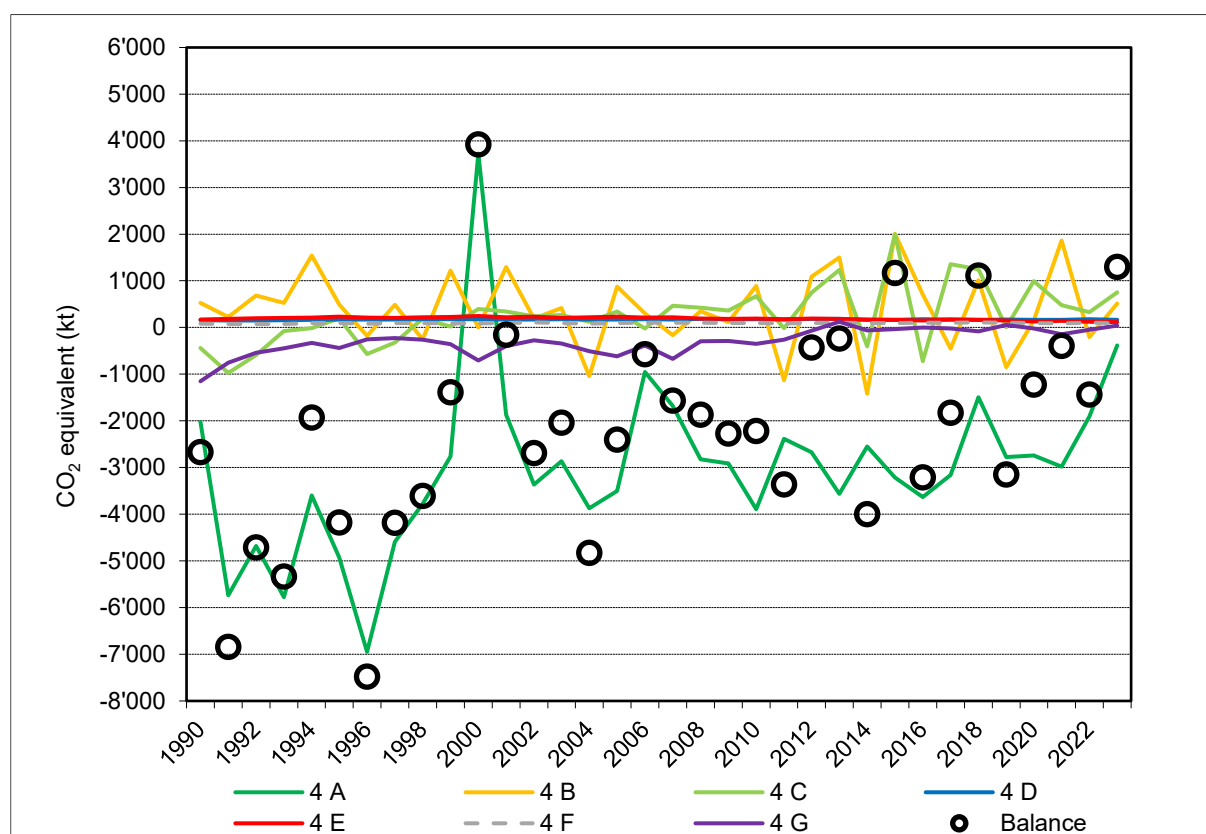


Figure 2-9 Net GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) emissions and removals in the LULUCF sector (in kt CO<sub>2</sub> eq) broken down by categories 4A-4G. Balance indicates the annual net total. Positive values refer to net emissions, negative values refer to net removals. Category 4D is almost completely hidden by the other lines.

4B, 4C: The agricultural use of Cropland and Grassland affects the carbon stock in soils. For example, ploughing promotes the decomposition of soil organic matter, whereas spreading farmyard manure or leaving harvest residues on the fields increases soil carbon stocks. Along with the management method, the crops grown and the weather conditions are the main factors influencing the annual fluctuations of CO<sub>2</sub> fluxes. The case of drained former peatlands is a special one. When subjected to intense agricultural use, these organic soils release large amounts of CO<sub>2</sub> and N<sub>2</sub>O. In both categories 4B Cropland and 4C Grassland, consequently, the curves of net CO<sub>2</sub> eq emissions and removals are shifted upwards by persistently high emissions from organic soils (Figure 6-11 and Figure 6-15, respectively). Overall, category 4B shows fluctuating net CO<sub>2</sub> eq emissions and removals at an intermediate level over the inventory period, while category 4C acts as a decreasing sink in the first decade, to later resemble the signal of category 4B (Figure 2-9).

4D: Unproductive wetlands only account for a small part of the land area. As most remaining peatlands are impaired by the consequences of previous use (particularly drainage), many organic soils are now net GHG sources. CO<sub>2</sub> eq emissions in category 4D are low and show no trend (Figure 2-9; Figure 6-19).

4E: The development of new settlements and infrastructure resulted in low CO<sub>2</sub> eq emissions since 1990 (Figure 2-9; Figure 6-20). Emissions in category 4E are mainly produced by the loss of plant biomass and soil organic carbon during construction work. In contrast, increasing greening in the sealed areas over the last decades has helped to curb net emissions. Overall, the change in net CO<sub>2</sub> eq emissions since 1990 is -33 %, with emissions initially rising until ca. 2000 and then falling more sharply.

4F: Mudflows, erosion, landslides, and dynamic changes in stream beds were identified as the main processes causing land-use changes to other land. The contribution to the GHG balance of the LULUCF sector (in the form of emissions) remains small (Figure 2-9; Figure 6-21). Over the inventory period, a slight upward trend can be seen in the annual fluctuations, and the value for the latest reporting year is 19 % higher than in the base year.

### 2.2.3. Emission trends for precursor gases

The methodologies concerning calculation of emissions of the precursor gases NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> (IPCC 2006, Volume 1, Chapter 7) are provided in detail in Switzerland's Informative Inventory Report (FOEN 2025b). Emission trends for precursor gases show a very pronounced decline (see Table 2-6 and Figure 2-10). A strict air pollution control policy and the implementation of a large number of emission reduction measures led to decreasing emissions of precursor gases over the period 1990–2023.

Overall, the most effective reduction measures were the abatement of exhaust emissions from road vehicles and stationary installations and the incentive taxes on VOC (since 2000) and on fossil combustible fuels (since 2008). The latter measure was (jointly) responsible for the significant shift in the fuel mix of standard fossil fuels in industry from solid and liquid fuels to natural gas and the complete disappearance of residual fuel oil. As a result, NO<sub>x</sub>, NMVOC and CO emissions clearly declined between 1990 and 2023.

In addition, the legal restrictions of the sulphur content in liquid fuels and the switch from gas oil to natural gas in residential heating are important for the significant decrease in SO<sub>x</sub> emissions (SO<sub>x</sub> = SO<sub>2</sub> + SO<sub>3</sub>, expressed as SO<sub>2</sub> equivalents) observed. The lowering of the maximum sulphur content in liquid fuels is shown in Table A – 15. Annual fluctuations of SO<sub>x</sub> emissions occur mainly due to annual variations of heating degree days, which affects the consumption of gas oil.

Table 2-6 Emissions of precursor gases (kt) (excluding NO<sub>x</sub>, CO and NMVOC from LULUCF).

Precursor gases and SO <sub>2</sub>	1990	1995	2000	2005	2010						
	kt										
NO <sub>x</sub>	144	115	102	93	83						
CO	810	527	415	319	251						
NMVOC	304	210	156	114	98						
SO <sub>2</sub>	39	26	16	14	10						
Precursor gases and SO <sub>2</sub>	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs. 1990 %
	kt										
NO <sub>x</sub>	76	71	69	65	62	58	52	50	46	44	-70%
CO	192	183	183	177	167	166	150	151	141	140	-83%
NMVOC	84	80	77	76	75	74	72	72	72	72	-76%
SO <sub>2</sub>	6.7	5.7	5.0	4.7	4.5	4.2	3.6	3.5	3.1	2.7	-93%

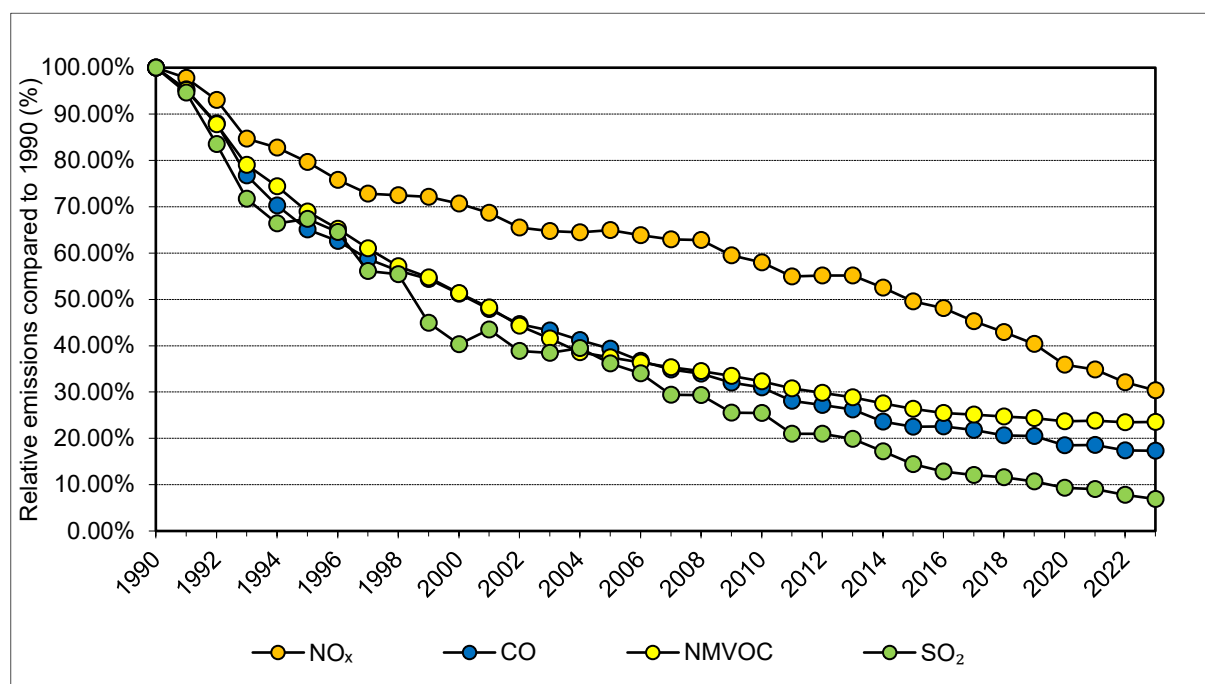


Figure 2-10: Relative trends for precursor gas emissions (excluding NO<sub>x</sub>, CO and NMVOC from LULUCF; base year 1990 = 100 %).

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 4 LULUCF is the dominant source followed by sector 2 Industrial processes and product use (see Figure 2-11).

Table 2-7: Precursor gas emissions (kt) by source category in 2023. Totals include LULUCF emissions.

Sectors	NO <sub>x</sub>		CO		NMVOC		SO <sub>2</sub>	
	kt	%	kt	%	kt	%	kt	%
1 Energy	40	91.0%	134	94.9%	16	10.4%	2.4	88.9%
2 IPPU	0.20	0.5%	4.4	3.1%	36	24.4%	0.26	9.4%
3 Agriculture	3.6	8.2%	NA	NA	18	11.9%	NA	NA
4 LULUCF	0.032	0.1%	0.96	0.7%	78	52.1%	0.0088	0.3%
5 Waste	0.12	0.3%	1.4	1.0%	1.8	1.2%	0.030	1.1%
6 Other sources	0.014	0.0%	0.46	0.3%	0.068	0.0%	0.0072	0.3%
<b>Total</b>	<b>44</b>	<b>100%</b>	<b>141</b>	<b>100%</b>	<b>149</b>	<b>100%</b>	<b>2.7</b>	<b>100%</b>

Figure 2-11 shows the relative contributions of the various sectors for each individual precursor gas excluding LULUCF (data deduced from Table 2-7).

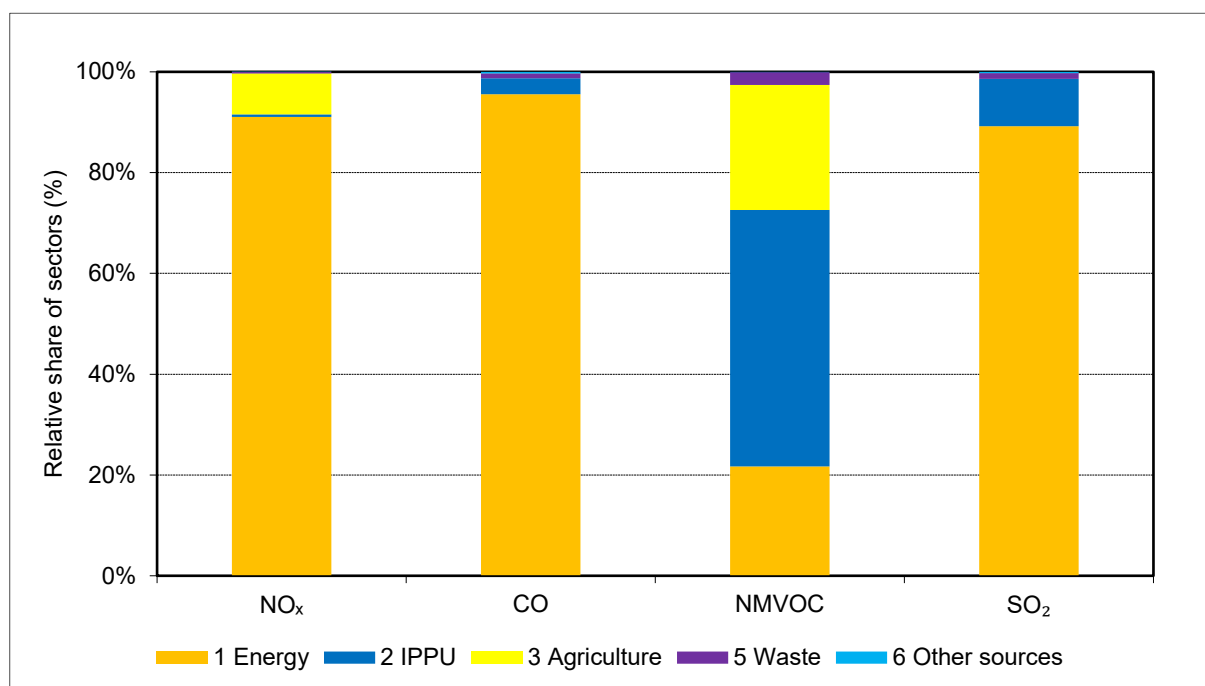


Figure 2-11: Relative contributions of individual sectors to precursor gas emissions in 2023 (excluding LULUCF, note data given in Table 2-7 especially for NMVOC).

## 3. Energy

Responsibilities for sector Energy	
Overall responsibility	Anouk-Aimée Bass (FOEN)
Experts for source-categories	Anouk-Aimée Bass (FOEN; Overview, Stationary sources in 1A1, 1A4, Bunker fuels, Country-specific issues, Mobile sources in 1A2-1A5), Peter Bonsack (FOEN; Model for stationary engines and gas turbines), Myriam Guillevic (FOEN; Waste related processes), Harald Jenk (FOEN; Road transportation), Benedikt Notter (INFRAS; Non-road and Road transportation), Theo Rindlisbacher (FOCA; Civil Aviation), Sabine Schenker (FOEN; Sectoral/Reference Approach, Feedstocks and non-energy use of fuels, Wood combustion, 1A2 (stationary)), Adrian Schilt (FOEN; Country-specific issues Fuel consumption, Industry Model)
EMIS database operation	Anouk-Aimée Bass (FOEN), Myriam Guillevic (FOEN), Sabine Schenker (FOEN)
Annual updates (NID text, tables, figures)	Dominik Eggli (Meteotest), Anna Ehrler (INFRAS), Fabio Fasel (Meteotest), Beat Rihm (Meteotest), Regine Röthlisberger (FOEN), Adrian Schilt (FOEN), Felix Weber (INFRAS)
Quality control NID (annual updates)	Dominik Eggli (Meteotest), Regine Röthlisberger (FOEN), Adrian Schilt (FOEN), Felix Weber (INFRAS)
Internal review	Anouk-Aimée Bass (FOEN), Peter Bonsack (FOEN; Model for stationary engines and gas turbines), Myriam Guillevic (FOEN; Waste related processes), Harald Jenk (FOEN; Road transportation), Simone Krähenbühl (FOEN), Benedikt Notter (INFRAS; Non-road and Road transportation), Theo Rindlisbacher (FOCA; Civil Aviation), Regine Röthlisberger (FOEN), Sabine Schenker (FOEN), Adrian Schilt (FOEN)

### 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 1990–2023 are illustrated in Figure 3-1 and Table 3-1.

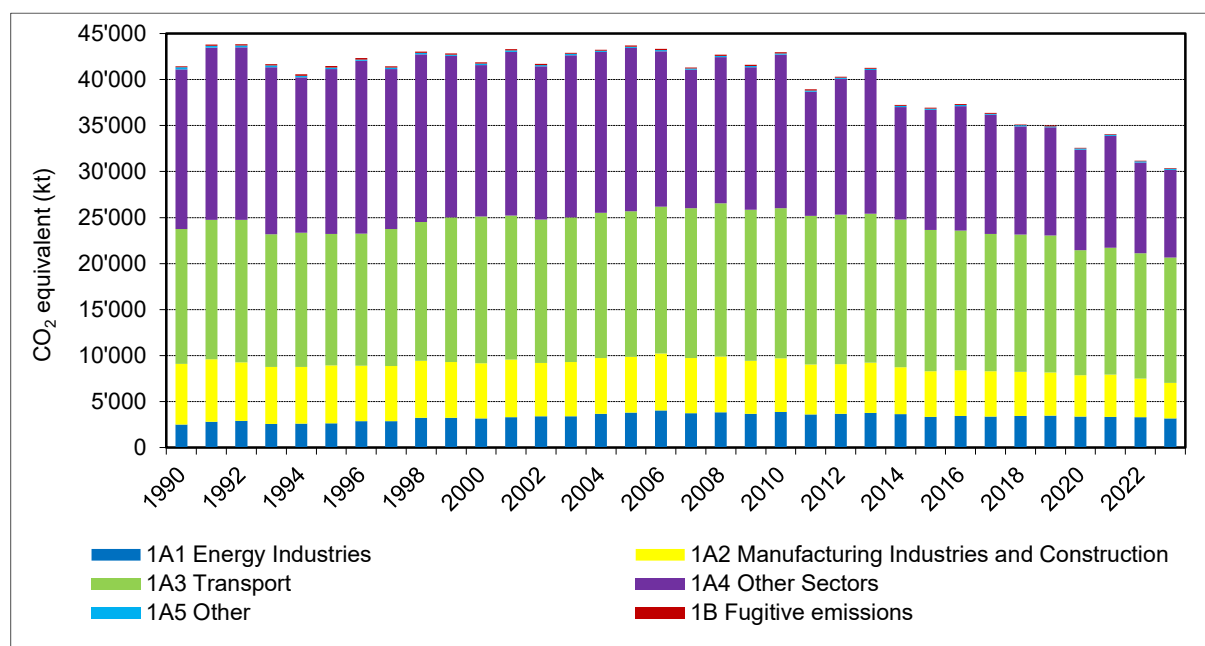


Figure 3-1 Switzerland's GHG emissions of sector 1 Energy in CO<sub>2</sub> equivalent (kt).

Considering total emissions of sector 1 Energy, fluctuations without any distinct trend are observed in the period 1990–2010. From 2011 onwards, a decreasing trend can be identified, again superposed by fluctuations. The years 2022 and 2023 show the lowest values of the entire period 1990–2023. The following source categories contribute to the total emissions (see also Figure 2-6 and explanations in chp. 2.2.2.2):

- 1A3 Transport and 1A4 Other sectors are the main sources of the sector 1 Energy with 1A3 Transport being the most important category over the last years. Emissions in 1A3 Transport increased after 1990, reaching a maximum in 2008 and decreasing again below 1990 level thereafter. Emissions from 1A4 Other sectors are strongly influenced by meteorological conditions. A systematic decrease of emissions from 1A4 is observed since 2005.
- 1A1 Energy industries and 1A2 Manufacturing industries and construction contribute to total emissions as well, but are less important. Emissions in 1A1 Energy industries increased until 2006 and show a slightly decreasing trend since then except for a stepwise reduction in 2015, when one of two refineries closed. Emissions from 1A2 Manufacturing industries are gradually decreasing since 1990.
- 1A5 Other and 1B Fugitive emissions from fuels play only a minor role. Both categories show a decrease since 1990.

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<sub>2</sub>. Fluctuations reflect inter alia the climatic variability in Switzerland (see Figure 2-7 and related comments). A decreasing trend is observed since approximately 2005, predominantly due to the decrease in 1A4 Other sectors, but also due to decreasing fuel tourism and the closure of one refinery in 2015. The strong reduction of CO<sub>2</sub> emissions in 2020 compared to previous years is a result of the measures to contain the COVID-19 pandemic leading to reduced CO<sub>2</sub> emissions from source category 1A3b Road transportation and mild winter temperatures leading to reduced emissions from source category 1A4 Other sectors.

- The decreasing trend of CH<sub>4</sub> emissions in the energy sector 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 – stationary sources also contribute to the decreasing trend.
- The changes in N<sub>2</sub>O emissions can mainly be explained by changes in the emission of road transportation due to changes in emission factors for diesel oil and gasoline combustion. The first generation of catalytic converters generated N<sub>2</sub>O as an unintended by-product in the exhaust gases, leading to an increase in N<sub>2</sub>O emissions until 1997. With new converter materials being used, the emission factors are decreasing since 1999 with strongest reduction in the course of the introduction of the Euro 3 standard during 2003 and 2004 (see Figure 3-2). The massive effective reduction of the maximum sulphur content of the fuels from 2003 to 2004 led to a higher efficiency of the catalytic converters, which additionally strengthened the effect (see Table A – 16). Since 2007, the N<sub>2</sub>O emissions are slightly increasing in line with increasing mileages (see Table 3-88). For further details, see chp. 3.2.9.2.2.

Table 3-1 GHG emissions of source category 1 Energy by gas in CO<sub>2</sub> equivalent (kt)

Gas	1990	1995	2000	2005	2010
CO <sub>2</sub> equivalent (kt)					
CO <sub>2</sub>	40'924	40'939	41'362	43'358	42'622
CH <sub>4</sub>	426	366	307	272	246
N <sub>2</sub> O	284	326	336	208	218
Sum	41'634	41'631	42'005	43'838	43'086

Gas	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs. 2022	2023 vs. 1990
CO <sub>2</sub> equivalent (kt)											%	
CO <sub>2</sub>	36'945	36'627	37'030	36'063	34'791	34'684	32'280	33'758	30'862	30'066	-2.6%	-27%
CH <sub>4</sub>	170	169	169	166	153	149	140	146	131	128	-1.8%	-70%
N <sub>2</sub> O	213	216	225	228	233	239	232	242	234	232	-1.1%	-18%
Sum	37'328	37'012	37'424	36'458	35'177	35'072	32'653	34'145	31'226	30'425	-2.6%	-27%



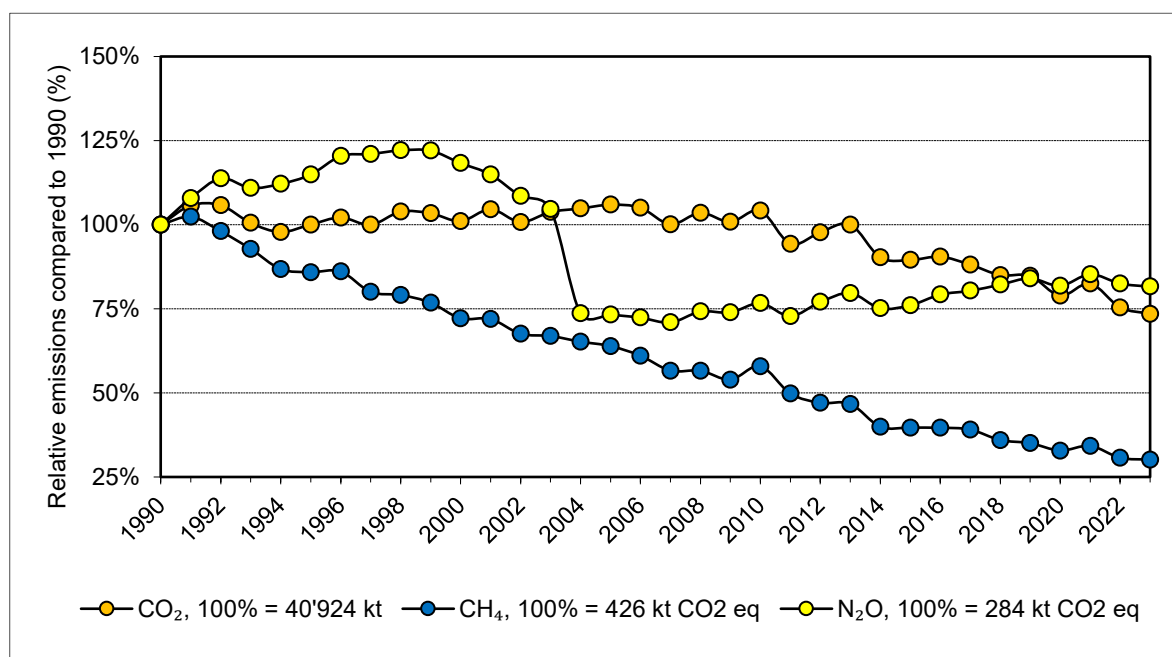


Figure 3-2 Relative trends of the greenhouse gas emissions of sector 1 Energy. The base year 1990 represents 100 %.

The following table summarises the emissions of sector 1 Energy in 2023. The table also includes two additional lines with emissions from international bunkers (aviation and marine) as well as CO<sub>2</sub> emissions from biomass burning, which both are not accounted for under the UNFCCC but are included in the reporting tables.

Table 3-2 Summary of sector 1 Energy, emissions in 2023 in kt CO<sub>2</sub> equivalent (Total: rounded values). For full biomass CO<sub>2</sub> emissions see Table 3-33.

Sector Energy	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total
	CO <sub>2</sub> equivalent (kt)			
1 Energy	30'066	128	232	30'425
1A Fuel combustion	30'052	86	232	30'370
1A1 Energy industries	3'133	1.01	38	3'172
1A2 Manufacturing industries and construction	3'828	3.7	32	3'863
1A3 Transport	13'485	22	109	13'616
1A4 Other sectors	9'483	60	51	9'594
1A5b Other (mobile)	123	0.040	0.97	124
1B Fugitive emissions from fuels	14	42	-	56
International bunkers	5'029	0.40	37	5'066
CO <sub>2</sub> emissions from biomass	8'101	-	-	8'101

In 2023, a total of 44 key source categories are identified in the Swiss greenhouse gas inventory (Table 1-6). Amongst these, 19 belong to sector 1 Energy. The key categories for approaches 1 and 2 (according to level and trend) from sector 1 Energy are shown in Figure 3-3. While 19 categories are identified as key according to approach 1, only 4 categories are also identified as key according to approach 2. Indeed, Sector 1 Energy is the major sector in terms of emissions, while sector 3 Agriculture and 4 LULUCF dominate the uncertainty contribution (see also Figure 5-3 to compare with sector 3 Agriculture).

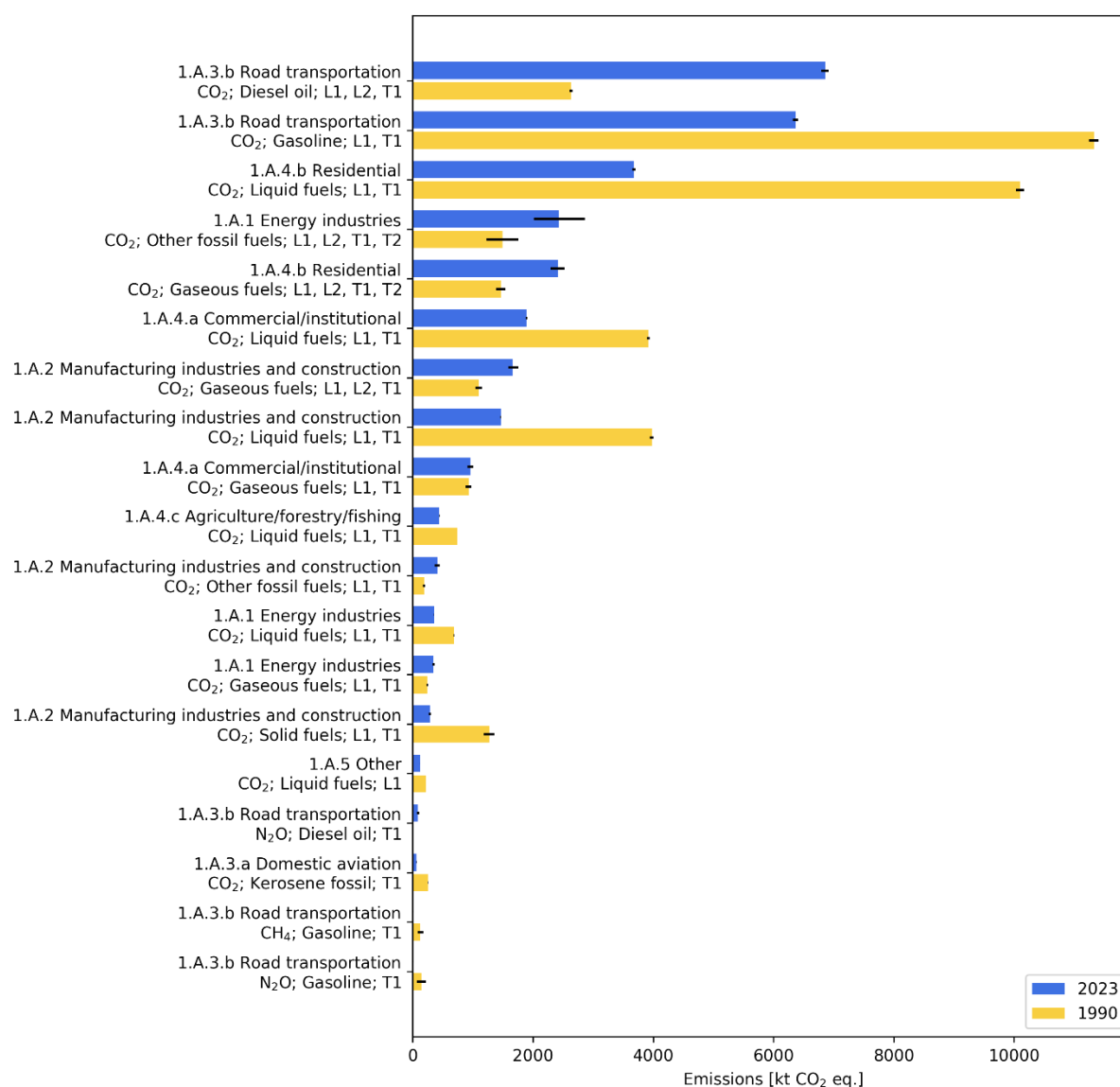


Figure 3-3 Key categories in the Swiss GHG inventory from sector 1 Energy determined by the key category analyses, approaches 1 and 2. Categories are set out in order of decreasing emissions in 2023. L1: key category according to approach 1 level in 2023; L2: same for approach 2; T1: key category according to approach 1 trend 1990–2023; T2: same for approach 2. Black uncertainty bars represent the narrowest 95 % confidence interval obtained by Monte Carlo simulations (see chp. 1.6 for details).

## 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<sub>2</sub> emissions from the sector 1 Energy, the Sectoral Approach and the Reference Approach. The Sectoral Approach is based on sectoral energy consumption data from the Swiss overall energy statistics (SFOE 2024) 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 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 2024). Apparent consumption (in tonnes) is derived from imports and exports of primary fuels (crude oil, natural gas, coal), 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 3-10 and Table 3-11, Table 3-13 and Table 3-14 in chp. 3.2.4.2 and 3.2.4.4). After the deduction of feedstocks and non-energy use of fuels (see chp. 3.2.3), the net carbon emissions and effective CO<sub>2</sub> 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).

Figure 3-4 shows the input data used and the disaggregation of fuel types for each of the two approaches.

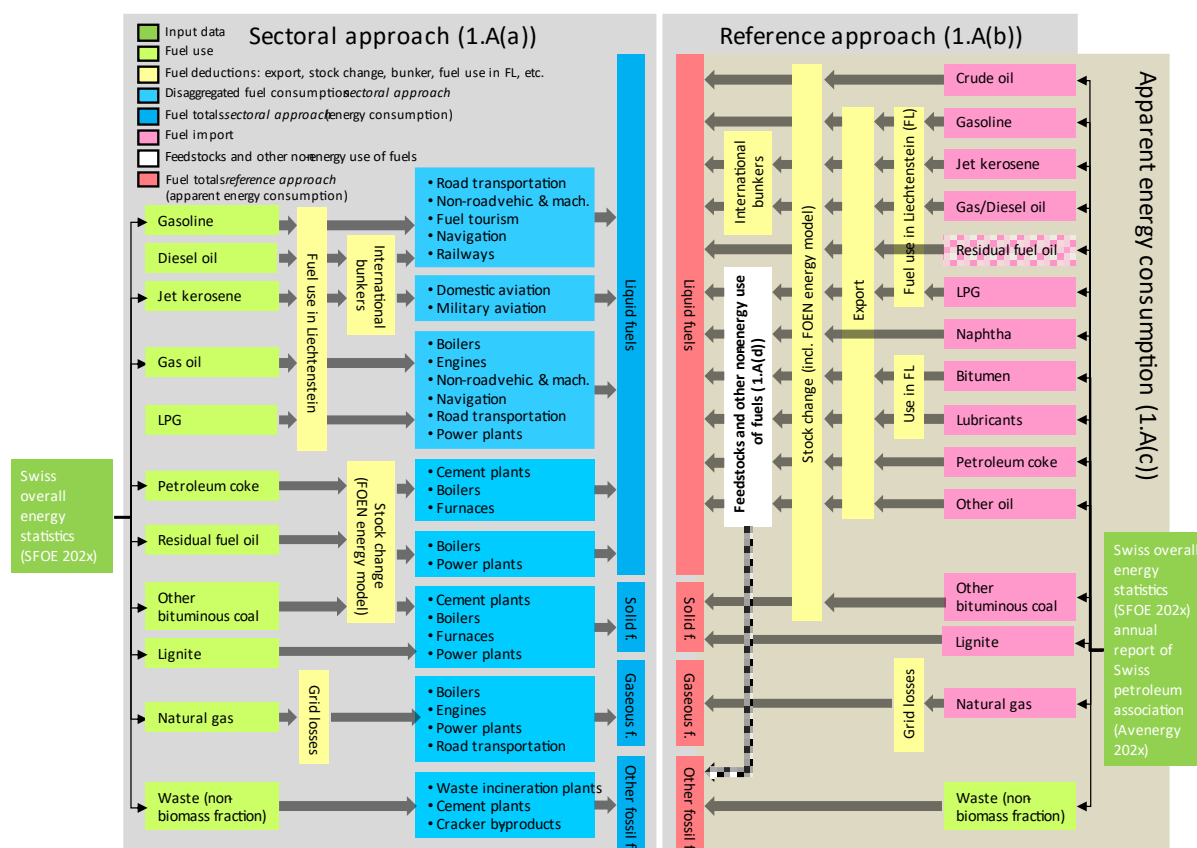


Figure 3-4 Calculation of Reference and Sectoral Approach. The input data for both approaches stem from the Swiss overall energy statistics (SFOE 2024). For the Reference Approach, additional information from Avenergy Suisse (formerly Swiss Petroleum Association) (Avenergy 2024) is used. While the Reference 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<sub>2</sub> emissions from cracker by-products (originating from feedstock use of liquefied petroleum gas 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. Coke oven coke and anthracite are included under other bituminous coal.

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 3-10. In contrast, marine bunkers consist of diesel oil only and are reported using the country-specific NCV as of Table 3-10.
- Liechtenstein's liquid fossil fuel consumption is subtracted from the input figures in SFOE (2024), 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<sub>2</sub> emissions between Reference and Sectoral Approach are calculated within the EMIS database. For the entire period, they are below 1 % for energy consumption and in the range of about 1 % for CO<sub>2</sub> emissions, as shown in Table

3-3 and in Figure 3-5. 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 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 are discussed in Annex A3.2.

Table 3-3 Differences in energy consumption and CO<sub>2</sub> 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	2010
	%				
Energy consumption	0.7	0.8	0.5	0.5	0.5
CO <sub>2</sub> emissions	0.8	1.0	0.8	0.9	1.0

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	%									
Energy consumption	0.4	0.2	0.6	0.3	0.1	0.7	0.1	-0.1	-0.1	0.2
CO <sub>2</sub> emissions	1.0	0.6	1.1	0.8	0.8	1.2	0.7	0.4	0.4	1.5

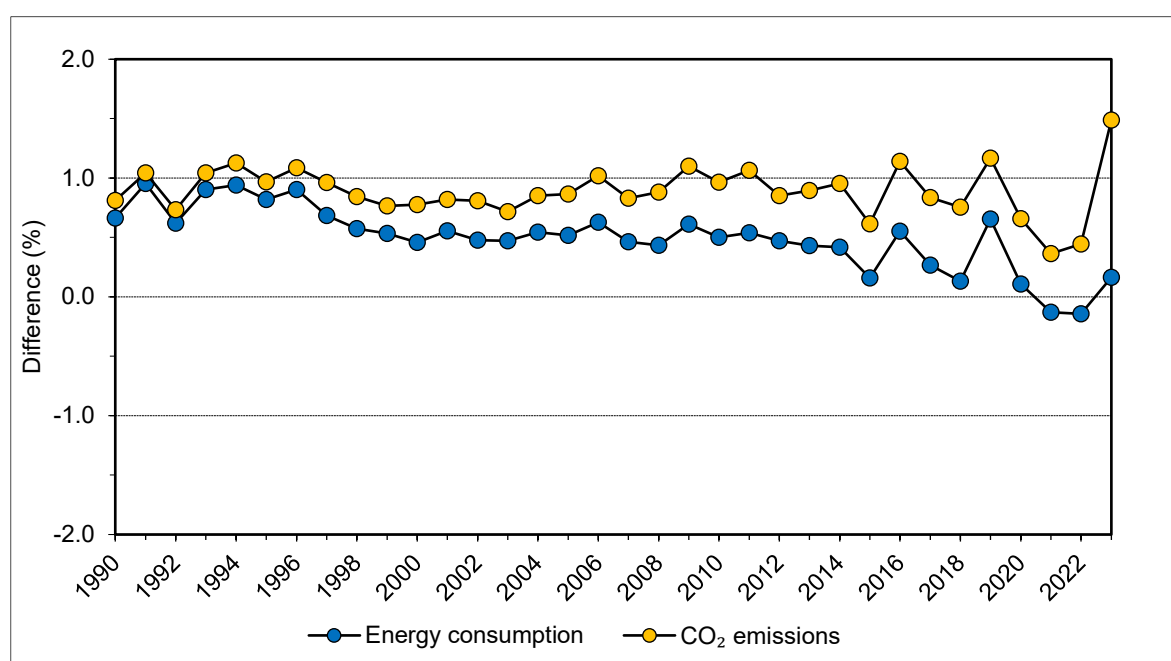


Figure 3-5 Time series for the differences between Reference and Sectoral Approach. Numbers are taken from Table 3-3. See caption there for further information.

### 3.2.1.1. Category-specific recalculations for the Reference Approach

- 1AB: Recalculations for the import of bitumen (2021, 2022) and lubricants (2021) and for the stock change of bitumen (2021, 2022), lubricants (2021) and petroleum coke (2022) due to revised data in the annual report of the Swiss petroleum association (Avenergy 2024).
- 1AB: Recalculations for the import of other bituminous coal, lignite in 2022 and natural gas in 2020-2022, the export of other bituminous coal in 2022 and the stock changes of other bituminous coal in 2019-2022 due to revised data in the Swiss overall energy statistics (SFOE 2024).

- 1AB: Recalculations for the production and carbon emission factor of waste (non-biomass fraction) in the years 1991-2011 and 2013-2022 due to revised values of the fossil fraction of waste incinerated in municipal solid waste incineration plants (1A1a).

## 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 category	Specification
1D1a	International aviation (aviation bunkers)	Bunker fuels include fuel used for international aviation only.
1D1b	International navigation (marine bunkers)	Marine bunkers of the Rhine river and navigation on the Lake Geneva and the Lake Constance.

### 3.2.2.2. Methodological issues for 1D

#### 3.2.2.2.1. *International aviation / aviation bunkers (1D1a)*

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

The Tier 3A method follows standard modelling procedures at the level of single aircraft movements based on detailed movement statistics. For international aviation (aviation bunkers), the flights departing from Switzerland to a destination abroad are selected. The emission factors are country-specific based on measurement and analyses of fuel samples. The activity data of the international aviation bunker are summarised in Table 3-6 (see also Table 3-85). Given that detailed information about activity data is available, the resulting fuel consumption is considered complete. Despite this, there remain small differences between the fuel consumption modelled bottom-up and the total fuel sold (SFOE 2024, FOCA 2024). In 1990, the modelled consumption adds up to 1.01 million tonnes, whereas 1.05 million tonnes of fuel were 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. 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 2023, the bunker fuel consumption and the emissions had to be expanded by the factor 1.05, the correction factor was 0.954 (FOCA 2024). For the years 2020 and 2021, the overestimation of emissions from international aviation was very high compared to previous years because the modelling of aircraft fuel consumption is based on practically fully loaded aircraft (high load).

Due to exceptional measures to contain the COVID-19 pandemic during the years 2020 and 2021, many flights were very lightly loaded which in terms of aircraft led to lower fuel consumption per route. More direct flight paths (low traffic volume) may be another reason. These effects relate almost exclusively to international flights. Since 2022, aircraft seat load factors increased to high values again, with aircraft operating at their usual weights. Thus, overestimation of the fuel burn from the model decreased again. For the more recent years, the modelled and actual total fuel sales are listed in Table 3-5.

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

Modelled and actual fuel sales	Unit	2007	2008	2009	2010	2011	2012	2013
Modelled fuel sales domestic	FC in t	43'968	37'627	39'626	39'252	42'047	43'414	42'064
Modelled fuel sales international	FC in t	1'287'062	1'391'656	1'345'919	1'395'428	1'511'279	1'527'522	1'528'863
Actual fuel sales SFOE minus modelled fuel sales domestic	FC in t	1'289'152	1'382'835	1'324'224	1'390'824	1'488'805	1'523'116	1'539'963
Correction factor for emission international		0.967	0.967	0.954	0.969	0.957	0.969	0.980
Overestimation emission international (modelled)	%	3.3%	3.3%	4.6%	3.1%	4.3%	3.1%	2.0%

Modelled and actual fuel sales	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Modelled fuel sales domestic	FC in t	44'462	43'680	44'716	37'985	36'561	36'357	24'449	18'763	21'845	20'530
Modelled fuel sales international	FC in t	1'561'678	1'590'013	1'711'227	1'741'752	1'818'355	1'836'385	727'941	818'030	1'388'366	1'672'108
Actual fuel sales SFOE minus modelled fuel sales domestic	FC in t	1'549'228	1'602'319	1'679'034	1'723'717	1'823'917	1'846'453	677'093	756'549	1'352'840	1'615'425
Correction factor for emission international		0.964	0.980	0.955	0.968	0.983	0.986	0.897	0.902	0.959	0.954
Overestimation emission international (modelled)	%	3.6%	2.0%	4.5%	3.2%	1.7%	1.4%	10.3%	9.8%	4.1%	4.6%

Table 3-6 International bunker fuels (1D1a): aviation bunkers. Consumption of jet kerosene in TJ (Liechtenstein's jet kerosene consumption is subtracted, see chp. 3.2.4).

1D1a International aviation	1990	1995	2000	2005	2010
	Fuel consumption in TJ				
1D1a International aviation	41'884	49'918	63'726	47'775	58'334
1990 = 100%	100%	119%	152%	114%	139%

1D1a International aviation	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	Fuel consumption in TJ									
1D1a International aviation	65'006	67'333	70'603	72'824	77'214	78'196	28'194	31'872	57'499	68'899
1990 = 100%	155%	161%	169%	174%	184%	187%	67%	76%	137%	164%

### 3.2.2.2.2 International navigation / navigation bunkers (1D1b)

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<sub>2</sub> (with country-specific carbon contents) and with a Tier 1 approach for CH<sub>4</sub> and N<sub>2</sub>O using IPCC default emission factors. On the river Rhine and on Lake Geneva and Lake Constance, 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 oil 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 1997–2023 (SFOE 2024f).
- 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 around the 2013 level. The values from INFRAS 2011 have been adapted to the new measures of



the net calorific value of diesel oil for the year 2013 as shown in table 3-10. For the years 1990 to 1994, proxies such as passenger data on a national basis had to be consulted. As marine lake bunkers provided only a minor share of the total international navigation in the early 1990s (about 7 %) this approach is justified. The emission factor for CO<sub>2</sub> is country-specific and in accordance with Table 3-13.

Table 3-7 International bunker fuels (1D1b): Navigation. Consumption of diesel oil in TJ.

1D1b International navigation	1990	1995	2000	2005	2010
Fuel consumption in TJ					
1D1b International navigation	821	739	531	493	471
1990 = 100%	100%	90%	65%	60%	57%

1D1b International navigation	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Fuel consumption in TJ										
1D1b International navigation	299	342	299	256	200	197	189	228	207	200
1990 = 100%	36%	42%	36%	31%	24%	24%	23%	28%	25%	24%

### 3.2.2.3. Uncertainties and time-series consistency for 1D

International bunker fuels: 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. 1.5. 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

There were no recalculations implemented in submission 2025.

### 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 2024) 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 Avenenergy Suisse (formerly Swiss petroleum association, EV) (Avenenergy 2024). 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 types. For submission 2015, a more differentiated breakdown of feedstocks and non-energy use of fuels was developed, which is described 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 chp. 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 is partly emissive. According to the 2006 IPCC Guidelines (IPCC 2006), 20 % of those lubricants are oxidized during use (ODU). All CO<sub>2</sub> 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 Avenergy Suisse (Avenergy 2024). 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 Avenergy Suisse (Avenergy 2024). Use of paraffin waxes is considered partly emissive (see source category 2D2 under chp. 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. The net consumption of non-energy use of fuels reported in the Swiss overall energy statistics includes also sulphur produced by the refineries. This amount of sulphur is subtracted, resulting in lower fuel quantities for non-energy use of other oil for the entire time series compared to the Swiss overall energy statistics.
- 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). Based on personal communication with the relevant experts for the Swiss overall energy statistics, the feedstock use of anthracite is 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<sub>2</sub> emissions from feedstocks and non-energy use of fuels.

### 3.2.3.1. Category-specific recalculations for 1AD

- 1AD: CO<sub>2</sub> emissions from lubricants use (reported under 2D1) changed due to recalculated gasoline consumption of 2-stroke motorcycles (1A3biv) for the entire time series 1990-2022.
- 1AD: The 2022 domestic sales of bitumen were adjusted in the annual report of the Swiss petroleum association (Avenergy 2024) due to a revised import volume, which led to recalculations of the fuel quantity of bitumen and other oil for non-energy use and thus of carbon excluded from reference approach in 2022

### 3.2.4. Country-specific issues of 1A Fuel combustion

#### 3.2.4.1. System boundaries: Differences between UNFCCC and CLRTAP reporting

Switzerland uses the same data base for the Swiss greenhouse gas inventory as for the Swiss air pollution inventory and 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 types of reporting 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.

#### Fuel used or fuel sold approach in 1A3b Road transportation

There are two different approaches for calculating emissions in source category 1A3b Road transportation. One is the fuel used approach, which is based on the road transportation model, that calculates the fuel consumption using kilometres driven per vehicle category in the Swiss territory as described in chapter 3.2.9.2.2. The other one is the fuel sold approach, which bases on the total amount of fuel sold as reported in the Swiss energy statistics. The difference between the calculated fuel consumption of diesel oil, gasoline, biodiesel, bioethanol and natural gas in the road transportation model and the Swiss energy statistics is called “statistical difference and fuel tourism”. “Fuel tourism” refers to the amount of fuel sold in Switzerland but consumed abroad or vice versa. To calculate the emissions for the fuel sold approach, this difference in fuel consumption per fuel type is distributed proportionally across each vehicle category, whereby the activity data in GJ, driven kilometres and the number of vehicles is adjusted proportionally in each category.

As Switzerland is a small country, the difference between these 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.

It is assumed that no fuel tourism takes place with non-road vehicles and therefore the differences between fuel used and fuel sold are attributed to 1A3b Road transportation for gasoline, diesel oil, natural gas, bioethanol and biodiesel (see Figure 3-9, Figure 3-16 and Figure 3-20). The difference for biogas is attributed to 1A4ai Other sectors (stationary) – commercial/institutional (see Figure 3-18) and the one from liquefied petroleum gas to 1A2gvii Other (boilers) (see Figure 3-13).

Under the UNFCCC, there is no difference between the reported national total and the national total for assessing compliance as it is based on fuel sold within the national territory. Under the CLRTAP, the national total is based on fuel sold but for assessing compliance it is based on fuel used (fu) in 1A3b Road transportation within the Swiss boundaries (see Table 3-9).

#### Only domestic flights or only LTO cycles in 1A3a Aviation (civil)

Another difference concerns emissions from 1A3a Aviation: International flights are flights from a Swiss airport to a destination abroad. International flights with landing in Switzerland are not accounted for because they bought their fuel at the departure airport abroad. Domestic flights are flights with departure and destination in Switzerland. For the GHG inventory only emissions from domestic flights are accounted for, while emissions from international flights are reported as aviation bunker, i.e. as a memo item (1D1a International aviation), see also UNFCCC (2019, Paragraph 53). For the reporting of air pollutants under

the CLRTAP, landing and take-off (LTO) cycle emissions of domestic and international flights are accounted for, while emissions of domestic and international cruise flights are reported as memo items only (see Table 3-9). Note that emissions from overflights without landing in Switzerland are not considered in either approach.

Table 3-9 Accounting rules for emissions from 1A3a Domestic aviation and 1A3b Road transportation under the CLRTAP and the UNFCCC.

Differences between reporting under CLRTAP and UNFCCC concerning the accounting to the national total			CLRTAP / NFR tables			UNFCCC / CRT tables	
			accounted to			National total	Bunker (1D)
			National total	National total for compliance	Separated information / Memo items		
1A3b - Road transportation	1A3bi-v (fu) Fuel used - approach	Based on statistics of driven km and vehicle categories	No	Yes	Yes	No	No
	1A3bi-v Fuels sold - approach	The activity data of the fuel used-approach are adapted to reflect the total of fuel sold as reported in statistics.	Yes	No	No	Yes	No
1A3a - Aviation	Civil and 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
		Fuel Dumping	No	No	Yes	No	Yes
		Overflights	No	No	No	No	No

### 3.2.4.2. Net calorific values (NCVs)

Table 3-10 summarises the net calorific values (NCVs) which are used in order to convert from energy amounts in tonnes into energy quantities in gigajoules (GJ). More detailed explanations including information about the origin of the NCVs of the different fuels are given below.

Table 3-10 Net calorific values (NCVs) of various fuels. Where values for two years are indicated, the NCV is interpolated between these two years and constant NCVs are used before the first and after the second year (corresponding to the two indicated values). For the NCV of wood, a range covering all facility categories and years is provided. For the NCVs of natural gas and biogas see Table 3-11.

Fuel	Year	NCV	Unit	Data sources
<b>Fossil fuel</b>				
Gasoline	until 1998	42.5	GJ/t	EMPA (1999)
	from 2013	42.6	GJ/t	SFOE/FOEN (2014)
Jet kerosene	until 1998	43.0	GJ/t	EMPA (1999)
	from 2013	43.2	GJ/t	SFOE/FOEN (2014)
Diesel oil	until 1998	42.8	GJ/t	EMPA (1999)
	from 2013	43.0	GJ/t	SFOE/FOEN (2014)
Gas oil	until 1998	42.6	GJ/t	EMPA (1999)
	from 2013	42.9	GJ/t	SFOE/FOEN (2014)
Residual fuel oil	from 1990	41.2	GJ/t	EMPA (1999)
Liquefied petroleum gas	from 1990	46.0	GJ/t	SFOE (2024)
Petroleum coke	until 1998	35.0	GJ/t	SFOE (2024)
	from 2010	31.8	GJ/t	SFOE (2024)
Other bituminous coal	until 1998	28.052	GJ/t	SFOE (2024)
	from 2010	25.5	GJ/t	SFOE (2024)
Lignite	until 1998	20.097	GJ/t	SFOE (2024)
	from 2010	23.6	GJ/t	SFOE (2024)
<b>Biofuel</b>				
Biodiesel	from 1990	32.7	GJ/m3	SFOE (2024)
Bioethanol	from 1990	21.1	GJ/m3	SFOE (2024)
Wood	from 1990	8.6-14.6	GJ/t	SFOE (2024b)

### Gasoline, jet kerosene, diesel oil and gas oil

For gasoline, jet kerosene, diesel oil and gas oil, the NCV for 1998 and 2013 are based on national measurement campaigns and are the same as used by the Swiss Federal Office of Energy (SFOE 2024). A first campaign was conducted by the Swiss Federal Laboratories for Materials Science and Technology (Empa) in 1998 (EMPA 1999). Since earlier data are not available, the values for 1990–1998 are assumed to be constant at the 1998 levels. A second campaign, commissioned by the Swiss Federal Office of Energy (SFOE) and the Swiss Federal Office for the Environment (FOEN), was conducted in 2013 (SFOE/FOEN 2014). This study was based on representative samples covering summer and winter fuel qualities from the main import streams. The sampling started in July 2013 and lasted six months. Samples were taken fortnightly from nine different sites (large-scale storage facilities and the two refineries operating at that time in Switzerland) and analysed for carbon contents and NCVs amongst other. These updated values are used from 2013 onwards, while the NCVs for 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 the Swiss energy supply. Therefore, this fuel was not analysed in the most recent measurement campaign in 2013 (SFOE/FOEN 2014). Thus, the respective NCV refers to the measurement campaign in 1998 (EMPA 1999). The NCV for residual fuel oil, which is the same as used by the Swiss Federal Office of Energy (SFOE 2024), is assumed to be constant over the entire reporting period. The same approach is applied for the CO<sub>2</sub> emission factor (see Table 3-13).

### **Liquefied petroleum gas**

The NCV of liquefied petroleum gas is the same as used by the Swiss Federal Office of Energy (SFOE 2024) and is – as in the Swiss overall energy statistics – constant over the entire reporting period. It is assumed that liquefied petroleum gas is a mixture of propane and butane in equal proportions.

### **Petroleum coke, other bituminous coal, lignite**

For the entire reporting period, the NCVs of petroleum coke, other bituminous coal and lignite are the same as used by the Swiss Federal Office of Energy (SFOE 2024). For these fuels, the Swiss overall energy statistics contains NCVs for the years 1998 and 2010. Values in between are interpolated, with values before the first and after the last year of available data held constant. The NCVs for 2010 are based on measured samples taken from Switzerland's cement plants as they are the largest consumers of these fuels in Switzerland. Samples from the individual plants were taken from January to September 2010 and analysed for NCVs by an independent analytical laboratory (Cemsuisse 2010a). For each fuel, the measurements from the individual plants were weighted according to the relative consumption of each plant.

### **Natural gas, biogas**

The NCV of natural gas (and also the CO<sub>2</sub> emission factor of natural gas, see Table 3-14 ) is calculated based on measurements of gas properties and corresponding import shares of individual gas import stations. Measurements of gas properties are available from the Swiss Gas and Water Industry Association (SGWA) on an annual basis since 2009 and for selected years before. The latest report is SGWA (2024). 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). Values for the years in between are interpolated. The calculation procedure is documented in FOEN (2024i). The NCV of biogas is assumed to be equal to the NCV of natural gas since the raw biogas is treated to fulfil the same quality level including its energetic properties as natural gas.

Table 3-11 Net calorific values (NCVs) of natural gas and biogas for years with available data. Values for the years in between are linearly interpolated. Data source: Annual reports of the Swiss Gas and Water Industry Association (SGWA), the latest report is SGWA (2024). Spreadsheet to determine national averages: FOEN (2024i).

Year	NCV of natural gas and biogas [GJ/t]
1990	46.5
1991	46.5
1995	47.5
2000	47.2
2005	46.6
2007	46.3
2009	46.4
2010	46.3
2011	46.1
2012	45.8
2013	45.7
2014	45.7
2015	46.6
2016	47.1
2017	47.4
2018	47.6
2019	47.5
2020	47.6
2021	48.2
2022	48.0
2023	48.4

## Wood

The NCV of wood depends on the type of wood fuel (e.g. log wood, wood chips, pellets) and is based on the Swiss wood energy statistics (SFOE 2024b). Table 3-10 illustrates the range of the NCVs of all wood fuel types.

## Bioethanol and biodiesel

The NCVs of bioethanol and biodiesel are the same as used by the Swiss Federal Office of Energy (SFOE 2024) and are – as in the Swiss overall energy statistics – constant over the entire reporting period.

### 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 2024). 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. To calculate the correct Swiss fuel consumption, Liechtenstein's liquid fossil fuel consumption, given by Liechtenstein's energy statistics (OS 2024), 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 2024). 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 A3.1).

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

- The Swiss organization for the compulsory stockpiling of oil products (Carbura) and Avenenergy Suisse (formerly 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).
- Annual import data for petroleum products and coal from the Federal Office for Customs and Border Security (FOCBS).
- Data provided by industry associations (GVS, SGWA, Cemsuisse, VSG, VSTB, etc.).
- Swiss electricity statistics (SFOE 2024g).
- Swiss renewable energy statistics (SFOE 2024a).
- Swiss wood energy statistics (SFOE 2024b).
- Swiss statistics on combined heat and power generation (SFOE 2024c).

As can be seen in Figure 3-6, fossil fuels amount to slightly less than half of primary energy consumption (i.e. of the total energy demand including losses during transformation and distribution; the losses during transformation and distribution are larger for nuclear fuel and hydro power than for fossil fuels). 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 A3.1.

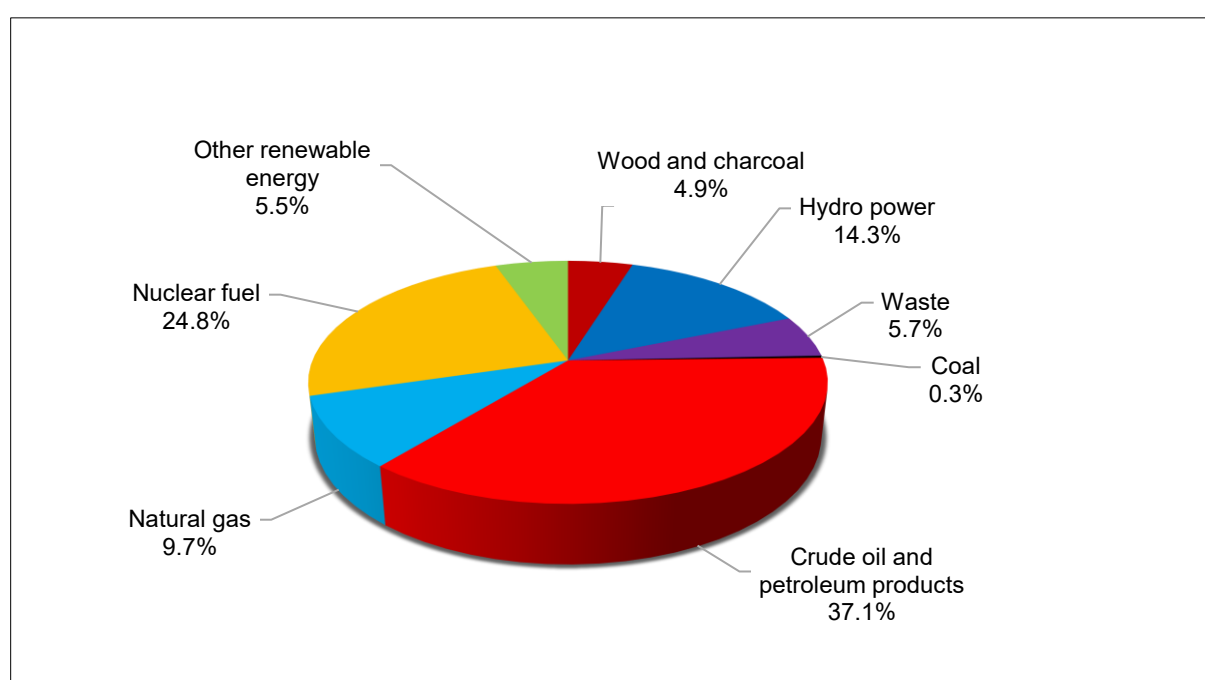


Figure 3-6 Switzerland's primary energy consumption in 2023 by fuels (see corresponding data in SFOE 2024).



Table 3-12 shows primary energy consumption excluding nuclear fuel and hydro power. On the one hand, the combined effect of decreasing consumption of gasoline and increasing consumption of jet kerosene and diesel oil led to an increasing trend until about 2010 and a stabilization thereafter in the transport sector. On the other hand, consumption of liquid fuels in the residential and services sectors (mainly gas oil) as well as in the industry sector (mainly gas oil and residual fuel oil) substantially decreased. Natural gas consumption increased since 1990, compensating to some extent the decreasing use of gas oil and residual fuel oil in the various sectors. Due to the restrictions related to the COVID-19 pandemic the years 2020 and 2021 are exceptional, with lower fuel consumption, especially in the transport sector. Compared to 2021, total fuel consumption strongly declined in 2022. In particular gas oil and natural gas consumption was lower compared to the previous years due to the warm winter and precautionary energy saving measures in anticipation of a potential energy shortage (electricity and natural gas). In 2023 total fuel consumption was on a similar level as in 2022.

Table 3-12 Switzerland's energy consumption by fuel type. Only those fuels are shown that are implemented in the EMIS database (no hydro and nuclear power). The numbers are based on the fuels sold principle; thus, they include gasoline, diesel oil and biofuels consumption from fuel tourism, as well as all jet kerosene sold for domestic and international aviation. Natural gas and gasoline losses due to fugitive emissions (reported in sector 1B) are not included.

Year	Gasoline	Jet kerosene (fossil) domestic aviation	Jet kerosene (fossil) international aviation (bunker)	Diesel oil (incl. fossil fraction of biodiesel)	Diesel oil international navigation (bunker)	Gas oil	Residual fuel oil	Refinery gas & Liquefied petroleum gas	Petroleum coke	Solid fuels	Gaseous fuels (excl. losses in 1B)	Other fossil fuels	Biomass (incl. Bio fuels)	Total as reported in CRT reporting tables	Total incl. bunker
	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ
1990	155'703	6'183	41'884	46'736	821	218'510	23'342	8'890	1'400	14'901	68'426	19'074	46'826	609'989	652'695
1991	162'063	5'690	40'872	47'417	737	238'602	23'590	12'437	980	12'162	76'724	18'503	48'827	646'995	688'604
1992	168'037	5'600	43'499	45'926	780	236'809	24'170	11'492	315	8'758	80'627	18'935	47'749	648'417	692'697
1993	155'808	5'434	45'342	44'197	781	225'920	17'165	12'388	1'120	7'442	84'574	19'041	48'092	621'179	667'302
1994	155'797	5'269	46'840	46'924	824	207'141	17'860	13'455	1'470	7'632	83'402	19'051	46'054	604'054	651'719
1995	151'094	5'029	49'918	47'865	739	217'523	17'278	12'756	1'260	7'962	91'942	19'586	48'095	620'389	671'046
1996	155'033	4'778	51'975	44'946	651	226'289	15'097	13'939	1'015	5'456	99'530	20'430	51'683	638'196	690'823
1997	161'031	4'791	53'983	46'731	657	212'223	12'581	14'236	280	4'590	96'083	21'501	48'540	622'587	677'227
1998	162'315	4'669	56'599	48'684	528	222'407	15'882	15'259	455	3'960	98'890	23'575	50'160	646'257	703'384
1999	167'815	4'419	60'824	51'629	558	212'349	11'058	15'805	521	4'105	102'415	24'197	50'918	645'232	706'615
2000	168'009	4'334	63'726	55'149	531	196'137	7'923	13'649	551	6'120	101'800	26'288	50'603	630'565	694'822
2001	163'442	4'055	60'153	56'266	447	213'089	9'942	14'089	410	6'233	105'966	26'775	53'894	654'142	714'741
2002	160'276	3'870	55'536	58'392	333	196'655	6'446	15'584	679	5'565	104'007	27'624	53'436	632'534	688'404
2003	159'512	3'598	49'840	61'812	443	208'040	7'061	13'642	202	5'663	109'957	27'369	56'020	652'876	703'158
2004	156'708	3'458	46'983	66'453	446	203'370	7'561	16'429	1'819	5'420	113'459	28'495	56'993	660'164	707'594
2005	151'966	3'326	47'775	72'583	493	205'729	5'805	16'432	2'906	5'940	116'493	28'833	59'152	669'165	717'433
2006	147'344	3'338	50'233	78'621	457	195'926	6'419	18'578	3'324	6'467	113'264	30'837	62'265	666'384	717'074
2007	145'923	3'473	53'692	84'437	465	171'313	5'179	15'587	2'730	7'196	110'252	29'617	61'312	637'019	691'176
2008	142'713	3'128	58'023	92'690	473	178'833	4'581	16'288	3'616	6'562	117'451	30'394	65'500	661'755	720'252
2009	138'883	3'239	55'426	94'156	425	173'219	3'530	16'301	3'254	6'193	112'674	29'314	65'671	646'434	702'285
2010	133'953	3'286	58'334	97'792	471	182'295	2'967	15'463	3'498	6'208	125'846	30'612	70'573	672'493	731'297
2011	128'775	3'235	62'461	100'466	428	143'760	2'292	14'856	2'957	5'792	111'617	30'320	66'243	610'315	673'204
2012	124'229	3'402	63'903	106'633	385	154'448	2'780	12'247	3'148	5'269	122'398	30'648	72'135	637'339	701'627
2013	118'572	3'359	64'709	111'502	342	162'532	1'959	15'053	2'735	5'567	128'912	30'403	75'741	655'334	721'385
2014	113'820	3'535	65'006	114'422	299	122'694	1'581	14'473	3'148	5'704	111'660	30'894	70'012	591'942	657'247
2015	105'540	3'454	67'333	112'888	342	129'349	862	9'822	1'145	5'205	119'314	31'838	73'282	592'699	660'374
2016	102'250	3'559	70'603	114'206	299	132'325	378	9'136	890	4'795	125'355	33'449	79'370	605'714	676'615
2017	99'112	3'110	72'824	113'952	256	123'726	350	8'770	763	4'609	125'602	33'289	82'597	595'879	668'959
2018	97'545	3'036	77'214	115'559	200	111'225	87	8'890	781	4'285	118'931	34'610	82'284	577'234	654'647
2019	96'748	2'874	78'196	115'638	197	108'625	111	8'108	777	3'842	121'941	35'264	84'682	578'610	657'003
2020	85'681	2'421	28'194	109'594	189	97'246	76	7'627	700	3'696	118'835	35'204	83'777	544'856	573'240
2021	87'541	2'112	31'847	110'738	228	107'991	139	7'522	604	3'726	129'419	34'707	90'589	575'088	607'164
2022	85'025	2'366	57'499	110'588	207	86'970	0	9'604	731	3'880	106'398	35'284	84'659	525'507	583'212
2023	87'805	2'319	68'881	108'357	200	84'286	41	9'024	763	3'065	98'606	34'597	87'068	515'932	585'014

### 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 2024). Activity data in sector 1 Energy are therefore calculated and disaggregated by the Swiss energy model, which is an integral part of the emission database EMIS. The model is developed and updated annually by the Swiss Federal Office for the Environment (FOEN). It relies on the Swiss overall energy statistics and is complemented with further data sources, e.g. Liechtenstein's liquid fuel sales (OS



2024), the Swiss renewable energy statistics (SFOE 2024a), the energy consumption statistics in the industry and services sectors (SFOE 2024d), as well as additional information from the industry. As wood energy consumption is not based on the Swiss overall energy statistics but directly on the figures from the Swiss wood energy statistics (SFOE2024b), its activity data are derived in a separate but analogous model.

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 3-7, 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 model of stationary engines and gas turbines. 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 chapter dedicated to the corresponding source category 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 (including the disaggregation of the separate model for wood energy combustion).

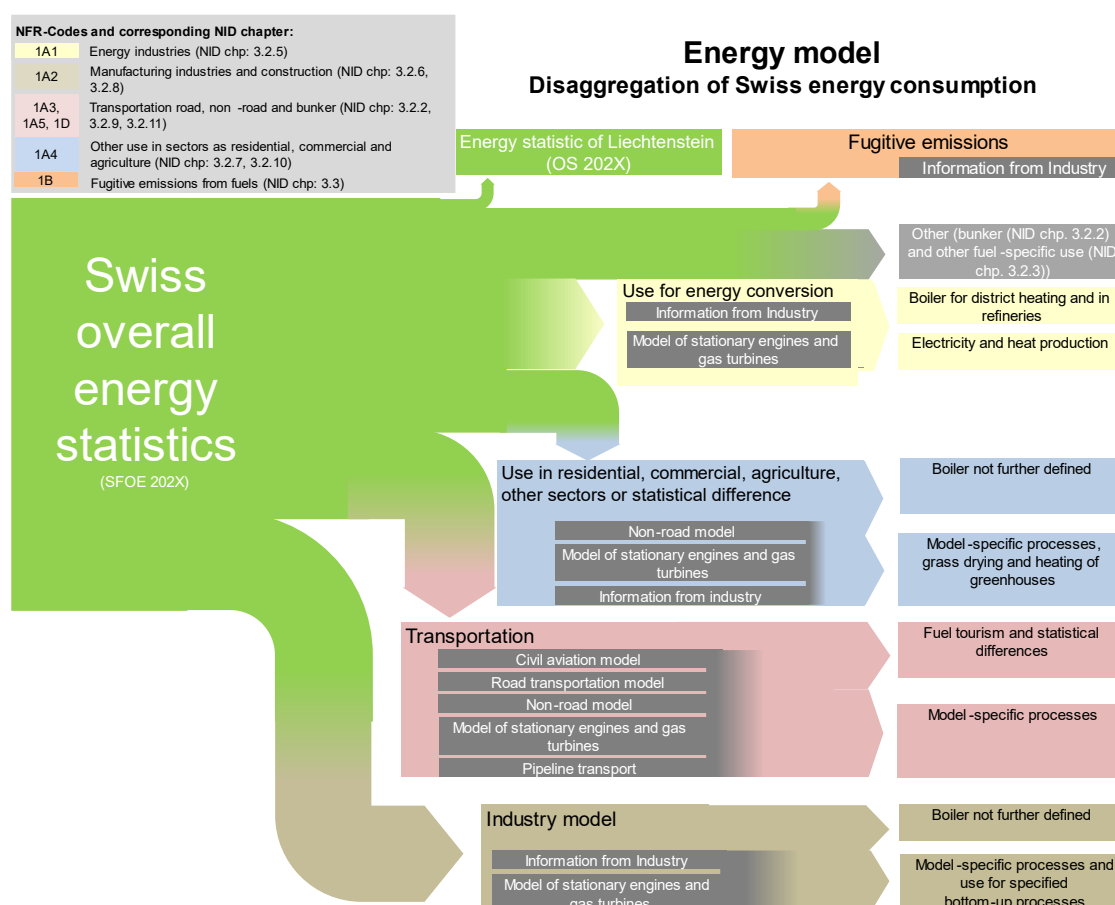


Figure 3-7 Overview of Switzerland's energy model. In the abbreviations SFOE 202X and OS 202X the “X” refers to the latest edition of the respective statistics.

**Industry model** (Details are given in chp. 3.2.6.2.1)

The industry model disaggregates the total fuel consumption in the industry sector (SFOE 2024) by source category and fuel type. It is based on the following two pillars. First, the energy consumption statistics in the industry and services sectors (SFOE 2024d) provide a comprehensive annual survey of fuel consumptions for all years since 1999 or 2002 (depending on the fuel type). These statistics are consistently extended back to 1990 based on a bottom-up industry model (Prognos 2013). Second, further disaggregation is achieved by using plant-level industry data for specific processes, as far as available.

**Civil aviation model** (Details are given in chp. 3.2.2.2.1 and 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 (see 3.2.9.2.2).

**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 or machinery numbers, their operation hours, engine power, and load factors to derive specific fuel consumption, emission factors and resulting emissions. Data stem from surveys among producers, various user associations, and the national database of non-road vehicles run by FEDRO.

**Model of stationary engines and gas turbines** (Details are given in chp. 3.2.4.5.2)

The model of stationary engines and gas turbines in 1A Fuel combustion activities is based on an inventory of installed capacities, technologies and operating hours of engines and gas turbines throughout Switzerland (INFRAS 2022a). The inventory is based on a survey with the cantonal authorities, information from websites and annual reports from industry, as well as from direct enquiries with the operators. The fuel consumption per engine and turbine type was derived from the inventory and the emissions are calculated using corresponding emission factors from different references.

### Model for wood energy combustion (Details are given in chp. 3.2.4.5.3)

Based on the Swiss wood energy statistics (SFOE 2024b), 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 2024) into the relevant source categories 1A1–1A5. Figure 3-9 to Figure 3-18 visualize for each fuel type separately the disaggregation process of the energy model (as shown schematically in Figure 3-7), the interaction between the different sub-models as well as additional data sources.

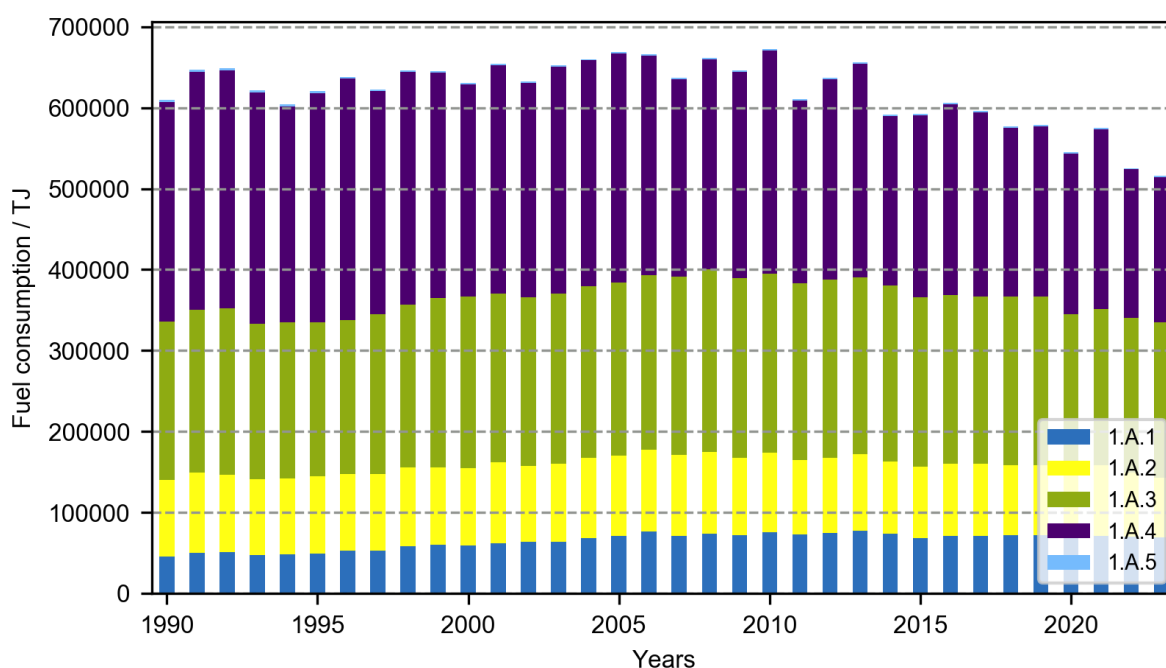


Figure 3-8 Switzerland's energy consumption in the source categories 1A1–1A5 based on the Swiss energy model, for the “fuel sold” approach. Since 1990 population has increased by about one third, industrial production by about three quarters and the motor vehicle fleet by almost three quarters (SFOE 2024, table 43a).

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:

- For source category 1A4ci Other sectors – Agriculture/forestry/fishing, specific bottom-up industry information is available for grass drying and heating of greenhouses. The fuel consumption for grass drying is provided by the Swiss association of grass drying plants

(VSTB). Further, based on annual energy consumption data from the Energy Agency of the Swiss Private Sector (EnAW) regarding agricultural greenhouses exempt from the CO<sub>2</sub> levy, total energy consumption of all greenhouses within Switzerland is extrapolated. The fuel consumption for grass drying and greenhouses is subtracted from the total fuel consumption of residential, commercial, agriculture and statistical differences (see Figure 3-7).

- In order to report all energy consumption, the statistical differences as reported in the Swiss overall energy statistics are allocated to source category 1A4ai Other sectors – Commercial/institutional (stationary combustion) and 1A3bi-iii Road transportation (see chp. 3.2.9.2.2 for a more detailed description).

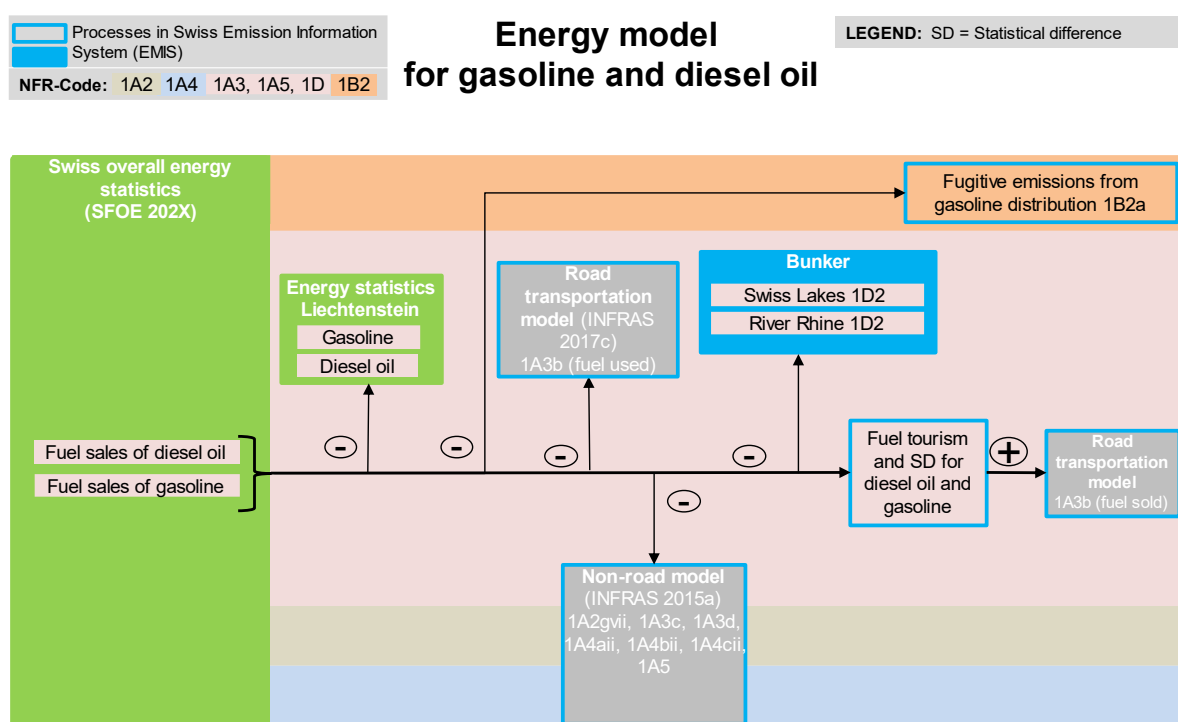


Figure 3-9 Schematic disaggregation of fuel consumption for gasoline and diesel oil. Marine bunker fuel consumption is based on the national customs statistics (see chp. 3.2.2.2.2)..

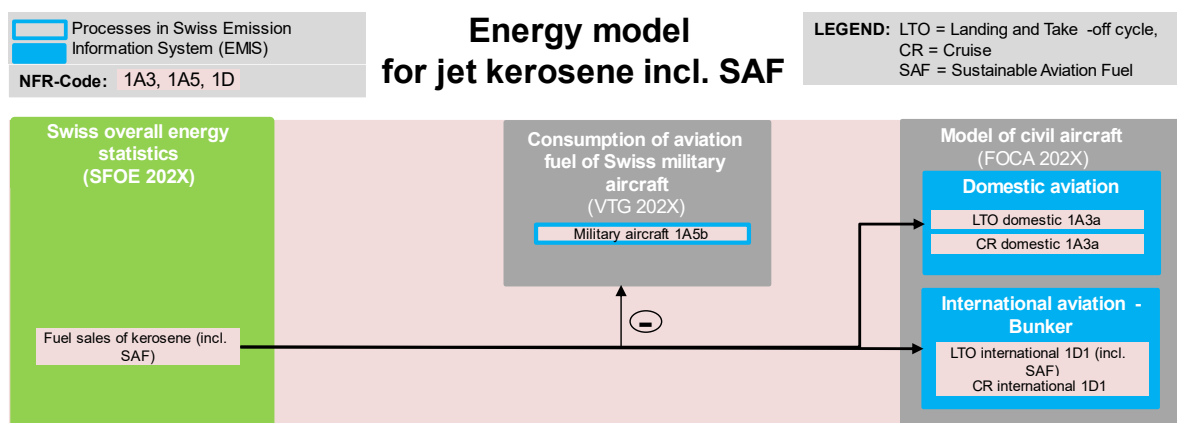


Figure 3-10 Schematic disaggregation of fuel consumption for jet kerosene. Fuel consumption for military aircraft is provided by the Swiss Air Force (part of the Swiss Armed Forces, VTG). The differentiation between domestic and international aviation as well as between CR and LTO is provided by the civil aviation model (see chp. 3.2.2.2.1).

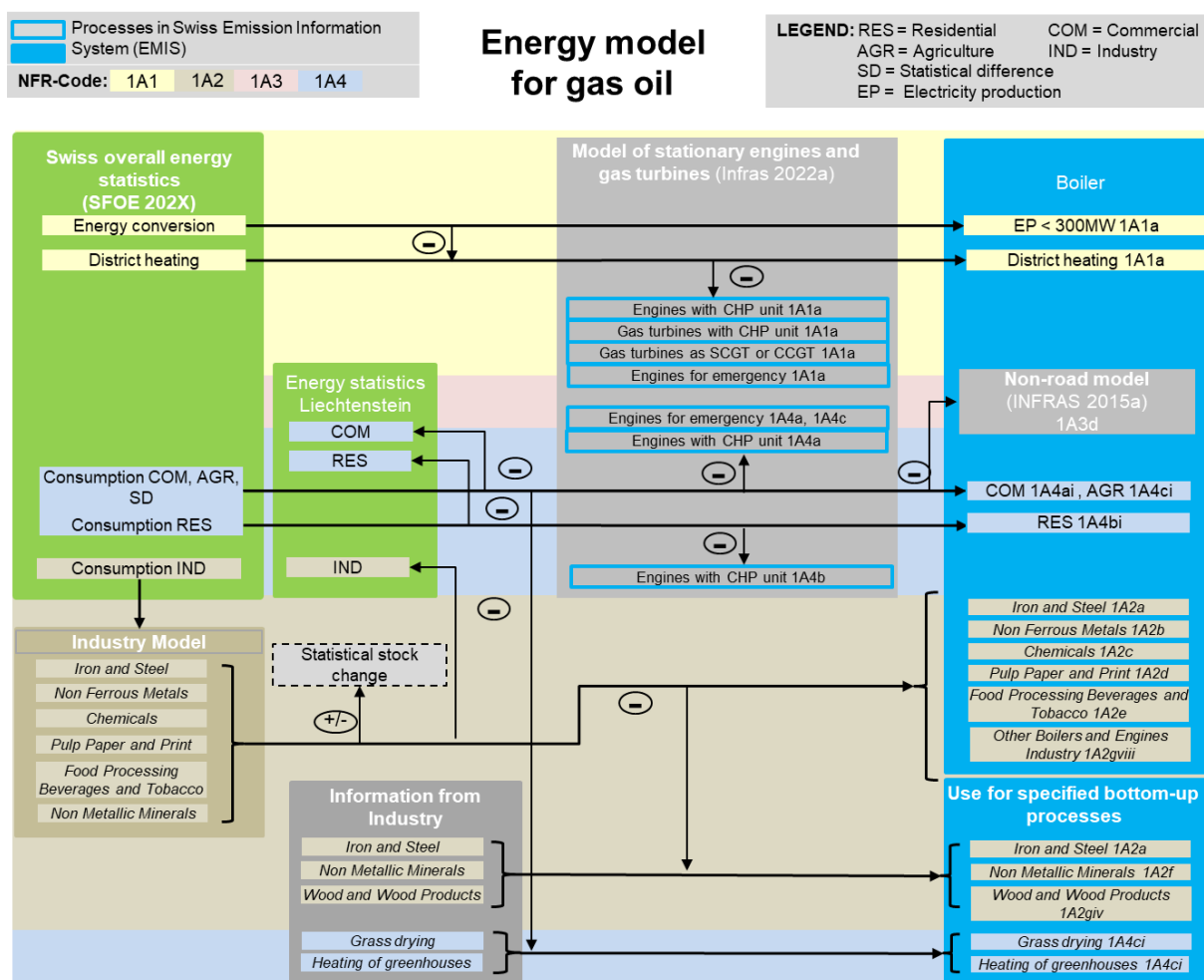


Figure 3-11 Schematic disaggregation of fuel consumption for gas oil. The Swiss overall energy statistics provides gas oil use for energy conversion and the amount thereof being used for district heating. Based on this information, gas oil use is split into the source categories 1A1ai Electricity generation and 1A1aiii Heat plants. According to the non-road model, a small amount of gas oil is consumed in source category 1A3d navigation (steam-powered vessels).

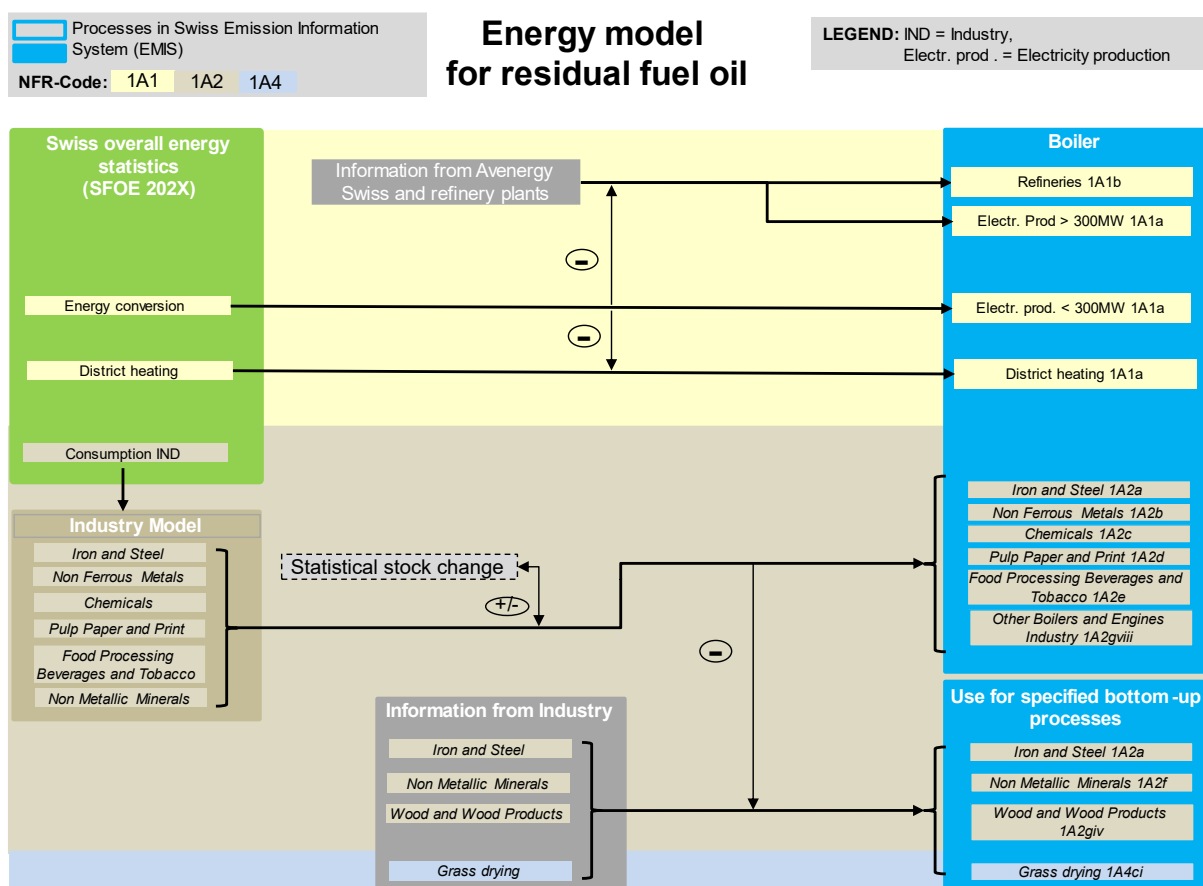


Figure 3-12 Schematic disaggregation of fuel consumption for residual fuel oil. The Swiss overall energy statistics reports residual fuel oil use in energy conversion and the amount thereof consumed in electricity production (one single fossil fuel power station, operational from 1985 to 1994), district heating, and in petroleum refineries. Based on this information, residual fuel oil use in Energy industries is split into the source categories 1A1ai Electricity generation, 1A1aiii Heat plants and 1A1b Petroleum refining.

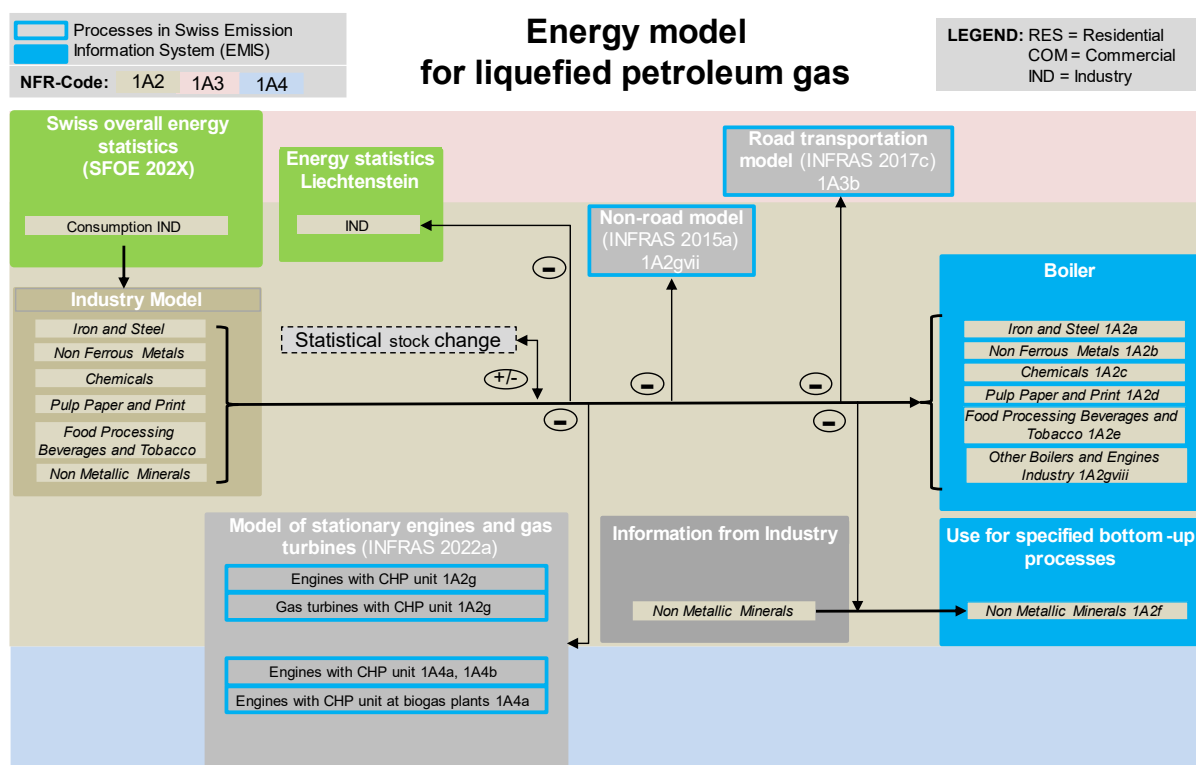


Figure 3-13 Schematic disaggregation of fuel consumption for liquefied petroleum gas.

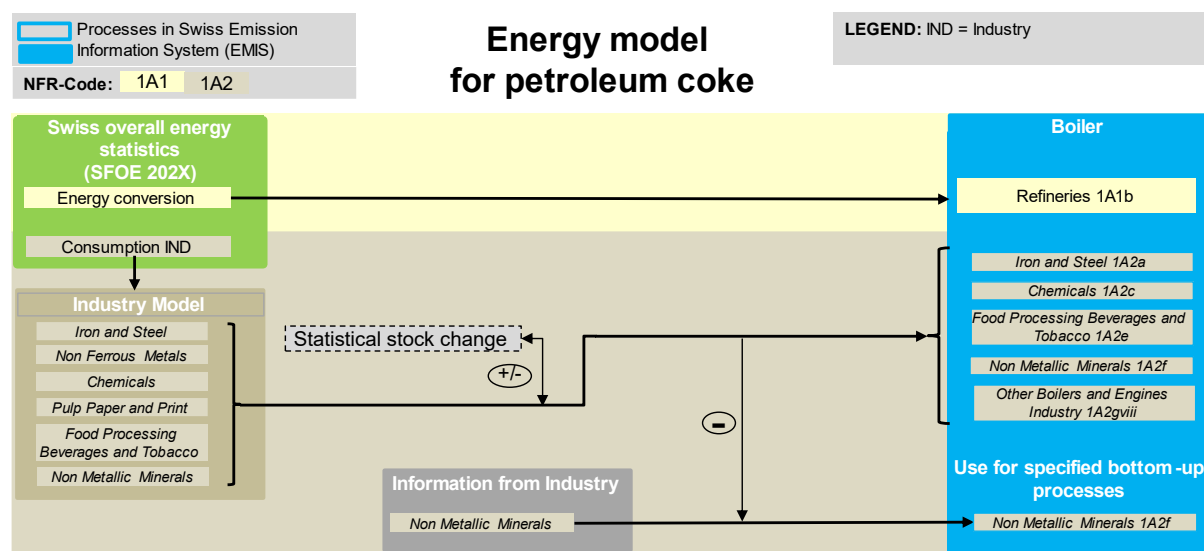


Figure 3-14 Schematic disaggregation of fuel consumption for petroleum coke.

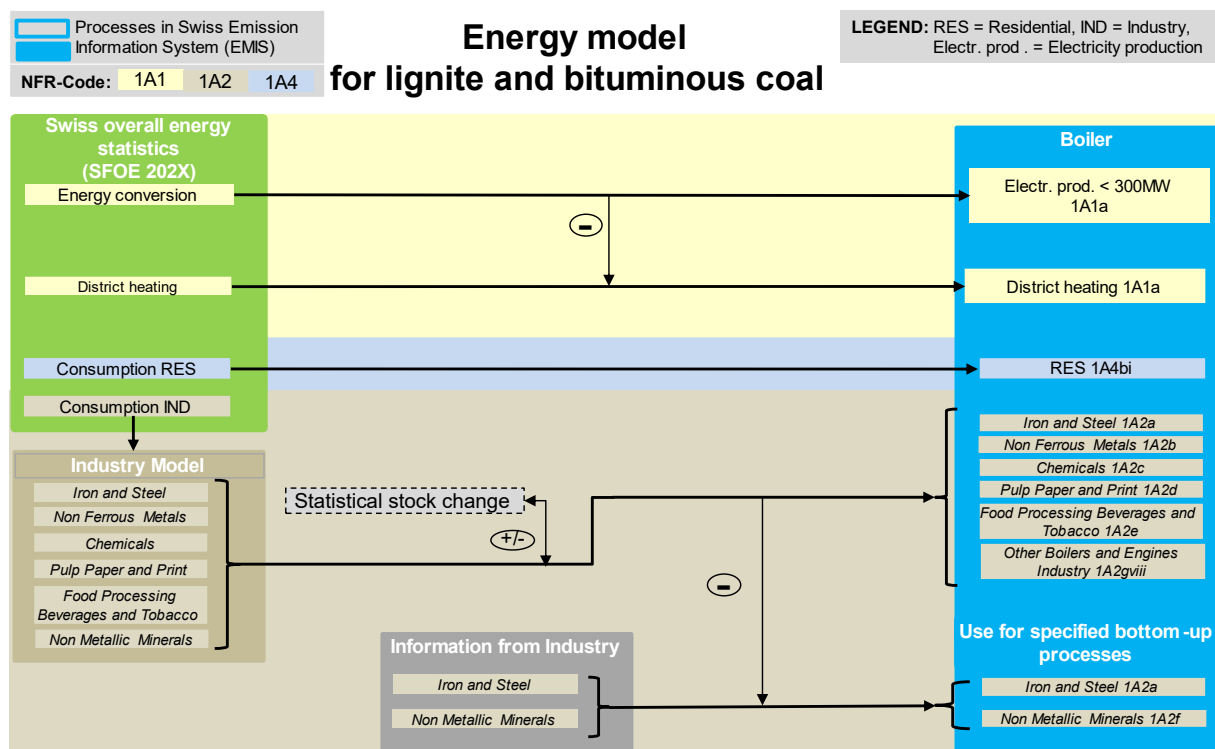


Figure 3-15 Schematic disaggregation of fuel consumption for lignite and bituminous coal. The Swiss overall energy statistics provides bituminous coal use for energy conversion and the amount thereof being used for district heating. Based on this information, use of bituminous coal in Energy industries is split into the source categories 1A1ai Electricity generation and 1A1aiii Heat plants up to 1995. Coal consumption for public electricity and heat production ceased thereafter.



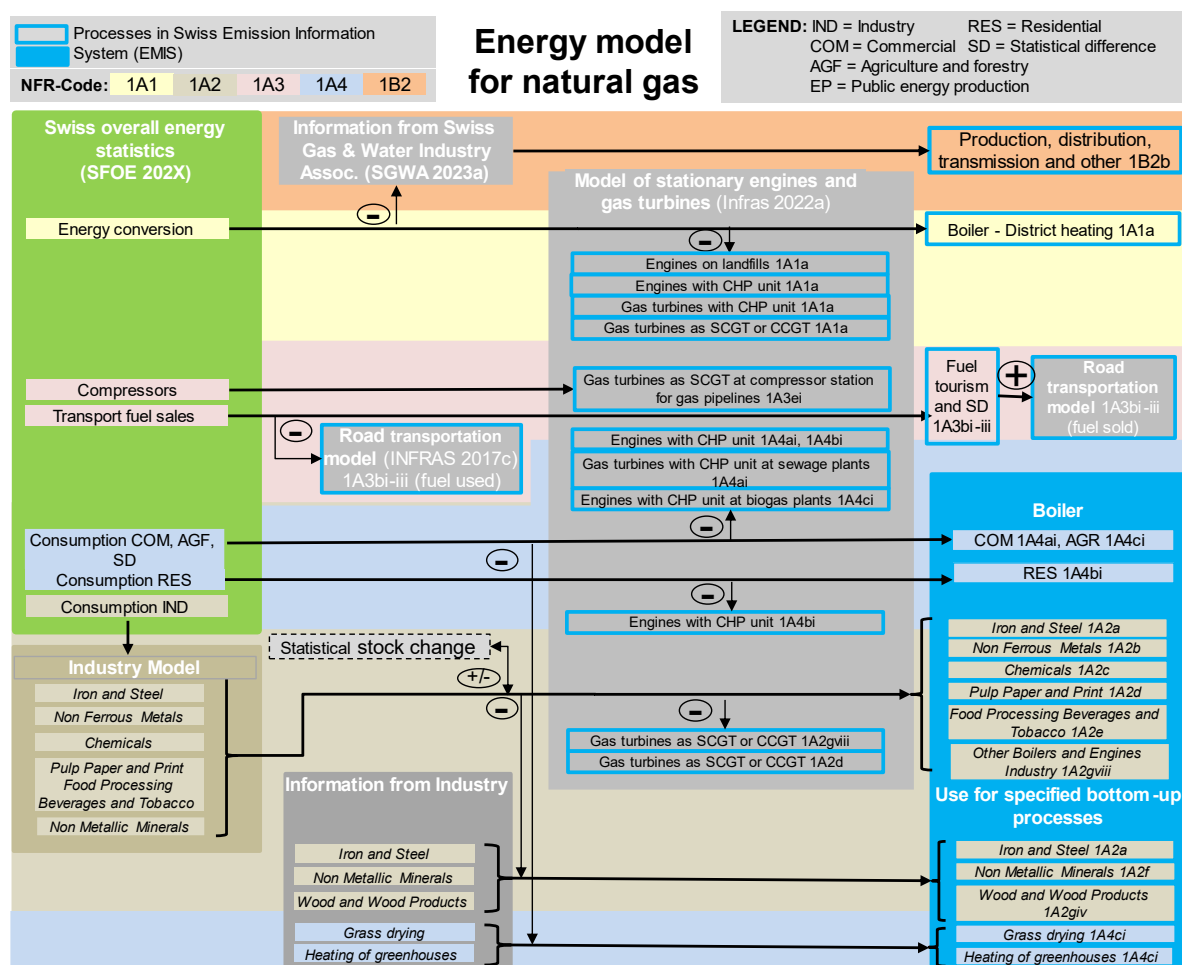


Figure 3-16 Schematic disaggregation of fuel consumption for natural gas. The Swiss overall energy statistics (SFOE 2024) provides gas use in the transformation sector (energy conversion and distribution losses). Distribution losses as estimated by the Swiss Gas and Water Industry Association (SGWA) are subtracted and reported under source category 1B2 Fugitive emissions from fuels. The remaining fuel consumption for natural gas is reported under source category 1A1a Public electricity and heat production.

A corresponding Figure 3-16b is available in the confidential version of this chapter, providing more details.

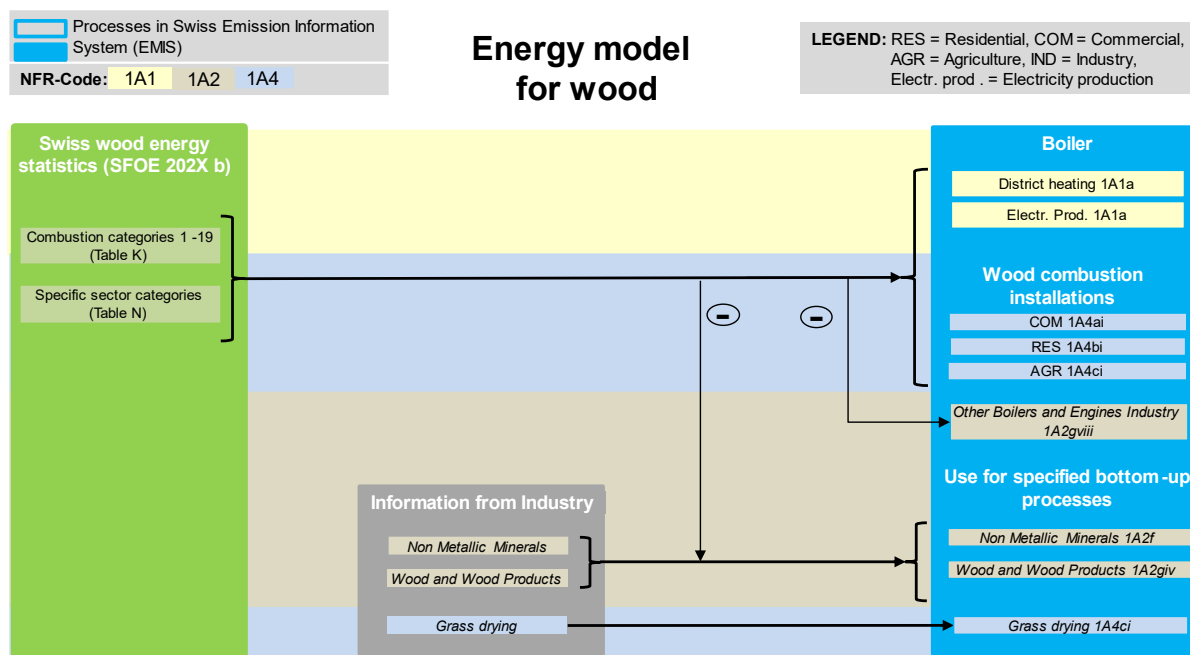


Figure 3-17 Schematic disaggregation of fuel consumption for wood (see chp. 3.2.4.5.2.)

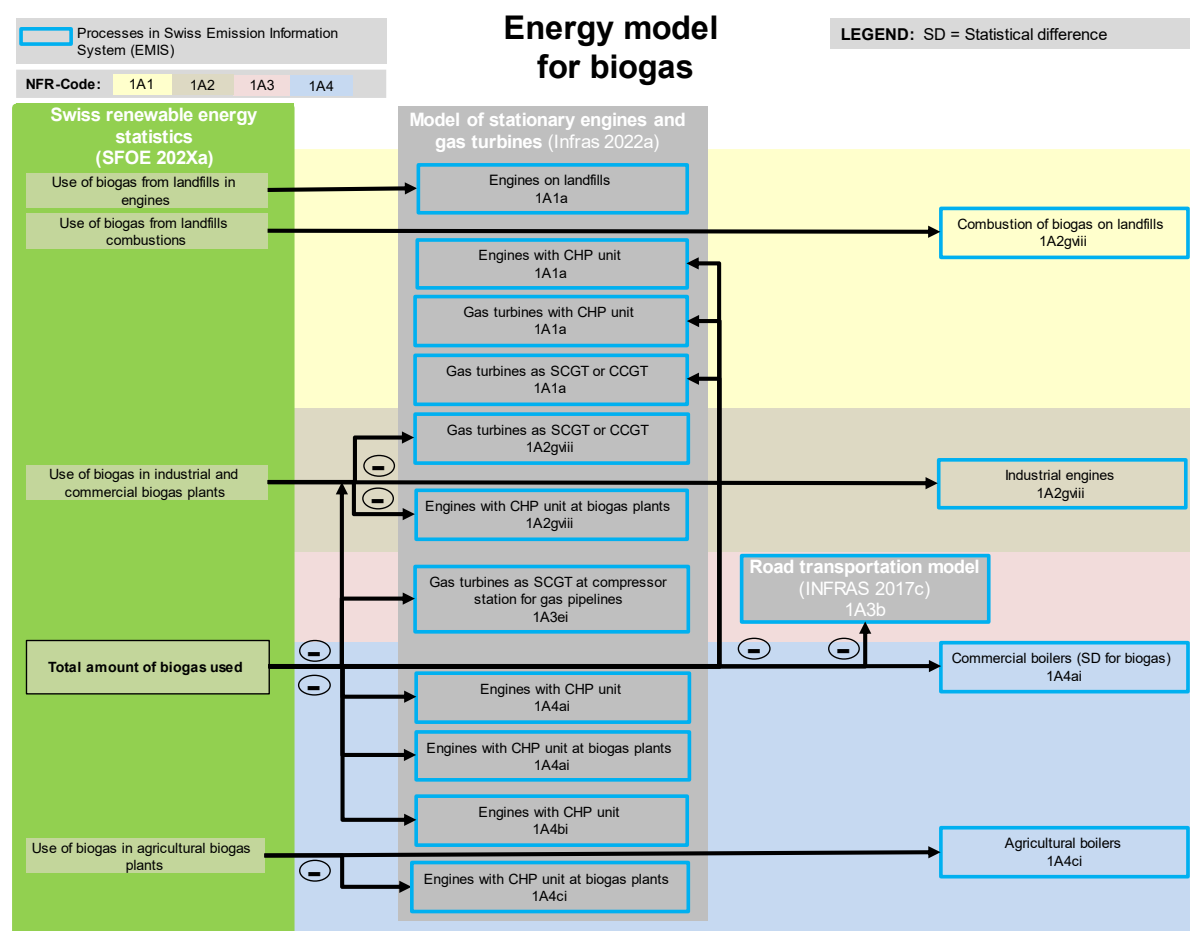


Figure 3-18 Schematic disaggregation of fuel consumption for biogas.

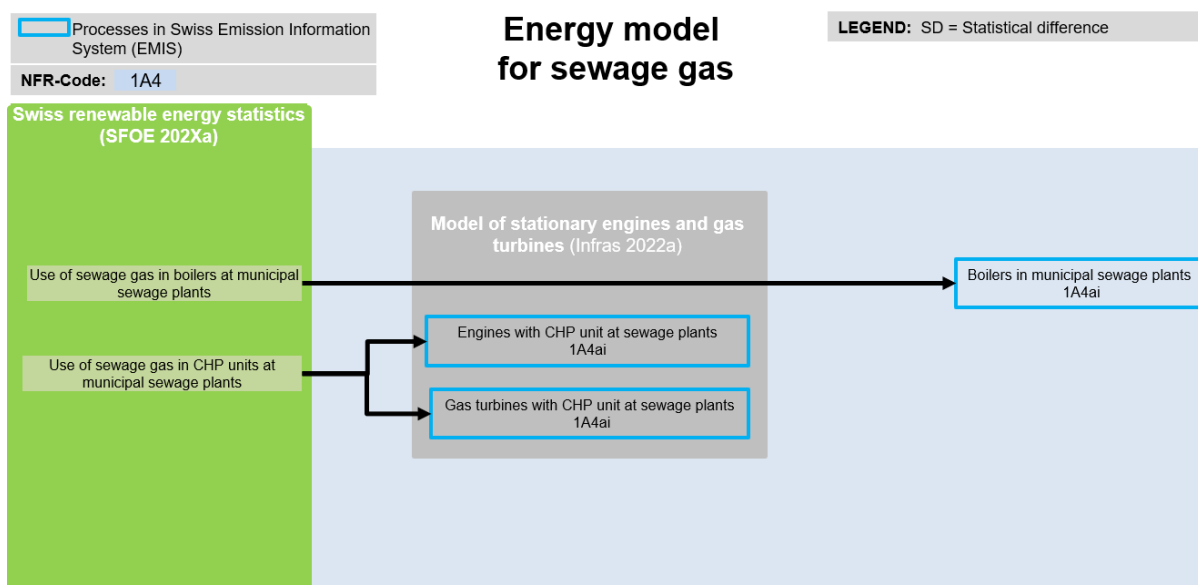


Figure 3-19 Schematic disaggregation of fuel consumption for sewage gas.

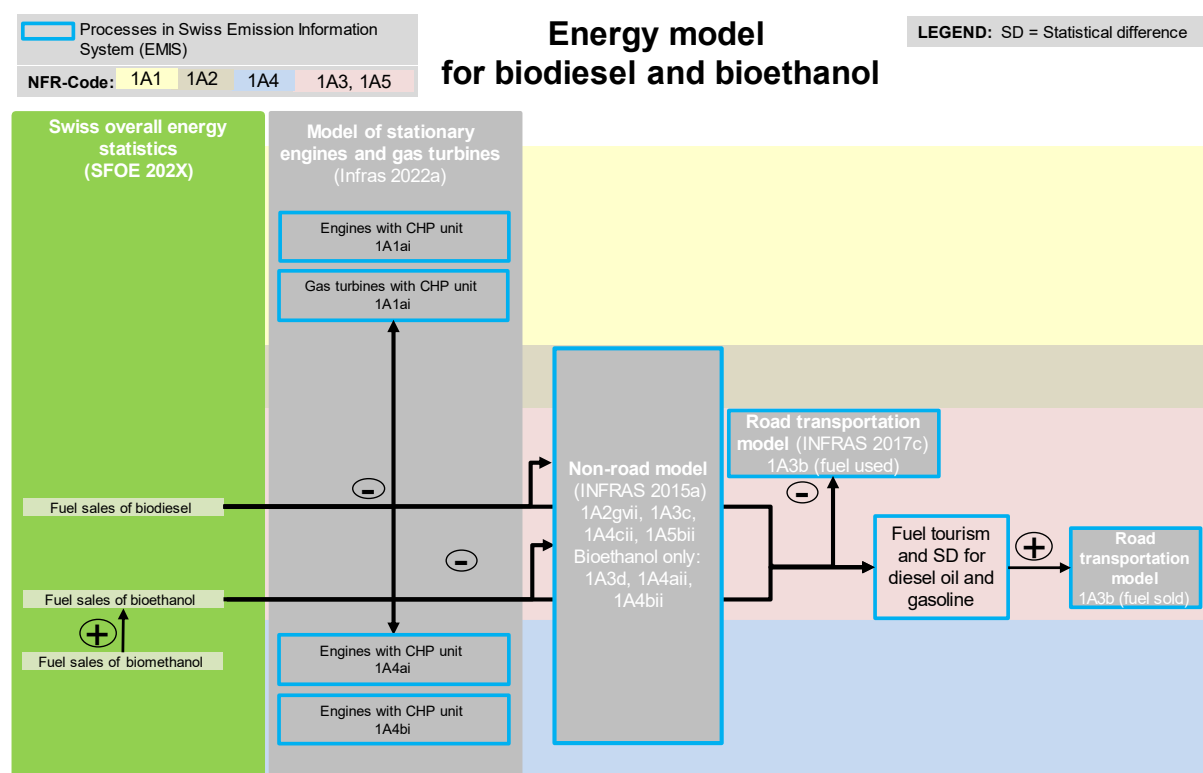


Figure 3-20 Schematic disaggregation of fuel consumption for biodiesel and bioethanol.

### Statistical stock change

In a few years the quantity of a fuel sold in a year according to total energy statistics may be smaller (or larger) than the quantity effectively used in the same year as reported from bottom-up data. The reason for such deviations is due to further stocks which are not taken into consideration at the level of the Swiss energy statistics and are managed at the

individual plant level. Some plants manage their own intermediate fuel stocks, which they may carry over for use in later years. To mitigate the difference between less fuel sold (according to the total energy statistics) than fuel used (according to bottom-up information) in one year, so-called “stock shifts” are assumed in the energy model. Stockpiling can only be performed in the years in which more fuel was sold according to total energy statistics than was used based on bottom-up information. Stock which was accumulated in such years can be used in later years to level out the deviations between the total energy statistics and bottom-up data. Currently, stocks are formed in different years for residual fuel oil, petroleum coke and other bituminous coal:

- For residual fuel oil stock was built up in the years 2008–2010, 2014, 2015 and used in the years 2011, 2012, 2016–2021.
- For petroleum coke stock was built up in the years 2007, 2018 and used in the years 2008, 2019.
- For other bituminous coal stock was built up in the years 1991, 1996, 2003, 2005–2007 and used in the years 1993, 1994, 1998–2001, 2011, 2012.

#### **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 (IPCC 2006) and the EU and Swiss guidelines for the Emissions Trading Scheme (ETS), where also a default oxidation factor of 100 % is applied.

Because an oxidation factor of 100 % is assumed, indirect CO<sub>2</sub> emissions from CH<sub>4</sub>, CO and NMVOC are implicitly reported as direct CO<sub>2</sub> emissions in source category 1A Energy. Therefore, from this source category no indirect CO<sub>2</sub> emissions are included in CRT Table6 as documented in chp. 9.

##### **3.2.4.4.2. CO<sub>2</sub> emission factors for 1A Fuel combustion**

###### **General CO<sub>2</sub> emission factors**

The CO<sub>2</sub> emission factors applied for the time series 1990–2023 are given in Table 3-13. 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 3-13 CO<sub>2</sub> 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 (SGWA). The CO<sub>2</sub> emission factor of liquefied petroleum gas (LPG) was derived assuming a composition of 50 % propane and 50 % butane using data from CRC (2024).

CO <sub>2</sub> emission factors			1990–1998	2013–2023
Fossil fuel	CS/D	Data sources	t CO <sub>2</sub> / TJ	t CO <sub>2</sub> / 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	see table caption	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
*Sum of CO <sub>2</sub> fossil and CO <sub>2</sub> biogenic from fossil and biogenic fraction of biodiesel				

### CO<sub>2</sub> emission factors for natural gas and biogas

CO<sub>2</sub> emission factors of natural gas and biogas are given in Table 3-14.

Table 3-14 Time series of CO<sub>2</sub> 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 (SGWA).

CO <sub>2</sub> emission factors			1990	1995	2000	2005	2010
Fuel	CS/D	Data sources	t CO <sub>2</sub> / TJ				
Natural gas/Biogas	CS	SGWA	56.1	55.7	56.2	56.4	56.5

CO <sub>2</sub> emission factors			2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Fuel	CS/D	Data sources	t CO <sub>2</sub> / TJ									
Natural gas/Biogas	CS	SGWA	56.5	56.4	56.4	56.3	56.2	56.4	56.2	55.9	56.0	55.9

### CO<sub>2</sub> emission factors for wood

The CO<sub>2</sub> emission factor for wood combustion activities is taken from Cemsuisse (2010a).

#### 3.2.4.4.3. CH<sub>4</sub> emission factors for 1A Fuel combustion

##### General CH<sub>4</sub> emission factors

An overview of the default CH<sub>4</sub> emission factors for stationary combustion according to the 2006 IPCC Guidelines (IPCC 2006) is given in Table 3-15. These default CH<sub>4</sub> emission factors, which depend on the fuels and the source categories, are used for most stationary combustion processes for the entire time period. Exceptions, e.g. for motors and gas turbines, are discussed in the chapters of the respective source categories. In Table 3-15, the respective cells (fuel/source category) are highlighted in blue, indicating that the default CH<sub>4</sub> emission factors are not applied in this case. A blue/white highlighting means that for the

respective fuel and source category there are processes that use the default CH<sub>4</sub> emission factors according to Table 3-15 as well as processes that use a different CH<sub>4</sub> emission factor as discussed in the chapters of the respective source categories. Where default CH<sub>4</sub> emission factors of fuels are not used at all in the respective source categories, the notation key “NO” is indicated in Table 3-15. For other bituminous coal, the default CH<sub>4</sub> emission factor for source category 1A2 is also used for source category 1A1 (highlighted purple and indicated with an arrow); this corresponds better to the situation in Switzerland, as there are no coal-fired power plants. For wood combustion, country-specific CH<sub>4</sub> emission factors are used (see details below, in particular Table 3-16). CH<sub>4</sub> emission factors related to transport activities (aviation, road and non-road transportation) are category-specific and given in the corresponding sectoral chapters.

Table 3-15 Default CH<sub>4</sub> emission factors for stationary combustion according to the 2006 IPCC Guidelines (IPCC 2006, Table 2.2 for 1A1, Table 2.3 for 1A2, Table 2.4 for 1A4ai and Table 2.5 for 1A4bi and 1A4ci) as well as the range of country-specific CH<sub>4</sub> emission factors for wood combustion according to Zotter and Nussbaumer (2022), see also Table 3-16. See text for further information and an explanation of the colour code. Where other than default CH<sub>4</sub> emissions factors are (also) used, this is indicated by the notation key “CS” and details are described in the chapters of the respective source categories.

CH <sub>4</sub> emission factors			1990–2023			
			1A1	1A2	1A4ai	1A4bi, 1A4ci
Fuel	D/CS	Data sources	g CH <sub>4</sub> / GJ			
Gas oil	D	IPCC (2006)	3 / CS	3	10 / CS	10 / CS
Residual fuel oil	D	IPCC (2006)	3	3	NO	NO
Liquefied petroleum gas	D	IPCC (2006)	NO	1 / CS	CS	CS
Petroleum coke	D	IPCC (2006)	NO	3	NO	NO
Other bituminous coal	D	IPCC (2006)	10 ←	10	NO	300
Lignite	D	IPCC (2006)	NO	10	NO	NO
Natural gas	D	IPCC (2006)	1 / CS	1 / CS	5 / CS	5 / CS
Biofuel	D/CS	Data Sources	g CH <sub>4</sub> / GJ			
Biodiesel (fossil / biogenic)	D	IPCC (2006)	CS	CS	CS	CS
Biogas	D	IPCC (2006)	CS	CS	5 / CS	CS
Wood	CS	Zotter and Nussbaumer (2022)	0.18–230			

### CH<sub>4</sub> emission factors for wood

There are many different combustion installations in use which have very different CH<sub>4</sub> emission factors. A detailed overview of all applied wood related CH<sub>4</sub> emission factors for the entire time series is given in Table 3-16. For mobile pellet combustion installations in source category 1A4ai that are used for temporary applications, the same CH<sub>4</sub> emission factors are assumed as for the installation category automatic pellet boilers 50-300 kW.

The CH<sub>4</sub> emission factors are based on a country-specific emission factor model for wood energy (Zotter and Nussbaumer 2022). The model is based on a large number of air pollution control measurements, laboratory and field measurements, literature data (e.g. beReal, emission factors in the Nordic countries) and the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA 2019) and covers the entire time series. The CH<sub>4</sub> emission factors are modelled based on VOC emissions of each combustion installation type and a mean CH<sub>4</sub> to VOC ratio of 0.3.

The CH<sub>4</sub> emission factor for the different combustion installations varies depending on the year, rated thermal input and technology used. The CH<sub>4</sub> emission factor 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 CH<sub>4</sub> emission factors.

Table 3-16 CH<sub>4</sub> emission factors for wood combustion installations.

1A Wood combustion	1990	1995	2000	2005	2010
	g CH <sub>4</sub> /GJ				
Open fireplaces	160	154	149	143	133
Closed fireplaces, log wood stoves	160	152	143	135	127
Pellet stoves	NO	NO	16	13	10
Log wood hearths	230	222	213	205	187
Log wood boilers	70	62	53	45	37
Log wood dual chamber boilers	230	222	213	205	187
Automatic chip boilers < 50 kW	60	52	43	35	27
Automatic pellet boilers < 50 kW	NO	NO	14	12	10
Automatic chip boilers 50–300 kW w/o wood proc. companies	30	27	24	22	17
Automatic pellet boilers 50–300 kW	NO	NO	7.8	6.7	5.0
Automatic chip boilers 50–300 kW within wood proc. companies	30	27	24	22	17
Automatic chip boilers 300–500 kW w/o wood proc. companies	30	27	24	22	17
Automatic pellet boilers 300–500 kW	NO	NO	NO	6.7	5.0
Automatic chip boilers 300–500 kW within wood proc. companies	30	27	24	22	17
Automatic chip boilers > 500 kW w/o wood proc. companies	10	8.9	7.8	6.7	5.0
Automatic pellet boilers > 500 kW	NO	NO	NO	3.0	2.3
Automatic chip boilers > 500 kW within wood proc. companies	12	11	10	9.5	7.0
Combined chip heat and power plants	NO	0.89	0.78	0.67	0.47
Plants for renewable waste from wood products	4.0	3.7	3.4	3.2	2.3

1A Wood combustion	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	g CH <sub>4</sub> /GJ									
Open fireplaces	120	120	120	120	120	120	120	117	114	111
Closed fireplaces, log wood stoves	120	118	117	115	113	112	110	107	104	101
Pellet stoves	6.0	6.0	6.0	6.0	6.0	6.0	6.0	5.8	5.6	5.4
Log wood hearths	160	158	157	155	153	152	150	146	143	139
Log wood boilers	30	30	30	30	30	30	30	29	29	28
Log wood dual chamber boilers	160	158	157	155	153	152	150	148	146	144
Automatic chip boilers < 50 kW	20	20	20	20	20	20	20	19	19	18
Automatic pellet boilers < 50 kW	10	9	8.7	8.0	7.3	6.7	6.0	5.7	5.5	5.2
Automatic chip boilers 50–300 kW w/o wood proc. companies	10	10	10	10	10	10	10	9.7	9.5	9.2
Automatic pellet boilers 50–300 kW	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.8
Automatic chip boilers 50–300 kW within wood proc. companies	10	10	10	10	10	10	10	9.7	9.5	9.2
Automatic chip boilers 300–500 kW w/o wood proc. companies	10	10	10	10	10	10	10	9.7	9.5	9.2
Automatic pellet boilers 300–500 kW	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.8
Automatic chip boilers 300–500 kW within wood proc. companies	10	10	10	10	10	10	10	9.7	9.5	9.2
Automatic chip boilers > 500 kW w/o wood proc. companies	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.8
Automatic pellet boilers > 500 kW	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Automatic chip boilers > 500 kW within wood proc. companies	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.8
Combined chip heat and power plants	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.19	0.19	0.18
Plants for renewable waste from wood products	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.95	0.92

### 3.2.4.4.4. N<sub>2</sub>O emission factors for 1A Fuel combustion

An overview of the default N<sub>2</sub>O emission factors for stationary combustion according to the 2006 IPCC Guidelines (IPCC 2006) is given in Table 3-17. These default N<sub>2</sub>O emission factors, which depend on the fuels and the source categories, are used for most stationary combustion processes for the entire time period. Exceptions, e.g. for motors and gas turbines, are discussed in the chapters of the respective source categories. In Table 3-17, the respective cells (fuel/source category) are highlighted in blue, indicating that the default N<sub>2</sub>O emission factors are not applied in this case. A blue/white highlighting means that for the respective fuel and source category there are processes that use the default N<sub>2</sub>O emission factors according to Table 3-17 as well as processes that use a different N<sub>2</sub>O emission factor as discussed in the chapters of the respective source categories. Where default N<sub>2</sub>O emission factors of fuels are not used at all in the respective source categories the notation key “NO” is indicated in Table 3-17. N<sub>2</sub>O emission factors related to transport activities (aviation, road and non-road transportation) are category-specific and given in the corresponding sectoral chapters.



Table 3-17 Default N<sub>2</sub>O emission factors for stationary combustion according to the 2006 IPCC Guidelines (IPCC 2006, Table 2.2 for 1A1, Table 2.3 for 1A2, Table 2.4 for 1A4ai and Table 2.5 for 1A4bi and 1A4ci). See text for further information and an explanation of the colour code. Where other than default N<sub>2</sub>O emissions factors are (also) used, this is indicated by the notation key "CS" and details are described in the chapters of the respective source categories.

N <sub>2</sub> O emission factors			1990–2023			
			1A1	1A2	1A4ai	1A4bi, 1A4ci
Fuel	CS/D	Data sources	g N <sub>2</sub> O / GJ			
Gas oil	D	IPCC (2006)	0.6 / CS	0.6	0.6 / CS	0.6 / CS
Residual fuel oil	D	IPCC (2006)	0.6	0.6	NO	NO
Liquefied petroleum gas	D	IPCC (2006)	NO	0.1 / CS	CS	CS
Petroleum coke	D	IPCC (2006)	NO	0.6	NO	NO
Other bituminous coal	D	IPCC (2006)	1.5	1.5	NO	1.5
Lignite	D	IPCC (2006)	NO	1.5	NO	NO
Natural gas	D	IPCC (2006)	0.1 / CS	0.1 / CS	0.1 / CS	0.1 / CS
Biofuel	CS/D	Data Sources	g N <sub>2</sub> O / GJ			
Biodiesel (fossil / biogenic)	D	IPCC (2006)	CS	CS	CS	CS
Biogas	D	IPCC (2006)	0.1 / CS	CS	0.1 / CS	CS
Wood	D	IPCC (2006)	4	4	4	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 in Fig. 3.3.1 in chp. 3. Mobile Combustion in IPCC (2006), complemented with:
  - Tier 2 for railways CO<sub>2</sub>, Fig. 3.4.1 in IPCC (2006)
  - Tier 3 for railways CH<sub>4</sub>, N<sub>2</sub>O and precursors, 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. Results are documented in FOEN (2015j). The non-road categories considered are listed in Table 3-18. All of them include several technologies, fuels (diesel oil, 2- or 4-stroke gasoline, liquefied petroleum gas, gas oil), and emission standards according to the classification shown in Figure 3-21.

Table 3-18 Non-road categories as specified in FOEN (2015j) and the corresponding code in the reporting tables (CRT).

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



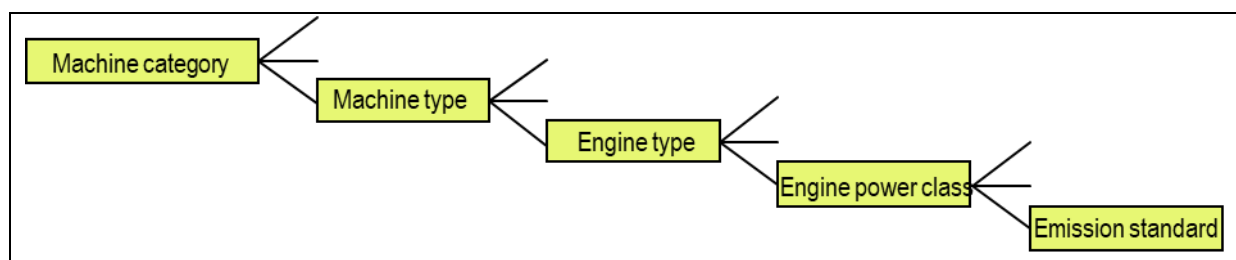


Figure 3-21 Each non-road vehicle is classified by its machine category, machine type, engine type and engine-power class and emission standard (FOEN 2015j, INFRAS 2015a).

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 3-21):

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

with

$Em$	=	emission per engine type (in g/a)
$N$	=	number of vehicles (without unit)
$H$	=	number of operation hours per year (h/a)
$P$	=	engine power output (kW)
$\lambda$	=	effective load factor (without unit)
$\varepsilon$	=	emission factor (g/kWh)
$CF_1$	=	correction factor for the effective load (without unit)
$CF_2$	=	correction factor for dynamical engine use (without unit)
$CF_3$	=	degradation factor due to aging (without unit)

With this equation, the emissions of the following gases and also the fuel consumption are calculated:

- GHG: CH<sub>4</sub>, N<sub>2</sub>O
- Precursor gases: NO<sub>x</sub>, CO
- Air pollutant: VOC
- Fuel consumption: in this case,  $\varepsilon$  represents the consumption instead of emission factor (in g/kWh)

For other gases, the following method is applied:

- CO<sub>2</sub> is calculated as product of fuel consumption and CO<sub>2</sub> emission factors (according to Table 3-13).
- SO<sub>2</sub> is calculated as product of fuel consumption and SO<sub>2</sub> emission factors (according to Table A – 17).

- NMVOC is calculated as the difference between VOC and CH<sub>4</sub>.
- CO<sub>2</sub> emissions from the use of lubricants as an additive in gasoline for 2-stroke engines are modelled separately and the corresponding CO<sub>2</sub> emissions from the lubricants are reported under 2D1 Lubricant use (chp. 4.5.2.1). Non-CO<sub>2</sub> emissions from the combustion of lubricants in 2-stroke engines however are reported in the energy sector (1A2gvii, 1A3b, 1A3d, 1A4aai, 1A4bii, 1A4cii, 1A5bii).

The total emission and consumption per non-road category are calculated by taking the sum over all engine-power classes, engine types, machine types and emission standards.

Emissions are only calculated in steps of 5 years from 1980 to 2050. Emissions for years in-between 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 FOEN (2015j). They have been derived from various sources based on measurements, modelling and literature:

- CO<sub>2</sub> and SO<sub>2</sub> emission factors are country-specific, see Table 3-13 and Table A – 17.
- For other gases, the main data sources are USEPA (2010), IFEU (2010), EMEP/EEA (2016), EMEP/EEA (2019) 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 developed by INFRAS (2015a).

### 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 information system for traffic admission (IVZ, formerly MOFIS) run by 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 like size distributions, fleet turnover, annual operating hours (age-dependent), load factors, year of market entry, and age

distributions, was derived. Details are documented in FOEN (2015j). All activity data (vehicle stock, operating hours, consumption factors) can be downloaded by query from the online non-road database INFRAS (2015a), which corresponds to the data described in FOEN (2015j). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels.

For biodiesel consumption, the fossil carbon fraction in biodiesel is estimated based on the method described in Sebos (2022). While all carbon in HVO (Hydrotreated Vegetable Oil) is of biogenic origin, FAME (Fatty Acid Methyl Esters) contains a fossil fraction due to the use of methanol from fossil sources in its production. The shares of FAME and HVO in biodiesel are available from the Swiss overall energy statistics (SFOE 2024). The fossil fraction of FAME depends on the feedstock it is derived from (e.g. rapeseed, soy, palm oil); since the feedstock shares are not captured in the Swiss energy statistics, they are based on European average values from HBEFA 4.1 (INFRAS 2019a). The resulting overall fossil fraction of biodiesel varies over time – around 4.0 to 5.4 % of total biodiesel are reported under “fossil liquid fuels” as “biodiesel fossil”. For technical reasons in our database, there is a split of the whole biodiesel amount in fossil and biogenic biodiesel and not only for the carbon fraction and CO<sub>2</sub>.

#### **3.2.4.5.2.     *Model of stationary engines and gas turbines***

##### **Choice of method**

The emissions from stationary engines and gas turbines in 1A Fuel combustion 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 model for calculating emissions from stationary engines and gas turbines underwent an extensive revision during the years 2021 to 2022 and the revised model was implemented for the submission in 2024. To calculate the final fuel consumption for each category of stationary engines and gas turbines, an inventory of power output values, distribution of exhaust gas technologies, average load factors and operating hours was elaborated. For large installations including engines and gas turbines with combined heat and power generation (CHP) along with gas turbines in simple cycle (SCGT) and combined cycle (CCGT) configuration, the available information was compiled individually for each unit. Most of the information was obtained from the cantonal air pollution control authorities, from publicly accessible websites and annual reports from industry, as well as from direct enquiries with the operators. Further details and results are documented in INFRAS (2022a). Emissions are calculated using the resulting fuel consumption for each category of stationary engines and gas turbines within 1A – Fuel consumption activities and multiplied with the respective emission factors.

##### **Emission factors**

Emission factors are based on the following sources according to INFRAS (2022a):

- CO<sub>2</sub> emission factors base on measurements as described in chp. 3.2.4.4.2.
- CH<sub>4</sub> as well as N<sub>2</sub>O emission factors originate from table 87 of the National Inventory Report for the German Greenhouse Gas Inventory 1990–2018 (UBA 2020).

Table 3-19 Emission factors of engines and gas turbines in 1A1 Energy industries in 2023.

1A1a Public electricity and heat production (engines and gas turbines)	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
	t/TJ		kg/TJ					
Gas turbines as SCGT or CCGT								
Gas oil	73.7	NA	1.2	2.9	83	0.18	0.84	2.6
Natural gas	55.9	NA	5.2	0.69	29	1.6	0.23	14
Biogas	NA	55.9	5.2	0.69	48	1.6	0.5	14
Gas turbines with CHP unit								
Gas oil	73.7	NA	1.2	2.9	83	0.18	0.84	2.6
Natural gas	55.9	NA	5.2	0.69	32	1.6	0.23	9.8
Biodiesel	NA	73.3	1.2	2.9	83	0.18	0.30	2.6
Biogas	NA	55.9	5.2	0.69	48	1.6	0.5	9.8
Engines with CHP unit								
Gas oil	73.7	NA	1.2	2.9	137	50	0.84	136
Natural gas	55.9	NA	5.2	0.69	71	89	0.23	54
Biodiesel	4.0	69.3	1.2	2.9	407	50	0.30	132
Biogas	NA	55.9	5.2	0.69	96	89	0.5	86
Engines used as emergency generators								
Gas oil	73.7	NA	1.2	2.9	942	50	0.84	137
Engines on landfills								
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	NA	55.9	5.2	0.69	98	89	0.5	125
1A1b Petroleum refining (gas turbines)	t/TJ		t/TJ					
Gas turbines as SCGT at refineries								
Refinery gas	NO	NO	NO	NO	NO	NO	NO	NO

Table 3-20 Emission factors of engines and gas turbines in 1A2 Manufacturing industry and construction in 2023.

1A2d Pulp, paper and print (gas turbines)	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>x</sub>	CO
	t/TJ		kg/TJ					
Gas turbines as SCGT or CCGT								
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO
1A2gviii Other (engines and gas turbines)	t/TJ		kg/TJ					
Gas turbines as SCGT or CCGT								
Natural gas	55.9	NA	5.2	0.69	85	1.6	0.23	10.9
Biogas	NA	55.9	5.2	0.69	48	1.6	0.5	10.9
Gas turbines with CHP unit								
Liquefied petroleum gas	65.5	NA	5.2	0.69	48	1.6	0.5	4.8
Engines with CHP unit								
Liquefied petroleum gas	65.5	NA	5.2	0.69	135	89	0.5	56
Engines with CHP unit at biogas plants								
Biogas	NA	55.9	5.2	0.69	99	89	0.5	132

Table 3-21 Emission factors of engines and gas turbines in 1A3 Transport in 2023.

1A3ei Pipeline transport (gas turbines)	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>x</sub>	CO
	t/TJ		kg/TJ					
Gas turbines as SCGT at compressor station for gas pipelines								
Natural gas	55.9	NA	5.2	0.69	30	1.6	0.23	11
Biogas	NA	55.9	5.2	0.69	48	1.6	0.5	11

Table 3-22 Emission factors of engines and gas turbines in 1A4ai Other sectors: commercial/institutional in 2023.

1A4ai Other sectors (stationary): Commercial/institutional (engines and gas turbines)	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>x</sub>	CO
	t/TJ		kg/TJ					
Engines with CHP unit								
Gas oil	73.7	NA	1.2	2.9	137	50	0.8	136
Natural gas	55.9	NA	5.2	0.69	71	89	0.23	54
Liquefied petroleum gas	65.5	NA	5.2	0.69	135	89	0.5	56
Biodiesel	4.0	69.3	1.2	2.9	407	50	0.30	132
Biogas	NA	55.9	5.2	0.69	96	89	0.5	86
Engines with CHP unit at biogas plants								
Liquefied petroleum gas	NO	NO	NO	NO	NO	NO	NO	NO
Biodiesel	4.0	69.3	1.2	2.9	157	50	0.30	136
Biogas	NA	55.9	5.2	0.69	99	89	0.5	132
Engines used as emergency generators								
Gas oil	73.7	NA	1.2	2.9	909	50	0.8	137
Gas turbines at sewage plants								
Natural gas	55.9	NA	5.2	0.69	53	1.6	0.23	25
Sewage gas	NA	55.9	5.2	0.69	48	1.6	0.5	10
Engines with CHP unit at sewage plants								
Natural gas	55.9	NA	5.2	0.69	310	89	0.23	76
Sewage gas	NA	55.9	5.2	0.69	101	89	0.5	141

Table 3-23 Emission factors of engines and gas turbines in 1A4bi Other sectors: residential in 2023.

1A4bi Other sectors (stationary): Residential (engines)	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>x</sub>	CO
	t/TJ		kg/TJ					
Engines with CHP unit								
Gas oil	73.7	NA	1.2	2.9	137	50	0.8	136
Natural gas	55.9	NA	5.2	0.69	71	89	0.23	54
Liquefied petroleum gas	65.5	NA	5.2	0.69	135	89	0.5	56
Biodiesel	4.0	69.3	1.2	2.9	407	50	0.30	132
Biogas	NA	55.9	5.2	0.69	96	89	0.5	86

Table 3-24 Emission factors of engines and gas turbines in 1A4ci Other sectors: agriculture/forestry/fishing in 2023.

1A4ci Agriculture/forestry/fishing (engines)	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>x</sub>	CO
	t/TJ		kg/TJ					
Engines used as emergency generators								
Gas oil	73.7	NA	1.2	2.9	942	50	0.84	137
Engines with CHP unit at biogas plants								
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	NA	55.9	5.2	0.69	97	89	0.5	108

## Activity data

Activity data were collected by surveys among the cantonal air pollution control authorities. For engines used as emergency generators, their proof of gas oil use, which is deposited with the Federal Office for Customs and Border Security (FOCBS), were the most important source of data. Furthermore, the statistics by the SFOE about the thermal electricity production including combined heat and power generation (CHP) in Switzerland (SFOE 2021c) served as the basis for activity data modelling. For large installations including engines as well as simple cycle gas turbines (SCGT) and combined cycle gas turbines (CCGT), the websites and annual reports of the operators provided relevant information on technical data, operating hours or fuel consumption. From these data sources, all necessary information like modelling of the quantity of installations, annual operating hours, load factors and rated thermal input were derived. Details are documented in INFRAS (2022a).

The activity data of engines using landfill gas in 1A1a Public electricity and heat production, engines using biogas in 1A2gviii Other - Manufacturing industries, 1A4ai Other – Commercial/institutional and 1A4ci Other – Agriculture/forestry /fishing, as well as gas turbines at the compressor station in 1A3ei Pipeline transport using natural gas is updated annually with newest available information concerning fuel consumption from SFOE 2024a and SFOE 2024 respectively.

For biodiesel consumption, the fossil carbon fraction in biodiesel is estimated based on the method described in Sebos (2022). While all carbon in HVO (Hydrotreated Vegetable Oil) is of biogenic origin, FAME (Fatty Acid Methyl Esters) contains a fossil fraction due to the use of methanol from fossil sources in its production. The shares of FAME and HVO in biodiesel are available from the Swiss overall energy statistics (SFOE 2024). The fossil fraction of FAME depends on the feedstock it is derived from (e.g. rapeseed, soy, palm oil); since the feedstock shares are not captured in the Swiss energy statistics, they are based on European average values from HBEFA 4.1 (INFRAS 2019a). The resulting overall fossil fraction of biodiesel varies over time – around 4.0 to 5.4 % of total biodiesel are reported under “fossil liquid fuels” as “biodiesel fossil”. For technical reasons in our database, there is a split of the whole biodiesel amount in fossil and biogenic biodiesel and not only for the carbon fraction and CO<sub>2</sub>.

Table 3-25 Activity data of engines and gas turbines in 1A1 Energy industries.

1A1 Energy industries (Engines and gas turbines)		Unit	1990	1995	2000	2005	2010					
Total fuel consumption		TJ	421	1'907	4'851	4'647	5'088					
1A1a Gas turbines as SCGT or CCGT	Gas oil	TJ	24	33	33	33	33					
1A1a Gas turbines as SCGT or CCGT	Natural gas	TJ	3.5	779	840	1'110	2'410					
1A1a Gas turbines as SCGT or CCGT	Biogas	TJ	NO	NO	NO	NO	NO					
1A1a Gas turbines with CHP unit	Gas oil	TJ	6.7	3.6	NO	8.1	3.6					
1A1a Gas turbines with CHP unit	Natural gas	TJ	66	31	NO	39	42					
1A1a Gas turbines with CHP unit	Biodiesel fossil	TJ	NO	NO	NO	0.0049	0.028					
1A1a Gas turbines with CHP unit	Biodiesel biogenic	TJ	NO	NO	NO	0.096	0.61					
1A1a Gas turbines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO					
1A1a Engines with CHP unit	Gas oil	TJ	7.5	47	179	167	55					
1A1a Engines with CHP unit	Natural gas	TJ	73	405	655	799	661					
1A1a Engines with CHP unit	Biodiesel fossil	TJ	NO	NO	NO	0.10	0.44					
1A1a Engines with CHP unit	Biodiesel biogenic	TJ	NO	NO	NO	2.0	9.5					
1A1a Engines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO					
1A1a Engines used as emergency generators	Gas oil	TJ	1.4	1.4	1.5	1.5	1.6					
1A1a Engines on landfills	Natural gas	TJ	NO	NO	NO	14	14					
1A1a Engines on landfills	Biogas	TJ	238	609	568	204	49					
1A1b Gas turbines as SCGT at refineries	Refinery gas	TJ	NO	NO	2'575	2'270	1'808					
1A1 Energy industries (Engines and gas turbines)		Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption		TJ	3'621	3'213	4'709	3'748	3'643	3'649	3'566	3'668	3'834	3'846
1A1a Gas turbines as SCGT or CCGT	Gas oil	TJ	33	33	33	33	33	33	7.2	7.4	7.7	7.8
1A1a Gas turbines as SCGT or CCGT	Natural gas	TJ	1'082	2'306	4'154	3'245	3'208	3'260	3'208	3'192	3'331	3'337
1A1a Gas turbines as SCGT or CCGT	Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	110	121	130
1A1a Gas turbines with CHP unit	Gas oil	TJ	0.69	0.59	0.29	0.20	0.12	0.16	0.16	0.16	0.16	0.15
1A1a Gas turbines with CHP unit	Natural gas	TJ	13	12	6.5	3.5	3.2	2.8	2.7	2.8	2.9	2.9
1A1a Gas turbines with CHP unit	Biodiesel fossil	TJ	0.012	0.010	0.0048	0.0028	0.0024	0.0025	0.0026	0.0029	0.0030	0.0029
1A1a Gas turbines with CHP unit	Biodiesel biogenic	TJ	0.21	0.18	0.100	0.062	0.055	0.054	0.053	0.053	0.054	0.053
1A1a Gas turbines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO	0.089	0.089	0.096	0.11	0.11
1A1a Engines with CHP unit	Gas oil	TJ	27	25	21	24	14	18	18	18	18	17
1A1a Engines with CHP unit	Natural gas	TJ	532	513	473	426	370	319	307	315	327	325
1A1a Engines with CHP unit	Biodiesel fossil	TJ	0.46	0.42	0.35	0.35	0.28	0.28	0.29	0.32	0.34	0.33
1A1a Engines with CHP unit	Biodiesel biogenic	TJ	8.4	7.5	7.3	7.6	6.4	6.1	6.0	6.0	6.1	5.9
1A1a Engines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO	NO	10	11	12	13
1A1a Engines used as emergency generators	Gas oil	TJ	1.7	1.7	1.7	1.7	1.8	1.8	1.7	1.8	1.8	1.8
1A1a Engines on landfills	Natural gas	TJ	11	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A1a Engines on landfills	Biogas	TJ	31	21	12	6.5	6.0	8.4	4.0	4.0	5.0	4.4
1A1b Gas turbines as SCGT at refineries	Refinery gas	TJ	1'879	293	NO	NO	NO	NO	NO	NO	NO	NO

Table 3-26 Activity data of engines and gas turbines in 1A2 Manufacturing industry and construction.

1A2 Manufacturing industries and construction (Engines and gas turbines)		Unit	1990	1995	2000	2005	2010					
Total fuel consumption		TJ	655	1'775	2'585	1'723	2'010					
1A2d Gas turbines as SCGT or CCGT	Natural gas	TJ	NO	955	1'616	490	422					
1A2gviii Gas turbines as SCGT or CCGT	Natural gas	TJ	613	721	810	1'073	1'355					
1A2gviii Gas turbines as SCGT or CCGT	Biogas	TJ	NO	NO	NO	NO	NO					
1A2gviii Gas turbines with CHP unit	Liquefied petroleum gas	TJ	0.68	0.87	NO	1.5	2.3					
1A2gviii Engines with CHP unit	Liquefied petroleum gas	TJ	0.75	11	33	30	35					
1A2gviii Engines with CHP unit at biogas plants	Biogas	TJ	41	87	126	128	195					
1A2 Manufacturing industries and construction (Engines and gas turbines)		Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption		TJ	1'156	1'111	451	415	353	354	346	363	398	372
1A2d Gas turbines as SCGT or CCGT	Natural gas	TJ	608	682	NO	NO	NO	NO	NO	NO	NO	NO
1A2gviii Gas turbines as SCGT or CCGT	Natural gas	TJ	238	145	145	145	145	145	145	144	150	151
1A2gviii Gas turbines as SCGT or CCGT	Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	5.0	5.5	5.9
1A2gviii Gas turbines with CHP unit	Liquefied petroleum gas	TJ	0.79	0.66	0.54	0.12	0.081	0.066	0.064	0.063	0.064	0.064
1A2gviii Engines with CHP unit	Liquefied petroleum gas	TJ	31	28	39	14	9.4	7.4	7.3	7.3	7.5	7.3
1A2gviii Engines with CHP unit at biogas plants	Biogas	TJ	278	256	267	256	199	201	194	206	235	208

Table 3-27 Activity data of engines and gas turbines in 1A3 Transport.

1A3(fu) Transport (Engines and gas turbines)		Unit	1990	1995	2000	2005	2010					
Total fuel consumption		TJ	560	310	340	1'070	830					
1A3ei Gas turbines at compressor stations for gas pipelines	Natural gas	TJ	560	310	340	1'070	830					
1A3ei Gas turbines at compressor stations for gas pipelines	Biogas	TJ	NO	NO	NO	NO	NO					
1A3(fu) Transport (Engines and gas turbines)		Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption		TJ	830	760	340	470	490	600	540	138	420	192
1A3ei Gas turbines at compressor stations for gas pipelines	Natural gas	TJ	830	760	340	470	490	600	540	120	400	170
1A3ei Gas turbines at compressor stations for gas pipelines	Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	18	20	22

Table 3-28 Activity data of engines and gas turbines in 1A4a Other sectors: commercial/institutional.

1A4ai Commercial/Institutional Stationary (Engines and gas turbines)		Unit	1990	1995	2000	2005	2010
Total fuel consumption		TJ	1'572	2'973	4'524	5'062	4'603
1A4ai Engines with CHP unit	Gas oil	TJ	44	171	580	539	178
1A4ai Engines with CHP unit	Liquefied petroleum gas	TJ	2.4	36	103	95	109
1A4ai Engines with CHP unit	Natural gas	TJ	355	1'407	2'169	2'596	2'089
1A4ai Engines with CHP unit	Biodiesel fossil	TJ	NO	NO	NO	0.32	1.4
1A4ai Engines with CHP unit	Biodiesel biogenic	TJ	NO	NO	NO	6.2	30
1A4ai Engines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO
1A4ai Engines with CHP unit at biogas plants	Liquefied petroleum gas	TJ	NO	2.9	5.6	NO	NO
1A4ai Engines with CHP unit at biogas plants	Biodiesel fossil	TJ	NO	NO	1.3	0.068	1.1
1A4ai Engines with CHP unit at biogas plants	Biodiesel biogenic	TJ	NO	NO	25	1.3	24
1A4ai Engines with CHP unit at biogas plants	Biogas	TJ	NO	29	82	143	394
1A4ai Engines used as emergency generators	Gas oil	TJ	383	383	391	396	405
1A4ai Gas turbines at sewage plants	Natural gas	TJ	NO	0.23	0.073	NO	0.019
1A4ai Gas turbines at sewage plants	Sewage gas	TJ	179	169	66	NO	18
1A4ai Engines with CHP unit at sewage plants	Natural gas	TJ	NO	1.0	1.2	1.4	1.4
1A4ai Engines with CHP unit at sewage plants	Sewage gas	TJ	610	775	1'100	1'284	1'351

1A4ai Commercial/Institutional Stationary (Engines and gas turbines)		Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption		TJ	4'349	4'260	4'181	4'008	3'813	3'643	3'639	3'648	3'751	3'741
1A4ai Engines with CHP unit	Gas oil	TJ	88	77	66	76	44	57	55	55	56	54
1A4ai Engines with CHP unit	Liquefied petroleum gas	TJ	97	87	121	44	29	23	23	23	23	23
1A4ai Engines with CHP unit	Natural gas	TJ	1'668	1'596	1'469	1'325	1'151	991	956	979	1'018	1'010
1A4ai Engines with CHP unit	Biodiesel fossil	TJ	1.4	1.3	1.1	1.1	0.88	0.88	0.91	1.0	1.1	1.0
1A4ai Engines with CHP unit	Biodiesel biogenic	TJ	26	23	23	24	20	19	19	19	19	18
1A4ai Engines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO	NO	31	34	37	39
1A4ai Engines with CHP unit at biogas plants	Liquefied petroleum gas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A4ai Engines with CHP unit at biogas plants	Biodiesel fossil	TJ	1.2	1.3	1.2	0.88	1.0	0.75	0.78	0.84	0.85	0.83
1A4ai Engines with CHP unit at biogas plants	Biodiesel biogenic	TJ	22	23	24	19	23	16	16	16	15	15
1A4ai Engines with CHP unit at biogas plants	Biogas	TJ	701	738	780	807	818	813	807	787	897	908
1A4ai Engines used as emergency generators	Gas oil	TJ	412	413	415	417	420	421	413	411	409	405
1A4ai Gas turbines at sewage plants	Natural gas	TJ	0.027	0.029	0.25	0.23	0.24	0.23	0.21	0.20	0.20	0.19
1A4ai Gas turbines at sewage plants	Sewage gas	TJ	25	25	26	26	34	33	34	34	33	32
1A4ai Engines with CHP unit at sewage plants	Natural gas	TJ	1.4	1.5	12	11	8.8	8.6	8.0	7.7	7.4	7.2
1A4ai Engines with CHP unit at sewage plants	Sewage gas	TJ	1'306	1'274	1'241	1'257	1'264	1'259	1'276	1'282	1'235	1'227

Table 3-29 Activity data of engines and gas turbines in 1A4b Other sectors: residential.

1A4bi Residential Stationary (Engines and gas turbines)		Unit	1990	1995	2000	2005	2010
Total fuel consumption		TJ	45	179	317	360	267
1A4bi Engines with CHP unit	Gas oil	TJ	4.9	19	64	60	20
1A4bi Engines with CHP unit	Liquefied petroleum gas	TJ	0.26	4.0	11	11	12
1A4bi Engines with CHP unit	Natural gas	TJ	39	156	241	288	232
1A4bi Engines with CHP unit	Biodiesel fossil	TJ	NO	NO	NO	0.035	0.15
1A4bi Engines with CHP unit	Biodiesel biogenic	TJ	NO	NO	NO	0.69	3.3
1A4bi Engines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO

1A4bi Residential Stationary (Engines and gas turbines)		Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption		TJ	209	198	187	163	138	121	121	123	128	127
1A4bi Engines with CHP unit	Gas oil	TJ	9.7	8.5	7.4	8.4	4.8	6.4	6.2	6.1	6.2	6.0
1A4bi Engines with CHP unit	Liquefied petroleum gas	TJ	11	9.6	14	4.9	3.3	2.6	2.5	2.5	2.6	2.5
1A4bi Engines with CHP unit	Natural gas	TJ	185	177	163	147	128	110	106	109	113	112
1A4bi Engines with CHP unit	Biodiesel fossil	TJ	0.16	0.15	0.12	0.12	0.097	0.098	0.10	0.11	0.12	0.11
1A4bi Engines with CHP unit	Biodiesel biogenic	TJ	2.9	2.6	2.5	2.6	2.2	2.1	2.1	2.1	2.1	2.1
1A4bi Engines with CHP unit	Biogas	TJ	NO	NO	NO	NO	NO	NO	3.5	3.7	4.1	4.4

Table 3-30 Activity data of engines and gas turbines in 1A4c Other sectors: agriculture/forestry/fishing.

1A4ci Agriculture/Forestry/Fishing Stationary (Engines and gas turbines)		Unit	1990	1995	2000	2005	2010						
Total fuel consumption		TJ	64	53	67	133	499						
1A4ci Engines used as emergency generators	Gas oil	TJ	2.1	2.1	2.1	2.1	2.1	2.1					
1A4ci Engines with CHP unit at biogas plants	Natural gas	TJ	2.7	1.3	2.5	2.3	NO						
1A4ci Engines with CHP unit at biogas plants	Biogas	TJ	59	49	62	128	497						
1A4ci Agriculture/Forestry/Fishing Stationary (Engines and gas turbines)		Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
Total fuel consumption		TJ	930	1'043	1'194	1'274	1'405	1'614	1'764	1'911	1'948	2'005	
1A4ci Engines used as emergency generators	Gas oil	TJ	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	
1A4ci Engines with CHP unit at biogas plants	Natural gas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
1A4ci Engines with CHP unit at biogas plants	Biogas	TJ	928	1'041	1'192	1'272	1'403	1'612	1'762	1'909	1'946	2'003	

### 3.2.4.5.3. Model for wood energy combustion

#### Choice of method

The emissions from wood combustion in 1A Fuel combustion are calculated by a Tier 2 method (except for a Tier 1 method for N<sub>2</sub>O) 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 2024b) distinguish 24 wood combustion installation types (excl. municipal solid waste plants) that are fired with logwood, pellets, chips or so-called renewable waste from wood products and provide both the annual wood consumption for the individual categories of combustion installation types (table 4.1, categories 1–19, see Table 3-31), and the allocations of the installation types to the sectoral consumer categories (table 6.1, 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 2025/1A Holzfeuerungen). Installation types of the wood energy statistics with the same emission behaviour are grouped together in one category in the emission factor model, see Table 3-31.

Table 3-31 Assignment of the categories of wood combustion installations from the Swiss wood energy statistics (SFOE 2024b) to the categories of the emission factor model (Zotter and Nussbaumer 2022).

Categories of wood combustion installations		
Swiss wood energy statistics		Emission factor model
1	Open fireplaces	Open fireplaces
2	Closed fireplaces	Closed fireplaces, log wood stoves
3	Log wood stoves	
4a	Heating stoves (living area)	
4b	Pellet stoves	Pellet stoves
5	Tiled stoves	Closed fireplaces, log wood stoves
6	Log wood hearths	Log wood hearths
7	Central heating hearths	
8	Log wood boilers <50 kW	Log wood boilers
9	Log wood boilers >50 kW	
10	Log wood dual chamber boilers	Log wood dual chamber boilers
11a	Automatic chip boilers < 50 kW	Automatic chip boilers < 50 kW
11b	Automatic pellet boilers < 50 kW	Automatic pellet boilers < 50 kW
12a	Automatic chip boilers 50–300 kW w/o wood processing companies	Automatic chip boilers 50–300 kW w/o wood processing companies
12b	Automatic pellet boilers 50–300 kW	Automatic pellet boilers 50–300 kW
13	Automatic chip boilers 50–300 kW within wood processing companies	Automatic chip boilers 50–300 kW within wood processing companies
14a	Automatic chip boilers 300–500 kW w/o wood processing companies	Automatic chip boilers 300–500 kW w/o wood processing companies
14b	Automatic pellet boilers 300–500 kW	Automatic pellet boilers 300–500 kW
15	Automatic chip boilers 300–500 kW within wood processing companies	Automatic chip boilers 300–500 kW within wood processing companies
16a	Automatic chip boilers > 500 kW w/o wood processing companies	Automatic chip boilers > 500 kW w/o wood processing companies
16b	Automatic pellet boilers > 500 kW	Automatic pellet boilers > 500 kW
17	Automatic chip boilers > 500 kW within wood processing companies	Automatic chip boilers > 500 kW within wood processing companies
18	Combined chip heat and power plants	Combined chip heat and power plants
19	Plants for renewable waste from wood products	Plants for renewable waste from wood products

## Emission factors

Emission factors are described in chp. 3.2.4.4.2 for CO<sub>2</sub>, 3.2.4.4.3 for CH<sub>4</sub>, and 3.2.4.4.4 for N<sub>2</sub>O.



## Activity data

Total activity data are based on the Swiss wood energy statistics (SFOE 2024b). 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, 1A2g<sub>iv</sub> and 1A4ci are allocated on the basis of industry information (see Figure 3-17 and EMIS 2025/1A Holzfeuerungen):

- 1A2: The wood energy consumption of 1A2f Brick and tile production (2000–2012) was subtracted from the activity data of 1A2g<sub>viii</sub> Automatic chip boiler >500 kW without wood processing companies, while that of wood waste in 1A2f Cement production and 1A2g<sub>iv</sub> Fibreboard is subtracted from the activity data of 1A2g<sub>viii</sub> Plants for renewable waste from wood products.
- 1A4: From 2013 onwards, also the wood energy consumption in 1A4ci Grass drying is available and is subtracted from the activity data in 1A4ci Automatic chip boiler >500 kW without wood processing companies.

Table 3-32 Wood energy consumption in 1A Fuel combustion.

1A Wood combustion	1990	1995	2000	2005	2010
	TJ				
Total	28'219	29'649	27'426	31'413	40'135
Open fireplaces	226	270	195	181	124
Closed fireplaces, log wood stoves	7'273	7'166	6'487	7'036	8'519
Pellet stoves	NO	NO	7.0	48	151
Log wood hearths	8'520	7'017	4'737	4'020	2'348
Log wood boilers	5'307	5'564	5'105	5'357	4'909
Log wood dual chamber boilers	1'964	1'777	977	480	273
Automatic chip boilers < 50 kW	239	433	550	753	1'008
Automatic pellet boilers < 50 kW	NO	NO	56	804	2'106
Automatic chip boilers 50–300 kW w/o wood proc. companies	464	858	1'161	1'862	2'735
Automatic pellet boilers 50–300 kW	NO	NO	3.0	114	601
Automatic chip boilers 50–300 kW within wood proc. companies	895	1'186	1'216	1'365	1'533
Automatic chip boilers 300–500 kW w/o wood proc. companies	237	521	713	1'000	1'503
Automatic pellet boilers 300–500 kW	NO	NO	NO	19	195
Automatic chip boilers 300–500 kW within wood proc. companies	412	570	588	632	674
Automatic chip boilers > 500 kW w/o wood proc. companies	314	1'096	1'732	2'400	4'483
Automatic pellet boilers > 500 kW	NO	NO	NO	9.0	186
Automatic chip boilers > 500 kW within wood proc. companies	1'389	2'128	2'368	2'768	2'960
Combined chip heat and power plants	NO	3.0	186	127	2'756
Plants for renewable waste from wood products	979	1'060	1'345	2'439	3'070

1A Wood combustion	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	TJ									
Total	37'314	38'920	42'573	43'570	41'149	43'332	42'660	49'787	44'915	46'931
Open fireplaces	62	64	68	67	62	62	58	59	42	40
Closed fireplaces, log wood stoves	6'824	7'446	7'862	7'540	6'926	6'943	6'375	7'280	6'056	6'110
Pellet stoves	159	181	199	196	186	187	175	198	166	170
Log wood hearths	978	1'006	992	900	792	763	675	748	617	589
Log wood boilers	2'820	2'970	3'032	2'852	2'597	2'596	2'320	2'523	2'039	2'035
Log wood dual chamber boilers	125	119	112	88	67	57	42	38	27	21
Automatic chip boilers < 50 kW	739	786	798	742	667	644	559	582	455	450
Automatic pellet boilers < 50 kW	2'099	2'376	2'610	2'619	2'538	2'676	2'489	2'909	2'719	2'825
Automatic chip boilers 50–300 kW w/o wood proc. companies	2'645	3'032	3'350	3'372	3'252	3'375	3'237	3'836	3'305	3'456
Automatic pellet boilers 50–300 kW	857	1'091	1'310	1'451	1'498	1'644	1'676	2'136	1'971	2'127
Automatic chip boilers 50–300 kW within wood proc. companies	1'282	1'400	1'489	1'486	1'426	1'421	1'370	1'530	1'333	1'379
Automatic chip boilers 300–500 kW w/o wood proc. companies	1'436	1'644	1'816	1'820	1'742	1'818	1'746	2'039	1'759	1'853
Automatic pellet boilers 300–500 kW	239	279	337	355	352	365	352	449	391	419
Automatic chip boilers 300–500 kW within wood proc. companies	570	600	632	623	617	589	569	623	540	558
Automatic chip boilers > 500 kW w/o wood proc. companies	5'015	5'843	6'575	6'778	6'525	6'927	7'032	8'312	7'134	7'638
Automatic pellet boilers > 500 kW	281	317	364	362	346	370	373	445	398	428
Automatic chip boilers > 500 kW within wood proc. companies	2'407	2'568	2'653	2'546	2'397	2'460	2'387	2'632	2'293	2'413
Combined chip heat and power plants	5'325	3'830	3'970	4'887	4'696	5'921	6'319	6'795	7'294	7'727
Plants for renewable waste from wood products	3'450	3'367	4'404	4'887	4'463	4'513	4'906	6'653	6'375	6'692

### 3.2.4.6. Emissions from biomass (memo item)

According to the 2006 IPCC Guidelines (IPCC 2006), CO<sub>2</sub> emissions from biomass do not count for the national total emissions and therefore are a memo item only. The CO<sub>2</sub> emissions from biomass as reported in the reporting tables are incomplete as the following CO<sub>2</sub> emissions from biomass 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, 5D Wastewater treatment and discharge as well as 6 Other. In contrast, CO<sub>2</sub> emissions from biomass from source category 5C Incineration and open burning of waste are included in CRT Table5.C but not accounted for in the total CO<sub>2</sub> emissions from biomass as shown in CRT Summary1.As3, CRT Summary2, CRT Table10s1 and CRT Table10s2 (these tables include CO<sub>2</sub> emissions from biomass from sector 1 Energy only). Similarly, CO<sub>2</sub> emissions from biomass from international aviation (source category 1D1) are included in CRT Table1.D but not accounted for elsewhere.

Table 3-33 provides an overview of latest effective CO<sub>2</sub> emissions from biomass and their reporting in the reporting tables (without land use, land-use change and forestry). For further information on the CO<sub>2</sub> emissions from biomass refer to the chapters of the respective source categories.

Table 3-33 Effective CO<sub>2</sub> emissions from biomass in the latest reporting year and their representation in the reporting tables.

CO <sub>2</sub> emissions from biomass	2023	Note
	kt	
1A1 Energy industries (without MSW incineration)	684	Included in reporting tables
1A1 Energy generation from MSW Incineration	2'105	Included in reporting tables
1A2 Manufacturing industries and construction	1'511	Included in reporting tables
thereof use of waste derived fuels in cement production	78	
thereof use of biofuels (1A2gvii)	28	
1A3 Transport	460	Included in reporting tables
1A4 Other sectors (Commercial/institutional, residential)	3'341	Included in reporting tables
1A5 Other	0.83	Included in reporting tables
2H2 Food and beverages industry	15	Not included in reporting tables
2G Other product use (Consumption of tobacco)	9.5	Not included in reporting tables
5A Solid waste disposal	31	Not included in reporting tables
5B Biological treatment of solid waste (composting and anaerobic digestion)	161	Not included in reporting tables
5C Incineration and open burning of waste (without MSW incineration)	121	Included in CRT Table5.C, but not accounted for in the summary reporting tables
5D Wastewater treatment and discharge	4.5	Not included in reporting tables
6 Other	1.6	Not included in reporting tables
Total CO <sub>2</sub> emissions from biomass in Switzerland in 2023	8'445	Without international aviation
Total CO <sub>2</sub> emissions from biomass included in the following summary reporting tables (energy-related CO <sub>2</sub> emissions from biomass combustion included in sector 1 Energy): CRT Summary1, CRT Summary2, CRT Table10s1 and CRT Table10s2	8'102	
International aviation (aviation bunkers)	1.311	Included in CRT Table1.D, but not accounted for in the summary reporting tables

### 3.2.4.7. Uncertainty and time series consistency for source category 1A

In the following, basic uncertainties of activity data and CO<sub>2</sub> emission factors by fuel type are presented for source category 1A Fuel combustion.

Table 3-34 Uncertainties of activity data, CO<sub>2</sub> emission factors and CO<sub>2</sub> emissions for 1A Fuel combustion.

Fuel type	Uncertainties		
	Activity data	CO <sub>2</sub> emission factors	CO <sub>2</sub> emissions
	%		
Jet kerosene	0.96	0.16	0.97
Gasoline	0.69	0.13	0.70
Diesel oil	0.88	0.068	0.88
Liquid fuels	0.69	0.081	0.69
Solid fuels	5	5.1	7.1
Gaseous fuels	5	0.38	5.0
Other fuels	5	9.2	10
Biomass	10	--	--

## Liquid fuels

### *Uncertainty of the CO<sub>2</sub> emission factors*

In 2013, a large measurement campaign was carried out to determine the CO<sub>2</sub> 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 3-35 as lower and upper values as well as relative uncertainties.

For mobile combustion, the 2006 IPCC Guidelines provide default uncertainties for the CO<sub>2</sub> emission factors of 2 % for jet kerosene, 4 % for gasoline and 1 % for diesel oil (IPCC 2006, vol. 2, TABLE 3.2.1). The Swiss 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<sub>2</sub> emission factors 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 3-35 Uncertainties of aggregated results of measurements of the CO<sub>2</sub> emission factors of selected liquid fuels (SFOE/FOEN 2014).

Fuel type	CO <sub>2</sub> emission factors (measurements)			95% uncertainties emission factors (CO <sub>2</sub> )		no. samples
	mean	lower	upper	absolute	relative	
	t/TJ	t/TJ	t/TJ	t/TJ	%	
Jet 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 3-36 are based on a written message of SFOE to FOEN (SFOE 2012a). It lists two kinds of relevant sources of uncertainties: measurement uncertainties and uncertainties of the conversion from mass to energy units. For diesel oil, the transformation to other products represents a third source of uncertainty. Since the used equations are multiplications, the relative uncertainties have to be summed up.

Table 3-36 Sources of uncertainties contributing to the total uncertainty of the activity data of selected liquid fuels (SFOE 2012a).

Source of uncertainty	Jet 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	-	-	0.20%	-
Total Uncertainty	0.96%	0.69%	0.88%	0.69%

## Gaseous fuels

### *Uncertainty of the CO<sub>2</sub> 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<sub>2</sub> 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 a factor of 1.96 to represent a 95 % uncertainty interval. This calculation has been carried out for all years with available data (selected years between 1990 and 2009 and all years thereafter). The uncertainties fluctuate from year to year. For the uncertainty analysis, the following values for the uncertainty of the CO<sub>2</sub> emission factor for gaseous fuels are used: 1.48 % for 1990 and of 0.38 % for 2023.

### *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 % to 5 % for industrial combustion and 3 % to 5 % for commercial, institutional and residential combustion. For Switzerland, an overall value of 5 % is used.

## Solid fuels

### *Uncertainty of the CO<sub>2</sub> 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 (mean 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 % to 5 % for industrial combustion and 3 % to 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<sub>2</sub> emission factor*

There are two factors influencing the uncertainty of CO<sub>2</sub> emissions from municipal solid waste incineration (1A1a), namely the carbon content of waste and the fossil carbon fraction of the carbon content.

- The carbon content is determined according to a study by Fellner et al. (2007). The relation between the calorific value of waste and the carbon content is derived therein, including upper and lower limits. The relation is verified by measurements. The relative

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 was determined in a study by Mohn et al. (2011). The radiocarbon ( $^{14}\text{C}$ ) method was used to determine the ratio of fossil versus biogenic  $\text{CO}_2$  emissions from five waste-to-energy plants. Gas samples for  $^{14}\text{CO}_2$  analysis were taken at the plants during miscellaneous seasons. Six field campaigns of three weeks were carried out for three plants and three field campaigns, again of three weeks, were carried out for two plants, leading to a total sampling duration of 72 weeks. The field campaigns provided a median and (absolute) 95 % confidence interval of the fossil fraction of  $(47.7 \pm 7.5) \%$  (Table 3-37). The relative uncertainty was thus 15.8 %. The results fit well to former field campaigns on three plants, which yielded a mean fossil fraction of 48.0 % (Mohn et al. 2008). For the greenhouse gas inventory and its uncertainty analysis the latest results from Mohn et al. (2011) are used.
- The emission factor for fossil  $\text{CO}_2$  results from the multiplication of the carbon content and the fossil fraction. The relative uncertainty of the  $\text{CO}_2$  emission factor is thus computed using uncertainty propagation:  $[(5.9 \%)^2 + (15.8 \%)^2]^{0.5} = 16.9 \%$ .

Table 3-37 Fossil fractions of municipal solid waste measured at five different incineration plants. The absolute uncertainty values (3<sup>rd</sup> column) are expressed in the same unit as the shares, in %.

Plant	Fossil shares	Uncertainty (95% confidence interval)		Field campaigns (duration) weeks
		absolute	relative	
	%	%	%	
Buchs	47.7			6 * 3 = 18
Winterthur	43.4			6 * 3 = 18
Linthgebiet	50.6			6 * 3 = 18
Linthgebiet	54.5			3 * 3 = 9
Zuchwil	45.9			3 * 3 = 9
Median / sum	47.7	7.5	15.8	72

### Uncertainty of activity data

There is no country-specific estimate of the uncertainty for the combustion of waste. It is taken from the 2006 IPCC Guidelines (IPCC 2006, vol. 2, p. 2.40), which state: "Experts believe that the uncertainty resulting from the two errors (*systematic*, *random*) combined is probably in the range of  $\pm 5 \%$  for most developed countries." In accordance with that statement, the value of 5 % is used.

## Biomass

### Uncertainty of the $\text{CO}_2$ emission factor

For  $\text{CO}_2$  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). An average uncertainty of 10 % is applied for biomass burning in all source categories.

## Uncertainty of CH<sub>4</sub> and N<sub>2</sub>O emission factors

Since the CO<sub>2</sub> emissions vastly dominate the GHG emissions of source category 1A (almost 99 % of total emissions), the uncertainty evaluation of the non-CO<sub>2</sub> emissions is carried out on a semi-quantitative level (see Table 3-38).

Only for **1A3b Road transportation**, a quantitative analysis has been performed. Following a study for the road transportation in Germany (IFEU/INFRAS 2010), where the same handbook of emission factors is used as in Switzerland, the uncertainties for the CH<sub>4</sub> and N<sub>2</sub>O emission factors have been determined (see rows 1A3b gasoline and diesel oil in Table 3-38). The uncertainties of CH<sub>4</sub> and N<sub>2</sub>O emissions of CNG (1A3b), which were not investigated in IFEU/INFRAS (2010), have been estimated qualitatively as “medium” according to Table 1-8. For the source categories **1A1, 1A2, 1A3a, 1A3c, 1A3d, 1A3e, 1A4a, 1A4b, 1A4c, 1A5** the uncertainties of CH<sub>4</sub> and N<sub>2</sub>O emissions have similarly been estimated qualitatively (see Table 3-38).

## Summary

Table 3-38 provides a summary of the uncertainties of 1A Fuel combustion as derived in the preceding sections. The combined uncertainty assigned to the CO<sub>2</sub> emissions is computed by propagating the uncertainties of the activity data and the emission factors.

Table 3-38 Uncertainties of 1A Fuel combustion categories for activity data, emission factors and combined uncertainties for 2022. The latter are calculated by uncertainty propagation (approach 1). For 1A2/Other Fuels a mean uncertainty is assumed based on semi-quantitative estimations from Table 1-8. The emission factor uncertainty is calculated “backward” ( $U(EF) = \sqrt{U(EM)^2 - U(AD)^2}$ ) from the combined and the activity data uncertainty. CH<sub>4</sub> and N<sub>2</sub>O: semi-quantitative uncertainties are used (see Table 1-8). For 1990, uncertainties are generally the same as for 2023, except for the CO<sub>2</sub> emission factor for gas (1.48 % for 1990).

1A Fuel Combustion Categories	Fuel type	Uncertainties				
		Activity data	CO <sub>2</sub> em. factors	CO <sub>2</sub> emissions	CH <sub>4</sub> emissions	N <sub>2</sub> O emissions
		%	%	%	--	--
1. Energy industries	liquid fuels	0.69	0.081	0.69	medium	medium
1. Energy industries	solid fuels	5.0	5.1	7.1	medium	medium
1. Energy industries	gaseous fuels	5.0	0.38	5.0	medium	medium
1. Energy industries	other fuels	5.0	9.2	10	medium	medium
2. Manufacturing industries and construction	liquid fuels	0.69	0.081	0.69	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	0.38	5.0	medium	medium
2. Manufacturing industries and construction	other fuels	5.0	9.2	10	medium	medium
3a. Transport; Domestic aviation	kerosene	0.96	0.16	0.97	high	high
3b. Transport; Road transportation	gasoline	0.69	0.13	0.70	37%	50%
3b. Transport; Road transportation	diesel oil	0.88	0.068	0.88	20%	22%
3b. Transport; Road transportation	gaseous fuels	5.0	0.38	5.0	medium	medium
3c. Transport; Railways	diesel oil	0.88	0.068	0.88	medium	high
3d. Transport; Domestic navigation	liquid fuels	0.69	0.081	0.69	medium	high
3e. Transport; Other transportation	gaseous fuels	5.0	0.38	5.0	medium	medium
4a. Other sectors; Commercial/institutional	liquid fuels	0.69	0.081	0.69	medium	medium
4a. Other sectors; Commercial/institutional	gaseous fuels	5.0	0.38	5.0	medium	medium
4b. Other sectors; Residential	liquid fuels	0.69	0.081	0.69	medium	medium
4b. Other sectors; Residential	solid fuels	5.0	5.1	7.1	medium	medium
4b. Other sectors; Residential	gaseous fuels	5.0	0.38	5.0	medium	medium
4c. Other sectors; Agriculture/forestry/fishing	liquid fuels	0.69	0.081	0.69	medium	medium
4c. Other sectors; Agriculture/forestry/fishing	gaseous fuels	5.0	0.38	5.0	medium	medium
5. Other	liquid fuels	0.69	0.081	0.69	medium	high
1A Stationary sources	biomass	10	--	--	medium	medium
1A Mobile sources	biomass	10	--	--	high	high



## Time series consistency 1A

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

### 3.2.4.8. Category-specific QA/QC and verification for 1A

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

### Comparison of emission estimates using different approaches

At the level of total energy-related CO<sub>2</sub> 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 2024). The differences in total CO<sub>2</sub> 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 2024) 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 Swiss Federal Office of Energy (SFOE) and the Swiss Federal Office for the Environment (FOEN) launched an in-depth investigation into the NCVs and CO<sub>2</sub> emission factors of gas oil, diesel oil, gasoline, and jet kerosene (SFOE/FOEN 2014, see chp. 3.2.4.2). The most recent results differ only marginally from previously used values. The CO<sub>2</sub> emission factors compare well with the IPCC default values (see Table 3-39).

Table 3-39 Comparison of default CO<sub>2</sub> emission factors from IPCC (2006) with current country-specific values of Switzerland for selected fuels.

CO <sub>2</sub> emission factors	IPCC 2006			Switzerland
	lower	upper	default	CS
	t CO <sub>2</sub> /TJ			t CO <sub>2</sub> /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

Switzerland's country-specific CO<sub>2</sub> emission factor for gasoline is higher than the upper limit of the IPCC range (Table 3-39). However, the value is based on more than 100 fuel samples taken from July to December 2013 (SFOE/FOEN 2014) and is in agreement with earlier measurements (EMPA 1999). Accordingly, the value is considered to correctly represent national circumstances.

For natural gas, the CO<sub>2</sub> emission factor is annually assessed. A country-specific CO<sub>2</sub> emission factor is calculated based on measurements of gas properties and corresponding import shares of individual gas import stations (see chp. 3.2.4.4). The resulting values are largely consistent with the CO<sub>2</sub> emission factor used by the countries from which gas is imported (i.e. Germany, the Netherlands, Norway, France, Italy and Denmark, with implied emission factors between 55.5 and 58.5 t CO<sub>2</sub>/TJ, based on submissions in 2023).

For submission 2021, the CH<sub>4</sub> emission factors from combustion of wood were scrutinized and revised based on Zotter and Nussbaumer (2022). The range of country-specific values is not entirely consistent with the lower IPCC default values (1A1, 1A2, Table 3-40). However, as the country-specific emission factors are based on an extensive measurement campaign, they are considered representative for Swiss circumstances.

Table 3-40 Comparison of default CH<sub>4</sub> emission factors from the 2006 IPCC Guidelines (IPCC 2006) with country-specific values for wood/wood waste.

CH <sub>4</sub> emission factors	IPCC 2006			Switzerland
	lower	upper	default	CS
	kg CH <sub>4</sub> /TJ			kg CH <sub>4</sub> /TJ
Wood/wood waste	10 (1A1, 1A2) 100 (1A4)	100 (1A1, 1A2) 900 (1A4)	30 (1A1, 1A2) 300 (1A4)	0.18–230

### Further QC procedures

The general QC procedures as described in chp. 1.5 (e.g. annual internal review, expert peer review, etc.) also apply to source category 1A.

### 3.2.4.9. Planned improvements for source category 1A in general

No category-specific improvements are planned.



### 3.2.5. Source category 1A1 – Energy industries (stationary)

#### 3.2.5.1. Source category description for 1A1 (stationary)

Table 3-41 Key categories of 1A1 Energy industries. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
1.A.1	Energy industries; Gaseous fuels	CO <sub>2</sub>	L1, T1
1.A.1	Energy industries; Liquid fuels	CO <sub>2</sub>	L1, T1
1.A.1	Energy industries; Other fossil fuels	CO <sub>2</sub>	L1, L2, T1, 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 are 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 2024). Emissions from industries producing heat and/or electricity (CHP) for their own use are included in category 1A2 Manufacturing Industries and Construction.

Table 3-42 Specification of source category 1A1 Energy Industries.

1A1	Source category	Specification
1A1a	Public electricity and heat production	Main sources are waste incineration plants with heat and power generation (Other fossil and biogenic fuels) and public district heating systems including boilers, and boilers with combined heat and power generation not further defined, as well as engines and gas turbines with fossil fuels and biogas, and engines on landfill sites or emergency generators. The only fossil fuelled public electricity generation unit “Vouvry” (300 MW <sub>e</sub> ; no public heat production) ceased operation in 1999.
1A1b	Petroleum refining	Combustion activities supporting the refining of petroleum products, excluding evaporative emissions. Use of refinery gas in gas turbines with SCGT at refineries.
1A1c	Manufacture of solid fuels and other energy industries	Emissions from 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 3-43). Energy recovery from municipal solid waste and special waste incineration is mandatory in Switzerland (Swiss Confederation 2015, Art. 27) 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 3-43 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 gas turbines	natural gas, gas oil, biogas, biodiesel
Engines on landfill sites	natural gas, landfill gas (biogas)
Municipal solid waste incineration plants	municipal solid waste (other, waste-to-energy)
Special waste incineration plants	special wastes (other, waste-to-energy)

### Methodology (1A1a)

For CO<sub>2</sub> 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<sub>4</sub> emissions, a Tier 2 method was applied using IPCC default emission factors (IPCC 2006), except for biomass, where country-specific emission factors are used. For N<sub>2</sub>O IPCC default values are used (Tier 1, IPCC 2006), except for municipal solid waste and special waste incineration plants, where country-specific emission factors are used (Tier 2).

### Emission factors (1A1a)

Table 3-44 presents the emission factors used in 1A1a. Emission factors for gas oil, natural gas, biomass and biogas (highlighted green in Table 3-44) are further explained in chp. 3.2.4.4. The use of fossil and biogenic fuels in engines and gas turbines as well as the fossil carbon fraction in biodiesel are described in the specific model description in chp. 3.2.4.5.2.

Table 3-44 Emission factors for 1A1a Public Electricity and Heat Production in 2023.

1A1a Public electricity and heat production	CO <sub>2</sub>	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	t/TJ		kg/TJ					
Gas oil	73.7	NA	2.9	0.76	38	4.3	0.84	10
Residual fuel oil	NO	NA	NO	NO	NO	NO	NO	NO
Other bituminous coal	NO	NA	NO	NO	NO	NO	NO	NO
Natural gas	55.9	NA	3.6	0.47	27	6.6	0.23	14
Other (waste-to-energy, MSW), fossil	92.2	NA	NE	1.1	5.5	0.41	0.76	1.0
Other (waste-to-energy, special waste), fossil	73.9	NA	NE	15	1.9	0.39	0.062	0.59
Other (waste-to-energy, MSW), biogenic	NA	92.2	NE	1.1	5.5	0.41	0.76	1.1
Biomass (wood, wood waste)	NA	99.9	0.41	4.0	67	0.53	6.7	24
Biogas (engines, co-generation from landfills and gas turbines)	NA	55.9	5.2	0.69	54	12	0.5	23
Biodiesel (engines and gas turbines)	73.3	73.3	1.2	2.9	404	50	0.30	131

### Emission factors for waste incineration and landfill gas use

Specific emission factors within 1A1a Public electricity and heat production apply for municipal solid waste incineration, special waste incineration and for landfill gas use. The emission factors for CO<sub>2</sub>, NO<sub>x</sub>, CO, NM VOC and SO<sub>2</sub> are country-specific and based on measurements and expert estimates. Emission factors for CH<sub>4</sub> and N<sub>2</sub>O are IPCC default

values (IPCC 2006), with the exception of waste and biomass as fuel, where country-specific emission factors are applied. Emission factors are documented in EMIS 2025/1A1a Kehrichtverbrennungsanlagen, EMIS 2025/1A1a Sondermüllverbrennungsanlagen and EMIS 2025/1A1a & 5A Kehrichtdeponien.

#### *Source-specific CO<sub>2</sub> emission factors for municipal solid waste incineration plants*

C-content of waste is calculated based on the net calorific value, which is deduced by a standard method and published on a yearly basis since 2009 by SFOE for each municipal solid waste incineration plant and as a Swiss average (FOEN/SFOE/VBSA 2022). In deviation from the general description of oxidation factors in chp. 3.2.4.4.1, an oxidation factor of 0.99 is assumed here. The assumption is based on measurements in two municipal solid waste incineration plants in Zurich (AWEL 2009) and on a study in Austria (Zeschmar-Lahl 2004), where the municipal solid waste incineration plants 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 clean air of 0.989.

The fossil fraction of waste incinerated in municipal solid waste incineration plants was analysed in Switzerland in the years 1992/1993, 2001/2002, 2012 and 2022 (FOEN, 2023n). Based on direct measurements of the radioactive isotope carbon-14 (<sup>14</sup>C) in the flue gas of municipal solid waste incineration plants made for calibration in the years 2010/2011 (Mohn et al. 2011), Ryttec (2014) established a method to translate the fossil fraction of waste incinerated to the fossil and biogenic fractions of CO<sub>2</sub> at the chimney. The CO<sub>2</sub> emission factor of municipal solid waste incineration plants fluctuates over the reporting period not only because of variations in the fossil fraction, but also because of gradual changes in the net calorific values of the waste (Table 3-45).

Table 3-45 Emission factor CO<sub>2</sub> total, share of CO<sub>2</sub> fossil and net calorific value (NCV) in municipal solid waste incineration plants (MSWIP).

1A1a Public electricity and heat production, Other fossil fuels	Unit	1990	1995	2000	2005	2010
CO <sub>2</sub> total (MSWIP)	t/TJ	92.80	91.86	91.09	91.49	92.32
Share of CO <sub>2</sub> fossil (MSWIP)	fraction	0.497	0.505	0.513	0.505	0.486
NCV of waste (MSWIP)	TJ/t	0.0114	0.0119	0.0124	0.0121	0.0117

1A1a Public electricity and heat production, Other fossil fuels	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO <sub>2</sub> total (MSWIP)	t/TJ	92.43	92.28	92.01	91.92	91.90	91.85	91.86	92.04	91.96	92.24
Share of CO <sub>2</sub> fossil (MSWIP)	fraction	0.483	0.485	0.488	0.490	0.493	0.495	0.498	0.500	0.503	0.503
NCV of waste (MSWIP)	TJ/t	0.0116	0.0117	0.0118	0.0119	0.0119	0.0119	0.0119	0.0118	0.0119	0.0117

Sodium bicarbonate and calcium carbonate are used in some municipal solid waste incineration plants 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 emissions are reported in source category 2A4d.

#### *Source-specific CO<sub>2</sub> 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<sub>2</sub>/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 2025/1A1a Sondermüllverbrennungsanlagen.

#### *Source-specific CH<sub>4</sub> emission factors in municipal and special waste incineration plants*

Emissions of CH<sub>4</sub> 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<sub>2</sub>O and CH<sub>4</sub> emission factors for municipal solid waste incineration plants (Mohn 2013). In this study, Empa evaluated measurements that were performed in 2011 in five Swiss municipal solid waste incineration plants with different Denox techniques (SCR, SNCR). For most of the measurements, CH<sub>4</sub> concentrations were below the detection limit of 0.3 ppm. The study concluded that "CH<sub>4</sub> emission concentrations were very low and below the background concentration of 1.8 ppm". These measurements, which showed that CH<sub>4</sub> concentration in the exhaust air was below the CH<sub>4</sub> concentration in ambient air, would point to CH<sub>4</sub> removal rather than emissions occurring. Therefore, CH<sub>4</sub> emissions from municipal waste incineration are reported as not estimated because they are considered insignificant. The same fact applies for special waste incineration.

#### *Source-specific N<sub>2</sub>O emission factors for municipal solid waste incineration*

In 2013, a study evaluated N<sub>2</sub>O 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, 2012, 2016 and 2020, weighted average N<sub>2</sub>O emission factors have been calculated, based on the amounts of waste burnt in every plant. For the years in between, the N<sub>2</sub>O emission factors were linearly interpolated. Since 2020, 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 new weighted averages for the N<sub>2</sub>O emission factors periodically every four years, depending on data available; see documentation in EMIS 2025/1A1a Kehricht- und Sondermüllverbrennungsanlagen. The emission factor is therefore not constant over time. For the entire time series, equal numeric values are used for emission factors of the fossil and the biogenic fraction.

#### *Source-specific N<sub>2</sub>O 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. From the year 2018 onwards, a country-specific emission factor of 14.6 g/GJ based on measured data is used (TBF 2021). The emission factor values for all years following 2018 are assumed equal. Data between 2003 and 2018 are linearly interpolated.

Table 3-46 N<sub>2</sub>O emission factors of municipal solid (MSWIP) and special waste incineration plants (SWIP) in 1A1a Public electricity and heat production.

1A1a Public electricity and heat production, Other fossil fuels	Unit	1990	1995	2000	2005	2010
N <sub>2</sub> O (MSWIP)	kg/TJ	5.26	2.96	2.06	1.44	1.40
N <sub>2</sub> O (SWIP)	kg/TJ	3.06	4.23	5.41	7.11	9.60

1A1a Public electricity and heat production, Other fossil fuels	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
N <sub>2</sub> O (MSWIP)	kg/TJ	1.29	1.21	1.13	1.13	1.13	1.12	1.12	1.13	1.13	1.14
N <sub>2</sub> O (SWIP)	kg/TJ	11.59	12.08	12.58	13.08	14.57	14.57	14.57	14.57	14.57	14.57

### Activity data (1A1a)

Activity data for liquid, gaseous, solid fuels and wood are based on the Swiss overall energy statistics (SFOE 2024) and additional data sources as described in chp. 3.2.4.3. Activity data for 'Other fuels' are based on the amount of waste incinerated in MSWIPs and SWIPs (FOEN 2024h, see Table 3-48). Activity data for combined heat and power generation in landfills are taken from the Swiss renewable energy statistics (SFOE 2024a).

Please note that waste-to-energy activities in CRT Table 1.A(a)s1 are allocated to fuel types 'Other fossil fuels' and 'Biomass'. 'Other fossil fuels' encompasses emissions from the fossil shares of MSWIP and SWIP, whereas 'Biomass' covers emissions from wood, waste wood, landfill gas use in co-generation and biogenic share from MSWIP.

The use of fossil and biogenic fuels in engines and gas turbines is described in the specific model description in chp. 3.2.4.5.2.

Table 3-47 Activity data in 1A1a Public Electricity and Heat Production.

1A1a Public electricity and heat production	Unit	1990	1995	2000	2005	2010
Total fuel consumption		40'379	39'179	49'913	56'978	61'750
Gas oil	TJ	980	554	790	1'300	490
Residual fuel oil	TJ	3'214	1'813	340	290	40
Other bituminous coal	TJ	530	46	NO	NO	NO
Natural gas	TJ	4'339	5'422	8'292	9'827	9'926
Other (waste-to-energy, MSW), fossil	TJ	13'995	13'662	17'784	20'181	21'044
Other (waste-to-energy, special waste), fossil	TJ	2'610	3'206	4'692	4'514	4'941
Biomass	TJ	14'711	14'476	18'015	20'866	25'309
Other (waste-to-energy), biogenic	TJ	14'163	13'396	16'894	19'813	22'292
Biomass (wood, wood waste)	TJ	301	466	547	844	2'958
Biogas (engines, co-generation from landfills and gas turbines)	TJ	247	614	573	207	49
Biodiesel (engines and gas turbines)	TJ	NO	NO	NO	2.2	11

1A1a Public electricity and heat production	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption		59'324	61'385	65'017	64'752	65'311	66'482	65'552	66'108	63'324	63'157
Gas oil	TJ	770	660	430	490	380	450	340	420	420	390
Residual fuel oil	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
Natural gas	TJ	5'032	7'050	8'926	7'907	8'111	8'444	7'501	8'551	6'568	5'861
Other (waste-to-energy, MSW), fossil	TJ	21'382	22'054	23'146	23'377	23'697	23'974	24'154	23'802	22'972	23'070
Other (waste-to-energy, special waste), fossil	TJ	4'886	5'115	4'979	4'641	5'013	5'148	4'722	4'276	5'127	4'101
Biomass	TJ	27'254	26'506	27'535	28'336	28'110	28'466	28'835	29'059	28'236	29'735
Other (waste-to-energy), biogenic	TJ	22'893	23'379	24'296	24'298	24'387	24'430	24'372	23'781	22'725	22'823
Biomass (wood, wood waste)	TJ	4'321	3'098	3'218	4'024	3'710	4'022	4'443	5'147	5'366	6'759
Biogas (engines, co-generation from landfills and gas turbines)	TJ	31	21	13	7	6.0	8.4	14	125	138	147
Biodiesel (engines and gas turbines)	TJ	9.1	8.2	7.7	8.0	6.7	6.5	6.3	6.3	6.5	6.3

Since 1990 the use of waste-derived fuels increased considerably. This is due to the fact that since 1 January 2000, disposal of combustible wastes in landfill sites is prohibited by law (Swiss Confederation 2015 (VVEA, Art. 25), and Swiss Confederation 1990 (the preceding Ordinance 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 1990s.

#### *Municipal solid waste incineration and special waste incineration*

Figure 7-5 in Sector 5 Waste gives an overview over the waste amounts, their treatment and their reporting in the Swiss greenhouse gas inventory. Municipal solid waste includes waste generated in households and waste of similar composition from other sources.

The amount of municipal solid waste reported in Table 3-48 is the total amount of waste burnt (it includes fossil and biogenic shares). The same quantities are reported both in kt and in TJ.

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 3-48 Activity data for 1A1aiv Other: Municipal solid waste and special waste incinerated with heat and/or power generation. The same amount of waste burnt is reported in TJ and in kt.

1A1aiii Public electricity and heat production (waste-related only)	Unit	1990	1995	2000	2005	2010
Total waste	TJ	30'768	30'264	39'371	44'508	48'277
Municipal solid waste fossil	TJ	13'995	13'662	17'784	20'181	21'044
Municipal solid waste biogenic	TJ	14'163	13'396	16'894	19'813	22'292
Special waste	TJ	2'610	3'206	4'692	4'514	4'941
Total waste	kt	2'603	2'433	3'040	3'527	3'968
Municipal solid waste (fossil and biogenic)	kt	2'470	2'270	2'801	3'297	3'717
Special waste	kt	133	163	239	230	252

1A1aiii Public electricity and heat production (waste-related only)	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total waste	TJ	49'161	50'548	52'422	52'316	53'097	53'552	53'248	51'859	50'825	49'994
Municipal solid waste fossil	TJ	21'382	22'054	23'146	23'377	23'697	23'974	24'154	23'802	22'972	23'070
Municipal solid waste biogenic	TJ	22'893	23'379	24'296	24'298	24'387	24'430	24'372	23'781	22'725	22'823
Special waste	TJ	4'886	5'115	4'979	4'641	5'013	5'148	4'722	4'276	5'127	4'101
Total waste	kt	4'066	4'150	4'264	4'248	4'297	4'322	4'312	4'245	4'115	4'130
Municipal solid waste (fossil and biogenic)	kt	3'817	3'889	4'010	4'011	4'042	4'059	4'072	4'027	3'853	3'921
Special waste	kt	249	261	254	236	255	262	241	218	261	209

### **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 2006, vol.2, chp. 2), Switzerland applies a Tier 3 approach with country-specific emission factors for CO<sub>2</sub> emissions. The calculations are based on measurements and data from the refining industry as documented in the EMIS database (EMIS 2025/1A1b Heizkessel Raffinerien).

### Emission factors (1A1b)

CO<sub>2</sub> emission factors of residual fuel oil, petroleum coke and refinery gas are estimated based on measurements from the refineries for the years 2005–2011 and 2013–2023 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<sub>2</sub> 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<sub>2</sub> emission factor of refinery gas is higher than the IPCC default value (IPCC 2006).

Table 3-49 Emission factors for 1A1b Petroleum refining in 2023.

1A1b Petroleum refining	Unit	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
Residual fuel oil	kg/TJ	NO	NO	NO	NO	NO	NO	NO
Refinery gas	kg/TJ	C	C	C	C	C	C	C
Petroleum coke	kg/TJ	NO	NO	NO	NO	NO	NO	NO
Natural gas	kg/TJ	C	C	C	C	C	C	C

### Activity data (1A1b)

Activity data on fuel combustion for 1A1b Petroleum refining is provided by the Swiss overall energy statistics (SFOE 2024) 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 2024). As one of the refineries ceased operation in 2015, the data are considered confidential since 2014. Data are available to reviewers on request.

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 months due to insolvency and the search for a new buyer (EV 2014). Between 2004 and 2015, one of the Swiss refineries was also using petroleum coke as a fuel. Natural gas is used additionally to residual fuel oil and refinery gas since 2017. In 2019, 2020, 2022 and 2023, the application of residual fuel oil was halted.

Net calorific values are provided by the annual monitoring reports of the refining industries for the years 2005–2011 and 2013–2023 that are required under the Swiss Federal Act and Ordinance on the Reduction of CO<sub>2</sub> Emissions (Swiss Confederation 2011, Swiss Confederation 2012). For years with missing data (1990–2004 and 2012), the weighted mean of the net calorific value is applied for residual fuel oil and petroleum coke. The net calorific value 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. The use of a plant-specific net calorific value leads to a slight difference to the energy consumption data provided by the Swiss overall energy statistics (SFOE 2024).

Table 3-50 Activity data for 1A1b Petroleum refining.

1A1b Petroleum refining	Unit	1990	1995	2000	2005	2010						
Total fuel consumption	TJ	5'629	9'836	9'636	14'548	14'176						
Residual fuel oil	TJ	1'259	1'786	1'908	902	891						
Refinery gas	TJ	4'370	8'050	7'728	11'833	11'282						
Petroleum coke	TJ	NO	NO	NO	1'813	2'003						
Natural gas	TJ	NO	NO	NO	NO	NO						

1A1b Petroleum refining	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	14'173	7'232	6'355	6'298	6'627	5'911	5'987	5'160	6'575	6'198
Residual fuel oil	TJ	1'330	C	C	C	C	NO	NO	C	NO	NO
Refinery gas	TJ	10'935	C	C	C	C	C	C	C	C	C
Petroleum coke	TJ	1'908	C	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	NO	NO	NO	C	C	C	C	C	C	C

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

#### Methodology (1A1c)

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

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

#### Emission factors (1A1c)

The CO<sub>2</sub> emission factor is based on literature (USEPA 1995, chapter 10.7). CH<sub>4</sub> as well as emission factors for precursors NO<sub>x</sub>, NMVOC and CO are taken from the revised 1996 IPCC Guidelines (IPCC 1997c, EMIS 2025/1A1c).

Table 3-51 Emission factors for 1A1c Manufacture of solid fuels and other energy industries in 2023. The CO<sub>2</sub> emission factor refers to CO<sub>2</sub> of biogenic origin.

1A1c Charcoal	Unit	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
Charcoal production	kg/TJ	16'900	1'000	NA	10	1'700	NE	7'000

#### Activity data (1A1c)

The annual amount of charcoal produced is based on detailed queries with the few remaining sites where charcoal is produced. The main producer is the Köhlerverein Romoos, small quantities are produced at individual traditional local trade shows (Karthause Ittingen, Freilichtmuseum Ballenberg), as documented in EMIS 2025/1A1c. 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 (Koehleri 2014).

Table 3-52 Activity data for 1A1c Manufacture of Solid Fuels and other energy industries.

1A1c Charcoal	Unit	1990	1995	2000	2005	2010
Charcoal production	TJ	1.3	1.4	2.2	3.4	3.6

1A1c Charcoal	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Charcoal production	TJ	4.3	3.8	4.1	3.9	4.3	5.1	3.9	4.0	3.4	3.6

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

The uncertainty of emission estimates for source category 1A1 (stationary) is described in the general uncertainty assessment of source category 1A Fuel combustion in chp. 3.2.4.7.

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. 1.5. 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, emissions and fuel combustion statistics are collected at large combustion plants for pollution legislation purposes. This plant-level data is 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 2025. Major recalculations, which contribute significantly to the total differences in GHG emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

- 1A1a: The fossil fraction of waste incinerated in municipal solid waste incineration plants could be determined for the year 2022 based on new analyses of the waste composition. This leads to a recalculation of the values (activity data) since the last survey in 2012 (linear interpolation to the new value for 2022). For the years 1991 to 2011, the linear interpolation was newly computed using additional significant digits.
- 1A1a: The fossil carbon fraction in biodiesel is now estimated based on the method described in Sebos (2022). The fossil fraction of FAME (Fatty Acid Methyl Ester) is based on the values from HBEFA 4.1 (relevant for the whole EU), while all carbon in HVO (Hydrotreated Vegetable Oil) is considered of biogenic origin. Because biodiesel as reported by Switzerland consists of the sum of FAME and HVO, the fossil fraction of biodiesel varies over time. Overall, around 4.0 to 5.4 % of the total biodiesel are now reported under “fossil liquid fuels” for the years 1996–2022 (no biodiesel in the years before). In consequence, this leads to recalculations in fuel categories including biodiesel as “biomass” or “biofuels” and “liquid fuels” as well.
- 1A1a: Due to new model-runs, there are small recalculations of activity data for all stationary engines and gas turbines 1990-2022.

- 1A1a: Due to an assignment error of sources in the database, the use of liquefied petroleum gas in gas turbines was assigned to source category 1A1a Public electricity and heat production in the CRT of the 2024 submission. Since the Swiss statistics of energy consumption do not report the use of liquefied petroleum gas in energy production, the use of liquefied petroleum gas in gas turbines is now assigned to 1A2g Other in the CRT of the 2025 submission.

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

No category-specific improvements are planned.

## 3.2.6. Source category 1A2 – Manufacturing industries and construction (stationary, without 1A2gvii)

### 3.2.6.1. Source category description for 1A2 (stationary)

Table 3-53 Key categories of 1A2 Manufacturing industries and construction. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
1.A.2	Manufacturing industries and construction; Gaseous fuels	CO <sub>2</sub>	L1, L2, T1
1.A.2	Manufacturing industries and construction; Liquid fuels	CO <sub>2</sub>	L1, T1
1.A.2	Manufacturing industries and construction; Solid fuels	CO <sub>2</sub>	L1, T1
1.A.2	Manufacturing industries and construction; Other fossil fuels	CO <sub>2</sub>	L1, T1

*[Source category 1A2 contains the sum of emissions of stationary and mobile sources – the statement on key categories holds for the aggregated emissions only. The CO<sub>2</sub> emissions of 1A2 from Liquid Fuels are dominated by the stationary sources, however, 43 % (2023) of the CO<sub>2</sub> emissions stem from mobile sources 1A2gvii.]*

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 CRT Table 1.A(d) and described in chp. 3.2.3.

Table 3-54 Specification of source category 1A2 Manufacturing industries and construction.

1A2	Source category	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, niacin, nitric acid (ceased in 2018), ethylene, acetic acid and sulphuric acid as well as silicon carbide (amongst others)
1A2d	Pulp, paper and print	Pulp, paper and print industry: furnaces of cellulose production (ceased in 2008), boilers and gas turbines
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 boilers, engines and gas turbines using fossil fuels and biomass (wood and biogas).

### 3.2.6.2. Methodological issues for 1A2 (stationary)

#### 3.2.6.2.1. Methodology (1A2) and industry model

For CO<sub>2</sub> emissions from fuel combustion in source category 1A2 Manufacturing industries and construction, Tier 2 and 3 methods are applied (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1) using country-specific emission factors – except for other fossil fuels (gasolio, heating gas, and synthesis gas) in 1A2c Chemicals, where plant-specific emission factors are used from 2018 onwards.

For all fuel combustion in 1A2f Cement production, and for wood combustion in 1A2f Brick and tile production (2000–2012), 1A2giv and 1A2gviii as well as for engines and gas turbines in 1A2d and 1A2gviii, CH<sub>4</sub> emissions are calculated by a Tier 2 approach using country-specific emission factors. For CH<sub>4</sub> 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<sub>2</sub>O 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

As a sub-model of the Swiss energy model (see chp. 3.2.4.3), the industry model disaggregates, for each fuel type, the total fuel consumption in the industry sector provided by the Swiss overall energy statistics (SFOE 2024, see also description in chp. 3.2.4.3) into the source categories and processes under 1A2 Manufacturing industries and construction. As visualized in Figure 3-22, the industry model is based on two pillars. First, the energy consumption statistics in the industry and services sectors (SFOE 2024d) provide a comprehensive annual survey of fuel consumptions for all years since 1999 or 2002

(depending on the fuel type, see paragraph “Energy consumption statistics in the industry and services sectors” below). These statistics are consistently extended back to 1990 based on a bottom-up industry model (Prognos 2013, see paragraph “Modelling of industry categories” below). Second, further disaggregation is achieved by using plant-level industry data for specific processes, as far as available (see paragraph “Bottom-up industry data” below).

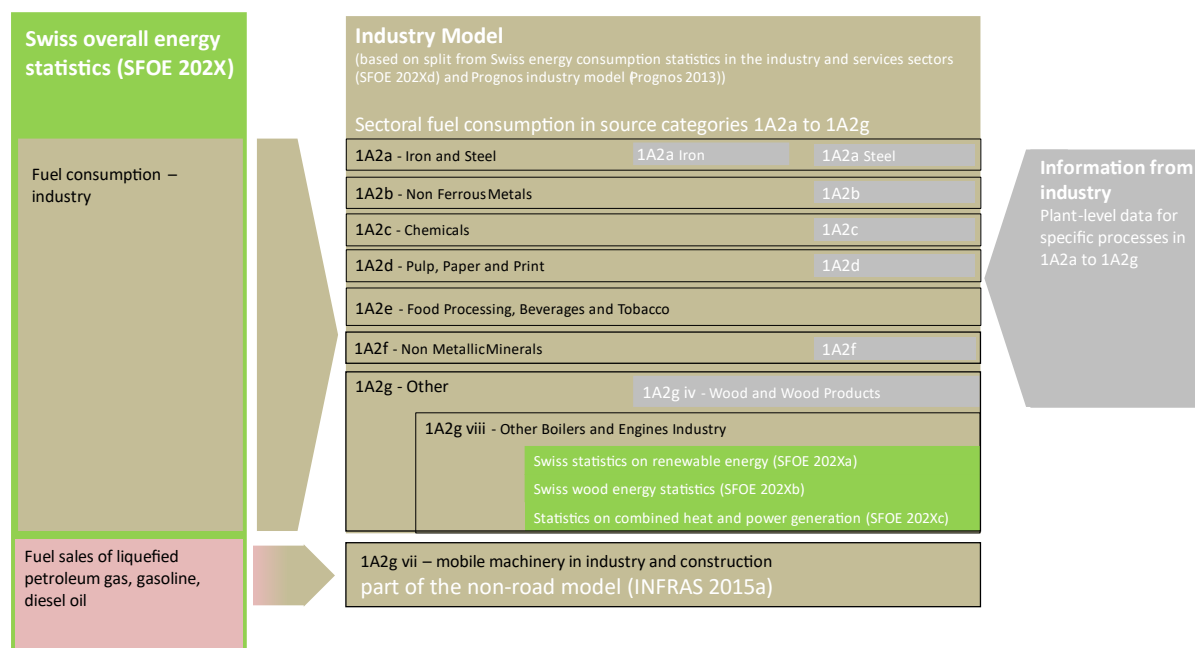


Figure 3-22 Schematic presentation of the data sources used for the industrial sectors 1A2a–1A2g. The references SFOE 202X, 202Xa, 202Xb and 202Xc refer to the 2024 edition of the corresponding energy statistics. For each fuel type, the Swiss overall energy statistics provide the total fuel consumption in the industry sector (SFOE 2024). The total fuel consumption is then distributed to the different source categories based on the energy consumption statistics in the industry and services sectors (SFOE 2024d) for all years since 1999 or 2002 (depending on the fuel type), consistently extended back to 1990 based on a bottom-up industry model (Prognos 2013). The grey boxes on the right show the further disaggregation achieved by using plant-level industry data for specific processes.

### *Energy consumption statistics in the industry and services sectors*

The energy consumption statistics in the industry and services sectors (SFOE 2024d) refer to representative annual surveys with about 13'000 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 represent a census covering all fuel consumed. The surveys 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 coal and lignite) data are available since 2002.

In 2015, a change in the survey method of the energy consumption statistics in the industry and services sectors was implemented (SFOE 2015d). 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 showed that the energy consumption in the source categories of 1A2 stationary are modified by less than one 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 solely consists 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 previous (1990–2012) and latest (since 2013) survey method are considered consistent.

#### *Modelling of industry categories*

As mentioned above, the energy consumption statistics in the industry and services sectors (SFOE 2024d) are available since 1999 or 2002. In order to get consistent time series starting in 1990, a bottom-up industry model (Prognos 2013) is used. 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 by multiplication of the process activity data with the process-specific fuel consumption factor.

The model 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 (i.e. surveys and model) 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 2019 Refinement to the 2006 IPCC Guidelines (IPCC 2019, Volume 1, chp. 5.3.3.1, overlap). To illustrate the approach, an example for gas oil attributed to source category 1A2c is provided in Figure 3-23. 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 2025/1A2 Sektorgliederung Industrie).

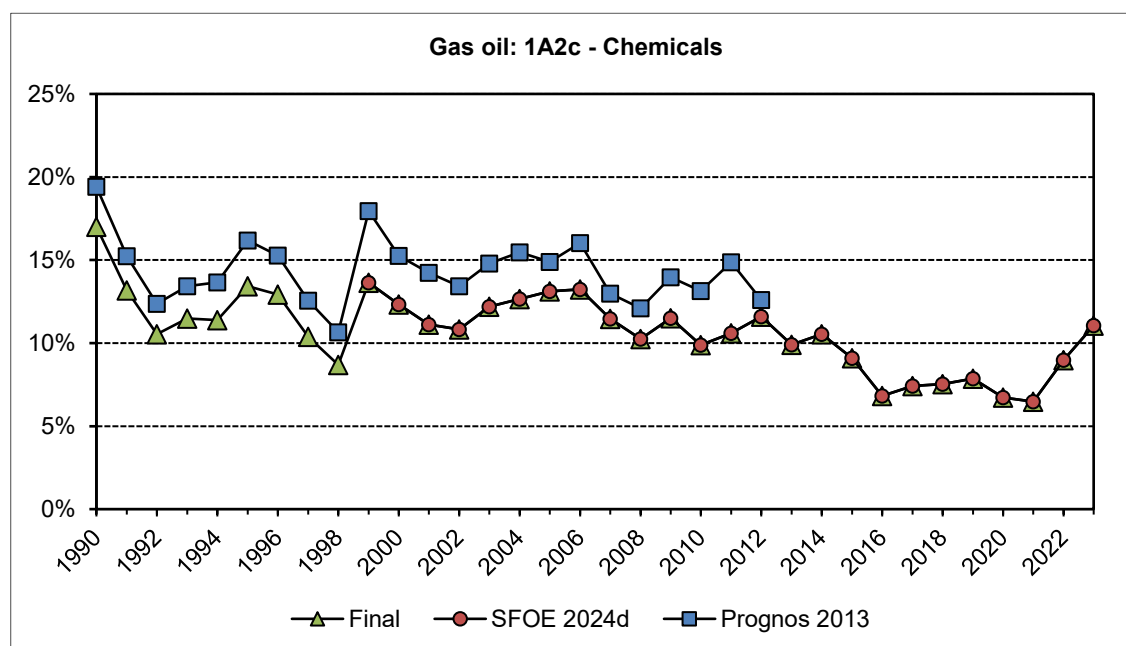


Figure 3-23 Illustrative example for combining time series with consistent overlap according to the 2019 Refinement (IPCC 2019, Volume 1, chp. 5.3.3.1, overlap). The y-axis indicates the share of source category 1A2c in total gas oil consumption in the industry sector. The green triangles correspond to the share finally used to calculate the fuel consumption in 1A2c, based on the combination of the shares from the energy consumption statistics in the industry and services sectors (SFOE 2024d, orange dots, since 1999) and the bottom-up industry model (Prognos 2013, blue squares, from 1990 to 2012). Similar calculations are performed for each source category and fuel type.

### Bottom-up industry data

Grey coloured boxes in Figure 3-22 represent source categories (i.e. 1A2a–d, 1A2f and 1A2g) for which bottom-up data from the industry are used in order to further 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<sub>2</sub> 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 assigned based on the energy consumption statistics in the industry and services sectors (SFOE 2024d) and the bottom-up industry model (Prognos 2013).

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

The share of fuel used for co-generation in turbines and engines within 1A2 is derived from a model of stationary engines developed by INFRAS 2022a (chp. 3.2.4.5.2) for the statistics on combined heat and power generation (SFOE 2024c).

Fuel consumption of wood, wood waste and biogas in manufacturing industries is based on the Swiss wood energy statistics (SFOE 2024b) as well as on data from the Swiss renewable energy statistics (SFOE 2024a) and the statistics on combined heat and power generation in Switzerland (SFOE 2024c), 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 industries and construction (see also chp. 3.2.4.4).

Table 3-55 Emission factors for 1A2 Manufacturing industries and construction in 2023. Values that are highlighted in green are described in more detail in chp. 3.2.4.4.

1A2 Emission factors for GHG (mix of bottom-up and top-down approach (modelling); without source category 1A2gvii Off-road vehicles and machinery)	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O
	t/TJ	t/TJ	kg/TJ	kg/TJ
Gas oil	73.7		<3 (lower IEF than default emission factor)	0.6
Residual fuel oil	77.0		<3 (lower IEF than default emission factor)	0.6
Liquefied petroleum gas	65.5		<1 (lower IEF than default emission factor)	0.1
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	55.9		<1 (lower IEF than default emission factor)	0.1
Other fossil fuels (including solvents, plastics, waste tyres and rubber (see 1A2c and 1A2f))	77.0		4.3	3.4
Biomass (wood, biogas and other biogenic waste)		97.9	2.4	4.0

Other fossil fuels comprise various fossil waste-derived fuels used in 1A2f Cement production as well as cracker by-products, i.e. gasolio, heating gas and synthesis gas used for steam production in a chemical plant in source category 1A2c. The emission factors of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are implied emission factors based on the fossil waste fuel mix. In addition, the CH<sub>4</sub> emission factor includes the total CH<sub>4</sub> emissions of the cement industry based on direct exhaust measurements at the chimneys of the cement plants (see documentation in EMIS 2025/1A2f Zementwerke\_Feuerung), based on industry data and emission declarations according to the Ordinance on Air Pollution Control (Swiss Confederation 1985). Implied CH<sub>4</sub> emission factors of source category 1A2 for residual fuel



oil, petroleum coke, other bituminous coal and lignite are lower than the default emission factors of source category 1A documented in chp. 3.2.4.4.3 (see detailed description below in chapter Cement (1A2f)).

The emission factors of the precursor gases NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> for all fuels in source category 1A2 are provided in Switzerland's Informative Inventory Report (FOEN 2025b, chp. 3.2.3.2.1). The emission factors for NO<sub>x</sub> and CO for natural gas and gas oil used in boilers were derived from a large number of air pollution control measurements of combustion installations (Leupro 2012, Zotter and Nussbaumer 2025). In both studies, large datasets from various cantons in Switzerland were analysed, collected between 2000 and 2011 and between 2020 and 2024, respectively. The emission factors for NO<sub>x</sub> 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<sub>x</sub> decreased significantly over the reporting period. NMVOC and SO<sub>2</sub> emission factors are country-specific and documented in SAEFL (2000).

In contrast to combustion in boilers, emission factors of precursors 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)

Table 3-56 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 over the reporting period. Since 1990, the use of residual fuel oil and other bituminous coal has decreased strongly. In the same period, natural gas consumption has about doubled, but a larger decrease of consumption was observed since 2022 (related to high gas prices due to the war in Ukraine). Currently, natural gas consumption accounts for the largest share of fuels used within Swiss industry, followed by biomass and gas oil.

Currently, source category 1A2gviii Other comprising emissions from boilers and engines and 1A2f Non-metallic minerals are the two largest fuel consumers within source category 1A2 Manufacturing Industries and construction. 1A2e Food processing, beverages and tobacco and 1A2c Chemicals are the third and fourth largest fuel consumers, respectively.



Table 3-56 Activity data for fuel consumption in 1A2 Manufacturing industries and construction.

1A2 Manufacturing industries and constr. (stationary sources)	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	88'850	89'257	87'412	90'689	89'353
Gas oil	TJ	22'910	24'471	25'892	25'317	21'137
Residual fuel oil	TJ	18'870	13'678	5'675	4'613	2'036
Liquefied petroleum gas	TJ	4'351	4'404	5'475	4'173	3'756
Petroleum coke	TJ	1'400	1'260	551	1'093	1'495
Other bituminous coal	TJ	13'476	7'303	5'866	4'799	4'348
Lignite	TJ	265	153	124	742	1'460
Natural gas	TJ	19'610	28'700	32'000	34'870	38'420
Other fossil fuels	TJ	2'469	2'718	3'812	4'138	4'625
Biomass	TJ	5'500	6'570	8'018	10'944	12'077

1A2 Manufacturing industries and constr. (stationary sources)	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	80'166	78'724	79'781	80'236	77'424	77'075	74'279	78'354	70'611	64'802
Gas oil	TJ	12'444	12'725	12'812	11'489	10'871	10'071	8'854	9'074	8'725	7'679
Residual fuel oil	TJ	231	196	155	123	34	111	76	55	NO	41
Liquefied petroleum gas	TJ	3'149	3'216	2'577	3'068	3'009	2'892	2'765	2'908	2'917	3'006
Petroleum coke	TJ	1'240	795	890	763	781	777	700	604	731	763
Other bituminous coal	TJ	2'403	1'946	1'517	1'634	1'665	1'481	1'186	1'184	1'364	1'070
Lignite	TJ	3'102	3'060	3'078	2'876	2'520	2'262	2'410	2'442	2'466	1'945
Natural gas	TJ	40'310	39'450	39'960	41'000	39'320	39'560	38'180	39'700	33'120	29'840
Other fossil fuels	TJ	4'558	4'566	5'178	5'085	5'608	5'759	5'815	5'806	5'665	5'304
Biomass	TJ	12'729	12'772	13'613	14'198	13'616	14'162	14'294	16'582	15'622	15'154

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 2025/1A2a-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<sub>2</sub> 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 2024). Additionally, also limestone is used as flux in cupola furnaces yielding geogenic CO<sub>2</sub> 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. 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 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. Up to 2022, the steel production remained about constant. In 2009, the production was considerably lower due to the financial crisis. Due to the economic situation, including the strong rise in electricity prices because of the war in Ukraine, production fell sharply from 2022 to 2023. 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 are used.

Table 3-57 Activity data fuel consumption in 1A2a Iron and steel.

1A2a Iron and steel	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	3'581	2'745	3'590	3'662	4'110
Gas oil	TJ	480	262	338	401	315
Residual fuel oil	TJ	346	131	20	39	51
Liquefied petroleum gas	TJ	408	193	286	217	219
Petroleum coke	TJ	85	46	56	72	47
Other bituminous coal	TJ	606	406	439	346	346
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	1'656	1'707	2'451	2'586	3'132

1A2a Iron and steel	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	4'014	4'294	4'177	4'630	4'776	4'440	4'447	4'389	4'141	3'576
Gas oil	TJ	86	136	134	123	127	97	81	80	57	58
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	388	392.8	327	368	358	342	327	342	342	352
Petroleum coke	TJ	81	69	78	77	71	57	43	NO	NO	NO
Other bituminous coal	TJ	325	313	303	321	319	307	285	258	209	183
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	3'135	3'383	3'335	3'742	3'902	3'637	3'710	3'709	3'533	2'983

### 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. The last primary aluminium 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 foundry 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. Fuels consumed in 2023 are mainly natural gas as well as gas oil and small amounts of 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 3-58 Activity data fuel consumption in 1A2b Non-ferrous metals.

1A2b Non-ferrous metals	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	2'392	1'980	1'566	980	1'221
Gas oil	TJ	587	347	236	125	112
Residual fuel oil	TJ	NO	NO	NO	NO	0.024
Liquefied petroleum gas	TJ	27	17	15	7.1	7.7
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	1'779	1'616	1'315	848	1'101

1A2b Non-ferrous metals	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	1'921	1'796	1'686	1'643	1'749	1'966	1'816	2'019	1'840	1'659
Gas oil	TJ	90	78	76	78	55	61	49	66	70	67
Residual fuel oil	TJ	NO	44	NO	3.7	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	10	9.9	8.3	9.3	9.0	8.6	8.3	8.6	8.6	8.9
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	1'821	1'664	1'602	1'552	1'686	1'897	1'758	1'945	1'762	1'583

#### 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, niacin, 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. In 2018 the cracker process and the subsequent integrated production chain were modified yielding synthesis gas as additional cracker by-product. For reasons of confidentiality, fuel consumption and emissions of these by-products are included in Other fossil fuels of 1A2f in the reporting tables. The CO<sub>2</sub> emission factors of gasolio, heating gas and synthesis gas are plant specific based on monitoring reports of the Swiss ETS. In 2017 the fuel quality of gasolio and heating gas have been re-analysed by the production plant yielding new net calorific values and CO<sub>2</sub> emission factors. Due to changes in the cracker operation the composition of the heating gas has changed considerably. The further process modification in 2018 resulted again in changes of both net calorific value and CO<sub>2</sub> emission factor mainly for heating gas.

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 (IPCC 2006) are assumed for CH<sub>4</sub> and N<sub>2</sub>O (see Table 3-15 and Table 3-17). For synthesis gas the same default IPCC emission factor as of natural gas is assumed for N<sub>2</sub>O (IPCC 2006). Whereas no CH<sub>4</sub> emissions are supposed from the combustion of synthesis gas.

Table 3-59 Emission factors for 1A2c Chemicals are documented in the confidential NID, which is available to reviewers on request.

The fuels consumed in 2023 include mainly natural gas as well as minor amounts of gas oil and other fossil fuels (cracker by-products). Fuel consumption in this source category has decreased by more than 40 % between 1990 and 2023. Consumption of gas oil and residual fuel oil has decreased or been stopped in that period, while natural gas consumption has increased until 2016 and is decreasing since then.

Table 3-60 Activity data fuel consumption in 1A2c Chemicals.

1A2c Chemicals	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	14'511	15'236	13'544	15'515	11'836
Gas oil	TJ	3'942	3'313	3'215	3'345	2'103
Residual fuel oil	TJ	1'434	693	252	36	66
Liquefied petroleum gas	TJ	15	13	12	10	7.5
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	9'119	11'217	10'065	12'124	9'660
Other fossil fuels	TJ	IE	IE	IE	IE	IE

1A2c Chemicals	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	12'155	12'551	14'401	13'834	13'312	11'834	10'956	10'733	9'202	8'035
Gas oil	TJ	1'321	1'167	881	860	825	799	602	593	790	858
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	8.9	9.0	7.5	8.4	8.2	7.9	7.5	7.9	7.9	8.1
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	10'825	11'375	13'512	12'966	12'479	11'026	10'346	10'132	8'405	7'168
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 ten 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. From 1992 to 2015 natural gas was also used in gas turbines (chp. 3.2.4.5.2, Table 3-26). In this source category only biomass (biogenic waste) from cellulose production (until 2008) is included, based on data from the only production site. The emissions were calculated using a country-specific CO<sub>2</sub> emission factor (EMIS 2025/1A2d Zellulose-Produktion) and default factors for CH<sub>4</sub> and N<sub>2</sub>O (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 statistical data exists to allocate biomass consumption to the specific industry sectors within 1A2 as explained in chp. 3.2.4.5.3. Therefore, from 2009 onwards, emissions from biomass are reported as "IE" in CRT 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 2023 are mainly natural gas as well as gas oil and small amounts of liquefied petroleum gas.

Table 3-61 Activity data of fuel consumption in 1A2d Pulp, paper and print.

1A2d Pulp, paper and print	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	11'786	13'752	11'610	11'397	6'786
Gas oil	TJ	1'188	1'751	1'403	1'456	852
Residual fuel oil	TJ	5'250	3'061	1'417	2'092	279
Liquefied petroleum gas	TJ	86	141	148	100	61
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	3'177	7'441	6'949	5'696	5'594
Biomass	TJ	2'085	1'358	1'694	2'053	NO

1A2d Pulp, paper and print	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	4'654	3'663	2'988	2'857	2'077	2'155	2'071	2'268	1'950	1'676
Gas oil	TJ	297	383	410	288	293	345	284	247	363	260
Residual fuel oil	TJ	22	19	9.0	8.8	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	60	60	50	57	55	53	50	53	53	54
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	4'275	3'200	2'518	2'504	1'729	1'757	1'737	1'968	1'534	1'362
Biomass	TJ	IE	IE	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 2024d) and Prognos (2013). Biomass (e.g. wood and wood waste) used in 1A2e Food processing, beverages and tobacco is reported in source category 1A2gviii, because no statistical data exists to allocate biomass consumption to the specific industry sectors within 1A2 as explained in chp. 3.2.4.5.2. Therefore, activity data and emissions from biomass are reported as "IE" in the CRT Table1.A(a)s2.

In 2023, the fuels used in this category were mainly natural gas as well as gas oil and small amounts of liquefied petroleum gas (Table 3-62). Overall, there was an increase in fuel consumption of approximately 30 % between 1990 and 2010. This was due to the increased production in this sector. Since 2010, the total consumption is fluctuating. The consumption of residual fuel oil ceased, and gas oil consumption has decreased, while natural gas and liquefied petroleum gas consumption has increased significantly until 2014 and are fluctuating since then. In 2022 and 2023, the consumption of natural gas decreased sharply compared to 2021.

Table 3-62 Activity data fuel consumption in 1A2e Food processing, beverages and tobacco.

1A2e Food processing, beverages and tobacco	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	9'867	8'802	10'457	10'256	13'181
Gas oil	TJ	7'410	5'511	5'515	4'070	3'778
Residual fuel oil	TJ	1'160	466	137	NO	NO
Liquefied petroleum gas	TJ	204	308	535	534	659
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	1'094	2'517	4'270	5'653	8'744
Biomass	TJ	IE	IE	IE	IE	IE

1A2e Food processing, beverages and tobacco	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	12'463	11'591	10'992	11'231	10'843	11'851	11'928	12'269	10'109	10'078
Gas oil	TJ	2'395	2'522	2'503	2'110	1'925	2'119	2'009	2'298	2'246	1'997
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	828	838	699	785	763	731	699	731	731	752
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	9'241	8'230	7'790	8'337	8'155	9'001	9'220	9'240	7'132	7'328
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 consumptions 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. Therefore, all emissions from biomass used in these processes are reported in source category 1A2f.

Between 1990 and 2023, there has been a switch in fuel consumption from other bituminous coal and residual fuel oil (ceased in 2022) to other fossil fuels, biomass, natural gas and lignite. 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 Table 3-63.



Table 3-63 Activity data fuel consumption in 1A2f Non-metallic minerals.

1A2f Non-metallic minerals	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	25'613	19'885	18'055	17'832	18'196
Gas oil	TJ	1'871	1'629	1'642	1'389	1'269
Residual fuel oil	TJ	5'382	5'578	3'649	2'420	1'519
Liquefied petroleum gas	TJ	523	498	468	324	102
Petroleum coke	TJ	550	300	480	638	1'130
Other bituminous coal	TJ	12'665	6'758	5'415	4'364	3'992
Lignite	TJ	265	153	124	737	1'348
Natural gas	TJ	1'769	1'566	1'496	1'861	2'048
Other fossil fuels	TJ	2'469	2'718	3'812	4'138	4'625
Biomass	TJ	119	685	970	1'962	2'162

1A2f Non-metallic minerals	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	17'677	16'484	16'518	16'536	16'766	16'581	16'257	16'623	16'722	15'194
Gas oil	TJ	1'204	1'098	1'020	1'118	1'078	1'054	997	995	1'059	1'027
Residual fuel oil	TJ	209	130	139	106	31	109	72	52	NO	NO
Liquefied petroleum gas	TJ	45	52	44	44	45	45	39	41	63	147
Petroleum coke	TJ	1'052	622	658	574	542	552	591	583	547	568
Other bituminous coal	TJ	1'973	1'498	1'089	1'210	1'256	1'085	767	879	1'098	852
Lignite	TJ	2'912	2'856	2'881	2'694	2'367	2'120	2'266	2'304	2'331	1'824
Natural gas	TJ	3'111	3'121	2'952	2'970	2'972	2'997	2'820	2'804	2'912	2'563
Other fossil fuels	TJ	4'558	4'566	5'178	5'085	5'608	5'759	5'815	5'806	5'665	5'304
Biomass	TJ	2'613	2'542	2'557	2'735	2'867	2'860	2'890	3'158	3'046	2'909

## Cement (1A2f)

### Methodology

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 occur by incinerating a wide variety of fuels: standard fossil fuels as well as mixed, biogenic and fossil, waste-derived fuels are used to generate the high temperatures needed for the calcination process. The fossil and biogenic shares are reflected in the activity data. Specific activity data have been created for the fossil and biogenic contributions, for each of the fuels. Equal numeric values are used for emission factors of the fossil and the biogenic fraction.

### Emission factors

The CH<sub>4</sub> emission factor includes the overall CH<sub>4</sub> emissions of the cement industry based on direct exhaust measurements at the chimneys of the cement plants. Therefore, these CH<sub>4</sub> emissions are reported under the fuel type other fossil fuels in the reporting tables.

Table 3-64 Emission factors for cement industry in 2023. Emission factors for CO<sub>2</sub> and N<sub>2</sub>O are fuel specific (see Table 3-13, Table 3-17 and Table 3-65).

Cement industry (part of 1A2f)	CO <sub>2</sub>	N <sub>2</sub> O	CH <sub>4</sub>	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
	t/TJ		g/t clinker				
Cement	fuel specific		7	775	67	280	2'600

The emission factors for CO<sub>2</sub> and N<sub>2</sub>O for standard fossil fuels are the same as used elsewhere (Table 3-13, Table 3-17). Regarding waste derived fuels, the NCVs and CO<sub>2</sub> emission factors for waste oil, solvents and residues from distillation, plastics, mix of special waste with saw dust (CSS), sewage sludge, wood waste, animal meal and saw dust are based on a study of Cemsuisse (Cemsuisse 2010a) providing measured values for the year 2010. A follow-up study of Cemsuisse (Cemsuisse 2018) provided measured values for the year 2017 for the three most relevant waste derived fuels – i.e. waste oil, solvents and

residues from distillation and plastics – as well as for mix of special waste with saw dust (CSS). Emission factors between 2010 (the year of the previous assessment) and 2017 are interpolated, while constant values are used before the first and after the last year with available data.

The values for waste tyres and rubber are taken from Hackl and Mauschwitz (2003). The biogenic fraction of waste tyres and rubber is based on an Austrian study and published by the German Ministry of Environment (UBA 2006). The emission factor of N<sub>2</sub>O is the same for all waste derived fuels and is taken from the IPCC Guidelines (IPCC 2006, vol. 2, chp. 2 table 2.3 industrial wastes).

Table 3-65 NCVs, fossil fractions as well as CO<sub>2</sub> (fossil and biogenic) and N<sub>2</sub>O emission factors of waste derived fuels (Other fossil fuels and Biomass) used in the cement industry. Where data for more than one year is available, values in between are interpolated and constant values are used before the first and after the last year with available data.

Cement industry (part of 1A2f) Waste derived fuel	Data sources	For the years		NCV	Fossil fraction	EF CO <sub>2</sub> fossil, biog.	EF N <sub>2</sub> O
				GJ/t	%	t CO <sub>2</sub> /TJ	kg N <sub>2</sub> O/TJ
Waste oil	Cemsuisse (2010a)	until	2010	32.5	100	74.4	4
	Cemsuisse (2018)	from	2017	31.0	92.7	73.2	4
Waste coke from coke filters	Cemsuisse (2001) Hackl and Mauschwitz (2003)	all		23.7	100	97	4
Mixed industrial waste	Cemsuisse, FOEN	all		18.3	100	74	4
Other fossil waste fuels	Cemsuisse, FOEN	all		20.9	100	97	4
Solvents and residues from distillation	Cemsuisse (2010a)	until	2010	23.6	99.1	74	4
	Cemsuisse (2018)	from	2017	23.5	89.7	70.7	4
Waste tyres and rubber	Hackl and Mauschwitz (2003) UBA (2006)	all		26.4	73.0	84	4
Plastics	Cemsuisse (2010a)	until	2010	25.2	72.3	84.7	4
	Cemsuisse (2018)	from	2017	23.6	76.6	84.5	4
Mix of special waste with saw dust (CSS)	Cemsuisse (2010a)	until	2010	9.2	21.5	102.4	4
	Cemsuisse (2018)	from	2017	9.1	27.0	112.2	4
Sewage sludge (dried)	Cemsuisse (2010a)	all		9.4	0	94.5	4
Wood waste	Cemsuisse (2010a)	all		16.3	0	99.9	4
Animal meal	Cemsuisse (2010a)	all		16.8	0	86.7	4
Agricultural waste / other biomass	Cemsuisse, FOEN	all		12.7	0	110.0	4

### 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 2025/1A2f Zementwerke Feuerung).

In 2023, the Swiss cement industry used about two-thirds of waste derived fuels and one-third of standard fossil fuels. Today, fossil fuels used in cement industry are mainly lignite, plastics, solvents and residues from distillation, waste oil, other bituminous coal and petroleum coke. Biogenic wastes contain mainly wood waste, sewage sludge and (bio)plastics. The main fossil fuel used in 1990 was other bituminous coal, but residual fuel oil, and waste oil were also of importance.

Fuel consumption in cement plants has decreased between 1990 and 2023. 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 standard fossil fuels to the above-mentioned mix of fuels.

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



Table 3-66 Activity data: Overview on fuel use in cement industry (part of 1A2f). The waste derived fuel is split into Other fossil fuels and Biomass.

<b>Cement industry (part of 1A2f)</b>	<b>Unit</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>
Total fuel consumption	TJ	17'194	12'774	11'017	11'623	12'388
Fossil fuels without waste	TJ	15'319	9'993	7'332	6'208	6'278
Gas oil	TJ	NO	NO	NO	72	5.4
Residual fuel oil	TJ	1'907	2'825	1'530	637	112
Petroleum coke	TJ	550	300	480	638	1'130
Other bituminous coal	TJ	12'235	6'547	5'176	4'120	3'662
Lignite	TJ	265	153	124	737	1'348
Natural gas	TJ	362	168	22	3.9	21
Waste derived fuels	TJ	1'874	2'781	3'685	5'415	6'109
Other fossil fuels	TJ	1'755	2'096	2'755	3'544	4'021
Industrial waste	TJ	NO	NO	NO	NO	NO
Mix of special waste with saw dust (CSS)	TJ	5.0	29	34	29	26
Other fossil waste fuels	TJ	NO	NO	NO	NO	45
Plastics	TJ	NO	40	413	608	905
Solvents and residues from distillation	TJ	281	180	422	967	1'178
Waste coke from coke filters	TJ	59	59	59	58	NO
Waste oil	TJ	1'170	1'485	1'520	1'411	1'253
Waste tyres	TJ	241	303	307	471	614
Biomass	TJ	119	685	930	1'871	2'088
Agricultural waste	TJ	NO	NO	NO	NO	7.3
Animal meal	TJ	NO	NO	198	856	624
Mix of special waste with saw dust (CSS)	TJ	18	106	124	105	97
Other biomass	TJ	NO	NO	NO	NO	5.7
Plastics	TJ	NO	15	158	233	347
Sewage sludge (dried)	TJ	9.4	128	333	494	477
Solvents and residues from distillation	TJ	2.5	1.6	3.8	8.8	11
Waste oil	TJ	NO	NO	NO	NO	NO
Waste tyres and rubber	TJ	89	112	114	174	227
Wood waste	TJ	NO	322	NO	NO	292

<b>Cement industry (part of 1A2f)</b>	<b>Unit</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>
Total fuel consumption	TJ	12'339	11'348	11'583	11'476	11'524	11'416	11'248	11'609	11'606	10'485
Fossil fuels without waste	TJ	5'847	4'917	4'544	4'354	4'015	3'673	3'500	3'617	3'833	3'149
Gas oil	TJ	75	87	50	56	63	43	54	61	93	81
Residual fuel oil	TJ	58	45	90	59	NO	63	35	52	NO	NO
Petroleum coke	TJ	1'052	622	658	574	542	552	591	583	547	568
Other bituminous coal	TJ	1'713	1'267	826	938	987	831	528	587	780	605
Lignite	TJ	2'912	2'856	2'881	2'694	2'367	2'120	2'266	2'304	2'331	1'824
Natural gas	TJ	37	41	39	34	56	65	26	28	82	71
Waste derived fuels	TJ	6'492	6'431	7'039	7'122	7'509	7'743	7'748	7'992	7'773	7'336
Other fossil fuels	TJ	3'884	3'895	4'486	4'393	4'645	4'885	4'861	4'834	4'727	4'427
Industrial waste	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Mix of special waste with saw dust (CSS)	TJ	25	20	26	21	20	16	0.043	0.58	0.674	0.42
Other fossil waste fuels	TJ	19	12	11	5.7	5.4	NO	NO	12.8	NO	NO
Plastics	TJ	1'016	887	890	1'071	1'319	1'246	1'558	1'688	1'692	1'704
Solvents and residues from distillation	TJ	1'193	1'194	1'397	1'254	1'238	1'456	1'155	1'107	1'265	1'121
Waste coke from coke filters	TJ	NO	NO	NO	66	61	48	52	48	30	24
Waste oil	TJ	884	1'083	1'469	1'215	1'239	1'359	1'353	1'253	1'009	973
Waste tyres	TJ	746	699	694	760	763	760	743	726	730	605
Biomass	TJ	2'608	2'536	2'553	2'729	2'864	2'858	2'887	3'158	3'046	2'909
Agricultural waste	TJ	NO	NO	NO	9.2	NO	NO	NO	NO	NO	NO
Animal meal	TJ	457	412	409	470	522	475	441	454	317	246
Mix of special waste with saw dust (CSS)	TJ	78	60	72	57	53	43	0.12	1.58	1.82	1.1
Other biomass	TJ	21	42	7.9	5.6	5.4	30.7	35.6	147	175	197
Plastics	TJ	343	290	281	327	403	381	476	516	517	520
Sewage sludge (dried)	TJ	428	420	479	499	519	512	553	572	578	526
Solvents and residues from distillation	TJ	80	98	137	144	142	167	133	127	145	129
Waste oil	TJ	39	60	98	96	98	107	107	99	79	77
Waste tyres and rubber	TJ	276	259	257	281	282	281	275	269	270	224
Wood waste	TJ	886	896	811	840	840	861	867	973	962	989

## Lime (1A2f)

In Switzerland there is only one plant producing lime. Fossil fuels are used for the burning process (calcination) of limestone. From 1990 to 1993, other bituminous coal was the primary fuel. Between 1994 and 2012, bituminous coal was replaced by residual fuel oil. In 2013, the main kiln has been switched to natural gas.

## Container glass (1A2f)

Today, there exists only one production plant for container glass in Switzerland. Fuel consumption has drastically decreased over the reporting period due to a reduction in

production. Until 2003, only residual fuel oil was used. From 2004 onwards, the share of natural gas has increased, reaching a stable share between 2006 and 2012. In autumn 2013, the plant has switched its glass kiln completely to natural gas.

### **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)**

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.

### **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.

Until 2001, the fuel mix consisted of natural gas and gas oil. Since then, gas oil consumption decreased continuously, so that from 2010 onwards (with exception in 2021), only natural gas is consumed. 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 increased considerably between 1990 and 2001. This results in a lower reduction of fuel consumption compared to the reduction in production between 1990 and 2023.

### **Brick and tile (1A2f)**

In Switzerland there are currently about 15 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<sub>2</sub> emission factors for wood and animal grease are based on a study of Cemsuisse (Cemsuisse 2010a), see Table 3-65, 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 2025/1A2f Ziegeleien).

For CH<sub>4</sub> and N<sub>2</sub>O, 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<sub>4</sub> emission factor according to the energy model for wood combustion (automatic chip boiler >500 kW, w/o wood processing companies), see chp. 3.2.4.5.3, and the default N<sub>2</sub>O emission factor from IPCC 2006 are used.

### **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 2023 are almost exclusively natural gas as well as small amounts of liquefied petroleum gas and gas oil. Apart from a production recovery in the years around 2004, the production has gradually decreased from 1990 to 2023, 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 were used from 2000 onwards and reported up to 2017, 2012 and 2020, respectively.

### **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 are gas oil and increasingly also natural gas.

## **3.2.6.2.8. Other (1A2g stationary)**

### **Methodology (1A2g stationary)**

Source category 1A2giv Wood and wood products includes fuel consumption of fibreboard production. Fibreboards were produced in two companies in Switzerland until 2019, where thermal energy is used for heating and drying processes. Since 2020 only one plant is left.

Source category 1A2gviii Other covers fossil fuel combustion in boilers not further specified in manufacturing industries and construction, as well as combustion of wood and wood waste in all manufacturing industries. Methodologically, the fossil fuel consumption in boilers of 1A2gviii represents the residual entities of the industry installations that could not be allocated to any other source categories in 1A2a–f.

The use of fossil fuels and biogas in engines and gas turbines is described in the specific model description in chp. 3.2.4.5.2.

This source category accounts for nearly 40 % of the overall fuel consumption in 2023 of 1A2 Manufacturing industries and construction (stationary).

### **Emission factors (1A2g stationary)**

The CO<sub>2</sub> emission factors for wood waste and animal grease in 1A2giv Wood and wood products are based on a study by Cemsuisse (2010a), see Table 3-65. For wood waste, the

respective CH<sub>4</sub> and N<sub>2</sub>O emission factors of the energy model for wood combustion, see chp. 3.2.4.5.2, and IPCC 2006, respectively, are taken, whereas for animal grease, the default values of IPCC 2006 for other liquid biofuels are used.

### Activity data (1A2g stationary)

#### 1A2giv Wood and wood products

In source category 1A2giv Wood and wood products, mainly wood waste as well as natural gas are used (Table 3-67). Since 1990, the production of fibreboard and thus the fuel consumption have increased significantly. The fuel mix has strongly shifted from fossil fuels to biomass (wood waste) between 1990 and 2023. 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 2025/1A2giv).

#### 1A2gviii Other Boilers and Engines Industry

Activity data for wood combustion is based on Swiss wood energy statistics (SFOE 2024b) whereas biogas consumption in engines and gas turbines at industrial and commercial biogas plants is based on the model of stationary engines and gas turbines (INFRAS 2022a, chp. 3.2.4.5.2) and data from the Swiss renewable energy statistics (SFOE 2024a). Further information on wood energy consumption is provided in chp. 3.2.4.5.3.

Since 1990, the consumption of residual fuel oil (halted in 2022) and liquefied petroleum gas has decreased, and since 2005 also that of gas oil. Solid fossil fuel consumption remained quite stable with fluctuations, whereas biomass and natural gas consumption increased significantly.

Table 3-67 Activity data fuel consumption in 1A2giv Wood and wood products and 1A2gviii Other (stationary).

1A2giv: Wood and wood products, 1A2gviii: Other (stationary)	Unit	1990	1995	2000	2005	2010						
Total fuel consumption	TJ	21'100	26'857	28'589	31'047	34'023						
Gas oil	TJ	7'431	11'657	13'542	14'531	12'707						
Residual fuel oil	TJ	5'298	3'749	199	26	122						
Liquefied petroleum gas	TJ	3'088	3'234	4'011	2'981	2'699						
Petroleum coke	TJ	765	914	15	383	318						
Other bituminous coal	TJ	205	140	12	88	11						
Lignite	TJ	NO	NO	NO	4.7	111						
Natural gas	TJ	1'018	2'637	5'456	6'102	8'140						
Other fossil fuels	TJ	NO	NO	NO	NO	NO						
Biomass	TJ	3'296	4'527	5'354	6'930	9'915						

1A2giv: Wood and wood products, 1A2gviii: Other (stationary)	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	27'282	28'346	29'021	29'505	27'901	28'249	26'804	30'053	26'647	24'584
Gas oil	TJ	7'050	7'342	7'788	6'913	6'568	5'597	4'831	4'794	4'141	3'412
Residual fuel oil	TJ	0.33	2.8	7.9	4.3	2.2	2.4	3.7	2.8	NO	41
Liquefied petroleum gas	TJ	1'810	1'853	1'441	1'798	1'772	1'705	1'634	1'725	1'712	1'683
Petroleum coke	TJ	108	104	155	113	168	169	65	21	185	195
Other bituminous coal	TJ	105	134	125	102	91	89	133	47	57	34
Lignite	TJ	189	204	197	182	153	141	144	138	135	122
Natural gas	TJ	7'903	8'477	8'251	8'930	8'397	9'244	8'588	9'902	7'842	6'853
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	10'116	10'230	11'056	11'464	10'749	11'301	11'404	13'424	12'576	12'245

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

The uncertainty of emission estimates for source category 1A2 (stationary) is described in the general uncertainty assessment of source category 1A Fuel combustion in chp. 3.2.4.7.

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. 1.5. 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)

The following recalculations were implemented in submission 2025. Major recalculations, which contribute significantly to the total differences in GHG emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

- 1A2a–g: Recalculations in all source categories 1A2a to 1A2g due to reallocations of all fuel types in these sub-categories of 1A2 Manufacturing industries and construction in the year 2022. The reason is that during the surveys for the energy consumption statistics in the industry and services sectors for the most recent year, the reports from the previous year are reviewed again and, if necessary, adjusted retroactively. Generally, this only affects the disaggregation and not the total amount of fuels used in 1A2 Manufacturing industries and construction for that year. However, additional recalculations were introduced in the overall energy statistics with regard to the total fuel consumption in the industry sector for the following fuel types: Natural gas (2021, 2022), bituminous coal and lignite (2019–2022).
- 1A2g: Due to an assignment error of sources in the database, the use of liquefied petroleum gas in gas turbines was assigned to source category 1A1a Public electricity and heat production in the CRT of the 2024 submission. Since the Swiss statistics of energy consumption do not report the use of liquefied petroleum gas in energy production, the use of liquefied petroleum gas in gas turbines is now assigned to 1A2g Other in the CRT of the 2025 submission.
- 1A2d: The activity data of 1A2d Gas turbines (years 1992–2015, see Table 3-26) increased by a factor of 2 due to a calculation error. It will be corrected in the next submission
- 1A2f: For source category 1A2f Cement production, the quantity of waste tyres burned was updated due to a change in the underlying statistics.
- 1A2f, 1A2gviii: A typing error in the activity data (natural gas) 2022 of source category 1A2f Container glass was corrected resulting in a revised activity data 2022 of 1A2gviii Boiler, natural gas as well.
- 1A2gviii: The activity data 2022 of 1A2gviii Boiler, other bituminous coal and 1A2gviii Boiler, natural gas were revised due to corrections of a typing error in the activity data (other bituminous coal) of source category 1A2a Iron foundries, cupola furnaces and in the activity data (natural gas) of source category 1A2f Container glass.
- 1A2gviii: The Swiss statistic of energy consumption (SFOE 2024) has recalculated the amount of other bituminous coal used in industry for the years 2019–2022. This leads to recalculation in other industrial boilers of source category 1A2gviii Other.
- 1A2gviii: Activity data of automatic wood combustion installations ( $\geq 50$  kW) in source category 1A2gviii were revised for 2019–2022 due to recalculations in the Swiss wood

energy statistics (SFOE 2024b), with the largest changes occurring in 2022. In addition, a typing error in the activity data 2022 of plants for renewable waste from wood products was corrected.

- 1A2gviii: Due to new model-runs, there are small recalculations of activity data for all stationary engines and gas turbines 1990-2022.

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

No category-specific improvements are planned.

### 3.2.7. Source category 1A4 – Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

#### 3.2.7.1. Source category description for 1A4 Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

Table 3-68 Key categories of 1A4 Other sectors. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
1.A.4.a	Commercial/institutional; Gaseous fuels	CO <sub>2</sub>	L1, T1
1.A.4.a	Commercial/institutional; Liquid fuels	CO <sub>2</sub>	L1, T1
1.A.4.b	Residential; Gaseous fuels	CO <sub>2</sub>	L1, L2, T1, T2
1.A.4.b	Residential; Liquid fuels	CO <sub>2</sub>	L1, T1
1.A.4.c	Agriculture/forestry/fishing; Liquid fuels	CO <sub>2</sub>	L1, T1

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<sub>2</sub> 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 1A4b. For 1A4c, however, the emissions of 1A4cii are more important than those of 1A4ci (see also chp. 3.2.10.1.)

Table 3-69 Specification of source category 1A4 Other sectors.

1A4	Source category	Specification
1A4ai	Commercial/institutional: Stationary	Stationary fuel combustion in commercial and institutional buildings as different wood combustions, boilers and engines with combined heat and power generation unit, engines and gas turbines at biogas and sewage plants, emergency generators
1A4bi	Residential: Stationary	Stationary fuel combustion in households, including different wood combustion installations, boilers and engines
1A4ci	Agriculture/Forestry/Fishing: Stationary	Stationary fuel combustion in agriculture, including different wood combustion installations, engines at biogas plants, emergency generators, heating of greenhouses and grass drying



### 3.2.7.2. Methodological issues for 1A4 Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

#### Methodology (1A4 stationary)

CO<sub>2</sub> 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 IPCC Guidelines (IPCC 2006, Volume 2 Energy, chp. 2 Stationary Combustion, Figure 2.1) for liquid, solid, gaseous fuels, biogas, wood (including bonfires), wood waste and animal grease.

A Tier 1 approach is applied with IPCC default emission factors for CH<sub>4</sub> emissions of residual fuel oil and gas oil for boilers and for N<sub>2</sub>O emissions of all fuels and technologies (IPCC 2006). CH<sub>4</sub> emissions of gas oil used in engines, gaseous fuels, biogas, wood and wood waste are calculated by a Tier 2 approach using country-specific emission factors. In 1A4ci Grass drying, also small amounts of crop residues are used as fuel; their emissions are calculated with default IPCC emission factors (IPCC 2006).

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. A considerable part (10–20 %) of the fuel consumption consists of wood and wood wastes. Source category 1A4ai also includes emissions from mobile pellet combustion installations (from 2017 onwards) that are used for temporary applications such as construction drying, events in large marquees or as emergency solutions in the event of heating failures.

The use of fossil and biogenic fuels in engines and gas turbines is described in the specific model description in chp. 3.2.4.5.2.

Emissions from 1A4ci Other sectors (stationary) – Agriculture/Forestry/Fishing originate from fuel combustion for the heating of greenhouses and grass drying, as well as from wood combustion for heating in agriculture and forestry. For grass drying, information is provided by the Swiss association of grass drying plants (VSTB). For greenhouses, information is provided by the Energy Agency of the Swiss Private Sector (EnAW).

#### Emission factors (1A4 stationary)

##### *Heat only boilers, engines and gas turbines*

The emission factors of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are described in chapters 3.2.4.4 for heat only boilers and in 3.2.4.5.2 for stationary engines and gas turbines. The emission factors of the precursor gases NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> in source category 1A4 are provided in Switzerland's Informative Inventory Report (FOEN 2025b, chp. 3.2.4.2).

##### *Charcoal use, bonfires and mobile pellet combustion installations*

Emission factors concerning CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions of charcoal use in the residential source categories (1A4bi) are taken from the IPCC Guidelines (IPCC 2006). Default emission factors according to the guidelines are also applied for CH<sub>4</sub> and N<sub>2</sub>O emissions resulting from bonfires. The CO<sub>2</sub> emission factor for bonfires is based on the value for wood combustion; see chp. 3.2.4.4. Emission factors of precursors are taken from the EMEP/EEA guidebook (2023) (Table 3.39). The mobile pellet combustion installations which are also reported in source category 1A4ai (see Table 3-70) under biomass (wood and wood waste) have the same emission factors as the category 12b, automatic pellet boilers 50–300 kW (see chp. 3.2.4.4.2 for CO<sub>2</sub>, 3.2.4.4.3 for CH<sub>4</sub>, and 3.2.4.4.4 for N<sub>2</sub>O).



Table 3-70 Emission factors for stationary combustion in 1A4ai Other sectors commercial/institutional in 2023. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A4ai Other sectors:	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	t/TJ		kg/TJ					
Gas oil (weighted average)	73.7	NA	9.8	0.64	42	6.8	0.8	7.7
Gas oil heat only boilers	73.7	NA	10	0.6	28	6	0.8	5.3
Gas oil engines	73.7	NA	1.2	2.9	819	50	0.8	137
Natural gas (weighted average)	55.9	NA	5.0	0.13	16	7.2	0.23	11
NG heat only boilers	55.9	NA	5	0.1	13	2	0.23	8.7
NG turbines	55.9	NA	5.2	0.69	53	1.6	0.23	25
NG engines	55.9	NA	5.2	0.69	72	89	0.23	54
Liquefied petroleum gas (engines)	65.5	NA	5.2	0.69	135	89	0.5	56
Biomass (weighted average)	NA	92	13	3.4	106	41	4.1	415
Biodiesel (engines)	3.9	69.4	1.2	2.9	295	50	0.30	134
Wood and wood waste (various furnaces)	NA	99.9	15	4	109	33	5.0	482
Biogas (engines and heat only boilers)	NA	55.9	5.2	0.69	98	89	0.5	130
Sewage gas (engines, gas turbines and heat only boilers)	NA	56	4.3	0.57	82	69	0.5	110

Table 3-71 Emission factors for stationary combustion in 1A4bi Other sectors residential in 2023. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A4bi Other sectors: Residential	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	t/TJ		kg/TJ					
Gas oil (weighted average)	73.7	NA	10	0.60	26	6.0	0.84	7.6
Gas oil heat only boilers	73.7	NA	10	0.6	26	6	0.84	7.6
Gas oil engines	73.7	NA	1.2	2.9	137	50	0.84	136
Natural gas (weighted average)	55.9	NA	5.0	0.10	11	4.2	0.23	10
NG heat only boilers	55.9	NA	5.0	0.1	11	4	0.23	10
NG engines	55.9	NA	5.2	0.69	71	89	0.23	54
Liquefied petroleum gas (engines)	65.5	NA	5.2	0.7	135	89	0.5	56
Other bituminous coal	92.7	NA	300	1.5	65	100	350	1'000
Biomass (weighted average)	NA	100	44	3.9	93	102	7.6	1'263
Biodiesel	3.9	69.4	1.2	2.9	407	50	0.30	132
Biogas	NA	55.9	5.2	0.69	96	89	0.50	86
Wood and wood waste (various furnaces)	NA	99.9	39	4	94	88	7.5	1183
Charcoal use	NA	112	200	1	50	600	11	4'000
Wood (bonfires)	NA	99.9	300	4	50	600	11	4'000

Table 3-72 Emission factors for stationary combustion in 1A4ci Agriculture/forestry/fishing in 2023. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A4ci Agriculture/forestry/fishing	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	t/TJ		kg/TJ					
Grass drying (fossil, biogenic) (weighted average)	63	97	2.5	1.05	79	99	89	609
Gas oil	73.7	NA	3	0.6	NA	NA	NA	NA
Residual fuel oil	NO	NA	NO	NO	NA	NA	NA	NA
Natural gas	55.9	NA	1	0.1	NA	NA	NA	NA
Biomass (crop residues, fat, wood)	NA	97	4.4	3.3	NA	NA	NA	NA
Heating of greenhouses (weighted average)	62	NA	1.7	0.3	18	2	0.44	7.5
Gas oil	73.7	NA	3	0.6	28	2	0.84	5.3
Natural gas	55.9	NA	1	0.1	13	2	0.23	8.7
Other fossil combustion (weighted average)	73.7	NA	1.2	2.9	942	50	0.84	137
Gas oil (engines)	73.7	NA	1.2	2.9	942	50	0.84	137
Natural gas (engines)	NO	NA	NO	NO	NA	NA	NA	NA
Other biomass combustion (weighted average)	NA	71	6.5	1.8	99	65	2.1	219
Biogas engines	NA	55.9	5.2	0.69	97	89	0.5	108
Wood and wood waste (various furnaces)	NA	99.9	8.9	4	101	19	5.1	434

## 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 chp. 3.2.4.3 for further information). Natural gas also includes the consumed amount of liquified natural gas (LNG) as supplied by the Swiss overall energy statistics (SFOE 2024). For other energy sources such as other bituminous

coal, activity data are provided directly by the Swiss overall energy statistics (SFOE 2024). The activity data on fuel consumption in 1A4ai Mobile pellet combustion installations used for temporary applications are based on information from the Swiss wood energy statistics publication (SFOE 2024b, chp. 1.4) and are reported in Table 3-73 under biomass (wood). However, they are not part of the wood energy statistics model. 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 2025/1A4ci Grastrocknung). The fuel consumption for the heating of greenhouses is extrapolated from the information provided by the Energy Agency of the Swiss Private Sector (EnAW) as documented in the EMIS database (EMIS 2025/1A4ci Gewächshäuser).

Table 3-73 Activity data in 1A4a Commercial/Institutional (stationary).

1A4ai Other sectors (stationary):	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	73'725	81'713	78'705	85'366	81'749
Gas oil	TJ	52'975	54'377	48'775	51'195	46'523
Gas oil heat only boilers	TJ	52'548	53'823	47'804	50'261	45'940
Gas oil engines	TJ	427	554	971	935	583
Natural gas	TJ	16'551	22'006	23'668	26'802	25'371
NG heat only boilers	TJ	16'196	20'597	21'497	24'205	23'281
NG turbines	TJ	NO	0.23	0.073	NO	0.019
NG engines	TJ	355	1'408	2'170	2'597	2'090
Liquefied petroleum gas (engines)	TJ	2.4	39	108	95	109
Biomass	TJ	4'198	5'292	6'154	7'274	9'745
Biodiesel (engines)	TJ	NO	NO	25	7.5	54
Wood and wood waste (various furnaces)	TJ	2'940	3'870	4'451	5'427	7'533
Biogas (engines and heat only boilers)	TJ	1.3	30	83	144	396
Sewage gas (engines, gas turbines and heat only boilers)	TJ	1'257	1'392	1'595	1'695	1'762

1A4ai Other sectors (stationary):	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	63'558	69'554	72'923	70'412	63'894	64'345	61'596	70'376	57'436	56'544
Gas oil	TJ	32'990	35'151	36'438	34'220	30'877	30'271	27'594	31'347	25'616	25'401
Gas oil heat only boilers	TJ	32'491	34'661	35'957	33'727	30'414	29'793	27'126	30'881	25'152	24'942
Gas oil engines	TJ	499	490	481	493	463	478	468	466	464	459
Natural gas	TJ	20'294	23'161	24'390	24'017	21'222	21'805	21'089	24'174	18'387	17'173
NG heat only boilers	TJ	18'624	21'564	22'909	22'680	20'062	20'806	20'125	23'187	17'361	16'156
NG turbines	TJ	0.027	0.029	0.252	0.23	0.24	0.23	0.21	0.20	0.20	0.19
NG engines	TJ	1'670	1'597	1'481	1'336	1'159	999	964	986	1'026	1'017
Liquefied petroleum gas (engines)	TJ	97	87	121	44	29	23	23	23	23	23
Biomass	TJ	10'177	11'156	11'973	12'131	11'765	12'245	12'890	14'832	13'410	13'947
Biodiesel (engines)	TJ	48	46	47	43	43	35	34	34	34	33
Wood and wood waste (various furnaces)	TJ	7'720	8'702	9'516	9'642	9'258	9'763	10'367	12'320	10'833	11'365
Biogas (engines and heat only boilers)	TJ	703	740	783	810	821	816	841	824	937	951
Sewage gas (engines, gas turbines and heat only boilers)	TJ	1'706	1'667	1'628	1'636	1'643	1'631	1'648	1'654	1'606	1'598

Table 3-74 Activity data in 1A4b Residential (stationary).

1A4bi Other sectors (stationary): Residential	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	185'560	189'596	170'753	186'290	182'296
Gas oil	TJ	136'887	133'548	116'295	124'024	111'731
Gas oil heat only boilers	TJ	136'882	133'529	116'231	123'964	111'712
Gas oil engines	TJ	4.87	19.0	64	60	20
Natural gas	TJ	26'115	34'391	36'511	42'843	48'427
NG heat only boilers	TJ	26'075	34'234	36'270	42'555	48'195
NG engines	TJ	39	156	241	288	232
Liquefied petroleum gas (engines)	TJ	0.26	4	11	11	12
Other bituminous coal	TJ	630	460	130	400	400
Biomass	TJ	21'928	21'193	17'805	19'013	21'726
Biodiesel	TJ	NO	NO	NO	0.72	3.4
Biogas	TJ	NO	NO	NO	NO	NO
Wood and wood waste (various furnaces)	TJ	21'457	20'741	17'353	18'540	21'222
Charcoal use	TJ	311	291	292	313	344
Wood (bonfires)	TJ	160	160	160	160	160

1A4bi Other sectors (stationary): Residential	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	135'296	145'010	151'174	145'048	133'301	134'208	124'773	140'012	114'671	111'183
Gas oil	TJ	75'136	79'406	81'340	76'113	67'901	66'642	59'375	66'048	51'247	49'800
Gas oil heat only boilers	TJ	75'126	79'398	81'332	76'104	67'896	66'635	59'369	66'042	51'241	49'794
Gas oil engines	TJ	9.7	8.5	7.4	8.4	4.8	6.4	6.2	6.1	6.2	6.0
Natural gas	TJ	42'554	46'295	49'026	48'527	46'120	47'781	47'414	53'294	45'525	43'104
NG heat only boilers	TJ	42'369	46'118	48'862	48'380	45'992	47'671	47'308	53'185	45'411	42'992
NG engines	TJ	185	177	163	147	128	110	106	109	113	112
Liquefied petroleum gas (engines)	TJ	11	10	14	4.9	3.3	2.6	2.5	2.5	2.6	2.5
Other bituminous coal	TJ	200	200	200	100	100	100	100	100	50	50
Biomass	TJ	17'396	19'099	20'595	20'303	19'177	19'682	17'882	20'567	17'847	18'226
Biodiesel	TJ	3.0	2.7	2.6	2.7	2.3	2.2	2.2	2.2	2.2	2.2
Biogas	TJ	NO	NO	NO	NO	NO	NO	3.5	3.7	4.1	4.4
Wood and wood waste (various furnaces)	TJ	16'878	18'582	20'099	19'766	18'661	19'195	17'312	20'037	17'327	17'704
Charcoal use	TJ	354	354	334	374	354	325	404	364	353	356
Wood (bonfires)	TJ	160	160	160	160	160	160	160	160	160	160

Table 3-75 Activity data in 1A4ci Agriculture/forestry/fishing (stationary).

<b>1A4ci Other sectors (stationary):</b>	<b>Unit</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>
Total fuel consumption	TJ	6'387	6'110	5'804	5'531	5'656
Grass drying	TJ	1'895	1'544	1'223	994	739
Gas oil	TJ	1'156	942	746	607	451
Residual fuel oil	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	739	602	477	388	288
Biomass (crop residues, fat, wood)	TJ	NO	NO	NO	NO	NO
Heating of greenhouses	TJ	4'000	4'000	4'000	3'735	3'677
Gas oil	TJ	3'490	3'490	3'490	3'133	1'803
Natural gas	TJ	510	510	510	601	1'874
Other fossil combustion	TJ	4.86	3.41	4.57	4.46	2.12
Gas oil (engines)	TJ	2.1	2.12	2.12	2.12	2.12
Natural gas (engines)	TJ	2.7	1.29	2.45	2.34	NO
Other biomass combustion	TJ	487	563	577	797	1'239
Biogas (engines)	TJ	59	49	62	128	497
Wood and wood waste (various furnaces)	TJ	428	514	515	669	741

<b>1A4ci Other sectors (stationary):</b>	<b>Unit</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>
Total fuel consumption	TJ	4'764	4'937	5'442	5'962	5'488	5'824	5'943	6'375	5'536	5'577
Grass drying	TJ	524	431	492	610	545	684	721	630	559	495
Gas oil	TJ	104	89	86	118	116	124	148	94	99	150
Residual fuel oil	TJ	20	22	18	25	13	NO	NO	NO	NO	NO
Natural gas	TJ	264	233	279	338	296	427	435	410	347	221
Biomass (crop residues, fat, wood)	TJ	136	88	109	129	120	132	138	126	113	124
Heating of greenhouses	TJ	2'800	2'900	2'899	3'238	2'754	2'732	2'537	2'753	2'114	2'125
Gas oil	TJ	1'095	1'165	1'066	1'145	930	916	788	861	717	720
Natural gas	TJ	1'705	1'735	1'834	2'093	1'824	1'816	1'749	1'892	1'397	1'405
Other fossil combustion	TJ	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Gas oil (engines)	TJ	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Natural gas (engines)	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other biomass combustion	TJ	1'438	1'605	2'048	2'112	2'187	2'406	2'682	2'989	2'862	2'954
Biogas (engines)	TJ	928	1'041	1'192	1'272	1'403	1'612	1'762	1'909	1'946	2'003
Wood and wood waste (various furnaces)	TJ	510	564	856	840	784	795	921	1'081	916	951

### Charcoal and bonfires

Besides the main fuels, also charcoal use and bonfires are accounted for in source category 1A4bi Other sectors (Stationary) – Residential. Charcoal is only used for charcoal grills. The total charcoal consumption under 1A4bi Other sectors (Stationary) – Residential is very small compared to other fuels used for heating purposes. The activity data are the sum of Swiss charcoal production as reported under 1A1c Manufacture of solid fuels and other energy industries and net imports provided by the Swiss overall energy statistics (SFOE 2024).

As the Swiss wood energy statistics (SFOE 2024b) cover wood used for heating and energy purposes only, no figures are available on wood burnt in source category 1A4bi Bonfires. The activity data of bonfires are thus expert judgements based on a per capita consumption. Two types of bonfires are considered: (public) traditional bonfires such as on national day and (private) bonfires for barbecuing. The number of traditional bonfires has declined, as fewer communities are holding national day bonfires. With the increasing use of gas barbecues, there has also been a decrease in bonfires for barbecuing. Overall, a constant wood consumption was therefore assumed for bonfires due to the declining per capita consumption and increasing population (EMIS 2025/1A4bi Lagerfeuer).

### **3.2.7.3. Uncertainties and time-series consistency for 1A4 Stationary combustion in other sectors (commercial, residential, agriculture and forestry)**

The uncertainty of emission estimates for source category 1A4 (stationary) is described in the general uncertainty assessment of source category 1A Fuel combustion in chp. 3.2.4.7.

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 combustion in other sectors (commercial, residential, agriculture and forestry)**

The general QA/QC procedures are described in chp. 1.5. 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 combustion in other sectors (commercial, residential, agriculture and forestry)**

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences in GHG emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

- 1A4: Activity data of automatic wood combustion installations ( $\geq 50$  kW) in source categories 1A4ai, 1A4bi and 1A4ci were revised for 2019–2022 due to recalculations in the Swiss wood energy statistics (SFOE 2024b).
- 1A4: Due to new model-runs, there are small recalculations of activity data for all stationary engines and gas turbines 1990–2022 in source categories 1A4ai, 1A4bi and 1A4ci.
- 1A4ai: Activity data of mobile pellet combustion installations were revised for 2021 and 2022 due to recalculations in the Swiss wood energy statistics publication (SFOE 2024b, chp. 1.3).
- 1A4ai: The Swiss statistic of energy consumption (SFOE 2024) has newly added the amount of liquefied natural gas (LNG) used to the total amount of natural gas used for the years 2020–2022. This leads to small recalculations mainly in source categories 1A3b Road transportation, 1A4ai Commercial/institutional (stationary) and 1B2b Natural gas losses.
- 1A4bi: The CH<sub>4</sub> emission factor of source category 1A4bi Boiler residential (gas), which was missing in the previous submission, was included again for the entire time series 1990–2022.

### **3.2.7.6. Category-specific planned improvements for 1A4 Stationary combustion in other sectors (commercial, residential, agriculture and forestry)**

No category-specific improvements are planned.

### 3.2.8. Source category 1A2 – Manufacturing industries and construction (mobile 1A2gvii)

#### 3.2.8.1. Source category description for 1A2 Manufacturing industries and construction (mobile 1A2gvii)

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<sub>2</sub> emissions of 1A2 from Liquid Fuels are dominated by the stationary sources. Less than the half of the CO<sub>2</sub> emissions of Liquid Fuels from 1A2 stem from mobile sources 1A2gvii.

Table 3-76 Specification of source category 1A2 Manufacturing industries and construction (mobile).

1A2	Source category	Specification
1A2gvii	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 industries and construction (mobile 1A2gvii)

##### Methodology (1A2gvii)

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<sub>2</sub> emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO<sub>2</sub> 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). In contrast, CH<sub>4</sub> and N<sub>2</sub>O emissions from lubricant use in 2-stroke engines are reported in source category 1A2gvii, since the emission factors are based on measurements including 2-stroke engines.

##### Emission factors (1A2gvii)

- The CO<sub>2</sub> emission factors applied for the time series 1990–2023 for diesel oil, gasoline, liquefied petroleum gas and biodiesel and bioethanol are country-specific and are given in Table 3-13.
- The CH<sub>4</sub> and N<sub>2</sub>O emission factors are country-specific and are shown in Table 3-77 to Table 3-79 for diesel oil, gasoline and liquefied petroleum gas engines for all emission standards.
- For SO<sub>2</sub> from diesel oil, gasoline, gas oil and liquefied petroleum gas see Table A – 17 in Annex A5.1.4.
- 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<sub>4</sub> emissions.
- The implied emission factors for the latest reporting year are shown in Table 3-80.

All emission factors (GHG, precursors) can be downloaded by query from the online 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.

Table 3-77 Emission factors CH<sub>4</sub> and N<sub>2</sub>O for industry and construction vehicles with diesel oil engines by emission standards including the year of entry into force.

Gas	Power class	PreEU-A <1996	PreEU-B 1996	EU-I 2002/03	EU-II 2002/04	EU-III A 2006/08	EU-III B 2011/12	EU-IV 2014
	kW	g/kWh						
CH <sub>4</sub>	<18	0.0547	0.0547	0.0384	0.0240	0.0142	0.0142	0.0142
CH <sub>4</sub>	18–37	0.0578	0.0578	0.0221	0.0134	0.0089	0.0089	0.0089
CH <sub>4</sub>	37–56	0.0319	0.0319	0.0156	0.0110	0.0079	0.0055	0.0058
CH <sub>4</sub>	56–75	0.0319	0.0319	0.0156	0.0110	0.0079	0.0031	0.0031
CH <sub>4</sub>	75–130	0.0218	0.0218	0.0108	0.0084	0.0067	0.0031	0.0031
CH <sub>4</sub>	130–560	0.0218	0.0218	0.0103	0.0072	0.0053	0.0031	0.0031
CH <sub>4</sub>	>560	0.0218	0.0218	0.0103	0.0072	0.0053	0.0031	0.0031
N <sub>2</sub> O	0–3000	0.035	0.035	0.035	0.035	0.035	0.035	0.035

Table 3-78 Emission factors CH<sub>4</sub> and N<sub>2</sub>O for industry and construction vehicles with gasoline engines by emission standards including the year of enforcement.

Gas	Power class	PreEU-A <1996	PreEU-B 1996	PreEU-C 2000	EU-I 2004	EU-II 2005/09
	ccm	g/kWh				
CH <sub>4</sub>	<66	2.040	2.040	2.040	1.394	1.394
CH <sub>4</sub>	66–100	1.360	1.360	1.360	1.088	1.088
CH <sub>4</sub>	100–225	0.680	0.680	0.680	0.408	0.408
CH <sub>4</sub>	>225	0.680	0.680	0.680	0.340	0.306
N <sub>2</sub> O	0–3000	0.03	0.03	0.03	0.03	0.03

Table 3-79 Emission factors CH<sub>4</sub> and N<sub>2</sub>O for industry and construction vehicles with liquefied petroleum gas engines (for all years).

Gas	without catalyst	with catalyst
	g/kWh	
CH <sub>4</sub>	0.552	0.035
N <sub>2</sub> O	0.05	0.05

Table 3-80 Implied emission factors 2023 for industry and construction vehicles.

1A2gvii Non-road vehicles and other machinery	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	t/TJ		kg/TJ					
Gasoline	73.8	NA	32.7	1.1	88	578	0.083	19'385
Diesel oil	73.3	NA	0.42	3.3	173	18	0.30	88
Liquefied petroleum gas	65.5	NA	1.16	4.0	163	15.0	NA	41
Biodiesel	3.7	69.6	0.41	3.2	169	18	0.30	86
Bioethanol	NA	0.011	10.8	1.21	58	305	0.19	18'557



### Activity data (1A2gvii)

Activity data for non-road (1A2gvii) are described in chp. 3.2.4.5.1 (non-road transportation model). Values are taken from FOEN (2015j). Data on biofuels are provided by the statistics of renewable energies (SFOE 2015a). Activity data are shown in Table 3-81 and in Annex A5.1.3. Detailed data can be downloaded from the non-road database (INFRAS 2015a). Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can also be downloaded by query from the online 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.

Table 3-81 Activity data for industry and construction vehicles.

1A2gvii Non-road vehicles and other machinery	Unit	1990	1995	2000	2005	2010						
Total fuel consumption	TJ	5'721	6'852	7'636	8'169	8'779						
Gasoline	TJ	196	224	227	225	220						
Diesel oil	TJ	5'359	6'380	7'108	7'630	8'259						
Liquefied petroleum gas	TJ	165	248	294	290	269						
Biodiesel	TJ	NO	NO	8.0	24	31						
Bioethanol	TJ	NO	NO	NO	NO	0.0029						

1A2gvii Non-road vehicles and other machinery	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	8'906	8'938	8'945	8'951	8'958	8'964	8'971	8'974	8'977	8'981
Gasoline	TJ	191	184	181	179	176	173	171	170	169	169
Diesel oil	TJ	8'384	8'416	8'368	8'321	8'273	8'226	8'178	8'225	8'273	8'320
Liquefied petroleum gas	TJ	235	226	215	203	192	180	168	142	115	88
Biodiesel	TJ	95	111	179	247	315	383	451	434	418	401
Bioethanol	TJ	0.64	0.80	1.1	1.4	1.7	1.9	2.2	2.5	2.7	2.9

### 3.2.8.3. Uncertainties and time-series consistency for 1A2gvii (mobile)

The uncertainty of emission estimates for source category 1A2gvii (mobile) is described in the general uncertainty assessment of source category 1A Fuel combustion in chp. 3.2.4.7. Uncertainties by fuel type are given in Table 3-38.

### 3.2.8.4. Category-specific QA/QC and verification for 1A2gvii (mobile)

The general QA/QC procedures are described in chp. 1.5. Furthermore, QA/QC procedures conducted for all 1A source categories are listed in chp. 3.2.4.8.

### 3.2.8.5. Category-specific recalculations for 1A2gvii (mobile)

The following recalculations were implemented in submission 2025.

- 1A2gvii: The fossil carbon fraction in biodiesel is now estimated based on the method described in Sebos (2022). The fossil fraction of FAME (Fatty Acid Methyl Ester) is based on the values from HBEFA 4.1 (INFRAS 2019a; averages for the whole EU), while all carbon in HVO (Hydrotreated Vegetable Oil) is considered of biogenic origin. Because biodiesel as reported by Switzerland consists of the sum of FAME and HVO, the fossil fraction of biodiesel varies over time. Overall, around 4.0 to 5.4 % of the total biodiesel are now reported under “fossil liquid fuels” for the years 1996–2022 (no biodiesel in the years before). In consequence, this leads to recalculations in fuel categories including biodiesel as “biomass” or “biofuels” and “liquid fuels” as well.



- 1A2gvii: An update of the fuel mix and consumption from non-road machinery leads to minor recalculations in all source categories affected by the non-road model and for all the years 1990-2022.

### 3.2.8.6. Category-specific planned improvements for 1A2gvii (mobile)

No category-specific improvements are planned.

## 3.2.9. Source category 1A3 – Transport

### 3.2.9.1. Source category description for 1A3

Table 3-82 Key categories of 1A3 Transport. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
1.A.3.a	Domestic aviation; Kerosene fossil	CO <sub>2</sub>	T1
1.A.3.b	Road transportation; Diesel oil	CO <sub>2</sub>	L1, L2, T1
1.A.3.b	Road transportation; Diesel oil	N <sub>2</sub> O	T1
1.A.3.b	Road transportation; Gasoline	CO <sub>2</sub>	L1, T1
1.A.3.b	Road transportation; Gasoline	CH <sub>4</sub>	T1
1.A.3.b	Road transportation; Gasoline	N <sub>2</sub> O	T1

Table 3-83 Specification of source category 1A3 Transport.

1A3	Source category	Specification
1A3aii	Domestic aviation	LTO and Cruise; Large (jet, turboprop) and small (piston) aircrafts, helicopters
1A3bi	Road Transportation	Passenger cars
1A3bii		Light duty trucks
1A3biii		Heavy duty trucks and buses
1A3biv		Motorcycles
1A3bv		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 (Committee on Aviation Environmental Protection 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). 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 3-24.

The Tier 3A method follows standard modelling procedures at the level of single aircraft 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/take-off (LTO) cycle are calculated with aircraft category dependent flight times and corresponding power settings. Cruise emissions are calculated based on the individual aircraft type with individual engine model (since 2021) 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/EEA guidebook (EMEP/EEA 2023), Swedish Defence Research Agency (FOI), aircraft engine manufacturers and Swiss FOCA measurements (precursors). Cruise emission factors are generally derived 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<sub>2</sub>O, the IPCC default emission factor of 2 kg/TJ is used (IPCC 2006). For the methane split of unburnt hydrocarbons, the 10 % methane share for the LTO, given in IPCC 2006 is used. For cruise emissions, no methane is reported.

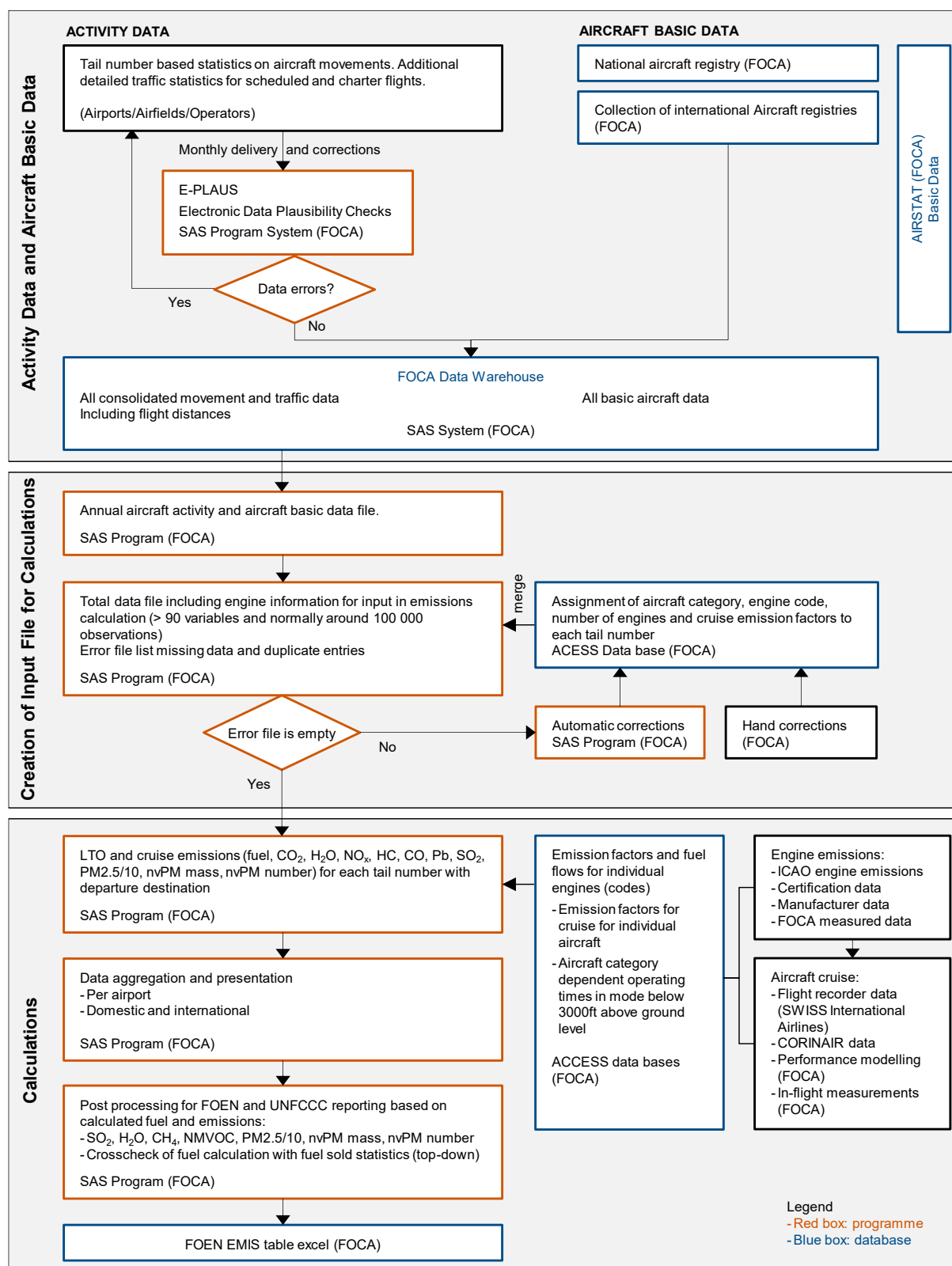


Figure 3-24 Modelling scheme (activity data, emission factors, emissions) for domestic aviation.

A complete emission modelling (LTO and cruise emissions for domestic and international flights) has been carried out by FOCA for 1990, 1995, 2000, 2002, 2004–2023. The results of the emission modelling have been transmitted from FOCA to FOEN in an aggregated form (FOCA 2006a, 2007–2024). 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 A5.1.1, more detailed descriptions of the emission modelling may be found in FOCA (2006).

## Emission factors (1A3a)

### *Landing/take-off (LTO) cycle*

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 databank. Emission factors for lower thrust engines, piston engines and helicopters were taken from manufacturers or from own measurements. Emission factors for turboprops could be obtained in collaboration with the Swedish Defence Research Agency (FOI) and engine manufacturers

### *Cruise*

The fuel flows of the whole Airbus fleet (which produces a great portion of the Swiss inventory) have been modelled based on real operational aircraft data from flight data recorders (FDR) of Swiss International Airlines. GHG emission factors have been modelled based on the ICAO engine databank and corrected to cruise conditions using FDR engine parameters. The correction of gaseous air pollutants to cruise conditions has been performed using the Boeing Fuel Flow Method 2. For older aircraft types (pre-2003), part of the cruise emission factors were taken from the EMEP/EEA guidebook (EMEP/EEA 2023) 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 databank. 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). Since then, FOCA 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.

## Gases

- CO<sub>2</sub>: the emission factor for jet kerosene is country-specific and is based on measurements and analyses of fuel samples (see Table 3-13 and Table 3-84)

- CH<sub>4</sub>, NMVOC (country-specific; CORINAIR): VOC emissions (see section “Precursors” below) of jet kerosene are split into CH<sub>4</sub> and NMVOC by a constant share of 0.1 (CH<sub>4</sub>) and 0.9 (NMVOC) for LTO. For cruise flights, the VOC emissions do not contain CH<sub>4</sub>. The implied emission factor for CH<sub>4</sub> for the latest reporting year is shown in Table 3-84.
- The N<sub>2</sub>O emission factor for jet kerosene corresponds to the default value given by the 2006 IPCC Guidelines (IPCC 2006, Table 3.6.5), see Table 3-84. 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 1990–2023.

*Precursors (further details see Switzerland's Informative Inventory Report (FOEN 2025b))*

- 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 2023: 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 A5.1.1 Table A – 9 Aircraft Engine Combinations).

FOCA determines the emission factors of different gases as given in Table 3-84.

Table 3-84 Implied emission factors of 1A3a in 2023. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3a/1D1 Civil aviation	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
	kg/TJ							
1A3a Domestic aviation								
1A3a Domestic aviation, LTO, Jet kerosene fossil	72'800	NA	14	2.0	231	129	20	3'591
1A3a Domestic aviation, CR, Jet kerosene fossil	72'800	NA	NA	2.0	252	82	22	764
1D1 International aviation (not part of national total)								
1D1 International aviation, LTO, Jet kerosene fossil	72'800	NA	2.4	2.0	332	21	23	260
1D1 International aviation, LTO, Jet kerosene biogenic	NA	72'800	2.3	2.0	349	21	23	253
1D1 International aviation, CR, Jet kerosene fossil	72'800	NA	NA	2.0	426	3.7	23	43
1D1 International aviation, CR, Jet kerosene biogenic	NA	72'800	NA	2.0	447	3.6	23	39

### 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 record 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 FOCA activity data contain both, instrument flight rules (IFR) traffic and visual flight rules (VFR) traffic. As visual flight rules traffic dominates the domestic flight activity, a complete inclusion of visual flight rules traffic is

important. 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 408'957 aircraft movements in the total of scheduled and charter traffic in 2023 (FSO 2024j). The number of aircraft movements in 2020 and 2021 was clearly lower than usual due to the COVID-19 pandemic (2020: 166'758, 2021: 191'219 movements), which also led to a strong reduction of fuel consumption from civil aviation (see Table 3-85). Since 2022, the number of aircraft movements has increased again, but is still slightly below pre-pandemic levels (e.g. 2019: 469'667).

### *Handling of small aircraft and helicopters*

- Airports and most of the airfields report individual aircraft data (aircraft registration). FOCA may therefore compute the inventory for small aircraft with a 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). 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 until 2014 based on investigations in 2004 (FOCA 2004). Since 2015, the statistics allows 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 3-85 summarises the activity data for 1A3a Civil aviation. It also includes international aviation, which belongs to the memo items, international bunkers/aviation (1D1, see also chp. 3.2.2). 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 2021 and 2020, in contrast to the years before, the modelled total fuel consumption in Switzerland was clearly higher than the fuel sold value (2021: 9.8 %), so the model showed a clear overestimation. For domestic aviation, the statistical data did not show systematic changes, which could have caused differences to the modelling of pre 2020 years. However, for international aviation, which is dominated by large and scheduled aircraft in Switzerland, FOCA investigation revealed a much lower load factor in 2020 and 2021 due

to the COVID-19 pandemic. The model fully accounts for the individual aircraft flying but calculates the fuel burn of normally loaded aircraft. In fact, many aircraft were flying lighter than usual, thus burning less fuel than usual on a given distance, which explains the 9.8 % difference observed in 2021. A small additional effect reported by a Swiss carrier were more direct routes in Europe due to the low traffic volume, especially in 2020. In 2023, this effect diminishes slightly as flight activity increased again, but there is still a 4.6% overestimation of the fuel consumption by the model. A cross comparison for the modelled difference for international aviation was done with Eurocontrol calculations for Switzerland's international flights, where the same phenomenon (overestimation by the model) was observed by Eurocontrol. For domestic flights, 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, 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.

Since 2021, sustainable aviation fuels (SAF) are included in the energy statistics and attributed to international flights. The amount is still very small compared to the amount of fossil jet fuel.



Table 3-85 Fuel consumption of civil aviation in TJ 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. Sustainable aviation fuels (SAF) are referred to as jet kerosene biogenic. (FOCA 2007, 2007a, 2008–2024).

1A3a/1D1 Civil aviation	1990	1995	2000	2005	2010
Fuel consumption in TJ					
1A3a Domestic aviation	3'450	3'075	2'541	1'702	1'694
1A3a Domestic aviation, LTO, Jet kerosene fossil	1'050	935	773	518	464
1A3a Domestic aviation, CR, Jet kerosene fossil	2'401	2'139	1'768	1'184	1'230
1D1 International aviation (not part of national total)	41'884	49'918	63'726	47'775	58'334
1D1 International aviation, LTO, Jet kerosene fossil	4'277	5'097	6'507	4'878	5'643
1D1 International aviation, LTO, Jet kerosene biogenic	NO	NO	NO	NO	NO
1D1 International aviation, CR, Jet kerosene fossil	37'608	44'821	57'219	42'896	52'691
1D1 International aviation, CR, Jet kerosene biogenic	NO	NO	NO	NO	NO
Total 1A3a/1D1 Civil aviation	45'334	52'993	66'267	49'477	60'028
1990 = 100%	100%	117%	146%	109%	132%

1A3a/1D1 Civil aviation	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Fuel consumption in TJ										
1A3a Domestic aviation	1'921	1'887	1'932	1'641	1'579	1'571	1'056	811	944	887
1A3a Domestic aviation, LTO, Jet kerosene fossil	525	387	421	384	346	321	170	183	227	236
1A3a Domestic aviation, CR, Jet kerosene fossil	1'396	1'500	1'511	1'257	1'234	1'250	886	628	717	651
1D1 International aviation (not part of national total)	65'006	67'333	70'603	72'824	77'214	78'196	28'194	31'872	57'499	68'899
1D1 International aviation, LTO, Jet kerosene fossil	6'142	6'459	6'529	6'728	6'953	6'963	2'395	2'718	5'129	5'915
1D1 International aviation, LTO, Jet kerosene biogenic	NO	NO	NO	NO	NO	NO	NO	2.0	0.029	1.44
1D1 International aviation, CR, Jet kerosene fossil	58'864	60'874	64'073	66'096	70'261	71'233	25'799	29'129	52'369	62'966
1D1 International aviation, CR, Jet kerosene biogenic	NO	NO	NO	NO	NO	NO	NO	24	0.33	17
Total Civil aviation	66'927	69'220	72'534	74'465	78'793	79'767	29'250	32'683	58'443	69'786
1990 = 100%	148%	153%	160%	164%	174%	176%	65%	72%	129%	154%

### 3.2.9.2.2. Road transportation (1A3b)

#### Methodology (1A3b)

##### Choice of method

- The CO<sub>2</sub> 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<sub>4</sub> and the N<sub>2</sub>O 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 Urea use in SCR catalysts of diesel engines (2D3d) as recommended in the reporting table's footnotes.
- CO<sub>2</sub> emissions from the use of lubricants as an additive in 2-stroke motorcycles are reported in chp. 4.5.2.1 under 2D1 Non-energy products from fuels and solvent use / lubricant use. Non-CO<sub>2</sub> emissions are reported under 1A3biv.



### *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 1A3b Road transportation and a model for non-road vehicles and machinery (mobile sources categories 1A2gvii, 1A3c, 1A3d, 1A4aii, 1A4bii, 1A4cii, 1A5b excl. military aviation). The general method of the road transportation model is described in the following paragraphs and Annex A5.1.2 (INFRAS 2017c, INFRAS 2019a, Matzer et al. 2019, Notter et al. 2022).

### *Fuel used or fuel sold approach in 1A3b Road transportation*

There are two different approaches for calculating emissions in source category 1A3b Road transportation fuel used approach and fuel sold approach. For the reporting of the national total under the UNFCCC the fuel sold approach is used. The difference of fuel consumption between the two approaches is called “fuel tourism and statistical difference” To calculate the emissions for the “fuel sold” approach, this difference in fuel consumption per fuel type is distributed proportionally across each vehicle category, whereby the activity data in GJ, driven kilometres and the number of vehicles is adjusted proportionally in each category. See also chapter 3.2.4.1 on system boundaries.

### *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, evaporative losses during operation)
  - number of starts/stops
  - vehicle stock (cold start, evaporative losses from gasoline passenger cars, light duty vehicles and motorcycles)
  - fuel consumption per vehicle category

Emissions are calculated as follows:

- Hot emissions:  $E_{hot} = VKT \cdot EF_{hot}$
- Cold start excess emissions:  $E_{start} = N_{start} \cdot EF_{start}$
- Evaporation soak VOC emissions:  $E_{evap\ s} = N_{evap\ s} \cdot EF_{evap\ s}$
- Evaporation diurnal VOC emissions:  $E_{evap\ d} = N_{evap\ d} \cdot EF_{evap\ d}$
- Evaporation running VOC losses:  $E_{evap\ RL} = VKT \cdot EF_{evap\ RL}$

with

- $EF_{hot}$ ,  $EF_{start}$ ,  $EF_{evap\ s}$ ,  $EF_{evap\ d}$ ,  $EF_{evap\ RL}$ : Emission factors for ordinary driving conditions (hot engine), cold start excess emissions, and evaporative (VOC) emissions (after stops, diurnal losses, and running losses)
- $VKT$ : Vehicle km travelled
- $N_{start}$ : Number of starts
- $N_{evap\ s}$ : Number of stops
- $N_{evap\ d}$ : Number of vehicles multiplied with the number of days in the reporting period

Emission factors are differentiated for all fuel types: Gasoline (4-stroke), gasoline (2-stroke), diesel oil, liquefied petroleum gas bioethanol, biodiesel, gas (CNG), biogas. In terms of vehicle categories, the emission factors are weighted according to the fleet composition in Switzerland (within HBEFA).

CO<sub>2</sub> 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<sub>2</sub> emissions are reported in source category 2D1 Lubricant use. In contrast, CH<sub>4</sub> and N<sub>2</sub>O emissions from lubricant use are reported in source category 1A3biv, since the emission factors are deduced from measurements on motorcycles including 2-stroke engines.

Cold start excess emissions for N<sub>2</sub>O were originally not accounted for in the model described. During the in-country review in 2016, the ERT identified a potential underestimation. Switzerland therefore estimated N<sub>2</sub>O cold start excess emissions for passenger cars and light duty vehicles by means of emission factors from the EMEP/EEA guidebook, as recommended by the ERT. The corresponding emission factors per Euro class are documented in the EMEP/EEA guidebook on p. 72 ff. (EMEP/EEA 2019).

## Emission factors (1A3b)

### CO<sub>2</sub>

- The country-specific CO<sub>2</sub> emission factors are described in chp. 3.2.4.4.2. Values are shown in Table 3-13 (gasoline, diesel oil, biofuels) and in Table 3-14 (natural gas, biogas). The values for the latest reporting year are also shown in Table 3-86.
- Emission factors for 2-stroke gasoline: For the gasoline part of the fuel, the CO<sub>2</sub> emission factor for gasoline according to Table 3-13 is applied. For the lubricant part of the fuel, the IPCC default CO<sub>2</sub> emission factor for lubricants is applied (see Table 4-36, IPCC 2006). The resulting emissions from the gasoline part are reported under 1A3biv, the emissions from the lubricant part, however, under source category 2D1 Lubricant use (see chp. 4.5.2.1).

### CH<sub>4</sub>

- Country-specific emission factors are applied. For details including data sources see below ("*Country-specific emission factors*"). Emission factors are applied based on HBEFA 4.2 (INFRAS 2022).
- For biofuels, no country-specific emission factors for CH<sub>4</sub> are available. Therefore, the same emission factors as for fossil fuels have been used (e.g. emission factor for gasoline was used for bioethanol, and emission factor for diesel oil for biodiesel).

### N<sub>2</sub>O

- N<sub>2</sub>O emissions from territorial traffic under hot operating condition: Country-specific emission factors are used, details see below (INFRAS 2022).

- Cold start N<sub>2</sub>O emission factors for gasoline, diesel oil, natural gas and liquefied petroleum gas vehicles are based on the EMEP/EEA guidebook (EMEP/EEA 2019) (see Annex A5.1.2 for details).
- For biofuels no country-specific emission factors for N<sub>2</sub>O are available. Therefore, the same emission factors as for fossil fuels have been used (e.g. emission factor for gasoline was used for bioethanol, and emission factor for diesel oil for biodiesel).

### *Country-specific emission factors*

Emission factors for gases other than CO<sub>2</sub> are derived from “emission functions” which are determined from a compilation of measurements from various European countries with programmes using similar driving cycles (legislative as well as standardized real-world cycles, like “Common Artemis Driving Cycle” (CADC)). The method was developed in 1990–1995 and has been extended and updated in 2000, 2004, 2010, 2017, 2019 and latest 2022. These emission factors are compiled in the “Handbook of Emission Factors for Road Transport” (HBEFA, see INFRAS 2022). The latest version 4.2 is presented on the website (<http://www.hbefa.net/>) and documented in Notter et al. 2022. Further descriptions can also be found in the former publications INFRAS (2017c), INFRAS (2019a) and Matzer et al. (2019). The emission factors are differentiated by so-called “traffic situations”, which represent characteristic patterns of driving behaviour determined by road type, speed limit, area type (rural/urban), traffic density, and road gradient. 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. Further details are shown in Annex A5.1.2.

### *Implied emission factors for GHG and precursors*

The following Table 3-86 presents implied emission factors for GHG and precursors for the latest reporting year in kg per TJ fuel consumption. More or less pronounced decreases of the emission factors have occurred in the last years due to new emission regulations and subsequent new exhaust technologies (optimized combustion, use of catalytic converters, particle filters, lower limits for sulphur content in diesel fuels). Early models of catalytic converters represented substantial sources of N<sub>2</sub>O, leading to an emission increase of this gas until 1998. More recent converter technologies have overcome this problem resulting in a decrease of the (mean) emission factor.

Table 3-86 Implied emission factors in 2023 for road transportation. For more details see Annex A5.1.2. The implied emission factors in the reporting tables (CRT) are slightly different because of the distribution of fuel tourism and statistical differences in the reporting tables (see chapter 3.2.9.2.2).

<b>1A3b Road Transportation Gasoline / Bioethanol</b>		<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>NMVOC</b>	<b>SO<sub>2</sub></b>	<b>CO</b>
		kg/TJ						
1A3bi	Passenger cars	73'800	3.6	0.51	31	43	0.19	539
1A3bii	Light duty vehicles	73'800	8.3	2.2	85	94	0.19	2465
1A3biii	Heavy duty vehicles	73'800	17	0.81	784	478	0.19	602
1A3biv	Motorcycles	73'800	61	1.3	65	310	0.19	1839
1A3bv	Other, gasoline	NO	NO	NO	NO	21	NO	NO

<b>1A3b Road Transportation Diesel oil / Biodiesel</b>		<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>NMVOC</b>	<b>SO<sub>2</sub></b>	<b>CO</b>
		kg/TJ						
1A3bi	Passenger cars	73'300	4.0	3.7	201	3.3	0.30	44
1A3bii	Light duty vehicles	73'300	2.4	2.9	224	1.6	0.30	49
1A3biii	Heavy duty vehicles	73'300	0.064	4.0	105	2.6	0.30	43
1A3biv	Motorcycles	NO	NO	NO	NO	NO	NO	NO
1A3bv	Other, gasoline	NO	NO	NO	NO	NO	NO	NO

<b>1A3b Road Transportation Natural gas / Biogas</b>		<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>NMVOC</b>	<b>SO<sub>2</sub></b>	<b>CO</b>
		kg/TJ						
1A3bi	Passenger cars	55'900	15	0.53	24	1.3	NA	170
1A3bii	Light duty vehicles	55'900	6.6	1.5	14	0.57	NA	1242
1A3biii	Heavy duty vehicles	55'900	17	NE	92	1.5	NA	54
1A3biv	Motorcycles	NO	NO	NO	NO	NO	NO	NO
1A3bv	Other, gasoline	NO	NO	NO	NO	NO	NO	NO

<b>1A3b Road Transportation Liquefied petroleum gas</b>		<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>NMVOC</b>	<b>SO<sub>2</sub></b>	<b>CO</b>
		kg/TJ						
1A3bi	Passenger cars	65'500	1.1	1.1	23	1.7	0.5	325
1A3bii	Light duty vehicles	NO	NO	NO	NO	NO	NO	NO
1A3biii	Heavy duty vehicles	NO	NO	NO	NO	NO	NO	NO
1A3biv	Motorcycles	NO	NO	NO	NO	NO	NO	NO
1A3bv	Other, gasoline	NO	NO	NO	NO	NO	NO	NO

## Activity data (1A3b)

### *Energy-related activity data (basis for modelling the CO<sub>2</sub> emissions)*

The Swiss overall energy statistics (SFOE 2024) provides the amount of liquid fuels (gasoline, diesel oil) and gaseous fuels (CNG) sold in Switzerland for road transportation. From the amount of liquid fuels sold, 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. Amounts of liquefied petroleum gas used for road transportation are very small and not provided in the Swiss overall energy statistics. Therefore, the liquefied petroleum gas consumption for road transportation is entirely based on the road transportation model.

The consumption of biofuels is based on the Swiss overall energy statistics (SFOE 2024), the Swiss renewable energy statistics (SFOE 2024a) and the Federal Office for Customs and Border Security (FOCBS 2024). The NCV of biogas is assumed to be equal to the NCV of natural gas since the raw biogas is treated to reach the same quality level including its energetic properties as natural gas (see NCV time series for natural gas and biogas in Table 3-11).

For biodiesel consumption, the fossil carbon fraction in biodiesel is estimated based on the method described in Sebos (2022). While all carbon in HVO (Hydrotreated Vegetable Oil) is of biogenic origin, FAME (Fatty Acid Methyl Esters) contains a fossil fraction due to the use of methanol from fossil sources in its production. The shares of FAME and HVO in biodiesel

are available from the Swiss overall energy statistics (SFOE 2024). The fossil fraction of FAME depends on the feedstock it is derived from (e.g. rapeseed, soy, palm oil); since the feedstock shares are not captured in the Swiss energy statistics, they are based on European average values from HBEFA 4.1 (INFRAS 2019a). The resulting overall fossil fraction of biodiesel varies over time – around 4.0 to 5.4 % of total biodiesel are reported under “fossil liquid fuels” as “biodiesel fossil”. For technical reasons in our database, there is a split of the whole biodiesel amount in fossil and biogenic biodiesel and not only for the carbon fraction and CO<sub>2</sub>.

Table 3-87 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 1A3b Road transportation are given as two different contributions in the rows “on road fuel consumption (model)” and “fuel tourism and statistical differences”. For details see chapter 3.2.4.1
- Consumption of biofuels for road transportation (biodiesel, bioethanol and biogas) starts in Switzerland in the year 1997.
- The table shows the total biodiesel consumption (fossil and biogenic fraction). Though, emissions related to the fossil fraction are reported in the CRT reporting tables under fossil “diesel oil”.

Table 3-87 Split of fuel sales between territorial “on-road consumption (model)”, “non-road consumption (models)” and “fuel tourism and statistical differences” (residual value to sold amounts) for gasoline, diesel oil, natural gas (CNG), liquefied petroleum gas, 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 on-road and non-road categories	Source category	1990	1995	2000	2005	2010
		PJ				
Gasoline						
on-road consumption (model)	1A3b	112	149	166	150	132
fuel tourism and statistical differences	1A3b	-11	-14	-18	-13	-12
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	1.7	2.4	2.3	2.1	1.9
Gasoline sold in Switzerland		103	137	150	139	122
Diesel oil						
on-road consumption (model)	1A3b	100	35	42	59	83
fuel tourism and statistical differences	1A3b	1.3	6.1	5.9	2.1	-0.50
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	15	12	14	14	15
Diesel oil sold in Switzerland		116	54	61	75	97
Natural gas						
on-road consumption (model)	1A3b	0.28	NO	NO	0.090	0.71
fuel tourism and statistical differences	1A3b	0.39	NO	NO	-0.039	-0.18
non-road consumption (models)		NO	NO	NO	NO	NO
Natural gas sold in on- and non-road categories in Switzerland		0.67	NO	NO	0.051	0.53
Liquefied petroleum gas (LPG)						
on-road consumption (model)	1A3b	0.015	NO	NO	NO	NO
non-road consumption (models)	1A2gvii	0.23	0.25	0.29	0.29	0.27
Liquefied petroleum gas sold in on- and non-road categories in Switzerland		0.25	0.25	0.29	0.29	0.27
Biodiesel (fossil and biogene)						
on-road consumption (model)	1A3b	0.47	NO	0.018	0.17	0.24
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	0.080	NO	0.0078	0.022	0.027
Biodiesel sold in Switzerland		0.55	NO	0.026	0.19	0.27
Bioethanol						
on-road consumption (model)	1A3b	0.16	NO	NO	0.019	0.055
non-road consumption (models)	1A2gvii; 1A3dii; 1A4bii; cii; 1A5b	0.0054	NO	NO	NO	0.000023
Bioethanol sold in Switzerland		0.17	NO	NO	0.019	0.055
Biogas						
on-road consumption (model)	1A3b	0.11	NO	NO	0.030	0.13
non-road consumption (models)		NO	NO	NO	NO	NO
Biogas sold in Switzerland		0.11	NO	NO	0.030	0.13

Activity data for on-road and non-road categories	Source category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
		PJ									
Gasoline											
on-road consumption (model)	1A3b	112	104	101	97	96	95	84	86	83	86
fuel tourism and statistical differences	1A3b	-11	-7.0	-7.2	-8.5	-8.5	-9.0	-6.6	-5.7	-2.8	-4.7
non-road consumption (models)	1A2gvii; 1A3dii; 1A4aii,bii,cii; 1A5b	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.5
Gasoline sold in Switzerland		103	99	95	91	89	88	79	82	82	83
Diesel oil											
on-road consumption (model)	1A3b	100	98	99	99	101	101	95	96	96	94
fuel tourism and statistical differences	1A3b	1.3	6.4	8.2	7.0	4.6	5.3	2.2	5.7	8.6	7.7
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	15	15	15	15	15	14	14	14	14	15
Diesel oil sold in Switzerland		116	119	122	121	120	121	112	116	119	116
Natural gas											
on-road consumption (model)	1A3b	0.67	0.63	0.60	0.57	0.59	0.58	0.58	0.62	0.60	0.51
fuel tourism and statistical differences	1A3b	-0.28	-0.25	-0.20	-0.20	-0.20	-0.20	-0.25	-0.26	-0.24	-0.10
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		0.39	0.38	0.40	0.37	0.39	0.38	0.33	0.36	0.36	0.41
Liquefied petroleum gas (LPG)											
on-road consumption (model)	1A3b	0.052	0.061	0.098	0.14	0.17	0.21	0.25	0.24	0.23	0.22
non-road consumption (models)	1A2gvii	0.23	0.23	0.21	0.20	0.19	0.18	0.17	0.14	0.11	0.09
Liquefied petroleum gas sold in on- and non-road categories in Switzerland		0.29	0.29	0.31	0.34	0.36	0.39	0.42	0.38	0.34	0.30
Biodiesel											
on-road consumption (model)	1A3b	0.47	1.2	2.4	4.0	5.7	5.7	5.1	4.0	4.0	4.2
non-road consumption (models)	1A2gvii; 1A3c,dii; 1A4cii; 1A5b	0.080	0.093	0.15	0.20	0.26	0.32	0.37	0.36	0.34	0.33
Biodiesel sold in Switzerland		0.55	1.3	2.5	4.2	6.0	6.0	5.5	4.4	4.3	4.6
Bioethanol											
on-road consumption (model)	1A3b	0.16	0.58	0.80	0.99	1.2	1.3	1.3	1.7	2.0	2.1
non-road consumption (models)	1A2gvii; 1A3dii; 1A4bii; cii; 1A5b	0.0054	0.0068	0.0093	0.012	0.014	0.017	0.019	0.021	0.023	0.025
Bioethanol sold in Switzerland		0.17	0.59	0.80	1.0	1.2	1.4	1.3	1.7	2.0	2.1
Biogas											
on-road consumption (model)	1A3b	0.11	0.12	0.12	0.12	0.11	0.12	0.12	0.13	0.11	0.14
non-road consumption (models)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas sold in Switzerland		0.11	0.12	0.12	0.12	0.11	0.12	0.12	0.13	0.11	0.14

*Mileage-related activity data (basis for modelling of the non-CO<sub>2</sub> emissions by means of a traffic model)*

The activity data are derived from different data sources:

- **Vehicle stock:** The federal vehicle registration database IVZ (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 overall vehicle stock numbers are published by the Federal Statistical Office (FSO 2024e). With the help of a fleet turnover model, the vehicle categories are assigned emission standards based on age and thereby 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 total mileage per vehicle category** is an input from the Federal Statistical Office (FSO 2024e, 2024f). It is based on periodical surveys/Mikrozensus (ARE 2002, ARE/SFSO 2005, 2012, 2017). By means of the vehicle stock data (see paragraph above), the specific mileage per vehicle category can be derived (FSO 2024e, SFOE 2024e, INFRAS 2017). Odometer reading data from periodical technical inspections (PTI), collected in the IVZ database (see above), provide the foundation to further disaggregate specific mileages by vehicles of different technologies, size classes, and construction years.
- **Numbers of starts/stops:** Derived from vehicle stock and periodical surveys/Mikrozensus (ARE/SFSO 2005, 2012, 2017).

The total mileage of each vehicle category is differentiated by “traffic situations” (characteristic patterns of driving behaviour) and gradients, which serve as a key to select the appropriate emission factors, which are also available per traffic situation and gradient. The relative shares of the traffic situations and gradients are derived from a national road traffic model (operated by the Federal Office of Spatial Development, see ARE (2022)). The traffic model is based on an origin-destination matrix that is assigned to a network of about 600'000 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 and gradients 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 3-88 shows the time series of the mileage per vehicle category. The total mileage has constantly been increasing since 1995. This trend was halted in 2020 and 2021, as total mileages decreased compared to the years before due to the restrictions related to the COVID-19 pandemic. Since 2022 total mileages have increased again to pre-pandemic levels. The major part of vehicle kilometres was driven by passenger cars over the whole period. In the same period, on-road fuel consumption increased less strongly, indicating improved fuel efficiency. This effect is also reflected in Table 3-89 that shows the specific fuel consumption per vehicle-km. Average consumption and the specific consumption for most of the vehicle categories have decreased in the period 1990–2023.



Table 3-88 Mileages in millions of vehicle kilometres. PC: passenger cars, LDV: light duty vehicles, HDV: heavy duty vehicles).

Veh. category	1990	1995	2000	2005	2010
million vehicle-km					
PC	47'186	44'945	50'407	51'696	56'026
LDV	2'775	2'786	2'970	3'260	3'595
HDV	1'880	1'800	1'989	2'050	2'239
Coaches and urban buses	266	258	261	323	367
2-Wheelers	2'260	1'724	1'910	1'957	2'039
Sum	54'366	51'512	57'537	59'287	64'266
(1990=100%)	100%	95%	106%	109%	118%

Veh. category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
million vehicle-km										
PC	59'103	57'713	58'531	60'388	61'632	62'200	55'569	57'744	59'682	61'613
LDV	4'015	3'949	4'025	4'189	4'408	4'512	4'754	4'728	4'707	4'830
HDV	2'208	2'099	2'068	2'099	2'148	2'120	2'155	2'148	2'074	2'053
Coaches and urban buses	394	383	386	394	416	424	418	428	431	454
2-Wheelers	2'119	2'070	2'119	2'188	2'230	2'269	2'070	2'104	2'043	2'117
Sum	67'839	66'213	67'128	69'258	70'833	71'524	64'965	67'152	68'937	71'068
(1990=100%)	125%	122%	123%	127%	130%	132%	119%	124%	127%	131%

Table 3-89 Specific fuel consumption of road transport, excluding fuel tourism and statistical differences. Numbers include additional fuel consumption by cold starts.

Veh. Category	Fuel	1990	1995	2000	2005	2010
MJ / veh-km						
PC	Gasoline	3.15	3.24	3.30	3.21	3.06
	Diesel oil	3.36	3.18	3.07	2.79	2.81
	Liquefied petroleum gas	NO	NO	NO	NO	NO
	CNG	NO	NO	NO	NO	3.06
LDV	Gasoline	3.85	3.75	3.65	3.61	3.52
	Diesel oil	4.57	4.54	4.36	4.01	3.79
	CNG	NO	NO	NO	NO	3.68
HDV	Gasoline	9.06	9.07	9.07	9.11	9.15
	Diesel oil	11.3	11.7	11.7	12.3	11.9
	CNG	NO	NO	NO	25.1	19.5
Busses	Gasoline	NO	NO	NO	NO	NO
	Diesel oil	15.0	15.2	15.4	15.4	14.7
	CNG	NO	NO	NO	NO	25.4
2-Wheeler	Gasoline	1.49	1.66	1.48	1.59	1.51
Average		3.54	3.67	3.69	3.56	3.39
(1990=100%)		100%	104%	104%	101%	96%

Veh. Category	Fuel	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
MJ / veh-km											
PC	Gasoline	2.80	2.73	2.67	2.53	2.48	2.44	2.41	2.36	2.29	2.26
	Diesel oil	2.74	2.72	2.71	2.65	2.65	2.66	2.67	2.67	2.64	2.63
	Liquefied petroleum gas	2.90	2.84	2.82	2.72	2.72	2.71	2.71	2.69	2.65	2.64
	CNG	3.01	3.08	2.96	2.94	2.82	2.84	2.96	2.87	2.72	2.79
LDV	Gasoline	3.32	3.27	3.21	3.02	2.92	2.88	2.83	2.77	2.64	2.54
	Diesel oil	3.72	3.71	3.70	3.55	3.50	3.46	3.41	3.37	3.33	3.30
	CNG	4.16	4.26	4.09	4.01	3.80	3.82	4.00	3.89	3.31	3.45
HDV	Gasoline	9.15	9.14	9.16	8.78	8.77	8.74	8.72	8.70	8.65	8.63
	Diesel oil	11.7	11.6	11.6	11.5	11.3	11.2	11.1	10.9	10.6	10.3
	CNG	19.9	20.5	20.1	20.6	17.1	17.2	16.6	17.2	16.4	17.1
Busses	Gasoline	NO	NO	NO	NO	8.91	8.88	8.86	8.83	NO	8.81
	Diesel oil	14.1	14.0	14.0	13.2	13.1	13.1	13.0	12.8	12.9	12.5
	CNG	25.3	26.1	25.5	24.5	24.2	24.5	25.8	25.3	24.3	26.3
2-Wheeler	Gasoline	1.55	1.59	1.55	1.50	1.54	1.55	1.56	1.56	1.42	1.45
Average		3.17	3.12	3.08	2.97	2.92	2.90	2.91	2.86	2.76	2.70
(1990=100%)		90%	88%	87%	84%	83%	82%	82%	81%	78%	76%

For modelling of evaporative emissions, the stock, the mileage and the number of stops of gasoline passenger cars, light duty vehicles and motorcycles are used. For modelling cold start excess emissions, also the numbers of starts of passenger cars and light duty vehicles are used as activity data. The corresponding numbers are summarised in Table 3-90.



Vehicle stock figures correspond to registration data. The starts and stops per vehicle are based on specific surveys (ARE/SFSO 2005, 2012, 2017).

Table 3-90 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	2010
	stock in 1000 veh. (gasoline/bioeth.)				
PC	2822	3'033	3'282	3'247	2'931
LDV	158	154	136	99	66
2-Wheelers	764	688	712	747	778
	starts per veh. per day				
PC	2.9	2.7	2.9	2.5	2.6
LDV	2.0	2.0	2.0	2.0	2.0

Veh. Category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	stock in 1000 veh. (gasoline/bioeth.)									
PC	2'719	2'667	2'625	2'621	2'626	2'623	2'705	2'736	2'686	2'732
LDV	50	48	46	44	42	41	42	41	39	46
2-Wheelers	829	845	862	882	903	915	946	983	967	983
	starts per veh. per day									
PC	2.5	2.5	2.6	2.6	2.6	2.6	2.3	2.4	2.6	2.6
LDV	2.0	2.0	2.0	2.0	1.9	2.0	2.0	2.0	2.0	2.0

Further details are given in Annex A5.1.2.

### 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. The following methods are used:

- Tier 2 for CO<sub>2</sub> (based on decision tree Fig. 3.4.1 in IPCC 2006)
- Tier 3 for CH<sub>4</sub>, N<sub>2</sub>O and precursors (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 2023 based on fuel used. For the years in-between, the emissions are interpolated linearly.

#### Emission factors (1A3c)

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

- The CO<sub>2</sub> emission factor applied for the time series 1990–2023 for diesel oil is country-specific and is given in Table 3-13.
- The CH<sub>4</sub> and N<sub>2</sub>O emission factors of diesel locomotives are shown in Table 3-91.

- The emission factors for precursors are country-specific and are given in FOEN (2015j). More details concerning the emission factor for SO<sub>2</sub> are shown in Table A – 15 (row diesel oil). NMVOC emissions are calculated as the difference between VOC and CH<sub>4</sub> emissions.
- Implied emission factors for the latest reporting year are shown in Table 3-92.

All emission factors (GHG, precursors) can be downloaded by query from the online 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 INFRAS (2015a)).

Table 3-91 CH<sub>4</sub> and N<sub>2</sub>O 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 <sub>4</sub>	<18	0.0547	0.0384	0.024	0.0142	0.0142
CH <sub>4</sub>	18–37	0.0578	0.0221	0.0134	0.0089	0.0089
CH <sub>4</sub>	37–56	0.0319	0.0156	0.011	0.0079	0.0055
CH <sub>4</sub>	56–75	0.0319	0.0156	0.011	0.0079	0.0031
CH <sub>4</sub>	75–130	0.0218	0.0108	0.0084	0.0067	0.0031
CH <sub>4</sub>	>130	0.0218	0.0103	0.0072	0.0053	0.0031
N <sub>2</sub> O	all	0.035	0.035	0.035	0.035	0.035

Table 3-92 Implied emission factors 2023 for rail vehicles. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3c Railways	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
	kg/TJ							
Diesel oil	73'300	NA	1.1	3.5	834	97	0.30	491
Biodiesel	3'676	69'624	1.1	3.5	816	95	0.30	480

### Activity data (1A3c)

Activity data for non-road, including 1A3c Railways, are described in chp. 3.2.4.5.1 (non-road transportation model). Values are taken from FOEN (2015j). Data on biofuels are provided by the statistics of renewable energies (SFOE 2015a). Activity data are shown in Table 3-93 and in Annex A5.1.3.

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can be downloaded by query from the online 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 INFRAS (2015a)).

Table 3-93 Activity data (diesel oil consumption) for railways.

1A3c Railways	Unit	1990	1995	2000	2005	2010
Diesel oil	TJ	390	441	455	472	492
Biodiesel	TJ	NO	NO	0.97	2.8	3.5
Total Railways	TJ	390	441	456	475	496
1990 = 100%		100%	113%	117%	122%	127%

1A3c Railways	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Diesel oil	TJ	411	391	388	385	382	379	376	377	378	379
Biodiesel	TJ	8.5	9.8	16	22	28	34	40	38	36	35
Total Railways	TJ	420	401	403	406	409	412	415	415	414	413
1990 = 100%		108%	103%	104%	104%	105%	106%	107%	106%	106%	106%

### 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 2 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 2023 based on fuel used. For the years in-between, the emissions are linearly interpolated.

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

CO<sub>2</sub> emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO<sub>2</sub> emission factor for lubricants, 73.3 t/TJ (IPCC 2006). However, these emissions are reported in source category 2D1 Lubricant use (see chp. 4.5.2.1). In contrast, CH<sub>4</sub> and N<sub>2</sub>O emissions from lubricant use are reported in source category 1A3d Domestic navigation, since the emission factors are deduced from measurements including 2-stroke engines.

#### Emission factors (1A3d)

- The CO<sub>2</sub> emission factor applied for the time series 1990–2023 for diesel oil, gasoline and gas oil are country-specific and are given in Table 3-13.
- The CH<sub>4</sub> and N<sub>2</sub>O emission factors are country-specific and are shown below in Table 3-94 to Table 3-96 for all fuel types and emission standards.
- For SO<sub>2</sub> the emission factors are country-specific. See also Table A – 17 in Annex A5.1.4 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<sub>4</sub> emissions.
- The implied emission factors for the latest reporting year are shown in Table 3-97.

All emission factors (GHG, precursors) can be downloaded by query from the online 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 INFRAS (2015a)).

Table 3-94 CH<sub>4</sub> and N<sub>2</sub>O emission factors for ships with diesel engines.

Gas	Power class	Ships with diesel oil engines				
		Pre SAV (<1995)	SAV 1995	EU-I 2003	EU-II 2008	EU-III 2009
	kW	g/kWh				
CH <sub>4</sub>	<18	0.0547	0.0547	0.0384	0.0240	0.0142
CH <sub>4</sub>	18–37	0.0578	0.0578	0.0221	0.0134	0.0089
CH <sub>4</sub>	37–56	0.0319	0.0319	0.0156	0.0110	0.0079
CH <sub>4</sub>	56–75	0.0319	0.0319	0.0156	0.0110	0.0079
CH <sub>4</sub>	75–130	0.0218	0.0218	0.0108	0.0084	0.0067
CH <sub>4</sub>	>130	0.0218	0.0218	0.0103	0.0072	0.0053
N <sub>2</sub> O	all	0.035	0.035	0.035	0.035	0.035

Table 3-95 CH<sub>4</sub> and N<sub>2</sub>O 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		
		Pre SAV <1995	SAV 1995	SAV/EU 2007	Pre SAV <1995	SAV 1995	SAV/EU 2007
	kW	g/kWh			g/kWh		
CH <sub>4</sub>	<18	18.2	1.54	1.75	1.25	1.10	1.25
CH <sub>4</sub>	18–37	18.2	0.84	0.91	1.00	0.60	0.65
CH <sub>4</sub>	37–56	18.2	0.42	0.56	1.00	0.30	0.40
CH <sub>4</sub>	56–75	18.2	0.42	0.56	1.00	0.20	0.30
CH <sub>4</sub>	75–130	18.2	0.42	0.56	1.00	0.17	0.25
CH <sub>4</sub>	130–560	18.2	0.42	0.56	1.00	0.10	0.25
N <sub>2</sub> O	0–300	0.01	0.01	0.01	0.03	0.03	0.03

Table 3-96 CH<sub>4</sub> and N<sub>2</sub>O emission factors for steamboats by the year of enforcement.

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

Table 3-97 Implied emission factors 2023 for navigation. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3d Navigation	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	kg/TJ							
Gasoline	73'800	NA	22.4	1.9	537	414	0.19	8'708
Diesel oil	73'300	NA	1.2	3.4	695	195	0.30	483
Gas oil	73'700	NA	0.24	0.73	27	1.6	0.84	6.9
Biodiesel	3'675	69'625	1.2	3.3	680	191	0.30	472
Bioethanol	NA	73'800	21	3.3	680	191	0.30	472

### 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 are provided by the statistics

of renewable energies (SFOE 2015a). Activity data are shown in Table 3-98 and in Annex A5.1.3.

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can be downloaded by query from the online 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 (INFRAS 2015a).

Table 3-98 Fuel consumption of (domestic) navigation.

1A3d Domestic na	Unit	1990	1995	2000	2005	2010
Gasoline	TJ	701	654	616	565	535
Diesel oil	TJ	738	724	792	800	868
Gas oil	TJ	110	139	147	150	159
Biodiesel	TJ	NO	NO	0.89	2.5	3.3
Bioethanol	TJ	NO	NO	NO	NO	0.008
Total Navigation	TJ	1'550	1'517	1'556	1'518	1'565
1990 = 100%		100%	98%	100%	98%	101%

1A3d Domestic na	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Gasoline	TJ	519	515	515	515	515	515	515	515	515	515
Diesel oil	TJ	877	880	871	863	855	847	839	839	840	841
Gas oil	TJ	153	151	150	149	148	147	146	145	144	144
Biodiesel	TJ	10	11.6	19	25	32	39	46	44	42	41
Bioethanol	TJ	2.0	2.5	3.4	4.4	5.4	6.4	7.4	8.1	8.9	9.7
Total Navigation	TJ	1'561	1'560	1'559	1'557	1'556	1'554	1'553	1'552	1'551	1'550
1990 = 100%		101%	101%	101%	101%	100%	100%	100%	100%	100%	100%

### 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 (1A3ei) from a compressor station located in Ruswil. Emissions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> 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<sub>2</sub> emission factor applied for the time series 1990–2023 for natural gas is country-specific and is given in Table 3-14.
- The CH<sub>4</sub> emission factor corresponds to the one used for gas turbines in Switzerland (SAEFL 2000) as suggested by expert judgement. The CH<sub>4</sub> emission factor 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<sub>4</sub> emissions of the gas turbine.
- For N<sub>2</sub>O emission factors the IPCC 2006 default value (Table 3-17) is used as displayed in Table 3-99.
- The emission factors for precursors are mostly country-specific. The NO<sub>x</sub> emission factor stems from the Factsheet Emission Factors Furnaces (FOEN 2015k). NMVOC and SO<sub>x</sub>

emission factors stem from section “Gasturbinen; Erdgas” in SAEFL (2000). More details concerning the emission factor for SO<sub>2</sub> are shown in Table A – 15 (row natural gas). The CO emission factor is a default factor from the EMEP/EEA guidebook (EMEP/EEA 2023).

- The emission factors for the latest reporting year are shown in Table 3-99.

Table 3-99 Emission factors of 1A3ei Pipeline transportation / compressor station located in Ruswil in 2023. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A3e Other transportation	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	kg/TJ							
Gas	55'900	NA	5.2	0.69	30	1.6	0.23	11.0
Biogas	NA	55'900	5.2	0.69	48	1.6	0.50	11.0

### 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 2024; Table 17).

Table 3-100 Activity data of 1A3e.

1A3ei Pipeline transport	Unit	1990	1995	2000	2005	2010
Natural gas	TJ	560	310	340	1'070	830
Biogas	TJ	NO	NO	NO	NO	NO
1990 = 100%		100%	55%	61%	191%	148%

1A3ei Pipeline transport	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Natural gas	TJ	830	760	340	470	490	600	540	120	400	170
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	18	20	22
1990 = 100%		148%	136%	61%	84%	88%	107%	96%	21%	75%	34%

### 3.2.9.3. Uncertainties and time-series consistency for 1A3

The uncertainty of emission estimates for source category 1A3 is described in the general uncertainty assessment of source category 1A Fuel combustion in chp. 3.2.4.7. Uncertainties by fuel type are given in Table 3-38.

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. 1.5. Furthermore, QA/QC procedures conducted for all 1A source categories are listed 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 consumption, total distance, number of passengers (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 per 100 passenger km is in line with expectations for 1990 passenger fleets. Current modern fleets are in the order of 2.5 kg fuel per 100 passenger km at usual aircraft loads. During the COVID-19 pandemic, the seat load factor was exceptionally low and therefore, a calculation of the fuel consumption per 100 passenger km is not representative.
- The implied emission factors were calculated for the latest reporting year 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 Instrument Flight Rules 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 visual flight rules and non-scheduled flights such as helicopter movements in alpine regions.
- Comparison between total movement numbers in the calculation and in the corresponding published statistics. Example: In 1990 calculation, FOCA considered all flights for which there was a form 'Traffic report to the airport authorities' filled in (total heavy aircraft). The total number of movements in 1990 is 263'951 (without Basel). The published number of movements for scheduled and charter flights in 1990 is: 263'952 (without Basel).
- The bottom-up calculation of total fuel matches the total fuel sold within a few percent, except for 2020 and 2021, where the difference is larger due to the COVID-19 pandemic.
- 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 (IPCC 2006) and Switzerland's emission factors:

- CO<sub>2</sub> (see also Table 3-39): 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 (IPCC 2006).
- CH<sub>4</sub>: 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 varied between 27.2 kg/TJ and 3.6 kg/TJ throughout the time series and is therefore in the lower part of and below IPCC's uncertainty range. For diesel oil, the IPCC default emission factors lie in the range of 1.6–9.5 kg/TJ (IPCC 2006), whereas Switzerland's range is on a lower level (0.8–4.0 kg/TJ).
- N<sub>2</sub>O: 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 varied between 5.4 kg/TJ and 0.5 kg/TJ 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 (IPCC 2006), whereas Switzerland's range is lower (0.2–3.7 kg/TJ).

The international project for the update of the emission factors for road vehicles is overseen by a group of external national and international experts that guarantees an independent quality control. For the update of the modelling of Switzerland's road transport emissions, which has last been carried out comprehensively between 2019–2020 in the framework of the update of Switzerland's energy perspectives, several experts from the federal administration have accompanied the project (INFRAS 2019a). The results have undergone extensive plausibility checks and comparisons with earlier estimates. A light update of the emission factors took place in 2022 (Notter et al. 2022).

The emission factors CH<sub>4</sub> and N<sub>2</sub>O used for the modelling of 1A3b Road Transportation are taken from version 4.2 of the Handbook Emission Factors for Road Transport (HBEFA) (INFRAS 2022), which is also applied in Germany, Austria, Norway, Sweden, and France. The Swiss emission factors for CH<sub>4</sub> and N<sub>2</sub>O used in 1A3b Road transportation were additionally compared with those shown in the CRT from Germany and a good match was found. Possible small differences might result from a varying fleet composition.

Use of implied emission factors from the 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 for national greenhouse gas and air pollutant emissions reporting (COPERT, EEA 1997). Nevertheless, the use of the implied Swiss emission factors 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 4.2. It is expected that an update of this comparison would result in similarly low differences with the neighbouring countries, since the underlying measurement data in the inventory models are the same (given the neighbouring countries also work with an eventually updated COPERT version).

The activity data for gasoline and diesel oil of the road transportation model (consumption without tank tourism and statistical difference) is verified due to the fact that more than 90 % of the gasoline and diesel oil sold 2023 in Switzerland, as reported by the Swiss overall energy statistic (SFOE 2024), is consumed by the road transportation model (see Table 3-87).

### 3.2.9.5. Category-specific recalculations for 1A3

The following recalculations were implemented in submission 2025. Major recalculations, which contribute significantly to the total differences in emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

- 1A3b: The difference between the fuel used approach from the road transportation model and the fuel sold information from the energy statistics was previously referred to as "fuel tourism and statistical difference". This was determined using average emission factors for each fuel type to calculate the difference in emissions. The resulting differences in activity data and emissions were subtracted from the activity data and the formerly calculated territorial emissions of each main vehicle category and fuel type in 1A3b road



transportation. Now, the relative difference between the territorial fuel consumption modelled by the road transportation model (fuel used) and the fuel sold from the energy statistics is calculated and proportionally attributed to each vehicle category. The emissions are then calculated based on the activity data adjusted to reflect the fuel sold. Therefore, the activity data for 1A3b road transportation (fuel sold) have been updated for all fuel types, for all emissions and for all years 1990-2022.

- 1A3b: The use of bioethanol has been adopted to the reported amount of bioethanol sold in the Swiss Energy statistics. Therefore, missing activity data have been implemented in 1A3b Road Transportation for all processes using bioethanol for the years 2005-2009.
- 1A3b: For the road traffic model in 1A3b Road transportation, adjustments were made to driving performance, mileage and energy consumption and emission factors with respect to the Handbook for Emission Factors (HBEFA) version 4.2. This leads to recalculations of activity data end emissions for all years 1990-2022.
- 1A3b: The Swiss statistic of energy consumption (SFOE 2024) has newly added the amount of liquefied natural gas (LNG) used to the total amount of natural gas used for the years 2020-2022. This leads to small recalculations mainly in source categories 1A3b Road transportation, 1A4ai Commercial/institutional (stationary) and 1B2b Natural gas losses.
- 1A3b, 1A3d: The fossil carbon fraction in biodiesel is now estimated based on the method described in Sebos (2022). The fossil fraction of FAME (Fatty Acid Methyl Ester) is based on the values from HBEFA 4.1 (INFRAS 2019a, relevant for the whole EU), while all carbon in HVO (Hydrotreated Vegetable Oil) is considered of biogenic origin. Because biodiesel as reported by Switzerland consists of the sum of FAME and HVO, the fossil fraction of biodiesel varies over time. Overall, around 4.0 to 5.4 % of the total biodiesel are now reported under “fossil liquid fuels” for the years 1996–2022 (no biodiesel in the years before). In consequence, this leads to recalculations in fuel categories including biodiesel as “biomass” or “biofuels” and “liquid fuels” as well.
- 1A3d: An update of the fuel mix and consumption from non-road machinery leads to minor recalculations in all source categories affected by the non-road model and for all the years 1990-2022.

### **3.2.9.6. Category-specific planned improvements for 1A3**

No category-specific improvements are planned.

## **3.2.10. Source category 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors**

### **3.2.10.1. Source category description for 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors**

#### **Key categories 1A4**

See key categories mentioned in chp. 3.2.7.1, Table 3-68.

Table 3-101 Specification of source category 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors (1A4a, 1A4b, 1A4c).

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

### 3.2.10.2. Methodological issues for 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors

#### Methodology (1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors)

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<sub>2</sub> emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO<sub>2</sub> 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). In contrast, CH<sub>4</sub> and N<sub>2</sub>O emissions from lubricant use in 2-stroke engines are reported in the corresponding source category in 1A4 Other non-road machinery sources in residential, commercial, agriculture and forestry sectors, since the emission factors are based on measurements including 2-stroke engines.

#### Emission factors (1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors)

All emission factors (GHG, precursors) can be downloaded by query from the online 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 INFRAS (2015a)).

- The CO<sub>2</sub> emission factors applied for the time series 1990–2023 are country-specific and are given in Table 3-13.
- The CH<sub>4</sub> and N<sub>2</sub>O emission factors are country-specific and are shown in Table 3-77 and Table 3-78 for diesel oil and gasoline engines for all emission standards.
- For SO<sub>2</sub> the emission factors are country-specific. See also Table A – 17 in Annex A5.1.4 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<sub>4</sub> emissions.
- Implied emission factors for the latest reporting year are shown in Table 3-102.

Table 3-102 Implied emission factors 2023 for 1A4 – Other non-road machinery sources in residential, commercial agriculture and forestry sectors (1A4a<sub>ii</sub> – 1A4c<sub>ii</sub> mobile). Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A4 Non-road machinery	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NM VOC	SO <sub>2</sub>	CO
	kg/TJ							
1A4a <sub>ii</sub> Gardening professional								
Gasoline	73'800	NA	81	1.2	162	1'255	0.19	26'391
Bioethanol	NA	73'800	20	1.6	90	566	0.19	24'727
1A4b <sub>ii</sub> Gardening								
Gasoline	73'800	NA	38	1.4	124	779	0.19	25'209
Bioethanol	NA	73'800	21	1.6	108	597	0.19	24'714
1A4c <sub>ii</sub> Forestry and agriculture								
Gasoline	73'800	NA	80	1.2	173	1'345	0.19	24'641
Diesel oil	73'300	NA	0.9	2.9	309	36	0.30	179
Biodiesel	3'676	69'624	0.9	2.9	303	35	0.30	175
Bioethanol	NA	73'800	26	1.45	110	753	0.19	23'554

### Activity data (1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors)

In Non-road vehicles and other machinery in categories 1A4a<sub>ii</sub> Commercial/institutional and 1A4b<sub>ii</sub> Residential, only gasoline (and a small share of bioethanol) is being used as fuel. In category 1A4c<sub>ii</sub> Agricultural/forestry/fishing, mainly diesel oil is consumed and only a small amount of gasoline (e.g. chainsaws) or biodiesel/bioethanol.

Activity data are described in chp. 3.2.4.5.1 (non-road transportation model) and are shown in Table 3-103 and in Annex A5.1.3.

Underlying activity data (vehicle stock, operating hours) of mobile non-road sources can be downloaded by query from the online 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 INFRAS 2015a).

Table 3-103 Activity data for non-road vehicles and machinery in 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors.

1A4 Non-road machinery	Unit	1990	1995	2000	2005	2010
1A4aii Gardening professional						
Gasoline	TJ	191	245	295	295	287
Bioethanol	TJ	NO	NO	NO	NO	0.0024
1A4bii Gardening						
Gasoline	TJ	142	155	165	166	163
Bioethanol	TJ	NO	NO	NO	NO	0.0021
1A4cii Forestry and agriculture						
Gasoline	TJ	1'160	1'070	963	824	689
Diesel oil	TJ	4'269	4'604	4'921	4'804	4'884
Biodiesel	TJ	NO	NO	5.5	15	18
Bioethanol	TJ	NO	NO	NO	NO	0.008
Total 1A4 non-road machinery	TJ	5'761	6'073	6'349	6'103	6'042
Relative values 1A4 (1990 = 100%)		100%	105%	110%	106%	105%

1A4 Non-road machinery	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1A4aii Gardening professional											
Gasoline	TJ	260	253	252	251	250	249	248	246	245	243
Bioethanol	TJ	0.60	0.75	1.05	1.34	1.6	1.9	2.2	2.5	2.7	2.9
1A4bii Gardening											
Gasoline	TJ	158	157	156	155	155	154	153	153	152	152
Bioethanol	TJ	0.53	0.67	0.93	1.19	1.4	1.7	2.0	2.2	2.4	2.6
1A4cii Forestry and agriculture											
Gasoline	TJ	593	569	553	538	523	508	492	480	467	454
Diesel oil	TJ	4'867	4'863	4'828	4'794	4'760	4'726	4'692	4'701	4'711	4'721
Biodiesel	TJ	55	64	103	142	181	220	259	248	238	228
Bioethanol	TJ	1.64	2.0	2.7	3.3	4.0	4.6	5.2	5.6	6	6
Total 1A4 non-road machinery	TJ	5'936	5'909	5'898	5'887	5'876	5'865	5'854	5'839	5'824	5'809
Relative values 1A4 (1990 = 100%)		103%	103%	102%	102%	102%	102%	102%	101%	101%	101%

### 3.2.10.3. Uncertainties and time-series consistency for 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors

The uncertainty of emission estimates for source category 1A4 Other sectors (mobile) is described in the general uncertainty assessment of source category 1A Fuel combustion in chp. 3.2.4.7. Uncertainties by fuel type are given in Table 3-38.

### 3.2.10.4. Category-specific QA/QC and verification for 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors

The general QA/QC procedures are described in chp. 1.5. 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 non-road machinery sources in residential, commercial, agriculture and forestry sectors

The following recalculations were implemented in submission 2025. Major recalculations, which contribute significantly to the total differences in emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

- 1A4aii, 1A4bii, 1A4cii: The fossil carbon fraction in biodiesel is now estimated based on the method described in Sebos (2022). The fossil fraction of FAME (Fatty Acid Methyl Ester) is based on the values from HBEFA 4.1 (INFRAS 2019a, relevant for the whole EU), while all carbon in HVO (Hydrotreated Vegetable Oil) is considered of biogenic origin. Because biodiesel as reported by Switzerland consists of the sum of FAME and HVO, the fossil fraction of biodiesel varies over time. Overall, around 4.0 to 5.4 % of the total biodiesel are now reported under “fossil liquid fuels” for the years 1996–2022 (no

biodiesel in the years before). In consequence, this leads to recalculations in fuel categories including biodiesel as “biomass” or “biofuels” and “liquid fuels” as well.

- 1A4bii, 1A4cii: An update of the fuel mix and consumption from non-road machinery leads to m recalculations in all source categories affected by the non-road model and for all the years 1990-2022.

### 3.2.10.6. Category-specific planned improvements for 1A4 – Other non-road machinery sources in residential, commercial, agriculture and forestry sectors

No category-specific improvements are planned.

## 3.2.11. Source category 1A5b – Other (mobile)

### 3.2.11.1. Source category description for 1A5b (mobile)

Table 3-104 Key categories of 1A5b – Other (mobile). Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
1.A.5	Other; Liquid fuels	CO <sub>2</sub>	L1

All of the Swiss source categories of 1A5 refer to mobile sources of military activities (1A5b). Stationary activities (1A5a) are not occurring.

Table 3-105 Specification of Swiss source category 1A5 Other.

1A5	Source category	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 (1A5bi)

##### Methodology (1A5bi Other, military aviation)

To calculate the emissions from military aviation, a Tier 2 method is used for CO<sub>2</sub>, while a Tier 1 method is used for CH<sub>4</sub> and N<sub>2</sub>O.

##### Emission factors (1A5bi Other, military aviation)

- The CO<sub>2</sub> emission factor applied for the time series 1990–2023 for jet kerosene is country-specific and is given in Table 3-13.

- CH<sub>4</sub>: Because there is no split in LTO and cruise flights in military aviation, the CH<sub>4</sub> emission factor of 1A3a Civil aviation (see chp. 3.2.9.2.1) cannot be applied. Therefore, the Tier 1 emission factor from IPCC 2006, table 3.6.5 is used.
- N<sub>2</sub>O: As for 1A3a Civil aviation, the Tier 1 IPCC default value is used (IPCC 2006, table 3.6.5).
- NO<sub>x</sub>, NMVOC, CO: average emission factors for military aircraft are calculated by the Federal Office of Civil Aviation (FOCA) based on collaborative measurement efforts of FOCA and the Federal Department of Defence, Civil Protection and Sport (DDPS) and the FOCA aircraft engine data bank. The fuel consumption per aircraft type in the year 2016–2017 is provided by DDPS (DDPS 2018b). The emission factors stay constant for the whole time series from 1990 onwards.
- SO<sub>2</sub>: the emission factor is taken from the EMEP/EEA guidebook (EMEP/EEA 2023, chapter 1.A.3.a Aviation 2023, Table 3.11, row “Switzerland/CCD” (where: CCD means: climb/cruise/descent)) and is assumed to be constant over the period 1990–2023.
- Implied emission factors for the latest reporting year are shown in Table 3-106.

Table 3-106 Implied emission factors 1A5bi military aviation in 2023. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A5bi Other: Military aviation	CO <sub>2</sub> fossil	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
	kg/TJ						
Jet kerosene	72'800	0.50	2.0	231	33	23	235

### Activity data (1A5bi Other, military aviation)

Fuel consumption data for 1990–2023 is available on an annual basis (VTG 2011, VTG 2024). A very small fraction of fuel is consumed for training abroad and might be allocated under “International aviation” (assumed to be 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 2006 IPCC Guidelines (IPCC 2006, chp. 3.6.1.4).

Table 3-107 Activity data (fuel consumption) for military aviation.

1A5bi Other: Military aviation	Unit	1990	1995	2000	2005	2010
Jet kerosene	TJ	2'733	1'955	1'794	1'624	1'592

1A5bi Other: Military aviation	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Jet kerosene	TJ	1'615	1'567	1'627	1'469	1'457	1'303	1'365	1'301	1'423	1'432

### 3.2.11.2.2. Military non-road vehicles (1A5bii Other, military machinery)

#### Methodology (1A5bii 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 decision tree Fig. 3.3.1 in chp. 3. Mobile Combustion in IPCC (2006).

CO<sub>2</sub> emissions from lubricants of gasoline 2-stroke engines are calculated by using the IPCC default CO<sub>2</sub> 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). In contrast, CH<sub>4</sub>

and N<sub>2</sub>O emissions from lubricant use in 2-stroke engines are reported in source category 1A5bii, since the emission factors are based on measurements including 2-stroke engines.

### Emission factors (1A5bii Other, military machinery)

- The CO<sub>2</sub> emission factors applied for the time series 1990–2023 for diesel oil, gasoline and biofuels are country-specific as shown in Table 3-13.
- The CH<sub>4</sub> and N<sub>2</sub>O emission factors are country-specific and are shown in Table 3-77 and Table 3-78 for diesel oil and gasoline engines for all emission standards.
- For SO<sub>2</sub> the emission factors are country-specific. See Table A – 17 in Annex A5.1.4, 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<sub>4</sub> emissions.
- Implied emission factors for the latest reporting year are shown in Table 3-108.

All emission factors (GHG, precursors) can be downloaded by query from the online 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 INFRAS (2015a)).

Table 3-108 Implied emission factors 1A5bii military non-road vehicles 2023. Emission factors that are highlighted in green are described in chp. 3.2.4.4.

1A5bii Military non-road	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
	kg/TJ							
Gasoline	73'800	NA	36	1.5	112	662	0.17	24'511
Diesel oil	73'300	NA	0.58	3.0	253	24	0.30	120
Biodiesel	3'676	69'624	0.57	2.9	247	23	0.30	117
Bioethanol	NA	73800	14	1.7	85	394	0.19	24'332

### Activity data (1A5bii Other, military machinery)

Activity data for military non-road vehicles (1A5bii) are described in chp. 3.2.4.5.1 (non-road transportation model). Values are taken from FOEN (2015j). Data on biofuels are provided by the statistics of renewable energies (SFOE 2015a). Activity data are shown in Table 3-109 and in Annex A5.1.3.

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 INFRAS 2015a).



Table 3-109 Activity data (fuel consumption) for military non-road vehicles.

1A5bii Military non-road	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	239	248	252	257	275
Gasoline	TJ	19	19	19	19	18
Diesel oil	TJ	220	228	233	238	256
Biodiesel	TJ	NO	NO	0.26	0.74	1.0
Bioethanol	TJ	NO	NO	NO	NO	0.00024

1A5bii Military non-road	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total fuel consumption	TJ	275	275	274	273	272	271	270	270	269	269
Gasoline	TJ	17	17	17	17	16	16	16	16	16	16
Diesel oil	TJ	255	255	252	249	246	243	240	241	241	241
Biodiesel	TJ	2.9	3.4	5.3	7.3	9.3	11.3	13.2	12.7	12.2	11.7
Bioethanol	TJ	0.058	0.072	0.10	0.13	0.16	0.18	0.21	0.23	0.25	0.27

### 3.2.11.3. Uncertainties and time-series consistency for 1A5b Other (mobile)

The uncertainty of emission estimates for source category 1A5b Other (mobile) is described in the general uncertainty assessment of source category 1A Fuel combustion in chp.

3.2.4.7. Uncertainties by fuel type are given in Table 3-38.

### 3.2.11.4. Category-specific QA/QC and verification for 1A5b Other (mobile)

The general QA/QC measures are described in chp. 1.5. Furthermore, QA/QC procedures conducted for all 1A source categories are listed in chp. 3.2.4.8.

The activity data of military aviation (1A5b), jet kerosene consumption, is provided by the Federal Department of Defence, Civil Protection and Sport. For a compatibility check with the emission database 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 following recalculations were implemented in submission 2025. Major recalculations, which contribute significantly to the total differences in emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

- 1A5b: The fossil carbon fraction in biodiesel is now estimated based on the method described in Sebos (2022). The fossil fraction of FAME (Fatty Acid Methyl Ester) is based on the values from HBEFA 4.1 (relevant for the whole EU), while all carbon in HVO (Hydrotreated Vegetable Oil) is considered of biogenic origin. Because biodiesel as reported by Switzerland consists of the sum of FAME and HVO, the fossil fraction of biodiesel varies over time. Overall, around 4.0 to 5.4 % of the total biodiesel are now reported under “fossil liquid fuels” for the years 1996–2022 (no biodiesel in the years before). In consequence, this leads to recalculations in fuel categories including biodiesel as “biomass” or “biofuels” and “liquid fuels” as well.
- 1A5b: An update of the fuel mix and consumption from non-road machineries leads to small recalculations in all source categories affected by the non-road model and for all the years 1990-2022.

### 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 – Fugitive emissions from fuels

Table 3-110 Key categories of 1B Fugitive emissions from fuels. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Source category 1B Fugitive emissions from fuels is not a key category.

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, only coal handling. 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 transforming crude oil into liquid fuels and the several gasoline stations and storage tanks for gasoline and jet kerosene. At the beginning of 2015, one of the two refineries ceased operation. Crude oil is imported by underground pipelines only. The extents of the two existing oil pipelines in Switzerland are approximately 40 km and 70 km, respectively.

Table 3-111 Specification of source category fugitive emissions from 1B2a Oil in Switzerland.

1B2	Source category	Specification
1B2aiii	Fugitive emissions oil: Transport	Emissions only stem from pipeline transport
1B2aiv	Fugitive emissions oil: Refining / storage	Emissions from oil refining process
1B2av	Fugitive emissions oil: Distribution of oil products	Distribution of oil products (from gasoline storage tanks and gasoline stations) (only precursor emissions NMVOC)

##### 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 3 (for 1B2aiii Fugitive emissions oil: Transport) and a Tier 2 (for 1B2aiv Fugitive emissions oil: Refining / storage, 1B2av

Fugitive emissions oil: Distribution of oil products) approach (IPCC 2006, Volume 2 Energy, chp. 4 Fugitive Emissions, Figure 4.2.3 and for precursors EMEP/EEA 2023, Figure 3-1).

For source category 1B2a Fugitive emissions from oil, fugitive emissions of CH<sub>4</sub> are reported. They occur only in 1B2a<sub>iii</sub> Transport and 1B2a<sub>iv</sub> Refining/storage. Indirect CO<sub>2</sub> emissions resulting from CH<sub>4</sub> and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9. As no CO emissions occur in source category 1B2a, from this source category no indirect CO<sub>2</sub> emissions from CO are included in CRT Table6 as documented in chp. 9.

### Emission factors (1B2a)

Crude oil transportation (1B2a<sub>iii</sub>): In Switzerland crude oil is transported by underground pipelines only. According to experts from the pipeline operator, there are no emissions along the pipelines but only at the pig trap. There is one pig trap per pipeline and one pipeline per refinery. Based on expert estimates 0.5 m<sup>3</sup> air saturated with VOC are emitted per week and pig trap. This leads to CH<sub>4</sub> emissions of 1–2 kg per year. The CH<sub>4</sub> to NMVOC ratio is assumed to be 1:10.

For oil refining and storage (1B2a<sub>iv</sub>), country-specific emission factors for CH<sub>4</sub> and NMVOC are used. The emission factors for CH<sub>4</sub> are delineated from an emission estimation project in one of the refineries in 1992 called CRISTAL (Raffinerie de Cressier 1992). The emission factor 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 2025/1B2a<sub>iv</sub>). This emission factor is used for all the years until 1995. For the years 2007–2019, total NMVOC emissions from 1A1b, 1B2a<sub>iv</sub> and 1B2c correspond to those reported in the Swiss Pollutant Release and Transfer Register (PRTR) from the two refineries. Since 2019, the emission factor is kept constant. Therefore, emission factors in 1B2a<sub>iv</sub> are adapted to reach the total NMVOC emissions as reported in the Swiss Pollutant Release and Transfer Register. Between the years 1995 and 2007, the emission factors are interpolated linearly. The ratio between CH<sub>4</sub> and NMVOC stays at 1:10 for all the years.

The emission factors for SO<sub>x</sub> emissions from Claus units in refineries are country-specific and based on measurements and data from industry and expert estimates.

For the distribution of oil products in gasoline stations (1B2a<sub>v</sub>): The emission factors of NMVOC from 1B2a<sub>v</sub> are country-specific and based on a bottom-up model (Luftkollektiv 2024) that sums up the different processes generating fugitive gasoline emissions, i.e. transport to the gasoline station, unloading to the tank at the gasoline station, opening the manhole, pressure equalisation, vapour recovery and finally refuelling of the vehicles. The bottom-up model developed was applied to the state of the years 1990, 2002, 2010 and 2030 and the respective emission factors were determined. In between, the emission factors are linearly interpolated.

For the distribution of oil products in gasoline and jet kerosene storage tank facilities (1B2a<sub>v</sub>): Emission factors for storage tanks are estimated by Carbura based on two studies, one for gasoline storage tanks (Carbura 2022) and one for jet kerosene storage tanks (Carbura 2023). NMVOC emissions were estimated on the basis of information on tank volumes, tank equipment, throughput quantities and maintenance (Carbura 2024). For gasoline storage tanks, detailed information is available for all inventory years. For jet kerosene storage tanks,

historical data is available since 2000. Due to lack of data for earlier years, the emission factor for 1990 is the same as the one calculated for 2000 and kept constant in between. It should be noted that the storage and handling of jet kerosene causes significantly lower NMVOC emissions than gasoline due to the significantly lower vapour pressure.

Table 3-112 Emission factors for fugitive emissions of source category 1B2a Oil in 2023.

1B2a Fugitive emissions attributed to oil	Per amount of	Unit	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
1B2ai Exploration		g/t	NO	NO	NO	NO	NO	NO	NO
1B2aii Production		g/t	NO	NO	NO	NO	NO	NO	NO
1B2aiii Transport of crude oil by pipelines	Number of refineries	g/No.	NA	1'000	NA	NA	10'000	NA	NA
1B2aiv Refining/Storage of crude oil	Crude oil imported	g/t	NA	7	NA	NA	75	5	NA
1B2av Distribution of oil products: Gasoline storage tank	Gasoline sold	g/GJ	NA	NA	NA	NA	1.1	NA	NA
1B2av Distribution of oil products: Gasoline station	Gasoline sold	g/GJ	NA	NA	NA	NA	22	NA	NA
1B2av Distribution of oil products: Kerosene storage tank	Jet kerosene imported	g/GJ	NA	NA	NA	NA	0.073	NA	NA

### Activity data (1B2a)

As crude oil is transported per pipeline to the refineries in Switzerland, activity data for oil transport (1B2aiii) reflects the number of pipelines, which is equal to the number of refineries. Activity data for oil refining and storage (1B2aiv) is the amount of crude oil imported. This data is provided by Avenergy Suisse (Avenergy 2024) in their annual statistics and also reported in the Swiss overall energy statistics (SFOE 2024).

For oil distribution from storage tanks and gasoline stations (1B2av), gasoline sales based on the Swiss overall energy statistics (SFOE 2024), corrected for consumption of Liechtenstein, are used as activity data.

Table 3-113 Activity data for fugitive emissions from 1B2a Oil.

1B2a Oil products	Amount of	Unit	1990	1995	2000	2005	2010						
1B2aiii Transport of crude oil by pipelines	Number of refineries	No.	2	2	2	2	2						
1B2aiv Refining/Storage	Crude oil imported	kt	3'127	4'657	4'649	4'877	4'546						
1B2av Gasoline distribution	Gasoline sold	TJ	156'516	151'672	168'353	152'182	134'129						
1B2av Jet kerosene distribution	Jet kerosene imported and produced	TJ	48'160	54'739	68'310	51'004	61'815						

1B2a Oil products	Amount of	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs. 1990 (%)
1B2aiii Transport of crude oil by pipelines	Number of refineries	No.	2	1	1	1	1	1	1	1	1	1	-50%
1B2aiv Refining/Storage	Crude oil imported	kt	4'975	2'836	3'006	2'889	3'076	2'789	2'857	2'339	3'102	2'868	-8%
1B2av Gasoline distribution	Gasoline sold	TJ	113'956	105'664	102'367	99'223	97'654	96'850	85'769	87'628	85'110	87'891	-44%
1B2av Jet kerosene distribution	Jet kerosene imported and produced	TJ	68'219	70'857	73'853	75'027	80'262	83'698	34'816	31'736	54'264	72'472	50%

### 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 1B2a results in medium confidence in the emissions estimate (see Table 1-8).

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. 1.5 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

There were no recalculations implemented in the latest submission.

For recalculations relating to indirect CO<sub>2</sub> emissions resulting from NMVOC emissions, please refer to recalculations reported in chp. 3 on Energy in Switzerland's Informative Inventory Report 2025 (FOEN 2025b).

### 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

In Switzerland, natural gas exploration activities (1B2bi) and natural gas processing activities (1B2biii) are not occurring. Emissions from natural gas production (1B2bii) only occurred during the years of operation of the only production plant in Switzerland from 1985 to 1994. The dominating emissions in source category 1B2b stem from natural gas transmission (1B2biv) and distribution (1B2bv). Emissions directly related to accidents affecting the gas pipeline system would be reported under source category 1B2bvi Other, but so far, no events with direct emissions have occurred (mudflows close to Guttannen in the year 2010 did not lead to any direct emissions, but to controlled venting of limited sections of the transit pipeline in the years 2010 and 2011; the respective emissions are therefore reported under source category 1B2biv Transmission).

Table 3-114 Specification of source category fugitive emissions from 1B2b Natural gas in Switzerland.

1B2	Source category	Specification
1B2bii	Fugitive emissions attributed to natural gas: Production	Emissions from natural gas production (1990-1994 only).
1B2biv	Fugitive emissions attributed to natural gas: Transmission	Emissions from natural gas transmission.
1B2bv	Fugitive emissions attributed to natural gas: Distribution	Emissions from natural gas distribution.

### 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 attributed to 1B2bii Production and a Tier 2 approach for fugitive emissions attributed to 1B2biv Transmission as well as 1B2bv Distribution. As source category 1B2 is not a key category (see Table 3-110) and as the contribution from 1B2bii Production is small, the use of a Tier 1 method for this source category is justified.

An important basis of the methodology to estimate fugitive emissions from natural gas transmission (1B2biv) and distribution (1B2bv) are the country-specific gas properties which are continuously measured at the various import stations. The Swiss Gas and Water Industry

Association (SGWA) reports annually weighted values for densities and net calorific values as well as concentrations of CO<sub>2</sub>, CH<sub>4</sub> and NMVOC (see chp. 3.2.4.2 for more details and references). The same country-specific properties are used for fugitive emissions from natural gas production (1B2bii) as there are no other data available.

Those fugitive emissions from natural gas production (1B2bii) are calculated based on annual production data and default emission factors (IPCC Tier 1 approach), taking into account the country-specific gas properties as mentioned above. There has been no natural gas production in Switzerland since 1994, due to the closure of the only production site at that time.

For transmission (1B2biv) and distribution (1B2bv), a country-specific methodology – established by Quantis (2014) and fully revised by the Swiss Gas and Water Industry Association (SGWA 2023a) – is applied to derive country-specific losses for each emission source. The methodology assesses losses from transmission and distribution pipelines, including from the transit pipeline and its single compressor station. Calculations of losses from the gas network are based on the length and material of the gas pipelines, distinguishing various pressure levels. Also comprised are leakages from gas devices and network components (e.g. control units and gas meters as well as appliances in households, industry and natural gas fuelling stations), pipeline fittings, small-scale damages and maintenance work. To estimate emissions resulting from the permanent leakiness of the different gas appliances, the number and kind of end users and connected gas appliances are considered. The methodology by SGWA (2023a) provides the amount of gas lost in cubic meters per year which serves – after conversion to energy units (GJ per year) based on the country-specific net calorific values – as the activity data. Finally, emissions of CO<sub>2</sub>, CH<sub>4</sub> and NMVOC are calculated by multiplying the losses (activity data) with the country-specific composition of the gas (emission factors).

Indirect CO<sub>2</sub> emissions resulting from CH<sub>4</sub> and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9. As no CO emissions occur in source category 1B2b, from this source category no indirect CO<sub>2</sub> emissions from CO are included in CRT Table6 as documented in chp. 9.

### Emission factors (1B2b)

For natural gas production (1B2bii), CO<sub>2</sub>, CH<sub>4</sub> and NMVOC default emission factors are taken from the 2006 IPCC Guidelines (IPCC 2006, see EMIS 2025/1B2b Gasproduktion). The default emission factors are provided in grams per cubic meter of gas produced and – to match the units of the activity data – are converted to grams per energy unit (GJ) produced based on the country-specific gas properties as mentioned above.

For natural gas transmission (1B2biv) and distribution (1B2bv), the emission factors represent the composition of the gas lost and are based on the country-specific gas properties as mentioned above.

Table 3-115 Emission factors for fugitive emissions of source category 1B2b Natural gas in 2023 (related to the amount of gas produced for 1B2bii and to the amount of gas lost for 1B2biv and 1B2bv).

1B2b Natural gas	Per amount of	Unit	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
1B2bii Production	Natural gas	g/GJ	NO	NO	NO	NO	NO	NO	NO
1B2biv Transmission, losses	Natural gas	g/GJ	264	17'981	NA	NA	2'145	NA	NA
1B2bv Distribution, losses	Natural gas	g/GJ	264	17'981	NA	NA	2'145	NA	NA

## Activity data (1B2b)

For natural gas production (1B2bii), activity data are the actual gas production data for the years 1990–1994 (SFOE 2024).

For gas transmission (1B2biv) and distribution (1B2bv), the activity data represent the amount of natural gas lost from the gas network. All the details are documented in SGWA (2024a) and EMIS 2025/1B2b Diffuse Emissionen.

The key points within 1B2biv Transmission are as follows:

- **Compressor Station:** Since 2016 the operator of the transit pipeline provides annual emissions data for specific areas (such as starting gas for turbines, compressor depressurization, control valves, gas meters, etc.). For the years before 2016 and for areas not covered by the operator's data, emission factors from Battelle (1989) are used. The calculations are performed by scaling with the actual compressor power (yearly average).
- **Transit pipeline:** Since 2016, the operator of the transit pipeline provides annual emissions data for losses from operation and maintenance of the transit pipeline. Before 2016, emission factors from Battelle (1989) are used. For pressure reducing and metering stations, emission factors from DVGW (2022) are applied. The calculations are performed by scaling with the pipeline length (gas statistics from SGWA).
- **Components of the transport network (excluding the transit pipeline):** Emission factors from DVGW (2022) for 2020 are converted to the structures of the Swiss gas network. The calculations are performed by scaling with the pipeline length (gas statistics from SGWA).
- **Network Maintenance of the transport network (excluding the transit pipeline):** For 1990, emission factors from Battelle (1989) are used with linear interpolation to the emissions factors for 2020 based on DVGW (2022). The calculations are performed by scaling with the pipeline length (without the share of the transit pipeline; gas statistics from SGWA).

The key points within 1B2bv Distribution are as follows:

- **Leakage:** The methodology is based on the actual number of leaks per kilometre for the years since 2017 (gas statistics from SGWA). For 1990, the number of leaks is derived from Battelle (1989). The various materials and pressure levels of the pipelines are distinguished. The losses per leak are based on measurements from DVGW (2022). The calculations are performed by scaling with the pipeline length (gas statistics from SGWA).
- **Damage by external influences (third-party damage):** The methodology is based on actual third-party damage per kilometre since 2017 (gas statistics from SGWA). For 1990, the amount of third-party damage per kilometre is derived from Battelle (1989). The losses per damage are determined based on DVGW (2022). The calculations are performed by scaling with the pipeline length (gas statistics from SGWA).
- **Permeation:** Permeation through polyethylene pipelines is estimated based on DVGW (2022), while permeation is considered to be negligible for other materials. The calculations are performed by scaling with the pipeline length (gas statistics from SGWA).
- **Components:** Emission factors from Battelle (1994) for 1990 and DVGW (2022) for 2020 are considered. The calculations are performed by scaling with the pipeline length (gas statistics from SGWA).
- **Network Maintenance:** Emission factors from Battelle (1994) for 1990 and DVGW (2022) for 2020 are considered. The calculations are performed by scaling with the pipeline length (gas statistics from SGWA).
- **Industrial Networks:** Emission factors are formed based on Battelle (1994), referring to the gas quantity used by industrial plants. The calculations are performed by scaling with



the gas quantity used by industrial plants (until 2019 based on statistics from the Swiss Gas Industry Association, thereafter estimated based on the total gas quantity).

- **House Installations:** Emission factors are based on usability tests – for 1990 based on Battelle (1994), for 2020 based on measurement campaigns by the network operators. The calculations are performed by scaling with the number of end users (gas statistics from SGWA).
- **Gas Stoves:** Emission factors according to Battelle (1994) are used. The number of gas stoves is estimated based on the number of end users (as determined by a survey by SGWA).
- **Gas Stations:** Emission factors according to Battelle (1994) are used.
- **Liquefied natural gas:** Calculations are based on the number of transfer operations and the dead volume of the couplings. Additional losses are estimated to amount to one per cent of the total liquefied natural gas quantity used.

Table 3-116 Activity data (amount of gas produced for 1B2bii and amount of gas lost for 1B2biv and 1B2bv) for fugitive emissions from 1B2b Natural gas.

1B2b Natural Gas	Amount of	Unit	1990	1995	2000	2005	2010
1B2bii Production	Natural gas	GJ	130'000	NO	NO	NO	NO
1B2biv Transmission, losses	Natural gas	GJ	11'975	13'072	13'620	13'324	47'990
1B2bv Distribution, losses	Natural gas	GJ	161'643	168'601	155'978	138'860	119'407

1B2b Natural Gas	Amount of	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs. 1990 (%)
1B2bii Production	Natural gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-100%
1B2biv Transmission, losses	Natural gas	GJ	12'304	11'641	10'381	18'062	11'269	11'105	14'361	7'805	8'864	7'223	-40%
1B2bv Distribution, losses	Natural gas	GJ	98'328	94'441	90'580	88'134	82'119	78'760	74'659	76'401	74'476	74'764	-54%

### 3.3.4.3. Uncertainties and time-series consistency for 1B2b

All sources in source category 1B2b are attributed to the uncertainty category medium according to Table 1-8.

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. 1.5.

As suggested by the 2006 IPCC Guidelines (IPCC 2006), the gas industry – represented by the Swiss Gas and Water Industry Association – was actively involved in the reassessment of fugitive emissions from the natural gas system, resulting in the updated methodology used since the 2024 submission (SGWA 2023a).

### 3.3.4.5. Category-specific recalculations for 1B2b

The following recalculations were implemented in the latest submission. Major recalculations which contribute significantly to the total differences in emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

- **1B2b:** The Swiss statistic of energy consumption (SFOE 2024) has newly added the amount of liquefied natural gas (LNG) used to the total amount of natural gas used for the years 2020-2022. This leads to small recalculations mainly in source categories 1A3b

Road transportation, 1A4ai Commercial/institutional (stationary) and 1B2b Natural gas losses.

### 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 (1B2ci Flaring). Since 2015, there is only one refinery in operation. In addition, CO<sub>2</sub> emissions from H<sub>2</sub> production in one of the two refineries are also reported under 1B2c.

Table 3-117 Specification of source category 1B2c Venting and flaring in Switzerland.

1B2	Source category	Specification
1B2cii1	Fugitive emissions attributed to venting and flaring: Flaring oil	The combustion of excess gas at the oil refinery (flaring) only.
1B2cii1	Fugitive emissions attributed to venting and flaring: H <sub>2</sub> production	Emissions from H <sub>2</sub> production (butane and natural gas).
1B2cii2	Fugitive emissions attributed to venting and flaring: Flaring gas	Emissions from gas production (1990-1994 only).

### 3.3.5.2. Methodological issues for 1B2c

#### Methodology (1B2c)

For source category 1B2ci Flaring, Oil, emissions of CO<sub>2</sub> as well as CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub>, CO and NMVOC are considered. According to the decision tree for crude oil transport, refining and upgrading, Switzerland follows a Tier 3 method for CO<sub>2</sub> emissions and a Tier 2 method for all further pollutants attributed to 1B2ci 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 CO<sub>2</sub> emission calculations, country-specific CO<sub>2</sub> emission factors and activity data are available from the refining industry.

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 1B2cii Flaring, Gas, emissions of CO<sub>2</sub> as well as CH<sub>4</sub>, N<sub>2</sub>O and NMVOC are considered.

One of the refining plants produces H<sub>2</sub>. Until 2017, butane was used for the production of H<sub>2</sub>, leading to process emissions of CO<sub>2</sub>. During 2017, additionally to butane, the refinery started to use natural gas in its hydrogen production unit. Emissions are estimated based on plant-specific data (Tier 3 method).



Since the CO<sub>2</sub> emission factors assume an oxidation of 100 %, no indirect emissions need to be accounted for. Therefore, no indirect emissions from this source category are included in CRT Table6 as documented in chp. 9.

### Emission factors (1B2c)

Emission factors concerning flaring of refinery gas during the refining process are documented in the internal emission database documentation (EMIS 2025/1B2c Raffinerie Abfackelung). The emission factor for CO<sub>2</sub> is based on a study from Frischknecht et al. (1996), the emission factor for N<sub>2</sub>O is based on the expert estimate in the German NIR 2019 (UBA 2019), and those for the other greenhouse gases and precursors base on a study from USEPA (1995b) and data from the refining industry.

Since 2005 (with the exception of 2012), the refining industry provides annual data on the CO<sub>2</sub> emissions from flaring under the Federal Act on the Reduction of CO<sub>2</sub> Emissions (Swiss Confederation 2011) based on daily measurements of CO<sub>2</sub> emission factors of the flared gases. From these data, annual emission factors are derived. Since 2005, the evolution of the other emission factors (CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub>, CO and NMVOC) is assumed to vary proportionally to the CO<sub>2</sub> 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.

CO<sub>2</sub> emission factors for H<sub>2</sub> production are confidential. Data are available to reviewers on request.

Table 3-118 Emission factors for 1B2c Venting and flaring in 2023.

1B2c Fugitive emissions attributed to venting and flaring	Per amount of	Unit	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	NMVOC	SO <sub>2</sub>	CO
1B2ci H2 production refinery	Butane	g/GJ	NO	NO	NO	NO	NO	NO	NO
1B2ci H2 production refinery	Natural gas	g/GJ	C	NA	NA	NA	NA	NA	NA
1B2cii1 Flaring Oil	Crude oil imported	g/t	C	C	C	C	C	C	C
1B2cii2 Flaring gas	Natural gas produced	g/GJ	NO	NO	NO	NO	NO	NO	NO

### Activity data (1B2c)

Before 2005, the amount of flared gas during the refining process is assumed to be proportional to the amount of crude oil processed in the refineries. Avenergy Suisse (formerly the Swiss petroleum association EV) provides data on the use of crude oil on an annual basis (Avenergy 2024). 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<sub>2</sub> production in one of the refining plants, annual data on butane and natural gas consumption are provided by the industry since 2005, when the H<sub>2</sub> production unit was installed. Data are confidential and they are available to reviewers on request.

Table 3-119 Activity data for 1B2c Venting/flaring.

1B2c Venting and flaring	Amount of	Unit	1990	1995	2000	2005	2010
1B2ci: H2 production in refinery	Butane and natural gas	GJ	NO	NO	NO	C	C
1B2cii1 Flaring Oil	Crude oil imported	kt	C	C	C	C	C
1B2cii2 Flaring Gas	Natural gas produced	GJ	130'000	NO	NO	NO	NO

1B2c Venting and flaring	Amount of	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1B2cii1 Flaring Oil	Crude oil imported	kt	C	C	C	C	C	C	C	C	C	C
1B2ci: H2 production in refinery	Butane and natural gas	GJ	C	C	C	C	C	C	C	C	C	C
1B2cii2 Flaring Gas	Natural gas produced	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

### 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 1-8).

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. 1.5 and partly also in chp. 3.2.4.8. No category-specific QA/QC activities were undertaken for venting and flaring (1B2c).

### 3.3.5.5. Category-specific recalculations for 1B2c

There were no recalculations implemented in the latest submission.

Major recalculations which contribute significantly to the total differences in emissions of sector 1 Energy between the latest and the previous submissions are presented also in chp. 10.1.2.1.

### 3.3.5.6. Category-specific planned improvements for 1B2c

No category-specific improvements are planned.

## 3.4. Source category 1C – CO<sub>2</sub> transport and storage

CO<sub>2</sub> transport and storage is not occurring in Switzerland.

## 4. Industrial processes and product use (IPPU)

Responsibilities for sector Industrial processes and product use (IPPU)	
Overall responsibility	Sabine Schenker (FOEN)
Method updates & authors	Sabine Schenker (FOEN), Cornelia Stettler (Carbotech; F-gases)
EMIS database operation	Myriam Guillevic (FOEN; F-gases), Sabine Schenker (FOEN)
Annual updates (NID text, tables, figures)	Dominik Eggli (Meteotest), Fabio Fasel (Meteotest), Beat Rihm (Meteotest), Cornelia Stettler (Carbotech; F-gases)
Quality control (NID annual updates)	Gavin Roberts (Carbotech; F-gases), Regine Röthlisberger (FOEN), Adrian Schilt (FOEN), Felix Weber (INFRAS)
Internal review	Stefan Reimann (Empa; F-gases), Regine Röthlisberger (FOEN), Sabine Schenker (FOEN), Adrian Schilt (FOEN; F-gases), Loïc Schmidely (FOEN, SF6)

### 4.1. Overview

This chapter provides information on the estimation of the GHG emissions from sector 2 Industrial processes and product use (Figure 4-1). 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<sub>2</sub> 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 energy sector (waste derived fuels, chp. 3.2.6).

Indirect CO<sub>2</sub> emissions resulting from fossil CH<sub>4</sub>, CO and NMVOC emissions as well as indirect N<sub>2</sub>O emissions resulting from NO<sub>x</sub> and NH<sub>3</sub> emissions are included in CRT Table6 as documented in chp. 9. However, indirect CO<sub>2</sub> emissions are taken into account when calculating the key categories of sector 2 (see Figure 4-4). Since the CO<sub>2</sub> 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 2B8b and 2C1) are not accounted for in the calculation of the indirect CO<sub>2</sub>

emissions. Biogenic CO and NMVOC emissions occur in source category 2H2 Food and beverages and 2G4 tobacco consumption and are not reported as indirect CO<sub>2</sub> emissions.

For several industrial processes within source categories 2A Mineral industry, 2B Chemical industry, 2C Metal industry and 2G Other product manufacture and use, data and information on emission factors and activity data are classified as confidential (C), because they refer to a single enterprise. For reviewers, there is an additional version of chp. 4 Industrial processes and product use (IPPU) available, including all confidential data and information.

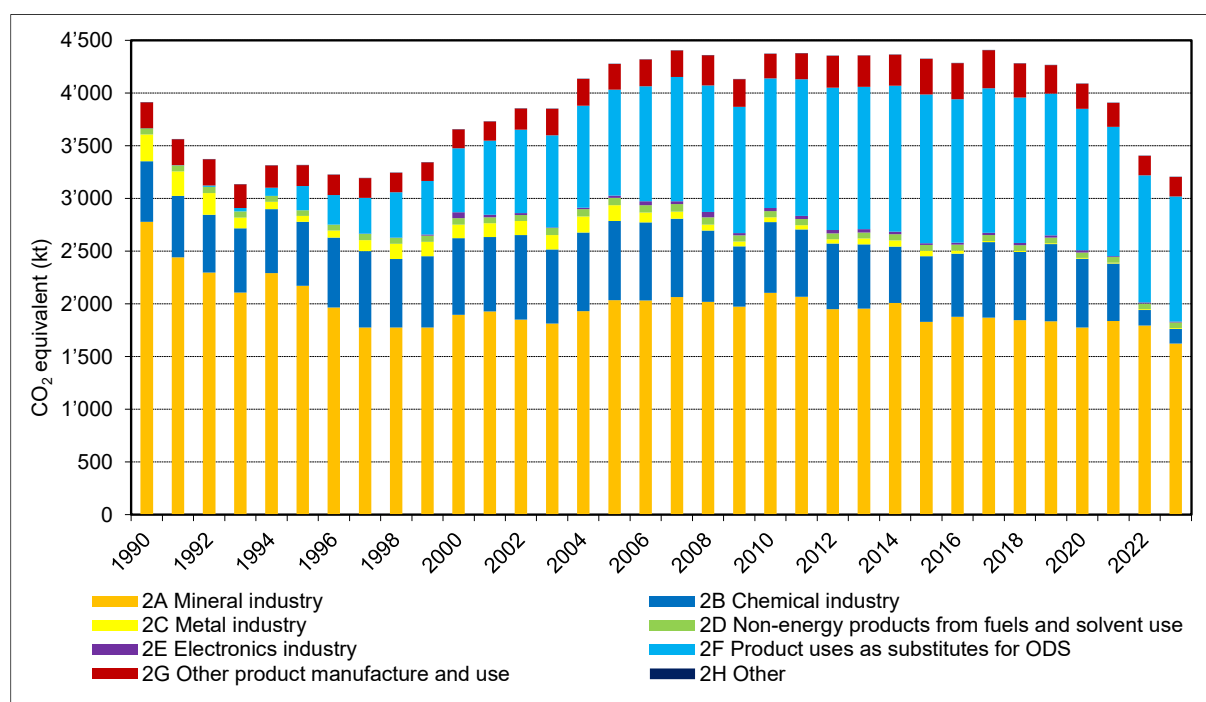


Figure 4-1 Switzerland's greenhouse gas emissions of sector 2 Industrial processes and product use.

2A Mineral industry remains the dominant source of sector 2, accounting for around 50 % of the GHG emissions in 2023 although absolute emissions have decreased since 1990. 2B Chemical industry shows no clear trend until 2021, but a strong decline in 2022, due to the installation of a catalytic converter in the niacin production plant late in the year 2021. Since 2022, it accounts for a small share only. 2C Metal industry shows a strong decreasing trend and accounts only for a negligibly small share in 2023. 2D Non-energy products have also only a minor contribution in 2023.

2F Product uses as substitutes for ozone depleting substances (ODSs) is of considerable importance: The emissions have increased from 1990 to 2015 due to the replacement of CFCs and other ODSs by HFCs in many technical applications. However, the emissions are gradually decreasing over the past years due to restrictions of HFC use in mobile air-conditioning and stationary refrigeration. They account for one third of total GHG emissions in sector 2 in 2023. 2G Other product manufacture and use shows, after an increase between 2000 and 2017, a decrease in emissions since then. 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<sub>2</sub> and F-gases in 2023 whereas N<sub>2</sub>O

and CH<sub>4</sub> have only minor contributions. 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 CO<sub>2</sub> equivalent (kt).

Gas	1990	1995	2000	2005	2010
	CO <sub>2</sub> equivalent (kt)				
CO <sub>2</sub>	3'122	2'396	2'188	2'350	2'346
CH <sub>4</sub>	4.0	6.6	5.8	7.0	7.8
N <sub>2</sub> O	541	575	646	667	572
F-gases	246	339	817	1'253	1'447
Sum	3'913	3'318	3'656	4'277	4'373

Gas	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	CO <sub>2</sub> equivalent (kt)									
CO <sub>2</sub>	2'234	2'065	2'128	2'103	2'089	2'075	2'001	2'081	2'028	1'849
CH <sub>4</sub>	6.4	6.3	7.9	7.9	8.4	7.8	7.2	6.8	7.7	5.1
N <sub>2</sub> O	446	517	477	613	531	617	545	425	38	37
F-gases	1'680	1'736	1'672	1'684	1'653	1'565	1'537	1'394	1'331	1'313
Sum	4'367	4'324	4'285	4'409	4'281	4'265	4'090	3'907	3'405	3'204

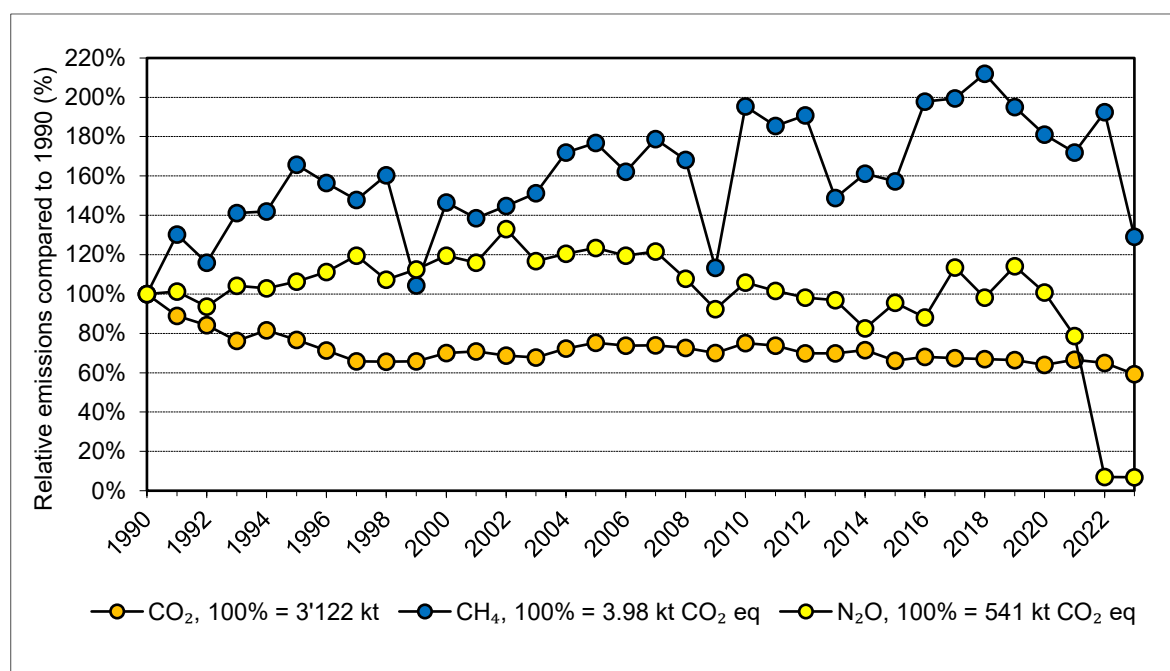


Figure 4-2 Relative trends of the greenhouse gas emissions (without F-gases, see Figure 4-3) of sector 2 Industrial processes and product use. The base year 1990 represents 100 %.

Figure 4-2 shows that the emissions of CO<sub>2</sub> decreased between 1990 and 1997 and since then, they have remained at a constant level. Emissions of N<sub>2</sub>O have increased slowly between 1990 and 2002 and decreased afterwards until 2014. Since 2014 there has been an increasing trend again with even higher emissions in 2017, 2019 and 2020 than in 1990. Clearly visible is the drop in N<sub>2</sub>O emissions starting in 2021 as explained above. Emissions of CH<sub>4</sub> have an increasing trend with considerable interannual fluctuations. However, absolute emissions are very small compared to CO<sub>2</sub> and N<sub>2</sub>O.

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 smelting process of aluminium production (chp. 4.4.2.2) and from the use of SF<sub>6</sub> in electrical equipment and soundproof windows (chp. 4.8.2.1 and chp. 4.8.2.2). The increase between 1995 and 2012 is due to the increasing product uses of HFCs as substitutes for ODS (chp.4.7) in refrigeration and air conditioning. Since 2012, total F-gas emissions have remained at a constant level with a visible drop after 2018. The main driver are the restrictions of HFC use in mobile air-conditioning and the progressing limitation of HFCs with a high GWP for stationary refrigeration. The most relevant and main source of F-gases emissions in 2023 is the use of HFC in refrigeration and air conditioning.

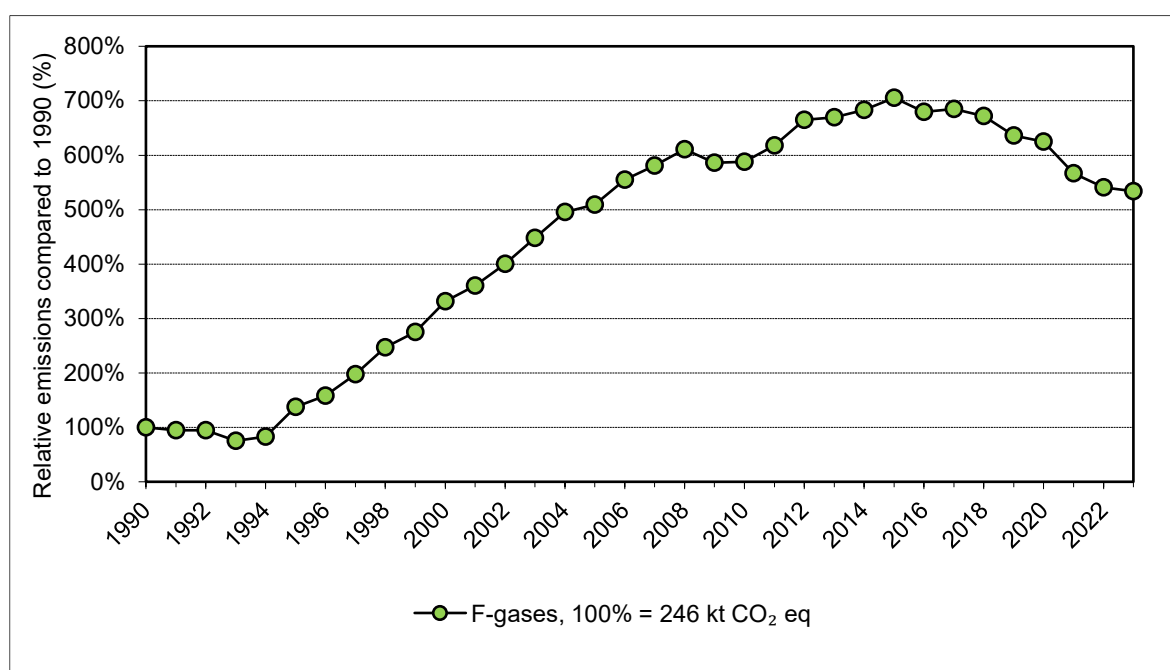


Figure 4-3 Relative trends in emissions of F-gases in sector 2 Industrial processes and product use. The base year 1990 represents 100 %.

There are a total of seven key categories identified in sector 2 IPPU, thereof six key categories with direct greenhouse gas emissions and one category with indirect CO<sub>2</sub> emissions (see Figure 4-4).

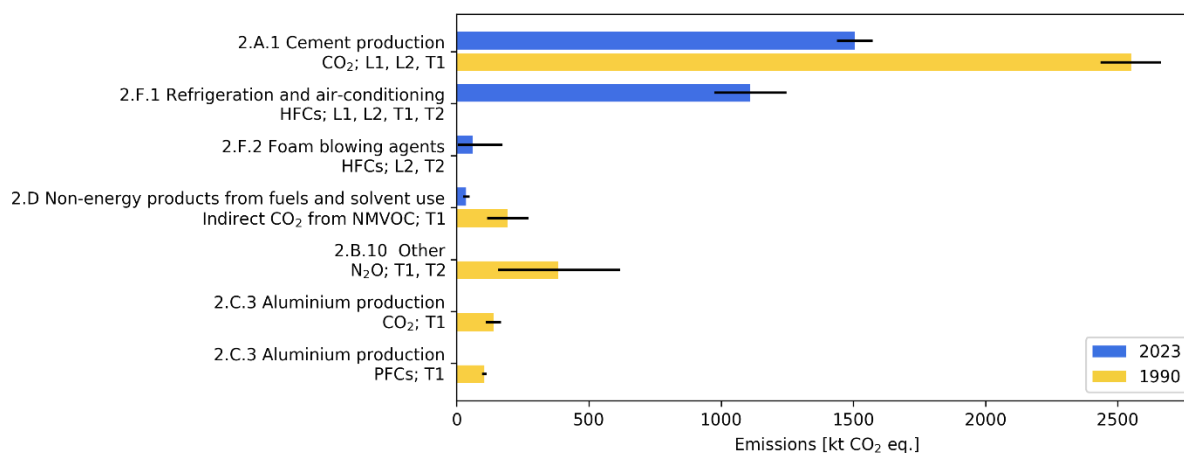


Figure 4-4 Key categories in the Swiss GHG inventory from sector 2 IPPU, including indirect CO<sub>2</sub> emissions, determined by the key category analyses, approaches 1 and 2. Categories are set out in order of decreasing emissions in 2023. L1: key category according to approach 1 level in 2023; L2: same for approach 2; T1: key category according to approach 1 trend 1990–2023; T2: same for approach 2. Black uncertainty bars represent the narrowest 95 % confidence interval obtained by Monte Carlo simulations (see chp. 1.6 for details).

## 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 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
2.A.1	Cement production	CO <sub>2</sub>	L1, L2, T1

Table 4-3 Specification of source category 2A Mineral industry.

2A	Source category	Specification
2A1	Cement production	Geogenic CO <sub>2</sub> emissions from calcination process in cement production
2A2	Lime production	Geogenic CO <sub>2</sub> emissions from calcination process in lime production
2A3	Glass production	Geogenic CO <sub>2</sub> emissions from production of container and tableware glass, and glass wool
2A4	Other process uses of carbonates	Geogenic CO <sub>2</sub> emissions from production of fine ceramics, bricks and tiles and rockwool; Geogenic CO <sub>2</sub> emissions from use of carbonates for sulphur oxide removal in municipal solid waste incineration plants, a combined heat and power plant that burns all classes of wood waste and cellulose production (ceased in 2008); Geogenic CO <sub>2</sub> emissions from use of sodium bicarbonate; Emissions of CO <sub>2</sub> , NO <sub>x</sub> , CO, NMVOC and SO <sub>2</sub> from blasting operations in cement, lime and plaster production

### 4.2.2. Methodological issues

#### 4.2.2.1. Cement production (2A1)

In Switzerland, there are six plants producing clinker and cement. The Swiss plants are rather small and do not exceed a capacity of 3'000 tonnes of clinker per day. All of them use modern dry process technology.

Emissions of geogenic CO<sub>2</sub> 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<sub>3</sub>), is heated (calcined) to produce lime (CaO) and CO<sub>2</sub> as by-product. The CaO reacts subsequently with minerals in the raw materials and yields clinker. During this reaction step no further CO<sub>2</sub> 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<sub>2</sub> and precursor greenhouse gases such as NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub>. These emissions are reported under source category 2A4d Other due to the structure of the CRT tables, which do not allow emissions of precursors (except of SO<sub>2</sub>) under source category 2A1 Cement production.



## Methodology

### Calcination process

The geogenic CO<sub>2</sub> emissions from the calcination process in cement production are determined in the years 1990–2004 and 2007 by a Tier 2 method and in the years 2005, 2006 and from 2008 onwards by a Tier 3 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 mostly 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.

## Emission factors

### Calcination process

The emission factor of CO<sub>2</sub> 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 emission factor is based on plant-specific measurements. For the time period from 1990–2021, the emission factor of the raw material is derived from measurements of CaO and MgO content of clinker in 2005, 2006, 2008–2011. The emissions from CKD not recycled to the kiln are estimated based on plant-specific data for 2013–2021. From 2022 onwards, the cement plants are required to provide detailed data to the ETS, including data on carbon content of the raw meal (carbonate and non-carbonate C) and CKD, which is used to calculate plant-specific emission factors.

While the plant-specific emission factors are assumed to be constant from 1990–2021, the share of each individual plant varies slightly over the years, so that the national average emission factor also shows some variations (see information below on activity data). However, variations are relatively small and do not exceed 0.4 %.

Table 4-4 CO<sub>2</sub> emission factor for calcination in 2A1 Cement Production 1990 to 2023.

2A1 Cement production	Unit	1990	1995	2000	2005	2010
Calcination, CO <sub>2</sub>	kg/t clink	530	530	530	530	530

2A1 Cement production	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Calcination, CO <sub>2</sub>	kg/t clink	530	531	530	530	530	531	530	530	528	528

## Activity data

Since 1990, data on annual clinker production are provided by the industry association cemsuisse as documented in the EMIS database (EMIS 2025/2A1\_Zementwerke Rohmaterial). In order to use plant-specific emission factors, also activity data are required at plant level. For 2005, 2006, 2008–2011 and from 2013 onwards, clinker production data is available for each individual plant based on annual monitoring reports from the Swiss Emissions Trading Scheme (ETS). The average share of 2005 and 2006 is used to

extrapolate the plant-specific production data from 1990–2004 and for 2007. The average of 2011 and 2013 is used to interpolate plant-specific production data for 2012.

Table 4-5 Activity data of clinker production.

2A1 Cement production	Unit	1990	1995	2000	2005	2010
Clinker production	kt	4'808	3'706	3'214	3'442	3'642

2A1 Cement production	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Clinker production	kt	3'502	3'195	3'296	3'279	3'239	3'227	3'129	3'227	3'155	2'855

#### 4.2.2.2. Lime production (2A2)

During the production of lime, calcium carbonate ( $\text{CaCO}_3$ ) is heated (calcined) yielding burnt lime ( $\text{CaO}$ ) and  $\text{CO}_2$  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  $\text{CO}_2$  is re-captured in the sugar production process and thus no  $\text{CO}_2$  emissions occur.

Blasting operations in quarries are another source of emissions for both  $\text{CO}_2$  and precursor emissions such as  $\text{NO}_x$ ,  $\text{CO}$ , NMVOC and  $\text{SO}_2$ . These emissions are reported under source category 2A4d Other due to the structure of the CRT tables, which do not allow emissions of precursors under source category 2A2 Lime production.

### Methodology

#### Calcination process

Since 2013, the geogenic  $\text{CO}_2$  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 the IPCC Guidelines (IPCC 2006, vol. 3, chp. 2.2 Lime production). Between 1990 and 2012, a Tier 2 method is applied.

### Emission factors

#### Calcination process

The emission factor for  $\text{CO}_2$  from calcination of limestone depends both on the purity of the limestone and the degree of calcination (i.e. amount of  $\text{CO}_2$  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 2025/2A2 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 4-6 $\text{CO}_2$ emission factor for calcination process in lime production in kg/t lime for 1990–2023 are documented in the confidential NID, which is available to reviewers on request.
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## Activity data

Activity data on annual lime production are provided by the only existing plant in Switzerland, as documented in the EMIS database (EMIS 2025/2A2 Kalkproduktion, Rohmaterial and EMIS 2025/2A2 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 4-7 In the confidential NID, 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<sub>2</sub> 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<sub>2</sub> emissions from glass production, a Tier 2 method according to the decision tree Fig. 2.3 of IPCC 2006 (vol. 3, chp. 2.4 Glass production) is used. For glass production in Switzerland this results in the following formula:

$$\text{CO}_2 \text{ Emissions} = M_{\text{Glass type}} \cdot EF_{\text{Glass type}} \cdot (1 - \text{cullet ratio})$$

The cullet ratio describes the share of recycled glass material which is used in the production. The melting of cullet causes no geogenic CO<sub>2</sub> emissions.

From 2005 onwards, the geogenic CO<sub>2</sub> emissions from 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.

For the two plants producing glass wool, the amount of soda ash used as raw material is available from 2013 and 2021 onwards, respectively. Accordingly, the geogenic CO<sub>2</sub> emission factor corresponds to a Tier 3 method from 2021 onwards. For the years 2013 to 2020, the emission factor is thus based on a Tier 3 method of one plant and a Tier 2 method of the other one.

## Emission factors

The emission factors for glass production in Switzerland are taken from IPCC 2006 (vol.3, chp. 2.4 Glass production, Table 2.6). For the production of container glass (1990–2004), tableware glass and glass wool (1990–2020) 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<sub>2</sub> 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. Whereas for the two plants producing glass wool, the amounts of soda ash are available from ETS monitoring reports from 2013 and 2021 onwards, respectively.

Table 4-8 Geogenic CO<sub>2</sub> emission factor 1990–2023 for glass production in g/t glass and g/t carbonate containing raw material (IPCC 2006).

<b>2A3 Glass production</b>	<b>Unit</b>	<b>CO<sub>2</sub> geogenic</b>	
Glass (speciality tableware)	g/t	100'000	
		<b>1990–2020</b>	<b>2013–2023</b>
Glass wool (fibre glass insulation)	g/t	250'000	
Soda use	g/t soda		414'920
		<b>1990–2004</b>	<b>2005–2023</b>
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 4-9 In the confidential NID, a comparison of implied CO<sub>2</sub> 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.

Figure 4-5 In the confidential NID, a comparison of Tier 2 and Tier 3 methods for deriving emission factors of geogenic CO<sub>2</sub> from 2A3 Container glass production is provided for the years between 2005 and 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 (EMIS 2025/2A3 Glaswolle Produktion Rohprodukt).

Activity data of tableware and container glass production are based on data from Swiss glass producers (EMIS 2025/2A3 Hohlglas Produktion, EMIS 2025/2A3 Glas übrige Produktion). For container glass, they are based on ETS monitoring reports from 2005 onward.

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.

Table 4-10 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	2010						
Container glass												
Production	kt	C	C	C	C	C						
Cullet ratio	%	C	C	C	NA	NA						
Soda use	kt	NA	NA	NA	C	C						
Dolomite use	kt	NA	NA	NA	C	C						
Limestone use	kt	NA	NA	NA	C	C						
Glass (speciality tableware)												
Production	kt	C	C	C	C	C						
Cullet ratio	%	C	C	C	C	C						
Glass wool												
Production	kt	24	24	31	37	36						
Cullet ratio	%	21	45	69	65	71						
Soda use	kt	NA	NA	NA	NA	NA						
2A3 Glass production	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
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	32	31	32	36	40	47	40	47	45	37	
Cullet ratio	%	C	C	C	C	C	C	C	NA	NA	NA	
Soda use	kt	C	C	C	C	C	C	C	2.7	2.5	1.6	

#### 4.2.2.4. Other process uses of carbonates (2A4)

Source category 2A4 Other process uses of carbonates comprises geogenic CO<sub>2</sub> emissions from production of fine ceramics (2A4a), bricks and tiles (2A4a) and rock wool (2A4d), from use of carbonates for sulphur oxide removal in municipal solid waste incineration plants (2A4d) and cellulose production (ceased in 2008) (2A4d), and from use of sodium bicarbonate (2A4d) as well as emissions of CO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> from blasting operations in quarries for cement, lime and plaster production (2A4d). The limestone use in cupola furnaces of iron foundries has been reallocated from source category 2A4d to 2C1.

Indirect CO<sub>2</sub> emissions resulting from NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> emissions in this source category are included in CRT Table6 as documented 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 2025/2A4a Feinkeramik Produktion.

### Methodology

The geogenic CO<sub>2</sub> emissions from fine ceramics production are determined by a Tier 2 method according to the decision tree Fig. 2.4 of IPCC 2006 (vol. 3, chp. 2.5 Other process uses of carbonates).

For fine ceramics production in Switzerland, this results in the following formula:

$$\text{CO}_2 \text{ Emissions} = (M_{\text{Limestone}} \bullet \text{EF}_{\text{Limestone}}) + (M_{\text{Dolomite}} \bullet \text{EF}_{\text{Dolomite}}) + (M_{\text{Soda Ash}} \bullet \text{EF}_{\text{Soda Ash}})$$

### Emission factors

The CO<sub>2</sub> 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 4-11 Geogenic CO<sub>2</sub> emission factors 1990–2023 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 <sub>2</sub> geogenic								
Fine ceramics		1990–2023								
Limestone use	g/t limestone	439'710								
Dolomite use	g/t dolomite	477'320								
Soda use	g/t soda	414'920								
		1990–2012	2016	2017	2018	2019	2020	2021	2022	2023
Brick and tile production	g/t	117'000	112'000	113'000	107'000	107'000	103'000	113'000	106'000	110'000

### Activity data

Activity data for carbonate containing raw materials (i.e. limestone, dolomite and soda ash) used in the glazes of the fine ceramics production are extrapolated values based on industry data from the largest production plant in Switzerland. Detailed activity data are considered confidential. They are available to the reviewers on request.

### Brick and tile production (2A4a)

In Switzerland, there are about 15 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<sub>2</sub> 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 2025/2A4a 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<sub>2</sub> Emissions, Swiss Confederation 2011 and Ordinance for the Reduction of CO<sub>2</sub> 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 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<sub>2</sub> (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<sub>2</sub> emission factor of 117 kg CO<sub>2</sub>/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<sub>2</sub> emissions from the carbonate containing raw materials. For emission factors see Table 4-11.

#### *Activity data*

Activity data are based on production data from the Swiss association of brick and tile industry (VSZ) and are presented in Table 4-12 (EMIS 2025/2A4). Since 2011 they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).



Table 4-12 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).

<b>2A4a Ceramics</b>	<b>Unit</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>
Fine ceramics production	kt	C	C	C	C	C
Limestone use	kt	C	C	C	C	C
Dolomite use	kt	C	C	C	C	C
Soda use	kt	C	C	C	C	C
Brick and tile production	kt	1'271	1'115	959	1'086	879
<b>2A4d Other</b>						
Rock wool production	kt	C	C	C	C	C
Carbonate use in waste incineration plants	kt	0.71	0.76	0.82	0.61	NO
Limestone use in cellulose production	kt	8.5	9.4	9.3	8.3	NO
Other use of carbonates	kt	5.9	5.4	7.0	7.3	6.9
Clinker production, blasting operations	kt	4'808	3'706	3'214	3'442	3'642
Lime production, blasting operations	kt	C	C	C	C	C
Plaster production	kt	319	304	288	327	335

<b>2A4a Ceramics</b>	<b>Unit</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>
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	765	726	660	622	581	554	531	484	521	449
<b>2A4d Other</b>											
Rock wool production	kt	C	C	C	C	C	C	C	C	C	C
Carbonate use in waste incineration plants	kt	1.9	6.5	6.6	6.8	7.2	7.0	7.0	8.3	9.2	9.6
Limestone use in cellulose production	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other use of carbonates	kt	7.5	6.7	6.8	6.5	7.4	7.8	7.9	8.7	9.0	10.0
Clinker production, blasting operations	kt	3'502	3'195	3'296	3'279	3'239	3'227	3'129	3'227	3'155	2'855
Lime production, blasting operations	kt	C	C	C	C	C	C	C	C	C	C
Plaster production	kt	166	140	148	146	152	149	122	C	C	C

### 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-). Based on a study investigating carbonate use in industry (INFRAS 2015), it is concluded that there are no known other uses of soda ash (2A4b) in Switzerland. No soda ash is used in flue gas or wastewater treatment. It was concluded that there is no other relevant emissive soda ash use and thus, reported as not occurring in the inventory so far.

During the in-depth review in 2019, the ERT raised the question about potential other uses of soda ash in Switzerland. Based on net imports of soda ash and the known uses in the production of glass (assuming for glass wool and speciality tableware glass the same soda ash content of carbonate raw materials as for container glass) and fine ceramics, an amount of about 11.6 kt resulted for 2017, of which it is not clear whether its use is emissive or not. In a conservative estimate, this would yield a maximum of about 4.8 kt of CO<sub>2</sub> emissions (default emission factor of 0.41492 t CO<sub>2</sub>/t soda ash, IPCC 2006), which corresponds to 0.01 % of the national total (excluding LULUCF) in 2017. Considering the entire time series, the share of the national total was largest in 1990 (0.02 %) and has remained about constant (0.01 %) since 2003. In accordance with decision 18/CMA.1 (UNFCCC 2019), annex, paragraph 32, this is below the significance threshold and thus, the ERT recommended that Switzerland reports CO<sub>2</sub> emissions from source category 2A4b Other use of soda ash as not estimated ("NE") in its inventory, which was implemented in the submission 2021.



## 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 2025/2A4d Steinwolle Produktion).

#### Methodology

Since 2013, rock wool manufacturers are legally obliged to report geogenic CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emission factor is based on measurements of the oxides (CaO, MgO, Na<sub>2</sub>O, K<sub>2</sub>O, 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<sub>2</sub> 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<sub>2</sub> emission factors are confidential. They are available to reviewers on request.

Table 4-13 Geogenic CO<sub>2</sub> emission factors used for rock wool production (in g/t product) and other carbonate uses (in g/t carbonate containing raw material), as well as emission factors for fossil CO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> from blasting operations in quarries of clinker, lime and plaster production (in g/t product and g/t raw material, respectively) for 2023.

2A4d Other	Unit	CO <sub>2</sub> geogenic	CO <sub>2</sub> fossil	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
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
Other carbonate uses	g/t	523'880	NA	NA	NA	NA	NA
Clinker production, blasting operations	g/t clinker	NA	34	3.3	3.3	8.6	0.14
Lime production, blasting operations	g/t lime	NA	C	C	C	C	C
Plaster production	g/t rocks	NA	C	C	C	C	C

Table 4-14 In the confidential NID, the respective table with geogenic CO<sub>2</sub> 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<sub>2</sub> 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<sub>3</sub>), dolomite (CaMg(CO<sub>3</sub>)<sub>2</sub>), sodium bicarbonate (NaHCO<sub>3</sub>) and soda ash (Na<sub>2</sub>CO<sub>3</sub>).

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 and one combined heat and power plant that burns all classes of wood waste (from 2021 onwards) are using sodium bicarbonate.

In cupola furnaces of iron foundries limestone is also used as flux. The resulting geogenic CO<sub>2</sub> emissions are reported in 2C1 Iron and steel production. Limestone is also used to neutralize acid wastewater in one chemical production plant. These emissions are reported in source category 2B10b Limestone pit.

Additionally, it is assumed, that all other applications of sodium bicarbonate result in a complete conversion to CO<sub>2</sub>. 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<sub>2</sub> 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 IPCC 2006 (vol. 3, chp. 2.5 Other process uses of carbonates).

The method for calculating the geogenic CO<sub>2</sub> 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 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<sub>3</sub> (IPCC 2006, vol. 3 chp. 2.1, table 2.1) and NaHCO<sub>3</sub> (CRC 2024), respectively, see Table 4-13. A conversion factor of 100 % is assumed for all applications 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 2025/1A2d Zellulose Produktion).

The activity data of limestone and sodium bicarbonate use in waste incineration plants and a combined heat and power plant fuelled with all classes of wood waste are provided by the industry as documented in the EMIS database (EMIS 2025/1A1a Kehrichtverbrennungsanlagen).

The activity data of sodium bicarbonate correspond to difference between the net import of sodium bicarbonate and the amount of sodium bicarbonate used in waste incineration plants and a wood waste plant. The net import data are provided by the Swiss customs administration as documented in the EMIS database (EMIS 2025/2A4d Karbonatanwendung weitere). For activity data see Table 4-12.

### **Quarrying and mining of minerals other than coal (2A4d)**

This source category covers the emissions of CO<sub>2</sub> and the precursor greenhouse gases NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> from blasting operations in the quarries of the currently six cement plants, the lime plant and the plaster production site (one closed in 2020). This approach was chosen because the CRT tables do not allow to report the precursor gases under the respective source categories 2A1 Cement production (except for SO<sub>2</sub>) and 2A2 Lime production.

#### *Methodology*

Emissions resulting from blasting operations during the digging of limestone are calculated by a Tier 2 method according to the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2A1 and chp. 2A2, Fig. 3.1) using country-specific emission factors. For gypsum mining, the emissions are determined by a country-specific approach corresponding to a Tier 2 method of the EMEP/EEA guidebook. These blasting emissions are related to the use of explosives in the quarries only and do not include combustion emissions from construction machinery such as bulldozers, etc. The share of CO<sub>2</sub> emissions from blasting operations in limestone quarries is well below one tenth of a percent of the geogenic CO<sub>2</sub> emissions from the calcination processes in cement and lime production.

#### *Emission factors*

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). They are assumed to be constant over the entire time period and are given per tonne of clinker and lime produced and gypsum mining (quarried rock), see Table 4-13.

The CO<sub>2</sub> emission factor for the use of blasting agents amounts to 600 kg CO<sub>2</sub>/t of blasting agent (EMIS 2025/2A1 Zementwerke übriger Betrieb). For cement production, the amount of explosives used is reported to be 0.13 kg/t cement on average, based on measurement data of four Swiss cement plants in 2002. Since these covered more than 60 % of the production volume, the value is considered representative for cement plants in Switzerland.

Since there are no emission data available from the quarry of the single lime plant, the same emission factors as for blasting operations in cement production are assumed as documented in EMIS 2025/2A2 Kalkproduktion, übriger Betrieb.

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 2025/2A4d

Gips-Produktion übriger Betrieb. Emission factors for Plaster production are confidential but available to reviewers on request.

#### *Activity data*

For clinker and lime produced see the respective activity data description of chp. 4.2.2.1 and chp. 4.2.2.2. 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 2025/2A4d Gips-Produktion übriger Betrieb (see Table 4-12). Activity data for Plaster production are confidential from 2021 onwards but available to reviewers on request.

### **4.2.3. Uncertainties and time-series consistency for 2A**

For all source categories in 2A, emitting CO<sub>2</sub>, an uncertainty of 2 % is assumed for activity data, since data at plant level are available and assumed to be fully representative. This is in agreement with the default range of 1 % to 3 % (IPCC 2006, vol. 3, chp. 2, p. 2.39).

For source category 2A1 Cement production, an uncertainty of 4 % is assumed for the CO<sub>2</sub> emission factor. This estimation comprises the measurement uncertainty for each plant and, since the emission factor is the mean over all plants weighted by the clinker production per plant, the uncertainty coming from the estimation of the clinker production per plant.

The uncertainty of the CO<sub>2</sub> emission factor is estimated to be 2 % for 2A2 Lime production, which is the mean value of the default range for Tier 3 (IPCC 2006, vol. 3, chp. 2, p. 2.31, suggested range of 1 % to 3 %).

For 2A3 Glass production, the uncertainty of the CO<sub>2</sub> emission factor is estimated to be 3 %, which is the upper value of the default range for Tier 3 (IPCC 2006, vol. 3, chp. 2, p. 2.31, suggested range of 1 % to 3 %).

For CO<sub>2</sub> emissions in source category 2A4 Other process uses of carbonates, most of the data are provided by industrial plants participating in the Swiss ETS, which requires that the uncertainty in the emissions does not exceed a given limit (1.5 % to 7.5 %, depending on the amount of emissions resulting from a given source) and from the Swiss Federal Customs Administration. For the emission factor, the chosen value of 3 % is also in agreement with the default range of 1 % to 5 % (IPCC 2006, vol. 3, chp. 2, p. 2.39).

Consistency: Time series for 2A Mineral industry are all considered consistent.

### **4.2.4. Category-specific QA/QC and verification for 2A**

The general QA/QC measures are described in chp. 1.5.

### **4.2.5. Category-specific recalculations for 2A**

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences in GHG emissions of sector 2 IPPU between the latest and the previous submissions are also presented in chp. 10.1.2.2.

- 2A1: Due to the structure of the CRT tables, which do not allow emissions of precursors (except of SO<sub>2</sub>) under source category 2A1 Cement production, emissions from blasting operations in quarries for cement and lime production are now reported under source category 2A4d Other.
- 2A2: Due to the structure of the CRT tables, which do not allow emissions of precursors under source category 2A2 Lime production, emissions from blasting operations in quarries for cement and lime production are now reported under source category 2A4d Other.
- 2A4d: Due to the structure of the CRT tables, which do not allow emissions of precursors under 2A1 and 2A2 to be reported, emissions from blasting operations in quarries for cement and lime production are now reported under source category 2A4d Other.

#### **4.2.6. Category-specific planned improvements for 2A**

There are no category-specific planned improvements.

## 4.3. Source category 2B – Chemical industry

### 4.3.1. Source category description

Table 4-15 Key categories of 2B Chemical industry. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
2.B.10	Other	N <sub>2</sub> O	T1, T2

Table 4-16 Specification of source category 2B Chemical industry.

2B	Source category	Specification
2B1	Ammonia production	Emissions of CO <sub>2</sub> and NMVOC are reported in 2B8b Ethylene production
2B2	Nitric acid production	Emissions of N <sub>2</sub> O and NO <sub>x</sub> from the production of nitric acid (ceased in 2018)
2B5	Carbide production	Emissions of CO <sub>2</sub> , CH <sub>4</sub> , CO and SO <sub>2</sub> from the production of silicon carbide and graphite
2B8	Petrochemical and carbon black production	Emissions of CO <sub>2</sub> and NMVOC from ethylene production. In Switzerland there is only ethylene production under this source category
2B10	Other	Emissions of CO <sub>2</sub> , CH <sub>4</sub> , CO and NMVOC from acetic acid production; CO <sub>2</sub> emissions from limestone pit; CO <sub>2</sub> , N <sub>2</sub> O, NO <sub>x</sub> and CO emissions from niacin production; NMVOC emissions from PVC production (ceased in 1996); SO <sub>2</sub> emissions from sulphuric acid production

### 4.3.2. Methodological issues

#### 4.3.2.1. Ammonia production (2B1)

Ammonia (NH<sub>3</sub>) is produced in one single plant in Switzerland by catalytic reaction of nitrogen and synthetic hydrogen (see Figure 4-6). Ammonia is not produced in an isolated reaction plant but is part of an integrated production chain (see Figure 4-6).

The starting production process is the thermal cracking of liquefied petroleum gas and light virgin naphtha yielding ethylene (ethene, C<sub>2</sub>H<sub>4</sub>), 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<sub>2</sub> and NMVOC) to every single product such as, e.g., ethylene, acetylene (ethyne, C<sub>2</sub>H<sub>2</sub>), cyanic acid or ammonia. Therefore, all CO<sub>2</sub> 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<sub>2</sub> and NMVOC emissions are reported as included elsewhere (IE). All information on the ammonia production and the cracking process is documented in EMIS 2025/2B1 Ammoniak-Produktion and EMIS 2025/2B8b Ethen-Produktion, respectively.

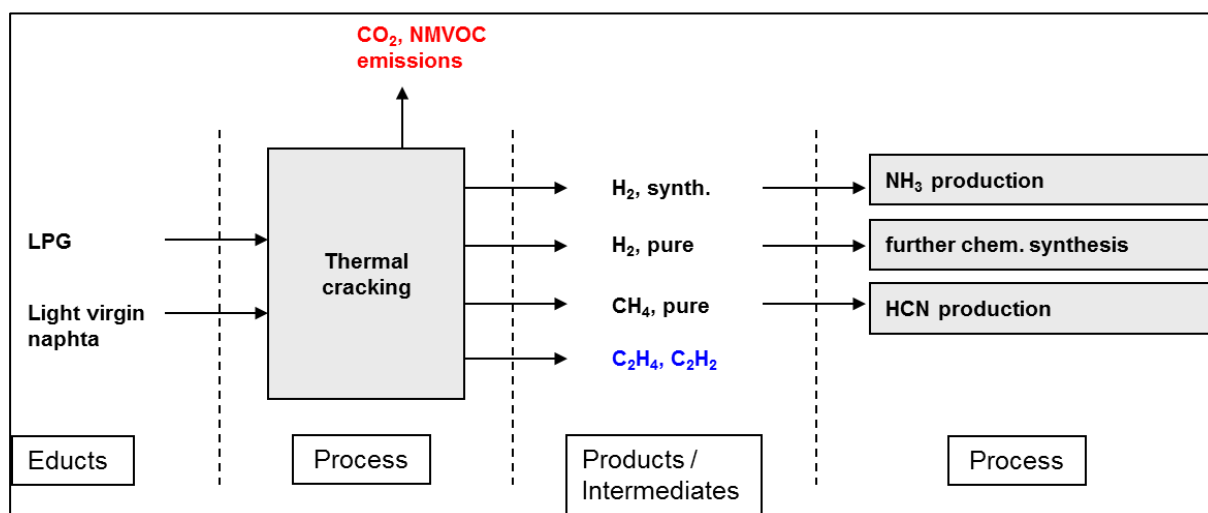


Figure 4-6 Process flow chart for the production of ethylene ( $C_2H_4$ ) and acetylene ( $C_2H_2$ ) by thermal cracking of liquefied petroleum gas (LPG) and light virgin naphtha. The intermediate product  $H_2$ , synth. is used as educt in the ammonia production in the same plant.

Table 4-17 Activity data for ammonia production in Switzerland are documented in the confidential NID, which is available to reviewers on request.

#### 4.3.2.2. Nitric acid production (2B2)

In Switzerland, there was one single plant producing nitric acid ( $HNO_3$ ) which stopped production in spring 2018. Nitric acid was produced by catalytic oxidation of ammonia ( $NH_3$ ) with air. At temperatures of  $800^\circ C$  nitric monoxide ( $NO$ ) is formed. During cooling, nitrogen monoxide reacted with excess oxygen to form nitrogen dioxide ( $NO_2$ ). The nitrogen dioxide reacted 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 was 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  $NO_x$  was done by selective catalytic reduction (SCR, installed in 1988), which reduced  $NO_x$  to  $N_2$  and  $O_2$  (the SCR in this plant was 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 IPCC 2006 (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 between 2013 and the end of production in 2018 based on direct measurements. The  $NO_x$  emissions are calculated by a Tier 2 method according to the decision tree Fig. 3.1 in the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2B Chemical industry) using a plant-specific emission factor.



## Emission factors

The N<sub>2</sub>O and NO<sub>x</sub> emission factors for nitric acid production in Switzerland are based on measurements from the single nitric acid production plant.

The measurement of N<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O concentration is then measured using a gas chromatograph with an electron capture detector. The measurement uncertainty is ±20 % (minimum ±0.5 mg/m<sup>3</sup>). On repeated enquiries 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<sub>2</sub>O-emission factor is assumed for this time period. A new catalyst installed in 2013 reduced the N<sub>2</sub>O emissions, which are measured online by NDIR photometry between 2013 and 2018.

The NO<sub>x</sub> 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 doubled. This modification together with the new catalyst in the production line slightly reduced the NO<sub>x</sub> emission factor. The values are documented in EMIS 2025/2B2 Salpetersäure Produktion.

Table 4-18 Emission factors for N<sub>2</sub>O for nitric acid production in Switzerland in kg/t nitric acid for 1990–2023 are provided in the confidential NID, which is available to reviewers on request.

## Activity data

Activity data on annual production of nitric acid (100 %) are provided annually by the Swiss production plant for the entire time period 1990–2018. 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 2025/2B2 Salpetersäure Produktion).

Table 4-19 Activity data for the production of nitric acid (100 %) in Switzerland are documented in the confidential NID, 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. Silicon carbide is produced together with graphite in a coupled process in an electric furnace at temperatures above 2000 °C using the Acheson process. The starting materials are quartz sand (SiO<sub>2</sub>), petroleum coke and anthracite (C) which yield silicon carbide (SiC) and carbon monoxide (CO). The CO is converted to CO<sub>2</sub> 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<sub>4</sub>) as an unintended by-product. No abatement techniques are installed to capture the CO<sub>2</sub> or CH<sub>4</sub> emissions.

Indirect CO<sub>2</sub> emissions resulting from CH<sub>4</sub> and CO emissions in this source category are included in CRT Table6 as documented in chp. 9.

## Methodology

According to decision tree Fig. 3.5 of IPCC 2006 (vol. 3, chp. 3.6 Carbide production), the CO<sub>2</sub> and CH<sub>4</sub> emissions from silicon carbide production are determined by a Tier 2 method. The NO<sub>x</sub>, CO and SO<sub>2</sub> emissions are calculated by a Tier 2 method according to the decision tree Fig. 3.1 in the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2B Chemical industry) using plant-specific emission factors.

## Emission factors

The CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> emission factors are confidential and available to reviewers on request. The values are partly based on data from the single silicon carbide production plant and are documented in EMIS 2024/2B5 Graphit und Siliziumkarbid Produktion.

The CO<sub>2</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> emission factors are based on data from the production plant. For CO<sub>2</sub> and CO, they are calculated based on the carbon mass balance of the production process and CO exhaust measurements from 2001 onwards. The SO<sub>2</sub> emission factor is derived from the sulphur content of the feedstocks, i.e. petroleum coke and anthracite. The CO<sub>2</sub> emission factors for the entire time series are listed in the following table.

Table 4-20 In the confidential NID, a respective table with emission factors of fossil CO <sub>2</sub> in kg/t silicon carbide are provided. Data are available to reviewers on request.
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Table 4-21 Emission factors for CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>x</sub> , CO and SO <sub>2</sub> for carbide production in kg/t silicon carbide in Switzerland for 2022 are provided in the confidential NID, which is available for reviewers upon request.
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## Activity data

Activity data on annual production of silicon carbide (and graphite) are provided annually from 1995 onwards by the production plant. For the time period 1990–1994 they are based on industry data.

The data are confidential but available to reviewers on request (see EMIS 2024/2B5 Graphit und Siliziumkarbid Produktion).

Table 4-22 In the confidential NID, the respective table with activity data on silicon carbide production in Switzerland is separately reported and available to reviewers.
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#### 4.3.2.4. Petrochemical and carbon black production (2B8)

##### Ethylene (2B8b)

Ethylene (ethene, C<sub>2</sub>H<sub>4</sub>) is produced by a single plant in Switzerland by thermal cracking of liquefied petroleum gas and virgin naphtha. Ethylene is not produced in an isolated process but is co-processed together with several other products such as H<sub>2</sub>, CH<sub>4</sub>, and C<sub>2</sub>H<sub>2</sub> (see flow chart in Figure 4-6 in chp. 4.3.2.1). From the thermal cracking process, emissions of CO<sub>2</sub> 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<sub>4</sub> emissions to the atmosphere do not occur since CH<sub>4</sub> is completely used as an educt in the downstream production of cyanic acid (HCN) in the same facility (again, see Figure 4-6 and for further information see EMIS 2025/2B8b Ethen-Produktion). Therefore, CH<sub>4</sub> emissions are reported as NA for ethylene production and only CO<sub>2</sub> and NMVOC emissions are reported.

The CO<sub>2</sub> 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 not included in the calculation of the indirect CO<sub>2</sub> emissions from sector 2 IPPU in order to avoid double counting.

##### Methodology

According to decision trees Fig. 3.8 of IPCC 2006 (vol. 3, chp. 3.9 Petrochemical and carbon black production) and Fig. 3.1 of the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2B Chemical industry), the CO<sub>2</sub> and NMVOC emissions, respectively, from ethylene production are determined by a Tier 2 method using plant-specific emission factors (EMIS 2025/2B8b Ethylene production).

##### Emission factors

The CO<sub>2</sub> 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 constant emission factors, i.e. the mean emission factors of the years 2000–2009 were assumed.

The emission factors for ethylene production are considered confidential; however, they are available to reviewers on request.

Table 4-23 Emission factors for CO<sub>2</sub> and NMVOC in ethylene production, NMVOC in acetic acid production, CO<sub>2</sub> in limestone pit, CO<sub>2</sub>, N<sub>2</sub>O, NO<sub>x</sub> and CO in niacin production and SO<sub>2</sub> in sulphuric acid production for 2023 in kg/t product.

<b>2B8 Petrochemical and carbon black</b>	<b>Unit</b>	<b>CO<sub>2</sub></b>	<b>N<sub>2</sub>O</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>NMVOC</b>	<b>SO<sub>2</sub></b>
2B8b Ethylene	kg/t	C	NA	NA	NA	C	NA
<b>2B10 Other</b>							
Acetic acid production	kg/t	NA	NA	NA	NA	C	NA
Limestone pit	kg/t	C	NA	NA	NA	NA	NA
Niacin production	kg/t	C	C	C	C	NA	NA
Sulphuric acid production	kg/t	NA	NA	NA	NA	NA	C

Table 4-24 CO<sub>2</sub> fossil emission factors in 2B8b Ethylene are documented in the confidential NID, 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 4-25 Activity data for the production of ethylene, acetic acid, niacin, PVC and sulphuric acid as well as for limestone pit in Switzerland.

	Unit	1990	1995	2000	2005	2010	2013–2023
<b>2B8 Petrochemical and carbon black production</b>							
2B8b Ethylene	kt	C	C	C	C	C	C
<b>2B10 Other</b>							
Acetic acid production	kt	30	27	24	8.4	20	C
Limestone pit	kt	C	C	C	C	C	C
Niacin production	kt	C	C	C	C	C	C
PVC production	kt	43	43	NO	NO	NO	NO
Sulphuric acid production	kt	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 (2B10b)

In Switzerland, there is only one plant producing acetic acid (CH<sub>3</sub>COOH) 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<sub>2</sub>, CH<sub>4</sub> and CO occurred.

Indirect CO<sub>2</sub> emissions resulting from CH<sub>4</sub>, CO and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

#### Methodology

In order to determine emissions of CO<sub>2</sub> and CH<sub>4</sub> from acetic acid a country-specific method analogous to a Tier 2 method according to IPCC 2006 (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 the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2B Chemical industry).

#### Emission factors

The emission factors for CO<sub>2</sub>, CH<sub>4</sub>, CO and NMVOC from acetic acid production in Switzerland are plant-specific and based on data from industry and expert estimates documented in EMIS 2025/2B10 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<sub>4</sub>, 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 4-26 In the confidential NID, the respective table with emission factors 1990–2012 for CO<sub>2</sub> and CH<sub>4</sub> in 2B10b 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 2025/2B10 Essigsäure-Produktion (see Table 4-25).

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 (2B10b)**

In one chemical plant acids are neutralized in a so-called limestone pit yielding geogenic CO<sub>2</sub> emissions.

#### *Methodology*

According to decision tree Fig. 2.4 of IPCC 2006 (vol. 3, chp. 2.5 Other process uses of carbonates), the CO<sub>2</sub> emissions from the limestone pit are determined by Tier 2 method using plant-specific emission factors.

#### *Emission factors*

The CO<sub>2</sub> 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 2025/2B10 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 are considered confidential but available to reviewers on request.

## Niacin production (2B10b)

In Switzerland, there is one plant producing niacin that emits CO<sub>2</sub>, N<sub>2</sub>O, NO<sub>x</sub> and CO. In the production process nitric acid is used as oxidizing agent. Since the nitric acid production plant was closed in spring 2018 the required nitric acid is directly produced within the niacin production plant using a so-called ammonia burner. In autumn 2021, a catalytic converter was installed to treat the non-absorbed gas components of the production plant (including ammonia burner). The nitrogen oxides are denitrified with ammonia, and nitrous oxide, hydrocyanic acid and carbon monoxide are decomposed to nitrogen, water and carbon dioxide.

### Methodology

In order to determine emissions of CO<sub>2</sub> and N<sub>2</sub>O from niacin production, a country-specific method analogous to a Tier 2 method according to IPCC 2006 (vol. 3) is used for the years 1990 to 2021. From 2022 onwards, a Tier 3 method based on continuous emissions monitoring (CEM) is applied. The NO<sub>x</sub> and CO emissions are calculated by a Tier 2 method based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in EMEP/EEA (2023) using plant-specific emission factors.

### Emission factors

The emission factors of CO<sub>2</sub>, N<sub>2</sub>O, NO<sub>x</sub> and CO are plant-specific based on measurement data from industry. From 2022 onwards, the plant is obliged to continuously monitor the emissions of CO<sub>2</sub> and N<sub>2</sub>O and provides the hourly averages as part of the ETS monitoring. Accordingly, the emission factors have since been derived from this data. For CO<sub>2</sub> (1990–2021) and CO, they are based on measurements in 2018 and 2021 before and after the production process was modified (i.e. including the ammonia burner) and after the installation of the catalytic converter, respectively. For N<sub>2</sub>O (1990–2021), the emission factor is derived from measurements in 2018 after the modification of the production process but with and without operating the ammonia burner and in 2021 (after catalytic converter installation). For NO<sub>x</sub>, the emission factor is based on measurements in 2017 and 2018 (after process modification) and 2021 (after converter installation). Due to lack of emission measurements in previous years, constant emission factors are assumed between 1990 and 2017 as documented in the EMIS database (EMIS 2025/2B10 Niacin-Produktion) The emission factors are considered confidential but available to reviewers on request.

Table 4-27 In the confidential NID, the respective table with emission factors for CO<sub>2</sub> and N<sub>2</sub>O emission factors for 2B10b Niacin production are separately reported and available to reviewers.

### Activity data

Activity data of annual niacin production were provided by the Swiss production plant for the entire time period as documented in EMIS 2025/2B10 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 (2B10b)**

Sulphuric acid ( $\text{H}_2\text{SO}_4$ ) is produced by one plant only in Switzerland. From this production process  $\text{SO}_2$  is emitted. Until 1996, also PVC was produced in Switzerland releasing NMVOC emissions.

Indirect  $\text{CO}_2$  emissions resulting from NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

#### *Methodology*

In order to determine NMVOC and  $\text{SO}_2$  emissions from sulphuric acid and PVC production, respectively, a Tier 2 method according to the decision tree Fig. 3.1 in the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2B Chemical industry) with plant-specific emission factors is used.

#### *Emission factors*

The emission factor for  $\text{SO}_2$  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 2025/2B10 Schwefelsäure-Produktion).

The  $\text{SO}_2$  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 2025/2B10 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 2025/2B10 Schwefelsäure-Produktion and EMIS 2025/2B10 PVC-Produktion (see Table 4-25).

The activity data for sulphuric acid production are confidential but available to reviewers on request.

### **4.3.3. Uncertainties and time-series consistency for 2B**

For all source categories in 2B, the activity data are based on plant level data and the corresponding uncertainties are therefore considered small and estimated to be 2 %.

For  $\text{N}_2\text{O}$  emissions from 2B2 Nitric acid production, the combined uncertainty is assumed to be 7.2 % (from 2013 – 2018) since the Swiss ETS requires that an uncertainty of 7.5 % is not exceeded for emission estimations based on continuous  $\text{N}_2\text{O}$  measurements. The uncertainty for the emission factor is derived using the activity data uncertainty of 2 %. For 1990 an uncertainty of 60 % is assumed for the emission factor, based on the uncertainty rating given in EMEP/EEA (2023) (part A, chp. 5, Table 2-2, rating B) since the calculated emissions are based on a single  $\text{N}_2\text{O}$  emission measurement in 2009.

For 2B5 Silicon carbide production, the uncertainty of the  $\text{CO}_2$  and  $\text{CH}_4$  emission factors is set at 10 %, which is the default value according to IPCC 2006 (vol. 3, chp. 3, p. 3.45).

For 2B8b Ethylene production, the uncertainty of the CO<sub>2</sub> emission factor is 10 % according to the default value for a Tier 2 methodology (IPCC 2006, vol. 3, chp. 3, p. 3.87).

The uncertainties for the CO<sub>2</sub> and N<sub>2</sub>O emission factors from 2B10b Niacin production are assumed to be 60 % according to the uncertainty rating given in EMEP/EEA (2023) (part A, chp. 5, Table 2-2, rating B) since the calculated emissions are based on (spot) measurement data from industry in 2018 and 2021 only.

Consistency: Time series for 2B Chemical industry are all considered consistent.

#### 4.3.4. Category-specific QA/QC and verification for 2B

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

#### 4.3.5. Category-specific recalculations for 2B

There were no recalculations implemented in submission 2025.

#### 4.3.6. Category-specific planned improvements for 2B

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 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
2.C.3	Aluminium production	CO <sub>2</sub>	T1
2.C.3	Aluminium production	PFCs	T1



Table 4-29 Specification of source category 2C Metal industry.

2C	Source category	Specification
2C1	Iron and steel production	Emissions of CO <sub>2</sub> , NO <sub>x</sub> , CO, NMVOC and SO <sub>2</sub> from the production of iron and steel; Geogenic CO <sub>2</sub> emissions from use of limestone in iron-foundries (cupola furnaces)
2C2	Ferroalloys production	Production is not occurring in Switzerland
2C3	Aluminium production	Emissions of PFC, CO <sub>2</sub> , NO <sub>x</sub> , CO, NMVOC, and SO <sub>2</sub> from the production of primary aluminium (ceased in 2006); Emissions from use of SF <sub>6</sub> in aluminium foundries
2C4	Magnesium production	Emissions from use of SF <sub>6</sub> in magnesium foundries
2C7	Other	Emissions of CO and NMVOC from non-ferrous metal foundries; Emissions of CO <sub>2</sub> , NO <sub>x</sub> , CO and SO <sub>2</sub> 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<sub>2</sub> 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<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> 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<sub>2</sub> emissions from other bituminous coal and limestone 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<sub>2</sub> emissions in source category 1A2a. This ensures consistency with the reported use of other bituminous coal as fuel in the Swiss overall energy statistics (SFOE 2024). In cupola furnaces of iron foundries, limestone is also used as flux as documented in the EMIS database (EMIS 2025/1A2a 2C1 Eisengiessereien Kupolöfen). The resulting geogenic CO<sub>2</sub> emissions are reported in 2C1.

The CO<sub>2</sub> 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 not included in the calculation of the indirect CO<sub>2</sub> emissions from sector 2 IPPU in order to avoid a double counting.

## Methodology

For determination of CO<sub>2</sub> emission from EAF in secondary 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 of 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<sub>2</sub> 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<sub>4</sub> emissions occur in the EAF process.

The method for calculating geogenic CO<sub>2</sub> emissions from limestone use in cupola furnaces of iron foundries corresponds to a Tier 2 method according to the decision tree Fig. 2.4 of IPCC 2006 (vol. 3, chp. 2.5 Other process uses of carbonates).

Emissions of all precursors are determined by a Tier 2 method based on the decision tree Fig. 3.1 in chapter 2C1 in the EMEP/EEA guidebook (EMEP/EEA 2023) using country-specific emission factors (EMIS 2025/2C1).

## Emission factors

The emission factors for EAF in secondary steel production in Switzerland are country-specific and are based on measurements from industry and expert estimates documented in the EMIS database (EMIS 2025/2C1 Stahl-Produktion Elektroschmelzöfen).

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<sub>2</sub> emission factor results. The reported CO<sub>2</sub> emission factor for Swiss steel industry is the production-weighted average (Table 4-30). As direct CO<sub>2</sub> emissions cover all carbon sources (carbon mass balance) from this source category, no indirect emissions are included in CRT Table6 as documented in chp. 9.

The plant-specific data are confidential but available to reviewers on request.

Table 4-30 CO<sub>2</sub> emission factor 1990–2023 of electric arc furnaces in 2C1 Steel production in kg/t.

2C1 Steel production	Unit	1990	1995	2000	2005	2010
CO <sub>2</sub>	kg/t	8.3	8.0	7.7	8.8	7.6

2C1 Steel production	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO <sub>2</sub>	kg/t	7.5	6.4	6.2	6.6	6.2	5.8	5.6	5.5	6.7	7.3

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<sub>x</sub>, CO, NMVOC, and SO<sub>2</sub> 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 factor of geogenic CO<sub>2</sub> from limestone use in cupola furnaces of iron foundries is based on the stoichiometry of CaCO<sub>3</sub> (IPCC 2006, vol. 3 chp. 2.1, table 2.1), see Table 4-31. A conversion factor of 100 % is assumed. The emission factors of the precursors from induction furnaces of iron foundries are provided by the Swiss foundry association (GVS).

Table 4-31 Emission factors for CO<sub>2</sub>, NO<sub>x</sub>, CO and NMVOC in iron production, for CO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> in steel production, for CO and NMVOC in non-ferrous metal production and for CO<sub>2</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> in battery recycling for 2023.

2C Metal industry	Unit	CO <sub>2</sub>	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
2C1 Iron production	kg/t	NA	0.01	4.1	4.0	NA
2C1 Limestone use in iron foundries (cupola furnaces)	kg/t	439.71	NA	NA	NA	NA
2C1 Steel production	kg/t	7.3	0.14	0.7	0.11	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).

The amount of limestone used as flux in iron foundries (cupola furnaces) is estimated by GVS 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 2025/1A2a\_2C1 Eisengiessereien Kupolöfen).

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	2010
2C1 Iron production	kt	170	130	120	67	53
2C1 Limestone use in iron foundries (cupola furnaces)	kt	6.2	4.1	3.8	2.3	0.98
2C1 Steel production	kt	1'108	716	1'022	1'159	1'218
2C3 Aluminium production	kt	87	21	36	45	NO
2C7a Non-ferrous metals	kt	60	56	53	33	20
2C7c Battery recycling	kt	NO	C	C	C	C

2C Metal industry	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
2C1 Iron production	kt	43	37	34	35	34	24	20	22	23	22
2C1 Limestone use in iron foundries (cupola furnaces)	kt	0.82	0.70	0.65	0.67	0.65	0.45	0.38	0.41	0.44	0.41
2C1 Steel production	kt	1'315	1'296	1'238	1'270	1'291	1'130	1'125	1'294	1'208	936
2C3 Aluminium production	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C7a Non-ferrous metals	kt	9.5	8.9	9.0	8.0	6.8	6.4	5.1	7.5	7.9	5.3
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 IPCC 2006 (vol. 3, chp. 4.4, fig. 4.11), CO<sub>2</sub> 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 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<sub>6</sub> imports to be related to the aluminium industry, referring to cleaning processes in foundries. The 2006 IPCC Guidelines mention use of SF<sub>6</sub> 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<sub>2</sub> of 1.6 tonnes per tonne of aluminium is country-specific. It is based on measurements and data from industry and expert estimates, as documented in the EMIS database (EMIS 2025/2C3 Aluminium Produktion). CO<sub>2</sub> 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, no indirect CO<sub>2</sub> emissions resulting from CO emissions from primary aluminium production are included in CRT Table6 as documented in chp. 9. However, the NMVOC emissions solely originate from the production of the electrodes at the plants. Accordingly, the respective indirect CO<sub>2</sub> emissions resulting from NMVOC in this source category are included in CRT Table6 as documented 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 emission factors of 0.17, 0.06 and 0.04 kg per tonne, respectively, for those three years (Alcan 2003). This was reported to be lower than the European averages, by factors of 4.0, 4.7 and 4.0, respectively. For other years no measurements have been made in Switzerland; thus, European Union (EU) average emission factors have been used, multiplied by a factor of 0.25 (Alcan 2002).

Figure 4-7 shows the resulting development of the emission factor for PFC over time. The European average has decreased by over 75 % from 0.68 kg PFC per tonne of aluminium to 0.16 kg PFC per tonne of aluminium between 1990 and 2000 (European Aluminium 2019).

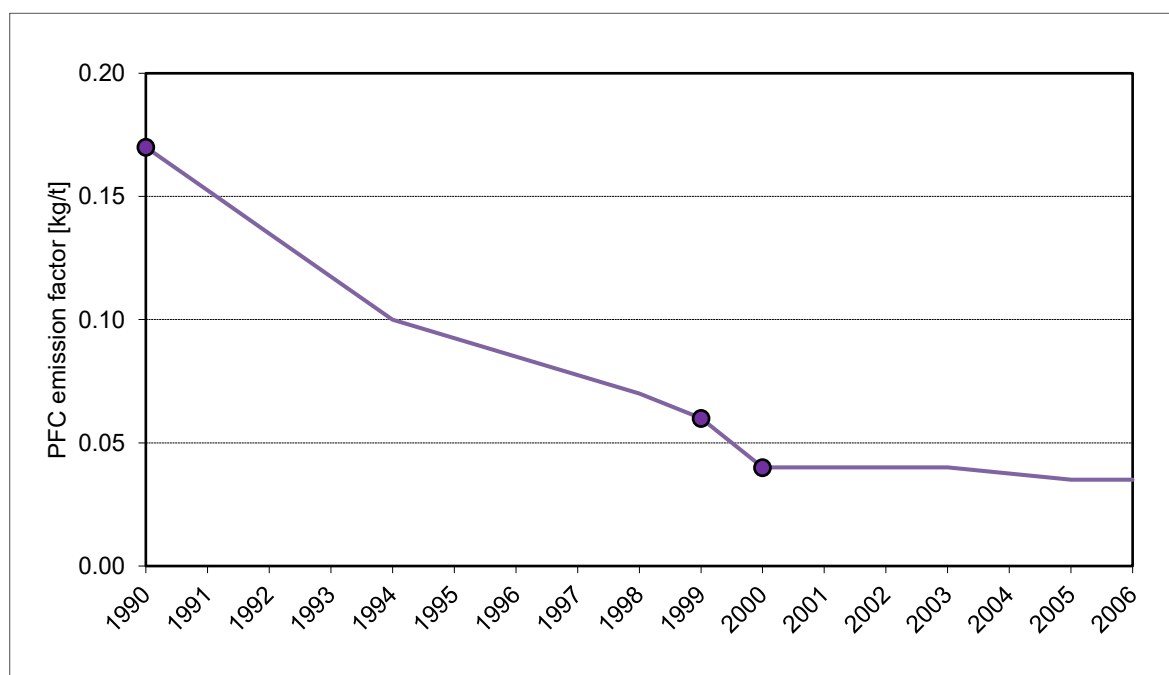


Figure 4-7 Extrapolation of PFC emission factor based on measurements in 1990, 1999 and 2000. The path for the reduction between measurements and the stagnation after the last measurements reflects the observed development of average emission factors in the European Union.

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 emission factors 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 1990–2006 for aluminium production in Switzerland. Aluminium production in Switzerland ceased in 2006.

Gas	Unit	1990	1995	2000	2005	2006	2007–2023
CF <sub>4</sub>	kg/t	0.15	0.083	0.036	0.032	0.032	NO
C <sub>2</sub> F <sub>6</sub>	kg/t	0.017	0.0093	0.0040	0.0035	0.0035	NO

There are no measurements of SF<sub>6</sub> emissions available from aluminium foundries to identify the fraction of SF<sub>6</sub> destroyed or transformed in the cleaning process. For SF<sub>6</sub> used in aluminium foundries (2C3) it is therefore assumed that the total imported amount is emitted, in accordance with the default emission factor (1'000 kg per tonne of imported substance) of the IPCC Guidelines (IPCC 2006).

## Activity data

In 2006, the last primary 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<sub>6</sub> used in aluminium foundries (2C3) is derived from import data from FOEN statistics. Import companies indicated in the year 2003 a portion of SF<sub>6</sub> 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). In 2011, a study was carried out among members of the Swiss Foundry Association (GVS), confirming that SF<sub>6</sub> 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<sub>6</sub> is assumed from 2003 until the final elimination of SF<sub>6</sub> 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<sub>6</sub> in magnesium foundries (2C4)

SF<sub>6</sub> was used in Swiss magnesium foundries in the time period 1997 to 2016. There have been two magnesium foundries known to be using SF<sub>6</sub>. 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 was using SF<sub>6</sub>.

The import of SF<sub>6</sub> for magnesium foundries has been prohibited in Switzerland since 2017.

## Methodology

SF<sub>6</sub> was 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<sub>6</sub> emissions available to identify the fraction of SF<sub>6</sub> destroyed or transformed in the process. For SF<sub>6</sub> used in magnesium foundries (2C4) it is therefore assumed that the total imported amount is emitted, in accordance with the default emission factor (1'000 kg per tonne of imported substance) of the 2006 IPCC Guidelines (IPCC 2006).

## Activity data

Activity data on SF<sub>6</sub> 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). The import of SF<sub>6</sub> ceased in 2016. Part of the import of the preceding year were considered for the phase-out 2016.

One of the magnesium foundries reported on the SF<sub>6</sub> consumption between 2008 to 2015 to the Swissmem statistics. The information is in accordance with import data obtained 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 which started operation in 1992. The recycling is done by applying the Sumitomo process. The batteries are first pyrolysed at temperatures of 700°C in a reducing atmosphere in a shaft kiln. The gas with the carbonised components then goes to a post-combustion step where it is completely oxidised at temperatures of 1000°C. The flue gas is then directed to a flue gas treatment installation. The metal fraction from the pyrolysis goes to a melting furnace where it is reduced by addition of coal and magnesium oxide. As reducing agent coke and Carburit is used.

In Switzerland, there are one large company and several small plants operating non-ferrous metal foundries producing mainly copper alloys. During the melting process emissions of CO and NMVOC occur.

Indirect CO<sub>2</sub> emissions resulting from CO and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

##### **Methodology**

To determine emissions of CO<sub>2</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> from battery recycling and of CO and NMVOC from non-ferrous metal foundries, Tier 2 methods according to the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2C7c and 2C7a) with country-specific emission factors are used.

##### **Emission factors**

The emission factors of CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, CO from battery recycling between 1992 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 assumed constant for the entire time period (EMIS 2025/2C7 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 (EMIS 2025/2C7 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 by industry (including monitoring reports of the Swiss ETS from 2006 onwards for the large non-ferrous metal company) and the foundry association as documented in the



EMIS database (EMIS 2025/2C7 Batterie-Recycling and EMIS 2025/2C7 Buntmetallgiessereien Elektroöfen). Activity data are confidential. They are available to reviewers on request.

#### 4.4.3. Uncertainties and time-series consistency for 2C

Production data of the steel industry have a high confidence and its uncertainty is estimated at 2 %. The uncertainty for the CO<sub>2</sub> emission factor is estimated at 50 %, due to the high uncertainty of the carbon content of the electric arc furnace slag. Since the geogenic CO<sub>2</sub> emissions from the limestone use in cupola furnaces (iron foundries) are comparatively small their contribution to the uncertainty calculation was neglected.

For source category 2C3 Aluminium production (1990–2006), the uncertainty of the activity data is estimated to be 5 %. The uncertainty of the CO<sub>2</sub> emission factor is estimated to be 20 %. For PFCs, the uncertainty of the emission factor is estimated -79 % to +112 % (Carbotech, 2023a).

For the emissions of SF<sub>6</sub> from the use in 2C4 Magnesium production (1990–2016), the combined uncertainty is estimated at 27.7 % (Carbotech, 2023a).

For CO<sub>2</sub> emissions from source category 2C7 Other, the uncertainty of the activity data is set at 2 % because plant level data are available. The uncertainty of the CO<sub>2</sub> emission factor is estimated to be 20 % (expert estimate based on the observed variability in the available data).

Consistency: Time series for 2C Metal industry are all considered consistent.

#### 4.4.4. Category-specific QA/QC and verification for 2C

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

#### 4.4.5. Category-specific recalculations for 2C

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences in GHG emissions of sector 2 IPPU between the latest and the previous submissions are also presented in chp. 10.1.2.2.

- 2C1: A typing error in the activity data 2022 of source category 2C1 Iron foundries was corrected resulting in a revised activity data of 2C1 Limestone use in iron foundries as well.

#### 4.4.6. Category-specific planned improvements for 2C

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

Table 4-34 Key categories of 2D Non-energy products from fuels and solvent use. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Direct emissions of Source category 2D Non-energy products from fuels and solvent use are not a key category. Indirect emissions are documented in chp. 9.

Table 4-35 Specification of source category 2D Non-energy products from fuels and solvent use in Switzerland.

2D	Source category	Specification
2D1	Lubricant use	Emissions of CO <sub>2</sub> from primary usage of lubricants in machinery and vehicles and from fully oxidised lubricants blended into gasoline for 2-stroke engines
2D2	Paraffin wax use	Emissions of CO <sub>2</sub> 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 <sub>2</sub> 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 <sub>2</sub> 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

CO<sub>2</sub> emissions from the use of lubricants in 2-stroke engines (road and non-road vehicles) are calculated by a Tier 1 method and default emission factor 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). CH<sub>4</sub> and N<sub>2</sub>O emissions from lubricant use in 2-stroke engines are reported in sector 1 Energy since these emissions are included in the

CH<sub>4</sub> and N<sub>2</sub>O emission factors of the respective 2-stroke engines (1A2gvii, 1A3biv, 1A3dii, 1A4aii, 1A4bii, 1A4cii and 1A5b).

CO<sub>2</sub> emissions from oxidation of all other lubricants and paraffin wax are calculated by a Tier 1 method according to the 2006 IPCC Guidelines applying the IPCC default oxidation fraction of 0.2 (IPCC 2006, vol. 3, chp. 5.2 and 5.3).

## Emission factors

The CO<sub>2</sub> emission factor for lubricants used in 2-stroke vehicles is based on the default emission factor and the net calorific value from IPCC 2006 (vol. 2, chp. 2 Stationary combustion, Table 2.2 and chp.1, Table 1.2, respectively), see Table 4-36 and EMIS 2025/2 D 1\_Schmiermittel-Verbrauch B2T. Non-CO<sub>2</sub> emissions from lubricant use in 2-stroke engines are included in the road and the non-road transportation model, since the emission factors are deduced from measurements on motorcycles including 2-stroke engines (see chp. 3.2.9.2.2).

The emission factors of CO<sub>2</sub> 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 2025/2D1 Lubricant use and EMIS 2025/2D2 Paraffin wax use.

Table 4-36 CO<sub>2</sub> emission factor of 2D1 Lubricant use and 2D2 Paraffin wax use for 2023.

	Unit	CO <sub>2</sub>
<b>2D1 Lubricant use</b>		
in two-stroke engines	kg/t	2'947
unspecified	kg/t	590
<b>2D2 Paraffin wax use</b>	kg/t	590

## Activity data

The annual amount of lubricant and paraffin wax used in Switzerland is derived from Avenergy Suisse (formerly Swiss petroleum association) (Avenergy 2024). The consumption of lubricants of Liechtenstein, which forms a customs union with Switzerland, is subtracted from the consumption reported by Avenergy Suisse. The resulting amount is further differentiated between application in 2-stroke engines and unspecified use. The amount of lubricants corresponds to 2 % of total gasoline consumption of all 2-stroke engines based on the road and non-road transportation models (INFRAS 2022, INFRAS 2015a).

Table 4-37 Use of lubricants and paraffin waxes.

	Unit	1990	1995	2000	2005	2010
<b>2D1 Lubricant use</b>						
in two-stroke engines	kt	0.66	0.44	0.52	0.37	0.30
unspecified	kt	79	61	62	72	55
<b>2D2 Paraffin wax use</b>	kt	11	10	12	10	5.0

	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
<b>2D1 Lubricant use</b>											
in two-stroke engines	kt	0.24	0.22	0.25	0.24	0.25	0.24	0.21	0.20	0.22	0.23
unspecified	kt	53	51	51	49	45	44	40	42	43	41
<b>2D2 Paraffin wax use</b>	kt	4.5	3.8	3.4	4.0	4.2	3.4	3.3	3.9	4.3	2.6

#### 4.5.2.2. Other (2D3)

##### Solvent use (2D3a)

Since the 2006 IPCC Guidelines (IPCC 2006, vol. 3, chp. 5.5) refer to the EMEP/EEA guidebook regarding methodologies for estimating NMVOC emissions from solvent use, the respective NFR codes are indicated as reference as well. Within 2D3a Solvent use, 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. Paint application on wood, paint application in construction, industrial and non-industrial paint application, production of fine chemicals and other industrial cleaning account for the largest share of NMVOC emissions from 2D3a in 2023. Indirect CO<sub>2</sub> emissions resulting from NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

##### Methodology

For the determination of NMVOC emissions from solvent use in coating applications (2D3d NFR), degreasing (2D3e NFR), dry cleaning (2D3f NFR) as well as production and processing of chemical products (2D3g NFR) a Tier 2 method according to the EMEP/EEA guidebook (EMEP/EEA 2023) is used. For coating applications, the emissions are based on the consumption of paints, lacquers, glazes, thinners etc. and their solvent content, for degreasing and dry cleaning on the solvent consumption and for production and processing of chemical products on the products manufactured or processed. Switzerland's Informative Inventory Report (FOEN 2025b, chp. 4.5.2.4–4.5.2.7) contains a detailed description of the country-specific emission factors and activity data of these four NFR source categories.

##### Post-combustion of NMVOC from solvent use (2D3a)

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<sub>2</sub> emissions from post-combustion of NMVOC are estimated based on industry data and expert estimates (Carbotech 2022a).

##### Methodology

The CO<sub>2</sub> 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 industrial plants (Carbotech 2022a). Post-combustion facilities are applied in source categories 2D3a Solvent use (industrial paint applications (2D3d NFR), metal degreasing (2D3e NFR) and chemical products, manufacture and processing (2D3g NFR)) and 2G4 Other. In 2018, the source category allocation of all post-combustion plants was verified. For the ten largest facilities (within 2D3a and 2G4), which are responsible for about 70 % of the emissions, the NMVOC quantities and respective carbon contents based on the composition of the solvents were updated annually whereas all the others every five years. For the submission 2022 (FOEN 2022), a complete update of all facilities was carried out by means

of a survey of all cantonal air pollution control authorities, in addition, with VOC balances. If no information of the solvent composition is available, mean source category-specific values were applied for the carbon content.

Source categories coating applications (2D3d NFR) and degreasing (2D3e NFR) comprise nine facilities each, whereas chemical products, manufacture and processing (2D3g NFR) comprise about 80 facilities. Not all facilities have been in use for the entire period. There was a significant increase in total number of facilities from 32 in the year 1990 to 115 in 2002. Since then, the number fluctuates around 120.

The 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

CO<sub>2</sub> emission factors are derived based on the composition of the solvents (carbon content) destroyed in each post-combustion installation. For the ten most important installations (within 2D3a and 2G4), amount and composition of solvents destroyed were updated annually (until 2020) whereas for all others at least every five years. In between, the values were kept constant (see Table 4-38). For installations with no information on the solvent composition, mean industry-specific values are applied. The emission factors given in Table 4-38 are (source category specific) implied emission factors that depend both on carbon content and respective amount of the destroyed NMVOC. Thus, the implied emission factors of source categories with large post-combustion facilities may vary significantly over the years, due to changes in solvent compositions and amounts, starting-up or shutting down of facilities, etc.

Table 4-38 CO<sub>2</sub> emission factors for post-combustion of NMVOC in 2D3a Solvent use.

2D3a Solvent use	Unit	CO <sub>2</sub>				
Post-combustion of NMVOC		1990	1995	2000	2005	2010
Coating applications (2D3d NFR)	t/t NMVOC	2.78	2.75	2.72	2.78	2.78
Degreasing (2D3e NFR)	t/t NMVOC	NO	2.63	2.63	2.64	2.65
Chemical products, manufacture and processing (2D3g NFR)	t/t NMVOC	2.02	1.71	1.96	1.97	2.23

2D3a Solvent use	Unit	CO <sub>2</sub>									
Post-combustion of NMVOC		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Coating applications (2D3d NFR)	t/t NMVOC	2.78	2.27	2.25	2.24	2.25	2.25	2.05	2.05	2.05	2.05
Degreasing (2D3e NFR)	t/t NMVOC	2.40	2.37	2.35	2.35	2.34	2.34	2.34	2.34	2.34	2.34
Chemical products, manufacture and processing (2D3g NFR)	t/t NMVOC	2.36	2.33	2.31	2.26	2.20	2.14	2.09	2.09	2.09	2.09

### Activity data

Activity data are the amounts of NMVOC destroyed in post-combustion installations and are provided by the industry, VOC balances and cantonal air pollution control authorities. For the ten most important installations (within 2D3a and 2G4), they were updated annually (until 2020) whereas for all others at least every five years.

Table 4-39 Activity data of NMVOC post-combustion in 2D3a Solvent use.

2D3a Solvent use	Unit	1990	1995	2000	2005	2010
<b>Post-combustion of NMVOC</b>						
Coating applications (2D3d NFR)	t NMVOC	443	662	756	986	1'104
Degreasing (2D3e NFR)	t NMVOC	NO	749	749	576	898
Chemical products, manufacture and processing (2D3g NFR)	t NMVOC	1'199	4'501	5'677	8'237	5'490

2D3a Solvent use	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
<b>Post-combustion of NMVOC</b>											
Coating applications (2D3d NFR)	t NMVOC	1'048	1'083	1'113	1'126	1'076	1'064	1'061	1'061	1'061	1'061
Degreasing (2D3e NFR)	t NMVOC	665	663	855	817	976	922	882	882	882	882
Chemical products, manufacture and processing (2D3g NFR)	t NMVOC	5'078	4'574	5'232	5'345	5'406	5'267	5'587	5'587	5'587	5'587

## 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 the EMEP/EEA guidebook (EMEP/EEA 2023), 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 2025/2D3b 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 4-40 Emission factors of 2D3b Road paving with asphalt, 2D3c Asphalt roofing and 2D3d Urea use in SCR catalysts (AdBlue) for 2023.

	Unit	CO <sub>2</sub>	CO	NMVOC
<b>2D3b Road paving</b>	kg/t asphalt concrete	NA	NA	0.54
<b>2D3c Asphalt roofing</b>	kg/t asphalt sealing sheeting	NA	0.0059	4.7
<b>2D3d Urea use in SCR catalysts</b>	t/t urea solution	0.240	NA	NA

### 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 4-41 Activity data for road paving with asphalt, asphalt roofing and urea use in SCR catalysts.

	Unit	1990	1995	2000	2005	2010
<b>2D3b Road paving with asphalt</b>						
Asphalt concrete	kt	5'500	4'800	5'170	4'780	5'250
<b>2D3c Asphalt roofing</b>						
Asphalt sealing sheeting	kt	54	56	58	51	68
<b>2D3d Urea use in SCR catalysts</b>						
AdBlue	kt	NO	NO	NO	0.26	20

	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
<b>2D3b Road paving with asphalt</b>											
Asphalt concrete	kt	5'260	4'850	4'710	5'260	5'180	5'210	4'910	4'960	4'970	5'000
<b>2D3c Asphalt roofing</b>											
Asphalt sealing sheeting	kt	75	75	76	76	76	77	77	77	77	78
<b>2D3d Urea use in SCR catalysts</b>											
AdBlue	kt	28	29	31	33	35	36	36	38	38	38

## 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 the EMEP/EEA guidebook (EMEP/EEA 2023), 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 2025/2D3c Dachpappen Produktion und Verlegung). Emissions of CO are determined based on a Tier 1 method using the default emission factor for the production process from the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2D3c, Table 3.1).

Indirect CO<sub>2</sub> emissions resulting from CO and NMVOC emissions in this source category are included in CRT Table6 as documented 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 factor of CO for the production process is taken from the EMEP/EEA guidebook (EMEP/EEA 2023, chp. 2D3c, Table 3.1) (see Table 4-40).

### Activity data

Activity data are based on data from industry and expert estimates as documented in the EMIS database (see Table 4-41).

## Urea use in SCR catalysts of diesel engines (2D3d)

This source category encompasses CO<sub>2</sub> 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 AdBlue is reported following a methodology suggested in the EMEP/EEA guidebook (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 AdBlue consumption estimates. Emissions are calculated according to following formula:

$$\text{CO}_2 \text{ Emissions} = \text{EF} \cdot \text{FC} \cdot \text{Share of SCR vehicles mileage} \cdot \text{Specific urea share}$$

“FC” relates to the fuel consumption in 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<sub>2</sub> emissions from urea use in SCR-catalysts in vehicles is a default value from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1.A.3.b.i-iv, page 46) considering the molecular mass conversion of urea into CO<sub>2</sub> during the reaction with water and the content of 32.5 % of the aqueous AdBlue urea solution (see Table 4-40).

#### *Activity data*

Activity data on AdBlue consumption as well as annual mileage are provided by INFRAS (INFRAS 2017, INFRAS 2022) on a yearly basis as documented in EMIS 2025/2D3d NFR Urea (AdBlue) Einsatz Strassenverkehr. For activity data see Table 4-41.

### **4.5.3. Uncertainties and time-series consistency for 2D**

The uncertainty of total CO<sub>2</sub> emissions from the entire source category 2D – Non-energy products from fuels and solvent use is estimated to be 14 % (expert estimate). This is the combined uncertainty according to uncertainty propagation assuming 10 % uncertainty of activity data and 10 % uncertainty for emission factors.

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 for 2D**

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

### **4.5.5. Category-specific recalculations for 2D**

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences in direct and indirect CO<sub>2</sub> emissions of sector 2 IPPU between the latest and the previous submissions are presented also in chp. 10.1.2.2.

- 2D1: The activity data of lubricant use in 2-stroke engines and thus also of unspecified lubricant use have changed for the entire time series due to recalculated gasoline and bioethanol consumption in 1A3biv 2-stroke motorcycles.

### 4.5.6. Category-specific planned improvements for 2D

There are no planned improvements.

## 4.6. Source category 2E – Electronics industry

### 4.6.1. Source category description

Table 4-42 Key categories of 2E Electronics industry. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Source category 2E Electronics industry is not a key category.

Source category 2E Electronics industry comprises HFC, PFC, NF<sub>3</sub> and SF<sub>6</sub> emissions from consumption of the applications listed in Table 4-43.

Table 4-43 Specification of source category 2E Electronics industry in Switzerland.

2E	Source category	Specification
2E1	Integrated circuit or semiconductor	Etching and cleaning processes in the production of IC and semiconductors (similar cleaning services for printed wiring boards included in the evaluation)
2E2	TFT flat panel display	No production of TFT flat panel displays in Switzerland, activities contained in the production of displays for watches
2E3	Photovoltaics	Emissions from photovoltaic manufacturing
2E4	Heat transfer fluids	No application in Switzerland assumed*
2E5	Other	Test activities (for example related to printed wiring boards), research activities

### 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 4-43 (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 is available from Carbotech (2025).

#### Methodology

A Tier 2a approach with specific parameters for each gas 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 according to the 2019 Refinement to the 2006 IPCC Guidelines (IPCC 2019). The Tier 2a method is for semiconductor sub-sector with revised emission factors, also accounting for additional precursors and by-products.

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 4-43 (Carbotech 2025). As a result, the peak of  $\text{NF}_3$  imports (and corresponding emissions) between 2009 and 2011 was found to be related to photovoltaic manufacture.

### Emission factors

Default emission factors according to the 2019 Refinement to the 2006 IPCC Guidelines are used for production and waste-air treatment (IPCC 2019). An exhaust treatment is assumed probable for most applications, in agreement with the requirements of the Chemical Risk Reduction Ordinance (Swiss Confederation 2005) to minimize emissions and in particular with the 5 % threshold for semiconductor production. Based on information available to the FOEN from several companies, a compliance with these requirements of close to 100 % can be expected (Wöhrnschimmel and Schmidely 2023). Therefore, for the purposes of calculating emissions, full compliance was assumed from 2021 onwards. In former years, a compliance of >60 % had been assumed, based on declarations from companies confirming the presence of exhaust treatment in a survey.

### Activity data

Activity data are based on FOEN import statistics and industry information.

#### 4.6.3. Uncertainties and time-series consistency for 2E

The uncertainty for the emissions from the use of HFC, PFC,  $\text{SF}_6$ , and  $\text{NF}_3$  in 2E Electronics industry was estimated based on a Monte Carlo simulation. The obtained distribution types and numeric values for the emission uncertainties are reported in Annex A2.1. More information is available from Carbotech (2025).

Consistency: Time series for 2E Electronics industry are all considered consistent.

#### 4.6.4. Category-specific QA/QC and verification for 2E

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

#### 4.6.5. Category-specific recalculations for 2E

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences in direct and indirect  $\text{CO}_2$  emissions of sector 2 IPPU between the latest and the previous submissions are presented also in chp. 10.1.2.2.

- 2E1: Additional emissions are accounted between 1997-2022; HFC-23 is built as a by-product from use of PFC.

#### **4.6.6. Category-specific planned improvements for 2E**

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 4-44 Key categories of 2F Product uses as substitutes for ozone depleting substances. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
2.F.1	Refrigeration and air-conditioning	HFCs	L1, L2, T1, T2
2.F.2	Foam blowing agents	HFCs	L2, 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 4-45.

Table 4-45 Specification of source category 2F Product uses as substitutes for ozone depleting substances in Switzerland.

2F	Source category	Specification
2F1	Refrigeration and air conditioning	Emissions from refrigeration and air conditioning (inclusive heat pumps and tumble dryers)
2F2	Foam blowing agents	Emissions from foam blowing, incl. polyurethan spray
2F3	Fire protection	No application in Switzerland assumed
2F4	Aerosols	Emissions from use as aerosols, incl. metered dose inhalers
2F5	Solvents	Emissions from use as solvents

Figure 4-8 shows HFC and PFC emissions from different applications in source category 2F. In 2023, stationary and mobile refrigeration and air conditioning equipment accounted by far for the highest emissions with a share of 96 % of the total emissions in source category 2F. Emissions are dominated by HFCs and only a minor contribution comes from PFCs (less than 1 %).

From 2015 onwards there is a decline in emissions as a result of the regulations from the Chemical Risk Reduction Ordinance (Swiss Confederation 2005). The regulations contain restrictions of F-gas import, limitation of HFCs with a high GWP for stationary refrigeration and a registration of equipment with more than 3 kg of refrigerants. Regarding the prefilled imported equipment, there is an effect of the EU F-gas regulation and the planned phase-out due to the Kigali Amendment. The results of the EU regulations are a complete replacement of HFCs in imported equipment for mobile air-conditioning and a lower HFC content in stationary refrigeration and air-conditioning equipment. Overall, this results in a decline of HFC emissions with a certain delay replacing the current stock of HFC in equipment. New substances such as hydrofluoroolefins (HFOs), HFO blends and hydrocarbons are replacing formerly used refrigerants with higher GWP and are also being used to substitute HFCs and PFCs in other applications such as foams, solvents and aerosols.

Additional factors for the decline are effects of monitoring of equipment, education and training. Some retailers maintain a monitoring program of refrigerant stock and emissions confirming improvements over time.

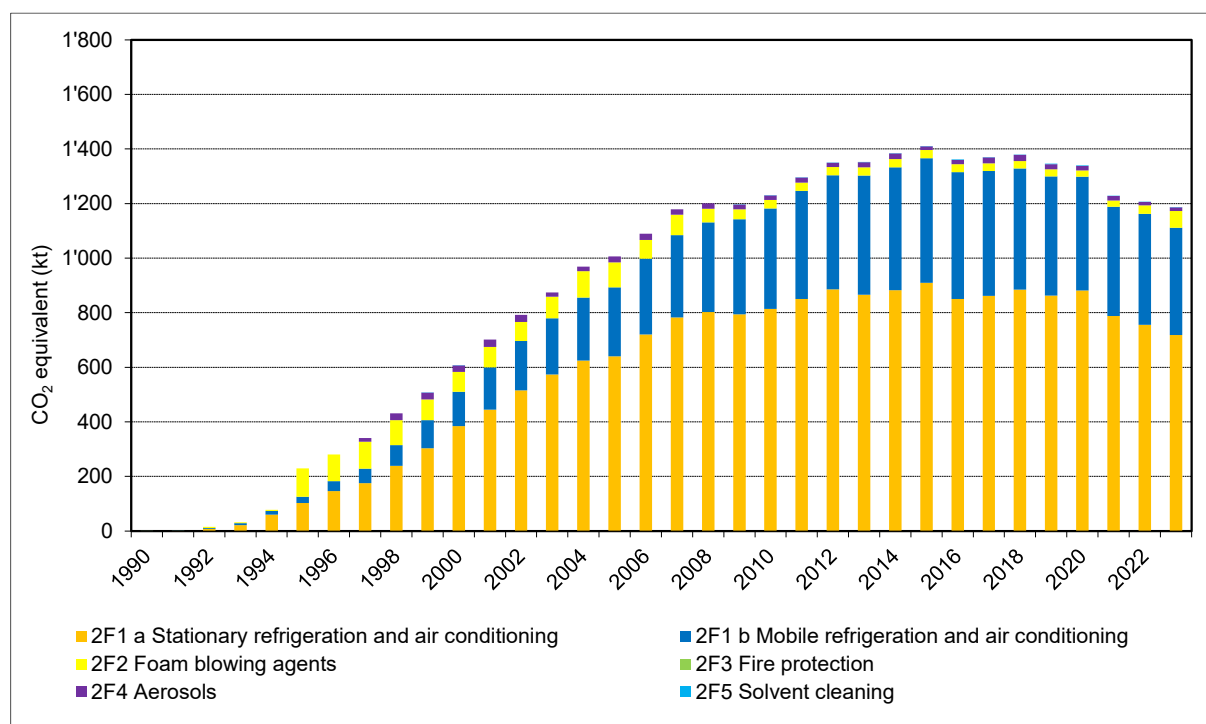


Figure 4-8 Development of emissions under source category 2F Product uses as substitutes for ozone depleting substances. HFC and small amounts of PFC are used as substitutes for ozone depleting substances. Most relevant today are emissions from the refrigerant stock in refrigeration and air conditioning equipment (2F1).

#### 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 NID. 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

##### 2F1b Mobile refrigeration and air conditioning

- Mobile air conditioning in different vehicle types
- Transport refrigeration for different vehicle types

Annex A5.2 shows an illustrative example of the model structure and parameters used for calculating emissions from mobile air conditioning in cars. The most important assumptions for the data model are documented in Table 4-46. More information of the individual data and models is available from Carbotech (2025) as well as related background documents. This

information is considered confidential, but it will be made available for consultation by reviewers on request.

#### 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 information and expert estimations:

- Domestic refrigeration
- Mobile air conditioning for different vehicle types (example illustrated in Annex A5.2)
- 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 is based on the bottom-up calculations of stock as given in the example of mobile air conditioning in Annex A5.2. A comparison to neighbouring countries shows higher stock and emissions from mobile air-conditioning in Switzerland. Model parameters were checked and a higher rate of air-conditioning of >95 % in vehicles is assumed plausible and is confirmed by companies dismantling vehicles.

Commercial and industrial refrigeration were evaluated together in former years. To obtain separate models, the total bulk refrigerant used for commercial and industrial applications is split based on the typical use of refrigerant blends and the available information on commercial and industrial equipment (Carbotech 2025). Parameters for commercial and industrial applications are given in Table 4-46. Furthermore, HFC-245fa, included under commercial and industrial refrigeration, was found to be used for organic rankine cycles (ORC).

The combination of bottom-up with top-down calculations leads to more comprehensive results than using just a single approach. Noteworthy, in the hypothetical but possible case of incomplete bottom-up evaluations, the remaining imported refrigerant would be attributed to the production and maintenance of industrial and commercial refrigeration equipment. This might be the reason why the resulting refrigerant stock of commercial and industrial refrigeration, which serves as the residual, 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 4-9 shows the required data for the model calculation of refrigeration and air conditioning.

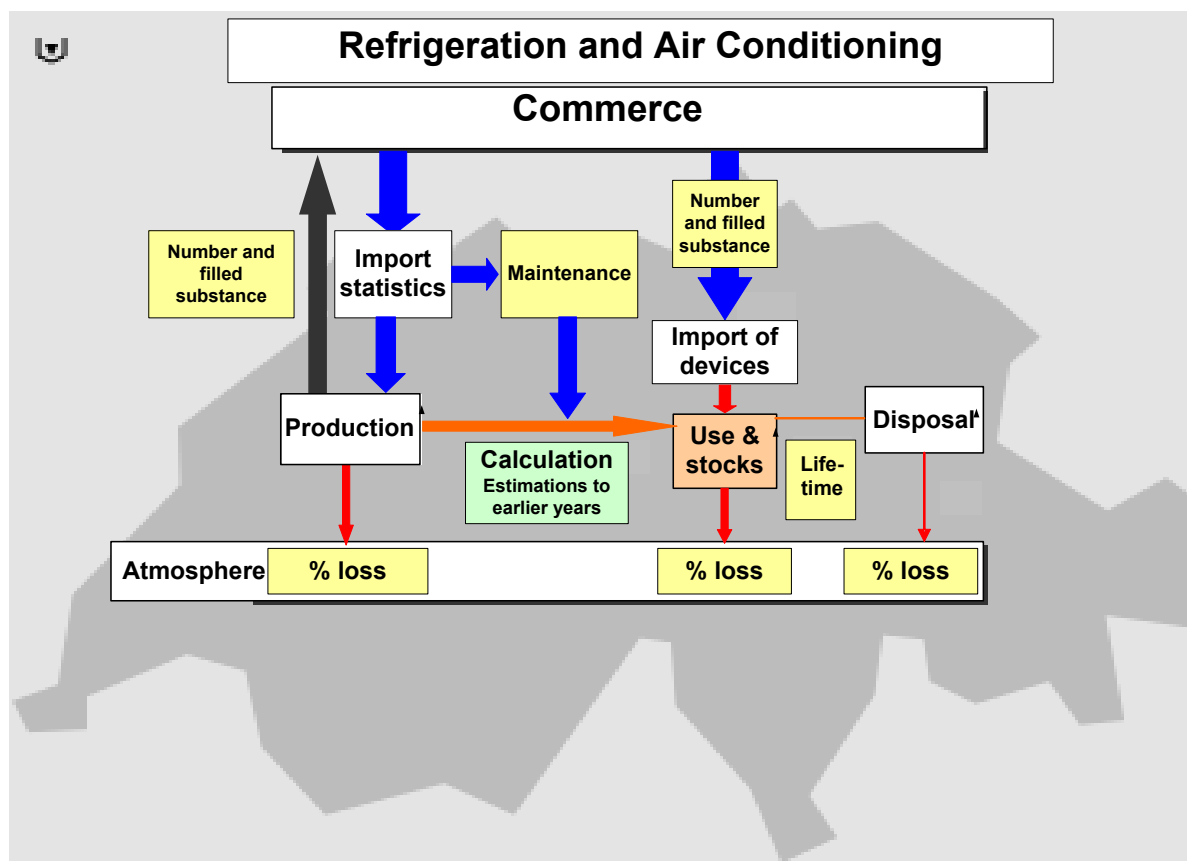


Figure 4-9 Required data for the model to calculate emissions from refrigeration and air conditioning in Switzerland.

Since 2008, operators handling equipment containing more than 3 kg of HFCs have been obligated to provide information to FOEN on the date of operation start, type of equipment, type and amount of refrigerant and date of disposal. This data source provides valuable information and is applied to improve the estimates used for modelling emissions under source category 2F and for the split of commercial and industrial equipment. However, it does not allow to directly draw the stock data or emission factors for the national inventory.

### Emission factors

Emission factors related to 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 the quality (confidential data from retailers and other industries). 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 4-46 displays the detailed model parameters used for the present submission and values used in the early period of HFC use (1990 to 1995). For product life emission factors of some equipment types, a dynamic model is applied, which implies that emissions decreased linearly between 1995 and 2015 due to improved production technologies and the continuous sensitisation of service technicians. The start/end values are based on expert statements (Carbotech 2025, UBA 2005, UBA 2007, Schwarz 2001, Schwarz and Wartmann 2005). Constant emission factors were assumed from 2015 onwards. The charge at the end of life for different applications has been analysed considering the technical minimal charge of the equipment and the expected frequency of the 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 on site or waste treatment by specialized companies.

Table 4-46 Typical values of lifetime, charge and emission factors used in the model calculations for 1990 to 2023 for refrigeration and air conditioning equipment. Changes of model parameters within this time period are indicated giving the initial value considered in the early time period of F-gas use around 1995 and the value used for modelling for 2023 (decrease between 1995 and 2015, steady values from 2015 onwards). The reduction of charge and losses is the result of improvement of technology and handling of equipment.

	Product life time	HFC/PFC Stock 2023	Composition of stock HFC/PFC	Initial charge of new product	Manufacturing emission factor	Product life emission factor	Disposal loss emission factor ***)	Charge at end of life *)	Export of retiring equipment **)
	[a]	[t]	Main products	[kg]	[% of initial charge]	[% per annum]	[% of remaining charge]	[% of initial charge of new product]	[% of retiring equipment]
Domestic refrigeration	16	1	HFC134a	0.1	NO	0.5	19 ****)	92.0	<3
Commercial refrigeration	8	1'536	R404a, R407C, R449a, R410a, R507, R422d, R448a	NR	0.5	1995: 12.5 2023: 7.8	24	80-90	NE
Industrial refrigeration	15	447	HFC134a, R410a, R407c, R404a, R422d, R507, R513a	NR	0.5	1995: 10 2023: 5	15	75-90	NE
Transport refrigeration: trucks/vans	10	57	R404a, R134a, R449a	1.8-7.8	1.5	15.0	28	86.0	90
Transport refrigeration: wagons	16			NR	NO	10.0	28	100.0	NE
Stationary air conditioning: direct cooling systems	15	2'430	R410a, HFC134a, R407c, R404a, HFC32, R417a, R449a, R513a, R452a	NR	1995: 3 2023: 1	1995:10 2023:4	28	74-89	NE
Stationary air conditioning: indirect cooling systems	15			NR	1.0	1995: 6 2023: 4	19	85-89	NE
Stationary air conditioning: heat pumps	15			1995: 4.7-7.5 2023: 2.8-4.5	1995: 3 2023: 1	2.0	19	86.0	NE
Stationary air conditioning: tumble dryers	15		HFC134a, R407c	0.4	0.5	2.0	19	74.0	NE
Mobile air conditioning: cars	15	2'386	HFC134a	1995: 0.84 2023: 0.55	NO	8.5	50	58.0	1995: 31-72 2023: 59
Mobile air conditioning: truck/van cabins	12			1.1	NO	1995: 10 2023: 8.5	50	69-73	90 trucks / 50 vans
Mobile air conditioning: buses	12			7.5	NO	1995: 20 2023:15	45	78.0	50
Mobile air conditioning: trains	16			20	NO	5.5	20	100.0	50

\*) 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 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 A5.2 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. 34 % of the total emissions (CO<sub>2</sub> eq) of source category 2F1 Refrigeration and air conditioning in the inventory 2023.

For the NIR 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. unrecorded exports of refrigeration equipment for second-hand use. Export rates used in model calculations are given in Table 4-46.

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 applications of foam production have been calculated (Tier 1a) as residual balance between FOEN import statistics and consumption in PU spray, PU and XPS foams.

Desktop research on HFC-245fa use in neighbouring countries was carried out for the inventory 2019 to identify the relevance of HFC-245fa emissions from the import of foam products. HFC-245fa has not been used for foam blowing in Switzerland, but measurements at the Jungfrauoch site by Empa (see chp. 4.7.4 and Annex A6.1) indicate emissions probably related to the import of foam products. Due to the low relevance, lacking data and the decreasing use in neighbouring countries since 2005 (partly through bans) the model calculations were not extended with HFC-245fa (Carbotech 2025).

##### **Emission factors**

For the emission factors and the lifetimes of XPS and PU foams, expert estimates and default values according to the 2006 IPCC Guidelines (IPCC 2006, Volume 3, p. 7.37) are used. For PU sprays, 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 4-47 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 in Switzerland has been HFC-free.

\*\* 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 the total production volume in the time period of the HFC use. About one third of the 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<sub>2</sub>). 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 and pipe insulation mentioned by an import company of foam blowing agents has not been confirmed). The import amount shows a decreasing trend and choice of HFC with lower GWP values. No import of in bulk HFC was reported for the production of foam in 2023. The replacement with HFO and HCFO is plausible and corresponds to the trend in the portfolio of foam blowing agents suppliers. A similar trend and phase-out within few years is assumed for import foam product containing HFC.

Without additional measurements, the release of F-gases from the disposal of PU and XPS foam product stock is assumed to occur approximately from 2050 onwards, thus resulting in an emission peak in the future. For the HFC blowing agents with unknown applications, emissions from disposal start in 2022 due to the assumed product lifetime of only 20 years.

Detailed activity data for this source category are considered confidential, but are available to reviewers on request.

#### 4.7.2.3. Fire protection (2F3)

No emissions occur in source category 2F3 within Switzerland. The application of HFCs, PFCs and SF<sub>6</sub> in fire extinguishers is prohibited by law.

#### 4.7.2.4. Aerosols (2F4)

##### Methodology

The Tier 2a emission model for Aerosol / metered dose inhalers is based on a top-down approach using import statistics for HFCs until 2020 (end of Swiss production of metered dose inhalers and further technical applications). The consumption of metered dose inhalers was extrapolated for the time period 2021 to 2023 considering the development of HFC use of former years and the reported consumption of inhalers containing HFC in Switzerland (Carbotech, 2025). For imports of HFC-365mfc considered for use in solvent sprays a Tier 2a approach is applied for the whole time period.

##### 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 (IPCC 2006).

##### 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 anymore. For special technical applications – especially metered dose inhalers (MDI) and cleaning sprays – 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 until 2023 and in the case of metered dose inhalers on extrapolations for the time period 2021 to 2023 after the end of the Swiss production considering the trend of HFC use and literature values on the consumption of inhalers containing HFC in Switzerland. Exports and imports of filled products are not known, but are assumed to be in a similar range for inhalers until 2020. No exports of inhalers are assumed after 2020, as the filling of aerosol bottles in Switzerland ended in 2020.

#### 4.7.2.5. Solvents (2F5)

##### Methodology

HFCs and PFCs have been used as solvents until 2020. Emissions are calculated with a Tier 1a method according to the 2006 IPCC Guidelines on the basis of a top-down approach using import statistics and industry information on the allocation of the imported HFC and PFC amounts for 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 have been 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.

The HFC import amount has been decreasing with alternatives of hydrofluorether HFE for the main applications. No HFC import was declared in 2023. A complete replacement with HFC-free options is expected for the future.

### 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 2F

For refrigeration equipment, air conditioning equipment as well as for foam blowing, a Monte Carlo analysis according to IPCC Good Practice Guidance (IPCC 2000) 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 latest GHG inventory (submission 2025), using the Cristal Ball Add-in for Excel. For the purpose of the Monte Carlo analysis, the uncertainty of all relevant parameters (e.g. initial appliance charge, product life emission factor, portion of products with HFC or HFC-blends, product lifetime, import and export volumes, etc.) used in the emission models for the applications as per Table 4-48 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 (defined by mean and standard deviation, and, if necessary, additional minimum and maximum cut-off values).

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 2025).

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 4-48. 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 4-48 Estimated uncertainty for the data of the imported substances.

Year	Std. Dev.	Minimal	Maximal	Remarks
Up to 1999	20%	50%	50%	Data can be incomplete or possible double declaration
2000 – 2003	20%	20%	20%	Data can be incomplete or possible double declaration
2004 –	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 4-49 illustrate the definition of ranges for the example of commercial refrigeration.

Table 4-49 Assumptions on probability ranges for the example of commercial refrigeration and mobile air conditioning applied in Monte Carlo analysis.

Parameter applied for commercial refrigeration	Likeliest	StdDev	Minimal	Maximal	Uncertainty range, distribution
Initial charge of product	NR	NR	NR	NR	Not relevant, calculated value
Manufacturing emission factor	0.5%	0.1%	0.3%	0.8%	Normal distribution, StdDev 10%, Min -50%, Max +50%
Prefilled import	25%	4%	13%	38%	Normal distribution, StdDev 15%, Min -50%, Max +50%
Product life emission factor	7.8%	2%	4%	12%	Normal distribution, StdDev 30%, Min -50%, Max +50%
Recharge of product life emissions	80%	12%	60%	100%	Normal distribution, StdDev 15%, Min -25%, Max +25%
Product lifetime in years*	8	1.2	6	10	Normal distribution, StdDev 15%, Min -20%, Max +20%
Charge at end of life	NR	NR	NR	NR	Not relevant, calculated value
Disposal loss emission factor (professional disposal)	10%	1%	5%	15%	Normal distribution, StdDev 20%, Min -50%, Max +50%
Professional disposal quote	85%	8.5%	72%	98%	Normal distribution, StdDev 10%, Min -15%, Max +15%

Parameter applied for mobile AC / car	Likeliest	StdDev	Minimal	Maximal	Uncertainty range, distribution
Initial charge of new product in kg	0.55	0.08	0.41	0.69	Lognormal distribution, StdDev 15%, Min -25%, Max +25%
Manufacturing emission factor	NR	NR	NR	NR	Not relevant, prefilled import of equipment
Prefilled import	100%	100%	100%	100%	No Swiss production of equipment
Product life emission factor (excluding service losses)	8.5%	1.7%	6.8%	10.2%	Lognormal distribution, StdDev 20%, Min -50%, Max +50%
Recharge of product life emissions	80%	12%	60%	100%	Normal distribution, StdDev 15%, Min -25%, Max +25%
Product lifetime in years	15	2	12	18	Normal distribution, StdDev 10%, Min -20%, Max +20%
Charge at end of life	NR	NR	NR	NR	Not relevant, calculated value
Disposal loss emission factor (professional disposal)	10%	2%	5%	15%	Normal distribution, StdDev 20%, Min -50%, Max +50%
Professional disposal	60%	3%	45%	75%	Normal distribution, StdDev 5%, Min -25%, Max +25%

Table 4-50 summarises the results for the application-specific emission models. The “value 2023” represents the reported emissions in kt CO<sub>2</sub> eq for the specific emission sources for the year 2023. The uncertainty values stem from the Monte Carlo analysis. Detailed data are available from background documents at FOEN (Carbotech 2025).

The uncertainty of the resulting total emissions from source category 2F Product uses as substitutes for ODS is about 20 %. 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 4-50 Summary of results for model parameter “emissions” from Monte Carlo analysis for 2023 data on selected emission sources.

Application	Value 2023 kt CO <sub>2</sub> -eq.	Average kt CO <sub>2</sub> -eq.	Median kt CO <sub>2</sub> -eq.	min. kt CO <sub>2</sub> -eq.	max. kt CO <sub>2</sub> -eq.	Uncertainty %
2F1 Refrigeration and air conditioning	1'138	1'213	1209	865	1'798	17
2F2 Foam blowing agents	52	93	82	10	1200	214
2F4 Aerosols	13	13	13	5	19	30
Total 2F Product use as substitutes	1'203	1'319	1'303	881	3'018	18

Consistency: Time series for 2F are all considered consistent.

#### 4.7.4. Category-specific QA/QC and verification for 2F

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

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 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 analyses of tropospheric background concentrations. However, under special meteorological conditions, an estimate of Swiss emissions can be derived from the measurements. For five HFCs (HFC-134a, HFC-125, HFC-152a, HFC-143a, HFC-32) and for SF<sub>6</sub> a comparison of the inventory data with the inferred emissions is presented in Annex A6.1. Estimated emissions based on measurements at Jungfraujoch agree fairly well with the emission estimates of HFC-125, HFC-143a, HFC-32 and of SF<sub>6</sub> of the Swiss greenhouse gas inventory. For HFC-134a a continuing decline is estimated from the Jungfraujoch-based estimates, whereas the emissions in the inventory are relatively stable. A decreasing trend is found in the inventory on the level of HFC-134a emissions from refrigerant stock. The decrease is balanced by higher contributions from the disposal of HFC-134a containing equipment and from the disposal of foam products. 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 for 2F

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences in direct and indirect CO<sub>2</sub> emissions of sector 2 IPPU between the latest and the previous submissions are presented also in chp. 10.1.2.2.

- 2F1: There are changes in activity data 2020–2022 for the disposal of HFC and PFC from commercial and industrial equipment: The modelling of the remaining refrigerant amount

in commercial equipment at the disposal was adjusted. The refrigerant recycling amount for use in stationary refrigeration was reduced.

- 2F1: There are changes in activity data 2022 of HFC and PFC use for mobile and air-conditioning and stationary refrigeration related to changes in the vehicle and equipment statistics.
- 2F1: There are changes in the activity data 2020–2022: The portion of HFC in air-conditioning of vans was revised.
- 2F2: There are changes in activity data 2020–2022 related to the portion of PU-Spray containing HFC-134a.

#### 4.7.6. Category-specific planned improvements for 2F

Changes are expected and will be analysed in this area due to the revision of the Chemical Risk Reduction Ordinance and CO<sub>2</sub> compensation programmes (share of products with HFC, recycling of HFC, replacement of HFC).

### 4.8. Source category 2G – Other product manufacture and use

#### 4.8.1. Source category description

Table 4-51 Key categories of 2G Other product manufacture and use. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Source category 2G Other product manufacture and use is not a key category.
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Table 4-52 Specification of source category 2G Other product manufacture and use.

2G	Source category	Specification
2G1	Electrical equipment	Emissions of SF <sub>6</sub> from use in electrical equipment
2G2	SF <sub>6</sub> and PFCs from other product use	Emissions of SF <sub>6</sub> and PFC not accounted in other source categories (i.e. for particle accelerators, soundproof windows, leakage detection, medicinal products, research and laboratory use)
2G3	N <sub>2</sub> O from product uses	Emissions of N <sub>2</sub> O from the use of N <sub>2</sub> O in hospitals; Emissions of N <sub>2</sub> O from the use of aerosol cans
2G4	Other	Emissions of NMVOC from domestic solvent use, printing, other solvent and product use as well as emissions of CO <sub>2</sub> resulting from post-combustion of NMVOC in exhaust gases of these sources; Emissions of CO <sub>2</sub> , NO <sub>x</sub> , CO, NMVOC and SO <sub>2</sub> from use of fireworks; Emissions of N <sub>2</sub> O from the production of rock wool; Emissions of NO <sub>x</sub> , CO and NMVOC from use of tobacco; Emissions of HFC not accounted elsewhere

## 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<sub>6</sub> on the 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<sub>6</sub> for other applications (i.e. research, magnesium foundry). Swissmem is collecting data from its members and is cross-checking the reported SF<sub>6</sub> consumption data with data from importers of SF<sub>6</sub>. Installations in operation with electrical equipment containing SF<sub>6</sub> are periodically inspected for leakage, and losses are refilled (topping up). The refilled quantities and any SF<sub>6</sub> 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<sub>6</sub> emissions.

#### Activity data

Activity data are based on industry information. The wide annual fluctuation of SF<sub>6</sub> 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<sub>6</sub> 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<sub>6</sub> and PFCs from other product use (2G2)

#### Methodology

The emissions reported under 2G2 are related to the use of SF<sub>6</sub> for industrial particle accelerators (2G2b), the use of SF<sub>6</sub> for soundproof windows (2G2c) and other PFC and SF<sub>6</sub> use (2G2e). 2G2e summarizes medicinal products, research/analytics and further applications that are not specified (including the unallocated difference in SF<sub>6</sub> 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<sub>6</sub> 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 for SF<sub>6</sub>. Therefore, the unallocated amount of SF<sub>6</sub> under 2G2e has been modelled assuming applications similar to those in 2G1.

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. They are available in the confidential NID for reviewers on request.

### **Emission factors**

For the unallocated amount of SF<sub>6</sub>, the emission factor is assumed to be 4 % for manufacturing and 1 % per year during the product life for the remaining amount. The remaining charge is completely 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 contribution from broken windows. For the manufacturing an emission factor of 33 % is assumed. However, since 2008, there is no production of windows with SF<sub>6</sub> in Switzerland.

### **Activity data**

Activity data are based on import statistics, Swissmen balances and industry information. For the unallocated amount of SF<sub>6</sub> an export rate of 80 % is assumed similar to electrical equipment 2G1.

No further details are provided due to confidentiality. They are available in the confidential NID for reviewers on request.

## **4.8.2.3. N<sub>2</sub>O from product uses (2G3)**

### **Methodology**

Emissions of N<sub>2</sub>O from the source category 2G3 occur from the anaesthesia use in hospitals (2G3a Medical applications) and from the use of aerosol cans in households and restaurants (2G3b Other). For both categories a Tier 2 method based on country-specific emission factors for the production/consumption of N<sub>2</sub>O 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<sub>2</sub>O sold for anaesthesia purpose in Switzerland divided by the number of inhabitants. The amount of N<sub>2</sub>O sold is derived from annual sales data from the main suppliers from 2005 onwards (EMIS 2025/2G3a Lachgasanwendung Spitäler).

Source category 2G3b Other includes N<sub>2</sub>O emissions from whipped-cream makers using gas capsules for private households and restaurants. The emission factor is calculated based on sales data and N<sub>2</sub>O content of gas capsules sold in Switzerland divided by the number of inhabitants (EMIS 2025/2G3b Lachgasanwendung Haushalt).

Table 4-53 N<sub>2</sub>O emission factors for the source categories 2G3a Medical applications and 2G3b Other.

2G3a Use of N <sub>2</sub> O for anaesthesia	Unit	1990	1995	2000	2005	2010
N <sub>2</sub> O	g/inhabitant	43	30	16	13	6.8
2G3b N <sub>2</sub> O from aerosol cans						
N <sub>2</sub> O	g/inhabitant	9.0	9.8	11	11	12

2G3a Use of N <sub>2</sub> O for anaesthesia	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
N <sub>2</sub> O	g/inhabitant	3.8	3.3	2.5	2.3	2.2	2.1	2.0	2.0	1.9	1.9
2G3b N <sub>2</sub> O from aerosol cans											
N <sub>2</sub> O	g/inhabitant	11	11	10	10	10	10	10	10	10	10

### Activity data

As the emission factors are expressed in g N<sub>2</sub>O per capita, the corresponding activity data for the source categories 2G3a Medical applications and 2G3b Other are the Swiss population (FSO 2024c).

Table 4-54 Activity data for the source categories 2G3a Use of N<sub>2</sub>O for anaesthesia and 2G3b N<sub>2</sub>O from aerosol cans.

2G3 N <sub>2</sub> O from product uses	Unit	1990	1995	2000	2005	2010
2G3a, 2G3b	inhabitants	6'712'000	7'041'000	7'184'000	7'437'000	7'825'000

2G3 N <sub>2</sub> O from product uses	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
2G3a, 2G3b	inhabitants	8'189'000	8'282'000	8'373'000	8'452'000	8'514'000	8'575'000	8'638'000	8'705'000	8'739'000	8'889'000

#### 4.8.2.4. Other (2G4)

##### Other solvent use (2G4)

Since the IPCC Guidelines (IPCC 2006, vol. 3, chp. 5.5) refer to the EMEP/EEA guidebook regarding methodologies for estimating NMVOC emissions from solvent use, the respective NFR codes are indicated as reference as well. Within 2G4 Other solvent use, 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. Domestic solvent use comprises mainly the use of cleaning agents, detergents, cosmetics and toiletries in private households whereas the other three NFR source categories consist of solvent applications in various production processes and services and the use of solvent-based products in various industrial processes, services and commerce. Domestic solvent use is by far the largest NMVOC emission source of 2G4 Other solvent use. Indirect CO<sub>2</sub> emissions resulting from NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

##### Methodology

For the determination of NMVOC emissions from domestic solvent use (2D3a NFR), printing (2D3h NFR), other solvent use (2D3i NFR) and other product use (2G NFR) a Tier 2 method according to the EMEP/EEA guidebook (EMEP/EEA 2023) is used. For domestic solvent use, the emissions are based on the products consumed and their solvent content and are calculated in proportion to the Swiss population. For package printing and other printing industry the emissions are based on the ink consumption, for other solvent use mainly on the number of employees and for other product use on the number of employees and products applied or manufactured. Switzerland's Informative Inventory Report (FOEN 2025b, chp. 4.5.2.1, 4.5.2.8, 4.5.2.9 and 4.6.2.1) contains a detailed description of the country-specific emission factors and activity data of these four NFR source categories.



## Post-combustion of NMVOC from other solvent use (2G4)

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<sub>2</sub> emissions from post-combustion of NMVOC are estimated based on industry data and expert estimates (Carbotech 2022a).

### Methodology

The CO<sub>2</sub> 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 2022a).

Post-combustion facilities are applied in source categories 2D3a Solvent use (see chp. 4.5.2.2) and 2G4 Other solvent use comprising printing (2D3h NFR), other solvent use (2D3i NFR) and other product use (2G NFR). In 2018, the source category allocation of all post-combustion plants has been verified. For the ten largest facilities (within 2D3a and 2G4), which are responsible for about 70 % of the emissions, the NMVOC quantities and respective carbon contents based on the composition of the solvents were updated annually whereas all the others every five years. For the submission 2022, a complete update of all facilities was carried out by means of a survey of all cantonal air pollution control authorities, in addition, with VOC balances. If no information of the solvent composition was available, mean source category-specific values were applied for the carbon content.

Not all facilities have been in use for the entire period. There was a significant increase in total number of facilities from 32 in the year 1990 to 115 in 2002. Since then, the number fluctuates around 120.

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

CO<sub>2</sub> emission factors are derived based on the composition of the solvents (carbon content) destroyed in each post-combustion installation. For the ten most important installations (within 2D3a and 2G4), amount and composition of solvents destroyed were updated annually (until 2020) whereas for all others at least every five years. In between the values were kept constant (see Table 4-55). For installations with no information on the solvent composition, mean industry-specific values are applied. The emission factors given in Table 4-55 are (source category specific) implied emission factors that depend both on carbon content and respective amount of the destroyed NMVOC. Thus, the implied emission factors of source categories with large post-combustion facilities may vary significantly over the years, due to changes in solvent compositions and amounts, starting-up or shutting down of facilities, etc.



Table 4-55 CO<sub>2</sub> emission factors for post-combustion of NMVOC in 2G4 Other.

2G4 Other	Unit	CO <sub>2</sub>				
Post-combustion of NMVOC		1990	1995	2000	2005	2010
Printing (2D3h NFR)	t/t NMVOC	2.25	2.20	2.17	2.14	2.14
Other solvent use (2D3i NFR)	t/t NMVOC	1.97	1.96	1.96	1.94	1.95
Other product use (2G NFR)	t/t NMVOC	1.30	1.60	1.64	1.71	1.90

2G4 Other	Unit	CO <sub>2</sub>									
Post-combustion of NMVOC		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Printing (2D3h NFR)	t/t NMVOC	2.15	2.09	2.10	2.10	2.09	2.10	2.00	2.00	2.00	2.00
Other solvent use (2D3i NFR)	t/t NMVOC	2.05	2.27	2.27	2.27	2.27	2.27	2.49	2.49	2.49	2.49
Other product use (2G NFR)	t/t NMVOC	1.74	1.67	1.71	1.69	1.75	1.79	1.83	1.83	1.83	1.83

### Activity data

Activity data are the amounts of NMVOC destroyed in post-combustion installations and are provided by the industry, VOC balances and cantonal air pollution control authorities. For the ten most important installations (within 2D3a and 2G4), they were updated annually (until 2020) whereas for all others at least every five years.

Table 4-56 Activity data of NMVOC post-combustion in 2G4 Other.

2G4 Other	Unit	1990	1995	2000	2005	2010
Post-combustion of NMVOC						
Printing (2D3h NFR)	t NMVOC	2'188	9'357	11'276	13'036	13'414
Other solvent use (2D3i NFR)	t NMVOC	288	474	530	395	554
Other product use (2G NFR)	t NMVOC	412	1'034	1'217	939	688

2G4 Other	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Post-combustion of NMVOC											
Printing (2D3h NFR)	t NMVOC	13'752	14'112	14'477	15'661	15'292	15'423	14'732	14'732	14'732	14'732
Other solvent use (2D3i NFR)	t NMVOC	364	368	360	352	344	336	58	58	58	58
Other product use (2G NFR)	t NMVOC	1'046	1'086	1'097	1'255	1'224	1'237	1'154	1'154	1'154	1'154

### Other product use (2G4)

In addition to NMVOC emissions from the use of solvent-based products in industrial processes, services and commerce, emissions of CO<sub>2</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> as well as of NO<sub>x</sub>, CO and NMVOC from the use of fireworks and tobacco, respectively, are reported in source category 2G4 Other product use (2G NFR).

Since the emissions of CO and NMVOC from tobacco use are of biogenic origin, they are not considered for calculation of indirect CO<sub>2</sub> emissions. Thus, indirect CO<sub>2</sub> emissions resulting from CO emissions from use of fireworks only are included in CRT Table6 as documented in chp. 9.

### Methodology

The emissions are determined by a Tier 2 method according to the EMEP/EEA guidebook (EMEP/EEA 2023) using country-specific emission factors. For tobacco use a description of the country-specific emission factors and activity data is given in Switzerland's Informative Inventory Report (FOEN 2025b, chp. 4.6.2).

### Emission factors

The emission factors for CO<sub>2</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> from the use of fireworks are documented in FOEN (2014p) and are displayed in Table 4-57.

Table 4-57 Emission factors for CO<sub>2</sub>, N<sub>2</sub>O, NO<sub>x</sub>, CO, SO<sub>2</sub> for source category 2G4 Use of fireworks and 2G4 Rock wool production in 2023.

2G4 Other	Unit	CO <sub>2</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	SO <sub>2</sub>
Other product use (2G NFR)						
Fireworks	kg/t	43	NA	0.26	7.4	4.1
Rock wool production	g/t	NA	C	NA	NA	NA

### Activity data

Activity data for the use of fireworks are annual sales figures based on import statistics (until 2009, EMIS 2025/2G4 Feuerwerke) and the statistics of the Swiss federal office for police (FEDPOL 2024).

Table 4-58 Activity data for source category 2G4 Use of Fireworks and Rock wool production.

2G4 Other	Unit	1990	1995	2000	2005	2010
Other product use (2G NFR)						
Fireworks	kt	0.84	1.0	1.5	1.4	1.7
Rock wool production	kt	C	C	C	C	C

2G4 Other		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Other product use (2G NFR)											
Fireworks	kt	1.8	1.6	1.2	1.7	1.8	1.0	1.0	1.5	1.9	0.8
Rock wool production	kt	C	C	C	C	C	C	C	C	C	C

### Rock wool production (2G4)

In connection with the updating of allocations under the 3rd commitment period of the Swiss Emissions Trading Scheme (ETS), it became apparent that nitrous oxide is also emitted during rock wool production. It seems that nitrous oxide is produced in the curing process due to the high temperatures. The binder used in the production process is assumed to be the source of the nitrogen. Small amounts of nitrous oxide are apparently also released from the cupola furnace process. These process emissions are now reported in the annual monitoring report of the Swiss Emission Trading System.

### Methodology

The N<sub>2</sub>O emissions from rock wool production are determined by an approach analogous to a Tier 2 method using a country-specific emission factor.

### Emission factor

The N<sub>2</sub>O emission factor is based on analyses and estimates of nitrous oxide emissions in various European rock wool plants. It is assumed that the emission factor is constant over the entire period. The data (Table 4-57) are confidential but available to reviewers.

### Activity data

Activity data on annual production of rock wool are provided annually by the Swiss production plant for the entire time period. Since 2013, activity data are taken from annual ETS monitoring reports. The data (Table 4-58) are confidential but available to reviewers (see EMIS 2025/2G4 Steinwolle-Imprägnierung).

### **HFC not accounted in other source categories (2G4)**

Emissions of HFC not accounted for in any other source categories are reported under 2G4 Other. For confidentiality reasons, no further details are provided here. Information is documented in the confidential NID.

#### *Methodology*

A Tier 2 approach is applied for HFCs with prompt emissive applications based on import statistics.

#### *Emission factors*

Prompt emissions of HFC are calculated following the IPCC Guidelines assuming a total loss of product within two years (50 % loss in the first and 50 % in the second year) (IPCC 2006).

#### *Activity data*

HFC activity data under 2G4 are based on FOEN import statistic and company data.

### **4.8.3. Uncertainties and time-series consistency for 2G**

The uncertainty of total CO<sub>2</sub> emissions from the entire source category 2G4 is obtained assuming 10 % uncertainty for the activity data (expert estimate) and 20 % uncertainty for the emission factor (expert estimate).

The uncertainty of N<sub>2</sub>O emissions from source category 2G3 is estimated at 80 % (expert estimate, see Table 1-8).

For N<sub>2</sub>O in source category 2G4 Rock wool production, the uncertainty of the activity data is estimated to be 1 % and the uncertainty of the emission factor 40 % (expert estimate).

The uncertainty of SF<sub>6</sub>, HFC and PFC emissions in source category 2G is estimated based on a Monte Carlo analysis and reported in Table A – 2 of Annex A2.1. Further details are available from background documents, confidential/internal excel calculations and the respective report (Carbotech 2024).

Time series is consistent, with exception of the source category 2G2 Electrical equipment where from the year 2000 onwards the data are based on a Tier 3a approach instead of model calculations according to Tier 2 as applied for data before the year 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 for 2G**

The general QA/QC measures are described in chp. 1.5.

For SF<sub>6</sub>, measurements at Jungfrauoch are used to estimate Swiss emissions for verification purposes (see chp. 4.7.4 and Annex A6.1). Estimated emissions based on measurements at Jungfrauoch agree within uncertainties with the emissions from the inventory.

### 4.8.5. Category-specific recalculations for 2G

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences emissions of sector 2 IPPU between the latest and the previous submissions are presented also in chp. 10.1.2.2.

- 2G2 (confidential): C<sub>6</sub>F<sub>14</sub>

### 4.8.6. Category-specific planned improvements for 2G

No category-specific improvements are planned.

## 4.9. Source category 2H – Other

### 4.9.1. Source category description

Table 4-59 Key categories of 2H Other. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Source category 2H Other is not a key category.

Table 4-60 Specification of source category 2H Other in Switzerland.

2H	Source category	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 <sub>2</sub> , NO <sub>x</sub> , CO, NMVOC and SO <sub>2</sub> from blasting and shooting; Emissions of NH <sub>3</sub> from use of NH <sub>3</sub> as cooling agent

### 4.9.2. Methodological Issues

#### 4.9.2.1. Pulp and paper (2H1)

##### Methodology

In 2023, the production of chipboard and fibreboard are the relevant industrial processes in the source category 2H1 Pulp and paper. In Switzerland, chipboard and fibreboard were produced in one and two plants, respectively, until 2019. Since 2020 only one plant is left. 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 the EMEP/EEA guidebook (EMEP/EEA 2023) using country-specific emission factors.

Indirect CO<sub>2</sub> emissions resulting from NMVOC emissions in this source category are included in CRT Table6 as documented 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 2025/2H1. The implied emission factor given in Table 4-61 is production-weighted and related to chipboard and fibreboard production. It is confidential but available to reviewers on request.

Table 4-61 Emission factors for CO and NMVOC in pulp and paper production and food and beverages industry, CO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> from blasting and shooting for 2023.

2H Other	Unit	CO <sub>2</sub>	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
2H1 Pulp and paper	g/t	NA	NA	NE	C	NE
2H2 Food and beverage industry (exc. beer, wine,	g/t	NA	NA	250	1'530	NA
2H2 Food and beverage industry (beer, wine, spirits)	g/m <sup>3</sup>	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 2025/2H1. Due to the production structure in Switzerland, i.e. one production site for cellulose (ceased in 2008), one for chipboard and two for fibreboard (one ceased in 2019), only the sum of the production volume of 2H1 Pulp and paper industry is provided, and since 2020 activity data are confidential. Detailed data can be accessed by reviewers on request.

Table 4-62 Pulp and paper production, food and beverages production and amount of explosives used.

2H Other	Unit	1990	1995	2000	2005	2010
2H1 Pulp and paper	kt	604	593	641	693	602
2H2 Food and beverage industry (exc. beer, wine,	kt	2'249	2'114	2'300	2'134	2'397
2H2 Food and beverage industry (beer, wine, spirits)	m3	538'458	482'064	479'352	452'392	464'064
2H3 Blasting and shooting; blasting agent and powder	kt	2.6	1.3	1.9	0.79	2.4

2H Other	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
2H1 Pulp and paper	kt	516	519	503	507	502	460	C	C	C	C
2H2 Food and beverage industry (exc. beer, wine,	kt	2'534	2'473	2'471	2'493	2'492	2'548	2'482	2'525	2'642	2'499
2H2 Food and beverage industry (beer, wine, spirits)	m3	443'806	444'195	433'285	435'426	457'265	464'866	437'731	430'891	458'157	452'680
2H3 Blasting and shooting; blasting agent and powder	kt	2.1	2.1	0.67	0.73	0.81	0.67	0.63	0.61	0.65	0.65

### 4.9.2.2. Food and beverages industry (2H2)

#### Methodology

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 the EMEP/EEA guidebook (EMEP/EEA 2023) using country-specific emission

factors. Since these CO and NMVOC emissions are of biogenic origin, they are not considered for calculation of indirect CO<sub>2</sub> emissions.

### **Emission factors**

The emission factors for CO and NMVOC emissions from food and beverages industry are country-specific and based on measurements and data from industry and expert estimates as documented in the EMIS database (EMIS 2025/2H2). The implied emission factors are production-weighted (Table 4-61).

### **Activity data**

The annual amount of food and beverages produced is based on data from industry and the farmers' association (SBV) and expert estimates as documented in EMIS 2025/2H2 (Table 4-62).

#### **4.9.2.3. Other (2H3)**

### **Methodology**

For determination of emissions of CO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> from blasting and shooting, an analogous Tier 2 method with country-specific emission factors is used as documented in the EMIS database (EMIS 2025/2H3 Sprengen und Schiessen).

Indirect CO<sub>2</sub> emissions resulting from CO and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

### **Emission factors**

The emission factors for CO<sub>2</sub>, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> from blasting and shooting activities are country-specific and based on measurements and data from industry and expert estimates (see Table 4-61).

### **Activity data**

The annual amount of used explosives is based on the Federal statistics on explosives (FEDPOL 2024a) (Table 4-62).

#### **4.9.3. Uncertainties and time-series consistency for 2H**

The uncertainty for CO<sub>2</sub> 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 for 2H**

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

#### **4.9.5. Category-specific recalculations for 2H**

There were no recalculations implemented in submission 2025.

#### **4.9.6. Category-specific planned improvements for 2H**

No category-specific improvements are planned.



## 5. Agriculture

Responsibilities for sector Agriculture	
Overall responsibility, author	Daniel Bretscher (Agroscope)
Sector experts (including QC)	Christoph Ammann (Agroscope), Thomas Kupper (HAFL), Chloé Wüst-Galley (Agroscope; QC)
EMIS database operation	Sabine Schenker (FOEN)
Technical contributors (including QC)	Dominik Egli (Meteotest), Fabio Fasel (Meteotest)
Annual updates (NID text, tables, figures)	Daniel Bretscher (Agroscope)
Internal review	Michael Bock (FOEN)

### 5.1. Overview

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

- 3A Enteric fermentation, CH<sub>4</sub> emissions from domestic livestock.
- 3B Manure management, emissions of CH<sub>4</sub>, N<sub>2</sub>O and NO<sub>x</sub>
- 3D Agricultural soils, emissions of N<sub>2</sub>O, NO<sub>x</sub> and NMVOC
- 3G Liming, emissions of CO<sub>2</sub>
- 3H Urea application; emissions of CO<sub>2</sub>

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<sub>2</sub> emissions from soils are reported under 4 Land use, land-use change and forestry (LULUCF). CO<sub>2</sub> emissions from energy use in agriculture are reported under 1A4c Agriculture/forestry/fishing.

Because CH<sub>4</sub> and NMVOC emissions from the Agriculture sector are of biogenic origin (CO emissions do not occur), from this sector no indirect CO<sub>2</sub> emissions are included in CRT Table 6 as documented in chp. 9.

Total greenhouse gas emissions from the Agriculture sector in 2023 were 6'001 kt CO<sub>2</sub> equivalent which is a contribution of 14.7 % to the total of Swiss greenhouse gas emissions (excluding indirect CO<sub>2</sub>, excluding LULUCF, Table 2-5, Table 5-1). Main agricultural sources of greenhouse gases were 3A Enteric fermentation, emitting 60 % of all agricultural greenhouse gases, followed by 3D Agricultural soils with 24 % and 3B Manure management with 16 % (Figure 5-1). 3G Liming and 3H Urea application contributed 0.5 % and 0.2 % respectively.

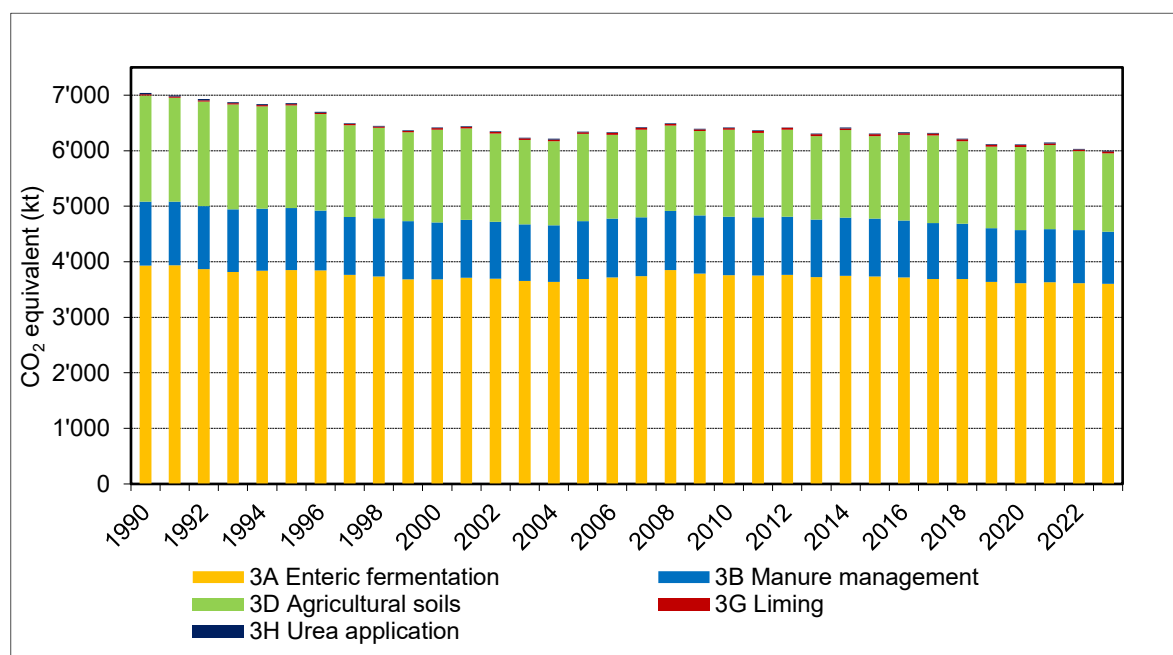


Figure 5-1 Greenhouse gas emissions of the agricultural sector in CO<sub>2</sub> equivalent (kt).

Table 5-1 Greenhouse gas emissions of the agricultural sector in CO<sub>2</sub> equivalent (kt).

Gas	1990	1995	2000	2005	2010
CO <sub>2</sub> equivalent (kt)					
CO <sub>2</sub>	49	42	39	42	44
CH <sub>4</sub>	4'707	4'607	4'362	4'376	4'450
N <sub>2</sub> O	2'286	2'210	2'019	1'926	1'927
Sum	7'043	6'860	6'421	6'344	6'421

Gas	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO <sub>2</sub> equivalent (kt)										
CO <sub>2</sub>	46	45	47	48	46	45	45	46	44	46
CH <sub>4</sub>	4'435	4'421	4'388	4'346	4'336	4'265	4'232	4'248	4'232	4'206
N <sub>2</sub> O	1'936	1'846	1'896	1'928	1'836	1'810	1'836	1'852	1'759	1'749
Sum	6'417	6'311	6'332	6'322	6'218	6'119	6'113	6'147	6'035	6'001

CH<sub>4</sub> and N<sub>2</sub>O emissions generally declined from 1990 until 2004 (Figure 5-2). Subsequently CH<sub>4</sub> emissions increased slightly until 2008 and decreased again afterwards. N<sub>2</sub>O emissions remained more or less on a constant level between 2004 and 2017 and started to decrease afterwards. 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 2019a, 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 2022). Most emission factors did not change significantly over the inventory years. CO<sub>2</sub> 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.

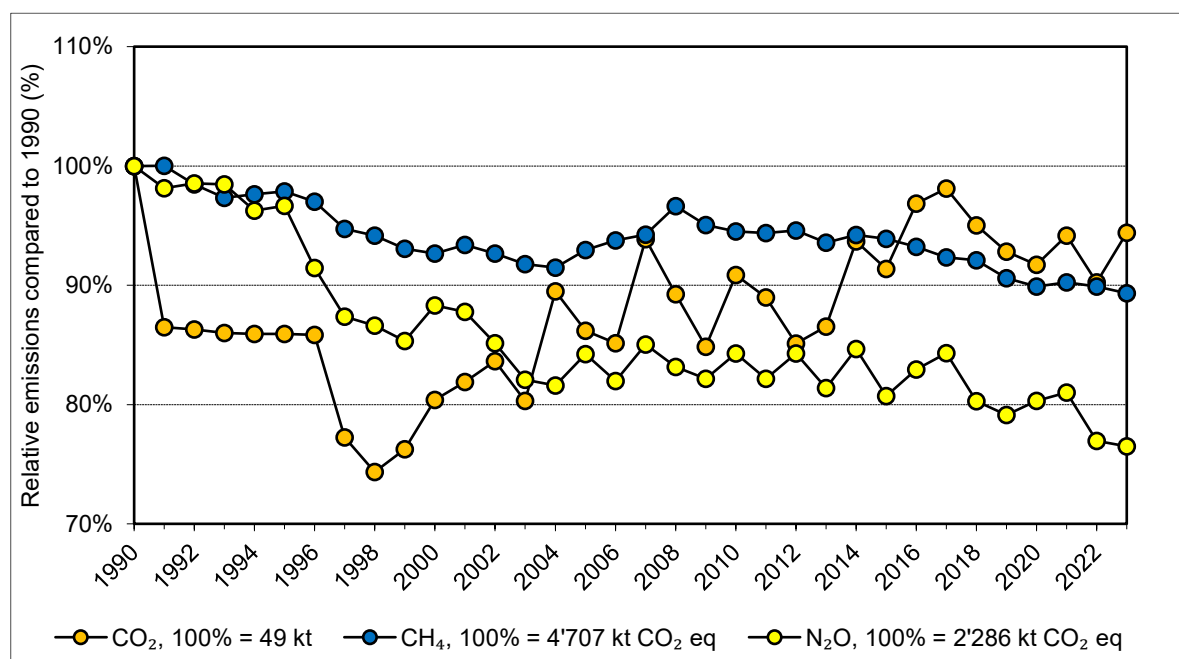


Figure 5-2 Relative trends of the greenhouse gas emissions of sector 3 Agriculture. The base year 1990 represents 100 %.

Among the key categories of the Swiss inventory, six are from the agricultural sector (Figure 5-3).

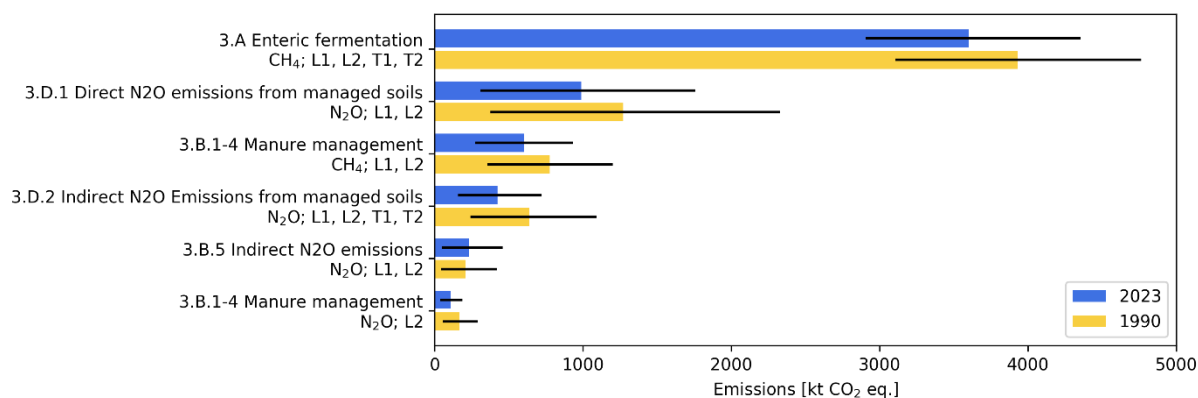


Figure 5-3. Key categories in the Swiss GHG inventory from sector 3 Agriculture determined by the key category analyses, approaches 1 and 2. Categories are set out in order of decreasing emissions in 2023. L1: key category according to approach 1 level in 2023; L2: same for approach 2; T1: key category according to approach 1 trend 1990–2023; T2: same for approach 2. Black uncertainty bars represent the narrowest 95 % confidence interval obtained by Monte Carlo simulations (see chp. 1.6 for details).

## 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 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
3.A	Enteric fermentation	CH <sub>4</sub>	L1, L2, T1, 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<sub>4</sub> emissions increased, whereas since 2008 they were decreasing again.

Cattle contribute over 90 % to the overall emissions from 3A Enteric fermentation and the contribution of mature dairy cattle is more than 60 %.

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 Welfare Act (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 <sup>1</sup> , 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 <sup>2</sup> , Fattening Cattle 4-12 months))
3A2	Sheep	Lambs < 1 year Mature Sheep
3A3	Swine	
3A4a	Buffalo	Bisons < 3 years <sup>3</sup> Bisons > 3 years <sup>3</sup>
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

<sup>1</sup>) Fattening for veal with a milk based diet (slaughtered at ap. 100 days). See chp. 5.2.2.3.

<sup>2</sup>) Fattening for beef meat (slaughtered at ap. 400 days). See chp. 5.2.2.3.

<sup>3</sup>) 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 2019 Refinement to the 2006 IPCC Guidelines (IPCC 2019).

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 2019 Refinement (IPCC 2019), the 2006 IPCC Guidelines (IPCC 2006) 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 2025).

### 5.2.2.2. Emission factors

All emission factors for 3A Enteric fermentation are country-specific, based on IPCC equation 10.21 (IPCC 2019):

$$EF = \frac{GE * (Y_m \div 100) * 365 \text{ days / y}}{55.65 \text{ MJ / kg CH}_4}$$

EF = annual CH<sub>4</sub> emission factor (kg/head/year)

GE = gross energy intake (MJ/head/day)

Y<sub>m</sub> = 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 metabolizable 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 category were calculated individually following the feeding recommendations for Switzerland provided in RAP (1999) and Morel et al. (2017). 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.

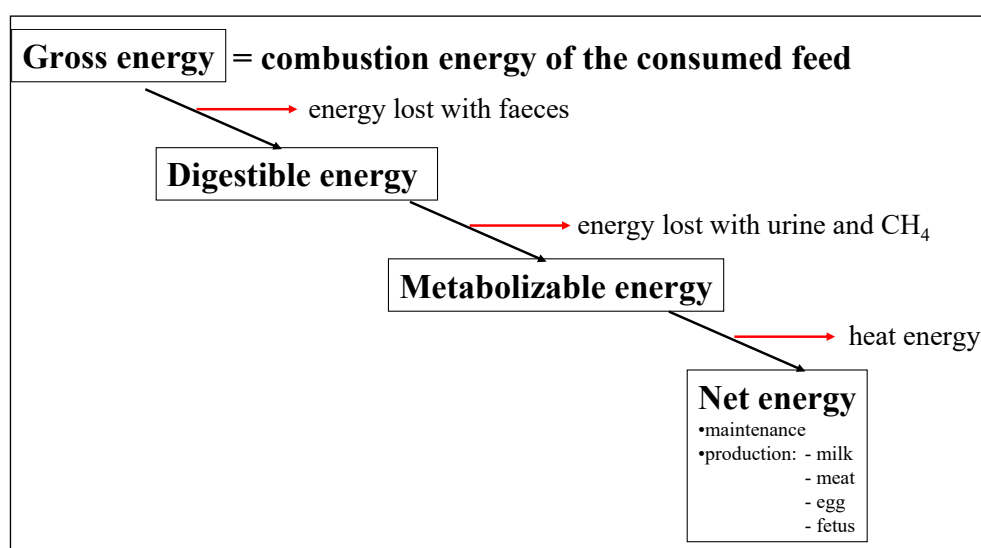


Figure 5-4 Levels of feed energy conversion (Soliva 2006).

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 2023.

Livestock Category		Conversion Factors	
Mature Dairy Cattle		NEL to GE	0.342
Other Mature Cattle		NEL to GE	0.263
Growing Cattle	<i>Fattening Calves</i>	<i>ME to GE</i>	0.939
	<i>Pre-Weaned Calves</i>	<i>NEL to GE</i>	0.299
	<i>Breeding Calves</i>	<i>NEL to GE</i>	0.358
	<i>Breeding Cattle (4-12 months)</i>	<i>NEL to GE</i>	0.319
	<i>Breeding Cattle (&gt; 1 year)</i>	<i>NEL to GE</i>	0.313
	<i>Fattening Calves (0-4 months)</i>	<i>NEV to GE</i>	0.355
	<i>Fattening Cattle (4-12 months)</i>	<i>NEV to GE</i>	0.397
Sheep	<i>Fattening Sheep</i>	<i>NEV to GE</i>	0.350
	<i>Milksheep</i>	<i>NEL to GE</i>	0.287
Swine		DE to GE	0.682
Buffalo		NA	NA
Camels 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 department 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). Live weight was estimated based on statistics of carcass weight according to Burren et al. (2021). Live weight increased more or less linearly from 637 kg in 1990 to 680 kg in 2023. Statistics of annual milk production are provided by the Swiss Farmers Union (SBV 2024, Table 5-5). Milk production includes marketed milk, milk consumed by calves on farms and milk sold outside the commercial industry (MISTA 2024). It should be noted that daily milk yield refers to milk production during the whole year (365 days) and not during lactation only (305 days). 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.

As suggested by Menzi et al. (2016) all calculations of feed intake and excretions rates for mature dairy cattle are based on the average between the model results of one first lactation



(primiparous) and two subsequent lactations. The feed requirements for the additional weight gain during the first lactation is included in the equations to estimate feed intake as these equations are directly derived from feeding experiments.

Average bio-chemical composition and properties of the total feed ration (e.g., energy content, protein content, digestibility) were derived accounting for one first and two subsequent lactations as mentioned above, and 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 1990–2023.

In the year 2004 yearly milk yield surpassed 6000 kg per head. 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 (2019a).

Table 5-5 Average daily milk production in Switzerland (yearly milk production divided by 365).

Milk Production Cattle		1990	1995	2000	2005	2010	2015
Population Size Mature Dairy Cattle	head	783'100	739'641	669'410	620'708	589'024	583'277
Lactation Period	day	305	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	13.21	14.13	15.57	17.15	18.76	19.32
Milk Yield Other Mature Cattle	kg/head/day	6.85	6.85	6.85	6.85	6.85	6.85

Milk Production Cattle		2016	2017	2018	2019	2020	2021	2022	2023
Population Size Mature Dairy Cattle	head	575'766	569'185	564'190	554'588	546'479	545'533	542'927	532'319
Lactation Period	day	305	305	305	305	305	305	305	305
Milk Yield Mature Dairy Cattle	kg/head/day	19.30	19.11	19.53	19.30	19.43	19.77	19.39	19.89
Milk Yield Other Mature Cattle	kg/head/day	6.85	6.85	6.85	6.85	6.85	6.85	6.85	6.85

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. (2017). 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 (for more detailed data see Annex A5.3). The method is described in detail in Soliva (2006) but has been revised slightly here. A distinction is made between 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 metabolizable energy (ME).

Table 5-6 Gross energy intake per head of different livestock groups. Sub-categories not contained in the reporting tables (CRT) are displayed in *italic*. The entire time series at a livestock sub-category level is provided in a separate spreadsheet (Agroscope 2025a).

Gross Energy Intake		1990-2015					
		1990	1995	2000	2005	2010	2015
		MJ/head/day					
Cattle							
Mature Dairy Cattle		255.2	265.0	279.2	294.1	302.4	305.7
Other Mature Cattle		250.6	250.6	250.6	250.6	250.6	250.6
Growing Cattle (weighted average)		103.3	103.9	103.6	101.0	99.8	99.7
	<i>Fattening Calves</i>	47.1	47.1	47.1	47.1	47.1	47.1
	<i>Pre-Weaned Calves</i>	60.1	60.1	60.1	60.1	60.1	60.1
	<i>Breeding Calves</i>	44.0	44.0	44.0	44.0	44.0	44.0
	<i>Breeding Cattle (4-12 months)</i>	90.1	90.1	90.1	90.1	90.1	90.1
	<i>Breeding Cattle (&gt; 1 year)</i>	143.6	143.6	143.6	143.6	143.6	143.6
	<i>Fattening Calves (0-4 months)</i>	56.9	56.9	56.9	56.9	56.9	56.9
	<i>Fattening Cattle (4-12 months)</i>	126.3	126.3	126.3	126.3	126.3	126.3
Sheep		21.2	24.0	22.4	22.8	22.6	22.5
Swine		25.7	26.5	25.1	24.5	24.7	25.4
Buffalo (weighted average)		NA	136.6	146.9	140.6	136.9	134.5
Camels (weighted average)		NA	NA	34.8	31.7	31.0	31.6
Deer (weighted average) <sup>1)</sup>		50.5	55.3	56.4	55.4	56.5	58.0
Goats		25.0	27.9	25.7	25.4	25.1	25.5
Horses (weighted average)		107.3	106.9	107.4	107.7	107.9	108.3
Mules and Asses (weighted average)		39.2	39.7	39.5	39.4	40.2	39.6
Poultry <sup>2)</sup>		1.2	1.2	1.3	1.1	1.0	1.1
Rabbits		1.2	1.2	1.2	1.2	1.2	1.2
Livestock NCAC (weighted average)		90.2	72.0	32.9	34.3	37.8	39.3

Gross Energy Intake		2016-2023							
		2016	2017	2018	2019	2020	2021	2022	2023
		MJ/head/day							
Cattle									
Mature Dairy Cattle		306.3	305.7	308.6	308.1	309.6	311.5	308.5	311.5
Other Mature Cattle		250.6	250.6	250.6	250.6	250.6	250.6	250.6	250.6
Growing Cattle (weighted average)		99.2	99.0	98.6	98.4	98.0	97.9	97.7	97.1
	<i>Fattening Calves</i>	47.1	47.1	47.1	47.1	47.1	47.1	47.1	47.1
	<i>Pre-Weaned Calves</i>	60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1
	<i>Breeding Calves</i>	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
	<i>Breeding Cattle (4-12 months)</i>	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1
	<i>Breeding Cattle (&gt; 1 year)</i>	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6
	<i>Fattening Calves (0-4 months)</i>	56.9	56.9	56.9	56.9	56.9	56.9	56.9	56.9
	<i>Fattening Cattle (4-12 months)</i>	126.3	126.3	126.3	126.3	126.3	126.3	126.3	126.3
Sheep		22.9	23.0	23.3	23.4	23.0	23.0	22.8	22.2
Swine		25.8	25.5	25.2	25.5	25.8	25.8	25.7	26.9
Buffalo (weighted average)		134.4	133.1	162.8	159.8	159.1	158.4	158.4	158.2
Camels (weighted average)		31.2	31.2	31.0	31.2	31.4	31.3	31.2	31.2
Deer (weighted average) <sup>1)</sup>		58.5	58.8	59.3	59.6	59.6	59.7	60.2	60.4
Goats		25.1	25.2	25.1	25.2	25.0	25.1	25.2	25.1
Horses (weighted average)		108.4	108.4	108.5	108.5	108.5	108.5	108.5	108.4
Mules and Asses (weighted average)		39.6	39.5	38.4	38.4	38.4	38.5	38.5	38.5
Poultry <sup>2)</sup>		1.0	1.1	1.1	1.0	1.1	1.1	1.0	1.1
Rabbits		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Livestock NCAC (weighted average)		40.3	40.4	36.9	37.5	37.5	37.6	37.5	36.9

<sup>1)</sup> Deer: Gross energy intake per animal place (mother with offspring)

<sup>2)</sup> 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 would be suggested by the IPCC (IPCC 2019), 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 2'500 kg per head and year (305 days of lactation) and has not changed over the inventory time period (Morel et al. 2017).

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. Nevertheless, energy intake from milk or milk products is 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 2024, Giuliani 2024). These estimates are not officially published anymore in the statistical yearbooks (e.g., SBV 2024) 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 and Sinaj (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 <sup>1)</sup>	Fallow Deer	2.74	50.55
	Red Deer	5.48	101.10

<sup>1)</sup> 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 and Sinaj (2017) (Table 5-7). According to the IPCC Guidelines an energy density of 18.45 MJ\*kg<sup>-1</sup> was used to convert dry matter to gross energy (IPCC 2019).

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 (2025). Resulting estimates are provided in Table 5-6 (main categories) and in a separate spreadsheet (Agroscope 2025a, 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 Zurich (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 **other mature cattle** categories the default value for low producing cows in table 10.12 in IPCC 2019 was used (i.e. 6.5%) as it is most consistent with milk production and feed characteristics. For all growing cattle the methane conversion rate is weighted, assuming a  $Y_m$  of zero for milk energy and a  $Y_m$  of 6.3 % (IPCC 2019, table 10.12) for all other energy.

For mature sheep an  $Y_m$  of 6.5 % was used as suggested for sheep with a dry matter intake higher than  $0.8 \text{ kg} \cdot \text{day}^{-1}$  (IPCC 2019). For lambs <1 year the  $Y_m$  values of 4.5 % from the 2006 IPCC Guidelines was adopted (IPCC 2006). Overall  $Y_m$  for **sheep** was subsequently weighted according to the population structure. For **buffalo** a  $Y_m$  of 6.3 % was applied as suggested for Western Europe in table 10A.4 of the 2019 IPCC Refinements (IPCC 2019). For **camels** and **deers** the same methane conversion rate as for sheep was applied, assuming the same relationship between adult and juvenile animals. For **goats**  $Y_m$  is 5.5 based on table 10.13 in IPCC 2019.

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). 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 metabolizable 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 2020). 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 were obtained from statistics published by the Swiss Farmers Union (SBV 2024) and the Federal Statistical Office (FSO 2024a) (Table 5-8). In 2011 activity data for the time series 1990–2010 were revised and harmonised during a joint effort of the Agroscope Reckenholz-Tänikon Research Station (ART) and the Swiss College of Agriculture (SHL) (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 (CRT). 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. The two sub-categories of fattening calves are distinguished by their weight at slaughter and their feeding regime. The first sub-category (“fattening calves”) refers to animals raised for veal with a milk-based diet (slaughtered at approximately 100 days) whereas the second sub-category (“fattening calves 0–4 months”) refers to animals fattened for beef meat (slaughtered at app. 400 days). 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 (CRT). Additional data on a livestock sub-category level are contained in a separate spreadsheet (Agroscope 2025a). The livestock category “buffalo” in the Swiss GHG Inventory contains only bison (*Bos bison* and/or *Bos bonasus*). Water buffalos (*bubalus bubalis*) are included under cattle. The category “camels” contains only llamas and alpacas.

For the categories “Fattening Pigs over 25 kg” (subcategory of swine) and “Broilers” (subcategory of poultry) adjustments were made in order to correctly consider animal turnover rates (Kupper et al. 2022, FSO 2024b). The values for these subcategories are thus higher here than in the official statistics.

Additional corrections of livestock population statistics implied to ensure time series consistency are described under chp. 5.2.3.

Additionally to official statistical data, population data of livestock not covered by the agricultural census of the Federal Statistical Office were assessed. The respective category “Livestock NCAC” (livestock not covered by agricultural census) consists of sheep, goats, horses and mules and asses held for non-agricultural purposes (e.g. horses for sports and leisure) and/or livestock held by private persons or enterprises that do not fulfil the criteria of an agricultural enterprise. Data for the respective horses, mules and asses were derived from background data of the gross nutrient balance of the Federal Statistical Office (FSO 2024b). For sheep and goats, data from individual cantons having full livestock census were used to estimate the relative share for the whole of Switzerland. The respective estimates were conducted in the course of the elaboration of the gross nutrient balance of the Federal Statistical Office (FSO 2024b).

Table 5-8 Activity data for calculating methane emissions from 3A Enteric fermentation (ART/SHL 2012, SBV 2024, FSO 2024a, FSO 2024b). The complete time series on a livestock sub-category level are provided in a separate spreadsheet (Agroscope 2025a).

Population Size		1990-2015					
		1990	1995	2000	2005	2010	2015
		1'000 head					
Cattle		1'855	1'748	1'588	1'555	1'591	1'554
Mature Dairy Cattle		783	740	669	621	589	583
Other Mature Cattle		12	23	45	78	111	118
Growing Cattle		1'060	986	874	856	891	853
	<i>Fattening Calves</i>	112	102	103	106	114	103
	<i>Pre-Weaned Calves</i>	10	18	36	62	86	91
	<i>Breeding Cattle 1st Year</i>	346	295	236	222	222	210
	<i>Breeding Calves</i>	214	166	76	75	75	71
	<i>Breeding Cattle (4-12 months)</i>	132	129	161	147	146	139
	<i>Breeding Cattle (&gt; 1 year)</i>	404	378	352	318	326	308
	<i>Breeding Cattle 2nd Year</i>	253	239	222	205	215	209
	<i>Breeding Cattle 3rd Year</i>	151	139	130	113	111	99
	<i>Fattening Cattle</i>	188	193	147	147	144	142
	<i>Fattening Calves (0-4 months)</i>	88	82	43	35	34	34
	<i>Fattening Cattle (4-12 months)</i>	100	110	105	112	110	108
Sheep		395	387	421	446	434	395
Swine		1'965	1'739	1'670	1'744	1'750	1'605
Buffalo		0	0	0	0	1	1
Camels		0	0	1	3	6	6
Deer <sup>1)</sup>		0	1	3	4	6	6
Goats		68	53	62	74	83	84
Horses		28	41	50	55	62	55
Mules and Asses		6	8	12	16	20	20
Poultry		7'310	6'656	7'160	8'911	10'629	12'541
Rabbits		61	41	28	25	35	25
Livestock NCAC		16	19	88	89	95	120

Population Size		2016-2023							
		2016	2017	2018	2019	2020	2021	2022	2023
		1'000 head							
Cattle		1'555	1'545	1'543	1'525	1'515	1'514	1'525	1'529
Mature Dairy Cattle		576	569	564	555	546	546	543	532
Other Mature Cattle		121	123	125	128	131	135	138	140
Growing Cattle		859	852	854	842	837	833	845	856
	<i>Fattening Calves</i>	107	108	111	110	110	110	112	119
	<i>Pre-Weaned Calves</i>	93	96	97	99	102	105	107	109
	<i>Breeding Cattle 1st Year</i>	211	209	208	201	199	199	203	203
	<i>Breeding Calves</i>	72	71	71	68	68	68	69	69
	<i>Breeding Cattle (4-12 months)</i>	139	138	137	133	131	131	134	134
	<i>Breeding Cattle (&gt; 1 year)</i>	306	305	302	295	290	290	293	291
	<i>Breeding Cattle 2nd Year</i>	209	208	207	204	203	203	204	205
	<i>Breeding Cattle 3rd Year</i>	97	98	94	91	87	88	88	86
	<i>Fattening Cattle</i>	141	134	136	136	136	130	130	134
	<i>Fattening Calves (0-4 months)</i>	33	32	32	32	32	31	31	32
	<i>Fattening Cattle (4-12 months)</i>	107	102	104	104	104	99	99	102
Sheep		397	398	403	400	398	398	403	409
Swine		1'553	1'546	1'501	1'447	1'449	1'470	1'475	1'409
Buffalo		1	1	1	0	0	0	0	0
Camels		6	7	7	7	6	6	7	7
Deer <sup>1)</sup>		6	6	6	7	7	7	7	7
Goats		85	88	91	92	90	91	92	92
Horses		56	56	46	47	47	47	48	48
Mules and Asses		20	21	34	34	33	33	33	33
Poultry		13'180	13'207	13'984	14'417	15'213	15'674	16'006	15'815
Rabbits		25	22	22	21	19	17	16	14
Livestock NCAC		113	110	108	103	102	103	101	100

<sup>1)</sup> Deer: numbers correspond to animal places i.e. mother with offspring.

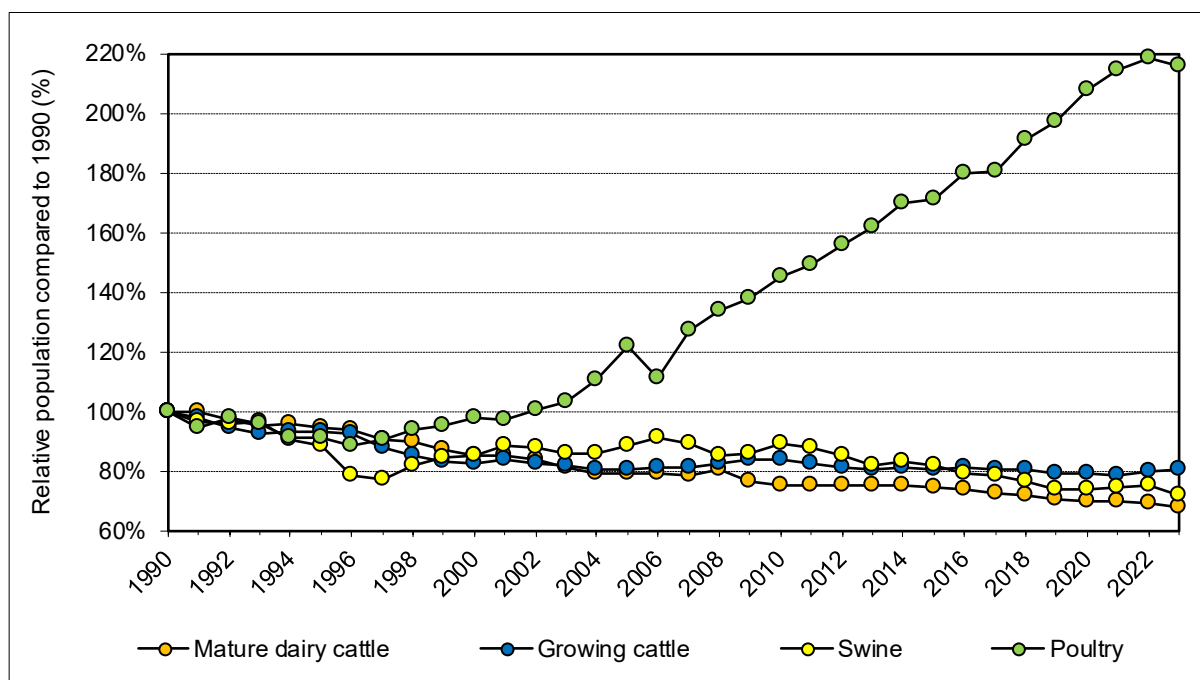


Figure 5-5 Relative development of the populations of main animal categories. The category with the strongest increase, i.e., other mature cattle, is not displayed, as it increases to over 1000 % of the 1990 value by 2023.

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. Relative development of the populations of main animal categories are shown in Figure 5-5. 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 slowly 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 is generally showing a slight decreasing trend with some short-term fluctuations. The number of poultry shows a rapid increase between 1990 and 2022 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 is increasing after a decline between 1990 and 1995.

### 5.2.3. Uncertainties and time-series consistency for 3A

For the uncertainty analysis the input data from ART (2008a) were used and were updated with the latest activity and emission data as well as with default uncertainties of the 2019 Refinement (IPCC 2019). The detailed input uncertainty values for category 3A are reported in Annex A2.1. The resulting, combined uncertainty for emissions is [-19 %; +21 %] according to approach 1 (uncertainty propagation, Annex A2.2), in concordance with results according to approach 2 (Monte Carlo simulations, Annex A2.3).

The time series 1990–2023 are all considered consistent, although the following issues should be considered:



- 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).
- Since 2009 the population statistics of growing cattle are derived from the animal traffic database (ATD 2024). 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. 2022). Data in the animal traffic database are considered more complete than the data from the survey of the FSO because the animal traffic database includes also animals held outside agricultural enterprises.
- Since 2015 the census date for sheep and goats is the 1 January instead of 1 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 based on background data of the gross nutrient balance of the Federal Statistical Office (FSO 2024b).
- Since 2018 the population statistics of bison is assessed in the animal traffic database. The age limit between young and adult bison changed from 3 years (1095 days) to 900 days. This causes a rupture in the time series. This has been corrected in the GHG Inventory based on background data of the gross nutrient balance of the Federal Statistical Office (FSO 2024b).
- Since 2018 the population statistics of horses, mules and asses are assessed in the animal traffic database (ATD 2024). The age limit between young and adult animals changed from 3 years (1095 days) to 900 days. Furthermore, allocation of different breeds to the categories horses, mules and asses changed. Additionally, the animal traffic database comprises now all animals, i.e. equids covered by the official agricultural census of the Federal Statistical Office and equids held by private persons or enterprises that do not fulfil the criteria of an agricultural enterprise. To assure time series consistency population statistics of equids were reconditioned by the Federal Statistical Office (FSO 2024b). Nevertheless, small ruptures may still occur particularly due to the assessment of equids not covered by agricultural census. However, influence on the overall emissions is small.
- Gross energy intake and implied emission factors of some of the aggregated animal categories reveal some fluctuations during the inventory period due to varying shares of the sub-categories.
- Gross energy intake as well as the implied emission factor for mature dairy cattle increase, mainly as a result of higher milk production and live weight (Table 5-5).

#### 5.2.4. Category-specific QA/QC and verification for 3A

General QA/QC measures are described in NID chp. 1.5.

All further category-specific QA/QC activities are described in a separate document (Agroscope 2019a). General information on agricultural structures and policies is provided and eventual differences between national and standard values (IPCC 2006, 2019) are being analysed and discussed. Furthermore, comparisons with data from other countries were conducted and discussed where possible. Agroscope (2019a) is periodically updated with the most recent inventory data.

A mutual peer review was conducted with the German GHG inventory group (Fuß et al. 2021). The respective recommendations were implemented as far as possible during the submissions 2022 and 2023.

Livestock data were compared with the livestock data provided by the FAO and checked for plausibility. In all cases the new recalculated data according to ART/SHL (2012) are considered more reliable than the FAO data. Small inconsistencies (usually in the order of  $\pm 2$  %) are due to updates of provisional data that are not considered by the FAO. For horses, mules and asses disagreements might be due to the different accounting of agricultural and non-agricultural equides. 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. For the categories "Fattening Pigs over 25 kg" (subcategory of swine) and "Broilers" (subcategory of poultry) adjustments were made in the GHG inventory in order to correctly consider animal turnover rates (Kupper et al. 2022; FSO 2024b). The values for these subcategories are thus higher than in the official statistics. The total numbers of poultry in the GHG inventory and the FAO data also show minor discrepancies due to different accounting of turkeys, geese, ducks and quails.

Seasonal fluctuation of the cattle population was analysed for the years 2005–2007 based on detailed information from the Swiss Farmers Union (SBV 2007a). Seasonal fluctuations are usually in the order of  $\pm 3$  % with census data (April) always slightly above the annual mean. Data from the animal traffic database (i.e., cattle populations for the years 2009–2023) 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 (2006, 2019) default values (refer to Annex A5.3).

Country-specific energy-intake rates for all cattle categories were compared to intake rates estimated with the IPCC (2006) Tier 2 default methodology (see Agroscope (2019a) 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 (2006) default method. Moreover, a discrepancy of approximately 5.9 % was found when comparing the overall GE-intake of the cattle population with the respective estimate of the Swiss Farmers Union (Giuliani 2019). As found for the comparison with the IPCC approach, different assumptions on net energy densities of the feed might explain the divergence.

For mature dairy cattle the implied methane emission factor was confirmed by a long-term field study, where methane emissions from a herd of twenty dairy cows were measured over a full grazing season with the eddy covariance method (Felber et al. 2015).

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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> emissions and independent atmospheric measurements over Switzerland. For the years 2017–2023 a different atmospheric transport model version has been used resulting in higher CH<sub>4</sub> emission estimates for the inversion, which will be investigated further (see Annex A6.2).

### 5.2.5. Category-specific recalculations for 3A

General information on recalculations is provided in chp. 10.

Recalculations with an overall impact of >0.5 kt CO<sub>2</sub> equivalent are assessed quantitatively. Other recalculations are only described qualitatively.

- CH<sub>4</sub> emissions from enteric fermentation of swine and poultry were recalculated for the years 2021 and 2022. AD for fattening pigs >25 kg and broilers were revised due to updated data from FSO 2024b. Overall emissions changed by <±0.2 kt CO<sub>2</sub> equivalents.
- CH<sub>4</sub> emissions from enteric fermentation of sheep, goats, swine and poultry were recalculated for the years 2021 and 2022. Emission factors were revised due to updated data on net energy requirements from the Swiss Farmers Union (Gualiani et al. 2024). Overall emissions increased by +0.2 kt CO<sub>2</sub> equivalents in 2021 and decreased by -0.9 kt CO<sub>2</sub> equivalents in 2022.

### 5.2.6. Category-specific planned improvements for 3A

No category-specific improvements are planned.

## 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 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
3.B.1-4	Manure management	CH <sub>4</sub>	L1, L2
3.B.1-4	Manure management	N <sub>2</sub> O	L2
3.B.5	Indirect N <sub>2</sub> O emissions	N <sub>2</sub> O	L1, L2

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<sub>4</sub>) respectively five (N<sub>2</sub>O) different manure management systems are considered as well as indirect N<sub>2</sub>O emissions from 3B Manure management (Table 5-11). Additionally, NO<sub>x</sub> and NMVOC emissions from manure management are estimated. In the reporting tables all NO<sub>x</sub> emissions are reported under 3D 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 declined slowly until 2023.

Significant contributors to CH<sub>4</sub> emissions from 3B Manure management are cattle with approximatively 65 % and swine with approximatively 31 % on average over the period 1990–2023. Cattle and swine contribute significantly to N<sub>2</sub>O emissions with 69 % and 19 %, respectively, on average over the period 1990–2023.

Leaching of NO<sub>3</sub><sup>-</sup> 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 Welfare Act (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 <sup>1</sup> , Pre-Weaned Calves, Breeding Cattle 1 <sup>st</sup> year (Breeding Calves + Breeding Cattle 4-12 months), Breeding Cattle > 1 year (Breeding Cattle 2 <sup>nd</sup> year + Breeding Cattle 3 <sup>rd</sup> year), Fattening Cattle (Fattening Calves 0-4 months <sup>2</sup> + 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 <sup>3</sup> Bisons > 3 years <sup>3</sup>
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

<sup>1</sup>) Fattening for veal with a milk based diet (slaughtered at ap. 100 days). See chp. 5.2.2.3.

<sup>2</sup>) Fattening for beef meat (slaughtered at ap. 400 days). See chp. 5.2.2.3.

<sup>3</sup>) Bisons (Bos bison and/or Bos bonasus). Water buffalos (Bubalus bubalis) are included under cattle. See chp. 5.2.2.3.

Table 5-11 Specification of source category 3B Manure management by manure management systems.

3B	Source	Specification CH <sub>4</sub>		Specification N <sub>2</sub> O	
3B6a	Direct Emissions	Liquid systems		Liquid systems --> Pit storage below animal confinement	
3B6b		Solid storage and dry lot		Solid storage and dry lot	
3B6c / 3D		Pasture, range and paddock		NA <sup>1</sup>	
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	

<sup>1</sup>) Reported under 3D Agricultural Soils

## 5.3.2. Methodological issues

### 5.3.2.1. Methodology

The calculation is based on methods described in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (CH<sub>4</sub>: IPCC 2019 equation 10.23; N<sub>2</sub>O: IPCC 2019 equation 10.25).

CH<sub>4</sub> 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 sheep, goats, buffalo, camels, horses, mules and asses and deer was equally estimated based on gross energy intake. For swine, poultry and rabbits default parameters were used. Methane conversion factors (MCF) are from IPCC (2019; solid storage, pasture range and paddock, poultry manure), country-specific (deep litter) or were modelled according to Mangino et al. (2001) (liquid systems, anaerobic digesters).

N<sub>2</sub>O 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. 2022). Detailed country-specific data on nitrogen excretion rates, manure management system distribution and nitrogen volatilisation were applied. Emission factors for direct N<sub>2</sub>O emissions (EF<sub>3</sub>) are based on IPCC (2019) and Kupper 2017 whereas the emission factor for indirect emissions from atmospheric deposition is country-specific (Bühlmann et al. 2015, Bühlmann 2014).

The N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O emissions, slightly different livestock sub-categories were used (Table 5-12). The livestock categories reported in the reporting tables (CRT) are the same, but the respective sub-categories as a basis for the calculation are different. The categorisation for the estimation of CH<sub>4</sub> emissions had to be adapted to data availability for energy requirements, while the categorisation for the estimation of N<sub>2</sub>O emissions is determined by the respective categorisation of the Swiss ammonia inventory (AGRAMMON, Kupper et al. 2022, Richner and Sinaj 2017). Nevertheless, there is no inconsistency in the total number of animals as they are the same both for CH<sub>4</sub> and N<sub>2</sub>O emissions. Note that although not growing cattle in the proper sense, bulls are contained in the categories breeding cattle >1 year, breeding cattle 3<sup>rd</sup> year and/or fattening cattle according to their purposes.

The calculation of CH<sub>4</sub> and N<sub>2</sub>O emissions is done by Agroscope, the Swiss centre of excellence for agricultural research (Agroscope 2025).

Table 5-12 Livestock categories for estimating CH<sub>4</sub> and N<sub>2</sub>O emissions from 3B Manure management.

3B	CH <sub>4</sub>	N <sub>2</sub> O
Cattle	Mature Dairy Cattle	Mature Dairy Cattle
	Other Mature Cattle	Other Mature Cattle
	Growing Cattle Fattening Calves <sup>1</sup> Pre-Weaned Calves Breeding Cattle 1 <sup>st</sup> year (Breeding Calves + Breeding Cattle 4-12 months) Breeding Cattle > 1 year  Fattening Cattle (Fattening Calves 0-4 months <sup>2</sup> + Fattening Cattle 4-12 months)	Growing Cattle Fattening Calves <sup>1</sup> Pre-Weaned Calves Breeding Cattle 1 <sup>st</sup> year  Breeding Cattle 2 <sup>nd</sup> year Breeding Cattle 3 <sup>rd</sup> 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 <sup>3</sup> Bisons > 3 years <sup>3</sup>	Bisons < 3 years <sup>3</sup> Bisons > 3 years <sup>3</sup>
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

<sup>1)</sup> Fattening for veal with a milk based diet (slaughtered at ap. 100 days). See chp. 5.2.2.3.

<sup>2)</sup> Fattening for beef meat (slaughtered at ap. 400 days). See chp. 5.2.2.3.

<sup>3)</sup> Bisons (Bos bison and/or Bos bonasus). Water buffalos (Bubalus bubalis) are included under cattle. See chp. 5.2.2.3.

### 5.3.2.2. Emission factors CH<sub>4</sub>

Calculation of CH<sub>4</sub> emissions from 3B Manure management is based on methods described in the 2019 Refinement (IPCC 2019, equation 10.23):

$$EF_T = VS_T \cdot 365 \text{ days / year} \cdot B_{0T} \cdot 0.67 \text{ kg / m}^3 \cdot \sum_S MCF_S \cdot MS_{TS}$$

EF<sub>T</sub> = annual CH<sub>4</sub> 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  $T$  ( $m^3/kg$ )

$0.67 \text{ kg}/m^3$  = conversion factor of  $m^3 \text{ } CH_4$  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 based on equation 10.24 in the 2019 Refinement (IPCC 2019):

$$VS = \left[ GE * \left( 1 - \frac{DE\%}{100} \right) \right] * \left[ \frac{1 - ASH}{EDF} \right]$$

$VS$  = 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 (%)

$ASH$  = 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)

IPCC equation 10.24 originally contains an additional term to take account for the urinary energy (IPCC 2019). However, Dämmgen et al. (2011) highlight that the organic matter in urine does not account for any  $CH_4$  formation and the term was hence omitted.

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 in the range of the values provided in table 10.2 of the 2019 Refinement (IPCC 2019) 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 digestibility depression at high feeding levels that are 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 2.6 percent 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.

For **calves and other growing cattle** IPCC default values were taken for the feed digestibility (IPCC 2019, table 10A.2). For the energy density of the feed ( $EDF$ ) the IPCC (2019) default value, i.e. 18.45 MJ/kg was adopted. Furthermore, an ash content of 8.0 % was used for all these categories.

For **sheep, goats, buffalo, camels, horses, mules and asses** and **deer** VS excretion was estimated based on equation 10.24 in IPCC 2019 with default values for feed digestibility of 65 % (sheep, goats, buffalo, camels and deer, IPCC 2019) and 70 % (horses, mules and asses, Stricker 2012). The energy density of the feed (EDF) was 18.45 MJ/kg. The ash content of manure was 8.0 % for sheep, goats, buffalo, camels and deer and 4.0 % for horses and mules and asses (IPCC 2006).

For VS excretion of the livestock categories **swine** and **poultry**, default values from IPCC were taken (IPCC 2006: Tables 10A-7, 10A-8, 10A-9). For **rabbits** the default value of IPCC 2019 was adopted.

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<sub>4</sub> producing capacity (B<sub>0</sub>)*

For the methane producing capacity (B<sub>0</sub>) default values were used (IPCC 2019). For deer and rabbits no default values were available. Consequently, the same value as for sheep was applied for deer and the value of IPCC 2006 was applied for rabbits. For all grazing animals a B<sub>0</sub> of 0.19 was adopted as suggested in table 10.16 of the 2019 Refinement (IPCC 2019).

#### 5.3.2.2.3. *Methane conversion factor (MCF)*

For estimating CH<sub>4</sub> emissions from manure management, six different manure management systems are distinguished. Switzerland has an average annual temperature below 15°C (MeteoSwiss 2022) 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 2019 Refinement (IPCC 2019) was used (Table 5-13).

**Liquid/slurry systems** are responsible for the major part of methane emissions from Manure management (87 % 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 the basis of the model used in the IPCC Guidelines, 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 1991–2020 time period were obtained from the Federal Office of Meteorology and Climatology (MeteoSwiss 2022). 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 13.7 % to 14.8 %. 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 (8.2 % of all volatile solids in 2023). 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 2024a) 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:

$$MCF_{PSAD} = MCF_{LS} * \left( \frac{14.49 * (e^{-k*AI_j} - 1)}{AI_j} + 1 \right)$$

$MCF_{PSAD}$  = CH<sub>4</sub> conversion factor for pre-storage of liquid manure before delivery to biogas plants (%)

$MCF_{LS}$  = CH<sub>4</sub> conversion factor for liquid/slurry systems (%)

k = degradation rate constant (0.069)

$AI_j$  = average pre-storage time period (day)

The average pre-storage time was estimated to be 12 days (Koehli 2014). The resulting weighted average MCF-value for anaerobic digestion varies between 2.6 % and 2.8 %. Variation is due to the variation of the underlying MCF of liquid/slurry systems.

Fattening calves, sheep, buffalo, camels, deer, goats and rabbits 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 in 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 (chp. 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 2019 Refinement (IPCC 2019).

Table 5-13 Manure management systems and methane conversion factors (MCFs). Blue: annually changing parameters, value for 2023.

Manure management system		Description	MCF (%)
Pasture		Manure is allowed to lie as it is, and is not managed (distributed, etc.).	0.5
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 systems		Combined storage of dung and urine under animal confinements for longer than 1 month.	13.8
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 and Sinaj (2017). Estimation is conducted within the Swiss ammonium model AGRAMMON based on expert judgement and values from the literature (1990, 1995) and on extensive farm surveys (2002, 2007, 2010, 2015 and 2019) (Kupper et al. 2022). 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 20<sup>th</sup> century. One of the most important voluntary programmes 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 so did the length of stay on the pasture. In the year 2007 78 % of the dairy cattle were held on farms participating in the RAUS programme. The average number of pasture days (including all farms) in that year was 178, and it was 173 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 are different for VS and nitrogen. This is because cattle stables often have simultaneously both liquid and solid manure storage systems. As volatile solids are excreted mainly in dung and nitrogen mainly in urine, the proportion of VS stored as solid manure is higher compared to the proportion of N. For cattle categories the MS-distribution for nitrogen as provided by Kupper et al. (2022) was thus adjusted using data on stable systems and manure accumulation from Richner and Sinaj (2017) as well as data on frequency of stable systems on farms from (Kupper et al. 2022) (for a more detailed description of the approach see chp. A5.3.4). More or less the same result could be gained by adjusting the distribution of nitrogen by the VS/N-ratio. Data provided in Table 5-14 refer to the distribution of nitrogen while data provided in CRT Table3.B(a) refer to the distribution of VS.

The amount of manure digested anaerobically was estimated based on total energy production (SFOE 2024a) 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<sub>4</sub>*

Activity data of all livestock categories covered by the official census were obtained from SBV (2024) and the FSO (2024a). In 2011 the respective data for the time series 1990–2010 were revised and harmonised during a joint effort of the Agroscope Reckenholz Tänikon Research Station (ART) and the Swiss College of Agriculture (SHL) (ART/SHL 2012). Additionally, to official statistical data, population data of livestock not covered by the agricultural census of the Federal Statistical Office were assessed based on background data of the gross nutrient balance of the Federal Statistical Office (FSO 2024b). 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 Agroscope (2025a).

Table 5-14 Manure management system distribution for nitrogen (MS) according to the AGRAMMON model. Detailed data on livestock sub-category levels for the distribution of nitrogen and volatile solids are provided in a separate spreadsheet (Agroscope 2025a).

MS Distribution		1990					1995					2002					2007				
		%					%					%					%				
		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)	Liquid / Slurry	Solid storage	Pasture range and paddock	Digesters	Other (Deep litter, Poultry manure)
Mature Dairy Cattle		65.6	25.5	8.3	0.5	0.0	67.5	22.5	9.6	0.5	0.0	65.4	17.1	16.9	0.6	0.0	68.1	13.1	17.3	1.5	0.0
Other Mature Cattle		41.0	28.8	29.6	0.5	0.0	38.5	31.4	29.6	0.5	0.0	43.3	19.5	36.7	0.6	0.0	53.7	17.0	27.8	1.5	0.0
Growing Cattle (weighted average)		49.4	29.9	15.8	0.5	4.4	50.0	29.2	15.9	0.5	4.4	45.2	22.3	27.1	0.6	4.8	48.6	20.3	25.2	1.5	4.4
	Fattening Calves	15.8	0.0	0.0	0.5	83.6	15.6	0.0	0.0	0.5	83.9	14.9	0.0	0.7	0.6	83.9	25.1	0.0	0.4	1.5	73.0
	Pre-Weaned Calves	41.0	28.8	29.6	0.5	0.0	38.5	31.4	29.6	0.5	0.0	40.2	23.8	35.5	0.6	0.0	52.7	16.7	29.2	1.5	0.0
	Breeding Cattle 1st Year	39.1	46.3	14.1	0.5	0.0	40.0	45.3	14.2	0.5	0.0	37.3	34.7	27.4	0.6	0.0	44.8	28.9	24.8	1.5	0.0
	Breeding Cattle 2nd Year	47.1	27.0	25.4	0.5	0.0	48.6	25.2	25.7	0.5	0.0	41.3	21.0	37.1	0.6	0.0	44.5	18.7	35.3	1.5	0.0
	Breeding Cattle 3rd Year	52.3	27.1	20.0	0.5	0.0	52.9	26.3	20.4	0.5	0.0	45.6	19.6	34.2	0.6	0.0	48.8	17.1	32.6	1.5	0.0
	Fattening Cattle	72.1	22.3	0.0	0.5	5.1	68.0	26.3	0.0	0.5	5.3	72.5	20.5	4.0	0.6	2.4	64.8	24.2	6.8	1.5	2.6
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	48.7	0.0	51.3	0.0	0.0	45.4	0.0	54.6
Swine (weighted average)		98.8	0.0	0.0	1.2	0.0	98.9	0.0	0.0	1.1	0.0	97.4	1.0	0.3	1.3	0.0	95.3	0.2	0.9	3.7	0.0
Buffalo (weighted average)		NA	NA	NA	NA	NA	0.0	0.0	25.7	0.0	74.3	0.0	0.0	37.1	0.0	62.9	0.0	0.0	35.3	0.0	64.7
Camels (weighted average)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0	0.0	48.7	0.0	51.3	0.0	0.0	45.4	0.0	54.6
Deer (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	48.7	0.0	51.3	0.0	0.0	45.4	0.0	54.6
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	28.5	0.0	71.5	0.0	0.0	27.3	0.0	72.7
Horses (weighted average)		0.0	87.2	12.8	0.0	0.0	0.0	87.2	12.8	0.0	0.0	0.0	76.5	23.5	0.0	0.0	0.0	76.0	24.0	0.0	0.0
Mules and Asses (weighted average)		0.0	87.2	12.8	0.0	0.0	0.0	87.2	12.8	0.0	0.0	0.0	84.0	16.0	0.0	0.0	0.0	76.7	23.3	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	2.7	0.0	97.3	0.0	0.0	3.2	0.0	96.8
Rabbits		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
Livestock NCAC (weighted average)		0.0	87.2	12.8	0.0	0.0	0.0	76.3	12.9	0.0	10.8	0.0	37.2	34.2	0.0	28.6	0.0	40.0	32.5	0.0	27.5

MS Distribution		2010					2015					2019				
		%					%					%				
		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		68.6	12.0	17.2	2.2	0.0	69.5	9.9	16.5	4.1	0.0	67.9	8.9	16.7	6.4	0.0
Other Mature Cattle		53.7	14.7	29.3	2.2	0.0	54.4	12.3	29.2	4.1	0.0	49.5	13.1	31.0	6.4	0.0
Growing Cattle (weighted average)		48.5	19.5	24.8	2.2	5.1	50.7	16.6	24.1	4.1	4.5	49.3	15.6	24.3	6.4	4.4
	Fattening Calves	25.4	0.0	1.0	2.2	71.5	33.3	0.0	1.2	4.1	61.3	37.2	0.0	1.7	6.4	54.7
	Pre-Weaned Calves	44.5	20.8	32.5	2.2	0.0	43.2	20.3	32.4	4.1	0.0	40.0	20.8	32.7	6.4	0.0
	Breeding Cattle 1st Year	47.9	25.8	24.2	2.2	0.0	48.4	24.1	23.4	4.1	0.0	49.2	21.1	23.3	6.4	0.0
	Breeding Cattle 2nd Year	46.2	16.8	34.8	2.2	0.0	45.5	15.4	35.0	4.1	0.0	47.1	12.7	33.8	6.4	0.0
	Breeding Cattle 3rd Year	50.7	15.3	31.8	2.2	0.0	52.5	13.2	30.2	4.1	0.0	50.2	12.7	30.7	6.4	0.0
	Fattening Cattle	60.2	28.3	5.9	2.2	3.3	68.2	19.0	6.3	4.1	2.4	60.4	21.3	9.2	6.4	2.7
Sheep (weighted average)		0.0	0.0	38.8	0.0	61.2	0.0	0.0	45.3	0.0	54.7	0.0	0.0	42.9	0.0	57.1
Swine (weighted average)		94.2	0.2	0.3	5.3	0.0	89.2	0.1	0.1	10.7	0.0	81.6	0.0	0.1	18.3	0.0
Buffalo (weighted average)		0.0	0.0	34.8	0.0	65.2	0.0	0.0	35.0	0.0	65.0	0.0	0.0	33.8	0.0	66.2
Camels (weighted average)		0.0	0.0	38.8	0.0	61.2	0.0	0.0	45.3	0.0	54.7	0.0	0.0	42.9	0.0	57.1
Deer (weighted average)		0.0	0.0	38.8	0.0	61.2	0.0	0.0	45.3	0.0	54.7	0.0	0.0	42.9	0.0	57.1
Goats		0.0	0.0	28.1	0.0	71.9	0.0	0.0	28.3	0.0	71.7	0.0	0.0	33.7	0.0	66.3
Horses (weighted average)		0.0	76.1	23.9	0.0	0.0	0.0	78.4	21.6	0.0	0.0	0.0	76.6	23.4	0.0	0.0
Mules and Asses (weighted average)		0.0	76.9	23.1	0.0	0.0	0.0	77.9	22.1	0.0	0.0	0.0	80.4	19.6	0.0	0.0
Poultry (weighted average)		0.0	0.0	2.8	0.0	97.2	0.0	0.0	3.0	0.0	97.0	0.0	0.0	3.4	0.0	96.6
Rabbits		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
Livestock NCAC (weighted average)		0.0	42.8	29.5	0.0	27.7	0.0	45.1	30.3	0.0	24.6	0.0	43.6	30.6	0.0	25.7

### 5.3.2.4. Emission factors N<sub>2</sub>O

Estimation of direct N<sub>2</sub>O emissions from manure management relies basically on the same animal waste management systems as the estimation of CH<sub>4</sub> emissions (compare chp. 5.3.2.2). For liquid/slurry storage systems an emission factor of 0.002 kg N<sub>2</sub>O-N/kg N as suggested for “Pit storage below animal confinements” was considered appropriate (IPCC 2019, Kupper 2017). The emission factor for poultry manure is based on the default value given in table 10.21 of IPCC 2019 whereas emissions factors for solid storage and anaerobic digesters are from the respective table in the 2006 IPCC Guidelines (see also Kupper 2017) (Table 5-15).

Table 5-15 Emission factors for calculating N<sub>2</sub>O emissions from manure management. Blue: annually changing parameters, value for 2023.

Animal waste management system	Emission factor
	kg N <sub>2</sub> O-N / kg N
Liquid/Slurry: Pit storage below animal confinement	0.002
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<sub>2</sub>O emissions after volatilisation of NH<sub>3</sub> and NO<sub>x</sub> 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 2019) and the indirect emission factor for (semi-)natural land (as provided in Bühlmann 2014 chp. 5.2.1) (Table 5-16). Due to slightly changing land use over the inventory time period, the resulting implied emission factor shows some small temporal variation around a mean value of 2.57 % (see also chp. 9.2.2).

Table 5-16 Data for estimating emission factors for indirect N<sub>2</sub>O emissions from atmospheric deposition according to Bühlmann (2014).

EF <sub>4</sub> atmospheric deposition	Unit	1990-2015					
		1990	1995	2000	2005	2010	2015
Share of deposition on agricultural land	%	0.573	0.574	0.575	0.569	0.543	0.543
Share of deposition in semi-natural ecosystems	%	0.427	0.426	0.425	0.431	0.457	0.457
EF <sub>4</sub> for agricultural land	kg N <sub>2</sub> O-N / total kg N-deposited	0.010	0.010	0.010	0.010	0.010	0.010
EF <sub>4</sub> for semi-natural ecosystems	kg N <sub>2</sub> O / kg N-deposited	0.030	0.030	0.030	0.031	0.033	0.033
EF <sub>4</sub> weighted	kg N <sub>2</sub> O-N / kg N-deposited	0.0248	0.0248	0.0248	0.0257	0.0264	0.0264

EF <sub>4</sub> atmospheric deposition	Unit	2016-2023							
		2016	2017	2018	2019	2020	2021	2022	2023
Share of deposition on agricultural land	%	0.543	0.543	0.543	0.543	0.543	0.543	0.543	0.543
Share of deposition in semi-natural ecosystems	%	0.457	0.457	0.457	0.457	0.457	0.457	0.457	0.457
EF <sub>4</sub> for agricultural land	kg N <sub>2</sub> O-N / total kg N-deposited	0.010	0.010	0.010	0.010	0.010	0.010	0.010	1.01
EF <sub>4</sub> for semi-natural ecosystems	kg N <sub>2</sub> O / kg N-deposited	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
EF <sub>4</sub> weighted	kg N <sub>2</sub> O-N / kg N-deposited	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.5694

### 5.3.2.5. Activity data N<sub>2</sub>O

Activity data for N<sub>2</sub>O emissions from 3B Manure management were estimated according to equation 10.25 of the IPCC 2019:

$$N_2O_{D(mm)} = \left[ \sum_S \left[ \sum_T (N_{(T)} \cdot Nex_{(T)} \cdot MS_{(T,S)}) \right] \cdot EF_{3(S)} \right] \cdot \frac{44}{28}$$

N<sub>2</sub>O<sub>D(mm)</sub> = direct N<sub>2</sub>O emissions from manure management (kg N<sub>2</sub>O/year)



$N_{(T)}$  = number of head of livestock species/category  $T$  (head)

$N_{ex(T)}$  = 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  $(N_2O-N)_{(mm)}$  emissions to  $N_2O_{(mm)}$  emissions

#### 5.3.2.5.1. *Livestock population*

Activity data of all livestock categories covered by the official census were obtained from SBV (2024) and the FSO (2024a). In 2011 the respective dataset for the time series 1990–2010 was revised and harmonised during a joint effort of the Agroscope Reckenholz Tänikon Research Station (ART) and the Swiss College of Agriculture (SHL) in 2011 (ART/SHL 2012). Additional to official statistical data, population data of livestock not covered by the agricultural census of the Federal Statistical Office were assessed based on background data of the gross nutrient balance of the Federal Statistical Office (FSO 2024b) and based on data of the Swiss animal traffic database (ATD 2024). 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 Agroscope (2025a).

#### 5.3.2.5.2. *Nitrogen excretion ( $N_{ex}$ )*

Data on nitrogen excretion per animal category (kg N/head/year) are country-specific and were obtained from Kupper et al. (2022) (Table 5-17). These values are based on the “Principles of Fertilisation in Arable and Forage Crop Production” (Richner and Sinaj 2017). As compared to the methods in IPCC 2019, the age structure of the animals and the different use of the animals (e.g. fattening and breeding) are considered in more detail. Generally, nitrogen excretion rates were determined by estimating nitrogen intake and then subtracting nitrogen retention in body tissue and products (milk, offspring). Most calculations are based on feeding requirements that were assessed in feeding trials at the Agroscope research station in Posieux as published e.g. in RAP (1999, ruminants) and Agroscope (2016c, swine). Additional data on feed ration composition and properties and nitrogen retention and excretion is available from the background literature listed for the specific animal categories below. 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. (2022)). This more disaggregated approach leads to considerably lower calculated nitrogen excretion rates compared to IPCC (2019) 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).

Nitrogen excretion rates of **mature dairy cattle** were adopted from the most recent version of the AGRAMMON model (Kupper et al. 2022). Regional data of animal performance and

feed ration composition were used to adjust standard nitrogen excretion rates from Richner and Sinaj (2017). The calculations are based on the same feeding model as used for the estimation of gross energy intake and the excretion of volatile solids (Agroscope 2014c; chp. 5.2.2.2.1, 5.3.2.2.1) and are further described in Menzi et al. (2016). Nitrogen excretion is calculated as the nitrogen intake minus the nitrogen excretion in the milk minus the nitrogen in the calf assuming no change in body weight of the cow. Accordingly, nitrogen excretion of mature dairy cattle is dependent on feed composition (use of feed concentrates, corn silage, corn cubes, and hay in summer and winter rations), feed properties (N-content and digestibility of the individual feed components) and milk production. Estimated values of crude protein contents of animal feeds in the Swiss Feed Database are based on an extensive measurement program particularly also for roughages (Agroscope 2014b). Nitrogen content of the feed is estimated as crude protein content divided by 6.25. Protein content in the milk was set to  $0.033 \text{ g*kg milk}^{-1}$ . Nitrogen content in the milk is estimated as protein content divided by 6.38. After the year 2006 the yearly increase of nitrogen excretion slowed down due to an increased use of energy dense feedstuff (concentrates) and a slower increase of the milk yield compared to earlier years.

For the category **other mature cattle** as well as all **growing cattle** categories the nitrogen excretion rates of the AGRAMMON model (Kupper et al. 2022) were adopted which are again based on the standard values of Richner and Sinaj (2017). The assessment of these standard values is based on the Swiss feeding recommendations (RAP et al. 1999, Morel et al. 2017, Schlegel et al. 2020, Rediger et al. 2019) which are elaborated based on a great number of feeding trials at the Agroscope research station in Posieux. Nitrogen excretion rates of some sub-categories are fluctuating along the time series due to changes in feeding and management practices.

**Sheep** in Switzerland are fed mainly on roughage from extensive pasture and meadows (Richner and Sinaj 2017) and are estimated to excrete approximately 8.1 kg N per head and year. This is somewhat lower than IPCC default (IPCC 2006, 2019). 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 2007, which can be explained by the increasing use of protein-reduced fodder (Kupper et al. 2022, Bracher and Spring 2011, Sollberger et al. 2013). Changing production techniques and increasing use of protein-reduced fodder are also drivers of nitrogen excretion rates for **poultry**.

Table 5-17 Nitrogen excretion rates of Swiss livestock. The complete time series on a livestock sub-category level are provided in a separate spreadsheet (Agroscope 2025a).

Nitrogen Excretion	1990-2015					
	1990	1995	2000	2005	2010	2015
	kg N/head/year					
Mature Dairy Cattle	100.4	101.5	104.1	107.4	110.1	111.1
Other Mature Cattle	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	33.1
<i>Fattening Calves</i>	13.0	13.0	13.0	14.2	16.0	18.0
<i>Pre-Weaned Calves</i>	22.0	22.0	22.0	22.0	22.0	22.0
<i>Breeding Cattle 1st Year</i>	25.0	25.0	25.0	25.0	25.0	25.0
<i>Breeding Cattle 2nd Year</i>	40.0	40.0	40.0	40.0	40.0	40.0
<i>Breeding Cattle 3rd Year</i>	55.0	55.0	55.0	55.0	55.0	55.0
<i>Fattening Cattle</i>	33.0	33.0	33.0	34.2	36.0	38.0
Sheep (weighted average)	7.5	7.6	8.0	8.1	8.5	8.4
Swine (weighted average)	14.3	14.0	11.0	9.6	9.2	9.1
Buffalo (weighted average)	NA	37.2	41.1	38.7	37.3	36.4
Camels (weighted average)	NA	NA	14.1	12.8	12.6	12.7
Deer (weighted average) <sup>1)</sup>	20.0	21.9	22.3	21.9	22.4	23.0
Goats	11.2	11.1	11.3	11.1	11.2	11.4
Horses (weighted average)	43.6	43.5	43.6	43.7	43.7	43.8
Mules and Asses (weighted average)	16.0	16.0	16.0	16.0	16.0	16.0
Poultry (weighted average)	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
Livestock NCAC (weighted average)	36.5	29.4	12.5	13.0	14.7	15.8

Nitrogen Excretion	2016-2023							
	2016	2017	2018	2019	2020	2021	2022	2023
	kg N/head/year							
Mature Dairy Cattle	111.1	111.2	111.3	111.4	111.4	111.4	111.4	111.4
Other Mature Cattle	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Growing Cattle (weighted average)	33.0	32.9	32.8	32.7	32.6	32.5	32.5	32.3
<i>Fattening Calves</i>	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
<i>Pre-Weaned Calves</i>	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
<i>Breeding Cattle 1st Year</i>	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
<i>Breeding Cattle 2nd Year</i>	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
<i>Breeding Cattle 3rd Year</i>	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
<i>Fattening Cattle</i>	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
Sheep (weighted average)	8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Swine (weighted average)	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Buffalo (weighted average)	36.4	35.9	47.1	45.9	45.7	45.4	45.4	45.3
Camels (weighted average)	12.6	12.6	12.5	12.6	12.6	12.6	12.6	12.6
Deer (weighted average) <sup>1)</sup>	23.1	23.3	23.4	23.6	23.6	23.6	23.8	23.9
Goats	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
Horses (weighted average)	43.8	43.9	43.9	43.9	43.9	43.9	43.9	43.9
Mules and Asses (weighted average)	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Poultry (weighted average)	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
Livestock NCAC (weighted average)	16.1	16.1	14.7	14.9	15.0	15.0	15.0	14.9

<sup>1)</sup> 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. 2022) and on data provided in Richner and Sinaj (2017). For cattle, the distribution of animal excreta to the various manure management systems is different with regard to estimating CH<sub>4</sub> emissions from 3B Manure management compared to estimating N<sub>2</sub>O emissions from 3B Manure management (for further information refer to chp. 5.3.2.2.4 and chp. A5.3.4). This is because cattle stables often have simultaneously both liquid and solid

manure storage systems. As volatile solids are excreted mainly in dung and nitrogen mainly in urine, the proportion of VS stored as solid manure is higher compared to the proportion of N. Data provided in Table 5-14 refer to the distribution of nitrogen while data provided in CRT Table 3.B(a) refer to the distribution of VS. A detailed table of the distribution of VS is provided in a separate spreadsheet (Agroscope 2025a).

#### **5.3.2.5.4. Volatilisation of $\text{NH}_3$ , $\text{NO}_x$ and $\text{N}_2$ from manure management systems**

For indirect  $\text{N}_2\text{O}$  emissions from manure management the deposition of volatilised  $\text{NH}_3$  and  $\text{NO}_x$  is 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. 2022). 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  $\text{NH}_3$  emissions). Accordingly, the overall fraction of reactive nitrogen ( $\text{NH}_3$ ,  $\text{NO}_x$ ) 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 14.5 to 20.4 %.

For the volatilisation of  $\text{NO}_x$  values from van Bruggen et al. (2014) were used. Accordingly, it is estimated that 0.2 %, 0.5 %, 1.0 % and 0.1 % of the total nitrogen in liquid/slurry, solid storage, deep litter and poultry manure systems are lost to the atmosphere, respectively. In this context the management systems “anaerobic digestion” is treated as liquid/slurry system.

For the estimation of the amount of animal manure applied to soils, the volatilisation of dinitrogen ( $\text{N}_2$ ) during manure management is also considered. It is estimated that 0.020 %, 0.025 %, 0.050 % and 0.025 % of the total nitrogen in liquid/slurry, solid storage, deep litter and poultry manure systems are lost to the atmosphere, respectively (van Bruggen et al. 2014).

Note that volatilisation from pasture, range and paddock manure is included under 3Db (Indirect  $\text{N}_2\text{O}$  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 5-21.

#### **5.3.2.6. NMVOC emissions from manure management**

The NMVOC emissions from animal husbandry are calculated by a Tier 1 approach according to the EMEP/EEA guidebook using country-specific and default emission factors (EMEP/EEA 2023, chp. 3B Manure management, Table 3.4) for cattle and all other livestock categories, respectively. A comprehensive literature study by Bühler and Kupper (2018) has shown that the data base of NMVOC emissions from animal husbandry is very scarce and that the derived emission factors differ widely. The studies on which the emission factors in EMEP/EEA (2016) (unchanged in EMEP/EEA 2023) are based show several inconsistencies that could affect significantly the emission factors. It remains also unknown, how the emissions from the studies performed in the United States were adapted to European agricultural feeding conditions and how the corresponding emission factors were derived. Therefore, a study was conducted between 2018 and 2021 in order to measure NMVOC emissions from dairy cattle with and without silage feeding in an experimental housing system during summer, winter and the transitional season and to derive emission factors that are representative for cattle husbandry in Switzerland (Schrade et al. 2025). Switzerland's

Informative Inventory Report (FOEN 2025b, chp. 5.2.2.) contains a detailed description of these country-specific emission factors for cattle.

### 5.3.3. Uncertainties and time-series consistency for 3B

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 default uncertainties from the 2019 Refinement (IPCC 2019). The detailed input uncertainty values for category 3B are reported in Annex A2.1. The resulting, combined uncertainty for emissions according to approach 1 (uncertainty propagation) are reported in Annex A2.2 and in Annex A2.3 for results obtained by approach 2 (Monte Carlo simulations). The 95 % confidence intervals obtained by Monte Carlo simulations are slightly narrower and, for non-symmetric distributions, slightly shifted towards the lower edge.

Table 5-18 Uncertainties for 3B Manure management. Approach 1: intervals are exactly from 2.5 % to 97.5 % of the distribution; Approach 2: the narrowest interval representing 95 % of the distribution is given.

Source category	Gas	Activity data uncertainty 2023		Emission factor uncertainty 2023		Emission combined uncertainty 2023	
		(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
Uncertainty propagation (approach 1)							
3.B.1-4 Manure management all livestock direct	CH4	6.5	6.5	55	55	55	55
3.B.1-4 Manure management all livestock direct	N2O	24	24	58	82	63	86
3.B.5 Manure management indirect	N2O	47	62	63	94	79	113
Monte Carlo simulations (approach 2)							
3.B.1-4 Manure management all livestock direct	CH4	6.4	6.5	54	54	54	55
3.B.1-4 Manure management all livestock direct	N2O	24	24	64	72	66	77
3.B.5 Manure management indirect	N2O	51	56	69	83	80	100

The time series 1990–2022 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 are available for the years 1990 and 1995 (expert judgement and literature) as well as for 2002, 2007, 2010, 2015 and 2019 (extensive surveys on approximately 3000 farms). Values in-between the assessment years were interpolated linearly. For 2020 to 2023 the same value as in 2019 was applied.
- The emission factor for indirect N<sub>2</sub>O emissions after volatilisation of NH<sub>3</sub> and NO<sub>x</sub> 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 for 3B

General QA/QC measures are described in NID chp. 1.5.

All further category-specific QA/QC activities are described in a separate document (Agroscope 2019a). General information on agricultural structures and policies is provided and eventual differences between national and standard values (IPCC 2006, 2019) are being analysed and discussed. Furthermore, comparisons with data from other countries were conducted and discussed where possible. Agroscope (2019a) is periodically updated with the most recent inventory data.

A mutual peer review was conducted with the German GHG inventory group (Fuß et al. 2021). The respective recommendations were implemented as far as possible during the submissions 2022 and 2023.

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<sub>4</sub>**

IPCC tables with data for estimating emission factors of all livestock categories (such as weight, feed digestibility, maximum CH<sub>4</sub> producing capacity (B<sub>0</sub>) or daily excretion of volatile solids) were filled in, checked for consistency and confidence and compared with IPCC (2006) default values (refer to Annex A5.3).

VS excretion rates of swine and poultry are based on IPCC default values (IPCC 2006). For swine, estimates using equation 10.24 from IPCC (2019) would yield very similar results. As for some of the parameters used in equation 10.24 (e.g. feed digestibility) no reliable country-specific data were available, it was decided to still use the default values for VS excretion.

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 somewhat lower than IPCC (2019) default. 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. 2022). Furthermore, a series of laboratory measurements of MCF-values by the group of animal nutrition from the Swiss Federal Institute of Technology in Zurich 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 A6.2.

#### **5.3.4.2. QA/QC and verification – N<sub>2</sub>O**

Estimation of N<sub>2</sub>O emissions is mainly based on the Swiss ammonium emission model AGRAMMON that is documented in Kupper et al. (2022).

All relevant data needed for the calculation of N<sub>2</sub>O emissions such as nitrogen excretion rates, manure management system distribution and N<sub>2</sub>O emission factors were checked for consistency and were compared to the corresponding values of other countries and to the IPCC (2006, 2019) default value if available (Agroscope 2019a).



As one of the most important parameters, nitrogen excretion rates were analysed in more detail. 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 (see e.g. Spiess 2011). There was good agreement (average discrepancy of  $\pm 2$  %) for the years 1990–2005. However, for later years the top-down estimates were on average 10 % higher than the bottom-up estimates. Reasons for this observation are not yet clear and this finding will be subject to further analysis.

$N_{\text{ex}}$ -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 IPCC 2019. For swine, the IPCC approach estimated on average 16 % lower  $N_{\text{ex}}$  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. After the year 2005 inventory estimates were lower than the IPCC approach using equation 10.32, which can be explained by the increased use of nitrogen reduced feed. Further QA/QC checks of the  $N_{\text{ex}}$  values are elaborated in Agroscope (2019a).

Henne et al. (2019) conducted a top-down assessment of Swiss  $N_2O$  emissions using atmospheric measurements and an inverse modelling framework. With recent updates, inverse estimates and NID estimates agree very closely for two different atmospheric transport model versions used in the inversion (see also Annex A6.2).

### 5.3.5. Category-specific recalculations for 3B

General information on recalculations is provided in chp. 10.

Recalculations with an overall impact of  $>0.5$  kt  $CO_2$  equivalent are assessed quantitatively. All other recalculations are only described qualitatively.

- Recalculation of livestock population data and gross energy intake (influencing VS-excretion rates) is reported under chp. 5.2.5.
- $CH_4$  emissions from manure management were recalculated for the years 1990 to 2022. EFs were revised due to updated data on the amount of manure digested anaerobically (SFOE 2024a). Overall emissions decreased slightly ( $<-0.5$  kt  $CO_2$  equivalents) particularly in the years 1990-1999.
- $CH_4$  and  $N_2O$  emissions from manure management were recalculated for 1990-2022. Allocation of manure to the different management systems (MS) was revised for buffalo and rabbits based on Kupper et al. 2022. The impact on overall emissions ranges from  $+0.4$  to  $+1.2$  kt  $CO_2$ -equivalents.
- $CH_4$  emissions from manure management in liquid systems and anaerobic digesters were recalculated for 1990-2022. The MCF-value for liquid systems (EF) was revised due to updated model projections based on slightly altered data for manure management system allocation (MS). The impact on overall emissions is negligible ( $< \pm 0.2$  kt  $CO_2$ -equivalents).



5.3.6. Category-specific planned improvements for 3B

In 2025 the AGRAMMON model (Kupper et al. 2022) will be updated and new data on farm management and production technology will become available from the latest survey. All emissions from 3B Manure management will be revised accordingly during the submission 2026 or 2027.

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 harvest of rice are not estimated by the Swiss Farmers Union (SBV 2024). Only one farm in the south of Switzerland is cultivating upland rice since 1997. CH<sub>4</sub> emissions are assumed to be zero. The area of upland rice is reported from 1997 onward in CRT Table3.C (EMIS 2025/4C “Reisanbau”).

5.5. Source category 3D – Agricultural soils

5.5.1. Source category description

Table 5-19 Key categories of 3D Agricultural soils. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
3.D.1	Direct N2O emissions from managed soils	N2O	L1, L2
3.D.2	Indirect N2O Emissions from managed soils	N2O	L1, L2, T1, T2

The source category 3D includes direct and indirect N<sub>2</sub>O emissions from managed soils (Table 5-20). Direct emissions are further subdivided in emissions from a. Inorganic N fertilisers, b. Organic N fertilisers, c. Urine and dung deposited by grazing animals, d. Crop residues, e. Mineralisation/immobilisation associated with loss/gain of soil organic matter, f. Cultivation of organic soils (i.e. histosols) and g. Other (i.e. Domestic use of synthetic fertilisers). Indirect N<sub>2</sub>O emissions are further subdivided in a. Atmospheric deposition and b. Nitrogen leaching and run-off. All indirect N<sub>2</sub>O emissions after deposition of NO<sub>x</sub> and NH<sub>3</sub> or after leaching of NO<sub>3</sub><sup>-</sup> are reported under source category 3D.2 Indirect N<sub>2</sub>O Emissions from managed soils. This includes indirect N<sub>2</sub>O emissions after NO<sub>3</sub><sup>-</sup> 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(III) Direct and indirect N<sub>2</sub>O emissions from nitrogen (N) mineralization/immobilization and not included in CRT Table6 (see also chp. 9).

Table 5-20 Specification of source category 3D Agricultural soils.

3D	Source	Specification
3D.1	Direct N <sub>2</sub> O emissions from managed soils	a. Inorganic N fertilisers b. Organic N fertilisers (i. animal manure applied to soils, ii. sewage sludge applied to soils, iii. other organic fertilisers applied to soils) c. Urine and dung deposited by grazing animals d. Crop residues (incl. residues from meadows and pasture) e. Mineralisation/immobilisation associated with loss/gain of soil organic matter f. Cultivation of organic soils (i.e. histosols) g. Other (domestic use of synthetic fertilisers)
3D.2	Indirect N <sub>2</sub> O emissions from managed soils	a. Atmospheric deposition b. Nitrogen leaching and run-off

Furthermore, NO<sub>x</sub> emissions from managed soils as well as NMVOC emissions are estimated.

Direct and indirect N<sub>2</sub>O emissions from managed soils have decreased since 1990 in almost all major sub-categories. Only N<sub>2</sub>O emissions from 3D.1.c (Urine and dung deposited by grazing animals) increased due to a higher share of manure excreted on pasture, range and paddock. NO<sub>x</sub> emissions have declined by almost 29 % 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 2019a, Leifeld and Fuhrer 2005). Major changes occurred mainly in the 1990s while most emissions were more or less stable after the year 2000.

The most significant N<sub>2</sub>O emission sources are animal manure applied to soils (24 %, mean 1990–2023), nitrogen in crop residues returned to soils (20 %, mean 1990–2023), nitrogen input from atmospheric deposition (17 %, mean 1990–2023), nitrogen from fertilizers and other agricultural inputs that is lost through leaching and run-off (14 %, mean 1990–2023) and inorganic nitrogen fertilisers (13 %, mean 1990–2023).

## 5.5.2. Methodological issues

### 5.5.2.1. Methodology

For the calculation of most N<sub>2</sub>O 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<sub>2</sub>O emissions from agriculture that basically uses the default emission factors (IPCC 2019), but adjusts the activity data to the particular situation of Switzerland. For the estimation of N<sub>2</sub>O emissions from animal manure applied to soils as well as for the estimation of indirect N<sub>2</sub>O 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. 2022). Furthermore, the updated version of the "Principles of Fertilisation in Arable and Forage Crop Production" (GRUD; Richner and Sinaj 2017) was used instead of obsolete data from Flisch et al. (2009), FAL/RAC (2001) and Walther et al. (1994). More recently, the N-flow model was extended to include all gaseous

N-species (including  $N_2$ ) and new  $NO_x$  emission factors were implemented (Kupper 2017). Emission factors for  $N_2O$  are all based on IPCC (2019) 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 2025) 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 5-21.

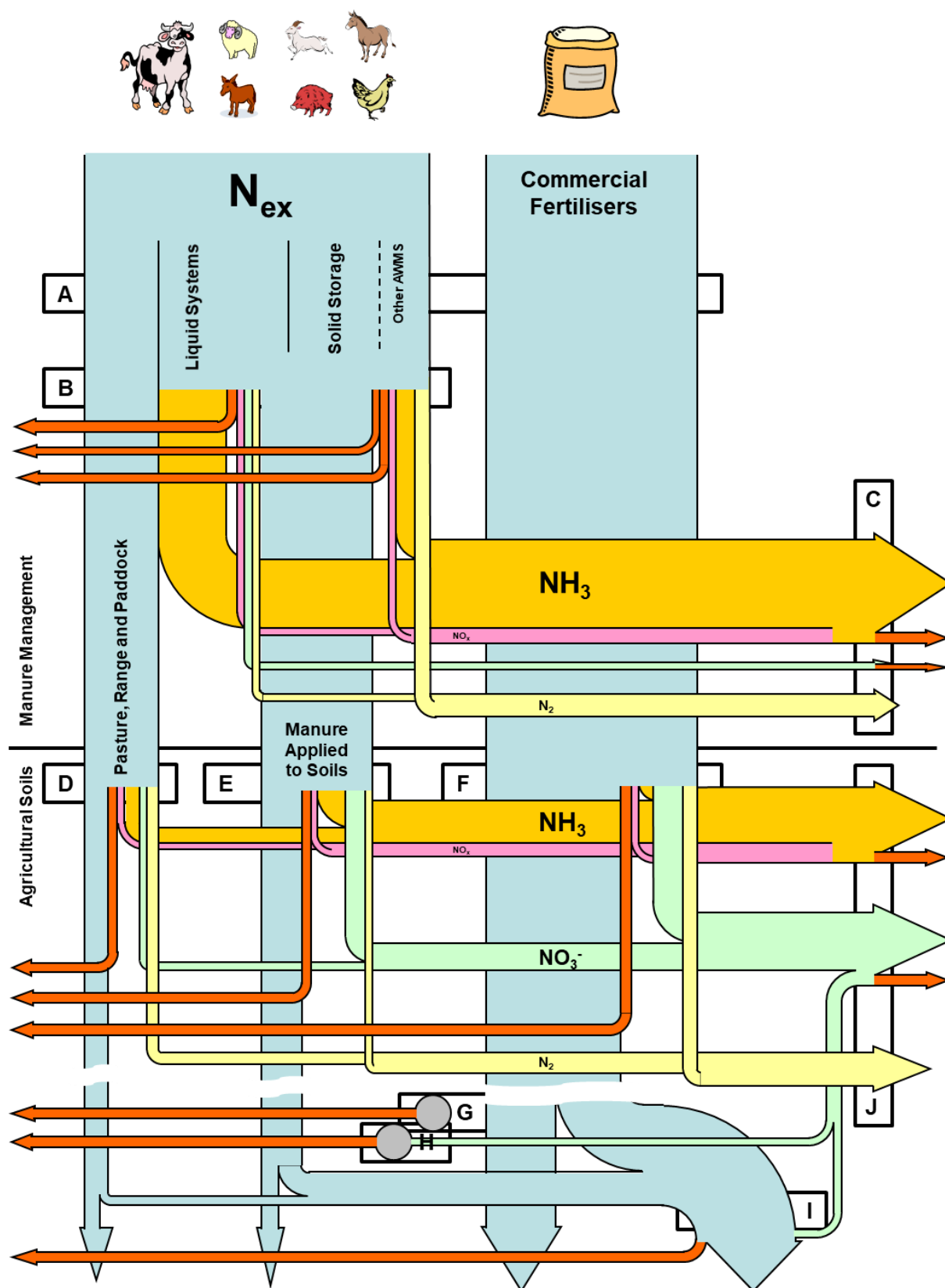


Figure 5-6 Diagram depicting the methodology of the approach to calculate the  $N_2O$  emissions in agriculture (red arrows). Black frames and the respective letters refer to the nitrogen flows in Table 5-21. Note that the figure shows explicitly the methodology of the approach and not necessarily the physical nitrogen flows. Commercial fertilisers refer to the sum of urea, other mineral fertilisers, sewage sludge, other organic fertilisers and domestic use of fertilisers. Blue: nitrogen; orange: ammonia ( $NH_3$ ); pink: nitrogen oxides ( $NO_x$ ); green: nitrate ( $NO_3^-$ ); yellow: dinitrogen ( $N_2$ ).

Table 5-21 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			CRT table
		1990	2023		
		tN			
A	1 Pasture, range and paddock	13'545	23'557	= B	3.D.1.c
	2 Liquid/slurry systems	97'199	68'486		3.B(b)
	3 Solid storage	32'497	13'413		3.B(b)
	4 Other AWMS	9'200	22'560		3.B(b)
	5 Commercial fertiliser	77'555	42'543	= F	3.D.1.a,b(ii.iii),g
B	1 Pasture, range and paddock	13'545	23'557	= A1 + A2 + A3 + A4	3.D.1.c
	2 NH <sub>3</sub> volatilisation housing	11'623	13'809		3.B(b)5
	3 N <sub>2</sub> O emission liquid/slurry	194	137		3.B(b)
	4 NO <sub>x</sub> volatilisation liquid/slurry and digester	196	159		3.B(b)5
	5 Leaching manure management	0	0		3.B(b)5
	6 N <sub>2</sub> volatilisation liquid/slurry and digester	1'963	1'587		3.B(b)5
	7 Manure applied to soils	118'244	82'979		3.D.1.b.i
	8 N <sub>2</sub> O emission solid storage	162	67		3.B(b)
	9 N <sub>2</sub> O emission other AWMS	47	52		3.B(b)
	10 NO <sub>x</sub> volatilisation solid storage and deep litter	210	119		3.B(b)5
	11 NH <sub>3</sub> volatilisation storage	8'154	6'805		3.B(b)5
	12 N <sub>2</sub> volatilisation solid storage and deep litter	1'126	741		3.B(b)5
C	1 NH <sub>3</sub> deposition manure management	19'776	20'614	= B2+B11	3.B(b)5
	2 NO <sub>x</sub> deposition manure management	406	278	= B4+B10	
	3 Leaching manure management	0	0	= B5	
D	1 Plant available N PR&P and N2 volatilisation	9'971	17'906	= B1	
	2 N <sub>2</sub> O emission PR&P	78	132		3.D.1.c
	3 NO <sub>x</sub> volatilisation PR&P	74	130		
	4 NH <sub>3</sub> volatilisation PR&P	630	1'187		
	5 Leaching and run-off PR&P	2'791	4'202		
E	1 Plant available N animal manure and N <sub>2</sub> vol.	64'196	50'588	= B7	
	2 N <sub>2</sub> O emission application animal manure	1'182	830		3.D.1.b.i
	3 NO <sub>x</sub> volatilisation application animal manure	634	445		
	4 NH <sub>3</sub> volatilisation application animal manure	28'487	16'669		
	5 Leaching and run-off application animal manure	23'745	14'447		
F	1 Plant available N com. fertiliser and N <sub>2</sub> vol.	55'123	31'474	= A5	
	2 N <sub>2</sub> O emission application com. fertiliser	776	418		3.D.1.a,b(ii.iii),g
	3 NO <sub>x</sub> volatilisation application com. fertiliser	427	234		
	4 NH <sub>3</sub> volatilisation application com. fertiliser	5'247	2'909		
	5 Leaching and run-off application com. fertiliser	15'983	7'508		
G	1 Cultivation of organic soils (ha)	18'887	17'990		3.D.1.f
H	1 Mineralisation/immobilisation soil organic matter	6'439	6'834		3.D.1.e
I	1 N input from crop residues PR&P	61'823	60'545		3.D.1.d
	2 N input from crop residues arable crops	12'816	13'174		
J	1 NH <sub>3</sub> deposition fertiliser appl. and PR&P	34'365	20'764	= D4+E4+F4	3.D.2.a
	2 NO <sub>x</sub> deposition fertiliser appl. and PR&P	1'135	809	= D3+E3+F3	
	4 Leaching and run-off fertiliser appl. and PR&P	42'519	26'158	= D5+E5+F5	3.D.2.b
	5 Leaching and run-off mineralisation SOM	1'327	1'219		
	6 Leaching and run-off crop residues	15'382	13'151		

### 5.5.2.2. Direct N<sub>2</sub>O emissions from managed soils (3D.1)

Calculation of Direct N<sub>2</sub>O 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<sub>2</sub>O<sub>Direct</sub>-N = annual direct N<sub>2</sub>O–N emissions produced from managed soils (kg N<sub>2</sub>O–N/year)

F<sub>SN</sub> = annual amount of synthetic fertiliser N applied to soils (kg N/year)

F<sub>ON</sub> = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (kg N/year)

F<sub>CR</sub> = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F<sub>SOM</sub> = 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<sub>OS</sub> = annual area of managed/drained organic soils (ha)

F<sub>PRP</sub> = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock (kg N/year)

EF<sub>1</sub> = emission factor for N<sub>2</sub>O emissions from N inputs (kg N<sub>2</sub>O–N/kg N input)

EF<sub>2</sub> = emission factor for N<sub>2</sub>O emissions from drained/managed organic soils (kg N<sub>2</sub>O–N/ha)

EF<sub>3</sub> = emission factor for N<sub>2</sub>O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals (kg N<sub>2</sub>O–N/kg N input)

#### 5.5.2.2.1. Emission factors

Emission factors for calculating 3D.1 Direct N<sub>2</sub>O emissions from managed soils are based on default values as provided in the 2019 Refinement (Table 5-22). For EF<sub>1</sub> the aggregated default value of 1 % is used (IPCC 2019). A rationale for the appropriateness is provided in chp. 5.5.4. Since the year 2007 mineral fertilisers with nitrification inhibitors are used in Switzerland. The use of nitrification inhibitors reduces direct N<sub>2</sub>O emissions from these fertilisers by 65 %. This reduction factor is ultimately based on Pfab et al. (2012) but also supported by studies of Weiske et al. (2001) and a meta-analysis by Akiyama et al. (2009) as described in First Climate (2017). The applied amounts are still small and the weighted emission factor (EF<sub>1</sub>) reported is thus only slightly below 1.0 %. The amount of fertilisers with nitrification inhibitors is classified as confidential (C). An additional table is available to reviewers on request, including all confidential data and information (Table 5-23). Due to the lack of data no other source specific emission factors were applied for EF<sub>1</sub>. The N<sub>2</sub>O emission factor for cultivated organic soils (EF<sub>2</sub>) is the area weighted mean of the IPCC default emission factors for N<sub>2</sub>O emissions from cultivated organic soils under cropland (drained 13.0 kg N<sub>2</sub>O–N/ha/year, IPCC 2014a) and grassland (deep-drained, nutrient rich 8.2 kg N<sub>2</sub>O–N/ha/year; IPCC 2014a). 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 in wet climates (EF<sub>3PRP,CPP</sub> = 0.006 kg N<sub>2</sub>O–N/kg N) and the emission factor for sheep and “other animals” (EF<sub>3PRP,SO</sub> = 0.003 kg N<sub>2</sub>O–N/kg N) according to the shares of nitrogen excreted by the respective animals (IPCC 2019).

Table 5-22 Emission factors for calculating direct N<sub>2</sub>O emissions from managed soils (based on IPCC 2019 and IPCC 2014a). Blue: annually changing parameters, value for 2023.

Emission source	Emission factor
EF <sub>1</sub> Inorganic N fertilisers (kg N <sub>2</sub> O-N/kg)	0.0098
EF <sub>1</sub> Organic N fertilisers (kg N <sub>2</sub> O-N/kg)	0.01
EF <sub>1</sub> Crop residue (kg N <sub>2</sub> O-N/kg)	0.01
EF <sub>1</sub> Mineralisation/immobilisation soil organic matter (kg N <sub>2</sub> O-N/kg)	0.01
EF <sub>1</sub> Other (domestic synthetic fertilisers) (kg N <sub>2</sub> O-N/kg)	0.01
EF <sub>2</sub> Cultivation of organic soils (kg N <sub>2</sub> O-N/ha)	10.6
EF <sub>3</sub> Urine and dung deposited by grazing animals (kg N <sub>2</sub> O-N/kg)	0.0056

Table 5-23 In the confidential NID, the amount of mineral fertilisers with and without nitrification inhibitors and corresponding emission factors are separately reported and available to reviewers.

#### 5.5.2.2.2. Activity data

Activity data for calculation of 3D.1 Direct soil emissions include a. Inorganic N fertilisers, b. Organic N fertilisers, c. Urine and dung deposited by grazing animals, d. Crop residues, e. Nitrogen from mineralisation/immobilisation associated with loss/gain of soil organic matter f. Area of organic soils (i.e. histosols) and g. 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 (2023). Fertiliser statistics are based on sales statistics of the compulsory stockpiling of fertilisers (“Pflichtlagerhalter”) and small importers. Agricura conducts plausibility checks with import-data received by the Federal Office for Customs and Border Security (FOCBS). The estimates contain fertilisers used in Liechtenstein which are subtracted for the Swiss GHG inventory. Furthermore, 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. 2022). These fertilisers are used in public green areas, sports grounds and home gardens. In the reporting tables (CRT) they are reported under 3D.1.g **Other (Domestic inorganic fertilisers)** while emission calculation is conducted together with 3D.1.a. In some occasions, as for instance for the estimation of indirect N<sub>2</sub>O 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 5-21).

**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 IPCC 2019, 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).  $Frac_{GASM}$  in CRT Table 3.D represents the amount of nitrogen volatilised as NH<sub>3</sub>, NO<sub>x</sub>, N<sub>2</sub>O and N<sub>2</sub> from housing and manure storage divided by the manure excreted in the stable (liquid/slurry, solid storage, digesters, deep litter and poultry manure). Subsequently the amount of nitrogen in bedding material is added. The data on straw production is based on statistics of the Swiss Farmers Union (SBV 2024). The nitrogen input from manure applied to soils under 3D.1.b.i in CRT



Table3.D can thus be calculated with the numbers given in CRT Table3.B(b) and Table3.D and the amount of nitrogen added in bedding material (Table 5-24).

Table 5-24 Nitrogen input from bedding material.

N input from bedding material	1990-2015					
	1990	1995	2000	2005	2010	2015
	tN					
N <sub>beddingMS</sub>	3'024	2'972	2'693	2'132	1'915	1'849

N input from bedding material	2016-2023							
	2016	2017	2018	2019	2020	2021	2022	2023
	tN							
N <sub>beddingMS</sub>	1'879	1'791	1'567	2'015	1'710	1'582	1'769	1'996

The amount of **sewage sludge** applied to agricultural soils was estimated according to Kupper et al. (2022). Since 2003 it is forbidden in Switzerland to use sewage sludge as a fertiliser. As of 2006, this prohibition has been made effective for all agricultural areas with a transition period to 2008 (UVEK 2003).

Additional to nitrogen from animal manure and sewage sludge the Swiss GHG inventory also considers **other organic fertilisers** applied to soils. These include compost, liquid and solid digestates from industrial biogas plants as well as co-substrates from agricultural biogas plants and nitrogen inputs from decentralised wastewater streams. Total amounts of compost are based on data from CVIS (Inspektorat der Kompostier- und Vergärbranche der Schweiz; CVIS 2023) while amounts of liquid and solid digestates as well as co-substrates from biogas plants are assessed based on the renewable energy statistics (SFOE 2024a). Nitrogen contents of these substrates are based on Kupper et al. (2022).

Nitrogen inputs from decentralised human wastewaters treated via manure tanks are estimated based on Vuna (2023, see also EMIS 2024/5D2 Kläranlagen kommunal). Thereby it is assumed that the respective wastewater enters directly liquid/slurry tanks on farms that keep mainly cattle. Losses of N<sub>2</sub>O, NO<sub>x</sub> and N<sub>2</sub> during liquid storage are subtracted in order to calculate the amount of nitrogen applied to soils. NH<sub>3</sub> losses are not accounted for since these are mainly dependent on the surface area, which is not increased by the additional amount of wastewater. All other loss rates are assessed as described under chp. 5.3.2.5.4. Note that emissions of CH<sub>4</sub> and N<sub>2</sub>O from storage of decentralised human wastewaters treated via manure tanks are reported under 7.5 Source category 5D – Wastewater treatment and discharge.

Calculation of emissions from **urine and dung deposited by grazing animals** is based on equation 11.5 of IPCC (2019). Estimation of total livestock nitrogen excretion was described under chp. 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. 2022; 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 Swiss farms (2000, 2007, 2010, 2015, 2019).

N<sub>2</sub>O 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 biomass was assessed based on area and yield estimates from the statistical yearbooks of the Swiss Farmers Union (SBV

2024) and the Federal Statistical Office (FSO 2024a). Based on country-specific allometric functions above ground and below ground carbon inputs from crop residues were derived for modelling soil organic carbon stock changes under 4B Cropland (Wüst-Galley et al. 2020, see also chp. 6.5.2.1.3.1). These carbon inputs used in the LULUCF sector were then converted to nitrogen inputs using C/N ratios (see A5.3.3). For above ground biomass a carbon content of 45 % and nitrogen contents from Rösemann et al. (2021) and BRDBMJ (2017) were adopted. For grain maize the resulting C/N ratio was considered unrealistic and the default N content for generic grains from IPCC (2019) was adopted. Furthermore, as there was no nitrogen content available for vegetables the respective value was assessed based on Richner and Sinaj (2017). For below ground inputs a carbon content of 45 % was assumed. As BRDBMJ (2017) does not provide data on nitrogen contents of below ground crop residues, nitrogen contents from IPCC (2019, 2006) were adopted as also suggested by Rösemann et al. (2021).

Crop residues from **meadows and pastures** were also assessed as suggested in the 2019 Refinement (IPCC 2019, other forages including perennial grasses and grass/clover pastures). Two thirds of the agricultural land consist of grassland which underscores the importance of this source for Switzerland. Based on the modelling framework for soil carbon stock changes in grassland soils, constant carbon inputs of 1.03 and 0.90 tonnes of carbon per hectare and year for all 6 grassland categories were estimated (Wüst-Galley et al. 2020, see also chp. 6.6.2.1.3.1). These carbon inputs were converted to nitrogen inputs based on a carbon content of 45 % and grassland category specific nitrogen contents from Richner and Sinaj (2017). For estimating belowground nitrogen inputs the C/N ratio was increased by 25 % as below ground biomass usually contains less nitrogen (see A5.3.3).

Crop residues from the production of **fruit and vine** were estimated based on yield data from SBV (2024) and the ratio between standard fresh matter yields and standard nitrogen yields from crop residues from Richner and Sinaj (2017).

It is assumed that 85% of all straw is removed from the fields for bedding material. All other crop residues are left on the fields (Wüst-Galley et al. 2020). 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.

Estimated values of yearly carbon inputs per hectare and C/N ratios are provided in Annex A5.3.3.

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 chp. A5.4.1 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 for grassland 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<sub>2</sub>O emissions from nitrogen mineralisation are not identical with the net carbon stock changes reported in the reporting table (Table 4.C). N<sub>2</sub>O emissions from nitrogen mineralisation of land converted to cropland or land converted to grassland are reported under category 4(III) "Direct nitrous oxide (N<sub>2</sub>O)

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<sub>2</sub>O emissions from **cultivated organic soils** are based on the area of cultivated organic soils under cropland and grassland and the IPCC default emission factors for N<sub>2</sub>O emissions from cultivated organic soils under cropland (drained 13.0 kg N<sub>2</sub>O-N/ha/year, IPCC 2014a) and grassland (deep-drained, nutrient rich 8.2 kg N<sub>2</sub>O-N/ha/year; IPCC 2014a). The area of cultivated organic soils corresponds to the total area of organic soils under cropland and grassland as reported in CRT Table 4.B and 4.C (see also chp. 6.2.2.1).

The relevant activity data for calculating N<sub>2</sub>O emissions from soils are displayed in Table 5-25. Additional information is given in a separate spreadsheet (Agroscope 2025a).

Table 5-25 Activity data for calculating 3D.1 Direct N<sub>2</sub>O emissions from managed soils.

Activity Data		1990-2015					
		1990	1995	2000	2005	2010	2015
		t N/yr					
1. Inorganic N fertilisers	Urea	16'286	10'708	7'632	6'606	7'102	7'224
	Other mineral fertilisers	50'398	47'659	43'048	43'485	45'991	36'527
2. Organic N fertilisers	a. Animal manure	118'244	109'469	89'957	84'567	87'877	86'420
	b. Sewage sludge	4'815	4'942	3'356	1'054	0	0
	c. Other organic fertilisers	817	1'286	1'829	2'169	3'281	4'908
3. Urine and dung deposited by grazing animals		13'545	14'277	21'269	23'956	24'235	23'671
4. Crop residues	Arable crops	12'816	12'417	13'891	13'828	13'257	14'004
	Residues M&P	61'823	62'756	63'708	63'332	62'956	61'771
5. Min./imm. associated with loss/gain of SOM		6'439	18'530	20'801	11'554	6'726	5'434
6. Cultivation of organic soils (ha)		18'887	18'723	18'567	18'418	18'279	18'181
7. Other (domestic inorganic fertilisers)		2'779	2'432	2'112	2'087	2'212	1'823

Activity Data		2016-2023							
		2016	2017	2018	2019	2020	2021	2022	2023
		t N/yr							
1. Inorganic N fertilisers	Urea	8'873	9'251	8'325	7'754	7'398	8'101	6'913	8'180
	Other mineral fertilisers	37'537	40'119	37'439	32'406	33'700	37'270	31'523	25'526
2. Organic N fertilisers	a. Animal manure	85'956	85'182	84'391	83'730	83'154	83'270	83'713	82'979
	b. Sewage sludge	0	0	0	0	0	0	0	0
	c. Other organic fertilisers	5'435	5'542	5'669	6'211	6'357	6'548	6'394	6'766
3. Urine and dung deposited by grazing animals		23'717	23'766	23'734	23'613	23'462	23'553	23'677	23'557
4. Crop residues	Arable crops	13'145	14'682	13'990	14'032	14'547	12'462	14'431	13'174
	Residues M&P	61'644	61'227	60'938	61'096	60'845	60'931	60'501	60'545
5. Min./imm. associated with loss/gain of SOM		14'274	17'793	6'212	9'434	14'507	14'298	1'427	6'834
6. Cultivation of organic soils (ha)		18'146	18'129	18'088	18'070	18'066	18'045	18'018	17'990
7. Other (domestic inorganic fertilisers)		1'934	2'057	1'907	1'673	1'712	1'890	1'602	1'404

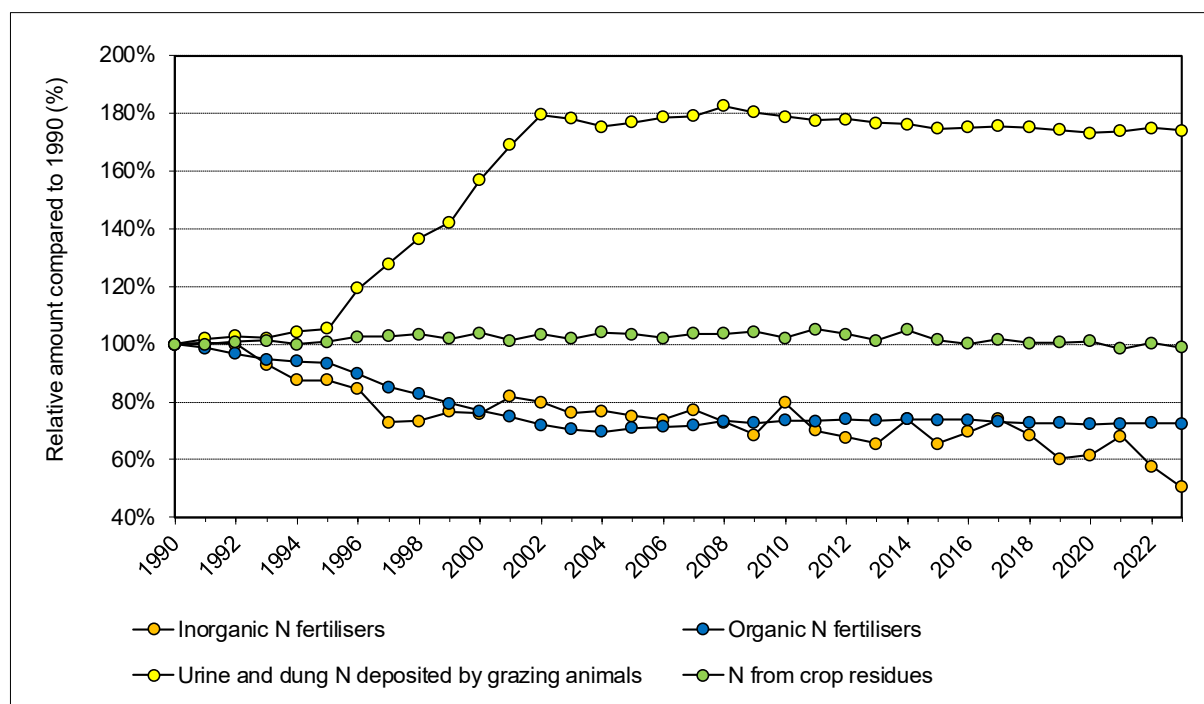


Figure 5-7 Relative development of the most important activity data for 3D.1 Direct N<sub>2</sub>O emissions from managed soils.

Figure 5-7 represents the development of the most important activity data for 3D.1 Direct N<sub>2</sub>O 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<sup>st</sup> 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<sub>2</sub>O emissions from atmospheric deposition of N volatilised from managed soils (3D.2.a)

N<sub>2</sub>O emissions from atmospheric deposition of N volatilised from managed soils were estimated based on equations 11.9 and 11.11 of IPCC 2019 Guidelines. However, the method was adapted to the far more detailed approach of Switzerland:

$$N_2O_{(ATD)} - N = \left\{ \left[ \sum_i (F_{CN_i} * Frac_{GASF_i}) + \sum_T (F_{AM_T} * Frac_{GASM_T}) + \sum_T (F_{PRP_T} * Frac_{GASP_T}) \right] + [(F_{CN} + F_{AM}) * Frac_{NOXA} + F_{PRP} * Frac_{NOXP}] \right\} * EF_4$$

N<sub>2</sub>O<sub>(ATD)</sub>-N = annual amount of N<sub>2</sub>O–N produced from atmospheric deposition of N volatilised from managed soils (kg N<sub>2</sub>O–N/year)

$F_{\text{CN}i}$  = annual amount of commercial fertiliser N of type  $i$  applied to soils (kg N/year)

$\text{Frac}_{\text{GASFi}}$  = fraction of commercial fertiliser N of type  $i$  that volatilises as  $\text{NH}_3$  (kg N/kg N)

$F_{\text{AMT}}$  = annual amount of managed animal manure N of livestock category  $T$  applied to soils (kg N/year)

$\text{Frac}_{\text{GASMT}}$  = fraction of applied animal manure N of livestock category  $T$  that volatilises as  $\text{NH}_3$  (kg N/kg N)

$F_{\text{PRPT}}$  = annual amount of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category  $T$  (kg N/year)

$\text{Frac}_{\text{GASPT}}$  = fraction of urine and dung N deposited on pasture, range and paddock by grazing animals of livestock category  $T$  that volatilises as  $\text{NH}_3$  (kg N/kg of N)

$F_{\text{CN}}$  = total amount of commercial fertiliser N applied to soils (kg N/year)

$F_{\text{AM}}$  = total amount of managed animal manure N applied to soils (kg N/year)

$\text{Frac}_{\text{NOXA}}$  = fraction of applied N (commercial fertilisers and animal manure) that volatilises as  $\text{NO}_x$  (kg N/kg N)

$F_{\text{PRP}}$  = total amount of urine and dung N deposited on pasture, range and paddock by grazing animals (kg N/year)

$\text{Frac}_{\text{NOXP}}$  = fraction of urine and dung N deposited on pasture, range and paddock that volatilises as  $\text{NO}_x$  (kg N/kg of N)

$\text{EF}_4$  = emission factor for  $\text{N}_2\text{O}$  emissions from atmospheric deposition of N on soils and water surfaces (kg  $\text{N}_2\text{O-N}$ / kg N volatilised).

#### 5.5.2.3.1. *Emission factor*

The emission factor for indirect  $\text{N}_2\text{O}$  emissions from atmospheric deposition of N volatilised from managed soils is the same as used for the assessment of indirect  $\text{N}_2\text{O}$  emissions after volatilisation of  $\text{NH}_3$  and  $\text{NO}_x$  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 2.57 %. For further information see chp. 5.3.2.4.

#### 5.5.2.3.2. *Activity data*

The estimation of volatilisation of ammonia and  $\text{NO}_x$  was harmonised with the Swiss ammonia model AGRAMMON using the same emission factors and basic parameters (Table 5-26). 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  $\text{NH}_3$  emissions, changes of agricultural structures (changes to more animal friendly housing systems) and techniques (manure management, measures to reduce  $\text{NH}_3$  emissions) are considered and explain temporal dynamics.

Ammonia volatilisation from **commercial fertiliser N** was estimated separately for synthetic fertilisers, sewage sludge, and other organic fertilisers (compost, liquid and solid digestates from industrial biogas plants, co-substrates from agricultural biogas plants and nitrogen

inputs from decentralised human wastewaters treated via manure tanks). Ammonia volatilisation of nitrogen in synthetic fertilisers was assessed separately for individual fertiliser types based on the EMEP/EEA guidebook (EMEP/EEA 2019). The weighted mean value for synthetic fertilisers excluding urea is 2.8 % (mean 1990–2023). 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. 2022). Other organic fertilisers include compost, liquid and solid digestates, co-substrates from agricultural biogas plants as well as nitrogen inputs from decentralised human wastewaters treated via manure tanks. Ammonia emission factors are 3.4 % for compost, 21 % to 30 % for liquid digestate (including co-substrates from agricultural biogas plants) and 4.0 % for solid digestate (Kupper et al. 2022). The ammonia loss rate for liquid digestates decreased from 2001 until 2010 due to the increasing use of trailing hoses during field application. For decentralised human wastewaters treated via manure tanks an ammonia loss rate of 21 % was assumed for soil application (mean 1990–2023). This value was estimated based on AGRAMMON (2024) assuming a basic loss rate of 35 % of TAN (total ammoniacal nitrogen) and a TAN-content of 70 %. As for liquid manure from cattle the ammonia loss rate declines along the time series due to the increased use of low emission slurry application techniques. The weighted ammonia emission factor for the sum of all recycling fertilisers varies along the inventory time period due to the development of the relative amounts of the different recycling fertilisers types.

Total  $\text{Frac}_{\text{GASF}}$  (including  $\text{NO}_x$  emissions) as reported in CRT Table3.D declined considerably from 7.3 % in 1990 to 5.2 % in 2006 and then increased again to 7.4 % in 2023 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. 2022). Overall weighted  $\text{Frac}_{\text{GASMT}}$  for animal manure applied to soils slightly declined from 24.6 % in the early 1990s to 20.6 % in 2023 (Table 5-26).

Ammonia volatilisation from **urine and dung N deposited on pasture, range and paddock by grazing animals** was also assessed individually for each livestock category (Kupper et al. 2022). Weighted mean loss rates ( $\text{Frac}_{\text{GASPT}}$ ) range from 5.2 % to 5.6 %.

**$\text{NO}_x$  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.  $\text{NO}_x$  emission factors ( $\text{Frac}_{\text{NOXA}}$  and  $\text{Frac}_{\text{NOXP}}$ ) 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 3D.2 Indirect  $\text{N}_2\text{O}$  emissions from managed soils are displayed in Table 5-27. Additional information is given in a separate spreadsheet (Agroscope 2025a).

Table 5-26 Overview of NH<sub>3</sub> and NO<sub>x</sub> emission factors used for the assessment of 3D.2 Indirect N<sub>2</sub>O emissions from atmospheric deposition. Complete time series on a livestock sub-category level are provided in a separate spreadsheet (Agroscope 2025a).

Emission factors volatilisation		1990-2015					
		1990	1995	2000	2005	2010	2015
		%					
NH <sub>3</sub> from commercial fertiliser N (Frac <sub>GASFI</sub> )		6.77	6.46	5.72	4.88	4.86	5.73
	Urea	13.11	13.11	13.11	13.11	13.11	13.11
	Other Mineral Fertilisers	2.72	2.72	2.51	2.76	3.07	3.29
	Recycling Fertilisers (weighted average)	17.60	19.97	18.80	13.40	9.37	11.74
	Sewage Sludge	20.00	23.94	26.07	26.07	26.07	26.07
	Compost	3.43	3.43	3.43	3.43	3.43	3.43
	Digestate Liquid	30.00	30.00	30.00	26.06	21.00	21.00
	Digestate Solid	4.00	4.00	4.00	4.00	4.00	4.00
	Decentralised wastewater	24.50	24.35	21.69	20.78	19.26	18.29
NH <sub>3</sub> from application of animal manure N (Frac <sub>GASMT</sub> )		24.09	23.87	22.77	22.73	21.47	20.26
	Mature Dairy Cattle	26.85	26.78	26.04	26.21	24.94	23.31
	Other Mature Cattle	22.86	22.06	22.38	22.72	22.47	21.59
	Growing Cattle (weighted average)	23.68	23.51	23.14	23.48	22.71	21.22
	Sheep (weighted average)	4.89	4.89	4.75	5.33	5.45	4.93
	Swine (weighted average)	24.20	23.95	21.93	21.28	19.09	18.22
	Other Livestock (weighted average)	10.12	10.09	9.10	9.54	9.99	10.04
NH <sub>3</sub> from urine and dung N deposited on PR&P (Frac <sub>GASPT</sub> )		4.65	4.69	4.80	4.89	4.89	4.91
	Mature Dairy Cattle	4.67	4.65	4.63	4.61	4.60	4.59
	Other Mature Cattle	4.56	4.57	4.56	4.56	4.56	4.56
	Growing Cattle (weighted average)	4.56	4.56	4.57	4.57	4.57	4.57
	Sheep (weighted average)	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
	Other Livestock (weighted average)	5.00	6.50	7.58	8.48	8.50	8.76
NO <sub>x</sub> from applied fertilisers (Frac <sub>NOXA</sub> )		0.55	0.55	0.55	0.55	0.55	0.55
NO <sub>x</sub> from urine and dung N deposited on PR&P (Frac <sub>NOXP</sub> )		0.55	0.55	0.55	0.55	0.55	0.55

Emission factors volatilisation		2016-2023							
		2016	2017	2018	2019	2020	2021	2022	2023
		%							
NH <sub>3</sub> from commercial fertiliser N (Frac <sub>GASFI</sub> )		5.62	5.70	5.79	6.11	6.08	5.88	5.96	6.84
	Urea	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11
	Other Mineral Fertilisers	2.80	2.99	3.05	3.12	3.20	3.01	2.85	3.06
	Recycling Fertilisers (weighted average)	11.64	11.84	12.07	12.04	12.30	12.35	12.66	12.69
	Sewage Sludge	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
	Digestate Liquid	21.00	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
	Decentralised wastewater	18.22	18.17	18.12	18.07	18.04	18.03	17.99	17.93
NH <sub>3</sub> from application of animal manure N (Frac <sub>GASMT</sub> )		20.24	20.25	20.32	20.19	20.21	20.23	20.17	20.09
	Mature Dairy Cattle	23.32	23.33	23.34	23.36	23.36	23.35	23.35	23.35
	Other Mature Cattle	21.53	21.46	21.40	21.34	21.33	21.33	21.33	21.33
	Growing Cattle (weighted average)	21.28	21.37	21.42	21.48	21.46	21.47	21.47	21.44
	Sheep (weighted average)	4.98	5.03	5.07	5.11	5.12	5.12	5.11	5.12
	Swine (weighted average)	18.24	18.27	18.30	18.32	18.34	18.34	18.34	18.34
	Other Livestock (weighted average)	10.16	10.17	10.41	10.42	10.57	10.61	10.63	10.61
NH <sub>3</sub> from urine and dung N deposited on PR&P (Frac <sub>GASPT</sub> )		4.94	4.96	4.98	5.00	5.04	5.04	5.04	5.04
	Mature Dairy Cattle	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
	Other Mature Cattle	4.56	4.56	4.56	4.56	4.56	4.56	4.56	4.56
	Growing Cattle (weighted average)	4.57	4.57	4.57	4.57	4.57	4.57	4.57	4.57
	Sheep (weighted average)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Swine (weighted average)	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
	Other Livestock (weighted average)	9.09	9.24	9.68	9.84	10.28	10.29	10.34	10.29
NO <sub>x</sub> from applied fertilisers (Frac <sub>NOXA</sub> )		0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
NO <sub>x</sub> from urine and dung N deposited on PR&P (Frac <sub>NOXP</sub> )		0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55



Table 5-27 Overview of N pools and flows for calculating 3D.2 Indirect N<sub>2</sub>O emission from managed soils. Complete time series are provided in a separate spreadsheet (Agroscope 2025a).

Nitrogen pools and flows		1990-2015					
		1990	1995	2000	2005	2010	2015
		t N/yr					
Deposition	Animals manure N applied to soils	118'244	109'469	89'957	84'567	87'877	86'420
	Commercial fertiliser	75'094	67'027	57'977	55'401	58'586	50'483
	Sum volatilised N (NH <sub>3</sub> and NO <sub>x</sub> )	35'499	32'279	25'802	24'032	23'865	22'480
	NH <sub>3</sub> emissions from commercial fertilisers	5'247	4'432	3'380	2'740	2'879	2'931
	NH <sub>3</sub> emissions from applied animal manure	28'487	26'136	20'479	19'226	18'868	17'509
	NH <sub>3</sub> emissions from pasture, range and paddock	630	670	1'021	1'172	1'185	1'163
	NO <sub>x</sub> emissions from commercial fertilisers	427	377	325	309	326	281
	NO <sub>x</sub> emissions from applied animal manure	634	586	480	453	473	465
Leaching and run-off	NO <sub>x</sub> emissions from PR&P	74	79	117	132	133	130
	Sum leaching and run-off	59'228	58'330	52'364	47'142	45'006	42'890
	Leaching and run-off from commercial fertilisers	15'983	14'129	11'629	10'536	10'552	9'094
	Leaching and run-off from applied animal manure	23'745	21'947	17'178	15'467	15'335	15'087
	Leaching and run-off from pasture, range and paddock	2'791	2'942	4'187	4'495	4'323	4'223
	Leaching and run-off from crop residues	15'382	15'492	15'276	14'477	13'596	13'518
	Leaching and run-off from mineralisation of SOM	1'327	3'819	4'095	2'168	1'200	969

Nitrogen pools and flows		2016-2023							
		2016	2017	2018	2019	2020	2021	2022	2023
		t N/yr							
Deposition	Animals manure N applied to soils	85'956	85'182	84'391	83'730	83'154	83'270	83'713	82'979
	Commercial fertiliser	53'778	56'969	53'340	48'044	49'167	53'810	46'432	41'877
	Sum volatilised N (NH <sub>3</sub> and NO <sub>x</sub> )	22'516	22'620	22'343	21'907	21'871	22'110	21'722	21'573
	NH <sub>3</sub> emissions from commercial fertilisers	3'058	3'284	3'128	2'975	3'030	3'201	2'808	2'909
	NH <sub>3</sub> emissions from applied animal manure	17'394	17'252	17'150	16'905	16'809	16'844	16'882	16'669
	NH <sub>3</sub> emissions from pasture, range and paddock	1'172	1'178	1'182	1'180	1'181	1'186	1'193	1'187
	NO <sub>x</sub> emissions from commercial fertilisers	299	317	297	268	274	300	259	234
	NO <sub>x</sub> emissions from applied animal manure	462	459	456	449	448	449	451	445
Leaching and run-off	NO <sub>x</sub> emissions from PR&P	130	131	131	130	129	130	130	130
	Sum leaching and run-off	44'793	46'026	43'002	42'401	43'482	43'974	40'735	40'528
	Leaching and run-off from commercial fertilisers	9'675	10'194	9'518	8'526	8'730	9'557	8'271	7'508
	Leaching and run-off from applied animal manure	14'999	14'876	14'775	14'577	14'529	14'573	14'618	14'447
	Leaching and run-off from pasture, range and paddock	4'231	4'240	4'234	4'212	4'185	4'202	4'224	4'202
	Leaching and run-off from crop residues	13'342	13'542	13'367	13'402	13'449	13'093	13'367	13'151
	Leaching and run-off from mineralisation of SOM	2'546	3'174	1'108	1'683	2'588	2'551	255	1'219

Figure 5-8 shows the development of the most important activity data for 3D.2 Indirect N<sub>2</sub>O 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<sub>3</sub> (Frac<sub>GASMT</sub>) declined slightly and also contributed to the decreasing trend.

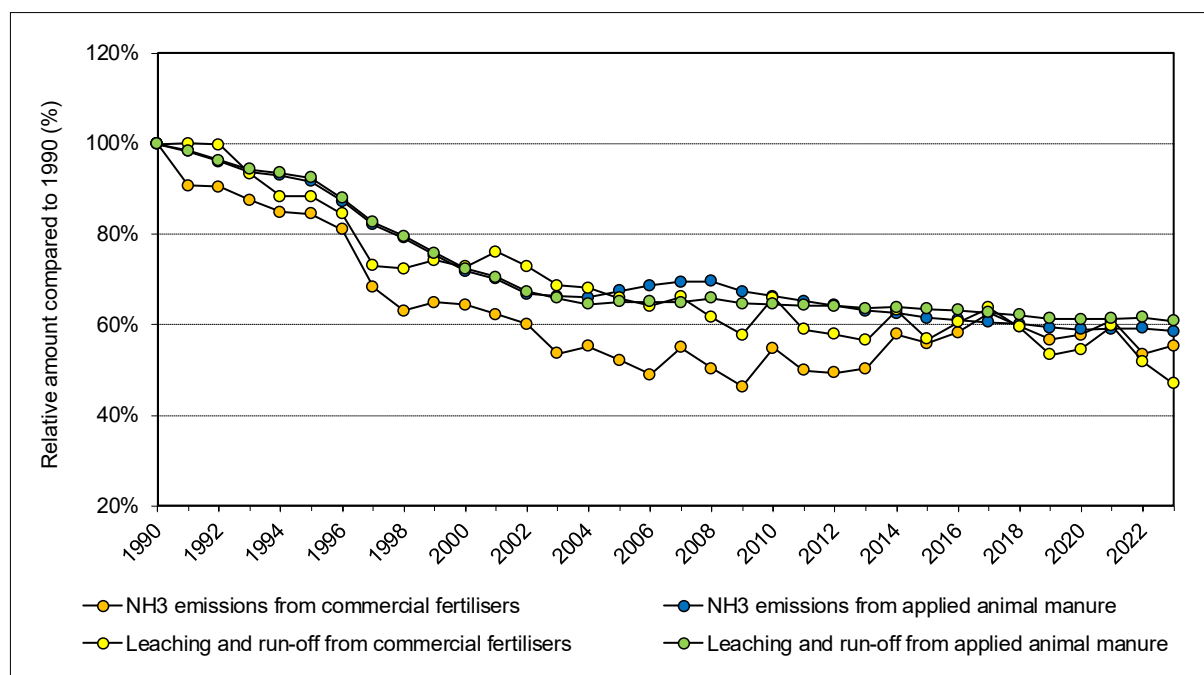


Figure 5-8 Relative development of the most important activity data for 3D.2 Indirect N<sub>2</sub>O emissions from managed soils.

#### 5.5.2.4. Indirect N<sub>2</sub>O emissions from leaching and run-off from managed soils (3D.2.b)

N<sub>2</sub>O emissions from leaching and run-off from managed soils are estimated based on equation 11.10 of IPCC 2019:

$$N_2O_{(L)} - N = (F_{CN} + F_{AM} + F_{PRP} + F_{CR} + F_{SOM}) \cdot \text{Frac}_{\text{LEACH-(H)}} \cdot EF_5$$

N<sub>2</sub>O<sub>(L)</sub>-N = annual amount of N<sub>2</sub>O-N produced from leaching and run-off of N additions to managed soils (kg N<sub>2</sub>O-N/year)

F<sub>CN</sub> = annual amount of commercial fertiliser N applied to soils (kg N/year)

F<sub>AM</sub> = annual amount of managed animal manure N applied to soils (kg N/year)

F<sub>PRP</sub> = annual amount of urine and dung N deposited by grazing animals (kg N/year)

F<sub>CR</sub> = annual amount of N in crop residues, including N-fixing crops, returned to soils (kg N/year)

F<sub>SOM</sub> = 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<sub>LEACH-(H)</sub> = fraction of all N added to/mineralised in managed soils that is lost through leaching and runoff (kg N/kg of N additions)

EF<sub>5</sub> = emission factor for N<sub>2</sub>O emissions from N leaching and run-off (kg N<sub>2</sub>O-N/kg N leached and run-off)

##### 5.5.2.4.1. Emission factor

The emission factor for indirect N<sub>2</sub>O emissions from leaching and run-off from managed soils is 0.011 kg N<sub>2</sub>O–N/kg N according to IPCC (2019).

#### 5.5.2.4.2. Activity data

For the calculation of N<sub>2</sub>O emissions from leaching and run-off from managed soils, N-leaching from commercial fertilisers (including synthetic fertilisers, sewage sludge, compost, liquid and solid digestates from industrial biogas plants, co-substrates of agricultural biogas plants as well as nitrogen inputs from decentralised human wastewaters treated via manure tanks) ( $F_{CN}$ ), 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 activity data are contained in Table 5-25.

Frac<sub>LEACH-H</sub> 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 (Table 5-28). 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 5-27.

Table 5-28 Fractions of N lost by leaching or run-off (Frac<sub>LEACH-(H)</sub>).

Leaching of nitrogen	1990-2015					
	1990	1995	2000	2005	2010	2015
	%					
Frac <sub>LEACH(H)</sub>	0.204	0.204	0.195	0.186	0.177	0.177

Leaching of nitrogen	2016-2023							
	2016	2017	2018	2019	2020	2021	2022	2023
	%							
Frac <sub>LEACH(H)</sub>	0.177	0.177	0.177	0.176	0.177	0.177	0.176	0.176

Figure 5-8 illustrates the development of the most important activity data for 3B.2 Indirect N<sub>2</sub>O 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<sub>LEACH-H</sub>).

#### 5.5.2.5. NMVOC emissions from agricultural soils

The NMVOC emissions from crop production and agricultural soils are calculated based on the Tier 2 approach of the EMEP/EEA guidebook (EMEP/EEA 2023). Three types of

agricultural areas are differentiated, i.e. cropland, grassland and summer pastures. The NMVOC emission factors for cropland and grassland are based on the values for wheat and grass (15°C), respectively, of Table 3-4 of the EMEP/EEA guidebook (EMEP/EEA 2023) taking into account country-specific values for the mean dry matter yield (Richner and Sinaj 2017). For summer pastures, the same NMVOC emission value as for grass (15°C) and a fraction of the growing period of 0.3 (Bühler and Kupper 2018) are assumed using a country-specific value for the mean dry matter yield (Richner and Sinaj 2017). The resulting NMVOC emission factors are constant for the entire time series.

### 5.5.3. Uncertainties and time-series consistency for 3D

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 2019 Refinement (IPCC 2019). The detailed input uncertainty values for category 3D are reported in Annex A2.1. The resulting, combined uncertainty for emissions according to approach 1 (uncertainty propagation) are reported in Annex A2.2 and in Annex A2.3 for results obtained by approach 2 (Monte Carlo simulations). The 95 % confidence intervals obtained by Monte Carlo simulations are slightly narrower and, for non-symmetric distributions, slightly shifted towards the lower edge.

Table 5-29 Uncertainties for 3D Agricultural soils. Approach 1: intervals are exactly from 2.5 % to 97.5 % of the distribution; Approach 2: the narrowest interval representing 95 % of the distribution is given.

Source category	Gas	Activity data uncertainty 2023		Emission factor uncertainty 2023		Emission combined uncertainty 2023	
		(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
Uncertainty propagation (approach 1)							
3.D.1 Direct emissions from managed soils	N2O	13	13	61	89	62	90
3.D.2 Indirect emissions from managed soils	N2O	28	33	52	72	59	79
Monte Carlo simulations (approach 2)							
3.D.1 Direct emissions from managed soils	N2O	13	14	66	78	69	78
3.D.2 Indirect emissions from managed soils	N2O	29	31	57	64	63	71

The time series 1990–2023 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 are available for the years 1990 and 1995 (expert judgement and literature) as well as for 2002, 2007, 2010, 2015 and 2019 (extensive surveys on approximatively 3000 farms). Values in-between the assessment years were interpolated linearly. For 2020 to 2023 the same values as in 2019 were used.
- $Frac_{GASF}$ ,  $Frac_{GASM}$  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<sub>2</sub>O emissions following volatilisation of NH<sub>3</sub> and NO<sub>x</sub> from applied fertilisers and urine and dung excreted on pasture, range and paddock 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 for 3D

General QA/QC measures are described in NID chp. 1.5.

All further category-specific QA/QC activities are described in a separate document (Agroscope 2019a). General information on agricultural structures and policies is provided and eventual differences between national and (IPCC 2006, 2019) standard values are being analysed and discussed.

The Swiss ammonium emission model AGRAMMON is documented in Kupper et al. (2022) and Agrammon (2024). Generally, the reporting of N<sub>2</sub>O emissions in the national GHG inventory is consistent with the reporting of other nitrogen compounds (NH<sub>3</sub>, NO<sub>x</sub>) under the CLRTAP.

All relevant parameters needed for the calculation of direct and indirect nitrogen inputs to agricultural soils (e.g. F<sub>CN</sub>, MS-distribution, Frac<sub>GASF</sub>, N<sub>ex</sub>, Frac<sub>GASMT</sub>, F<sub>ON</sub>, F<sub>CR</sub>, Frac<sub>LEACH-H</sub>) were checked for consistency and confidence and were compared (where possible) to IPCC default values (IPCC 2006, 2019), 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.

For the time being Switzerland is still using the aggregated default **emission factor for direct soil emissions (EF<sub>1</sub>)** from the 2019 Refinement (IPCC 2019) instead of using disaggregated emission factors for synthetic fertiliser and other nitrogen inputs in wet climates. Reasons for this are:

- Measurements conducted in Switzerland and neighbouring countries have not yet been fully evaluated in this respect. An extensive study in Germany did not indicate higher emission factors of synthetic fertilisers as compared to organic nitrogen inputs (Mathivanan 2021).
- Animal manure is mainly applied to grasslands whereas synthetic fertilisers are mainly applied on croplands. The effect of fertiliser type is thus interacting with land use, management and seasonal weather conditions potentially confounding systematic differences between organic and synthetic fertilisers.
- Emission factors may also differ between different types of synthetic fertilisers (e.g. Cowan et al. 2020, Harty et al. 2016) and different types of organic fertilisers (e.g. Charles et al. 2017) pointing out that the question of fertiliser type should be addressed in a broader way.

The question of the effect of fertiliser type on N<sub>2</sub>O emission factors will be further explored within ongoing field experiments and the current work on a process-oriented model-framework for the estimation of N<sub>2</sub>O emissions from agricultural soils in Switzerland (see chp. 5.5.6).

N<sub>2</sub>O 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 2019a). In 2018 a focus study in the context of the national research programme 68 (Nationales Forschungsprogramm 68: Ressource Boden) made an independent assessment of the N<sub>2</sub>O emission factors under Swiss conditions based on a literature review (Krause et al. 2018). The authors found that the N<sub>2</sub>O emission factors of mineral soils were 2.06±2.66 % for arable soils and 1.45±1.07 % for grassland soils. Based on the limited data availability and on the great variability between the different measurements they concluded, that these emission factors are not significantly different to

the IPCC (2019) values. Still, the numerical difference indicated that further efforts should be made to development country-specific emission factors (see chp. 5.5.6).

The Swiss FluxNet combines flux sites in Switzerland where GHG fluxes are measured at ecosystem scale using the eddy-covariance technique (<https://www.swissfluxnet.ethz.ch/>). It currently encompasses three grassland sites (Chamau, Frübüel, Alp Weissenstein/Crap Alv) and one cropland site (Oensingen), all run by the Grassland Science Group of the Federal Institute of Technology in Zurich (<https://gl.ethz.ch/>). Further sites with short-term measurements such as Dischma (winter measurements over grassland; closed down) and Oensingen (grassland; closed down) provided additional information. Long-term measurement of N<sub>2</sub>O on these sites provide a unique opportunity for independent validation of emission inventories (e.g. Feigenwinter et al. 2023; Merbold et al. 2021). In order to compare continuous flux measurements to the IPCC emission factor approach, either a source partitioning needs to be conducted, or emission totals and emission factors need to be predicted using empirical or mechanistical models (e.g. Fuchs et al. 2019). In 2020, Ammann et al. (2020) investigated the effect of management and weather variations on N<sub>2</sub>O emissions and the greenhouse gas budget of two grasslands in Oensingen (central plateau of Switzerland) during a 10-year experiment. The total N<sub>2</sub>O-flux was partitioned to the different categories using the IPCC emission factor approach and confirmed the validity of the respective default values. More recently dos Reis Martins et al. (2022) modelled N<sub>2</sub>O emissions of complex cropland management in Western Europe using DayCent and compared results with measurements and the IPCC default emission factor approaches. They found that the IPCC default emission factors tend to underestimate emissions although modelled mean values were still well within the large range of the measurements. Within this same project a process-oriented model-framework will be developed to improve estimation of N<sub>2</sub>O emissions from agricultural soils in Switzerland (see chp. 5.5.6). Recently, collaboration with the Grassland Science Group of the Federal Institute of Technology in Zürich has been intensified in order to make best use of existing and future datasets for emission inventory validation.

A study by Agroscope (2019b) analysed the greenhouse gas flux measurements of a **grazed pasture system** for dairy cows in western Switzerland over five years. The fertiliser-related N<sub>2</sub>O emission factor was on average close to the corresponding IPCC default value of 1%. The excreta-related factor was considerably lower than the 2 % proposed in IPCC (2006) albeit higher than the default emission factor of 0.6 % for cattle in wet climate of IPCC (2019). It could also be shown that there is a clear difference in the individual emission factors for urine and dung patches on the pasture. More recently, another study by Barczyk et al. (2023) investigated emissions from pasture, range and paddock. The resulting overall average EF<sub>urine</sub> was 0.67 % confirming the IPCC default approach (IPCC 2019). Further data analysis as well as process-based modelling are being conducted in order to consolidate these results (see chp. 5.5.6).

The reporting of nitrogen input from crop residues has been harmonised with the reporting of carbon stock changes under 4B Cropland and 4C Grassland to assure consistency of the model inputs. Carbon inputs from crop residues for the modelling of carbon stock changes are converted to nitrogen inputs using crop specific C/N ratios for above ground and below ground biomass. These C/N ratios were selected during a thorough review of the IPCC guidelines and the scientific literature (Richner and Sinaj 2017; Rittl et al. 2021; Rösemann et al. 2021; Thiébeau et al. 2021). The final approach was considered to provide the most accurate and consistent dataset.



The **N<sub>2</sub>O emission factor for cultivated organic soils** was validated by a study from Leifeld (2018) that used a large dataset of C/N ratios in Swiss organic soils to predict N<sub>2</sub>O 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. The current average area of organic soils (approximately 18'000 ha) is well within this range.

The country-specific value of  $Frac_{LEACH-H}$  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.

Henne et al. (2019) conducted a top-down assessment of Swiss N<sub>2</sub>O emissions using atmospheric measurements and an inverse modelling framework. With recent updates, inverse estimates and NID estimates agree very closely for two different atmospheric transport model versions used in the inversion (see also Annex A6.2).

### 5.5.5. Category-specific recalculations for 3D

General information on recalculations is provided in chp. 10.

Recalculations with an overall impact of >0.5 kt CO<sub>2</sub> equivalent are assessed quantitatively. All other recalculations are only described qualitatively.

- For recalculations of livestock population data and emissions from manure management (affecting the amount of animal manure applied to soils) refer to chp. 5.2.5 and chp.5.3.5.
- N<sub>2</sub>O emissions from other commercial fertilizers applied to soils were recalculated for 1990-2022. The amount of synthetic fertilizer applied in Liechtenstein was updated due to new data in from the NID of Liechtenstein. The impact on overall emissions is negligible (<±0.1 kt CO<sub>2</sub> equivalents).
- N<sub>2</sub>O emissions from manure applied to soils were recalculated for 1990-2022. N-input from bedding material was added to manure nitrogen as this nitrogen is no longer accounted for under nitrogen inputs from crop residues. The impact on overall emissions is +9.3 kt CO<sub>2</sub> equivalents (average 1990-2022, min=+6.5, max=+12.6).
- N<sub>2</sub>O emissions from other organic fertilizers applied to soils were recalculated for 1996-2022. The amount of nitrogen inputs from compost and digestates was revised due to new activity data from SFOE 2024a. The impact on overall emissions is negligible (<±0.2 kt CO<sub>2</sub> equivalents) with exception of the year 2022 where the recalculation decreased emissions by almost -1.0 kt CO<sub>2</sub> equivalents.
- N<sub>2</sub>O emissions from other organic fertilizers applied to soils were recalculated for 1990-2022. The amount of nitrogen inputs from decentralised human wastewaters applied to soils was revised (lower amounts of NH<sub>3</sub> volatilised during manure management). The impact on overall emissions is +3.8 kt CO<sub>2</sub> equivalents for 1990 and declines to +0.3 kt CO<sub>2</sub> equivalents in 2022.
- N<sub>2</sub>O emissions due to nitrogen in crop residues returned to soils was recalculated for 1990-2022. The whole methodology for assessing nitrogen inputs (AD) was revised and adjusted to the respective methodology for carbon inputs to soils in the LULUCF-sector. New estimates are considerably higher mainly due to the consideration of nitrogen inputs



from roots and higher nitrogen inputs from intensive meadows. The impact on overall emissions is +197.7 kt CO<sub>2</sub> equivalents (average 1990-2022, min=+185.1, max=217.5).

- N<sub>2</sub>O emissions from nitrogen in mineral soils that is mineralized/immobilized were recalculated for 1990-2022. New updated estimates for the amount of nitrogen mineralized (AD) from the LULUCF sector were adopted. The impact on overall emissions ranges from -66.0 to +54.9 kt CO<sub>2</sub> equivalents with a mean value of +7.7 kt CO<sub>2</sub> equivalents.
- N<sub>2</sub>O emissions from cultivated organic soils were recalculated for 1990-2022. New area estimates (AD) were adopted from the LULUCF sector. The impact on overall emissions was -8.1 kt CO<sub>2</sub> equivalents (-8.2 to -7.9 kt CO<sub>2</sub> equivalents).
- Indirect N<sub>2</sub>O emissions from volatilized and leached nitrogen from agriculture were recalculated for 1990-2022. The amount of nitrogen volatilised and leached was revised due to recalculations of the amount of nitrogen inputs to agricultural soils (AD) as described above. The impact on overall emissions was not estimated separately but is contained in the description of the respective recalculations above.

### 5.5.6. Category-specific planned improvements for 3D

In 2025 the AGRAMMON model (Kupper et al. 2022) will be updated and new data on farm management and production technology will become available from the latest survey. All emissions from 3D Agricultural soils will be revised accordingly during the submission 2026 or 2027.

FOEN funds the development of a process-oriented model for N<sub>2</sub>O emissions in agricultural soils subject to common Swiss management practices. Model selection, calibration, evaluation and first, simplified country-scale simulations were the components of the first phase of the project (LACHSIM; dos Reis Martins and Keel 2024). The results suggest that DayCent is an adequate model for reporting N<sub>2</sub>O emissions from Swiss agricultural soils with complex management, diverse crop rotations in croplands and different levels of management intensity in grasslands. DayCent simulations were clearly more accurate than default IPCC emission factor approaches. The remaining challenge is now to collect accurate management data in order to improve the quality of the upscaling to national scales. The combination of new FOAG geodata on cultivated agricultural areas ("Surfaces agricoles cultivées", <https://www.blw.admin.ch/blw/fr/home/politik/datenmanagement/geografisches-informationssystem-gis.html>; visualisation at <https://s.geo.admin.ch/iqqwpkwctvxb>) and surveys of management activity at cantonal and national levels could provide robust support. A difficult step, however, will be how to create a consistent time series back to 1990.

A number of measurement projects at Agroscope, partially financed by FOEN, contribute to the establishment of a country-specific emission factor for direct N<sub>2</sub>O emissions from urine and dung deposited by grazing animals (EF<sub>3PRP, CPP</sub>) (e.g. Barczyk et al. 2024). Accordingly, it is foreseen that the respective estimates for direct N<sub>2</sub>O emissions may be revised in the near future.

## 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.

Open burning of natural forest, field and garden waste 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. The 26 cantons have thus probably slightly different interpretations and implementations of the federal ordinance. An inquiry of some cantonal authorities was performed in order to assess the activity data for these processes (INFRAS 2014).

Emissions from open burning of branches in agriculture and forestry were reported here in the past. However, the respective emissions were moved to the sectors 4 LULUCF and 5 Waste based on recommendations from the UNFCCC expert review teams (e.g. FCCC/ARR/2016/CHE W12 and W13). Respective information can be found under category 4IV “Biomass Burning” (see chp. 6.4.2.5.4) 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

Table 5-30 Key categories of 3G Liming. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

CO<sub>2</sub> emission from 3G Liming is not a key category.

Emissions from the application of lime ( $\text{Ca}(\text{CO}_3)$ ) and dolomite ( $\text{CaMg}(\text{CO}_3)_2$ ) to agricultural soils are reported.

The emissions due to liming of agricultural soils range from 22.2 to 32.9 kt CO<sub>2</sub> per year.

### 5.8.2. Methodological issues

A simple Tier 1 approach was adopted using estimated amounts of lime and dolomite applied and IPCC (2006) 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  $\text{Ca}(\text{CO}_3)$ ) and for dolomite (0.13 t C per t  $\text{CaMg}(\text{CO}_3)_2$ ) were used (IPCC 2006).

#### 5.8.2.2. Activity data

The total annual amount of lime and dolomite applied to agricultural soils is between 50'300 Mg (1990) and 74'050 Mg (2008–2023). It was estimated by Agroscope in 2009 for the period 1990–2008. Major retailers / providers of lime in Switzerland were directly contacted and interviewed. For 2009–2023 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 remains constant (Agroscope 2014a). This assumption is further supported by the fact that agricultural structures and management did not change fundamentally in recent years. Furthermore, the import of calcium carbonate mixed with ammonium nitrate (contributing 20 % to lime use in Switzerland) is assessed yearly via the import statistics. These statistics do not show a significant trend along the past 20 years (FOCBS 2024a).

The split of lime into calcium carbonate and dolomite is based on the following assumptions and data:

- $\text{Ca}(\text{CO}_3)$  contained in mixed compound fertilisers as reported by Agricura (2023)
- All material originating from nuclear power plants and from the sugar beet industry is  $\text{Ca}(\text{CO}_3)$
- The remaining lime not covered under the points above was divided equally into  $\text{Ca}(\text{CO}_3)$  and  $\text{CaMg}(\text{CO}_3)_2$ .

### 5.8.3. Uncertainties and time-series consistency for 3G

The amount of total lime applied in agriculture is mainly based on expert judgement; the resulting number is uncertain. A normal distribution with a relative uncertainty of  $\pm 40\%$  for a 95 % coverage interval was used as an approximation (Agroscope 2014a). For the emission factor of lime, a lower uncertainty of  $\pm 5\%$  was chosen, because it is a simple chemical process. The detailed input uncertainty values for category 3G are reported in Annex A2.1. The resulting, combined uncertainty for emissions according to approach 1 (uncertainty propagation) is thus  $\pm 40\%$  (see Annex A2.2), in general concordance with results from approach 2 (Monte Carlo simulations, Annex A2.3).

Consistency: Time series for 3G Liming are all considered consistent.

### 5.8.4. Category-specific QA/QC and verification for 3G

General QA/QC measures are described in NID chp. 1.5. No category-specific QA/QC activities were undertaken.

### 5.8.5. Category-specific recalculations for 3G

General information on recalculations is provided in chp. 10.

There were no recalculations implemented in submission 2025.

### 5.8.6. Category-specific planned improvements for 3G

No category-specific improvements are planned.

## 5.9. Source category 3H – Urea application

### 5.9.1. Source category description

Table 5-31 Key categories of 3H Urea application. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

CO<sub>2</sub> emission from 3H Urea application is not a key category.

Adding urea to soils during fertilisation leads to a loss of CO<sub>2</sub> that was fixed during the industrial production process of the fertiliser. Emissions in Switzerland range from 8.7 to 26.7 kt CO<sub>2</sub> per year with a general decreasing trend during the 1990s and values near 12 kt CO<sub>2</sub> per year for the later part of the time series.

### 5.9.2. Methodological issues

A simple Tier 1 approach was adopted using estimated amounts of urea applied and IPCC (2006) default emission factors.

### 5.9.2.1. Emission factor

No country-specific emission factors are available. Consequently, the IPCC (2006) 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 (2023). Two positions of the customs tariff list were considered, namely “urea” (tariff number 3102.1000.011) and “urea-ammonia-nitrate” (tariff number 3102.8000.011). 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 Federal Office for Customs and Border Security (FOCBS).

### 5.9.3. Uncertainties and time-series consistency for 3H

An uncertainty of  $\pm 5\%$  for the activity data was estimated according to ART (2008a). An uncertainty of  $\pm 5\%$  was assumed for the emission factor since it is a simple chemical process (see input uncertainty values in Annex A2.1). The resulting, combined uncertainty for emissions according to approach 1 (uncertainty propagation) is reported in Annex A2.2 and in Annex A2.3 for approach 2 (Monte Carlo simulations). The combined approach 1 uncertainty is  $\pm 7\%$ , in concordance with approach 2.

Consistency: Time series for 3H Urea application are all considered consistent.

### 5.9.4. Category-specific QA/QC and verification for 3H

General QA/QC measures are described in NID chp. 1.5. No category-specific QA/QC activities were undertaken.

### 5.9.5. Category-specific recalculations for 3H

General information on recalculations is provided in chp. 10.

There were no recalculations implemented in submission 2025.

### 5.9.6. Category-specific planned improvements for 3H

No category-specific improvements are planned.

## 6. Land use, land-use change and forestry (LULUCF)

Responsibilities for sector Land use, land-use change and forestry (LULUCF)	
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### 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). Data acquisition and calculations are based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and their 2019 Refinement (IPCC 2006, 2019, Volume 4 "Agriculture, Forestry and Other Land Use" (AFOLU)).

In 1979, the Swiss Land Use Statistics AREA was launched. Aerial photos from the periods 1979–1985, 1990–1998, 2004–2009, 2012–2019 and 2020 were evaluated by the Federal Statistical Office. AREA produces geographically explicit land use data with a resolution of one hectare (following approach 3 for representing land areas; IPCC 2006). Since 2022, results of the fifth survey are available. The repeated assessment of land use allows for a harmonised tracking of land use and land-use change across the entire national territory over the inventory period.

The six main land-use categories required by IPCC (2006, 2019) are: 4A Forest land, 4B Cropland, 4C Grassland, 4D Wetlands, 4E Settlements and 4F Other land. These were subdivided into 17 land-use categories, which form the basis for LULUCF reporting. The land-use categories are usually referred to in this document together with their combination category (CC) code. Following the guidelines, lands in each land-use category were stratified by mineral and organic soil. Due to the mountainous topography of Switzerland, Forest land, Cropland and permanent grassland were further stratified by three elevation zones. For Forest land, an additional stratification based on the five production regions of the National Forest Inventory (NFI) was used. The sector LULUCF includes emissions and removals from the carbon pool in category 4G Harvested wood products (HWP).

For Forest land, country-specific carbon stocks and carbon stock change factors were derived from five National Forest Inventories (the completed NFI1, NFI2, NFI3, NFI4 and the ongoing NFI5). The inventories comprised ca. 3'400 (NFI5), 6'000 (NFI2, NFI3, NFI4) and 11'000 (NFI1) terrestrial plots, where biomass stock, gross growth, and cut and mortality were measured. The carbon dynamics in dead wood, litter and mineral soil were simulated with the model Yasso20. For Cropland and permanent grassland, a modelling approach using RothC formed the basis for reporting carbon fluxes in mineral soils. Living biomass on these two land-use categories was calculated using an allometric equation.

For the remaining land-use categories and carbon pools, carbon stocks and carbon stock change factors were derived from domestic surveys, particular research activities, measurements and expert estimates. Partially, above all for non-CO<sub>2</sub> emission factors, IPCC (2006, 2019) default values were used (see CRT Summary3).

In the latest submission, a geo-referenced approach was implemented for calculating LULUCF associated carbon stock changes based on the hectare grid of the AREA survey. This improvement also makes it possible to map GHG emissions and removals. Figure 6-2 shows an example of a comparison between the base year and the latest reporting year.

Please note: LULUCF information in the reporting tables is partly affected by current CRT reporter's shortcomings, see Annex 7.

## 6.1.2. Emissions and removals

### 6.1.2.1. CO<sub>2</sub> emissions and removals

Over the inventory period, total net emissions and removals of CO<sub>2</sub> varied between -7'541 kt (1996) and 3'869 kt (2000). Table 6-1 and Figure 6-1 show a breakdown of Switzerland's CO<sub>2</sub> balance in the LULUCF sector. Five components were differentiated:

- Carbon gains in living biomass on all land uses and due to land-use changes; this component acts as the largest sink of carbon.
- Carbon losses in living biomass on all land uses and due to land-use changes; this component acts as 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 on Land converted to or from Forest land. This component acted as a sink of carbon in most years.
- Net carbon stock changes in organic and mineral soils due to land use and land-use changes. In most years, 21 over the inventory period to be precise, soils were net emitters of CO<sub>2</sub>. As with DOM, the net fluxes are small compared to those of carbon gains and losses in living biomass.
- Net carbon stock changes in Harvested wood products. Except for the years 2013, 2016, 2019 and 2023 this component acted as a sink of carbon, i.e. the overall carbon stock stored in wood products was increasing.

The largest part of carbon gains and carbon losses in living biomass occurred in forests, where gross growth of biomass (carbon gains) exceeded cut and mortality (carbon losses), except for the year 2000. Overall, the LULUCF sector acted as a net sink of on average -2'253 kt CO<sub>2</sub> yr<sup>-1</sup> over the inventory period, but as a net source in the years 2000, 2015, 2018 and 2023 (Table 6-1; Figure 6-4 shows the time series for CO<sub>2</sub> eq).



Table 6-1 CO<sub>2</sub> emissions and removals in the LULUCF sector broken down by (1) CO<sub>2</sub> removals due to carbon gains in living biomass, (2) CO<sub>2</sub> emissions due to carbon losses in living biomass, (3) net CO<sub>2</sub> changes in dead organic matter, (4) net CO<sub>2</sub> changes in organic and mineral soils, and (5) net CO<sub>2</sub> changes in Harvested wood products. Mean indicates the mean value 1990 to 2023. Positive values refer to net emissions; negative values refer to net removals.

LULUCF	Unit	1990	1995	2000	2005	2010
Gains in living biomass	kt CO <sub>2</sub>	-13'089	-13'405	-13'549	-12'767	-13'307
Losses in living biomass	kt CO <sub>2</sub>	11'876	9'687	17'936	12'087	12'671
Net change in dead organic matter	kt CO <sub>2</sub>	185	-433	-403	-1'505	-1'574
Net change in organic and mineral soils	kt CO <sub>2</sub>	-573	349	589	351	290
LULUCF (excluding HWP)	kt CO <sub>2</sub>	-1601	-3803	4574	-1833	-1920
Net change in Harvested wood products (HWP)	kt CO <sub>2</sub>	-1'149	-436	-705	-620	-347
Total LULUCF	kt CO <sub>2</sub>	-2750	-4239	3869	-2453	-2267

LULUCF	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Mean
Gains in living biomass	kt CO <sub>2</sub>	-16'314	-13'395	-14'720	-14'513	-12'996	-14'761	-13'255	-12'971	-13'597	-13'012	-13'479
Losses in living biomass	kt CO <sub>2</sub>	11'539	13'992	10'874	11'768	14'579	11'804	12'163	13'828	12'825	12'854	11'891
Net change in dead organic matter	kt CO <sub>2</sub>	181	134	-86	-13	-432.0	-728	-985	-1'576	-889	1'144	-479
Net change in organic and mineral soils	kt CO <sub>2</sub>	601	424	662	895	-8	432	821	417	214	212	110
LULUCF (excluding HWP)	kt CO <sub>2</sub>	-3994	1155	-3270	-1862	1144	-3252	-1256	-301	-1447	1198	-1957
Net change in Harvested wood products (HWP)	kt CO <sub>2</sub>	-59	-37	1	-18	-80.3	51	-22	-145	-46	42	-297
Total LULUCF	kt CO <sub>2</sub>	-4'053	1118	-3269	-1881	1063	-3200	-1278	-447	-1493	1240	-2253

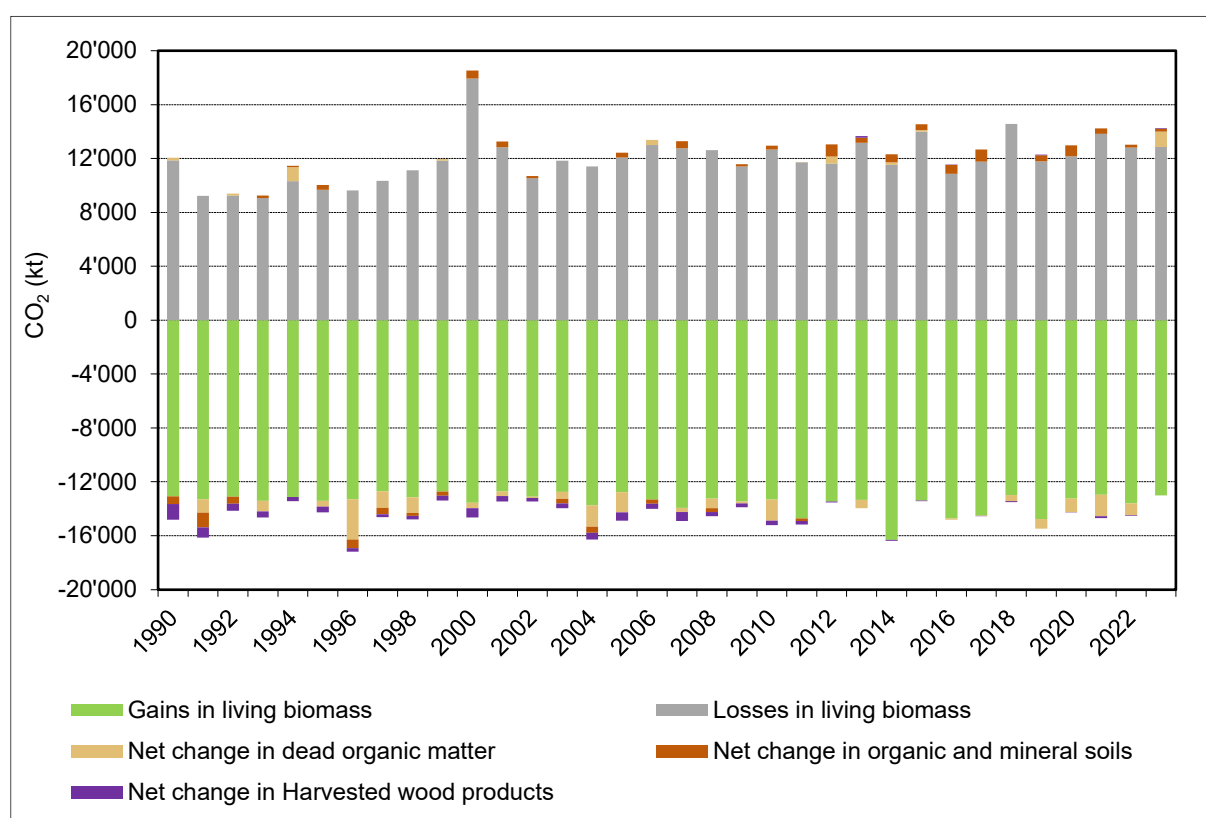


Figure 6-1 CO<sub>2</sub> emissions and removals in the LULUCF sector (in kt CO<sub>2</sub>) broken down by (1) carbon gains in living biomass, (2) carbon losses in living biomass, (3) net changes in dead organic matter, (4) net changes in organic and mineral soils, and (5) net changes in Harvested wood products. Positive values refer to net emissions, negative values refer to net removals.

Excluding the category 4G Harvested wood products, the LULUCF total was -1'601 kt CO<sub>2</sub> in the base year 1990 and 1'198 kt CO<sub>2</sub> in the latest reporting year (Table 6-1). Figure 6-2 shows the associated net emissions and removals for both years in a spatially explicit way.

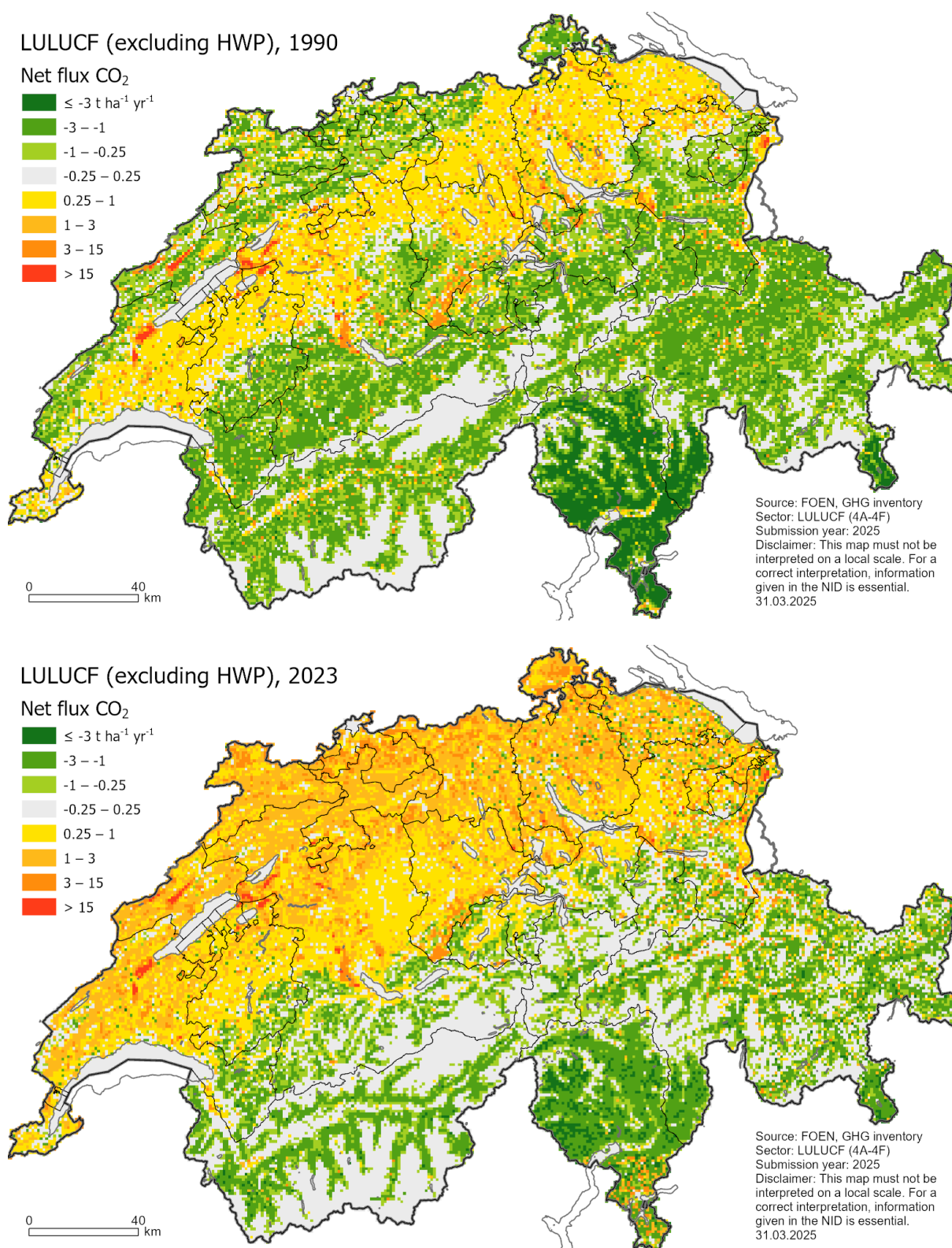


Figure 6-2 Map of net CO<sub>2</sub> emissions and removals in the LULUCF sector (excluding category 4G HWP) in Switzerland in 1990 (top panel) and in 2023 (bottom panel), aggregated to a 1x1 km<sup>2</sup> raster. Positive values refer to net emissions, negative values refer to net removals.

### 6.1.2.2. Non-CO<sub>2</sub> emissions

The non-CO<sub>2</sub> emissions associated with land use, land-use change and forestry were small. Maximum annual CH<sub>4</sub> emissions were 1.40 kt yr<sup>-1</sup> (39 kt CO<sub>2</sub> eq; 1997), and maximum annual N<sub>2</sub>O emissions were 0.20 kt yr<sup>-1</sup> (53 kt CO<sub>2</sub> eq; 1997) (Figure 6-3). The emissions arose from (1) drained organic soil (N<sub>2</sub>O; CRT Table4(II)), (2) flooded lands/reservoirs (CH<sub>4</sub>; CRT Table4(II)), (3) nitrogen mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils (direct and indirect N<sub>2</sub>O emissions; CRT Table4(III)), (4) wildfires on Forest land and Grassland (CH<sub>4</sub> and N<sub>2</sub>O; CRT Table4(IV)), and (5) controlled burning of residues from forestry (CH<sub>4</sub> and N<sub>2</sub>O; CRT Table4(IV)).

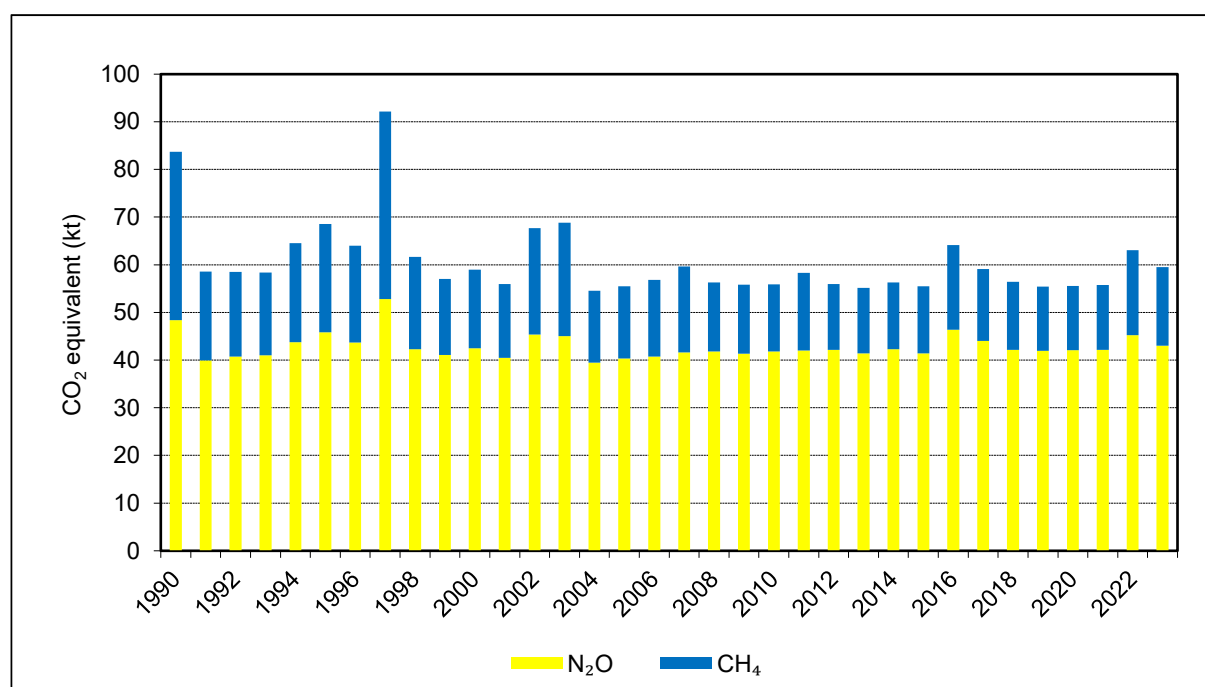


Figure 6-3 N<sub>2</sub>O and CH<sub>4</sub> emissions in the LULUCF sector (in kt CO<sub>2</sub> eq).

### 6.1.2.3. GHG emissions and removals

Figure 6-4 shows the resulting net GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) emissions and removals in the LULUCF sector over the inventory period broken down by categories 4A–4G. GHG fluxes were dominated by biomass dynamics in forests (4A). Further explanatory notes on LULUCF trends can be found in chp. 2.2.2.3 “Emission and removal trends in sector 4 LULUCF”.

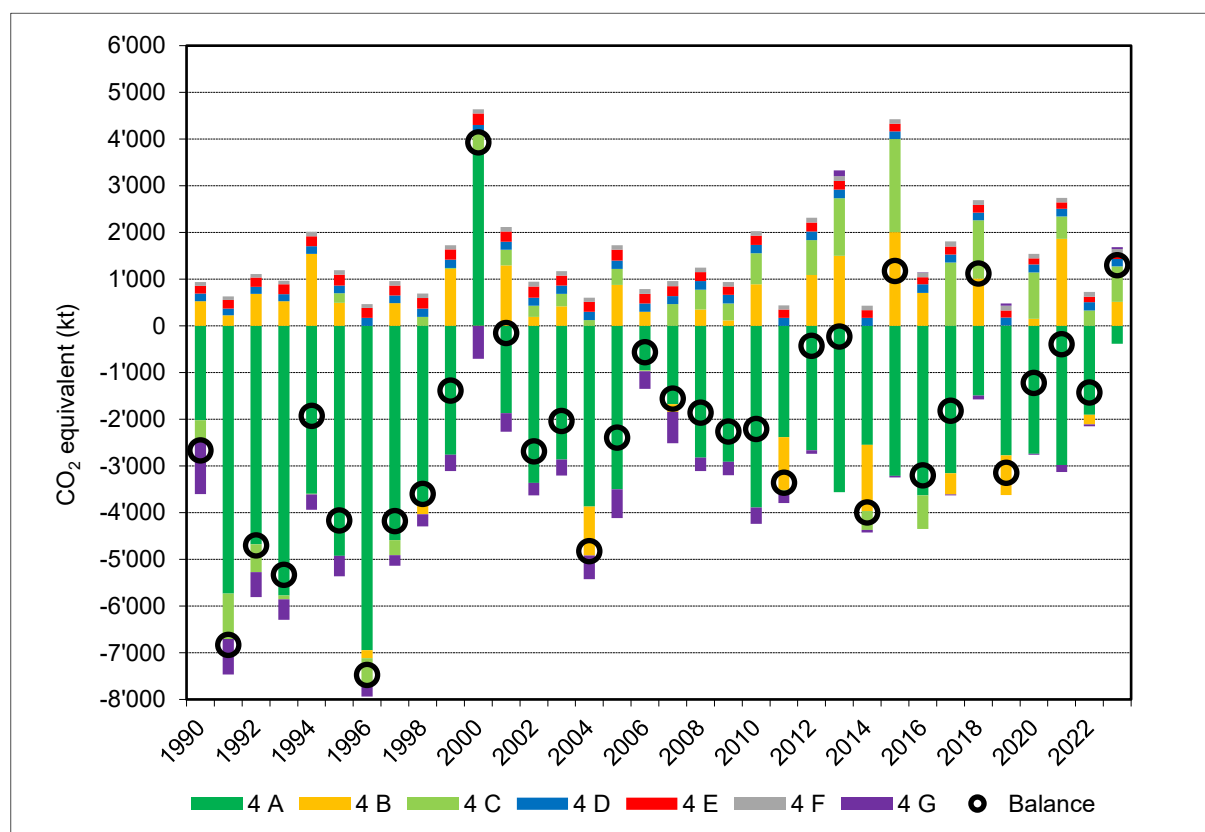


Figure 6-4 Stacked net GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) emissions and removals in the LULUCF sector (in kt CO<sub>2</sub> eq) broken down by categories 4A–4G. Balance indicates the annual net total. Positive values refer to net emissions, negative values refer to net removals. Figure 2-8 shows a simplified and Figure 2-9 an unstacked representation of the data set.

### 6.1.3. Approach for calculating carbon emissions and removals

#### 6.1.3.1. Work steps

The procedure for calculating carbon emissions and removals in the LULUCF sector in a geo-referenced way on the hectare grid of the Swiss Land Use Statistics AREA corresponds to a Tier 2 approach as described in IPCC 2006 (Volume 4, chp. 3). The geo-referenced approach is documented in a technical report (FOEN 2025g) and a manual (FOEN 2025h). 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 (see Table 6-2) is unmanaged. It is defined as the residual country's land area without relevant human activity.
- Define land-use categories in categories 4A–4F with respect to available land use data (see Table 6-2). Land-use categories were introduced as combination categories (CC), defined on the basis of the AREA land-use and land-cover categories (chp. 6.2.1 and Table 6-6).
- Define criteria and collect data for the spatial stratification of the land-use categories (chp. 6.2.2).
- Derive carbon stocks in living biomass (stockC<sub>l</sub>), dead wood (stockC<sub>d</sub>), litter (stockC<sub>h</sub>), and soil (stockC<sub>s</sub>) for each land-use category per spatial stratum. Define the year or years for which the carbon stocks are applied. (For Forest land see chp. 6.4.2.2. and chp. 6.4.2.3, Cropland: chp. 6.5.2.1, Grassland: chp. 6.6.2.1, Wetlands: chp. 6.7.2.1, Settlements: chp. 6.8.2.1, Other land: chp. 6.9.2).

- Derive carbon gains in living biomass ( $\text{gainC}_l$ ), carbon losses in living biomass ( $\text{lossC}_l$ ), net carbon stock change in dead wood ( $\text{changeC}_d$ ), litter ( $\text{changeC}_h$ ), and soil ( $\text{changeC}_s$ ) for each land-use category per spatial stratum. Do this on an annualised basis wherever possible. (For Forest land see chp. 6.4.2.2. and chp. 6.4.2.3, Cropland: chp. 6.5.2.2, Grassland: chp. 6.6.2.2, Wetlands: chp. 6.7.2.2, Settlements: chp. 6.8.2.2, Other land: chp. 6.9.2.).
- Determine the development of land use (in terms of combination categories CC) for each cell of the hectare raster over the inventory period. This is done by interpolation between the AREA surveys and extrapolation into the time before the first recorded and after the last available aerial photographs (chp. 6.2.3 and chp. 6.3.1). Backward extrapolation to 1971 produces land-use changes prior to 1990 (which are necessary when using a conversion time of 20 years).
- Calculate net carbon stock changes in living biomass ( $\text{deltaC}_l$ ), dead wood ( $\text{deltaC}_d$ ), litter ( $\text{deltaC}_h$ ), and soil ( $\text{deltaC}_s$ ) for all cells of the hectare raster (i.e. total Swiss land area) for each year under consideration. Choose a procedure so that the temporal development of each carbon pool in a cell is based on the stocks of the previous year. For raster cells without land-use change or with a land-use change after 2009, set 1990 as the starting year; for raster cells with a land-use change between 1990 and 2009, set the starting year up to 20 years earlier, depending on the conversion time. Assume that the initial carbon stocks (before a possible land-use change) 1971–1989 are those of 1990.
- Finally, for each year under consideration aggregate the results by summarising the carbon stock changes over all hectare raster cells according to the level of disaggregation displayed in the reporting tables. For non-Forest land, changes in dead wood ( $\text{changeC}_d$ ) and litter ( $\text{changeC}_h$ ) are summed up to changes in dead organic matter ( $\text{deltaC}_{\text{dom}}$ ).
- Calculate CO<sub>2</sub> emissions and removals of the carbon pool in category 4G Harvested wood products (HWP) (chp. 6.10).

Table 6-2 Six main land-use categories (according to IPCC 2006) and 17 land-use categories used for LULUCF reporting. Additionally, descriptive remarks, abbreviations used in the reporting tables, and combination categories codes are given (CC code; see chp. 6.2.1 and Table 6-6).

Main category	Land-use category	Remarks	Terminology in CRT tables	CC code
A. Forest land	productive forest	dense and open forest meeting the criteria of forest land		12
	unproductive forest	brush forest and forest on unproductive areas meeting the criteria of forest land		13
B. Cropland	cropland	arable and tillage land (annual crops and leys in arable rotations)		21
C. Grassland	permanent grassland	meadows, pastures (low-land and alpine)		31
	shrub vegetation	agricultural and unproductive areas predominantly covered by shrubs	4C2: woody	32
	vineyard, low-stem orchard, tree nursery	perennial agricultural plants with woody biomass and grass understorey	4C2: woody	33
	copse	agricultural and unproductive areas covered by perennial woody biomass including trees, with grass understorey	4C2: woody	34
	orchard	permanent grassland with fruit trees and grass understorey	4C2: woody	35
	stony grassland	grass, herbs and shrubs on stony surfaces	4C2: unproductive	36
	unproductive grassland	unproductive grass vegetation	4C2: unproductive	37
D. Wetlands	surface water	lakes and rivers		41
	unproductive wetland	reed, extensively managed 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	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 data (mean values per hectare) are required for each year of the inventory period. By default, they are quantified at the level of spatial strata for all land-use categories (CC). In the geo-referenced approach, there is the possibility to quantify input data at the level of individual raster cells (not yet implemented in the latest submission). Thus, the index  $i$  in the following definitions can either refer to a spatial stratum or to a raster cell, depending on the spatial resolution of the input data:

$\text{stockC}_{l,i,CC}$	carbon stock in living biomass ( $\text{t C ha}^{-1}$ )
$\text{stockC}_{d,i,CC}$	carbon stock in dead wood ( $\text{t C ha}^{-1}$ )
$\text{stockC}_{h,i,CC}$	carbon stock litter (organic soil horizons) ( $\text{t C ha}^{-1}$ )
$\text{stockC}_{s,i,CC}$	carbon stock in soil ( $\text{t C ha}^{-1}$ ), given for mineral soil $\text{stockC}_{s\_m,i,CC}$ or organic soil $\text{stockC}_{s\_o,i,CC}$
$\text{gainC}_{l,i,CC}$	annual carbon gain in living biomass ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ )
$\text{lossC}_{l,i,CC}$	annual carbon loss in living biomass ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ )
$\text{changeC}_{d,i,CC}$	annual net carbon stock change in dead wood ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ )
$\text{changeC}_{h,i,CC}$	annual net carbon stock change in litter ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ )
$\text{changeC}_{s,i,CC}$	annual net carbon stock change in soil ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ ), given for mineral soil $\text{changeC}_{s\_m,i,CC}$ or organic soil $\text{changeC}_{s\_o,i,CC}$

In the reporting tables on non-Forest land (Table 4.B to Table 4.F), the carbon stocks and carbon stock changes of dead wood and litter are merged into dead organic matter (DOM):

$$\text{stockC}_{\text{dom},i,CC} = \text{stockC}_{d,i,CC} + \text{stockC}_{h,i,CC}$$

$$\text{changeC}_{\text{dom},i,CC} = \text{changeC}_{d,i,CC} + \text{changeC}_{h,i,CC}$$

The input data were spatially assigned to the raster cells. Based on this dataset and by adding the activity data, annual changes in carbon stocks ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ ) in living biomass ( $\Delta C_l$ ), dead wood ( $\Delta C_d$ ), litter ( $\Delta C_h$ ), and soils ( $\Delta C_s$ ) were calculated for each cell of the nationwide hectare raster, starting with the year 1990. To do this, it was first determined whether or not a land-use change had occurred on a raster cell in the current year or in the preceding 1–20 years (depending on the conversion time applied to the carbon pool under consideration). The applicable calculation approach was then selected from Table 6-3. In this way, a consistent time series since 1990 is created for each carbon pool in each raster cell across Switzerland.

Equations 6.1–6.8 show, according to the IPCC Guidelines (IPCC 2006, Volume 4), the two common 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 for calculating (net) carbon stock changes for a raster cell is defined as:



$$\text{deltaC}_{l,rc,ba} = ( \text{gainC}_{l,i,a} - \text{lossC}_{l,i,a} ) * A_{rc} \quad (6.1)$$

$$\text{deltaC}_{d,rc,ba} = \text{changeC}_{d,i,a} * A_{rc} \quad (6.2)$$

$$\text{deltaC}_{h,rc,ba} = \text{changeC}_{h,i,a} * A_{rc} \quad (6.3)$$

$$\text{deltaC}_{s,rc,ba} = \text{changeC}_{s,i,a} * A_{rc} \quad (6.4)$$

The stock-difference approach for calculating carbon stock changes is defined as:

$$\text{deltaC}_{l,rc,ba} = [ ( \text{stockC}_{l,i,a} - \text{stockC}_{l,i,b} ) / \text{CT} ] * A_{rc} \quad (6.5)$$

$$\text{deltaC}_{d,rc,ba} = [ ( \text{stockC}_{d,i,a} - \text{stockC}_{d,i,b} ) / \text{CT} ] * A_{rc} \quad (6.6)$$

$$\text{deltaC}_{h,rc,ba} = [ ( \text{stockC}_{h,i,a} - \text{stockC}_{h,i,b} ) / \text{CT} ] * A_{rc} \quad (6.7)$$

$$\text{deltaC}_{s,rc,ba} = [ ( \text{stockC}_{s,i,a} - \text{stockC}_{s,i,b} ) / \text{CT} ] * A_{rc} \quad (6.8)$$

The change in dead organic matter (DOM) is the sum of the changes in dead wood and litter:

$$\text{deltaC}_{\text{dom},rc,ba} = \text{deltaC}_{d,rc,ba} + \text{deltaC}_{h,rc,ba} \quad (6.9)$$

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	index referring either to a spatial stratum or to a raster cell
rc	individual raster cell
$A_{rc}$	area of a raster cell (equals to one hectare)
CT	conversion time (yr), see chp. 6.1.3.3.

Remarks:

- The result of the gain-loss approach does neither depend on former land use nor on carbon stocks.
- The stock-difference approach (equations 6.5–6.8) is only applied, if a land-use change has occurred within the preceding 1–20 years (depending on the conversion time applied to the carbon pool under consideration).
- The stock-difference approach is shown in its generic form. In the geo-referenced approach,  $\text{stockC}_{i,b}$  is related to the carbon stock of the raster cell in the previous year. For the calculation, this means that as the conversion time elapses, the parameter CT in the formulas must be adjusted (FOEN 2025g).

Table 6-3 defines the calculation approaches. The gain-loss approach was used in cases of no change in land use 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).

Conversions between both forest land-use categories were dealt with as follows: For CC12 to CC13 the stock-difference approach and for CC13 to CC12 the gain-loss approach was used, respectively (see Table 6-3).

In case of a land-use change to "Buildings and constructions" (CC51) a loss of 20 % of the initial soil carbon stock was reported (for a detailed documentation see chp. 6.8.2.2.3). In case of land-use changes from CC51 to other categories the regular stock-difference approach according to equation 6.8 and Table 6-3, respectively, were applied.

Table 6-3 Calculation approaches (gain-loss or stock-difference with conversion time in years) applied for different land-use changes and carbon pools. Combination category codes CC12–CC61 were introduced in Table 6-2.

Change in land-use category	Living biomass	Dead wood, litter (dead organic matter)	Mineral soil	Organic soil	Remarks
no change in category	gain-loss	gain-loss	gain-loss	gain-loss	
4A1: CC13 to CC12	gain-loss	stock-diff., 20	stock-diff., 20	gain-loss	forest land internal changes
4A1: CC12 to CC13	stock-diff., 20	stock-diff., 20	stock-diff., 20	gain-loss	forest land internal changes
4A2: change to CC12-13	gain-loss	stock-diff., 20	stock-diff., 20	gain-loss	change to forest land
4B2: change to CC21	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	change to cropland
4C1: change among CC31-37	stock-diff., 1	stock-diff., 1	stock-diff., 1	gain-loss	grassland internal changes
4C2: change to CC31, CC36, CC37	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	change to permanent and unproductive grassland categories
4C2: change to CC32-35	stock-diff., 20	stock-diff., 1	stock-diff., 20	gain-loss	change to woody grassland categories
4D1: change among CC41-42	stock-diff., 1	stock-diff., 1	stock-diff., 1	gain-loss	wetlands internal changes
4D2: change to CC41	stock-diff., 1	stock-diff., 1	stock-diff., 1	gain-loss	change to surface water
4D2: change to CC42	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	change to unproductive wetland
4E1: change among CC51-54	stock-diff., 1	stock-diff., 1	stock-diff., 1	gain-loss	settlements internal changes
4E2: change to CC51	stock-diff., 1	stock-diff., 1	stock-diff., 20 (20%)	stock-diff., 20 (20%)	change to sealed settlement areas; soil carbon stock reduced by 20%
4E2: change to CC52-54	stock-diff., 1	stock-diff., 1	stock-diff., 20	gain-loss	change to unsealed settlement areas
4F2: change to CC61	stock-diff., 1	stock-diff., 1	stock-diff., 20	stock-diff., 20	change to other land

### 6.1.3.3. Conversion time 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, dead organic matter (dead wood, litter), and soil 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 do not occur in one year but are distributed evenly over the 20 years following the land-use change.

A conversion time of 20 years was applied to all mineral soil carbon stock changes except for land converted to surface water and for internal changes in Grassland, Wetlands and Settlements. 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.

### 6.1.3.4. Displaying results in the Common Reporting Tables (CRT)

In the reporting tables CRT Table4.A to CRT Table4.F, a part of the land-use categories and associated spatial strata are shown at an aggregated level. The raster-based values of  $\Delta C_{rc}$  were summarised accordingly. Positive values of  $\Delta C_{l,rc,ba}$  were inserted in the column "Gains" and negative values in the column "Losses", respectively. The values of  $\Delta C_{d,rc,ba}$  and  $\Delta C_{h,rc,ba}$  were inserted into columns "Net carbon stock change in dead wood" and "Net carbon stock change in litter" in CRT Table4.A, and the values of  $\Delta C_{dom,rc,ba}$  were inserted into columns "Net carbon stock change in dead organic matter" in the reporting tables CRT Table4.B to CRT Table4.F. The values of  $\Delta C_{s\_m,rc,ba}$  and  $\Delta C_{s\_o,rc,ba}$  were inserted into the corresponding columns under "Net carbon stock change in soils" in the reporting tables CRT Table4.A to CRT Table4.F.

The reporting tables Table4.A 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 land use 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) is reported in CRT Table4.C1 in the subdivision "Permanent grassland". As CC31 and CC32 do have different carbon stocks in biomass and soils, carbon stock changes are calculated according to the equations presented in chp. 6.1.3.2.

Please note: LULUCF information in the reporting tables is partly affected by current CRT reporter's shortcomings, see Annex 7.

### 6.1.4. Overview: Carbon stocks and carbon stock changes in the individual land-use categories

Table 6-4 presents carbon stocks, carbon gains, carbon losses and net changes in carbon stocks for the pools living biomass, dead wood, litter, and mineral and organic soil stratified by land-use category and spatial strata for the year 1990. For non-Forest land, dead wood and litter were merged and shown as dead organic matter. These data were used to calculate the net CO<sub>2</sub> emissions and removals presented in the reporting tables according to the methods introduced in chp. 6.1.3.

The values shown in Table 6-4 remain constant during the inventory period with the following exceptions (highlighted cells):

- Productive forest (CC12): (1) Carbon stocks in living biomass, carbon gains and carbon losses in living biomass, (2) carbon stocks and net carbon stock changes in dead wood, (3) carbon stocks and net carbon stock changes in litter, and (4) net carbon stock changes in mineral soil. Derivation of data and annual values are described in chp. 6.4.2.2.
- Cropland (CC21): (1) Carbon stocks in living biomass, carbon gains and carbon losses in living biomass, (2) carbon stocks and net carbon stock changes in mineral soil. Derivation of data and annual values are described in chp. 6.5.2.
- Permanent grassland (CC31): (1) Carbon stocks in living biomass, carbon gains and carbon losses in living biomass, (2) carbon stocks and net carbon stock changes in mineral soil. Derivation of data and annual values are described in chp. 6.6.2.

The derivation of the individual carbon stocks, carbon gains, carbon losses, and net carbon stock changes is explained in detail in chapters 6.4 to 6.9.

With regard to the columns "Carbon stock in" in Table 6-4, the entry "0" indicates the absence of biomass or soil organic carbon in the corresponding carbon pool.

With regard to the columns "Carbon gains in living biomass", "Carbon losses in living biomass", and "Net change in", the following applies:

- Positive values refer to gains, negative values refer to losses in the respective carbon pool.
- The notation key NA indicates a Tier 1 approach, where the carbon pool is assumed to be in equilibrium (in accordance with the conclusions and recommendations from the 16<sup>th</sup> meeting of the GHG inventory Lead Reviewers, Bonn, March 2019). When using the formulas in chp. 6.1.3.2, this entry is transferred into the numerical value 0.
- The notation key NO indicates that the process did not exist in 1990. When using the formulas from in chp. 6.1.3.2, this entry is transferred into the numerical value 0.
- For Forest land, the net change of carbon stocks in drained organic soil is -2.6 t C ha<sup>-1</sup> yr<sup>-1</sup>. 3 % of the area of organic soil is estimated to be drained (see chp. 6.4.2.2.2.9), which leads to a correspondingly smaller implied carbon stock change factor of -0.08 t C ha<sup>-1</sup> yr<sup>-1</sup> in CRT Table4.A. In contrast, organic soil on non-Forest land is assumed to have 100 % drainage with the land-use category surface waters (CC41) as the only exception (see chp. 6.7.2.2.2).

Table 6-4 Carbon stocks and carbon stock changes in living biomass, dead wood, litter, mineral and organic soil for land-use categories, stratified by elevation zone, NFI production region, and soil type. For non-Forest land, dead organic matter is shown. The values apply to the whole inventory period except in the highlighted cells, where the values change annually (the figures shown are for 1990); see main text. Carbon stocks are used for the stock-difference calculation approach, whereas data on carbon stock changes apply where the gain-loss calculation approach is used (see Table 6-3 and equations 6.1–6.8 in chp. 6.1.3.2).

CC code, land-use category	NFI region	Elevation zone	Carbon stock in living biomass (stockC <sub>l,i</sub> )	Carbon stock in dead wood (stockC <sub>d,i</sub> )	Carbon stock in litter (stockC <sub>h,i</sub> )	Carbon stock in mineral soil (stockC <sub>s,i</sub> )	Carbon stock in organic soil (stockC <sub>s,i</sub> )	Carbon gains in living biomass (gainC <sub>l,i</sub> )	Carbon losses in living biomass (lossC <sub>l,i</sub> )	Net change in dead wood (changeC <sub>d,i</sub> )	Net change in litter (changeC <sub>h,i</sub> )	Net change in mineral soil (changeC <sub>s,i</sub> )	Net change in (drained) organic soil (changeC <sub>s,i</sub> )
	Strata		[t C ha <sup>-1</sup> ]					[t C ha <sup>-1</sup> yr <sup>-1</sup> ]					
12 Productive forest	L1	Z1	126.71	5.57	13.81	56.54	145.6	3.66	-2.71	-0.02	-0.22	0.01	-2.6
	L1	Z2	121.77	6.34	15.06	101.16	145.6	3.32	-2.76	-0.02	-0.17	0.01	-2.6
	L1	Z3	85.09	6.01	13.80	129.46	145.6	2.08	-1.70	-0.07	-0.29	0.00	-2.6
	L2	Z1	134.45	9.12	14.18	50.30	145.6	4.75	-4.72	-0.05	-0.25	0.01	-2.6
	L2	Z2	146.60	9.05	15.62	64.13	145.6	4.66	-4.48	-0.05	-0.23	0.01	-2.6
	L2	Z3	146.60	9.05	15.62	128.23	145.6	4.66	-4.48	-0.05	-0.23	0.01	-2.6
	L3	Z1	148.46	8.92	17.20	63.42	145.6	4.23	-3.58	0.02	-0.15	0.02	-2.6
	L3	Z2	148.46	8.92	17.20	80.18	145.6	4.23	-3.58	0.02	-0.15	0.02	-2.6
	L3	Z3	116.33	7.71	18.43	103.28	145.6	2.49	-2.56	-0.03	-0.12	0.02	-2.6
	L4	Z1	97.95	6.45	13.50	69.96	145.6	2.63	-2.14	0.04	-0.06	0.02	-2.6
	L4	Z2	97.95	6.45	13.50	77.51	145.6	2.63	-2.14	0.04	-0.06	0.02	-2.6
	L4	Z3	92.93	7.11	18.26	73.68	145.6	1.91	-1.94	0.08	0.07	0.02	-2.6
	L5	Z1	71.14	2.14	9.40	119.86	145.6	2.42	-1.00	0.05	0.09	0.02	-2.6
	L5	Z2	71.14	2.14	9.40	112.91	145.6	2.42	-1.00	0.05	0.09	0.02	-2.6
	L5	Z3	74.88	2.25	12.25	97.05	145.6	1.65	-0.61	0.01	0.13	0.01	-2.6
13 Unproductive forest	L1	Z1	38.53	0	12.10	57.08	145.6	NA	NA	NA	NA	NA	-2.6
	L1	Z2	51.10	0	12.92	106.91	145.6	NA	NA	NA	NA	NA	-2.6
	L1	Z3	51.34	0	10.57	123.61	145.6	NA	NA	NA	NA	NA	-2.6
	L2	Z1	20.45	0	12.07	52.49	145.6	NA	NA	NA	NA	NA	-2.6
	L2	Z2	35.83	0	13.01	65.35	145.6	NA	NA	NA	NA	NA	-2.6
	L2	Z3	51.33	0	13.01	125.59	145.6	NA	NA	NA	NA	NA	-2.6
	L3	Z1	20.45	0	14.62	61.82	145.6	NA	NA	NA	NA	NA	-2.6
	L3	Z2	47.53	0	14.62	80.81	145.6	NA	NA	NA	NA	NA	-2.6
	L3	Z3	42.36	0	13.55	103.24	145.6	NA	NA	NA	NA	NA	-2.6
	L4	Z1	21.60	0	12.02	70.90	145.6	NA	NA	NA	NA	NA	-2.6
	L4	Z2	31.48	0	12.02	77.52	145.6	NA	NA	NA	NA	NA	-2.6
	L4	Z3	29.88	0	14.86	82.29	145.6	NA	NA	NA	NA	NA	-2.6
	L5	Z1	20.83	0	8.74	100.90	145.6	NA	NA	NA	NA	NA	-2.6
	L5	Z2	23.82	0	11.45	99.71	145.6	NA	NA	NA	NA	NA	-2.6
	L5	Z3	24.35	0	12.53	102.48	145.6	NA	NA	NA	NA	NA	-2.6

<b>Legend</b>					
<i>Elevation zones:</i>			<i>NFI regions:</i>	n.s. = no stratification	
Z1	< 601 m		L1	Jura	Annual data
Z2	601 - 1200 m		L2	Central Plateau	
Z3	> 1200 m		L3	Pre-Alps	
			L4	Alps	
			L5	Southern Alps	

(Table 6-4 continued)

CC code, land-use category	NFI region	Elevation zone	Carbon stock in living biomass (stockCl,i)	Carbon stock in dead organic matter (DOM) (stockCd,i + stockCh,i)	Carbon stock in mineral soil (stockCs,i)	Carbon stock in organic soil (stockCs,i)	Carbon gains in living biomass (gainCl,i)	Carbon losses in living biomass (lossCl,i)	Net change in dead organic matter (DOM) (changeCd,i + changeCh,i)	Net change in mineral soil (changeCs,i)	Net change in (drained) organic soil (changeCs,i)
	Strata		[t C ha <sup>-1</sup> ]				[t C ha <sup>-1</sup> yr <sup>-1</sup> ]				
21 Cropland	n.s.	Z1	6.35	0	58.37	240	0.01	NO	NA	-0.08	-9.52
	n.s.	Z2	6.34	0	59.86	240	NO	-0.01	NA	-0.18	-9.52
	n.s.	Z3	6.05	0	51.95	240	0.12	NO	NA	0.05	-9.52
31 Permanent Grassland	n.s.	Z1	5.74	0	63.06	240	NO	-0.14	NA	-0.07	-9.52
	n.s.	Z2	5.27	0	58.95	240	NO	-0.12	NA	0.10	-9.52
	n.s.	Z3	3.34	0	46.21	240	0.01	NO	NA	0.62	-9.52
32 Shrub Vegetation	n.s.	Z1	20.45	0	55.5	240	NA	NA	NA	NA	-5.30
	n.s.	Z2	20.45	0	43.3	240	NA	NA	NA	NA	-5.30
	n.s.	Z3	20.45	0	36.7	240	NA	NA	NA	NA	-5.30
33 Vineyards et al.	n.s.	n.s.	5.5	0	50.8	240	NA	NA	NA	NA	-9.52
34 Copse	n.s.	Z1	20.45	0	62.6	240	NA	NA	NA	NA	-5.30
	n.s.	Z2	20.45	0	57.4	240	NA	NA	NA	NA	-5.30
	n.s.	Z3	20.45	0	37.6	240	NA	NA	NA	NA	-5.30
35 Orchards	n.s.	n.s.	23.1	0	62.9	240	NA	NA	NA	NA	-9.52
36 Stony Grassland	n.s.	n.s.	7.2	0	13.5	240	NA	NA	NA	NA	-5.30
37 Unproductive Grassland	n.s.	n.s.	3.5	0	37.5	240	NA	NA	NA	NA	-5.30
41 Surface Waters	n.s.	n.s.	0	0	0	240	NA	NA	NA	NA	0
42 Unproductive Wetland	n.s.	n.s.	6.5	0	56.9	240	NA	NA	NA	NA	-5.30
51 Buildings, Constructions	n.s.	n.s.	0	0	0	0	NA	NA	NA	NA	NA
52 Herbaceous Biomass in S.	n.s.	n.s.	9.54	0	57.2	240	NA	NA	NA	NA	-9.52
53 Shrubs in Settlements	n.s.	n.s.	15.43	0	52.0	240	NA	NA	NA	NA	-5.30
54 Trees in Settlements	n.s.	n.s.	20.72	0	56.5	240	NA	NA	NA	NA	-5.30
61 Other Land	n.s.	n.s.	0	0	0	0	NA	NA	NA	NA	NA

<b>Legend</b>			<i>Elevation zones:</i>	<i>NFI regions:</i>	n.s. = no stratification
	Z1	< 601 m		L1	Jura
	Z2	601 - 1200 m		L2	Central Plateau
	Z3	> 1200 m		L3	Pre-Alps
				L4	Alps
				L5	Southern Alps
					Annual data

### 6.1.5. Uncertainty estimates

Table 6-5 gives an overview of uncertainty estimates of activity data, carbon stock change factors (CO<sub>2</sub> emissions and removals in land-use categories 4A–4G), and emission factors (CH<sub>4</sub> and N<sub>2</sub>O emissions in 4(II)–4(IV)).

For categories 4A–4F, the uncertainties of activity data mainly depend on the uncertainty of the AREA survey data (see chp. 6.3.1.3.1 and Table 6-10). For categories 4D1, 4(II)–4(IV), and 4G other data sources are viewed as more relevant, e.g. for 4D1 the uncertainty of the area of organic soil. Details are presented in the chapters 6.4.3 to 6.10.3, along with the uncertainty estimates for carbon stock change factors and emission factors.

For categories 4B, 4C and 4D2, the uncertainties are given separately for the carbon pools living biomass (per gains and losses), dead organic matter, mineral soil and organic soil. The overall uncertainty is calculated as described in chp. 1.6.2.

In general, the uncertainty of activity data is lower than the uncertainty of carbon stock change factors and emission factors, because most activity data are based on a systematic survey with high spatial resolution (such as AREA), while carbon stock change factors and

emission factors include parameters that are difficult to measure or to model such as carbon stocks in biomass, growth rates and biogeochemical processes.

Possible very large relative uncertainties for carbon stock change factors in categories 4B and 4C are due to the calculation approach, in which absolute uncertainties (in t C ha<sup>-1</sup> yr<sup>-1</sup>) of the carbon stock changes in categories 4B1, 4B2, 4C1 and 4C2 were divided by the associated net carbon stock changes (chp. 6.5.3.1.2 and chp. 6.6.3.1.2).

For the N<sub>2</sub>O emission factors in category 4(III) (direct and indirect emissions), the uncertainty is modelled by an (asymmetrical) gamma distribution rather than by a normal distribution.

The detailed input parameters used for uncertainty computation, approaches 1 and 2, are documented in Annex A2.1. Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

Table 6-5 Uncertainty estimates expressed as half of the 95 % confidence intervals. Transcriptions used: CS-CH-LB Carbon gains: carbon gains in living biomass; CS-CH-LB Carbon losses: carbon losses in living biomass; Net CS-CH-S Carbon min soils: net carbon stock change in mineral soil; Net CS-CH-S Carbon org soils: net carbon stock change in organic soil; Net CS-CH-DOM Carbon: net carbon stock change in dead organic matter; 4(III)\*D/I: direct/indirect N<sub>2</sub>O emissions; std. dev: standard deviation; Corr.: correlated across years.

Code	Gas	Activity data uncertainty for a 95 %					Emission factor uncertainty for a 95 %				
		Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.	Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.
Year 2023											
4.A.1	CO2	normal	1.1	1.1	1.1	yes	normal	34.9	34.9	34.9	yes
4.A.2	CO2	normal	1.5	1.5	1.5	yes	normal	34.9	34.9	34.9	yes
4.B.1; CS-CH-LB Carbon gains	CO2	normal	4.9	0.0	0.0	yes	normal	13.0	0.0	0.0	yes
4.B.1; CS-CH-LB Carbon losses	CO2	normal	4.9	4.9	4.9	yes	normal	13.0	13.0	13.0	yes
4.B.1; Net CS-CH-S Carbon min soils	CO2	normal	4.9	4.9	4.9	yes	normal	135.9	135.9	135.9	no
4.B.1; Net CS-CH-S Carbon org soils	CO2	normal	37.3	37.3	37.3	yes	normal	23.0	23.0	23.0	yes
4.B.1; Net CS-CH-DOM Carbon	CO2	normal	4.9	0.0	0.0	yes	normal	0.5	0.0	0.0	yes
4.B.2; CS-CH-LB Carbon gains	CO2	normal	5.1	5.1	5.1	yes	normal	13.0	13.0	13.0	yes
4.B.2; CS-CH-LB Carbon losses	CO2	normal	5.1	5.1	5.1	yes	normal	13.0	13.0	13.0	yes
4.B.2; Net CS-CH-S Carbon min soils	CO2	normal	5.1	5.1	5.1	yes	normal	450.1	450.1	450.1	no
4.B.2; Net CS-CH-S Carbon org soils	CO2	normal	37.3	37.3	37.3	yes	normal	23.0	23.0	23.0	yes
4.B.2; Net CS-CH-DOM Carbon	CO2	normal	5.1	0.0	0.0	yes	normal	0.5	0.0	0.0	yes
4.C.1; CS-CH-LB Carbon gains	CO2	normal	5.2	5.2	5.2	yes	normal	13.0	13.0	13.0	yes
4.C.1; CS-CH-LB Carbon losses	CO2	normal	5.2	5.2	5.2	yes	normal	13.0	13.0	13.0	yes
4.C.1; Net CS-CH-S Carbon min soils	CO2	normal	5.2	5.2	5.2	yes	normal	1'108.0	1'108.0	1'108.0	no
4.C.1; Net CS-CH-S Carbon org soils	CO2	normal	68.6	68.6	68.6	yes	normal	23.0	23.0	23.0	yes
4.C.1; Net CS-CH-DOM Carbon	CO2	normal	5.2	0.0	0.0	yes	normal	0.5	0.0	0.0	yes
4.C.2; CS-CH-LB Carbon gains	CO2	normal	5.3	5.3	5.3	yes	normal	13.0	13.0	13.0	yes
4.C.2; CS-CH-LB Carbon losses	CO2	normal	5.3	5.3	5.3	yes	normal	13.0	13.0	13.0	yes
4.C.2; Net CS-CH-S Carbon min soils	CO2	normal	5.3	5.3	5.3	yes	normal	107.8	107.8	107.8	no
4.C.2; Net CS-CH-S Carbon org soils	CO2	normal	68.6	68.6	68.6	yes	normal	23.0	23.0	23.0	yes
4.C.2; Net CS-CH-DOM Carbon	CO2	normal	5.3	5.3	5.3	yes	normal	0.5	0.5	0.5	yes
4.D.1	CO2	normal	90.8	90.8	90.8	yes	normal	72.2	72.2	72.2	yes
4.D.2; CS-CH-LB Carbon gains	CO2	normal	3.7	3.7	3.7	yes	normal	13.0	13.0	13.0	yes
4.D.2; CS-CH-LB Carbon losses	CO2	normal	3.7	3.7	3.7	yes	normal	13.0	13.0	13.0	yes
4.D.2; Net CS-CH-S Carbon min soils	CO2	normal	3.7	3.7	3.7	yes	normal	50.0	50.0	50.0	yes
4.D.2; Net CS-CH-S Carbon org soils	CO2	normal	90.8	90.8	90.8	yes	normal	72.2	72.2	72.2	yes
4.D.2; Net CS-CH-DOM Carbon	CO2	normal	3.7	3.7	3.7	yes	normal	0.5	0.5	0.5	yes
4.E.1	CO2	normal	4.4	4.4	4.4	yes	normal	50.0	50.0	50.0	yes
4.E.2	CO2	normal	4.6	4.6	4.6	yes	normal	50.0	50.0	50.0	yes
4.F.2	CO2	normal	3.1	3.1	3.1	yes	normal	50.0	50.0	50.0	yes
4.G	CO2	normal	11.2	11.2	11.2	yes	normal	54.8	54.8	54.8	yes
4(II)	CH4	normal	10.0	10.0	10.0	yes	normal	70.0	70.0	70.0	yes
4(II)	N2O	normal	50.8	50.8	50.8	yes	normal	66.9	66.9	66.9	yes
4(III)*D	N2O	normal	83.5	83.5	83.5	yes	gamma	90.0	68.8	108.1	yes
4(III)*I	N2O	normal	85.8	85.8	85.8	yes	gamma	100.0	73.7	122.0	yes
4(IV)	CH4	normal	30.0	30.0	30.0	yes	normal	70.0	70.0	70.0	yes
4(IV)	N2O	normal	30.0	30.0	30.0	yes	normal	70.0	70.0	70.0	yes
Specific uncertainties for the year 1990											
4.B.1; Net CS-CH-S Carbon min soils	CO2	normal	4.9	4.9	4.9	yes	normal	237.8	237.8	237.8	no
4.B.2; Net CS-CH-S Carbon min soils	CO2	normal	5.1	5.1	5.1	yes	normal	156.1	156.1	156.1	no
4.C.1; Net CS-CH-S Carbon min soils	CO2	normal	5.2	5.2	5.2	yes	normal	86.0	86.0	86.0	no
4.C.2; Net CS-CH-S Carbon min soils	CO2	normal	5.3	5.3	5.3	yes	normal	103.3	103.3	103.3	no



## 6.2. Land-use definitions and classification systems

### 6.2.1. Combination Categories (CC) as derived from AREA Land Use Statistics

The standard nomenclature version 2004 (NOAS04; SFSO 2006a; FSO 2022i) of the Swiss Land Use Statistics (AREA) processed by the Federal Statistical Office is the basis for the selection of the land-use categories used for land area representation. In the course of an AREA survey (see chp. 6.3.1.1), every sample point on a hectare grid in Switzerland is assigned to a land-use category (NOLU04) and to a land-cover category (NOLC04). The interpretation is backed by a large set of geodata that can be superimposed if required (For just a public subset of geodata available to the FSO interpreters see the federal geoportal, e.g. topic FOEN: <https://s.geo.admin.ch/378b0vophaie>, topic swisstopo: <https://s.geo.admin.ch/9cecf4d9d6> or topic FOAG: <https://s.geo.admin.ch/b8hseagdw4a>). 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 also visited by the AREA staff to verify the on-screen classification of land use (ground control).

The AREA survey is an advanced and well-established land use statistic (see the links to visualization examples in chp. 6.3.1.4.3. It allows for the identification of country-specific categories that are more detailed than those defined in IPCC (2006) (see Table 6-2). The 46 NOLU04 categories and 27 NOLC04 categories were aggregated to 17 combination categories (CC), following the assignment shown in Table 6-6, and adopted as land-use categories for LULUCF reporting. The first digit of the CC code represents the IPCC (2006) main land-use category, whereas the second digit stands for the respective land-use category. The approach enables more accurate estimates for carbon stocks and carbon stock changes than on the basis of the IPCC (2006) main categories alone because each land-use category can be fed with individual carbon data and distinctive carbon dynamics can be assumed (see below).

The combination categories 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 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 stock 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 combination categories in Table 6-6. With regard to carbon stock changes in living biomass, dead organic matter, and soil the 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 living biomass, dead organic matter, and soil.

For individual combination categories further spatial stratifications were introduced (especially for Forest land, see chp. 6.2.2) with the intention to match the spatial variability of vegetation and soil conditions as closely as possible.

The underlying criteria to include land-use categories such as shrub vegetation, vineyards, low-stem orchards, tree nurseries, copse and orchards under Grassland with woody biomass are: (1) They do not fulfil the criteria for forests; (2) There is an agricultural management in general; (3) They all have woody biomass (i.e. perennial vegetation) with grass understory. Under Cropland, in contrast, there are no perennial crops, but annual crops and leys in arable rotations. All perennial crops are included in the Grassland land-use categories.

Table 6-6 Derivation of 17 combination categories (CC) from AREA NOLU04 and NOLC04 categories. They were adopted as land-use categories for LULUCF reporting.

Land Use (NOLU04) acc. to AREA		Combination Categories (CC)																
Land Cover (NOLC04) acc. to AREA	Combination Categories (CC)	Combination Categories (CC):																
		Combination Categories (CC):																
10 Artificial areas	Settlement and urban areas	Building areas																
		101 Industrial and commercial areas > 1 ha	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		102 Industrial and commercial areas < 1 ha	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		103 Residential areas (one and two-family houses)	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		104 Residential areas (terraced houses)	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		105 Residential areas (blocks of flats)	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		106 Public buildings and surroundings	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		107 Agricultural buildings and surroundings	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		108 Unspecified buildings and surroundings	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		121 Motorways	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
20 Grass and herb vegetation	Transport surfaces	122 Roads	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		123 Parking areas	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		124 Railway surface	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
	Special urban areas	125 Airports and airfields	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		141 Energy supply plants	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		142 Waste treatment plants	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		143 Other supply or waste treatment plants	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		144 Dumps	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		145 Quarries, mines	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		146 Construction sites	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		147 Unexploited urban areas	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		161 Public parks	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
30 Brush vegetation	Recreational areas and cemeteries	162 Sport facilities	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		163 Golf courses	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		164 Camping areas	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		165 Garden allotments	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
		166 Cemeteries	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
	Agricultural areas	201 Orchards	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		202 Vineyards	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		203 Horticulture	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		221 Arable land, in general	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		222 Semi-natural grassland, in general	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		223 Farm pastures, in general	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		241 Alpine meadows, in general	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		242 Alpine pastures, in general	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		243 Alpine sheep grazing pastures, in general	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		301 Forest	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
40 Tree vegetation	Forest (not used for agriculture)	302 Afforestation	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
		303 Lumbering areas	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
		304 Damaged forest	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	Unproductive areas	401 Lakes	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		402 Streams, rivers	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		403 Flood protection structures	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		421 Unused	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		422 Avalanche and rockfall protection structures	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		423 Alpine sports facilities	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		424 Landscape intervention	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
50 Bare land	Other land	61 Water	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		62 Glacier, perpetual snow	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		63 Wetlands	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		64 Reedy marshes	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
60 Watery areas	Other land	61 Water	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		62 Glacier, perpetual snow	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		63 Wetlands	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
		64 Reedy marshes	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
			61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61

All land-use categories of Forest land, Grassland and Wetlands are defined as managed and reported under managed land in CRT Table 4.1. 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 category 4F Other land – is reported to be managed.

## 6.2.2. Spatial stratification

### 6.2.2.1. Soil type

Most soils in Switzerland are mineral soil types. A digital map estimating the surface of organic soils in Switzerland was generated by Wüst-Galley et al. (2015) and updated by Wüst-Galley and Zehnder (2024) and Wüst-Galley and Leifeld (2025). 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. Two important spatially explicit and recent data sets are the Federal Inventory of Raised and Transition Bogs of National Importance and the Federal Inventory of Fens of National Importance (cf. <https://s.geo.admin.ch/tg32oazxx70z>). The total area of organic soils is 32.8 kha (0.79 % of the total area covered by soils; see Figure 6-5 and Table 6-7).

The definition of organic soil 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 soil 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; Wüst-Galley and Zehnder 2024; Wüst-Galley and Leifeld 2025). This definition was also used for the ground-truthing of forest habitat maps and fen inventories. It also formed the basis of the classification of soil types from soil maps, as organic or mineral (soil types 'Halbmoor' and 'Moor' were considered organic soils). Here however, two soil sub-types ("anmoorig" and "antorfig") could not be classified; the ranges of SOC values and peat depths characterising these sub-types overlap only partially with those SOC values and peat depths used to define organic soil (IPCC 2006), meaning they cannot be classified ambiguously as either mineral or organic soils. Also, because their distribution is poorly known, they were not explicitly considered in the estimate of organic soil (see Wüst-Galley et al. 2015: 14–15 and 61; Wüst-Galley and Leifeld 2025).

For the other data sets used in the construction of the organic soils map (geology maps, hydrogeology maps and habitat maps), no information on SOC is available, and the presence of peat was used as evidence of organic soil. The carbon content of peat meets the IPCC (2006) definition of organic soil.

Consistency: A single map of organic soil is applied to all years (1990 to present), meaning the classifications used are consistent through time. The same definition of organic soil was used across the whole country.

### 6.2.2.2. Elevation

For Forest land (CC12, CC13), Cropland (CC21) 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 6-5). Elevation data from the Federal Office of Topography

(swisstopo) on a 25x25 m raster (product DHM25) were used to map the three zones. The elevation zones are coded Z1, Z2 and Z3 in the reporting tables (with increasing elevation).

### 6.2.2.3. Forest production region

Forest land was differentiated into the five production regions of the National Forest Inventory (Brändli and Hägeli 2019: chp. 1.5.2; Figure 6-5, see also <https://s.geo.admin.ch/8d972b5708>). These are (in brackets the coding in the reporting tables):

Jura (L1), Central Plateau (L2), Pre-Alps (L3), Alps (L4) and Southern Alps (L5).

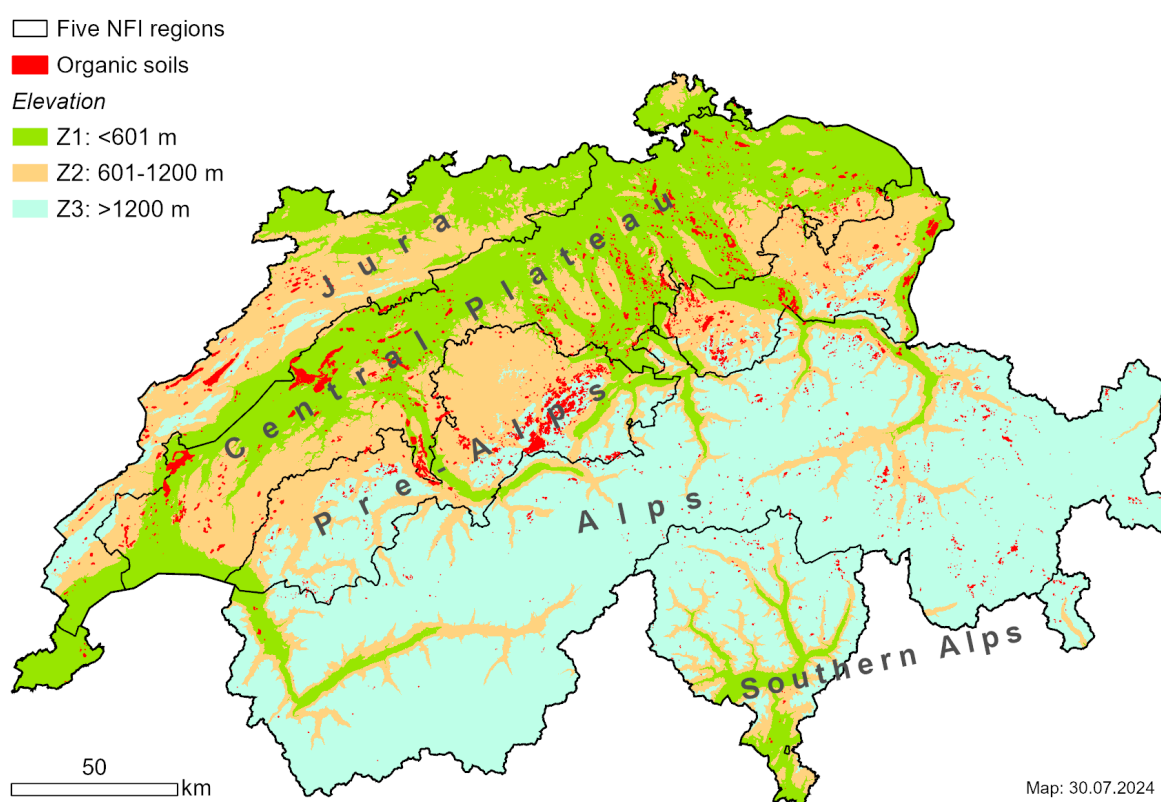


Figure 6-5 Map showing the spatial stratification according to NFI production region, elevation zone, and soil type.

### 6.2.2.4. Strata

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 are realised and applied for the calculation of CO<sub>2</sub> eq emissions and removals.

## 6.2.3. 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. 6.3.1.2) are exemplarily shown for the year 1990. The table gives also the area size of the individual spatial strata (column "Sum").

Table 6-7 Land use projection by the end of 1990 for land-use categories (shown by their CC codes), stratified separately for elevation (Z1-Z3), soil type (mineral or organic) and NFI production region (L1-L5), in kha, rounded values. The country's total area is 4'129'071 ha (FSO 2024).

CC	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
<b>Elevation</b>																		
Z1	225.9	6.2	299.6	154.0	2.6	22.5	32.3	1.2	0.5	2.9	138.6	5.2	116.5	47.7	2.8	18.6	2.0	1079.1
Z2	505.6	18.1	130.4	359.7	8.7	3.9	29.9	0.3	2.4	1.5	9.7	5.7	46.2	17.1	0.9	5.4	8.2	1153.9
Z3	379.2	80.0	0.4	425.4	144.3	0.0	27.2	0.0	148.8	61.9	13.2	14.3	11.3	3.7	0.2	1.0	585.1	1896.1
	1110.7	104.2	430.5	939.2	155.6	26.4	89.4	1.5	151.7	66.3	161.6	25.1	174.1	68.5	3.9	25.0	595.2	4129.1
<b>Soil</b>																		
mineral	1105.6	103.9	419.7	932.1	155.4	26.3	88.9	1.5	151.7	66.1	161.4	18.9	172.8	67.9	3.9	24.9	595.2	4096.3
organic	5.1	0.3	10.8	7.1	0.2	0.0	0.5	0.0	0.0	0.2	0.3	6.1	1.3	0.6	0.0	0.1	0.051	32.8
	1110.7	104.2	430.5	939.2	155.6	26.4	89.4	1.5	151.7	66.3	161.6	25.1	174.1	68.5	3.9	25.0	595.2	4129.1
<b>NFI region</b>																		
L1	197.9	8.3	77.9	122.8	0.9	4.7	11.9	0.3	0.2	0.6	23.6	1.1	26.6	10.9	0.5	4.7	0.5	493.5
L2	227.9	4.1	305.9	153.6	0.9	9.9	27.4	1.0	0.2	1.6	70.5	4.1	84.7	34.9	1.6	12.6	0.7	941.5
L3	215.3	13.0	29.9	261.7	10.4	0.8	17.9	0.1	8.5	6.8	30.7	12.0	26.7	9.2	0.5	2.9	14.9	661.2
L4	332.8	56.1	13.8	365.4	110.1	9.5	24.4	0.2	118.1	49.2	26.2	7.2	26.8	9.8	0.8	3.0	524.8	1678.2
L5	136.9	22.7	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
	1110.7	104.2	430.5	939.2	155.6	26.4	89.4	1.5	151.7	66.3	161.6	25.1	174.1	68.5	3.9	25.0	595.2	4129.1

Table 6-8 shows the overall trends of land-use changes over the inventory period. For example, the area of cropland (CC21) decreased by 13 % during this period, while the area of productive forests (CC12) increased by 5 %.

Table 6-8 Statistics of land use for land-use categories (shown by their CC codes; in kha, rounded values) and relative change (in %, rounded values; see bottom line) between 1990 and 2023. The country's total area is 4'129'071 ha (FSO 2024).

CC	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	Sum
<b>Year</b>																		
1990	1'110.7	104.2	430.5	939.2	155.6	26.4	89.4	1.5	151.7	66.3	161.6	25.1	174.1	68.5	3.9	25.0	595.2	4'129.1
1991	1'112.8	104.4	429.6	937.5	155.2	26.4	88.3	1.5	151.5	66.2	161.6	25.1	175.7	69.1	4.0	25.3	594.9	4'129.1
1992	1'114.9	104.6	428.7	935.6	154.7	26.5	87.3	1.4	151.2	66.0	161.6	25.1	177.5	69.6	4.1	25.7	594.5	4'129.1
1993	1'116.9	104.8	427.8	934.1	154.3	26.5	86.3	1.4	151.0	65.9	161.6	25.0	179.0	70.2	4.1	26.0	594.1	4'129.1
1994	1'118.6	105.0	426.2	933.6	153.8	26.5	85.3	1.3	150.8	65.7	161.6	25.0	180.6	70.8	4.2	26.2	593.7	4'129.1
1995	1'120.3	105.2	424.2	933.6	153.2	26.5	84.3	1.3	150.7	65.5	161.7	25.1	182.4	71.5	4.1	26.3	593.3	4'129.1
1996	1'121.6	105.4	422.2	933.9	152.8	26.4	83.3	1.3	150.6	65.4	161.7	25.1	183.9	72.2	4.1	26.3	592.9	4'129.1
1997	1'123.0	105.5	419.9	934.7	152.3	26.3	82.4	1.3	150.5	65.2	161.7	25.1	185.3	73.0	4.2	26.2	592.4	4'129.1
1998	1'124.1	105.5	417.7	935.3	152.2	26.2	81.5	1.2	150.6	65.0	161.8	25.1	186.8	73.8	4.2	26.1	591.9	4'129.1
1999	1'125.2	105.7	414.7	936.4	151.9	26.1	80.5	1.2	150.6	64.8	161.9	25.2	188.5	74.7	4.2	26.1	591.4	4'129.1
2000	1'126.1	105.7	412.2	937.4	151.7	26.0	79.5	1.2	150.7	64.6	161.9	25.2	190.1	75.7	4.2	25.9	590.9	4'129.1
2001	1'127.5	105.8	410.3	937.8	151.4	25.9	78.8	1.1	150.7	64.3	161.9	25.2	191.4	76.4	4.2	25.9	590.4	4'129.1
2002	1'128.6	105.7	408.0	938.4	151.2	25.9	77.8	1.1	150.7	64.2	162.0	25.3	193.0	77.3	4.1	25.8	589.9	4'129.1
2003	1'129.9	105.8	405.9	938.8	151.0	25.7	76.8	1.1	150.8	63.9	162.0	25.3	194.5	78.1	4.2	25.7	589.5	4'129.1
2004	1'131.0	105.8	403.7	939.5	150.8	25.7	75.8	1.1	150.8	63.8	162.1	25.3	196.0	78.9	4.2	25.6	589.0	4'129.1
2005	1'132.2	106.0	401.9	939.2	150.7	25.6	74.9	1.1	151.0	63.5	162.1	25.4	197.8	79.6	4.1	25.5	588.6	4'129.1
2006	1'133.3	106.0	400.1	939.0	150.7	25.5	74.1	1.0	151.1	63.3	162.2	25.4	199.3	80.3	4.1	25.5	588.1	4'129.1
2007	1'134.9	105.6	398.3	938.6	150.8	25.4	73.5	1.0	151.3	63.1	162.2	25.4	200.9	80.8	4.1	25.6	587.4	4'129.1
2008	1'136.8	105.4	396.5	937.5	151.1	25.3	73.2	1.0	151.6	62.8	162.3	25.4	202.7	81.0	4.1	25.9	586.3	4'129.1
2009	1'138.9	105.2	394.8	936.0	151.3	25.3	73.2	1.1	152.1	62.5	162.4	25.5	204.3	81.1	4.1	26.3	585.1	4'129.1
2010	1'140.9	105.1	393.2	934.5	151.5	25.3	73.2	1.1	152.5	62.2	162.4	25.5	205.9	81.1	4.0	26.8	583.8	4'129.1
2011	1'142.9	105.1	391.7	933.1	151.8	25.2	73.2	1.1	152.8	62.0	162.5	25.5	207.5	81.0	4.0	27.2	582.7	4'129.1
2012	1'145.1	105.0	389.9	931.7	151.9	25.2	73.1	1.2	153.2	61.7	162.5	25.5	209.1	81.0	3.9	27.6	581.4	4'129.1
2013	1'147.1	104.8	388.2	930.4	152.2	25.2	73.2	1.2	153.7	61.4	162.6	25.5	210.7	81.0	3.9	28.0	580.1	4'129.1
2014	1'149.2	104.6	386.8	928.8	152.4	25.2	73.3	1.3	154.1	61.1	162.6	25.5	212.2	80.9	3.9	28.5	578.8	4'129.1
2015	1'151.6	104.4	385.8	926.9	152.5	25.2	73.5	1.3	154.5	60.8	162.6	25.5	213.5	80.9	3.8	28.9	577.4	4'129.1
2016	1'153.7	104.5	384.2	925.0	152.7	25.2	73.5	1.4	155.0	60.5	162.7	25.5	215.2	80.8	3.7	29.4	575.9	4'129.1
2017	1'155.7	104.6	383.0	923.4	152.8	25.1	73.6	1.4	155.4	60.3	162.7	25.5	216.6	80.8	3.7	29.7	574.7	4'129.1
2018	1'157.6	104.7	381.9	921.8	152.8	25.1	73.8	1.5	155.9	60.1	162.7	25.5	217.8	80.8	3.6	30.0	573.4	4'129.1
2019	1'159.6	104.7	380.7	920.2	152.9	25.1	74.0	1.5	156.3	59.9	162.7	25.5	219.0	80.9	3.6	30.3	572.2	4'129.1
2020	1'161.0	104.7	379.6	919.3	153.0	25.0	74.0	1.5	156.6	59.8	162.7	25.5	220.1	80.9	3.5	30.5	571.3	4'129.1
2021	1'162.5	104.7	378.5	918.3	153.0	25.0	74.1	1.5	156.9	59.6	162.8	25.5	221.2	80.9	3.5	30.8	570.4	4'129.1
2022	1'164.0	104.6	377.0	917.5	153.0	24.9	74.0	1.6	157.2	59.4	162.8	25.5	222.3	81.1	3.5	31.1	569.6	4'129.1
2023	1'165.4	104.6	375.6	916.7	153.0	24.9	74.0	1.6	157.5	59.3	162.8	25.5	223.4	81.3	3.4	31.4	568.7	4'129.1
<b>Change:</b>	5	0	-13	-2	-2	-6	-17	2	4	-11	1	2	28	19	-13	26	-4	0

The annual land-use changes across the entire territory of Switzerland (change matrices, see examples for 1990 and 2023 in Table 6-9) were obtained by adding up the annual changes on a hectare basis per land-use category. For calculating the carbon stock changes, fully



stratified (see chp. 6.2.2) land-use change tables were used for each year (Meteotest 2025). More aggregated land transition matrices are reported in CRT Table4.1 for each year of the inventory period.

In general, the numbers given in the change matrices (Table 6-9) cannot be directly compared with the activity data in categories 2 in CRT 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 reported year is recorded (see the description of conversion time of 20 years in chp. 6.1.3.3). In contrast, the change matrices below present the land-use changes occurring in the specified year only.

Table 6-9 Annual land-use changes in 1990 and in 2023 (change matrices). Units: ha/year, rounded values. Empty cells indicate that no change occurred.

1990		change to CC																	
		12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	decrease
change from CC	12		161	6	120	94	2	51		9	21	13	9	108	27	13	18	58	710
	13	651		7	324	48	7	85		3	1	3	6	40	22		14	5	1216
	21	8	5		658	6	183	32	1	5	7	5	4	627	306	23	20	22	1912
	31	280	458	653		1044	122	301	9	42	49	8	7	754	459	24	40	63	4313
	32	1095	741	2	124		7	299		10	14	5		29	10	4		41	2381
	33	2	6	129	70	4		29	4		1			52	42	1	2	4	346
	34	533	48	159	803	65	35		20	11	27	8	2	168	109	5	44	12	2049
	35		1	4	14	1	3	49						7	2		2		83
	36	32	30	2	163	237		41			83	5	1	6	1			38	639
	37	28	5	2	8	245		75		3		5	1	7	3		1	10	393
	41	3	2	2		8		4		2	2		15	14	3	3		109	167
	42	33	8		5	2		4		1		10		5					68
	51	50	1	77	155	13	2	7		7	6	7	7		279	67	44	5	727
	52	11		19	24	1	1	2		1	3	3	2	295		63	361	2	788
	53	14	1	3	8	1	1	3					4	45	28		35		143
	54	7		3	3	1	1	7			1		7	61	127	11			229
	61	56	15	16	56	87	7	44		302	31	100	1	13	2		1		731
	increase	2803	1482	1084	2535	1857	371	1033	34	396	246	172	66	2231	1420	214	582	369	16895

2023		change to CC																	
		12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61	decrease
change from CC	12		362		245	94	3	82	4	27	15	18	13	75	24	6	15	58	1041
	13	932			342	132	1	82		10	3		2	17	10	1	12	16	1560
	21		2		2570	2	120	39	8	3	2	3	4	363	164	3	3	16	3302
	31	131	450	1701		1081	65	329	10	98	66	9	18	621	346	8	13	68	5014
	32	680	564		169			515		27	17	5	1	7	2	1		34	2022
	33	4	1	76	87	3		26	2					28	19	1	1	2	250
	34	571	68	21	421	38	6		20	9	19	6	1	56	31	1	27	13	1308
	35				8			11											19
	36	38	30		168	325		76			110	5		4				70	826
	37	21	2		16	265		60		41		4		3	1			13	426
	41	3				7		3		6	4		12	4				124	163
	42	29	6		2			3				15		1	1			1	58
	51	24		42	111	5		2		5	6	5	1		412	33	43	7	696
	52	9		12	51			2			3	1		485		43	608		1214
	53	16		2	7	2		1						37	51		52		168
	54	9			3			3						120	319	18			472
	61	42	19	7	60	93	3	56		895	21	107	2	5					1310
	increase	2509	1504	1861	4260	2047	198	1290	44	1121	266	178	54	1826	1380	115	774	422	19849

## 6.3. Country-specific approaches

### 6.3.1. Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

#### 6.3.1.1. Swiss Land Use Statistics (AREA)

Data of the Swiss Land Use Statistics (AREA) processed by the Federal Statistical Office form the basis of activity data. In the course of an AREA survey, every hectare of Switzerland's territory (4'129'071 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; FSO 2022i).

For the reconstruction of the land use conditions in Switzerland during the inventory period data from five surveys were available:

- 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: completed  
(see press conference: <https://www.bfs.admin.ch/bfs/en/home.gnpdetail.2021-0316.html>)
- Land Use Statistics "2020/25" (AREA5), status: 14.5 % of national territory processed  
(see map: <https://www.bfs.admin.ch/bfs/fr/home/statistiques/espace-environnement/utilisation-couverture-sol.assetdetail.32386995.html>; as of 17.03.2025).

The aerial photos for AREA1, AREA2, AREA3, AREA4 and AREA5 were taken 1979–1985, 1990–1998, 2004–2009, 2012–2019 and in 2020, respectively. All photos were interpreted according to the standard nomenclature NOAS04 (SFSO 2006a; FSO 2022i).

The inter-survey period is not identical throughout the Swiss territory but varies regionally (see flyover periods shown above). It averages approximately 12 years for AREA1, AREA2 and AREA3. For AREA4 and AREA5 it was shortened to approximately 9 and 7 years, respectively. This methodical characteristic needs to be considered when reconstructing the annual nationwide status of land use or when calculating annual rates of land-use change.

#### 6.3.1.2. Modelling annual land-use maps

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 the two aerial image acquisition dates (AREA surveys). In this study, it was assumed that the probability of a land-use change between two surveys is uniformly distributed over the respective interim period. Therefore, the observed land-use changes, each type on its own (e.g. CC34 copse to CC51 buildings and constructions), must be equally distributed over the specific interim period.

For an interim period of  $x$  years, it is assumed that  $1/x$  of the changes takes place 1 year after the previous flight year, another share of  $1/x$  takes place 2 years after the previous flight year, and so on. This procedure is valid for all interim periods between two fully recorded AREA surveys (Figure 6-6). The most recent AREA5 data is only available for a part of the land area, which is why the remaining area will be left without an update until the end of the ongoing aerial survey period at the latest. On the other hand, no updated information is



available for the land areas that have already been surveyed from the year 1 after the AREA5 air photo was taken. Both cases of spatio-temporal data gaps require an extrapolation of the land use beyond the time of the last interpretation. Likewise, a data gap exists for land-use changes that occurred before the AREA1 survey (Figure 6-6).

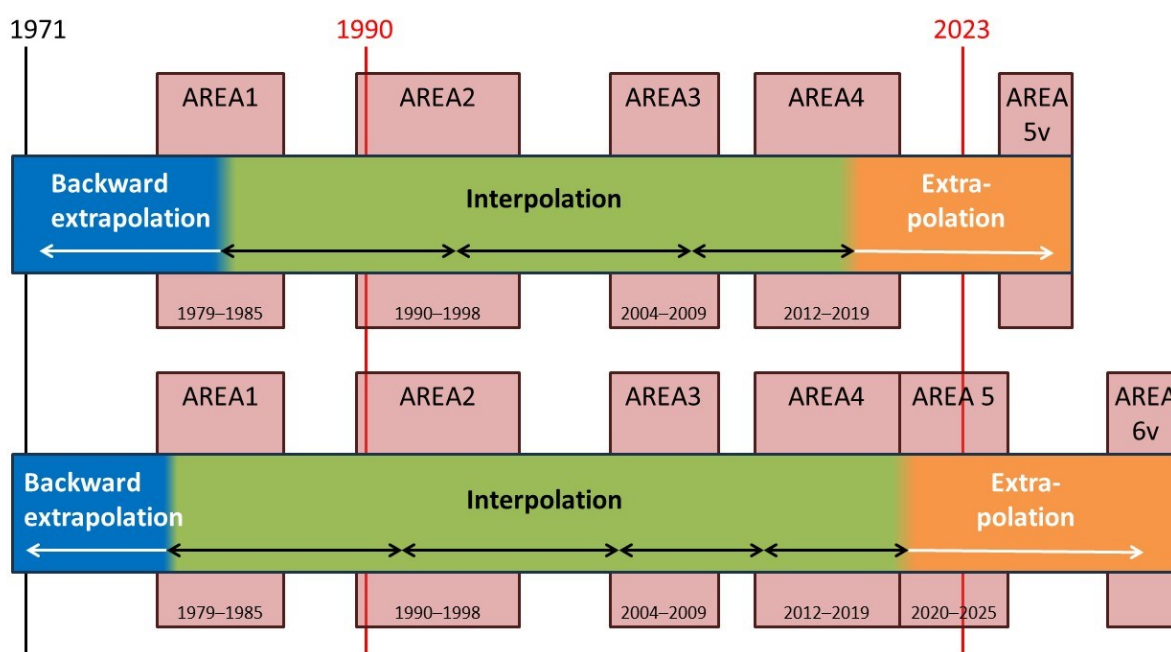


Figure 6-6 Procedures for determining the land-use categories 1990-2023 on a hectare cell, where (i) top: AREA5 data is pending: Interpolation between the AREA surveys 1 to 4, extrapolation after AREA4 using a virtual 5th survey (AREA5v) and backward extrapolation to account for land-use changes that occurred before the AREA1 survey. The arrows show an example of a hectare cell that was covered in 1982, 1995, 2008 and 2017; (ii) bottom: AREA5 data is available: Interpolation between the AREA surveys 1 to 5, extrapolation after AREA5 using a virtual 6th survey (AREA6v) and backward extrapolation to account for land-use changes that occurred before the AREA1 survey. The arrows show an example of a hectare cell that was covered in 1979, 1992, 2004, 2012 and 2020.

The following procedures are used to obtain consistent and complete nationwide activity data for each year (Sigmaplan 2025):

- 1) For hectares not yet covered by AREA5 (85.5 % of national territory), the land-use types after the flight year of AREA4 were interpolated between AREA4 and a "virtual" 5th survey (AREA5v; see Figure 6-6). AREA5v was modelled 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 the same elevation zone and NFI region. AREA5v is continuously being reduced in size and replaced by AREA5.
- 2) For hectares already covered by AREA5 (14.5 % of national territory), the land-use types after the flight year of AREA5 were interpolated between AREA5 and a "virtual" 6th survey (AREA6v; see Figure 6-6). AREA6v was modelled for each sample point using a Markov-chain approach, where transition probabilities between AREA5 and AREA6v were assessed based on the transition distribution between AREA4 and AREA5 within the same elevation zone and NFI region. AREA6v is being continuously expanded.
- 3) There are no consistent data sources on land-use changes before the AREA1 survey, but it is well known, that the main trends of the Swiss land-use dynamics, e.g. increase of forest

area (FOEN 2025f: Figure 1.4; Ginzler et al. 2011) and settlements (ARE/FOEN 2007) arose before 1972. Therefore, it was assumed that between 1971 and 1989 the annual rates of all types of land-use change (per elevation zone and NFI region) were the same as the corresponding rates between the AREA1 and AREA2 surveys. Based on this assumption it was possible to model the land-use changes before 1990 by backward extrapolation (Figure 6-6). Knowledge of the earlier land-use pattern is required to calculate the carbon stock changes induced by land-use changes that occurred between 1971 and 1989, given a conversion time of up to 20 years (cf. chp. 6.1.3.3).

In the extrapolation modelling, land-use changes were randomly assigned within the respective spatial strata, taking exclusion zones into account. These zones, in which no land-use changes were to occur, were defined as continuous areas of uniform land use, based on the assumption that land-use changes occur primarily in the border area.

### 6.3.1.3. Uncertainties and time-series consistency of activity data

#### 6.3.1.3.1. Land Use Statistics (AREA)

An overview of uncertainty estimates of activity data, carbon stock change factors and emission factors is shown in Table 6-5. Details related to uncertainties of AREA data are presented in this chapter, while the remaining uncertainties of other activity data (such as consumption of Harvested wood products) and of carbon stock change factors and emission factors are presented in the respective chapters 6.4.3 to 6.10.3.

In most cases, the uncertainty of activity data for categories 4A–4F depends on the quality of the AREA survey data. For categories with relevant emissions from drained organic soil, also the uncertainty of the spatial allocation of organic soil (see chp. 6.2.2.1 and below) was considered.

The uncertainty of AREA-based activity data has two main sources (Table 6-10). They were quantified as follows, using data from FSO (2023):

1) Interpretation uncertainty: 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 better information is available.

2) Statistical sampling uncertainty: In the AREA survey, the land-use classes are interpreted on points situated on a regular 100x100 m grid. Thus, the uncertainty of the measured surface area covered by a certain land-use class or land-use change decreases with increasing numbers of sampling points that are used for the measurement. Assuming a binomial distribution of the errors, this uncertainty was calculated as

$$U_{\text{sampling}} = 100 * 1.96 * (\text{number of points})^{-0.5}$$

The number of sampling points lies between 2'905 (for 4D2) and 1'333'938 (for 4C1) leading to values of  $U_{\text{sampling}}$  between 3.6 % and 0.2 %.

The overall uncertainty was calculated as:

$$U_{\text{overall}} = (U_{\text{interpret}}^2 + U_{\text{sampling}}^2)^{0.5}$$

Table 6-10 Sources of uncertainty of activity data and overall uncertainties in the allocation of land-use categories, expressed as half of the 95 % confidence intervals. Calculations are based only on AREA data from FSO (2023); uncertainties with respect to other data sources (organic soil, wildfires) are not included, see main text.

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	1.5
4B1	Cropland remaining cropland	4.9	0.3	4.9
4B2	Land converted to cropland	4.9	1.4	5.1
4C1	Grassland remaining grassland	5.2	0.2	5.2
4C2	Land converted to grassland	5.2	0.8	5.3
4D1	Wetlands remaining wetlands	0.9	0.5	1.0
4D2	Land converted to wetlands	0.9	3.6	3.7
4E1	Settlements remaining settlements	4.4	0.4	4.4
4E2	Land converted to settlements	4.4	1.3	4.6
4F1	Other land remaining other land	1.4	0.3	1.4
4F2	Land converted to other land	1.4	2.8	3.1

#### 6.3.1.3.2. Organic soil

An update of the uncertainty analysis of the spatial allocation of organic soil published by Wüst-Galley et al. (2015) resulted in 35.3 % for Forest land, 37.3 % for Cropland, 68.6 % for Grassland and 90.8 % for Wetlands (Table 6-5; Wüst-Galley 2019). For Forest land (chp. 6.4.3.1), CO<sub>2</sub> emissions from organic soil were not considered in the calculation of the overall uncertainty (Meteotest 2025). For Settlements (chp. 6.8.3.1), the uncertainty of CO<sub>2</sub> emissions from organic soil was not calculated separately.

#### 6.3.1.3.3. Wildfires

Activity data for wildfires were taken from the Swissfire database (see chp. 6.4.2.5.4 and chp. 6.6.2.3.3). 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 (Table 6-5).

#### **6.3.1.3.4. Time-series consistency**

Time series for activity data are all considered consistent; they were calculated based on consistent methods for interpolation and extrapolation and homogenous databases.

#### **6.3.1.4. QA/QC and verification of activity data**

The general QA/QC measures are described in chp. 1.5.

##### **6.3.1.4.1. QA/QC measures**

The AREA survey is a well-defined and controlled, long-term process in the responsibility of the Federal Statistical Office (SFSO 2006a; FSO 2022i). Last year, the Federal Statistical Office carried out extensive QA/QC activities that improved the time series consistency of the AREA data (FSO 2024l). The data supplied by FSO (2024) were checked for consistency (Sigmaplan 2025).

The temporal interpolation and extrapolation of the AREA sample is quite a complex procedure, whose internal consistency is checked systematically as described in Sigmaplan (2025). Further checks (interannual comparisons, plausibility) were carried out after producing the land-use change tables presented in chp. 6.2.3.

##### **6.3.1.4.2. Country area**

The total country area remains constant over the inventory period.

##### **6.3.1.4.3. Federal geoportal**

The federal geoportal <https://www.geo.admin.ch/en> provides digital access to the maps, aerial photographs and geographic information of the federal administration covering the entire territory of Switzerland. The map viewer <https://map.geo.admin.ch> allows a visualization of the completed AREA surveys. See the example <https://s.geo.admin.ch/96e44254c8> for the change in direct neighbourhood of a FOEN building in Bern-Ittigen. Legend: yellow crosses represent sample points; circles represent land cover (standard nomenclature NOLC04), triangles, they appear when clicking on "Land use statistics standard", represent land use statistics (standard nomenclature NOAS04). Click circles and triangles for object information. Select different years and observe the changes. To get a clue on the topographic situation prior to the construction of the FOEN building check the box "Journey through time – Maps" (pre-set 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. Examples of characteristic landscape changes in Switzerland across the four survey phases can be found under "Documentation of landscape change" (zoom out to see them).

The free availability and ease of use of the federal geoportal increase the transparency of the (raw) activity data used in the LULUCF reporting and provides an opportunity for public reviewing.

### 6.3.1.5. Recalculations of activity data

Activity data 1990–2022 were recalculated as follows:

- 4A–F, land use areas: There were recalculations in all years (Table 6-11), as the AREA1 to AREA4 results had been improved by the Federal Statistical Office with regard to various errors and time-series consistency (FSO 2024; Sigmaphan 2025).
- 4A–F, land use areas: The most recent land-use data from the fifth area survey (AREA5) were included (based on aerial photographs from 2020; FSO 2024), leading to recalculations of the areas of all land-use categories from 2013 onwards (Table 6-11). The two smallest land-use categories orchards (CC35) and shrubs in settlements (CC53) (see Table 6-8) exceed a relative change of 1 % as a result of the latter two recalculations.
- 4A–F: In the latest submission a geo-referenced approach was implemented for calculating carbon stock changes based on the hectare grid of the AREA survey. In contrast to the previous statistical approach, multiple land-use changes on the same hectare point can now be modelled unambiguously on the time axis. Such hectares no longer appear twice or even multiple times in the cumulative areas under categories 4X2 Land converted to. This leads to somewhat larger areas in the CRT categories 4X1 at the cost of categories 4X2 in all inventory years. The total difference in categories 4A–4F is between -14 kha (in 1994) and -40 kha (in 2022), on the average -19 kha. In 2022, for example, the relative reduction in the areas of 4X2 is between -9 % for 4A2 Forest land and -16 % for 4C2 Grassland (not evident in Table 6-11, since the sums of 4X1 and 4X2 are reported there).
- 4A–F, organic soil: The update of the dataset defining the geographical distribution of organic soils in Switzerland was finalised (Wüst-Galley and Zehnder 2024; Wüst-Galley and Leifeld 2025). In the second phase of the study the total area of organic soil decreased from 34.3 to 32.8 kha (Table 6-7). Category-specific differences in areas of organic soil between the latest and the previous submissions are shown in Figure 6-7.

### 6.3.1.6. Planned improvements for activity data

#### 6.3.1.6.1. AREA5 data

Interpretation and processing of AREA4 were completed in 2021; results of AREA5 are available since 2022. New AREA5 data will be successively added as they become available. The survey is planned with aerial photographs from 2020 to 2025, which would shorten the period between the last two image recordings to six years towards the end.

#### 6.3.1.6.2. Use of remote sensing data

The FOEN is evaluating the suitability of newly available satellite data (e.g. Sentinel 2) in the field of environmental reporting. Several feasibility studies were commissioned. Depending on the results (and on the future availability of Copernicus LMS data in Switzerland) it is intended to refine the spatio-temporal pattern of land use dynamics in Switzerland provided by the Land Use Statistics AREA by the use of satellite data in the medium term. In the course of this evaluation the design of the land-use categories used for LULUCF reporting will be scrutinised.

Table 6-11 Differences of areas per year and land-use category (shown by CC code) between the latest and the previous submissions (in kha). The bottom line shows the percentage change in 2022.

CC	12	13	21	31	32	33	34	35	36	37	41	42	51	52	53	54	61
Year																	
1990	-0.051	0.013	-1.506	1.760	-0.088	-0.082	0.042	-0.013	0.081	0.044	0.052	-0.055	-0.476	0.332	-0.005	0.039	-0.091
1991	-0.072	-0.010	-1.580	1.865	-0.020	-0.066	0.022	0.008	0.080	0.025	0.032	-0.064	-0.543	0.350	0.022	0.054	-0.105
1992	-0.050	-0.033	-1.678	1.817	0.048	-0.013	0.004	-0.003	0.100	0.009	0.052	-0.061	-0.472	0.325	0.041	0.052	-0.140
1993	-0.003	-0.080	-1.616	1.731	0.070	-0.007	0.095	-0.010	0.105	0.020	0.052	-0.080	-0.489	0.309	0.022	0.049	-0.170
1994	-0.111	-0.047	-1.736	1.903	0.092	-0.035	0.078	-0.009	0.053	0.043	0.062	-0.092	-0.484	0.376	-0.003	0.043	-0.136
1995	-0.066	-0.091	-1.865	1.979	0.064	-0.005	0.050	-0.005	0.091	0.027	0.058	-0.102	-0.336	0.303	-0.036	0.051	-0.119
1996	-0.069	-0.067	-1.980	2.121	0.078	-0.012	-0.060	0.004	0.096	0.039	0.043	-0.103	-0.315	0.274	-0.034	0.066	-0.081
1997	0.016	-0.082	-2.135	2.408	-0.033	-0.034	-0.061	0.003	0.060	0.069	0.057	-0.097	-0.415	0.267	-0.019	0.068	-0.072
1998	-0.040	-0.087	-2.294	2.569	0.067	-0.054	0.023	0.000	0.073	0.041	0.058	-0.103	-0.455	0.227	-0.012	0.078	-0.095
1999	-0.070	0.003	-3.202	3.282	0.060	-0.019	-0.010	0.000	0.072	0.012	0.081	-0.104	-0.300	0.292	-0.006	0.087	-0.177
2000	-0.214	0.004	-3.669	3.755	0.062	-0.032	-0.124	-0.014	0.083	0.016	0.093	-0.110	-0.207	0.457	0.017	0.022	-0.142
2001	0.072	-0.016	-3.500	3.762	-0.106	-0.030	0.113	-0.007	0.073	0.002	0.054	-0.114	-0.512	0.331	0.000	0.093	-0.217
2002	0.035	-0.139	-3.718	3.917	-0.098	-0.034	0.072	-0.005	0.021	0.039	0.065	-0.100	-0.366	0.388	-0.037	0.105	-0.146
2003	0.188	-0.093	-3.754	3.865	-0.107	-0.053	0.028	0.006	0.062	0.003	0.057	-0.112	-0.398	0.333	-0.029	0.106	-0.104
2004	0.233	-0.144	-3.948	4.095	-0.034	-0.031	0.032	0.004	0.000	0.051	0.048	-0.133	-0.463	0.309	-0.027	0.106	-0.101
2005	0.138	0.027	-4.023	4.080	-0.006	-0.028	-0.013	0.000	0.046	0.020	0.034	-0.134	-0.290	0.249	-0.052	0.103	-0.152
2006	0.039	-0.015	-3.974	4.120	0.076	-0.015	0.015	-0.007	0.035	0.032	0.059	-0.161	-0.391	0.300	-0.032	0.077	-0.160
2007	0.070	-0.131	-4.023	4.294	0.035	-0.046	-0.004	-0.005	0.021	0.054	0.046	-0.146	-0.450	0.372	-0.018	0.060	-0.129
2008	0.066	-0.198	-4.114	4.285	0.017	-0.040	-0.009	0.004	0.040	0.046	0.066	-0.135	-0.324	0.374	-0.043	0.100	-0.137
2009	0.125	-0.228	-4.054	4.147	-0.055	-0.034	0.069	0.004	0.149	0.026	0.084	-0.133	-0.339	0.415	-0.040	0.118	-0.255
2010	0.041	-0.128	-4.006	4.077	-0.032	-0.044	0.073	0.008	0.120	0.047	0.094	-0.139	-0.327	0.383	-0.049	0.105	-0.224
2011	-0.053	-0.061	-3.865	4.082	0.004	-0.060	0.047	0.000	-0.013	0.070	0.087	-0.150	-0.340	0.351	-0.044	0.081	-0.136
2012	0.024	0.002	-3.988	4.140	-0.057	-0.043	0.011	0.011	0.011	0.080	0.093	-0.135	-0.370	0.327	-0.054	0.105	-0.158
2013	-0.047	-0.048	-3.825	4.070	-0.016	-0.021	0.047	-0.004	0.083	0.045	0.096	-0.134	-0.400	0.290	-0.036	0.090	-0.191
2014	0.124	-0.230	-3.312	3.550	-0.059	0.000	0.081	0.002	0.114	0.005	0.078	-0.141	-0.411	0.271	-0.026	0.150	-0.198
2015	0.513	-0.296	-2.430	2.695	-0.209	0.026	0.218	-0.002	0.070	-0.006	0.075	-0.133	-0.595	0.215	-0.019	0.170	-0.292
2016	0.782	-0.258	-1.999	1.798	-0.195	0.041	0.273	0.000	0.195	-0.096	0.070	-0.123	-0.328	0.143	-0.024	0.224	-0.505
2017	0.866	-0.212	-1.468	1.236	-0.136	0.018	0.305	-0.015	0.217	-0.098	0.052	-0.139	-0.372	0.093	-0.032	0.194	-0.511
2018	0.831	-0.144	-0.885	0.893	-0.060	0.034	0.380	-0.022	0.204	-0.110	0.038	-0.138	-0.655	0.022	-0.026	0.132	-0.495
2019	0.809	-0.149	-0.293	0.548	0.050	0.059	0.439	-0.029	0.189	-0.116	0.016	-0.132	-0.976	-0.042	-0.018	0.067	-0.424
2020	0.247	-0.124	0.315	0.792	0.022	0.065	0.454	-0.042	0.081	-0.038	0.001	-0.126	-1.405	-0.143	-0.015	-0.025	-0.060
2021	-0.341	-0.114	0.976	1.051	-0.049	0.078	0.429	-0.054	-0.033	0.018	-0.002	-0.115	-1.836	-0.184	-0.034	-0.090	0.297
2022	-0.908	-0.137	1.287	1.528	-0.125	0.069	0.372	-0.051	-0.118	0.059	-0.024	-0.117	-2.246	-0.112	-0.048	-0.106	0.674
2022 (in %)	-0.1%	-0.1%	0.3%	0.2%	-0.1%	0.3%	0.5%	-3.2%	-0.1%	0.1%	0.0%	-0.5%	-1.0%	-0.1%	-1.4%	-0.3%	0.1%

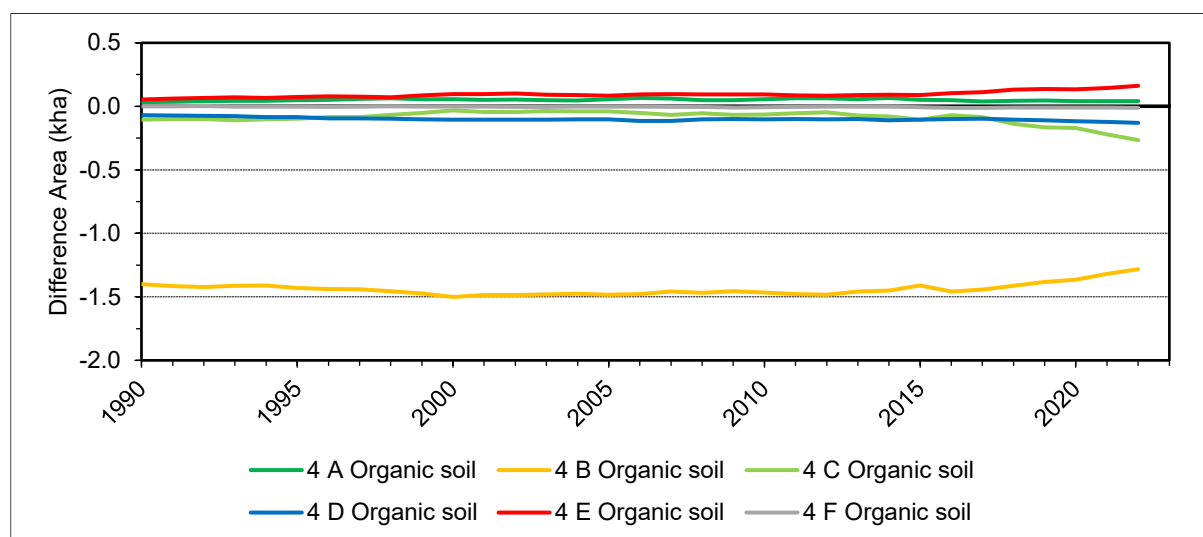


Figure 6-7 Differences in areas of organic soil (in kha) between the latest and the previous submissions for main land-use categories 4A–4F.

### 6.3.2. Information on approaches used for natural disturbances

No provisions for natural disturbances will be applied (FOEN 2025d).



### 6.3.3. Information on approaches used for harvested wood products

For reporting harvested wood products (HWP), the approach B (production approach) as described in chp. 12, Volume 4 of IPCC (2019) was applied. The wood products pool contains only products made from wood harvested in Switzerland. It includes products made from domestic harvest that are exported to foreign countries. Details and results are presented in chp. 6.10.

## 6.4. Category 4A – Forest land

### 6.4.1. Description

Table 6-12 Key categories in category 4A Forest land. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
4.A.1	Forest land remaining forest land	CO <sub>2</sub>	L1, L2, T1, T2
4.A.2	Land converted to forest land	CO <sub>2</sub>	L1, L2, T1

#### 6.4.1.1. Forest land

Only temperate forests occur 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 to the criteria of minimum stand height and minimum crown cover, but must have the potential to achieve it: afforested, regenerated, as well as burnt, cut or damaged areas. Some land categories were explicitly excluded from the land-use category Forest land, although they may partly fulfil the (quantitative) requirements of the Swiss forest definition (FOEN 2006h; Table 6-6):

- Vineyards, low-stem orchards, tree nurseries, copses and orchards in the main land-use category Grassland;
- Cemeteries, public parks, open tree formations in settlements, gardens, sports and parking fields in the main land-use category Settlements.

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 deliberate reduction in forest area has to be authorized. Therefore, all forests in Switzerland are considered to be under management.

Forest land is reported using two land-use categories, productive forest (CC12) and unproductive forest (CC13) (chp. 6.1.3 and Table 6-2).

#### 6.4.1.2. Productive forest

The methodological approach for calculating carbon stocks and carbon stock changes in productive forest is described in chp. 6.4.2.2.



### 6.4.1.3. Unproductive forest

The land-use category unproductive forest consists 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 forest. In unproductive forest, wood is not harvested for economic reasons. Only in exceptional cases there can be an intervention (e.g. moving a wood log that is blocking a hiking trail), but no wood is removed from the stand.

The NFI does not include unproductive stands in its regular inventory scheme because (1) the plots are not relevant for timber production 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 (unproductive 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: p. 89). They are mainly located in the Alps and often grow on sites of low productivity, including rocky sites and sites at high elevation near the tree line with a short vegetation period and low biological activity.
- **Unproductive forest 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 both the Swiss NFI and the Land Use Statistics AREA. 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 combinations 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; see Table 6-6).

The methodology for reporting unproductive forest is covered in chp. 6.4.2.3.

### 6.4.1.4. Temporal development of Forest land area

Forest land is expanding in Switzerland (see areas of productive forest CC12 and unproductive forest CC13 and the relative changes since 1990 in Table 6-8). The land-use change matrices show that expansions are mainly occurring on former grasslands (CC3X to CC12 or to CC13; see Table 6-9) and are primarily due to natural forest regeneration in the alpine area and not by plantation (Gehrig-Fasel et al. 2007; Rutherford et al. 2008; SWI 2009; Brändli 2014; Rigling and Schaffer 2015; Brändli et al. 2020; Allgaier Leuch and Fischer 2023). Such newly forested areas typically exhibit a large diversity in diameter at breast height and tree age.

### 6.4.1.5. Temporal development of net emissions and removals

In the inventory period, the net emissions and removals of category 4A1 Forest land remaining forest land range from -6'057 kt CO<sub>2</sub> in 1996 to 4'440 kt CO<sub>2</sub> in 2000 (average -2'220 kt CO<sub>2</sub>; Figure 6-8 top panel). Particularly the pools losses in living biomass, dead wood and litter introduce temporal variability (Figure 6-8 both panels).

Category 4A2 Land converted to forest land acted as a net sink in all years (average -797 kt CO<sub>2</sub>; Figure 6-8 top panel) with small fluctuations mainly due to slight variations in land use change rates over the inventory period and the associated living biomass on these areas.

More information on the temporal development of net emissions and removals in category 4A Forest land can be found in chp. 2.2.2.3.

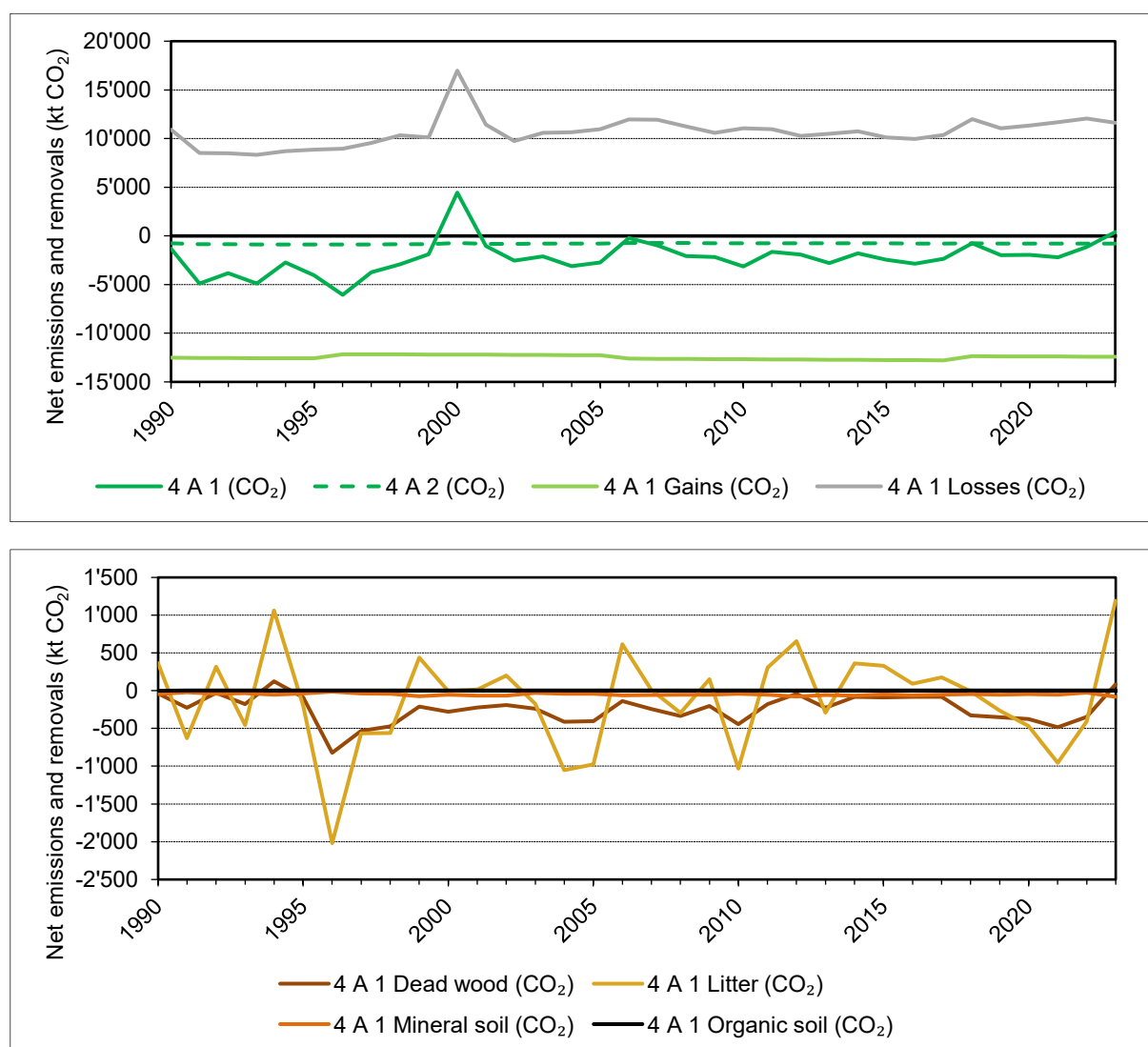


Figure 6-8 Net CO<sub>2</sub> emissions (positive values) and removals (negative values) from categories 4A1 and 4A2. Category 4A1 is broken down by gains and losses in living biomass (top panel), and net carbon stock changes in dead wood, litter, mineral soil and organic soil (bottom panel). Note the different scaling of the y-axis. The net changes in organic soil are too small to be distinguished from the zero line.

## 6.4.2. Methodological issues

### 6.4.2.1. Choice of methods

#### 6.4.2.1.1. National Forest Inventory

##### 6.4.2.1.1.1. National Forest Inventory data

The National Forest Inventory (NFI) is the primary source for estimating carbon stock change factors for Forest land. The estimates are based on measurements of tally trees with a diameter at breast height (DBH)  $\geq 12$  cm. For tally trees, allometric relationships were developed to obtain accurate data on whole tree volume and biomass (Lanz et al. 2019).

Data from four completed National Forest Inventories (NFI1, NFI2, NFI3, NFI4, finalized in 1985, 1995, 2006 and 2017, respectively) and from the first five years (2018–2022) of the ongoing NFI5 (2018–2026) are currently available. Descriptions of NFI1, NFI2, and NFI3 results can be found in EAFV/BFL (1988), in Brassel and Brändli (1999), and in Brändli (2010), respectively. These inventories were based on full surveys that were repeated in intervals of approximately 10 years. Starting with the NFI4, a continuous survey approach is used where annually a nationally representative subsample of approximately 12 % of the Swiss forests is surveyed and evaluated (Brändli et al. 2020). Otherwise, the methodology remained consistent with previous inventories. A detailed description of the current methods to estimate volume based on section-wise measured stems and branches, biomass based on measured wood densities, and carbon for LULUCF reporting can be found in Herold et al. (2019) and Didion et al. (2019). Results of the first five years of the NFI5 are available online in Abegg et al. (2023) and summarized in Allgaier Leuch and Fischer (2023) and FOEN (2023g).

For compiling the results for the latest GHG inventory, NFI5 data for the years 2018–2022 were used in addition to the data from NFI1, NFI2, NFI3 and NFI4, and the respective inventory periods NFI1-2, NFI2-3, NFI3-4, and NFI4-5 (2018–2022). The calculation approaches for land-use changes within, from and to Forest land are shown in Table 6-3.

Table 6-13 Number of surveyed sample plots and tally trees in the National Forest Inventories NFI1, NFI2, NFI3, NFI4, and NFI5 (first five years 2018–2022) for accessible forest plots without brush forest based on the 1.41x1.41 km grid (Brändli and Hägeli 2019). Note that for the NFI5 intermediate results are presented and that for the NFI1 the number of sample plots and tally trees based on the 1x1 km grid originally used is given in brackets.

	NFI1	NFI2	NFI3	NFI4	NFI5
Inventory cycle	1983-1985	1993-1995	2004-2006	2009-2017	2018-2022
Terrestrial sample plots	5'517 (10'981)	5'679	5'920	6'042	3'435
Tally trees	64'414 (128'441)	67'297	70'061	71'962	40'537

##### 6.4.2.1.1.2. Updating NFI data

In general, new NFI data have an influence on the time series of carbon stock changes (gains and losses in living biomass, dead wood, litter and mineral soil) because they are calculated based on observed changes between two consecutive forest inventories.

The change from periodic sampling (NFIs 1 to 3) to a continuous sampling starting with the NFI4 required a modification of the estimation of carbon stock changes affecting estimates from 2006 onwards. The adapted method requires NFI data from a shifting five-year window

to ensure accuracy and consistency of the estimates of carbon stock changes. The method will also be used in future submissions and thus, recalculations will be performed when new NFI data become available (see Didion et al. 2023: chp. 1.1 and chp. 2.3). The continuous survey approach allows regular updates of data to obtain the most current and accurate estimates for carbon stocks as well as gains and losses in living biomass. The differences in the results arising by an update of the five-year period reflect the uncertainty in the data as the sample plots used for the estimate are exchanged, but time series remain consistent as carbon stock change estimates are still based on representative subsamples of the NFI sample plots.

#### **6.4.2.1.1.3. Data available in the NFI for estimating biomass**

The field surveys are based on two nested circular sample plots with 200 m<sup>2</sup> and 500 m<sup>2</sup> in area, respectively. On the smaller plot, trees with DBH  $\geq 12$  cm are measured, whereas all trees with DBH  $\geq 36$  cm are measured on the larger plot. In order to assess the regeneration of the forest, young trees and the main shrub species with a minimum height of 10 cm and DBH  $< 12$  cm are assessed on a separate set of four circular sample plots with radii between 0.9 and 4 m (Brändli and Hägeli 2019).

For estimating carbon stocks and carbon stock changes for LULUCF reporting, (1) trees with DBH  $< 12$  cm with branches, foliage, and roots, and (2) non-tree understory vegetation including shrubs, ferns, grasses, sedges, and herbs are not considered because Switzerland's country-specific allometric functions only apply to trees  $\geq 12$  cm DBH. The omission is justified because of their negligible effect on carbon stocks and carbon stock changes of living biomass, dead wood, litter, and soil in productive forests in Switzerland (see chp. 6.4.4.1 for more information).

#### **6.4.2.1.2. Forest land stratification**

Forests in Switzerland reveal a high heterogeneity in terms of elevation, growth conditions, tree species composition, and interannual growth variability. The suitability of a spatial stratification was analysed for Forest land (Thürig et al. 2005a: Table 2b; Didion et al. 2023: Table 3). The analyses indicated that tree species type, production region and elevation all significantly explain differences in gross growth. Accordingly, a spatial stratification into five production regions and three elevation zones was applied (see chp. 6.2.2). For the calculation of growing stock, gross growth, harvesting and mortality these strata were then further divided into two tree species types: coniferous and broadleaved species (Didion et al. 2023).

Forest land was further stratified by soil type (mineral or organic; see chp. 6.2.2.1).

The continuous survey approach since the NFI4 and the use of a five-year shifting window to regularly update estimates of carbon stocks, gains and losses resulted in a reduced number of sample plots that are simultaneously available for estimating the forest carbon balance (Table 6-14), and several spatial strata are represented by a low number of plots. Due to the large variability of the forest structure and composition between sample plots a minimum number of sample plots is needed to obtain reliable estimates of means and sampling errors. Smaller strata are thus merged with neighbouring strata and treated as single strata. This applies to:

- NFI production region 2 Central Plateau 601-1200 m and >1200 m:  
stratum NFI production region 2 Central Plateau >600 m
- NFI production region 3 Pre-Alps ≤600 m and 601-1200 m:  
stratum NFI production region 3 Pre-Alps ≤1200 m
- NFI production region 4 Alps ≤600 m and 601-1200 m:  
stratum NFI production region 4 Alps ≤1200 m
- NFI production region 5 Southern Alps ≤600 m and 601-1200 m:  
stratum NFI production region 5 Southern Alps ≤1200 m

#### **6.4.2.1.3. 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 IPCC (2006, Volume 4, Table 4.3) and on the fact that in Switzerland coniferous trees are more abundant than broadleaved trees (Brändli et al. 2020: Table 056).

#### **6.4.2.1.4. Soil carbon model Yasso20**

The soil carbon model Yasso20 (Viskari et al 2022) is used to estimate temporal changes in carbon stocks in dead wood, organic soil horizons (LFH; litter) and mineral forest soil (0–100 cm depth) for the land-use category productive forest. Yasso20 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, Yasso20 requires information on carbon inputs (see below) and climate (annual mean monthly temperature and annual precipitation sum). By default, Yasso20 does not provide separate estimates of carbon pool sizes for dead wood, litter and mineral soil. In order to report estimates for each pool, the model structure of Yasso07 was examined to obtain separate estimates. Dead wood, litter and soil pools could be correlated with modelled data based on the category of carbon input (non-woody and woody material) and the five carbon compartments in Yasso07, i.e. four chemical compounds (insoluble, soluble in ethanol, soluble in water or in acid) and a more stable compartment. The approach was validated using independent, measured data (Didion et al. 2012). The basic model structure, i.e., five carbon compartment, is still the same in Yasso20 (Viskari et al. 2022). The separation of the model results into dead wood, litter, and mineral soil was examined and found to still be plausible although the fluxes between the three pools and within the mineral soil pool are more dynamic (Didion 2023: chp. 2.2 and chp. 3.1) due to improved and more realistic model calibration (Viskari et al. 2022).

The implementation of Yasso20 for LULUCF reporting is described in detail in Didion (2023). Didion et al. (2014a) demonstrated the validity of the previous model version Yasso07 for application in Swiss forests by comparing simulated with measured mass loss in foliage and fine root litter and in coarse dead wood. This evaluation was repeated using Yasso20 (Didion 2023: chp. 2.2). The results demonstrated a moderately higher accuracy of the new model version Yasso20. Following these findings and consideration of the further improvements introduced in Yasso20, including a revision of decomposition rates of the carbon compartments based on experimental data, it was decided to use the new model version.

The Yasso model is currently also used for LULUCF reporting in Austria (Yasso20 for the combined litter and mineral soil pools; Umweltbundesamt 2023), Finland (Yasso07 for the combined dead wood, litter, and soil pools; Statistics Finland 2023), and in Norway (Yasso07, separately for dead wood, litter and soil; Norwegian Environment Agency 2023).

## 6.4.2.2. Productive forest

### 6.4.2.2.1. Carbon stocks and carbon stock changes in living biomass

#### 6.4.2.2.1.1. Data sources

To estimate carbon stocks and carbon stock changes in above- and belowground living biomass NFI data for trees  $\geq 12$  cm DBH were used. Total tree biomass and carbon stocks comprise stemwood over bark including tree top and stump, large and small branches, foliage, and coarse roots (Didion et al. 2019). The stock was estimated based on sample plots in a particular NFI (Table 6-13) to also account for sample plots that have been converted to forest since the previous inventory. Carbon stock change factors were derived from the observed changes on sample plots common to two consecutive NFIs (Table 6-14; for a detailed description, see Didion et al. 2023). The most recent results are published in Didion et al. (2024).

#### 6.4.2.2.1.2. Carbon stocks in living biomass – growing stock

Carbon stocks are represented by the state of total tree biomass of all living and standing tally trees (see chp. 6.4.2.1.1.1; Didion et al. 2023: chp. 2.3).

#### 6.4.2.2.1.3. Carbon stock changes in living biomass

##### 6.4.2.2.1.3.1. Carbon gains – gross growth

Carbon gains in living biomass are represented by the change in total biomass increment of tally trees between two forest inventories and are assumed to remain constant within a particular inter-survey period. Temporal dynamics of forest land (see chp.6.4.1.4) lead to different totals of plots common to two consecutive NFIs due to land-use changes to or from Forest land (see Table 6-14).

Table 6-14 Number of NFI sample plots in each NFI inter-survey period: number of plots which were forest also in the previous NFI inter-survey period, the number of plots newly converted to forest in the following period, and the resulting total for a particular period. Footnote 1: not applicable in the first NFI period; footnote 2: for the period NFI4-5 sample plots common to the NFI4 and NFI5 visited in the years 2018 to 2022 were considered.

NFI period	NFI inter-survey period	Forest in previous period	Converted to forest since previous period	Total for period
		Number of sample plots		
NFI1-2	1985-1995	NA <sup>1</sup>	NA <sup>1</sup>	5'456
NFI2-3	1996-2005	5'370	211	5'581
NFI3-4	2006-2017	5'521	303	5'824
NFI4-5 <sup>2</sup>	2018-2022	3'242	95	3'337



#### 6.4.2.2.1.3.2. Carbon losses – cut and mortality

Carbon losses in living biomass are represented by the change in total biomass drain due to fellings and natural mortality. Carbon losses were annualised using data of the national forest statistics (Table 6-15; FOEN 2025f and previous editions; Federal Statistical Office: Wood harvest in Switzerland since 1975, <https://www.pxweb.bfs.admin.ch>) and the fellings obtained from the NFI. The fraction affected by natural mortality was not annualised as this process is not related to the harvest statistics. To annualise the mean annual felling estimates for conifers and broadleaves (represented by constant values for an NFI inter-survey period), harvest statistics data were used to calculate annual weighting factors for both tree species based on the ratio between the harvested volume in a given year and the mean of the annual harvests within an NFI inter-survey period (Didion et al. 2023: Table 5).

For the annualisation of fellings the harvesting statistics data were used as they capture the annual variability due to forest management. Fellings and the resulting losses of living biomass were particularly high after the storms Vivian (February 1990) and Lothar (December 1999). If these two events are ignored, harvesting rates in Swiss forests gradually increased between 1991 and 2007. After two minor peaks in 2006 and 2007 harvesting rates decreased due to international and domestic economic framework conditions. Since then, the numbers have fluctuated in a narrow range around a value of 5'000'000 m<sup>3</sup>.

Table 6-15 Annual domestic harvesting amount in m<sup>3</sup> merchantable wood specified for five NFI production region as well as for coniferous (Conif.) and broadleaved (Broadl.) tree species (FOEN 2025f and previous editions; <https://www.pxweb.bfs.admin.ch>).

Year	1. Jura		2. Central plateau		3. Pre-Alps		4. Alps		5. Southern Alps		Country		
	Conif.	Broadl.	Conif.	Broadl.	Conif.	Broadl.	Conif.	Broadl.	Conif.	Broadl.	Conif.	Broadl.	Total
	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]	[m <sup>3</sup> ]
1990	687'327	358'647	1'769'813	606'718	1'285'639	138'126	1'301'313	70'064	21'575	22'456	5'065'667	1'196'011	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	3'461'045	1'075'864	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	3'274'417	1'172'136	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	3'172'844	1'164'931	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	3'449'297	1'160'618	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	3'456'046	1'222'362	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	2'796'054	1'198'861	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	3'154'339	1'228'819	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	3'480'517	1'364'530	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	3'408'099	1'319'610	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	7'610'407	1'627'567	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	4'474'629	1'186'951	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	3'499'532	1'057'085	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	4'047'322	1'073'649	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	4'068'558	1'091'964	5'160'522
2005	653'049	359'808	1'810'839	614'845	1'010'979	180'546	514'905	70'603	35'462	33'614	4'025'234	1'259'416	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	4'245'213	1'456'314	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	4'209'356	1'481'202	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	3'723'244	1'538'955	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	3'360'646	1'519'050	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	3'511'655	1'617'344	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	3'411'532	1'663'556	5'075'088
2012	566'782	488'626	970'748	719'003	825'019	225'988	665'506	94'480	51'475	50'757	3'079'530	1'578'854	4'658'384
2013	576'744	521'122	948'706	739'180	834'166	254'726	670'170	117'841	64'745	50'928	3'094'531	1'683'797	4'778'328
2014	619'002	539'721	945'695	777'852	863'150	259'888	654'300	110'816	95'192	47'603	3'177'339	1'735'880	4'913'219
2015	528'202	505'431	916'020	766'645	753'783	244'149	625'555	96'230	62'233	53'649	2'885'793	1'666'104	4'551'897
2016	549'561	509'699	859'677	737'207	766'647	236'279	570'415	103'416	65'254	60'836	2'811'554	1'647'437	4'458'991
2017	543'937	513'581	995'491	766'306	806'033	242'423	596'105	96'622	72'298	54'746	3'013'864	1'673'678	4'687'542
2018	564'468	492'343	1'421'416	719'879	910'871	216'813	649'759	94'766	61'417	66'470	3'607'931	1'590'271	5'198'202
2019	537'886	478'869	1'181'674	630'237	787'296	214'837	530'476	94'646	92'495	65'622	3'129'827	1'484'211	4'614'038
2020	604'675	457'399	1'360'224	633'451	814'466	205'946	543'583	74'541	45'401	62'539	3'368'349	1'433'876	4'802'225
2021	695'736	473'009	1'195'542	684'866	907'322	236'511	594'717	83'734	54'734	71'112	3'448'051	1'549'832	4'997'883
2022	660'511	513'857	1'119'397	784'029	985'351	252'863	638'486	93'503	59'118	71'284	3'462'863	1'715'536	5'178'399
2023	632'336	489'938	1'028'479	769'105	850'854	261'751	616'313	103'817	66'165	71'402	3'194'147	1'696'013	4'890'160



#### 6.4.2.2.1.4. Carbon stocks in living biomass – calculation of time series

In order to develop a consistent time series, annual carbon stocks of living biomass (growing stocks) per species type ( $stockC_i$ ) were calculated per spatial strata (i) for productive forests (CC12) forward starting from the growing stock in 1985. This was obtained based on all living trees on the total sample plots of the NFI1 (EAFV/BFL 1988). The forward calculation used the net change of the growth estimated for subsequent NFI periods (carbon gains in living biomass,  $gainC_i$ ) and annualised carbon losses in living biomass ( $lossC_i$ ) (abbreviations were introduced in chp. 6.1.3.2).

$$f_{stockC_{l,i,CC12}}(y) = stockC_{l,i,CC12,1985} + \sum_{n=1986}^y (gainC_{l,i,CC12,n} + lossC_{l,i,CC12,n})$$

where  $y$  is the inventory year (running from 1986 to the latest reported inventory year).

Since the growth and drain estimates were based on plots common to two consecutive NFIs and thus do not account for sample plots converted to forest between two inventories, forward calculated stocks were scaled to the observed stocks in subsequent inventories NFIs 2–4 and 5 (2018–2022) (shown in detail in Didion et al. 2023: Figure 2).

Table 6-16 shows the time series of growing stocks (carbon stocks in living biomass), gross growth (carbon gains in living biomass), and cut and mortality (carbon losses in living biomass), specified for all spatial strata.

Table 6-16 Carbon stocks in living biomass (stock<sub>Cl</sub>), carbon gains in living biomass (gross growth, gain<sub>Cl</sub>), and carbon losses in living biomass (cut and mortality, loss<sub>Cl</sub>) for the land-use category productive forest (CC12) stratified for NFI production region (NFI) and elevation zone (Elev.) (chp. 6.4.2.1.2). 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 (stock <sub>Cl,i</sub> ) [t C ha <sup>-1</sup> ]											
L1	Z1	126.71	128.14	129.49	130.86	132.19	133.44	133.32	133.02	132.35	131.80
L1	Z2	121.77	123.12	124.47	125.87	127.18	128.44	129.59	130.61	131.43	132.31
L1	Z3	85.09	85.39	85.73	86.08	86.34	86.59	87.32	88.00	88.61	89.23
L2	Z1	134.45	135.65	136.84	138.09	139.19	140.22	140.54	140.57	140.19	139.91
L2	Z2, Z3	146.60	148.06	149.52	151.06	152.44	153.76	154.24	154.41	154.20	154.09
L3	Z1, Z2	148.46	150.19	151.97	153.80	155.51	157.18	157.79	158.15	158.23	158.37
L3	Z3	116.33	116.82	117.38	117.97	118.47	118.96	119.16	119.26	119.25	119.26
L4	Z1, Z2	97.95	98.81	99.67	100.56	101.38	102.18	103.24	104.23	105.14	106.06
L4	Z3	92.93	92.98	93.08	93.21	93.26	93.30	93.72	94.06	94.34	94.62
L5	Z1, Z2	71.14	72.88	74.59	76.33	78.07	79.79	80.91	82.02	83.08	84.15
L5	Z3	74.88	75.54	76.19	76.83	77.46	78.06	78.45	78.79	79.10	79.38
Country		113.53	114.46	115.40	116.38	117.26	118.11	118.58	118.91	119.06	119.25

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: carbon stock in living biomass (stock <sub>Cl,i</sub> ) [t C ha <sup>-1</sup> ]											
L1	Z1	129.29	128.64	128.57	128.28	127.95	127.31	127.33	127.33	127.43	127.65
L1	Z2	131.71	132.39	133.46	134.35	135.23	135.99	136.19	136.39	136.80	137.41
L1	Z3	89.19	89.69	90.35	90.93	91.50	92.05	92.45	92.85	93.38	94.01
L2	Z1	136.23	135.38	135.40	135.01	134.58	133.95	133.01	132.05	131.39	131.01
L2	Z2, Z3	150.36	149.54	149.61	149.23	148.82	148.29	147.61	146.93	146.60	146.58
L3	Z1, Z2	155.63	155.14	155.34	155.17	154.98	154.73	154.47	154.22	154.30	154.66
L3	Z3	117.96	117.64	117.62	117.43	117.24	117.05	116.96	116.88	116.96	117.16
L4	Z1, Z2	106.21	106.98	107.96	108.83	109.70	110.53	110.62	110.71	110.89	111.16
L4	Z3	94.12	94.21	94.46	94.61	94.75	94.89	95.39	95.89	96.47	97.09
L5	Z1, Z2	85.14	86.21	87.30	88.37	89.43	90.45	91.40	92.34	93.27	94.20
L5	Z3	79.47	79.66	79.86	80.02	80.15	80.25	80.91	81.57	82.24	82.93
Country		117.84	117.73	118.01	118.09	118.15	118.15	118.16	118.17	118.35	118.68

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: carbon stock in living biomass (stock <sub>Cl,i</sub> ) [t C ha <sup>-1</sup> ]											
L1	Z1	127.73	127.78	128.03	128.16	126.13	124.26	122.41	120.46	117.19	114.20
L1	Z2	137.88	138.37	139.07	139.71	138.55	137.57	136.62	135.55	133.40	131.55
L1	Z3	94.59	95.19	95.90	96.59	96.32	96.12	95.95	95.70	95.02	94.50
L2	Z1	130.40	129.80	129.55	129.16	128.22	127.59	127.03	126.30	124.97	124.08
L2	Z2, Z3	146.33	146.12	146.26	146.29	146.13	146.27	146.49	146.51	146.08	146.14
L3	Z1, Z2	154.85	155.09	155.63	156.10	155.37	154.90	154.49	153.91	152.61	151.66
L3	Z3	117.30	117.47	117.74	118.00	119.41	120.93	122.49	123.99	125.38	126.90
L4	Z1, Z2	111.35	111.56	111.87	112.13	111.85	111.65	111.48	111.24	110.73	110.37
L4	Z3	97.69	98.29	98.95	99.59	100.05	100.54	101.04	101.50	101.89	102.33
L5	Z1, Z2	95.11	96.00	96.91	97.79	98.81	99.83	100.84	101.83	102.52	103.23
L5	Z3	83.60	84.26	84.94	85.61	86.53	87.47	88.40	89.33	89.88	90.49
Country		118.90	119.14	119.55	119.91	119.76	119.76	119.78	119.71	119.22	118.93

NFI	Elev.	2020	2021	2022	2023
CC12: carbon stock in living biomass (stock <sub>Cl,i</sub> ) [t C ha <sup>-1</sup> ]					
L1	Z1	111.19	110.18	109.03	107.98
L1	Z2	129.64	129.16	128.53	128.03
L1	Z3	93.93	94.06	94.14	94.31
L2	Z1	123.11	122.54	121.77	121.18
L2	Z2, Z3	146.05	145.87	145.49	145.35
L3	Z1, Z2	150.61	150.48	150.24	150.18
L3	Z3	128.38	129.14	129.90	130.72
L4	Z1, Z2	109.97	110.23	110.43	110.71
L4	Z3	102.73	103.61	104.49	105.40
L5	Z1, Z2	103.93	104.79	105.63	106.49
L5	Z3	91.07	91.73	92.38	93.06
Country		118.58	118.79	118.92	119.16

(Table 6-16 continued)

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC12: carbon gains in living biomass (gainCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	3.66	3.66	3.66	3.66	3.66	3.66	3.34	3.34	3.34	3.34
L1	Z2	3.32	3.32	3.32	3.32	3.32	3.32	3.03	3.03	3.03	3.03
L1	Z3	2.08	2.08	2.08	2.08	2.08	2.08	1.80	1.80	1.80	1.80
L2	Z1	4.75	4.75	4.75	4.75	4.75	4.75	4.66	4.66	4.66	4.66
L2	Z2, Z3	4.66	4.66	4.66	4.66	4.66	4.66	4.52	4.52	4.52	4.52
L3	Z1, Z2	4.23	4.23	4.23	4.23	4.23	4.23	4.11	4.11	4.11	4.11
L3	Z3	2.49	2.49	2.49	2.49	2.49	2.49	2.50	2.50	2.50	2.50
L4	Z1, Z2	2.63	2.63	2.63	2.63	2.63	2.63	2.54	2.54	2.54	2.54
L4	Z3	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
L5	Z1, Z2	2.42	2.42	2.42	2.42	2.42	2.42	2.19	2.19	2.19	2.19
L5	Z3	1.65	1.65	1.65	1.65	1.65	1.65	1.78	1.78	1.78	1.78
Country		3.17	3.17	3.17	3.17	3.17	3.17	2.97	2.97	2.97	2.97

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: carbon gains in living biomass (gainCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	3.34	3.34	3.34	3.34	3.34	3.34	3.50	3.50	3.50	3.50
L1	Z2	3.03	3.03	3.03	3.03	3.03	3.03	3.25	3.25	3.25	3.25
L1	Z3	1.80	1.80	1.80	1.80	1.80	1.80	2.02	2.02	2.02	2.02
L2	Z1	4.66	4.66	4.66	4.66	4.66	4.66	4.51	4.51	4.51	4.51
L2	Z2, Z3	4.52	4.52	4.52	4.52	4.52	4.52	4.74	4.74	4.74	4.74
L3	Z1, Z2	4.11	4.11	4.11	4.11	4.11	4.11	4.07	4.07	4.07	4.07
L3	Z3	2.50	2.50	2.50	2.50	2.50	2.50	2.41	2.41	2.41	2.41
L4	Z1, Z2	2.54	2.54	2.54	2.54	2.54	2.54	2.61	2.61	2.61	2.61
L4	Z3	1.91	1.91	1.91	1.91	1.91	1.91	2.06	2.06	2.06	2.06
L5	Z1, Z2	2.19	2.19	2.19	2.19	2.19	2.19	2.38	2.38	2.38	2.38
L5	Z3	1.78	1.78	1.78	1.78	1.78	1.78	1.90	1.90	1.90	1.90
Country		2.97	2.97	2.97	2.97	2.97	2.97	3.11	3.11	3.11	3.11

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: carbon gains in living biomass (gainCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	2.86	2.86
L1	Z2	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.01	3.01
L1	Z3	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	1.97	1.97
L2	Z1	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.11	4.11
L2	Z2, Z3	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.74	4.66	4.66
L3	Z1, Z2	4.07	4.07	4.07	4.07	4.07	4.07	4.07	4.07	3.99	3.99
L3	Z3	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.32	2.32
L4	Z1, Z2	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.58	2.58
L4	Z3	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.19	2.19
L5	Z1, Z2	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.21	2.21
L5	Z3	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	2.07	2.07
Country		3.11	3.11	3.11	3.11	3.11	3.11	3.11	3.11	2.96	2.96

NFI	Elev.	2020	2021	2022	2023
CC12: carbon gains in living biomass (gainCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]					
L1	Z1	2.86	2.86	2.86	2.86
L1	Z2	3.01	3.01	3.01	3.01
L1	Z3	1.97	1.97	1.97	1.97
L2	Z1	4.11	4.11	4.11	4.11
L2	Z2, Z3	4.66	4.66	4.66	4.66
L3	Z1, Z2	3.99	3.99	3.99	3.99
L3	Z3	2.32	2.32	2.32	2.32
L4	Z1, Z2	2.58	2.58	2.58	2.58
L4	Z3	2.19	2.19	2.19	2.19
L5	Z1, Z2	2.21	2.21	2.21	2.21
L5	Z3	2.07	2.07	2.07	2.07
Country		2.96	2.96	2.96	2.96

(Table 6-16 continued)

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC12: carbon losses in living biomass (lossCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	-2.71	-2.27	-2.35	-2.32	-2.37	-2.45	-3.56	-3.73	-4.10	-3.99
L1	Z2	-2.76	-2.13	-2.13	-2.09	-2.19	-2.23	-2.13	-2.26	-2.46	-2.40
L1	Z3	-1.70	-1.22	-1.17	-1.14	-1.22	-1.23	-0.97	-1.03	-1.11	-1.09
L2	Z1	-4.72	-3.65	-3.67	-3.61	-3.76	-3.84	-4.24	-4.54	-4.96	-4.84
L2	Z2, Z3	-4.48	-3.41	-3.40	-3.33	-3.49	-3.56	-4.04	-4.35	-4.73	-4.63
L3	Z1, Z2	-3.58	-2.71	-2.67	-2.61	-2.75	-2.79	-3.14	-3.39	-3.66	-3.59
L3	Z3	-2.56	-1.95	-1.88	-1.85	-1.95	-1.95	-2.02	-2.14	-2.24	-2.22
L4	Z1, Z2	-2.14	-1.72	-1.71	-1.68	-1.75	-1.77	-1.29	-1.36	-1.45	-1.43
L4	Z3	-1.94	-1.48	-1.43	-1.40	-1.48	-1.48	-1.01	-1.08	-1.14	-1.13
L5	Z1, Z2	-1.00	-0.93	-0.97	-0.96	-0.96	-0.99	-0.83	-0.84	-0.86	-0.85
L5	Z3	-0.61	-0.55	-0.54	-0.54	-0.55	-0.55	-0.41	-0.43	-0.44	-0.44
Country		-2.77	-2.15	-2.14	-2.10	-2.19	-2.23	-2.13	-2.27	-2.45	-2.41

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: carbon losses in living biomass (lossCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	-5.95	-4.08	-3.52	-3.73	-3.77	-4.08	-3.46	-3.48	-3.38	-3.25
L1	Z2	-3.85	-2.61	-2.22	-2.40	-2.42	-2.53	-3.23	-3.23	-3.03	-2.85
L1	Z3	-1.79	-1.22	-1.05	-1.13	-1.14	-1.17	-1.81	-1.80	-1.67	-1.56
L2	Z1	-8.28	-5.43	-4.56	-4.98	-5.02	-5.21	-5.31	-5.32	-5.02	-4.72
L2	Z2, Z3	-8.23	-5.35	-4.46	-4.91	-4.94	-5.06	-5.45	-5.44	-5.09	-4.77
L3	Z1, Z2	-6.45	-4.22	-3.53	-3.89	-3.91	-3.96	-4.40	-4.38	-4.05	-3.76
L3	Z3	-3.54	-2.55	-2.24	-2.42	-2.42	-2.41	-1.99	-1.97	-1.80	-1.67
L4	Z1, Z2	-2.22	-1.57	-1.37	-1.47	-1.48	-1.52	-2.34	-2.34	-2.24	-2.14
L4	Z3	-1.95	-1.33	-1.14	-1.25	-1.26	-1.25	-1.21	-1.20	-1.12	-1.05
L5	Z1, Z2	-0.92	-0.83	-0.80	-0.80	-0.81	-0.84	-1.18	-1.18	-1.18	-1.17
L5	Z3	-0.62	-0.48	-0.44	-0.46	-0.47	-0.47	-0.74	-0.73	-0.70	-0.68
Country		-4.04	-2.72	-2.31	-2.51	-2.53	-2.60	-2.92	-2.92	-2.74	-2.58

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: carbon losses in living biomass (lossCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	-3.40	-3.41	-3.22	-3.33	-3.41	-3.25	-3.20	-3.29	-4.05	-3.79
L1	Z2	-2.98	-2.96	-2.75	-2.82	-2.89	-2.71	-2.66	-2.77	-3.62	-3.33
L1	Z3	-1.62	-1.59	-1.48	-1.50	-1.54	-1.44	-1.42	-1.48	-1.93	-1.76
L2	Z1	-4.95	-4.93	-4.57	-4.71	-4.84	-4.53	-4.45	-4.64	-4.85	-4.41
L2	Z2, Z3	-4.99	-4.96	-4.60	-4.71	-4.83	-4.52	-4.44	-4.64	-4.98	-4.50
L3	Z1, Z2	-3.93	-3.88	-3.58	-3.65	-3.74	-3.48	-3.42	-3.58	-4.26	-3.89
L3	Z3	-1.73	-1.69	-1.57	-1.58	-1.61	-1.51	-1.48	-1.55	-1.59	-1.47
L4	Z1, Z2	-2.21	-2.20	-2.09	-2.13	-2.17	-2.07	-2.05	-2.10	-2.38	-2.22
L4	Z3	-1.08	-1.06	-1.01	-1.01	-1.02	-0.97	-0.96	-0.99	-1.20	-1.12
L5	Z1, Z2	-1.19	-1.19	-1.17	-1.19	-1.20	-1.18	-1.17	-1.18	-1.32	-1.30
L5	Z3	-0.69	-0.68	-0.66	-0.66	-0.67	-0.65	-0.64	-0.66	-1.27	-1.19
Country		-2.69	-2.67	-2.49	-2.54	-2.60	-2.45	-2.41	-2.50	-2.81	-2.59

NFI	Elev.	2020	2021	2022	2023
CC12: carbon losses in living biomass (lossCl,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]					
L1	Z1	-3.82	-3.96	-4.12	-4.01
L1	Z2	-3.39	-3.52	-3.66	-3.53
L1	Z3	-1.82	-1.87	-1.92	-1.84
L2	Z1	-4.50	-4.69	-4.92	-4.72
L2	Z2, Z3	-4.63	-4.82	-5.01	-4.79
L3	Z1, Z2	-4.01	-4.13	-4.25	-4.06
L3	Z3	-1.52	-1.55	-1.55	-1.49
L4	Z1, Z2	-2.27	-2.33	-2.38	-2.30
L4	Z3	-1.16	-1.17	-1.18	-1.14
L5	Z1, Z2	-1.30	-1.31	-1.32	-1.31
L5	Z3	-1.23	-1.24	-1.25	-1.20
Country		-2.65	-2.73	-2.82	-2.71

#### **6.4.2.2.2. Carbon stocks and carbon stock changes in dead wood, litter, mineral soil and organic soil**

##### **6.4.2.2.2.1. Data sources**

The NFI is the source of carbon inputs and the description of a (possible) state change for each sample tree between two consecutive inventories (i.e., (1) alive in both inventories, (2) alive in the first and dead or removed in the second inventory, (3) present in the second inventory only). The tree state in two consecutive NFIs determines the type and quantity of carbon inputs. Turnover rates reflecting the longevity of leaves and needles, seeds and fruits, fine roots, and small branches were used to estimate carbon inputs that were produced annually. Stemwood, including tree top and stump, large branches, and coarse roots were assumed to accrue only as the result of mortality. Depending on the cause of mortality (natural or timber harvesting) either the total mass of the latter tree elements or only the non-merchantable fraction (coarse root, stump, top, and small branches) was considered for carbon inputs. Consistent with the estimation procedure for living biomass, the model was applied on sample plots common to two consecutive NFIs (chp. 6.4.2.1.1; Table 6-14; for a detailed description see Didion 2023). The most recent results are published in Didion (2024).

##### **6.4.2.2.2.2. Carbon stocks in dead wood**

Carbon stocks in dead wood were obtained from simulations with Yasso20 and a separation of the total simulated annual carbon stocks based on the source of carbon inputs, including (1) stemwood of trees with DBH  $\geq 12$  cm, (2) large branches  $\geq$  ca. 7 cm in diameter, and (3) dead coarse roots  $>$  ca. 5 mm in diameter. These tree elements were estimated according to Didion (2023: Table 3). Data are given in Table 6-17.

##### **6.4.2.2.2.3. Carbon stocks in litter**

Carbon stocks in litter were derived from Yasso20 simulations of carbon inputs of the tree elements small branches and twigs  $<$  ca. 7 cm in diameter, bark of the tree bole, foliage (Didion 2023: Table 3), seeds and fruits (based on published allometries; see Didion and Zell 2019), and fine roots  $<$  ca. 5 mm (estimated as fraction of coarse roots; Perruchoud et al. 1999). Data are given in Table 6-17.

##### **6.4.2.2.2.4. Carbon stocks in mineral soil**

Carbon stocks in mineral soil were not taken from Yasso20 simulations. Due to the incomplete knowledge of the origin of the high carbon stocks in mineral soils, particularly pyrogenic carbon in the mountainous soils of Southern Switzerland (Eckmeier et al. 2010; Nussbaum et al. 2014; Zanelli et al. 2006), they cannot be reproduced by models yet. Hence, soil carbon stocks were taken from Nussbaum and Burgos (2021), a spatial statistical analysis of soil profile data using the machine learning approach "random forest" (Baltensweiler et al. 2021). The sample material was taken from the soil sample archive (pedothek) maintained at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) ( $n = 1033$  sites). Additional 1060 sites either sampled by WSL or in the course of cantonal projects were used. The soil samples were collected over the past 50 years, by far the most between 1990 and 2015, and distributed over different forest types

throughout Switzerland. Because of the distribution of sampling over a long time span, it is not possible to attribute the carbon stocks estimates in mineral forest soils to one single year. A combination of these carbon stocks and the carbon stock changes derived from the Yasso20 model (see chp. 6.4.2.2.2.8) would not result in a consistent time series for soil carbon stocks. Thus, it was assumed that the values from Nussbaum and Burgos (2021) are representative of mineral soil in land-use category productive forest for the whole inventory period and were considered constant. Data are given in Table 6-4.

#### **6.4.2.2.2.5. Carbon stocks in organic soil**

The mean soil organic carbon stock (0–30 cm) for organic soil in the land-use category productive forest is  $145.6 \pm 24.1 \text{ t C ha}^{-1}$  (Table 6-4; Wüst-Galley et al. 2016).

#### **6.4.2.2.2.6. Carbon stock changes in dead wood**

Annual stratified values of carbon stock changes in dead wood were calculated from the simulated annual stocks (chp. 6.4.2.2.2.2). Results are given in Table 6-18.

The carbon stock change in the dead wood pool is to a large extent driven by the increase in dead wood volume in Swiss forests since the mid-1990s (Brändli 2010). Dead wood accumulation as a consequence of the two storms Vivian (1990) and, in particular, Lothar (1999), strongly affects the results of the change analysis for dead wood volume in the period NFI2 to NFI3 (1996–2005). Although the majority of the wind thrown 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 increased dead wood stock acts as a sustained carbon sink (Figure 6-9:  $\text{changeC}_d$ ; see also Figure 6-8 bottom panel). The trend of decreasing harvesting rates for several years after NFI3 (2004–2006; see Table 6-15) further sustained the carbon sink of dead wood as mature trees, which could be harvested, remained in the forest and potentially contributed to the dead wood pool. The increased mortality in more recent years (Allgaier Leuch and Fischer 2023; FOEN 2023g) results in further accumulation of dead wood in Swiss forests. A further reason for the accumulation since the mid-2010s was the comparably dry weather that slowed the decomposition. By contrast, above-average precipitation and record temperatures in 2023 enhanced decomposition resulting, on a national average, in the first net carbon losses from the dead wood pool in almost 30 years (Didion 2024).

Table 6-17 Carbon stocks in dead wood (stock<sub>Cd</sub>) and in litter (stock<sub>Ch</sub>) for the land-use category productive forest (CC12) stratified for NFI production region (NFI) and elevation zone (Elev.) (chp. 6.4.2.1.2). 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 dead wood (stock <sub>Cd,i</sub> ) [t C ha <sup>-1</sup> ]											
L1	Z1	5.57	5.62	5.59	5.61	5.55	5.53	5.90	6.23	6.49	6.66
L1	Z2	6.34	6.37	6.35	6.37	6.32	6.31	6.38	6.45	6.52	6.52
L1	Z3	6.01	5.97	5.91	5.88	5.80	5.76	5.54	5.42	5.34	5.23
L2	Z1	9.12	9.18	9.14	9.17	9.07	9.03	9.39	9.70	9.94	10.05
L2	Z2, Z3	9.05	9.09	9.05	9.06	8.96	8.94	9.29	9.62	9.90	10.06
L3	Z1, Z2	8.92	9.00	9.02	9.08	9.03	9.07	9.55	9.92	10.26	10.50
L3	Z3	7.71	7.71	7.69	7.71	7.65	7.65	7.48	7.52	7.59	7.61
L4	Z1, Z2	6.45	6.52	6.55	6.62	6.62	6.68	6.57	6.56	6.55	6.50
L4	Z3	7.11	7.21	7.26	7.35	7.39	7.47	7.23	7.21	7.20	7.16
L5	Z1, Z2	2.14	2.19	2.23	2.28	2.30	2.34	2.21	2.16	2.11	2.06
L5	Z3	2.25	2.27	2.27	2.29	2.28	2.31	2.17	2.16	2.15	2.14
Country		6.97	7.03	7.03	7.08	7.04	7.07	7.10	7.23	7.34	7.38

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: carbon stock in dead wood (stock <sub>Cd,i</sub> ) [t C ha <sup>-1</sup> ]											
L1	Z1	6.87	7.02	7.16	7.36	7.55	7.74	7.67	7.70	7.78	7.82
L1	Z2	6.56	6.57	6.58	6.62	6.68	6.74	6.83	7.00	7.19	7.33
L1	Z3	5.13	5.04	4.96	4.86	4.82	4.78	4.64	4.68	4.72	4.74
L2	Z1	10.21	10.31	10.42	10.60	10.79	10.97	10.86	10.88	10.96	11.00
L2	Z2, Z3	10.24	10.38	10.53	10.69	10.90	11.11	11.09	11.14	11.25	11.30
L3	Z1, Z2	10.75	10.97	11.16	11.32	11.58	11.80	11.72	11.77	11.87	11.91
L3	Z3	7.64	7.67	7.69	7.67	7.74	7.79	7.30	7.23	7.19	7.12
L4	Z1, Z2	6.46	6.44	6.40	6.38	6.41	6.45	6.32	6.53	6.72	6.88
L4	Z3	7.12	7.10	7.07	7.04	7.07	7.10	6.62	6.62	6.62	6.61
L5	Z1, Z2	2.02	1.99	1.95	1.93	1.91	1.92	1.93	2.01	2.08	2.14
L5	Z3	2.13	2.12	2.11	2.10	2.10	2.12	1.97	2.04	2.11	2.16
Country		7.45	7.50	7.54	7.59	7.69	7.79	7.50	7.56	7.64	7.69

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: carbon stock in dead wood (stock <sub>Cd,i</sub> ) [t C ha <sup>-1</sup> ]											
L1	Z1	7.93	7.99	7.97	8.02	8.04	8.10	8.11	8.14	9.04	9.15
L1	Z2	7.53	7.65	7.72	7.83	7.91	7.99	8.06	8.14	8.37	8.58
L1	Z3	4.80	4.81	4.81	4.82	4.83	4.81	4.81	4.81	4.38	4.59
L2	Z1	11.13	11.20	11.18	11.23	11.24	11.28	11.26	11.29	11.08	11.12
L2	Z2, Z3	11.46	11.54	11.53	11.59	11.61	11.64	11.64	11.67	12.22	12.25
L3	Z1, Z2	12.04	12.06	12.06	12.13	12.13	12.12	12.13	12.13	11.60	11.83
L3	Z3	7.11	7.03	6.96	6.93	6.88	6.80	6.76	6.71	5.79	5.82
L4	Z1, Z2	7.08	7.20	7.29	7.43	7.52	7.59	7.67	7.73	7.78	7.89
L4	Z3	6.64	6.62	6.59	6.60	6.59	6.56	6.56	6.54	6.40	6.38
L5	Z1, Z2	2.21	2.26	2.30	2.35	2.38	2.42	2.47	2.50	2.38	2.33
L5	Z3	2.22	2.27	2.30	2.35	2.38	2.41	2.45	2.48	2.74	2.90
Country		7.79	7.83	7.84	7.89	7.90	7.92	7.94	7.96	7.90	7.98

NFI	Elev.	2020	2021	2022	2023
CC12: carbon stock in dead wood (stock <sub>Cd,i</sub> ) [t C ha <sup>-1</sup> ]					
L1	Z1	9.26	9.36	9.46	9.42
L1	Z2	8.77	8.99	9.15	9.19
L1	Z3	4.79	5.00	5.14	5.24
L2	Z1	11.18	11.25	11.32	11.22
L2	Z2, Z3	12.28	12.37	12.41	12.30
L3	Z1, Z2	12.04	12.30	12.46	12.48
L3	Z3	5.86	5.92	5.93	5.90
L4	Z1, Z2	8.02	8.18	8.31	8.32
L4	Z3	6.39	6.42	6.43	6.38
L5	Z1, Z2	2.30	2.29	2.27	2.23
L5	Z3	3.06	3.22	3.38	3.47
Country		8.07	8.18	8.26	8.24



(Table 6-17 continued)

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC12: carbon stock in litter (stockCh,i) [t C ha <sup>-1</sup> ]											
L1	Z1	13.81	13.99	13.78	13.88	13.51	13.38	13.77	13.90	13.90	13.65
L1	Z2	15.06	15.25	15.09	15.21	14.88	14.83	15.25	15.37	15.49	15.34
L1	Z3	13.80	13.74	13.53	13.53	13.20	13.16	13.00	13.02	13.16	13.10
L2	Z1	14.18	14.36	14.19	14.24	13.85	13.75	14.11	14.25	14.24	13.97
L2	Z2, Z3	15.62	15.79	15.63	15.71	15.33	15.28	15.63	15.72	15.76	15.53
L3	Z1, Z2	17.20	17.39	17.29	17.40	17.04	17.08	17.51	17.58	17.70	17.56
L3	Z3	18.43	18.55	18.47	18.62	18.30	18.40	18.17	18.20	18.43	18.40
L4	Z1, Z2	13.50	13.64	13.59	13.70	13.53	13.60	13.70	13.87	14.05	13.94
L4	Z3	18.26	18.45	18.46	18.66	18.51	18.70	18.46	18.67	18.91	18.84
L5	Z1, Z2	9.40	9.49	9.56	9.65	9.54	9.72	9.96	10.20	10.41	10.53
L5	Z3	12.25	12.37	12.42	12.55	12.40	12.65	12.44	12.71	12.96	13.13
Country		15.42	15.58	15.50	15.62	15.35	15.40	15.55	15.70	15.84	15.73

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: carbon stock in litter (stockCh,i) [t C ha <sup>-1</sup> ]											
L1	Z1	13.67	13.52	13.41	13.63	13.82	13.99	13.53	13.41	13.43	13.34
L1	Z2	15.40	15.34	15.28	15.35	15.57	15.78	15.38	15.39	15.56	15.57
L1	Z3	13.10	13.09	13.09	12.96	13.17	13.35	12.82	12.96	13.20	13.25
L2	Z1	13.91	13.74	13.63	13.80	13.98	14.14	13.48	13.29	13.27	13.15
L2	Z2, Z3	15.47	15.34	15.26	15.31	15.55	15.73	15.28	15.12	15.13	15.00
L3	Z1, Z2	17.54	17.50	17.42	17.31	17.59	17.74	17.21	17.13	17.19	17.05
L3	Z3	18.45	18.47	18.47	18.24	18.55	18.75	17.69	17.65	17.76	17.62
L4	Z1, Z2	13.94	13.98	13.91	13.97	14.27	14.51	13.74	13.80	13.90	13.93
L4	Z3	18.82	18.92	18.89	18.94	19.29	19.60	18.31	18.41	18.49	18.55
L5	Z1, Z2	10.58	10.77	10.78	10.92	11.11	11.51	10.97	11.12	11.15	11.13
L5	Z3	13.21	13.41	13.46	13.56	13.82	14.33	12.52	12.74	12.85	12.89
Country		15.73	15.73	15.68	15.72	15.99	16.23	15.42	15.43	15.50	15.47

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: carbon stock in litter (stockCh,i) [t C ha <sup>-1</sup> ]											
L1	Z1	13.51	13.49	13.22	13.23	13.14	13.20	13.09	13.10	12.46	12.46
L1	Z2	15.91	15.85	15.65	15.71	15.65	15.60	15.56	15.61	15.07	15.08
L1	Z3	13.61	13.54	13.46	13.55	13.54	13.41	13.40	13.42	12.68	12.73
L2	Z1	13.31	13.30	13.06	13.06	12.94	12.95	12.80	12.79	12.56	12.51
L2	Z2, Z3	15.21	15.15	14.91	14.92	14.76	14.71	14.59	14.55	14.73	14.72
L3	Z1, Z2	17.26	17.06	16.87	16.95	16.76	16.58	16.52	16.42	15.67	15.81
L3	Z3	17.89	17.61	17.43	17.51	17.37	17.12	17.08	16.96	17.83	17.92
L4	Z1, Z2	14.22	14.15	14.04	14.17	14.09	14.00	14.02	13.94	13.35	13.40
L4	Z3	18.88	18.81	18.66	18.79	18.76	18.64	18.70	18.63	17.50	17.59
L5	Z1, Z2	11.33	11.35	11.32	11.39	11.29	11.29	11.34	11.31	10.68	10.85
L5	Z3	13.15	13.16	13.13	13.23	13.21	13.18	13.25	13.23	12.58	12.76
Country		15.73	15.65	15.49	15.56	15.47	15.39	15.37	15.32	14.82	14.88

NFI	Elev.	2020	2021	2022	2023
CC12: carbon stock in litter (stockCh,i) [t C ha <sup>-1</sup> ]					
L1	Z1	12.46	12.46	12.51	12.19
L1	Z2	15.11	15.26	15.25	14.91
L1	Z3	12.79	13.03	12.93	12.71
L2	Z1	12.48	12.51	12.54	12.20
L2	Z2, Z3	14.70	14.81	14.81	14.44
L3	Z1, Z2	15.94	16.23	16.25	15.95
L3	Z3	18.06	18.40	18.31	18.03
L4	Z1, Z2	13.52	13.76	13.89	13.58
L4	Z3	17.82	18.18	18.41	18.11
L5	Z1, Z2	11.08	11.39	11.68	11.55
L5	Z3	13.02	13.40	13.73	13.57
Country		15.00	15.24	15.35	15.05

#### **6.4.2.2.7. Carbon stock changes in litter**

Annual stratified values of carbon stock changes in litter were calculated from the simulated annual stocks (chp. 6.4.2.2.3). Results are given in Table 6-18.

Carbon stock changes in litter are higher and more erratic than those in the dead wood and soil pools (Figure 6-9:  $\text{changeC}_h$ ; see also Figure 6-8 bottom panel). This is expected since non-woody material decomposes faster than dead wood (Tuomi et al. 2011) and its decomposition is more sensitive to interannual changes in temperature and precipitation (Liski et al. 2003). Similar to the dead wood pool, decomposition of the litter pool was reduced in recent years due to weather conditions. The favourable decomposition conditions in 2023 due to extended periods of moist and warm weather reversed the picture. The litter pool experienced net carbon losses in all strata, and the nationwide mean was only comparably low in 1994.

#### **6.4.2.2.8. Carbon stock changes in mineral soil**

Annual stratified values of carbon stock changes in mineral soil were calculated from the simulated annual stocks (even if these themselves were not reported, see chp. 6.4.2.2.4). Results are given in Table 6-18.

Carbon stock changes in the soil pool are small compared to those in dead wood and litter (Figure 6-9:  $\text{changeC}_{s\_m}$ ; see also Figure 6-8 bottom panel). Despite limitations to reproduce the comparably high carbon stocks in mineral soils in Swiss forests (see chp. 6.4.2.2.4), the carbon stock changes derived from simulated stocks can be expected to be accurate because (1) the pyrogenic carbon which is found particularly in the soils of the Southern Alps is very stable (Eckmeier et al. 2010), and (2) the simulated carbon stock changes including standard error are less than the minimum detection limit of repeated soil carbon stock measurements (see chp. 6.4.4.4). Furthermore, simulated soil carbon stocks were highly variable and did not show a clear correlation to environmental variables such as elevation. This is consistent with results from a study in the Bernese Alps by Hoffmann et al. (2014) who found a large unexplained variability in SOC stocks not correlated with environmental variables.

Table 6-18 Net carbon stock change in dead wood (changeC<sub>d</sub>), in litter (changeC<sub>h</sub>) and in mineral soil (changeC<sub>s\_m</sub>) for the land-use category productive forest (CC12) stratified for NFI production region (NFI) and elevation zone (Elev.) (chp. 6.4.2.1.2). 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 (changeC <sub>d,i</sub> ) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	-0.02	0.04	-0.03	0.02	-0.06	-0.03	0.44	0.33	0.26	0.17
L1	Z2	-0.02	0.04	-0.02	0.02	-0.06	-0.01	0.15	0.07	0.06	0.01
L1	Z3	-0.07	-0.04	-0.06	-0.03	-0.08	-0.03	-0.06	-0.11	-0.09	-0.11
L2	Z1	-0.05	0.06	-0.04	0.02	-0.10	-0.03	0.42	0.32	0.23	0.12
L2	Z2, Z3	-0.05	0.04	-0.04	0.01	-0.10	-0.03	0.45	0.33	0.28	0.16
L3	Z1, Z2	0.02	0.08	0.02	0.06	-0.04	0.03	0.50	0.37	0.34	0.24
L3	Z3	-0.03	0.01	-0.03	0.02	-0.06	0.01	0.13	0.04	0.07	0.03
L4	Z1, Z2	0.04	0.07	0.03	0.06	0.01	0.05	0.04	-0.01	-0.01	-0.05
L4	Z3	0.08	0.09	0.06	0.09	0.03	0.08	0.02	-0.02	0.00	-0.05
L5	Z1, Z2	0.05	0.05	0.04	0.04	0.02	0.05	-0.05	-0.06	-0.05	-0.05
L5	Z3	0.01	0.01	0.01	0.01	-0.01	0.02	0.00	-0.01	-0.01	-0.01
Country		0.01	0.06	0.01	0.04	-0.03	0.02	0.20	0.12	0.11	0.05

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: net change in dead wood (changeC <sub>d,i</sub> ) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	0.21	0.15	0.14	0.20	0.19	0.19	-0.04	0.03	0.08	0.04
L1	Z2	0.04	0.01	0.01	0.03	0.06	0.07	0.14	0.17	0.19	0.14
L1	Z3	-0.10	-0.09	-0.08	-0.10	-0.05	-0.04	0.01	0.03	0.05	0.02
L2	Z1	0.16	0.10	0.11	0.18	0.19	0.19	-0.03	0.02	0.08	0.03
L2	Z2, Z3	0.18	0.14	0.14	0.17	0.21	0.21	0.00	0.06	0.11	0.05
L3	Z1, Z2	0.25	0.22	0.19	0.16	0.26	0.23	-0.01	0.05	0.10	0.03
L3	Z3	0.03	0.03	0.02	-0.02	0.07	0.05	-0.12	-0.07	-0.04	-0.07
L4	Z1, Z2	-0.04	-0.02	-0.04	-0.02	0.03	0.03	0.23	0.21	0.19	0.16
L4	Z3	-0.04	-0.02	-0.03	-0.02	0.03	0.03	-0.01	0.00	0.00	-0.01
L5	Z1, Z2	-0.05	-0.03	-0.04	-0.02	-0.02	0.00	0.09	0.08	0.07	0.06
L5	Z3	-0.02	-0.01	-0.01	-0.01	0.00	0.02	0.08	0.08	0.06	0.05
Country		0.06	0.05	0.04	0.05	0.10	0.10	0.03	0.06	0.08	0.05

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: net change in dead wood (changeC <sub>d,i</sub> ) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	0.11	0.06	-0.02	0.05	0.02	0.06	0.01	0.03	0.08	0.11
L1	Z2	0.20	0.12	0.07	0.11	0.08	0.08	0.07	0.08	0.19	0.20
L1	Z3	0.06	0.00	0.00	0.02	0.01	-0.02	0.00	0.00	0.23	0.22
L2	Z1	0.13	0.07	-0.02	0.05	0.01	0.05	-0.02	0.02	0.03	0.04
L2	Z2, Z3	0.16	0.07	0.00	0.06	0.01	0.04	0.00	0.02	0.01	0.03
L3	Z1, Z2	0.13	0.02	0.00	0.07	0.00	-0.01	0.02	0.00	0.25	0.23
L3	Z3	0.00	-0.08	-0.07	-0.03	-0.06	-0.07	-0.04	-0.05	0.03	0.03
L4	Z1, Z2	0.20	0.12	0.09	0.14	0.09	0.07	0.09	0.06	0.10	0.11
L4	Z3	0.03	-0.02	-0.03	0.01	-0.01	-0.02	0.00	-0.02	-0.03	-0.02
L5	Z1, Z2	0.07	0.05	0.04	0.05	0.03	0.04	0.04	0.03	-0.05	-0.05
L5	Z3	0.06	0.05	0.04	0.04	0.03	0.03	0.04	0.03	0.17	0.16
Country		0.10	0.04	0.01	0.05	0.02	0.02	0.02	0.02	0.07	0.08

NFI	Elev.	2020	2021	2022	2023
CC12: net change in dead wood (changeC <sub>d,i</sub> ) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]					
L1	Z1	0.11	0.10	0.10	-0.04
L1	Z2	0.19	0.22	0.16	0.04
L1	Z3	0.20	0.21	0.14	0.10
L2	Z1	0.05	0.07	0.07	-0.10
L2	Z2, Z3	0.03	0.08	0.04	-0.11
L3	Z1, Z2	0.21	0.26	0.16	0.02
L3	Z3	0.04	0.06	0.01	-0.03
L4	Z1, Z2	0.13	0.16	0.13	0.00
L4	Z3	0.01	0.03	0.02	-0.06
L5	Z1, Z2	-0.03	-0.01	-0.01	-0.04
L5	Z3	0.16	0.16	0.16	0.09
Country		0.09	0.11	0.08	-0.02

(Table 6-18 continued)

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC12: net change in litter (changeCh,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	-0.22	0.18	-0.21	0.10	-0.37	-0.13	0.53	0.14	0.00	-0.26
L1	Z2	-0.17	0.18	-0.15	0.12	-0.34	-0.04	0.58	0.12	0.12	-0.15
L1	Z3	-0.29	-0.06	-0.21	0.00	-0.34	-0.04	0.44	0.02	0.13	-0.05
L2	Z1	-0.25	0.18	-0.17	0.05	-0.39	-0.10	0.46	0.14	-0.01	-0.27
L2	Z2, Z3	-0.23	0.17	-0.16	0.07	-0.38	-0.05	0.47	0.09	0.05	-0.23
L3	Z1, Z2	-0.15	0.19	-0.10	0.11	-0.35	0.04	0.56	0.07	0.13	-0.14
L3	Z3	-0.12	0.13	-0.09	0.15	-0.32	0.09	0.58	0.03	0.22	-0.03
L4	Z1, Z2	-0.06	0.14	-0.05	0.11	-0.17	0.08	0.49	0.17	0.17	-0.11
L4	Z3	0.07	0.20	0.01	0.20	-0.14	0.19	0.50	0.21	0.24	-0.07
L5	Z1, Z2	0.09	0.08	0.08	0.09	-0.12	0.18	0.49	0.24	0.20	0.13
L5	Z3	0.13	0.12	0.05	0.12	-0.14	0.24	0.56	0.27	0.26	0.17
Country		-0.09	0.16	-0.08	0.12	-0.27	0.06	0.52	0.15	0.15	-0.11

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: net change in litter (changeCh,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	0.02	-0.14	-0.11	0.22	0.18	0.17	-0.41	-0.12	0.02	-0.09
L1	Z2	0.06	-0.06	-0.06	0.07	0.22	0.21	-0.25	0.01	0.18	0.01
L1	Z3	0.00	-0.01	0.00	-0.14	0.21	0.18	-0.07	0.14	0.23	0.05
L2	Z1	-0.06	-0.18	-0.10	0.16	0.18	0.17	-0.39	-0.19	-0.02	-0.12
L2	Z2, Z3	-0.06	-0.13	-0.08	0.06	0.23	0.18	-0.40	-0.16	0.01	-0.13
L3	Z1, Z2	-0.02	-0.05	-0.08	-0.11	0.28	0.15	-0.31	-0.08	0.07	-0.15
L3	Z3	0.06	0.02	0.00	-0.23	0.31	0.19	-0.32	-0.03	0.11	-0.14
L4	Z1, Z2	0.00	0.04	-0.07	0.06	0.30	0.24	0.04	0.06	0.10	0.03
L4	Z3	-0.02	0.10	-0.03	0.05	0.35	0.31	0.07	0.10	0.08	0.06
L5	Z1, Z2	0.05	0.19	0.00	0.14	0.19	0.40	0.15	0.14	0.04	-0.02
L5	Z3	0.08	0.20	0.05	0.10	0.26	0.51	0.19	0.23	0.11	0.04
Country		0.00	0.00	-0.05	0.04	0.27	0.25	-0.14	0.00	0.07	-0.03

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: net change in litter (changeCh,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	0.16	-0.01	-0.28	0.01	-0.09	0.07	-0.11	0.00	-0.17	0.00
L1	Z2	0.34	-0.05	-0.21	0.06	-0.06	-0.05	-0.04	0.04	-0.20	0.01
L1	Z3	0.36	-0.06	-0.09	0.09	-0.01	-0.14	0.00	0.02	-0.10	0.05
L2	Z1	0.16	-0.01	-0.23	0.00	-0.12	0.01	-0.15	-0.01	-0.10	-0.05
L2	Z2, Z3	0.21	-0.06	-0.24	0.01	-0.15	-0.05	-0.12	-0.04	-0.07	-0.01
L3	Z1, Z2	0.21	-0.20	-0.19	0.08	-0.19	-0.19	-0.05	-0.11	0.13	0.15
L3	Z3	0.27	-0.28	-0.17	0.07	-0.14	-0.25	-0.04	-0.12	0.04	0.08
L4	Z1, Z2	0.29	-0.07	-0.11	0.13	-0.08	-0.09	0.02	-0.08	-0.04	0.05
L4	Z3	0.33	-0.08	-0.14	0.12	-0.03	-0.12	0.06	-0.07	0.04	0.09
L5	Z1, Z2	0.19	0.03	-0.03	0.06	-0.09	-0.01	0.06	-0.03	0.22	0.17
L5	Z3	0.26	0.01	-0.03	0.10	-0.02	-0.04	0.08	-0.02	0.19	0.17
Country		0.26	-0.08	-0.16	0.07	-0.09	-0.09	-0.02	-0.05	0.00	0.07

NFI	Elev.	2020	2021	2022	2023
CC12: net change in litter (changeCh,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]					
L1	Z1	0.01	0.00	0.05	-0.32
L1	Z2	0.03	0.15	-0.01	-0.35
L1	Z3	0.06	0.24	-0.10	-0.22
L2	Z1	-0.03	0.03	0.03	-0.34
L2	Z2, Z3	-0.03	0.11	0.00	-0.37
L3	Z1, Z2	0.12	0.30	0.01	-0.30
L3	Z3	0.15	0.34	-0.09	-0.28
L4	Z1, Z2	0.13	0.23	0.13	-0.31
L4	Z3	0.23	0.36	0.23	-0.31
L5	Z1, Z2	0.23	0.31	0.30	-0.13
L5	Z3	0.26	0.38	0.33	-0.15
Country		0.12	0.24	0.10	-0.29

(Table 6-18 continued)

NFI	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC12: net change in mineral soil (changeCs,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	0.009	-0.001	0.008	0.002	0.009	0.008	-0.002	0.004	0.010	0.018
L1	Z2	0.011	0.002	0.010	0.006	0.011	0.009	0.000	0.008	0.009	0.016
L1	Z3	0.002	-0.003	0.000	-0.003	0.000	-0.003	-0.010	-0.004	-0.005	-0.001
L2	Z1	0.008	-0.003	0.004	0.002	0.007	0.005	-0.005	0.000	0.005	0.014
L2	Z2, Z3	0.009	-0.002	0.005	0.003	0.008	0.005	-0.003	0.003	0.005	0.015
L3	Z1, Z2	0.016	0.008	0.014	0.012	0.017	0.013	0.007	0.015	0.015	0.024
L3	Z3	0.017	0.012	0.015	0.012	0.019	0.013	0.006	0.015	0.012	0.019
L4	Z1, Z2	0.018	0.014	0.018	0.016	0.019	0.016	0.011	0.016	0.017	0.025
L4	Z3	0.015	0.012	0.016	0.014	0.019	0.014	0.009	0.013	0.013	0.022
L5	Z1, Z2	0.019	0.019	0.020	0.021	0.023	0.018	0.020	0.024	0.025	0.028
L5	Z3	0.014	0.014	0.016	0.016	0.019	0.012	0.013	0.017	0.018	0.021
Country		0.013	0.007	0.012	0.010	0.015	0.011	0.005	0.011	0.012	0.020

NFI	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC12: net change in mineral soil (changeCs,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	0.007	0.015	0.014	-0.006	0.007	0.007	0.017	0.011	0.007	0.007
L1	Z2	0.009	0.014	0.013	0.001	0.007	0.006	0.017	0.013	0.010	0.011
L1	Z3	-0.004	-0.002	-0.004	-0.008	-0.007	-0.007	-0.002	-0.004	-0.005	-0.004
L2	Z1	0.005	0.012	0.008	-0.009	0.002	0.002	0.009	0.006	0.001	0.001
L2	Z2, Z3	0.007	0.013	0.010	-0.005	0.003	0.004	0.012	0.009	0.005	0.005
L3	Z1, Z2	0.018	0.022	0.022	0.015	0.014	0.018	0.022	0.019	0.015	0.018
L3	Z3	0.014	0.017	0.017	0.016	0.010	0.014	0.015	0.011	0.007	0.011
L4	Z1, Z2	0.020	0.021	0.023	0.013	0.013	0.015	0.017	0.020	0.020	0.019
L4	Z3	0.019	0.017	0.020	0.012	0.010	0.011	0.013	0.014	0.016	0.014
L5	Z1, Z2	0.029	0.025	0.030	0.021	0.025	0.019	0.027	0.027	0.032	0.032
L5	Z3	0.023	0.020	0.023	0.018	0.018	0.011	0.016	0.016	0.020	0.021
Country		0.015	0.017	0.017	0.007	0.010	0.010	0.015	0.014	0.013	0.013

NFI	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC12: net change in mineral soil (changeCs,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
L1	Z1	0.005	0.003	0.015	0.008	0.007	-0.002	0.009	0.003	0.000	0.000
L1	Z2	0.007	0.012	0.020	0.015	0.014	0.010	0.015	0.010	0.013	0.011
L1	Z3	-0.007	-0.003	0.002	-0.001	-0.002	-0.002	-0.002	-0.004	-0.006	-0.006
L2	Z1	-0.002	-0.003	0.007	0.002	0.002	-0.007	0.004	-0.004	-0.008	-0.004
L2	Z2, Z3	0.001	0.001	0.011	0.006	0.007	-0.002	0.007	0.001	-0.001	0.003
L3	Z1, Z2	0.014	0.018	0.021	0.016	0.020	0.015	0.016	0.016	0.007	0.011
L3	Z3	0.005	0.012	0.012	0.007	0.010	0.009	0.007	0.008	0.010	0.011
L4	Z1, Z2	0.017	0.022	0.026	0.020	0.025	0.022	0.022	0.024	0.020	0.021
L4	Z3	0.011	0.016	0.020	0.014	0.016	0.015	0.014	0.016	0.016	0.016
L5	Z1, Z2	0.029	0.030	0.032	0.031	0.035	0.030	0.030	0.031	0.026	0.029
L5	Z3	0.018	0.020	0.023	0.020	0.023	0.020	0.020	0.021	0.021	0.023
Country		0.010	0.013	0.018	0.013	0.015	0.011	0.014	0.012	0.010	0.012

NFI	Elev.	2020	2021	2022	2023
CC12: net change in mineral soil (changeCs,i) [t C ha <sup>-1</sup> yr <sup>-1</sup> ]					
L1	Z1	-0.001	0.007	-0.008	0.006
L1	Z2	0.010	0.014	0.006	0.019
L1	Z3	-0.007	-0.005	-0.007	-0.001
L2	Z1	-0.005	0.000	-0.014	0.000
L2	Z2, Z3	0.003	0.006	-0.005	0.009
L3	Z1, Z2	0.013	0.014	0.010	0.022
L3	Z3	0.010	0.010	0.010	0.019
L4	Z1, Z2	0.019	0.019	0.013	0.029
L4	Z3	0.012	0.012	0.007	0.025
L5	Z1, Z2	0.028	0.027	0.021	0.035
L5	Z3	0.021	0.020	0.015	0.031
Country		0.010	0.012	0.005	0.020

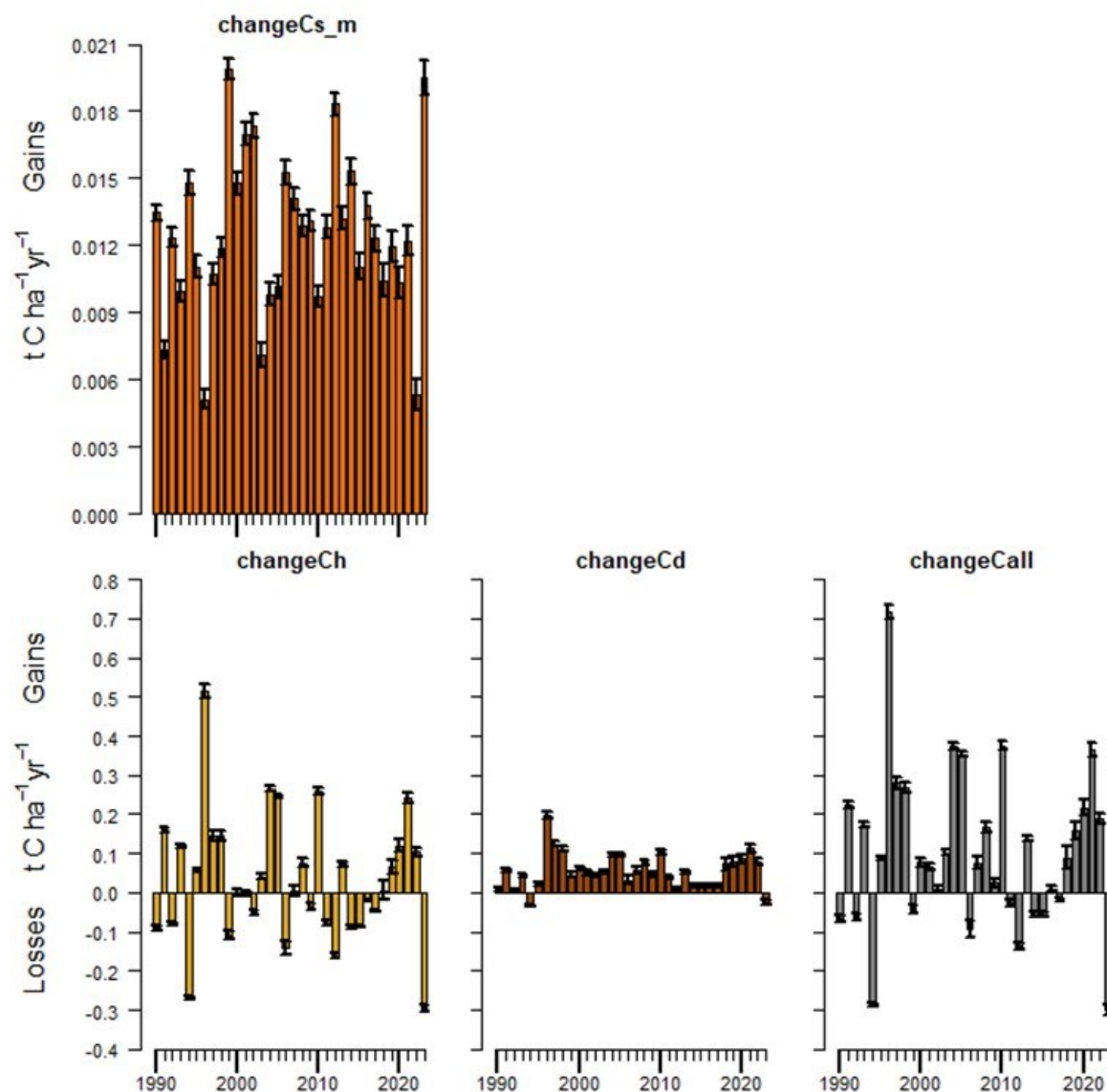


Figure 6-9 Mean carbon stock changes for three pools mineral soil ( $\text{changeCs}_m$ , 0–100 cm), litter ( $\text{changeCh}$ ), dead wood ( $\text{changeCd}$ ) and their sum ( $\text{changeCall}$ ) in  $\text{t C ha}^{-1} \text{yr}^{-1}$  over the inventory period. Note the difference of the y-axis scales. Negative values indicate losses in carbon stock, positive values indicate gains in carbon stock. The error bars indicate the double standard error.

#### 6.4.2.2.2.9. Carbon stock changes in organic soil

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 soil by comparing information on drainage from NFI plots with spatial data of organic soil in Switzerland produced by Wüst-Galley et al. (2015): 3 % of organic soil on Forest land appeared to be subject to drainage.

For the calculation of carbon stock changes in organic soil, the default emission factor of  $2.6 \text{ t C ha}^{-1} \text{yr}^{-1}$  was applied for the land-use category productive forest (CC12; Table 6-4) according to the Wetlands Supplement (IPCC 2014a: Table 2.1).

### 6.4.2.3. Unproductive forest

#### 6.4.2.3.1. Data sources

Unproductive forests encompass brush forest, inaccessible stands and unproductive forests not covered by the NFI. Currently the data to estimate carbon stocks and particularly carbon stock changes are limited.

#### 6.4.2.3.2. Carbon stocks in living biomass

- Brush forest: Brush forests in Switzerland mainly consist of *Alnus viridis*, horizontal *Pinus mugo* subsp. *mugo* with a percentage cover of 65 % and 16 %, respectively (Düggelin and Abegg 2011: Table 1). Following the NFI definition, brush forests are dominated by more than two thirds by shrubs. In a case study, Düggelin and Abegg (2011) analysed the carbon stock of living biomass of woody shrub species in Swiss brush forests and found an average value of 20.45 t C ha<sup>-1</sup>.
- Inaccessible stands: Inaccessible stands are considered the same as 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<sup>3</sup> ha<sup>-1</sup> 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<sup>-1</sup> was estimated, which corresponds to 51.38 t C ha<sup>-1</sup> (using a carbon content of 50 %; see chp. 6.4.2.1.3).

The carbon stock of living biomass (C<sub>l</sub>) 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:

$$\text{stockC}_{l,i,CC13} = F_i * \text{stockC}_{l,i,CC13bi} + (1 - F_i) * \text{stockC}_{l,i,CC13u}$$

where:

- $F_i$  is the fraction of the brush and inaccessible forest per spatial stratum  $i$ ;
- $\text{stockC}_{l,i,CC13bi}$  is the carbon stock in brush and inaccessible forest (20.45 t C ha<sup>-1</sup>);
- $\text{stockC}_{l,i,CC13u}$  is the carbon stock in unproductive forest not covered by NFI (51.38 t C ha<sup>-1</sup>).

Table 6-19 shows the resulting carbon stocks in living biomass of the land-use category unproductive forest per spatial stratum in t C ha<sup>-1</sup>. The data was transferred to Table 6-4.



Table 6-19 Area of brush forest, inaccessible 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 ( $\text{t C ha}^{-1}$ ) for the land-use category unproductive forest (CC13) specified for all spatial strata ( $\text{stockC}_{i,i,\text{CC13}}$ ).

NFI region	Elevation [m]	Brush forest [ha]	Inaccessessible 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 ( $\text{stockC}_{i,i,\text{CC13}}$ ) [ $\text{t C ha}^{-1}$ ]
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

#### 6.4.2.3.3. Carbon stocks in dead wood

Carbon stocks in dead wood, litter and mineral soil under unproductive forest reveal a high spatial heterogeneity, and specific data are not available.

Dead wood on unproductive forest stands was assumed to be zero (Table 6-4).

#### 6.4.2.3.4. Carbon stocks in litter

Carbon stocks in litter in the land-use category unproductive forest were assigned to the mean value of the modelled CC12 litter stocks for the inventory period 1990–2021 (see FOEN 2023: chp. 6.4.2.4.4). Data is given in Table 6-4.

#### 6.4.2.3.5. Carbon stocks in mineral soil

Carbon stocks in mineral soil in the land-use category unproductive forest were taken from Nussbaum and Burgos (2021) (see description in chp. 6.4.2.2.2.4). Data is given in Table 6-4.

#### 6.4.2.3.6. Carbon stocks in organic soil

The mean soil organic carbon stock (0–30 cm) for organic soil in the land-use category unproductive forest is  $145.6 \pm 24.1 \text{ t C ha}^{-1}$  (Wüst-Galley et al. 2016) (Table 6 4).

#### **6.4.2.3.7. Carbon stock changes in living biomass**

For unproductive forests not covered by NFI and inaccessible stands no NFI data are available. For brush forests there are only few case studies and, similar to mountainous neighbouring countries, only incomplete forest inventory data available. As no harvesting is conducted in unproductive forests, gross growth and cut and mortality of these forest were assumed to be in equilibrium (Tier 1 approach). This approach is transcribed into “ $\text{gainC}_{l,i,13} = \text{lossC}_{l,i,13} = 0$ ” and reported as NA in Table 6-4 and CRT Table 4.A.

#### **6.4.2.3.8. Carbon stock changes in dead wood, litter and mineral soil**

Applying a Tier 1 approach, carbon stock changes in dead wood, litter, and mineral soil were assumed to be in equilibrium for unproductive forest. This approach is transcribed into “ $\text{changeC}_{d,i,13} = \text{changeC}_{h,i,13} = \text{changeC}_{s,i,13} = 0$ ” and reported as NA in Table 6-4 and CRT Table 4.A.

#### **6.4.2.3.9. Carbon stock changes in organic soil**

3 % of organic soil on Forest land is assumed to be subject to drainage (see chp. 6.4.2.2.9; Abegg 2017). For the calculation of carbon stock changes in organic soil, the default emission factor of  $2.6 \text{ t C ha}^{-1} \text{ yr}^{-1}$  was applied for the land-use category unproductive forest (Table 6-4) according to the Wetlands Supplement (IPCC 2014a: Table 2.1).

#### **6.4.2.4. Land-use change**

In the case of land-use change, the net carbon stock changes in biomass and soils of land-use categories productive forest and unproductive forest were calculated as described in chp. 6.1.3.

#### **6.4.2.5. Non-CO<sub>2</sub> emissions from Forest land**

##### **6.4.2.5.1. Direct and indirect N<sub>2</sub>O emissions from N inputs to managed soils**

Fertilisation 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 Chemical Risk Reduction Ordinance (Swiss Confederation 2005: Art. 4) prohibits the application of fertilisers, including liming, in forests. Hence, the application of fertilisers, 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. Additionally, the reporting of N<sub>2</sub>O emissions from fertiliser application in the Agriculture sector encompasses all fertilisers applied in Switzerland. Therefore, no emissions were reported in category A in CRT Table 4(I) (notation key NO).

#### **6.4.2.5.2. *N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage of organic soil***

N<sub>2</sub>O emissions from drainage of organic soil was calculated for Forest land with an emission factor of 2.8 kg N<sub>2</sub>O-N ha<sup>-1</sup> for 3 % of the area of organic soil (see chp. 6.4.2.2.2.9 and chp. 6.4.2.3.9) and reported in category A(II)A1 in CRT Table4(II). The emission factor used is the default value given in the Wetlands Supplement (IPCC 2014a: Table 2.5) for temperate forest land.

CH<sub>4</sub> emissions in category 4(II)A1 Forest land remaining forest land were not estimated (notation key NE) as reporting is not mandatory for this category.

#### **6.4.2.5.3. *Direct and indirect N<sub>2</sub>O emissions from mineral soils***

The calculations of direct and indirect N<sub>2</sub>O emissions from nitrogen mineralisation in mineral soil (category 4(III)A) in Forest land are described in Annex A5.4.

#### **6.4.2.5.4. *CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning***

##### **6.4.2.5.4.1. *Controlled burning***

Emissions from controlled burning on Forest land covers the burning of harvest residues only since controlled burning of whole forest stands is not allowed in Switzerland.

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 was performed in order to assess the activity data for these processes.

CH<sub>4</sub> and N<sub>2</sub>O 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 were calculated by multiplying the annual estimate of residues burnt (in kt, see FOEN 2025b: chp. 7.3) by emission factors as documented in EMIS 2025/5C2: 6.8 kg t<sup>-1</sup> for CH<sub>4</sub> and 0.180 kg t<sup>-1</sup> for N<sub>2</sub>O.

CO<sub>2</sub> emissions from controlled burning were noted IE in the CRT Table4(IV).A.1 and are encompassed in the data in CRT Table4.A since carbon losses in living biomass are reflected in the NFI data set.

The emission factors of CH<sub>4</sub> and N<sub>2</sub>O of burning of residues from forestry were calculated based on the EMEP/EEA guidebook (EMEP/EEA 2023, chapter 5C2), see also documentation in EMIS 2025/5C2\_4VA1 Abfallverbrennung Land- und Forstwirtschaft (Waste incineration in agriculture and forestry).

##### **6.4.2.5.4.2. *Wildfires***

Data on wildfires affecting Forest land were obtained from cantonal authorities and were compiled by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL, Swissfire database, <http://www.wsl.ch/swissfire>). These data are updated regularly based on analysing data from cantonal archives (Pezzatti et al. 2019). Table 6-20 shows the time series of affected areas and associated CH<sub>4</sub> and N<sub>2</sub>O emissions.

As controlled burning of forest stands is not allowed in Switzerland all fires in forests were considered wildfires. All fires were assigned to the land-use category productive forest. This approach reflects reality quite well, since fires in land-use category unproductive forest are rather unlikely to occur because the available fuel is small since tree cover is not very dense and there is very little dead woody material on the surface which can catch fire (Zumbrunnen et al. 2012). Moreover, in remote areas the cause of fire is restricted to lightning strikes.

CO<sub>2</sub> emissions from wildfires were noted IE in CRT Table4(IV).A and are encompassed in the data in CRT Table4.A. since carbon losses in living biomass are reflected in the NFI data set. Carbon changes in dead wood, litter and mineral soil calculated with Yasso20 also cover the influence of forest fires and other disturbances by using NFI data as an input (see Didion 2023: chp. 2.4.2).

CH<sub>4</sub> and N<sub>2</sub>O emissions from wildfires (Table 6-20) were calculated using equation 2.27 in Volume 4 of IPCC (2019) with the following parameters:

- For CH<sub>4</sub> the default emission factor of 4.7 g kg<sup>-1</sup> dry matter burnt and for N<sub>2</sub>O, the default emission factor of 0.26 g kg<sup>-1</sup> dry matter burnt were applied (IPCC 2019, Volume 4, Table 2.5).
- The mass of available fuel encompasses carbon stocks in living biomass, dead wood, and litter. A continuous time series of the mass of available fuel was derived from NFI data for living biomass (see chp. 6.4.2.2.1.2) and from Yasso20 modelled data for dead wood and litter (see chp. 6.4.2.2.2.2 and chp. 6.4.2.2.2.3).
- The fraction of the biomass combusted was 0.45 (IPCC 2019, Volume 4, Table 2.6).

CH<sub>4</sub> and N<sub>2</sub>O emissions caused by wildfires are reported in category A1 in CRT Table4(IV), 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(IV)A2 is labelled as IE.

Table 6-20 Forest land affected by wildfires (WSL, Swissfire database) and resulting CH<sub>4</sub> and N<sub>2</sub>O emissions.

Forest land	Unit	1990	1995	2000	2005	2010
Area burnt	ha	1'067	363	58	41	42
CH <sub>4</sub>	t	614	216	34	25	25
N <sub>2</sub> O	t	34	12	1.9	1.4	1.4

Forest land	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Area burnt	ha	43	45	256	110	58	17	15	27	274	197
CH <sub>4</sub>	t	26	27	154	66	35	9.9	9.0	16	164	118
N <sub>2</sub> O	t	1.4	1.5	8.5	3.6	1.9	0.55	0.50	0.88	9.1	6.5

#### 6.4.2.5.5. Precursor gas emissions (NO<sub>x</sub>, CO, NMVOC)

CRT Table4 presents emissions of NO<sub>x</sub>, CO and NMVOC from 4(IV)A Controlled burning of residues from forestry and from 4(IV)A Wildfires on Forest land as described by FOEN (2025b: chp. 7.3). In addition, CRT Table4 includes the annual biogenic emissions of NMVOC from the forest stands as shown in FOEN (2025b: chp. 7.4).

The biogenic NMVOC emissions from forest stands were calculated for the years 1900–2022 and 2050 on the basis of monthly maps for the parameters temperature, vegetation period and for 12 different tree species (Meteotest 2019a and EMIS 2025/11C Wald (Forest)). The

year 2023 was interpolated between 2022 and 2050. This corresponds to the simplified method according to chp. 11C in the EMEP/EEA guidebook (EMEP/EEA 2023).

In 1990, NMVOC emissions from forest stands were 60.83 kt; from 1990 to 2022 these emissions increased on average by 0.66 % per year. The emissions from burning of residues in forestry and from wildfires (FOEN 2025b: chp. 7.3) are much smaller; they fluctuated between 0.02 and 0.73 kt over the same period.

### 6.4.3. Uncertainties and time-series consistency for 4A

#### 6.4.3.1. Uncertainties

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

##### 6.4.3.1.1. Activity data

Uncertainties of activity data of category 4A Forest land are described in chp. 6.3.1.3.1.

##### 6.4.3.1.2. Carbon stock change factors

Uncertainties were estimated for the pools living biomass, dead wood, litter and soil. One source of uncertainty common to all pools is the error resulting from the estimates of changes in the pools between two NFIs based on shifting samples of sample plots common to NFI3 and five-year NFI4 subsets (see chp. 6.4.2.1.1.2), i.e. 2009–2011 (GHG inventory submission 2013), 2009–2012 (GHG inventory submission 2014), 2009–2013 (GHG inventory submissions 2015 and 2016), 2011–2015 (GHG inventory submissions 2017 and 2018), and 2013–2017 (GHG inventory submissions 2019 and 2020). This was taken into account to obtain a multi-annual uncertainty estimate.

#### Living biomass

Sources of uncertainty (relative uncertainty, 2 SE) considered are:

- NFI sampling between NFIs 3 and 5-year NFI4 subsets: 30.2 %
- Carbon content in solid wood: 2 % based on 2 % relative standard deviation (RSD) in Monni et al. (2007) and 4-8 % RSD in Lamtom and Savidge (2003)
- Biomass expansion function (for Forest land allometric functions for individual trees were applied) and conversion into mass with wood density: 21.2 % sampling uncertainty and 22.2 % model uncertainty; based on Lehtonen and Heikkinen (2016).

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):

$$U_{liv.biom} = \sqrt{30.2^2 + 2^2 + 21.2^2 + 22.2^2} = 43.1 \%$$

## Dead wood, litter, soil

In the Monte Carlo simulation approach described in Didion (2020a: chp. 2.3) the following sources of uncertainty were considered:

- NFI sampling between NFIs 3 and 5-year NFI4 subsets
- Carbon input estimates obtained from the NFI (measurement errors, allometries, etc.)
- Decomposition parameters used in the Yasso07 model.

The resulting relative uncertainties are:

- $U_{\text{Soil}} = 37.0 \%$
- $U_{\text{Litter}} = 96.7 \%$
- $U_{\text{Dead wood}} = 16.6 \%$ .

## Overall uncertainty categories 4A1 and 4A2

The total uncertainty associated with carbon stock change in all four pools was estimated using equation 3.2 in chp. “Quantifying Uncertainties” (IPCC 2006, Volume 1):

$$U_{\text{tot}} = \frac{\sqrt{(U_{\text{liv.biom}} * X_{\text{liv.biom}})^2 + (U_{\text{soil}} * X_{\text{soil}})^2 + (U_{\text{Litter}} * X_{\text{Litter}})^2 + (U_{\text{Deadwood}} * X_{\text{Deadwd}})^2}}{|X_{\text{liv.biom}} + X_{\text{soil}} + X_{\text{Litter}} + X_{\text{Deadwood}}|}$$

with long-term mean carbon stock changes based on Didion et al. (2023) and Didion (2023) in

- living biomass ( $X_{\text{liv.biom}}$ ):  $0.474 \text{ t C ha}^{-1} \text{ yr}^{-1}$
- soil ( $X_{\text{Soil}}$ ):  $0.012 \text{ t C ha}^{-1} \text{ yr}^{-1}$
- litter ( $X_{\text{Litter}}$ ):  $0.042 \text{ t C ha}^{-1} \text{ yr}^{-1}$
- dead wood ( $X_{\text{Deadwood}}$ ):  $0.058 \text{ t C ha}^{-1} \text{ yr}^{-1}$

where positive values refer to gains in carbon stock and negative values refer to losses in carbon stock.

The resulting relative uncertainty of the total carbon stock change for Forest land is 34.9 %. This value is used for categories 4A1 and 4A2 for the whole inventory period (see Table 6-5).

## Organic soil

The CO<sub>2</sub> emissions from drained organic forest soils are very small and were neglected in the uncertainty calculation.

### 6.4.3.1.3. Uncertainties in category 4(II) Drainage of organic soil (N<sub>2</sub>O)

The contribution of Forest land (category 4(II)A) to N<sub>2</sub>O emissions from drained organic soil is small (around 5 %). Its uncertainty was included in the uncertainty calculation for Wetlands (see chp. 6.7.3.1.4).

#### **6.4.3.1.4. Uncertainties in category 4(IV) Biomass burning ( $CH_4$ , $N_2O$ )**

The emission factor uncertainty for category 4(IV)A is 70 %. It is derived from 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. 6.3.1.3.3 and Table 6-5).

#### **6.4.3.2. Time-series consistency**

Consistent time series of annual carbon stocks in living biomass were calculated forward starting from the growing stock in 1985 (see chp. 6.4.2.2.1.4).

Consistent time series of annual carbon stocks in dead wood and litter were calculated with the model Yasso20 (see chp. 6.4.2.2.2.2 and chp. 6.4.2.2.2.3).

### **6.4.4. Category-specific QA/QC and verification for 4A**

The general QA/QC measures are described in chp. 1.5.

#### **6.4.4.1. Living biomass – omission of trees <12 cm DBH and of non-tree understory vegetation**

In Forest land, trees with DBH <12 cm and non-tree understory vegetation are not considered (see chp. 6.4.2.1.1.3). The omission is justified because of their negligible effect on carbon stocks and carbon stock changes in living biomass, dead wood, litter, and soil in productive forests in Switzerland (justification in response to UNFCCC 2022, ID#L.4). In detail:

- Trees with DBH <12 cm contribute only little to total forest biomass and carbon stock (Peichl and Arain 2006). Dunger et al. (2012) estimated this contribution to 1–2 % for forests with similar forest structure as common in Switzerland. Their contribution to annual litter production and hence to carbon stock changes in dead wood, litter, and soil is small compared to mature trees with larger diameters (He et al. 2012).
- Carbon gains in biomass of trees with BDH <12 cm are implicitly accounted for in the trees above this threshold as the cumulative carbon uptake. This is a statistically valid and accurate approach, particularly for the gain/loss approach applied by Switzerland ensuring that carbon stock change factors are neither over- nor underestimated.
- Biomass of non-tree understory vegetation presents <1 % of the above ground biomass carbon pool in the Swiss NFI (Didion 2020b), and thus has a negligible contribution to annual litter production. Consistent with the inventory guidelines (IPCC 2006, Volume 4, Annex 4A.1), it can therefore be excluded from the inventory.

#### **6.4.4.2. Carbon stocks in mineral soil**

The trend of a minor increase in soil carbon stocks since 1990, based on the Yasso20 simulations (chp. 6.4.2.2.2.8 and Figure 6-9), supports the assumption that carbon stocks from Nussbaum and Burgos (2021) are representative of mineral soil in the land-use category productive forest and can be considered constant for the whole inventory period (chp. 6.4.2.2.2.4).



#### 6.4.4.3. 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 L2), and at a subalpine coniferous forest over 12 years (Davos; 1997–2009; NFI production region L4).

(1) Etzold et al. (2011) determined the 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. NEE of the Lägeren forest ranged from  $-366$  to  $-662$  g C m<sup>-2</sup> yr<sup>-1</sup> (mean:  $-415$  g C m<sup>-2</sup> yr<sup>-1</sup>), and of the Davos forest from  $-47$  to  $-274$  g C m<sup>-2</sup> yr<sup>-1</sup> (mean:  $-154$  g C m<sup>-2</sup> yr<sup>-1</sup>).

(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).

#### 6.4.4.4. Carbon stock changes in mineral soil – Soil organic carbon (SOC) data set 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, such as concentrations of harmful substances, organic carbon, the microbiology, and its development over time (Gross et al. 2024). NABO operates about 110 long-term monitoring sites throughout Switzerland covering all relevant land uses, such as cropland, grassland, and forest. Most of the monitoring sites were sampled for the first time between 1985 and 1989 and resampled every five years ever since (SAEFL 1993, 2000a; Meuli et al. 2014; Gubler et al. 2015; Gross et al. 2024).

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 Gubler et al. (2015). Currently, results of sampling campaigns 1 to 7 are available for the cultivation types forest, grassland and cropland (Gross et al. 2024).

The spatial variation of bulk density was included in calculating the carbon stocks. Bulk density and soil skeleton (fragments >2 mm) were measured repeatedly for all monitoring sites at the occasion of sampling campaigns 4 to 7 (2000–2019), 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 stocks (t C / ha) in 0–20 cm depth were calculated as  $D$  (g/cm<sup>3</sup>) \* SOC (%) \* 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 data presented here are based on samples collected from 1985 to 2019 at 28 forest sites (NABO 2021). SOC stocks for the top 20 cm of forest soils ranged from 41 to 149 t C

ha<sup>-1</sup> with a mean of 72 t C ha<sup>-1</sup>. Few sites have stocks higher than 90 t C ha<sup>-1</sup> (Figure 6-10 top panel). There were no significant changes in SOC stocks over time except for the periods between the second and third, and the third and fourth sampling campaigns due to the exceptionally high SOC stocks in the third campaign (Figure 6-10 bottom panel). Previous NABO studies showed that the elevated SOC stocks for the third sampling campaign must be considered as artefact, induced by sub-optimal conditions during field work (Meuli et al. 2014; Gubler et al. 2015). These samples were collected earlier in the year and, thus, soils were moister. It is known that soil carbon has a high natural variation which may be pronounced if soil moisture differences are high. For instance, six resamplings within three years at two forest sites revealed short-term variation of SOC contents between  $\pm 1.8\%$  and  $\pm 0.6\%$  (single standard errors; Keller et al. 2006).

The monitoring scheme applied by NABO is able to detect relative changes in SOC contents of roughly 2.5 % per 10 years for mineral forest soils (minimum detectable change for 30 monitoring sites including three or more sampling campaigns). Regarding the measured SOC stocks (mean 72 t ha<sup>-1</sup>), this corresponds to a minimum detectable change of roughly 0.18 t C ha<sup>-1</sup> yr<sup>-1</sup> for SOC stocks. In comparison, the mean change in SOC stocks obtained with Yasso07 for the period 1991–2010 was  $-0.00075 \pm 0.00053$  t C ha<sup>-1</sup> yr<sup>-1</sup> (2SE; based on data in Didion and Thürig 2017). This value is several orders of magnitude smaller than the minimum detectable change that can be identified in the NABO monitoring scheme.

In conclusion, NABO data indicate that mineral soils on Forest land acted neither as a significant net source nor as a significant net sink of carbon when considered over the entire inventory period.

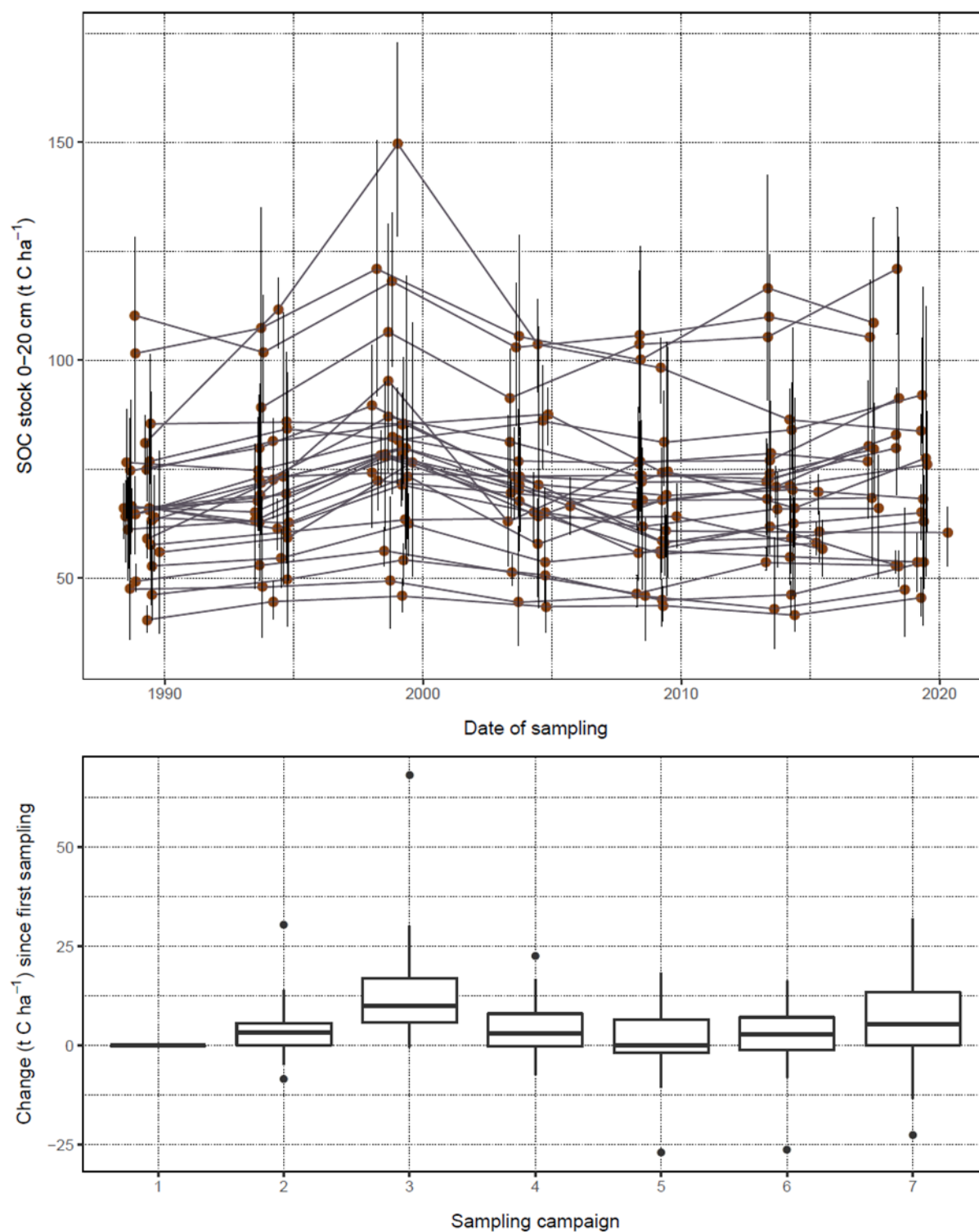


Figure 6-10 Measured SOC stocks for topsoils (0–20 cm) and their changes for 28 NABO long-term monitoring sites in forest during the period 1985–2019. The elevation of the sites ranges from 383 to 1690 m a.s.l. Top panel: SOC stocks 0–20 cm per site and sampling; the dots indicate the mean and the bars the range of 5 % and 95 % percentiles of bootstrap samples taking into account the variability in SOC content of the individual replicates per site and sampling as well as the variations of the bulk density. Bottom panel: boxplot of changes in SOC stocks in each case related to the first sampling (boxes indicate the lower and 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).

#### 6.4.4.5. Uncertainty estimates

The double standard errors for the dead wood, litter and mineral soil carbon are 16.6 %, 96.7 %, and 37.0 %, respectively (chp. 6.4.3.1.2). The total uncertainty of the carbon stock change in DOM and mineral soil was estimated as 17.1 % (Didion 2023: chp. 3.1.4). This is in the range of uncertainty estimates of parties where the older version of the soil carbon model (Yasso07) was applied. For example, Norway reported an uncertainty of 15.5 %, which applied to both the DOM and mineral soil pools (Norwegian Environment Agency 2023: chp. 6.4.1.2), and Finland reported an uncertainty of 31.5 % in the net carbon stock changes in DOM and mineral soil (Lehtonen and Heikkinen 2016; Statistics Finland 2023: chp. 6.4.3.2).

#### 6.4.5. Category-specific recalculations for 4A

The following recalculations were implemented.

- 4A, activity data (areas): Data 1990–2022 were updated (see chp. 6.3.1.5). The inclusion of most recent data from the AREA5 survey, updates of the AREA1-4 surveys and the new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations (Table 6-11).
- 4A, activity data (organic soil): The update of the dataset defining the geographical distribution of organic soils in Switzerland was finalised (see chp. 6.3.1.5). The total area of organic soil on Forest land increased by less than 0.1 kha, e.g. to 5.4 kha for 1990 (Figure 6-7 and Table 6-7). Figure 10-10 shows the minimal changes in CO<sub>2</sub> emissions from organic soil of less than 0.02 kt resulting from both recalculations of activity data.
- 4A, productive forest (CC12): An error correction of derived tree height data in the NFI5 affected the estimated growth between the NFI4 and NFI5. On a national scale, the growing stock in the NFI5 was underestimated by approximately 1 % and growth by up to 6 %. The drain was not affected by the error (source: notification from NFI on 09.09.2024: <https://www.lfi.ch/en/result-query-system/instructions>). The recalculations cover (i) the time series of carbon gains from 2018 onward (i.e. the first year of the NFI5) and (ii) the time series of carbon stocks from 2014 onward (i.e. after the mid-point of the NFI4 in 2013). Details of the recalculations are given in Didion et al. (2024). The (i) recalculated carbon gains abruptly increase the CO<sub>2</sub> eq removals in 2018 by around 450 kt (see shift in differences in category 4A in Figure 10-9).
- 4(IV)A1a controlled burning: The activity data for source category 4(IV)A1a Open burning of natural residues from forestry was updated by correcting the application of the input data (INFRAS 2014). This leads to small recalculations of the N<sub>2</sub>O and CH<sub>4</sub> emissions for the years 1990-2022 (<1.2 kt CO<sub>2</sub> eq).
- 4(IV)A: The time series of CH<sub>4</sub> and N<sub>2</sub>O emissions from wildfires 1990–2022 was recalculated for specific years due to updated activity data in the Swissfire database. Even the three largest changes in the years 1997, 2000 and 2010 resulted in negligible changes in CH<sub>4</sub> and N<sub>2</sub>O emissions (chp. 6.4.2.5.4.2).

## 6.4.6. Category-specific planned improvements for 4A

### 6.4.6.1. Revisions

#### 6.4.6.1.1. *Definition of forest*

The forest definition, which had to be aligned with the requirements of the Kyoto Protocol in the First Initial Report for reporting under Article 3, paras 3 and 4 (FOEN 2006h), will be revised in the next submission.

#### 6.4.6.1.2. *Land-use category Unproductive forest*

In the next submission, unproductive forest, which currently consists of three subcategories (chp. 6.4.1.3), will be rearranged to increase transparency.

### 6.4.6.2. Living biomass

#### 6.4.6.2.1. *Productive forest*

As a result of the continuous monitoring of the Swiss Forests, new NFI data will be available regularly (see chp. 6.4.2.1.1.2). The adoption of new NFI data (based on a shifting five-year window) can affect the estimates of all reported pools as well as the calculation of the available fuel for wildfires in forests.

#### 6.4.6.2.2. *Unproductive forest*

For the submission 2029 data to compare the changes in growing stock of brush forest between NFIs 4 and 5 will be available. Carbon stocks change factors for brush forest will be derived based on conversion factors from volume to biomass and carbon.

### 6.4.6.3. Dead wood, litter, and mineral soil

The implementation of the soil carbon model Yasso20 to improve the accuracy in the estimates of temporal changes in soil carbon, litter and dead wood is continuously developed. Depending on the availability of relevant data and studies, planned improvements include:

- Improving the uncertainty estimates for litter production by revising allometries and by estimating tree compartments using a Monte Carlo approach. This is expected to improve the accuracy of the estimates of carbon stocks and carbon stock changes.
- Taking advantage of further Yasso20 development arising from national and international projects, particularly in the context of the EU-Horizon project Pathfinder (<https://pathfinder-heu.eu/>) and the contribution by WSL to task 3.3 "Modelling carbon flux among pools".

## 6.5. Category 4B – Cropland

### 6.5.1. Description

Table 6-21 Key categories in category 4B Cropland. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
4.B.1	Cropland remaining cropland	CO <sub>2</sub>	L1, L2

Swiss croplands belong to the cold temperate wet climatic zone. Land-use category Cropland (CC21) includes annual crops and leys in arable rotations (see Table 6-2 and Table 6-6).

In the inventory period, total net emissions and net removals of category 4B1 Cropland remaining cropland range from -1'289 kt CO<sub>2</sub> in 2014 to 1'887 kt CO<sub>2</sub> in 2015 (mean: 389 kt CO<sub>2</sub>; Figure 6-11). The pronounced annual fluctuations are mainly due to climatic influences on carbon stocks in living biomass and in mineral soil. High stable carbon losses in organic soil shift the annual net figures in category 4B1 upwards by an average of 335 kt CO<sub>2</sub> (with a decreasing trend in the range of range 364–303 kt CO<sub>2</sub>), although organic soil accounts only for 2.5 % of cropland area in Switzerland (Table 6-7). Carbon stocks in living biomass increased, whereas those in mineral soil decreased over the inventory period (see upper panels in Figure 6-12 and Figure 6-13).

Category 4B2 Land converted to cropland oscillates around the zero line with low values. On average, it acts as a very small net sink of -0.2 kt CO<sub>2</sub>; Figure 6-11). Carbon gains due to new soil formation and re-vegetation on former landfills and gravel pits under category 4B2d Settlements converted to cropland are roughly compensated by carbon losses in the conversion from grassland to cropland (4B2b).

Total net emissions and net removals from category 4B Cropland range between -1'422 and 2'007 kt CO<sub>2</sub> (in 2014 and in 2015, respectively; not shown).

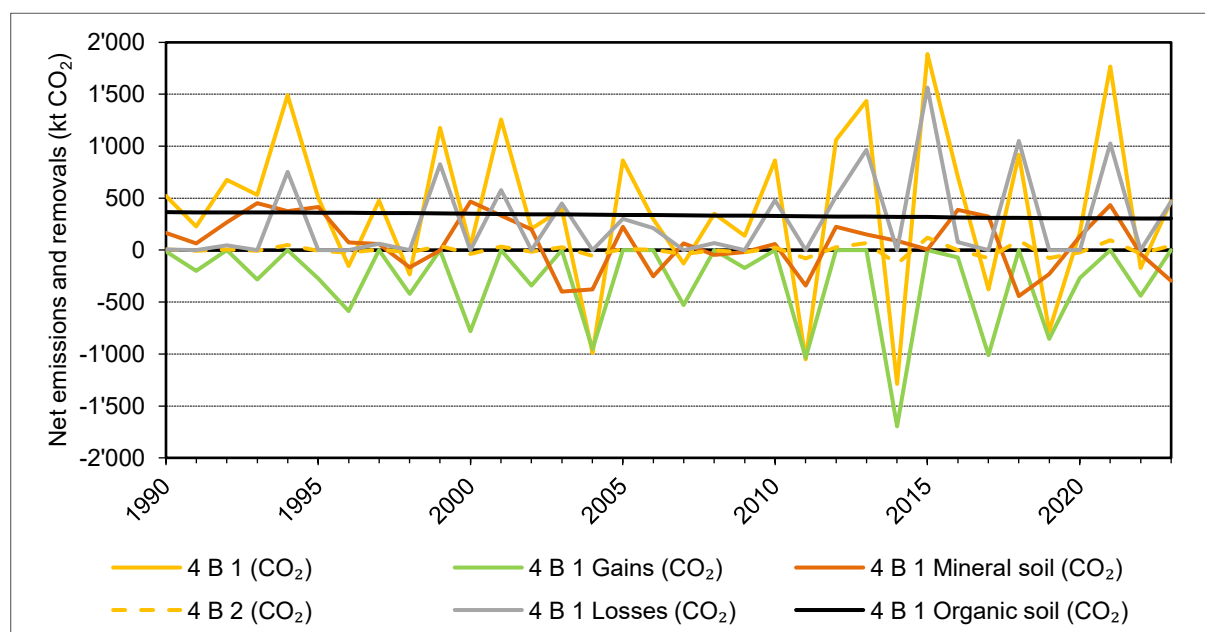


Figure 6-11 Net CO<sub>2</sub> emissions (positive values) and removals (negative values) from categories 4B1 and 4B2. Category 4B1 is broken down by gains in living biomass, losses in living biomass, net carbon stock changes in mineral soil, and net carbon stock changes in organic soil.

## 6.5.2. Methodological issues

Carbon stocks in living biomass as well as carbon stocks in mineral soil were estimated with a Tier 3 approach. The results were integrated in category 4B by calculating area-weighted (using the relative surface of crops) average values per elevation zone. The differences in carbon stocks between two consecutive years were reported as net changes for living biomass and for mineral soil.

### 6.5.2.1. Carbon stocks

#### 6.5.2.1.1. Carbon stocks in living biomass

Annual carbon stocks in living biomass per elevation zone (see chp. 6.2.2.2) were calculated as area-weighted means of harvested biomass for the 19 most important annual crops (barley, broad beans ("Ackerbohnen"), fallow, fodder beet, maize (grain), oat, peas ("Eiweisserbsen"), potatoes, rape (cooking oil), rye, sugar beet, silage and green corn, sun flowers (cooking oil), soybean, spelt, triticale, vegetables, wheat) and as cumulated annual harvested biomass for clover-grass (leys).

Annual values 1990–2023 for harvested yields (dt ha<sup>-1</sup>) were published by the Swiss Farmers Union (SBV 2024 and previous editions). The same allometric equation as used for soil organic carbon modelling was applied to estimate total biomass including roots (Wüst-Galley et al. 2020). A carbon fraction of 0.45 was assumed based on Bolinder et al. (2007).

Annual carbon stocks in living biomass were reported (Table 6-22 and in Figure 6-12 upper panel). Figure 6-12 also shows moving averages over five years (from year-2 to year+2; the previous and latest reporting years are given as four-year (year-2 to year+1) and three-year (year-2 to latest reporting year) moving averages, respectively).



The resulting area-weighted (across the three elevation zones) mean carbon stock in living biomass for Cropland over the inventory period was 6.84 t C ha<sup>-1</sup>.

Table 6-22 Area-weighted (using the relative surface of crops per elevation zone) carbon stocks (t C ha<sup>-1</sup>) and net carbon stock changes (t C ha<sup>-1</sup> yr<sup>-1</sup>) in living biomass of arable crops for land-use category Cropland (CC21), stratified for elevation zone (Elev.: Elevation Z1 = <601 m, Z2 = 601-1200 m, Z3 = >1200 m; see chp. 6.2.2.2). Highlighted data for 1990 are displayed in Table 6-4.

Living biomass	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
Stock	Z1	6.35	6.49	6.45	6.65	6.12	6.32	6.73	6.68	6.96	6.37
Stock	Z2	6.34	6.47	6.46	6.62	6.15	6.32	6.71	6.68	6.98	6.46
Stock	Z3	6.05	6.14	6.29	6.32	5.82	5.93	6.23	6.25	6.82	6.35
Net change	Z1	0.01	0.13	-0.04	0.20	-0.53	0.19	0.41	-0.05	0.28	-0.59
Net change	Z2	-0.01	0.13	-0.01	0.16	-0.47	0.17	0.39	-0.03	0.30	-0.52
Net change	Z3	0.12	0.10	0.15	0.04	-0.50	0.11	0.29	0.02	0.57	-0.47

Living biomass	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
Stock	Z1	6.93	6.50	6.76	6.42	7.13	6.91	6.73	7.13	7.10	7.23
Stock	Z2	6.95	6.62	6.80	6.54	7.14	6.95	6.87	7.21	7.12	7.23
Stock	Z3	6.76	6.61	6.60	6.64	7.04	6.99	7.07	7.37	7.15	7.16
Net change	Z1	0.57	-0.44	0.26	-0.34	0.71	-0.22	-0.18	0.40	-0.03	0.13
Net change	Z2	0.50	-0.33	0.18	-0.27	0.61	-0.20	-0.08	0.34	-0.09	0.11
Net change	Z3	0.41	-0.14	-0.01	0.04	0.40	-0.05	0.07	0.30	-0.22	0.01

Living biomass	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
Stock	Z1	6.87	7.65	7.26	6.53	7.83	6.67	6.58	7.41	6.61	7.24
Stock	Z2	6.89	7.63	7.27	6.53	7.81	6.54	6.72	7.38	6.53	7.28
Stock	Z3	6.85	7.52	7.26	6.46	7.64	6.18	6.92	7.21	6.29	7.29
Net change	Z1	-0.36	0.78	-0.40	-0.72	1.29	-1.16	-0.08	0.83	-0.80	0.63
Net change	Z2	-0.34	0.74	-0.36	-0.74	1.28	-1.27	0.18	0.66	-0.85	0.75
Net change	Z3	-0.31	0.67	-0.26	-0.80	1.19	-1.46	0.73	0.30	-0.93	1.00

Living biomass	Elev.	2020	2021	2022	2023	
		CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]				
Stock	Z1	7.46	6.62	7.01	6.61	
Stock	Z2	7.47	6.74	7.00	6.70	
Stock	Z3	7.39	6.88	6.89	6.74	
Net change	Z1	0.22	-0.84	0.38	-0.40	
Net change	Z2	0.19	-0.74	0.26	-0.30	
Net change	Z3	0.10	-0.51	0.00	-0.15	

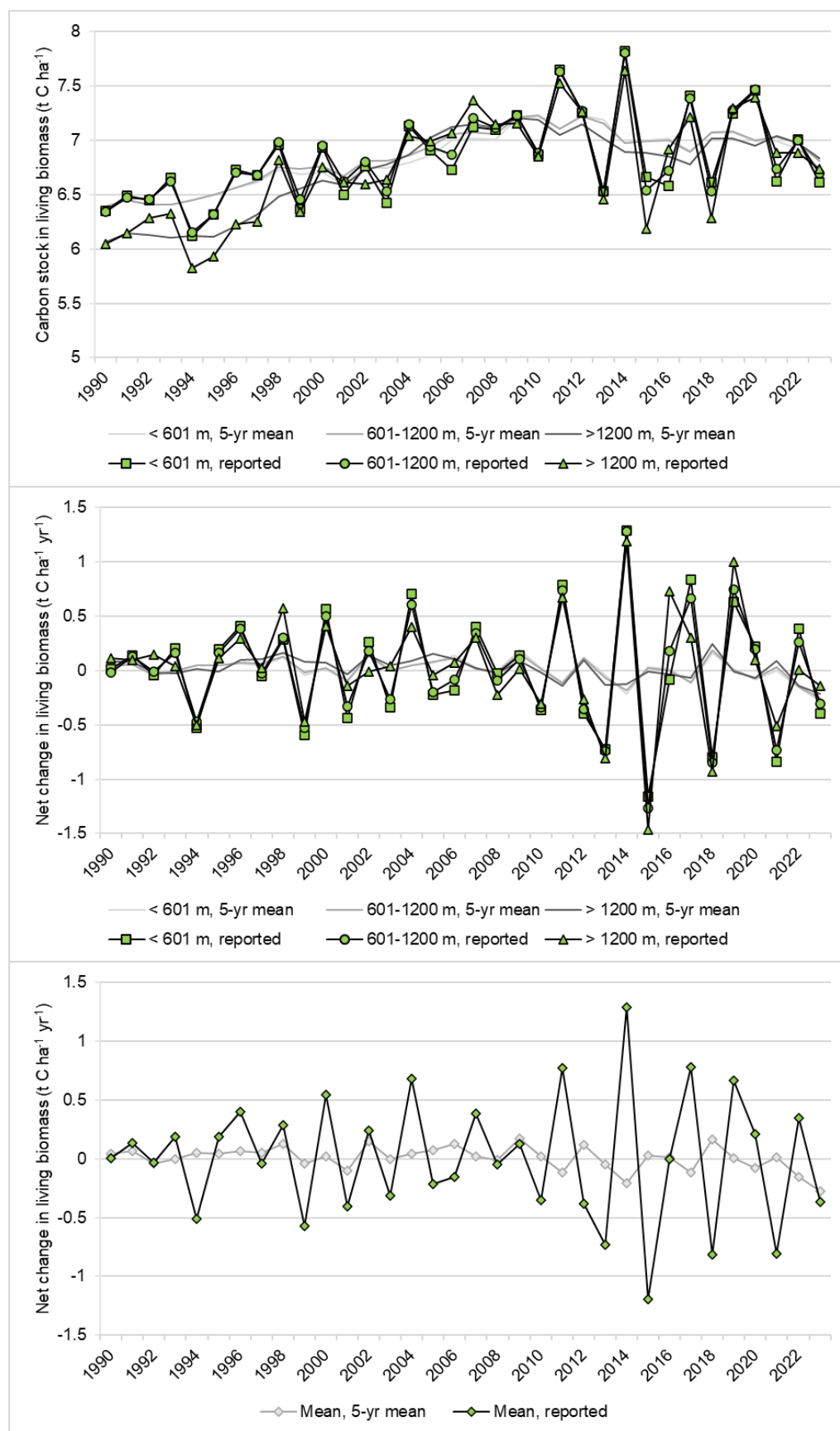


Figure 6-12 Reported carbon stocks ( $\text{t C ha}^{-1}$ ) and net carbon changes ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ ) in living biomass of Cropland, stratified for elevation zone, each with the moving average (upper and middle panel) and area-weighted means (across three elevation zones) with moving average (lower panel). Upper and lower confidence intervals for means in the lower panel are too small to be displayed. Elevation zone  $> 1200 \text{ m}$  is less important as it covers only 0.1 % of the total cropland area (see Table 6-7).

### 6.5.2.1.2. *Carbon stocks in dead organic matter*

Carbon stocks in dead organic matter were assumed to be zero.

### 6.5.2.1.3. *Carbon stocks in soil*

#### 6.5.2.1.3.1. *Mineral soil*

##### **Initial carbon stocks**

Initial carbon stocks in mineral soil under Cropland were calculated using a digital soil mapping approach, as described in Stumpf et al. (2023). In this approach, a regression model describing the statistical relationship between a soil property (e.g., carbon concentration) measured at many points and continuous variables that influence soil properties (e.g., climate relief or parent rock material) is estimated. This relationship is then applied to those continuous variables to predict that soil property for the whole surface of interest.

Stumpf et al. (2023) estimated soil organic carbon stocks for individual points using the following equation:

$$\text{SOC}_{\text{stock}} = \text{SOC}_{\text{conc}} \times \text{BD} \times (1 - \text{CF}) \times D$$

where  $\text{SOC}_{\text{stock}}$  is the carbon stock ( $\text{kg m}^{-2}$ ) in the upper 30 cm of soil,  $\text{SOC}_{\text{conc}}$  is the carbon concentration (%), BD is the bulk density of soil ( $\text{g cm}^{-3}$ ), CF is the proportion of coarse fragments in the soil and D is the thickness of the sample (here, 30 cm).

Soil carbon concentration measurements were available for 10'258 points (of which 4'815 were from cropland; obtained from the national soil information system database (NABODAT, <https://www.nabodat.ch>); mean sample density for cropland: 1.3 samples per  $\text{km}^2$ ). Bulk density measurements were available for 10 % of these soil samples. For the remaining 90 %, bulk density was estimated using a pedotransfer function, describing bulk density as a function of: soil carbon concentration, soil cover, climate, vegetation or land use, relief and parent rock material. This function was estimated using a regression forest model. The proportion of coarse fragments was derived from the nationwide soil suitability map (Bodeneignungskarte; SFSO 2000a).

To estimate the nation-wide carbon stocks, Stumpf et al. (2023) then estimated the statistical relationship between the above-mentioned carbon stock point information and 668 continuous variables related to climate, land use, relief, parent rock material, and a 'bare soil map' derived from satellite data. The statistical relationship was derived using a regression forest method.

The products of this mapping are raster data sets of 30 m resolution showing soil carbon stocks for the upper 30 cm of soils across Switzerland, per year, for the period 1995–2020. An average of the estimates of carbon stocks for the years 1995 to 2000 was used to represent the initial soils carbon stocks for 1987 in the RothC modelling for each of the regions simulated (see below). No earlier SOC stock estimates are available. The mean initial soil organic carbon stock (0–30 cm) for Cropland soils is  $59.1 \text{ t C ha}^{-1}$  (standard deviation =  $10.5 \text{ t C ha}^{-1}$ ).

## Simulation of carbon stocks through time

Switzerland used the soil carbon model RothC (Coleman et al. 1997; Coleman and Jenkinson 1999) to estimate carbon stocks in mineral soil (0–30 cm) under Cropland for the inventory period. The implementation of RothC in LULUCF reporting is described in detail in Wüst-Galley et al. (2020) and Wüst-Galley et al. (2019: p. 71, the up-scaling to elevation zone). In contrast to Wüst-Galley et al. (2020), the years 1975–1986 (referred to as “historic simulations”, see p. 63) are no longer included in the current simulations, because the new initial SOC stocks are already influenced by recent agricultural management. The first simulated year is 1987, allowing a five-year average for the carbon stock change for 1990 (calculated as difference between 1989 and 1990) to be calculated.

RothC is a model for the turnover of organic carbon in mineral soil, implementing four active carbon pools each associated with their own decomposition rates. In addition, there is a small carbon pool that is considered to be stable (inert). The model runs and calculates soil carbon stocks on a monthly basis. The decomposition rates are altered by temperature, moisture, soil cover and the soil's clay content. RothC requires information on climate (monthly precipitation, temperature and evapotranspiration), monthly carbon inputs (from organic manures and from plants, including above- and below ground harvest residues and root exudates) and soil (clay content, monthly soil cover). Testing and validation of RothC are described in Wüst-Galley et al. (2020).

## Input data

Gridded climate data were obtained from the Federal Office of Meteorology and Climatology (MeteoSwiss 2021, 2024), including updated temperature, precipitation and short wave radiation (SIS) data. Monthly evapotranspiration was calculated with the Priestley-Taylor method using these two data sets as well as monthly surface incoming short wave radiation (SIS), also obtained from MeteoSwiss. The most important 19 crops (as introduced in chp. 6.5.2.1.1, covering over 99 % of Swiss cropland area) were considered. Annual crop yields ( $\text{dt ha}^{-1}$ ) were obtained from the Swiss Farmers Union (SBV 2024 and previous editions). Based on yield data from crops, plant carbon inputs to the soil from crop residues, roots and rhizodeposition were estimated using an allometric function adapted from Bolinder et al. (2007), as described in Wüst-Galley et al. (2020). Annual carbon inputs from organic manures to different types of crops or grasslands were calculated based on: (1) organic manure production, calculated as a function of excretion rate of volatile solids, using the method described in chp. 5.3.2.2.1; (2) animal herd size, described in chp. 5.3.2.5.1; (3) the share of manure management systems, described in chp. 5.3.2.2.4 (using the data for volatile solids); (4) the tendency of farmers to apply different types of manure onto four different crop / grass categories, using information obtained from the Swiss ammonium model AGRAMMON (Kupper et al. 2022); (5) the different fertilisation needs of individual crops or grasslands of differing management intensities (obtained from the “Principles of Fertilisation of Agricultural Crops in Switzerland” (GRUD; Richner and Sinaj 2017); (6) straw production, using annual values published by the Swiss Farmers Union (SBV 2024 and previous editions); (7) the amount of manure digested anaerobically in biogas plants, as described in chp. 5.3.2.2.3; (8) the amount of liquid and solid digestates, as described in chp. 5.5.2.2.2; and (9) the number of livestock units moving annually to the summer pasture regions, using annual data (1999 to 2022, prior years and 2023 using extrapolation) that are collected for the calculation of subsidies for this summer grazing (“Sömmerungsbeiträge”), from the Federal Office for Agriculture. Soil cover and the distribution of plant inputs throughout the year were determined using sowing and harvest dates from various

agricultural guidelines, as described in Wüst-Galley et al. (2020). Information on the clay content was estimated using a digital soil mapping approach, as detailed in Stumpf et al. (2023a, 2024).

### Up-scaling

The RothC modelling was carried out for 4'560 different combinations (19 crops x 240 regions) representing similar climate, crop type, management systems and clay content, as described in Wüst-Galley et al. (2020). Based on the estimate of clay content (see previous paragraph), 10 clay classes were derived (2.5 % to 42.5 %, in 5 % increments, and > 45 %). An average initial soil organic carbon stock was calculated for the cropland area in each of the 240 regions. The simulated carbon stocks were then upscaled using the proportion of different crop types within each region, as well as the surface of each region, to calculate weighted means (Wüst-Galley et al. 2020).

### Reporting

Carbon stocks in mineral soil were integrated in category 4B by calculating area-weighted (using the relative surface of crops) average values per elevation zone. Annual data are shown in Table 6-23 and in Figure 6-13 upper panel.

Annual data mainly reflect effects of climatic conditions, whereas long-term trends related to e.g. changes in agricultural management are better visible when the data are smoothed. Therefore, Figure 6-13 also shows moving averages over five years (from year-2 to year+2; the previous and latest reporting years are given as four-year (year-2 to year+1) and three-year (year-2 to latest reporting year) moving averages, respectively).

The resulting area-weighted (across the three elevation zones) mean carbon stock in mineral cropland soil over the inventory period was 57.61 t C ha<sup>-1</sup>.

Table 6-23 Area-weighted (using the relative surface of crops per elevation zone) carbon stocks (t C ha<sup>-1</sup>) and net carbon stock changes (t C ha<sup>-1</sup> yr<sup>-1</sup>) in mineral soil (0-30 cm) for land-use category Cropland (CC21), stratified for elevation zone (Elev: Elevation Z1 = <601 m, Z2 = 601-1200 m, Z3 = >1200 m; see chp. 6.2.2.2). Highlighted data for 1990 are displayed in Table 6-4.

Mineral soil	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in mineral soil [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
Stock	Z1	58.37	58.32	58.12	57.80	57.53	57.23	57.17	57.12	57.26	57.27
Stock	Z2	59.86	59.82	59.67	59.39	59.16	58.89	58.87	58.84	58.91	58.90
Stock	Z3	51.95	52.12	52.27	52.21	52.09	51.96	52.05	52.25	52.41	52.55
Net change	Z1	-0.08	-0.04	-0.20	-0.33	-0.27	-0.30	-0.07	-0.05	0.14	0.01
Net change	Z2	-0.18	-0.05	-0.15	-0.27	-0.24	-0.27	-0.02	-0.03	0.07	-0.01
Net change	Z3	0.05	0.18	0.14	-0.06	-0.12	-0.13	0.09	0.20	0.16	0.14

Mineral soil	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in mineral soil [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
Stock	Z1	56.91	56.66	56.50	56.84	57.16	56.97	57.16	57.10	57.13	57.14
Stock	Z2	58.61	58.40	58.29	58.46	58.65	58.54	58.71	58.68	58.75	58.76
Stock	Z3	52.76	52.94	53.03	53.72	54.27	54.62	55.04	54.99	55.00	55.06
Net change	Z1	-0.35	-0.25	-0.16	0.34	0.31	-0.19	0.19	-0.05	0.02	0.01
Net change	Z2	-0.29	-0.21	-0.12	0.17	0.19	-0.11	0.18	-0.03	0.07	0.01
Net change	Z3	0.21	0.18	0.09	0.69	0.54	0.35	0.42	-0.04	0.01	0.05

Mineral soil	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in mineral soil [t C ha <sup>-1</sup> yr <sup>-1</sup> ]											
Stock	Z1	57.09	57.38	57.21	57.09	57.01	57.02	56.69	56.43	56.85	57.08
Stock	Z2	58.74	58.94	58.75	58.65	58.61	58.58	58.34	58.07	58.27	58.35
Stock	Z3	55.13	55.17	54.94	54.77	54.67	54.54	54.48	54.08	54.50	54.87
Net change	Z1	-0.05	0.29	-0.16	-0.12	-0.08	0.00	-0.33	-0.25	0.42	0.23
Net change	Z2	-0.02	0.20	-0.19	-0.10	-0.04	-0.03	-0.25	-0.26	0.19	0.09
Net change	Z3	0.07	0.05	-0.24	-0.17	-0.11	-0.13	-0.05	-0.40	0.42	0.37

Mineral soil	Elev.	2020	2021	2022	2023	
		CC21: carbon stock [t C ha <sup>-1</sup> ] and net change in mineral soil [t C ha <sup>-1</sup> yr <sup>-1</sup> ]				
Stock	Z1	56.97	56.61	56.62	56.87	
Stock	Z2	58.24	57.93	58.00	58.23	
Stock	Z3	54.90	54.80	55.09	55.27	
Net change	Z1	-0.10	-0.37	0.02	0.25	
Net change	Z2	-0.11	-0.30	0.06	0.23	
Net change	Z3	0.02	-0.09	0.29	0.18	

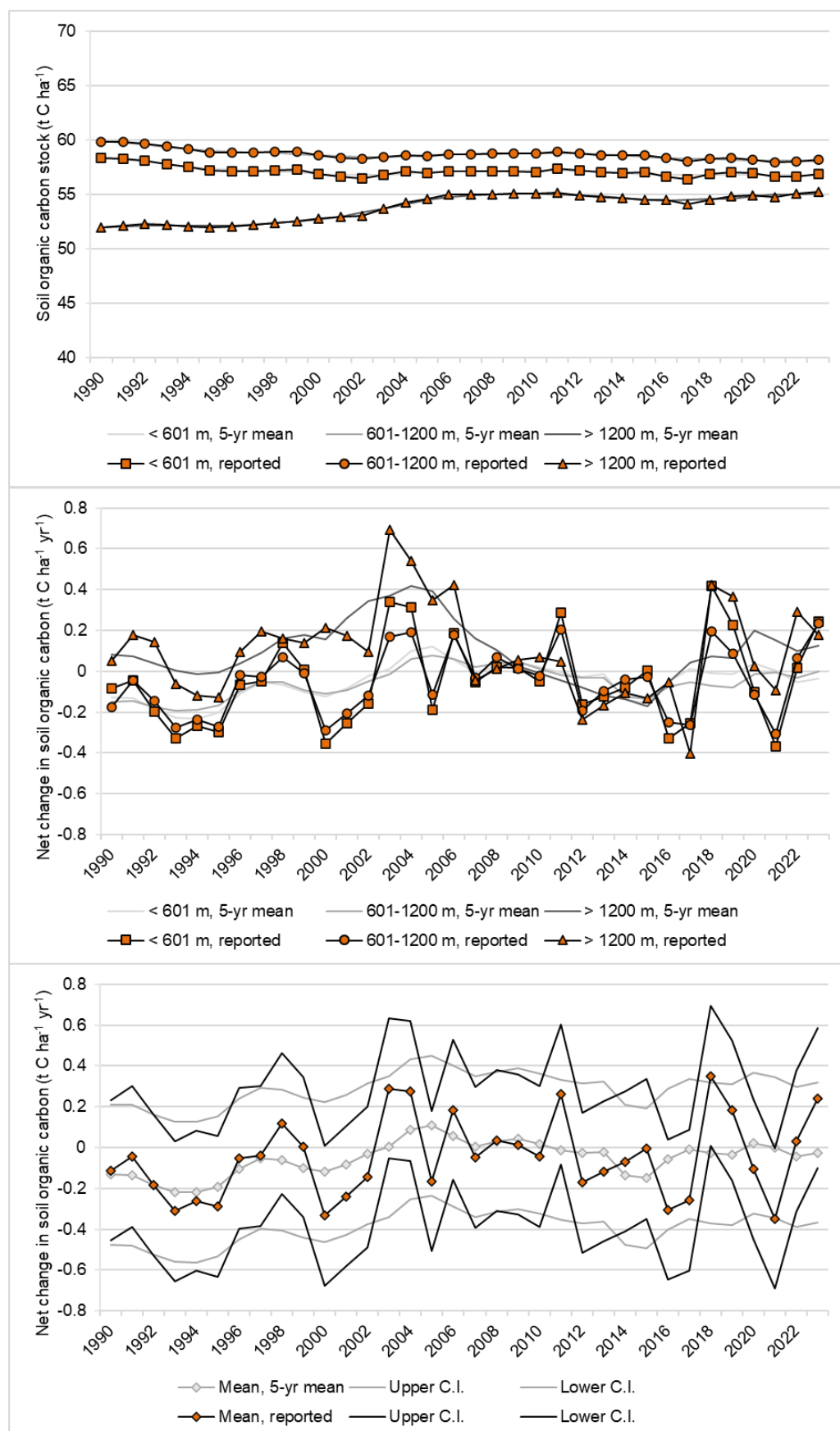


Figure 6-13 Reported carbon stocks ( $\text{t C ha}^{-1}$ ) and net carbon changes ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ ) in Cropland mineral soil (0–30 cm), stratified for elevation zone, each with the moving average (upper and middle panel) and area-weighted means (across three elevation zones) with moving average (lower panel) plus upper and lower confidence intervals (C.I.; see chp. 6.5.3.1.2). Elevation zone >1200 m is less important as it covers only 0.1 % of the total cropland area.



#### **6.5.2.1.3.2. Organic soil**

The soil carbon stock in organic soil on Cropland was calculated based on Presler and Gysi (1989) and Leifeld et al. (2003, 2005). The estimate from Presler and Gysi (1989) is based on data from field measurements, whereas the approach of Leifeld et al. (2003, 2005) was based on (i) assumed carbon stocks in peatlands in 1885, and (ii) an annual rate of carbon loss from peatlands converted to cropland. For both estimates a mean soil depth of 1.16 m was assumed (taken from Presler and Gysi 1989), resulting in a mean carbon stock of  $240 \pm 48 \text{ t C ha}^{-1}$  for the uppermost 30 cm in cultivated organic soil (uncertainty 20 %).

### **6.5.2.2. Changes in carbon stocks**

#### **6.5.2.2.1. Carbon stock changes in living biomass**

The difference in biomass carbon stock between two consecutive years was reported as net carbon stock change (gain or loss) (see Table 6-22 and Figure 6-12 middle panel). In addition to annual changes in carbon stocks five-year moving averages are also displayed in Figure 6-12. The mean area-weighted carbon stock change across all elevation zones was  $0.009 \text{ t C ha}^{-1} \text{ yr}^{-1}$  for the inventory period.

#### **6.5.2.2.2. Carbon stock changes in dead organic matter**

Applying a Tier 1 approach, carbon stock changes in dead organic matter were assumed to be in equilibrium for Cropland remaining cropland.

#### **6.5.2.2.3. Carbon stock changes in soil**

##### **6.5.2.2.3.1. Mineral soil**

The difference in carbon stock between two consecutive years was reported as net carbon stock change (gain or loss) in Cropland mineral soil (see Table 6-23 and Figure 6-13 middle panel). In addition to annual changes in carbon stocks five-year moving averages were also displayed in Figure 6-13.

The mean carbon stock change in the inventory period for elevation zone 1 was  $-0.046 \text{ t C ha}^{-1} \text{ yr}^{-1}$  and for elevation zone 2  $-0.053 \text{ t C ha}^{-1} \text{ yr}^{-1}$  (elevation zone 3 is less important as it covers 0.1 % of Cropland; see Table 6-7). The mean area-weighted carbon stock change across all elevation zones was  $-0.048 \text{ t C ha}^{-1} \text{ yr}^{-1}$ .

##### **6.5.2.2.3.2. Organic soil**

The annual net carbon stock change in organic soil was estimated to  $-9.52 \text{ t C ha}^{-1}$  according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and verified by ART (2009b) and Paul and Alewell (2018).

#### **6.5.2.2.4. Land-use change**

In the case of land-use change, the net carbon stock changes in biomass and soils were calculated as described in chp. 6.1.3.

### 6.5.2.3. Non-CO<sub>2</sub> emissions from Cropland

#### 6.5.2.3.1. *N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage of organic soil*

N<sub>2</sub>O emissions from drainage of organic soil on Cropland (including category 4(II)B2 Land converted to cropland (notation key IE)) were reported in the Agriculture sector (category 3D1f Cultivation of organic soils; see chp. 5.5.1).

CH<sub>4</sub> emissions in category 4(II)B1 Cropland remaining cropland in CRT Table 4(II) were not estimated (notation key NE) as reporting is not mandatory for this category.

#### 6.5.2.3.2. *Direct and indirect N<sub>2</sub>O emissions from mineral soils*

The calculations of direct and indirect N<sub>2</sub>O emissions from nitrogen mineralisation in mineral soil are described in Annex A5.4.

Direct and indirect N<sub>2</sub>O emissions from Cropland remaining cropland were included in the Agriculture sector in category 3D1e Mineralisation (see chp. 5.5.1), whereas those from Lands converted to cropland (category 4(III)B2) were reported under LULUCF.

#### 6.5.2.3.3. *CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning*

CH<sub>4</sub> emissions and N<sub>2</sub>O emissions from biomass burning in Cropland (category 4(IV)B) were not occurring (notation key NO).

## 6.5.3. Uncertainties and time-series consistency for 4B

### 6.5.3.1. Uncertainties

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

#### 6.5.3.1.1. *Activity data*

Uncertainties of activity data of category 4B Cropland are described in chp. 6.3.1.3.1.

#### 6.5.3.1.2. *Overall uncertainties of carbon stock changes and emission factors*

For calculating the overall uncertainty of category 4B, all emissions and removals from living biomass, dead organic matter, mineral soil and organic soil were considered. The uncertainties of carbon stock change factors and emission factors were calculated for 1990 and the latest reporting year (see overview in Table 6-5).

### Living biomass

The relative uncertainty in yield determination was estimated as 13 % for biomass carbon from agricultural land (Leifeld and Fuhrer 2005).

## Dead organic matter

Emissions from the dead organic matter pool occur only by land-use changes from Forest land to Cropland as the carbon stock of dead organic matter is assumed to be zero in the non-forest land-use categories. Thus, the uncertainty of these emissions corresponds to the uncertainty of carbon stocks in litter and dead wood on Forest land. Based on the results of the NFI4 and the Yasso20 model supplied by Didion (2023), a relative uncertainty of 0.5 % was calculated for the total carbon stock in litter and dead wood (Meteotest 2025).

## Mineral soil

The absolute uncertainty of  $0.344 \text{ t C ha}^{-1} \text{ yr}^{-1}$  was used for annual carbon stock changes in categories 4B1 and 4B2, as calculated by a Monte Carlo analysis (Wüst-Galley et al. 2020). That uncertainty analysis considered variation in the following input parameters: carbon inputs from farmyard manure and plants, the extent of summer pastures, and monthly temperature, precipitation and evapotranspiration. For the Monte Carlo analysis it was assumed that the extent of variation in input parameters is unchanged from one year to the next. By comparison, the range of annual SOC changes identified for 71 different treatments of Swiss agricultural long-term experiments is  $1.87 \text{ t C ha}^{-1}$  (Keel et al. 2019), suggesting that the calculated uncertainty might have been underestimated (Wüst-Galley et al. 2020).

The resulting relative uncertainty in submission 2024 (FOEN 2024), calculated with the implied carbon stock change factors of mineral soil, was 135.9 % for category 4B1 and 450.1 % for category 4B2. The same values were used for the year 2023 in the latest submission.

## Organic soil

The uncertainty of the activity data (area of organic soil) is 37.3 % (see chp. 6.3.1.3.2). The uncertainty of the carbon stock change factor in organic soil is 23 % as reported by Leifeld et al. (2003: 56).

## Overall uncertainties categories 4B1 and 4B2

Using the detailed input uncertainties as described above, the uncertainty propagation for categories 4B1 and 4B2 was computed using Monte Carlo simulations (see chp. 1.6.2). The resulting overall uncertainties of approach 2 for categories 4B1 and 4B2 emissions and removals in 2023 are (-89, +93 %) and (-26, +25 %), respectively (see Annex A2.3).

### 6.5.3.2. Time-series consistency

Time series for category 4B Cropland are all considered consistent; they were calculated based on consistent methods and homogenous databases (Wüst-Galley et al. 2020). Small inconsistencies in the input data for the RothC model (related to livestock husbandry, compare chp. 5.2.3 and chp. 5.3.3) are barely relevant for the overall results.

## 6.5.4. Category-specific QA/QC and verification for 4B

The general QA/QC measures are described in chp. 1.5.

### 6.5.4.1. Carbon stocks in living biomass

The crop yield data for the latest reporting year are available always in the most recent Swiss Farmers' Union's annual report. Since this report is usually not available in time, the inventory is prepared with a provisional value for the latest reporting year, using the value for the last year for which data are available. The correction of this provisional value in the following submission leads by default to a recalculation for the year in question.

### 6.5.4.2. Carbon stock changes in mineral soil

#### 6.5.4.2.1. RothC

RothC, used to model SOC stock changes, is a relatively simple model that does not represent certain soil processes such as feedback due to microbial processes or consider other nutrient cycles. It was however the best-performing model given the available data for Switzerland, considering also temporal resolution (Wüst-Galley et al. 2020). The calibration of the allometric equations (for deriving carbon inputs from crop yields), as well as a comparison of simulated SOC stock changes with measured values from field experiments is described in Wüst-Galley et al. (2020). A sensitivity analysis of the RothC simulations and of the system used to upscale these simulations to the national scale was completed (Wüst-Galley et al. 2021). The model performance is evaluated on an ongoing basis.

In 2018 the mean area-weighted SOC stock increase was exceptionally high (see Figure 6-13 lower panel). The peak carbon stock change might be explained by strongly reduced SOC decomposition in RothC caused by high soil moisture deficits (this summer was exceptionally warm and dry in Switzerland leading to high evapotranspiration relative to precipitation). Such model behaviour in RothC was also identified by Falloon et al. (2011). Model experiments for potato and maize in the most important cropping region of Switzerland support this explanation by showing reduced SOC stocks with irrigation. In 2018, the peak SOC change value was obtained for cropland but not for permanent grassland (see Figure 6-17). This can be explained by the distribution of these two land-use types: Cropland is concentrated in regions prone to high topsoil moisture deficit (lowlands), whereas permanent grassland is distributed more evenly across the country, including wetter and cooler (upland) regions.

The recalculations related to newly available soil information in the previous submission (described in detail in FOEN 2024: chp. 10.1.2.4) had an influence on the carbon stock changes of Cropland. There is on-going work investigating the effects of these new initial carbon stocks and the omission of a warm-up phase in the model (both recalculations of submission 2024) on soil carbon changes. For the majority of years, the mean stock change is now negative (i.e., SOC was lost; Figure 6-13 lower panel). This trend is dominated by the results for the two lower elevation zones (Z1 and Z2; Figure 6-13 middle panel). However, due to high uncertainties, mean stock changes across all elevation zones are generally not statistically significant (see confidence intervals in Figure 6-13 lower panel).

The negative mean SOC stock change for the entire inventory period ( $-0.048 \text{ t C ha}^{-1} \text{ yr}^{-1}$ ) agrees with the European-scale decline in SOC content that was estimated by De Rosa et al.

(2024) for cropland remaining cropland based on data from the Land Use/Land Cover Area Frame Survey (LUCAS) for the years 2009–2018. If only stock changes for the identical time span (i.e., 2009–2018) are compared, the direction of change still agrees ( $-0.034 \text{ t C ha}^{-1} \text{ yr}^{-1}$ ; Figure 6-13 lower panel). Quantitative comparisons, however, are not possible because different metrics were used.

#### **6.5.4.2.2. Swiss Soil Monitoring Network (NABO)**

The SOC stocks measured at 30 cropland monitoring sites of the NABO (NABO 2021a; Gross et al. 2024; see chp. 6.4.4.4) featuring mineral soils indicate no significant changes from 1990 to 2019. The apparent decline of SOC stocks from the first to the sixth sampling campaign (see Figure 6-14 bottom panel) was identified as artefact induced 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 stocks. Changes in SOC stocks over time are less pronounced when compared to the second sampling campaign, as shown in Gubler et al. (2019). The range of the calculated SOC stocks in 0–20 cm depth was large ( $20\text{--}87 \text{ t C ha}^{-1}$ ) with a mean of  $47 \text{ t C ha}^{-1}$  (Figure 6-14 top panel). Minor changes in SOC stocks occurred only on single cropland sites and could be assigned to changed amounts of farmyard manure applications (Gubler et al. 2019).

The monitoring scheme applied by NABO is able to detect relative changes in SOC contents of roughly 3.5 % per 10 years for mineral cropland soils (minimum detectable change for 30 monitoring sites including three or more sampling campaigns; Gubler et al. 2019). Regarding the measured SOC stocks (mean  $47 \text{ t C ha}^{-1}$ ) this corresponds to a minimum detectable change of roughly  $0.16 \text{ t C ha}^{-1} \text{ yr}^{-1}$  for SOC stocks.

The mean change in SOC which was calculated with RothC for the years 1990–2023 was  $-0.048 \pm 0.344 \text{ t C ha}^{-1} \text{ yr}^{-1}$  (area-weighted mean across three elevation zones  $\pm$  absolute uncertainty based on a Monte Carlo analysis; see Figure 6-13 lower panel and chp. 6.5.3.1.2). In comparison, the modelled net carbon change is clearly smaller than the detectable change by NABO and suggests that modelled SOC stock changes agree with the repeated soil inventories in the NABO network.

In conclusion, the NABO data indicate that Cropland mineral soils acted neither as a significant net source nor as a significant net sink of carbon when considered over the entire inventory period. Gubler et al. (2019) concluded that SOC contents in cropland sites of the NABO have approached a steady state at sites where agricultural management and crop rotation have remained relatively constant.

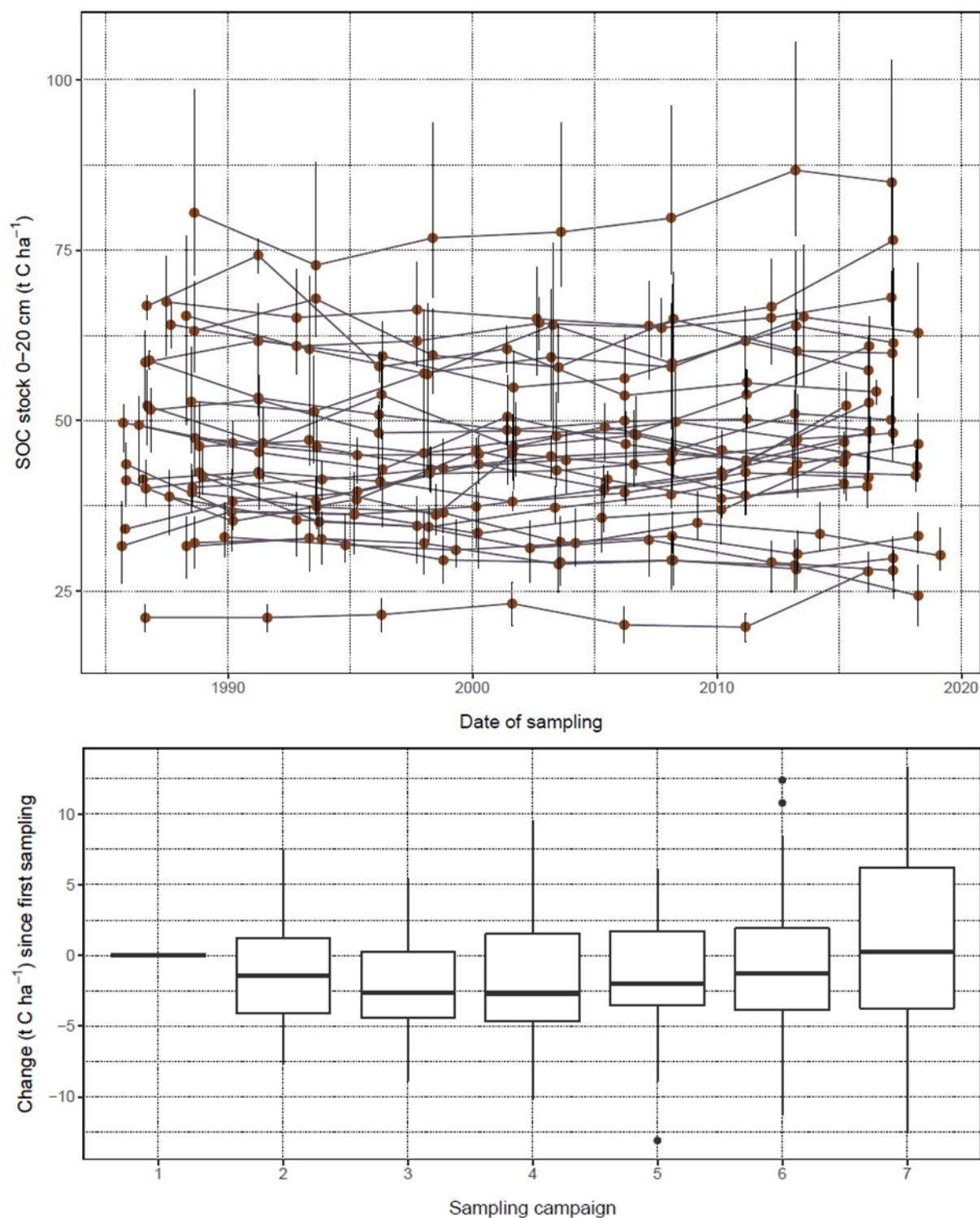


Figure 6-14 Measured SOC stocks for topsoils (0–20 cm) and their changes for 30 NABO long-term monitoring sites used as cropland during the period 1985–2019. The elevation of the sites ranges from 324 to 945 m a.s.l. Top panel: SOC stocks 0–20 cm per site and sampling; the dots indicate the mean and the bars the range of 5 % and 95 % percentiles of bootstrap samples taking into account the variability in SOC content of the individual replicates per site and sampling as well as the variations of the bulk density. Bottom panel: boxplot of changes in SOC stocks in each case related to the first sampling (boxes indicate the lower and 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).



### 6.5.4.3. Short-term land-use changes in arable rotations

Short-term land-use changes between apparent 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 usual sense (i.e. land-use category CC31 permanent grassland). 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 the main land-use categories Cropland and Grassland and vice versa were adequately reported in the GHG inventory.

### 6.5.5. Category-specific recalculations for 4B

The following recalculations were implemented.

- 4B, activity data (areas): Data 1990–2022 were updated (see chp. 6.3.1.5). The inclusion of most recent data from the AREA5 survey, updates of the AREA1-4 surveys and the new geo-referenced approach for interpolating and extrapolating yearly land-use data led to losses of area (<1 %), mostly in favour of permanent grassland (CC31) (Table 6-11).
- 4B, activity data (organic soil): The update of the dataset defining the geographical distribution of organic soils in Switzerland was finalised (see chp. 6.3.1.5). The total area of organic soil on Cropland decreased markedly, e.g. from 12.2 to 10.8 kha for 1990 (Figure 6-7 and Table 6-7). Figure 10-10 shows the strong decline in CO<sub>2</sub> emissions from organic soil by an average of 50 kt resulting from both recalculations of activity data.
- 4B: Results of the RothC model for carbon stock changes in biomass and mineral soils are reported on annual basis whereas 5-year moving averages were reported in previous submissions. The abandonment of multi-year averaging led to a much stronger annual fluctuation of CO<sub>2</sub> emissions and removals in living biomass and in mineral soil. This recalculation explains the largest part of the differences in net emissions and removals between the latest and the previous submissions in category 4B, which range from -2'277.2 kt CO<sub>2</sub> eq in 2014 to 1'499.8 kt CO<sub>2</sub> eq in 2021 (mean: -54.5 kt CO<sub>2</sub> eq). The resulting time series shows the expected pronounced zigzag pattern (Figure 10-9).
- 4B: Carbon stocks and carbon stock changes in mineral soil were recalculated for the whole inventory period (RothC simulations), applying
  - new meteorological data for the period 1975-2023, based on a release of new data from MeteoSwiss in 2024 (MeteoSwiss 2024). The recalculation had a negligible effect on mineral soil carbon stock changes, though it explains almost all differences in carbon stock changes between the latest submission and the previous one (aside from those related to the new reporting on an annual basis);
  - updated information used for the calculation of organic amendments for the year 2022 (animal numbers, straw production and the amount of manure going to biogas plants), following the availability of new data (SBV 2023, for biogas as described in chp. 5.3.2.2.3). This recalculation had a negligible effect on mineral soil carbon changes;
  - updated yield data for 2022, based on the newly available data (SBV 2023). This recalculation had a negligible effect on mineral soil carbon changes.



## 6.5.6. Category-specific planned improvements for 4B

### 6.5.6.1. Living biomass

Price et al. (2017) created a nationwide model for above ground 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 categories where tree biomass has either not been included or only roughly estimated until now. The tree biomass model of Price et al. (2017) was calibrated and evaluated based on reference plots from the NFI. The model showed promising results at the Tier 3 level. However, further improvement could be achieved if additionally specific reference data from non-Forest land would be available. In a pioneering study, 62 felled urban reference trees with actual above ground tree biomass as well as many detailed predictor variables were surveyed (Mathys et al. 2019; Kükenbrink et al. 2021). To account for the detected differences in tree geometry and associated biomass pattern a nationwide non-Forest land field survey of above ground tree biomass at the plot level was initiated by FOEN (aiming for 1'500 reference plots within the project duration 2018–2024). The overall objective is to calculate a wall-to-wall above ground tree biomass database and map for Switzerland, using the LiDAR survey 2017–2023 of the Federal Office of Topography (completed in 2024, see current availability of LiDAR data: <https://s.geo.admin.ch/82a044701f>). The field work has now been completed, and the biomass model is being calibrated with the final set of LiDAR data. The first set of nationwide data is expected in summer 2025. The continuation of the LiDAR survey (see <https://www.swisstopo.admin.ch/en/lidar-data-swisstopo>) will allow the data to be tested for its suitability to derive carbon stock changes of tree biomass in non-Forest land.

### 6.5.6.2. Mineral soil

Activities at the Competence Center for Soils (CCSoils) address the shortcomings of the lack of comprehensive, nationwide soil information in Switzerland. The results of a digital soil mapping project (Stumpf et al. 2023, 2023a, 2024) are used since GHG inventory submission 2024 (FOEN 2024). It can be viewed as a first step towards a switch to grid-based SOC modelling with RothC for Cropland. Further steps are planned for the following years.

Additionally, the predicted soil carbon stocks from 1995–2000 are currently used to derive the initial soil carbon stocks, as these are the earliest years for which data are available (chp. 6.5.2.1.3.1). The initial soil carbon stock estimate might be improved however by using predicted soil carbon stocks from an earlier period, e.g. 1990–1995, if these would become available.

## 6.6. Category 4C – Grassland

### 6.6.1. Description

Table 6-24 Key categories in category 4C Grassland. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
4.C.1	Grassland remaining grassland	CO <sub>2</sub>	L1, L2, T1, T2
4.C.2	Land converted to grassland	CO <sub>2</sub>	L1, L2, T1

Swiss grasslands belong to the cold temperate wet climatic zone.

Grasslands were subdivided into the land-use categories 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 CRT Table 4.C, the land-use categories CC32, CC33, CC34 and CC35 were merged under the notation 'Woody' and CC36 and CC37 were merged under 'Unproductive' (see Table 6-2 Table 6-2).

In the inventory period, total net emissions and net removals of category 4C1 Grassland remaining grassland range from -1'191 kt CO<sub>2</sub> in 1991 to 1'467 kt CO<sub>2</sub> in 2015 (mean: -93 kt CO<sub>2</sub>; Figure 6-15). The year-to-year variability is very low in the earlier years for biomass, i.e. for carbon gains and losses in living biomass (see chp. 6.6.2.1.1.1). High stable carbon losses in organic soil (especially under permanent grassland) shift the annual net figures in category 4C1 upwards by about 250 kt CO<sub>2</sub>, although only 0.8 % of permanent grassland soils (CC31) are organic soil (Table 6-7). Contributions of other Grassland remaining grassland land-use categories (CC32–CC37) were of minor importance except for a noticeable gain in living biomass for shrub vegetation (CC32) which can be explained mainly by the conversion of abandoned alpine and jurassic pastures (i.e., summer pastures, which belonged to CC31; well above 1 kha in many years, see also Table 6-9) to this latter land-use category.

Carbon stocks in living biomass of the two lower elevation zones in category 4C1 permanent grassland decreased significantly over the inventory period, while the 1990 level in the highest elevation zone was largely maintained (Figure 6-16 upper panel). Carbon stocks in permanent grassland mineral soil in the two lower elevation zones decreased moderately (< 601 m) or remained largely stable (601–1200 m), while in the highest elevation zone the stock increased significantly (Figure 6-17 upper panel).

Category 4C2 Land converted to grassland acted as a net source in all years (mean: 344 kt CO<sub>2</sub>; Figure 6-15). The highest individual contribution came consistently from category 4C2a Forest land converted to grassland. Most of this source was due to net changes in living biomass from deforestation. In contrast, the categories 4C2c to 4C2e acted as net sinks mainly due to sequestration of CO<sub>2</sub> in mineral soil in the course of the conversion to grassland.

Total net emissions and net removals from category 4C Grassland range between -989 and 1'974 kt CO<sub>2</sub> (in 1991 and in 2015, respectively; not shown).

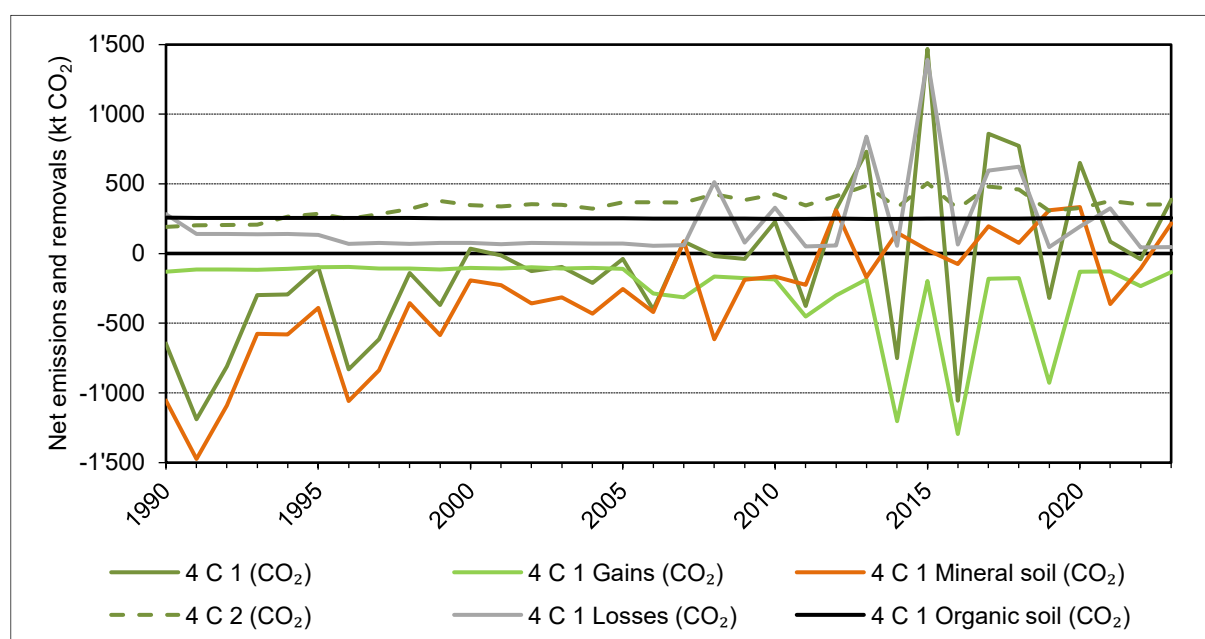


Figure 6-15 Net CO<sub>2</sub> emissions (positive values) and removals (negative values) from categories 4C1 and 4C2. Category 4C1 is broken down by gains in living biomass, losses in living biomass, net carbon stock changes in mineral soil, and net carbon stock changes in organic soil.

## 6.6.2. Methodological issues

For permanent grassland (CC31), carbon stocks in living biomass as well as carbon stocks in mineral soil were estimated with a Tier 3 approach. The results were integrated in category 4C by calculating area-weighted (using the relative surface of the six grassland types) average values per elevation zone. The differences in carbon stocks between two consecutive years were reported as net changes for living biomass and for mineral soil. For the remaining Grassland land-use categories CC32–CC37, constant carbon stocks in living biomass and in mineral soil were assumed (i.e. no carbon stock changes occur if the land use does not change; changes of Grassland land-use categories among themselves do contribute to net emissions and removals in category 4C1) (see Table 6-3 and Table 6-4).

### 6.6.2.1. Carbon stocks

#### 6.6.2.1.1. Carbon stocks in living biomass

##### 6.6.2.1.1.1. Permanent grassland (CC31)

Permanent grasslands range in elevation from <300 m to 3000 m above sea level. Because both biomass productivity and soil carbon dynamics rely on the prevailing climatic and pedogenic conditions, grassland stocks were calculated separately for three elevation zones (see chp. 6.2.2.2).

Standing biomass for permanent grasslands (t C ha<sup>-1</sup>) was calculated as the annual cumulative yield of six differentially managed grasslands for three elevation zones. Total harvested biomass for the years 1990–2023 was adopted from annual statistics of the Swiss Farmers Union (SBV 2023 and previous editions) and allocated to the below listed different

grassland types and elevation zones based on standard yields from Richner and Sinaj (2017) and area data from the Farm Structure Survey (SFSO 2016g):

- extensive meadow
- less intensive meadow
- intensive meadow
- extensive pasture
- intensive pasture
- summer pasture

A carbon fraction of 0.45 was assumed (Bolinder et al. 2007). For grassland, yield was assumed to be equal to above ground biomass. Root biomass was estimated based on an allometric function as described in Wüst-Galley et al. (2020).

Annual carbon stocks in living biomass were reported (Table 6-25 and Figure 6-16 upper panel). Figure 6-16 also shows moving averages over five years (from year-2 to year+2; the previous and latest reporting years are given as four-year (year-2 to year+1) and three-year (year-2 to latest reporting year) moving averages, respectively).

Year-to-year variability of reported biomass data is lower in earlier years compared to recent years because prior to 2007, data on the extent of individual grassland types (used to calculate yields) were reported only every five years, and yields in between were interpolated.

The resulting area-weighted (across the three elevation zones) mean carbon stock in living biomass for permanent grassland over the inventory period was  $4.30 \text{ t C ha}^{-1}$ .

Table 6-25 Area-weighted (using the relative surface of the six grassland types) carbon stocks (t C ha<sup>-1</sup>) and net carbon stock changes (t C ha<sup>-1</sup> yr<sup>-1</sup>) in living biomass (including roots) of land-use category permanent grassland (CC31), stratified for elevation zone (Elev: Elevation Z1 = <601 m, Z2 = 601-1200 m, Z3 = >1200 m; see chp. 6.2.2.2). Highlighted data for 1990 are displayed in Table 6-4. Please note: Associated data in CRT Table 4.C.1 also include land-use changes within the Grassland land-use categories CC31–CC37 and therefore differ from the data shown here (see also chp. 6.1.3.4).

Living biomass	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC31: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]									
Stock	Z1	5.74	5.70	5.66	5.62	5.58	5.54	5.53	5.52	5.50	5.48
Stock	Z2	5.27	5.23	5.20	5.17	5.13	5.10	5.09	5.09	5.09	5.08
Stock	Z3	3.34	3.34	3.33	3.32	3.32	3.31	3.32	3.33	3.33	3.34
Net change	Z1	-0.14	-0.04	-0.04	-0.04	-0.04	-0.04	-0.01	-0.02	-0.02	-0.02
Net change	Z2	-0.12	-0.03	-0.03	-0.03	-0.03	-0.03	0.00	0.00	0.00	0.00
Net change	Z3	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.01	0.01	0.01

Living biomass	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC31: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]									
Stock	Z1	5.47	5.45	5.43	5.42	5.40	5.38	5.46	5.54	5.32	5.30
Stock	Z2	5.08	5.08	5.07	5.07	5.07	5.07	5.14	5.22	5.03	5.02
Stock	Z3	3.35	3.36	3.36	3.36	3.37	3.37	3.40	3.43	3.36	3.36
Net change	Z1	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.08	0.08	-0.22	-0.02
Net change	Z2	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	-0.19	-0.01
Net change	Z3	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.03	-0.07	0.00

Living biomass	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
		CC31: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]									
Stock	Z1	5.16	5.29	5.33	4.95	5.42	4.78	5.28	5.02	4.75	5.09
Stock	Z2	4.91	5.03	5.07	4.74	5.18	4.60	5.07	4.83	4.58	4.91
Stock	Z3	3.32	3.37	3.39	3.27	3.44	3.22	3.41	3.32	3.23	3.35
Net change	Z1	-0.14	0.12	0.04	-0.38	0.47	-0.64	0.49	-0.26	-0.27	0.35
Net change	Z2	-0.11	0.12	0.05	-0.34	0.44	-0.58	0.47	-0.23	-0.25	0.33
Net change	Z3	-0.04	0.05	0.02	-0.12	0.17	-0.21	0.18	-0.09	-0.09	0.13

Living biomass	Elev.	2020	2021	2022	2023	
		CC31: carbon stock [t C ha <sup>-1</sup> ] and net change in living biomass [t C ha <sup>-1</sup> yr <sup>-1</sup> ]				
Stock	Z1	5.01	4.88	4.93	4.93	
Stock	Z2	4.84	4.72	4.76	4.76	
Stock	Z3	3.34	3.29	3.30	3.30	
Net change	Z1	-0.09	-0.13	0.05	0.00	
Net change	Z2	-0.07	-0.12	0.05	0.00	
Net change	Z3	-0.01	-0.05	0.02	0.00	

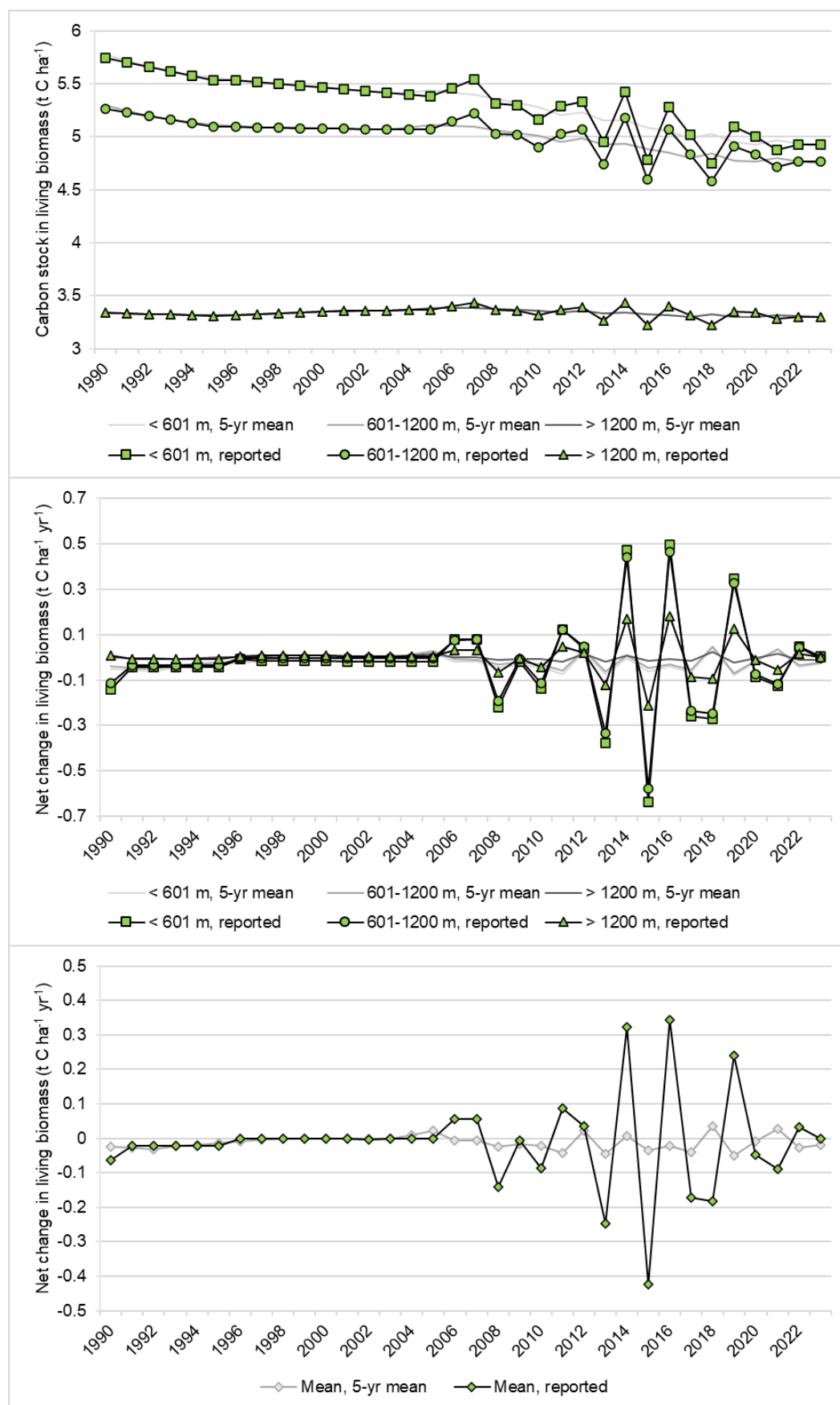


Figure 6-16 Reported carbon stocks (t C ha<sup>-1</sup>) and net carbon changes (t C ha<sup>-1</sup> yr<sup>-1</sup>) in living biomass of permanent grassland (CC31), stratified for elevation zone, each with the moving average (upper and middle panel) and area-weighted means (across three elevation zones) with moving average (lower panel). Upper and lower confidence intervals for means in the lower panel are too small to be displayed.

#### 6.6.2.1.1.2. 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. 6.4.2.3.1: 20.45 t C ha<sup>-1</sup> (Düggelin and Abegg 2011).

#### 6.6.2.1.1.3. 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 are vineyards (SFSO 2005) and 240 ha are low-stem orchards (Widmer 2006).

The standing carbon stock of living biomass per ha (Cl) for CC33 was therefore calculated as:

$$Cl = \frac{[(Cl_{vineyards} * area_{vineyards}) + (Cl_{low-stem orchards} * area_{low-stem orchards})]}{(area_{vineyards} + area_{low-stem orchards})}$$

Cl of vineyards (5.35 t C ha<sup>-1</sup>) was calculated as the sum of the woody biomass (3.61 t C ha<sup>-1</sup>) and the biomass in the grass layer (1.74 t C ha<sup>-1</sup>).

Woody biomass for vineyards was calculated based on the mean stand density (5'556 vines ha<sup>-1</sup>) and the mean carbon content in the woody biomass of one plant including roots (0.65 kg C; Ruffner 2005).

The mean carbon stock of the grass layer in vineyards was calculated using the following information and assumptions: (1) Most vineyards in Canton Valais (around 5'000 ha) have no grass layer, in the other cantons the share of vineyards with grass understorey is very high (95 %). Thus, it can be assumed that on the average 65 % of the Swiss vineyards exhibit a grass layer. (2) The grass layer between the vine rows has a lower carbon stock than permanent grassland. It is assumed that it is 50 % less than the carbon stock of CC31 (elevation <600 m, average of the period 1990–2020 as reported in FOEN 2023: chp. 6.6.2.1.1.3).

Cl of low-stem orchards (14.93 t C ha<sup>-1</sup>) was calculated as the sum of the woody biomass (12.25 t C ha<sup>-1</sup>) and the biomass in the grass layer (2.68 t C ha<sup>-1</sup>).

For small fruit trees on low-stem orchards, no literature value was found for biomass expansion factors. Therefore, the following assumptions were made: Diameter at breast height (DBH) of such trees was assumed to be 10 cm and the stem height was assumed to be 1 m. The bole shape of low-stem apple trees can be approximated by a cylinder shape.

$$\text{Stem wood volume} = r^2 * \pi * \text{height} = (5 \text{ cm})^2 * 3.1 * 100 \text{ cm} = 7.75 \text{ dm}^3$$

Based on expert knowledge (Kaufmann 2005), the percentage of branches was estimated as 100 %, and the percentage of roots was estimated as 30 % of the stem wood volume. This results in a BEF of 2.3. A wood density of 0.55 kg dm<sup>-3</sup> (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 stock of a tree of the type low-stem ('Niederstamm') was calculated as follows:



$$\begin{aligned}\text{C low-stem} &= \text{stem wood volume} * \text{BEF} * \text{wood density} * \text{carbon content} \\ &= 7.75 \text{ dm}^3 * 2.3 * 0.55 \text{ kg/dm}^3 * 0.5 = 4.9 \text{ kg C}\end{aligned}$$

The mean stand density of low-stem orchards was estimated as 2500 ha<sup>-1</sup> (Widmer 2006), resulting in a CI of 12.25 t C ha<sup>-1</sup> in woody biomass.

The mean carbon stock of the grass layer in low-stem orchards was calculated using the following information and assumptions: (1) All low-stem orchards have a grass layer. (2) The grass layer between the tree rows has a lower carbon stock than permanent grassland. It is assumed that it is 50 % less than the carbon stock of CC31 (elevation <600 m, average of the period 1990–2020 as reported in FOEN 2023: chp. 6.6.2.1.1.3).

The resulting carbon stock in living biomass (CI) for land-use category CC33 is 5.5 t C ha<sup>-1</sup>.

#### 6.6.2.1.1.4. Orchards (CC35)

Orchards consists of larger fruit trees ('Hochstammobst') planted at a low density with grass understory. CI of orchards trees was calculated as:

$$\begin{aligned}\text{CI biomass} &= (\text{carbon per fruit tree [t C]} * \text{number of fruit trees} / \text{area orchards [ha]}) \\ &\quad + \text{carbon in grass [t C ha}^{-1}\text{]}\end{aligned}$$

The carbon stock of a large fruit tree with a DBH of 25–35 cm was calculated as follows:

$$\text{C (Hochstamm)} = \text{Stem wood volume} * \text{KE-Factor} = 225 \text{ kg C}$$

where:

- Stem wood volume of an apple tree assuming a cylindrical stem with mean DBH of 30 cm and a stem height of 7 m amounts to 0.5 m<sup>3</sup>, and
- KE-Factor [t C m<sup>-3</sup>] = BEF \* Density \* carbon content = 0.45 (Wirth et al. 2004: p. 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<sup>-1</sup>. The resulting carbon stock in woody biomass of CC35 is thus 17.78 t C ha<sup>-1</sup>. Because orchards typically have a grass understory, the biomass of CC31 was added to the woody biomass. In FOEN (2023: chp. 6.6.2.1.1.4), the average biomass 1990–2020 of CC31 was weighted with the area of CC35 in the three elevation zones, resulting in 5.29 t C ha<sup>-1</sup>. The value was left unchanged for this submission and added to the woody biomass to obtain a total carbon stock of 23.1 t C ha<sup>-1</sup> for land-use category CC35.

#### 6.6.2.1.1.5. Stony grassland (CC36)

Approximately 35 % of the surface of land-use category 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<sup>-1</sup>; see chp. 6.4.2.3; Düggelein and Abegg 2011) was multiplied by 0.35 to account for the 35 % vegetation coverage. This results in a carbon stock for stony grassland of 7.2 t C ha<sup>-1</sup>.

#### **6.6.2.1.1.6. Unproductive grassland (CC37)**

Land-use 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 are biomass data currently available. Therefore, the CC37-area-weighted mean (see Table 6-7) of carbon stocks of permanent grasslands (CC31; average 1990–2020 as reported in FOEN 2023: chp. 6.6.2.1.1.6) in the three elevation zones was assumed to be representative of the carbon stock on unproductive grassland. Carbon stock in living biomass in unproductive grassland appeared to be  $3.5 \text{ t C ha}^{-1}$ .

#### **6.6.2.1.2. Carbon stocks in dead organic matter**

Carbon stocks in dead organic matter were assumed to be zero.

#### **6.6.2.1.3. Carbon stocks in soil**

##### **6.6.2.1.3.1. Mineral soil: Permanent grassland (CC31)**

Initial carbon stocks in mineral soil under Grassland were calculated using a digital soil mapping approach (Stumpf et al. 2023, 2023a, 2024), as described in chp. 6.5.2.1.3.1. The mean initial soil organic carbon stock (0–30 cm) for permanent grassland is  $53.0 \text{ t C ha}^{-1}$  (standard deviation =  $12.3 \text{ t C ha}^{-1}$ ). The mean carbon stock of each of the 240 regions simulated was used to initialise the RothC simulations.

Switzerland used the soil carbon model RothC to estimate carbon stocks in mineral soil (0–30 cm) under permanent grassland, as described in chp. 6.5.2.1.3.1, in Wüst-Galley et al. (2020) and in Wüst-Galley et al. (2019: p. 71, the upscaling to elevation zone). Six differently managed permanent grassland types (as listed in chp. 6.6.2.1.1.1, covering over 99 % of Swiss permanent grassland) were considered. Plant carbon inputs into the soil from grasslands were assumed to be constant, in accordance with the approach in Franko et al. (2011) and as detailed in Wüst-Galley et al. (2020).

Carbon stocks in mineral soil were integrated in category 4C by calculating area-weighted (using the relative surface of the six grassland types) average values per elevation zone. Annual data are shown in Table 6-26 and in Figure 6-17 upper panel.

Annual data mainly reflect effects of climatic conditions, whereas long-term trends related to e.g. changes in agricultural management are better visible when the data are smoothed. Therefore, Figure 6-17 also shows moving averages over five years (from year-2 to year+2; the previous and latest reporting years are given as four-year (year-2 to year+1) and three-year (year-2 to latest reporting year) moving averages, respectively).

The resulting area-weighted (across the three elevation zones) mean carbon stock in mineral soil for permanent grassland over the inventory period was  $56.10 \text{ t C ha}^{-1}$ .

Table 6-26 Area-weighted (using the relative surface of the six grassland types) carbon stocks ( $\text{t C ha}^{-1}$ ) and net carbon stock changes ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ ) in mineral soil (0-30 cm) for land-use category permanent grassland (CC31), stratified for elevation zone (Elev: Elevation Z1 = <601 m, Z2 = 601-1200 m, Z3 = >1200 m; see chp. 6.2.2.2). Highlighted data for 1990 are displayed in Table 6-4. Please note: Associated data in CRT Table4.C.1 also include land-use changes within the Grassland land-use categories CC31–CC37 and therefore differ from the data shown here (see also chp. 6.1.3.4).

Mineral soil	Elev.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		CC31: carbon stock [ $\text{t C ha}^{-1}$ ] and net change in mineral soil [ $\text{t C ha}^{-1} \text{ yr}^{-1}$ ]									
Stock	Z1	63.06	63.12	63.08	62.82	62.58	62.32	62.31	62.24	62.08	61.94
Stock	Z2	58.95	59.22	59.39	59.37	59.35	59.29	59.45	59.55	59.52	59.55
Stock	Z3	46.21	46.92	47.50	47.97	48.43	48.82	49.37	49.84	50.14	50.55
Net change	Z1	-0.07	0.06	-0.03	-0.26	-0.24	-0.26	0.00	-0.08	-0.15	-0.15
Net change	Z2	0.10	0.27	0.17	-0.02	-0.01	-0.06	0.16	0.10	-0.03	0.03
Net change	Z3	0.62	0.71	0.58	0.47	0.46	0.39	0.55	0.48	0.30	0.40

Mineral soil	Elev.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		CC31: carbon stock [ $\text{t C ha}^{-1}$ ] and net change in mineral soil [ $\text{t C ha}^{-1} \text{ yr}^{-1}$ ]									
Stock	Z1	61.67	61.40	61.22	61.31	61.42	61.17	61.20	61.04	60.96	60.80
Stock	Z2	59.47	59.39	59.38	59.32	59.33	59.32	59.36	59.23	59.34	59.32
Stock	Z3	50.82	51.12	51.42	51.65	51.89	52.16	52.40	52.51	52.87	53.08
Net change	Z1	-0.27	-0.27	-0.18	0.09	0.12	-0.26	0.03	-0.16	-0.08	-0.16
Net change	Z2	-0.08	-0.08	-0.01	-0.06	0.01	-0.01	0.04	-0.13	0.11	-0.01
Net change	Z3	0.28	0.30	0.30	0.22	0.24	0.27	0.24	0.11	0.36	0.21

Mineral soil	Elev.	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
		CC31: carbon stock [ $\text{t C ha}^{-1}$ ] and net change in mineral soil [ $\text{t C ha}^{-1} \text{ yr}^{-1}$ ]									
Stock	Z1	60.61	60.53	60.27	60.10	59.78	59.73	59.73	59.48	59.43	59.28
Stock	Z2	59.29	59.26	59.11	59.12	58.97	58.88	58.84	58.72	58.60	58.44
Stock	Z3	53.29	53.50	53.52	53.70	53.84	53.93	54.04	54.10	54.19	54.17
Net change	Z1	-0.19	-0.08	-0.26	-0.17	-0.31	-0.05	0.00	-0.25	-0.05	-0.15
Net change	Z2	-0.03	-0.03	-0.15	0.01	-0.15	-0.09	-0.05	-0.12	-0.12	-0.16
Net change	Z3	0.22	0.21	0.01	0.19	0.14	0.09	0.11	0.06	0.08	-0.01

Mineral soil	Elev.	2020	2021	2022	2023	
		CC31: carbon stock [ $\text{t C ha}^{-1}$ ] and net change in mineral soil [ $\text{t C ha}^{-1} \text{ yr}^{-1}$ ]				
Stock	Z1	58.96	58.86	58.84	58.81	
Stock	Z2	58.28	58.35	58.37	58.30	
Stock	Z3	54.19	54.42	54.49	54.42	
Net change	Z1	-0.32	-0.09	-0.02	-0.03	
Net change	Z2	-0.16	0.07	0.02	-0.07	
Net change	Z3	0.02	0.23	0.06	-0.07	

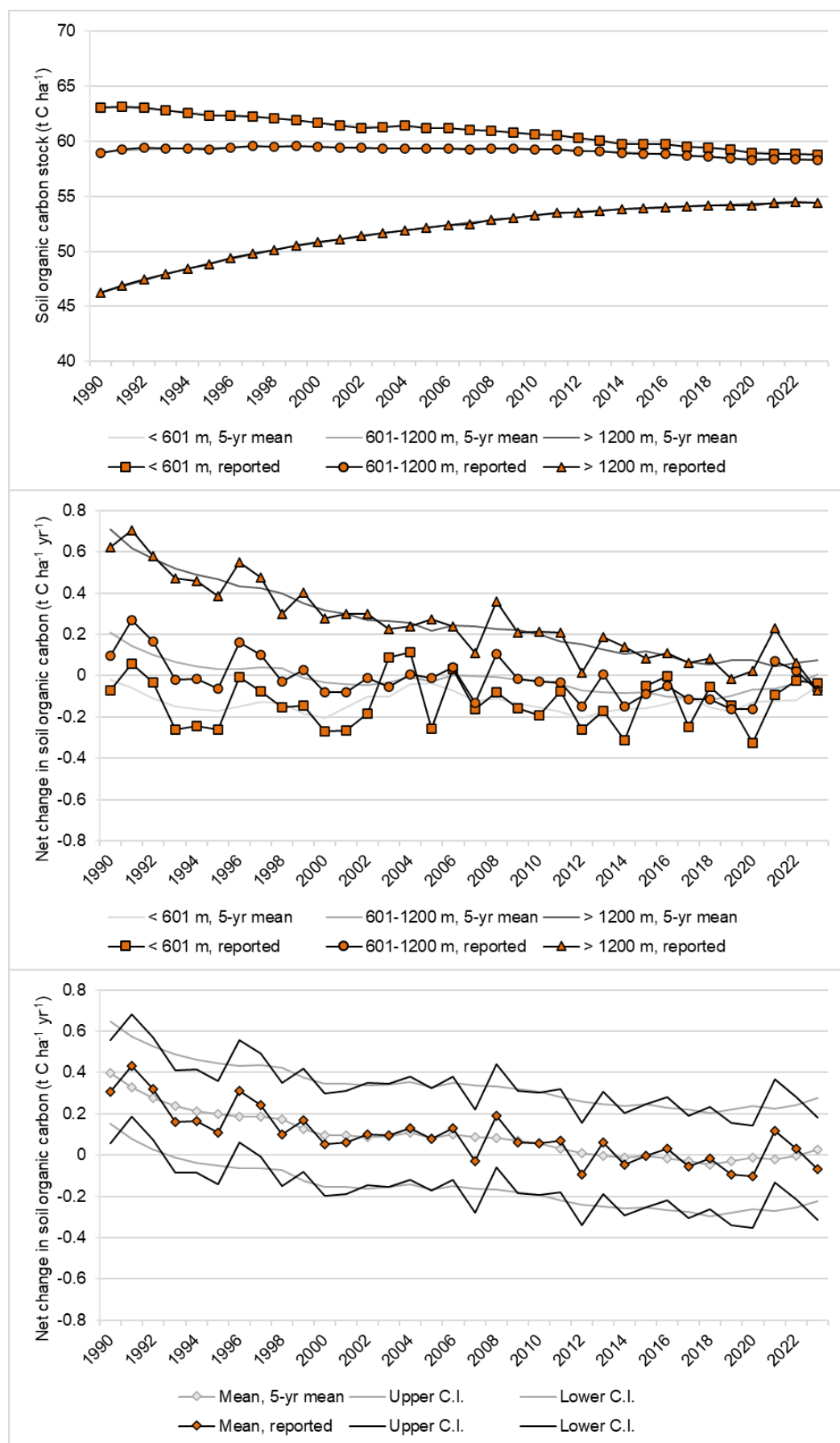


Figure 6-17 Reported carbon stocks ( $\text{t C ha}^{-1}$ ) and net carbon changes ( $\text{t C ha}^{-1} \text{ yr}^{-1}$ ) in permanent grassland mineral soil (0–30 cm), stratified for elevation zone, each with the moving average (upper and middle panel) and area-weighted means (across three elevation zones) with moving average (lower panel) plus upper and lower confidence intervals (C.I.; see chp. 6.6.3.1.2).

### 6.6.2.1.3.2. Mineral soil: Remaining Grassland land-use categories (CC32–37)

For the estimation of carbon stocks in mineral soil on the remaining Grassland land-use categories the digital soil maps provided by Stumpf et al. (2023) were used. A subset of the maps represents the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories (status of AREA4), mean carbon stocks were calculated, where appropriate for each elevation zone (Metetest 2025):

- Shrub vegetation (CC32)  
Elevation zone 1: 55.5 t C ha<sup>-1</sup>  
Elevation zone 2: 43.3 t C ha<sup>-1</sup>  
Elevation zone 3: 36.7 t C ha<sup>-1</sup>
- Vineyards, low-stem orchards and tree nurseries (CC33): 50.8 t C ha<sup>-1</sup>
- Copse (CC34)  
Elevation zone 1: 62.6 t C ha<sup>-1</sup>  
Elevation zone 2: 57.4 t C ha<sup>-1</sup>  
Elevation zone 3: 37.6 t C ha<sup>-1</sup>
- Orchards (CC35): 62.9 t C ha<sup>-1</sup>
- Stony grassland (CC36): 13.5 t C ha<sup>-1</sup>  
In accordance with the assumptions in chp. 6.6.2.1.1.5 the calculation took into account that only 35% of the area has a mineral soil that is surrounded by bare rock.
- Unproductive grassland (CC37): 37.5 t C ha<sup>-1</sup>

### 6.6.2.1.3.3. Organic soil

The soil carbon stock in organic soil on Grassland was calculated based on Presler and Gysi (1989) and Leifeld et al. (2003, 2005) without differentiating between Cropland and Grassland. The mean soil organic carbon stock (0–30 cm) in organic soil is 240±48 t C ha<sup>-1</sup> (uncertainty 20 %); see chp. 6.5.2.1.3.2 for methodological details.

For the land-use category stony grassland (CC36) it was assumed that the small area covered by organic soil (see Table 6-7), 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.

## 6.6.2.2. Changes in carbon stocks

### 6.6.2.2.1. Carbon stock changes in living biomass

For permanent grassland (CC31), the difference in carbon stock in living biomass between two consecutive years was reported as net carbon stock change (gain or loss) (see Table 6-25 and Figure 6-16 middle panel). In addition to annual changes in carbon stocks five-year moving averages were also displayed in Figure 6-16. The mean area-weighted carbon stock change across all elevation zones was -0.012 t C ha<sup>-1</sup> yr<sup>-1</sup> for the inventory period.

Applying a Tier 1 approach, carbon stock changes in living biomass were assumed to be in equilibrium for Grassland remaining grassland in the other land-use categories CC32–CC37.

#### **6.6.2.2.2. Carbon stock changes in dead organic matter**

Applying a Tier 1 approach, carbon stock changes in dead organic matter were assumed to be in equilibrium for Grassland remaining grassland.

#### **6.6.2.2.3. Carbon stock changes in soil**

##### **6.6.2.2.3.1. Mineral soil: Permanent grassland (CC31)**

The difference in carbon stock between two consecutive years was reported as net carbon stock change (gain or loss) in permanent grassland mineral soil (see Table 6-26 and Figure 6-17 middle panel). In addition to annual changes in carbon stocks, five-year moving averages were also displayed in Figure 6-17.

The mean carbon stock change in the inventory period for elevation zone 1 was  $-0.127 \text{ t C ha}^{-1} \text{ yr}^{-1}$ , for elevation zone 2  $-0.016 \text{ t C ha}^{-1} \text{ yr}^{-1}$  and for elevation zone 3  $0.259 \text{ t C ha}^{-1} \text{ yr}^{-1}$ . The mean area-weighted carbon stock change across all elevation zones was  $0.091 \text{ t C ha}^{-1} \text{ yr}^{-1}$ .

##### **6.6.2.2.3.2. Mineral soil: Remaining Grassland land-use categories (CC32–37)**

A Tier 1 approach (changes in soil carbon stocks are in equilibrium) was assumed for carbon stock changes in mineral soil in the land-use categories CC32–37.

##### **6.6.2.2.3.3. Organic soil**

The annual net carbon stock change in organic soil on managed grassland (CC31, CC33, CC35) was estimated as  $-9.52 \text{ t C ha}^{-1}$  according to measurements in Europe including Switzerland as compiled by Leifeld et al. (2003, 2005) and verified by ART (2009b) and Paul and Alewell (2018). For extensively managed grasslands (CC32, CC34, CC36, CC37) the emission from organic soil was estimated as  $5.30 \text{ t C ha}^{-1} \text{ yr}^{-1}$  according to available domestic data (ART 2011b; Paul and Alewell 2018; Paul et al. 2021).

#### **6.6.2.2.4. Land-use change**

In the case of land-use change, the net carbon stock changes in biomass and soils of land-use categories CC31, CC32, CC33, CC34, CC35, CC36, and CC37 were calculated as described in chp. 6.1.3.

### **6.6.2.3. Non-CO<sub>2</sub> emissions from Grassland**

#### **6.6.2.3.1. N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage of organic soil**

N<sub>2</sub>O emissions from drainage of organic soil on Grassland (including category 4(II)C2 Land converted to grassland (notation key IE)) were reported in the Agriculture sector (category 3D1f Cultivation of organic soils; see chp. 5.5.1).

CH<sub>4</sub> emissions in category 4(II)C1 Grassland remaining grassland in CRT Table4(II) were not estimated (notation key NE) as reporting is not mandatory for this category.

### 6.6.2.3.2. *Direct and indirect N<sub>2</sub>O emissions from mineral soils*

The calculations of direct and indirect N<sub>2</sub>O emissions from nitrogen mineralisation in mineral soil are described in Annex A5.4.

Direct and indirect N<sub>2</sub>O emissions from Grasslands remaining grasslands (category 4(III)C1) were included in the Agriculture sector in category 3D1e Mineralisation (see chp. 5.5.1) (notation key IE), whereas those from Lands converted to grasslands (category 4(III)C2) were reported under LULUCF.

### 6.6.2.3.3. *CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning*

Data on wildfires affecting Grassland are obtained from cantonal authorities and were compiled by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL, Swissfire database, <http://www.wsl.ch/swissfire>; Pezzatti et al. 2019). Table 6-27 shows selected data from the time series 1990 to 2023 of affected areas and associated emissions. The Swissfire database differentiates between 'grassland' and 'unproductive land'. As 'unproductive land' can partially cover the Grassland land-use 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, and controlled burning was reported as not occurring (NO).

The CH<sub>4</sub> and N<sub>2</sub>O emissions were calculated using equation 2.27 in Volume 4 of IPCC (2019) with the following parameters:

- 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 16.44 t biomass ha<sup>-1</sup> (7.4 t C ha<sup>-1</sup>). This value was derived from the carbon stocks (average 1990–2020) of all Grassland land-use categories (CC31–CC37) as an area-weighted mean using the geographical extensions in 1990 (using raw data from FOEN 2023). A carbon fraction of 0.45 was applied.
- The fraction of the biomass combusted was assumed to be 0.74 (IPCC 2019, Volume 4, Table 2.6, Savanna grasslands).
- For CH<sub>4</sub> the default emission factor of 2.3 g (kg combusted dry biomass)<sup>-1</sup> and for N<sub>2</sub>O, the default emission factor of 0.21 g (kg combusted dry biomass)<sup>-1</sup> was applied (IPCC 2019, Volume 4, Table 2.5, Savanna and Grassland).

The resulting annual CH<sub>4</sub> and N<sub>2</sub>O emissions on burnt areas in category 4C Grassland are shown in Table 6-27 and are reported in CRT Table4(IV).

Table 6-27 Grassland affected by wildfires (WSL, Swissfire database) and resulting CH<sub>4</sub> and N<sub>2</sub>O emissions.

Grassland	Unit	1990	1995	2000	2005	2010
Area burnt	ha	637	82	22	20	1.3
CH <sub>4</sub>	t	18	2.3	0.61	0.55	0.037
N <sub>2</sub> O	t	1.6	0.21	0.056	0.051	0.0034

Grassland	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Area burnt	ha	2.6	14	213	38	32	16	31	9.9	63	9.1
CH <sub>4</sub>	t	0.072	0.39	6.0	1.1	0.88	0.46	0.85	0.28	1.8	0.25
N <sub>2</sub> O	t	0.0066	0.036	0.54	0.098	0.081	0.042	0.078	0.025	0.16	0.023



#### **6.6.2.3.4. Precursor gas emissions ( $\text{NO}_x$ , CO, NMVOC)**

CRT Table4 presents annual emissions of  $\text{NO}_x$ , CO and NMVOC from 4(IV)C Wildfires on Grassland as described by FOEN (2025b: chp. 7.3). In addition, CRT Table4 includes an estimate for the biogenic emissions of NMVOC on unproductive grassland that is not included in the Agriculture sector. Based on SAEFL (1996a), a value of  $0.51 \text{ kt yr}^{-1}$  was used over the entire time series (FOEN 2025b: chp. 7.4).

### **6.6.3. Uncertainties and time-series consistency for 4C**

#### **6.6.3.1. Uncertainties**

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

##### **6.6.3.1.1. Activity data**

Uncertainties of activity data of category 4C Grassland are described in chp. 6.3.1.3.1.

##### **6.6.3.1.2. Overall uncertainties of carbon stock changes and emission factors**

For calculating the overall uncertainty of category 4C, the relevant emissions and removals from living biomass, dead organic matter, mineral soil and organic soil were considered. The uncertainties of carbon stock change factors and emission factors were calculated for 1990 and the latest reporting year (see overview in Table 6-5).

#### **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 were derived from many agricultural field experiments and have a high reliability (SBV 2023; Richner and Sinaj 2017).

#### **Dead organic matter**

Emissions from the dead organic matter pool occur only by land-use changes from Forest land to Grassland as the carbon stock of dead organic matter is assumed to be zero in the non-forest land-use categories. Thus, the uncertainty of these emissions corresponds to the uncertainty of carbon stocks in litter and dead wood on Forest land. Based on the results of the NFI4 and the Yasso20 model presented by Didion (2023), a relative uncertainty of 0.5 % was calculated for the total carbon stock in litter and dead wood (Meteotest 2025).

#### **Mineral soil**

The absolute uncertainty of  $0.249 \text{ t C ha}^{-1} \text{ yr}^{-1}$  was used for annual carbon stock changes in categories 4C1 and 4C2. This value was calculated by a Monte Carlo analysis (Wüst-Galley et al. 2020), see chp. 6.5.3.1.2. By comparison, the range of annual SOC changes identified

for 9 different treatments of Swiss agricultural long-term experiments is  $0.51 \text{ t C ha}^{-1} \text{ yr}^{-1}$  (Keel et al. 2019), indicating that the calculated uncertainty is plausible.

The resulting relative uncertainty in submission 2024 (FOEN 2024), calculated with the implied carbon stock change factors of mineral soil, was 1'108.0 % for category 4C1 and 107.8 % for category 4C2. The same values were used for the year 2023 in the latest submission.

### Organic soil

The uncertainty of the activity data (area of organic soil) is 68.6 % (see chp. 6.3.1.3.2). The uncertainty of the carbon stock change factor in organic soil is 23 % as reported by Leifeld et al. (2003: 56).

### Overall uncertainties categories 4C1 and 4C2

Using the detailed input uncertainties as described above, the uncertainty propagation for categories 4C1 and 4C2 was computed using Monte Carlo simulations (see chp. 1.6.2). The resulting overall uncertainties of approach 2 for categories 4C1 and 4C2 emissions and removals in 2023 are (-622, +616 %) and (-17, +17 %), respectively (see Annex A2.3).

#### 6.6.3.1.3. *Uncertainties in category 4(IV) Biomass burning, Wildfires ( $\text{CH}_4$ , $\text{N}_2\text{O}$ )*

For wildfires, the activity data uncertainty is 30 % (see chp. 6.3.1.3.3). The emission factor uncertainties of  $\text{CH}_4$  and  $\text{N}_2\text{O}$  were set to 70 % (same as in Forest land, see chp. 6.4.3.1).

#### 6.6.3.2. Time-series consistency

Time series for category 4C Grassland are all considered consistent; they were calculated based on consistent methods and homogenous databases (Wüst-Galley et al. 2020). Small inconsistencies in the input data for the RothC model (related to livestock husbandry, compare chp. 5.2.3 and chp. 5.3.3) are barely relevant for the overall results.

### 6.6.4. Category-specific QA/QC and verification for 4C

The general QA/QC measures are described in chp. 1.5.

#### 6.6.4.1. Carbon stocks in living biomass

The grassland yield data for the latest reporting year are available always in the most recent Swiss Farmers' Union's annual report. Since this report is usually not available in time, the inventory is prepared with a provisional value for the latest reporting year, using the value for the last year for which data are available. The correction of this provisional value in the following submission leads by default to a recalculation for the year in question.

## 6.6.4.2. Carbon stock changes in mineral soil

### 6.6.4.2.1. RothC

RothC, used to model SOC stock changes, is a relatively simple model that does not represent certain soil processes such as feedback due to microbial processes or consider other nutrient cycles. It was however the best-performing model given the available data for Switzerland, considering also temporal resolution (Wüst-Galley et al. 2020). The calibration of the allometric equations (for deriving carbon inputs from the cumulative yield of six differentially managed grasslands), as well as a comparison of simulated SOC stock changes with measured values from field experiments is described in Wüst-Galley et al. (2020). A sensitivity analysis of the RothC simulations and of the system used to upscale these simulations to the national scale was completed (Wüst-Galley et al. 2021). The model performance is evaluated on an ongoing basis.

The recalculations related to newly available soil information in the previous submission (described in detail in FOEN 2024: chp. 10.1.2.4) had a strong influence on the carbon stock changes of permanent grassland. There is on-going work investigating the effects of these new initial carbon stocks and the omission of a warm-up phase in the model (both recalculations of submission 2024) on soil carbon changes. It seems that these changes are especially important for Grassland soil carbon changes in upland regions. For the years 1990–2006 stock changes are consistently above zero with a clear decreasing trend until about 2012 (Figure 6-17 lower panel). This trend is dominated by the results for the highest elevation zone (Z3), but is also visible to a lesser extent during the first years for the two lower elevation zones (Figure 6-17 middle panel). However, due to high uncertainties mean stock changes across all elevation zones are only statistically significant for the first three years as well as for 1996 (i.e., lower confidence interval in Figure 6-17 lower panel is above zero).

The positive mean SOC stock change for the entire inventory period ( $0.091 \text{ t C ha}^{-1} \text{ yr}^{-1}$ ) agrees with the European-scale increase in SOC content that was estimated by De Rosa et al. (2024) for grassland remaining grassland based on data from the Land Use/Land Cover Area Frame Survey (LUCAS) for the years 2009–2018. If only stock changes for identical years (i.e., 2009–2018) are compared, the direction of change no longer agrees, because there is no change in the inventory data ( $0.007 \text{ t C ha}^{-1} \text{ yr}^{-1}$ ; Figure 6-17 lower panel). Quantitative comparisons, however, are not possible because different metrics were used.

### 6.6.4.2.2. Swiss Soil Monitoring Network (NABO)

NABO provides data from 33 monitoring sites identified as grassland (NABO 2021b; Gross et al. 2024; see chp. 6.4.4.4) according to the land-use categorisation used for LULUCF (see chp. 6.2). The selected sites include 26 meadows and pastures, but also 4 vineyards and 3 orchards. SOC stocks for the top 20 cm of these soils ranged from 25 to  $144 \text{ t C ha}^{-1}$  with a mean of  $75 \text{ t C ha}^{-1}$  (Figure 6-18 top panel). The highest carbon stocks 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 (Figure 6-18 bottom panel). However, these minor changes were statistically non-significant. In addition, previous studies showed that the elevated SOC stocks for the third sampling campaign must be considered as an artefact, induced by sub-optimal conditions during field work (Meuli et al. 2014; Gubler et al. 2015). From sampling campaigns 4 to 7, SOC stocks 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 30 monitoring sites including three or more sampling campaigns). Regarding the measured SOC stocks (mean 75 t ha<sup>-1</sup>) this corresponds to a minimum detectable change of roughly 0.19 t C ha<sup>-1</sup> yr<sup>-1</sup> for SOC stocks.

The mean change in SOC which was calculated with RothC for the years 1990–2023 was 0.091±0.249 t C ha<sup>-1</sup> yr<sup>-1</sup> (area-weighted mean across three elevation zones ± the absolute uncertainty based on a Monte Carlo analysis; see Figure 6-17 lower panel and chp. 6.6.3.1.2). In comparison, the modelled net carbon change is clearly smaller than the detectable change by NABO and suggests that modelled SOC stock changes agree with the repeated soil inventories in the NABO network.

In conclusion, NABO data provide evidence that Grassland mineral soils acted neither as a significant net source nor as a significant net sink of carbon when considered over the entire inventory period (see also Moll-Mielewczik et al. 2023 and Keel et al. 2024).

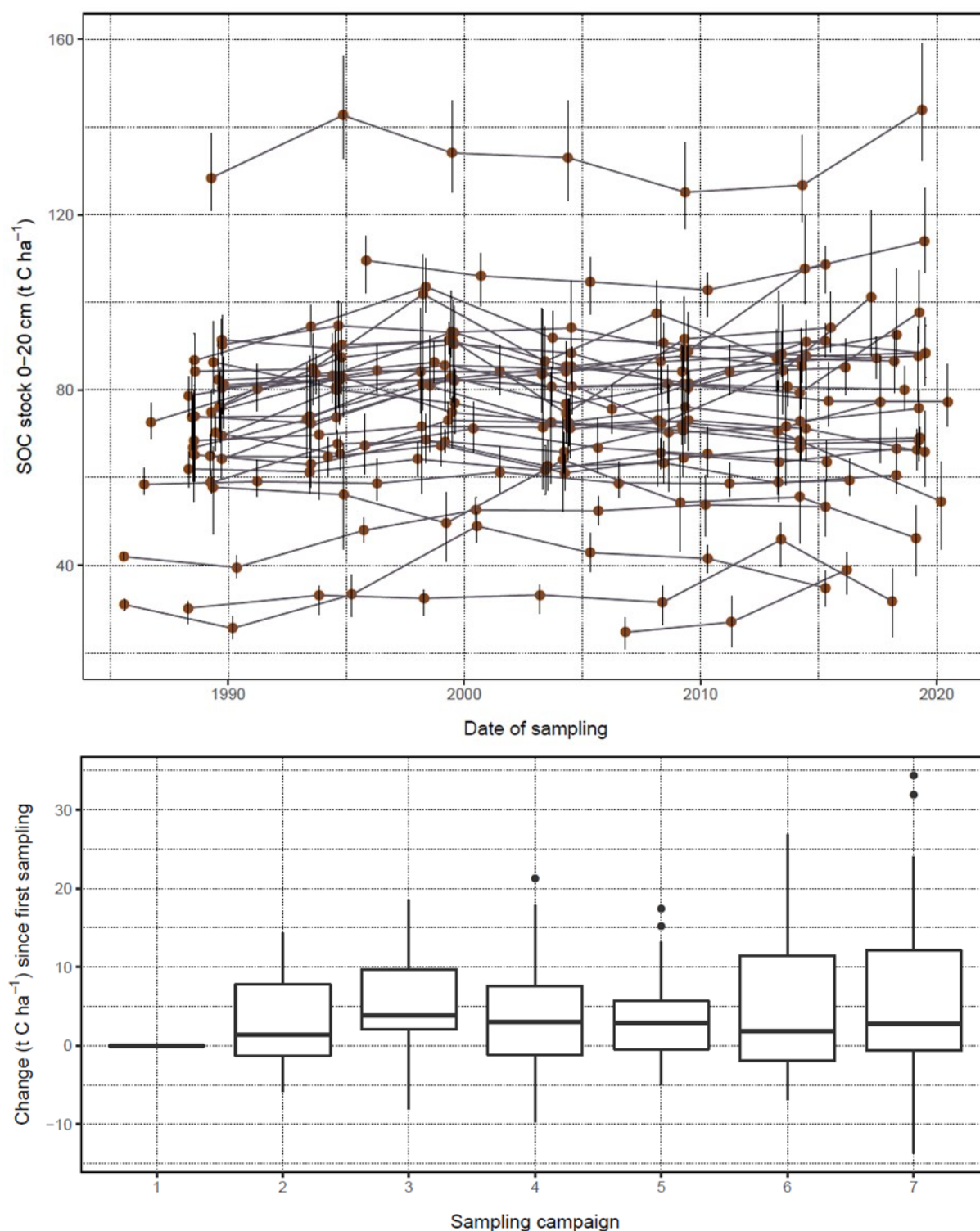


Figure 6-18 Measured SOC stocks for topsoils (0–20 cm) and their changes for 33 NABO long-term monitoring sites used as grassland during the period 1985–2019. The elevation of the sites ranges from 265 to 2400 m a.s.l. Top panel: SOC stocks 0–20 cm per site and sampling; the dots indicate the mean and the bars the range of 5 % and 95 % percentiles of bootstrap samples taking into account the variability in SOC content of the individual replicates per site and sampling as well as the variations of the bulk density. Bottom panel: boxplot of changes in SOC stocks in each case related to the first sampling (boxes indicate the lower and 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).

#### 6.6.4.3. Short-term land-use changes between Grassland and Cropland

See chp. 6.5.4.3.

### 6.6.5. Category-specific recalculations for 4C

The following recalculations were implemented.

- 4C, activity data (areas): Data 1990–2022 were updated (see chp. 6.3.1.5). The inclusion of most recent data from the AREA5 survey, updates of the AREA1–4 surveys and the new geo-referenced approach for interpolating and extrapolating yearly land-use data led to area gains in permanent grassland (CC31; above all at the expense of CC21 Cropland) and very small recalculations for the other grassland land-use categories (CC32–CC37) (Table 6-11).
- 4C, activity data (organic soil): The update of the dataset defining the geographical distribution of organic soils in Switzerland was finalised (see chp. 6.3.1.5). The total area of organic soil on Grassland slightly decreased, e.g. from 8.2 to 8.1 kha for 1990 (Figure 6-7 and Table 6-7). Figure 10-10 shows the small to moderate changes in CO<sub>2</sub> emissions from organic soil (in the range between -9.2 and -0.7 kt) resulting from both recalculations of activity data.
- 4C, permanent grassland (CC31): Results of the RothC model for carbon stock changes in biomass and mineral soils are reported on annual basis whereas 5-year moving averages were reported in previous submissions. The abandonment of multi-year averaging led to a much stronger annual fluctuation of CO<sub>2</sub> emissions and removals in living biomass and in mineral soil. This recalculation explains almost all of the differences in net emissions and removals between the latest and the previous submissions in category 4C, which range from -1'199.2 kt CO<sub>2</sub> eq in 2016 to 1'502.8 kt CO<sub>2</sub> eq in 2015 (mean: 176.6 kt CO<sub>2</sub> eq). The resulting time series shows the expected pronounced zigzag pattern (Figure 10-9).
- 4C, permanent grassland (CC31): Carbon stocks and carbon stock changes in mineral soil were recalculated for the whole inventory period (RothC simulations), applying
  - new meteorological data for the period 1975–2023, based on a release of new data from MeteoSwiss in 2024 (MeteoSwiss 2024). The recalculation had a negligible effect on mineral soil carbon changes, though it explains almost all differences in carbon stock changes between the latest submission and the previous one (aside from those related to the new reporting on an annual basis);
  - updated information used for the calculation of organic amendments for the year 2022 (animal numbers, straw production and the amount of manure going to biogas plants), following the availability of new data (SBV 2023, for biogas as described in chp. 5.3.2.2.3). This recalculation had a negligible effect on mineral soil carbon changes.
- 4C, remaining land-use categories CC32–CC37: Carbon stocks in mineral soil were updated based on the digital soil maps provided by Stumpf et al. (2023).
- 4(IV)C: CH<sub>4</sub> and N<sub>2</sub>O emissions from wildfires 1997, 1998, 2001, 2002, 2003, 2005, 2007 and 2015–2022 were recalculated based on updated areas of open land fires in the Swissfire database. Very small changes resulted from this recalculation.

### 6.6.6. Category-specific planned improvements for 4C

#### 6.6.6.1. Living biomass

The project process to achieve a sound wall-to-wall above ground tree biomass database and map for Switzerland is described in chp. 6.5.6.1. The suitability of the methodology for reporting in category 4C is subject to ongoing evaluation. The first set of nationwide data is expected in summer 2025.



### 6.6.6.2. Mineral soil

The information in chp. 6.5.6.2 on the switch to grid-based SOC modelling with RothC and on the potential for improvement using predicted soil carbon stocks from an earlier period also applies to permanent grassland mineral soil. The progress of digital soil modelling at CCSoils will continue to be used to improve estimates soil carbon stocks in the remaining Grassland land-use categories.

## 6.7. Category 4D – Wetlands

### 6.7.1. Description

Table 6-28 Key categories in category 4D Wetlands. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
4.D.1	Wetlands remaining wetlands	CO <sub>2</sub>	L2

Wetlands were subdivided into surface water (CC41) and unproductive wetland such as shore vegetation, fens or (raised) bogs (CC42) (see Table 6-2 and Table 6-6).

Figure 6-19 shows the time series of net CO<sub>2</sub> emissions and net CO<sub>2</sub> removals from categories 4D1 Wetlands remaining wetlands and 4D2 Land converted to wetlands. Emissions from organic soil largely dominate category 4D1 alone. Net emissions from category 4D2 remained at almost double the early 1990s level for many years and appear to be decreasing slightly towards the end (with carbon losses in living biomass and in mineral soil from Forest land converted to other wetlands as both most important and driving process). Total net emissions from category 4D Wetlands range between 131 and 169 kt CO<sub>2</sub> (in 1991 and in 2012, respectively; not shown).

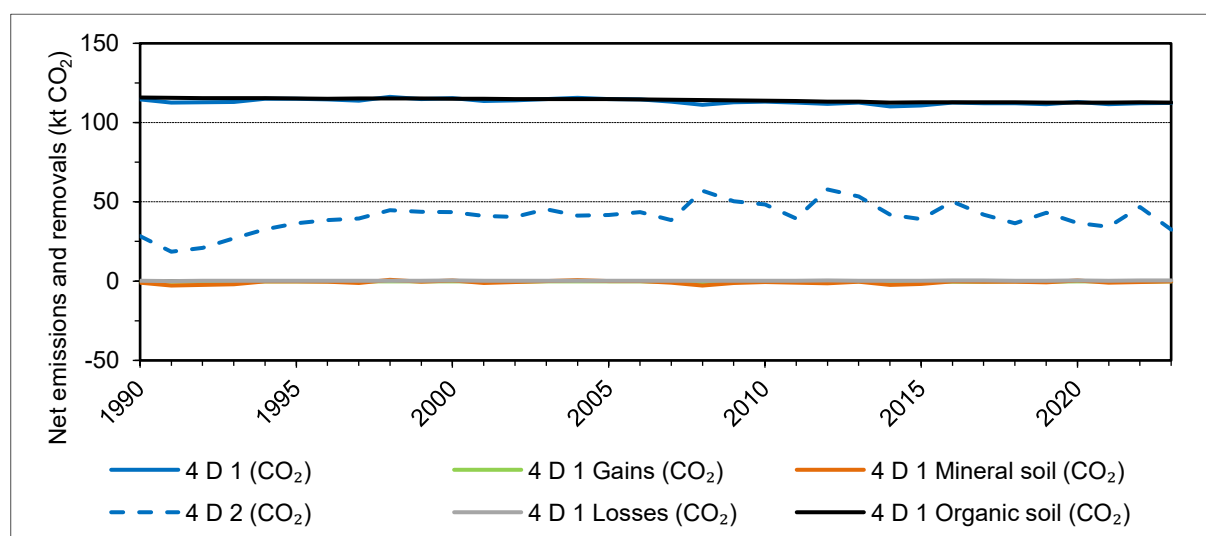


Figure 6-19 Net CO<sub>2</sub> emissions (positive values) and removals (negative values) from categories 4D1 and 4D2. Category 4D1 is broken down by gains in living biomass, losses in living biomass, net carbon stock changes in mineral soil, and net carbon stock changes in organic soil. Gains and losses in living biomass are too small to be distinguished from the zero line.



## 6.7.2. Methodological issues

### 6.7.2.1. Carbon stocks

#### 6.7.2.1.1. *Carbon stocks in living biomass*

##### 6.7.2.1.1.1. **Surface waters (CC41)**

Surface waters have no carbon stocks in living biomass by definition.

##### 6.7.2.1.1.2. **Unproductive wetland (CC42)**

Land-use category CC42 consists of (very) extensively managed grassland, bushes or tree groups. The carbon stock of living biomass was estimated as  $6.5 \text{ t C ha}^{-1}$  (Mathys and Thürig 2010: Table 7).

##### 6.7.2.1.2. *Carbon stocks in dead organic matter*

Carbon stocks in dead organic matter were assumed to be zero.

#### 6.7.2.1.3. *Carbon stocks in soil*

##### 6.7.2.1.3.1. **Surface waters (CC41)**

The mineral soil carbon stock for surface waters (CC41) is zero.

For CC41 situated in areas with organic soil (chp. 6.2.2.1 and Table 6-7), a soil carbon stock of  $240 \text{ t C ha}^{-1}$  (0–30 cm) was assumed (see chp. 6.5.2.1.3.2). These surface waters were assumed to be shallow ponds as integrated parts of fens or bogs.

##### 6.7.2.1.3.2. **Unproductive wetland (CC42)**

Land cover in CC42 includes (raised) bogs and fens protected by Federal Legislation (Swiss Confederation 1991a, 1994) as well as reed. Nearly 25 % of the unproductive wetland are located on organic soil (see Table 6-7). In this case the soil carbon stock is  $240 \text{ t C ha}^{-1}$  (0–30 cm) (see chp. 6.5.2.1.3.2).

The carbon stock of CC42 on mineral soil was retrieved from the digital soil maps provided by Stumpf et al. (2023) (see chp. 6.5.2.1.3.1). A subset of the maps represents the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories (status of AREA4), a mean carbon stock was calculated (Meteotest 2025):  $56.9 \text{ t C ha}^{-1}$ .

### 6.7.2.2. Changes in carbon stocks

#### 6.7.2.2.1. *Carbon stock changes in living biomass, dead organic matter, and mineral soil*

Applying a Tier 1 approach, carbon stock changes in living biomass, dead organic matter, and mineral soil were assumed to be in equilibrium for Wetlands remaining wetlands.

#### **6.7.2.2.2. Carbon stock changes in organic soil**

Carbon losses in organic soil in land-use category CC41 Surface waters were assumed to be zero because the respective areas are not drained.

Carbon losses in organic soil in land-use category CC42 were estimated to be  $5.30 \text{ t C ha}^{-1} \text{ yr}^{-1}$  according to domestic data (ART 2011b; Paul and Alewell 2018). This value was used for weakly managed ecosystems such as fens and (very) extensively managed ecosystems such as raised bogs. Most bogs and fens are protected by Federal Ordinances (Swiss Confederation 1991a, 1994) and drainage is not allowed any more. However, the impact of old drainages constructed before 1990 still triggers certain emissions.

#### **6.7.2.2.3. Land-use change**

In the case of land-use change, the net carbon stock changes in biomass and soils of both land-use categories 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). For carbon stock changes in mineral soil the conversion time is 20 years.

### **6.7.2.3. Non-CO<sub>2</sub> emissions from Wetlands**

#### **6.7.2.3.1. Direct and indirect N<sub>2</sub>O emissions from N inputs to managed soils**

No emissions were reported in category D in CRT Table4(I) (notation key NO). Input of nitrogen fertilisers to land-use category 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 fertilising is prohibited.

#### **6.7.2.3.2. N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage and rewetting of organic and mineral soils**

N<sub>2</sub>O emissions on rewetted mineral soils in category 4(II)D1b Flooded land remaining flooded land in CRT Table4(II) were not estimated (notation key NE) as reporting is not mandatory for this category.

An estimate of  $0.4 \text{ kt CH}_4 \text{ yr}^{-1}$  emitted by reservoirs was given by Hiller et al. (2014). The estimate encompasses 97 artificial lakes covering a total area of 10.6 kha. This emission source is reported under Rewetted mineral soils in category 4(II)D1b Flooded land remaining flooded land in CRT Table4(II) (labelled as "Flooded lands").

N<sub>2</sub>O emissions from drainage of organic soil was calculated for unproductive wetland (CC42) and reported in category 4(II)D1c Other wetlands remaining other wetlands in CRT Table4(II) (labelled as "Wetlands drained"). Activity data correspond to the total area of organic soil for all subdivisions "Unproductive wetland" (CC42) in CRT Table4.D. The emission factor of  $1.6 \text{ kg N}_2\text{O-N ha}^{-1}$  used is the default value given in the IPCC Wetlands Supplement (IPCC 2014a: Table 2.5) for shallow-drained, nutrient-rich grassland.

CH<sub>4</sub> emissions in category 4(II)D1c Other wetlands remaining other wetlands in CRT Table4(II) were not estimated (notation key NE) as reporting is not mandatory for this category.

#### **6.7.2.3.3. Direct and indirect N<sub>2</sub>O emissions from mineral soils**

The calculations of direct and indirect N<sub>2</sub>O emissions from nitrogen mineralisation in mineral soil (category 4(III)D) in Wetlands are described in Annex A5.4.

#### **6.7.2.3.4. CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning**

CH<sub>4</sub> emissions and N<sub>2</sub>O emissions from biomass burning in Wetlands (category 4(IV)D) were not occurring (notation key NO).

### **6.7.3. Uncertainties and time-series consistency for 4D**

#### **6.7.3.1. Uncertainties**

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

##### **6.7.3.1.1. Activity data**

Uncertainties of activity data of category 4D Wetlands are described in chp. 6.3.1.3.1.

##### **6.7.3.1.2. Overall uncertainties of carbon stock changes and emission factors**

###### **6.7.3.1.2.1. Category 4D1 Wetlands remaining wetlands**

For calculating the overall uncertainty of category 4D1, only the relevant emissions from organic soil were considered (see Table 6-5).

The uncertainty of the activity data (area of organic soil) is 90.8 % (see chp. 6.3.1.3.2). The uncertainty of the carbon stock change factor in organic soil is 72.2 % both for 1990 and 2023. It was calculated on the basis of measurement data compiled by ART (2011b).

###### **6.7.3.1.2.2. Category 4D2 Land converted to wetlands**

For calculating the overall uncertainty of category 4D2, the relevant emissions and removals from living biomass, dead organic matter, mineral soil and organic soil were considered (see overview in Table 6-5).

#### **Living biomass**

The relative uncertainty in yield determination was estimated as 13 % for biomass carbon from both Cropland and Grassland (Leifeld and Fuhrer 2005).

#### **Dead organic matter**

Emissions from the dead organic matter pool occur only by land-use changes from Forest land to Wetlands as the carbon stock of dead organic matter is assumed to be zero in the non-forest land-use categories. Thus, the uncertainty of these emissions corresponds to the uncertainty of the carbon stock in litter and dead wood on Forest land. Based on the results

of the NFI4 and the Yasso20 model presented by Didion (2023), a relative uncertainty of 0.5 % was calculated for the total carbon stock of litter and dead wood (Meteotest 2025).

### **Mineral soil**

Based on expert judgement, an uncertainty of 50 % was chosen for the carbon stock changes calculated with the stock-difference approach in category 4D2.

### **Organic soil**

The uncertainty of the activity data (area of organic soil) is 90.8 % (see chp. 6.3.1.3.2). The uncertainty of the carbon stock change factor in organic soil is 72.2 % calculated on the basis of measurement data compiled in ART (2011b).

### **Overall uncertainty category 4D2**

Using the detailed input uncertainties as described above, the uncertainty propagation for category 4D2 was computed using Monte Carlo simulations (see chp. 1.6.2). The resulting overall uncertainty of approach 2 for 4D2 emissions in 2022 is 22 % (see Annex A2.3).

#### **6.7.3.1.3.      *Uncertainties in category 4(II)D1b Flooded lands (CH<sub>4</sub>)***

The emission factor uncertainty for CH<sub>4</sub> 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<sub>4</sub> emission factor of category 4(II)D1b (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.

#### **6.7.3.1.4.      *Uncertainties in category 4(II)D1c Wetlands drained (N<sub>2</sub>O)***

For N<sub>2</sub>O emissions from drainage of organic soil (category 4(II)D1c), 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 Table 6-5). The respective activity data uncertainty is 50.8 % (Meteotest 2025). It was calculated by area-weighting and combining the uncertainties of the areas of organic soil for Forest land (35.3 %) and for Wetlands (90.8 %) (see chp. 6.3.1.3.2).

### **6.7.3.2. Time-series 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 for 4D

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

#### 6.7.5. Category-specific recalculations for 4D

The following recalculations were implemented:

- 4D, activity data (areas): Data 1990–2022 were updated (see chp. 6.3.1.5). The inclusion of most recent data from the AREA5 survey, updates of the AREA1-4 surveys and the new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations (Table 6-11).
- 4D, activity data (organic soil): The update of the dataset defining the geographical distribution of organic soils in Switzerland was finalised (see chp. 6.3.1.5). The total area of organic soil in Wetlands slightly decreased, e.g. from 6.2 to 6.1 kha on unproductive wetland (CC42) for 1990 (Figure 6-7 and Table 6-7). Figure 10-10 shows the small decrease in CO<sub>2</sub> emissions from organic soil (in the range between -2.4 and -1.0 kt) resulting from both recalculations of activity data.
- 4D, land-use category CC42: Carbon stock in mineral soil was updated based on the digital soil maps provided by Stumpf et al. (2023).

The resulting differences in net emissions and removals between the latest and the previous submissions for category 4D are shown in Figure 10-9. They are small and range from -18.0 kt CO<sub>2</sub> eq in 2021 to 9.5 kt CO<sub>2</sub> eq in 2012 (mean: -1.3 kt CO<sub>2</sub> eq).

#### 6.7.6. Category-specific planned improvements for 4D

##### 6.7.6.1. Living biomass

The project process to achieve a sound wall-to-wall above ground tree biomass database and map for Switzerland is described in chp. 6.5.6.1. The suitability of the methodology for reporting in category 4D is subject to ongoing evaluation. The first set of nationwide data is expected in summer 2025.

##### 6.7.6.2. Mineral soil

The progress of digital soil modelling at CCSOils mentioned in chp. 6.5.6.2 will continue to be used to improve estimates of carbon stock in unproductive wetland mineral soil.

## 6.8. Category 4E – Settlements

### 6.8.1. Description

Table 6-29 Key categories in category 4E Settlements. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
4.E.2	Land converted to settlements	CO <sub>2</sub>	L1, L2

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).

Figure 6-20 shows the time series of net CO<sub>2</sub> emissions and net CO<sub>2</sub> removals. Category 4E1 Settlements remaining settlements consistently acts as a small CO<sub>2</sub> sink, with a weak minimum formed in the middle of the inventory period. Since 2000, net emissions in category 4E2 Land converted to settlements has declined to a 40 % lower level. Forest land converted to settlements and Grassland converted to settlements together are the most important land-use changes in 4E2. Total net emissions from category 4E Settlements range between 102 and 235 kt CO<sub>2</sub> (in 2023 and in 2000, respectively; not shown).

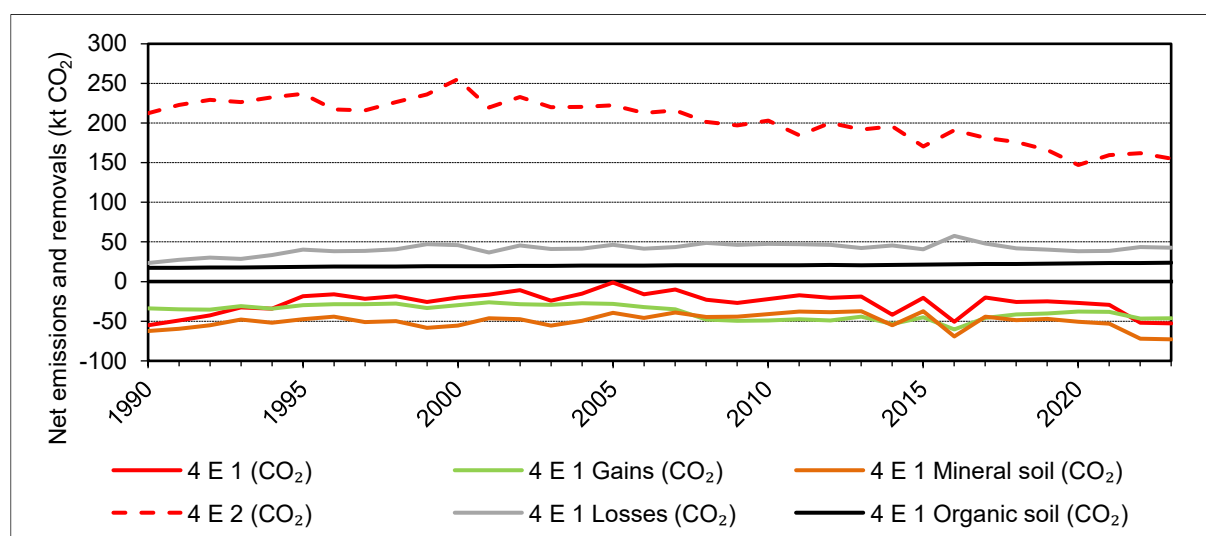


Figure 6-20 Net CO<sub>2</sub> emissions (positive values) and removals (negative values) from categories 4E1 and 4E2. Category 4E1 is broken down by gains in living biomass, losses in living biomass, net carbon stock changes in mineral soil, and net carbon stock changes in organic soil.

## 6.8.2. Methodological issues

### 6.8.2.1. Carbon stocks

#### 6.8.2.1.1. *Carbon stocks in living biomass*

##### 6.8.2.1.1.1. **Buildings and constructions (CC51)**

By default, buildings and constructions have no carbon stocks.

##### 6.8.2.1.1.2. **Herbaceous biomass, shrubs and trees in settlements (CC52, CC53, CC54)**

Carbon stocks in living biomass are: 9.54 t C ha<sup>-1</sup> for CC52, 15.43 t C ha<sup>-1</sup> for CC53, and 20.72 t C ha<sup>-1</sup> for CC54 (Mathys and Thürig 2010: Table 7).

##### 6.8.2.1.2. *Carbon stocks in dead organic matter*

Carbon stocks in dead organic matter were assumed to be zero.

#### 6.8.2.1.3. *Carbon stocks in soil*

##### 6.8.2.1.3.1. **Buildings and constructions (CC51)**

The carbon stocks in mineral and in organic soil for CC51 were assumed to be zero.

##### 6.8.2.1.3.2. **Herbaceous biomass, shrubs and trees in settlements (CC52, CC53, CC54)**

The carbon stocks in mineral soil for the land-use categories CC52, CC53, and CC54 were retrieved from the digital soil maps provided by Stumpf et al. (2023) (see chp. 6.5.2.1.3.1). A subset of the maps represents the soil carbon stocks at 0–30 cm depth in the period 1995–2020. Based on a spatial overlay with the land-use categories (status of AREA4), mean carbon stocks were calculated (Meteotest 2025):

- CC52: 57.2 t C ha<sup>-1</sup>
- CC53: 52.0 t C ha<sup>-1</sup>
- CC54: 56.5 t C ha<sup>-1</sup>

For organic soil, a carbon stock of 240 t C ha<sup>-1</sup> (0–30 cm) was assumed for CC52, CC53, and CC54 (see chp. 6.5.2.1.3.2).

### 6.8.2.2. Changes in carbon stocks

#### 6.8.2.2.1. *Carbon stock changes in living biomass, dead organic matter, and mineral soil*

Applying a Tier 1 approach, carbon stock changes in living biomass, dead organic matter, and mineral soil were assumed to be in equilibrium for Settlements remaining settlements.



#### 6.8.2.2.2. Carbon stock changes in organic soil

On organic soil, the following carbon stock change factors were applied:

- As CC51 has no carbon stock, carbon stock changes in organic soil were assumed to be zero (labelled as NA in Table 6-4).
- 9.52 t C ha<sup>-1</sup> yr<sup>-1</sup> 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 and Alewell 2018).
- 5.30 t C ha<sup>-1</sup> yr<sup>-1</sup> for CC53 and CC54. This corresponds to the value used for extensively managed grasslands (ART 2011b; Paul and Alewell 2018).

#### 6.8.2.2.3. Land-use change

In case of land-use changes from non-CC51 to CC51 on mineral or on organic soil 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 % of 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:

$$\Delta C_{s,rc,b51} = [ 0.2 * (0 - \text{stock}C_{s,i,b}) / CT ] * A_{rc}$$

where:

stockC <sub>s,i,b</sub>	carbon stock in soil (t C ha <sup>-1</sup> )
b	land-use category before conversion (CC = b ≠ 51)
b51	land use conversion from b to CC51
i	spatial stratum
A <sub>rc</sub>	area of a raster cell (equals to one hectare)
CT	conversion time (20 years; see Table 6-3).

In case of land-use changes from land-use category CC51 to non-CC51 land-use categories, the regular stock-difference approach and gain-loss approach, respectively, according to chp. 6.1.3.2 and Table 6-3 were applied.

In the case of land-use change from or to land-use categories CC52, CC53, and CC54, the net carbon stock changes in biomass and soils of CC52, CC53, and CC54 were calculated as described in chp. 6.1.3.2.

### 6.8.2.3. Non-CO<sub>2</sub> emissions from Settlements

#### 6.8.2.3.1. *Direct and indirect N<sub>2</sub>O emissions from N inputs to managed soils*

Direct and indirect N<sub>2</sub>O emissions from N inputs to managed soils in Settlements (category 4(I)E) were included in the Agriculture sector (categories 3D1a Inorganic N fertilisers and 3D1g Other, see chp. 5.5.1) (notation key IE).

#### 6.8.2.3.2. *Direct and indirect N<sub>2</sub>O emissions from mineral soils*

The calculations of direct and indirect N<sub>2</sub>O emissions from nitrogen mineralisation in mineral soil (category 4(III)E) in Settlements are described in Annex A5.4.

#### 6.8.2.3.3. *CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning*

CH<sub>4</sub> emissions and N<sub>2</sub>O emissions from biomass burning in Settlements (category 4(IV)E) were not occurring (notation key NO).

### 6.8.3. Uncertainties and time-series consistency for 4E

#### 6.8.3.1. Uncertainties

Uncertainties of activity data of category 4E Settlements are described in chp. 6.3.1.3.1.

Based on expert judgement, a value of 50 % was chosen for the carbon stock change factor uncertainty in category 4E (Table 6-5).

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

#### 6.8.3.2. Time-series 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 for 4E

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

### 6.8.5. Category-specific recalculations for 4E

The following recalculations were implemented:

- 4E, activity data (areas): Data 1990–2022 were updated (see chp. 6.3.1.5). The inclusion of most recent data from the AREA5 survey, updates of the AREA1-4 surveys and the new geo-referenced approach for interpolating and extrapolating yearly land-use data led to small recalculations (slightly larger for land-use category CC51 in the last years of the inventory period; Table 6-11).

- 4E, activity data (organic soil): The update of the dataset defining the geographical distribution of organic soils in Switzerland was finalised (see chp. 6.3.1.5). The total area of organic soil in Settlements slightly increased, e.g. from 1.98 to 2.03 kha for 1990 (Figure 6-7 and Table 6-7). Figure 10-10 shows the minor changes in CO<sub>2</sub> emissions from organic soil (in the range between -1.0 and 1.0 kt) resulting from both recalculations of activity data.
- 4E, land-use categories CC52–CC54: Carbon stocks in mineral soil were updated based on the digital soil maps provided by Stumpf et al. (2023).

The resulting differences in net emissions and removals between the latest and the previous submissions for category 4E are shown in Figure 10-9. They are moderate and range from -74.2 kt CO<sub>2</sub> eq in 1990 to -8.5 kt CO<sub>2</sub> eq in 2000 (mean: -34.3 kt CO<sub>2</sub> eq).

## 6.8.6. Category-specific planned improvements for 4E

### 6.8.6.1. Living biomass

The project process to achieve a sound wall-to-wall above ground tree biomass database and map for Switzerland is described in chp. 6.5.6.1. The suitability of the methodology for reporting in category 4E is subject to ongoing evaluation (Gardi et al. 2016). The first set of nationwide data is expected in summer 2025.

### 6.8.6.2. Mineral soil

The progress of digital soil modelling at CCSoils mentioned in chp. 6.5.6.2 will continue to be used to improve estimates of carbon stocks in Settlements mineral soil.

## 6.9. Category 4F – Other land

### 6.9.1. Description

Table 6-30 Key categories in category 4F Other land. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

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, screes and shores.

The area of category 4F2 Land converted to other land has increased since 1990 from 369 ha yr<sup>-1</sup> to 422 ha yr<sup>-1</sup> in 2023 (see change matrices in Table 6-9). Primarily the conversions of Forest land and Grassland to Other land led to CO<sub>2</sub> emissions caused by the loss of biomass and soil organic carbon. Mudflows, erosion, landslides, and dynamic changes in stream beds were identified as the main processes causing the land-use changes. The trigger for the altered morphodynamics is not known, but a connection with climate change can be assumed.

Another phenomenon strongly linked to climate change, namely the shift of vegetation zones in mountainous regions (as especially expressed in category 4C2e Other land converted to stony grassland (CC36), see Table 6-9), however, has a higher rate of land-use change. As a consequence, the total area of Other land has decreased by 4 % over the inventory period (Table 6-8).

In category 4F1 Other land remaining other land, only areas are reported. Figure 6-21 shows the time series of CO<sub>2</sub> emissions from category 4F2 Land converted to other land. They fluctuated over the inventory period with a slight upward trend in a range between 69 kt CO<sub>2</sub> (1991) and 102 kt CO<sub>2</sub> (2018). Forest land converted to other land and Grassland converted to other land together are the most important land-use changes.

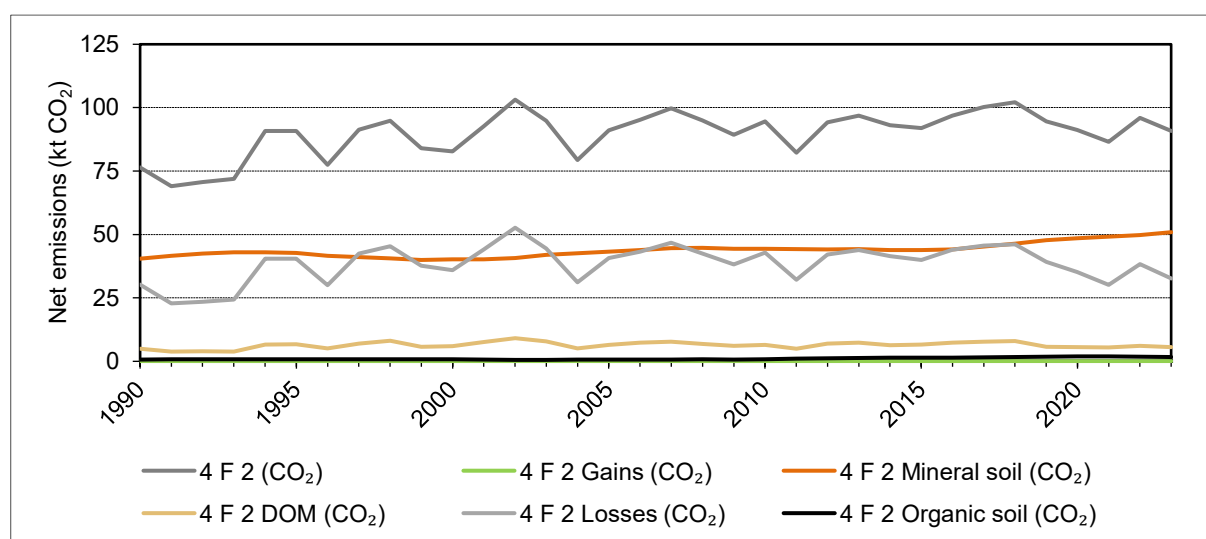


Figure 6-21 CO<sub>2</sub> emissions from category 4F2 Land converted to other land, broken down by gains in living biomass, losses in living biomass, net carbon stock changes in dead organic matter (DOM), net carbon stock changes in mineral soil, and net carbon stock changes in organic soil. Gains in living biomass are not occurring and changes in organic soil are too small to be distinguished from the zero line.

## 6.9.2. Methodological issues

By definition, Other land has no carbon stocks. Coherently, carbon stock changes in living biomass, dead organic matter, mineral and organic soil were assumed to be zero for Other land remaining other land (see Table 6-4).

In the case of land converted to other land, the net carbon changes in biomass and soils were calculated as described in chp. 6.1.3.

The calculations of direct and indirect N<sub>2</sub>O emissions from nitrogen mineralisation in mineral soil (category 4(III)F) in Other land are described in Annex A5.4.

## 6.9.3. Uncertainties and time-series consistency for 4F

### 6.9.3.1. Uncertainties

Uncertainties of activity data of category 4F Other Land are described in chp. 6.3.1.3.1.

Based on expert judgement, a value of 50 % was chosen for the carbon stock change factor uncertainty in category 4F2 (Table 6-5).

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

#### **6.9.3.2. Time-series 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 for 4F**

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

#### **6.9.5. Category-specific recalculations for 4F**

The following recalculations were implemented:

- 4F, activity data (areas): Data 1990–2022 were updated (see chp. 6.3.1.5). The inclusion of most recent data from the AREA5 survey, updates of the AREA1-4 surveys and the new approach for interpolating and extrapolating yearly land-use data led to small recalculations (Table 6-11).
- 4F, activity data (organic soil): The update of the dataset defining the geographical distribution of organic soils in Switzerland was finalised (see chp. 6.3.1.5). The total area of organic soil in 4F2 remained almost the same (see Figure 6-7 and Table 6-7 for category 4F as a whole).

The resulting differences of both recalculations between the latest and the previous submissions for category 4F are insignificantly small (see Figure 10-10 for organic soil). The recalculations of carbon stocks in mineral soil on Cropland (chp. 6.5.5), Grassland (chp. 6.6.5), Wetlands (chp. 6.7.5), and on Settlements (chp. 6.8.5) had a greater impact when calculating the carbon stock changes in category 4F2 according to Table 6-3. The overall impact on differences in emissions between the latest and the previous submissions for category 4F, as shown in Figure 10-9, is moderate and ranges from -40.1 kt CO<sub>2</sub> eq in 2021 to -6.1 kt CO<sub>2</sub> eq in 1994 (mean: -22.5 kt CO<sub>2</sub> eq).

#### **6.9.6. Category-specific planned improvements for 4F**

No category-specific improvements are planned.

## 6.10. Category 4G – Harvested wood products

### 6.10.1. Description

Table 6-31 Key categories in category 4G Harvested wood products. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
4.G	Harvested wood products	CO <sub>2</sub>	T1, T2

Estimates of net emissions and removals from Harvested wood products (HWP) due to losses and gains of carbon, respectively, were reported. Gains refer to annual carbon inflow to the HWP pool, whereas losses refer to annual carbon outflow from the HWP pool.

The approach to calculate carbon stock changes in HWP corresponds to a production approach as described in chp. 12, Volume 4 of IPCC (2019). 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 panels, and paper and paperboard) that are processed in Switzerland and that are used for material (i.e. not for energetic) purposes.

The HWP pool includes products made from domestic harvest that were exported and are in use in other countries. Imported HWP are not included in the HWP pool.

To calculate carbon stock changes in HWP, product categories and half-lives were used following the methodologies described in IPCC (2014) and IPCC (2019). Further details and result evaluations are presented in FOEN (2025e). The resulting CO<sub>2</sub> emissions and removals per product category are listed in Table 6-32 and shown in Figure 6-22.

Table 6-32 CO<sub>2</sub> emissions and removals from Harvested wood products derived from sawnwood (changeC<sub>HWP-sawnwood</sub>), panels (changeC<sub>HWP-panels</sub>), and paper and paperboard (changeC<sub>HWP-paper and paperboard</sub>) in kt CO<sub>2</sub> (positive values refer to emissions, negative values refer to removals).

	Unit	1990	1995	2000	2005	2010
HWP	kt CO <sub>2</sub>	-1'149	-436	-705	-620	-347
changeC <sub>HWP-sawnwood</sub>	kt CO <sub>2</sub>	-648	-224	-351	-237	-85
changeC <sub>HWP-panels</sub>	kt CO <sub>2</sub>	-456	-221	-380	-374	-286
changeC <sub>HWP-paper and paperboard</sub>	kt CO <sub>2</sub>	-45	8.4	25	-8.5	24

	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
HWP	kt CO <sub>2</sub>	-59	-37	1.5	-18	-80.3	51	-22	-145	-46	42
changeC <sub>HWP-sawnwood</sub>	kt CO <sub>2</sub>	68	65	69	65	19	20	-10	-67	-67	-29
changeC <sub>HWP-panels</sub>	kt CO <sub>2</sub>	-123	-117	-87	-96	-114	19	-41	-98	-32	26
changeC <sub>HWP-paper and paperboard</sub>	kt CO <sub>2</sub>	-4	16.0	20	12	14	12	29	20	53	45

Fluctuations in the HWP pool are mainly caused by changes in the production of sawnwood and wood panels. The share of paper and paperboard is relatively small (see Table 6-32). Because of the strong reduction in the production of sawnwood since 2011, HWP became a net CO<sub>2</sub> source in 2013 and 2016, and the relative contribution of panels and paper and paperboard to the HWP pool considerably increased (see Figure 6-22). In 2019, the production of wood panels decreased by almost 25 % and, as a consequence, HWP became a net CO<sub>2</sub> source in 2019 and, again, in 2023.

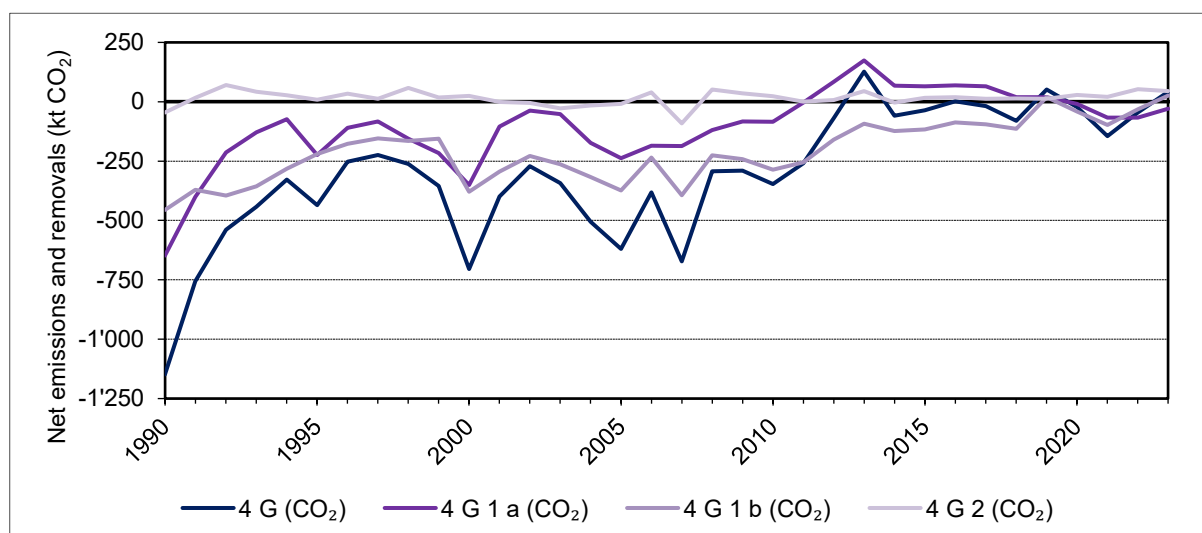


Figure 6-22 Net CO<sub>2</sub> emissions (positive values) and removals (negative values) from category 4G broken down by 4G1a Sawnwood, 4G1b Wood panels, and 4G2 Paper and paperboard.

## 6.10.2. Methodological issues

### 6.10.2.1. Choice of methods

Switzerland decided to continue the HWP reporting according to the production approach (see chp. 6.3.3) that had been used under the Kyoto Protocol, including minor modifications. For the estimation of carbon stocks and carbon stock changes, the equations described in IPCC (2014: chp. 2.8) were used. A Tier 2 approach, first order decay, was applied for the product categories sawnwood, wood panels, and paper and paperboard according to equation 2.8.5 in IPCC (2014).

- The starting year used to estimate the delayed emissions from the existing pools is 1900.
- Emissions from wood harvested for energy purposes were accounted for on the basis of instantaneous oxidation (FOEN 2025e).
- HWP going to solid waste disposals were not included in the HWP pool for LULUCF, i.e. instantaneous oxidation is assumed. Information on wood in solid waste disposals is given in the waste sector, see chp. 7.2.2.
- Imported HWP were not included in the HWP pool.
- Exported HWP were included in the HWP pool.
- The share of industrial roundwood ( $f_{IRW}$ ) used for calculating the domestic production of HWP originating from domestic forests was derived according to equation 2.8.1 in IPCC (2014).  $f_{IRW}$  was applied in the period 1961–2016 for sawnwood and in the period 1961–2020 for panels. After these periods, national surveys of the production including the domestic shares were available (FOEN 2025e).
- For estimating the domestic HWP contribution of paper and paperboard, the feedstock factors  $f_{IRW}$  and  $f_{PULP}$  (see equation 2.8.2 in IPCC 2014) were applied according to equation 2.8.4 in IPCC (2014).  $f_{IRW}$  and  $f_{PULP}$  were applied in the period 1961–2020. For 2021–2023, national surveys of the production including the domestic shares were available (FOEN 2025e).



- For estimating the HWP contribution of paper and paperboard, the recovered wood pulp from recovered paper was excluded from the feedstock. For this purpose, the net consumption of recovered pulp was calculated from FAO data on production, export and import of recovered fibre pulp in the period 1961–2020. For 2021–2023, the share of recovered pulp was taken from national surveys (FOEN 2025e).
- The change in HWP carbon stocks was estimated separately for each product category and differentiating HWP from deforestation (biomass losses in categories 4B21 to 4F21 Forest land converted to X) and from Forest land (category 4A) by applying equation 2.8.4 in IPCC (2014). Instantaneous oxidation was assumed for HWP originating from deforestation as reported in the previous submission (FOEN 2024); for 2023, the same share of HWP originating from deforestation was assumed as in 2022.

### 6.10.2.2. Activity data

The time series is shown in CRT Table4.Gs2. The activity data are described in detail in FOEN (2025e):

- Production data for wood panels, paper and paperboard, and recovered fibre pulp were retrieved from FAOSTAT for the years 1961–2020, for sawnwood 1961–2016 (<http://www.fao.org/faostat/en/#data/FO>, Forestry Production and Trade). For the years 2021–2023 (2017–2023 for sawnwood), the following data sources were used: National statistics provided data on production and domestic share of sawnwood (FSO 2024k) and of paper/paperboard (RPK 2024). Surveys on the enterprise level provided production data and domestic share of wood panels (FOEN 2024k).
- In order to estimate the share of industrial roundwood and the share of fibre pulp originating from domestic forests as feedstock for HWP production, data from national wood processing statistics and foreign trade statistics (import and export) available from FAOSTAT 1961–2020 were used.

In order to estimate carbon stocks in each HWP category, default carbon conversion factors were taken from IPCC (2014: Table 2.8.1) for wood panels.

For sawnwood, country-specific wood density values measured by the wood industry and checked against the values published by the National Forest Inventory (Werner 2019a) were adopted:

- Coniferous sawnwood: 0.41 t dry mass / m<sup>3</sup>
- Non-coniferous sawnwood: 0.59 t dry mass / m<sup>3</sup>

The IPCC (2019) default carbon fraction of 0.5 was used for sawnwood.

### 6.10.2.3. Carbon stock change factors

Carbon stock change factors for specific product categories were calculated following equation 2.8.5 in IPCC (2014) using default half-lives of 25 years for wood panels, 35 years for sawnwood and 2 years for paper products (IPCC 2014: Tab. 2.8.2).

### 6.10.3. Uncertainties and time-series consistency for 4G

#### 6.10.3.1. Uncertainties

For category 4G HWP, the following information on relative uncertainty was used:

##### 6.10.3.1.1. Activity data

A mean uncertainty of 11.2 % (Table 6-5) was estimated based on the following expert judgements considering the type and reliability of data source:

- Roundwood harvest: 5 % (national activity data from the Swiss Forestry Statistics, annual complete survey)
- Sawnwood production: 5 % (national activity from survey on wood processing in sawmills, combined survey)
- Wood Panels production: 5 % (national activity from survey in the wood industry)
- Paper and Paperboard production: 5 % (activity data from FAOSTAT)
- Share of domestic wood used in the production of sawnwood, panels and paper: 10 % (based on foreign trade statistics in the FAO database)

$$U_{\text{HWP AD}} = \sqrt{5^2 + 10^2} = 11.2 \%, \text{ for each product category.}$$

##### 6.10.3.1.2. Conversion factors (carbon stock change factors)

The uncertainties of conversion factors used to calculate emission factors were based on the following sources:

- Wood density: 20 %; a preliminary uncertainty assessment based on expert judgement results in medium to high uncertainty for the country-specific measurements of the wood industry. According to Werner (2019a), the main source of uncertainty is the water content of the HWP.
- Carbon contents in wood products: 10 % (Lamlom and Savidge 2003, assessment of carbon content in wood; IPCC 2006, Volume 4, Table 12.6).
- Half-lives: 50 % (default from IPCC 2006, Volume 4, Table 12.6).

The resulting uncertainty of the carbon stock change factors (CSCF) for HWP amounts to 54.8 % (Table 6-5):

$$U_{\text{HWP CSCF}} = \sqrt{20^2 + 10^2 + 50^2} = 54.8 \%$$

##### 6.10.3.1.3. Overall uncertainty 4G

The overall relative uncertainty of HWP was thus calculated as:

$$U_{\text{HWP Combined}} = \sqrt{11.2^2 + 54.8^2} = 55.9 \%$$

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

### 6.10.3.2. Time-series consistency

Time series for category 4G Harvested wood products are all considered consistent; they were calculated based on consistent methods and homogenous databases.

The inclusion of national statistics for the years 2017–2023 instead of FAO statistics, which were used in the preceding years, is an improvement of quality (availability, transparency). It does not lead to inconsistencies as in principle both sources should provide the same information.

### 6.10.4. Category-specific QA/QC and verification for 4G

The general QA/QC measures are described in chp. 1.5.

Since submission 2024, production data for the most recent years were taken directly from national surveys (see chp. 6.10.2.2). This is a more transparent and reliable way than using the FAO statistics. Furthermore, the share of domestic wood used in the production is also provided by the national surveys, thus, the export/import data of FAOSTAT is not required for calculating the domestic shares. For practical reasons, this procedure could not be applied so far for years before 2021 (2017 for sawnwood).

As shown in FOEN (2025e), there was an implausible outlier in the domestic fraction of the feedstock for HWP in 2007. The outlier was due to exceptionally high values for import and export of non-coniferous industrial roundwood (IRW) in the FAOSTAT database. Therefore, a fresh data extract was made from the customs statistics of the Federal Office for Customs and Border Security (FOCBS) for the period 1988–2023 including all tariff codes that are relevant for IRW. The newly retrieved customs data did not contain any outlying values in 2007 and also some other years were different from the FAOTAT database (FOEN 2025e). As there was no explanation for the differences it was decided to use the new data extract for import and export of IRW, replacing the so far used data from FAOSTAT; however, FAOSTAT is still used for the years 1960–1987. This led to recalculations in category 4G for all reported years 1990–2022.

### 6.10.5. Category-specific recalculations for 4G

The following recalculations were implemented:

- 4G1a, 2017-2020: Instead of FAOSTAT, national surveys were used as data source of production and domestic shares for sawnwood. Thus, export and import data were not used any more for calculating the domestic shares.
- 4G, 1990-2020: Import and export of industrial roundwood (IRW) were retrieved directly from national customs statistics instead of FAOSTAT because an outlier was detected in the FAOSTAT data 2007 (see chp. 6.10.4). For most years, the values do not change much, however, for some years implausible values found in FAOSTAT were corrected, mainly in the period 2004–2014, and especially the outlier for non-coniferous wood in 2007.

The resulting differences of all recalculations between the latest and the previous submissions for category 4G are shown in Figure 10-9. Their values are between -334 kt CO<sub>2</sub> (2007) and 131 kt CO<sub>2</sub> (2006). Except for the period 2004–2014, the course of net CO<sub>2</sub> emissions and removals in category 4G as shown in Figure 6-22 is largely the same as in the previous submission.

#### **6.10.6. Category-specific planned improvements for 4G**

Further improvement could be achieved if plant-specific activity data could also be used for the years before 2021 instead of exclusively FAO statistics, e.g. for the share of domestic wood used for producing wood panel. The availability of such data for reporting in category 4G is subject to ongoing evaluation.

## 7. Waste

Responsibilities for sector Waste	
Overall responsibility	Myriam Guillevic (FOEN)
Method updates & authors	Myriam Guillevic (FOEN)
EMIS database operation	Myriam Guillevic (FOEN)
Annual updates (NID text, tables, figures)	Dominik Eggli (Meteotest), Beat Rihm (Meteotest)
Quality control NID (annual updates)	Dominik Eggli (Meteotest), Myriam Guillevic (FOEN), Adrian Schilt (FOEN)
Internal review	Adrian Schilt (FOEN)

### 7.1. Overview

#### 7.1.1. Greenhouse gas emissions

Within sector 5 Waste, emissions from five source categories are considered (Figure 7-1):

- 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 included in CRT Table6 as documented in chp. 9)

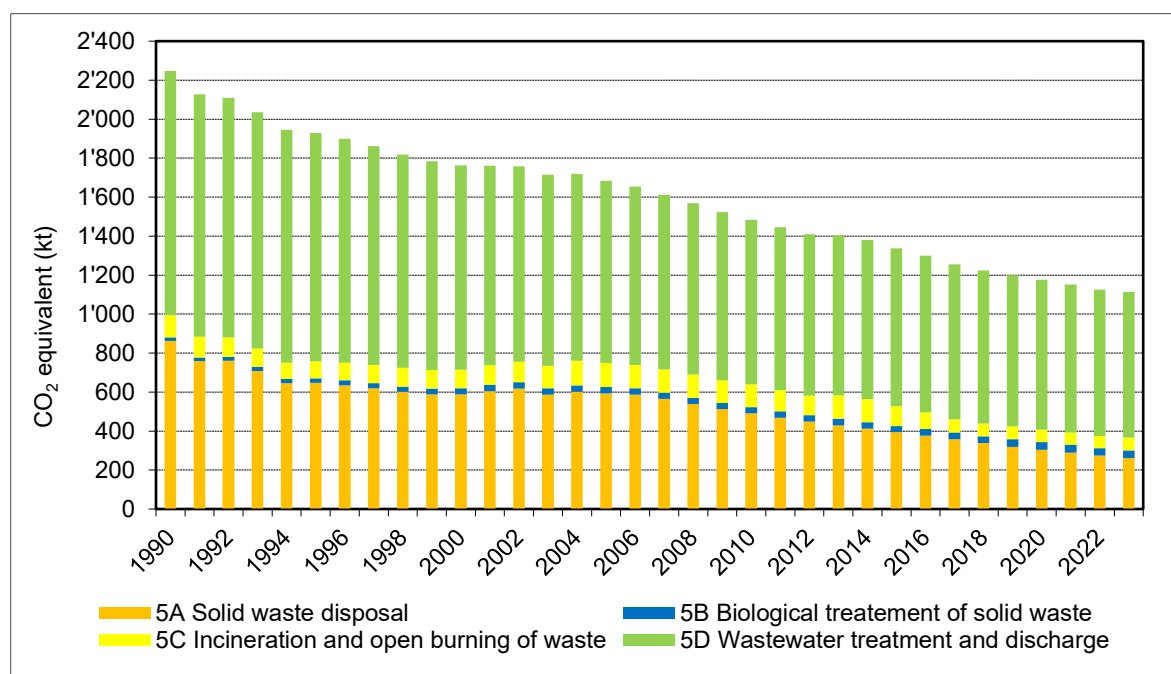


Figure 7-1 Switzerland's greenhouse gas emissions from sector 5 Waste. There are no direct greenhouse gas emissions from sector 5E Other.

The total greenhouse gas emissions from sector 5 Waste show a decrease within the reporting period (Figure 7-1 and Table 7-1). 5A Solid waste disposal and 5D Wastewater

treatment and discharge are the two dominant source categories, both showing decreasing greenhouse gas emissions.

Table 7-1 Trend of total GHG emissions from sector 5 Waste in Switzerland.

Gas	1990	1995	2000	2005	2010
CO <sub>2</sub> equivalent (kt)					
CO <sub>2</sub>	40	22	17	12	11
CH <sub>4</sub>	1'083	860	801	805	713
N <sub>2</sub> O	1'125	1'047	945	868	759
Sum	2'248	1'929	1'763	1'684	1'483

Gas	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO <sub>2</sub> equivalent (kt)										
CO <sub>2</sub>	10	10	10	9.8	9.6	9.4	9.2	9.1	8.6	8.3
CH <sub>4</sub>	648	632	621	607	590	576	562	549	537	528
N <sub>2</sub> O	722	695	669	639	624	614	604	593	579	578
Sum	1'380	1'338	1'300	1'256	1'224	1'199	1'176	1'152	1'125	1'114

CH<sub>4</sub> and N<sub>2</sub>O are dominant and of similar importance in sector 5 Waste over the entire reporting period. Overall, these two gases show a decreasing trend. CO<sub>2</sub> is of low importance (<2 %) in sector 5 Waste (Table 7-1). The relative trends of all greenhouse gases are shown in Figure 7-2.

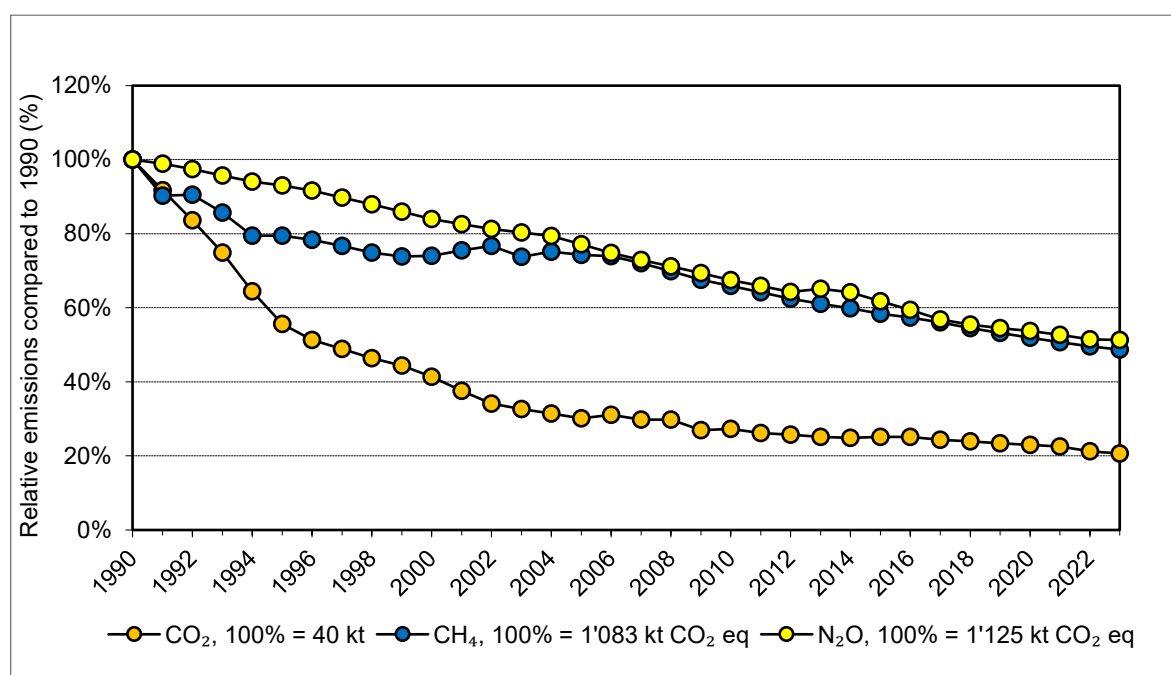


Figure 7-2 Relative trends of greenhouse gas emissions from sector 5 Waste. The base year 1990 represents 100 %.

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 7-5). 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 NID.

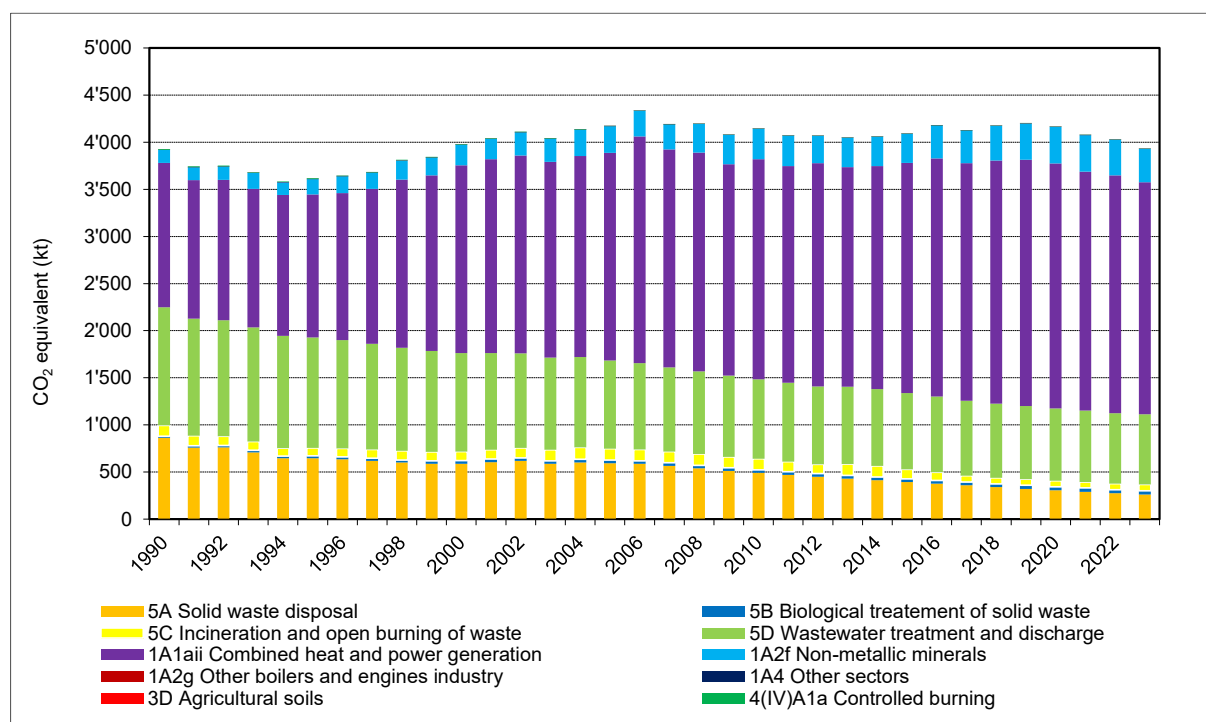


Figure 7-3 Total waste-related GHG emissions, reported in different sectors. The energetic use of waste-related biomass is not considered in this figure, as it predominantly leads to emissions of biogenic CO<sub>2</sub> (and only very minor emission of CH<sub>4</sub> and N<sub>2</sub>O).

For sector 5 Waste, there is a total of four identified key categories, emitting CH<sub>4</sub> and N<sub>2</sub>O (see Figure 7-4).

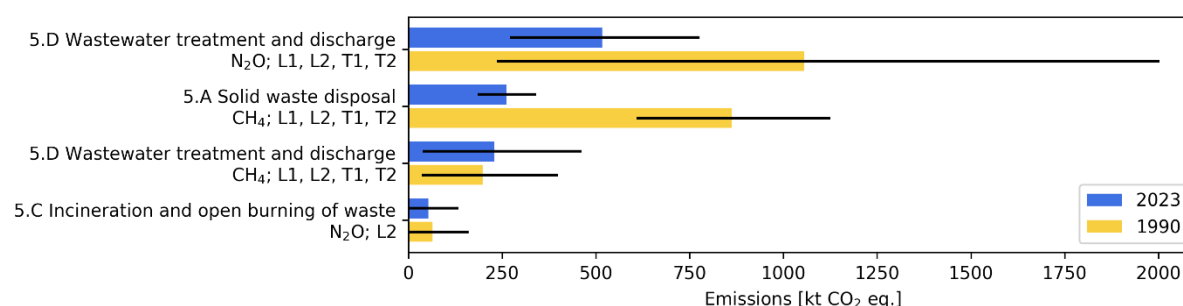


Figure 7-4 Key categories in the Swiss GHG inventory from sector 5 Waste determined by the key category analyses, approaches 1 and 2. Categories are set out in order of decreasing emissions in 2023. L1: key category according to approach 1 level in 2023; L2: same for approach 2; T1: key category according to approach 1 trend 1990–2023; T2: same for approach 2. Black uncertainty bars represent the narrowest 95 % confidence interval obtained by Monte Carlo simulations (see chp. 1.6 for details).

## 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 on the Avoidance and the Disposal of Waste (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 7-5 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 NID. The following details can be provided regarding the different sectors:

- **1 Energy:** In accordance with the IPCC Guidelines (IPCC 2006) emissions from waste-to-energy activities, where waste is used as an alternative fuel for energy production, are reported in 1A Fuel combustion. This applies to municipal solid waste incineration plants and special waste incineration plants, where energy is recovered (1A1a). Municipal solid waste incineration plants 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 in agricultural and industrial biogas facilities and of sewage sludge in wastewater treatment plants as well as the use of landfill gas are also reported in sector 1 Energy (source categories 1A1a, 1A2gviii and 1A4ci), as such biogas and sewage gas are 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 1A1a, 1A2, 1A4ai and 1A4bi and 1A4ci.
- **3 Agriculture:** Since 2003 it is forbidden in Switzerland to use sewage sludge as a fertiliser. As of 2006, this prohibition has been made effective for all agricultural areas with a transition period to 2008. Since 2009, sewage sludge has no longer been applied; however, the use of 3D1biii Other organic fertilisers applied to soils has increased and includes nitrogen inputs from compost, liquid and solid digestates from industrial biogas plants, co-substrates from agricultural biogas plants and decentralised wastewater streams (see chp. 5.5.2.2 Direct N<sub>2</sub>O emissions from managed soils, Table 5-25).
- **5 Waste:** Only emissions from waste management activities not used for energy production are reported under sector 5 Waste. Solid waste disposal is no longer practiced in Switzerland as incineration has been mandatory for the 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 municipal solid waste incineration plants and are therefore reported under sector 1 Energy. Emissions related to wastewater treatment are reported under 5D.

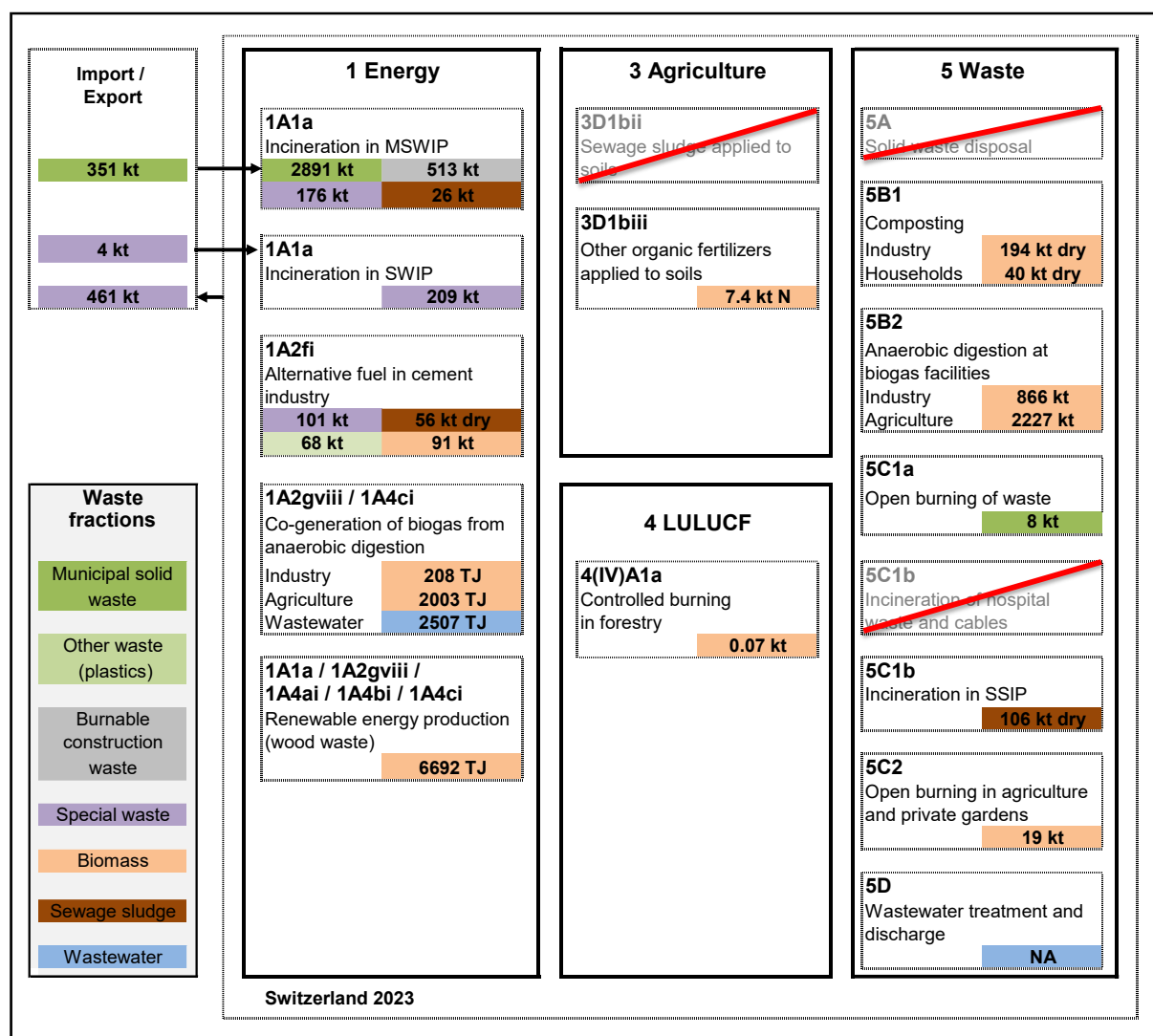


Figure 7-5 Overview on the type of treatment and amounts of waste treated in the respective sectors in Switzerland in 2022. Abbreviations: MSWIP: Municipal Solid Waste Incineration Plant, SWIP: Special Waste Incineration Plant, SSIP: Sewage Sludge Incineration Plant.

Regarding the treatment and amounts of relevant waste types the following details can be provided (recycled amounts are not shown in Figure 7-5 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 2024h). The amount of waste incinerated includes imported municipal solid waste, 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 municipal solid waste incineration plants. 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 2024h). Only the amount of incinerated special waste is relevant for emissions (EMIS 2025/1A1a Kehrichtverbrennungsanlagen and EMIS 2025/1A1a Sondermüllverbrennungsanlagen). Some special waste is also used as an alternative fuel in the cement production (EMIS 2025/1A2f i Zementwerke Feuerung).
- **Sewage sludge:** Since 2009 sewage sludge has not been used anymore as a fertiliser in agriculture. Such use has been prohibited due to the content of organic contaminants, heavy metals and other substances (see chp. 5.5.2.2.2). Therefore, all sewage sludge is incinerated, either in municipal solid waste incineration plants or in sewage sludge incineration plants 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 2025/1A2f i 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 e. g. from the food industry. Biomass from agriculture, forestry and private gardens are burnt without energy recovery (EMIS 2025/5C2 & 4VA1 Abfallverbrennung Land- und Forstwirtschaft). Biomass is also digested or composted (in large-scale composting facilities or backyards). Quantities of biomass refer to dry matter. Biomass such as used wood or animal fat is used as an alternative fuel in the cement industry (EMIS 2025/1A2f i Zementwerke Feuerung). Compost is used as a fertiliser and quantities refer to dry matter (see Table 5-25 “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 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
5.A	Solid waste disposal	CH <sub>4</sub>	L1, L2, T1, T2

Source category 5A1 Managed waste disposal sites comprise all emissions from managed solid waste landfill sites. As incineration has been mandatory for combustible waste since 2000, inputs into managed solid waste landfill sites have dropped to zero. Remaining emissions thus originate from landfilling before 2000. Emissions from 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, less than four managed biogenically active landfill sites were equipped to recover landfill gas from 2018 onwards (SFOE 2024a). 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).

Emissions from the usage of landfill gas in combined heat and power units are reported in sector 1 Energy in source category 1A1a Public electricity and heat production (see Figure 3-18).

Table 7-3 Specification of source category 5A Solid waste disposal in Switzerland.

5A	Source category	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)
5A3	Uncategorized waste disposal sites	Not occurring in Switzerland

## 7.2.2. Methodological issues

### Methodology (5A)

Emissions are calculated by a Tier 2 method based on the decision tree in the IPCC Guidelines (IPCC 2006, vol. 5, chp. 3, Fig. 3.1, no refinement in 2019). The spreadsheet for the First Order Decay (FOD) model provided by IPCC (2006) has been applied and parametrised for Swiss conditions (FOEN 2024c).

The values for the parameter degradable organic carbon are provided for each waste fraction (Table 7-4). For all waste types the IPCC (2006) 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 values for fractions of different waste compositions (weight fraction, wet basis).

Waste composition (weight fraction, wet basis)	IPCC default value		Values used in Switzerland	
	Range	Default	Value	Reference and remarks
Food waste	0.08 - 0.20	0.15	0.15	IPCC default value
Garden	0.18 - 0.22	0.2	0.2	IPCC default value
Paper	0.36 - 0.45	0.4	0.4	IPCC default value
Wood and straw	0.39 - 0.46	0.43	0.43	IPCC default value
Textiles	0.20 - 0.40	0.24	0.24	IPCC default value
Disposable nappies	0.18 - 0.32	0.24	NO	Not relevant / no activity data
Sewage sludge	0.04 - 0.05	0.05	0.05	IPCC default value
Industrial waste	0.00 - 0.54	0.15	0.43	Same as wood and straw

The methane generation rate [1/yr] is chosen according to wet temperate conditions (Table 7-5). For all waste types the IPCC (2006) 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 (weight fraction, wet basis)	IPCC default value		Values used in Switzerland	
	Range	Default	Value	Reference and remarks
Food waste	0.10 - 0.20	0.185	0.185	IPCC default value
Garden	0.06 - 0.10	0.1	0.1	IPCC default value
Paper	0.05 - 0.07	0.06	0.06	IPCC default value
Wood and straw	0.02 - 0.04	0.03	0.03	IPCC default value
Textiles	0.05 - 0.07	0.06	0.06	IPCC default value
Disposable nappies	0.06 - 0.10	0.1	NO	Not relevant / no activity data
Sewage sludge	0.10 - 0.20	0.185	0.185	IPCC default value
Industrial waste	0.08 - 0.10	0.09	0.03	Same as wood and straw

The general parameters are set as follows:

- DOCf (fraction of degradable organic carbon dissimilated) = 0.5 (IPCC (2006) and IPCC (2019) default value)
- Delay time (months) = 6 (IPCC (2006) and IPCC (2019) default value)
- Fraction of methane (F) in developed landfill gas = 0.5 (IPCC (2006) and IPCC (2019) default value)
- Conversion factor, C to CH<sub>4</sub> = 1.33 (IPCC (2006) and IPCC (2019) default value)
- Oxidation factor (OX) = 0.1

The oxidation factor has been set to 0.1 according to the 2006 IPCC Guidelines (IPCC 2006, vol. 5, chp. 3, no refinement in 2019), 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 municipal solid waste and industrial waste):

- Methane correction factor for unmanaged, shallow solid waste disposal sites (SWDS) = 0.4 (IPCC (2006) and IPCC (2019) default value)
- Methane correction factor for unmanaged, deep solid waste disposal sites = 0.8 (IPCC (2006) and IPCC (2019) default value)
- Methane correction factor for managed solid waste disposal sites = 1 (IPCC (2006) and IPCC (2019) default value)
- The other methane correction factors (managed well – semi-aerobic, managed poorly - semi-aerobic, managed well – active-aeration, managed poorly – active-aeration and uncategorised) are not relevant because such solid waste disposal sites are not occurring in Switzerland, i. e. no waste has been distributed to such sites.

As shown in Table 7-6, the composition of municipal solid waste deposited has changed during the last 60 years.

Table 7-6 Composition of municipal solid waste going to solid waste disposal sites (BUS 1978, BUS 1984, FOEN 2014a). Remark: No disposal occurred after 2009 and therefore the waste composition is assumed constant since 2010.

Waste fraction	1950–1979	1980–1989	1990–1999	2000–2009	since 2010
Food	20.0%	26.5%	21.4%	26.6%	31.5%
Garden	8.0%	2.9%	1.6%	1.4%	1.7%
Paper	36.0%	30.6%	28.0%	21.0%	17.2%
Wood	4.0%	4.3%	5.0%	2.0%	1.8%
Textile	4.0%	3.1%	3.0%	3.0%	3.2%
Nappies	0.0%	0.0%	0.0%	0.0%	0.0%
Plastics, other inert	28.0%	32.6%	41.0%	46.0%	44.6%

With these parametrisations and the activity data for municipal solid waste, industrial waste and sewage sludge the amount of CH<sub>4</sub> generated in landfills is calculated. The amount of CH<sub>4</sub> 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<sub>4</sub> burnt (Table 7-7).

Long-term storage of carbon in waste disposal sites, annual change in total long-term storage of carbon and annual change in total long-term storage of carbon in wood products has been calculated with the parametrised spreadsheet model provided by IPCC (2006) as well and is reported in CRT Table5 as memo item. The wood stored in waste disposal sites is not included in sector 4G (HWP), see chp. 6.10. As incineration has been mandatory for combustible waste since 2000 in Switzerland and solid waste disposal activities have ceased, the amount of carbon deposited is zero since 2009.

### Emission factors (5A)

Emission factors for CO<sub>2</sub>, CH<sub>4</sub>, CO, NMVOC and SO<sub>2</sub> are country-specific based on measurements and expert estimates, as documented in EMIS 2025/1A1 & 5A Kehrichtdeponien. The emission factor of NMVOC from flaring has been introduced based on a study on emissions from landfill gas installations (Butz 2003) suggesting emissions of 82.15 grams of NMVOC per tonne of CH<sub>4</sub> flared with an uncertainty of ±10 %. CO<sub>2</sub> emissions from non-biogenic waste are included, while CO<sub>2</sub> 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 2023.

5A1 Managed waste disposal sites	Unit	CO <sub>2</sub> biogen	CO <sub>2</sub> fossil	CH <sub>4</sub>	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Direct emissions from landfill	t / t CH <sub>4</sub> produced	3	NA	1	NA	NA	0.013	NA
Flaring	kg / t CH <sub>4</sub> burnt	2750	NA	NA	1	17	0.082	NA
Open burning	kg / t waste burnt	569	521	6	2.5	50	16	0.75

### Activity data (5A)

There are three kinds of activity data for 5A1 Managed waste disposal sites: Waste quantities disposed on landfills, direct CH<sub>4</sub> emissions and CH<sub>4</sub> flared.

For the calculation of these three kinds of activity data, the amounts of municipal solid waste, construction waste and sewage sludge (deposited on managed waste disposal sites) are relevant.

Table 7-8 Activity data in 5A1: Waste disposed on managed waste disposal sites since 1950 (documented in EMIS 2025/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1950	1960	1970	1980	1990	1995	2000	2005	2010 - 2023
Municipal solid waste (MSW)	kt	570	675	864	532	650	540	292	14	NO
Construction waste (CW)	kt	9.9	11	36	85	150	60	54	1.4	NO
Sewage sludge (SS)	kt (dry)	NO	NO	3.2	30	60	28	4.2	0.98	NO
Open burnt waste	kt	299	294	226	97	NO	NO	NO	NO	NO
Total waste quantity	kt	879	980	1129	744	860	628	350	16	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 2025/1A1a & 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. While open burning of waste on managed waste disposal sites occurred in the distant past it is assumed that, by reason of legal requirements and regulations, open burning has not taken place since 1990 anymore (Consaba 2016) and is therefore NO in Table 7-8.

With these primary activity data total CH<sub>4</sub> emissions generated are calculated using the spreadsheet first order decay model provided by IPCC (2006). For the calculation of direct CH<sub>4</sub> emissions, CH<sub>4</sub> flared and used in co-generation units is determined and subtracted from total CH<sub>4</sub> 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 CRT Table 5.A.

The amount of CH<sub>4</sub> used in co-generation is taken from the Swiss statistics of renewable energies (SFOE 2024a). The amount of landfill gas flared has been assessed in a separate investigation (Consaba 2016). The CH<sub>4</sub> flared has been estimated as follows:

- A list of all managed waste disposal sites that are still operated or have been closed since 1990 was compiled.
- Their technical equipment was assessed and deduced (motors, torches, gas drainage, etc.).
- Four types of managed landfill sites according to their equipment and CH<sub>4</sub> management were distinguished:
  - landfills with gas recovery in combined heat and power generation, boiler and torch; category a),
  - landfills with gas recovery or thermal treatment (boiler, torch, non-catalytic oxidation, flameless oxidation; category b),
  - landfill gas recovery without methane elimination (bio filter, aerobiosation); category c),
  - landfills without gas treatment (direct release); category d).



- A survey was conducted in 14 managed waste disposal sites and data on their operation mode has been collected.
- With these data the amounts flared in managed waste disposal sites categories a) and b) were estimated.
- The amount flared on all managed waste disposal sites has been extrapolated considering the waste amounts deposited.
- A time series for the amount of methane torched relative to the total amount of CH<sub>4</sub> estimated with the Swiss first order decay IPCC 2006 model (managed and unmanaged sites) has been calculated.

The amount flared is expressed as a percentage of CH<sub>4</sub> produced in all managed waste disposal sites in Switzerland. The percentage flared varies between 5 and 15 % since 1990.

Table 7-9 Activity data in 5A1: Direct CH<sub>4</sub> emissions, CH<sub>4</sub> flared and CH<sub>4</sub> used in combined heat and power units (as documented in EMIS 2025/1A1a & 5A Kehrichtdeponien).

5A1 Managed waste disposal sites	Unit	1990	1995	2000	2005	2010					
CH <sub>4</sub> direct emissions	kt	31	23	21	21	18					
CH <sub>4</sub> flared	kt	1.8	5.3	5.6	3.4	2.4					
CH <sub>4</sub> used in co-generation units (reported under 1A1a)	kt	4.9	12	11	4.1	1.0					

5A1 Managed waste disposal sites	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CH <sub>4</sub> direct emissions	kt	15	14	13	13	12	11	11	10	9.8	9.3
CH <sub>4</sub> flared	kt	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.2
CH <sub>4</sub> used in co-generation units (reported under 1A1a)	kt	0.63	0.43	0.25	0.13	0.12	0.17	0.079	0.079	0.10	0.088

Waste quantities disposed in landfills started to decrease in the early 1990s and have ceased completely from 2009 onwards. The continuous decrease of CH<sub>4</sub> generated by decaying waste over time, in combination with the relative increase of CH<sub>4</sub> recovery from 1990 until 2017 yields a pronounced trend of CH<sub>4</sub> emissions from source category 5A.

### 7.2.3. Uncertainties and time-series consistency for 5A

#### Uncertainty in CH<sub>4</sub> emissions from 5A Solid waste disposal

For lack of a detailed uncertainty analysis with the first order decay model, a combined uncertainty of 30 % is assumed for the CH<sub>4</sub> emissions (EMIS 2025/1A1a & 5A Kehrichtdeponien).

Consistency: Time series for 5A Solid waste disposal are all considered consistent.

### 7.2.4. Category-specific QA/QC and verification for 5A

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

### 7.2.5. Category-specific recalculations for 5A

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences emissions of sector 5 between the latest and the previous submissions are presented also in chp. 10.1.2.5.

- 5A1, amount of CH<sub>4</sub> for energy recovery: There was a mistake in the formula used to compute the sum: the amount of natural gas (fossil) used by engines was included as well. This error caused an overestimation of the amount recovered for the years 2001-2014 by up to 40 %. This correction has no impact on the reported emission, which remains correct.

### 7.2.6. Category-specific planned improvements for 5A

No category-specific improvements are planned.

## 7.3. Source category 5B – Biological treatment of solid waste

### 7.3.1. Source category description

Table 7-10 Key categories of 5B – Biological treatment of solid waste. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

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 is 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<sub>4</sub> losses from biogas facilities and emerging from biogas upgrading are included. Emissions related to the use of biogas for combined heat and power generation are reported in sector 1 Energy source categories 1A2gviii Other and 1A4ci Agriculture/forestry/fishing (see Figure 3-18). Emissions related to the use of upgraded biogas fed into the natural gas grid are reported in sector 1 Energy source categories 1A3bi-iii Road transportation and 1A4ai Commercial boilers (see Figure 3-18).

Table 7-11 Specification of source category 5B Biological treatment of solid waste.

5B	Source category	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 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 2025/5B1 Kompostierung, which serves as basis for greenhouse gas emission estimates, has been revised accordingly.

Both activity data and emission factors are reported with reference to mass of dry matter as requested in CRT Table5.B. A transfer factor from wet to dry matter of 40.0 % has been suggested by Baier (2023).

#### Emission factors (5B1)

Emission factors used for source category 5B1 Composting are summarised in Table 7-12 and documented in detail in EMIS 2025/5B1 Kompostierung. Emission factors are country-specific and encompass CH<sub>4</sub>, N<sub>2</sub>O and NMVOC based on measured or estimated values reported in the literature. The emission factors are based on a recommendation by Schleiss (2017) based on Dinkel et al. (2012). They are based on measurements and taking into account the predominantly non-industrial (ban on refuse composting) origin of composted material in Switzerland resulting in a rotting process as aerobic as possible to produce compost of marketable quality. This yields a lower emission factor for CH<sub>4</sub> compared to reference values (IPCC 2006).

#### Activity data (5B1)

Activity data for source category 5B1 Composting are shown in Table 7-13 and documented in detail in EMIS 2025/5B1 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 additional 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. As of 2014, activity data for industrial composting are adopted from the annual statistical reports by the inspectorate system for the composting and fermentation industry in Switzerland (CVIS) as

recommended by Schleiss (2017). Since submission 2023 the annual statistical data have to be obtained from the presentation from the "Kantonstag des Vereins Inspektorat" as the association ceased to produce an annual report but presents the data during this annual meeting (CVIS 2023). The data for the year 2023 were not yet available at the time of data collection and therefore assumed equal to the data for the year 2022.

Activity data for backyard composting were reassessed in 2017 (Schleiss 2017). Basically, amounts of organic waste composted in backyards are based on expert assessments and are derived from data from a small number of cities and villages. The experts took into account different parameters affecting waste amounts composted in backyards over time, i.e. urban or rural situation, communication e.g. by community authorities and incentive programmes, and on the availability of separate door-to-door collection of organic wastes. As of 2008, activity data for backyard composting are assumed to be constant as recommended by Schleiss (2017).

### **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 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 using a constant emission factor for each biogas facility. This is based on an evaluation of measurement data for CH<sub>4</sub> losses that has shown that those losses are not dependent on the amount of substrate processed in a particular facility. Therefore, CH<sub>4</sub> 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 2025/1A1a & 5 B 2 Vergärung LW and EMIS 2025/1A1a & 5 B 2 Vergärung IG. However, as CH<sub>4</sub>, CO and NMVOC emissions from source category 5B are of biogenic origin, no indirect CO<sub>2</sub> emissions from this source category are included in CRT Table6 as documented in chp. 9.

N<sub>2</sub>O emissions from source category 5B2 are considered to be negligible according to the IPCC Guidelines (IPCC 2006, vol. 5, chp. 4.1.3), and are therefore set to zero.

## Emission factors (5B2)

Table 7-12 presents the emission factors used in 5B2 Anaerobic digestion at biogas facilities. As documented in FOEN (2015n), the emission factor for CH<sub>4</sub> for anaerobic digestion at industrial and agricultural biogas facilities is based on investigations performed in the framework of the greenhouse gas 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<sub>4</sub> 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<sub>4</sub> from biogas upgrading is based on official regulations regarding maximal CH<sub>4</sub> leakage, as well as studies focussing on CH<sub>4</sub> emissions from biogas upgrading. Accordingly, regulations by the Swiss Gas and Water Association (SGWA 2016a) set an emission limit value for CH<sub>4</sub> 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 emission limit value 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 % to 2.5 % are state of the art.

Table 7-12 Emission factors for 5B Biological treatment of solid waste in 2023.

5B Biological treatment of solid waste	Unit	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
Composting (industrial)	g/t composted waste	2'500	125	NA	NA	750	NA
Composting (backyard)	g/t composted waste	2'500	125	NA	NA	750	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

## Activity data (5B2)

Activity data for 5B2 Anaerobic digestion at biogas facilities, as shown in Table 7-13, are based on data from the Swiss renewable energy statistics (SFOE 2024a). Relevant are the number of industrial and agricultural biogas facilities, as well as the total amount of biogas upgraded.

Table 7-13 Activity data in 5B Biological treatment of solid waste.

5B Biological treatment of solid waste	Unit	1990	1995	2000	2005	2010
Composting (industrial)	kt (dry)	96	144	208	210	212
Composting (backyard)	kt (dry)	44	62	72	68	48
Digestion (industrial biogas facilities)	number	NO	4.0	11	14	22
Digestion (agricultural biogas facilities)	number	102	76	68	72	72
Biogas up-grade	GJ	NO	NO	19'930	40'719	121'449

5B Biological treatment of solid waste	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Composting (industrial)	kt (dry)	191	172	201	196	190	218	209	219	194	194
Composting (backyard)	kt (dry)	40	40	40	40	40	40	40	40	40	40
Digestion (industrial biogas facilities)	number	25	26	27	28	28	29	27	28	28	29
Digestion (agricultural biogas facilities)	number	98	99	98	106	111	112	119	121	126	127
Biogas up-grade	GJ	337'401	408'056	442'684	456'499	473'349	551'924	600'094	624'825	633'116	705'395

To improve transparency the CH<sub>4</sub> and N<sub>2</sub>O emissions of source category 5B Biological treatment of solid waste are shown on a completely disaggregated level in Table 7-14.

Table 7-14 CH<sub>4</sub> and N<sub>2</sub>O emissions of 5B Biological treatment of solid waste.

5B Biological treatment of solid waste	Gas	Unit	1990	1995	2000	2005	2010					
Composting (industrial)	CH <sub>4</sub>	t	240	360	519	526	530					
	N <sub>2</sub> O	t	12	18	26	26	26					
Composting (backyard)	CH <sub>4</sub>	t	110	155	180	170	120					
	N <sub>2</sub> O	t	5.5	7.8	9.0	8.5	6.0					
Digestion (industrial)	CH <sub>4</sub>	t	NO	4.9	14	17	27					
Digestion (agricultural)	CH <sub>4</sub>	t	125	93	84	89	89					
Biogas up-grade	CH <sub>4</sub>	t	NO	NO	16	28	71					

5B Biological treatment of solid waste	Gas	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Composting (industrial)	CH <sub>4</sub>	t	478	430	503	490	475	544	523	548	484	484
	N <sub>2</sub> O	t	24	21	25	24	24	27	26	27	24	24
Composting (backyard)	CH <sub>4</sub>	t	100	100	100	100	100	100	100	100	100	100
	N <sub>2</sub> O	t	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Digestion (industrial)	CH <sub>4</sub>	t	31	32	33	34	34	36	33	34	34	36
Digestion (agricultural)	CH <sub>4</sub>	t	121	122	121	130	137	138	146	149	155	156
Biogas up-grade	CH <sub>4</sub>	t	169	204	221	228	237	276	300	312	317	353

### 7.3.3. Uncertainties and time-series consistency for 5B

#### Uncertainty in CH<sub>4</sub> and N<sub>2</sub>O 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 2025/5B1 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 2025/1A1a & 5 B 2 Vergärung LW and EMIS 2025/1A1a & 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 for 5B

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

### 7.3.5. Category-specific recalculations for 5B

The following recalculations were implemented in submission 2025.

- 5B2: The activity data for 5B2 Anaerobic digestion at biogas facilities have been updated due to an update in the underlying statistics (Swiss statistics of renewable energies). This affects all years from 1994 until 2022.

### 7.3.6. Category-specific planned improvements for 5B

No category-specific improvements are planned.

## 7.4. Source category 5C – Incineration and open burning of waste

### 7.4.1. Source category description

Table 7-15 Key categories of 5C Incineration and open burning of waste. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
5.C	Incineration and open burning of waste	N <sub>2</sub> O	L2

There is a long tradition in Switzerland to incinerate waste. Since 1991, the incineration of waste has only been legally permitted in appropriate plants with a rated thermal input of at least 350 kW (Ordinance on Air Pollution Control (Swiss Confederation 1985)).

Consequently, the open burning of waste has been prohibited. The heat generated during the incineration has to be recovered in accordance with the Ordinance on the Avoidance and the Disposal of Waste (Swiss Confederation 2015). Following the 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 cremations.

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 burnt off-site. Field burning of agricultural residues does not occur in Switzerland. Emissions from open burning of residues in forestry are reported in LULUCF sector 4(IV)A (chp. 6.4.2.5.4.1).

Table 7-16 Overview of waste incineration sources reported under 5C.

5C	Source category	Specification
5C1	Hospital waste incineration	Emissions from incinerating hospital waste in hospital incinerators
	Municipal waste incineration (illegal)	Emissions from illegal incineration of municipal solid wastes at home. Emissions from waste incineration at construction sites (open burning)
	Industrial waste incineration	Emissions from incinerating cable insulation materials
	Sewage sludge incineration	Emissions from sewage sludge incineration plants
	Cremation	Emissions from the burning of bodies in crematoria
5C2	Open burning of natural residues in agriculture and private households	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 IPCC Guidelines (IPCC 2006, vol. 5, chp. 5.2). In general, the greenhouse gas emissions are calculated by multiplying the waste quantity incinerated by emission factors. For crematoria, the greenhouse gas 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. The emission factors are based on emission declarations from three incineration plants in 2002 and 2015, respectively 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, municipal waste incineration (illegal) and industrial waste incineration (consists of cable insulation materials), 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 IPCC Guidelines (IPCC 2006, vol. 5, chp. 5.2). Emission factors are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, EMEP/EEA 2002).

Indirect CO<sub>2</sub> emissions resulting from fossil CH<sub>4</sub>, CO and NMVOC emissions from hospital waste incineration, municipal waste incineration (illegal) and industrial waste incineration (consists of cable insulation materials) are included in CRT Table6 as documented in chp. 9.

### Emission factors (5C)

Table 7-17 presents an overview of the emission factors for 5C for the latest reported inventory year. Documentation and sources are given in: EMIS 2025/5 C 1 (5 C 1 b iii UNECE)\_Spitalabfallverbrennung, EMIS 2025/5 C 1 (5 C 1 a UNECE)\_ Abfallverbrennung illegal, EMIS 2025/5 C 1 (5 C 1 b i UNECE)\_Kabelabbrand, EMIS2025/5 C 1\_(5 C 1 b iv UNECE)\_Klärschlammverbrennung, EMIS2025/ 5 C 2\_4 V A 1\_Abfallverbrennung Land- und Forstwirtschaft and EMIS 2025/5 C 1 (5 C 1 b v UNECE)\_Krematorien.

Table 7-17 Emission factors for 5C Waste incineration and open burning of waste in 2023.

5C Waste incineration and open burning of waste	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
	t/t		kg/t					
Hospital waste incineration	0.9	NA	NO	0.06	1.5	1.4	0.3	1.3
Municipal fossil waste incineration (illegal)	1.1	NA	6	0.15	2.5	50	16	0.75
Municipal biogenic waste incineration (illegal)	NA	1.1	6	0.15	2.5	50	16	0.75
Industrial waste incineration	1.3	NA	NO	NE	1.3	2.5	0.5	6
Sewage sludge incineration	NA	0.82	0.095	1.9	0.4	0.097	0.19	0.16
Open burning of natural residues in agriculture	NA	1.7	6.8	0.18	1.4	49	1.5	0.03
Open burning of natural residues in private households	NA	1.7	6.8	0.18	1.4	49	1.5	0.03

	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
	kg/crem.							
Cremation	NA	NA	NA	NA	0.21	0.037	0.0058	NA

Comments on CO<sub>2</sub> emission factors:

- For all waste incineration categories, only CO<sub>2</sub> 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<sub>2</sub> emission factor is taken from SAEFL (2000). Since 2002 no emissions from hospital waste incineration have occurred, as all hospital waste incinerator plants have been closed and hospital waste is incinerated in municipal solid waste incineration plants (accounted for in 1A1a).
- Municipal waste incineration (illegal): The CO<sub>2</sub> emission factor is estimated by using the same assumption as in case of municipal solid waste incineration: The C-content is based on the study by FOEN (2014I). See also chp. 3.2.5.2 and detailed information in EMIS 2025/1A1a Kehrlichtverbrennungsanlagen (pp. 5–7).
- Industrial waste incineration (consists of cable insulation materials): The CO<sub>2</sub> emission factor is based on measurements of the flue gas treatment of a cable disassembling site where O<sub>2</sub> was measured in the flue gas. Assuming that the ratio of CO<sub>2</sub>/O<sub>2</sub> is the same as in municipal solid waste incineration plants, a fraction of 7 % of CO<sub>2</sub> 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 have occurred.
- Sewage sludge incineration plants: As sewage sludge is biogenic waste, the emission factor for CO<sub>2</sub> 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<sub>2</sub>) gases:

- Hospital waste incineration: All emission factors are taken from SAEFL (2000). Following IPCC (2006), no CH<sub>4</sub> emissions are estimated (see issue W.8 in UNFCCC 2023)
- Municipal waste incineration (illegal): The emission factor for N<sub>2</sub>O is taken from the IPCC Guidelines (IPCC 2006, vol. 5), the emission factors for CH<sub>4</sub>, NO<sub>x</sub>, NMVOC and SO<sub>2</sub> from SAEFL (2000) and USEPA (1995a).
- Industrial waste incineration (consists of cable insulation materials): All emission factors are adopted from SAEFL (2000). Following IPCC (2006), no CH<sub>4</sub> emissions are estimated (see issue W.8 in UNFCCC 2023). Due to low relevance, and considering that the process ceased in 1995, no N<sub>2</sub>O emission factor has been estimated for 1990–1994 (see issue W.9 in UNFCCC 2023).
- Sewage sludge incineration plants: For 1990, emission factors are taken from SAEFL (2000). From 2002 to 2015, constant emission factors are used, which are deduced from measurements (LHA 2004) taken at the largest sewage sludge incineration plant incinerating at that time roughly one third of Switzerland's sewage sludge. In 2015 new emission factors for all pollutants other than CO<sub>2</sub> and CH<sub>4</sub> have been deduced based on measurements on three sewage sludge incineration plants (EMIS 2025/5C1 Klärschlammverbrennung). Between 1990 and 2002 as well as between 2002 and 2015, the emission factors are interpolated. Emission factors for CH<sub>4</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> decrease due to gradual technical improvements. Emission factors for N<sub>2</sub>O have been deduced differently (EMIS 2025/5C1 Klärschlammverbrennung): From 1990 to 2014, the evaluation of results from 7 emissions measurements over the years 2005–2013 on three sewage sludge incineration plants yielded an N<sub>2</sub>O emission factor of 4.10 kg/t (Meyer 2016, Wunderlin 2013). No indications suggested changes in emissions reductions technology over this period. In 2015, one plant accounting for incinerating 30 % of the total sewage sludge in Switzerland applied a new emissions reduction technology resulting in N<sub>2</sub>O emissions of only 0.03 kg/t (TBF 2021). By accounting for this improvement, the N<sub>2</sub>O emission factor for 2015–2016 was reduced to 3.3 kg/t. TBF (2021) investigated that as of 2017 two additional sewage sludge incineration plants, accounting for the incineration of additional 30 % of Switzerland's sewage sludge, have

implemented emissions reductions measures. This led to the implementation of a new N<sub>2</sub>O emission factor of 1.85 kg/t from 2017 onwards.

- 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 2025/5C1 Krematorien). Following IPCC (2006), no CH<sub>4</sub> emissions are estimated. There is no methodology for N<sub>2</sub>O emissions from cremation in the IPCC Guidelines (IPCC 2006). Hence, there is no explanation required according to the UNFCCC reporting guidelines (UNFCCC 2019, paragraph 30) and no N<sub>2</sub>O emissions from cremation are estimated.
- The emission factors of burning of branches in agriculture and gardening are calculated based on the EMEP/EEA guidebook (EMEP/EEA 2019) except for CH<sub>4</sub> and N<sub>2</sub>O for which emission factors are based on EMEP/CORINAIR (EMEP/EEA 2002), see also documentation in EMIS 2025/5C2 & 4VA1 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<sub>2</sub> emissions resulting from fossil CH<sub>4</sub>, CO and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

### Activity data (5C)

The activity data for 5C Waste incineration are the quantities of waste incinerated, see Table 7-18. 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 CRT Table5.C are aggregated.

Table 7-18 Activity data for the different emission sources within source category 5C Waste incineration and open burning of waste.

5C Incineration and open burning of	Unit	1990	1995	2000	2005	2010
Hospital waste incineration	kt	15	8.8	2.5	NO	NO
Municipal fossil waste incineration	kt	16	13	13	11	10
Municipal biogenic waste incineration	kt	16	13	12	11	11
Industrial waste incineration	kt	7.5	NO	NO	NO	NO
Sewage sludge incineration	kt (dry)	57	50	64	95	90
Open burning of natural residues in	kt	13	12	12	12	11
Open burning of natural residues in private households	kt	4.4	3.6	2.8	2.0	1.2
Total	kt	129	101	107	130	123
Cremation	Numb.	37'513	40'968	44'821	48'169	52'813

5C Incineration and open burning of	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Hospital waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Municipal fossil waste incineration	kt	9.3	9.4	9.3	9.0	8.8	8.6	8.4	8.3	7.8	7.7
Municipal biogenic waste incineration	kt	10	9.9	9.8	9.3	9.1	8.8	8.5	8.3	7.8	7.6
Industrial waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge incineration	kt (dry)	93	97	99	102	98	100	97	96	97	106
Open burning of natural residues in	kt	11	11	11	11	11	11	10	10	10	10
Open burning of natural residues in private households	kt	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Total	kt	124	129	130	132	128	129	126	125	124	133
Cremation	Numb.	55'616	59'664	54'634	57'694	54'842	57'746	68'148	64'106	65'688	63'546

Hospital waste incineration: Does not occur anymore in specific hospital waste incineration plants since 2002. Such waste is nowadays incinerated in municipal solid waste incineration plants and is therefore reported under sector 1 Energy. The amount of hospital waste burnt in 1990 stems from BUS (1988).

Municipal waste incineration (illegal): 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 linearly decreases to 0.25 % in 2030 (and then remains constant). The fossil carbon fraction is assumed equal to the value for municipal solid waste incineration and was determined by Rytec (2014). See also chp. 3.2.5.2 and detailed information in EMIS 2025/1A1a Kehrichtverbrennungsanlagen.

Industrial waste incineration (consists of cable insulation materials): Does not occur anymore since 1995. Such waste is nowadays incinerated in municipal solid waste incineration plants and is therefore reported under sector 1 Energy. The amount burnt in 1990 is estimated by the amount reported by a company that was supposed to burn approx. 1/3 of all cable insulation materials in Switzerland.

Sewage sludge incineration: Activity data for sewage sludge incineration for the years 1990, 1994, and 1999 are taken from Külling et al. (2002a). As of 2000 the total amount of sewage sludge produced in Switzerland is calculated by multiplying the sludge production per person and year as reported by VBSA (2017) with the total population. The per capita sewage sludge production for 2000, 2004, 2008, 2012, 2016 and 2017 (VBSA 2017) have been derived by compiling the respective amounts of sewage sludge incinerated in municipal solid waste incineration plants, sewage sludge incineration plants and used as alternative fuel in the cement industry and dividing it by the total population count (VBSA 2017). Per capita sludge productions for the intervening years were interpolated linearly. As of 2016, annual per capita sludge production amounted to 21.2 kg (VBSA 2017).

Open burning of natural residues: The quantity 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 (Swiss Confederation 1985), Article 26b. In Switzerland, cantonal authorities are responsible for the implementation of these regulations. 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 for 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 is also 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 approved by the authorities. Based on the evaluated numbers from the cantons, an extrapolation to the amount burnt in Switzerland has been made. For the extrapolation the statistics on the harvesting of wood has been used (FOEN 2012i). For the determination of a time series of natural residues burnt, senior 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 (5C2ii) are reported in LULUCF sector 4(IV)A (chp. 6.4.2.5.4.1).

Cremations: Activity data are reported by the Swiss Cremation Association. These statistics are updated every year.

### 7.4.3. Uncertainties and time-series consistency for 5C

The uncertainty assessment, based on expert judgment, results in high combined uncertainties for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O of 40 %, 60 % and 150 % of emission estimates, respectively (see Table 1-8 for quantification of “high”). In addition, the expert estimate for the activity data uncertainty is 50 % for CH<sub>4</sub> and 30 % for CO<sub>2</sub> and N<sub>2</sub>O (see details in Annex A2.1).

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 for 5C

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

### 7.4.5. Category-specific recalculations for 5C

The following recalculations were implemented in submission 2025.

- 5C1a: The fossil fraction of waste incinerated in municipal solid waste incineration plants (in 1A1a) could be determined for the year 2022 based on new analyses of the waste composition. This leads to a recalculation of the values since the last survey in 2012 (linear interpolation to the new value for 2022). For the years 1991 to 2011, the linear interpolation was newly computed using additional significant digits. Since the fossil fraction for 5C1a Illegal waste incineration is assumed equal, this affects the activity data for source category 5C1a as well.
- 5C2: The activity data for 5C2 Open burning of waste was updated based on a newly used study (INFRAS 2014, see method description). This leads to a recalculation in the years 1990–2022.

### 7.4.6. Category-specific planned improvements for 5C

No category-specific improvements are planned.

## 7.5. Source category 5D – Wastewater treatment and discharge

### 7.5.1. Source category description

Table 7-19 Key categories of 5D Wastewater treatment and discharge. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
5.D	Wastewater treatment and discharge	CH <sub>4</sub>	L1, L2, T1, T2
5.D	Wastewater treatment and discharge	N <sub>2</sub> O	L1, L2, T1, 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). Since submission 2023 emissions from decentralised wastewater treatment and since submission 2024 CH<sub>4</sub> emissions from effluents are estimated as well.

In Switzerland, municipal wastewater treatment (WWT) plants treat wastewater from single cities or several cities and municipalities together. Here, wastewater in general is treated in three steps:

- Mechanical treatment
- Biological treatment
- Chemical treatment

The treated wastewater flows into a receiving system (lake, river or stream). Pre-treated industrial effluents are also handled for final treatment in municipal wastewater treatment plants (see Figure 7-6). In the following, these are called "domestic wastewater treatment plants" according to the terminology of 5D1 Domestic wastewater.

Switzerland's wastewater management infrastructure – comprising about 850 wastewater treatment plants and 40'000–50'000 km of public sewers – is practically complete today (FOEN 2017I). The vast majority of wastewater treatment plants apply an anaerobic sludge treatment with sewage gas recovery, and use the sewage gas for heat production. About 290 wastewater treatment plants also apply combined heat and power units. See also EMIS 20254/5D1 Wastewater Treatment Plants.

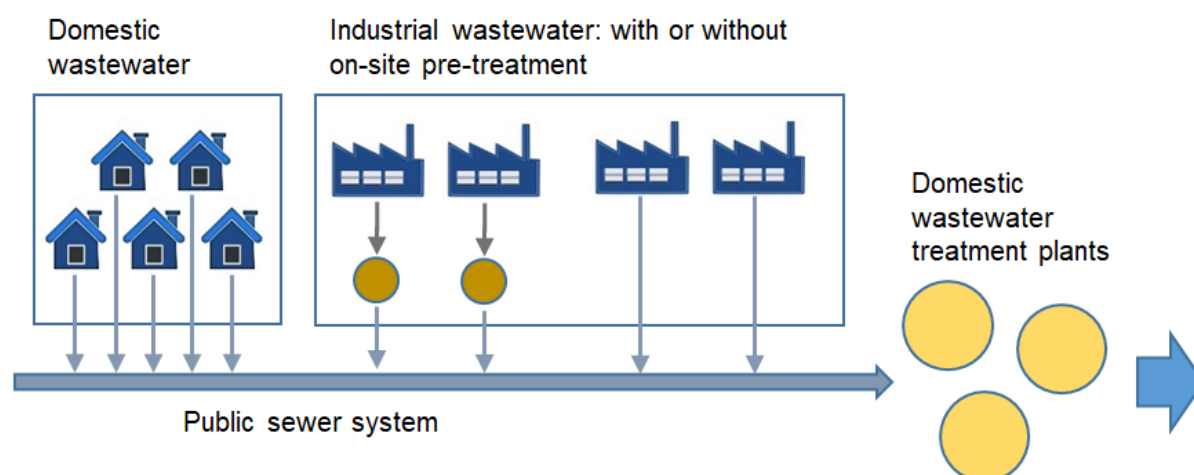


Figure 7-6 Graphical representation of domestic and industrial wastewater streams towards centralised wastewater treatment plants. Decentralised wastewater treatment is not shown here.

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 domestic wastewater treatment 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 wastewater treatment plants pre-treat wastewater before its discharge to the domestic sewage system, where the industrial wastewater is additionally treated together with domestic wastewater in domestic wastewater treatment plants (see Figure 7-6 and Figure 7-7). 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<sub>x</sub>, CO, NMVOC, SO<sub>2</sub>), domestic and industrial wastewater streams are distinguished (i. e. different emission factors are applied, see below). See also EMIS 2025/5D2 Kläranlagen industriell (Luftschadstoffe).

Table 7-20 Specification of source category 5D Wastewater treatment and discharge.

5D	Source category	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 <sub>4</sub> and N <sub>2</sub> O are implemented in 5D1)
5D3	Other	Not occurring in Switzerland

Category 5D contains all direct emissions from wastewater handling, including direct emissions of sewage gas (leakage), torching and upgrading of sewage gas to natural gas quality (to be fed into the natural gas network and/or used as fuel). Emissions from the usage



of sewage gas in combined heat and power (CHP) units and boilers (only heat production) are reported in sector 1 Energy in source category 1A2gviii Other (see Figure 3-18).

Wastewater treatment also leads to emissions reported in other categories, as illustrated in Figure 7-7. Emissions associated with sewage sludge drying are assumed to be negligible. The discharge of sewage sludge from centralised wastewater treatment plants on agricultural soils has been phased out since 2003 and is generally forbidden since 2009. Therefore, this process is crossed out in Figure 7-7. The same applies to solid waste disposal sites (5A). All sewage sludge is incinerated either in municipal solid waste incineration plants (1A1a), sewage sludge incineration plants (5C) or used as alternative fuel in the cement industry (1A2f).

According to legislation (Swiss Confederation 1992b and 1998b) and as stated in Vuna (2023) the pathway mentioned above is also applied to all sludge from on-site wastewater treatment in small scale wastewater treatment plants. On-site wastewater management is here defined as a solution for the collection, treatment and/or disposal of wastewater at or near its point of generation, without the connection to a public sewer network. On-site wastewater management systems are often called decentralised or small-scale sanitation systems. CH<sub>4</sub> and N<sub>2</sub>O emissions from such systems are estimated according to a desk study (Vuna 2023).

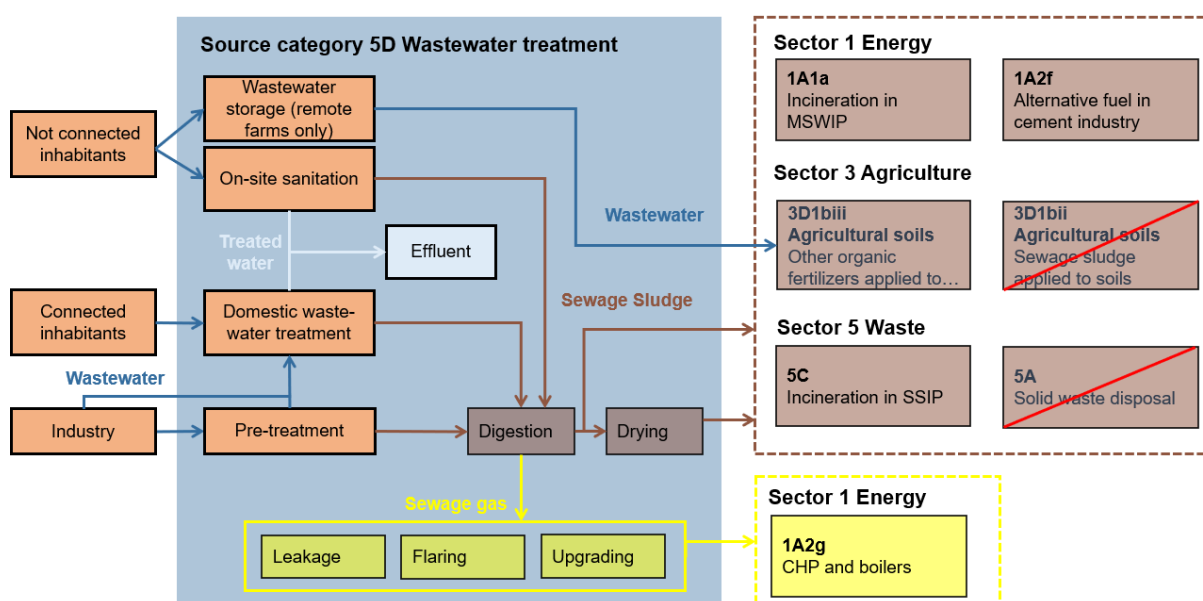


Figure 7-7 System boundaries of processes related to wastewater treatment. CHP = Combined heat and power generation. MSWIP = Municipal solid waste incineration plant. SSIP = Sewage sludge incineration plant.

## 7.5.2. Methodological issues

Emissions from wastewater treatment are estimated according to Gruber et al. (2021) for the centralised system and according to Vuna (2023) for decentralised wastewater management.

Centralised CH<sub>4</sub> emissions (treatment and discharge) are calculated by applying a Tier 2 method based on the decision trees of the IPCC Guidelines (IPCC 2006, vol. 5, chp. 6, Fig. 6.2 and Fig. 6.3 and IPCC 2019, vol. 5, chp. 6, Fig. 6.2). N<sub>2</sub>O emissions are calculated using a country-specific method according to IPCC (2006). According to IPCC (2019) N<sub>2</sub>O emissions are calculated by a Tier 2 method concerning treatment and by a Tier 1 method

concerning discharge (IPCC 2019, vo. 5. Chp. 6, Fig. 6.4). Details regarding the calculation of CH<sub>4</sub> and N<sub>2</sub>O emissions are provided in the following.

In Switzerland, 90 % of all inhabitants (urban and rural) were connected to wastewater treatment plants in 1990. This share reached 97 % in 2007 and is assumed to be at 97.3 % since 2011 (FOEN 2021m). Hence, about 2.7 % of the population are currently not connected to public sewer networks and can be distinguished as follows:

- Farms which cannot be connected to public sewer networks and hold at least eight cows or pigs are entitled to connect their domestic wastewater to the liquid manure (slurry) tank and to dispose of the manure and sewage by land application.
- Residents that cannot be connected to public networks and rely on on-site or decentralised sanitation solutions, such as septic tanks, holding tanks or small-scale wastewater treatment plants.

An overview concerning emissions from wastewater treatment via manure tanks on the one hand and on-site sanitation systems (including their characteristics and rough estimates on their penetration rates in Switzerland) on the other hand is presented in a desk study (Vuna 2023). Therein, Table 2 provides an overview of the on-site sanitation technologies applied in Switzerland. However, it is stated that not all the technologies are relevant in terms of CH<sub>4</sub> or N<sub>2</sub>O emissions, either because they are rare or because their emission potential is negligible. Table 4 thus compiles the relevant technologies, taking into account their occurrence in Switzerland and their emission potentials (Vuna 2023).

Finally, it is assumed that residents whose principal residence is connected to the sewer system are on occasion spending time in rural areas. Vuna (2023) takes this into account for two reasons. Firstly, people connected to the centralised wastewater treatment system should neither be overlooked nor double counted if they temporarily use on-site sanitation systems. It is thus assumed that the wastewater of an estimated 0.7 % of the Swiss population is actually managed in decentralised systems, despite the fact that these residents are connected to sewers most of the time (Vuna 2023). Secondly, the emission factors for on-site sanitation systems are higher than for well-managed centralised wastewater treatment plants. Emission estimates for CH<sub>4</sub> and N<sub>2</sub>O for the entire time series take these considerations into account. See Vuna (2023) for a detailed presentation of the corresponding calculations. Notably, Table 7-21 displays population numbers for the centralised and decentralised sanitation systems adjusted for the mentioned 0.7 % of total population using both systems.

Accordingly, an overview of the relevant numbers of persons, the implied emission factors and emission estimates of CH<sub>4</sub> and N<sub>2</sub>O from the various wastewater treatment pathways for source category 5D Wastewater treatment and discharge is given in Table 7-21. Detailed information is given in EMIS 2025/5D1 5D2 Abwasserbehandlung GHG.

Table 7-21 Country-specific implied emission factors (IEF) and emission estimates (EM) for CH<sub>4</sub> and N<sub>2</sub>O for source category 5D Wastewater treatment and discharge in 2023. The IEF from wastewater treatment in centralised plants is derived from four sources of emissions: 1) the sewer system, 2) the wastewater treatment plant, 3) gas losses, 4) the effluent. Numbers in the column named "Relevant population" reflect the fact that a fraction of the population is connected to the centralised system but using decentralised sanitation systems from time to time (see text). Numbers in the last row represent total population and corresponding values as given in the reporting tables.

5D Wastewater treatment and discharge	Relevant population	IEF CH <sub>4</sub>		IEF N <sub>2</sub> O	
	persons	g/person	kt/yr	g/person	kt/yr
<b>Centralised WWTP</b>	8'588'454				
Sewer		140	1.2		
Plant		515	4.4	197	1.7
Gas losses (upgrading)		101	0.87		
Effluent (all types of receiving waters)		56	0.48	20	0.17
<b>Decentralised (on-site SSWWTP)</b>	172'544				
SSWWTP including effluent		6725	1.2	495	0.085
<b>Wastewater storage on remote farms</b>	128'002				
Wastewater storage (excl. manure application)		606	0.078	17	0.0022
<b>Total (Wastewater treatment 5D)</b>	8'889'000	923	8.2	219	1.9

## 7.5.2.1. CH<sub>4</sub> emissions

### 7.5.2.1.1. Methodology for centralised wastewater treatment (5D, CH<sub>4</sub>)

CH<sub>4</sub> emission estimates from centralised wastewater treatment and discharge take into account emissions from the degradation of organically degradable material in wastewater and emissions related to sewage gas production (and recovery) from sewage sludge (in domestic as well as industrial installations). Accordingly, the contribution of industrial wastewater is taken into account in the calculation of CH<sub>4</sub> emissions from domestic wastewater by means of a correction factor for additional industrial chemical oxygen demand (COD) discharged into the domestic sewer system. Considering COD discharged to effluents, emissions from different receiving waters are estimated. Industries handling wastewater with high chemical oxygen demand usually use anaerobic digesters to produce sewage gas. The emissions related to sewage gas production (and recovery) during industrial pre-treatment of wastewater are also taken into account in the calculation of emissions from domestic wastewater treatment plants, because the underlying Swiss renewable energy statistics (see below) does not differentiate between sewage gas production in domestic and industrial wastewater treatment plants. Four pathways for CH<sub>4</sub> emissions are characterised according to Gruber et al. (2021, see chapter 4.2.1 in the report) and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2019) and summed up, namely emissions from:

- The sewer system (CH<sub>4</sub>, SEWER)
- Wastewater treatment (water line and sludge line) (CH<sub>4</sub>, WWTP)
- Sewage gas (leakage losses, treatment/upgrading, torches) (CH<sub>4</sub>, SEWAGE GAS)
- Effluent (CH<sub>4</sub>, EFFLUENT)

In short, CH<sub>4,SEWER</sub> is calculated by multiplying total organically degradable material in the sewer (TOW<sub>SEWER</sub>) with an emission factor for the sewer system (EF<sub>CH<sub>4</sub>, SEWER</sub>).

CH<sub>4</sub> emissions from wastewater treatment is calculated by multiplying TOW<sub>SEWER</sub> with an emission factor for entire wastewater treatment plants (EF<sub>CH<sub>4</sub>, WWTP</sub>).

The CH<sub>4</sub> 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 ( $EF_{CH_4, \text{sewage gas}}$ , see below), which is normalized with population (P).

Since submission 2024, the CH<sub>4</sub> emissions from effluents (CH<sub>4, EFFLUENT</sub>) are calculated by multiplying remaining organically degradable material discharged ( $TOW_{DISCHARGED}$ ) with distinguished emissions factors ( $EF_{CH_4, \text{effluent, river}}$ ,  $EF_{CH_4, \text{effluent, lake}}$ ) for receiving waters (IPCC 2019).

### Emission factors (centralised 5D, CH<sub>4</sub>)

Emission factors for CH<sub>4</sub> are chosen according to chp. 3.2.2. in Gruber et al. (2021) and IPCC (2019).

#### Sewer system

For the sewer system, a CH<sub>4</sub> emission factor ( $EF_{CH_4, SEWER}$ ) is chosen that represents the average of different assessments: 0.00255 kg CH<sub>4</sub> / kg COD (Gruber et al. 2021).

#### Wastewater treatment (water line and sludge line)

Gruber et al. (2021) discuss different CH<sub>4</sub> emission factors for the water line and sludge line and conclude that an emission factor representing whole plant measurements is most appropriate ( $EF_{CH_4, WWTP}$ ). Hence, the median value according to Gruber et al. (2021) is used: 0.0094 kg CH<sub>4</sub> / kg COD.

#### Sewage gas

To calculate the country-specific implied emission factor  $EF_{CH_4, \text{sewage gas}}$  for CH<sub>4</sub> 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 (SFOE 2024a). These statistics provide the amount of sewage gas used in furnaces and combined heat and power 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 implied emission factor  $EF_{CH_4, \text{sewage gas}}$  is adapted on a yearly basis due to the respective annual changes in population and the total production of sewage gas.

#### Effluent

According to VSA/SVKI (2023) different types of receiving waters can be distinguished. Accordingly, Tier 2 emission factors from IPCC (2019, Volume 5 Waste, Chapter 6 Wastewater Treatment and Discharge, Table 6.3) are applied to estimate CH<sub>4</sub> emissions from effluents for rivers ( $EF_{CH_4, \text{effluent, river}} = 0.009 \text{ kg CH}_4 / (\text{kg COD})$ ) and for lakes ( $EF_{CH_4, \text{effluent, lake}} = 0.048 \text{ kg CH}_4 / (\text{kg COD})$ ).

### *Values of emission factors referred to the number of inhabitants*

The implied CH<sub>4</sub> emission factors for 5D Wastewater treatment and discharge in centralised wastewater treatment plants are summarised in Table 7-21.

### **Activity data (centralised 5D, CH<sub>4</sub>)**

Activity data for CH<sub>4</sub> are specified according to chp. 2.2.2. in Gruber et al. (2021) and Dominguez (2023).

### *Sewer system and wastewater treatment (water line and sludge line)*

Total organically degradable material (TOW) is used as activity data for emissions from both, sewers and wastewater treatment plants. TOW is calculated by multiplying the number of persons, connection rate to sewer system, per capita load of organically degradable material, and a correction factor ( $I = 1.25$  (default IPCC 2006)) for additional industrial COD discharged into sewers (Gruber 2021, p. 14).

### *Sewage gas*

As elaborated above, a per capita implied emission factor ( $EF_{CH_4, \text{sewage gas}}$ ) is calculated for CH<sub>4</sub> emissions from separate sewage sludge treatment, and the respective activity data are total population.

### *Effluent*

Since submission 2024, the CH<sub>4</sub> emissions from effluents (CH<sub>4, EFFLUENT</sub>) are calculated based on data presented in VSA/SVKI (2023). From COD measurements in the discharge from wastewater treatment plants that are attributable to a known number of connected persons, an average for chemical oxygen demand (COD) of 10.24 g COD/(person\*day) of treated water discharged is derived (Dominguez 2023). From the same data base (VSA/SVKI 2023), different types of receiving waters can be attributed to and weighted with the number of connected persons. As a result, 84.5 % of treated water is fed to rivers and 15.5 % is fed to lakes (Dominguez 2023).

### **7.5.2.1.2. Methodology for decentralised wastewater treatment (5D, CH<sub>4</sub>)**

Concerning CH<sub>4</sub> emissions from decentralised wastewater treatment two pathways are considered: storage in manure tanks on remote farms and other housing with on-site sanitation systems with anaerobic primary treatment stages are relevant (Vuna 2023). Since submission 2024 also CH<sub>4</sub> emissions from effluents of on-site systems are considered (IPCC 2019).

- CH<sub>4</sub> emissions from remote farms (via manure handling) are estimated to occur due to storage of wastewater in manure tanks. Resulting emissions are calculated within the agricultural model (Agroscope 2025) according to the methodologies for 3B manure management (see chp. 5.3.2.2). The IEF in Table 7-21 is estimated based on the per capita excretion of volatile solids (VS, see below under “activity data”) and the CH<sub>4</sub> emissions per kg of VS (see below under “emission factor”). VS is equivalent to the total organic carbon (TOC).

- CH<sub>4</sub> emissions from on-site sanitation systems are estimated by multiplying total organically degradable material (TOW) by emission factors for primary only or primary and secondary treatments.
- CH<sub>4</sub> emissions from effluents of on-site sanitation systems are estimated by multiplying remaining, discharged organic matter (TOW<sub>DISCHARGED</sub>) by EF<sub>CH<sub>4</sub>,effluent,river</sub> (IPCC, 2019).

Furthermore, Vuna (2023) confirms that it is valid to assume that all sludge of unconnected inhabitants which is not discharged on farm land after storage in manure tanks, is transported to large-scale, centralised wastewater treatment plants. There, the sludge is typically fed into the sludge thickener or digester for treatment together with the primary and secondary sludge of the plant.

### Emission factors (decentralised 5D, CH<sub>4</sub>)

CH<sub>4</sub> emissions for wastewater storage in manure tanks on remote farms are estimated based on IPCC equation 10.23 (IPCC 2019) as described under 3B Manure management (chp. 5.3). For the maximum methane producing capacity (B<sub>0</sub>), the same value for humans as for swine (i. e. 0.45 m<sup>3</sup> kg<sup>-1</sup>, IPCC 2019) is adopted due to the similarities of the respective digestive systems. It is assumed that all wastewater is handled in liquid/slurry systems. The respective methane conversion factor (MCF) is assessed as described under chp. 5.3.2.2.3. Average CH<sub>4</sub> emissions per kg of volatile solids (VS, corresponding to total organic carbon, TOC) are thus 0.042 kg and range from 0.041 to 0.045 according to fluctuations of the MCF.

For primary and secondary treatments in different on-site sanitation systems, CH<sub>4</sub> emission factors are used according to IPCC Guidelines (IPCC 2006, 2014a, 2019) as described in Vuna (2023, chp. 3.3.3 Emission factors of SSWWTPs, and in particular also Table 7).

According to Dominguez (2023) all small-scale wastewater treatment plants in Switzerland discharge into streams. Accordingly, the Tier 2 emission factor from IPCC (2019, Volume 5 Waste, Chapter 6 Wastewater Treatment and Discharge, Table 6.3) for rivers is used to estimate CH<sub>4</sub> emissions from effluents (EF<sub>CH<sub>4</sub>,effluent,river</sub> = 0.009 kg CH<sub>4</sub>/(kg COD)).

### Activity data (decentralised 5D, CH<sub>4</sub>)

According to Vuna (2023) about 1.44 % of the Swiss population's wastewater is treated via manure tanks on remote farms today. Based on this fraction and the chemical oxygen demand (COD) per person (chp. 2.2.2. in Gruber et al. (2021)) multiplied by a conversion factor (TOC = 1/3 \* COD, according to Metcalf and Eddy (2003) and Dominguez (2023)), quantities of total organic carbon (TOC) in wastewater going to manure tanks are estimated. It is assumed that the TOC corresponds to the volatile solids (VS) as used for emission calculations during manure management (equation 10.23, IPCC 2019). The per capita excretion of VS is thus 0.04 kg person<sup>-1</sup> day<sup>-1</sup>.

According to Vuna (2023) about 1.26 % of the Swiss population's wastewater is treated in on-site sanitation systems today. Based on this fraction and the chemical oxygen demand (COD) per person (chp. 2.2.2. in Gruber et al. (2021)) quantities of total organic degradable material (TOW) in wastewater going to on-site sanitation systems are estimated. Relevant on-site technologies in terms of CH<sub>4</sub> are listed in Table 4 of Vuna (2023) and fractions for



secondary treatment techniques are quantified in Figure 3 of Vuna (2023). Hereof only constructed wetlands (according to IPCC 2014a) are considered relevant for CH<sub>4</sub> emissions.

The ratio of the two given fractions is assumed to be constant over the time series as no data is available (Vuna 2023). Together with time series for total population and the share of people not connected to the centralised system, the ratio is used to calculate the number of people living on remote farms or using on-site sanitation systems.

Concerning CH<sub>4</sub> emissions from effluents (CH<sub>4, EFFLUENT</sub>), the remaining organically degradable material in the outflow of small-scale wastewater treatment plants (SSWWTPs) is estimated via the reduction potential for organics in wastewater of such systems in Switzerland: TOW reduction in primary treatment amounts to 30 % (Dominguez 2023, Vuna 2023). Furthermore, it is required by Federal legislation that COD is reduced by 80 % in SSWWTPs with primary and secondary treatments (Swiss Confederation 1998b). The carbon removal rate of individual SSWWTP is regularly controlled by cantonal authorities and therefore considered plausible. Also, these numbers compare well to default values given in IPCC (2019, Volume 5 Waste, Chapter 6 Wastewater Treatment and Discharge, Table 6.6).

## 7.5.2.2. N<sub>2</sub>O emissions

### 7.5.2.2.1. *Methodology for centralised wastewater treatment (5D, N<sub>2</sub>O)*

Direct N<sub>2</sub>O emissions from centralized wastewater treatment plants and N<sub>2</sub>O emissions from wastewater effluent are calculated using a country-specific method in accordance with the IPCC Guidelines (IPCC 2006).

The method is described in detail in Gruber et al. (2021) and Gruber (2022). Therein, two pathways for N<sub>2</sub>O emissions are characterised (see chapter 4.1.1 in Gruber et al. (2021)) and summed up, namely emissions from:

- Wastewater treatment plants (N<sub>2</sub>O<sub>PLANT</sub>)
- Effluent (N<sub>2</sub>O<sub>EFFLUENT-WATERBODY</sub>)

In short, N<sub>2</sub>O emissions from wastewater treatment plants (N<sub>2</sub>O<sub>PLANT</sub>) are calculated by multiplying nitrogen load in the influent (N<sub>INFLUENT</sub>) by an emission factor (EF<sub>N<sub>2</sub>O, PLANT</sub>). N<sub>2</sub>O emissions from the effluent are calculated by multiplying nitrogen load in the effluent (N<sub>EFFLUENT</sub>) by an emission factor (EF<sub>N<sub>2</sub>O, EFFLUENT-WATERBODY</sub>).

## Emission factors (centralised 5D, N<sub>2</sub>O)

### *Wastewater treatment plants (EF<sub>N<sub>2</sub>O, PLANT</sub>)*

Gruber et al. (2021) selected a suite of wastewater treatment plants representative for Switzerland. They then set up an off-gas monitoring system and measured N<sub>2</sub>O emissions from each selected plant throughout the year. The latter is important as it was shown that seasonal emission patterns are evident. The authors assessed emission factors evaluating 14 monitoring campaigns. Accordingly, three emission factors from wastewater treatment plants were derived, corresponding to three different nutrient removal categories: (a) carbon removal, (b) nitrification only, (c) year-round nitrogen removal (see Table 3 of Gruber et al. (2021)). It is generally assumed that a lower nitrogen removal results in higher N<sub>2</sub>O emissions. The estimation of the country-wide emission factor (EF<sub>N<sub>2</sub>O, PLANT</sub>) is calculated by multiplying the respective share of nitrogen load treated in wastewater treatment plants



belonging to a nutrient removal category by the respective emission factor. The categorization used is described in a written communication by Gruber (2022) updating Figure 9 of Gruber et al. (2021). As such, technical development over the time series is reflected with increasing nitrogen removal from 1990 to today.

In addition, N<sub>2</sub>O emissions from unaerated process stages are considered. Gruber et al. (2021) assume that the respective share of emissions ( $F_{N_2O,UNAERATED}$ ) corresponds to 25 % of the emission from aerated processes (calculated with  $EF_{N_2O, PLANT}$ , see above). The authors assume a constant share over the whole reporting period.

#### *Effluent ( $EF_{N_2O,EFFLUENT}$ )*

Following Gruber et al. (2021) the emission factor for N<sub>2</sub>O emitted from nitrogen in the effluent of wastewater treatment plants is kept at the default value given in the IPCC Guidelines (IPCC 2006):  $EF_{N_2O, EFFLUENT} = 0.005$  kg N<sub>2</sub>O-N/kg N.

#### **Activity data (centralised 5D, N<sub>2</sub>O)**

Nitrogen loads for wastewater treatment plants are interpolated linearly following references and data presented in Table 1 of Gruber et al. (2021). Influent nitrogen load to wastewater treatment plants ( $N_{INFLUENT}$ ) is then calculated by multiplying population, nitrogen load (kg N/(person\*year)) and connection rate ( $T_{PLANT}$ ).

An average nitrogen removal rate ( $r_{NITROGEN\ REMOVAL\ RATE}$ ) is calculated based on Table 1 of Gruber et al. (2021) and is used to calculate nitrogen load in the effluent ( $N_{EFFLUENT} = N_{INFLUENT} * (1 - r_{NITROGEN\ REMOVAL\ RATE})$ ).

#### **7.5.2.2.2. Methodology for decentralised wastewater treatment (5D, N<sub>2</sub>O)**

Concerning N<sub>2</sub>O emissions from decentralised wastewater treatment two relevant pathways are considered: 1) handling via manure tanks on remote farms and 2) other housing with on-site sanitation systems with secondary treatment stages (Vuna 2023).

N<sub>2</sub>O emissions from wastewater storage on remote farms (via manure handling) are estimated within the agricultural model (Agroscope 2025) according to the methodologies for 3B manure management (see chp. 5.3.2). The IEF in Table 7-21 is estimated based on the per capita nitrogen load (see below under “activity data”) and the cumulated direct and indirect N<sub>2</sub>O emissions per kg of nitrogen (see below under “emission factor”).

According to Vuna (2023) and references therein N<sub>2</sub>O emissions from on-site sanitation systems are estimated as follows:

- Nitrogen influent to on-site sanitation systems is calculated by multiplying the number of persons served by on-site sanitation with nitrogen load per person (as in chp. 7.5.2.2.1) in accordance with Gruber et al. (2021).
- Nitrogen removed in primary treatment is subtracted (5 %) to receive nitrogen influent to secondary treatments.
- Several secondary treatment technologies are differentiated for different small scale wastewater treatment plants leading to different N<sub>2</sub>O emission strengths.
- Nitrogen removal in secondary treatment is set to 25 % as a weighted average of the various relevant treatment technologies.

- A constant emission factor for  $\text{N}_2\text{O}$  from effluents is assumed (as in chp. 7.5.2.2.1), based on the IPCC Guidelines (2006) and in accordance with Gruber et al. (2021), and multiplied with residual nitrogen in effluent to yield in  $\text{N}_2\text{O}$  emissions from effluents.

### Emission factors (decentralised 5D, $\text{N}_2\text{O}$ )

$\text{N}_2\text{O}$  emissions for wastewater storage in manure tanks on remote farms is estimated based on IPCC equations 10.25, 10.26 and 10.28 (IPCC 2019). It is assumed that all wastewater is handled in liquid/slurry systems. For direct  $\text{N}_2\text{O}$  emissions a nitrogen loss rate ( $\text{EF}_3$ ) of 0.2 % is assumed based on IPCC (2019). For indirect  $\text{N}_2\text{O}$  emissions, the amount of nitrogen volatilised as  $\text{NH}_3$  and  $\text{NO}_x$  during storage must be estimated.  $\text{NH}_3$  losses are assumed to be zero since these are mainly dependent on the surface area of the slurry tanks, which is not increased by the additional amount of wastewater. Losses of  $\text{NO}_x$  are 0.2 % according to van Bruggen et al. (2014). Subsequently, indirect  $\text{N}_2\text{O}$  emissions are estimated by multiplying the amount of nitrogen volatilised by  $\text{EF}_4$  (see chp. 5.3.2.4). Average  $\text{N}_2\text{O}$  emissions per kg of nitrogen are thus  $3.2 \text{ g N}_2\text{O-N}^*(\text{kg N})^{-1}$ .

No  $\text{N}_2\text{O}$  is emitted from primary treatments of on-site sanitation systems (IPCC 2019, Vuna 2023).

For different on-site technologies using secondary treatments and for effluents,  $\text{N}_2\text{O}$  emission factors are used according to IPCC Guidelines (IPCC 2006, 2014a, 2019) as described in Vuna (2023, chp. 3.3.3 Emission factors of SSWWTPs, and in particular also Table 7).

### Activity data (decentralised 5D, $\text{N}_2\text{O}$ )

According to Vuna (2023) about 1.44 % of the Swiss population's wastewater is treated via manure tanks on remote farms today. Based on this fraction and the per capita nitrogen load (5.33 to  $7.04 \text{ kg person}^{-1} \text{ year}^{-1}$ , Gruber et al. (2021), Table 1), estimates for total nitrogen loads going to manure tanks are established.

According to Vuna (2023) about 1.26 % of the Swiss population's wastewater is treated in on-site sanitation systems today. Relevant on-site technologies in terms of  $\text{N}_2\text{O}$  are listed in Table 4 of Vuna (2023) and fractions for secondary treatment techniques are quantified in Figure 3 of Vuna (2023).

The ratio of the two given fractions is assumed to be constant over the time series as no data is available (Vuna 2023). Together with time series for total population and the share of people not connected to the centralised system, the ratio is used to calculate the number of people living in remote farms or using on-site sanitation systems.

### 7.5.2.3. Other gases

The sewage gas production generates emissions of further gases from flaring:  $\text{CO}_2$  (biogenic),  $\text{NO}_x$ , CO, NMVOC, and  $\text{SO}_2$ . The emissions are calculated by multiplying population (as activity data, see Table 7-21) with country-specific emission factors based on measurements and expert estimates, documented in EMIS 2025/5D1 Wastewater Treatment Plants and EMIS 2025/5D2 Pre-treatment of industrial wastewater. The emission factors used are summarised in Table 7-22.

Table 7-22 Emission factors of CO<sub>2</sub> (biogenic), CH<sub>4</sub>, N<sub>2</sub>O, NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> for flaring in 5D Wastewater treatment and discharge in 2023.

5D Wastewater treatment and discharge	CO <sub>2</sub> fossil	CO <sub>2</sub> biog.	N <sub>2</sub> O	CH <sub>4</sub>	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
	kg/person		g/person					
5D1 Domestic wastewater	NA	0.42	219	923	0.57	0.28	0.011	0.0029
5D2 Industrial wastewater	NA	0.09	IE	IE	0.13	0.063	0.0026	0.00064

### 7.5.3. Uncertainties and time-series consistency for 5D

#### Uncertainty in CH<sub>4</sub> and N<sub>2</sub>O emissions from 5D

Uncertainty input data (see Annex A2.1) has been estimated as follows:

- According to Gruber et al. (2021) for centralised wastewater treatment for both gases.
- According to Vuna (2023) for on-site sanitation for both gases.
- According to the EMEP/EEA guidebook (EMEP/EEA 2019, part A, chp. 5, Table 2-2) and expert judgement for wastewater storage on remote farms for both gases.
- According to given ranges of methane conversion factors (MCF) in IPCC (2019, vol. 5, chp. 6, Tab. 6.3) for CH<sub>4</sub> from receiving waters.

#### 7.5.3.1. CH<sub>4</sub> emissions

Combined uncertainty input for CH<sub>4</sub> for relative uncertainties for wastewater treatment in the centralised system (106 %), in on-site sanitation systems (200 %), for wastewater storage on remote farms (200 %) and for effluents (100 %) has been weighted by the respective shares of population, leading to a rounded value of 100 %. For the assumption of a gamma distribution the uncertainty analyses resulted in a combined uncertainty U(Em CH<sub>4</sub>) of -74 % to +122 % for approach 1 and of -84 % to +100 % for approach 2 (see Annexes A2.2 and A2.3).

#### 7.5.3.2. N<sub>2</sub>O emissions

Combined uncertainty input for N<sub>2</sub>O for relative uncertainties for wastewater treatment in the centralised system (54 %), in on-site sanitation systems (200 %) and for wastewater storage on remote farms (200 %) has been weighted by the respective shares of population, leading to a rounded value of 50 %. For the assumption of a gamma distribution the uncertainty analyses resulted in a combined uncertainty U(Em N<sub>2</sub>O) of -44 % to +56 % for approach 1 and of -48 % to +50 % for approach 2 (see Annexes A2.2 and A2.3).

Consistency: Time series for 5D Wastewater treatment and discharge are all considered consistent.

### 7.5.4. Category-specific QA/QC and verification for 5D

The general QA/QC measures are described in chp. 1.5.

Following IPCC (2019), emission estimates for CH<sub>4</sub> from receiving waters have been included in submission 2024.

### 7.5.5. Category-specific recalculations for 5D

The following recalculations were implemented in submission 2025. Major recalculations which contribute significantly to the total differences emissions of sector 5 between the latest and the previous submissions are presented also in chp. 10.1.2.5.

- 5D1, emission factor for N<sub>2</sub>O for 5D1 Domestic wastewater treatment: There was a mistake in the formula used to compute the quantity of N<sub>2</sub>O in the effluent for the year 1990 only. The correction causes a reduction in the N<sub>2</sub>O emissions by 0.02 %.
- 5D1, emission factor for N<sub>2</sub>O for 5D1 Domestic wastewater treatment: For the years 2020–2022, the country-specific model newly uses the assumption of a constant nitrogen load per person and per year equal to the last available value for the year 2020, instead of a decreasing trend. This causes an increase of the emission factor for N<sub>2</sub>O by up to 4 %.
- 5D1: The model to estimate N<sub>2</sub>O emission from wastewater storage on remote farms has been updated. NH<sub>3</sub> emissions from storage of decentralized human sewage sludge are now set to zero and hence there are no more indirect N<sub>2</sub>O emissions from storage. This decision is based on the fact that NH<sub>3</sub> emissions mainly depend on the size of the surface and thus should not increase due to more N-input into the same tanks.

### 7.5.6. Category-specific planned improvements for 5D

No category-specific improvements are planned.

## 7.6. Source category 5E – Other

### 7.6.1. Source category description

Table 7-23 Key categories of 5E Other. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

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 oil) and motor oil in the tanks and motors of the shredded vehicles. Direct GHG emissions do not occur.

Table 7-24 Specification of source category 5E Other (car shredding)

5E	Source category	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<sub>2</sub> emissions resulting from fossil CO and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

#### 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 2025/5E Shredder Anlagen). For CO a constant emission factor is applied over the entire reporting period.

Table 7-25 CO and NMVOC emission factors for 5E Other (car shredding) in 2023.

5E Other waste	Unit	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
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 2025/5E Shredder Anlagen).

Table 7-26 Activity data 5E Other (car shredding).

5E Other waste	Unit	1990	1995	2000	2005	2010
Shredding	kt	280	300	300	300	300

5E Other waste	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Shredding	kt	300	300	300	300	300	300	300	300	300	300

### 7.6.3. Uncertainties and time-series consistency for 5E

Uncertainties of CO and NMVOC emissions are documented in Switzerland's Informative Inventory Report 2024 (FOEN 2025b). The uncertainties of the emission factors are partly based on values provided by the EMEP/EEA guidebook (EMEP/EEA 2019, part A, chp. 5, Table 2-2) and expert judgements (see detailed input uncertainties in Annex A2.1).

Consistency: Time series for 5E Other are all considered consistent.

### 7.6.4. Category-specific QA/QC and verification for 5E

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

### 7.6.5. Category-specific recalculations for 5E

There were no recalculations implemented in submission 2025.

### 7.6.6. Category-specific planned improvements for 5E

No category-specific improvements are planned.

## 8. Other

Responsibilities for chapter Other	
Overall responsibility	Myriam Guillevic (FOEN)
Method updates & authors	Myriam Guillevic (FOEN)
EMIS database operation	Myriam Guillevic (FOEN)
Annual updates (NID text, tables, figures)	Beat Rihm (Meteotest)
Quality control (NID annual updates)	Dominik Egli (Meteotest), Adrian Schilt (FOEN)
Internal review	Adrian Schilt (FOEN)

### 8.1. Overview

Within the sector 6 Other emissions from two sources are considered:

- Fire damage buildings (6A1a)
- Fire damage motor vehicles (6A1b)

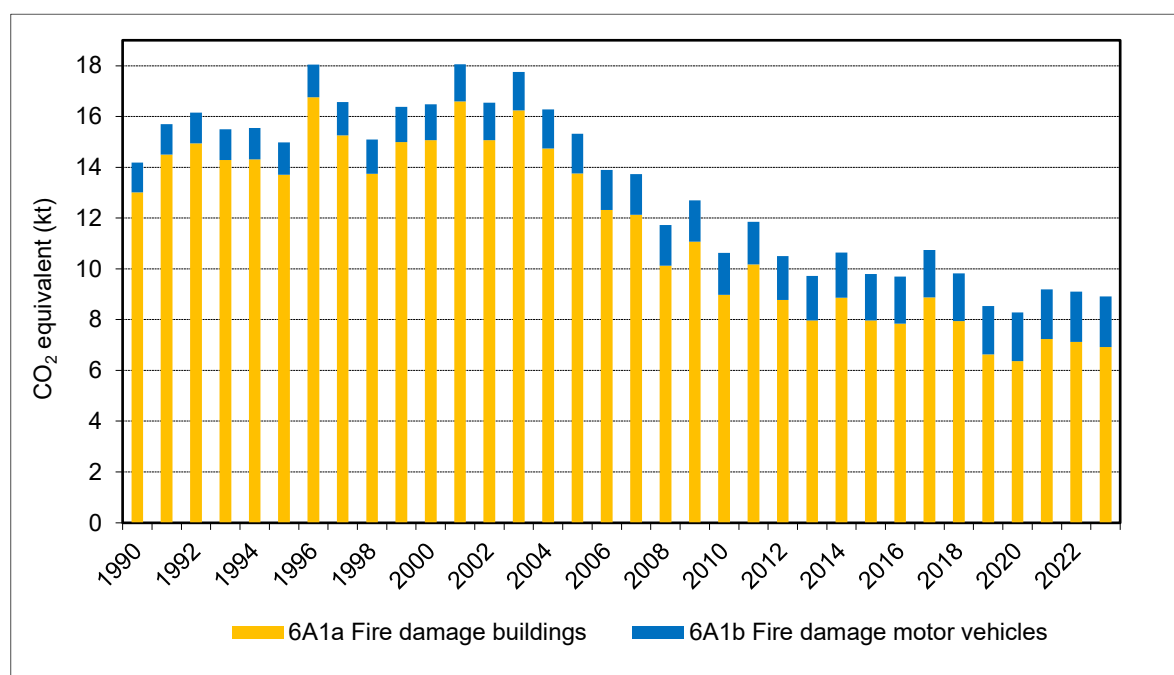


Figure 8-1 Switzerland's greenhouse gas emissions in sector 6 Other.



Gas	1990	1995	2000	2005	2010
CO <sub>2</sub> equivalent (kt)					
CO <sub>2</sub>	13	14	15	14	9.7
CH <sub>4</sub>	0.83	0.81	0.84	0.78	0.55
N <sub>2</sub> O	0.60	0.58	0.60	0.55	0.36
Sum	14	15	16	15	11

Gas	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO <sub>2</sub> equivalent (kt)										
CO <sub>2</sub>	9.7	9.0	8.9	9.8	9.0	7.8	7.6	8.4	8.3	8.2
CH <sub>4</sub>	0.55	0.51	0.50	0.55	0.51	0.44	0.43	0.48	0.47	0.46
N <sub>2</sub> O	0.35	0.32	0.31	0.35	0.31	0.26	0.25	0.29	0.28	0.27
Sum	11	9.8	9.7	11	9.8	8.5	8.3	9.2	9.1	8.9

Table 8-1 Trend of total GHG emissions from sector 6 Other in Switzerland.

In sector 6 Other, Fire damage buildings account for most of the emissions, the rest originates from Fire damage motor vehicles. The emission trend is generally decreasing since 2004, mostly due to a gradually decreasing number of building fires per year. The total greenhouse gas emissions of this sector show emissions of less than 20 kt CO<sub>2</sub> eq in each year during the reporting period. Consequently, sector 6 Other is an emission source of minor importance for the national total.

## 8.2. Source category 6A – Other

### 8.2.1. Source category description

Table 8-2 Key categories of 6A – Other. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Source category 6A – Other is not a key category.
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The sources reported in source category 6A Other are shown in Table 8-3.

Table 8-3 Specification of source category 6A Other.

6A	Source category	Specification
6A1a	Fire damage buildings	Emissions from fires in buildings.
6A1b	Fire damage motor vehicles	Emissions from fires in motor vehicles.

### 8.2.2. Methodological issues

#### Methodology (6A Other)

CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions are calculated by a Tier 1 method based on the decision tree of the IPCC Guidelines (IPCC 2006, vol. 5, chp. 5, Fig. 5.1 and Fig. 5.2). Emission factors are country-specific.

## Emission factors (6A Other)

### a) Fire damage buildings

Emission factors for CO<sub>2</sub>, CO, NO<sub>x</sub> and SO<sub>2</sub> are country-specific, based on measurements and expert estimates originally gained for illegal waste incineration. It is assumed that for fire damage in buildings, emission factors are the same as for illegal waste incineration (chp. 7.4.1 and EMIS 2025/6A Immobilienbrände).

Emission factors for CH<sub>4</sub> and N<sub>2</sub>O are estimated based on data in FM Global (2010).

Indirect CO<sub>2</sub> emissions resulting from fossil CH<sub>4</sub>, CO and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

### b) Fire damage motor vehicles

Emission factors for CO<sub>2</sub>, NO<sub>x</sub>, CO and SO<sub>2</sub> are country-specific, based on measurements obtained by car fire experiments (Lönnermark and Blomqvist 2006, ADEME 2013, INERIS 2019), EMIS 2025/6A Fahrzeugbrände).

The emission factor for CH<sub>4</sub> from fire damage in motor vehicles is based on USEPA (1992). It is of the same order of magnitude but slightly higher than the value published in INERIS 2019 (5 t/kt vs 3 t/kt burnt material, respectively).

N<sub>2</sub>O emissions have not been estimated for this source category.

It is assumed that the emission factor for NMVOC is the same as for illegal waste incineration (chp. 7.4.1 and EMIS 2025/6A Fahrzeugbrände).

Indirect CO<sub>2</sub> emissions resulting from fossil CH<sub>4</sub>, CO and NMVOC emissions in this source category are included in CRT Table6 as documented in chp. 9.

Table 8-4 Emission factors for fire damages in 2023 (EMIS 2025/6A).

6A Other	Unit	CO <sub>2</sub> biogenic	CO <sub>2</sub> fossil	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC	SO <sub>2</sub>
6A1a Fire damage buildings	t / kt burnt good	1'900	1'900	3	0.25	3	100	16	1
6A1b Fire damage motor vehicles	t / kt burnt good	NO	2'295	5	NE	4.5	52	2	5

## Activity data (6A Other)

### a) Fire damage buildings

Activity data are estimated yearly based on the number of building fires reported to insurance companies for the given year. This information is annually published 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. Using the data from 1992 to 2001, the average damage sum per fire incident in buildings amounts to approximately CHF 16'000. This corresponds – based on the assumption of typical damage costs of CHF 20'000 per 1'000 kg of burnt material – to 800 kg of flammable material per case. It is further assumed that on average 50 % of the flammable material gets destroyed during an incident because of the intervention of the fire brigade, yet without actually being set on fire. Thus, an average amount of 400 kg of burnt material per fire case is estimated and held constant throughout the time series. This is the same order of magnitude as the range of 272–417 kg of burnt material estimated based on a test fire as

published in FM Global (2010). With these assumptions, the amount of burnt material for each year can be estimated using the total number of building fires published by VKF (EMIS 2025/6A Immobilienbrände), multiplied by the burnt material (400 kg) per fire incident. The resulting value of 9 kt burnt goods is used for the year 1990.

The fraction of fossil material burnt is assumed to be 20 % from 1900 until 1950. It is then assumed to increase linearly until 2000, when it reaches a fraction of 80 %, and to remain constant at a fraction of 80 % afterwards.

#### *b) Fire damage motor vehicles*

Activity data are estimated yearly based on the vehicle number published annually by the Federal Statistical Office FSO (EMIS 2025/6A Fahrzeugbrände).

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. This results in one fire case per 790 vehicles for the year 2002. It is assumed that this ratio has remained constant during the reporting period. By applying this ratio to the actual vehicle number published annually by the FSO, the total number of vehicles with fire damages in Switzerland can be calculated for each year.

During a car fire incident, a car burns down only partially. It is assumed that approximately 100 kg of material burns down during a car fire. With these assumptions, the total mass of material burnt is calculated from the total number of car fire incidents in Switzerland.

It is assumed that the burnt material is entirely of fossil origin.

Table 8-5 Activity data of burnt goods (documented in EMIS 2025/6A).

6A	Unit	1990	1995	2000	2005	2010						
6A1a Fire damage buildings (fossil)	kt	6.1	6.5	7.2	6.6	4.3						
6A1a Fire damage buildings (biog.)	kt	2.9	2.3	1.8	1.6	1.1						
6A1b Fire damage motor vehicles	kt	0.48	0.52	0.58	0.64	0.68						

6A	Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
6A1a Fire damage buildings (fossil)	kt	4.2	3.8	3.8	4.2	3.8	3.2	3.0	3.5	3.4	3.3
6A1a Fire damage buildings (biog.)	kt	1.06	0.95	0.94	1.1	0.95	0.79	0.76	0.87	0.85	0.83
6A1b Fire damage motor vehicles	kt	0.73	0.75	0.76	0.77	0.77	0.78	0.79	0.80	0.81	0.82

### 8.2.3. Uncertainties and time series consistency for 6A

For building fires, the assigned uncertainty value for the total amount of burnt good is 50 %. This results in an uncertainty of 50 % for the activity data for CH<sub>4</sub> and N<sub>2</sub>O. For CO<sub>2</sub>, the uncertainty of the fossil fraction increases the uncertainty of the activity data to 60 %. For car fires, the assigned uncertainty for the activity data (amount of burnt material) for all gases is 50 %.

For building fires and car fires, the uncertainty assigned to the emission factors is 100 % for CH<sub>4</sub>, 120 % for CO<sub>2</sub> and 150 % for N<sub>2</sub>O (see also Table A – 2).

Consistency: Time series for 6Ad Fire damages are all considered consistent.

#### **8.2.4. Category-specific QA/QC and verification for 6A**

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

#### **8.2.5. Category-specific recalculations for 6A**

There were no recalculations implemented in submission 2025.

#### **8.2.6. Category-specific planned improvements for 6A**

No category-specific improvements are planned.

## 9. Indirect CO<sub>2</sub> and N<sub>2</sub>O emissions

Responsibilities for chapter Indirect CO <sub>2</sub> and N <sub>2</sub> O emissions	
Overall responsibility	Adrian Schilt (FOEN)
Method updates & authors	Adrian Schilt (FOEN) and sector experts
EMIS database operation	Myriam Guillevic (FOEN)
Annual updates (NID text, tables, figures)	Dominik Eggli (Meteotest), Anna Ehrler (INFRAS)
Quality control (NID annual updates)	Dominik Eggli (Meteotest), Adrian Schilt (FOEN)
Internal review	Anouk-Aimée Bass (FOEN), Daniel Bretscher (Agroscope), Myriam Guillevic (FOEN), Sabine Schenker (FOEN), Adrian Schilt (FOEN)

### 9.1. Overview

In this chapter, indirect CO<sub>2</sub> emissions that result from the atmospheric oxidation of CH<sub>4</sub>, CO and NMVOC as well as indirect N<sub>2</sub>O emissions that are induced by the deposition of NO<sub>x</sub> and NH<sub>3</sub> are documented. While indirect CO<sub>2</sub> emissions of fossil origin reported in this chapter are accounted for in the national total, indirect N<sub>2</sub>O emissions are not.

Indirect emissions of CO<sub>2</sub> and N<sub>2</sub>O are shown in CRT Table6, together with the emissions of the precursor gases CH<sub>4</sub>, CO, NMVOC, NO<sub>x</sub> and NH<sub>3</sub>. While all emissions of precursor gases are shown in both CRT Table6 and in the respective sectors, the indirect emissions of CO<sub>2</sub> and N<sub>2</sub>O shown in CRT Table6 only represent emissions not already included in direct emissions in other sectors (in order to avoid double counting). Further, in the case of indirect CO<sub>2</sub> emissions, only carbon of fossil origin is considered. Accordingly, while CH<sub>4</sub>, CO and NMVOC of biogenic origin are shown as precursor gases in CRT Table6, they are not included for the calculation of indirect CO<sub>2</sub> emissions. Consequently, the implied emission factors may vary from sector to sector and also from year to year.

Chapter 9.2 explains in detail the methodological issues to derive indirect CO<sub>2</sub> and N<sub>2</sub>O emissions based on the emissions of the precursor gases CH<sub>4</sub>, CO and NMVOC as well as NO<sub>x</sub> and NH<sub>3</sub> from the different sectors. As an overview, the resulting indirect CO<sub>2</sub> emissions are shown in Table 9-1, as well as in Figure 9-1 and Figure 9-2. The resulting indirect N<sub>2</sub>O emissions are shown in Table 9-2, as well as in Figure 9-3 and Figure 9-4.

To provide further details with regard to the CH<sub>4</sub>, CO and NMVOC emissions relevant for the indirect CO<sub>2</sub> emissions as shown in CRT Table6, the emissions of these precursor gases are shown for each sector, disaggregated by source category, in Table 9-3 (for sector 1 Energy), in Table 9-4 (for sector 2 Industrial processes and product use), in Table 9-5 (for sector 5 Waste) and in Table 9-6 (for sector 6 Other). In these tables, the percentages provided in parentheses reflect the share of emissions of precursor gases that are relevant for indirect CO<sub>2</sub> emissions, i.e. the share of fossil emissions of precursor gases not already considered under the direct CO<sub>2</sub> emissions. This information – together with the factors for the stoichiometric conversion of CH<sub>4</sub>, CO and NMVOC to indirect CO<sub>2</sub> as provided in chp. 9.2.1 – allows for an interpretation of the implied emission factors.

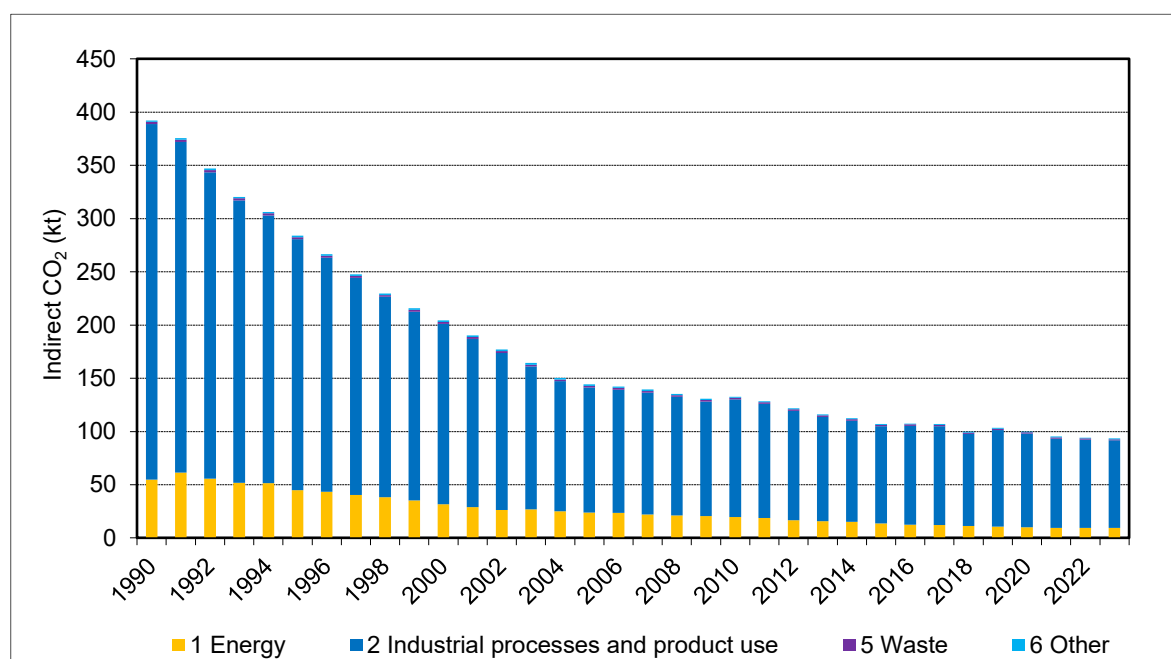
Indirect CO<sub>2</sub> emissions are considered for both the uncertainty analysis (see chp. 1.6) and the key category analysis (see chp. 1.4). Indirect N<sub>2</sub>O emissions are neither considered for the uncertainty analysis (see chp. 1.6), nor for the key category analysis (see chp. 1.4).

Table 9-1 Indirect fossil CO<sub>2</sub> emissions.

Indirect fossil CO <sub>2</sub> emissions by source category	1990	1995	2000	2005	2010
kt CO <sub>2</sub>					
<b>1 Energy</b>	<b>55</b>	<b>45</b>	<b>32</b>	<b>24</b>	<b>20</b>
1B Fugitive emissions from fuels	55	45	32	24	20
<b>2 Industrial processes and product use</b>	<b>334</b>	<b>236</b>	<b>170</b>	<b>117</b>	<b>110</b>
2A Mineral industry	0.15	0.12	0.11	0.11	0.12
2B Chemical industry	8.0	6.8	8.4	7.3	8.1
2C Metal industry	3.4	2.4	2.2	1.3	0.93
2D Non-energy products from fuels and solvent use	194	127	92	51	49
2G Other product manufacture and use	126	97	65	57	50
2H Other	2.8	2.0	1.9	1.3	2.3
<b>5 Waste</b>	<b>2.2</b>	<b>1.9</b>	<b>1.8</b>	<b>1.6</b>	<b>1.5</b>
5C Waste incineration and open burning of waste	2.2	1.7	1.7	1.4	1.3
5E Other	0.064	0.10	0.13	0.13	0.13
<b>6 Other</b>	<b>1.3</b>	<b>1.4</b>	<b>1.5</b>	<b>1.4</b>	<b>0.93</b>
6Ad Fire damages	1.3	1.4	1.5	1.4	0.93
<b>Total</b>	<b>392</b>	<b>284</b>	<b>205</b>	<b>144</b>	<b>133</b>

Indirect fossil CO <sub>2</sub> emissions by source category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
kt CO <sub>2</sub>										
<b>1 Energy</b>	<b>15</b>	<b>14</b>	<b>12</b>	<b>12</b>	<b>11</b>	<b>11</b>	<b>9.9</b>	<b>9.5</b>	<b>9.5</b>	<b>9.4</b>
1B Fugitive emissions from fuels	15	14	12	12	11	11	9.9	9.5	9.5	9.4
<b>2 Industrial processes and product use</b>	<b>95</b>	<b>91</b>	<b>93</b>	<b>93</b>	<b>86</b>	<b>91</b>	<b>88</b>	<b>84</b>	<b>83</b>	<b>82</b>
2A Mineral industry	0.10	0.092	0.095	0.094	0.094	0.094	0.089	0.089	0.087	0.080
2B Chemical industry	6.6	7.1	14	14	8.1	13	11	6.8	5.8	5.0
2C Metal industry	0.78	0.67	0.63	0.65	0.64	0.46	0.41	0.43	0.46	0.41
2D Non-energy products from fuels and solvent use	42	39	37	37	36	36	36	36	36	36
2G Other product manufacture and use	43	42	40	40	40	40	40	40	40	40
2H Other	2.0	1.9	1.0	1.0	1.1	0.94	0.88	0.92	0.88	0.80
<b>5 Waste</b>	<b>1.3</b>	<b>1.4</b>	<b>1.3</b>	<b>1.3</b>	<b>1.3</b>	<b>1.3</b>	<b>1.2</b>	<b>1.2</b>	<b>1.2</b>	<b>1.1</b>
5C Waste incineration and open burning of waste	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.0	1.0
5E Other	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
<b>6 Other</b>	<b>0.92</b>	<b>0.84</b>	<b>0.83</b>	<b>0.93</b>	<b>0.84</b>	<b>0.71</b>	<b>0.69</b>	<b>0.77</b>	<b>0.77</b>	<b>0.75</b>
6Ad Fire damages	0.92	0.84	0.83	0.93	0.84	0.71	0.69	0.77	0.77	0.75
<b>Total</b>	<b>112</b>	<b>107</b>	<b>108</b>	<b>107</b>	<b>100</b>	<b>103</b>	<b>100</b>	<b>95</b>	<b>94</b>	<b>94</b>

Figure 9-1 Switzerland's indirect fossil CO<sub>2</sub> emissions.

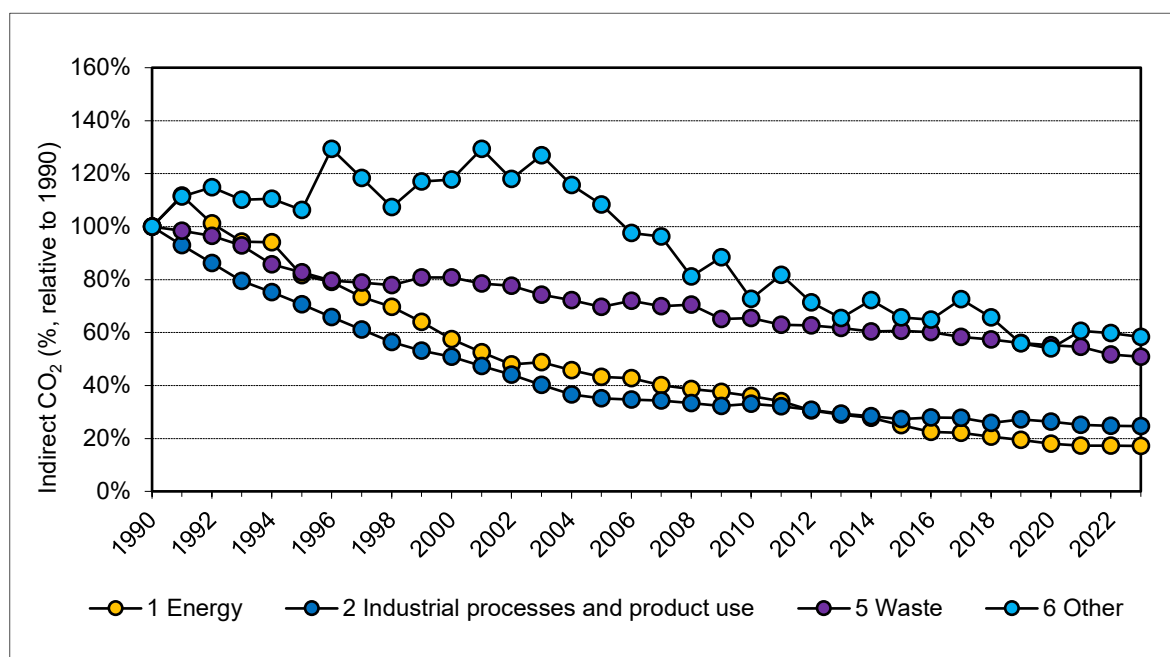


Figure 9-2 Relative trends of the indirect fossil CO<sub>2</sub> emissions by sector. The base year 1990 represents 100 %.

Table 9-2 Indirect N<sub>2</sub>O emissions.

Indirect N <sub>2</sub> O emissions by source category	1990	1995	2000	2005	2010
kt N <sub>2</sub> O					
<b>1 Energy</b>	<b>1.7</b>	<b>1.4</b>	<b>1.3</b>	<b>1.2</b>	<b>1.1</b>
1A Fuel combustion activities	1.7	1.4	1.3	1.2	1.1
1B Fugitive emissions from fuels	0.0025	0.0037	0.0037	0.0034	0.0014
<b>2 Industrial processes and product use</b>	<b>0.018</b>	<b>0.014</b>	<b>0.017</b>	<b>0.016</b>	<b>0.012</b>
2A Mineral industry	0.00021	0.00017	0.00015	0.00016	0.00018
2B Chemical industry	0.0016	0.0014	0.0014	0.0013	0.0015
2C Metal industry	0.0038	0.0023	0.0024	0.0025	0.0026
2G Other product manufacture and use	0.0069	0.0068	0.0080	0.0081	0.0035
2H Other	0.0054	0.0038	0.0051	0.0035	0.0044
<b>5 Waste</b>	<b>0.033</b>	<b>0.030</b>	<b>0.031</b>	<b>0.032</b>	<b>0.032</b>
5A Solid waste disposal	0.020	0.015	0.014	0.014	0.012
5B Biological treatment of solid waste	0.0060	0.0086	0.012	0.012	0.014
5C Waste incineration and open burning of waste	0.0037	0.0028	0.0025	0.0026	0.0027
5D Wastewater handling and discharge	0.0032	0.0034	0.0034	0.0036	0.0039
<b>6 Other</b>	<b>0.00029</b>	<b>0.00029</b>	<b>0.00030</b>	<b>0.00028</b>	<b>0.00021</b>
6Ad Fire damages	0.00029	0.00029	0.00030	0.00028	0.00021
<b>Total</b>	<b>1.7</b>	<b>1.4</b>	<b>1.4</b>	<b>1.3</b>	<b>1.1</b>

Indirect N <sub>2</sub> O emissions by source category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
kt N <sub>2</sub> O										
<b>1 Energy</b>	<b>0.96</b>	<b>0.90</b>	<b>0.87</b>	<b>0.82</b>	<b>0.77</b>	<b>0.73</b>	<b>0.64</b>	<b>0.62</b>	<b>0.58</b>	<b>0.55</b>
1A Fuel combustion activities	0.96	0.90	0.87	0.82	0.77	0.73	0.64	0.62	0.58	0.55
1B Fugitive emissions from fuels	0.0011	0.00063	0.000039	0.000030	0.000031	0.000020	0.000022	0.000017	0.0000075	0.0000073
<b>2 Industrial processes and product use</b>	<b>0.012</b>	<b>0.010</b>	<b>0.0095</b>	<b>0.010</b>	<b>0.0095</b>	<b>0.0091</b>	<b>0.0083</b>	<b>0.0084</b>	<b>0.0081</b>	<b>0.0070</b>
2A Mineral industry	0.00016	0.00015	0.00015	0.00015	0.00015	0.00015	0.00014	0.00014	0.00014	0.00013
2B Chemical industry	0.0012	0.00094	0.0012	0.0013	0.00078	0.00055	0.00050	0.00049	0.00029	0.00021
2C Metal industry	0.0027	0.0027	0.0026	0.0026	0.0027	0.0024	0.0023	0.0026	0.0025	0.0020
2G Other product manufacture and use	0.0025	0.0023	0.0024	0.0026	0.0029	0.0029	0.0028	0.0029	0.0028	0.0025
2H Other	0.0051	0.0040	0.0031	0.0036	0.0030	0.0031	0.0025	0.0022	0.0023	0.0021
<b>5 Waste</b>	<b>0.031</b>	<b>0.031</b>	<b>0.032</b>	<b>0.031</b>	<b>0.031</b>	<b>0.032</b>	<b>0.032</b>	<b>0.032</b>	<b>0.031</b>	<b>0.031</b>
5A Solid waste disposal	0.010	0.0096	0.0092	0.0088	0.0083	0.0078	0.0075	0.0071	0.0067	0.0064
5B Biological treatment of solid waste	0.014	0.014	0.016	0.016	0.016	0.018	0.018	0.019	0.018	0.018
5C Waste incineration and open burning of waste	0.0028	0.0029	0.0026	0.0022	0.0018	0.0018	0.0018	0.0018	0.0017	0.0018
5D Wastewater handling and discharge	0.0041	0.0042	0.0042	0.0043	0.0043	0.0044	0.0044	0.0044	0.0044	0.0045
<b>6 Other</b>	<b>0.00021</b>	<b>0.00019</b>	<b>0.00019</b>	<b>0.00021</b>	<b>0.00019</b>	<b>0.00017</b>	<b>0.00017</b>	<b>0.00018</b>	<b>0.00018</b>	<b>0.00018</b>
6Ad Fire damages	0.00021	0.00019	0.00019	0.00021	0.00019	0.00017	0.00017	0.00018	0.00018	0.00018
<b>Total</b>	<b>1.0</b>	<b>0.94</b>	<b>0.91</b>	<b>0.86</b>	<b>0.81</b>	<b>0.77</b>	<b>0.68</b>	<b>0.66</b>	<b>0.62</b>	<b>0.58</b>



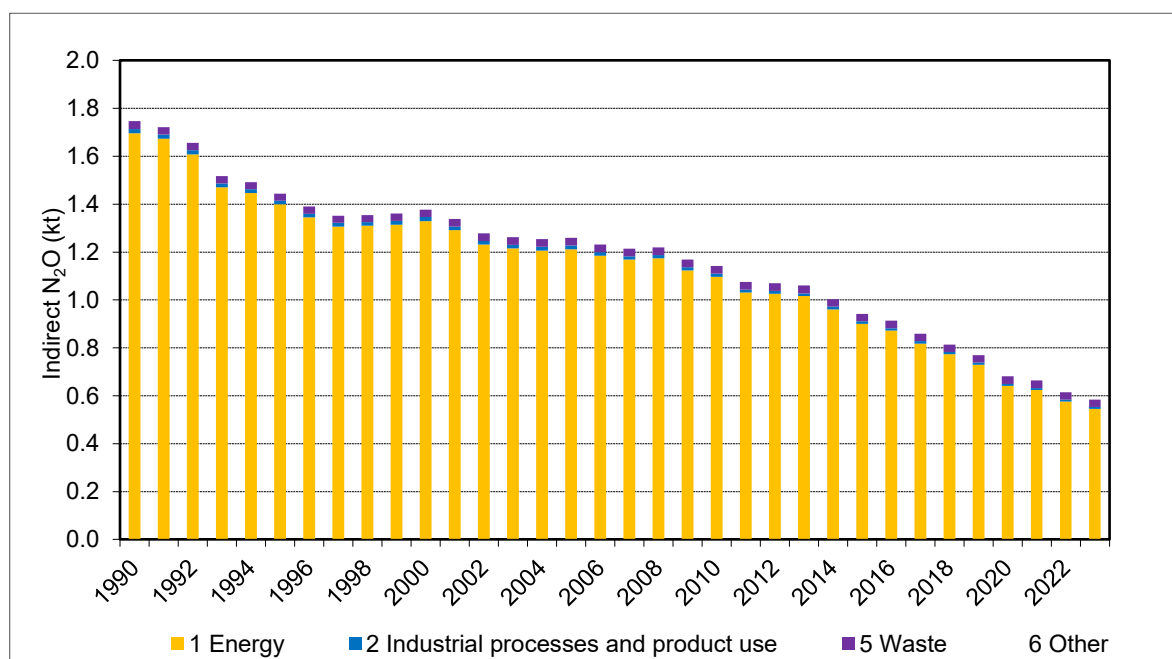


Figure 9-3 Switzerland's indirect N<sub>2</sub>O emissions.

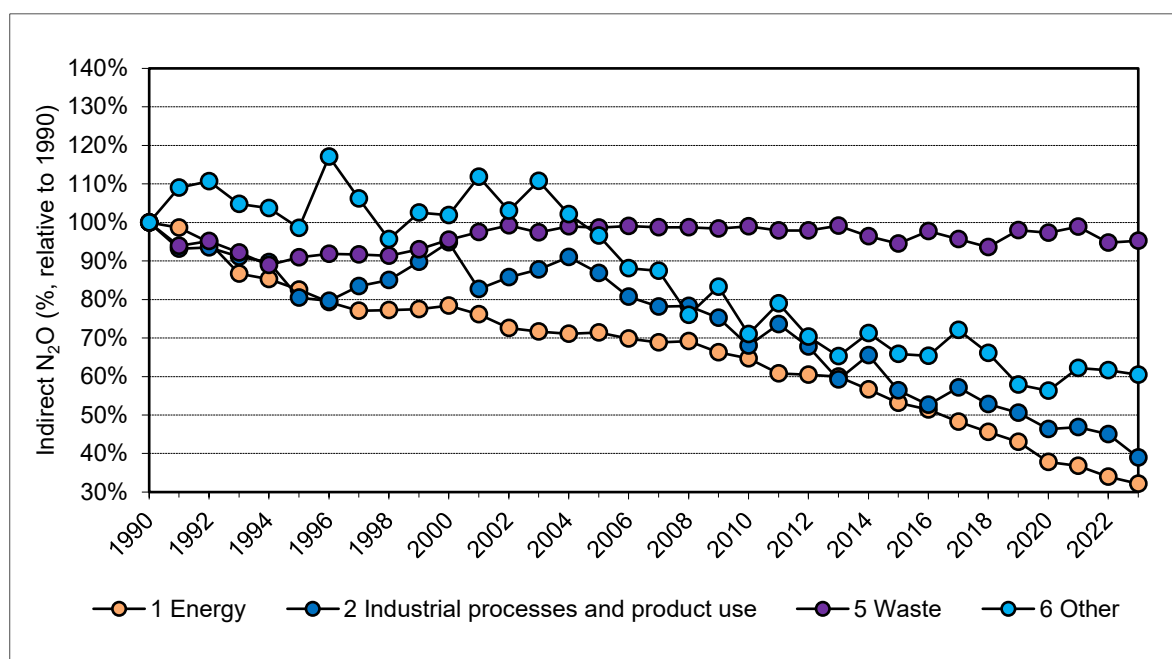


Figure 9-4 Relative trends of the indirect N<sub>2</sub>O emissions by sector. The base year 1990 represents 100 %.

Table 9-3 Switzerland's emissions of the precursor gases CH<sub>4</sub>, CO and NMVOC in the source categories of sector 1 Energy, together with the respective indirect CO<sub>2</sub> emissions. The numbers in parentheses indicate the fractions of precursor gases that are relevant for indirect CO<sub>2</sub>, i.e. the share of fossil emissions of precursor gases not already considered under the direct CO<sub>2</sub> emissions. To derive the indirect CO<sub>2</sub> emissions, the emissions of precursor gases need to be multiplied by the provided fractions as well as by the factors for the stoichiometric conversion of CH<sub>4</sub>, CO and NMVOC to indirect CO<sub>2</sub> as given in the text (chp. 9.2.1). As an illustrative example, an emission of NMVOC indicated as "150 (40.0 %)" leads to indirect CO<sub>2</sub> emissions of 132 kt (150 kt \* 40.0 % \* 0.6 \* 44/12 = 132 kt, with 0.6 corresponding to the carbon content of NMVOC, see formula in chp. 9.2.1).

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	1990	1995	2000	2005	2010
	kt				
<b>1 Energy: CH<sub>4</sub></b>	<b>15.2 (21.8%)</b>	<b>13.1 (27.7%)</b>	<b>11.0 (29.6%)</b>	<b>9.7 (29.4%)</b>	<b>8.8 (34.3%)</b>
1A Fuel combustion	11.9 (0.0%)	9.4 (0.0%)	7.7 (0.0%)	6.8 (0.0%)	5.8 (0.0%)
1B Fugitive emissions from fuels	3.3 (99.6%)	3.6 (99.4%)	3.3 (99.4%)	2.9 (99.4%)	3.0 (99.8%)
<b>1 Energy: CO</b>	<b>796 (0.0%)</b>	<b>517 (0.0%)</b>	<b>403 (0.0%)</b>	<b>308 (0.0%)</b>	<b>242 (0.0%)</b>
1A Fuel combustion	796 (0.0%)	517 (0.0%)	403 (0.0%)	308 (0.0%)	242 (0.0%)
1B Fugitive emissions from fuels	0.0 (0.0%)	0.1 (0.0%)	0.1 (0.0%)	0.1 (0.0%)	0.0 (0.0%)
<b>1 Energy: NMVOC</b>	<b>139 (14.9%)</b>	<b>89.1 (17.8%)</b>	<b>66.7 (15.4%)</b>	<b>45.7 (15.8%)</b>	<b>32.2 (16.1%)</b>
1A Fuel combustion	118 (0.0%)	73.2 (0.0%)	56.4 (0.0%)	38.5 (0.0%)	27.0 (0.0%)
1B Fugitive emissions from fuels	20.8 (99.9%)	15.9 (99.9%)	10.3 (99.8%)	7.2 (99.7%)	5.2 (99.8%)
<b>1 Energy: Total indirect CO<sub>2</sub></b>	<b>55</b>	<b>45</b>	<b>32</b>	<b>24</b>	<b>20</b>
1A Fuel combustion	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	55	45	32	24	20
<b>1 Energy: Indirect CO<sub>2</sub> from CH<sub>4</sub></b>	<b>9.1</b>	<b>10</b>	<b>8.9</b>	<b>7.9</b>	<b>8.3</b>
1A Fuel combustion	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	9.1	10	8.9	7.9	8.3
<b>1 Energy: Indirect CO<sub>2</sub> from CO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
1A Fuel combustion	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	NO	NO	NO	NO	NO
<b>1 Energy: Indirect CO<sub>2</sub> from NMVOC</b>	<b>46</b>	<b>35</b>	<b>23</b>	<b>16</b>	<b>11</b>
1A Fuel combustion	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	46	35	23	16	11

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	kt									
<b>1 Energy: CH<sub>4</sub></b>	<b>6.1 (34.0%)</b>	<b>6.0 (32.2%)</b>	<b>6.0 (30.3%)</b>	<b>5.9 (32.3%)</b>	<b>5.5 (31.4%)</b>	<b>5.3 (30.5%)</b>	<b>5.0 (32.2%)</b>	<b>5.2 (29.9%)</b>	<b>4.7 (32.5%)</b>	<b>4.6 (32.6%)</b>
1A Fuel combustion	4.0 (0.0%)	4.1 (0.0%)	4.2 (0.0%)	4.0 (0.0%)	3.7 (0.0%)	3.7 (0.0%)	3.4 (0.0%)	3.6 (0.0%)	3.2 (0.0%)	3.1 (0.0%)
1B Fugitive emissions from fuels	2.1 (99.7%)	1.9 (99.8%)	1.8 (100.0%)	1.9 (100.0%)	1.7 (100.0%)	1.6 (100.0%)	1.6 (100.0%)	1.6 (100.0%)	1.5 (100.0%)	1.5 (100.0%)
<b>1 Energy: CO</b>	<b>183 (0.0%)</b>	<b>174 (0.0%)</b>	<b>171 (0.0%)</b>	<b>165 (0.0%)</b>	<b>159 (0.0%)</b>	<b>155 (0.0%)</b>	<b>140 (0.0%)</b>	<b>143 (0.0%)</b>	<b>134 (0.0%)</b>	<b>134 (0.0%)</b>
1A Fuel combustion	183 (0.0%)	174 (0.0%)	171 (0.0%)	165 (0.0%)	159 (0.0%)	155 (0.0%)	140 (0.0%)	143 (0.0%)	134 (0.0%)	134 (0.0%)
1B Fugitive emissions from fuels	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
<b>1 Energy: NMVOC</b>	<b>23.5 (18.6%)</b>	<b>21.7 (17.5%)</b>	<b>20.8 (16.0%)</b>	<b>19.9 (15.8%)</b>	<b>19.0 (15.9%)</b>	<b>18.2 (15.5%)</b>	<b>16.4 (14.5%)</b>	<b>16.4 (15.6%)</b>	<b>15.4 (15.6%)</b>	<b>15.5 (15.5%)</b>
1A Fuel combustion	19.1 (0.0%)	17.9 (0.0%)	17.4 (0.0%)	16.8 (0.0%)	15.9 (0.0%)	15.3 (0.0%)	13.9 (0.0%)	14.1 (0.0%)	13.0 (0.0%)	13.1 (0.0%)
1B Fugitive emissions from fuels	4.4 (99.8%)	3.8 (99.8%)	3.3 (99.9%)	3.1 (99.8%)	3.0 (99.8%)	2.8 (99.8%)	2.5 (99.8%)	2.4 (99.8%)	2.4 (99.8%)	2.4 (99.8%)
<b>1 Energy: Total indirect CO<sub>2</sub></b>	<b>15</b>	<b>14</b>	<b>12</b>	<b>12</b>	<b>11</b>	<b>11</b>	<b>10</b>	<b>9.5</b>	<b>9.5</b>	<b>9.4</b>
1A Fuel combustion	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	15	14	12	12	11	11	10	9.5	9.5	9.4
<b>1 Energy: Indirect CO<sub>2</sub> from CH<sub>4</sub></b>	<b>5.7</b>	<b>5.3</b>	<b>5.0</b>	<b>5.3</b>	<b>4.7</b>	<b>4.5</b>	<b>4.4</b>	<b>4.3</b>	<b>4.2</b>	<b>4.1</b>
1A Fuel combustion	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	5.7	5.3	5.0	5.3	4.7	4.5	4.4	4.3	4.2	4.1
<b>1 Energy: Indirect CO<sub>2</sub> from CO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
1A Fuel combustion	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>1 Energy: Indirect CO<sub>2</sub> from NMVOC</b>	<b>10</b>	<b>8.4</b>	<b>7.3</b>	<b>6.8</b>	<b>6.6</b>	<b>6.2</b>	<b>5.5</b>	<b>5.2</b>	<b>5.3</b>	<b>5.3</b>
1A Fuel combustion	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B Fugitive emissions from fuels	10	8.4	7.3	6.8	6.6	6.2	5.5	5.2	5.3	5.3

Table 9-4 Switzerland's emissions of the precursor gases CH<sub>4</sub>, CO and NMVOC in the source categories of sector 2 Industrial processes and product use, together with the respective indirect CO<sub>2</sub> emissions. The numbers in parentheses indicate the fractions of precursor gases that are relevant for indirect CO<sub>2</sub>, i.e. the share of fossil emissions of precursor gases not already considered under the direct CO<sub>2</sub> emissions. To derive the indirect CO<sub>2</sub> emissions, the emissions of precursor gases need to be multiplied by the provided fractions as well as by the factors for the stoichiometric conversion of CH<sub>4</sub>, CO and NMVOC to indirect CO<sub>2</sub> as given in the text (chp. 9.2.1). As an illustrative example, an emission of NMVOC indicated as "150 (40.0 %)" leads to indirect CO<sub>2</sub> emissions of 132 kt (150 kt \* 40.0 % \* 0.6 \* 44/12 = 132 kt, with 0.6 corresponding to the carbon content of NMVOC, see formula in chp. 9.2.1).

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	1990	1995	2000	2005	2010
	kt				
<b>2 IPU: CH<sub>4</sub></b>	<b>0.1 (100.0%)</b>	<b>0.2 (100.0%)</b>	<b>0.2 (100.0%)</b>	<b>0.3 (100.0%)</b>	<b>0.3 (100.0%)</b>
2B Chemical industry	0.1 (100.0%)	0.2 (100.0%)	0.2 (100.0%)	0.3 (100.0%)	0.3 (100.0%)
<b>2 IPU: CO</b>	<b>11.1 (50.2%)</b>	<b>7.1 (66.2%)</b>	<b>9.1 (66.9%)</b>	<b>8.1 (58.8%)</b>	<b>7.2 (78.4%)</b>
2A Mineral industry	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
2B Chemical industry	4.0 (100.0%)	3.7 (100.0%)	4.9 (100.0%)	4.2 (100.0%)	4.6 (100.0%)
2C Metal industry	5.3 (13.3%)	2.0 (26.7%)	2.6 (19.0%)	2.9 (9.8%)	1.1 (20.7%)
2D Non-energy products from fuels and solvent use	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
2G Other product manufacture and use	0.9 (0.7%)	0.9 (0.9%)	0.9 (1.3%)	0.7 (1.4%)	0.7 (1.8%)
2H Other	0.9 (94.6%)	0.4 (91.4%)	0.6 (96.8%)	0.3 (94.1%)	0.8 (97.8%)
<b>2 IPU: NMVOC</b>	<b>149 (98.9%)</b>	<b>105 (98.5%)</b>	<b>74.1 (97.9%)</b>	<b>51.2 (97.0%)</b>	<b>47.4 (96.6%)</b>
2A Mineral industry	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
2B Chemical industry	0.6 (96.5%)	0.2 (90.7%)	0.0 (30.9%)	0.0 (21.4%)	0.0 (32.9%)
2C Metal industry	1.1 (92.0%)	0.8 (92.7%)	0.7 (89.9%)	0.5 (82.1%)	0.3 (75.6%)
2D Non-energy products from fuels and solvent use	88.2 (100.0%)	57.8 (100.0%)	42.0 (100.0%)	23.0 (100.0%)	22.3 (100.0%)
2G Other product manufacture and use	57.1 (99.9%)	44.4 (99.8%)	29.4 (99.7%)	25.9 (99.8%)	22.8 (99.7%)
2H Other	2.1 (33.5%)	2.0 (31.0%)	1.8 (24.8%)	1.8 (23.1%)	1.9 (26.0%)
<b>2 IPU: Total indirect CO<sub>2</sub></b>	<b>334</b>	<b>236</b>	<b>170</b>	<b>117</b>	<b>110</b>
2A Mineral industry	0.15	0.12	0.11	0.11	0.12
2B Chemical industry	8.0	6.8	8.4	7.3	8.1
2C Metal industry	3.4	2.4	2.2	1.3	0.93
2D Non-energy products from fuels and solvent use	194	127	92	51	49
2G Other product manufacture and use	126	97	65	57	50
2H Other	2.8	2.0	1.9	1.3	2.3
<b>2 IPU: Indirect CO<sub>2</sub> from CH<sub>4</sub></b>	<b>0.39</b>	<b>0.65</b>	<b>0.57</b>	<b>0.69</b>	<b>0.76</b>
2B Chemical industry	0.39	0.65	0.57	0.69	0.76
<b>2 IPU: Indirect CO<sub>2</sub> from CO</b>	<b>8.8</b>	<b>7.4</b>	<b>9.5</b>	<b>7.5</b>	<b>8.9</b>
2A Mineral industry	0.044	0.037	0.034	0.038	0.039
2B Chemical industry	6.3	5.8	7.8	6.6	7.3
2C Metal industry	1.1	0.85	0.79	0.44	0.35
2D Non-energy products from fuels and solvent use	0.00075	0.00067	0.00062	0.00045	0.00061
2G Other product manufacture and use	0.010	0.012	0.018	0.016	0.020
2H Other	1.3	0.64	0.91	0.39	1.2
<b>2 IPU: Indirect CO<sub>2</sub> from NMVOC</b>	<b>325</b>	<b>228</b>	<b>160</b>	<b>109</b>	<b>101</b>
2A Mineral industry	0.10	0.081	0.071	0.077	0.081
2B Chemical industry	1.3	0.35	0.017	0.013	0.027
2C Metal industry	2.3	1.6	1.4	0.82	0.58
2D Non-energy products from fuels and solvent use	194	127	92	51	49
2G Other product manufacture and use	125	97	65	57	50
2H Other	1.6	1.4	1.0	0.91	1.1

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	kt									
<b>2 IPU: CH<sub>4</sub></b>	<b>0.2 (100.0%)</b>	<b>0.2 (100.0%)</b>	<b>0.3 (100.0%)</b>	<b>0.3 (100.0%)</b>	<b>0.3 (100.0%)</b>	<b>0.3 (100.0%)</b>	<b>0.3 (100.0%)</b>	<b>0.2 (100.0%)</b>	<b>0.3 (100.0%)</b>	<b>0.2 (100.0%)</b>
2B Chemical industry	0.2 (100.0%)	0.2 (100.0%)	0.3 (100.0%)	0.3 (100.0%)	0.3 (100.0%)	0.3 (100.0%)	0.3 (100.0%)	0.2 (100.0%)	0.3 (100.0%)	0.2 (100.0%)
<b>2 IPU: CO</b>	<b>6.2 (75.4%)</b>	<b>6.5 (76.9%)</b>	<b>10.1 (85.5%)</b>	<b>10.1 (85.1%)</b>	<b>6.5 (77.2%)</b>	<b>9.5 (85.7%)</b>	<b>8.4 (83.5%)</b>	<b>5.7 (73.7%)</b>	<b>4.9 (71.7%)</b>	<b>4.4 (72.8%)</b>
2A Mineral industry	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
2B Chemical industry	3.8 (100.0%)	4.1 (100.0%)	8.3 (100.0%)	8.2 (100.0%)	4.6 (100.0%)	7.8 (100.0%)	6.7 (100.0%)	3.9 (100.0%)	3.2 (100.0%)	2.9 (100.0%)
2C Metal industry	1.1 (16.5%)	1.1 (14.6%)	1.0 (14.3%)	1.0 (14.3%)	1.0 (13.8%)	0.9 (11.4%)	0.9 (9.9%)	1.0 (9.2%)	0.9 (10.4%)	0.7 (12.2%)
2D Non-energy products from fuels and solvent use	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
2G Other product manufacture and use	0.6 (2.2%)	0.6 (2.1%)	0.6 (1.5%)	0.6 (2.1%)	0.6 (2.3%)	0.6 (1.3%)	0.6 (1.3%)	0.6 (2.0%)	0.6 (2.5%)	0.5 (1.1%)
2H Other	0.7 (97.5%)	0.7 (97.5%)	0.2 (92.5%)	0.2 (93.1%)	0.3 (93.7%)	0.2 (92.6%)	0.2 (91.7%)	0.2 (92.3%)	0.2 (92.3%)	0.2 (92.1%)
<b>2 IPU: NMVOC</b>	<b>41.1 (96.2%)</b>	<b>39.2 (96.0%)</b>	<b>37.3 (95.9%)</b>	<b>37.2 (95.9%)</b>	<b>36.8 (95.8%)</b>	<b>36.6 (95.8%)</b>	<b>36.3 (95.8%)</b>	<b>36.4 (95.8%)</b>	<b>36.4 (95.8%)</b>	<b>36.4 (95.8%)</b>
2A Mineral industry	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
2B Chemical industry	0.0 (22.6%)	0.0 (12.4%)	0.0 (5.6%)	0.0 (8.7%)	0.0 (10.0%)	0.0 (13.2%)	0.0 (15.3%)	0.0 (10.4%)	0.0 (11.7%)	0.0 (12.7%)
2C Metal industry	0.3 (70.8%)	0.3 (68.3%)	0.3 (67.8%)	0.3 (68.0%)	0.3 (67.3%)	0.2 (63.7%)	0.2 (61.1%)	0.2 (59.3%)	0.2 (62.1%)	0.2 (65.2%)
2D Non-energy products from fuels and solvent use	19.2 (100.0%)	17.9 (100.0%)	16.8 (100.0%)	16.9 (100.0%)	16.6 (100.0%)	16.5 (100.0%)	16.1 (100.0%)	16.2 (100.0%)	16.2 (100.0%)	16.2 (100.0%)
2G Other product manufacture and use	19.7 (99.7%)	19.1 (99.7%)	18.4 (99.7%)	18.3 (99.7%)	18.3 (99.7%)	18.2 (99.7%)	18.2 (99.7%)	18.3 (99.7%)	18.3 (99.7%)	18.4 (99.8%)
2H Other	1.8 (22.9%)	1.8 (22.9%)	1.7 (18.6%)	1.7 (18.7%)	1.7 (18.6%)	1.7 (16.6%)	1.6 (15.7%)	1.7 (17.0%)	1.7 (15.5%)	1.6 (13.4%)
<b>2 IPU: Total indirect CO<sub>2</sub></b>	<b>95</b>	<b>91</b>	<b>93</b>	<b>93</b>	<b>86</b>	<b>91</b>	<b>88</b>	<b>84</b>	<b>83</b>	<b>82</b>
2A Mineral industry	0.10	0.092	0.095	0.094	0.094	0.094	0.089	0.089	0.087	0.080
2B Chemical industry	6.6	7.1	14	14	8.1	13	11	6.8	5.8	5.0
2C Metal industry	0.78	0.67	0.63	0.65	0.64	0.46	0.41	0.43	0.46	0.41
2D Non-energy products from fuels and solvent use	42	39	37	37	36	36	36	36	36	36
2G Other product manufacture and use	43	42	40	40	40	40	40	40	40	40
2H Other	2.0	1.9	1.0	1.0	1.1	0.9	0.88	0.92	0.88	0.80
<b>2 IPU: Indirect CO<sub>2</sub> from CH<sub>4</sub></b>	<b>0.63</b>	<b>0.61</b>	<b>0.77</b>	<b>0.78</b>	<b>0.83</b>	<b>0.76</b>	<b>0.71</b>	<b>0.67</b>	<b>0.75</b>	<b>0.50</b>
2B Chemical industry	0.63	0.61	0.77	0.78	0.83	0.76	0.71	0.67	0.75	0.50
<b>2 IPU: Indirect CO<sub>2</sub> from CO</b>	<b>7.3</b>	<b>7.8</b>	<b>14</b>	<b>13</b>	<b>7.9</b>	<b>13</b>	<b>11</b>	<b>6.6</b>	<b>5.6</b>	<b>5.0</b>
2A Mineral industry	0.029	0.026	0.027	0.027	0.027	0.027	0.025	0.024	0.023	0.022
2B Chemical industry	6.0	6.5	13	13	7.2	12	11	6.1	5.0	4.5
2C Metal industry	0.29	0.24	0.23	0.23	0.23	0.16	0.14	0.14	0.15	0.14
2D Non-energy products from fuels and solvent use	0.00070	0.00070	0.00071	0.00071	0.00071	0.00071	0.00071	0.00071	0.00071	0.00071
2G Other product manufacture and use	0.021	0.019	0.014	0.020	0.021	0.012	0.012	0.018	0.022	0.0093
2H Other	1.0	1.0	0.32	0.35	0.39	0.33	0.31	0.30	0.32	0.31
<b>2 IPU: Indirect CO<sub>2</sub> from NMVOC</b>	<b>87</b>	<b>83</b>	<b>79</b>	<b>79</b>	<b>78</b>	<b>77</b>	<b>76</b>	<b>77</b>	<b>77</b>	<b>77</b>
2A Mineral industry	0.073	0.066	0.068	0.068	0.067	0.067	0.064	0.065	0.064	0.058
2B Chemical industry	0.011	0.0056	0.0019	0.0024	0.0033	0.0046	0.0051	0.0036	0.0040	0.0042
2C Metal industry	0.49	0.43	0.40	0.42	0.41	0.31	0.27	0.29	0.30	0.27
2D Non-energy products from fuels and solvent use	42	39	37	37	36	36	36	36	36	36
2G Other product manufacture and use	43	42	40	40	40	40	40	40	40	40
2H Other	0.92	0.91	0.69	0.69	0.69	0.61	0.57	0.63	0.56	0.48

Table 9-5 Switzerland's emissions of the precursor gases CH<sub>4</sub>, CO and NMVOC in the source categories of sector 5 Waste, together with the respective indirect CO<sub>2</sub> emissions. The numbers in parentheses indicate the fractions of precursor gases that are relevant for indirect CO<sub>2</sub>, i.e. the share of fossil emissions of precursor gases not already considered under the direct CO<sub>2</sub> emissions. To derive the indirect CO<sub>2</sub> emissions, the emissions of precursor gases need to be multiplied by the provided fractions as well as by the factors for the stoichiometric conversion of CH<sub>4</sub>, CO and NMVOC to indirect CO<sub>2</sub> as given in the text (chp. 9.2.1). As an illustrative example, an emission of NMVOC indicated as "150 (40.0 %)" leads to indirect CO<sub>2</sub> emissions of 132 kt (150 kt \* 40.0 % \* 0.6 \* 44/12 = 132 kt, with 0.6 corresponding to the carbon content of NMVOC, see formula in chp. 9.2.1).

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	1990	1995	2000	2005	2010
	kt				
<b>5 Waste: CH<sub>4</sub></b>	<b>38.7 (0.2%)</b>	<b>30.7 (0.3%)</b>	<b>26.6 (0.3%)</b>	<b>28.7 (0.2%)</b>	<b>25.5 (0.2%)</b>
5A Solid waste disposal	30.8 (0.0%)	23.1 (0.0%)	21.0 (0.0%)	21.2 (0.0%)	17.6 (0.0%)
5B Biological treatment of solid waste	0.5 (0.0%)	0.6 (0.0%)	0.8 (0.0%)	0.8 (0.0%)	0.8 (0.0%)
5C Incineration and open burning of waste	0.3 (30.2%)	0.3 (29.1%)	0.3 (29.8%)	0.2 (28.2%)	0.2 (27.8%)
5D Waste water treatment and discharge	7.1 (0.0%)	6.7 (0.0%)	6.5 (0.0%)	6.5 (0.0%)	6.9 (0.0%)
<b>5 Waste: CO</b>	<b>2.6 (32.8%)</b>	<b>2.2 (30.2%)</b>	<b>2.1 (30.5%)</b>	<b>1.8 (29.7%)</b>	<b>1.7 (29.4%)</b>
5A Solid waste disposal	0.0 (0.0%)	0.1 (0.0%)	0.1 (0.0%)	0.1 (0.0%)	0.0 (0.0%)
5B Biological treatment of solid waste	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
5C Incineration and open burning of waste	2.5 (33.4%)	2.1 (31.6%)	2.0 (32.0%)	1.8 (30.6%)	1.7 (30.1%)
5D Waste water treatment and discharge	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
5E Other	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
<b>5 Waste: NMVOC</b>	<b>1.1 (25.7%)</b>	<b>1.0 (25.9%)</b>	<b>1.0 (25.4%)</b>	<b>1.0 (22.7%)</b>	<b>1.2 (18.8%)</b>
5A Solid waste disposal	0.4 (0.0%)	0.3 (0.0%)	0.3 (0.0%)	0.3 (0.0%)	0.2 (0.0%)
5B Biological treatment of solid waste	0.2 (0.0%)	0.2 (0.0%)	0.3 (0.0%)	0.3 (0.0%)	0.5 (0.0%)
5C Incineration and open burning of waste	0.6 (48.0%)	0.4 (47.9%)	0.4 (48.5%)	0.4 (47.2%)	0.4 (45.2%)
5D Waste water treatment and discharge	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
5E Other	0.0 (100.0%)	0.0 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)
<b>5 Waste: Total indirect CO<sub>2</sub></b>	<b>2.2</b>	<b>1.9</b>	<b>1.8</b>	<b>1.6</b>	<b>1.5</b>
5A Solid waste disposal	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	2.2	1.7	1.7	1.4	1.3
5D Waste water treatment and discharge	NO	NO	NO	NO	NO
5E Other	0.064	0.10	0.13	0.13	0.13
<b>5 Waste: Indirect CO<sub>2</sub> from CH<sub>4</sub></b>	<b>0.26</b>	<b>0.22</b>	<b>0.21</b>	<b>0.18</b>	<b>0.17</b>
5A Solid waste disposal	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	0.26	0.22	0.21	0.18	0.17
5D Waste water treatment and discharge	NO	NO	NO	NO	NO
<b>5 Waste: Indirect CO<sub>2</sub> from CO</b>	<b>1.3</b>	<b>1.1</b>	<b>1.0</b>	<b>0.86</b>	<b>0.80</b>
5A Solid waste disposal	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	1.3	1.1	1.0	0.86	0.80
5D Waste water treatment and discharge	NO	NO	NO	NO	NO
5E Other	0.0022	0.0024	0.0024	0.0024	0.0024
<b>5 Waste: Indirect CO<sub>2</sub> from NMVOC</b>	<b>0.64</b>	<b>0.57</b>	<b>0.58</b>	<b>0.52</b>	<b>0.49</b>
5A Solid waste disposal	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	0.58	0.47	0.45	0.38	0.36
5D Waste water treatment and discharge	NO	NO	NO	NO	NO
5E Other	0.062	0.099	0.13	0.13	0.13

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	kt									
<b>5 Waste: CH<sub>4</sub></b>	<b>23.1 (0.2%)</b>	<b>22.6 (0.2%)</b>	<b>22.2 (0.3%)</b>	<b>21.7 (0.2%)</b>	<b>21.1 (0.3%)</b>	<b>20.6 (0.3%)</b>	<b>20.1 (0.3%)</b>	<b>19.6 (0.3%)</b>	<b>19.2 (0.2%)</b>	<b>18.9 (0.2%)</b>
5A Solid waste disposal	14.7 (0.0%)	14.1 (0.0%)	13.4 (0.0%)	12.8 (0.0%)	12.1 (0.0%)	11.4 (0.0%)	10.9 (0.0%)	10.3 (0.0%)	9.8 (0.0%)	9.3 (0.0%)
5B Biological treatment of solid waste	0.9 (0.0%)	0.9 (0.0%)	1.0 (0.0%)	1.0 (0.0%)	1.0 (0.0%)	1.1 (0.0%)	1.1 (0.0%)	1.1 (0.0%)	1.1 (0.0%)	1.1 (0.0%)
5C Incineration and open burning of waste	0.2 (27.0%)	0.2 (27.1%)	0.2 (27.2%)	0.2 (26.9%)	0.2 (26.9%)	0.2 (26.7%)	0.2 (26.7%)	0.2 (26.7%)	0.2 (26.0%)	0.2 (25.6%)
5D Waste water treatment and discharge	7.3 (0.0%)	7.4 (0.0%)	7.6 (0.0%)	7.7 (0.0%)	7.8 (0.0%)	7.9 (0.0%)	7.9 (0.0%)	8.0 (0.0%)	8.1 (0.0%)	8.2 (0.0%)
<b>5 Waste: CO</b>	<b>1.6 (29.0%)</b>	<b>1.6 (29.3%)</b>	<b>1.6 (29.4%)</b>	<b>1.5 (29.2%)</b>	<b>1.5 (29.3%)</b>	<b>1.5 (29.1%)</b>	<b>1.5 (29.1%)</b>	<b>1.4 (29.1%)</b>	<b>1.4 (28.5%)</b>	<b>1.4 (28.2%)</b>
5A Solid waste disposal	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
5B Biological treatment of solid waste	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
5C Incineration and open burning of waste	1.6 (29.5%)	1.6 (29.8%)	1.6 (29.9%)	1.5 (29.7%)	1.5 (29.8%)	1.4 (29.7%)	1.4 (29.7%)	1.4 (29.6%)	1.4 (29.0%)	1.3 (28.7%)
5D Waste water treatment and discharge	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
5E Other	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)	0.0 (100.0%)
<b>5 Waste: NMVOC</b>	<b>1.4 (15.3%)</b>	<b>1.4 (14.8%)</b>	<b>1.5 (13.8%)</b>	<b>1.5 (13.3%)</b>	<b>1.6 (12.8%)</b>	<b>1.7 (11.8%)</b>	<b>1.7 (11.3%)</b>	<b>1.8 (10.9%)</b>	<b>1.7 (10.6%)</b>	<b>1.8 (10.2%)</b>
5A Solid waste disposal	0.2 (0.0%)	0.2 (0.0%)	0.2 (0.0%)	0.2 (0.0%)	0.2 (0.0%)	0.2 (0.0%)	0.1 (0.0%)	0.1 (0.0%)	0.1 (0.0%)	0.1 (0.0%)
5B Biological treatment of solid waste	0.8 (0.0%)	0.8 (0.0%)	0.9 (0.0%)	1.0 (0.0%)	1.0 (0.0%)	1.1 (0.0%)	1.2 (0.0%)	1.3 (0.0%)	1.3 (0.0%)	1.3 (0.0%)
5C Incineration and open burning of waste	0.3 (44.4%)	0.3 (44.5%)	0.3 (44.3%)	0.3 (43.9%)	0.3 (43.8%)	0.3 (43.8%)	0.3 (44.0%)	0.3 (44.1%)	0.3 (44.0%)	0.3 (43.6%)
5D Waste water treatment and discharge	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
5E Other	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)	0.1 (100.0%)
<b>5 Waste: Total indirect CO<sub>2</sub></b>	<b>1.3</b>	<b>1.4</b>	<b>1.3</b>	<b>1.3</b>	<b>1.3</b>	<b>1.3</b>	<b>1.2</b>	<b>1.2</b>	<b>1.2</b>	<b>1.1</b>
5A Solid waste disposal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.0	1.0
5D Waste water treatment and discharge	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5E Other	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
<b>5 Waste: Indirect CO<sub>2</sub> from CH<sub>4</sub></b>	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>	<b>0.14</b>	<b>0.14</b>	<b>0.14</b>	<b>0.13</b>	<b>0.13</b>
5A Solid waste disposal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13
5D Waste water treatment and discharge	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>5 Waste: Indirect CO<sub>2</sub> from CO</b>	<b>0.74</b>	<b>0.74</b>	<b>0.73</b>	<b>0.71</b>	<b>0.69</b>	<b>0.68</b>	<b>0.67</b>	<b>0.66</b>	<b>0.62</b>	<b>0.61</b>
5A Solid waste disposal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	0.73	0.74	0.73	0.71	0.69	0.67	0.66	0.66	0.62	0.61
5D Waste water treatment and discharge	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5E Other	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
<b>5 Waste: Indirect CO<sub>2</sub> from NMVOC</b>	<b>0.46</b>	<b>0.46</b>	<b>0.46</b>	<b>0.45</b>	<b>0.44</b>	<b>0.43</b>	<b>0.43</b>	<b>0.43</b>	<b>0.41</b>	<b>0.40</b>
5A Solid waste disposal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5B Biological treatment of solid waste	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5C Incineration and open burning of waste	0.33	0.33	0.33	0.32	0.31	0.30	0.30	0.29	0.28	0.27
5D Waste water treatment and discharge	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5E Other	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Table 9-6 Switzerland's emissions of the precursor gases CH<sub>4</sub>, CO and NMVOC in the source categories of sector 6 Other, together with the respective indirect CO<sub>2</sub> emissions. The numbers in parentheses indicate the fractions of precursor gases that are relevant for indirect CO<sub>2</sub>, i.e. the share of fossil emissions of precursor gases not already considered under the direct CO<sub>2</sub> emissions. To derive the indirect CO<sub>2</sub> emissions, the emissions of precursor gases need to be multiplied by the provided fractions as well as by the factors for the stoichiometric conversion of CH<sub>4</sub>, CO and NMVOC to indirect CO<sub>2</sub> as given in the text (chp. 9.2.1). As an illustrative example, an emission of NMVOC indicated as "150 (40.0 %)" leads to indirect CO<sub>2</sub> emissions of 132 kt (150 kt \* 40.0 % \* 0.6 \* 44/12 = 132 kt, with 0.6 corresponding to the carbon content of NMVOC, see formula in chp. 9.2.1).

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	1990	1995	2000	2005	2010
	kt				
6 Other: CH <sub>4</sub>	0.0 (70.6%)	0.0 (76.3%)	0.0 (81.9%)	0.0 (82.3%)	0.0 (83.5%)
6 Other: CO	0.9 (68.9%)	0.9 (74.8%)	0.9 (80.6%)	0.9 (80.8%)	0.6 (81.2%)
6 Other: NMVOC	0.1 (68.2%)	0.1 (74.2%)	0.1 (80.2%)	0.1 (80.2%)	0.1 (80.3%)
6 Other: Total indirect CO <sub>2</sub>	1.3	1.4	1.5	1.4	0.93
6 Other: Indirect CO <sub>2</sub> from CH <sub>4</sub>	0.057	0.061	0.068	0.063	0.045
6 Other: Indirect CO <sub>2</sub> from CO	1.0	1.1	1.2	1.1	0.73
6 Other: Indirect CO <sub>2</sub> from NMVOC	0.22	0.23	0.26	0.23	0.15

Emissions of NMVOC, CO and CH <sub>4</sub> as well as indirect CO <sub>2</sub>	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	kt									
6 Other: CH <sub>4</sub>	0.0 (83.7%)	0.0 (84.2%)	0.0 (84.2%)	0.0 (83.9%)	0.0 (84.3%)	0.0 (84.9%)	0.0 (85.1%)	0.0 (84.7%)	0.0 (84.8%)	0.0 (85.0%)
6 Other: CO	0.6 (81.3%)	0.5 (81.5%)	0.5 (81.5%)	0.6 (81.4%)	0.5 (81.5%)	0.4 (81.8%)	0.4 (81.9%)	0.5 (81.7%)	0.5 (81.8%)	0.5 (81.9%)
6 Other: NMVOC	0.1 (80.3%)	0.1 (80.4%)	0.1 (80.4%)	0.1 (80.4%)	0.1 (80.4%)	0.1 (80.5%)	0.1 (80.5%)	0.1 (80.5%)	0.1 (80.5%)	0.1 (80.5%)
6 Other: Total indirect CO <sub>2</sub>	0.92	0.84	0.83	0.93	0.84	0.71	0.69	0.77	0.77	0.75
6 Other: Indirect CO <sub>2</sub> from CH <sub>4</sub>	0.045	0.042	0.041	0.046	0.042	0.037	0.036	0.040	0.039	0.039
6 Other: Indirect CO <sub>2</sub> from CO	0.73	0.66	0.65	0.73	0.66	0.56	0.54	0.61	0.60	0.59
6 Other: Indirect CO <sub>2</sub> from NMVOC	0.15	0.14	0.14	0.15	0.14	0.12	0.11	0.13	0.12	0.12

## 9.2. Indirect CO<sub>2</sub> and N<sub>2</sub>O emissions from all source categories of the GHG inventory

Table 9-7 Key categories of indirect CO<sub>2</sub> emissions. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Code	IPCC category	Gas	Identification criteria
2.D	Non-energy products from fuels and solvent use	Ind. CO <sub>2</sub> (NMVOC)	T1

As described in chp. 9.1, indirect CO<sub>2</sub> emissions cover all emissions that result from the atmospheric oxidation of CH<sub>4</sub>, CO and NMVOC, while indirect N<sub>2</sub>O emissions reflect emissions that are induced by the deposition of NO<sub>x</sub> and NH<sub>3</sub>. Accordingly, a large number of source categories – contributing to the emissions of precursor gases CH<sub>4</sub>, CO, NMVOC, NO<sub>x</sub> and NH<sub>3</sub> – are involved (see Table 9-1 and Table 9-2 for an overview as well as Table 9-3 to Table 9-6 for the full details). Only the contribution of one source category was identified as key category of indirect CO<sub>2</sub> emissions as shown in Table 9-7.

### 9.2.1. Methodological issues to derive indirect CO<sub>2</sub> emissions

Indirect CO<sub>2</sub> emissions resulting from the atmospheric oxidation of CH<sub>4</sub> and CO are calculated based on the stoichiometric conversion (molecular weight of CO<sub>2</sub> divided by the molecular weight of CH<sub>4</sub> or CO, respectively). Indirect CO<sub>2</sub> emissions from the atmospheric oxidation of NMVOC are also calculated based on the stoichiometric conversion (carbon content fraction multiplied by the molecular weight of CO<sub>2</sub> divided by the molecular weight of carbon). Thereby, a constant carbon content of NMVOC of 60 % is assumed, based on the IPCC Guidelines (IPCC 2006). Thus, indirect CO<sub>2</sub> emissions (Em) result from the following equations:

- $Em_{CO_2, \text{ indirect from CH}_4} = Em_{CH_4, \text{ fossil}} * 44/16$
- $Em_{CO_2, \text{ indirect from CO}} = Em_{CO, \text{ fossil}} * 44/28$
- $Em_{CO_2, \text{ indirect from NMVOC}} = Em_{NMVOC, \text{ fossil}} * 0.6 * 44/12$

#### *Activity data for the calculation of indirect CO<sub>2</sub> emissions*

Activity data to calculate indirect CO<sub>2</sub> emissions consists of CH<sub>4</sub>, CO and NMVOC emissions as reported in each individual sector and source category, carefully excluding CH<sub>4</sub>, CO and NMVOC emissions of biogenic origin and emissions already included as direct CO<sub>2</sub> emissions (e.g. when using an oxidation factor of 100 %). For the different sectors and source categories, the situation is as follows:

**1A Fuel combustion activities:** Since according to the IPCC Guidelines (IPCC 2006) emission factors in source category 1A Fuel combustion activities are based on the assumption of complete oxidation (100 %), CO<sub>2</sub> resulting from the atmospheric oxidation of CH<sub>4</sub>, CO and NMVOC emitted from this source category is already accounted for in the corresponding emission factors for direct CO<sub>2</sub> emissions. The respective emissions are thus

implicitly reported as direct CO<sub>2</sub> emissions in 1A Fuel combustion activities and no indirect CO<sub>2</sub> emissions from 1A Fuel combustion activities are reported (see chp. 3.2.4.4.1).

**1B Fugitive emissions from fuels:** CO<sub>2</sub> resulting from the atmospheric oxidation of CH<sub>4</sub>, CO and NMVOC emitted from source category 1B Fugitive emissions from fuels is reported as indirect CO<sub>2</sub> emissions unless it is already accounted for implicitly as direct CO<sub>2</sub> emissions in 1B (chp. 3.3). For 1B, Table 9-8 illustrates in which processes CH<sub>4</sub>, CO and NMVOC emissions occur, and whether the related CO<sub>2</sub> emissions are reported as indirect CO<sub>2</sub> emissions or implicitly as direct CO<sub>2</sub> emissions. In summary, all CO<sub>2</sub> resulting from the atmospheric oxidation of CO emitted from 1B is implicitly included in 1B as direct CO<sub>2</sub> and is therefore not reported as indirect CO<sub>2</sub>. CO<sub>2</sub> resulting from the atmospheric oxidation of CH<sub>4</sub> and NMVOC emitted from 1B is reported as indirect CO<sub>2</sub>, except for source category 1B2c Venting and flaring, where an oxidation factor of 100 % is applied to calculate direct CO<sub>2</sub> emissions.

Table 9-8 Sources of indirect CO<sub>2</sub> emissions from source category 1B Fugitive emissions from fuels. Only relevant source categories are shown. Blue cells mark processes for which CO<sub>2</sub> emissions resulting from the atmospheric oxidation of CH<sub>4</sub>, CO or NMVOC emissions are not accounted for as indirect CO<sub>2</sub> emissions because they are already considered under the direct CO<sub>2</sub> emissions.

1B Fugitive emissions from fuels		CO <sub>2</sub> resulting from CH <sub>4</sub>	CO <sub>2</sub> resulting from CO	CO <sub>2</sub> resulting from NMVOC
1.B.2.a Oil	Transport (1.B.2.a.iii)	Reported as indirect CO <sub>2</sub>	NO	Reported as indirect CO <sub>2</sub>
	Refining/storage (1.B.2.a.iv)			
	Distribution of oil products (1.B.2.a.v)	NO		
1.B.2.b Natural gas	Production (1.B.2.b.ii)	Reported as indirect CO <sub>2</sub>	NO	Reported as indirect CO <sub>2</sub>
	Transmission and storage (1.B.2.b.iv)			
	Distribution (1.B.2.b.v)			
	Other leakage (1.B.2.b.vi)			
1.B.2.c Venting and flaring	Flaring Oil (1.B.2.c.ii.1)	Included in direct CO <sub>2</sub> emissions (CO <sub>2</sub> emission factors assume full oxidation)	Included in direct CO <sub>2</sub> emissions (CO <sub>2</sub> emission factors assume full oxidation)	Included in direct CO <sub>2</sub> emissions (CO <sub>2</sub> emission factors assume full oxidation)
	H <sub>2</sub> Production refinery (1.B.2.c.i)	NO	NO	NO
	Flaring from gas production (1.B.2.c.ii.2)	Included in direct CO <sub>2</sub> emissions (CO <sub>2</sub> emission factors assume full oxidation)		Included in direct CO <sub>2</sub> emissions (CO <sub>2</sub> emission factors assume full oxidation)

**2 Industrial processes and product use:** CO<sub>2</sub> resulting from the atmospheric oxidation of CH<sub>4</sub>, CO and NMVOC emitted from sector 2 IPPU is reported as indirect CO<sub>2</sub> emissions unless it is of biogenic origin or already accounted for implicitly as direct CO<sub>2</sub> emissions in sector 2 (chp. 4). For sector 2 IPPU, Table 9-9 illustrates in which processes CH<sub>4</sub>, CO and NMVOC emissions occur, and whether the related CO<sub>2</sub> emissions are reported as indirect CO<sub>2</sub> emissions or implicitly as direct CO<sub>2</sub> emissions. In summary, only few of the CO<sub>2</sub> emissions resulting from the atmospheric oxidation of CH<sub>4</sub>, CO and NMVOC emitted from sector 2 IPPU are already considered under the direct CO<sub>2</sub> emissions and thus not accounted for as indirect CO<sub>2</sub> emissions, namely:

- Emissions that are based on a carbon mass balance or material flows (including the carbon content) considering all carbon sources and sinks of the process. Examples are NMVOC from the cracker in source category 2B8b Ethylene or NMVOC and CO from steel production in electric arc furnaces in source category 2C1 Iron and steel production.
- Emissions from processes where full oxidation is assumed. An example is CO from source category 2C3 Aluminium production, where full oxidation of the anodes is



assumed. In contrast, NMVOC emissions from this process solely originate from the production of the electrodes at the plants. Therefore, these emissions are considered for the calculation of indirect CO<sub>2</sub> emissions.

- Emissions of biogenic origin. Examples are biogenic CO and NMVOC from tobacco consumption in source category 2G4 Other or from source category 2H2 Food and beverages industry.

The source categories 2D3a Solvent use and 2G4 Other include direct CO<sub>2</sub> emissions from post-combustion of NMVOC as well as indirect CO<sub>2</sub> emissions from oxidation of NMVOC in the atmosphere. Thereby, the CO<sub>2</sub> emissions resulting from NMVOC destroyed in post-combustion facilities are reported as direct CO<sub>2</sub> emissions (the respective NMVOC are therefore not part of the reported NMVOC emissions of the source categories 2D3a Solvent use and 2G4 Other).

Table 9-9 Sources of indirect CO<sub>2</sub> emissions from sector 2 Industrial processes and product use (IPPU). Only relevant source categories are shown. Blue cells mark processes for which CO<sub>2</sub> emissions resulting from the atmospheric oxidation of CH<sub>4</sub>, CO or NMVOC emissions are not accounted for as indirect CO<sub>2</sub> emissions, either because they are already considered under the direct CO<sub>2</sub> emissions or because they are of biogenic origin.

2 Industrial processes and product use			CO <sub>2</sub> resulting from CH <sub>4</sub>	CO <sub>2</sub> resulting from CO	CO <sub>2</sub> resulting from NMVOC
2.A Mineral industry			NO	Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>
2.B Chemical industry	2.B.5 Carbide production		Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>	NO
	2.B.8 Petrochemical and carbon black production		NO	NO	Included in direct CO <sub>2</sub> emissions (carbon mass balance)
	2.B.10 Other		Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>
2.C Metal industry	2.C.1 Iron and steel production	Steel production in electric arc furnaces	NO	Included in direct CO <sub>2</sub> emissions (carbon mass balance)	Included in direct CO <sub>2</sub> emissions (carbon mass balance)
		Remaining emission sources	NO	Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>
	2.C.3 Aluminium production		NO	Included in direct CO <sub>2</sub> emissions (full oxidation of anodes assumed)	Reported as indirect CO <sub>2</sub>
	2.C.7 Other		NO	Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>
2.D Non-energy products from fuels and solvent use	2.D.3.a Solvent use		NO	NO	Reported as indirect CO <sub>2</sub>
	2.D.3.b Road paving with asphalt		NO	NO	Reported as indirect CO <sub>2</sub>
	2.D.3.c Asphalt roofing		NO	Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>
2.G Other product manufacture and use	2.G.4 Other	Tobacco consumption	NO	Not reported as indirect CO <sub>2</sub> emissions (biogenic origin)	Not reported as indirect CO <sub>2</sub> emissions (biogenic origin)
		Remaining emission sources	NO	Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>
2.H Other	2.H.1 Pulp and paper		NO	NO	Reported as indirect CO <sub>2</sub>
	2.H.2 Food and beverages industry		NO	Not reported as indirect CO <sub>2</sub> emissions (biogenic origin)	Not reported as indirect CO <sub>2</sub> emissions (biogenic origin)
	2.H.3 Other		NO	Reported as indirect CO <sub>2</sub>	Reported as indirect CO <sub>2</sub>

**3 Agriculture and 4 LULUCF:** CH<sub>4</sub>, CO and NMVOC emissions from the sectors 3 Agriculture and 4 LULUCF are of biogenic origin. Accordingly, no indirect CO<sub>2</sub> emissions are reported for these sectors.

**5 Waste:** CH<sub>4</sub>, CO and NMVOC emissions from sector 5 Waste contain fossil and biogenic shares. Only indirect CO<sub>2</sub> resulting from the atmospheric oxidation of fossil CH<sub>4</sub>, CO and NMVOC is included in CRT Table6. Emissions of fossil CH<sub>4</sub>, CO and NMVOC originate from the following processes:

- Hospital waste incineration (CO and NMVOC emissions): Completely fossil, see chp. 7.4 Incineration and open burning of waste (5C1), since 2002 no emissions from hospital waste incineration have occurred.
- Municipal solid waste incineration (illegal) (CH<sub>4</sub>, CO and NMVOC emissions): Partly fossil, fossil share is assumed to be the same as for waste incinerated in municipal solid waste incineration plants, see chp. 7.4 Incineration and open burning of waste (5C1).
- Industrial waste incineration (consists of cable insulation materials) (CO and NMVOC emissions): Completely fossil, see chp. 7.4 Incineration and open burning of waste (5C1), since 1995 no emissions from incinerating cable insulation materials have occurred.
- Shredding (CO and NMVOC emissions): Completely fossil, see chp. 7.6 Other (5E Other).

Further emissions of CH<sub>4</sub>, CO and NMVOC from sector 5 Waste – such as from solid waste disposal (5A), biological treatment of solid waste (5B) and wastewater treatment and discharge (5D) – are of biogenic origin and therefore not considered for the calculation of indirect CO<sub>2</sub> emissions as presented in CRT Table6.

**6 Other:** CH<sub>4</sub>, CO and NMVOC emissions from sector 6 Other contain fossil and biogenic shares. Only CO<sub>2</sub> resulting from the atmospheric oxidation of fossil CH<sub>4</sub>, CO and NMVOC is reported as indirect CO<sub>2</sub>. Emissions of fossil CH<sub>4</sub>, CO and NMVOC originate from the following processes:

- Fire damage buildings: The share of fossil CH<sub>4</sub>, CO and NMVOC emissions is assumed to be equal to the share of fossil CO<sub>2</sub> emissions, which increased linearly from 20 % in 1950 to 80 % in 2000 and is assumed to have remained constant since then, see chp. 8.2 (6Ad).
- Fire damage motor vehicles: The share of fossil CH<sub>4</sub>, CO and NMVOC emissions is assumed to be 100 %, see chp. 8.2 (6Ad).

### 9.2.2. Methodological issues to derive indirect N<sub>2</sub>O emissions

Indirect N<sub>2</sub>O emissions are estimated using a country-specific method according to a study of indirect N<sub>2</sub>O emissions induced by nitrogen deposition in Switzerland (Bühlmann 2014, Bühlmann et al. 2015). In this study, ecosystem-specific emission factors for indirect N<sub>2</sub>O 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 data set 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<sub>2</sub>O 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<sub>2</sub>O-N per N-deposition (deposited in form of NO<sub>x</sub> or NH<sub>3</sub>, see also chp. 5.3.2.4). The resulting total emission factor is in the order of 2.6 % 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<sub>2</sub>O emissions result compared to the emissions that would result by applying the IPCC Guidelines (IPCC 2006, see also Bühlmann et al. 2015).

To calculate indirect N<sub>2</sub>O emissions induced by the deposition of NO<sub>x</sub> and NH<sub>3</sub> according to Bühlmann (2014) and Bühlmann et al. (2015), total N-deposition is needed. It is derived from

NO<sub>x</sub> (which is always reported in NO<sub>2</sub> equivalents) and NH<sub>3</sub> emissions using the stoichiometric conversion according to the following equation:

$$\text{Mass-N} = \text{Mass-NO}_{2,\text{eq}} * 14/46 + \text{Mass-NH}_3 * 14/17$$

Note: The emissions referred to as indirect N<sub>2</sub>O emissions in CRT Table3.B and in CRT Table3.D are not addressed in this chapter, as they are not reported as indirect N<sub>2</sub>O emissions in CRT Table6 and in CRT Table10 (these emissions are instead included in Sector 3 Agriculture along with direct N<sub>2</sub>O emissions).

#### *Activity data for the calculation of indirect N<sub>2</sub>O emissions*

The activity data to calculate indirect N<sub>2</sub>O emissions from a specific sector corresponds to the NO<sub>x</sub> and NH<sub>3</sub> emissions reported in the respective source categories. However, the following exceptions need to be considered:

- Indirect N<sub>2</sub>O emissions from sector 3 Agriculture are reported in the respective sector together with direct N<sub>2</sub>O emissions (chp. 5.3.2.5.4 Volatilisation of NH<sub>3</sub> and NO<sub>x</sub> from manure management systems, chp. 5.5.2.3 Indirect N<sub>2</sub>O emissions from atmospheric deposition of N volatilised from managed soils (3D2a) and chp. 5.5.2.4 Indirect N<sub>2</sub>O emissions from leaching and run-off from managed soils (3D2b)).
- For sector 6, the only indirect N<sub>2</sub>O emissions to be considered are those resulting from NO<sub>x</sub> emissions in source category 6Ad Fire damages.

### **9.2.3. Uncertainties and time series consistency**

Indirect CO<sub>2</sub> emissions are included in the uncertainty analysis, but indirect N<sub>2</sub>O emissions are not included.

Uncertainties of indirect CO<sub>2</sub> emissions are based on respective uncertainties of CH<sub>4</sub>, CO and NMVOC emissions. Uncertainties of CH<sub>4</sub> emissions are described in the respective chapters above. Uncertainties of CO and NMVOC emissions are documented in Switzerland's Informative Inventory Report 2025 (FOEN 2025b). The uncertainties of the emission factors are partly based on values provided by the EMEP/EEA guidebook (EMEP/EEA 2023, part A, chp. 5, Table 2-2) and expert judgements. The estimated uncertainties distinguish between fossil and biogenic shares.

Combined uncertainties of indirect CO<sub>2</sub> emissions, for each category, are given in Annex A2.1.

Consistency: Time series for indirect CO<sub>2</sub> and N<sub>2</sub>O emissions are all considered consistent.

### **9.2.4. Category-specific QA/QC and verification for indirect emissions**

The general QA/QC measures are described in chp. 1.5.

The same QA/QC and verification procedures are conducted as for CH<sub>4</sub>, CO, NMVOC, NO<sub>x</sub> and NH<sub>3</sub> related source categories in chp. 3 (Energy), chp. 4 (Industrial processes and product use), chp. 7 (Waste) and chp. 8 (Other).

### **9.2.5. Category-specific recalculations for indirect emissions**

The following recalculations were implemented in submission 2025:

- See CH<sub>4</sub> related recalculations reported in chp. 3 (Energy), chp. 4 (Industrial processes and product use), chp. 7 (Waste) and chp. 8 (Other).
- See CO related recalculations reported in chp. 4 (Industrial processes and product use), chp. 6 (Waste) and chp. 7 (Other) in Switzerland's Informative Inventory Report 2025 (FOEN 2025b).
- See NMVOC related recalculations reported in chp. 3 (Energy), chp. 4 (Industrial processes and product use), chp. 6 (Waste) and chp. 7 (Other) in Switzerland's Informative Inventory Report 2025 (FOEN 2025b).
- See NO<sub>x</sub> and NH<sub>3</sub> related recalculations reported in chp. 3 (Energy), chp. 4 (Industrial processes and product use), chp. 6 (Waste) and chp. 7 (Other) in Switzerland's Informative Inventory Report 2025 (FOEN 2025b).

General information, focussing on major recalculations which contribute significantly to the total differences in indirect emissions between the latest and the previous submissions, is presented in chp. 10.1.2.7.

#### **9.2.6. Category-specific planned improvements for indirect emissions**

No category-specific improvements are planned.

## 10. Recalculations and improvements

Responsibilities for chapter Recalculations and improvements	
Authors & annual updates (NID text, tables, figures)	Michael Bock (FOEN), Daniel Bretscher (Agroscope), Nele Rogiers (FOEN), Andreas Schellenberger (FOEN), Adrian Schilt (FOEN)
EMIS database operation	Adrian Schilt (FOEN)
Quality control NID (annual updates)	Michael Bock (FOEN), Adrian Schilt (FOEN)
Internal review	Anouk-Aimée Bass (FOEN), Myriam Guillevic (FOEN), Sabine Schenker (FOEN), sector experts

### 10.1. Explanations and justifications for recalculations, incl. in response to the review process

The implementation of recommendations and encouragements from the UNFCCC review process are listed in chp. 10.1.1. Additionally, major recalculations are presented in chp. 10.1.2. In the relevant sectoral chapters, also minor recalculations are listed and a brief explanation for each is provided. A list with all recalculations and specifics of the recalculations is compiled by the EMIS experts and available to the reviewers on demand (partly in German).

#### 10.1.1. Recommendations and encouragements from ERT and their implementation

The most recent in-depth review of the inventory was based on the submission of April 2022 (UNFCCC 2023). The recommendations and encouragements could already be addressed and implemented in the following submission (FOEN 2023) (see Table 10-1 and Table 10-2).

Table 10-1 Implementation of recommendations from the in-depth review in 2022 (UNFCCC 2023) as documented in FOEN (2023).

ID	classification	Recommendation from ARR 2022 (UNFCCC 2023)	Answer including reference to chapter in NID
<b>IPPU</b>			
I.1	2.F.1 Refrigeration and air conditioning – HFCs	The ERT recommends that Switzerland provide in the NIR the reasons for the decreasing trends in the EFs and emissions for this category and the drivers behind the trends (in AD and EFs) in the most significant subcategories.	Text added in NID chp. 4.7.1 starting with: "From 2015 onwards there is a decline in emissions as a result of the regulations from the Chemical Risk Reduction Ordinance (Swiss Confederation 2005)...."
<b>Agriculture</b>			
A.2	3.B.1 Cattle – N <sub>2</sub> O (A.6, 2021) Transparency	Provide information in the NIR on the algorithms and background input data (e.g. crude protein intake, milk protein content and N retention, to the extent possible) used to evaluate the Nex rates for cattle (by subcategory).	Additional text as well as additional references to background literature for individual animal categories has been added to chp. 5.3.2.5.2.
A.3	3.D.a.4 Crop residues – N <sub>2</sub> O (A.7, 2021) Transparency	Clarify the model used to estimate N <sub>2</sub> O emissions from crop residues left on fields by including in the NIR information on the reference source for the model, the data sources and the calculation parameters used.	More specific references to the data tables in FAL/RAC (2001) and Richner et al. (2017) are provided in chp. 5.5.2.2.2. An additional paragraph on nitrogen in straw used as bedding material was added in chp. 5.5.2.2.2. Reference sources have been added to the headers of the tables on crop residues in Annex A5.3.
A.5	3.A.1 Cattle – CH <sub>4</sub> , N <sub>2</sub> O	The ERT recommends that Switzerland report in NIR table 5.5 and CRF table 3.As2 milk production for mature dairy cattle based on annual milk production, that is, a period covering 365 days, rather than on a lactation period of 305 days.	Milk production reported in the NID and CRF table 3.As2 is now calculated by dividing yearly milk production by 365 days instead of 305 days (which would be the standard lactation period). The respective paragraphs and tables in NID section 5.2.2.2.1 were updated
<b>Waste</b>			
W.4	5.D.1 Domestic wastewater – CH <sub>4</sub> (W.5, 2021) Completeness	Estimate CH <sub>4</sub> emissions from wastewater treatment systems not connected to the public sewer system, specifically from those systems that are very similar to centralized wastewater treatment plants, and include the emissions in the national total.	According to the mentioned desk study (Vuna 2023) emissions from decentralised wastewater treatment do occur and are estimated as explained in chapter 7.5 of the NID.
W.5	5.D.1 Domestic wastewater – CH <sub>4</sub> (W.6, 2021) Transparency	Provide in the NIR a justification that simple systems serving as alternatives for wastewater treatment plants not connected to the public sewer system do not produce CH <sub>4</sub> emissions, for example by providing air and soil temperature profiles for the regions where these systems are typically used.	According to the mentioned desk study (Vuna 2023) emissions from decentralised wastewater treatment do occur and are estimated as explained in chapter 7.5 of the NID.
W.6	5.D.1 Domestic wastewater – CH <sub>4</sub> (W.7, 2021) Transparency	Explain in the NIR that the sewage sludge treated in centralized wastewater treatment plants or municipal waste incineration plants includes all sludge from wastewater treatment systems not connected to the public sewer system.	According to the mentioned desk study (Vuna 2023) all sludge from on-site sanitation systems is included in centralised treatment. Please see chapters 7.5.1 and 7.5.2.1.2 of the NID.
W.7	5.D.1 Domestic wastewater – CH <sub>4</sub> (W.7, 2021) Transparency	Include in the NIR additional information on the fraction of wastewater in rural areas not connected to the public sewer system that is possibly spread to agricultural soils as a fraction of slurry	According to the mentioned desk study (Vuna 2023) activity data for emissions from decentralised wastewater treatment via manure tank storage and usage are estimated. Emissions are estimated according to the agricultural model as explained in chapter 7.5 of the NID.
W.8	5.C.1 Waste incineration – CH <sub>4</sub>	The ERT recommends that Switzerland include in the NIR the explanation provided during the review as to why CH <sub>4</sub> emissions from the incineration of hospital waste, the incineration of industrial waste and cremation are not estimated, that is, that incineration of these sources is performed at high temperature with complete combustion processes and therefore CH <sub>4</sub> EFs can be considered as zero, in accordance with the 2006 IPCC Guidelines (vol. 5, chap. 5, section 5.2.2.3, p.5.13).	A note on the applicability of an emission factor for CH <sub>4</sub> was included in the section describing emission factors for the incineration of hospital waste, the incineration of industrial waste and cremation, respectively, in Chp. 7.4.2
W.9	5.C.1 Waste incineration – N <sub>2</sub> O	The ERT recommends that Switzerland correct the notation keys reported in CRF table 5.C for industrial waste for 1990–1994 (from "NO" to "NE" for the N <sub>2</sub> O IEFs and N <sub>2</sub> O emissions) and in NIR table 7-16 (from "NA" to "NE" for the N <sub>2</sub> O EFs). The ERT recommends that the Party either estimate and report these emissions for industrial waste or justify the use of "NE" based on the likely level of emissions, in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. The ERT also encourages the Party to explain in the NIR why N <sub>2</sub> O emissions from cremation were not estimated.	A note on the omission of an emission factor for N <sub>2</sub> O was included in the section describing emission factors for the incineration of industrial waste in Chp. 7.4.2 Also a note is added, stating why N <sub>2</sub> O from cremation is not estimated.

Table 10-2 Implementation of encouragements from the in-depth review in 2022 (UNFCCC 2023) as documented in FOEN (2023).

ID	classification	Encouragement from ARR 2022 (UNFCCC 2023)	Answer including reference to chapter in NID
<b>Energy</b>			
E.1	1. General (energy sector) – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	The ERT encourages Switzerland to consult with the secretariat on how to use CRF Reporter to report "NO" in CRF tables 1.A(a)s1, 1.A(a)s3–1.A(a)s4, 1.A(b) and 1.A(d) in all cases where cells have been left blank when the corresponding fuel is not used in the country (and thus there are no AD).	We consulted with the helpdesk (ANAIS-4120) and could fill some of the gaps. However, as there is no option in the CRF reporter to auto fill "NO" for empty cells, there are still empty cells. It has been decided to use the available resources for QC efforts instead of filling empty cells manually.
<b>IPPU</b>			
I.2	2.F.1 Refrigeration and air conditioning – HFCs	The ERT encourages Switzerland to provide in its NIR a rationale for the main driver(s) of the high share (33 per cent) of emissions for category 2.F.1.e (mobile air conditioning) in the total emissions for category 2.F.1.	Text added in NID chapter 4.7.2.1. A comparison to neighbour countries shows higher stock and emissions from mobile air-conditioning in Switzerland. Model parameters were checked and a higher rate of air-conditioning of >95% in vehicles is assumed plausible and is confirmed by companies dismantling vehicles.

### 10.1.2. Major recalculations and improvements implemented in the latest submission

In this chapter, the most important recalculations are presented. The figures show the differences between net emissions and removals in submission 2024 (previous) and submission 2025 (latest). Explanations are provided for categories that underwent recalculations larger than 2 % of the corresponding category emissions and resulted in absolute changes larger than 5 kt CO<sub>2</sub> eq (approximately 0.01 % of the national total emissions) for the sectors Energy, IPPU, Agriculture, Waste and Other. In the LULUCF sector, a summary of the effects of the recalculations is shown, with the emissions from organic soils being highlighted. Additional recalculations and corrections of minor errors, which had a smaller impact than the above thresholds, are listed in the relevant sectoral chapters only.

#### 10.1.2.1. Energy

The total changes in emissions in the energy sector due to all recalculations are shown in Figure 10-1 for CO<sub>2</sub>, Figure 10-2 for CH<sub>4</sub> and Figure 10-3 for N<sub>2</sub>O.

- 1A1a, CO<sub>2</sub>: The fossil fraction of waste incinerated in municipal solid waste incineration plants could be determined for the year 2022 based on new analyses of the waste composition. This leads to a recalculation of the values since the last survey in 2012 (linear interpolation to the new value for 2022). For the years 1991 to 2011, the linear interpolation was newly computed using additional significant digits.
- 1 Energy (largest impact in 1A3), CO<sub>2</sub>: Switzerland assessed the origin of biofuels in order to identify and separate fossil from biogenic feedstocks (e.g. in case fossil-fuel derived methanol is used for biodiesel production). In consequence, this leads to recalculations (additional fossil CO<sub>2</sub> emissions) in all source categories that include biodiesel, in particular 1A3 with the highest consumption of biodiesel.



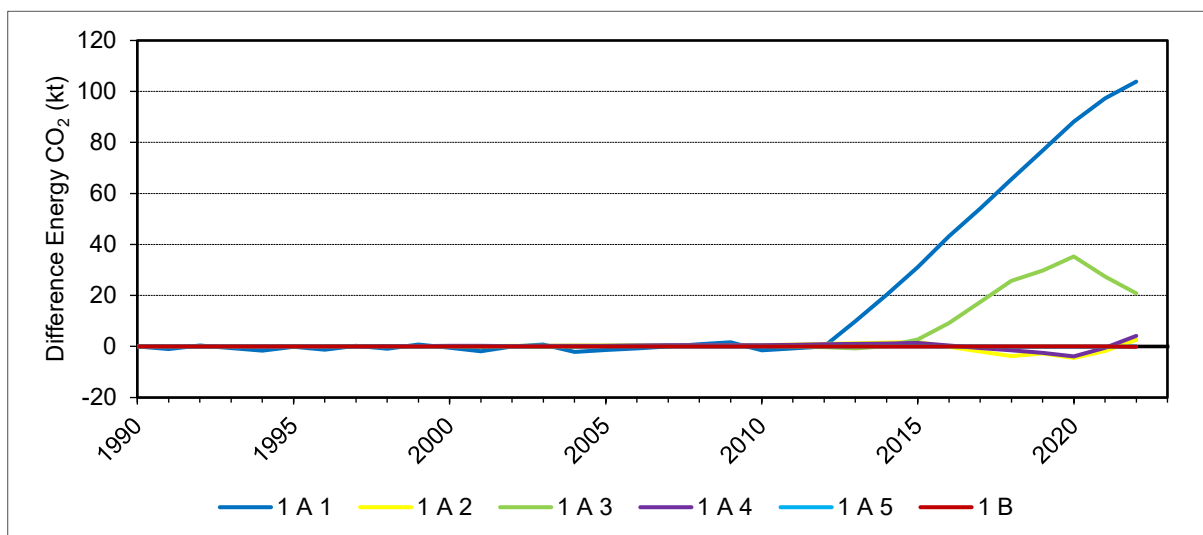


Figure 10-1 Differences in CO<sub>2</sub> emissions (in kt CO<sub>2</sub>) between the latest and the previous submissions for various source categories in the energy sector. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.

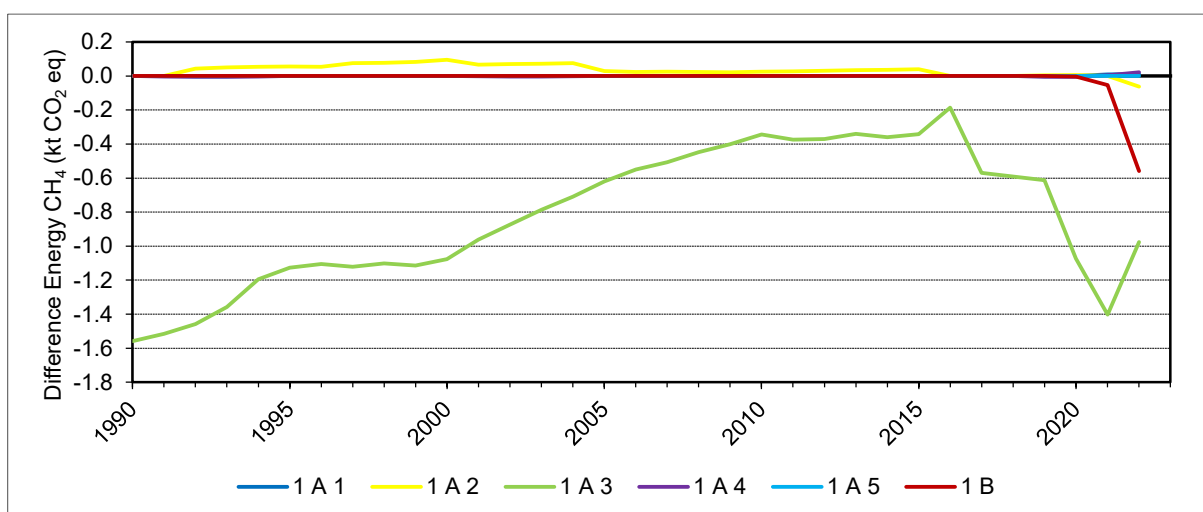


Figure 10-2 Differences in CH<sub>4</sub> emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for various source categories in the energy sector. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.

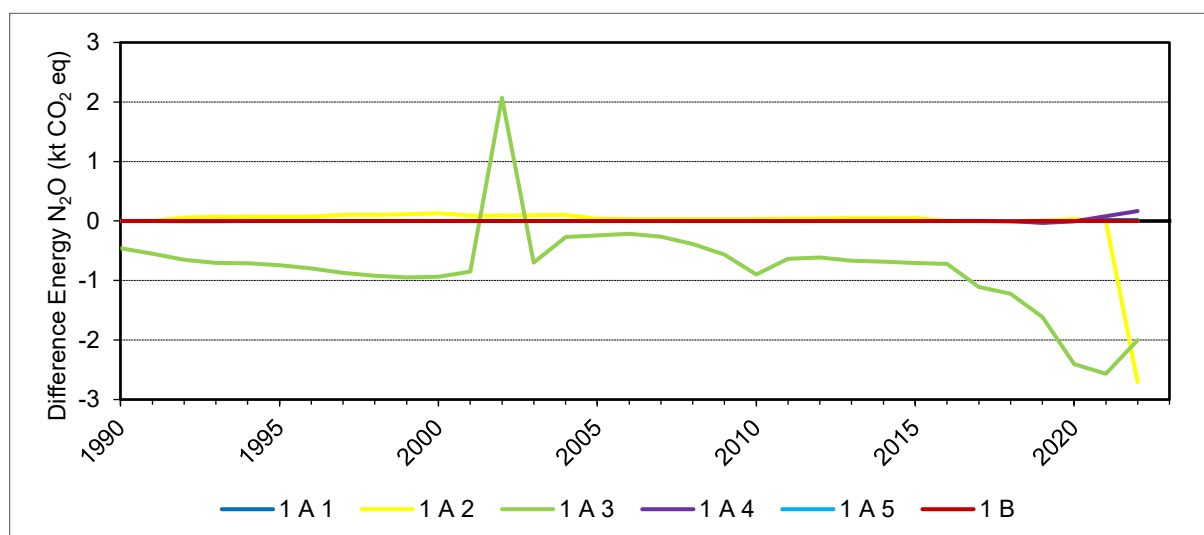


Figure 10-3 Differences in N<sub>2</sub>O emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for various source categories in the energy sector. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.

#### 10.1.2.2. Industrial processes and other product use

The total changes in emissions in the IPPU sector due to all recalculations are shown in Figure 10-4 for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, and in Figure 10-5 for HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>.

Large recalculations in sector 4 IPPU are mainly due to:

- 2E1: Additional emissions accounted between 1997-2022, HFC-23 built as a by-product from use of PFC
- 2F1: There are changes in activity data 2017-2022 for the disposal of HFC and PFC from commercial and industrial equipment: The modelling of the remaining refrigerant amount in commercial equipment at the disposal was adjusted. The refrigerant recycling amount for use in stationary refrigeration was reduced.
- 2F1: There are changes in activity data 2022 of HFC and PFC use for mobile and air-conditioning and stationary refrigeration related to changes in the vehicle and equipment statistics.
- 2F1: There are changes in the activity data 2020-2022: The portion of HFC in air-conditioning of vans was revised.

All other recalculations had an impact that was smaller than 5 kt CO<sub>2</sub> eq (see Figure 10-4 and Figure 10-5).

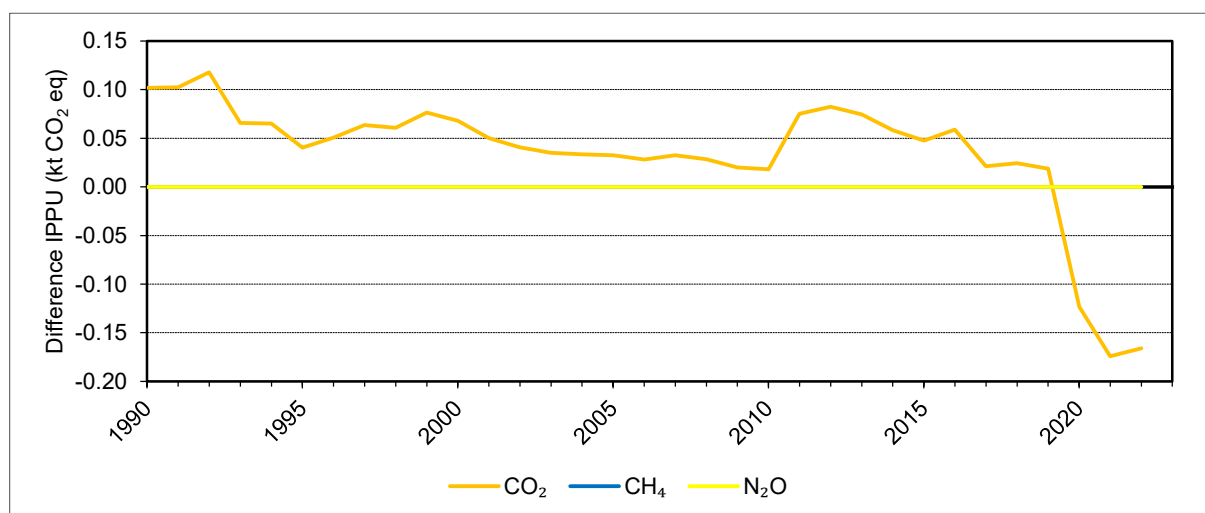


Figure 10-4 Differences in CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for sector IPPU. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.

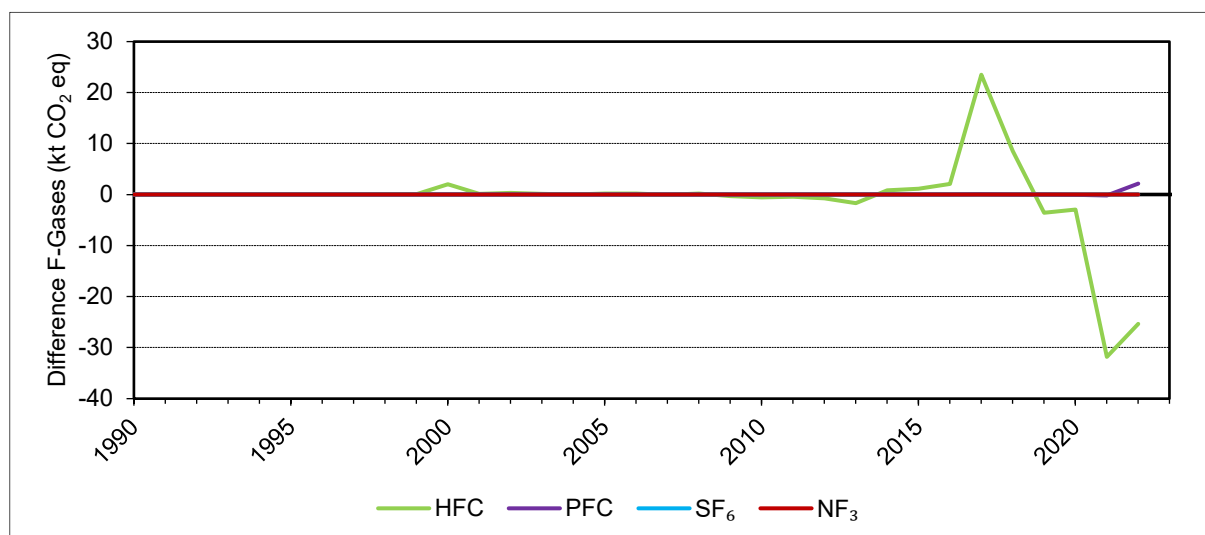


Figure 10-5 Differences in HFC, PFC, SF<sub>6</sub> and NF<sub>3</sub> emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for the sector IPPU. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.

### 10.1.2.3. Agriculture

The total changes in emissions in the Agriculture sector due to all recalculations are shown in Figure 10-6 for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, and for the most important recalculations aggregated for all greenhouse gases in Figure 10-7.

The largest recalculations concern N<sub>2</sub>O emissions from 3D, see comprehensive details in chapter 5.5.5, here an overview of the most important changes is given:

- 3.D.1.b.i: N<sub>2</sub>O emissions from manure applied to soils were recalculated for 1990-2022. N-input from bedding material was added to manure nitrogen as this nitrogen is no longer accounted for under nitrogen inputs from crop residues. The impact on overall emissions is +9.3 kt CO<sub>2</sub> equivalents (average 1990-2022, min=+6.5, max=+12.6).

- 3.D.1.b.iii: N<sub>2</sub>O emissions from other organic fertilizers applied to soils were recalculated for 1990-2022. The amount of nitrogen inputs from decentralised human wastewaters applied to soils was revised (lower amounts of NH<sub>3</sub> volatilised during manure management). The impact on overall emissions is +3.8 kt CO<sub>2</sub> equivalents for 1990 and declines to +0.3 kt CO<sub>2</sub> equivalents in 2022.
- 3.D.1.d: N<sub>2</sub>O emissions due to nitrogen in crop residues returned to soils was recalculated for 1990-2022. The whole methodology for assessing nitrogen inputs (AD) was revised and adjusted to the respective methodology for carbon inputs to soils in the LULUCF-sector. New estimates are considerably higher mainly due to the consideration of nitrogen inputs from roots and higher nitrogen inputs from intensive meadows. The impact on overall emissions is +197.7 kt CO<sub>2</sub> equivalents (average 1990-2022, min=+185.1, max=217.5).
- 3.D.1.e: N<sub>2</sub>O emissions from nitrogen in mineral soils that is mineralized/immobilized were recalculated for 1990-2022. New updated estimates for the amount of nitrogen mineralized (AD) from the LULUCF sector were adopted. The impact on overall emissions ranges from -66.0 to +54.9 kt CO<sub>2</sub> equivalents with a mean value of +7.7 kt CO<sub>2</sub> equivalents.
- 3.D.1.f: N<sub>2</sub>O emissions from cultivated organic soils were recalculated for 1990-2022. New area estimates (AD) were adopted from the LULUCF sector. The impact on overall emissions was -8.1 kt CO<sub>2</sub> equivalents (-8.2 to -7.9 kt CO<sub>2</sub> equivalents).

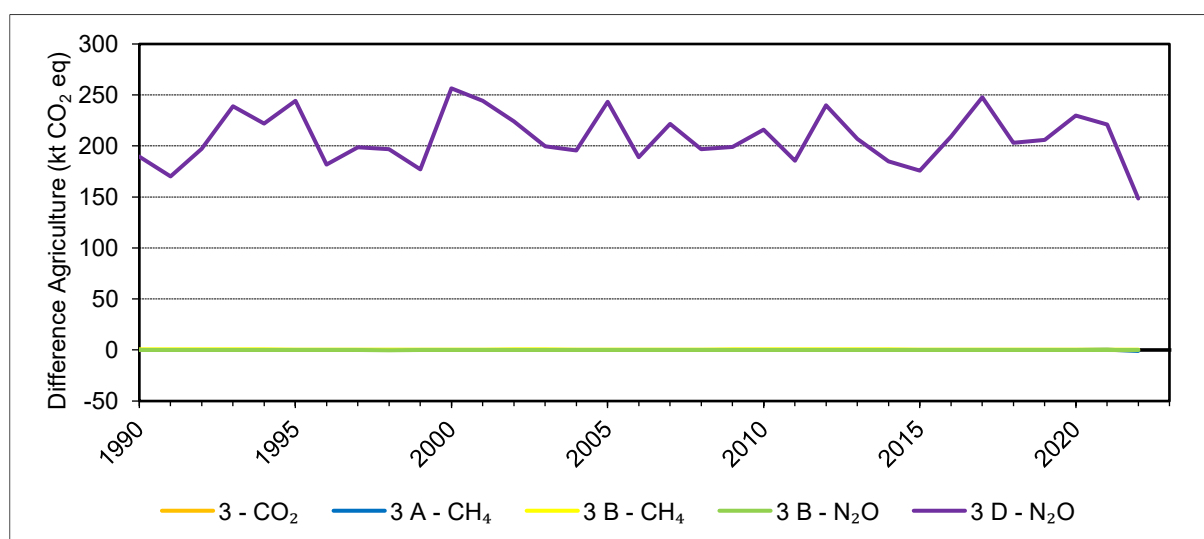


Figure 10-6 Differences in CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for sector Agriculture. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.

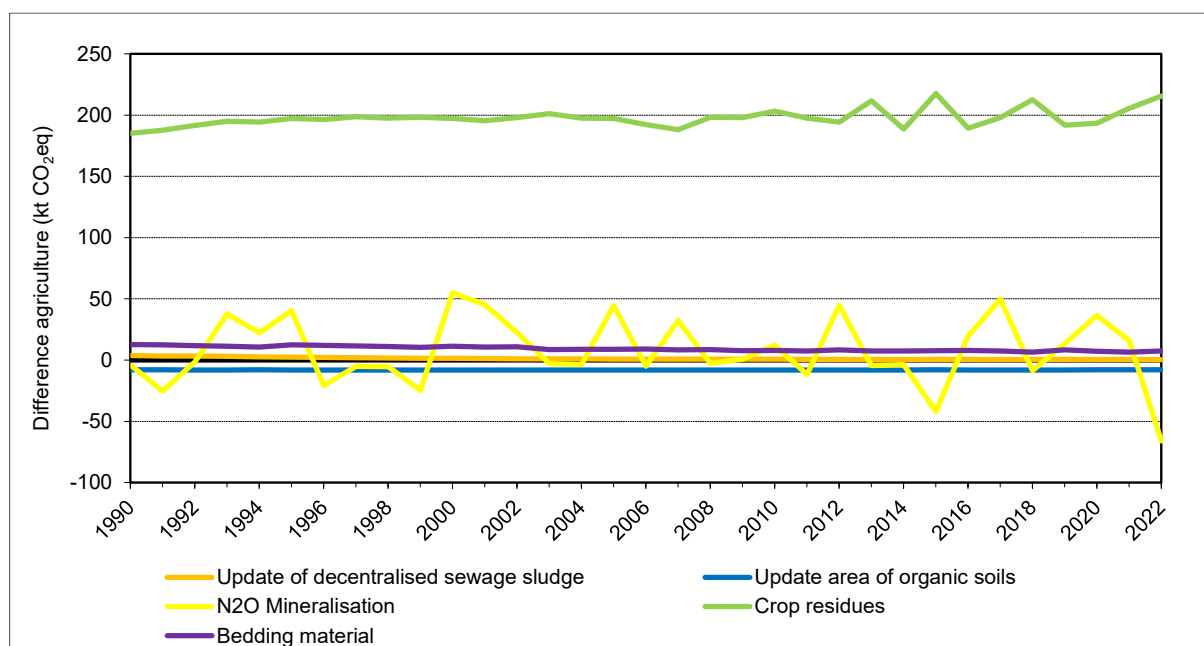


Figure 10-7 Differences in overall GHG emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for sector Agriculture due to the most important recalculations. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission. Note that due to the successive implementation of the different recalculations the amounts are not always exact but must be understood as approximations.

#### 10.1.2.4. Land Use, Land-Use change and Forestry

Overall changes in GHG emissions by sources and removals by sinks in the LULUCF sector due to all recalculations realised for the latest submission are shown in Figure 10-8. The trend in net emissions and removals remains basically the same (Figure 10-16).

The zigzag pattern of the deviation of CO<sub>2</sub> eq net emissions and removals between the latest and the previous submissions (range from -3'293 kt CO<sub>2</sub> eq in 2014 to 2'717 kt CO<sub>2</sub> eq in 2015; Figure 10-8) is controlled by recalculations in categories 4B and 4C (Figure 10-9). They affect the entire inventory period, with the resulting annual fluctuation increasing over time. Further elements that stand out in Figure 10-9 are the recalculations in category 4A Forest land, especially from 2018 onwards, and the correction of a FAOSTAT outlier for the year 2007 in category 4G Harvested wood products. In some years, the changes in the individual land-use categories largely offset each other (Figure 10-8).

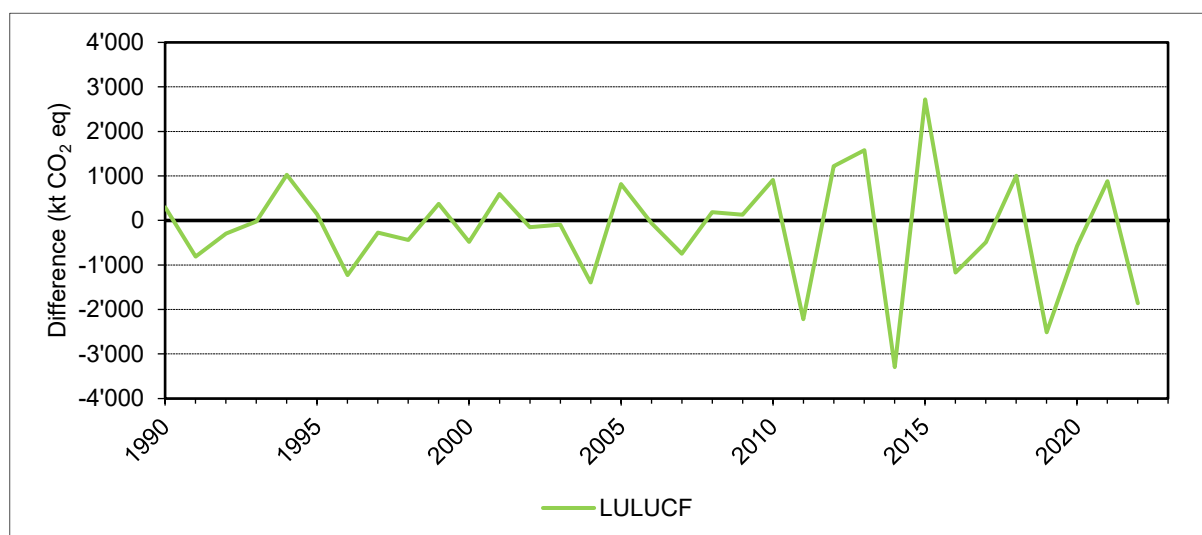


Figure 10-8 Differences in net emissions and removals (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for the LULUCF sector. Positive values refer to higher emissions/lower removals and negative values to lower emissions/higher removals in the latest submission compared to the previous submission.

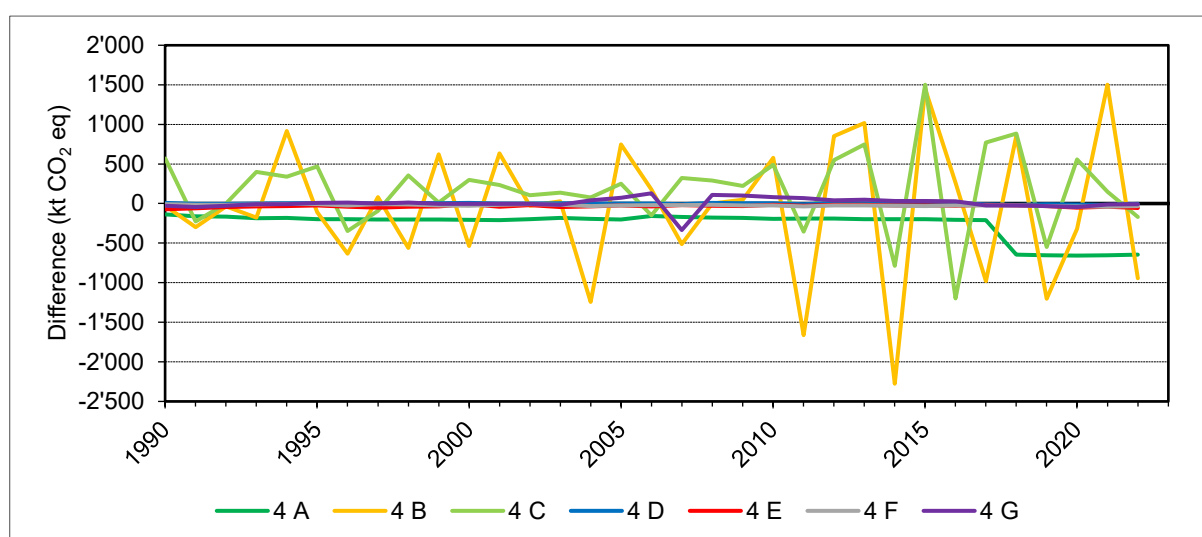


Figure 10-9 Differences in net emissions and removals (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for main land-use categories 4A–4G in the LULUCF sector. Positive values refer to higher emissions/lower removals and negative values to lower emissions/higher removals in the latest submission compared to the previous submission. Categories 4D, 4E and 4F fall close to the zero line and are therefore hardly distinguishable.

The updated estimate of the area of organic soil in Switzerland, in combination with the revision of the activity data for 1990–2022, is entirely responsible for changes in CO<sub>2</sub> emissions from organic soils in all categories (see chp. 6.3.1.5 with Figure 6-7, and Figure 10-10).

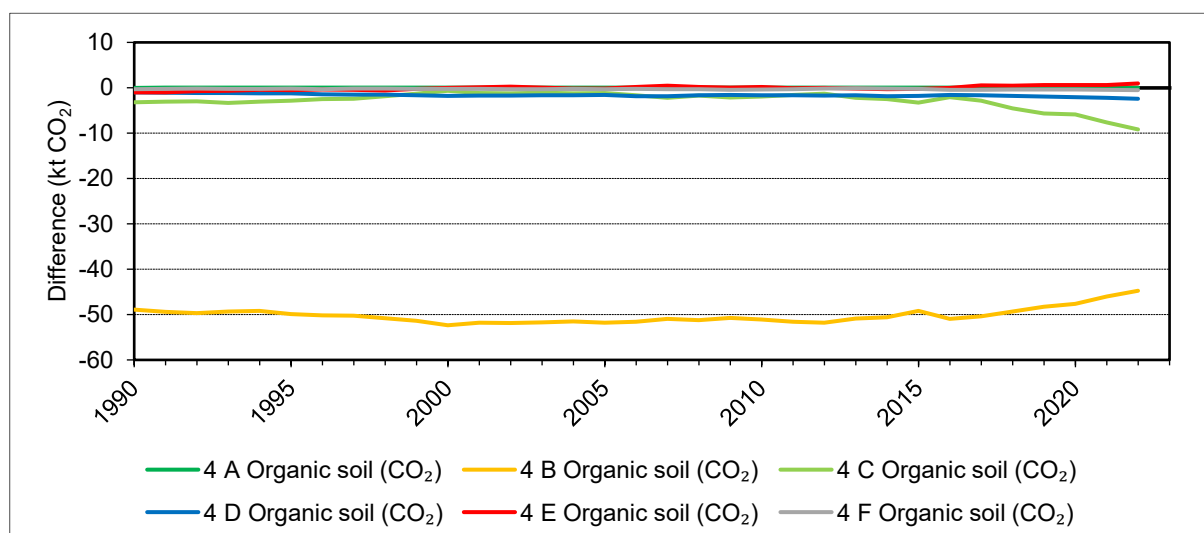


Figure 10-10 Differences in emissions (in kt CO<sub>2</sub>) between the latest and the previous submissions for organic soils of the main LULUCF land-use categories. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission. Category 4A coincides with the zero line and is hidden by the other lines.

#### 10.1.2.5. Waste

The total changes in emissions in the Waste sector due to all recalculations are shown in Figure 10-11 for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O.

Largest changes are due to

- 5D1, emission factor for N<sub>2</sub>O for 5D1 Domestic wastewater treatment: constant nitrogen load per person and per year, equal to the last available value for the year 2020, instead of a decreasing trend. This causes an increase of the emission factor for N<sub>2</sub>O by up to 4%.

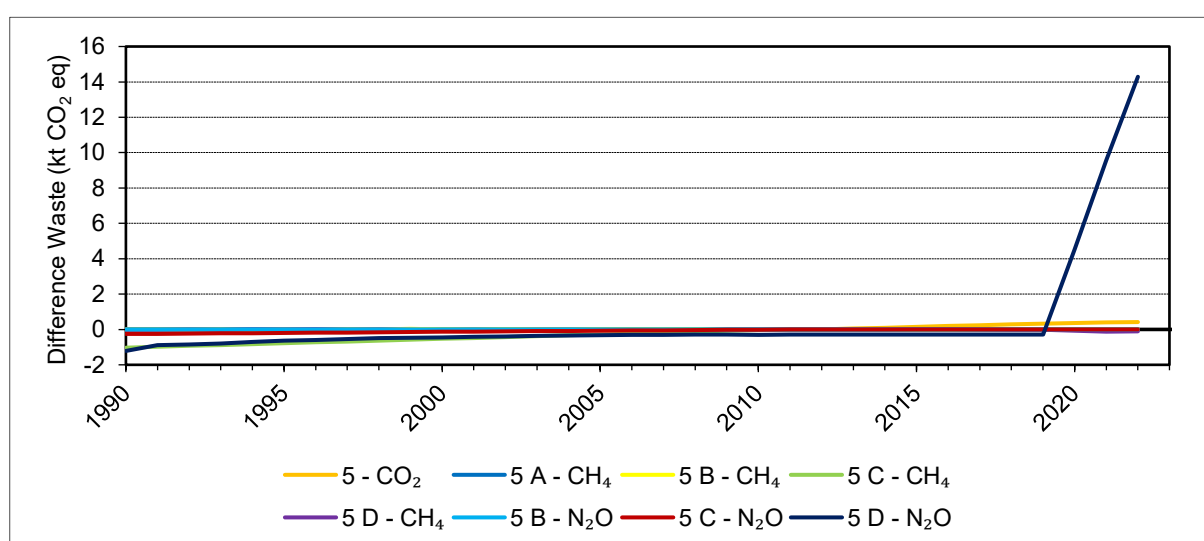


Figure 10-11 Differences in CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions for sector Waste. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.



### 10.1.2.6. Other

There were no recalculations implemented in submission 2025.

### 10.1.2.7. Indirect CO<sub>2</sub> Emissions

The total changes in indirect CO<sub>2</sub> emissions due to all recalculations are shown in Figure 10-12. No large changes were implemented in submission 2025.

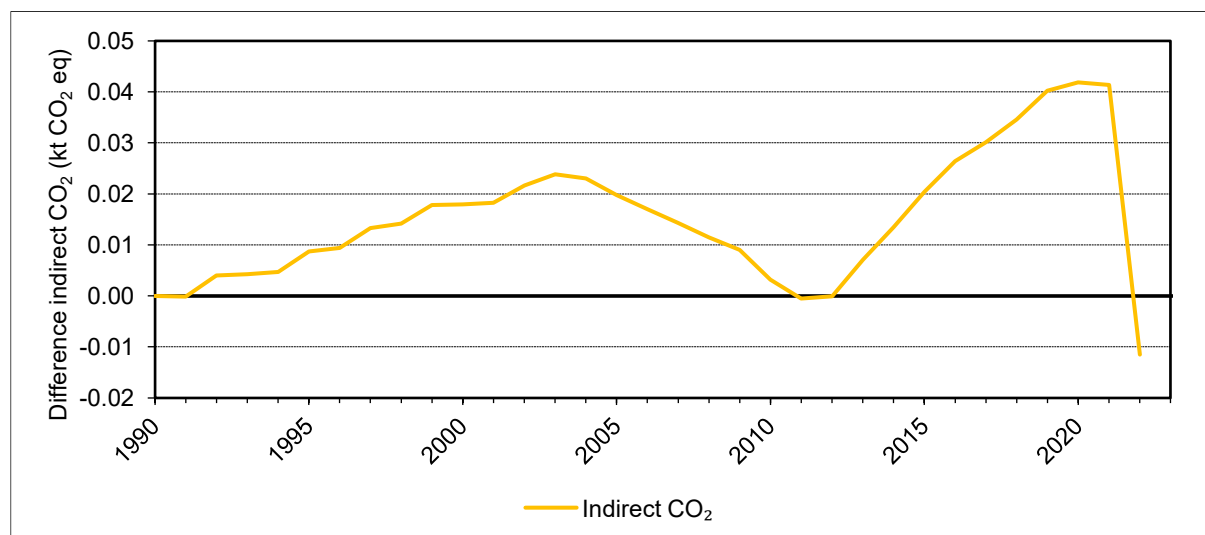


Figure 10-12 Differences in indirect CO<sub>2</sub> emissions (in kt CO<sub>2</sub> eq) between the latest and the previous submissions. Positive values refer to higher emissions and negative values to lower emissions in the latest submission compared to the previous submission.

## 10.2. Implications for emission and removal levels

Table 10-3 and Table 10-4 show the aggregated effect of all recalculations on the emission estimates for the base year 1990 and for the year 2022, respectively.

Table 10-3 Implications of recalculations for emission levels in 1990. Emissions are shown for the previous submission (FOEN 2024) and the latest submission. The difference refers to absolute values (Latest - Previous).

Emissions for 1990	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O			F-Gases			Sum of all gases		
	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference
CO <sub>2</sub> equivalent (kt)															
1 Energy	40'924	40'924	0.0	425.7	427.2	-1.6	283.8	284.2	-0.5				41'634	41'636	-2.0
2 IPPU	3'122	3'122	0.1	4.0	4.0	0.0	540.5	540.5	0.0	246.0	246.0	0.0	3'913	3'913	0.1
3 Agriculture	48.9	48.9	0.0	4'707	4'707	0.7	2'286	2'097	189.8				7'043	6'852	190.5
5 Waste	40.2	40.2	0.0	1'083	1'084	-1.0	1'125.4	1'126.8	-1.5				2'248	2'251	-2.5
6 Other	12.8	12.8	0.0	0.8	0.8	0.0	0.6	0.6	0.0				14.2	14.2	0.0
CO <sub>2</sub> indirect	392.3	392.3	0.0										392.3	392.3	0.0
<b>Total excluding LULUCF</b>	<b>44'541</b>	<b>44'541</b>	<b>0.1</b>	<b>6'220</b>	<b>6'222</b>	<b>-1.9</b>	<b>4'237</b>	<b>4'049</b>	<b>187.9</b>	<b>246</b>	<b>246</b>	<b>0.0</b>	<b>55'244</b>	<b>55'058</b>	<b>186.1</b>
	100.0%	100.0%	0.0%	100.0%	100.0%	0.0%	104.6%	100.0%	4.6%	100.0%	100.0%	0.0%	100.3%	100.0%	0.3%
4 LULUCF	-2'750	-3'047	297.3	35.3	34.4	1.0	48.4	53.9	-5.5				-2'666.5	-2'959	292.8
<b>Total including LULUCF</b>	<b>41'791</b>	<b>41'493</b>	<b>297.4</b>	<b>6'256</b>	<b>6'257</b>	<b>-1.0</b>	<b>4'285</b>	<b>4'103</b>	<b>182.4</b>	<b>246.0</b>	<b>246.0</b>	<b>0.0</b>	<b>52'577</b>	<b>52'099</b>	<b>478.9</b>
	100.7%	100.0%	0.7%	100.0%	100.0%	0.0%	104.4%	100.0%	4.4%	100.0%	100.0%	0.0%	100.9%	100.0%	0.9%

Emissions for 1990	HFC			PFC			SF <sub>6</sub>			NF <sub>3</sub>		
	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference
CO <sub>2</sub> equivalent (kt)												
2 IPPU	0.0	0.0	0.0	104.8	104.8	0.0	141.2	141.2	0.0	0.0	0.0	0.0

Table 10-4 Implications of recalculations for emission levels in 2022. Emissions are shown for the previous submission (FOEN 2024) and the latest submission. The difference refers to the absolute values (Latest - Previous).

Emissions for 2022	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O			F-Gases			Sum of all gases		
	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference
	CO <sub>2</sub> equivalent (kt)														
1 Energy	30'862	30'730	131.4	130.6	132.2	-1.6	234.3	238.8	-4.5				31'226	31'101	125.3
2 IPPU	2'028	2'028	-0.2	7.7	7.7	0.0	37.6	37.6	0.0	1'331.4	1'354.6	-23.3	3'405	3'428	-23.4
3 Agriculture	44.1	44.1	0.0	4'232	4'233	-0.8	1'759	1'611	148.6				6'035	5'888	147.8
5 Waste	8.6	8.1	0.4	537	537	-0.1	579.4	565.1	14.3				1'125	1'110	14.6
6 Other	8.3	8.3	0.0	0.5	0.5	0.0	0.3	0.3	0.0				9.1	9.1	0.0
CO <sub>2</sub> indirect	94.3	94.3	0.0										94.3	94.3	0.0
<b>Total excluding LULUCF</b>	<b>33'045</b>	<b>32'913</b>	<b>131.7</b>	<b>4'907</b>	<b>4'910</b>	<b>-2.5</b>	<b>2'611</b>	<b>2'453</b>	<b>158.4</b>	<b>1'331</b>	<b>1'355</b>	<b>-23.3</b>	<b>41'895</b>	<b>41'630</b>	<b>264.3</b>
	<b>100.4%</b>	<b>100.0%</b>	<b>0.4%</b>	<b>99.9%</b>	<b>100.0%</b>	<b>-0.1%</b>	<b>106.5%</b>	<b>100.0%</b>	<b>6.5%</b>	<b>98.3%</b>	<b>100.0%</b>	<b>-1.7%</b>	<b>100.6%</b>	<b>100.0%</b>	<b>0.6%</b>
4 LULUCF	-1'493	365	-1'857.1	17.8	17.7	0.1	45.2	50.8	-5.6				-1'429.5	433	-1'862.6
<b>Total including LULUCF</b>	<b>31'552</b>	<b>33'278</b>	<b>-1'725.4</b>	<b>4'925</b>	<b>4'928</b>	<b>-2.3</b>	<b>2'656</b>	<b>2'504</b>	<b>152.7</b>	<b>1'331.4</b>	<b>1'354.6</b>	<b>-23.3</b>	<b>40'465</b>	<b>42'064</b>	<b>-1'598.3</b>
	<b>94.8%</b>	<b>100.0%</b>	<b>-5.2%</b>	<b>100.0%</b>	<b>100.0%</b>	<b>0.0%</b>	<b>106.1%</b>	<b>100.0%</b>	<b>6.1%</b>	<b>98.3%</b>	<b>100.0%</b>	<b>-1.7%</b>	<b>96.2%</b>	<b>100.0%</b>	<b>-3.8%</b>

Emissions for 2022	HFC			PFC			SF <sub>6</sub>			NF <sub>3</sub>		
	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference	Latest	Previous	Difference
2 IPPU	1'247.5	1'272.9	-25.4	27.8	25.7	2.1	55.8	55.8	0.0	0.3	0.3	0.0

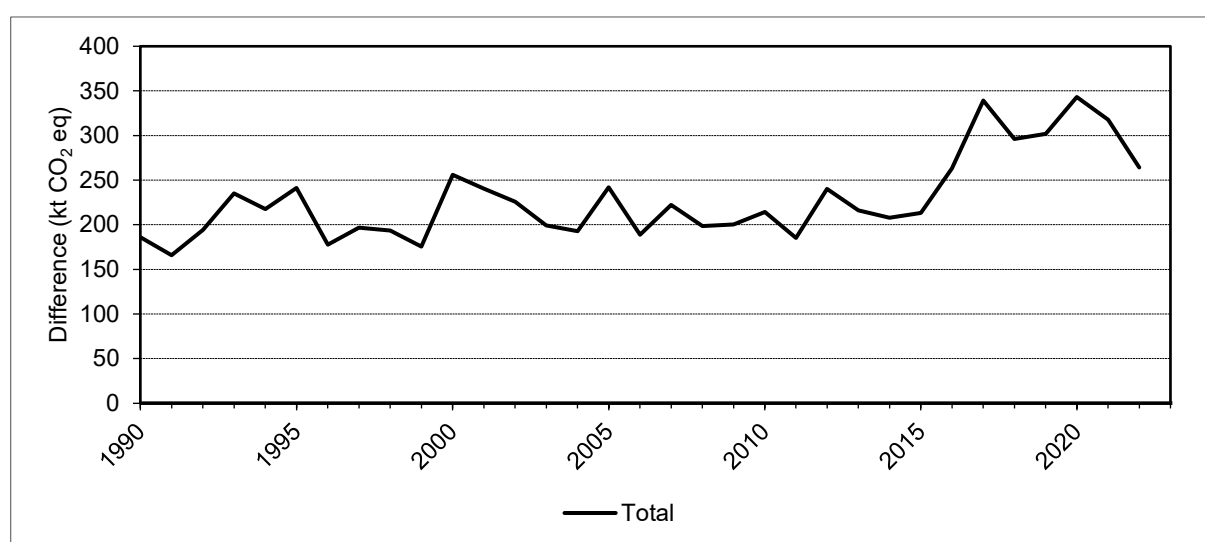


Figure 10-13 Implications of recalculations for the national total emissions (including indirect CO<sub>2</sub>, without LULUCF). Positive values refer to higher emissions and negative values to lower emissions in the latest compared to the previous submission. For the implications of recalculations for LULUCF see Figure 10-8.

Figure 10-13 shows the aggregated effect of all the recalculations on national total emissions without LULUCF. The effect of the recalculations ranges from +186 kt CO<sub>2</sub> eq in 1990 to +264 kt CO<sub>2</sub> eq in 2022 (with the largest effect of +343 kt CO<sub>2</sub> eq in 2020), corresponding to +0.3 % of annual total emissions in 1990 and +0.8 % in 2022.

The aggregated effect of all recalculations on total net emissions and net removals from LULUCF are shown in Figure 10-8. Furthermore, Figure 10-22 shows the aggregated effect of all the recalculations on national total emissions with LULUCF.

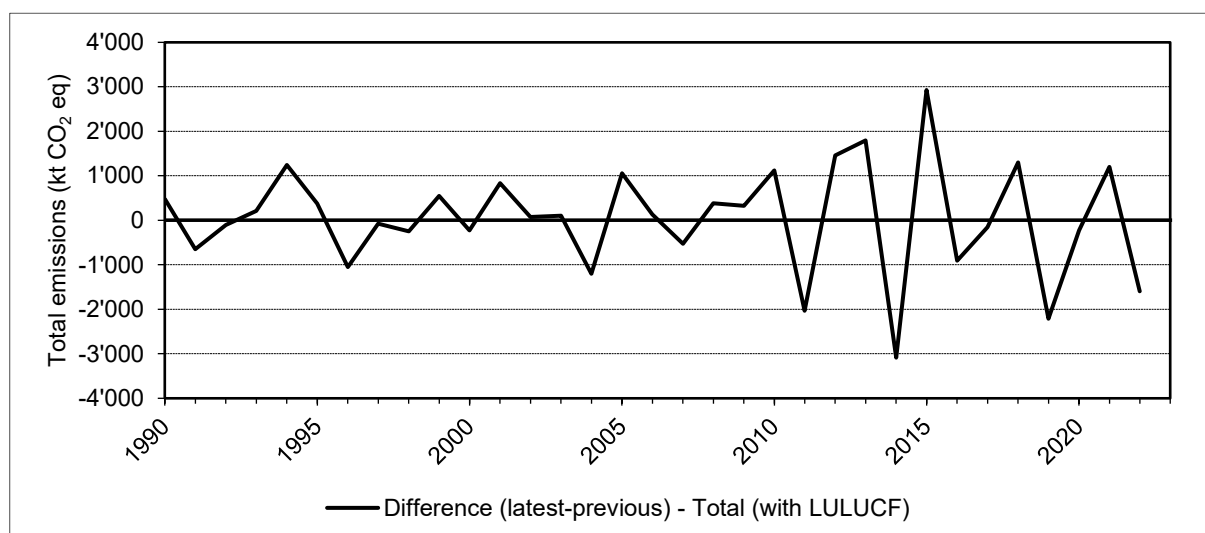


Figure 10-14 Implications of recalculations for the national total emissions (including indirect CO<sub>2</sub>, with LULUCF). Positive values refer to higher emissions and negative values to lower emissions in the latest compared to the previous submission.

To further visualize the aggregated effect of all the recalculations, the following figures compare total emissions as reported in the previous and the latest submissions in absolute terms (instead of showing differences as in the figures above): Total emissions (without LULUCF) in Figure 10-15, and total net emissions and net removals from LULUCF in Figure 10-16.

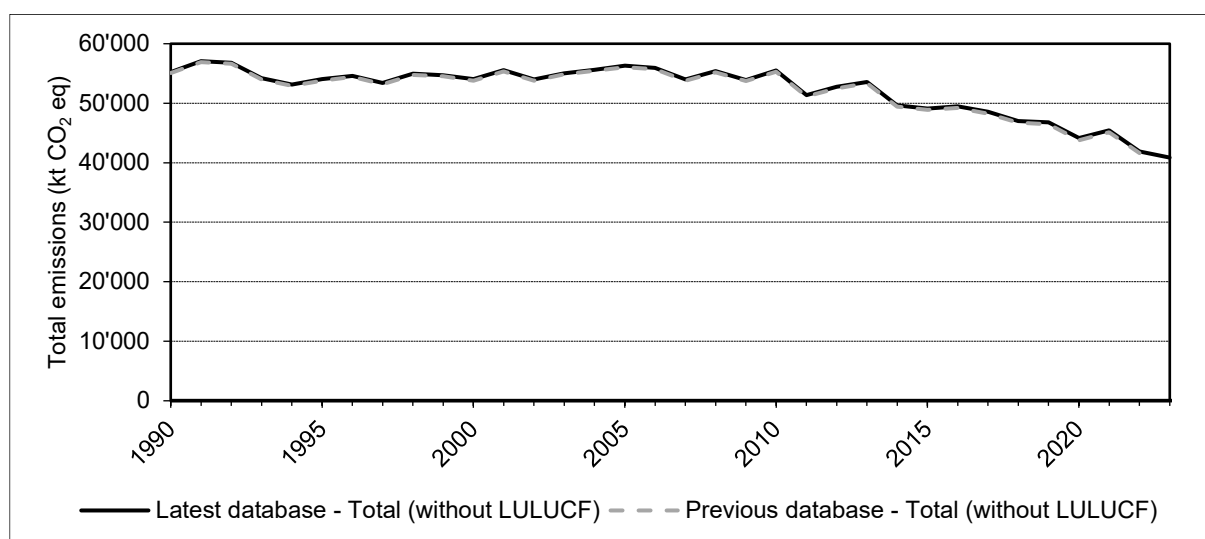


Figure 10-15 Comparison of total emissions (including indirect CO<sub>2</sub>, without LULUCF) as reported in the previous and the latest submissions.

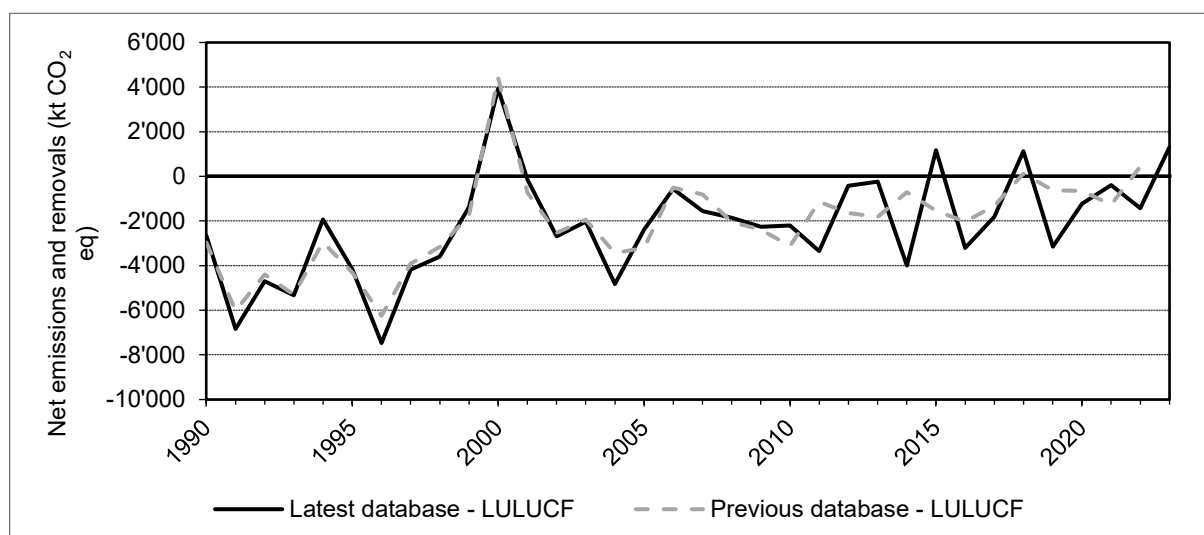


Figure 10-16 Comparison of net emissions (positive values) and net removals (negative values) from LULUCF as reported in the previous and the latest submissions.

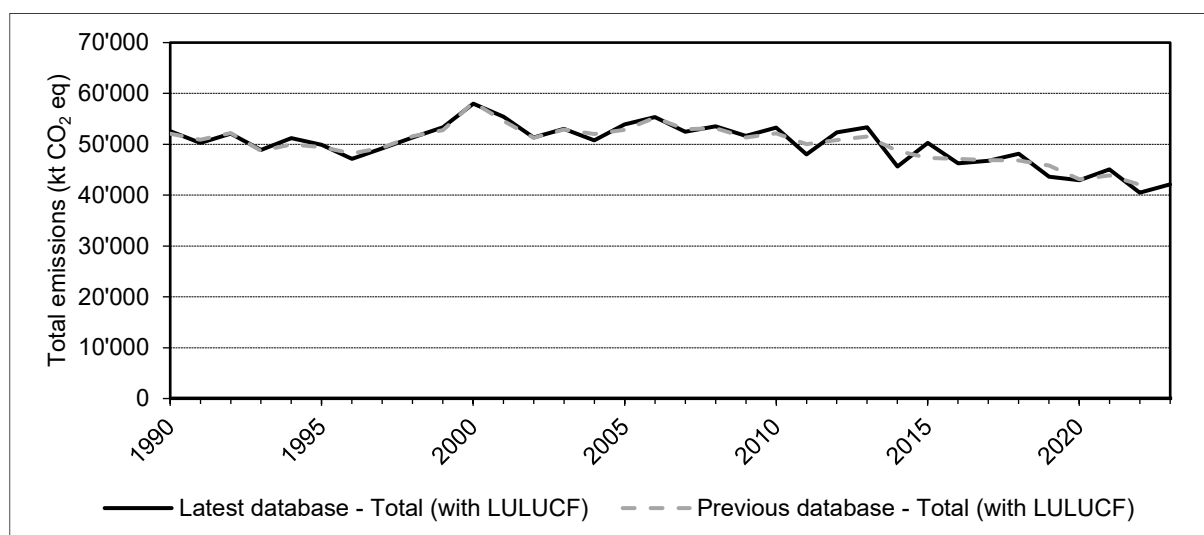


Figure 10-17 Comparison of total emissions (including indirect CO<sub>2</sub>, with LULUCF) as reported in the previous and the latest submissions.

### 10.3. Implications for emission and removal trends, including time series consistency

As recalculations are applied to the entire time series (as appropriate), time series consistency is maintained. The emission trend for the total emissions (including indirect CO<sub>2</sub>, excluding LULUCF) from 1990–2022 has changed (see Table 10-5) slightly.

Table 10-5 Estimated emission trends 1990–2022, calculated based on national total emissions including indirect CO<sub>2</sub> as shown in the previous and the latest submission (for additional details see Table 10-3 and Table 10-4).

Trend	1990		2022		Change 1990/2022	
	Latest	Previous	Latest	Previous	Latest	Previous
	CO <sub>2</sub> equivalent (kt)				%	
Total excluding LULUCF	55'244	55'058	41'895	41'630	-24.2%	-24.4%
Total including LULUCF	52'577	52'099	40'465	42'064	-23.0%	-19.3%

## 10.4. Areas of improvement, including in response to the review process

All categories mentioned hereafter have been identified as key categories, or contain categories identified as key categories, according to the key category analysis (see overview of key categories in Table 1-6).

- 3B/3D: In 2025 the AGRAMMON model (Kupper et al. 2022) will be updated and new data on farm management and production technology will become available from the latest survey. All emissions from 3B Manure management and 3D Agricultural soils will be revised accordingly during the submission 2026 or 2027.
- 3D: After the suitability of the DayCent model for reporting N<sub>2</sub>O emissions has been proven (LACHSIM project), it is now to be integrated into the reporting of the Agriculture sector. Three years (2024–2026) are planned for the compilation of the necessary input data (in particular type and intensity of management) and the creation of a consistent time series back to 1990.
- 3D: Development of a country-specific emission factor for direct N<sub>2</sub>O emissions from urine and dung deposited by grazing animals.
- 4: The suitability of satellite data for land area representation in Switzerland is being evaluated.
- 4A: The forest definition will be revised in the next submission.
- 4A: The land-use category unproductive forest will be rearranged to increase transparency in the next submission.
- 4A: First data on carbon dynamics in brush forests will be derived from NFIs 4 and 5. Their implementation in LULUCF reporting is planned for the 2029 submission.
- 4A: Planned progress on Yasso focuses on improving the accuracy of estimates on dead wood and litter production, and opportunities arising from national and international projects, particularly in the context of the EU-Horizon project Pathfinder.
- 4B, 4C, 4D, 4E: The biomass model for trees outside the forest will be finalised in the course of 2025.
- 4B, 4C, 4D, 4E: The progress of digital soil modelling at the Competence Center for Soils (CCSoils) will continue to be used to improve estimates of carbon stock in mineral non-Forest soils. The switch to grid-based SOC modelling with RothC for Cropland and Grassland will be pursued further.
- 4G: It is planned to explore the availability of plant-specific activity data for wood panels for the years before 2021.

## Annexes

## Annex 1 Key categories

Table A – 1 Overview of Switzerland's key category analysis, including LULUCF categories and indirect CO<sub>2</sub> emissions. Columns A (category code) and B (category name) contain the complete disaggregation level of categories used for the key category analysis. L: level assessment (2023); T: trend assessment (1990–2023); 1: KCA approach 1; 2: KCA approach 2. For none of the categories, SF<sub>6</sub> and NF<sub>3</sub> are key (therefore, the respective columns for SF<sub>6</sub> and NF<sub>3</sub> are disabled in the columns C and D). Results of the level assessment for the base year are not reported in this table. Columns A to D are labelled according to Table 4-4 in the 2006 IPCC Guidelines, vol.1, chp. 4 (IPCC 2006).

SUMMARIES TO IDENTIFY KEY CATEGORIES							
A	B	C & D					
Code	IPCC category	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFCs	PFCs	Ind. CO <sub>2</sub> (NMVOC)
1.A.1	Energy industries; Biomass	NA			NA	NA	NA
1.A.1	Energy industries; Gaseous fuels	L1, T1			NA	NA	NA
1.A.1	Energy industries; Liquid fuels	L1, T1			NA	NA	NA
1.A.1	Energy industries; Solid fuels				NA	NA	NA
1.A.1	Energy industries; Other fossil fuels	L1, L2, T1, T2	NA		NA	NA	NA
1.A.2	Manufacturing industries and construction; Biomass	NA			NA	NA	NA
1.A.2	Manufacturing industries and construction; Gaseous fuels	L1, L2, T1			NA	NA	NA
1.A.2	Manufacturing industries and construction; Liquid fuels	L1, T1			NA	NA	NA
1.A.2	Manufacturing industries and construction; Solid fuels	L1, T1			NA	NA	NA
1.A.2	Manufacturing industries and construction; Other fossil fuels	L1, T1			NA	NA	NA
1.A.3.a	Domestic aviation; Kerosene fossil	T1			NA	NA	NA
1.A.3.b	Road transportation; Biomass	NA			NA	NA	NA
1.A.3.b	Road transportation; Gaseous fuels				NA	NA	NA
1.A.3.b	Road transportation; Diesel oil	L1, L2, T1		T1	NA	NA	NA
1.A.3.b	Road transportation; Gasoline	L1, T1	T1	T1	NA	NA	NA
1.A.3.b	Road transportation; Liquefied petroleum gas				NA	NA	NA
1.A.3.b	Road transportation; Other fossil fuels				NA	NA	NA
1.A.3.c	Railways; Biomass	NA			NA	NA	NA
1.A.3.c	Railways; Liquid fuels				NA	NA	NA
1.A.3.d	Domestic navigation; Biomass	NA			NA	NA	NA
1.A.3.d	Domestic navigation; Liquid fuels				NA	NA	NA
1.A.3.e	Other transportation; Gaseous fuels				NA	NA	NA
1.A.4.a	Commercial/institutional; Biomass	NA			NA	NA	NA
1.A.4.a	Commercial/institutional; Gaseous fuels	L1, T1			NA	NA	NA
1.A.4.a	Commercial/institutional; Liquid fuels	L1, T1			NA	NA	NA
1.A.4.b	Residential; Biomass	NA			NA	NA	NA
1.A.4.b	Residential; Gaseous fuels	L1, L2, T1, T2			NA	NA	NA
1.A.4.b	Residential; Liquid fuels	L1, T1			NA	NA	NA
1.A.4.b	Residential; Solid fuels				NA	NA	NA
1.A.4.c	Agriculture/forestry/fishing; Biomass	NA			NA	NA	NA
1.A.4.c	Agriculture/forestry/fishing; Gaseous fuels				NA	NA	NA
1.A.4.c	Agriculture/forestry/fishing; Liquid fuels	L1, T1			NA	NA	NA
1.A.5	Other; Biomass	NA			NA	NA	NA
1.A.5	Other; Liquid fuels	L1			NA	NA	NA
1.B	Fugitive emissions from fuels; All fuels	NA	NA	NA	NA	NA	
1.B.2.a	Oil; All fuels	NA		NA	NA	NA	NA
1.B.2.b	Natural gas; All fuels			NA	NA	NA	NA
1.B.2.c	Venting and flaring; All fuels				NA	NA	NA
2.A	Mineral industry	NA	NA	NA	NA	NA	
2.A.1	Cement production	L1, L2, T1	NA	NA	NA	NA	NA
2.A.2	Lime production		NA	NA	NA	NA	NA
2.A.3	Glass production		NA	NA	NA	NA	NA
2.A.4	Other process uses of carbonates		NA	NA	NA	NA	NA
2.B	Chemical industry	NA	NA	NA	NA	NA	
2.B.2	Nitric acid production	NA	NA		NA	NA	NA
2.B.5	Carbide production			NA	NA	NA	NA
2.B.8	Petrochemical and carbon black production		NA	NA	NA	NA	NA
2.B.10	Other			T1, T2	NA	NA	NA
2.C	Metal industry	NA	NA	NA	NA	NA	
2.C.1	Iron and steel production		NA	NA	NA	NA	NA
2.C.3	Aluminium production	T1	NA	NA	NA	T1	NA
2.C.4	Magnesium production	NA	NA	NA	NA	NA	NA
2.C.7	Other		NA	NA	NA	NA	NA
2.D	Non-energy products from fuels and solvent use	NA	NA	NA	NA	NA	T1
2.D.1	Lubricant use		NA	NA	NA	NA	NA
2.D.2	Paraffin wax use		NA	NA	NA	NA	NA
2.D.3	Other		NA	NA	NA	NA	NA
2.E.1	Integrated circuit or semiconductor	NA	NA	NA			NA
2.E.3	Photovoltaics	NA	NA	NA	NA	NA	NA
2.E.5	Other	NA	NA	NA	NA		NA
2.F.1	Refrigeration and air-conditioning	NA	NA	NA	L1, L2, T1, T2		NA
2.F.2	Foam blowing agents	NA	NA	NA	L2, T2	NA	NA
2.F.4	Aerosols	NA	NA	NA		NA	NA
2.F.5	Solvents	NA	NA	NA		NA	NA
2.G	Other product manufacture and use	NA	NA	NA			
2.G.3	N <sub>2</sub> O from product uses	NA	NA		NA	NA	NA
2.G.4	Other		NA		NA	NA	NA
2.H	Other	NA	NA	NA	NA	NA	
2.H.3	Other		NA	NA	NA	NA	NA



Table A – 1 (continued)

SUMMARIES TO IDENTIFY KEY CATEGORIES							
A	B	C & D					
Code	IPCC category	CO2	CH4	N2O	HFCs	PFCs	Ind. CO2 (NMVOC)
3.A	Enteric fermentation	NA	L1, L2, T1, T2	NA	NA	NA	NA
3.B.1-4	Manure management	NA	L1, L2	L2	NA	NA	NA
3.B.5	Indirect N2O emissions	NA	NA	L1, L2	NA	NA	NA
3.D.1	Direct N2O emissions from managed soils	NA	NA	L1, L2	NA	NA	NA
3.D.2	Indirect N2O Emissions from managed soils	NA	NA	L1, L2, T1, T2	NA	NA	NA
3.G	Liming		NA	NA	NA	NA	NA
3.H	Urea application		NA	NA	NA	NA	NA
4.A.1	Forest land remaining forest land	L1, L2, T1, T2	NA	NA	NA	NA	NA
4.A.2	Land converted to forest land	L1, L2, T1	NA	NA	NA	NA	NA
4.B.1	Cropland remaining cropland	L1, L2	NA	NA	NA	NA	NA
4.B.2	Land converted to cropland		NA	NA	NA	NA	NA
4.C.1	Grassland remaining grassland	L1, L2, T1, T2	NA	NA	NA	NA	NA
4.C.2	Land converted to grassland	L1, L2, T1	NA	NA	NA	NA	NA
4.D.1	Wetlands remaining wetlands	L2	NA	NA	NA	NA	NA
4.D.2	Land converted to wetlands		NA	NA	NA	NA	NA
4.E.1	Settlements remaining settlements		NA	NA	NA	NA	NA
4.E.2	Land converted to settlements	L1, L2	NA	NA	NA	NA	NA
4.F.2	Land converted to other land		NA	NA	NA	NA	NA
4.G	Harvested wood products	T1, T2	NA	NA	NA	NA	NA
4(II)	Drainage and rewetting	NA			NA	NA	NA
4(III)*D	Direct	NA	NA		NA	NA	NA
4(III)*I	Indirect	NA	NA		NA	NA	NA
4(IV)	Wildfires	NA			NA	NA	NA
5.A	Solid waste disposal		L1, L2, T1, T2	NA	NA	NA	NA
5.B	Biological treatment of solid waste	NA			NA	NA	NA
5.C	Incineration and open burning of waste			L2	NA	NA	
5.D	Wastewater treatment and discharge	NA	L1, L2, T1, T2	L1, L2, T1, T2	NA	NA	NA
5.E	Other	NA	NA	NA	NA	NA	
6.A	Other				NA	NA	
Total number of key categories		26	5	9	2	1	1

## Annex 2 Uncertainty assessment

### A2.1 Input uncertainty values

Table A – 2 Input uncertainties for the year 2023, including LULUCF categories and indirect CO<sub>2</sub> emissions. Input uncertainties are assigned to activity data (column E) and emissions factors (column F) or, if unknown, to emissions only (column G). The uncertainties are given considering a 95 % confidence interval (from 2.5 % to 97.5 %) and expressed as the distance from edge to mean, in percentage of the mean. Columns are labelled according to Table 3-2 in the 2006 IPCC Guidelines, vol.1, chp. 3 (IPCC 2006). Abbreviations used within sector 4 LULUCF: CS-CH-LB Carbon gains: carbon gains in living biomass. CS-CH-LB Carbon losses: carbon losses in living biomass. Net CS-CH-S Carbon min soils: net carbon stock change in mineral soil. Net CS-CH-S Carbon org soils: net carbon stock change in organic soils. Net CS-CH-DOM Carbon: net carbon stock change in dead organic matter. 4(III)\*D/I: direct/indirect N<sub>2</sub>O emissions.

A	B	E					F					G				
Year 2023																
Code	Gas	Activity data uncertainty for a 95 %					Emission factor uncertainty for a 95 %					Emission uncertainty for a 95 % confidence				
		Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.	Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.	Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.
1.A.1; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	28.3	28.3	28.3	yes					
1.A.1; Biomass	N2O	normal	10.0	10.0	10.0	no	normal	79.4	79.4	79.4	yes					
1.A.1; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	0.4	0.4	0.4	no					
1.A.1; Gaseous fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.1; Gaseous fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.1; Liquid fuels	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	yes					
1.A.1; Liquid fuels	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.1; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	normal	80.0	80.0	80.0	yes					
1.A.1; Solid fuels	CO2	normal	5.0	0.0	0.0	no	normal	5.1	0.0	0.0	yes					
1.A.1; Solid fuels	CH4	normal	5.0	0.0	0.0	no	normal	29.6	0.0	0.0	yes					
1.A.1; Solid fuels	N2O	normal	5.0	0.0	0.0	no	normal	79.8	0.0	0.0	yes					
1.A.1; Other fossil fuels	CO2	normal	5.0	5.0	5.0	no	normal	16.9	16.9	16.9	yes					
1.A.1; Other fossil fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	no					
1.A.2; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	28.3	28.3	28.3	yes					
1.A.2; Biomass	N2O	normal	10.0	10.0	10.0	no	normal	79.4	79.4	79.4	yes					
1.A.2; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	0.4	0.4	0.4	no					
1.A.2; Gaseous fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.2; Gaseous fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.2; Liquid fuels	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	yes					
1.A.2; Liquid fuels	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.2; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	normal	80.0	80.0	80.0	yes					
1.A.2; Solid fuels	CO2	normal	5.0	5.0	5.0	no	normal	5.1	5.1	5.1	yes					
1.A.2; Solid fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.2; Solid fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.2; Other fossil fuels	CO2	normal	5.0	5.0	5.0	no	normal	9.2	9.2	9.2	yes					
1.A.2; Other fossil fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.2; Other fossil fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	no					
1.A.3.a; Kerosene fossil	CO2	normal	1.0	1.0	1.0	no	normal	0.2	0.2	0.2	no					
1.A.3.a; Kerosene fossil	CH4	normal	1.0	1.0	1.0	no	normal	60.0	60.0	60.0	yes					
1.A.3.a; Kerosene fossil	N2O	normal	1.0	1.0	1.0	no	gamma	150.0	90.7	196.0	yes					
1.A.3.b; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	59.2	59.2	59.2	yes					
1.A.3.b; Biomass	N2O	normal	10.0	10.0	10.0	no	gamma	149.7	90.7	195.5	yes					
1.A.3.b; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	0.4	0.4	0.4	no					
1.A.3.b; Gaseous fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.3.b; Gaseous fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.3.b; Diesel oil	CO2	normal	0.9	0.9	0.9	no	normal	0.1	0.1	0.1	no					
1.A.3.b; Diesel oil	CH4	normal	0.9	0.9	0.9	no	normal	20.0	20.0	20.0	yes					
1.A.3.b; Diesel oil	N2O	normal	0.9	0.9	0.9	no	normal	22.0	22.0	22.0	yes					
1.A.3.b; Gasoline	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	no					
1.A.3.b; Gasoline	CH4	normal	0.7	0.7	0.7	no	normal	37.0	37.0	37.0	yes					
1.A.3.b; Gasoline	N2O	normal	0.7	0.7	0.7	no	normal	50.0	50.0	50.0	yes					
1.A.3.b; Liquefied petroleum gas	CO2	normal	0.7	0.7	0.7	no	normal	10.0	10.0	10.0	yes					
1.A.3.b; Liquefied petroleum gas	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.3.b; Liquefied petroleum gas	N2O	normal	0.7	0.7	0.7	no	normal	80.0	80.0	80.0	yes					
1.A.3.b; Other fossil fuels	CO2	normal	0.9	0.9	0.9	no	normal	0.1	0.1	0.1	no					
1.A.3.b; Other fossil fuels	CH4	normal	0.9	0.9	0.9	no	normal	20.0	20.0	20.0	yes					
1.A.3.b; Other fossil fuels	N2O	normal	0.9	0.9	0.9	no	normal	22.0	22.0	22.0	yes					
1.A.3.c; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	59.2	59.2	59.2	yes					
1.A.3.c; Biomass	N2O	normal	10.0	10.0	10.0	no	gamma	149.7	90.7	195.5	yes					
1.A.3.c; Liquid fuels	CO2	normal	0.9	0.9	0.9	no	normal	0.1	0.1	0.1	no					
1.A.3.c; Liquid fuels	CH4	normal	0.9	0.9	0.9	no	normal	30.0	30.0	30.0	yes					
1.A.3.c; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	normal	80.0	80.0	80.0	yes					
1.A.3.d; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	59.2	59.2	59.2	yes					
1.A.3.d; Biomass	N2O	normal	10.0	10.0	10.0	no	gamma	149.7	90.7	195.5	yes					
1.A.3.d; Liquid fuels	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	no					
1.A.3.d; Liquid fuels	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.3.d; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	gamma	150.0	90.7	196.0	yes					
1.A.3.e; Biomass	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.3.e; Biomass	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.3.e; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	0.4	0.4	0.4	no					
1.A.3.e; Gaseous fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.3.e; Gaseous fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.4.a; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	28.3	28.3	28.3	yes					
1.A.4.a; Biomass	N2O	normal	10.0	10.0	10.0	no	normal	79.4	79.4	79.4	yes					
1.A.4.a; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	0.4	0.4	0.4	no					
1.A.4.a; Gaseous fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					

Table A – 2 (continued)

A		B		E				F				G				
Year 2023																
Code	Gas	Activity data uncertainty for a 95 %				Emission factor uncertainty for a 95 %				Emission uncertainty for a 95 % confidence						
		Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.	Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.	Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.
1.A.4.a; Gaseous fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.4.a; Gaseous fuels	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	yes					
1.A.4.a; Liquid fuels	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.4.a; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	normal	80.0	80.0	80.0	yes					
1.A.4.b; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	28.3	28.3	28.3	yes					
1.A.4.b; Biomass	N2O	normal	10.0	10.0	10.0	no	normal	79.4	79.4	79.4	yes					
1.A.4.b; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	0.4	0.4	0.4	no					
1.A.4.b; Gaseous fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.4.b; Gaseous fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.4.b; Liquid fuels	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	yes					
1.A.4.b; Liquid fuels	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.4.b; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	normal	80.0	80.0	80.0	yes					
1.A.4.b; Solid fuels	CO2	normal	5.0	5.0	5.0	no	normal	5.1	5.1	5.1	yes					
1.A.4.b; Solid fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.4.b; Solid fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.4.c; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	28.3	28.3	28.3	yes					
1.A.4.c; Biomass	N2O	normal	10.0	10.0	10.0	no	normal	79.4	79.4	79.4	yes					
1.A.4.c; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	0.4	0.4	0.4	no					
1.A.4.c; Gaseous fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.A.4.c; Gaseous fuels	N2O	normal	5.0	5.0	5.0	no	normal	79.8	79.8	79.8	yes					
1.A.4.c; Liquid fuels	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	yes					
1.A.4.c; Liquid fuels	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.4.c; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	normal	80.0	80.0	80.0	yes					
1.A.5; Biomass	CH4	normal	10.0	10.0	10.0	no	normal	59.2	59.2	59.2	yes					
1.A.5; Biomass	N2O	normal	10.0	10.0	10.0	no	gamma	149.7	90.7	195.5	yes					
1.A.5; Liquid fuels	CO2	normal	0.7	0.7	0.7	no	normal	0.1	0.1	0.1	no					
1.A.5; Liquid fuels	CH4	normal	0.7	0.7	0.7	no	normal	30.0	30.0	30.0	yes					
1.A.5; Liquid fuels	N2O	normal	0.7	0.7	0.7	no	gamma	150.0	90.7	196.0	yes					
1.B; All fuels	Indirect CO2 from CH4											normal	29.6	29.6	29.6	no
1.B; All fuels	Indirect CO2 from NMVOC											normal	34.1	34.1	34.1	no
1.B.2.a; All fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.B.2.b; All fuels	CO2	normal	5.0	5.0	5.0	no	normal	8.7	8.7	8.7	yes					
1.B.2.b; All fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.B.2.c; All fuels	CO2	normal	5.0	5.0	5.0	no	normal	8.7	8.7	8.7	yes					
1.B.2.c; All fuels	CH4	normal	5.0	5.0	5.0	no	normal	29.6	29.6	29.6	yes					
1.B.2.c; All fuels	N2O	normal	5.0	0.0	0.0	no	normal	79.8	0.0	0.0	yes					
2.A	Indirect CO2 from CO											gamma	182.2	96.1	246.7	no
2.A	Indirect CO2 from NMVOC											gamma	186.8	96.6	254.1	no
2.A.1	CO2	normal	2.0	2.0	2.0	no	normal	4.0	4.0	4.0	yes					
2.A.2	CO2	normal	2.0	2.0	2.0	no	normal	2.0	2.0	2.0	no					
2.A.3	CO2	normal	2.0	2.0	2.0	no	normal	3.0	3.0	3.0	no					
2.A.4	CO2	normal	2.0	2.0	2.0	no	normal	3.0	3.0	3.0	no					
2.B	Indirect CO2 from CH4											normal	10.2	10.2	10.2	no
2.B	Indirect CO2 from CO											normal	22.0	22.0	22.0	no
2.B	Indirect CO2 from NMVOC											normal	40.0	40.0	40.0	no
2.B.2	N2O	normal	2.0	0.0	0.0	no	normal	7.2	0.0	0.0	no					
2.B.5	CO2	normal	2.0	2.0	2.0	no	normal	22.0	22.0	22.0	yes					
2.B.5	CH4	normal	2.0	2.0	2.0	no	normal	10.0	10.0	10.0	yes					
2.B.8	CO2	normal	2.0	2.0	2.0	no	normal	10.0	10.0	10.0	no					
2.B.10	CO2	normal	2.0	2.0	2.0	no	normal	20.0	20.0	20.0	no					
2.B.10	CH4	normal	2.0	0.0	0.0	no	normal	60.0	0.0	0.0	yes					
2.B.10	N2O	normal	2.0	2.0	2.0	no	normal	60.0	60.0	60.0	no					
2.C	Indirect CO2 from CO											gamma	192.9	97.2	263.9	no
2.C	Indirect CO2 from NMVOC											gamma	99.5	73.5	121.3	no
2.C.1	CO2	normal	2.0	2.0	2.0	no	normal	50.0	50.0	50.0	no					
2.C.3	CO2	normal	5.0	0.0	0.0	no	normal	20.0	0.0	0.0	yes					
2.C.3	SF6											normal	10.0	0.0	0.0	no
2.C.3	C2F6											normal	10.0	0.0	0.0	no
2.C.3	CF4											normal	10.0	0.0	0.0	no
2.C.4	SF6											normal	30.0	0.0	0.0	no
2.C.7	CO2	normal	2.0	2.0	2.0	no	normal	20.0	20.0	20.0	yes					
2.D	Indirect CO2 from CO											gamma	202.0	97.9	278.7	no
2.D	Indirect CO2 from NMVOC											normal	35.8	35.8	35.8	no
2.D.1	CO2	normal	20.0	20.0	20.0	yes	normal	50.0	50.0	50.0	yes					
2.D.2	CO2	normal	10.0	10.0	10.0	yes	gamma	100.0	73.7	122.0	yes					
2.D.3	CO2	normal	10.0	10.0	10.0	no	normal	20.0	20.0	20.0	no					
2.E.1	SF6											gamma	94.5	71.0	114.3	no
2.E.1	C2F6											gamma	85.8	66.5	102.3	no
2.E.1	C3F8											gamma	95.0	71.3	115.0	no
2.E.1	c-C4F8											gamma	95.1	71.4	115.1	no
2.E.1	CF4											gamma	91.2	69.4	109.7	no
2.E.1	HFC-23											gamma	86.8	67.1	103.7	no
2.E.3	NF3											gamma	92.4	70.0	111.3	no
2.E.5	C6F14											gamma	85.9	66.6	102.4	no
2.F.1	C2F6											normal	33.5	33.5	33.5	no
2.F.1	C3F8											gamma	173.3	95.0	232.5	no
2.F.1	CF4											normal	31.9	31.9	31.9	no
2.F.1	HFC-125											normal	17.0	17.0	17.0	no
2.F.1	HFC-134a											normal	23.3	23.3	23.3	no
2.F.1	HFC-143a											normal	23.1	23.1	23.1	no
2.F.1	HFC-152a											gamma	50.0	0.0	0.0	no
2.F.1	HFC-23											gamma	55.8	47.7	63.0	no
2.F.1	HFC-236fa											gamma	188.1	96.8	256.2	no
2.F.1	HFC-245fa											normal	8.2	8.2	8.2	no
2.F.1	HFC-32											normal	17.4	17.4	17.4	no
2.F.2	HFC-134a											gamma	211.7	98.5	294.4	no
2.F.2	HFC-152a											gamma	1512.2	100.0	761.3	no
2.F.2	HFC-227ea											gamma	114.3	79.8	142.5	no
2.F.2	HFC-365mfc											gamma	118.4	81.4	148.5	no
2.F.4	HFC-134a											normal	29.6	29.6	29.6	no
2.F.4	HFC-152a											gamma	50.0	0.0	0.0	no
2.F.4	HFC-227ea											gamma	50.0	0.0	0.0	no
2.F.4	HFC-245fa											gamma	50.0	0.0	0.0	no
2.F.4	HFC-365mfc											gamma	52.6	45.5	59.0	no
2.F.5	HFC-43-10mee											gamma	60.0	0.0	0.0	no

Table A – 2 (continued)

Code	Gas	Year 2023										Emission uncertainty for a 95 % confidence				
		Activity data uncertainty for a 95 %					Emission factor uncertainty for a 95 %					Emission uncertainty for a 95 % confidence				
		Distribution type	std. dev. %	(-)%	(+)%	Corr.	Distribution type	std. dev. %	(-)%	(+)%	Corr.	Distribution type	std. dev. %	(-)%	(+)%	Corr.
2.G	Indirect CO2 from CO											gamma	302.6	100.0	444.2	no
2.G	Indirect CO2 from NMVOC											gamma	74.6	60.1	87.3	no
2.G.1	SF6											normal	6.8	6.8	6.8	no
2.G.2	SF6											normal	45.4	45.4	45.4	no
2.G.2	C3F8											normal	19.5	19.5	19.5	no
2.G.2	C4F10											normal	10.0	0.0	0.0	no
2.G.2	C6F14											normal	6.8	6.8	6.8	no
2.G.2	CF4											normal	10.0	0.0	0.0	no
2.G.3	N2O	normal	1.0	1.0	1.0	no	normal	80.0	80.0	80.0	yes					
2.G.4	CO2	normal	10.0	10.0	10.0	no	normal	20.0	20.0	20.0	no					
2.G.4	N2O	normal	1.0	1.0	1.0	no	normal	40.0	40.0	40.0	yes					
2.G.4	HFC-134a											normal	20.0	20.0	20.0	no
2.H	Indirect CO2 from CO											gamma	200.1	97.8	275.5	no
2.H	Indirect CO2 from NMVOC											gamma	172.3	94.8	230.9	no
2.H.3	CO2	normal	5.0	5.0	5.0	no	gamma	100.0	73.7	122.0	yes					
3.A	CH4	normal	6.5	6.5	6.5	no	gamma	19.2	18.3	20.1	no					
3.B.1-4	CH4	normal	6.5	6.5	6.5	no	normal	54.6	54.6	54.6	no					
3.B.1-4	N2O	normal	24.0	24.0	24.0	no	gamma	70.9	57.9	82.4	no					
3.B.5	N2O	gamma	55.0	47.2	62.0	no	gamma	80.0	63.3	94.4	yes					
3.D.1	N2O	normal	13.3	13.3	13.3	no	gamma	75.8	60.8	88.9	no					
3.D.2	N2O	gamma	30.5	28.1	32.7	no	gamma	62.5	52.4	71.5	no					
3.G	CO2	normal	40.0	40.0	40.0	no	normal	5.0	5.0	5.0	yes					
3.H	CO2	normal	5.0	5.0	5.0	no	normal	5.0	5.0	5.0	yes					
4.A.1	CO2	normal	1.1	1.1	1.1	yes	normal	34.9	34.9	34.9	yes					
4.A.2	CO2	normal	1.5	1.5	1.5	yes	normal	34.9	34.9	34.9	yes					
4.B.1; CS-CH-LB Carbon gains	CO2	normal	4.9	0.0	0.0	yes	normal	13.0	0.0	0.0	yes					
4.B.1; CS-CH-LB Carbon losses	CO2	normal	4.9	4.9	4.9	yes	normal	13.0	13.0	13.0	yes					
4.B.1; Net CS-CH-S Carbon min soils	CO2	normal	4.9	4.9	4.9	yes	normal	135.9	135.9	135.9	no					
4.B.1; Net CS-CH-S Carbon org soils	CO2	normal	37.3	37.3	37.3	yes	normal	23.0	23.0	23.0	yes					
4.B.1; Net CS-CH-DOM Carbon	CO2	normal	4.9	0.0	0.0	yes	normal	0.5	0.0	0.0	yes					
4.B.2; CS-CH-LB Carbon gains	CO2	normal	5.1	5.1	5.1	yes	normal	13.0	13.0	13.0	yes					
4.B.2; CS-CH-LB Carbon losses	CO2	normal	5.1	5.1	5.1	yes	normal	13.0	13.0	13.0	yes					
4.B.2; Net CS-CH-S Carbon min soils	CO2	normal	5.1	5.1	5.1	yes	normal	450.1	450.1	450.1	no					
4.B.2; Net CS-CH-S Carbon org soils	CO2	normal	37.3	37.3	37.3	yes	normal	23.0	23.0	23.0	yes					
4.B.2; Net CS-CH-DOM Carbon	CO2	normal	5.1	0.0	0.0	yes	normal	0.5	0.0	0.0	yes					
4.C.1; CS-CH-LB Carbon gains	CO2	normal	5.2	5.2	5.2	yes	normal	13.0	13.0	13.0	yes					
4.C.1; CS-CH-LB Carbon losses	CO2	normal	5.2	5.2	5.2	yes	normal	13.0	13.0	13.0	yes					
4.C.1; Net CS-CH-S Carbon min soils	CO2	normal	5.2	5.2	5.2	yes	normal	1'108.0	1'108.0	1'108.0	no					
4.C.1; Net CS-CH-S Carbon org soils	CO2	normal	68.6	68.6	68.6	yes	normal	23.0	23.0	23.0	yes					
4.C.1; Net CS-CH-DOM Carbon	CO2	normal	5.2	0.0	0.0	yes	normal	0.5	0.0	0.0	yes					
4.C.2; CS-CH-LB Carbon gains	CO2	normal	5.3	5.3	5.3	yes	normal	13.0	13.0	13.0	yes					
4.C.2; CS-CH-LB Carbon losses	CO2	normal	5.3	5.3	5.3	yes	normal	13.0	13.0	13.0	yes					
4.C.2; Net CS-CH-S Carbon min soils	CO2	normal	5.3	5.3	5.3	yes	normal	107.8	107.8	107.8	no					
4.C.2; Net CS-CH-S Carbon org soils	CO2	normal	68.6	68.6	68.6	yes	normal	23.0	23.0	23.0	yes					
4.C.2; Net CS-CH-DOM Carbon	CO2	normal	5.3	5.3	5.3	yes	normal	0.5	0.5	0.5	yes					
4.D.1	CO2	normal	90.8	90.8	90.8	yes	normal	72.2	72.2	72.2	yes					
4.D.2; CS-CH-LB Carbon gains	CO2	normal	3.7	3.7	3.7	yes	normal	13.0	13.0	13.0	yes					
4.D.2; CS-CH-LB Carbon losses	CO2	normal	3.7	3.7	3.7	yes	normal	13.0	13.0	13.0	yes					
4.D.2; Net CS-CH-S Carbon min soils	CO2	normal	3.7	3.7	3.7	yes	normal	50.0	50.0	50.0	yes					
4.D.2; Net CS-CH-S Carbon org soils	CO2	normal	90.8	90.8	90.8	yes	normal	72.2	72.2	72.2	yes					
4.D.2; Net CS-CH-DOM Carbon	CO2	normal	3.7	3.7	3.7	yes	normal	0.5	0.5	0.5	yes					
4.E.1	CO2	normal	4.4	4.4	4.4	yes	normal	50.0	50.0	50.0	yes					
4.E.2	CO2	normal	4.6	4.6	4.6	yes	normal	50.0	50.0	50.0	yes					
4.F.2	CO2	normal	3.1	3.1	3.1	yes	normal	50.0	50.0	50.0	yes					
4.G	CO2	normal	11.2	11.2	11.2	yes	normal	54.8	54.8	54.8	yes					
4(II)	CH4	normal	10.0	10.0	10.0	yes	normal	70.0	70.0	70.0	yes					
4(II)	N2O	normal	50.8	50.8	50.8	yes	normal	66.9	66.9	66.9	yes					
4(III)*D	N2O	normal	83.5	83.5	83.5	yes	gamma	90.0	68.8	108.1	yes					
4(III)*I	N2O	normal	85.8	85.8	85.8	yes	gamma	100.0	73.7	122.0	yes					
4(IV)	CH4	normal	30.0	30.0	30.0	yes	normal	70.0	70.0	70.0	yes					
4(IV)	N2O	normal	30.0	30.0	30.0	yes	normal	70.0	70.0	70.0	yes					
5.A	CO2											normal	10.0	0.0	0.0	yes
5.A	CH4											normal	30.0	30.0	30.0	yes
5.B	CH4	normal	30.0	30.0	30.0	no	normal	30.0	30.0	30.0	yes					
5.B	N2O	normal	30.0	30.0	30.0	no	normal	30.0	30.0	30.0	yes					
5.C	CO2	normal	30.0	30.0	30.0	no	normal	26.5	26.5	26.5	yes					
5.C	CH4	normal	50.0	50.0	50.0	no	normal	33.2	33.2	33.2	yes					
5.C	N2O	normal	30.0	30.0	30.0	no	gamma	147.0	90.0	191.4	yes					
5.C	Indirect CO2 from CH4											gamma	60.6	51.1	69.1	no
5.C	Indirect CO2 from CO											gamma	71.9	58.5	83.7	no
5.C	Indirect CO2 from NMVOC											gamma	71.8	58.4	83.6	no
5.D	CH4											gamma	100.0	73.7	122.0	no
5.D	N2O											gamma	50.0	43.6	55.9	no
5.E	Indirect CO2 from CO											normal	28.3	28.3	28.3	no
5.E	Indirect CO2 from NMVOC											normal	31.0	31.0	31.0	no
6.A	Indirect CO2 from CH4											gamma	87.8	67.6	105.0	no
6.A	Indirect CO2 from CO											gamma	76.9	61.5	90.3	no
6.A	Indirect CO2 from NMVOC											gamma	58.8	49.9	66.8	no
6.A.1.a	CO2	normal	60.0	60.0	60.0	no	gamma	120.0	82.0	150.8	yes					
6.A.1.a	CH4	normal	50.0	50.0	50.0	no	gamma	100.0	73.7	122.0	yes					
6.A.1.a	N2O	normal	50.0	50.0	50.0	no	gamma	150.0	90.7	196.0	yes					
6.A.1.b	CO2	normal	50.0	50.0	50.0	no	gamma	120.0	82.0	150.8	yes					
6.A.1.b	CH4	normal	50.0	50.0	50.0	no	gamma	100.0	73.7	122.0	yes					

Table A – 3 Input uncertainties for the year 1990, including LULUCF categories and indirect CO<sub>2</sub> emissions. Only uncertainty inputs not equal to their corresponding value for the latest reporting year are reported here. Input uncertainties are assigned to activity data (column E) and emissions factors (column F) or, if unknown, to emissions only (column G). The uncertainties are given considering a 95 % confidence interval (from 2.5 % to 97.5 %) and expressed as the distance from edge to mean, in percentage of the mean. Columns are labelled according to Table 3-2 in the 2006 IPCC Guidelines, vol.1, chp. 3 (IPCC 2006). Abbreviations used within sector 4 LULUCF: Net CS-CH-S Carbon min soils: net carbon stock change in mineral soils.

A		B		E					F					G				
Year 1990																		
Code	Gas	Activity data uncertainty for a 95 %					Emission factor uncertainty for a 95 %					Emission uncertainty for a 95 % confidence						
		Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.	Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.	Distribu- tion type	std. dev. %	(-)%	(+)%	Corr.		
1.A.1; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	1.5	1.5	1.5	no							
1.A.2; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	1.5	1.5	1.5	no							
1.A.3.e; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	1.5	1.5	1.5	no							
1.A.4.a; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	1.5	1.5	1.5	no							
1.A.4.b; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	1.5	1.5	1.5	no							
1.A.4.c; Gaseous fuels	CO2	normal	5.0	5.0	5.0	no	normal	1.5	1.5	1.5	no							
1.B; All fuels	Indirect CO2 from CH4											normal	28.8	28.8	28.8	no		
1.B; All fuels	Indirect CO2 from NMVOC											normal	37.0	37.0	37.0	no		
2.A	Indirect CO2 from CO											gamma	222.3	99.0	311.8	no		
2.A	Indirect CO2 from NMVOC											gamma	183.8	96.3	249.2	no		
2.A.2	CO2	normal	2.0	2.0	2.0	no	normal	6.0	6.0	6.0	no							
2.A.3	CO2	normal	2.0	2.0	2.0	no	normal	30.0	30.0	30.0	no							
2.A.4	CO2	normal	2.0	2.0	2.0	no	normal	30.0	30.0	30.0	no							
2.B	Indirect CO2 from CH4											normal	10.0	10.0	10.0	no		
2.B	Indirect CO2 from CO											normal	21.6	21.6	21.6	no		
2.B	Indirect CO2 from NMVOC											normal	40.0	40.0	40.0	no		
2.B.2	N2O	normal	2.0	2.0	2.0	no	normal	60.0	60.0	60.0	no							
2.B.10	CO2	normal	2.0	2.0	2.0	no	normal	60.0	60.0	60.0	no							
2.C	Indirect CO2 from CO											gamma	196.1	97.5	269.1	no		
2.C	Indirect CO2 from NMVOC											gamma	94.9	71.2	114.8	no		
2.D	Indirect CO2 from CO											gamma	202.0	97.9	278.7	no		
2.D	Indirect CO2 from NMVOC											normal	40.3	40.3	40.3	no		
2.D.3	CO2	normal	10.0	10.0	10.0	no	normal	50.0	50.0	50.0	no							
2.G	Indirect CO2 from CO											gamma	302.6	100.0	444.2	no		
2.G	Indirect CO2 from NMVOC											gamma	83.3	65.2	98.9	no		
2.G.4	CO2	normal	10.0	10.0	10.0	no	normal	50.0	50.0	50.0	no							
2.H	Indirect CO2 from CO											gamma	200.1	97.8	275.5	no		
2.H	Indirect CO2 from NMVOC											gamma	165.6	93.8	220.4	no		
3.A	CH4	normal	6.4	6.4	6.4	no	gamma	20.1	19.1	21.1	no							
3.B.1-4	CH4	normal	6.4	6.4	6.4	no	normal	54.1	54.1	54.1	no							
3.B.1-4	N2O	normal	21.0	21.0	21.0	no	gamma	70.8	57.7	82.2	no							
3.B.5	N2O	gamma	53.1	45.9	59.7	no	gamma	80.0	63.3	94.4	yes							
3.D.1	N2O	normal	13.5	13.5	13.5	no	gamma	80.1	63.4	94.6	no							
3.D.2	N2O	gamma	29.8	27.5	31.9	no	gamma	62.5	52.4	71.5	no							
4.B.1; Net CS-CH-S Carbon min soils	CO2	normal	4.9	4.9	4.9	yes	normal	237.8	237.8	237.8	no							
4.B.2; Net CS-CH-S Carbon min soils	CO2	normal	5.1	5.1	5.1	yes	normal	156.1	156.1	156.1	no							
4.C.1; Net CS-CH-S Carbon min soils	CO2	normal	5.2	5.2	5.2	yes	normal	86.0	86.0	86.0	no							
4.C.2; Net CS-CH-S Carbon min soils	CO2	normal	5.3	5.3	5.3	yes	normal	103.3	103.3	103.3	no							
5.C	Indirect CO2 from CH4											gamma	60.7	51.2	69.2	no		
5.C	Indirect CO2 from CO											gamma	68.4	56.3	79.1	no		
5.C	Indirect CO2 from NMVOC											gamma	69.6	57.0	80.7	no		
5.D	N2O											gamma	90.0	68.8	108.1	no		
5.E	Indirect CO2 from CO											normal	28.4	28.4	28.4	no		
5.E	Indirect CO2 from NMVOC											normal	30.9	30.9	30.9	no		
6.A	Indirect CO2 from CH4											gamma	102.0	74.6	124.9	no		
6.A	Indirect CO2 from CO											gamma	76.9	61.5	90.3	no		
6.A	Indirect CO2 from NMVOC											gamma	58.8	49.9	66.8	no		

## A2.2 Detailed results of approach 1 uncertainty analysis

Table A – 4 Uncertainty analysis of greenhouse gas emissions and removals, approach 1, for 2023 and for the trend 1990–2023, including LULUCF categories and indirect CO<sub>2</sub> emissions. The uncertainties are given considering a 95 % confidence interval (from 2.5 % to 97.5 %), and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission. “d.EM”: stands for direct emission and indicates that input uncertainties are given for the emission but neither for activity data nor for emission factor. Columns are labelled according to Table 3-2 in the 2006 IPCC Guidelines, vol.1, chp. 3 (IPCC 2006). “Agg.”: indicates that values for AD and EF cannot be computed because the row results from an aggregation. Abbreviations 4(III)\*D/I: direct/indirect N<sub>2</sub>O emissions.

IPCC category; fuel/source	Gas	C	D	G		H		I	J	K		L		M	
		Emissions 1990	Emissions 2023	Emission combined uncertainty 2023		Category contribution to inventory variance 2023		Sensitivity if corr. (type A)	Sensitivity if not corr. (type B)	Contribution to inventory trend uncertainty from AD		Contribution to inventory trend uncertainty from EF		Contribution to inventory trend uncertainty from EM	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1.A.1; Biomass	CH <sub>4</sub>	0.10	0.20	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.1; Biomass	N <sub>2</sub> O	20.12	14.10	80	80	0.001	0.001	0.000	0.000	0.004	0.004	0.003	0.003	0.000	0.000
1.A.1; Gaseous fuels	CO <sub>2</sub>	243.40	345.62	5	5	0.002	0.002	0.003	0.007	0.046	0.046	0.004	0.004	0.002	0.002
1.A.1; Gaseous fuels	CH <sub>4</sub>	0.14	0.61	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.1; Gaseous fuels	N <sub>2</sub> O	0.14	0.74	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1.A.1; Liquid fuels	CO <sub>2</sub>	685.86	356.53	1	1	0.000	0.000	0.004	0.007	0.007	0.007	0.000	0.000	0.000	0.000
1.A.1; Liquid fuels	CH <sub>4</sub>	0.58	0.20	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.1; Liquid fuels	N <sub>2</sub> O	1.01	0.24	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1.A.1; Solid fuels	CO <sub>2</sub>	49.13	NO	NO	NO	NO	NO	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.1; Solid fuels	CH <sub>4</sub>	0.15	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.1; Solid fuels	N <sub>2</sub> O	0.21	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.1; Other fossil fuels	CO <sub>2</sub>	1'491.55	2'430.90	18	18	1.033	1.033	0.023	0.046	0.327	0.327	0.397	0.397	0.264	0.264
1.A.1; Other fossil fuels	N <sub>2</sub> O	21.63	22.81	80	80	0.002	0.002	0.000	0.000	0.003	0.003	0.049	0.049	0.002	0.002
1.A.2; Biomass	CH <sub>4</sub>	2.91	1.01	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1.A.2; Biomass	N <sub>2</sub> O	4.69	16.20	80	80	0.001	0.001	0.000	0.000	0.004	0.004	0.019	0.019	0.000	0.000
1.A.2; Gaseous fuels	CO <sub>2</sub>	1'100.12	1'668.06	5	5	0.039	0.039	0.015	0.032	0.224	0.224	0.017	0.017	0.051	0.051
1.A.2; Gaseous fuels	CH <sub>4</sub>	0.61	0.85	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.2; Gaseous fuels	N <sub>2</sub> O	0.62	0.81	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.2; Liquid fuels	CO <sub>2</sub>	3'974.10	1'465.33	1	1	0.001	0.001	0.033	0.028	0.027	0.027	0.003	0.003	0.001	0.001
1.A.2; Liquid fuels	CH <sub>4</sub>	5.14	1.00	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
1.A.2; Liquid fuels	N <sub>2</sub> O	11.87	8.84	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1.A.2; Solid fuels	CO <sub>2</sub>	1'274.70	286.10	7	7	0.002	0.002	0.014	0.005	0.038	0.038	0.071	0.071	0.007	0.007
1.A.2; Solid fuels	CH <sub>4</sub>	0.35	0.16	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.2; Solid fuels	N <sub>2</sub> O	5.46	1.20	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.000	0.000
1.A.2; Other fossil fuels	CO <sub>2</sub>	192.37	408.16	10	10	0.010	0.010	0.005	0.008	0.055	0.055	0.045	0.045	0.005	0.005
1.A.2; Other fossil fuels	CH <sub>4</sub>	0.87	0.63	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.2; Other fossil fuels	N <sub>2</sub> O	1.97	4.83	80	80	0.000	0.000	0.000	0.000	0.001	0.001	0.010	0.010	0.000	0.000
1.A.3.a; Kerosene fossil	CO <sub>2</sub>	252.55	64.57	1	1	0.000	0.000	0.003	0.001	0.002	0.002	0.000	0.000	0.000	0.000
1.A.3.a; Kerosene fossil	CH <sub>4</sub>	0.19	0.09	60	60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.a; Kerosene fossil	N <sub>2</sub> O	1.83	0.47	91	196	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.004	0.000	0.000
1.A.3.b; Biomass	CH <sub>4</sub>	NO	0.68	60	60	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1.A.3.b; Biomass	N <sub>2</sub> O	NO	4.18	91	196	0.000	0.000	0.000	0.000	0.001	0.001	0.007	0.016	0.000	0.000
1.A.3.b; Gaseous fuels	CO <sub>2</sub>	NO	28.51	5	5	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000	0.000	0.000
1.A.3.b; Gaseous fuels	CH <sub>4</sub>	NO	0.22	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b; Gaseous fuels	N <sub>2</sub> O	NO	0.04	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b; Diesel oil	CO <sub>2</sub>	2'631.94	6'860.11	1	1	0.021	0.021	0.090	0.130	0.163	0.163	0.013	0.013	0.027	0.027
1.A.3.b; Diesel oil	CH <sub>4</sub>	2.56	7.14	20	20	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
1.A.3.b; Diesel oil	N <sub>2</sub> O	5.37	90.27	22	22	0.002	0.002	0.002	0.002	0.002	0.002	0.036	0.036	0.001	0.001
1.A.3.b; Gasoline	CO <sub>2</sub>	11'328.41	6'365.75	1	1	0.011	0.011	0.052	0.121	0.117	0.117	0.022	0.022	0.014	0.014
1.A.3.b; Gasoline	CH <sub>4</sub>	127.19	13.27	37	37	0.000	0.000	0.002	0.000	0.000	0.000	0.062	0.062	0.004	0.004
1.A.3.b; Gasoline	N <sub>2</sub> O	142.64	12.79	50	50	0.000	0.000	0.002	0.000	0.000	0.000	0.097	0.097	0.009	0.009
1.A.3.b; Liquefied petroleum gas	CO <sub>2</sub>	NO	1.39	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b; Liquefied petroleum gas	CH <sub>4</sub>	NO	0.00	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b; Liquefied petroleum gas	N <sub>2</sub> O	NO	0.01	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b; Other fossil fuels	CO <sub>2</sub>	NO	16.81	1	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b; Other fossil fuels	CH <sub>4</sub>	NO	0.02	20	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b; Other fossil fuels	N <sub>2</sub> O	NO	0.22	22	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.c; Biomass	CH <sub>4</sub>	NO	0.00	60	60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.c; Biomass	N <sub>2</sub> O	NO	0.02	91	196	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.c; Liquid fuels	CO <sub>2</sub>	28.69	27.82	1	1	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
1.A.3.c; Liquid fuels	CH <sub>4</sub>	0.03	0.01	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.c; Liquid fuels	N <sub>2</sub> O	0.38	0.36	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.d; Biomass	CH <sub>4</sub>	NO	0.01	60	60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.d; Biomass	N <sub>2</sub> O	NO	0.04	91	196	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.d; Liquid fuels	CO <sub>2</sub>	114.27	110.38	1	1	0.000	0.000	0.000	0.002	0.002	0.002	0.000	0.000	0.000	0.000
1.A.3.d; Liquid fuels	CH <sub>4</sub>	1.88	0.35	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1.A.3.d; Liquid fuels	N <sub>2</sub> O	1.03	1.05	91	196	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
1.A.3.e; Gaseous fuels	CO <sub>2</sub>	31.42	9.50	5	5	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
1.A.3.e; Gaseous fuels	CH <sub>4</sub>	0.08	0.02	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.e; Gaseous fuels	N <sub>2</sub> O	0.10	0.03	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.4.a; Biomass	CH <sub>4</sub>	9.55	5.08	30	30	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
1.A.4.a; Biomass	N <sub>2</sub> O	3.27	12.49	80	80	0.001	0.001	0.000	0.000	0.003	0.003	0.015	0.015	0.000	0.000
1.A.4.a; Gaseous fuels	CO <sub>2</sub>	928.49	959.99	5	5	0.013	0.013	0.004	0.018	0.129	0.129	0.010	0.010	0.017	0.017
1.A.4.a; Gaseous fuels	CH <sub>4</sub>	2.32	2.41	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.4.a; Gaseous fuels	N <sub>2</sub> O	0.49	0.61	80	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.A.4.a; Liquid fuels	CO <sub>2</sub>	3'918.47	1'891.60	1	1	0.001	0.001	0.024	0.036	0.035	0.035	0.002	0.002	0.001	0.001

Table A – 4 (continued)

A	B	C	D	G	H	I	J	K	L	M
IPCC category; fuel/source	Gas	Emissions 1990	Emissions 2023	Emission combined uncertainty 2023	Category contribution to inventory variance 2023	Sensitivi- ty if corr. (type A)	Sensitivi- ty if not corr. (type B)	Contribution to inventory trend uncertainty from AD	Contribution to inventory trend uncertainty from EF	Contribution to inventory trend uncertainty from EM
				(-)% (+)%	(-)% (+)%			(-)% (+)%	(-)% (+)%	(-)% (+)%
1.A.4.a; Liquid fuels	CH4	16.89	7.55	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.003 0.003	0.000 0.000
1.A.4.a; Liquid fuels	N2O	8.72	4.40	80 80	0.000 0.000	0.000	0.000	0.000 0.000	0.004 0.004	0.000 0.000
1.A.4.b; Biomass	CH4	103.98	22.47	30 30	0.000 0.000	0.001	0.000	0.006 0.006	0.033 0.033	0.001 0.001
1.A.4.b; Biomass	N2O	23.00	19.03	80 80	0.001 0.001	0.000	0.000	0.005 0.005	0.001 0.001	0.000 0.000
1.A.4.b; Gaseous fuels	CO2	1'465.04	2'409.54	5 5	0.082 0.082	0.023	0.046	0.324 0.324	0.025 0.025	0.106 0.106
1.A.4.b; Gaseous fuels	CH4	3.66	6.04	30 30	0.000 0.000	0.000	0.000	0.001 0.001	0.002 0.002	0.000 0.000
1.A.4.b; Gaseous fuels	N2O	0.70	1.16	80 80	0.000 0.000	0.000	0.000	0.000 0.000	0.001 0.001	0.000 0.000
1.A.4.b; Liquid fuels	CO2	10'099.09	3'681.59	1 1	0.004 0.004	0.084	0.070	0.068 0.068	0.007 0.007	0.005 0.005
1.A.4.b; Liquid fuels	CH4	39.01	14.10	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.010 0.010	0.000 0.000
1.A.4.b; Liquid fuels	N2O	21.81	7.98	80 80	0.000 0.000	0.000	0.000	0.000 0.000	0.014 0.014	0.000 0.000
1.A.4.b; Solid fuels	CO2	58.40	4.64	7 7	0.000 0.000	0.001	0.000	0.001 0.001	0.004 0.004	0.000 0.000
1.A.4.b; Solid fuels	CH4	5.29	0.42	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.002 0.002	0.000 0.000
1.A.4.b; Solid fuels	N2O	0.25	0.02	80 80	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.A.4.c; Biomass	CH4	1.22	0.57	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.A.4.c; Biomass	N2O	0.46	1.65	80 80	0.000 0.000	0.000	0.000	0.000 0.000	0.002 0.002	0.000 0.000
1.A.4.c; Gaseous fuels	CO2	70.22	90.87	5 5	0.000 0.000	0.001	0.002	0.012 0.012	0.001 0.001	0.000 0.000
1.A.4.c; Gaseous fuels	CH4	0.04	0.05	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.A.4.c; Gaseous fuels	N2O	0.03	0.04	80 80	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.A.4.c; Liquid fuels	CO2	742.46	444.67	1 1	0.000 0.000	0.003	0.008	0.008 0.008	0.000 0.000	0.000 0.000
1.A.4.c; Liquid fuels	CH4	7.52	1.20	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.003 0.003	0.000 0.000
1.A.4.c; Liquid fuels	N2O	4.29	3.97	80 80	0.000 0.000	0.000	0.000	0.000 0.000	0.001 0.001	0.000 0.000
1.A.5; Biomass	CH4	NO	0.00	60 60	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.A.5; Biomass	N2O	NO	0.01	91 196	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.A.5; Liquid fuels	CO2	217.65	123.18	1 1	0.000 0.000	0.001	0.002	0.002 0.002	0.000 0.000	0.000 0.000
1.A.5; Liquid fuels	CH4	0.13	0.04	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.A.5; Liquid fuels	N2O	1.64	0.96	91 196	0.000 0.000	0.000	0.000	0.000 0.000	0.001 0.001	0.000 0.000
1.B; All fuels	Indirect CO2 from CH4	9.12	4.11	30 30	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
1.B; All fuels	Indirect CO2 from NMVOC	45.75	5.29	34 34	0.000 0.000	0.001	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
1.B.2.a; All fuels	CH4	3.94	0.56	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.001 0.001	0.000 0.000
1.B.2.b; All fuels	CO2	0.09	0.02	10 10	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.B.2.b; All fuels	CH4	88.96	41.28	30 30	0.001 0.001	0.001	0.001	0.006 0.006	0.017 0.017	0.000 0.000
1.B.2.c; All fuels	CO2	25.96	13.99	10 10	0.000 0.000	0.000	0.000	0.002 0.002	0.001 0.001	0.000 0.000
1.B.2.c; All fuels	CH4	0.38	0.00	30 30	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
1.B.2.c; All fuels	N2O	0.02	NO	NO NO	NO NO	NO	0.000	0.000 0.000	0.000 0.000	0.000 0.000
2.A	Indirect CO2 from CO	0.04	0.02	96 247	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.A	Indirect CO2 from NMVOC	0.10	0.06	97 254	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.A.1	CO2	2'550.12	1'506.36	4 4	0.026 0.026	0.010	0.029	0.081 0.081	0.041 0.041	0.008 0.008
2.A.2	CO2	53.34	50.12	3 3	0.000 0.000	0.000	0.001	0.003 0.003	0.003 0.003	0.000 0.000
2.A.3	CO2	15.25	3.99	4 4	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
2.A.4	CO2	160.33	62.92	4 4	0.000 0.000	0.001	0.001	0.003 0.003	0.005 0.005	0.000 0.000
2.B	Indirect CO2 from CH4	0.39	0.50	10 10	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.B	Indirect CO2 from CO	6.33	4.54	22 22	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.B	Indirect CO2 from NMVOC	1.29	0.00	40 40	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.B.2	N2O	58.24	NO	NO NO	NO NO	NO	0.001	0.000 0.000	0.000 0.000	0.000 0.000
2.B.5	CO2	15.36	9.19	22 22	0.000 0.000	0.000	0.000	0.000 0.000	0.001 0.001	0.000 0.000
2.B.5	CH4	3.88	5.14	10 10	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
2.B.8	CO2	94.08	106.56	10 10	0.001 0.001	0.001	0.002	0.006 0.006	0.029 0.029	0.001 0.001
2.B.10	CO2	17.34	18.10	20 20	0.000 0.000	0.000	0.000	0.001 0.001	0.010 0.010	0.000 0.000
2.B.10	CH4	0.10	NO	NO NO	NO NO	NO	0.000	0.000 0.000	0.000 0.000	0.000 0.000
2.B.10	N2O	384.50	1.21	60 60	0.000 0.000	0.006	0.000	0.000 0.000	0.002 0.002	0.000 0.000
2.C	Indirect CO2 from CO	1.10	0.14	97 264	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.C	Indirect CO2 from NMVOC	2.25	0.27	73 121	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.C.1	CO2	11.91	7.02	50 50	0.000 0.000	0.000	0.000	0.000 0.000	0.009 0.009	0.000 0.000
2.C.3	CO2	139.26	NO	NO NO	NO NO	NO	0.002	0.000 0.000	0.000 0.000	0.000 0.000
2.C.3	PFCs	104.71	NO	NO NO	NO NO	NO	Agg.	Agg.	Agg.	Agg.
2.C.7	CO2	NO	1.30	20 20	0.000 0.000	0.000	0.000	0.000 0.000	0.000 0.000	0.000 0.000
2.D	Indirect CO2 from CO	0.00	0.00	98 279	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.D	Indirect CO2 from NMVOC	194.04	35.56	36 36	0.001 0.001	0.002	0.001	d.EM d.EM	d.EM d.EM	0.001 0.001
2.D.1	CO2	48.34	25.09	54 54	0.001 0.001	0.000	0.000	0.005 0.005	0.013 0.013	0.000 0.000
2.D.2	CO2	6.32	1.53	74 122	0.000 0.000	0.000	0.000	0.001 0.001	0.005 0.005	0.000 0.000
2.D.3	CO2	3.65	25.03	22 22	0.000 0.000	0.000	0.000	0.007 0.007	0.013 0.013	0.000 0.000
2.E.1	HFCs	NO	0.27	67 104	0.000 0.000	Agg.	Agg.	Agg.	Agg.	Agg.
2.E.1	PFCs	NO	4.61	46 72	0.000 0.000	Agg.	Agg.	Agg.	Agg.	Agg.
2.E.1	SF6	NO	2.87	71 114	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000
2.E.3	NF3	NO	0.62	70 111	0.000 0.000	0.000	0.000	d.EM d.EM	d.EM d.EM	0.000 0.000



Table A – 4 (continued)

A	B	C	D	G		H		I	J	K		L		M	
IPCC category; fuel/source	Gas	Emissions 1990	Emissions 2023	Emission combined uncertainty 2023		Category contribution to inventory variance 2023		Sensitivity if corr. (type A)	Sensitivity if not corr. (type B)	Contribution to inventory trend uncertainty from AD		Contribution to inventory trend uncertainty from EF		Contribution to inventory trend uncertainty from EM	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
2.E.5	PFCs	NO	0.14	67	102	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
2.F.1	HFCs	0.02	1'109.54	12	12	0.106	0.106	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.136	0.136
2.F.1	PFCs	0.05	2.10	24	26	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
2.F.2	HFCs	NO	61.47	84	251	0.015	0.134	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.019	0.172
2.F.4	HFCs	NO	13.39	28	28	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
2.G	HFCs	NO	41.67	20	20	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.001	0.001
2.G	PFCs	NO	21.20	7	7	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
2.G	SF6	141.21	54.88	27	27	0.001	0.001	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.002	0.002
2.G	Indirect CO2 from CO	0.01	0.01	100	444	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
2.G	Indirect CO2 from NMVOC	125.50	40.32	60	87	0.003	0.007	0.001	0.001	d.EM	d.EM	d.EM	d.EM	0.004	0.009
2.G.3	N2O	92.49	28.82	80	80	0.003	0.003	0.001	0.001	0.001	0.001	0.069	0.069	0.005	0.005
2.G.4	CO2	6.07	31.75	22	22	0.000	0.000	0.001	0.001	0.009	0.009	0.017	0.017	0.000	0.000
2.G.4	N2O	5.31	6.83	40	40	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
2.H	Indirect CO2 from CO	1.27	0.31	98	276	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
2.H	Indirect CO2 from NMVOC	1.56	0.48	95	231	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
2.H.3	CO2	1.04	0.26	74	122	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
3.A	CH4	3'930.28	3'603.51	19	21	2.754	3.266	0.009	0.069	0.626	0.626	1.774	1.951	3.539	4.197
3.B.1-4	CH4	776.91	602.24	55	55	0.617	0.617	0.000	0.011	0.105	0.105	0.884	0.884	0.793	0.793
3.B.1-4	N2O	168.20	106.74	63	86	0.025	0.047	0.001	0.002	0.069	0.069	0.166	0.237	0.032	0.061
3.B.5	N2O	208.60	229.94	79	113	0.185	0.380	0.001	0.004	0.292	0.383	0.076	0.113	0.091	0.160
3.D.1	N2O	1'271.39	989.71	62	90	2.140	4.455	0.001	0.019	0.355	0.355	1.620	2.366	2.750	5.725
3.D.2	N2O	638.23	423.09	59	79	0.356	0.623	0.002	0.008	0.320	0.372	0.596	0.814	0.458	0.801
3.G	CO2	22.25	32.78	40	40	0.001	0.001	0.000	0.001	0.035	0.035	0.001	0.001	0.001	0.001
3.H	CO2	26.66	13.39	7	7	0.000	0.000	0.000	0.000	0.002	0.002	0.001	0.001	0.000	0.000
4.A.1	CO2	-1'286.33	393.41	35	35	0.106	0.106	0.027	0.007	0.030	0.030	0.946	0.946	0.895	0.895
4.A.2	CO2	-767.08	-786.02	35	35	0.424	0.424	0.003	0.015	0.005	0.005	0.114	0.114	0.013	0.013
4.B.1	CO2	523.25	471.36	91	91	1.039	1.039	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	1.193	1.193
4.B.2	CO2	5.98	42.46	26	26	0.001	0.001	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
4.C.1	CO2	-644.51	386.74	624	624	32.816	32.816	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	41.941	41.941
4.C.2	CO2	191.09	351.96	17	17	0.019	0.019	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.012	0.012
4.D.1	CO2	114.68	112.46	116	116	0.096	0.096	0.000	0.002	0.035	0.035	0.028	0.028	0.002	0.002
4.D.2	CO2	28.38	32.45	22	22	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
4.E.1	CO2	-55.24	-52.85	50	50	0.004	0.004	0.000	0.001	0.001	0.001	0.008	0.008	0.000	0.000
4.E.2	CO2	212.33	155.01	50	50	0.034	0.034	0.000	0.003	0.001	0.001	0.014	0.014	0.000	0.000
4.F.2	CO2	76.41	90.75	50	50	0.012	0.012	0.001	0.002	0.002	0.002	0.028	0.028	0.001	0.001
4.G	CO2	-1'149.13	41.98	56	56	0.003	0.003	0.018	0.001	0.205	0.205	1.004	1.004	1.050	1.050
4(II)	CH4	11.20	11.20	71	71	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
4(II)	N2O	4.27	4.18	84	84	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
4(III)+D	N2O	26.96	30.62	108	137	0.006	0.010	0.000	0.001	0.014	0.014	0.012	0.019	0.000	0.001
4(III)+F	N2O	6.11	6.00	113	149	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.000	0.000
4(IV)	CH4	24.13	5.28	76	76	0.000	0.000	0.000	0.000	0.008	0.008	0.019	0.019	0.000	0.000
4(IV)	N2O	11.04	2.23	76	76	0.000	0.000	0.000	0.000	0.004	0.004	0.009	0.009	0.000	0.000
5.A	CH4	862.11	261.32	30	30	0.035	0.035	0.008	0.005	d.EM	d.EM	d.EM	d.EM	0.060	0.060
5.B	CH4	13.32	31.60	42	42	0.001	0.001	0.000	0.001	0.026	0.026	0.012	0.012	0.001	0.001
5.B	N2O	4.64	7.74	42	42	0.000	0.000	0.000	0.000	0.006	0.006	0.002	0.002	0.000	0.000
5.C	CO2	40.23	8.31	40	40	0.000	0.000	0.000	0.000	0.007	0.007	0.012	0.012	0.000	0.000
5.C	CH4	8.93	5.05	60	60	0.000	0.000	0.000	0.000	0.007	0.007	0.001	0.001	0.000	0.000
5.C	N2O	64.27	53.28	95	194	0.014	0.060	0.000	0.001	0.043	0.043	0.003	0.006	0.002	0.002
5.C	Indirect CO2 from CH4	0.26	0.13	51	69	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
5.C	Indirect CO2 from CO	1.32	0.61	58	84	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
5.C	Indirect CO2 from NMVOC	0.58	0.27	58	84	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
5.D	CH4	198.20	229.85	74	122	0.162	0.443	0.001	0.004	d.EM	d.EM	d.EM	d.EM	0.208	0.569
5.D	N2O	1'056.47	516.55	44	56	0.285	0.469	0.006	0.010	d.EM	d.EM	d.EM	d.EM	0.367	0.602
5.E	Indirect CO2 from CO	0.00	0.00	28	28	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
5.E	Indirect CO2 from NMVOC	0.06	0.13	31	31	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
6.A	CO2	12.76	8.17	81	130	0.000	0.001	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
6.A	CH4	0.83	0.46	71	104	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
6.A	N2O	0.60	0.27	104	202	0.000	0.000	Agg.	Agg.	Agg.	Agg.	Agg.	Agg.	0.000	0.000
6.A	Indirect CO2 from CH4	0.06	0.04	68	105	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
6.A	Indirect CO2 from CO	1.00	0.59	61	90	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
6.A	Indirect CO2 from NMVOC	0.22	0.12	50	67	0.000	0.000	0.000	0.000	d.EM	d.EM	d.EM	d.EM	0.000	0.000
Total				Emissions 2023 uncertainty (%)		42.5	46.5			Trend uncertainty (%):				54.1	58.9
Total				Emissions 2023 uncertainty (%)		6.5	6.8			Trend uncertainty (%):				7.4	7.7

## A2.3 Detailed results of approach 2 uncertainty analysis

Table A – 5 Uncertainty analysis of greenhouse gas emissions and removals, approach 2, for 2023 and for the trend 1990–2023, including LULUCF categories and indirect CO<sub>2</sub> emissions. “d.EM” stands for direct emission and indicates that input uncertainties are given for the emission but neither for the activity data nor for the emission factor. Monte Carlo simulations were run 100'000 times. The reported uncertainties correspond to the borders of the narrowest 95 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission. Columns A to J are labelled according to Table 3-3 in the 2006 IPCC Guidelines, vol.1, chp. 3 (IPCC 2006). “Agg.”: indicates that values for AD and EF cannot be computed because the row results from an aggregation. Abbreviations 4(III)\*D/I: direct/indirect N<sub>2</sub>O emissions.

A IPCC category; fuel/source	B Gas	C Emissions 1990	D Emissions 2023	E Activity data uncertainty 2023		F Emission factor uncertainty 2023		G Emission combined uncertainty 2023		H Emission contribution to variance 2023	I Contribution to trend	J Contribution to uncertainty of trend	
		kt CO <sub>2</sub> eq.	kt CO <sub>2</sub> eq.	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1.A.1; Biomass	CH <sub>4</sub>	0.10	0.20	10	10	29	28	30	30	0.000	0.000	0.000	0.000
1.A.1; Biomass	N <sub>2</sub> O	20.12	14.10	10	10	81	78	81	80	0.000	-0.011	0.011	0.010
1.A.1; Gaseous fuels	CO <sub>2</sub>	243.40	345.62	5	5	0	0	5	5	0.000	0.195	0.042	0.042
1.A.1; Gaseous fuels	CH <sub>4</sub>	0.14	0.61	5	5	30	30	31	30	0.000	0.001	0.000	0.000
1.A.1; Gaseous fuels	N <sub>2</sub> O	0.14	0.74	5	5	81	78	81	79	0.000	0.001	0.001	0.001
1.A.1; Liquid fuels	CO <sub>2</sub>	685.86	356.53	1	1	0	0	1	1	0.000	-0.627	0.029	0.029
1.A.1; Liquid fuels	CH <sub>4</sub>	0.58	0.20	1	1	30	30	30	30	0.000	-0.001	0.000	0.000
1.A.1; Liquid fuels	N <sub>2</sub> O	1.01	0.24	1	1	80	81	82	79	0.000	-0.001	0.001	0.001
1.A.1; Solid fuels	CO <sub>2</sub>	49.13	NO	NO	NO	NO	NO	NO	NO	0.000	-0.093	0.008	0.008
1.A.1; Solid fuels	CH <sub>4</sub>	0.15	NO	NO	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000
1.A.1; Solid fuels	N <sub>2</sub> O	0.21	NO	NO	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000
1.A.1; Other fossil fuels	CO <sub>2</sub>	1'491.55	2'430.90	5	5	17	17	17	18	0.023	1.788	0.405	0.409
1.A.1; Other fossil fuels	N <sub>2</sub> O	21.63	22.81	5	5	83	78	81	80	0.000	0.002	0.048	0.047
1.A.2; Biomass	CH <sub>4</sub>	2.91	1.01	10	10	29	28	31	30	0.000	-0.004	0.001	0.001
1.A.2; Biomass	N <sub>2</sub> O	4.69	16.20	10	10	81	79	81	81	0.000	0.022	0.018	0.018
1.A.2; Gaseous fuels	CO <sub>2</sub>	1'100.12	1'668.06	5	5	0	0	5	5	0.001	1.081	0.197	0.202
1.A.2; Gaseous fuels	CH <sub>4</sub>	0.61	0.85	5	5	29	30	31	29	0.000	0.000	0.000	0.000
1.A.2; Gaseous fuels	N <sub>2</sub> O	0.62	0.81	5	5	81	78	81	79	0.000	0.000	0.000	0.000
1.A.2; Liquid fuels	CO <sub>2</sub>	3'974.10	1'465.33	1	1	0	0	1	1	0.000	-4.774	0.209	0.215
1.A.2; Liquid fuels	CH <sub>4</sub>	5.14	1.00	1	1	30	30	30	30	0.000	-0.008	0.002	0.002
1.A.2; Liquid fuels	N <sub>2</sub> O	11.87	8.84	1	1	81	78	81	79	0.000	-0.006	0.005	0.005
1.A.2; Solid fuels	CO <sub>2</sub>	1'274.70	286.10	5	5	5	5	7	7	0.000	-1.881	0.176	0.172
1.A.2; Solid fuels	CH <sub>4</sub>	0.35	0.16	5	5	29	30	30	30	0.000	0.000	0.000	0.000
1.A.2; Solid fuels	N <sub>2</sub> O	5.46	1.20	5	5	80	80	79	81	0.000	-0.008	0.007	0.006
1.A.2; Other fossil fuels	CO <sub>2</sub>	192.37	408.16	5	5	9	9	11	10	0.000	0.411	0.059	0.061
1.A.2; Other fossil fuels	CH <sub>4</sub>	0.87	0.63	5	5	29	30	30	30	0.000	0.000	0.000	0.000
1.A.2; Other fossil fuels	N <sub>2</sub> O	1.97	4.83	5	5	81	79	80	81	0.000	0.005	0.008	0.008
1.A.3.a; Kerosene fossil	CO <sub>2</sub>	252.55	64.57	1	1	0	0	1	1	0.000	-0.358	0.016	0.016
1.A.3.a; Kerosene fossil	CH <sub>4</sub>	0.19	0.09	1	1	59	61	59	61	0.000	0.000	0.000	0.000
1.A.3.a; Kerosene fossil	N <sub>2</sub> O	1.83	0.47	1	1	99	150	99	150	0.000	-0.003	0.004	0.003
1.A.3.b; Biomass	CH <sub>4</sub>	NO	0.68	10	10	59	59	61	60	0.000	0.001	0.001	0.001
1.A.3.b; Biomass	N <sub>2</sub> O	NO	4.18	10	10	99	150	99	151	0.000	0.008	0.008	0.012
1.A.3.b; Gaseous fuels	CO <sub>2</sub>	NO	28.51	5	5	0	0	5	5	0.000	0.054	0.004	0.004
1.A.3.b; Gaseous fuels	CH <sub>4</sub>	NO	0.22	5	5	30	29	30	30	0.000	0.000	0.000	0.000
1.A.3.b; Gaseous fuels	N <sub>2</sub> O	NO	0.04	5	5	79	80	81	80	0.000	0.000	0.000	0.000
1.A.3.b; Diesel oil	CO <sub>2</sub>	2'631.94	6'860.11	1	1	0	0	1	1	0.000	8.046	0.374	0.364
1.A.3.b; Diesel oil	CH <sub>4</sub>	2.56	7.14	1	1	20	20	20	20	0.000	0.009	0.002	0.002
1.A.3.b; Diesel oil	N <sub>2</sub> O	5.37	90.27	1	1	22	22	22	22	0.000	0.162	0.037	0.036
1.A.3.b; Gasoline	CO <sub>2</sub>	11'328.41	6'365.75	1	1	0	0	1	1	0.000	-9.443	0.449	0.429
1.A.3.b; Gasoline	CH <sub>4</sub>	127.19	13.27	1	1	37	38	37	37	0.000	-0.217	0.081	0.080
1.A.3.b; Gasoline	N <sub>2</sub> O	142.64	12.79	1	1	50	50	50	50	0.000	-0.247	0.122	0.124
1.A.3.b; Liquefied petroleum gas	CO <sub>2</sub>	NO	1.39	1	1	10	10	10	10	0.000	0.003	0.000	0.000
1.A.3.b; Liquefied petroleum gas	CH <sub>4</sub>	NO	0.00	1	1	30	30	30	30	0.000	0.000	0.000	0.000
1.A.3.b; Liquefied petroleum gas	N <sub>2</sub> O	NO	0.01	1	1	79	82	78	82	0.000	0.000	0.000	0.000
1.A.3.b; Other fossil fuels	CO <sub>2</sub>	NO	16.81	1	1	0	0	1	1	0.000	0.032	0.001	0.001
1.A.3.b; Other fossil fuels	CH <sub>4</sub>	NO	0.02	1	1	20	20	20	20	0.000	0.000	0.000	0.000
1.A.3.b; Other fossil fuels	N <sub>2</sub> O	NO	0.22	1	1	22	22	22	22	0.000	0.000	0.000	0.000
1.A.3.c; Biomass	CH <sub>4</sub>	NO	0.00	10	10	58	61	60	60	0.000	0.000	0.000	0.000
1.A.3.c; Biomass	N <sub>2</sub> O	NO	0.02	10	10	99	150	99	151	0.000	0.000	0.000	0.000
1.A.3.c; Liquid fuels	CO <sub>2</sub>	28.69	27.82	1	1	0	0	1	1	0.000	-0.002	0.001	0.001
1.A.3.c; Liquid fuels	CH <sub>4</sub>	0.03	0.01	1	1	30	30	30	30	0.000	0.000	0.000	0.000
1.A.3.c; Liquid fuels	N <sub>2</sub> O	0.38	0.36	1	1	81	79	81	79	0.000	0.000	0.000	0.000
1.A.3.d; Biomass	CH <sub>4</sub>	NO	0.01	10	10	59	58	61	58	0.000	0.000	0.000	0.000
1.A.3.d; Biomass	N <sub>2</sub> O	NO	0.04	10	10	99	150	99	150	0.000	0.000	0.000	0.000
1.A.3.d; Liquid fuels	CO <sub>2</sub>	114.27	110.38	1	1	0	0	1	1	0.000	-0.007	0.002	0.002
1.A.3.d; Liquid fuels	CH <sub>4</sub>	1.88	0.35	1	1	29	31	29	31	0.000	-0.003	0.001	0.001
1.A.3.d; Liquid fuels	N <sub>2</sub> O	1.03	1.05	1	1	99	149	99	149	0.000	0.000	0.000	0.000
1.A.3.e; Gaseous fuels	CO <sub>2</sub>	31.42	9.50	5	5	0	0	5	5	0.000	-0.042	0.004	0.004
1.A.3.e; Gaseous fuels	CH <sub>4</sub>	0.08	0.02	5	5	29	30	31	29	0.000	0.000	0.000	0.000
1.A.3.e; Gaseous fuels	N <sub>2</sub> O	0.10	0.03	5	5	79	80	81	79	0.000	0.000	0.000	0.000
1.A.4.a; Biomass	CH <sub>4</sub>	9.55	5.08	10	10	28	28	30	30	0.000	-0.009	0.003	0.003
1.A.4.a; Biomass	N <sub>2</sub> O	3.27	12.49	10	10	80	79	80	81	0.000	0.018	0.014	0.014
1.A.4.a; Gaseous fuels	CO <sub>2</sub>	928.49	959.99	5	5	0	0	5	5	0.000	0.060	0.131	0.128
1.A.4.a; Gaseous fuels	CH <sub>4</sub>	2.32	2.41	5	5	29	30	29	31	0.000	0.000	0.000	0.000
1.A.4.a; Gaseous fuels	N <sub>2</sub> O	0.49	0.61	5	5	79	80	80	81	0.000	0.000	0.000	0.000
1.A.4.a; Liquid fuels	CO <sub>2</sub>	3'918.47	1'891.60	1	1	0	0	1	1	0.000	-3.857	0.171	0.180

Table A – 5 (continued)

A	B	C	D	E		F		G		H	I	J	
IPCC category; fuel/source	Gas	Emissions 1990	Emissions 2023	Activity data uncertainty 2023		Emission factor uncertainty 2023		Emission combined uncertainty 2023		Emission contri- bution to variance 2023	Contri- bution to trend	Contribution to uncertainty of trend	
		kt CO2 eq.	kt CO2 eq.	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1.A.4.a; Liquid fuels	CH4	16.89	7.55	1	1	30	29	30	30	0.000	-0.018	0.005	0.005
1.A.4.a; Liquid fuels	N2O	8.72	4.40	1	1	80	80	80	80	0.000	-0.008	0.007	0.007
1.A.4.b; Biomass	CH4	103.98	22.47	10	10	28	28	29	31	0.000	-0.155	0.050	0.048
1.A.4.b; Biomass	N2O	23.00	19.03	10	10	80	78	81	79	0.000	-0.008	0.009	0.008
1.A.4.b; Gaseous fuels	CO2	1'465.04	2'409.54	5	5	0	0	5	5	0.002	1.797	0.277	0.292
1.A.4.b; Gaseous fuels	CH4	3.66	6.04	5	5	30	29	30	30	0.000	0.005	0.002	0.002
1.A.4.b; Gaseous fuels	N2O	0.70	1.16	5	5	79	81	81	80	0.000	0.001	0.001	0.001
1.A.4.b; Liquid fuels	CO2	10'099.09	3'681.59	1	1	0	0	1	1	0.000	-12.211	0.538	0.548
1.A.4.b; Liquid fuels	CH4	39.01	14.10	1	1	30	30	30	30	0.000	-0.047	0.015	0.014
1.A.4.b; Liquid fuels	N2O	21.81	7.98	1	1	78	81	78	81	0.000	-0.026	0.021	0.022
1.A.4.b; Solid fuels	CO2	58.40	4.64	5	5	5	5	7	7	0.000	-0.102	0.009	0.009
1.A.4.b; Solid fuels	CH4	5.29	0.42	5	5	30	30	31	30	0.000	-0.009	0.003	0.003
1.A.4.b; Solid fuels	N2O	0.25	0.02	5	5	80	80	80	81	0.000	0.000	0.000	0.000
1.A.4.c; Biomass	CH4	1.22	0.57	10	10	28	28	30	30	0.000	-0.001	0.000	0.000
1.A.4.c; Biomass	N2O	0.46	1.65	10	10	80	79	79	81	0.000	0.002	0.002	0.002
1.A.4.c; Gaseous fuels	CO2	70.22	90.87	5	5	0	0	5	5	0.000	0.039	0.011	0.011
1.A.4.c; Gaseous fuels	CH4	0.04	0.05	5	5	30	29	30	30	0.000	0.000	0.000	0.000
1.A.4.c; Gaseous fuels	N2O	0.03	0.04	5	5	80	79	81	79	0.000	0.000	0.000	0.000
1.A.4.c; Liquid fuels	CO2	742.46	444.67	1	1	0	0	1	1	0.000	-0.567	0.027	0.027
1.A.4.c; Liquid fuels	CH4	7.52	1.20	1	1	30	30	31	29	0.000	-0.012	0.004	0.004
1.A.4.c; Liquid fuels	N2O	4.29	3.97	1	1	80	79	78	81	0.000	-0.001	0.000	0.000
1.A.5; Biomass	CH4	NO	0.00	10	10	59	59	60	60	0.000	0.000	0.000	0.000
1.A.5; Biomass	N2O	NO	0.01	10	10	99	149	99	150	0.000	0.000	0.000	0.000
1.A.5; Liquid fuels	CO2	217.65	123.18	1	1	0	0	1	1	0.000	-0.180	0.008	0.008
1.A.5; Liquid fuels	CH4	0.13	0.04	1	1	30	30	30	30	0.000	0.000	0.000	0.000
1.A.5; Liquid fuels	N2O	1.64	0.96	1	1	100	149	99	150	0.000	-0.001	0.002	0.001
1.B; All fuels	Indirect CO2 from CH4	9.12	4.11	d.EM	d.EM	d.EM	d.EM	30	30	0.000	-0.010	0.005	0.006
1.B; All fuels	Indirect CO2 from NMVOC	45.75	5.29	d.EM	d.EM	d.EM	d.EM	34	34	0.000	-0.077	0.032	0.033
1.B.2.a; All fuels	CH4	3.94	0.56	5	5	30	30	30	30	0.000	-0.006	0.002	0.002
1.B.2.b; All fuels	CO2	0.09	0.02	5	5	9	9	10	10	0.000	0.000	0.000	0.000
1.B.2.b; All fuels	CH4	88.96	41.28	5	5	29	30	30	30	0.000	-0.091	0.029	0.028
1.B.2.c; All fuels	CO2	25.96	13.99	5	5	8	9	10	10	0.000	-0.023	0.004	0.004
1.B.2.c; All fuels	CH4	0.38	0.00	5	5	29	29	30	29	0.000	-0.001	0.000	0.000
1.B.2.c; All fuels	N2O	0.02	NO	NO	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000
2.A	Indirect CO2 from CO	0.04	0.02	d.EM	d.EM	d.EM	d.EM	100	185	0.000	0.000	0.000	0.000
2.A	Indirect CO2 from NMVOC	0.10	0.06	d.EM	d.EM	d.EM	d.EM	100	190	0.000	0.000	0.000	0.000
2.A.1	CO2	2'550.12	1'506.36	2	2	4	4	4	4	0.001	-1.986	0.161	0.159
2.A.2	CO2	53.34	50.12	2	2	2	2	3	3	0.000	-0.006	0.007	0.007
2.A.3	CO2	15.25	3.99	2	2	3	3	4	4	0.000	-0.021	0.009	0.009
2.A.4	CO2	160.33	62.92	2	2	3	3	4	4	0.000	-0.185	0.093	0.091
2.B	Indirect CO2 from CH4	0.39	0.50	d.EM	d.EM	d.EM	d.EM	10	10	0.000	0.000	0.000	0.000
2.B	Indirect CO2 from CO	6.33	4.54	d.EM	d.EM	d.EM	d.EM	22	22	0.000	-0.003	0.003	0.003
2.B	Indirect CO2 from NMVOC	1.29	0.00	d.EM	d.EM	d.EM	d.EM	40	40	0.000	-0.002	0.001	0.001
2.B.2	N2O	58.24	NO	NO	NO	NO	NO	NO	NO	0.000	-0.111	0.067	0.066
2.B.5	CO2	15.36	9.19	2	2	22	22	22	22	0.000	-0.012	0.003	0.003
2.B.5	CH4	3.88	5.14	2	2	10	10	10	10	0.000	0.002	0.000	0.000
2.B.8	CO2	94.08	106.56	2	2	10	10	10	10	0.000	0.024	0.027	0.028
2.B.10	CO2	17.34	18.10	2	2	20	20	20	20	0.000	0.001	0.021	0.021
2.B.10	CH4	0.10	NO	NO	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000
2.B.10	N2O	384.50	1.21	2	2	59	61	59	60	0.000	-0.729	0.427	0.447
2.C	Indirect CO2 from CO	1.10	0.14	d.EM	d.EM	d.EM	d.EM	100	195	0.000	-0.002	0.004	0.003
2.C	Indirect CO2 from NMVOC	2.25	0.27	d.EM	d.EM	d.EM	d.EM	83	100	0.000	-0.004	0.004	0.003
2.C.1	CO2	11.91	7.02	2	2	51	49	51	49	0.000	-0.009	0.013	0.013
2.C.3	CO2	139.26	NO	NO	NO	NO	NO	NO	NO	0.000	-0.265	0.056	0.055
2.C.3	PFCs	104.71	NO	Agg.	Agg.	Agg.	Agg.	NO	NO	0.000	-0.199	0.019	0.019
2.C.7	CO2	NO	1.30	2	2	20	20	20	20	0.000	0.002	0.000	0.001
2.D	Indirect CO2 from CO	0.00	0.00	d.EM	d.EM	d.EM	d.EM	100	207	0.000	0.000	0.000	0.000
2.D	Indirect CO2 from NMVOC	194.04	35.56	d.EM	d.EM	d.EM	d.EM	35	36	0.000	-0.301	0.151	0.151
2.D.1	CO2	48.34	25.09	20	20	50	51	53	55	0.000	-0.044	0.025	0.023
2.D.2	CO2	6.32	1.53	10	10	84	100	86	99	0.000	-0.009	0.009	0.008
2.D.3	CO2	3.65	25.03	10	10	20	20	22	22	0.000	0.041	0.011	0.011
2.E.1	HFCs	NO	0.27	Agg.	Agg.	Agg.	Agg.	75	87	0.000	0.001	0.000	0.000
2.E.1	PFCs	NO	4.61	Agg.	Agg.	Agg.	Agg.	56	61	0.000	0.009	0.005	0.005
2.E.1	SF6	NO	2.87	d.EM	d.EM	d.EM	d.EM	81	94	0.000	0.005	0.004	0.005
2.E.3	NF3	NO	0.62	d.EM	d.EM	d.EM	d.EM	80	92	0.000	0.001	0.001	0.001

Table A – 5 (continued)

A	B	C	D	E		F		G		H	I	J	
IPCC category; fuel/source	Gas	Emissions 1990	Emissions 2023	Activity data uncertainty 2023		Emission factor uncertainty 2023		Emission combined uncertainty 2023		Emission contri- bution to variance 2023	Contri- bution to trend	Contribution to uncertainty of trend	
		kt CO <sub>2</sub> eq.	kt CO <sub>2</sub> eq.	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
2.E.5	PFCs	NO	0.14	Agg.	Agg.	Agg.	Agg.	74	88	0.000	0.000	0.000	0.000
2.F.1	HFCs	0.02	1'109.54	Agg.	Agg.	Agg.	Agg.	12	12	0.002	2.111	0.278	0.273
2.F.1	PFCs	0.05	2.10	Agg.	Agg.	Agg.	Agg.	24	25	0.000	0.004	0.001	0.001
2.F.2	HFCs	NO	61.47	Agg.	Agg.	Agg.	Agg.	95	183	0.002	0.118	0.112	0.216
2.F.4	HFCs	NO	13.39	Agg.	Agg.	Agg.	Agg.	28	28	0.000	0.025	0.007	0.007
2.G	HFCs	NO	41.67	Agg.	Agg.	Agg.	Agg.	20	20	0.000	0.079	0.016	0.016
2.G	PFCs	NO	21.20	Agg.	Agg.	Agg.	Agg.	7	8	0.000	0.040	0.003	0.003
2.G	SF <sub>6</sub>	141.21	54.88	Agg.	Agg.	Agg.	Agg.	28	27	0.000	-0.164	0.075	0.072
2.G	Indirect CO <sub>2</sub> from CO	0.01	0.01	d.EM	d.EM	d.EM	d.EM	100	310	0.000	0.000	0.000	0.000
2.G	Indirect CO <sub>2</sub> from NMVOC	125.50	40.32	d.EM	d.EM	d.EM	d.EM	68	74	0.000	-0.162	0.210	0.189
2.G.3	N <sub>2</sub> O	92.49	28.82	1	1	78	82	80	81	0.000	-0.121	0.100	0.095
2.G.4	CO <sub>2</sub>	6.07	31.75	10	10	20	20	22	22	0.000	0.049	0.015	0.015
2.G.4	N <sub>2</sub> O	5.31	6.83	1	1	40	40	40	40	0.000	0.003	0.001	0.001
2.H	Indirect CO <sub>2</sub> from CO	1.27	0.31	d.EM	d.EM	d.EM	d.EM	100	206	0.000	-0.002	0.006	0.004
2.H	Indirect CO <sub>2</sub> from NMVOC	1.56	0.48	d.EM	d.EM	d.EM	d.EM	100	172	0.000	-0.002	0.006	0.004
2.H.3	CO <sub>2</sub>	1.04	0.26	5	5	83	100	83	101	0.000	-0.001	0.001	0.001
3.A	CH <sub>4</sub>	3'930.28	3'603.51	6	7	19	19	19	21	0.067	-0.613	2.097	2.081
3.B.1-4	CH <sub>4</sub>	776.91	602.24	6	6	54	54	54	55	0.014	-0.331	1.018	1.018
3.B.1-4	N <sub>2</sub> O	168.20	106.74	24	24	64	72	66	77	0.001	-0.117	0.291	0.279
3.B.5	N <sub>2</sub> O	208.60	229.94	51	56	69	83	80	100	0.007	0.040	0.355	0.375
3.D.1	N <sub>2</sub> O	1'271.39	989.71	13	14	66	78	69	78	0.073	-0.530	2.452	2.447
3.D.2	N <sub>2</sub> O	638.23	423.09	29	31	57	64	63	71	0.011	-0.410	1.049	0.994
3.G	CO <sub>2</sub>	22.25	32.78	41	39	5	5	40	41	0.000	0.020	0.030	0.030
3.H	CO <sub>2</sub>	26.66	13.39	5	5	5	5	7	7	0.000	-0.025	0.003	0.003
4.A.1	CO <sub>2</sub>	-1'286.33	393.41	1	1	35	35	34	35	0.002	3.202	1.129	1.169
4.A.2	CO <sub>2</sub>	-767.08	-786.02	1	2	35	35	35	35	0.010	-0.036	0.013	0.013
4.B.1	CO <sub>2</sub>	523.25	471.36	Agg.	Agg.	Agg.	Agg.	89	93	0.024	-0.098	1.072	1.073
4.B.2	CO <sub>2</sub>	5.98	42.46	Agg.	Agg.	Agg.	Agg.	26	25	0.000	0.069	0.047	0.046
4.C.1	CO <sub>2</sub>	-644.51	386.74	Agg.	Agg.	Agg.	Agg.	622	616	0.738	1.971	4.929	4.873
4.C.2	CO <sub>2</sub>	191.09	351.96	Agg.	Agg.	Agg.	Agg.	17	17	0.000	0.306	0.086	0.085
4.D.1	CO <sub>2</sub>	114.68	112.46	90	92	73	73	105	125	0.002	-0.004	0.005	0.004
4.D.2	CO <sub>2</sub>	28.38	32.45	Agg.	Agg.	Agg.	Agg.	22	22	0.000	0.008	0.001	0.001
4.E.1	CO <sub>2</sub>	-55.24	-52.85	4	4	49	50	50	50	0.000	0.005	0.002	0.002
4.E.2	CO <sub>2</sub>	212.33	155.01	5	5	51	49	50	50	0.001	-0.109	0.054	0.056
4.F.2	CO <sub>2</sub>	76.41	90.75	3	3	50	49	51	49	0.000	0.027	0.014	0.014
4.G	CO <sub>2</sub>	-1'149.13	41.98	11	11	56	54	56	56	0.000	2.268	1.308	1.299
4(II)	CH <sub>4</sub>	11.20	11.20	10	10	70	70	70	71	0.000	0.000	0.000	0.000
4(II)	N <sub>2</sub> O	4.27	4.18	52	50	67	67	80	88	0.000	0.000	0.000	0.000
4(III)*D	N <sub>2</sub> O	26.96	30.62	83	84	78	90	100	135	0.000	0.007	0.007	0.009
4(III)*I	N <sub>2</sub> O	6.11	6.00	86	85	84	100	103	147	0.000	0.000	0.000	0.000
4(IV)	CH <sub>4</sub>	24.13	5.28	30	29	70	70	74	80	0.000	-0.036	0.028	0.027
4(IV)	N <sub>2</sub> O	11.04	2.23	30	30	69	71	74	80	0.000	-0.017	0.013	0.012
5.A	CH <sub>4</sub>	862.11	261.32	d.EM	d.EM	d.EM	d.EM	29	30	0.001	-1.143	0.344	0.338
5.B	CH <sub>4</sub>	13.32	31.60	30	30	30	30	41	44	0.000	0.035	0.021	0.023
5.B	N <sub>2</sub> O	4.64	7.74	30	30	31	29	40	44	0.000	0.006	0.005	0.006
5.C	CO <sub>2</sub>	40.23	8.31	30	30	26	26	39	40	0.000	-0.061	0.029	0.028
5.C	CH <sub>4</sub>	8.93	5.05	50	50	33	33	58	62	0.000	-0.007	0.010	0.010
5.C	N <sub>2</sub> O	64.27	53.28	30	30	99	146	99	151	0.001	-0.021	0.080	0.056
5.C	Indirect CO <sub>2</sub> from CH <sub>4</sub>	0.26	0.13	d.EM	d.EM	d.EM	d.EM	57	61	0.000	0.000	0.000	0.000
5.C	Indirect CO <sub>2</sub> from CO	1.32	0.61	d.EM	d.EM	d.EM	d.EM	63	75	0.000	-0.001	0.002	0.002
5.C	Indirect CO <sub>2</sub> from NMVOC	0.58	0.27	d.EM	d.EM	d.EM	d.EM	65	72	0.000	-0.001	0.001	0.001
5.D	CH <sub>4</sub>	198.20	229.85	d.EM	d.EM	d.EM	d.EM	83	101	0.007	0.061	0.587	0.601
5.D	N <sub>2</sub> O	1'056.47	516.55	d.EM	d.EM	d.EM	d.EM	47	50	0.008	-1.014	1.893	1.639
5.E	Indirect CO <sub>2</sub> from CO	0.00	0.00	d.EM	d.EM	d.EM	d.EM	29	28	0.000	0.000	0.000	0.000
5.E	Indirect CO <sub>2</sub> from NMVOC	0.06	0.13	d.EM	d.EM	d.EM	d.EM	31	31	0.000	0.000	0.000	0.000
6.A	CO <sub>2</sub>	12.76	8.17	Agg.	Agg.	Agg.	Agg.	85	112	0.000	-0.009	0.025	0.017
6.A	CH <sub>4</sub>	0.83	0.46	Agg.	Agg.	Agg.	Agg.	74	92	0.000	-0.001	0.001	0.001
6.A	N <sub>2</sub> O	0.60	0.27	Agg.	Agg.	Agg.	Agg.	99	163	0.000	-0.001	0.001	0.001
6.A	Indirect CO <sub>2</sub> from CH <sub>4</sub>	0.06	0.04	d.EM	d.EM	d.EM	d.EM	74	90	0.000	0.000	0.000	0.000
6.A	Indirect CO <sub>2</sub> from CO	1.00	0.59	d.EM	d.EM	d.EM	d.EM	68	78	0.000	-0.001	0.002	0.002
6.A	Indirect CO <sub>2</sub> from NMVOC	0.22	0.12	d.EM	d.EM	d.EM	d.EM	55	60	0.000	0.000	0.000	0.000
Total, Monte Carlo simulations		52'578.4	42'147.5					6.8	6.6	1.0	-19.8	6.3	6.2
Total, inventory		52'577.4	42'146.1								-19.8		

## Annex 3 Detailed description of the reference approach (including inputs to the reference approach such as the national energy balance) and the results of the comparison of national estimates of emissions with those obtained using the reference approach

### A3.1 National energy balance


The national energy balance is provided in Table A – 6. A detailed description of the reference approach and the results of the comparison is provided in chp. 3.2.1.

Table A – 6 Switzerland's energy balance 2023 (SFOE 2024) in TJ. Liechtenstein's consumption of liquid fuels is included in the numbers (see general remarks in FOEN (2024d) on final Swiss energy consumption).

Bilan énergétique de la Suisse pour 2023 (en TJ)														
		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		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
Inlandproduktion	(a)	48 040	–	54 170	0	–	0	146 810	–	49 570	–	–	298 590	Production indigène
+ Import	(b)	1 920	3 140	4 140	122 270	286 900	98 930	–	254 550	6 610	98 860	–	877 320	+ Importation
+ Export	(c)	– 140	– 10	–	–	– 17 560	–	–	–	–	– 121 880	–	– 139 590	+ Exportation
+ Lagerveränderung <sup>1</sup>	(d)	–	– 70	–	430	– 11 690	–	–	–	–	–	–	– 11 330	+ Variation de stock <sup>1</sup>
= Bruttoverbrauch	(e)	49 820	3 060	58 310	122 700	257 650	98 930	146 810	254 550	56 180	– 23 020	–	1 024 990	= Consommation brute
+ Energieumwandlung:														+ Transformation d'énergie:
· Wasserkraftwerke	(f)	–	–	–	–	–	–	– 146 810	–	–	146 810	–	0	· Centrales hydrauliques
· Kernkraftwerke	(g)	–	–	–	–	–	–	–	– 254 550	–	84 000	1 430	– 169 120	· Centrales nucléaires
· konventionell-thermische Kraft-, Fernheiz- und Fernheizkraftwerke	(h)	– 4 150	0	– 46 520	–	– 390	– 5 760	–	–	–	7 880	23 130	– 25 810	· Centrales thermiques class., chauffage à distance, centrales chaleur-force
· Gaswerke	(i)	–	–	–	–	–	0	–	–	–	–	–	0	· Usines à gaz
· Raffinerien	(j)	–	–	–	– 122 700	122 700	–	–	–	–	–	–	0	· Raffineries
· Diverse Erneuerbare	(k)	– 3 050	–	–	–	–	1 580	–	–	– 21 550	20 700	0	– 2 320	· Renouvelables div.
+ Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherungen	(l)	–	–	–	–	– 6 030	– 120	–	–	–	– 34 530	– 2 250	– 42 930	+ Consommation propre du secteur énergétique, pertes de réseau, pompage d'accumulation
+ Nichtenergetischer Verbrauch	(m)	–	–	–	–	– 17 360	–	–	–	–	–	–	– 17 360	+ Consommation non énergétique
= Endverbrauch	(n)	42 620	3 060	11 790	0	356 570	94 630	0	0	34 630	201 840	22 310	767 450	= Consommation finale
Haushalte	(o)	17 740	50	–	–	49 880	43 160	–	–	20 630	69 180	9 380	210 020	Ménages
Industrie	(p)	12 890	3 010	11 510	–	10 710	29 840	–	–	2 180	58 510	8 320	136 970	Industrie
Dienstleistungen	(q)	10 960	–	280	–	25 660	18 720	–	–	4 140	57 140	4 610	121 510	Services
Verkehr	(r)	–	–	–	–	268 250	680	–	–	7 080	13 690	–	289 700	Transport
Statistische Differenz inkl. Landwirtschaft	(s)	1 030	–	–	–	2 070	2 230	–	–	600	3 320	0	9 250	Différence statistique y compris l'agriculture

<sup>1</sup> +: Lagerabnahme  
–: Lagerzunahme

<sup>1</sup> +: diminution de stocks  
–: augmentation de stocks

 BFE. Schweizerische Gesamtenergiestatistik 2023 (Tab. 4)

<sup>1</sup> +: Lagerabnahme  
–: Lagerzunahme

<sup>1</sup> +: diminution de stocks  
–: augmentation de stocks

BFE, Schweizerische Gesamtenergiestatistik 2023 (Tab. 4)  
OFEN, Statistique globale suisse de l'énergie 2023 (tabl. 4)

### A3.2 Differences between International Energy Agency (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 in FOEN (2024d).

## Annex 4 QA/QC plan

Since 2007, the National Inventory System (NIS) quality management system (QMS) has been certified to comply with ISO 9001. The QMS has been audited annually and recertified according to the ISO 9001 requirements ever since. The latest audit according to ISO 9001:2015 was on 27 June 2024 and the current certificate is valid until 2025 (Swiss Safety Center 2022).

Here, information on the quality assurance / quality control (QA/QC) plan for the Swiss Greenhouse gas inventory as required by UNFCCC (2019, paragraphs 34 and 35) and the IPCC Guidelines (IPCC 2006, IPCC 2019) are provided.

In the quality management system (QMS) for the Swiss greenhouse gas inventory, the QA/QC plan is represented in an internal quality manual as formerly required by the ISO 9001:2008 standard. It has been updated ever since, also under ISO 9001:2015 (FOEN 2025a). Therein, all information and documents relevant to quality assurance (QA) and quality control (QC) are compiled (in German). The quality manual is reviewed annually and modified by the QA/QC officer where necessary. The process owner is reviewing the changes accordingly. The quality manual is made available via a SharePoint for all persons involved in the inventory preparation. It will be made available for the Expert Review Team in line with the procedures agreed under the UNFCCC for the technical review of GHG inventories (UNFCCC 2019) upon request.

The quality manual (FOEN 2025a) provides information regarding:

- The scope and the quality policy and data quality objectives;
- the management structure, institutional arrangements and responsibilities;
- a risk analysis, requirements, process flow charts, and results;
- scheduled time frame for the inventory preparation until submission and associated QA/QC activities including verification activities;
- archiving, internal and external audits, internal and external reviews;
- documents and a description of feedback loops allowing improvement;
- links to supporting documents and official inventory submission data.

As such the QMS is fit for purpose, in the sense that the following inventory principles are achieved:

- Timeliness
- Completeness
- Consistency (internal consistency as well as time series consistency)
- Comparability
- Accuracy
- Transparency
- Improvement

## **Annex 5 Other detailed methodological descriptions for individual source or sink categories**

### **A5.1 Sector Energy**

#### **A5.1.1 Civil aviation**

This paragraph contains further information on the emission modelling. More complete information is provided in FOCA (2006, 2006a, 2007–2024) and on request for reviewers by FOCA.



## Emission factors (1A3a)

Table A – 7 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 (Aerocert 2012, FOCA 2007b, ZRH 2017).

Table A – 8 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 – 9 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-Honeywell
GA TPE331-11U-612G		ECHZH	2	T310	2T	FA3	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHZR	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-86Q (WINGLETS)	ECHZS	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECHZU	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIAA	2	J090	2J	CRJ2	1GE034
FJ44-1A	CESSNA 525 CITATIONJET	ECIAB	2	B001	2B	C525	FOCA
CFM56-5B4/P	AIRBUS A320-214	ECIAG	2	J067	2J	A320	3CM026
V2527-A5	AIRBUS A320-232	ECIAZ	2	J220	2J	A320	1IA003
BRBR700-710A2-20	BOMBARDIER BD-700-1A10 GLOBAL EX-PRE	ECIBD	2	J854	2J	GLEX	4BR009
PT6A-60A	BEECH-CRAFT KING AIR 350 (RAYTHEON B	ECIBK	2	T738	2T	B350	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIBM	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-81Q (WINGLETS)	ECICD	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECICK	2	J067	2J	A320	3CM026

## Emissions (1A3a)

The output of the FOCA emission modelling consists of tables with the following structure:

Table A – 10 Extract of the output file of FOCA emission and fuel consumption modelling (example for 2004). Emissions and fuel consumption in tonnes.

Airport	Distance	Type Traffic	Movements	Type	Aircraft ICAO	Engine Name	Fuel (LTO) tons	Emissions (LTO) in tons					
	Km		No.					CO <sub>2</sub>	H <sub>2</sub> O	SO <sub>2</sub>	NO <sub>x</sub>	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

## A5.1.2 Road transportation

### Base emission factors (1A3b)

The derivation of the emission factors for road transport is described in detail in INFRAS (2019a), Matzer et al. (2019) and Notter et al. (2022). The emission factors are contained in the “Handbook Emission Factors for Road Transport (HBEFA)” (version 4.2), which is available publicly as a database application (INFRAS 2022). Some important features of the emission factor methodologies are summarised in the following paragraphs.

HBEFA differentiates emission factors by emission category, vehicle types and traffic situations.

The following **emission categories** are accounted for:

- a) Hot emissions – the emissions caused by vehicles on the road with hot engines;
- b) Cold start (excess) emissions – the excess emissions caused by vehicles after cold start when the engine is still cold (note that these emissions can be negative in some cases, when the cold engine produces less emissions than in the hot state)
- c) Evaporation emissions – evaporation of hydrocarbons (i.e. methane, NMVOC) from the fuel tank of gasoline vehicles. Three sub-processes are distinguished:
  - Soak emissions: evaporation after stopping when the engine is still hot,
  - Diurnal emissions: evaporation caused by the daily temperature variation,
  - Running losses: evaporation during driving.

The hot emissions are generally the most relevant emission category; results show that for CO<sub>2</sub> the hot exhaust emissions contribute about 98 % of the total in the year 2019. Only 2 % stem from cold start excess emissions. For CH<sub>4</sub>, however, the picture is different. Hot exhaust emissions contribute about two thirds to the total, cold start emissions about one third. For N<sub>2</sub>O, the cold start emission factors are based on the EMEP guidebook (EMEP/EEA 2019). According to these emission factors, the share of cold start emissions amounts to roughly 7 % of total emissions in the year 2019.

Regarding **vehicle types**, HBEFA distinguishes six vehicle categories at the highest aggregation level (i.e. passenger cars, light commercial vehicles, urban buses, coaches, heavy goods vehicles and motorcycles). Each vehicle category is further differentiated by technology (in turn related to fuel type), emission standard, and (optionally) size class. The following table illustrates the segmentation of passenger cars. Similar “segmentations” hold for the other vehicle categories, too.

Table A – 11 Vehicle segmentation of passenger cars for different fuel types (according to HBEFA 4.2, INFRAS 2022).

Technology	Vehicle sub-segment	Technology	Vehicle sub-segments
Gasoline	<ECE	Bifuel CNG/Gasoline	Euro-2
	AGV82 (CH)		Euro-3
	ECE-15'00		Euro-4
	ECE-15'01/02		Euro-5
	ECE-15'03		Euro-6
	PreEuro 3WCat <1987	Bifuel LPG/Gasoline	Euro-2
	PreEuro 3WCat 1987-90		Euro-3
	Euro-1		Euro-4
	Euro-2		Euro-5
	Euro-3		Euro-6
	Euro-4	Flex-fuel E85	Euro-3
	Euro-5		Euro-4
	Euro-6ab		Euro-5
	Euro-6c		Euro-6
Diesel	Euro-6d-temp	PHEV	Euro-4
	Euro-6d		Euro-5
	conv		Euro-6d
	1986-1988		Euro-6ab
	Euro-1	Electricity	BEV
	Euro-2	FuelCell	FuelCell
	Euro-3		
	Euro-4		
	Euro-5		
	Euro-5 EA189 before software update		
	Euro-5 EA189 after software update		
	Euro-6ab		
	Euro-6c		
	Euro-6d-temp		
	Euro-6d		

**Traffic situations** are relevant for hot emissions. They are defined by a scheme (see table below) taking into account 4 parameters: area type (urban/rural areas), 10 road types, speed limits and 5 levels of service (i.e. traffic density classes). This leads to the definition of 365 different traffic situations in total. Each traffic situation implies a typical driving behaviour. The traffic situations have been defined based on driving behaviour studies in Germany and in Switzerland (see Ericsson et al. 2019, INFRAS 2015b).

Table A – 12 Traffic situation-scheme in HBEFA 4.2 (INFRAS 2022). Every traffic situation is characterised by a typical driving pattern (i.e. a speed-time curve). Legend: Orange colour = urban, blue colour = rural, green colour = motorway.

			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.	5 levels of service													
	Semi-Motorway	5 levels of service													
	TrunkRoad/Primary-Nat.	5 levels of service													
	Distributor/Secondary	5 levels of service													
	Distributor/Secondary(sinuous)	5 levels of service													
	Local/Collector	5 levels of service													
	Local/Collector(sinuous)	5 levels of service													
	Access-residential	5 levels of service													
Urban	Motorway-Nat.	5 levels of service													
	Motorway-City	5 levels of service													
	TrunkRoad/Primary-Nat.	5 levels of service													
	TrunkRoad/Primary-City	5 levels of service													
	Distributor/Secondary	5 levels of service													
	Local/Collector	5 levels of service													
	Access-residential	5 levels of service													

Traffic situations are defined independently of vehicle categories (LDV, HDV, 2-wheelers). But for the same traffic situation, each vehicle category is assigned its own “driving pattern” which is expressed as a speed curve (i.e. speed time series).

(Hot) emission factors for these driving patterns are developed by first creating engine maps (i.e. emissions by torque and engine speed) based on measurements performed both on laboratory test benches and on the road using Portable Emission Measurement Systems (PEMS); the PHEM model (Passenger car and Heavy duty Emission model) is then used to simulate emissions for the HBEFA driving patterns by using the emission maps as input. This process is described in detail in Matzer et al. (2019). Hot emission factors are differentiated for 7 gradient classes (flat, +/-2 %, +/-4 %, +/-6 %) within each traffic situation. The driving pattern is adapted automatically in PHEM if it cannot be realised at a given gradient (e.g. a fully loaded truck might not be able to accelerate as quickly on an upward slope as on a flat or downhill road).

For **cold start and evaporation emission factors**, not the driving pattern is determining but ambient conditions. These include climatic parameters (diurnal temperature and humidity profiles for all seasons) but also diurnal profiles of traffic volumes, trip length and parking time distributions. The methodology for the development of cold start emission factors is described in INFRAS (2004, 2019a). The methodology for the evaporation emission factors is adopted from EMEP/EEA guidebook (EMEP/EEA 2016); its implementation in HBEFA is described in INFRAS (2019a).

**Cold start excess emissions for N<sub>2</sub>O** are estimated on the basis of the Tier 3 emission factors for cold-start and hot-start urban conditions published in Tables 3-56 ff. in the EMEP/EEA guidebook (EMEP/EEA 2019). Based on these emission factors, two N<sub>2</sub>O emission calculations are carried out for Switzerland – one hypothetical calculation assuming all starts are hot starts, and a second calculation using the actual cold start share in Switzerland. The difference between the two emission values are the cold start excess emissions. These are divided by the number of cold starts in order to obtain the cold start excess emission factors in g/start.

### Activity data (1A3b)

Activity data for the emission model include (see also chp. 3.2.9.2.2.):

- a) mileage (vehicle kilometres) for hot emissions and evaporation running losses.
- b) the number of starts for cold start excess emissions.
- c) the number of stops for evaporation soak emissions.
- d) the number of vehicles multiplied by the number of days in the reporting period for evaporation diurnal emissions.

Mileage must be differentiated by vehicle types, traffic situations, and gradients in order to be able to link it to the hot emission factors differentiated by the same parameters. To do so, 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

- a) for historical periods (ex-post) on the basis of vehicle stock and age distributions, and
- b) for future periods on the basis of new registrations and by applying survival probabilities.

Trends in traffic volume per vehicle category and segment, including structural changes (size distributions, shares of diesel vehicles) are then combined to model the continuous 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 the following Figure A-1 (INFRAS 2017).

2. The total mileage is an input dataset by the Federal Statistical Office (FSO 2024f, 2024g).

3. Assignment of the traffic situations to the mileage for all vehicle categories: This step requires the use of a traffic model: Each road network link carries the information on modelled traffic volume and can be characterized with the parameters defining traffic situations (described above) and gradients, which allows the assignment sought.

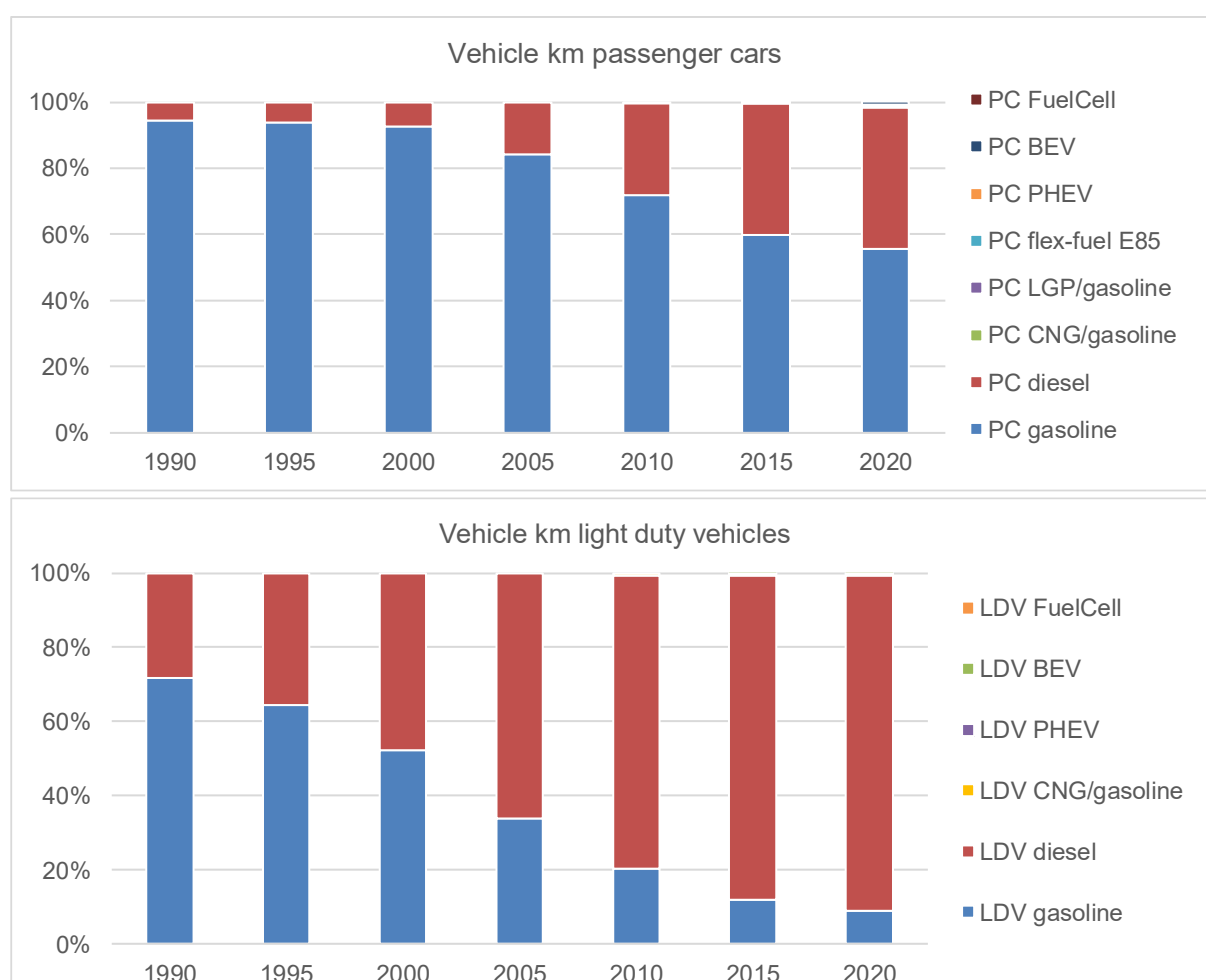


Figure A – 1 Vehicle kilometres per fleet composition for passenger cars (PC, above) and light duty vehicles (LDV, below). Data source: INFRAS (2022).

### Aggregated emission factors (1A3b)

From the base emission factors differentiated by vehicle type, traffic situations and gradients, aggregated emissions can be derived by using the activity data described above – i.e. taking into account the fleet composition, which varies from year to year, and the distribution of



vehicle kilometres across traffic situations (temporally dynamic as well, derived from traffic models – see section on activity data below).

Mean emission factors by vehicle and emission category for Switzerland are shown in the next table.

Table A – 13 Mean emission factors of passenger cars (PC), light duty vehicles (LDV), heavy duty vehicles (HDV), coaches and urban buses (Bus) and Motorcycles (MC) in grams per kilometre (from HBEFA 4.2). Cold start excess emissions are given in g/start.

Pollutant	Year	PC	LDV	HDV	Bus	MC	PC	LDV
		Emission factors in gram per vehicle kilometre					Cold starts in gram per start	
CH <sub>4</sub>	1990	0.032	0.056	0.036	0.045	0.183	0.670	0.715
CH <sub>4</sub>	1995	0.017	0.041	0.029	0.041	0.125	0.420	0.500
CH <sub>4</sub>	2000	0.013	0.029	0.019	0.032	0.152	0.280	0.291
CH <sub>4</sub>	2005	0.010	0.016	0.013	0.019	0.141	0.185	0.141
CH <sub>4</sub>	2010	0.006	0.007	0.005	0.055	0.131	0.120	0.064
CH <sub>4</sub>	2015	0.005	0.004	0.003	0.031	0.097	0.073	0.032
CH <sub>4</sub>	2020	0.006	0.005	0.001	0.016	0.079	0.051	0.019
CO	1990	6.9	25.2	3.8	5.1	12.2	40.4	59.1
CO	1995	3.0	19.4	3.3	4.9	12.5	29.0	46.8
CO	2000	1.7	13.4	2.4	4.1	12.2	21.8	31.3
CO	2005	1.2	7.0	2.0	2.9	10.9	15.6	16.6
CO	2010	0.8	3.1	2.0	1.8	8.8	10.3	8.1
CO	2015	0.5	1.2	1.9	1.6	5.5	6.6	4.4
CO	2020	0.5	0.6	0.8	0.8	3.0	5.1	2.9
CO <sub>2</sub> (fossil)	1990	226	289	832	1102	110	108	140
CO <sub>2</sub> (fossil)	1995	231	286	859	1122	123	102	134
CO <sub>2</sub> (fossil)	2000	235	283	858	1131	109	99	126
CO <sub>2</sub> (fossil)	2005	225	277	900	1130	117	101	115
CO <sub>2</sub> (fossil)	2010	213	266	875	1082	110	104	104
CO <sub>2</sub> (fossil)	2015	194	260	850	1027	114	92	98
CO <sub>2</sub> (fossil)	2020	177	238	809	947	109	82	95
VOC	1990	0.86	1.64	1.50	1.88	3.02	7.09	6.75
VOC	1995	0.37	1.05	1.21	1.71	2.32	5.71	5.63
VOC	2000	0.17	0.53	0.79	1.35	2.40	4.64	4.17
VOC	2005	0.09	0.21	0.48	0.78	1.56	3.30	2.37
VOC	2010	0.03	0.06	0.18	0.28	1.02	2.20	1.22
VOC	2015	0.02	0.02	0.08	0.12	0.64	1.35	0.62
VOC	2020	0.01	0.01	0.04	0.05	0.45	0.95	0.37
N <sub>2</sub> O	1990	0.0097	0.0056	0.0086	0.0107	0.0016	0.0175	0.0017
N <sub>2</sub> O	1995	0.0134	0.0079	0.0091	0.0107	0.0018	0.0376	0.0185
N <sub>2</sub> O	2000	0.0118	0.0098	0.0094	0.0102	0.0018	0.0424	0.0326
N <sub>2</sub> O	2005	0.0050	0.0077	0.0079	0.0080	0.0019	0.0026	0.0344
N <sub>2</sub> O	2010	0.0030	0.0058	0.0294	0.0167	0.0019	0.0105	0.0321
N <sub>2</sub> O	2015	0.0030	0.0057	0.0424	0.0299	0.0019	0.0085	0.0199
N <sub>2</sub> O	2020	0.0040	0.0078	0.0457	0.0368	0.0019	0.0067	0.0051
NM VOC	1990	0.83	1.59	1.47	1.84	2.83	6.42	6.03
NM VOC	1995	0.35	1.01	1.18	1.67	2.19	5.29	5.13
NM VOC	2000	0.16	0.50	0.77	1.31	2.24	4.36	3.87
NM VOC	2005	0.08	0.19	0.47	0.76	1.42	3.12	2.23
NM VOC	2010	0.03	0.06	0.17	0.23	0.89	2.08	1.16
NM VOC	2015	0.01	0.02	0.08	0.09	0.54	1.28	0.59
NM VOC	2020	0.00	0.01	0.04	0.04	0.37	0.90	0.35
NO <sub>x</sub>	1990	0.99	2.41	12.44	17.21	0.15	0.56	0.03
NO <sub>x</sub>	1995	0.58	1.91	11.73	16.62	0.20	1.19	0.53
NO <sub>x</sub>	2000	0.45	1.48	10.34	15.23	0.19	1.19	0.57
NO <sub>x</sub>	2005	0.42	1.35	8.72	12.57	0.21	0.75	0.21
NO <sub>x</sub>	2010	0.41	1.51	5.45	8.75	0.24	0.37	0.00
NO <sub>x</sub>	2015	0.41	1.50	3.63	5.97	0.19	0.28	-0.08
NO <sub>x</sub>	2020	0.29	0.97	1.43	3.04	0.12	0.22	0.03
SO <sub>2</sub>	1990	0.0351	0.1007	0.7785	1.0338	0.0126	0.0163	0.0442
SO <sub>2</sub>	1995	0.0278	0.0452	0.2081	0.2721	0.0140	0.0122	0.0205
SO <sub>2</sub>	2000	0.0230	0.0407	0.1749	0.2308	0.0101	0.0097	0.0175
SO <sub>2</sub>	2005	0.0007	0.0010	0.0034	0.0043	0.0004	0.0003	0.0004
SO <sub>2</sub>	2010	0.0007	0.0011	0.0038	0.0048	0.0003	0.0003	0.0004
SO <sub>2</sub>	2015	0.0007	0.0011	0.0039	0.0048	0.0003	0.0003	0.0004
SO <sub>2</sub>	2020	0.0006	0.0010	0.0035	0.0041	0.0003	0.0003	0.0004

### **Modelling total emissions (1A3b)**

The road transportation model produces estimates for activity data (mileage and corresponding fuel consumption) which correspond to the territorial or fuel used approach; they do not yet contain the activity data contribution from fuel tourism and statistical differences. The difference between the calculated fuel consumption of diesel oil, gasoline, biodiesel, bioethanol and natural gas in the road transportation model and the Swiss energy statistics is called “statistical difference and fuel tourism”. To calculate the activity data for the fuel sold approach, the difference in fuel consumption per fuel type is distributed proportionally across each vehicle category, whereby the activity data in GJ, driven kilometres and the number of vehicles is adjusted proportionally in each category (as described in chp. 3.2.9.2.2). Emissions are subsequently calculated based on the adjusted activity data representing the fuel sold approach, multiplied by the category specific emission factors. Please see also chapter 3.2.4.1 on system boundaries.

#### **A5.1.3 Non-road vehicles and machinery: supplementary activity data**

The following table shows some aggregated information on stock numbers and annual operation hours of non-road vehicles and machinery. 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 – 14 Overview over stock and operating hours of non-road vehicles and machinery (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
<b>Total</b>	<b>1'701'994</b>	<b>2'098'151</b>	<b>2'528'136</b>	<b>2'889'193</b>	<b>3'026'135</b>	<b>3'060'441</b>

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
Military machinery	64	64	63	73	74	74

Category	1980	1990	2000	2010	2020	2030
million operating hours per year						
Construction machinery	16	19	21	24	26	27
Industrial machinery	18	29	48	48	47	47
Agricultural machinery	40	39	38	33	31	29
Forestry machinery	2.4	2.8	2.6	2.3	2.0	1.9
Garden-care / hobby appliances	15	26	39	150	191	201
Navigation machinery	3.7	3.9	3.5	3.4	3.4	3.4
Railway machinery	0.50	0.80	0.80	0.50	0.50	0.50
Military machinery	0.80	0.90	0.90	0.90	0.90	0.90
<b>Total</b>	<b>95</b>	<b>121</b>	<b>155</b>	<b>261</b>	<b>301</b>	<b>311</b>

#### A5.1.4 Sulphur dioxide (SO<sub>2</sub>): Country-specific and fuel-specific default emission factors for 1A Fuel combustion

##### Methodology

For fossil standard fuels in source category 1A Fuel combustion, country-specific and fuel-specific default emission factors are used for SO<sub>2</sub>. This means that the same emission factor values are applicable to several source categories. This is appropriate for SO<sub>2</sub> because in many cases, the amount of SO<sub>2</sub> emitted per amount of fuel burnt directly depends on the sulphur content of the fuel. For a given fuel, the sulphur content for the whole country is considered homogenous. For other pollutants, the emission factors depend on the combustion process as well and are reported in their specific chapters.

The country-specific default emission factors for SO<sub>2</sub> are estimated as follow:

Where available, we use sulphur content measured annually in fuels in Switzerland, usually expressed as a mass of sulphur per mass of fuel. For liquid fuels, due to yearly fluctuating average values probably caused by a low number of samples per year, we use as annual sulphur content the average value from all samples available from the given year as well as the previous and subsequent year. In case no data are available for a given year, we

use a linear interpolation between existing 3-year-average data points. An overview of the available measured data is presented in Table A – 16. These data are available for diesel oil, gasoline, gas oil and residual fuel oil.

In case no measurement is available, we assume that the legal emission limits are respected and use these legal limits as emission factors. An overview of applicable maximal emission limits as defined in the Federal Ordinance on Air Pollution Control OAPC (Swiss Confederation 1985) is given in Table A – 15. This approach is used in particular for bituminous coal and lignite.

The SO<sub>2</sub> emission factor expressed as mass per energy amount of a given fuel *i* is computed as:

$$EF_{SO_2,i} = \frac{M_{SO_2}}{M_S} * \frac{C_{S,i}}{NCV_i}$$

Where:

EF<sub>SO<sub>2</sub>,i</sub> is the emission factor for SO<sub>2</sub> for a given fuel *i* (g/GJ)

M<sub>SO<sub>2</sub></sub> is the molar mass of SO<sub>2</sub> (g/mol)

M<sub>S</sub> is the molar mass of sulphur (g/mol)

C<sub>S,i</sub> is the measured sulphur content of the given fuel *i* if applicable, otherwise the maximum legal limit for sulphur content (g/t)

NCV<sub>i</sub> is the net calorific value for the given fuel *i* (GJ/t)

The obtained country-specific and fuel-specific SO<sub>2</sub> emission factors are reported in Table A – 17.

### Ongoing measurement surveys

“Schwerpunktaktion, SPA”: The data produced by the Federal Office for Customs and Border Security (FOCBS) through its measurement project “Schwerpunktaktion Brenn und Treibstoffe” (“SPA”) are used from 2004 onwards. This project aims at estimating the sulphur content for diesel oil, gasoline, gas oil Euro and Eco and residual fuel oil.

“Tankstellensurvey, TSS”: For diesel oil and gasoline, the measurement project “Tankstellensurvey” (“TSS”), piloted by the FOEN, started in 2009 and is conducted annually. Samples are taken from a representative set of fueling stations in Switzerland and analysed for sulphur content.

### Details per fuel type

#### Gas oil, heating gas

2006 saw the introduction to the market of low-sulphur eco-grade gas oil with a maximum legal sulphur limit of 50 g/t. From 2009 onwards, FOCBS measurements (“SPA” campaign) include both standard Euro- and eco-grade gas oil. For eco-grade gas oil for the years before

2009, values are assumed equal to those from 2009. For each year, the sulphur content for the sum of gas oil is the measured sulphur content for each grade, weighted by the respective total annual fuel consumption. From 2014 onwards, the detailed annual fuel consumption for the two grades is available from the activity report of Carbura (latest report: Carbura 2023b). The fraction of used eco-grade is interpolated linearly between 2006 and 2013. Measurements from both the SPA (from 2004 onwards) and the TSS (from 2009 onwards) campaigns are used. Before 2004, we use data as published in SAEFL 2000.

The emission factor for heating gas (used as fuel in source category 1A2c Chemicals) is assumed equal to the one for gas oil.

#### *Diesel oil, Biodiesel*

Measurements from both the SPA (from 2004 onwards) and the TSS (from 2009 onwards) campaigns are used. Before 1994, data are assumed equal to the measured values for Gas oil (Euro grade). Between 1994 and 2004, data are used as published in SAEFL 2000.

The emission factor for biodiesel is assumed equal to the one for diesel oil.

#### *Gasoline, Bioethanol*

Measurements from both the SPA (from 2004 onwards) and the TSS (from 2009 onwards) campaigns are used. Due to the absence of data for 1990-2000 included, the sulphur content in gasoline is assumed to be 10 % less than the legal maximum limit of 200 g/t, producing a value of 180 g/t. Values are linearly interpolated between 2000 and 2004.

The emission factor for bioethanol is assumed equal to the one for gasoline.

#### *Residual fuel oil, Gasolio*

Measurements from the SPA campaign are used from 2004 onwards. For previous years, we use data as published in SAEFL 2000.

The emission factor for gasolio (used as fuel in source category 1A2c Chemicals) is assumed equal to the one for residual fuel oil.

#### *Liquefied petroleum gas*

No data is available for liquified petroleum gas. We assume that the sulphur content is near the legal limit of 190 g/t for natural gas and therefore use a value of 0.5 g/GJ.

#### *Natural gas*

For natural gas for 2003, 2006, 2009 and then annually from 2011 onwards, we use the measured sulphur content as published by the SGWA (latest report: SGWA 2024). We use the annual data without averaging over 3 years because fluctuations between years are likely caused by different field origins of the natural gas. We also use a linear interpolation in case of missing data. For all years before 2003, we assume that the sulphur content in natural gas is near the legal limit of 190 g/t and therefore use a value of 0.5 g/GJ.

### *Gaseous fuels of biogenic origin*

For biogas, sewage gas and landfill gas, no data are available. We assume that the sulphur content is near the legal limit of 190 g/t and therefore use a value of 0.5 g/GJ.

### *Other bituminous coal*

There are no measured data and we assume that the sulphur content is 20 % below the legal limit. The legal limit of sulphur content depends on the size of the heat capacity of the combustion system. The value of 1 % sulphur content (350 g SO<sub>2</sub>/GJ) shown in Table A – 15 holds for heat capacity below 1 MW (see OAPC Annex 3, §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 g SO<sub>2</sub>/GJ).

### *Lignite*

There are no measured data and we assume that the sulphur content is 10 % below the legal limit, which is the same as for bituminous coal.

### *Jet kerosene*

There is no default, country-specific emission factor for SO<sub>2</sub> for jet kerosene. Category-specific emission factors are reported in their respective chapters.

Table A – 15 Maximum legal limits of sulphur content in various fuels.

Fuel	Diesel oil	Gasoline	Gas oil (Euro extra-light)	Gas oil (eco extra-light)	Natural gas	Res. fuel oil Class A	Res. fuel oil Class B	Coal, thermal input < 1MW	Coal, thermal input > 1MW
Ref. OAPC 2022	OAPC Annex 5 §6	OAPC Annex 5 §5	OAPC Annex 5 §11bis a	OAPC Annex 5 §11bis b	OAPC Annex 5 §42	OAPC Annex 3, §421, lit.2	OAPC Annex 5 §11bis c	OAPC Annex 3 §513	OAPC Annex 5 §2
Unit	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t	g/t
1990	2'000	200	2'000	NO	190	15'000	28'000	10'000	30'000
1991	2'000	200	2'000	NO	190	10'000	28'000	10'000	30'000
1992	2'000	200	2'000	NO	190	10'000	28'000	10'000	30'000
1993	2'000	200	2'000	NO	190	10'000	28'000	10'000	30'000
1994	2'000	200	2'000	NO	190	10'000	28'000	10'000	30'000
2000	350	150	2'000	NO	190	10'000	28'000	10'000	30'000
2005	50	50	2'000	NO	190	10'000	28'000	10'000	30'000
2008	50	50	2'000	NO	190	10'000	28'000	10'000	30'000
2009	10	10	1'000	NO	190	10'000	28'000	10'000	30'000
2018	10	10	1'000	50	190	10'000	28'000	10'000	30'000
2023	10	10	1'000	50	190	10'000	28'000	10'000	30'000



Table A – 16 Measured sulphur content in various fuels.

Fuel	Measured sulphur content in fuels				
	Diesel oil	Gasoline	Gas oil (Euro)	Gas oil (Eco)	Res. fuel oil Class A
Unit	g/t	g/t	g/t	g/t	g/t
1990	NE	NE	1'600	NO	9'747
1991	NE	NE	1'300	NO	8'900
1992	NE	NE	1'200	NO	8'600
1993	NE	NE	1'000	NO	8'700
1994	434	NE	1'350	NO	7'710
1995	341	NE	1'170	NO	7'770
1996	372	NE	1'160	NO	7'770
1997	353	NE	1'250	NO	7'000
1998	402	NE	926	NO	8'300
1999	443	NE	650	NO	6'200
2000	272	NE	680	NO	6'600
2001	250	NE	830	NO	8'200
2002	235	NE	798	NO	8'200
2003	200	NE	NE	NO	7'900
2004	5.2	3.8	730	NO	7'600
2005	6.4	5.6	808	NO	7'800
2006	NE	NE	NE	NE	NE
2007	NE	NE	NE	NE	NE
2008	NE	NE	NE	NE	NE
2009	7.6	5.3	641	25	9'217
2010	6.7	4.3	631	34	8'825
2011	6.6	4.7	531	21	8'967
2012	6.5	4.8	672	26	9'100
2013	7.1	4.5	308	25	8'967
2014	6.8	4.4	502	27	7'800
2015	7.7	4.2	516	14	8'233
2016	7.0	4.2	246	10	8'450
2017	7.7	5.0	248	19	9'833
2018	7.5	5.2	486	5	9'133
2019	NE	NE	NE	NE	NE
2020	6.2	NE	319	18	5'533
2021	7.1	NE	337	19	5'600
2022	6.6	4.8	551	17	6'567
2023	6.4	3.7	NE	14	5'500

Table A – 17 Sulphur dioxide emission factors used for the inventory.

SOx emission factors		Unit	1990	1995	2000	2005	2010
Fuel combustion	Gasoline	g/GJ	8.46	8.46	6.80	0.233	0.219
Fuel combustion	Diesel oil	g/GJ	69.1	17.8	15.0	0.280	0.319
Fuel combustion	Gas oil	g/GJ	72.4	57.5	33.7	34.6	23.0
Fuel combustion	Residual fuel oil	g/GJ	466	376	339	381	438
Fuel combustion	Liquefied petroleum gas	g/GJ	0.500	0.500	0.500	0.500	0.500
Fuel combustion: Boilers manufacturing industry	Other bituminous coal	g/GJ	500	500	500	500	500
Fuel combustion: Boilers residential	Other bituminous coal	g/GJ	350	350	350	350	350
Fuel combustion	Lignite	g/GJ	500	500	500	500	500
Fuel combustion	Natural gas	g/GJ	0.500	0.500	0.500	0.451	0.425
Fuel combustion	Biodiesel biogenic	g/GJ	69.1	17.8	15.0	0.280	0.319
Fuel combustion	Bioethanol	g/GJ	8.46	8.46	6.80	0.233	0.219
Fuel combustion	Biogas	g/GJ	0.500	0.500	0.500	0.500	0.500
Fuel combustion	Sewage gas	g/GJ	0.500	0.500	0.500	0.500	0.500

SOx emission factors		Unit	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Fuel combustion	Gasoline	g/GJ	0.205	0.200	0.209	0.218	0.236	0.240	0.217	0.222	0.190	0.194
Fuel combustion	Diesel oil	g/GJ	0.335	0.333	0.347	0.342	0.333	0.325	0.316	0.307	0.309	0.305
Fuel combustion	Gas oil	g/GJ	14.2	13.8	10.6	8.85	8.38	7.84	6.79	4.88	1.94	0.841
Fuel combustion	Residual fuel oil	g/GJ	416	396	448	453	460	356	269	290	290	283
Fuel combustion	Liquefied petroleum gas	g/GJ	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Fuel combustion: Boilers manufacturing industry	Other bituminous coal	g/GJ	500	500	500	500	500	500	500	500	500	500
Fuel combustion: Boilers residential	Other bituminous coal	g/GJ	350	350	350	350	350	350	350	350	350	350
Fuel combustion	Lignite	g/GJ	500	500	500	500	500	500	500	500	500	500
Fuel combustion	Natural gas	g/GJ	0.440	0.434	0.432	0.377	0.379	0.129	0.155	0.0393	0.175	0.231
Fuel combustion	Biodiesel biogenic	g/GJ	0.335	0.333	0.347	0.342	0.333	0.325	0.316	0.307	0.309	0.305
Fuel combustion	Bioethanol	g/GJ	0.205	0.200	0.209	0.218	0.236	0.240	0.217	0.222	0.190	0.194
Fuel combustion	Biogas	g/GJ	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Fuel combustion	Sewage gas	g/GJ	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500

## A5.2 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 of between 0.5 % to 20 % depending on the equipment type (see Table 4-46). 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 information on air conditioning equipment. There is no production of air conditioning equipment for cars in Switzerland, equipment is imported already charged.

Table A – 18 Applied model parameters and assumption for mobile air conditioning of cars.

<b>Characteristic values</b>			
Initial charge in kg HFC per unit AC	1994	0.81	kg
	2002	0.70	kg
	2014	0.55	kg
Extrapolation of other years			
Lifetime		15	years
<b>Production</b>			
Import of precharged equipment		100	%
<b>Operation</b>			
Annual losses		8.5	%
Recharge of losses (7.2% of 8.5%)		85	%
Additional service losses over lifetime		10	%
Disposal			
Export rate		31-72	%
Share with total loss of refrigerant		40	%
Disposal loss of professional recovery		15	%

Since 1991 HFC-134a has been used to replace ODS in the mobile air conditioning sector leading to a considerable stock of about 1'530 t of HFC-134a in registered cars in the reporting year 2023 (peak value of stock about 2'420 t of HFC-134a in 2014 (in cars)). A phase-out of HFC-134a and replacement with HFO-1234yf is under way, due to regulations in the European Union and their implementation in Switzerland. AC-refrigerants exceeding a GWP of 150 are not allowed for new car models since 2011. Since 2017, no new cars with AC-refrigerant exceeding a GWP of 150 are allowed. Due to safety concerns with alternative use of HFO-1234yf (GWP 4), there has been a delay in the replacement of HFC-134a.

Interviews were carried out 2014, 2017 and 2018 with garages in Switzerland to follow the development of HFC-134a replacement. The first interviews held in 2014 showed that only few of the imported brands switched to HFO-1234yf (GWP 4). In 2014, garages confirmed a minor portion below 5 % of equipment with HFO-1234yf. In 2017 feedback of garages on the sold vehicles of the former year varied widely depending on the models sold and origin of cars. In interviews carried out in 2018, garages confirmed complete phase-out of HFC-134a in new vehicles sold in 2017 (excluding sold vehicles from former years in stock and second-hand vehicles). Most of them switched to HFO-1234yf, few models apply CO<sub>2</sub> (R744). A

complete replacement of HFC-134a was assumed for all new vehicles models sold since 2020.

Table A – 19 Bottom-up calculations to identify the 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		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	0.9
1990	327'456	2'985'399	234'557	6	0	0	0	0	0	0.8
1991	314'824	3'057'800	242'423	7	10	2'204	0	2'204	0	0.8
1992	296'009	3'091'230	262'579	9	30	7'992	0	10'196	0	0.8
1993	262'814	3'109'524	244'520	14	66	24'284	1	34'480	0	0.8
1994	270'009	3'165'043	214'490	19	90	46'172	3	80'652	0	0.8
1995	272'897	3'229'169	208'771	24	100	65'495	5	146'147	0	0.8
1996	269'529	3'268'073	230'625	38	100	102'421	8	248'568	0	0.8
1997	272'441	3'323'421	217'093	52	100	141'669	12	390'237	0	0.8
1998	297'336	3'383'275	237'482	68	100	202'188	18	592'425	0	0.8
1999	317'985	3'467'275	233'985	75	100	238'489	24	830'914	0	0.7
2000	315'398	3'545'247	237'426	77	100	242'856	30	1'073'770	0	0.7
2001	317'126	3'629'713	232'660	85	100	269'557	37	1'343'327	0	0.7
2002	295'109	3'704'822	220'000	87	100	256'745	43	1'600'072	0	0.7
2003	271'541	3'754'000	222'363	89	100	241'671	49	1'841'743	0	0.7
2004	269'211	3'811'351	211'860	91	100	244'982	55	2'086'725	0	0.7
2005	259'426	3'863'807	206'970	92	100	238'672	60	2'325'397	0	0.7
2006	269'421	3'899'917	233'311	96	100	258'644	66	2'581'837	2'204	0.7
2007	284'674	3'955'787	228'804	96	100	273'287	72	2'847'132	7'992	0.6
2008	288'525	4'030'965	213'347	96	100	276'984	77	3'099'832	24'284	0.6
2009	266'018	4'051'569	245'414	96	100	255'377	82	3'309'037	46'172	0.6
2010	294'239	4'119'370	226'438	96	100	282'469	86	3'526'011	65'495	0.6
2011	327'896	4'209'300	237'966	96	100	314'780	90	3'738'370	102'421	0.6
2012	328'139	4'254'725	282'714	96	100	315'013	92	3'911'714	141'669	0.6
2013	310'154	4'320'885	243'994	96	92	273'928	92	3'983'454	202'188	0.6
2014	304'083	4'384'490	240'478	96	85	248'132	91	3'993'097	238'489	0.6
2015	327'143	4'458'069	253'564	96	77	241'510	90	3'991'751	242'856	0.6
2016	319'331	4'524'029	253'371	96	69	211'525	87	3'933'719	269'557	0.6
2017	315'032	4'570'823	268'238	96	30	90'729	82	3'767'703	256'745	0.6
2018	300'887	4'602'688	269'022	97	10	29'186	77	3'555'218	241'671	0.6
2019	312'377	4'623'952	291'113	97	6	18'211	72	3'328'447	244'982	0.6
2020	238'475	4'658'335	204'092	97	0	0	66	3'089'775	238'672	0.6
2021	242'022	4'688'235	212'122	97	0	0	60	2'831'131	258'644	0.6
2022	229'403	4'721'280	196'358	97	0	0	54	2'557'844	273'287	0.6
2023	255'981	4'760'948	216'313	97	0	0	48	2'280'860	276'984	0.6

Table A – 20 Results and structure of emission calculations of HFC-134a from mobile air conditioning of cars for 1990 to 2023.

HFC-134a	Activity			Emissions				Recharge	Disposal
	Input with vehicles	Stock	Retiring vehicles (incl. Export)	Production	Stock incl. Recharge	Disposal	Total	import in bulk	recovered for disposal
	[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	115	0	NO	11	0	11	5	0
1996	79	193	0	NO	18	0	18	9	0
1997	107	297	0	NO	27	0	27	15	0
1998	151	444	0	NO	41	0	41	23	0
1999	175	612	0	NO	56	0	56	35	0
2000	175	779	0	NO	71	0	71	48	0
2001	191	960	0	NO	88	0	88	61	0
2002	180	1'126	0	NO	103	0	103	75	0
2003	166	1'277	0	NO	117	0	117	88	0
2004	165	1'425	0	NO	131	0	131	100	0
2005	158	1'563	0	NO	143	0	143	111	0
2006	168	1'709	1	NO	157	0	157	122	1
2007	174	1'856	4	NO	170	1	171	133	2
2008	173	1'992	12	NO	183	3	186	145	6
2009	156	2'096	25	NO	192	8	200	155	13
2010	169	2'206	31	NO	202	9	211	163	16
2011	185	2'311	50	NO	212	14	226	172	26
2012	181	2'376	81	NO	218	18	236	180	41
2013	155	2'408	90	NO	221	24	245	185	46
2014	136	2'415	96	NO	221	26	247	188	49
2015	133	2'412	102	NO	221	26	247	188	52
2016	117	2'385	111	NO	219	29	247	188	57
2017	50	2'284	118	NO	209	27	239	186	60
2018	16	2'149	119	NO	197	24	228	178	61
2019	10	2'000	130	NO	183	28	216	167	66
2020	0	1'882	90	NO	173	19	196	156	46
2021	0	1'760	96	NO	161	10	186	147	49
2022	0	1'649	87	NO	151	23	183	137	44
2023	0	1'532	94	NO	140	19	140	128	48

## A5.3 Agriculture

### A5.3.1 Additional data for estimating CH<sub>4</sub> emission from 3A Enteric fermentation

Table A – 21 Data for estimating enteric fermentation emission factors for cattle (Table according to outline in IPCC 1997c, p 4.31–4.33).

Type	Age <sup>a</sup>	Weight <sup>a</sup> kg	Weight Gain <sup>a</sup> kg*day <sup>-1</sup>	Feeding Situation / Further Specification <sup>a</sup>	Milk <sup>b</sup> kg*day <sup>-1</sup>	Work hrs*day <sup>-1</sup>	Pregnant <sup>a</sup> %	Digestibility of Feed % <sup>d</sup>	Y <sub>m</sub> <sup>d</sup> %	Em. Factor kg*head <sup>-1</sup> *year <sup>-1</sup> <sup>e</sup>
Mature Dairy Cattle	NA	680	0		13.2-19.9 <sup>c</sup>	0	305 days of lactation	72	6.90	115.5 - 141.0
Other Mature Cattle	NA	650	0		6.85	0		62	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	95	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	4.00	15.8
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	73	3.99	29.0
Breeding Cattle (4-12 months)	4-12 month	210	0.80	Premature race (Milk-race)	0	0	0	65	6.30	
Breeding Cattle (> 1 year)	12-28/30 month	450	0.80	Premature race (Milk-race)	0	0	0	65	6.30	59.3
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	73	5.54	41.9
Fattening Cattle (4-12 months)	4-12 month	361	1.37	Feeding recommendations for fattening steers, concentrate based	0	0	0	65	6.30	

<sup>a</sup> Data source: RAP 1999 and calculations according to Soliva 2006.

<sup>b</sup> Milk production in kg/day is calculated by dividing the average annual milk production per head by 365 days.

<sup>c</sup> data source: Swiss farmers union (MISTA 2024).

<sup>d</sup> data source: IPCC 2019 and Zeltz et al. 2012.

<sup>e</sup> For better comparability emission factors of young cattle were converted to kg\*head<sup>-1</sup>\*year<sup>-1</sup> although the time span of most of the individual categories is less than 365 days.

### A5.3.2 Additional data for estimating CH<sub>4</sub> and N<sub>2</sub>O emission from 3B Manure management

Table A – 22 Data for estimating manure management CH<sub>4</sub> emission factors (Table according to outline in IPCC 1997c, Tables B-1 to B-7).

Type	Weight kg <sup>a</sup>	Digestibility of Feed % <sup>b</sup>	Energy Intake MJ*day <sup>-1</sup>	Feed Intake kg*day <sup>-1</sup>	% Ash Dry Basis <sup>b</sup>	VS kg*head <sup>-1</sup> *day <sup>-1</sup>	B <sub>0</sub> m <sup>3</sup> CH <sub>4</sub> *kgVS <sup>-1</sup> <sup>b</sup>
Mature Dairy Cattle	680	72	255 - 312	15.34 <sup>c</sup>	8.8 - 9.1	3.51 - 4.30	0.24
Other Mature Cattle	650	62	251	13.70 <sup>c</sup>	8	4.75	0.18
Fattening Calves	124	95	47	2.02 <sup>a</sup>	8	0.12	0.18
Pre-Weaned Calves	195	65	60	2.99 <sup>a</sup>	8	0.67	0.18
Breeding Calves	85	73	44	2.19 <sup>a</sup>	8	0.37	0.18
Breeding Cattle (4-12 months)	210	65	90	4.88 <sup>a</sup>	8	1.57	0.18
Breeding Cattle (> 1 year)	450	65	144	7.78 <sup>a</sup>	8	2.51	0.18
Fattening Calves (0-4 months)	115	73	57	3.00 <sup>a</sup>	8	0.67	0.18
Fattening Cattle (4-12 months)	361	65	126	6.84 <sup>a</sup>	8	2.20	0.18
Sheep	NA	65	21 - 24	1.08-1.24 <sup>c</sup>	8	0.40	0.19
Swine	NA	75	24 - 27	NA	6	0.31	0.45
Buffalo	NA	65	129 - 163	7.00-8.82 <sup>c</sup>	8	2.76	0.10
Camels	NA	65 <sup>d</sup>	31 - 38	1.68-2.05 <sup>c</sup>	8	0.55	0.26
Deer	NA	65	51 - 60	2.74-3.28 <sup>c</sup>	8	1.04	0.19
Goats	NA	65	25 - 28	1.34-1.40 <sup>c</sup>	8	0.44	0.18
Horses	NA	70	107 - 109	7.73-7.89 <sup>c</sup>	4	1.69	0.30
Mules and Asses	NA	70	38 - 40	2.76-2.83 <sup>c</sup>	4	0.60	0.33
Poultry	NA	NA	1.0 - 1.4 <sup>c</sup>	NA	NA	0.01	0.37 <sup>#</sup>
Rabbits	NA	NA	1.2	NA	NA	0.10	0.32
Livestock NCAC	NA	NA	NA	NA	NA	0.62	0.25

<sup>a</sup> RAP 1999

<sup>b</sup> IPCC 2006 and IPCC 2019

<sup>c</sup> Richner and Sinaj 2017

<sup>d</sup> Llamas and alpacas: same value as for sheep

<sup>e</sup> metabolizable energy (ME)

<sup>#</sup> weighted average

### A5.3.3 Additional data for estimating N<sub>2</sub>O emissions from 3D Agricultural soils

Table A – 23 Additional data for estimating N<sub>2</sub>O emission from crop residues: C-Input and C/N ratios.

2023		Above ground		Below ground		Overall
		C input	C/N	C input	C/N	N input
		t C/ha/yr	-	t C/ha/yr	-	kg N/ha/yr
Cereals	Wheat	0.434	77.40	0.265	50.00	10.90
	Barley	0.512	77.40	0.265	32.14	14.85
	Maize	3.310	75.00	0.205	64.29	47.32
	Oats	0.371	77.40	0.265	56.25	9.49
	Rye	0.405	77.40	0.265	40.91	11.70
	Triticale	0.457	77.40	0.265	50.00	11.20
	Spelt	0.292	77.40	0.265	50.00	9.07
Pulse	Dry Beans	1.218	25.80	0.354	20.45	64.51
	Peas (Eiweisserbsen)	1.129	25.80	0.102	20.45	48.71
	Soybeans	1.294	25.80	0.363	20.45	67.91
Tuber and Root	Potatoes	1.326	33.75	0.010	32.14	39.58
	Fodder Beet	4.114	28.80	0.017	32.14	143.39
	Sugar Beet	4.129	20.25	0.017	32.14	204.45
Other	Silage Corn	0.349	33.51	0.488	64.29	18.00
	Vegetables	1.061	19.26	0.004	31.56	55.19
	Sunflowers	1.620	38.70	0.455	50.00	50.97
	Rape	5.281	55.29	1.803	45.00	135.60
	Cover crop fodder	0.091	55.29	0.036	45.00	2.44
	Cover crop manure	1.040	55.29	0.324	45.00	26.01
	Fallow	1.029	32.14	0.897	40.18	54.35
Meadows and pastures	Intensive Meadows	1.029	20.45	0.897	25.57	85.41
	Meadows Extensive	1.029	32.14	0.897	40.18	54.35
	Intensive Meadows	1.029	20.45	0.897	25.57	85.41
	Meadows little Intensive	1.029	25.00	0.897	31.25	69.88
	Pasture Intensive	1.029	16.67	0.897	20.83	104.82
	Pasture Extensive	1.029	22.50	0.897	28.13	77.65
	Fruit	NA	NA	NA	NA	63.50
	Vine	NA	NA	NA	NA	42.00



Table A – 24 Additional data for estimating N<sub>2</sub>O emission from crop residues: Frac-values.

The table will again be generated for Submission 2026.

### A5.3.4 Estimation of the distribution of nitrogen and volatile solids to manure management systems for cattle animals

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 cattle category.

In a first step the share of manure deposited on pasture, range and paddock is calculated assuming that the amount of deposited manure is proportional to the time spent grazing. The estimated grazing time is based on expert judgement and values from the literature (1990, 1995) and on extensive farm surveys (2002, 2007, 2010, 2015 and 2019) (Kupper et al. 2022). The approach is consistent for nitrogen and volatile solids.

Subsequently, the remaining manure is distributed to the different manure management systems. Data for manure management system distribution for cattle are different for VS and nitrogen. This is because cattle stables often have simultaneously both liquid and solid manure storage systems. As volatile solids are excreted mainly in dung and nitrogen mainly in urine, the proportion of VS stored as solid manure is higher compared to the proportion of N.

Estimation of the distribution of nitrogen is conducted within the Swiss ammonium model AGRAMMON and follows a nitrogen mass balance approach. Further details are provided in Kupper et al. (2022).

The distribution of VS was estimated using data on stable systems, manure accumulation and manure properties from Richner and Sinaj (2017; chapter 4, table 4 and 6). For this purpose five different stable systems are distinguished. For tie stall and loose housing systems with slurry production only ("Vollgülle") it is assumed that all manure goes to liquid systems. For loose housing systems with deep litter 100 % of the manure is allocated to "deep litter". For tie stall and loose housing systems with simultaneous production of liquid slurry and solid manure (dung) the distribution to the respective storage systems is conducted as exemplified for mature dairy cattle in Table A – 25. The final shares of volatile solids in the different manure management systems is then calculated based on the frequency of the 5 different stable systems as assessed based on expert judgement and values from the literature (1990, 1995) and on extensive farm surveys (2002, 2007, 2010, 2015 and 2019) (Kupper et al. 2022) (Table A – 26).

Table A – 25 Production of slurry and dung and manure management system distribution for nitrogen and volatile solids for mature dairy cattle in stable systems with simultaneous production of slurry and dung (according to Richner and Sinaj 2017).

	slurry*	dung	Richner and Sinaj 2017, chapter 4
Production per year	11 m <sup>3</sup> *year <sup>-1</sup>	8.9 t*year <sup>-1</sup>	table 4
Content of nitrogen	4.5 kg*m <sup>-3</sup>	4.5 kg*t <sup>-1</sup>	table 6
Total amount of nitrogen produced	49.5 kg*year <sup>-1</sup>	40.1 kg*year <sup>-1</sup>	
<b>Distribution of nitrogen</b>	<b>55.3%</b>	<b>44.7%</b>	
Content of volatile solids	40 kg*m <sup>-3</sup>	150 kg*t <sup>-1</sup>	table 6
Total amount of volatile solids produced	440 kg*year <sup>-1</sup>	1335 kg*year <sup>-1</sup>	
<b>Distribution of volatile solids</b>	<b>24.8%</b>	<b>75.2%</b>	

\* all values are for undiluted slurry

Table A – 26 Distribution of nitrogen and volatile solids to different storage systems in different stable systems for mature dairy cattle.

	Distribution of nitrogen <sup>*</sup>		Distribution of volatile solids		Frequency of stable system 2019	Distribution of nitrogen <sup>*</sup>		Distribution of volatile solids	
	Liquid Slurry / Digesters	Solid manure / Deep litter	Liquid Slurry / Digesters	Solid manure / Deep litter		Liquid Slurry / Digesters	Solid manure / Deep litter	Liquid Slurry / Digesters	Solid manure / Deep litter
Tie stall with slurry ("Vollgülle")	100.0	0.0	100.0	0.0	12.8%	80.4%	19.6%	67.7%	32.3%
Tie stall with liquid slurry and solid manure	55.3	44.7	24.8	75.2	29.5%				
Loose housing system with slurry ("Vollgülle")	100.0	0.0	100.0	0.0	44.6%				
Loose housing system with liquid slurry and solid manure	55.3	44.7	24.8	75.2	12.0%				
Loose housing system with deep litter	0.0	100.0	0.0	100.0	1.1%				

<sup>\*</sup> all values for nitrogen are only indicative here as the exact distribution is assessed in a more detailed mass balance approach within the AGRAMMON-model

In order to assess the quality of the final result the distribution of volatile solids was calculated alternatively by multiplying the distribution of nitrogen from the AGRAMMON-model with average VS/N ratios for slurry and solid manure. The resulting values differ only slightly from the estimated distribution of volatile solids.

## A5.4 Land use, land-use change and forestry (LULUCF)

### A5.4.1 Category 4(III) – Direct and indirect N<sub>2</sub>O emissions

#### A5.4.1.1 Description

Table A – 27 Key categories in category 4(III) Direct and indirect N<sub>2</sub>O emissions from disturbance. Combined KCA results, level for 2023 and trend for 1990–2023, including LULUCF categories (L1/2 = level, Approach 1 or 2; T1/2 = trend, Approach 1 or 2).

Category 4(III) Direct and indirect N<sub>2</sub>O emissions are not a key category.

This chapter presents the method for calculating direct and indirect N<sub>2</sub>O emissions from nitrogen (N) mineralisation in mineral soil (category 4(III)). The source of nitrogen is N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils. As the approaches applied are not Tier 3, no N<sub>2</sub>O immobilisation is reported (see footnote 1 in CRT Table4(III)).

On productive forest land, the Yasso model simulates small annual changes in soil carbon stocks (chp. 6.4.2.2.8). These changes were deliberately not considered for the calculation of N<sub>2</sub>O emissions in category 4(III) as they are not associated with a land-use change or any change in management. Accordingly, N<sub>2</sub>O emissions for category 4A.1 in CRT Table4(III) are reported as NO.

Direct N<sub>2</sub>O emissions on Cropland remaining cropland (no category registered in CRT Table4(III)) and on Grassland remaining grassland (category 4(III)C1) were included in the Agriculture sector (category 3D1e, see chp. 5.5.1). In Switzerland, grassland is considered to be under agricultural management. Likewise, indirect N<sub>2</sub>O emissions due to nitrogen leaching and run-off on Cropland remaining cropland and on Grassland remaining grassland were included in the Agriculture sector (category 3D2, see chp. 5.5.1).

#### A5.4.1.2 Methodological issues

For  $\Delta C_s = 0$  or  $\Delta C_s > 0$  (carbon gain), there are no N<sub>2</sub>O emissions provoked by the specific change of land use or management.

For  $\Delta C_s < 0$ , direct and indirect N<sub>2</sub>O emissions were calculated according to IPCC (2019, Volume 4, chp. 11, equation 11.1 and equation 11.10, respectively):

$$\text{Direct Emission(N}_2\text{O)} = - \Delta C_s \cdot 1 / (\text{C:N}) \cdot \text{EF}_1 \cdot 44/28 \quad (\text{kt N}_2\text{O})$$

$$\text{Indirect Emission(N}_2\text{O)} = - \Delta C_s \cdot \text{Frac}_{\text{LEACH-(H)}} / (\text{C:N}) \cdot \text{EF}_5 \cdot 44/28 \quad (\text{kt N}_2\text{O})$$

where:

- $\Delta C_s$ : soil carbon stock change induced by change of land use or management (calculated according to the methodology described in chp. 6.1.3.2) (kt C)
- C:N: C to N ratio of the soil before the land-use change
- $\text{EF}_1$ : default emission factor = 0.01 kg N<sub>2</sub>O-N (kg N)<sup>-1</sup> (IPCC 2019, Volume 4, Table 11.1)
- $\text{EF}_5$ : default emission factor = 0.011 kg N<sub>2</sub>O-N (kg N)<sup>-1</sup> (IPCC 2019, Volume 4, Table 11.3)

- $\text{Frac}_{\text{LEACH-(H)}}$ : fraction of mineralised N lost by leaching or run-off; see Table 5-28.

The value of the C:N ratio is related to the land-use category before the change. For Forest land, the default value of C:N = 15 was used (IPCC 2019, Volume 4, equation 11.8). For Cropland and Grassland, the ratio is 9.8 according to Leifeld et al. (2007). This value was also used for mineral soil in unproductive wetland (CC42) and unsealed settlement areas (CC52, CC53, CC54).

#### A5.4.1.3 Uncertainties and time-series consistency for 4(III)

##### Uncertainties

###### *Activity data*

The uncertainty of the activity data corresponds to the uncertainty of the amount of mineralised N. It was calculated as the combined uncertainty of:

- Uncertainty of the carbon stock losses in mineral soil: Land converted to settlements (category 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<sub>2</sub> emission factor (50.0 %) were combined to estimate the uncertainty of the carbon stock loss: 50.2 %.
- Uncertainty of the C:N ratio: The uncertainty of the C:N ratio for Forest land was used. With a value of 15 and a 95 %-range between 10 and 30 (IPCC 2019, Volume 4, equation 11.8) the mean uncertainty results in 66.7 %.

The resulting uncertainty of activity data is 83.5 % for direct N<sub>2</sub>O emissions (Table 6-5), calculated as  $(50.2^2 + 66.7^2)^{0.5}$ .

The uncertainty of the activity data for indirect N<sub>2</sub>O emissions is 85.8 %. It is the combined uncertainty of the amount of leached N, which was adopted from the amount of mineralised N (uncertainty 83.5 %, see above) and  $\text{Frac}_{\text{LEACH-(H)}}$  (uncertainty 20 %, adopted from ART 2008a) (Table 6-5).

###### *Emission factors*

A relative uncertainty for the emission factors was taken from IPCC (2019, Volume 4, Table 11.1 and Table 11.3). Since the uncertainty envelopes are skewed and no negative values occur, a gamma distribution was chosen (see Annex A2.1):

- Uncertainty EF<sub>1</sub>: gamma distribution, corresponding to a 95 % confidence interval of -90 %, +90 %
- Uncertainty EF<sub>5</sub>: gamma distribution, corresponding to a 95 % confidence interval of -100 %, +100 %

##### *Results*

Detailed results of approach 1 and approach 2 uncertainty analyses are given in Annex A2.2 and Annex A2.3, respectively.

### **Time-series consistency**

Time series for categories 4(III) N<sub>2</sub>O emissions from nitrogen mineralisation are all considered consistent; they were calculated based on consistent methods and homogenous databases.

#### **A5.4.1.4 Category-specific QA/QC and verification for 4(III)**

The general QA/QC measures are described in chp. 1.5. No category-specific QA/QC activities were undertaken.

The indirect N<sub>2</sub>O emissions in CRT Table 4(III) are not broken down by land-use category (similar to former CRF Table (IV)). Instead, the total of indirect emissions is reported under category 4(III)C2a and the notation key IE is used for the other land-use categories. This is due to a technical reason as the EMIS database has not yet been extended for a disaggregated reporting of the indirect emissions. This is planned for the next submission.

#### **A5.4.1.5 Category-specific recalculations for 4(III)**

- 4(III) Activity data: The areas of land-use categories for 1990–2022 were updated (see chp. 6.3.1.5).
- 4(III) Activity data: The dataset defining the geographical distribution of organic soils in Switzerland was updated (see chp. 6.3.1.5). This led to a recalculation of the stratification between mineral and organic soils and thus to changes in the amount of soil organic matter loss in mineral soils.
- 4(III) Activity data: The loss of soil organic matter in the case of a land-use change was recalculated due to recalculations of carbon stocks in mineral soil. The recalculated carbon stocks in mineral soils of Cropland, Grassland, Wetlands and Settlements (see chp. 6.5.5, chp. 6.6.5, chp. 6.7.5 and chp. 6.8.5, respectively) led to recalculations of soil carbon stock changes (deltaCs) following the stock-difference approach (see Table 6-3) and – in a next step – of resulting direct and indirect N<sub>2</sub>O emissions.

#### **A5.4.1.6 Category-specific planned improvements for 4(III)**

See note in chp. A5.4.1.4. No further category-specific improvements are planned.

## Annex 6 Additional information on verification activities

### A6.1 Independent verification of the National Greenhouse Gas 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 (3'580 m a.s.l.). These measurements are used for estimating emissions of fluorinated greenhouse gases (HFCs, SF<sub>6</sub>, PFCs) from Switzerland and neighbouring countries. The 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 either consistency in support of the inventory or discrepancies, which could lead to a reassessment for identifying sources for disagreement and options for improvements.

For the independent assessment of fluorinated greenhouse gas emissions from Switzerland the so-called tracer-ratio method is applied, where Swiss pollution events of HFCs and SF<sub>6</sub>, 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 – 2 for a graphical illustration of the method). Similar approaches are also used for the independent verification of greenhouse gas emissions in the United Kingdom (UK MetOffice – using atmospheric observations from Mace Head (Ireland) combined with atmospheric transport models), in Australia (CSIRO – using the tracer-ratio method with measurements from Cape Grim, Tasmania) and in the US (NOAA – using a combination of airborne and ground-based samples).

#### *Method description*

For estimates of annual Swiss HFC, SF<sub>6</sub> and PFC emissions, only observations at the high-Alpine station Jungfraujoch are taken from air masses that are predominantly influenced by emissions from Switzerland. The number of events which can be used each year depends on the meteorological conditions and lies between 7-15 days per year (mostly in the summer). The process to select these periods is shown in Figure A – 2 and is shortly described here. First, the footprints from the COSMO-model are screened for periods when the Jungfraujoch site is 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 halogenated greenhouse gases are compared with those of CO. Periods which show a concurrent increase 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 Jungfraujoch. Third, the emissions are calculated for each case/day using the formula given in Figure A – 2. 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 of these individual cases. These annual estimates are merged to a 3-year annual average centred over a 3-year period (e.g. the estimate for the 2023 emissions is calculated by using data from 2022–2024). Since 2009, the uncertainty of the estimates for HFCs has been assessed by using the range of the 25 % to 75 % percentiles of the estimates from single pollution events. For estimates between 2001–2008 the average of the 2009–2011 uncertainties has been taken. For SF<sub>6</sub>, with comparably low emissions and a higher degree of uncertainty, an overall uncertainty of 50 % is estimated, based on the long-term average of the 25 % to 75 % percentiles. An



additional systematic error could occur if the Swiss emissions of CO are over/underestimated by the inventory. This would linearly impact the emissions of the fluorinated greenhouse gases. Uncertainties may vary from year to year due to the limited amount of data for performing the analysis. Therefore, even subsequent years of lower or higher uncertainty do not signify a change towards lower or higher uncertainty but are just a result of this.

For the emissions from the inventory, uncertainties are provided for the first time for each F-gas individually. These were calculated using the same method as for the uncertainty analysis, approach 2, i.e. uncertainty propagation by Monte Carlo simulations (see chp. 1.6 and details about the computational method in chp. 1.6.2.2). Detailed input uncertainties per gas and per process can be found in Annex 2.

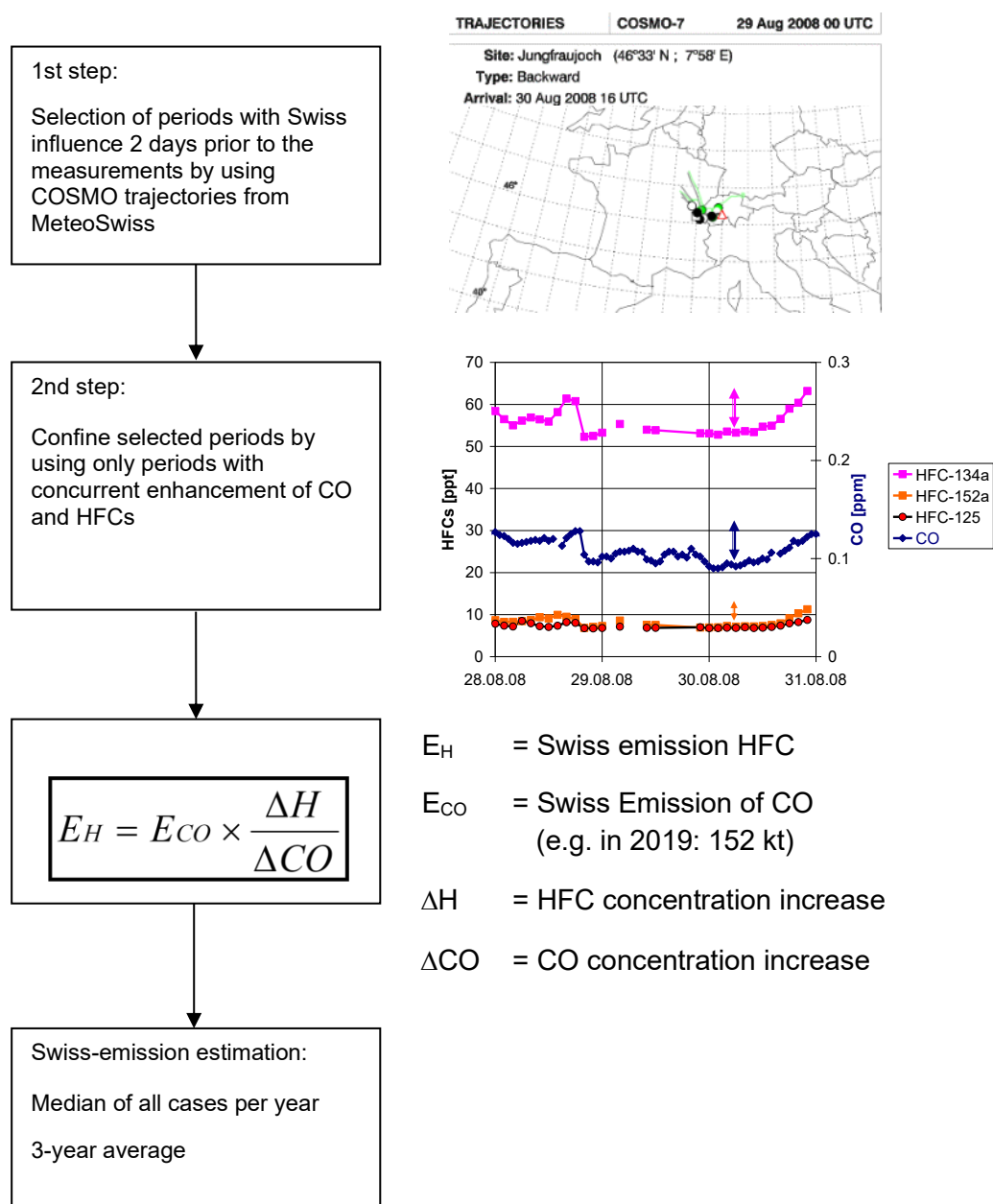


Figure A – 2 Description of the procedure to estimate annual emissions of halogenated greenhouse gases from Switzerland by using continuous measurements of HFCs at Jungfraujoch (Switzerland). Swiss emission of CO ( $E_{CO}$ ) values are taken from FOEN (2021b), see chp. 3.2.4.1 concerning system boundaries.

### *Results and discussion*

In the following, Swiss emissions of five HFCs (HFC-134a, HFC-125, HFC-152a, HFC-143a, HFC-32) and of SF<sub>6</sub> and the total of perfluorinated carbons (PFCs) 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 Documents (NID) upon availability.

#### *HFC-134a*

HFC-134a is the most important anthropogenic HFC. One of its main sources is the diffuse emission from its usage as cooling agent in mobile air conditioners (MACs). Further relevant applications are the usage in cooling mixtures in the industrial and commercial refrigeration as well as in stationary air conditioners and heat pumps and as propellant. The stock of HFC-134a in MACs and the related emissions have been steadily increasing until 2016 but are declining in most recent years due to the replacement of HFC-134a in this application by HFO-1234yf. Furthermore, in recent years, HFC-134a is also replaced in other cooling applications, which leads to a steady decline of its emissions.

After a common increase of estimated emissions from 2001 until 2007 both the estimate from Jungfraujoch and the inventory showed a stabilization of the emissions. This could be related to the decreasing HFCs used in propellants and to optimizations in the industrial and commercial refrigeration. In the inventory increasing tendencies are found again from 2008 until 2018, whereas the measurement-based estimate shows no clear trend and fluctuates around 300 tonnes/year. Overall, the agreement between the two methods was excellent from 2001 – 2006; while a discrepancy of ca. 25 % to 40 % is observed between 2012 and 2018 (Figure A – 3). Interestingly, also emission estimates for HFC-134a for the United Kingdom of Great Britain and Northern Ireland show a similar discrepancy in the comparison between measurement-based emission estimates (comparable to those performed here) and the UK inventory (Brown et al. 2019). Between 2019 and 2021 both estimates show consistent declining numbers, which is more pronounced for the inventory-based emissions. Afterwards, the measurement-based estimate shows a decline, whereas the inventory shows a small increase in emissions.

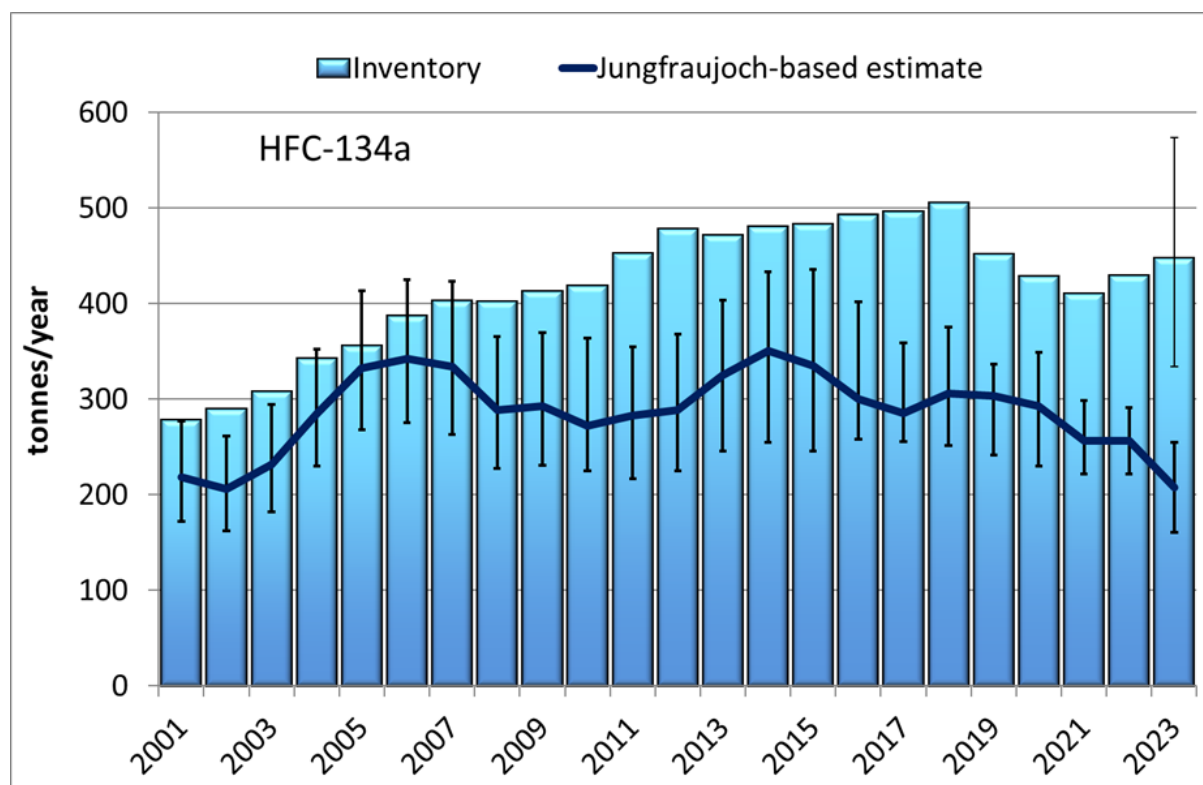


Figure A – 3 Comparison of HFC-134a emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

#### HFC-125

HFC-125 is mainly used in cooling mixtures in air conditioners and commercial refrigeration equipment. Estimated emissions from Jungfrauoch measurement data tend to be slightly but consistently lower than in the inventory (Figure A – 4). Emission estimates from Jungfrauoch show a steady decrease of emissions since 2016. Due to efforts to eliminate high-GWP HFCs from refrigeration applications and the related elimination of HFC-125 containing blends, the emissions based on the inventory are also decreasing in recent years but less pronounced. Potentially the timing between the two approaches is different due to differences in the real-world usage of HFC-125 and the model approach in the inventory.

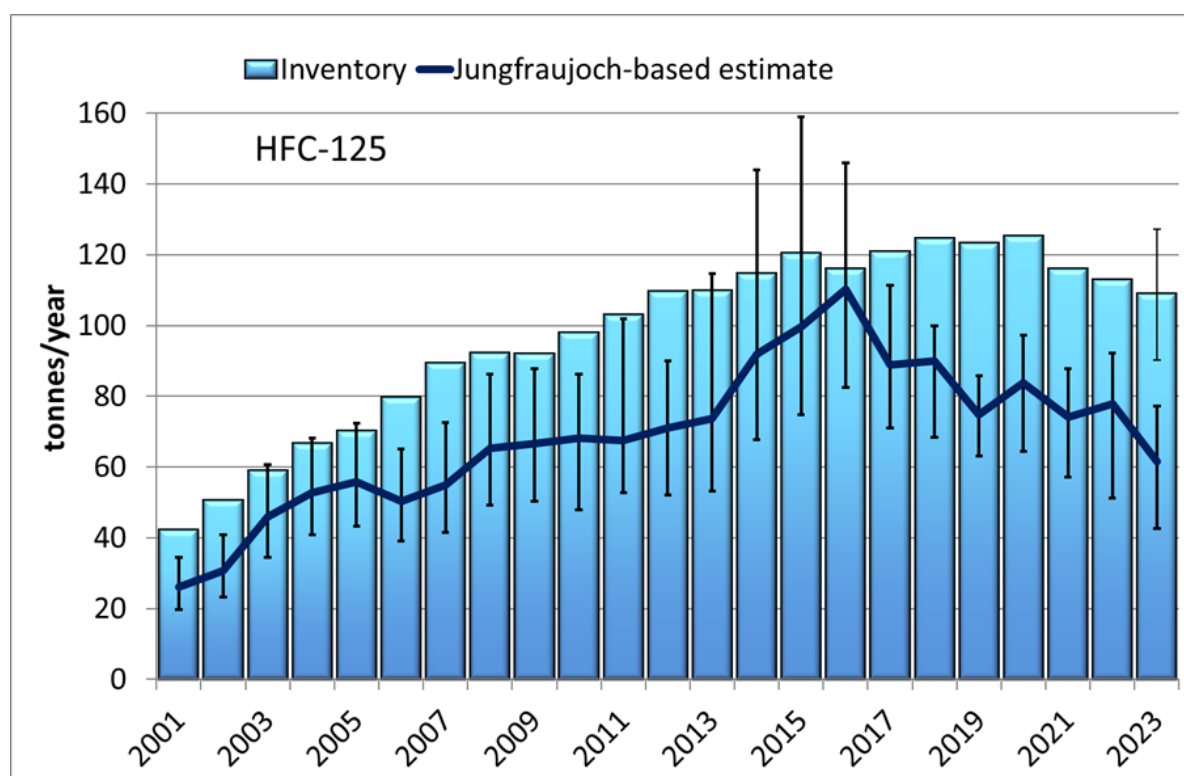


Figure A – 4 Comparison of HFC-125 emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

#### 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, part of the blowing agent remains in the product and emissions occur over its lifetime, with a rate 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 % to 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 Jungfrauoch 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 occur during the usage of the products (e.g. for insulation) in Switzerland and are, therefore, reflected in the measurements but, by definition, not in the inventory. 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. Emissions estimated from Jungfrauoch

show a consistent decrease related to the partial phase-out of HFC-152a from the foam-blowing applications (Figure A – 5).

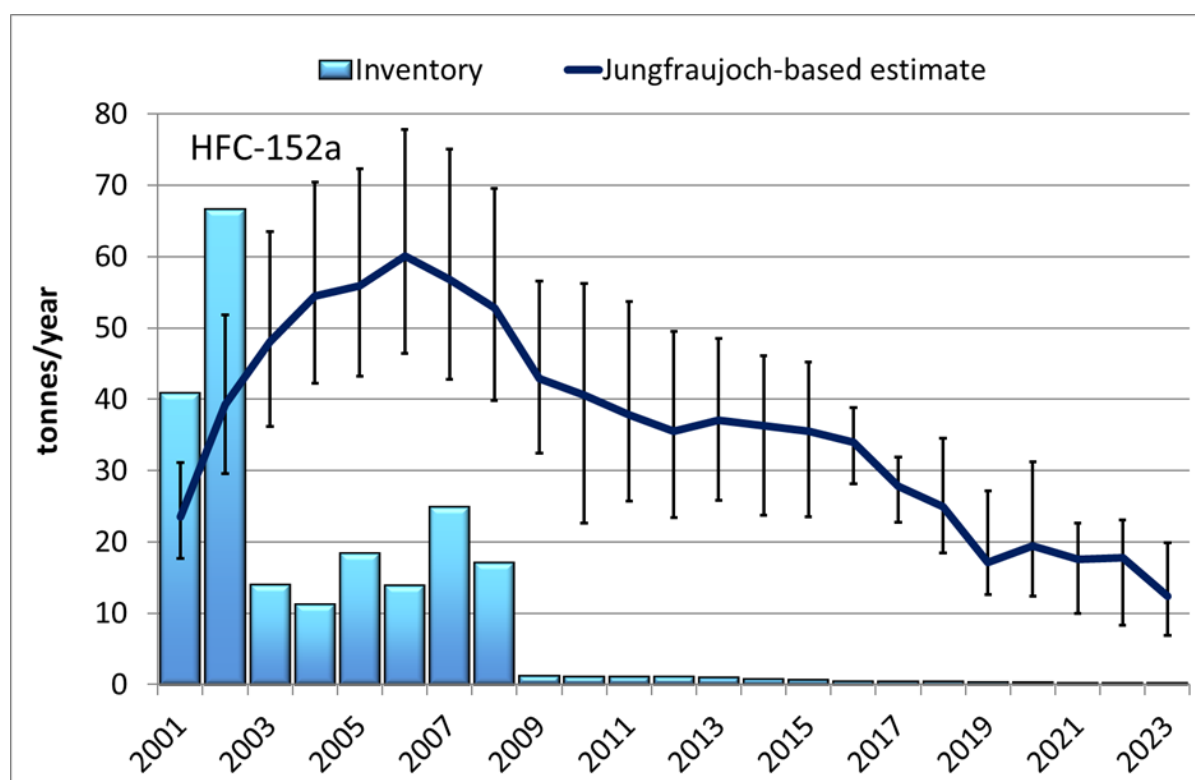


Figure A – 5 Comparison of HFC-152a emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

#### *HFC-143a and HFC-32*

HFC-143a (Figure A – 6) and HFC-32 (Figure A – 7) 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 Jungfrauoch measurement data were slightly lower than those from the inventory. From 2014–2016, there was a very good agreement between the two methods and a slight decrease in emissions in most recent years, which is seen by both methods. Since 2017 a downward trend is seen by both methods, with a more pronounced tendency by the Jungfrauoch-based method. A further decline is expected in the future because of regulations of HFCs with a high GWP for refrigeration applications and the related elimination of HFC-143a containing blends.

For HFC-32, the measurement-based estimates of HFC-32 have been consistently lower (by about 40 %) than the data from the inventory between 2010 and 2018. In contrast to HFC-125 and HFC-143a, emissions of HFC-32 increased until 2018. This could be due to the fact that HFC-32 has a lower GWP than the other two compounds and is therefore preferably used in new air-conditioner applications. Since 2016, however, slowly increasing emissions are estimated by the measurement-based method estimates, whereas the inventory-based method sees a stronger and steady increase of emissions. Emissions of HFC-32 are in fact expected to increase in the next years, as its low GWP allows its use also in the future for cooling applications. The different behaviour of the two estimates could point to more leak-tight systems but could also be of transient nature, as real-world emissions are hold back

and will only occur in the future.

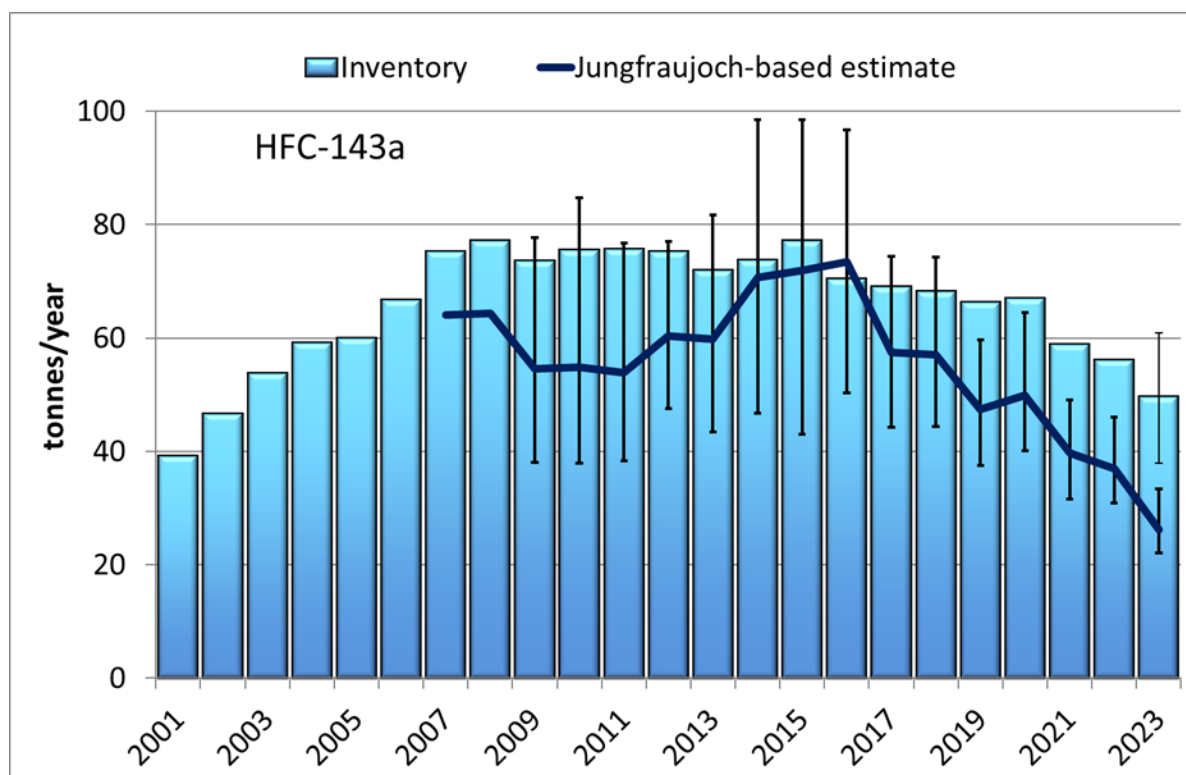


Figure A – 6 Comparison of HFC-143a emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

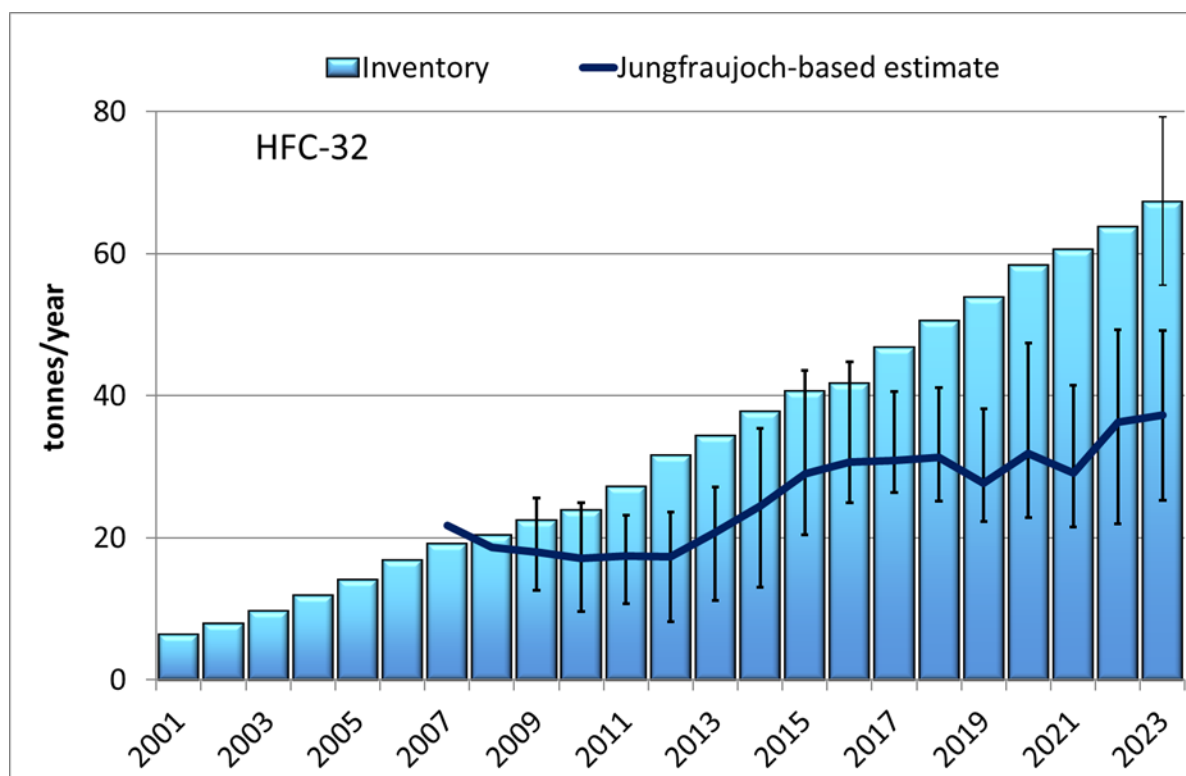


Figure A – 7 Comparison of HFC-32 emissions from Switzerland: Inventory and estimates from measurements at Jungfrauoch.

### *Sulfur hexafluoride (SF<sub>6</sub>)*

Until 2010, emissions of SF<sub>6</sub> 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 decommissioning of insulating windows have been dominant but are declining in recent years. Additional other emissions arise from magnesium smelters, industrial particle accelerators and various other applications. Generally, emission estimates for both methods show a remarkable similarity in the trend. Increasing SF<sub>6</sub> emissions were estimated between 2010 and 2015 and could be the result of the increased disposal of insulating windows (all SF<sub>6</sub> released) during this period. Since then, emissions from the inventory are constantly falling, whereas the Jungfraujoch-based estimate shows more or less stable emissions (Figure A – 8).

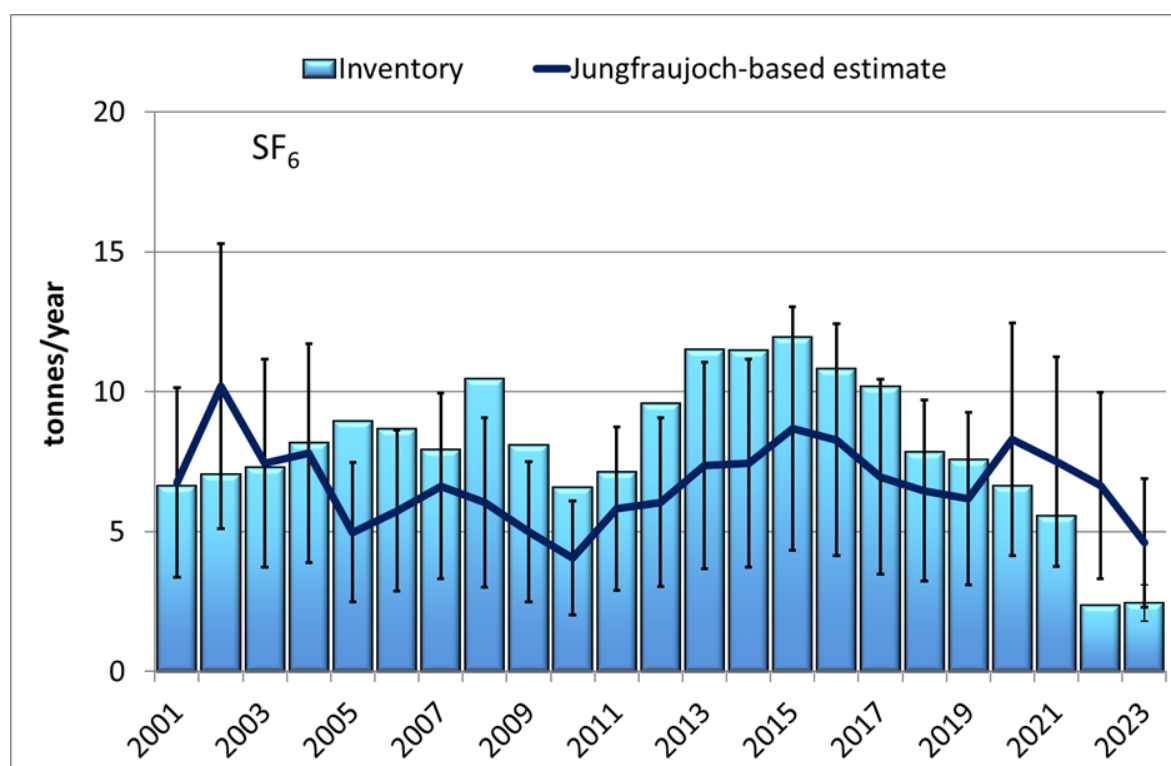


Figure A – 8 Comparison of SF<sub>6</sub> emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

### *Perfluorinated carbons (PFCs)*

Perfluorinated carbons are mainly used and emitted in the electronics industry. Since 2014, all PFCs contained in the NID have been measured at Jungfraujoch, which enables an independent verification of the inventory. Emissions of single PFCs are very small. Therefore, only results for the whole group are reported. The inventory-based estimate shows a stabilization in the recent years, whereas the measurement-based estimate shows an increase. The amounts of both methods are, however, overlapping when uncertainties are taken into consideration (Figure A – 9).



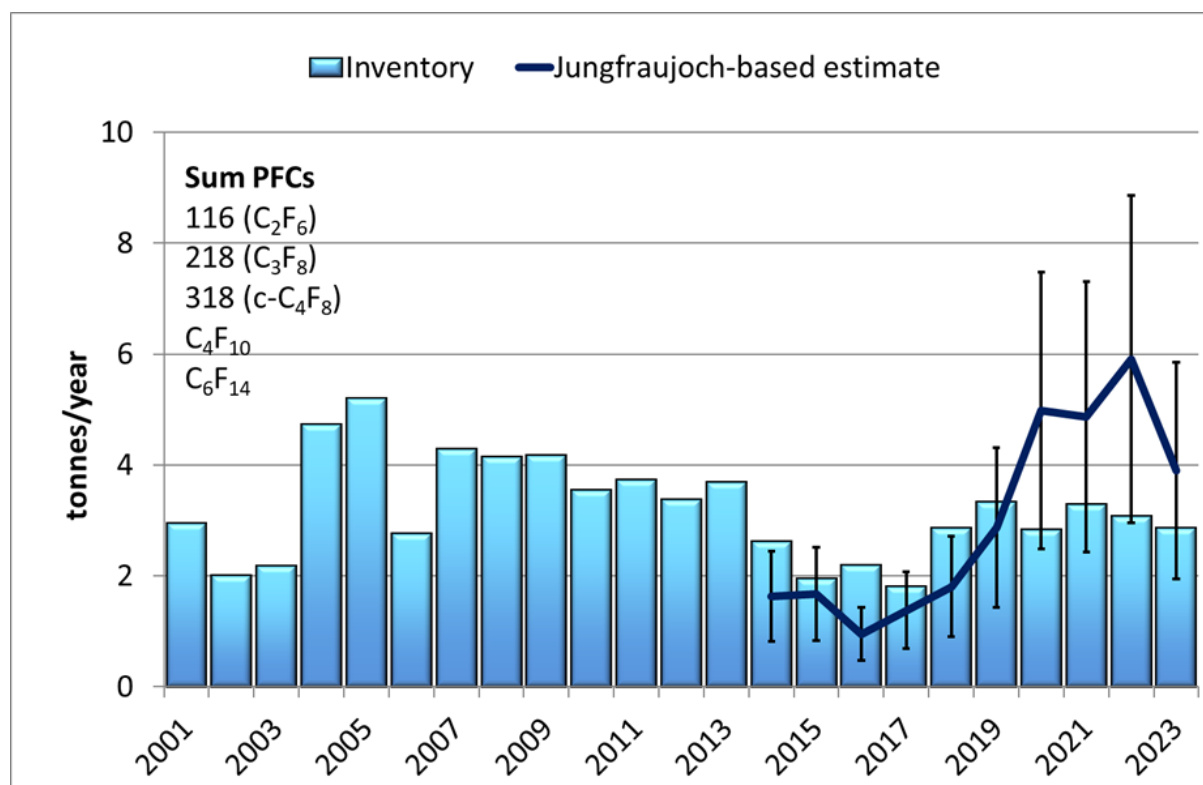


Figure A – 9 Comparison of PFC emissions from Switzerland: Inventory and estimates from measurements at Jungfraujoch.

## A6.2 Independent verification of methane and nitrous oxide emissions by inverse modelling

### Introduction

In 2013 the Swiss Federal Laboratories for Material Science and Technology (Empa), ETH Zurich 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](http://www.carbocount.ch)). The network consisted of four sites that continuously measure the atmospheric concentration of carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>). 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 (March 2025), 3 of the 4 sites (Beromünster, Lägern-Hochwacht, Gimmiz) are still operational, whereas the measurements at Frübüel 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 a FOEN-funded validation study to analyse the sensitivity of inverse modelling 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 (Empa) and Schauinsland (Germany, UBA, mountain top). High precision measurements of N<sub>2</sub>O commenced in March 2017 at the tall tower site Beromünster and additional N<sub>2</sub>O observations are available from Jungfraujoch and Schauinsland. Additional CH<sub>4</sub> and N<sub>2</sub>O observations in the vicinity of Switzerland became available in recent years as part of the Integrated Carbon Observing Network (ICOS; <https://www.icos-cp.eu>). ICOS sites used here include the French sites Puy de Dome (PUY),

Observatoire pérenne de l'environnement (OPE), the German sites Karlsruhe (KIT) and Hohenpeissenberg (HPB), and the Italian site Ispra (IPR).

Here, the results of inverse modelling to validate total Swiss CH<sub>4</sub> and N<sub>2</sub>O emissions are reported. A previous analysis for CH<sub>4</sub> had been 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 NID reporting and the top-down inverse modelling (Henne et al. 2016). That study also raised further questions regarding the spatial and temporal distribution of the emissions and the sensitivity to boundary conditions (i.e., CH<sub>4</sub> baseline concentrations) required for the regional inversion. Additional sensitivity tests concerning the use of additional measurements in north-eastern Switzerland and the use of baseline concentrations from global scale models were reported in a previous NIR (FOEN 2018). Here, results for CH<sub>4</sub> are given for the period 2013 to 2024, whereas for N<sub>2</sub>O inverse modelling results are given for 2017 to 2024.

### Methods

The inversion approach applied here was described in detail in Henne et al. (2016). It is based on 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<sup>-1</sup> 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) until 29 October 2020 (decommission of COSMO-7 forecasts and respective compute hardware). For FLEXPART simulations until the end of 2021, COSMO-7 analysis fields were calculated by Empa following the previous MeteoSwiss setup as closely as possible. In addition, FLEXPART simulations were conducted using operational MeteoSwiss COSMO-1 analysis fields for the period 2017-01-01–2024-08-31. Since September 2024 MeteoSwiss employs the next generation weather and climate model ICON as their operational analysis and forecast tool. Similar to COSMO, ICON is operated in an Ensemble Kalman Filter data assimilation configuration with nominal horizontal resolution of 1 km. A novel version of FLEXPART was developed to directly use the output of ICON on its native triangular grid. Here transport simulations starting from 2024-09-01 using FLEXPART-ICON are combined with FLEXPART-COSMO simulations beforehand. Since the COSMO-1 and ICON-1 domains are too small to represent the regional greenhouse gas signal sufficiently, FLEXPART-C1 simulations were extended using FLEXPART simulations based on larger-scale analysis fields taken from the European Centre for Medium-range Weather Forecast (ECMWF). 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 and 8 days backward in time for FLEXPART-C7 and FLEXPART-C1/FLEXPART-ECMWF, respectively. More details to the model setup can be found in Katharopoulos et al. (2022) and Katharopoulos et al. (2023).

When convoluting source sensitivities with gridded 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 modelling” an optimized (*a posteriori*) emission distribution 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 from the total observed concentration

Two sets of inversions were run based on the two different transport model versions: i) FLEXPART-C7 from 2013 to 2021 and ii) FLEXPART-C1 from 2018 to 2024. 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 here, varying some key aspects of the transport model and the inversion system. For inversions based on FLEXPART-C7 these were particle release height, absolute *a priori* emissions, and seasonality. For FLEXPART-C1 inversions three (two) different prior distributions, low/high prior emission uncertainty and low/high prior background uncertainty are evaluated in a total of seven (six) sensitivity inversions for CH<sub>4</sub> (N<sub>2</sub>O).

As *a priori* emissions for Switzerland, the MAIOLICA CH<sub>4</sub> 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 were 176 kt yr<sup>-1</sup>, which corresponds to the Swiss CH<sub>4</sub> emissions in 2012 as reported by the NIR in 2014 (FOEN 2014). The MAIOLICA inventory also includes a small contribution from natural sources of 3 kt yr<sup>-1</sup> (<2 %). For the application to more recent years the Swiss national total emissions were scaled to those included in the NIR in 2016 (FOEN 2016). For FLEXPART-C1 inversions the *a priori* emissions were updated based on a spatial disaggregation of the national inventory for the year 2015 (Heldstab et al. 2021) and using TNO Version 1.1 (Kuenen et al. 2014) and/or EDGAR Version 6.0 (Crippa et al. 2019), both taken for the base year 2015.

The same inversion technique as for CH<sub>4</sub> was also applied to N<sub>2</sub>O for the period March 2017 to December 2024. In addition to the grid-resolved inversion used for CH<sub>4</sub>, an additional sector-based inversion system was set-up for N<sub>2</sub>O, allowing for the distinction between emissions from different source sectors, but at a reduced spatial resolution (Henne et al. 2019). *A priori* emissions for the N<sub>2</sub>O inversion were developed with a spatial resolution of 500 m by 500 m and for 26 emission sectors based on EMIS/NID total national emission estimates and an evaluation of indirect emissions from (semi-)natural ecosystems (Bühlmann et al. 2015).

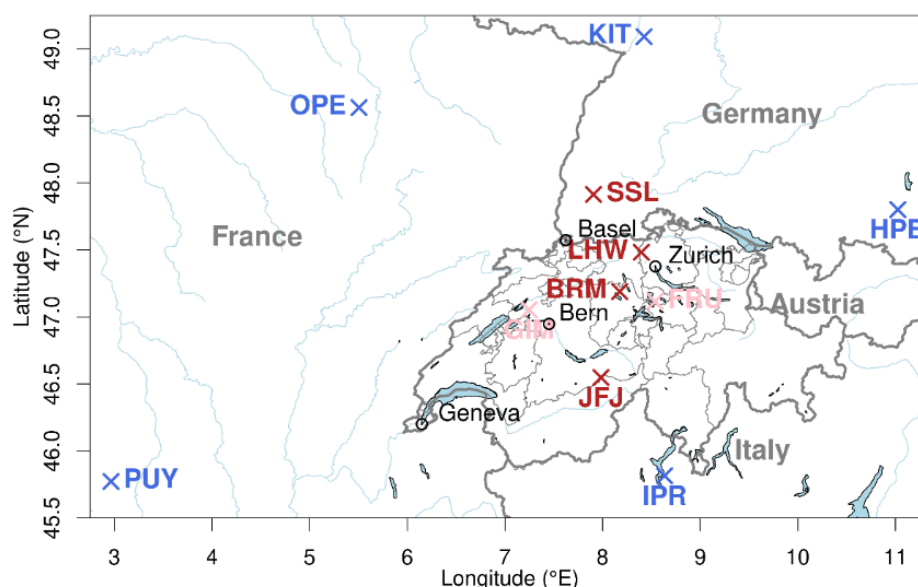


Figure A – 10 Map of Switzerland illustrating the location of observational sites used in FLEXPART-C7 inversions (red), additional ICOS sites used in FLEXPART-C1 inversions (blue), supplementary sites (pink), cantonal and national borders (grey) as well as major cities (black). The sites are: Beromünster (tall tower, BEO), Lägern Hochwacht (mountain top, tower, LHW), Gimmiz (flat, tower, GIM), Fröhnbühl (mountain, near surface, FRU), Schauinsland (mountain top, SSL), Jungfrauoch (high Alpine, JFJ), Puy de Dome (mountain top, PUY), Observatoire pérenne de l'environnement (tall tower, OPE), Karlsruhe (tall tower, KIT), Hohenpeissenberg (mountain top, HPB), Ispra (tall tower, IPR).

### *Methane emissions*

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).

Two sets of inversions were run based on FLEXPART-C7 and FLEXPART-C1/I1. The former covered the period 2013 to 2021, whereas the latter the period 2017 to 2024. Since the results of the two inversion sets differ systematically, they are compared separately with the NID reporting. The overall mean inverse estimate of total Swiss CH<sub>4</sub> emissions by the FLEXPART-C7 inversions for the period 2013 to 2021 was  $198 \pm 15$  kt yr<sup>-1</sup> (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 slightly (8 %) larger than NID values (incl. emissions from LULUCF) reported in the latest submission (2025) for the same period of 183 kt yr<sup>-1</sup> (CRT Table10s3) but well within the 1-σ uncertainty range of  $\pm 15$  kt yr<sup>-1</sup> as given for the reporting year 2022. Since inverse modelling estimates integrate all fluxes (sources and sinks) between the land surface and the atmosphere, they need to be compared to inventory emissions including those from LULUCF. For the period 2017 to 2023 the inverse estimate using the FLEXPART-C1/I1 simulations resulted in average emissions of  $245 \pm 14$  kt yr<sup>-1</sup>, 38 % larger than the NID reporting. It is apparent that FLEXPART-C1/I1 estimates are systematically larger than FLEXPART-C7 estimates (see Figure A – 11). Potential reasons are the differences in transport simulations, different sets of sensitivity inversions, different treatment/adjustment of baseline concentrations and the extended set of observations. For the FLEXPART-C1/I1 inversions larger-than-average emissions were

obtained when using an *a priori* based on the EDGAR inventory, increased *a priori* uncertainties and reduced background uncertainty. Further refinement of the inverse method is required to explain these discrepancies.

For the period 2013 to 2023, the NID suggests a CH<sub>4</sub> emission (incl. LULUCF) reduction of 14 kt (from 189 to 174 kt yr<sup>-1</sup> between 2013 and 2023), whereas the inversion estimates showed large inter-annual variability with considerably lower emissions in some years (FLEXPART-C7: 2018, 2019) and increased emissions in recent years (FLEXPART-C1/I1: 2019, 2021, 2023, 2024) (Figure A – 11). On one hand, this variability may reflect the uncertainty of the inverse modelling system itself, on the other hand, same variability may result from year-to-year variations in environmental drivers (e.g., temperature, precipitation). Due to this variability, it is currently not possible to determine or validate the reported trend. Additional years of observations and further improvements in the inverse modelling are required for this purpose.

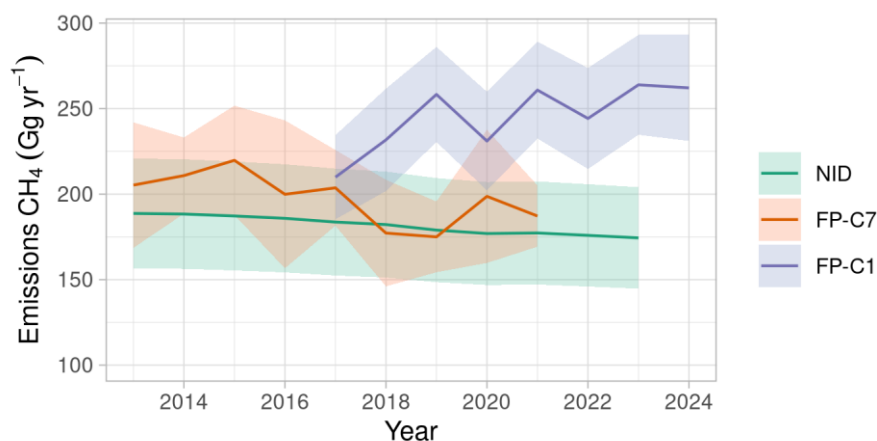


Figure A – 11 Time series of inversely estimated and NID reported Swiss CH<sub>4</sub> emissions. (NID reported and inversely estimated annual values and their uncertainties are given by lines, symbols and uncertainty ribbons. FP-C7 refers to the coarser FLEXPART-C7 simulations/inversions, whereas FP-C1 refers to the high-resolution FLEXPART-C1/I1 simulations/inversions. All uncertainty indicators refer to 2-σ levels. Results for 2024 are based on preliminary atmospheric observations.

In Figure A – 12 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 – 13 (FLEXPART-C7) and Figure A – 14 (FLEXPART-C1). 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 wastewater treatment reported in the NID.

The *a posteriori* results for the FLEXPART-C7 period (2013 to 2021) 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. In contrast results from FLEXPART-C1/I1 (2017–2024) were more variable in

annual total emissions and exhibited less of the east-west pattern in the emission increments than seen in FLEXPART-C7.

Analysing the inversion results on a seasonal level, reveals different seasonal variability for the two inversion sets. For FLEXPART-C7 reduced wintertime and increased spring emissions were detected for most years and as an average over all years (Figure A – 15). In contrast, FLEXPART-C1/I1 inversions resulted in lower-than-average winter/spring and larger than average summer/fall emissions (Figure A – 16). This seasonal trend seems to be driven by several years with exceptionally larger summer/fall emissions (2019, 2021, 2023), but is also present, although less prominent, in other years (2017, 2018). The contradictory behaviour between the different inversions and the potential relation to environmental drivers like temperature and precipitation requires further analysis. For example, the year 2021, with exceptionally large summer/fall emissions was characterised by a very wet summer (largest summer precipitation on record for several sites north of the Alps) followed by a warmer than average fall.

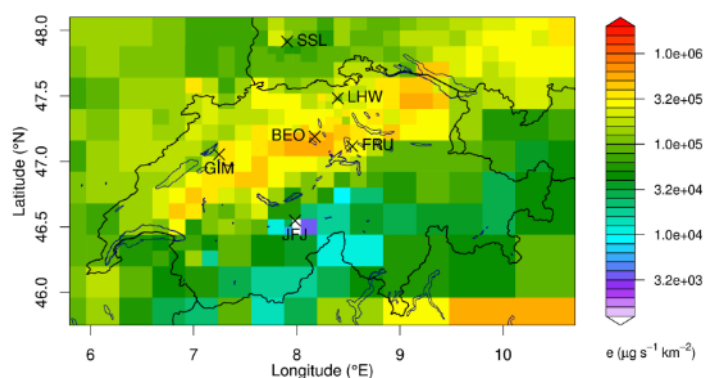


Figure A – 12 Spatial distribution of *a priori* CH<sub>4</sub> emissions. Within Switzerland the distribution follows that derived by Hiller et al. (2014), scaled to the bottom-up estimates of the NIR 2016 (FOEN 2016), outside Switzerland the bottom-up inventory of TNO/MACC (Kuenen et al. 2014) was used.



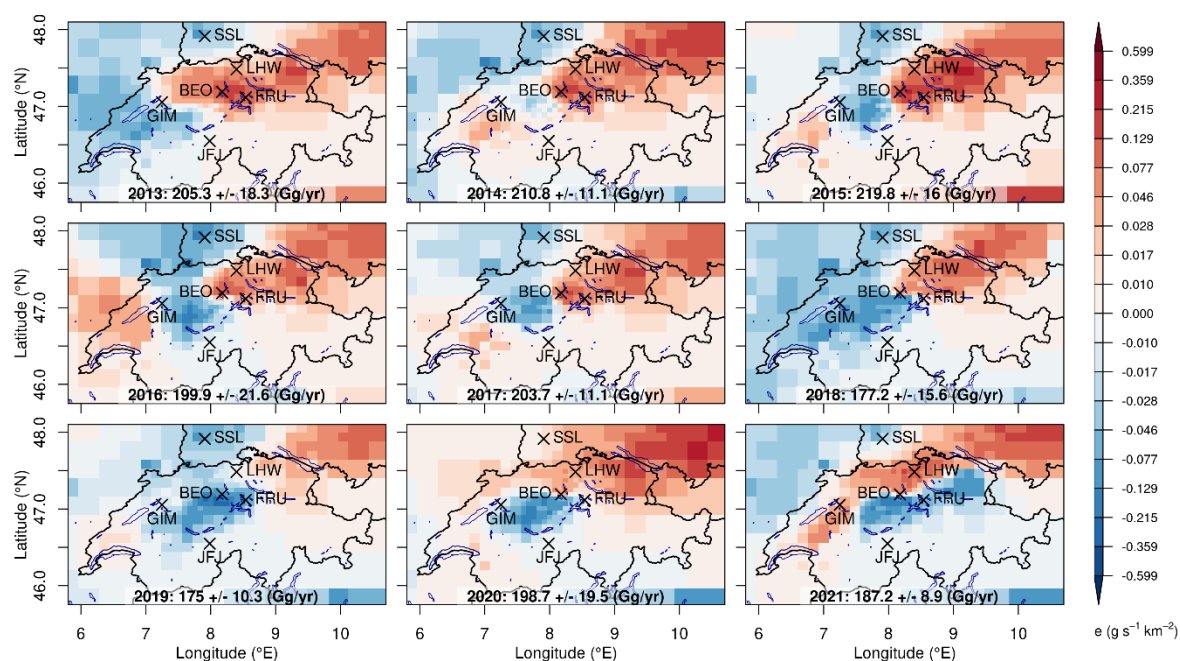


Figure A – 13 Absolute difference between *a posteriori* and *a priori* mean annual CH<sub>4</sub> emissions (each being the mean over 8 sensitivity runs) as obtained with FLEXPART-C7. The numbers given in the plots refer to the total *a posteriori* Swiss emissions and their uncertainty ( $1\sigma$  level) for the given year.

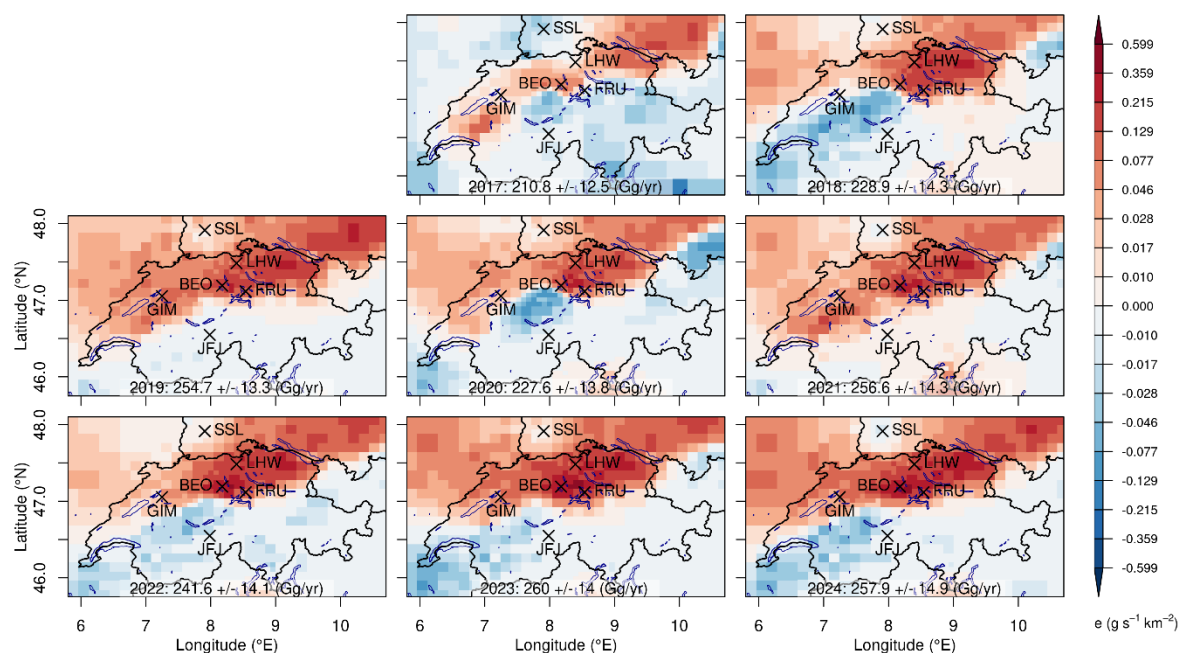


Figure A – 14 Absolute difference between *a posteriori* and *a priori* mean annual CH<sub>4</sub> emissions (base inversion only) as obtained with FLEXPART-C1. The numbers given in the plots refer to the total *a posteriori* Swiss emissions and their uncertainty ( $1\sigma$  level) for the given year. Results for 2023 are based on preliminary atmospheric observations.



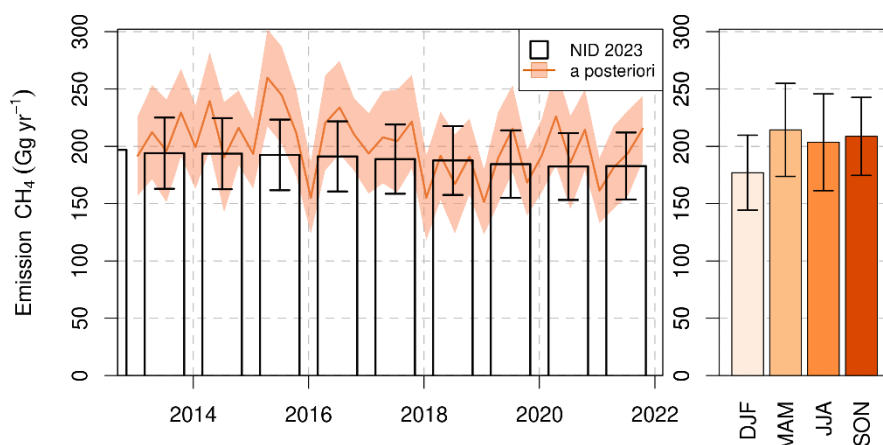


Figure A – 15 Seasonality of Swiss CH<sub>4</sub> emissions as obtained with FLEXPART-C7. Left panel: NID values and their uncertainties are given as black bars and error bars. *A posteriori* emissions are given as orange line and uncertainty ribbons. Average *a posteriori* emissions by season are given on the right panel (DJF: December, January, February; MAM: March, April, May; JJA: June, July, August; SON: September, October, November). All uncertainties refer to 2- $\sigma$  confidence intervals.

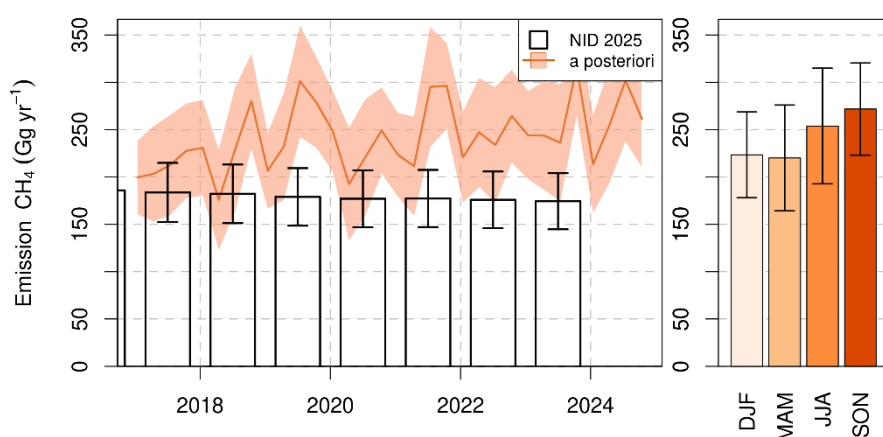


Figure A – 16 Seasonality of Swiss CH<sub>4</sub> emissions as obtained with FLEXPART-C1. Left panel: NID values and their uncertainties are given as black bars and error bars. *A posteriori* emissions are given as orange line and uncertainty ribbons. Average *a posteriori* emissions by season are given on the right panel (DJF: December, January, February; MAM: March, April, May; JJA: June, July, August; SON: September, October, November). All uncertainties refer to 2- $\sigma$  confidence intervals. Results for 2024 are based on preliminary atmospheric observations.

### Nitrous oxide emissions

With the N<sub>2</sub>O observations established at the Beromünster tall tower site in 2017, it was possible to estimate Swiss N<sub>2</sub>O emissions by inverse methods at the country scale for the period March 2017 to April 2018 (Henne et al. 2019). Inversely estimated Swiss N<sub>2</sub>O emissions were slightly larger than reported N<sub>2</sub>O emission. However, due to the large uncertainties connected to these numbers, the inverse estimates are not significantly different from the NID estimates. The relative uncertainty of the inverse modelling estimate was smaller than that of the NID estimate. The uncertainty range of the inverse method was calculated from the spread across 14 sensitivity inversions. These comprised the application of two different inversion approaches: one focussing on the spatial distribution (grid inversion), the other on the temporal evolution and emissions by sector (sector inversion). The largest contributors to the *a posteriori* spread were the definition and uncertainty of a

baseline of the atmospheric concentrations required by the model approach and systematic differences between grid and sector inversions.

The inverse modelling methodology described in Henne et al. (2019) was extended to the period 2017 to 2024. A slightly different set of 11 sensitivity inversions (per year) was selected, using both inversion approaches and varying important factors of the inversion setup: baseline, *a priori* emissions, receptor height above model ground.

The best inverse estimate of Swiss annual  $\text{N}_2\text{O}$  emissions for the years 2018 to 2023 was  $11.3 \pm 1.8 \text{ Gg yr}^{-1}$  based on FLEXPART-C1/I1 inversions. This compares to 11.6 (8.0 to 15.3)  $\text{Gg yr}^{-1}$  given for the same period in this NID (incl. emissions from LULUCF; 2- $\sigma$  confidence range; compare Figure A – 17). With recent updates in the present NID, inverse estimates and NID estimates agree very closely. The small downward trend, as present in the NID for the most recent years and especially since 2022 due to decreased industrial emissions, can only partly be seen in the inverse estimate (FLEXPART-C7 inversions) but is less evident in FLEXPART-C1/I1 inversions.

The inversion model assigned the largest changes of  $\text{N}_2\text{O}$  emissions (*a priori* to *a posteriori* difference) to ‘industry’ (smaller than *a priori*) and ‘agriculture’ (larger than *a priori*), whereas emissions in all other categories remained similar to the *a priori*. Reductions in the uncertainty of these estimates were largest for the sectors ‘agriculture’ and ‘industry’, whereas they remained almost unchanged for the other categories. Further support for reduced industry emissions is provided by the grid inversions, which estimated that emissions in urban areas are potentially overestimated in the *a priori*. In general, *a posteriori* emissions were larger (smaller) in eastern (western) Switzerland (compare Figure A – 18 for spatial distributions of emissions; Figure A – 19 for emissions by sector).

All inversions suggested a pronounced seasonality in the emissions with a mean amplitude over all inversions of around  $\pm 40\%$  of the annual total (Figure A – 20). Largest emissions were estimated in summer, smallest in winter. However, there was considerable spread in the seasonal amplitude as well, with the tendency of inversions with smaller annual total emissions to predict smaller summertime emissions and correspondingly smaller seasonal amplitudes. Seasonality was dominated by emissions from soils. The strong seasonality obtained here for Switzerland compares well with other recent inverse estimates of  $\text{N}_2\text{O}$  emissions in Europe. Some of these studies also highlight a similarly pronounced seasonality (Ganesan et al. 2015, Brown et al. 2019).

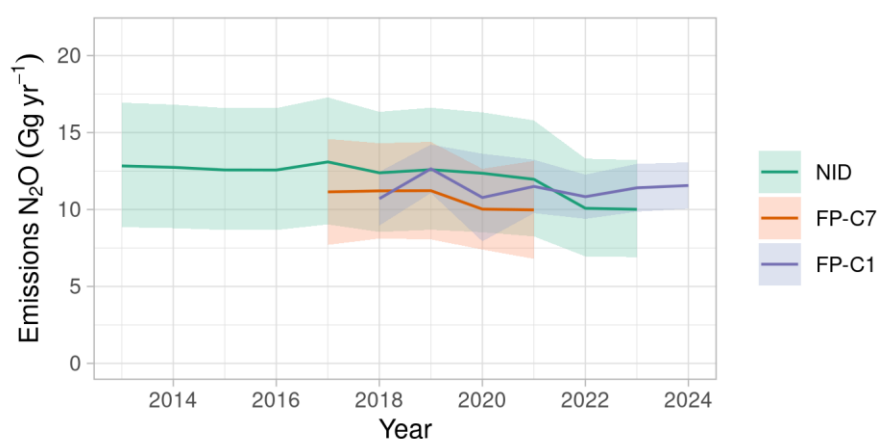


Figure A – 17 Time series of inversely estimated and NID reported Swiss  $\text{N}_2\text{O}$  emissions. (NID reported and inversely estimated annual values and their uncertainties are given by lines, symbols and uncertainty ribbons. FP-C7 refers to the coarser FLEXPART-C7 simulations/inversions, whereas FP-C1 refers to the high-resolution FLEXPART-C1/I1 simulations/inversions. All uncertainty indicators refer to 2- $\sigma$  levels. Results for 2024 are based on preliminary atmospheric observations.

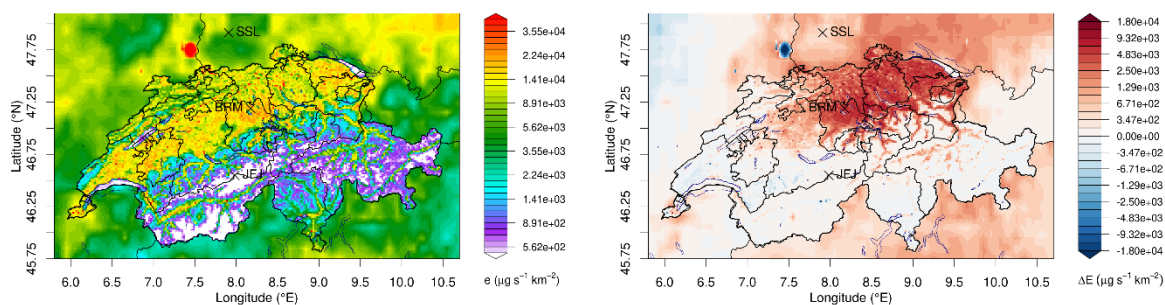


Figure A – 18 (Left) mean *a priori* and (right) *a posteriori* minus *a priori*  $\text{N}_2\text{O}$  emission distribution over all FLEXPART-C1/I1 sensitivity inversions for the period March 2018 to November 2024.

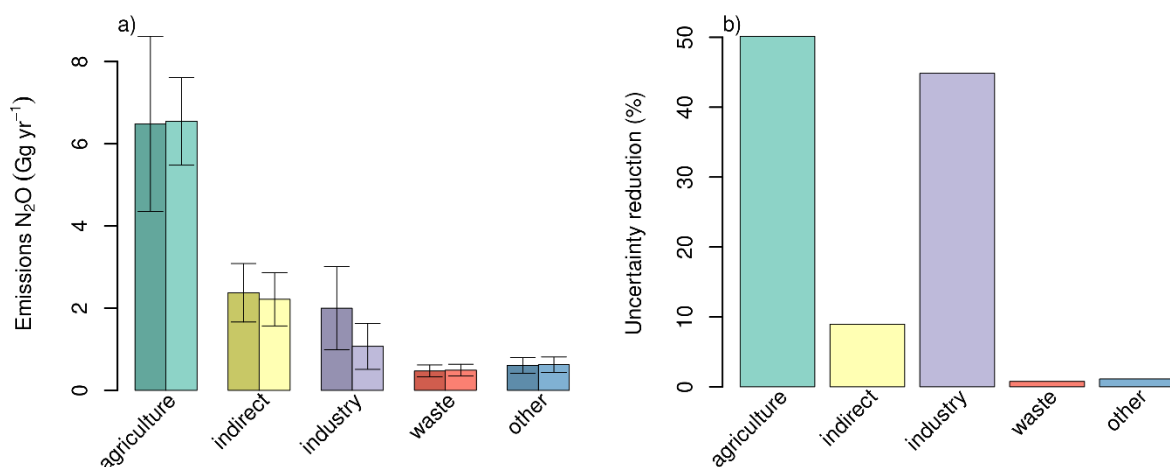


Figure A – 19 (Left) contributions to Swiss  $\text{N}_2\text{O}$  emissions: *a priori* darker colours, *a posteriori* lighter colours. (right) reduction of uncertainty estimate from *a priori* assumption to inverse *a posteriori* estimate. Results present the average for the period March 2018 to November 2024. Uncertainty bars represent 2- $\sigma$  confidence intervals.

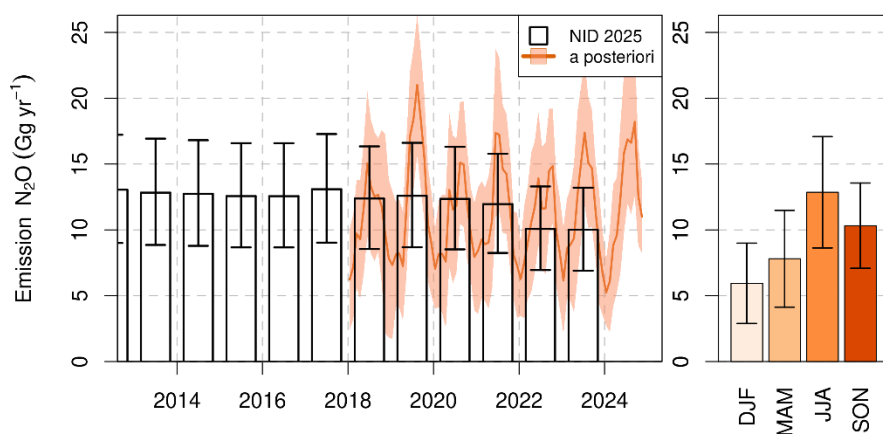


Figure A – 20 Seasonality of Swiss N<sub>2</sub>O emissions based on FLEXPART-C1/I1 inversions. Left panel: NID values and their uncertainties are given as black bars and error bars. Monthly *a posteriori* emissions are given as orange line and uncertainty ribbons. Average *a posteriori* emissions by season are given on the right panel (DJF: December, January, February; MAM: March, April, May; JJA: June, July, August; SON: September, October, November). All uncertainties refer to 2- $\sigma$  confidence intervals. Results for 2024 are based on preliminary atmospheric observations.

## Annex 7 Information on the ETF Reporting tools (ETF-GHGI tool, CRT reporter)

For the submission at hand the ETF Reporting Tools, specifically the ETF-GHG-inventory reporting tool (CRT reporter), provided by UNFCCC (<https://myapps.unfccc.int/myapps>) has been used to create reporting tables (CRT).

Switzerland makes use of the .json file export/import capabilities of the ETF-GHGI tool. A country-specific .json file is produced by a custom made command line application with inputs from the Swiss EMIS database. This set-up was successfully used for timely submission 2024 (CRT 1990–2022, FOEN (2024)). However, Switzerland experienced severe performance problems using the ETF Reporting tools in the preparation of the submission 2025.

Since January 2025, the CRT reporter has become increasingly unresponsive and almost impossible to work with. Switzerland sent several questions to the helpdesk and a Q&A session, but answers did hardly help to resolve the issues and have only been provided with considerable delays. This development had serious consequences for the creation of the reporting tables (CRT) and thus on our time schedule and most importantly on the QA/QC process because a lot of time was lost to handle the ETF tool. For example, for QC tasks priority was given to correct numbers but notation keys and further textual information as documentation boxes could not be updated properly due to limited resources.

After personal contact, the UNFCCC secretariat provided support in various video calls in March 2025. We learned that the latest version of the tool (released 6 February 2025) included technical shortcomings concerning country-specific nodes at least for .json imports to the tool (Personal communication with Renat Ishmukhametov, Kristina Kaar and Nashib Kafle, 2025). As it was not possible to import .json files including all country-specific nodes and values to the CRT reporter, Switzerland decided to submit a version of reporting tables (CRT) that does not include a full view on country-specific nodes. Provided there is a functioning CRT reporter and provided that the time resources are available, Switzerland aims to produce complete reporting tables 1990–2023.

For the previous submission (FOEN 2024), the tool seemed to generate errors in the (numerical) output of some reporting tables. A non-exhaustive list of issues and errors identified so far was provided in Table A – 29 in FOEN (2024).

Aspects described above should be taken into consideration when comparing information in the NID with the reporting tables (CRT).

## Annex 8 Common reporting tables

This NID describes Common reporting tables (CRT) produced by the ETF Reporting Tools, specifically by the ETF-GHG-inventory reporting tool (CRT Reporter) as released on 6 February 2025, making use of GWP values from the 5. Assessment Report of the IPCC (Myhre et al. 2013) for the years 1990–2023.

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All links to external sources were verified prior to submission. If a link is no longer valid, please reach out for assistance - references can be provided from the internal database (see contact details in section **Reader's comments** on page 4).

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## References to EMIS database comments

Table A – 28 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. In case the code corresponding to the CLRTAP nomenclature is different compared to the code given by the UNFCCC nomenclature, or in case the code is only applicable for the CLRTAP, the code for the CLRTAP is given in square brackets.

"NFR code" for reporting to the UNFCCC and CLRTAP, if different, code for CLRTAP in brackets []	Title in EMIS	"NFR code" for reporting to the UNFCCC and CLRTAP, if different, code for CLRTAP in brackets []	Title in EMIS
1 A	Energiemodell***	2 D 3 a [2 D 3 g]	Feinchemikalien-Produktion**
1 A	Holzfeuerungen	2 D 3 a [2 D 3 g]	Gummi-Verarbeitung**
1 A	Non-Road	2 D 3 a [2 D 3 g]	Klebband-Produktion
1 A	Stationary engines and gas turbines	2 D 3 a [2 D 3 g]	Klebstoff-Produktion**
1 A 2	Sektorgliederung Industrie	2 D 3 a [2 D 3 g]	Lösungsmittel-Umschlag und -Lager
1 A 1 a	Kehrichtverbrennungsanlagen	2 D 3 a [2 D 3 g]	Pharmazeutische Produktion**
1 A 1 a	Sondermüllverbrennungsanlagen	2 D 3 a [2 D 3 g]	Polyester-Verarbeitung**
1 A 1 a & 5 A	Kehrichtdeponien	2 D 3 a [2 D 3 g]	Polystyrol-Verarbeitung**
1 A 1 b	Heizkessel Raffinerien* (ab 2015)	2 D 3 a [2 D 3 g]	Polyurethan-Verarbeitung
1 A 1 c	Holzkohle Produktion	2 D 3 a [2 D 3 g]	PVC-Verarbeitung
1 A 2 a & 2 C 1	Eisengießereien Kupolöfen	2 D 3 a [2 D 3 g]	Gerben von Ledermaterialien
1 A 2 a	Stahl-Produktion Wärmeföfen**	2 D 3 b	Strassenbelagsarbeiten**
1 A 2 b	Buntmetallgießereien übriger Betrieb**	2 D 3 c	Dachpappe**
1 A 2 b & 2 C 3	Aluminium Produktion	2 D 3 d	Urea (AdBlue) Einsatz Strassenverkehr
1 A 2 c & 2 B 8 b [2 B 10 a]	Ethen-Produktion*	2 G 3 a	Lachgasanwendung Spitäler**
1 A 2 d & 2 A 4 d	Zellulose-Produktion Feuerung*	2 G 3 b	Lachgasanwendung Haushalt**
1 A 2 f	Kalkproduktion, Feuerung*	2 G 4 [2 D 3 a]	Pharma-Produkte im Haushalt
1 A 2 f	Mischgut Produktion	2 G 4 [2 D 3 a]	Reinigungs- und Lösemittel; Haushalte
1 A 2 f	Zementwerke Feuerung	2 G 4 [2 D 3 h]	Verpackungsdruckereien**
1 A 2 f & 2 A 3	Glas übrige Produktion*	2 G 4 [2 D 3 h]	Druckereien übrige**
1 A 2 f & 2 A 3	Glaswolle Produktion Rohprodukt**	2 G 4 [2 D 3 i]	Entfernung von Farben und Lacken**
1 A 2 f & 2 A 3	Hohlglas Produktion*	2 G 4 [2 D 3 i]	Entwachsung von Fahrzeugen
1 A 2 f & 2 A 4 a	Feinkeramik Produktion*	2 G 4 [2 D 3 i]	Kosmetika-Produktion**
1 A 2 f & 2 A 4 a	Ziegeleien**	2 G 4 [2 D 3 i]	Lösungsmittel-Emissionen IG nicht zugeordnet
1 A 2 f & 2 A 4 d	Steinwolle Produktion*	2 G 4 [2 D 3 i]	Öl- und Fettgewinnung
1 A 2 g iv [1 A 2 g viii]	Faserplatten Produktion* (ab 2020)	2 G 4 [2 D 3 i]	Papier- und Karton-Produktion**
1 A 2 g viii & 5 B 2	Vergärung IG (industriell-gewerblich)	2 G 4 [2 D 3 i]	Parfum- und Aromen-Produktion**
1 A 3 a & 1 A 5	Flugverkehr	2 G 4 [2 D 3 i]	Tabakwaren Produktion**
1 A 3 b i-v [1 A 3 b i-vi]	Strassenverkehr	2 G 4 [2 D 3 i]	Textilien-Produktion**
1 A 3 c	Schienerverkehr	2 G 4 [2 D 3 i]	Wissenschaftliche Laboratorien
1 A 3 e	Gastransport Kompressorstation	2 G 4 [2 G]	Korrosionsschutz im Freien
1 A 4 b i	Holzkohle-Verbrauch	2 G 4 [2 G]	Betonzusatzmittel-Anwendung
1 A 4 b i	Lagerfeuer	2 G 4 [2 G]	Coffeursalons
1 A 4 c i	Gewächshäuser**	2 G 4 [2 G]	Fahrzeug-Unterbodenschutz**
1 A 4 c i	Gastrocknung**	2 G 4 [2 G]	Feuerwerke
1 A 4 c i & 5 B 2	Vergärung LW (landwirtschaftlich)	2 G 4 [2 G]	Flächenenteisung Flughäfen
1 B 2 a iii	Raffinerie, Pipelinetransport	2 G 4 [2 G]	Flugzeug-Enteisung
1 B 2 a iv	Raffinerie, Leckverluste*	2 G 4 [2 G]	Frostschutzmittel Automobil
1 B 2 a iv	H2-Produktion*	2 G 4 [2 G]	Gas-Anwendung
1 B 2 a iv	Raffinerie, Clausanlage*	2 G 4 [2 G]	Gesundheitswesen, übrige**
1 B 2 a v	Benzinumschlag Tanklager	2 G 4 [2 G]	Glaswolle Imprägnierung**
1 B 2 a v	Benzinumschlag Tankstellen	2 G 4 [2 G]	Holzschutzmittel-Anwendung
1 B 2 b ii & 1 B 2 c ii 2	Gasproduktion & Gasproduktion, Flaring	2 G 4 [2 G]	Klebstoff-Anwendung**
1 B 2 b iv-vi	Netzverluste Erdgas	2 G 4 [2 G]	Kosmetik-Institute
1 B 2 c ii 1	Raffinerie, Abfackelung	2 G 4 [2 G]	Kühlschmiermittel-Verwendung
2 A 1	Zementwerke Rohmaterial	2 G 4 [2 G]	Medizinische Praxen**
2 A 4 d [2 A 1]	Zementwerke übriger Betrieb	2 G 4 [2 G]	Pflanzenschutzmittel-Verwendung
2 A 2	Kalkproduktion, Rohmaterial*	2 G 4 [2 G]	Reinigung Gebäude IGD**
2 A 4 d [2 A 2]	Kalkproduktion, übriger Betrieb*	2 G 4 [2 G]	Schmierstoff-Verwendung
2 A 4 d	Kehrichtverbrennungsanlagen Karbonat**	2 G 4 [2 G]	Spraydosen IndustrieGewerbe
2 A 4 d	Karbonatanwendung weitere	2 G 4 [2 G]	Tabakwaren Konsum
2 A 4 d [2 A 5 a]	Gips-Produktion übriger Betrieb* (ab 2021)	2 G 4 [2 G]	Steinwolle-Imprägnierung*
2 A 5 a	Kieswerke	2 H 1	Faserplatten Produktion* (ab 2020)
2 B 1	Ammoniak-Produktion*	2 H 1	Zellulose Produktion übriger Betrieb*
2 B 10 b [2 B 10 a]	Ammoniumnitrat-Produktion*	2 H 1	Spanplatten Produktion*
2 B 10 b [2 B 10 a]	Chlorgas-Produktion*	2 H 2	Bierbrauereien
2 B 10 b [2 B 10 a]	Essigsäure-Produktion* (ab 2013)	2 H 2	Branntwein Produktion
2 B 10 b [2 B 10 a]	Formaldehyd-Produktion	2 H 2	Brot Produktion
2 B 10 b [2 B 10 a]	PVC-Produktion	2 H 2	Fleischräuchereien
2 B 10 b [2 B 10 a]	Salzsäure-Produktion*	2 H 2	Kaffeeröstereien
2 B 10 b [2 B 10 a]	Schwefelsäure-Produktion*	2 H 2	Müllereien
2 B 10 b	Kalksteingrube*	2 H 2	Wein Produktion
2 B 10 b [2 B 10 a]	Niacin-Produktion*	2 H 2	Zucker Produktion
2 B 2	Salpetersäure Produktion*	2 H 3	Sprengen und Schiessen
2 B 5	Graphit und Siliziumkarbid Produktion*	[2 I]	Holzbearbeitung
2 C - 2 G	Synthetische Gase	[2K, 1A1a, 2C1, 5A, 5C1, 5E & 6A5]	Emissions due to former PCB usage
2 C 1	Eisengießereien Elektroschmelzöfen	2 H 3 [2 L]	NH3 aus Kühlanlagen
2 C 1	Eisengießereien übriger Betrieb	3	Landwirtschaft
2 C 1 & 1 A 2 a	Stahl-Produktion Elektroschmelzöfen**	3 B	Tierhaltung
2 C 1	Stahl-Produktion übriger Betrieb**	3 C	Reisanbau
2 C 1	Stahl-Produktion Walzwerke**	[3 D e]	Landwirtschaftsflächen
2 C 7 a	Buntmetallgießereien Elektroöfen**	4 (IV) A 1 [11 B]	Waldbrände
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 a i & 5 C 1 b i [5 C 1 a]	Abfallverbrennung illegal
2 D 1	Schmiermittel-Verbrauch B2T	5 C 1 b ii 1 [5 C 1 b i]	Kabelabbrand
2 D 2	Paraffinwachs-Anwendung	5 C 1 b ii 3 [5 C 1 b iii]	Spitalabfallverbrennung
2 D 3 a [2 D 3 d]	Farben-Anwendung Bau	5 C 1 a ii 4 [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 (IV) A 1 (Forstwirtschaft)	Abfallverbrennung Land- und Forstwirtschaft und Private
2 D 3 a [2 D 3 d]	Farben-Anwendung Holz	5 D 1	Kläranlagen kommunal (Luftschadstoffe)
2 D 3 a [2 D 3 d]	Farben-Anwendung Autoreparatur**	5 D 2	Kläranlagen industriell (Luftschadstoffe)
2 D 3 a [2 D 3 e]	Elektronik-Reinigung**	5 D 1 & 5 D 2	Abwasserbehandlung 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 1 [6 A 4]	Brand- und Feuerschäden Immobilien
2 D 3 a [2 D 3 f]	Chemische Reinigung**	6 A 1 [6 A 4]	Brand- und Feuerschäden Motorfahrzeuge
2 D 3 a [2 D 3 g]	Druckfarben Produktion**	[11 C]	NMVOE Emissionen Wald
2 D 3 a [2 D 3 g]	Farben-Produktion**	1, 2, 5, 6 - indirect	Indirekte Emissionen

\* confidential process

\*\* confidential EMIS comment

\*\*\* work in progress

Italic: process not relevant for the years after 1990.

New model / comment for the current submission.