Switzerland’s Informative Inventory Report 2024 (IIR)

Submission under the UNECE Convention on Long-range Transboundary Air Pollution

Submission of March 2024
to the United Nations ECE Secretariat

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IIR_CHE_2024

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Glossary

AD	Activity data
Avenergy	Avenergy Suisse (Swiss Petroleum Association, formerly Erdöl-Vereinigung (EV))
BaP	Benzo(a)pyrene (CLRTAP: POP)
BbF	Benzo(b)fluoranthene (CLRTAP: POP)
BC	Black Carbon
BkF	Benzo(k)fluoranthene (CLRTAP: POP)
Carbura	Swiss organisation for the compulsory stockpiling of oil products
CCGT	Combined cycle gas turbine
CEIP	EMEP Centre on Emission Inventories and Projections
Cd	Cadmium (CLRTAP: priority heavy metal)
Cemsuisse	Association of the Swiss cement industry
CHP	Combined heat and power
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
CO_2	Carbon dioxide
CRF	Common Reporting Format (UNFCCC)
CRT	Common Reporting Tables (UNFCCC; https://unfccc.int/documents/311076)
DDPS	Federal Department of Defense, Civil Protection and Sport
DETEC	Department of the Environment, Transport, Energy and Communications
DIY	Do it youself markets
EF	Emission Factor
EMIS	Swiss Emission Information System
EMEP	European Monitoring and Evaluation Programme: Co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe (under the CLRTAP)
EMPA	Swiss Federal Laboratories for Material Testing and Research
EPA	Federal Act on the Protection of the Environment
EV	Erdöl-Vereinigung (petroleum association), since 2019: Avenergy Suisse
ex	In combination with pollutant (PM2.5 ex, PM10 ex, TSP ex, BC ex or Cd ex)) exhaust fraction of this pollutant emissions
FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2013 Agroscope)
FCA	Federal Customs Administration, since 03.01.2022: Federal Office for Customs and Border Security (FOCBS)

FEDRO	Swiss Federal Roads Office
FOCA	Federal Office of Civil Aviation
FOEN	Federal Office for the Environment (former name SAEFL until 2005)
FOCBS	Federal Office for Customs and Border Security, formerly Federal Customs Administration (FCA)
FSKB	Fachverband der Schweizerischen Kies- und Betonindustrie
FSO	Federal Statistical Office (formerly SFSO)
Gas oil	Light fuel oil
GHG	Greenhouse Gas
GVS	Giesserei Verband der Schweiz / Swiss Foundry Association
ha	Hectare
HAFL	School of Agricultural, Forest and Food Sciences at Bern University of Applied Sciences
HCB	Hexachlorobenzene
Hg	Mercury (CLRTAP: priority heavy metal)
HM	Heavy Metals
IcdP	Indeno(1,2,3-cd)pyrene (CLRTAP: POP)
IIR	Informative Inventory Report (CLRTAP)
INFRAS	Research and consulting company, Zurich/Berne
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ICAO	International Civil Aviation Organization
I-Teq	International Toxic Equivalent (unit of toxic equivalent factors for PCB’s, PCDDs, PCDFs for Human and Wildlife by WHO
IVZ	Swiss information system traffic admission (Informationssystem Verkehrszulassung IVZ) run by FEDRO, formerly MOFIS
kt	Kilo tonne (1000 tonnes)
L1, L2	Key category according to level assessment with approach 1, approach 2
LTO	Landing and Takeoff-Cycle (Aviation)
LUBW	Baden-Württemberg State Institute for Environmental Protection (Landesanstalt für Umweltschutz Baden-Württemberg), Germany
LULUCF	Land Use, Land-Use Change and Forestry
MOFIS	Swiss federal vehicle registration database run by FEDRO (since 2022: IVZ)
MSW	Municipal Solid Waste
NCV	Net Calorific Value
NFR	Nomenclature For Reporting
NH_3	Ammonia
NID	National Inventory Document

NIS	National Inventory System
NMVOC	Non-Methane Volatile Organic Compounds
NO_x, NO_2, NO	Nitrogen oxides, nitrogen dioxide, nitrogen monoxide
NA, NE, IE, NO, NR	(official notation keys) Not Applicable, Not Estimated, Implied Elsewhere, Not Occuring, Not Relevant
nx	In combination with pollutant (PM2.5 nx, PM10 nx, TSP nx, BC nx or Cd nx)) non-exhaust fraction of this pollutant emissions
OAPC	Ordinance on Air Pollution Control
PAH	Polycyclic aromatic hydrocarbons (CLRTAP: POP)
PCDD/PCDF	Polychlorinated Dibenzodioxins and -Furanes (CLRTAP: POP)
Pb	Lead (CLRTAP: priority heavy metal)
PCB	Polychlorinated Biphenyls
PM, PM2.5, PM10	Suspended Particulate Matter (PM) with an aerodynamic diameter of less than 2.5 µm or 10 µm, respectively.
POPs	Persistent Organic Pollutants
QA/QC	Quality Assurance/Quality Control: QA includes a system of review procedures conducted by persons not directly involved in the inventory development process. QC is a system of routine technical activities to control the quality of the inventory.
QMS	Quality Management System
SAEFL	Swiss Agency for the Environment, Forests and Landscape (since 2006: Federal Office for the Environment FOEN)
SBV	Swiss farmer's union ("Schweizer Bauernverband") or Swiss association of builders ("Schweizerischer Baumeisterverband")
SCGT	Simple cycle gas turbine
SFOE	Swiss Federal Office of Energy
SFSO	Swiss Federal Statistical Office, now: Federal Statistical Office (FSO)
SO_x, SO_2	Sulphur oxides, sulphur dioxide
SGWA	Swiss Gas and Water Industry Association
SPA	"Schwerpunktaktion", measurement project by the Federal Office for Customs and Border Security (FOCBS) to estimate the sulphur content for diesel oil, gasoline, gas oil Euro and Eco and residual fuel oil
swissmem	Swiss Mechanical and Electrical Engineering Industries (Schweizer Maschinen-, Elektro- und Metallindustrie)
T1, T2	Key category according to trend assessment with approach 1, approach 2
TAN	Total Ammonia Nitrogen
TFEIP	Task Force on Emission Inventory and Projections
TSP	Total Suspended Particulate matter
TSS	"Tankstellensurvey", measurement project by the Federal Office for Customs and Border Security (FOCBS) to estimate the sulphur content for diesel oil and gasoline
UNFCCC	United Nations Framework Convention on Climate Change

VKTS	Swiss supervising association of textile cleaning
VOC	Volatile Organic Compounds
VSG/SGIA	Swiss Gas Industry Association
VSLF	Swiss association for coating and paint applications
VSTB	Swiss association of grass drying plants
VTG	Swiss Armed Forces – Defence (“Die Gruppe Verteidigung“)
WaM	Scenario “With additional Measures”
WM	Scenario “With Measures”
ZPK	Swiss association of pulp, paper and paperboard industry

Executive Summary

Swiss CLRTAP inventory system

The Swiss inventory system has been developed and is managed by the Federal Office for the Environment (FOEN) under the auspices of the Federal Department of the Environment, Transport, Energy and Communications (DETEC).

FOEN's Air Pollution Control and Chemicals Division maintains a database called EMIS (**EM**issions**I**nformationssystem **S**chweiz, Swiss Emission Information System) containing all basic data needed to prepare the CLRTAP inventory. Background information on data sources, activity data, emission factors and methods used for emission estimation are documented in EMIS.

A number of data suppliers provide input data that is fed into EMIS. The inventory's most relevant data sources are the Swiss overall energy statistics, existing models for road transportation and non-road vehicles and machines, data from industry associations and agricultural statistics and models.

Typically, emissions are calculated according to standard methods and procedures as described in the revised UNECE Guidelines 2023 for Estimating and Reporting Emission Data under the Convention on Long Range Transboundary Air Pollution (ECE 2023) and in the EMEP/EEA Air Pollutant Emission Inventory Guidebook, editions 2016, 2019 and 2023 (EMEP/EEA 2016, 2019, 2023). With a few exceptions, calculations of emissions are consistent with methodological approaches in the greenhouse gas (GHG) inventory under the UNFCCC. However, some relevant differences exist. For example, the Swiss CLRTAP Inventory system applies the "fuel used" principle for road traffic emissions for estimating compliance with the emission reduction ceilings, while for the GHG inventory, the "fuel sold" principle applies. This means that the so called "fuel tourism" and statistical differences is accounted for in the emissions of the GHG inventory, but not in the CLRTAP Inventory. Note that in the official emission reporting templates the Swiss "National total for the entire territory" (row 141 in the reporting tables) is reported as "fuel sold" in order to be comparable to other countries. **But the Swiss "national total for compliance" with Gothenburg Protocol commitments (row 152 in the reporting tables) is the national total based on the "fuel used"** as mentioned before. The difference between the two approaches can amount to several percent, but deviations varied considerably in the period 1990–2022 due to fluctuating fuel price differences between Switzerland and its neighbouring countries. Also, methodological approaches to determine emissions from aviation under the CLRTAP deviate from the GHG inventory: for the national total CLRTAP, so-called landing and take-off (LTO) emissions of domestic and international flights are taken into account while emissions of international and domestic cruise flights are reported under memo items only (see also chp. 3.1.6.1).

Switzerland and CLRTAP

Switzerland is a Party to the 1979 Geneva Convention on Long-range Transboundary Air Pollution (CLRTAP). The aim of the Convention is to protect the population and the environment against air pollution and to limit and gradually reduce and prevent air pollution including long-range transboundary air pollution. The seven CLRTAP Protocols including the Gothenburg Protocol, require an annual emission reporting. The 1999 Gothenburg Protocol is a multi-pollutant protocol designed to reduce acidification, eutrophication and ground-level ozone by setting national emissions ceilings for sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia, which were to be met by 2010 and maintained afterwards. A revision of the Protocol including emission reduction commitments for 2020 and beyond expressed as a percentage reduction from the 2005 emission level was adopted in 2012 and entered into force on 7 October 2019. It includes newly also PM2.5 commitments. This amended protocol entered into force for Switzerland on 22 October 2019.

Following its obligations under the CLRTAP, Switzerland annually submits its air pollution emission inventory (“CLRTAP Inventory”) as well as an Informative Inventory Report (IIR) according to the revised emission reporting guidelines under the CLRTAP. The emission inventory exists since the mid 80’s while the very first IIR as a report was submitted in 2008 (FOEN 2008) in accordance with the Guidelines for Reporting Emission Data under the Convention. The report on hand is now the seventeenth IIR of Switzerland.

The report has substantially improved over the years due to recurring external and internal reviews. Stage 1 and stage 2 centralized reviews took place annually, centralized stage 3 reviews in 2010 (UNECE 2010), 2016 (UNECE 2016), 2020 (UNECE 2020a) and 2022 (UNECE 2022a). For the latest submission and driven by this last centralized stage 3 review, specific improvements have been implemented. For a list of the most important improvements, see chapter 1.4.1. Additional information on specific improvements is given in the chapters of the respective sectors and source categories.

Key categories, uncertainties and completeness

In order to identify the most relevant source categories, key category analyses were conducted according to approaches 1 and 2. For both approaches, level assessments were conducted for the years 2022 and 1990 and a trend assessment for 1990-2022. The key category analysis highlights that for the year 2022, Sector 1 Energy is responsible for the majority of emissions of NO_x, SO_x, PM2.5 and PM10. Sector 2 IPPU and Sector 3 Agriculture contribute most to NMVOC emissions. The large majority of NH_3 emissions are caused by livestock production within Sector 3 Agriculture.

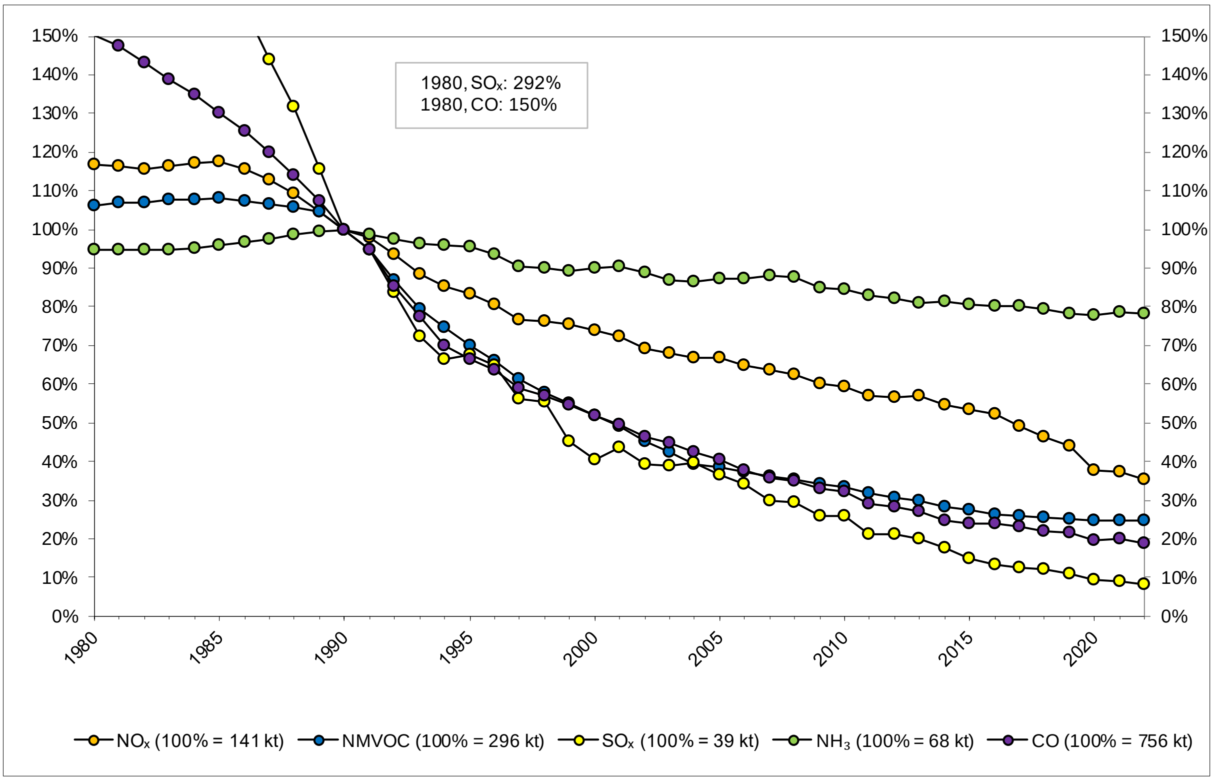
For the main pollutants (NO_x, NMVOC, SO_x, NH_3) as well as for PM2.5 and PM10, the uncertainty of the inventory, resulting from uncertainties from each category, is evaluated according to two methods: uncertainty propagation (approach 1) and Monte Carlo simulations (approach 2). In addition, a Tier 2 approach uncertainty estimation was conducted for agricultural NH_3 emissions in 2021. The uncertainty analysis has been carried out for level emissions for the years 1990 and 2022 and for the trend 1990-2022.

Complete emission estimates are accomplished for all known sources and air pollutants. According to current knowledge, the Swiss CLRTAP inventory is complete.

Quality assurance and quality control (QA/QC)

A QA/QC system for the GHG inventory is in place that also covers most of the preparation process of the CLRTAP Inventory. The National GHG Inventory, which is also derived from the Swiss Emission Information System (EMIS), complies with the ISO 9001:2015 standard (Swiss Safety Center 2022). It was certified by the Swiss Association for Quality and Management Systems in December 2007 and has been re-audited annually. A separate and formalized CLRTAP Inventory quality system is not foreseen. However, a centralised plausibility check for emissions was established that compares emissions of the previous and the latest submission.

Emission trends 1980-2022



ES Figure 1.1 Relative trends for the total emissions of main pollutants and CO in Switzerland.

Overall, ES Figure 1.1 shows a decreasing trend of all main air pollutants and CO between 1990 and 2022. The significant decline of NO_x, NMVOC and CO emissions is caused by effective reduction measures: abatement of exhaust emissions from road vehicles and stationary installations, taxation of solvents and voluntary agreements with industry sectors. As a result of the legal restriction of sulphur content in liquid fuels and the decrease of coal consumption, SO_x emissions decreased significantly as well. In contrast to the other main pollutants, NH_3 emissions show a smaller reduction mainly due to the decrease of animal numbers and changes in agricultural production techniques.

The drop of emissions in 2020/2021, especially visible for NO_x and CO, is due to reduced traffic volumes during the COVID-19 pandemic.

Emission trends for PM2.5 (not included in ES Figure 1.1, see Figure 2-3) reveal a significant decline between 1980 and 2022 mainly as a result of the abatement of exhaust emissions from road vehicles and also - to a minor extent - from non-road machinery and from improved residential heating equipment.

Characteristics of the sectors

- 1 Energy: the energy sector encompasses stationary and mobile fuel combustion activities and fugitive emissions from handling of fuels, such as losses in the gas network or refining and storage of gasoline and coal. Compared to the other sectors, fuel combustion activities are the main emission source of all air pollutants reported in the IIR except for NH_3, NMVOC, TSP and PCB. Within sector 1 Energy, source category 1A3 Transport is the predominant source of all main pollutants except for SO_x and PM2.5, where 1A2 Manufacturing industries and construction and 1A4 Other sectors, respectively, are the most important sources. The emissions of all pollutants from the sector decreased compared to 1990. Note that regarding Pb emissions, sector 1 Energy was the dominant source in 1990 (mainly due to 1A3b Road transportation) but has become less relevant over time due to the fact that only unleaded gasoline is sold in Switzerland since 2000.

- 2 Industrial processes and product use: this sector comprises process emissions from the mineral, chemical and metal industry. Included are also other production industries such as pulp and paper industry and food and beverages industry as well as other solvent and product use, e.g. emissions from paint applications and domestic solvent use. Emissions from industrial processes and product use are the main emission source of NMVOC and an important source of particulate matter (mainly PM2.5, but also PM10 and TSP), SO_x as well as heavy metals (particularly Cd) emissions. NMVOC emissions originate mainly from source category 2D3 Other solvent use. 2A1 Cement production, 2A5a Quarrying and mining other than coal, 2G Other product use (i.e. use of fireworks) and 2H1 Pulp and paper industry are responsible for considerable amounts of PM2.5 emissions, whereas 2C1 Iron and steel production is a crucial source of heavy metal emissions. SO_x is generated mainly by 2B5 Carbide production as well as 2C3 Aluminium production (until 2006). In source category 2K Consumption of POPs and heavy metals, considerable emissions of PCB are reported. Since 1990, the emissions of all pollutants decreased more or less continuously, although in the past few years, the decrease has been less pronounced for most of the pollutants.
- 3 Agriculture: this sector encompasses emissions from livestock production and agricultural soils. Overall, sector 3 Agriculture clearly is the predominant contributor to total Swiss NH_3 emissions, also contributing to a relevant share of NMVOC, NO_x, PM10 and TSP emissions. Within the sector, the NH_3 emissions are attributed to the source categories 3B Manure management and 3D Agricultural soils. Most NH_3 emission reductions in agriculture occurred between 1990 and 2004, followed by an increase until 2007 and then showed a slight but rather constant decrease again. Emissions of NO_x reveal a decreasing trend since 1990 with slight fluctuations. NMVOC emissions mainly stem from 3B Manure management (silage feeding of cattle).
- 4 Land Use, Land-Use Change and Forestry (LULUCF): The emissions of this sector are not accounted for in the commitments of the Gothenburg Protocol. Only forest fires (under 11B) and other natural emissions (under 11C) are reported under memo items in the official emission reporting templates and are described in chapter 7 Other and natural emissions.
- 5 Waste: This sector encompasses solid waste disposal on land, biological treatment of solid waste, waste incineration and open burning of waste, wastewater handling and other waste. Overall, emissions of the main pollutants are minor when compared to the other sectors. The heat generated in waste incineration plants has to be recovered in Switzerland, and in accordance with the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from the combustion of waste-to-energy activities are therefore dealt within 1A Fuel combustion. Relevant pollutants within sector 5 Waste are NMVOC, PM2.5, heavy metals (especially Pb) and POPs. NMVOC emissions are mainly caused by 5B Biological treatment of solid waste. PM2.5, heavy metals, PCDD/PCDF and PAH emissions mainly originate from source category 5C waste incineration. Emissions in sector 5 Waste have declined since 1990, with the exception of NMVOC (increase).
- 6 Other: In this sector, mainly emissions from human and pet ammonia, private application of synthetic fertiliser as well as fire damages in buildings and in motor vehicles are reported. It is an important source of Pb, PCDD/PCDF, PAH and PCB, mainly due to 6Ad fire damage. Regarding the main pollutants, emissions from sector 6 Other are minor when compared to sectors 1 to 5. Overall, emissions are fluctuating without any significant trends.

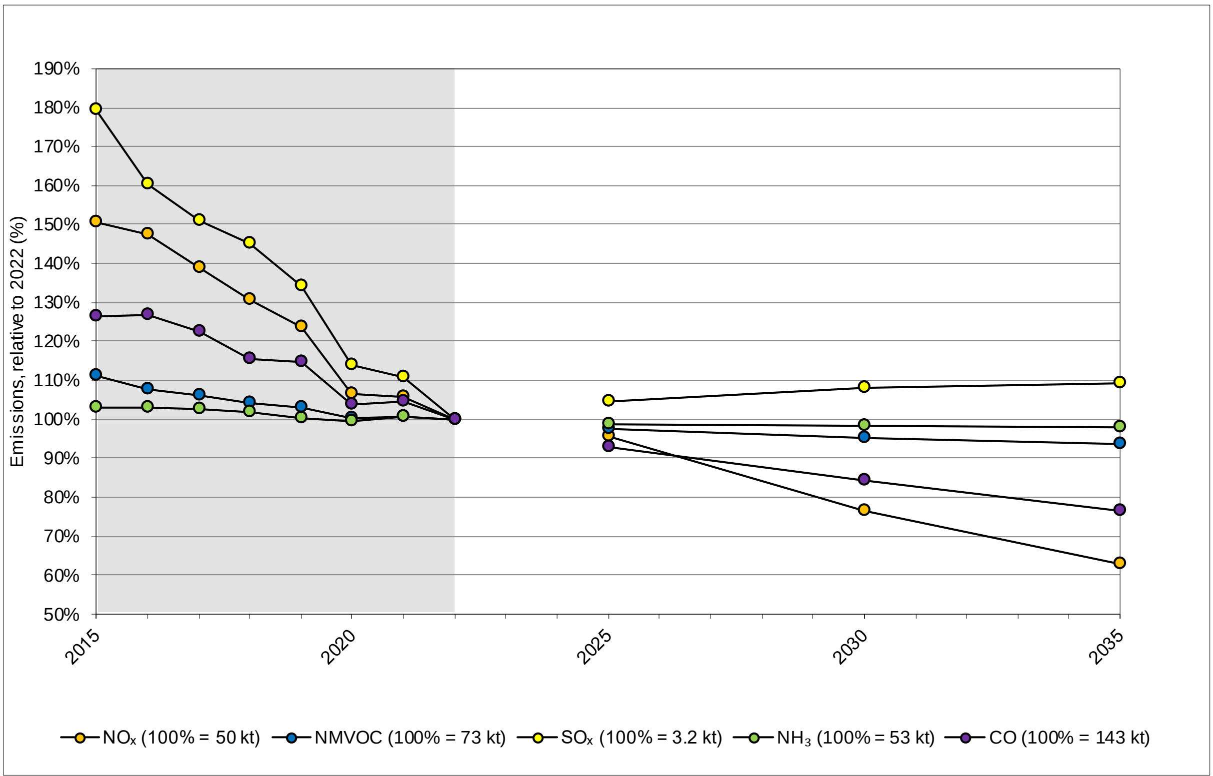
Projections for emissions until 2030

The emission projections of air pollutants in Switzerland have been fully revised for the submission 2021 and a new “With Measures” (WM) scenario was elaborated.

The projected data for the energy consumption and resulting production quantities in industrial processes are mainly in accordance with the scenarios of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020).

For all activities depending on population size the latest perspectives for Switzerland’s inhabitants are integrated (SFSO 2020p), and for the agricultural sector an independent scenario was developed (Swiss Confederation 2017, FOAG 2011, Mack and Möhring 2021).

ES Figure 1.2 shows the past emissions from 2015-2022 and the projected emissions between 2025 and 2035 for main air pollutants under the WM scenario.



ES Figure 1.2 Relative trends for the total emissions from 2015-2022 (grey area) and the projected emissions between 2025 and 2035 for main pollutants and CO in the WM scenario. 100 % corresponds to levels of the latest reporting year.

According to the projections 2025-2035, the main pollutants will develop differently. Total NO_x and CO emissions will continue to decrease significantly, while total emissions of NMVOC, SO_x and NH_3 will remain at more or less constant levels.

For suspended particulate matter emissions, the smaller fractions of suspended particulate matter (PM2.5) and BC are expected to continue to decrease, whereas the larger fractions (PM10, TSP) are expected to remain at more or less constant levels.

Pb emissions are projected to slightly decrease between 2025 and 2035, whereas total Cd and Hg emissions are remaining about constant.

Total emissions of all persistent organic pollutants (POP) will decrease.

Gothenburg Protocol

Under the CLRTAP, the 1999 Gothenburg Protocol requires that parties shall reduce and maintain the reduction in annual emission in accordance with national emission targets set for 2010. The following table shows the emission ceilings, the reported emissions for 2010 and the respective compliance. Accordingly, Switzerland is in compliance with the Gothenburg Protocol emission ceilings for all pollutants except for NO_x in 2010. All emissions 2022 are in compliance with the emission ceilings 2010.

ES Table 1.1 Emission ceilings of the Gothenburg Protocol for 2010 and beyond compared to the reported emissions for 2010 and 2022 of the latest submission (2024).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2024)	Compliance with emission ceilings 2010 in 2010	Emissions 2022 (Subm. 2024)	Compliance with emission ceilings 2010 in 2022
	kt	kt		kt	
SO_x (as SO_2)	26	10	yes	3.2	yes
NO_x (as NO_2)	79	83	no	50	yes
NMVOC	144	98	yes	73	yes
NH_3	63	58	yes	53	yes

The 2012 revised Gothenburg Protocol included emission reduction commitments for 2020 and beyond expressed as a percentage reduction from the 2005 emission level. On 22 October 2019, the amended protocol including the new reduction commitments for 2020, including newly PM2.5, has entered into force for Switzerland. ES Table 1.2 shows the emission reduction commitments for 2020 and the corresponding level of the emissions 2022. The emission reduction commitments 2020 are achieved for all pollutants.

ES Table 1.2 Reported emission reductions 2020 and 2022 versus level of 2005 and reduction commitments per 2020. The emission reduction commitments 2020 are defined as reductions in percentages from 2005.

Pollutant	Emission reduction commitments 2020	Reduction achieved in 2020	Compliance with reduction commitments 2020 in 2020	Reduction achieved in 2022	Compliance with reduction commitments 2020 in 2022
	%-reduction of 2005 level	*%-reduction of 2005 level*		*%-reduction of 2005 level*	
SO_x (as SO_2)	21%	74%	yes	77%	yes
NO_x (as NO_2)	41%	43%	yes	47%	yes
NMVOC	30%	36%	yes	36%	yes
NH_3	8%	11%	yes	11%	yes
PM2.5	26%	51%	yes	53%	yes

Recalculations and improvements

In 2021, recalculations have a significant effect on the emission levels compared to previous submissions. The recalculations cause a higher emission level between 23 % and 4 % for PM2.5, PM10, TSP and PAH. A decrease due to recalculations between 37 % and 4 % is observed for Pb, Cd, Hg, PCDD/PCDF and SO_x. For all other pollutants, the difference in emissions due to recalculations for 2021 does not exceed 2.1 %.

Also in 1990, recalculations have a significant effect on the emission levels compared to previous submissions. The recalculations cause a higher emission level between 64 % and 6 % for PM2.5, PM10, TSP and SO_x. A decrease due to recalculations of 5 % is observed for Cd. For all other pollutants, the difference in emissions due to recalculations for 1990 does not exceed 1.3 %.

In the latest submission 2024, several improvements were conducted and a number of further planned improvements are identified. The following improvements, which were announced in the previous submission and were conducted in submission 2024, had a relevant impact on the inventory:

- 1A: The emissions of PM2.5, PM10 and TSP from wood and wood waste combustion now also comprise the condensable PM fractions (Zotter and Nussbaumer 2022).
- 1B2b: The model of fugitive NMVOC emissions from gas pipelines has been revised for the years 1990-2022.

Switzerland prioritizes inventory improvements according to the key category analysis (KCA) and the uncertainty analysis where appropriate. The results of the uncertainty analysis are used to prioritize improvements through the results of the key category analysis, approach 2, in which source categories are sorted by decreasing order of contribution to the inventory uncertainty.

1 Introduction

1.1 National inventory background

Switzerland has signed and ratified the 1979 Geneva Convention on Long-range Transboundary Air Pollution (CLRTAP) and its Protocols (Swiss Confederation 2004):

- The 1985 Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 %.
- The 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes.
- The 1991 Geneva Protocol on the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes.
- The 1994 Oslo Protocol on Further Reduction of Sulphur Emissions.
- The 1998 Aarhus Protocol on Heavy Metals and its amendment 2012.
- The 1998 Aarhus Protocol on Persistent Organic Pollutants and its both amendments adopted in 2009.
- The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone and its amendment 2012 (national emission reduction commitments for 2020 for SO_x (as SO_2), NO_x (as NO_2), NH_3, NMVOC and newly for PM2.5).

According to the obligations of the CLRTAP, Switzerland is annually submitting its emission inventory (CLRTAP Inventory). For the present submission in March 2024, Switzerland provides for the seventeenth time an Informative Inventory Report (IIR) with the documentation on hand.

1.2 Institutional arrangements

The Swiss inventory system for the CLRTAP is developed and managed under the auspices of the Federal Office for the Environment (FOEN). As stipulated in the Ordinance on Air Pollution Control of 16 December 1985 (Swiss Confederation 1985), this Office has the lead within the Federal administration regarding air pollution policy and its implementation.

The FOEN publishes overviews of emissions and air quality levels. It has also built up and maintains the Swiss Emission Information System (EMIS) that contains all basic data needed to prepare the CLRTAP Inventory (and which contains also all greenhouse gas emissions as required for the preparation of the UNFCCC Greenhouse Gas Inventory).

1.3 Inventory preparation process

Various data suppliers collect the data needed for the preparation of the CLRTAP Inventory. The individual data suppliers are in charge for the quality of the data provided, so they are also responsible for the collection of activity data and for the selection of emission factors and methods. Thereby, the relevant guidelines including the Guidelines for Reporting Emissions and Projections data under the Convention on Long-range Transboundary Air Pollution (ECE 2023, ECE 2023a), the EMEP/EEA guidebook (EMEP/EEA 2019 and EMEP/EEA 2023) and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories as well as the 2019 Refinement (IPCC 2006, 2019) are also required to be taken into account. Various

QA/QC activities (see chp. 1.6) provide provisions for maintaining and successively improving the quality of inventory data.

As mentioned above, the Air Pollution Control and Chemicals Division at FOEN maintains the EMIS database, which contains all basic data needed for the preparation of the CLRTAP Inventory. Simultaneously, background information on data sources, activity data, emission factors and methods used for emission estimation is also documented in EMIS and cited in the subsequent chapters as EMIS 2024/(*NFR-Code*).

Figure 1-1 illustrates in a simplified manner the data collection and processing steps leading to the EMIS database and its main outputs into the CLRTAP air pollution emission inventory and into the IPCC/UNFCCC greenhouse gas inventory.

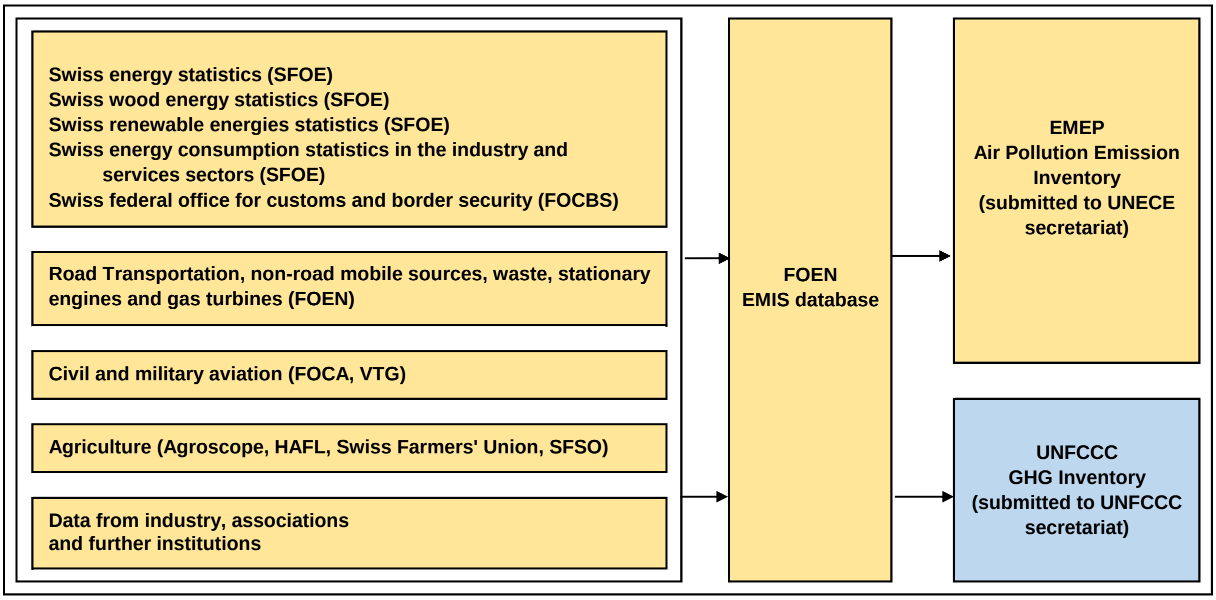


Figure 1-1 Data collection for EMIS database and CLRTAP air pollution emission inventory (GHG: Greenhouse Gas).

The preparation of the CLRTAP Inventory is closely connected to the preparation of the GHG inventory. Therefore, there are several parallel working steps. Also, the compilation of the Informative Inventory Report (IIR, the document on hand) and of the National Inventory Document (NID, see FOEN 2024) are going on simultaneously and are, partly, updated by the same persons. Therefore, both reports are structured similarly.

Annual Stage 1 and 2 reviews were carried out by the EMEP Centre on Emission Inventories and Projections (CEIP) and documented on the EMEP Website (UNECE 2023). Additionally, four in-depth Stage 3 reviews took place in 2010, 2016, 2020, 2022 and 2023 documented in UNECE (2010, 2016, 2020a, 2022a, 2023a). The recommendations of the latest Stage 1, 2 and 3 reviews were implemented in the latest emission inventory and in the IIR as far as possible.

Archiving of the database and related internal documentation is carried out by the inventory compiler, while any other material is archived on the internal data management system by the QA/QC officer.

1.4 Methods and data sources

1.4.1 Improvements conducted for this submission

The following issues were mentioned as planned improvements in the IIR of submission 2023 in chp. 8.2 (FOEN 2023b). Switzerland prioritises inventory improvements according to the key category analysis (KCA) and the uncertainty analysis where appropriate. The list shows the current state of realisation:

- *1A stationary combustion: based on a new data collection and model emissions from stationary engines and gas turbines were reestimated for all the years and has been implemented in the latest inventory. Within source category 1A4, several sub-categories are key categories for the main pollutants NO_x, NMVOC, SO_x, PM2.5 and PM10.*
  Current state: Done.
- *2D3 Other solvent use and 2G Other product use: A comprehensive update of all NMVOC emissions from solvent and product use is on-going. Several sub-categories within 2D3 as well as source category 2G are key categories for NMVOCs.*
  Current state: In progress.

Further additional improvements have been implemented for this submission 2024 as follows:

1A: The emissions of PM2.5, PM10 and TSP from wood and wood waste combustion now also comprise the condensable PM fractions (Zotter and Nussbaumer 2022). Source categories 1A1, 1A2gviii, 1A4ai, 1A4bi and 1A4ci are key categories for PM2.5 and PM10.

1B2b: The model of fugitive NMVOC emissions from gas pipelines has been revised for the years 1990-2022. Source category 1B2b is not a key category for NMVOC.

1.4.2 General description

Emission key categories and uncertainties are calculated on the basis of the standard methods and procedures as described in:

- UNECE: Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution (ECE 2023).
- EMEP/EEA air pollutant emission inventory guidebook — version 2023 (EMEP/EEA 2023), including:
  - Chp. 2. Key category analysis and methodological choice
  - Chp. 5. Uncertainties

Note that there is an important statement regarding the system boundaries for emission modelling in chapter V “Methods”, section A “Emission estimation methods and principles” of the Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution. Paragraph 23 states:

“For Parties for which emission ceilings or emission reduction commitments are derived from national energy projections based on the amount of fuels sold, compliance checking will be based on fuels sold in the geographic area of the Party. Other Parties within the EMEP region (i.e., Austria, Belgium, Ireland, Lithuania, Luxembourg, the Netherlands, Switzerland and the United Kingdom of Great Britain and Northern Ireland) may choose to use the national emission total calculated on the basis of fuels used in the geographic area of the Party as a basis for compliance with their respective emission ceilings or emission reduction commitments.” (ECE 2023)

This means that the national totals of the emissions as reported in the NFR tables as "National total for the entire territory (based on fuel sold)" (row 141 in the corresponding template) deviate from "National total for compliance assessment) as reported in row 152 of the template because Switzerland's compliance assessment refers to "fuel used" and not to "fuel sold". Differences exclusively occur in sector 1A3b Road transportation (see Table 3-6 and description of system boundaries in chapter 3.1.6.1). When comparing numbers from the IIR with the NFR tables, please refer to the blue coloured line in the NFR table reporting the national compliance assessment. The KCA and the uncertainty analysis were carried out with emission values based on fuel used.

The methods used for the NFR sectors are given in the following Table 1-1. The classification follows the EMEP/EEA guidebook (EMEP/EEA 2019) in the respective chapters for the source categories.

Table 1-1 Overview of applied methods, emission factors and activity by NFR category. CS = country-specific, D default, T1 = Tier 1, T2 = Tier 2, T3 = Tier 3. Default emission factors mainly stem from EMEP/EEA 2019.

Sector	Source category	Method applied	Emission factors	Activity data
1	**Energy**			
1A1	Energy industries	T1, T2	CS, D	CS
1A2	Manufacturing industries and construction	T1, T2, T3	CS, D	CS
1A3	Transport	T2, T3	CS, D	CS
1A4	Other Sectors	T2 (stationary), T3 (non-road)	CS, D	CS
1A5	Other (military)	T3 (non-road), T2 (aviation)	CS, D	CS
1B	Fugitive emissions from fuels	T1, T2, T3	CS, D	CS
2	**Industrial processes and product use**			
2A	Mineral products	T2	CS, D	CS
2B	Chemical industry	T2	CS	CS
2C	Metal production	T2	CS, D	CS
2D	Other solvent and product use	T1, T2	CS, D	CS
2G	Other product use	T2	CS, D	CS
2H	Other	T2	CS	CS
2I	Wood processing	T2	CS	CS
2K	Consumption of POPs and heavy metals	T2	CS	CS
2L	Other production, consumption, storage, transportation or handling of bulk products	T2	CS	CS
3	**Agriculture**			
3B	Manure management	T1, T2, T3	CS, D	CS
3D	Crop production and agricultural soils	T1, T2, T3	CS, D	CS
5	**Waste**			
5A	Biological treatment of waste - Solid waste disposal on land	T2	CS	CS
5B	Biological treatment of waste - Composting and anaerobic digestion at biogas facilities	T2	CS	CS
5C	Waste incineration and open burning of waste	T2	CS, D	CS
5D	Wastewater handling	T2	CS	CS
5E	Other waste	T2	CS	CS
6	**Other**			
6A	Other sources	T1, T2, T3	CS, D	CS
11	**Natural emissions**			
11B	Forest fires	T2	CS	CS
11C	Other natural emissions	T2	CS	CS

1.4.3 Swiss emission inventory system

Emission data is extracted from the Swiss emission information system (EMIS), which is operated by FOEN (see FOEN 2006). EMIS was established at SAEFL (former name of FOEN) in the late 1980s. Its initial purpose was to record and monitor emissions of air pollutants. Since then, it has been extended to cover greenhouse gases, too. Its structure corresponds to the EMEP/EEA system for classifying emission-generating activities. EMEP/EEA uses the Nomenclature for Reporting ("NFR code", ECE 2023).

EMIS maintains a database where emissions for various pollutants and greenhouse gases are calculated using emission factors and activity data according to the EMEP/EEA methodology, respectively IPCC Guidelines. Pollutants included are NO_x, NMVOC, SO_x, NH_3, particulate matter (PM2.5, PM10, TSP and BC), CO, priority heavy metals (Pb, Cd and Hg), POPs (PCDD/PCDF and PAHs), HCB and PCB, as well as the greenhouse gases CO_2 (fossil/geogenic origin and CO_2 from biomass), CH_4, N_2O and F-gases. The input data originates from a variety of sources such as various emission measurements, production data and emission factors from the industry, industry associations and research institutions and from Swiss statistics concerning population size, employment, waste and agriculture. Amongst others, these are the SFOE Swiss overall energy statistics, the SFOE Swiss wood energy statistics, FOEN statistics and models for emissions from road transportation, statistics and models of non-road activities, waste statistics and agricultural models and statistics (see Figure 1-1).

EMIS is documented in an internal FOEN manual for the database (FOEN 2006). The original EMIS database underwent a full redesign in 2005/2006. It was extended to incorporate more data sources, updated, and migrated to a new software platform. Simultaneously, activity data and emission factors were being checked and updated. Ever since then, updating is an ongoing process. Therefore, the data used in this submission are referenced to the specific EMIS data source.

1.4.4 Data suppliers

Table 1-2 Primary and secondary data suppliers: 1–13 provide annual updates, 14–21 provide sporadic updates.

No.	Institution	Subject	Data supplied for inventory category										
			1A1	1A2	1A3	1A4	1A5	1B	2	3	5	6	11
	Data suppliers (annual updates)												
1	FOEN, Air Pollution Control	EMIS database	x	x		x	x	x	x	x	x	x	x
2	FOEN, Climate	Swiss ETS monitoring reports	x	x		x		x	x				
3	FOEN, Waste and Raw Materials	Waste statistics	x	x							x		
4	SFOE	Swiss overall energy statistics	x	x	x	x		x			x		
5	SFOE	Swiss wood energy statistics	x	x		x							
6	SFOE	Swiss renewable energy statistics	x	x	x	x					x		
7	SFOE	Energy consumption statistics in the industry and services sectors		x									
8	FOCA	Civil aviation			x								
9	DDPS	Military machinery and aviation					x						
10	SFSO	Transport, Solvents, Agriculture, Waste, Other			x				x	x	x	x	
11	HAFL	Agriculture								x			
12	Industry and Industry Associations	Ind. processes and solvents	x					x	x				
13	Avernergy Suisse / Swiss Petroleum Association	Oil statistics						x	x				
	Data suppliers (sporadic updates)												
14	FOEN, Air Pollution Control	Non-road database		x	x	x	x						
15	SGWA	Gas distribution losses						x					
16	Empa	Various emission factors	x	x	x	x							
17	INFRAS	On-road emission model			x								
18	INFRAS	Non-road emission model		x	x	x	x						
19	INFRAS	Model of stationary engines and gas turbines	x	x	x	x							
20	ecolot	Solvents and product use							x				
21	Verenum	Wood energy, emission factor model	x	x		x							

1.5 Key categories

In order to identify the source categories which are the main contributors to the emissions of each pollutant (“level assessment”), or to the emission trend between the base year 1990 and the reporting year (“trend assessment”), and/or to the associated uncertainties, a Key Category Analysis (KCA) is performed according to the methodology described in the EMEP/EEA guidebook (EMEP/EEA 2023). Note that to compute the trend assessment, we use the formula from the 2019 Refinement to the 2006 IPCC Guidelines (IPCC 2019). The KCA can be performed based on two approaches: in approach 1, categories are set out in decreasing order of contribution to the inventory emissions or trend. In approach 2, this ranking is weighted by the uncertainty assigned to each category. Approach 1 therefore highlights categories which mostly contribute to emissions or to emission changes, while approach 2 identifies categories mostly contributing to the inventory uncertainty. A key category is prioritised within the inventory system because its estimate has a significant influence on the national total.

Note that for this submission, the key category analysis is performed based on the approach “fuels used”, (in contrast to “fuels sold”; for differentiation of the two approaches see chapter 3.1.6.1). For approach 2 of the KCA, the emission uncertainty of each category is taken from the results of the Monte Carlo simulations (see details in chp. 1.7).

For the pollutants for which uncertainty estimates are available (NO_x, NMVOC, SO_x, NH_3, PM2.5 and PM10), key category analyses were conducted according to approach 1 and 2, for the base year, the reporting year and the trend. A KCA according to approach 1 was also conducted for TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, HCB and PCBs. All level and trend assessments were performed for all emission sources accounting for 80 % of the total national emissions (or total national trend).

1.5.1 Summary of KCA results, approaches 1 and 2

By comparison to the previous submission, the major sources of pollutants remain very similar:

- For NO_x, a large fraction of emissions for the year 2022 are caused by category 1A3 Transport. The three source categories 1A3bi Passenger cars, 1A3bii Light duty-vehicles and 1A3biii Heavy-duty vehicles and buses represents almost half of the inventory emissions. Each of these categories has a pronounced decreasing trend between 1990 and 2022 (see also chp. 2.3.1 and Annex A1.2).
- For NMVOCs, the major contributors are categories 2D Other solvent use and 3B1 Manure management.
- For SO_x, category 1A2f Non-metallic minerals represents about 45 % of emissions. Its trend for 1990-2022 is decreasing.
- Almost all NH_3 emissions originate from livestock production within Sector 3 Agriculture, particularly from 3Da2a Animal manure applied to soils and 3B Manure management.
- For PM2.5 the main source is category 1A4bi Residential: stationary plants, 29 % of emissions, followed by 1A3bvi Road transportation: automobile tyre and brake wear (14 %, note that this category contains only non-exhaust emissions) The trend 1990-2022 for category 1A3bvi is positive whereas it is negative for 1A4bi.
- The main source of PM10 emissions is category 1A3bvi Road transportation: automobile tyre and brake wear, representing 18 % of emissions, followed by categories 1A2gvii Mobile combustion in manufacturing industries and construction (16 %). As for PM2.5, the trend 1990-2022 for category 1A3bvi is positive.

A few categories, which were not key for the year 2021 (for any of the approaches, level or trend) became key categories for the year 2022 according to at least one criterion:

- Category 1A3ai(i) Civil aviation (domestic, landing/take-off) is a new key category for SO_x regarding level (L1) and trend (T1, T2). It is the category with the lowest contribution for all three approaches (L1, T1, T2).
- Category 2C1 Iron and steel production is a new key category for SO_x regarding level (L2). It is the category with the lowest contribution.
- Category 5B1 Biological treatment of waste - Anaerobic digestion at biogas facilities is a new key category for NMVOC regarding trend (T1). It is the category with the lowest contribution.

The following categories were key for the year 2021, for at least one of the criteria, but are not key anymore for the year 2022:

- 1A2f Non Metallic Minerals is not a key category anymore regarding trend for PM2.5 (T1) and PM10 (T1, T2). In the previous submission 1A2f only had a minor contribution regarding trend for PM2.5 (T1) and PM10 (T1, T2).
- 1A3bi(fu) Road transportation: passenger cars (fuel used) is not a key category anymore regarding trend for SO_x (T1) and for PM10 (T1). For SO_x the trend 1990-2022 has decreased compared to the trend in the previous submission (1990-2021), which might explain why it is not key anymore. In the previous submission 1A3bi was the category with the lowest contribution regarding trend for PM10 (T1).
- 1A3bii(fu) is not a key category anymore regarding trend for NMVOC (T1). In the previous submission 1A3bii(fu) had the lowest contribution regarding trend for NMVOC (T1).
- 1B2aiv Fugitive emissions oil: refining / storage is not a key category anymore regarding trend for SO_x (T2). The trend (1990-2022) decreased slightly compared to the previous submission (1990-2021), which might explain why it is not key anymore.
- 2B10a Chemical industry: other is not a key category anymore regarding level and trend for SO_x (L2, T2). In the previous submission 2B10a had a minor contribution regarding level and trend for SO_x (L2, T2).
- 2H1 Pulp and paper industry is not a key category anymore regarding level for PM10 (L2). In the previous submission 2H1 only had a minor contribution regarding level PM10 (L2).

The detailed results of the key category analysis, approaches 1 and 2, level and trend assessments, are reported in Table 1-3 to Table 1-11, where numeric values represent the percentage contributions to the assessment total, for each pollutant. In each table, the source categories are set out in order according to their NFR code.

1.5.2 KCA approach 1 results

1.5.2.1 Level key category analysis (approach 1)

The results of the key category analysis according to approach 1, level, are summarised in Table 1-3 for the year 1990 and in Table 1-4 for the year 2022 for NO_x, NMVOC, SO_x, NH_3, PM2.5 and PM10. See Table 1-5 and Table 1-6 for TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, HCB and PCBs.

Table 1-3 List of Switzerland's approach 1 level key categories for 1990, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 1: % level contribution to totals 1990						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a	4.5		9.4		2.9	2.9	20
1A2d			8.3				8.3
1A2f	7.5		9.0			2.3	19
1A2gvii	4.5				2.7	5.9	13
1A2gviii			9.0		3.2	2.5	15
1A3bi(fu)	31	19	4.1				54
1A3bii(fu)	4.4						4.4
1A3biii(fu)	21		4.7		5.8	4.3	36
1A3bv(fu)		5.7					5.7
1A3bvi(fu)					2.5	5.6	8.1
1A3c						2.7	2.7
1A4ai			9.9		5.0	3.9	19
1A4bi	8.3	3.4	26		53	42	133
1A4ci					2.6		2.6
1B2av		6.5					6.5
2C1					3.0	4.1	7.1
2D3a		3.0					3.0
2D3d		14					14
2D3e		4.0					4.0
2D3g		9.3					9.3
2D3h		6.9					6.9
2G		7.6					7.6
2I						2.4	2.4
3B1a		2.2		14			16
3B1b				7.6			7.6
3B3				10			10
3Da2a				50			50
3De						2.9	2.9
Total	81	81	81	82	81	81	

Table 1-4 List of Switzerland's approach 1 level key categories 2022, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 1: % level contribution to totals 2022						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a	4.3		7.3				12
1A2f	6.4		46				52
1A2gvii					5.9	16	22
1A2gviii	4.1		9.8		2.9		17
1A3ai(i)	3.3		3.7				7.0
1A3bi(fu)	32	5.3					37
1A3bii(fu)	7.9						7.9
1A3biii(fu)	6.5						6.5
1A3bv(fu)		2.6					2.6
1A3bvi(fu)					14	18	32
1A3c					3.1	9.2	12
1A4ai	5.9				6.5	3.2	16
1A4bi	8.0	3.3	8.3		29	14	62
1A4ci					3.3		3.3
1A4cii	3.4						3.4
1A5b						1.8	1.8
1B2av		2.7					2.7
2A5a					3.4	3.1	6.6
2B5			9.0				9.0
2D3a		8.8					8.8
2D3b		3.7					3.7
2D3d		11					11
2D3g		4.4					4.4
2D3h		5.0					5.0
2D3i		2.7					2.7
2G		8.7			6.6	4.2	19
2H1					2.7		2.7
2H2		2.8				2.2	4.9
3B1a		9.3		19			29
3B1b		10		13			24
3B3				9.3			9.3
3Da2a				38			38
3De						7.0	7.0
5C1a					3.4	1.7	5.2
Total	82	81	84	80	81	81	

Table 1-5 List of Switzerland's approach 1 level key categories 1990, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 1: % level contribution to totals 1990										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCB	
1A1a	1.9			8.4	54	62	68				194
1A2b									100		100
1A2f	2.2				20						23
1A2gvii	5.4	4.5									9.8
1A3bi(fu)		4.2	56	60							120
1A3bii(fu)			9.6								9.6
1A3biii(fu)	2.8	14									17
1A3bvi(fu)	3.6										3.6
1A3c	2.3										2.3
1A4ai	2.7	5.2									7.9
1A4bi	29	56	15				9.2	70			179
2B10a						6.1					6.1
2C1	4.8			17	14	18	6.5				59
2C3								12			12
2I	7.7										7.7
2K										65	65
3De	19										19
5E										9.2	9.2
6A										12	12
Total	81	84	81	85	88	86	83	82	100	87	

Table 1-6 List of Switzerland's approach 1 level key categories 2022, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 1: % level contribution to totals 2022										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCB	
1A1a				20	33	50	7.5		53		163
1A2f			6.3		6.0	11					23
1A2gvii	12										12
1A2gviii				10	5.0	5.9	6.6				28
1A3aii(i)				8.3							8.3
1A3bi(fu)		4.5	33					8.6			46
1A3biv(fu)			3.9								3.9
1A3bvi(fu)	9.1	11			20						39
1A3c	6.2										6.2
1A3dii			3.5								3.5
1A4ai		8.8	4.3				9.1	11	10		43
1A4aii			4.6								4.6
1A4bi	7.4	49	17		5.3	8.0	34	58	25		202
1A4cii		9.7	8.8								18
2A5a	3.1										3.1
2C1						8.4					8.4
2G	2.1			5.3	16						23
2K										90	90
3B3	2.3										2.3
3B4gi	2.6										2.6
3De	35										35
5C1a				18			20				38
5C2								8.0			8.0
6A				21			8.0				29
Total	81	82	81	83	85	83	85	85	88	90	

1.5.2.2 Trend key category analysis (approach 1)

The results of the KCA according to approach 1, trend, for 1990-2022 are summarised in Table 1-7 and Table 1-8.

Table 1-7 List of Switzerland's approach 1 key categories for the trend 1990-2022, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 1: % contribution to trend 1990 - 2022						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a					2.8	2.7	5.5
1A2d			7.9				7.9
1A2f	2.8		35				38
1A2gvii	3.3				4.2	11	19
1A2gviii	6.9						6.9
1A3ai(i)	6.6		3.3				9.9
1A3bi(fu)		19					19
1A3bii(fu)	9.4						9.4
1A3biii(fu)	39		4.2		6.8	4.3	54
1A3bv(fu)		4.3					4.3
1A3bvi(fu)					15	13	29
1A3c					3.2	7.0	10
1A3dii	2.9						2.9
1A4ai	6.1		6.1				12
1A4bi			17		32	30	79
1B2av		5.2					5.2
2A5a					3.6		3.6
2B5			7.1				7.1
2C1					3.7	4.3	8.0
2D3a		8.1					8.1
2D3b		2.8					2.8
2D3d		3.3					3.3
2D3e		2.5					2.5
2D3g		6.8					6.8
2D3h		2.6					2.6
2G					6.1	2.8	8.9
2H1					2.4		2.4
2H2		2.9					2.9
3B1a		9.8		16			25
3B1b		12		16			28
3Da1				5.8			5.8
3Da2a	3.9			33			37
3Da2b				4.6			4.6
3Da2c				4.9			4.9
3Da3				4.2			4.2
3De						4.4	4.4
5B2		2.1					2.1
Total	80	81	81	84	80	80	

Table 1-8 List of Switzerland's approach 1 key categories for the trend 1990-2022, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 1: % contribution to trend 1990 - 2022										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCB	
1A1a				7.1	21	20	41		27	14	130
1A2b									50		50
1A2f	2.1		7.2		15	12					36
1A2gvii	8.1	4.4									12
1A2gviii				6.4	4.1	9.0					20
1A3bi(fu)			37	37				15			89
1A3bii(fu)			11								11
1A3biii(fu)	3.1	25									28
1A3bvi(fu)	6.3	20			18						44
1A3c	4.5										4.5
1A4ai		7.3	4.5			7.0	5.5	9.2			33
1A4aii			6.4								6.4
1A4bi	25	15	3.6			11	17	25	12		109
1A4bii			3.6								3.6
1A4cii		12	8.0								20
2A5a	2.2										2.2
2B10a						9.7					9.7
2C1	5.4			8.8	13	15					42
2C3								24			24
2G					13						13
2I	6.8										6.8
2K										50	50
3De	19										19
5C1a				11			12				23
5E										17	17
6A				12			4.9	7.8			25
Total	82	83	82	82	83	83	81	81	89	81	

1.5.3 KCA approach 2 results

1.5.3.1 Level key category analysis (approach 2)

The results of the KCA according to approach 2, level assessment, are summarised in Table 1-9 for the year 1990 and in Table 1-10 for the year 2022.

Table 1-9 List of Switzerland's approach 2 level key categories 1990, for the main pollutants, PM2.5 and PM10.Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 2: % level contribution to totals 1990						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a	3.7		13		2.7	2.5	21
1A2d			6.5				6.5
1A2f	4.9		9.6				14
1A2gvii						3.6	3.6
1A2gviii			9.6		2.7	1.9	14
1A3bi(fu)	45	14					59
1A3bii(fu)	5.4						5.4
1A3biii(fu)	14		2.6		2.1		19
1A3biv(fu)		6.8					6.8
1A3bv(fu)		3.3					3.3
1A3bvi(fu)						3.3	3.3
1A4ai			5.6		5.1	3.6	14
1A4bi	4.3	3.3	16		53	38	114
1B2aiv			3.3				3.3
1B2av		3.6					3.6
2A1					1.8	1.9	3.6
2A5a					2.4	3.3	5.7
2C1					4.3	5.3	9.6
2C3			15				15
2D3d		8.8					8.8
2D3e		3.6					3.6
2D3g		13					13
2D3h		4.4					4.4
2D3i		3.8					3.8
2G		17			2.3	1.8	21
2H2					2.5	2.8	5.3
2I					2.8	7.7	11
3B1a				12			12
3B1b				6.4			6.4
3B3				13			13
3B4gi				3.6			3.6
3Da1	3.3			9.5			13
3Da2a				34			34
3De						5.2	5.2
6A				4.0			4.0
Total	81	81	81	82	82	81	

Table 1-10 List of Switzerland's approach 2 level key categories 2022, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 2: % level contribution to totals 2022						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a	3.2		9.1				12
1A2f	3.8		45				49
1A2gvii					3.3	8.9	12
1A2gviii			9.7				9.7
1A3bi(fu)	42	3.6					46
1A3bii(fu)	8.8						8.8
1A3biii(fu)	4.1						4.1
1A3biv(fu)		3.7					3.7
1A3bvi(fu)					8.1	9.7	18
1A3c						5.0	5.0
1A4ai	3.3				5.7	2.7	12
1A4bi	3.8	2.9	4.6		25	11	47
2A1					4.1	2.8	6.9
2A5a					11	9.4	20
2B5			9.4				9.4
2C1			2.5				2.5
2D3a		5.7					5.7
2D3b		4.4					4.4
2D3d		6.6					6.6
2D3g		5.5					5.5
2D3h		2.9					2.9
2D3i		4.9					4.9
2G		17			7.0	4.3	28
2H1					4.8		4.8
2H2		3.3			7.9	6.5	18
2I					2.3	4.1	6.4
3B1a		7.2		17			24
3B1b		9.3		11			20
3B3				11			11
3B4gi						2.4	2.4
3B4gii		3.1		3.2		3.3	9.6
3Da1	4.8			5.9			11
3Da2a	5.1			24			29
3Da3	2.9			4.8			7.7
3De						12	12
5C1a					2.2		2.2
6A				5.5			5.5
Total	82	80	80	82	81	82	

1.5.3.2 Trend key category analysis (approach 2)

The results of the KCA according to approach 2, trend assessment, for 1990-2022 are summarised in Table 1-11.

Table 1-11 List of Switzerland's approach 2 key categories for the trend 1990-2022, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR Code	Key categories approach 2: % contribution to trend 1990 - 2022						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a			3.0		2.4		5.4
1A2d			6.9				6.9
1A2f			41				41
1A2gvii					2.4	6.6	9.1
1A2gviii	4.6						4.6
1A3ai(i)	5.2		2.1				7.3
1A3bi(fu)	2.7	14					17
1A3bii(fu)	12						12
1A3biii(fu)	27		2.6				30
1A3biv(fu)		3.8					3.8
1A3bv(fu)		2.5					2.5
1A3bvi(fu)					9.0	7.8	17
1A3c						4.1	4.1
1A4ai	3.8		3.8				7.6
1A4bi			11		28	27	67
1B2av		3.0					3.0
1B2c	2.4						2.4
2A1					3.5		3.5
2A5a					11	7.4	19
2B5			8.8				8.8
2C1					4.8	5.5	10
2D3a		5.9					5.9
2D3b		3.8					3.8
2D3e		2.3					2.3
2D3g		9.5					9.5
2D3i		2.3					2.3
2G		3.4			6.7	3.1	13
2H1					4.4		4.4
2H2		3.9			7.8	4.6	16
2I						3.4	3.4
3B1a		8.6		13			22
3B1b		12		12			24
3B3		2.2		2.7			4.9
3B4gii		4.5		5.6		3.3	13
3Da1	5.6			8.2			14
3Da2a	7.7			21			28
3Da2c	2.4			7.5			10.0
3Da3	7.0			7.5			14
3De						7.9	7.9
6A				4.7			4.7
Total	81	82	80	83	81	81	

1.6 QA/QC and verification methods

The national inventory system (NIS), which covers air pollutant as well as greenhouse gases, has an established quality management system (QMS) that complies with the requirements of ISO 9001:2015 standard. Certification has been obtained in 2007 and is upheld since through annual audits. The latest audit according to ISO 9001:2015 was on 6th July 2023 and the current certificate is valid until 2025 (Swiss Safety Center 2022). The QMS is designed to comply with the UNFCCC reporting guidelines (UNFCCC 2014a) to ensure and continuously improve transparency, consistency, comparability, completeness, accuracy, and confidence in national GHG emission and removal estimates. Since the inventory system also covers air pollutants, the same quality requirements as ensured for GHG also hold for air pollutants. The quality manual (FOEN 2024a) contains all relevant information regarding the QMS. It is updated annually and made available to everyone contributing to the GHG inventory.

The NIS quality management system covers data compilation and inventory preparation based on the EMIS database, which is – as mentioned above – not only the tool for modelling the GHG emissions but also at the same time for modelling the air pollution emissions, which means that the process of emission modelling of air pollutants is also part of the quality management system.

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

Checks regarding the correct aggregation are done on initial set-up of the various aggregations. There are also routine checks implemented in the database in order to identify incorrect internal aggregation processes.

Recalculations are compiled in a document and made available to the data compilers and the IIR authors. The recalculations file is of great importance in the QC procedures regarding the reporting tables (NFR) and in the preparation of the IIR. QC procedures regarding the reporting tables (NFR) comprise a detailed comparison of the reporting tables (NFR) of the previous submission with those of the latest submission for the base year and the latest common year. In addition, the time-series consistency is incrementally checked by comparing the latest inventory year with the preceding year. Any exceptional deviations are investigated by the sectoral or the EMIS database experts. These checks are performed in an iterative process: a first check is done by collaborators of the Air Pollution Control and Chemicals division and sectoral experts, providing feedback and comments to the EMIS database experts. Based on the comments, changes to the reporting tables or database are made as required. The process is repeated twice before producing the final reporting tables.

The QA/QC process can therefore be summarised as follows: The preparation steps for the production of the CLRTAP Inventory including data collection, compilation, emissions modelling within the EMIS database and generating the official emission reporting templates are part of the existing quality management system. So far, informal QC activities have been performed by the FOEN experts involved in the CLRTAP Inventory preparation and by the external authors of the Informative Inventory Report on hand. A separate and formalised CLRTAP Inventory quality system as it exists for the GHG emission inventory is not foreseen, however, a centralised plausibility check is in place.

Diverse QC procedures are implemented in the process of data-collection and generation of reporting tables and tables for the IIR. For example:

- Checks of consistency of activity data and emission factors in the individual sectors and subsectors while collecting data every year.
- Crosschecks of input and output (in particular within the energy model)
- Crosschecks between EMIS database and reporting tables

- Crosschecks with the greenhouse gas inventory concerning activity data and precursors (NO_x, CO, NMVOC and SO_x)
- Selective checks of emission factors of the inventory. For example, for submission 2020 a general comparison of emission factors with the newly published EMEP/EEA guidebook (EMEP/EEA 2019) has been conducted.
- Every year specific projects are implemented to improve the inventory in particular sections.

In addition to the QA/QC measures mentioned above, Switzerland regularly performs verification checks with data outside of the air pollutant inventory:

- The air pollutant inventory is intertwined with the GHG inventory, so any verification checks regarding precursor emissions or activity data in the GHG inventory are also applied to the air pollutant inventory.
- Switzerland systematically compares the emission factors with other European countries, especially if new emission factors are introduced to the inventory or if the accuracy of an emission factor or of a data source is questioned in an internal or external review process.
- Switzerland carries out sector-specific verification processes for individual source categories or processes.
- Switzerland regularly compares the emissions from the air pollutant inventory with the results of the national ambient concentration modelling “PolluMap” (NO_2, PM2.5 and PM10).

The continuous improvement of the inventory is in particular addressing recommendations and encouragements from the latest stage 3 review of Switzerland’s emission inventory (UNECE 2022a). Switzerland prioritizes inventory improvements based on the findings from the stage 3 reviews and according to the key category analysis (KCA) and the uncertainty analysis, where appropriate.

1.7 General uncertainty evaluation

1.7.1 Data sources and data used

The uncertainty analysis is conducted using activity data and emission factors at the same level of aggregation as used for the NFR reporting tables (classification according to EMEP/EEA 2019). As for the key category analysis, emissions based on fuel used are considered.

Several sources of uncertainties are listed below. Uncertainty values for activity data and emission factors were updated where appropriate.

- Uncertainties of activity data are taken from the uncertainty analysis of Switzerland’s GHG Inventory (FOEN 2024).
- Uncertainties for the emission factors and emissions of mobile sources are from the study IFEU/INFRAS (2010), in which uncertainties are evaluated for road and non-road categories.
- Uncertainties of emission factors for sector 2 Industrial processes and product use are based on default uncertainty values from the EMEP/EEA guidebook (EMEP/EEA 2019, part A, chp. 5, Table 2-2).

- To estimate the uncertainties associated with NH_3 emissions from sector 3 Agriculture, a model essentially based on the nitrogen-flow model AGRAMMON was previously developed by INFRAS (2015c, 2017b). Since then, the AGRAMMON model has been revised and in addition, a new survey on production techniques in Swiss agriculture has been performed in 2019. Based on these updates, INFRAS made a new uncertainty analysis for the year 2019 (INFRAS 2021). The new uncertainty estimate for ammonia emissions from Swiss agriculture is 12.6 %, which is slightly lower than the 13.6 % estimated in the previous study. Numeric values can be found in Annex A5.1.
- Detailed numeric values and references for the uncertainties are reported in Annex 5.

1.7.2 Methodology

The uncertainty aggregation for the main pollutants and particulate matter 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. For the main pollutants, PM2.5 and PM10, a total of 127 categories were considered, as in the NFR tables used to report emissions.

Uncertainties are assessed in accordance with the EMEP/EEA guidebook (EMEP/EEA 2019: Part A, chapter 5) and with the 2006 IPCC Guidelines (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 reporting year for the same input variable.
- The following statistical distributions can 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 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. For non-symmetrical distributions obtained by Monte Carlo simulations, the reported uncertainties represent the narrowest 95 % interval, in agreement with JCGM (2008, S1). 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.

1.7.2.1 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 are programmed. Results of approach 1 for the reporting year and for the trend for each considered pollutant are summarised in Table 1-12.

1.7.2.2 Aggregation of uncertainties using approach 2: Monte Carlo simulations

The Monte Carlo simulations were performed for the base year 1990, the reporting year 2022 and the trend at the aggregation level required for the KCA. All input variables can be found in Annex 5. Results for each pollutant are summarised in Table 1-12.

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.

In our settings, each input quantity is an activity data 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 (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 activity data and emission factors and by then adding up all emissions. Intermediate sums can also be obtained, for example the sum for a given sector.

For each input quantity, 500’000 random values were generated resulting in equal numbers of values for the base year, the reporting year and the trend.

The average offset between the obtained mean for each process and the input mean is less than 0.1 % for each pollutant. 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 reporting year (RY) for the same process are fully correlated, a random number is generated for the base year only, written BY_{random}. The random value for the reporting year RY_{random} is then computed as:

$RY_{random} = BY_{random} * RY_{input,\ mean}/BY_{input,\ mean}$, where $RY_{input, mean}$ and $BY_{input, mean}$ are the input mean values for the variables in the reporting year and the base year, respectively.

This method implicitly assumes that the uncertainty for the base year and the 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 reporting year.

The sensitivity of a total value (total base year emission, total 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 500’000 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, we expect only positive correlations.

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 platform with the repository name <inventory_uncertainty_UNFCCC_CLRTAP>.

1.7.3 Results of approach 1 and 2 uncertainty evaluation

Table 1-12 shows the results of the uncertainty evaluation using approaches 1 and 2 for the base year, the reporting year and the trend. Due to the availability of uncertainty data, the analysis was restricted to the main pollutants (NO_x, NMVOC, SO_x, NH_3) as well as PM2.5 and PM10. The total emissions in the base year and the reporting year as well as the emission trends 1990-2022 of these pollutants are also shown in Table 1-12. Since emission factors are generally the major sources of uncertainty (compared to activity data) and since they are considered correlated across years this may result in smaller uncertainties for the trends than for the emission levels.

Table 1-12 For each pollutant, emission levels for 1990 and 2022, trend and associated relative uncertainties obtained from the uncertainty propagation (approach 1) and from Monte Carlo simulations (approach 2), for the main pollutants, PM2.5 and PM10. Note that the trend and its associated uncertainties are expressed in the same unit, in percent. As an example, for a trend of -10 % with uncertainties of 2 %, the trend is comprised between -12 % and -8 %.

Pollutant	Emissions 1990			Emissions 2022			Trend 1990-2022		
	Value t	U(-)%	U(+)%	Value t	U(-)%	U(+)%	Value %	U(-)%	U(+)%
Uncertainty propagation (approach 1)									
NOx	140'801	13	13	49'907	13	13	-65	1.2	1.2
NMVOC	295'705	17	30	72'515	16	30	-75	3.5	4.2
SOx	39'168	5.1	6.9	3'214	9.4	9.4	-92	0.64	0.64
NH3	68'496	13	13	53'436	12	12	-22	4.6	4.6
PM2.5	27'275	41	43	6'577	25	42	-76	5.1	8.1
PM10	36'575	33	40	14'350	19	42	-61	9.5	13
Monte Carlo simulations (approach 2)									
NOx	140'801	13	13	49'907	13	13	-65	1.2	1.2
NMVOC	295'705	23	25	72'515	22	25	-75	3.8	3.9
SOx	39'168	5.8	6.1	3'214	9.4	9.4	-92	0.71	0.69
NH3	68'496	13	13	53'436	12	12	-22	4.8	4.9
PM2.5	27'275	41	42	6'577	33	34	-76	5.9	7.4
PM10	36'575	36	37	14'350	29	32	-61	11	12

In general, uncertainties resulting from approaches 1 and 2 are in concordance, especially for the upper range uncertainty. For the lower range uncertainty, approach 1 may result in a smaller estimate in cases where the inventory probability distribution is asymmetric. We therefore recommend taking into consideration the uncertainty estimate provided by approach 2 (Monte Carlo simulations).

The level and trend uncertainty estimations for the latest submission remained similar for all pollutants compared to the values of the previous submission.

The detailed information on the uncertainties of activity data and the emission factors are provided in Annex 5.

For the other air pollutants such as heavy metals, the uncertainties are assumed to be in the range of 50 % to 100 %. For POPs, uncertainties might be even higher.

The Monte Carlo simulations provide data to conduct a sensitivity analysis between emissions from each category and the inventory (total) emission for NO_x, NMVOC, NH_3, SO_x, PM2.5 and PM10. 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 reporting year are shown in Annex A5.3.2. 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. 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.

1.8 General assessment of completeness

Complete estimates were accomplished for all known sources for all gases. Compared with the obligations of the EMEP/EEA guidebook (EMEP/EEA 2019), the Swiss CLRTAP Inventory is complete.

1.8.1 Sources not estimated (NE)

Emissions of additional (non-priority) heavy metals in all sectors are not estimated. There are no large sources of non-priority heavy metals in Switzerland. For the most important processes (e.g. waste wood furnaces, waste incineration plants, steelworks), measured emissions values for non-priority heavy metals are not available. Due to limited resources, the focus lies on priority heavy metals in Switzerland's inventory.

In few other source categories, specific pollutants were "not estimated" (NE). For further details, see respective list in Annex 3.

1.8.2 Sources included elsewhere (IE)

Emissions of a number of source categories are specified as "included elsewhere" (IE). For further information about the whereabouts of the emissions from these source categories please refer to the respective list in Annex 3.

1.8.3 Other notation keys

Not occurring (NO)

Various pollutants or emissions do not occur in Switzerland since related processes do not exist or did not exist in the reporting period in Switzerland. Therefore, the activity data do not exist, and specific emissions are reported as "not occurring (NO)".

Not applicable (NA)

A number of source categories do occur within in the Swiss inventory but do not result in emissions of one or several specific pollutants. These are reported as "not applicable (NA)".

2 Emission trends 1980-2022

General remark concerning emission results presented in this chapter:
Note that all the values for emissions in this chapter refer to the “national total for compliance assessment” based on “fuel used”, which deviates from the “national total for the entire territory” based on “fuel sold”. Be aware that the reporting tables contain information on both, “national total emissions for the entire territory” (based on “fuel sold”) as well as “national total for compliance assessment” (based on “fuel used”). When comparing numbers from this chapter with the reporting tables, the reader shall refer to the blue coloured lines in the reporting tables, which relate to the “national total for compliance assessment”.
For further information concerning this differentiation, see chapter 3.1.6.1.

2.1 Comments on trends

2.1.1 General trend

Switzerland’s emissions of air pollutants are generally decreasing in the period 1980-2022 (see Table 2-1). Only the emissions of non-exhaust particulate matter (PM2.5, PM10, TSPs) are increasing. Note that there is a methodological difference between data before 1990 and data from 1990 onward due to lower data availability before 1990. This can lead to interpolation-based edges in the time series.

Table 2-1 Total emissions of main pollutants, particulate matter, CO, priority heavy metals and POPs (including trends). Note that numbers refer to the national total for compliance assessment (based on fuel used), which deviate from the national total for the entire territory based on fuel sold.

Pollutant	Unit	1980	1990	2005	2022	1980–2022	1990–2022	2005–2022
NO_x	kt	165	141	94	50	-70%	-65%	-47%
NMVOC	kt	314	296	113	73	-77%	-75%	-36%
SO_2	kt	114	39	14	3.2	-97%	-92%	-77%
NH_3	kt	65	68	60	53	-17%	-22%	-11%
PM2.5 total	kt	26	27	14	6.6	-75%	-76%	-53%
PM2.5 exhaust	kt	24	25	12	4.1	-83%	-83%	-65%
PM2.5 non-exhaust	kt	2.3	2.4	2.3	2.5	8%	1%	8%
PM10 total	kt	36	37	22	14	-60%	-61%	-34%
PM10 exhaust	kt	27	27	13	4.6	-83%	-83%	-63%
PM10 non-exhaust	kt	9.5	9.5	9.0	9.7	3%	3%	8%
TSP total	kt	61	56	36	28	-53%	-50%	-21%
TSP exhaust	kt	33	30	13	5.0	-85%	-83%	-63%
TSP non-exhaust	kt	28	27	22	23	-16%	-12%	4%
BC total	kt	4.9	5.7	3.6	0.88	-82%	-85%	-75%
BC exhaust	kt	4.9	5.7	3.5	0.79	-84%	-86%	-77%
BC non-exhaust	kt	0.026	0.071	0.078	0.096	272%	36%	24%
CO	kt	1'135	756	307	143	-87%	-81%	-53%
Pb	t	1'326	354	18	8.4	-99%	-98%	-53%
Cd	t	5.3	3.3	0.54	0.46	-91%	-86%	-15%
Hg	t	7.5	6.3	0.73	0.58	-92%	-91%	-21%
PCDD/PCDF	g I-Teq	444	192	31	13	-97%	-94%	-60%
BaP	t	2.3	2.3	1.4	0.70	-70%	-70%	-51%
BbF	t	2.6	2.7	1.6	0.75	-71%	-72%	-53%
BkF	t	1.6	1.7	1.0	0.48	-70%	-73%	-54%
IcdP	t	1.2	1.4	0.82	0.42	-64%	-70%	-49%
PAH tot	t	7.6	8.1	4.9	2.4	-69%	-71%	-52%
HCB	kg	97	173	0.44	0.34	-100%	-100%	-24%
PCB	t	3.6	2.3	1.3	0.34	-91%	-85%	-73%

2.1.2 Legal basis for the implementation of reduction measures

The mainly decreasing trend is the result of the implementation of a consistent clean air policy of the Swiss government. It is based on the Federal Environmental Protection Act (EPA) and the Ordinance on Air Pollution Control (OAPC), which were introduced in 1983 and 1985, respectively. The EPA contains the fundamental principles whereas the OAPC contains the detailed prescriptions on air pollution control, e.g. specific emission limit values for stationary sources, ambient air quality standards, prescriptions on enforcement, etc. Main goal of the OAPC is to protect human beings, animals, plants, their biological communities and habitats and the soil against harmful effects or nuisances of air pollution. In addition, the OAPC exclusively contains a limit value for particle number emissions for construction machinery operating on construction sites. For other non-road machinery, in general, the same legislation holds as in the European Union with Regulation (EU) 2016/1628. Requirements for road vehicles are integrated into the Swiss road traffic legislation and are all in accordance with the European Union (Euro standards).

The air pollution control policy is based on:

- Federal Constitution of the Swiss Confederation: Article 74 “Protection of the environment” (Swiss Confederation 1999).
- Federal Act on the Protection of the Environment (EPA) (Swiss Confederation 1983).
- Ordinance on Air Pollution Control (OAPC) (Swiss Confederation 1985, see Figure 2-1 for an overview of the revisions).
- Federal Council’s “Concept on Air Pollution Control”: On behalf of the Swiss Parliament, the Federal Council has adopted a strategy containing national emission reduction targets, actions and measures at the national level, which will allow for reaching the air quality standards and an improved air quality in general. The strategy is regularly updated, the last version dates from 2009 and is still currently applicable (Swiss Confederation 2009).
- Ordinance on the Technical Standards for Motor Vehicles and their Trailers (Swiss Confederation 1995).
- Ordinance on the incentive tax on volatile organic compounds (VOC) since 2000 (Swiss Confederation 1997).
- Federal Act on the reduction of CO_2 emissions (Swiss Confederation 2011).
- Ratification of the seven additional protocols containing emission reduction commitments to the 1979 CLRTAP (Swiss Confederation 2004), including the 1985 Sulphur Protocol (ratified in 1987), the 1988 NO_x Protocol (ratified in 1990), the 1991 VOC Protocol (ratified in 1994), the 1994 Sulphur Protocol (ratified in 1998), the 1998 POP Protocol and 1998 Heavy Metals Protocol (both ratified in 2000) as well as the 1999 (2012) Gothenburg Protocol (ratified in 2005), and the revised 2012 Gothenburg Protocol (ratified in 2019).

Generally, revisions and amendments of the Air Pollution Control Strategy and the Ordinance on Air Pollution Control (OAPC) in Switzerland are driven by scientific findings or advancements in state-of-the-art abatement technologies. In addition, the harmonization of specific regulations (e.g. placing on the market of combustion installations, placing on the market of machinery) with the European Union leads to revisions and amendments. Main steps of revisions and amendments of the OAPC and its driving facts are outlined in Figure 2-1 below.

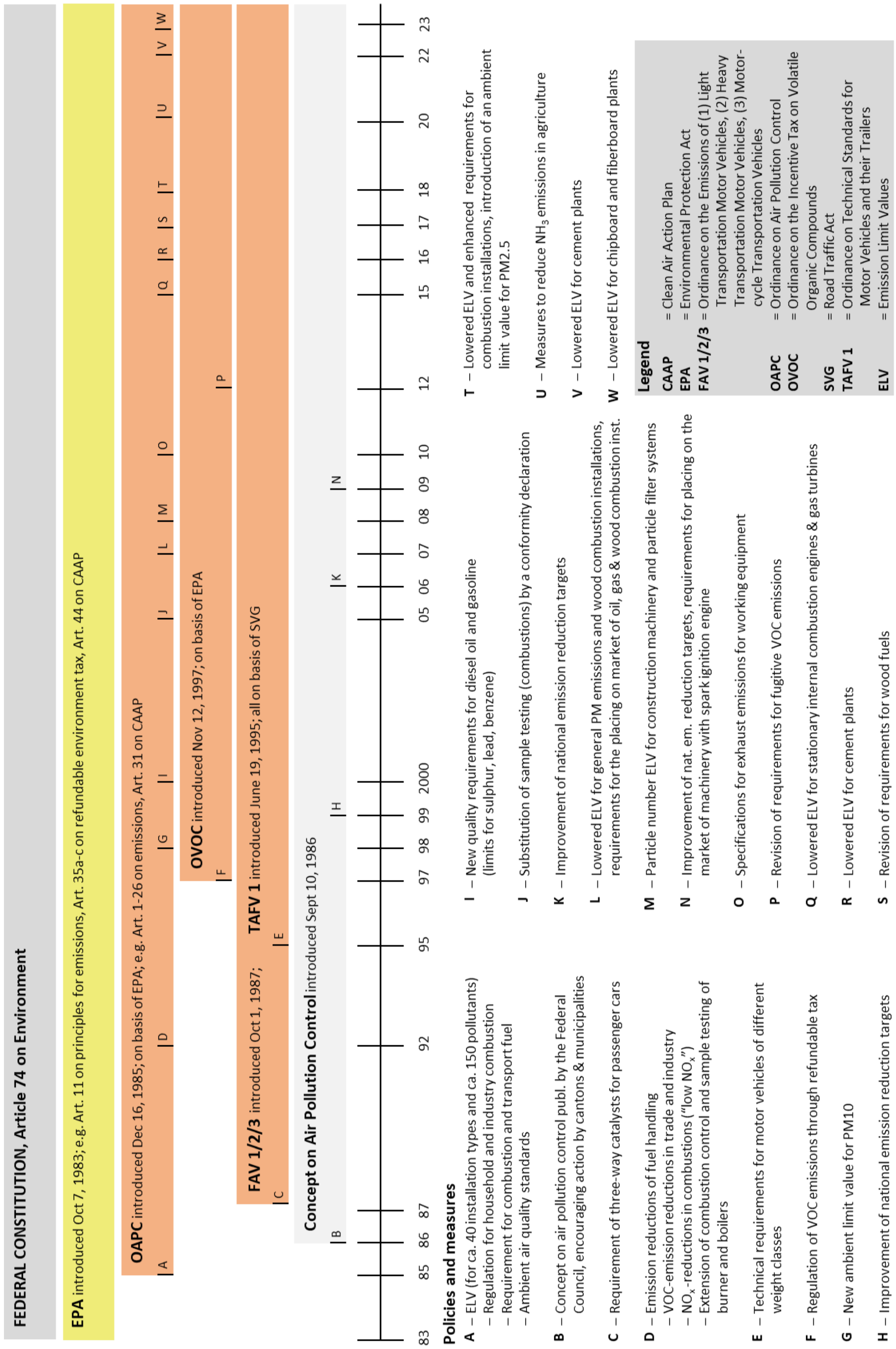


Figure 2-1 Overview of the OAPC Revisions in Switzerland. The Concept on Air Pollution Control is also referred to as the Air Pollution Control Strategy.

For further information on legislation on the abatement of air pollution, see https://www.bafu.admin.ch/bafu/en/home/topics/air/law.html [24.01.2024].

2.2 Overall trends of total emissions

2.2.1 Main air pollutants and CO

Emission trends of the main air pollutants and CO show a decline over the past 40 years as a result of the strict air pollution control policy and the implementation of a large number of emission reduction measures (see Figure 2-2 and Table 2-2).

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_x, NMVOC and CO emissions clearly declined between 1980 and 2022.

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_x emissions observed. The lowering of the maximum sulphur content in liquid fuels is shown in Table 3-28. Annual fluctuations of SO_x emissions occur mainly due to annual variations of heating degree days, which affects the consumption of gas oil.

The reduction of NH_3 emissions since 1980 is not as pronounced as for the other pollutants mentioned above. NH_3 emissions are influenced by changes in the number of livestock (and thus N excretions), changes in housing systems due to developments in animal welfare regulations as well as changes in agricultural production techniques including a decline in the use of mineral fertiliser (see Figure 2-2). Between 1990 and 2020, the amount of N excreted by livestock decreased by 17 % (Kupper et al. 2022), which had a corresponding effect on NO_x and NH_3 emissions from agriculture (see chapters 5.1.1 and 5.1.3).

In the year 2020, a drop of NO_x emissions happened mainly due to the COVID-19 pandemic measures and the resulting reduction of traffic in Switzerland. The reduced traffic volumes affected all pollutants which are emitted by a large share from the source category 1A3 Transport (in particular 1A3b Road transportation).

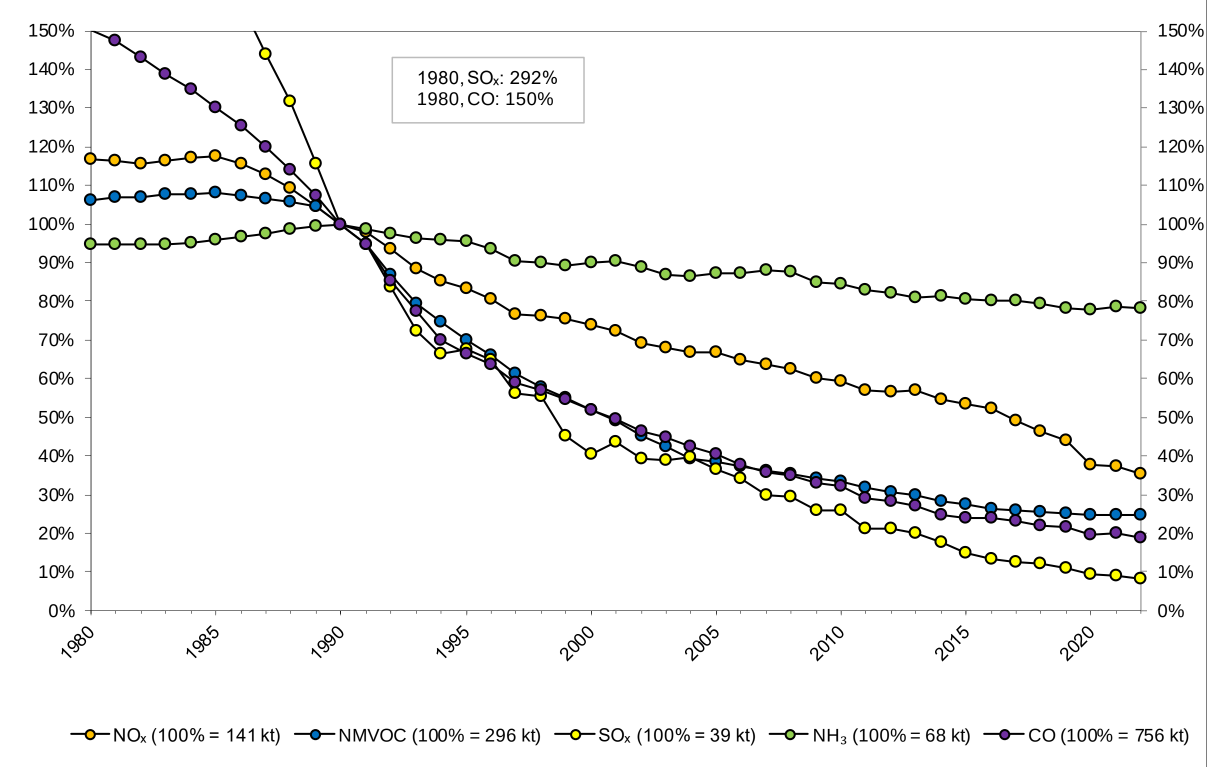


Figure 2-2 Relative trends for the total emissions of main air pollutants and CO in Switzerland 1980–2022 in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

Table 2-2 Main pollutants: Total emissions in kt. Note that numbers refer to the national total for compliance assessment (based on fuel used), which deviate from the national total for the entire territory based on fuel sold.

Year	NO_x	NMVOC	SO_x	NH_3	CO
	kt				
1980	165	314	114	65	1'135
1985	165	319	68	66	985
1990	141	296	39	68	756
1995	117	207	26	65	503
2000	104	154	16	62	393
2005	94	113	14	60	307
2010	83	98	10	58	242
2013	80	88	7.9	55	206
2014	77	84	6.8	56	186
2015	75	81	5.8	55	180
2016	74	78	5.2	55	181
2017	69	77	4.9	55	175
2018	65	76	4.7	54	165
2019	62	75	4.3	54	164
2020	53	73	3.7	53	148
2021	53	73	3.6	54	150
2022	50	73	3.2	53	143
2022 vs. 2005 (%)	-47%	-36%	-77%	-11%	-53%

2.2.2 Suspended particulate matter

Emissions for suspended particulate matter (PM2.5, PM10, TSP and BC) show a significant decline since 1980 (BC since 1990, see Figure 2-3 and Table 2-3). This decline can be mainly attributed to a reduction of exhaust particulate matter emissions (see Figure 2-4 and Table 2-4). The following measures were important for the reductions:

- The abatement of exhaust emissions from road vehicles and from residential heating systems, mainly affecting the fractions of fine particles (PM2.5, BC).
- An action plan to reduce particulate matter emissions was initiated by the Federal Council in 2006, including 14 measures on the national level. Some of these measures led to a revision of the Ordinance of Air Pollution Control (OAPC) in 2007 and in 2018 with more stringent emission limit values for general dust emissions and total solids emission limit values for wood combustion installations.
- Another OAPC revision in 2008 introduced a particle number emission limit value for construction machines and particle filter systems. With the OAPC revision in 2018, the particle number emission limit value became mandatory for new machines in all sectors in accordance with new EU regulations. It aims at reducing the fine fraction of particulate matter (PM2.5) and soot (see also Figure 2-1).

In contrast to exhaust particulate matter emissions, non-exhaust emissions show an increasing trend since about 2003 (see Figure 2-5, Table 2-5). This increase is mainly due to growing activity data (annual mileage and machine hours) of mobile sources, and in absolute terms it is more distinctive for TSP and PM10 than for PM2.5 (see chp. 2.4.4). Since annual mileage dropped in 2020 and 2021 due to the COVID-19 pandemic measures, non-exhaust particulate matter emissions have decreased in 2020 and 2021 compared to 2019 as well (see Figure 2-5).

Note that in the years 1980 to 1990, BC exhaust emissions increased due to a large increase in the consumption of wood energy mainly in households (1A4bi), and to a lower extent also in the commercial sector (1A4ai) and in agriculture and forestry (1A4ci).

Condensable fractions are included in TSP, PM10 and PM2.5 emissions of wood energy combustion (1A1a, 1A2gviii, 1A4ai/bi/ci; see respective sections in chp. 3.2.1.1.2), road transportation (1A3b), non-road vehicles and machinery (1A2gvii, 1A3c/d, 1A4aii/bii/cii and 1A5b), bonfires (1A4bi) and charcoal use (1A4bi).

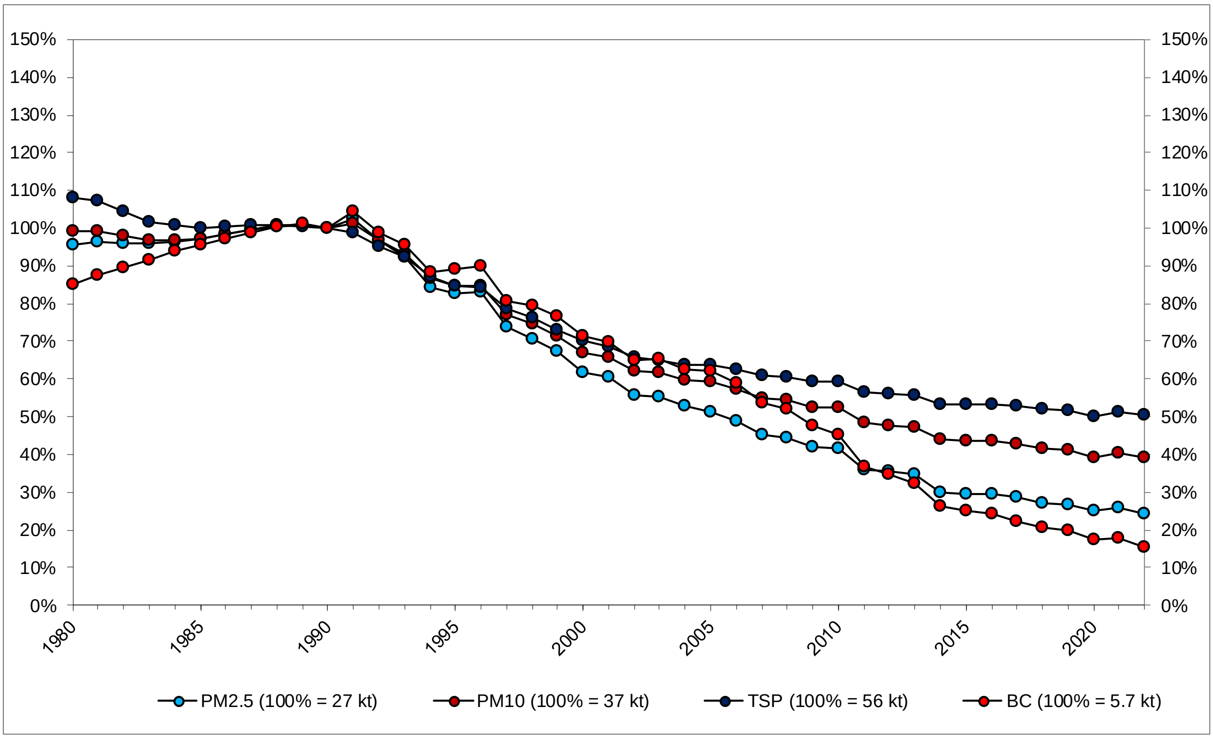


Figure 2-3 Total emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2022 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

Table 2-3 Total emissions of particulate matter in kt. Note that numbers refer to the national total for compliance assessment (based on fuel used), which deviate from the national total for the entire territory based on fuel sold.

Year	**PM2.5**	**PM10**	**TSP**	**BC**
	kt	kt	kt	kt
1980	26	36	61	4.9
1985	26	36	56	5.5
1990	27	37	56	5.7
1995	23	31	48	5.1
2000	17	25	39	4.1
2005	14	22	36	3.6
2010	11	19	33	2.6
2013	9.4	17	31	1.9
2014	8.2	16	30	1.5
2015	8.1	16	30	1.4
2016	8.0	16	30	1.4
2017	7.8	16	30	1.3
2018	7.4	15	29	1.2
2019	7.2	15	29	1.1
2020	6.8	14	28	1.0
2021	7.1	15	29	1.0
2022	6.6	14	28	0.88
2022 vs. 2005 (%)	-53%	-34%	-21%	-75%

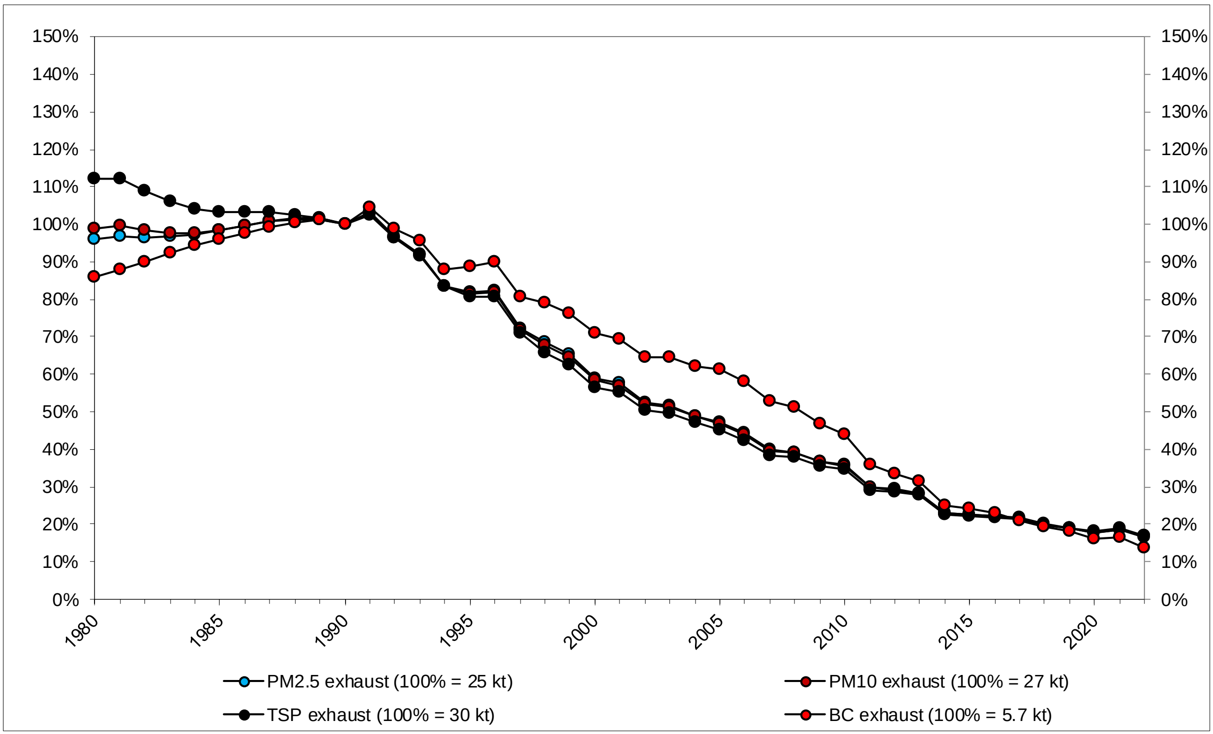


Figure 2-4 Exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2022 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

Table 2-4 Exhaust emissions of particulate matter in kt. Note that numbers refer to the national total for compliance assessment (based on fuel used), which deviate from the national total for the entire territory based on fuel sold.

Year	PM2.5 ex	PM10 ex	TSP ex	BC ex
	kt	kt	kt	kt
1980	24	27	33	4.9
1985	24	27	31	5.4
1990	25	27	30	5.7
1995	20	22	24	5.0
2000	15	16	17	4.0
2005	12	13	13	3.5
2010	8.9	9.6	10	2.5
2013	7.0	7.7	8.2	1.8
2014	5.7	6.3	6.7	1.4
2015	5.6	6.2	6.6	1.4
2016	5.5	6.1	6.5	1.3
2017	5.3	5.9	6.3	1.2
2018	4.9	5.5	5.9	1.1
2019	4.7	5.2	5.5	1.0
2020	4.4	4.9	5.2	0.91
2021	4.6	5.1	5.5	0.93
2022	4.1	4.6	5.0	0.79
2022 vs. 2005 (%)	-65%	-63%	-63%	-77%

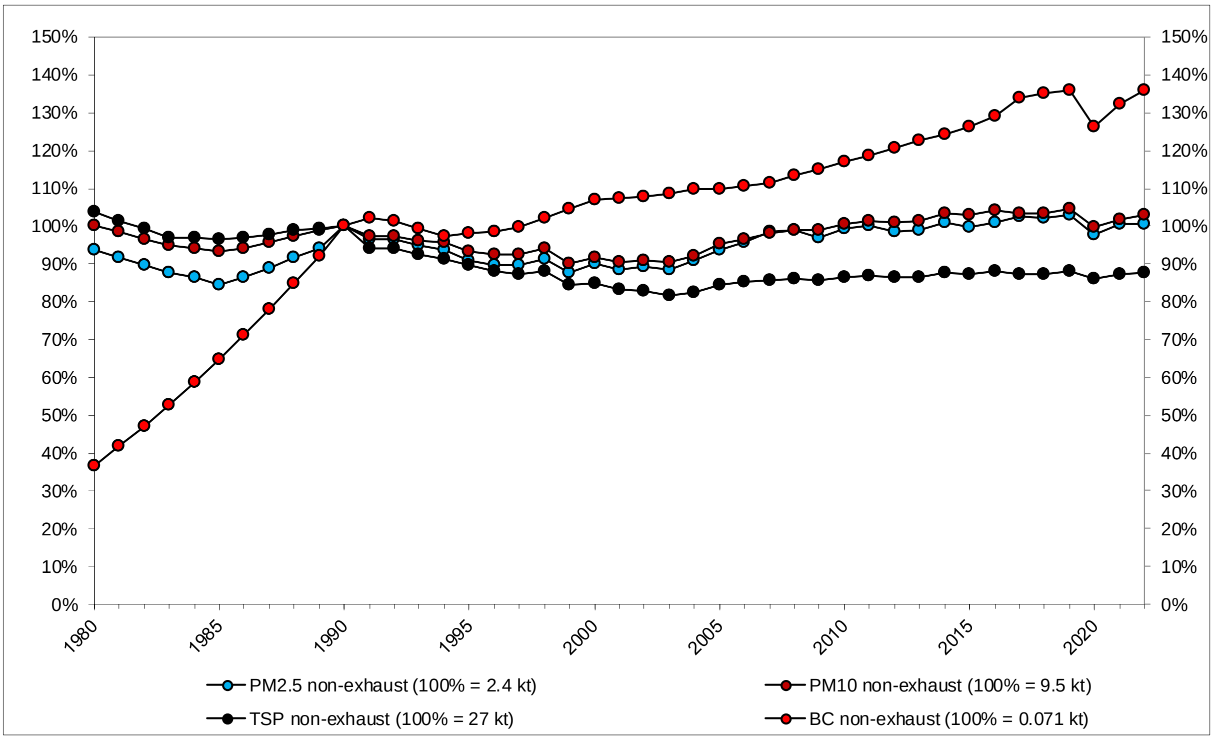


Figure 2-5 Non-exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2022 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

Table 2-5 Non-exhaust emissions of particulate matter in kt. Note that numbers refer to the national total for compliance assessment (based on fuel used), which deviate from the national total for the entire territory based on fuel sold.

Year	PM2.5 nx	PM10 nx	TSP nx	BC nx
	kt	kt	kt	kt
1980	2.3	9.5	28	0.026
1985	2.1	8.8	26	0.046
1990	2.4	9.5	27	0.071
1995	2.2	8.8	24	0.069
2000	2.2	8.7	23	0.076
2005	2.3	9.0	22	0.078
2010	2.4	9.5	23	0.083
2013	2.4	9.6	23	0.087
2014	2.5	9.8	23	0.088
2015	2.4	9.8	23	0.089
2016	2.5	9.9	23	0.091
2017	2.5	9.8	23	0.094
2018	2.5	9.8	23	0.095
2019	2.5	9.9	23	0.096
2020	2.4	9.4	23	0.089
2021	2.5	9.6	23	0.093
2022	2.5	9.7	23	0.096
2022 vs. 2005 (%)	7.6%	8.1%	3.8%	24%

2.2.3 Priority heavy metals

Between 1980 and 2003, emissions of priority heavy metals (Pb, Cd and Hg) show a pronounced decline (see Figure 2-6 and Table 2-6). The continuous decrease of the lead content in gasoline and the final ban on leaded gasoline in 2000 resulted in an important decrease of Pb emissions. The decrease of Cd and Hg emissions is mainly due to the strict emission limit values for waste incineration plants. Since 2003, the decrease of heavy metals emissions is less pronounced.

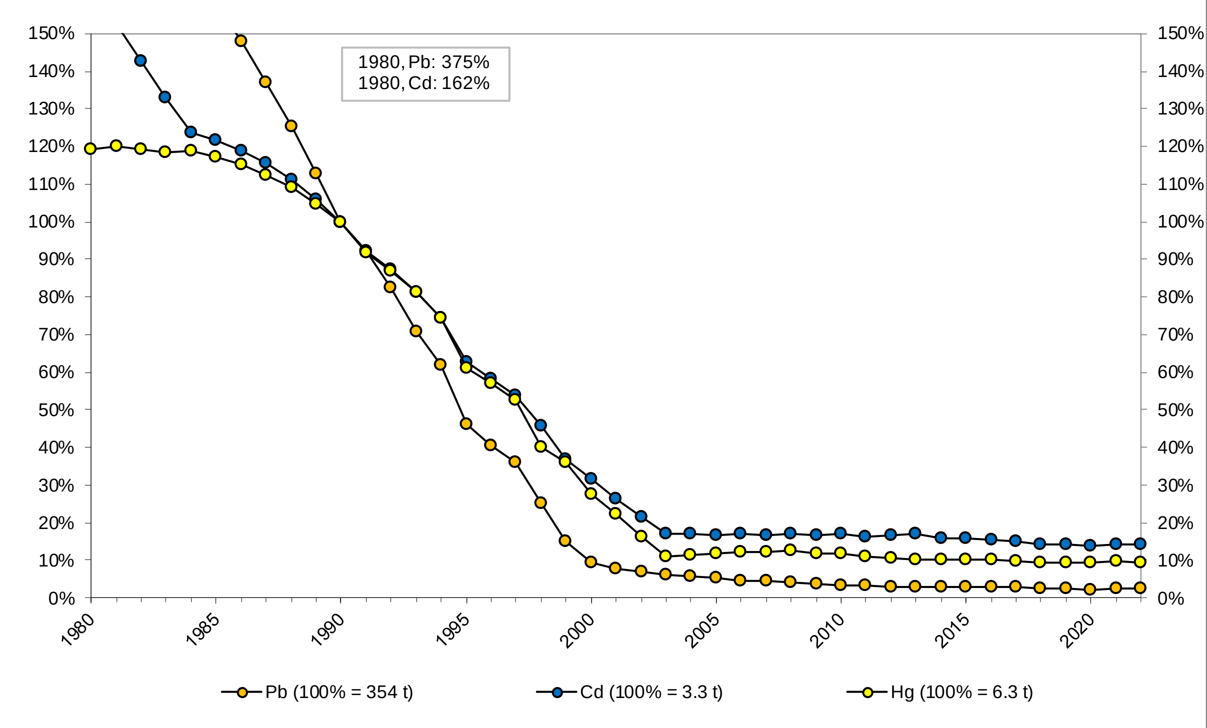


Figure 2-6 Emissions of priority heavy metals in Switzerland 1980–2022 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

Table 2-6 Total emissions of priority heavy metal in tons. Note that numbers refer to the national total for compliance assessment (based on fuel used), which deviate from the national total for the entire territory based on fuel sold.

Year	Pb	Cd	Hg
	t	t	t
1980	1'326	5.3	7.5
1985	560	4.0	7.4
1990	354	3.3	6.3
1995	164	2.0	3.9
2000	33	1.0	1.7
2005	18	0.54	0.73
2010	12	0.56	0.74
2013	10	0.55	0.65
2014	10	0.52	0.63
2015	9.6	0.51	0.64
2016	9.4	0.50	0.64
2017	9.5	0.49	0.61
2018	8.9	0.46	0.59
2019	8.2	0.46	0.59
2020	8.0	0.45	0.58
2021	8.5	0.46	0.60
2022	8.4	0.46	0.58
2022 vs. 2005 (%)	-53%	-15%	-21%

2.2.4 Persistent organic pollutants (POPs)

The emissions of persistent organic pollutants have generally declined since 1980 (see Figure 2-7 and Table 2-7).

Between 1980 and 2003, PCDD/PCDF emissions decreased as a result of an indirect effect of the equipment of waste incineration plants with DeNOx techniques. From 2003 onward, emissions continue to decrease, albeit with a reduced rate.

Emissions of (total) PAH increased slightly in the period 1980-1991, but since then strongly decreased due to reduction measures for waste incineration plants and technological improvements of wood combustion installations in 1A Fuel combustion. In addition, the wood energy consumption decreased by more than half in manually operated furnaces and increased by about a factor of eight in automatic combustion installations since 1990.

HCB emissions are strongly influenced by activity data of the secondary aluminium production. The trend shown in Figure 2-7 is primarily a reflection of the activity of the single plant for secondary aluminium production in Switzerland which ceased in 1993. Since then, total HCB emissions remain on a generally low level with a slight further decrease. The remaining sources of HCB emissions are waste incineration plants in source category 1A1 Energy industries, all wood combustion installations and with a smaller share the use of coal (other bituminous coal and lignite) in 1A Fuel combustion. The annual fluctuations in HCB emissions are due to the wood consumption in 1A4bi Residential: Stationary, which is strongly influenced by climate variabilities, in particular by the winter mean temperatures (heating degree days).

With the exception of a sudden sharp increase in 1999, PCB emissions decreased continuously since 1980. Although the use of PCBs in anti-corrosive paints and joint sealants (so-called open applications) is prohibited since 1972, they are the predominant PCB emission sources for most of the time. In 1986, a total ban was placed on any form of PCB use in Switzerland. Between 1975 and 1985 and around 2000, burning of PCB contaminated waste oil in outdoor fires (ceased in 1999) and shredding of electronic waste containing PCBs in small capacitors, respectively, were the dominant PCB sources. The latter was also the cause for the sudden sharp emission increase in 1999. Mainly in the seventies and eighties, accidental release by fire, small and large capacitors and waste incineration were important emission sources as well.

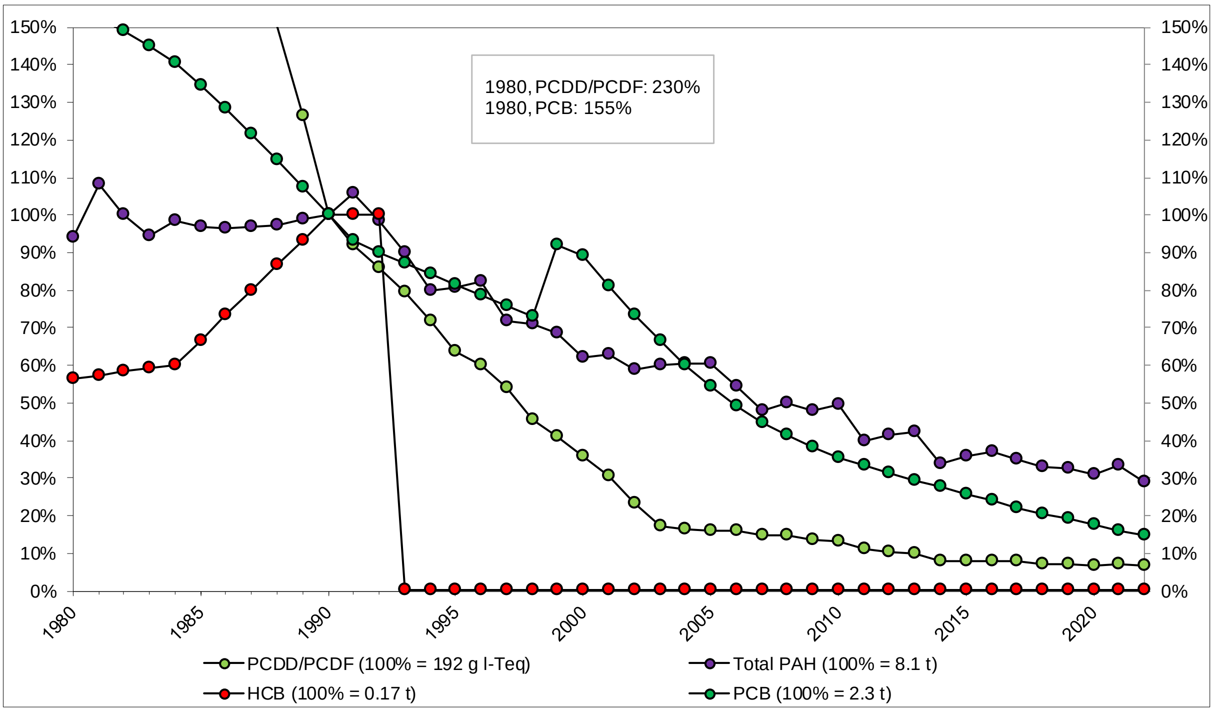


Figure 2-7 Emissions of POPs Annex III[1]: PAH – as the sum of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene – PCDD/PCDF, HCB and PCB in Switzerland 1980–2022. Note that values for PCDD/PCDF before 1989 are not displayed here but illustrated in the table below. Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

Table 2-7 Total emissions of POPs Annex III (see footnote 1, p. 52). Please consider the different units. Note that numbers refer to the national total for compliance assessment (based on fuel used), which deviate from the national total for the entire territory based on fuel sold.

Year	PCDD/ PCDF	BaP	BbF	BkF	IcdP	PAH tot	HCB	PCB
	g I-Teq	t	t	t	t	t	kg	kg
1980	444	2.3	2.6	1.6	1.2	7.6	97	3'607
1985	397	2.3	2.6	1.7	1.3	7.9	115	3'140
1990	192	2.3	2.7	1.7	1.4	8.1	173	2'332
1995	123	2.0	2.1	1.3	1.2	6.5	0.49	1'901
2000	69	1.5	1.6	1.1	0.87	5.0	0.43	2'079
2005	31	1.4	1.6	1.0	0.82	4.9	0.44	1'270
2010	25	1.2	1.3	0.77	0.70	4.0	0.45	827
2013	19	1.1	1.1	0.67	0.60	3.4	0.40	686
2014	16	0.84	0.89	0.54	0.48	2.8	0.35	642
2015	16	0.88	0.93	0.57	0.51	2.9	0.36	600
2016	16	0.91	0.96	0.59	0.53	3.0	0.38	559
2017	15	0.86	0.91	0.57	0.51	2.8	0.37	519
2018	14	0.81	0.86	0.53	0.48	2.7	0.36	481
2019	14	0.80	0.85	0.53	0.47	2.7	0.36	444
2020	13	0.76	0.80	0.50	0.45	2.5	0.35	408
2021	14	0.82	0.86	0.54	0.48	2.7	0.37	374
2022	13	0.70	0.75	0.48	0.42	2.4	0.34	341
2022 vs. 2005 (%)	-60%	-51%	-53%	-54%	-49%	-52%	-24%	-73%

[1] Annex III of the 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs)

2.3 Trends of main pollutants per gas and sectors

2.3.1 Trends for NO_x

Switzerland's emissions of NO_x (sum of NO and NO_2, expressed as NO_2 equivalents) mainly stem from sector 1 Energy. The trend of NO_x emissions per sector is given in Table 2-8 and Figure 2-8. Overall, NO_x emissions in Switzerland constantly declined between 1990 and 2022.

The decline has mainly occurred due to emission reductions in the energy sector. Within the energy sector, in particular categories 1A3 Transport, 1A4 Other sectors and 1A2 Manufacturing industries are relevant for NO_x emissions in 2022. The decrease of NO_x emissions in sector 1 Energy was primarily due to the abatement of exhaust emissions from road vehicles (in category 1A3 Transport) and from production of process heat in manufacturing industries (1A2) and in residential, commercial and institutional heating (1A4).

- The reductions in 1A3b Road transportation were triggered by the implementation of new strict emission standards for road vehicles. The first step happened in the late 80's when Switzerland reduced the standards to a level that required the equipment of three-way catalysts for new passenger cars. Later, when the European Union introduced the first Euro standards in 1993, Switzerland adopted the subsequent reduction path (Euro 2/II in 1995, Euro 3/III in 2000, Euro 4/IV in 2005, Euro V in 2008, Euro 5 in 2009, Euro VI in 2013 and Euro 6 in 2014). However, the reduction of NO_x emissions due to emission standards has not been as pronounced as expected in the years before 2015 because of an increasing share of diesel-powered passenger cars and higher emission factor than expected (the "dieselgate" scandal[2], detected in the year 2015).
- In the years 2020 and 2021, the COVID-19 pandemic led to measures that resulted in a massive reduction in transport activities (1A3). The lower traffic volume led to a strong decrease in NO_x emissions from 1A3b Road transportation and a sharp drop in emissions from 1A3a Aviation, especially international aviation. However, the share of NO_x emissions from 1A3a Aviation in 1A3 Transport is smaller than that from 1A3b Road transportation, in particular due to the system boundaries (only LTO emissions from air traffic are taken into account in the national total, see chapter 3.1.6.1).
- The reductions in 1A2 Manufacturing industries and construction were a result of three main factors: First, there has been a fuel switch from residual fuel oil, coal and gas oil towards natural gas and a reduction in total fuel use since 2008. Second, a reduction has been reached due to an on-going sectoral agreement (from 1998) targeting NO_x emissions of the cement industry. Third, manufacturing plants reduced NO_x emissions through technical improvements (e.g. $DeNO_x$ technology, selective non-catalytic reduction technology SNCR).
- In the past, the number of buildings and apartments increased, as well as the average floor space per person and workplace. Both effects resulted in an increase of the total heated area. On the other hand higher standards were specified for insulation and for combustion equipment efficiency for new or renovated buildings including low-NO_x standards. Furthermore, a substantial substitution of gas oil by natural gas under 1A4 Other sectors resulted in further reductions of NO_x emissions (i.e. natural gas consumption increased by half from 1990 to 2022). These emission reductions compensate for the expected increase in emissions due to higher demand for heating energy as a result of

[2] Dieselgate: «The EPA had found that Volkswagen had intentionally programmed turbocharged direct injection diesel engines to activate certain emissions controls only during laboratory emissions testing. Volkswagen deployed this programming in about eleven million cars worldwide» Source: https://en.wikipedia.org/wiki/Volkswagen_emissions_scandal [25.01.2023]

more heating surface, and lead to a total reduction of NO_x emissions under category 1A4 Other sectors.

NO_x emissions from Agriculture decrease on a rather low absolute emission level. This was mainly due to a reduction and thus N excretions of livestock (-17 % between 1990 and 2020) and a strong decrease of N fertiliser use (-38 % N applied between 1990 and 2020) due to nutrient balance restrictions.

Table 2-8 NO_x emissions, trends and share per sector as well as emission ceiling for 2010 from the Gothenburg Protocol (national total for compliance; fuels used).

NO_x emissions	**1990**	**2005**	**2010**	**2022**	**1990–2010**	**2005–2022**	**2005–2022**	**share in 2022**
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	135	89	79	46	-56	-44	-49%	92%
1A Fuel combustion	135	89	79	46	-56	-43	-49%	92%
1A1 Energy industries	6.8	3.0	3.1	2.5	-3.7	-0.51	-17%	5.0%
1A2 Manufacturing industries	23	14	12	7.5	-10	-6.8	-48%	15%
1A3 Transport	83	54	48	26	-35	-28	-52%	53%
1A4 Other sectors	22	17	15	9.1	-6.8	-7.5	-45%	18%
1A5 Other (Military)	0.88	0.60	0.54	0.40	-0.34	-0.20	-34%	0.80%
1B Fugitive emissions from fuels	0.21	0.29	0.11	0.0006	-0.10	-0.28	-100%	0.001%
2 IPPU	0.49	0.32	0.38	0.22	-0.11	-0.092	-29%	0.45%
3 Agriculture	4.9	3.8	4.0	3.6	-0.97	-0.25	-6.4%	7.2%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.30	0.16	0.15	0.12	-0.15	-0.041	-25%	0.24%
6 Other	0.092	0.097	0.100	0.090	0.0079	-0.0076	-7.9%	0.18%
National total for compliance	141	94	83	50	-58	-44	-47%	100%
Gothenburg Protocol			**2010**			Gothenburg Protocol revised		**2005-2020**
Emission ceiling / reduction			79					-41%

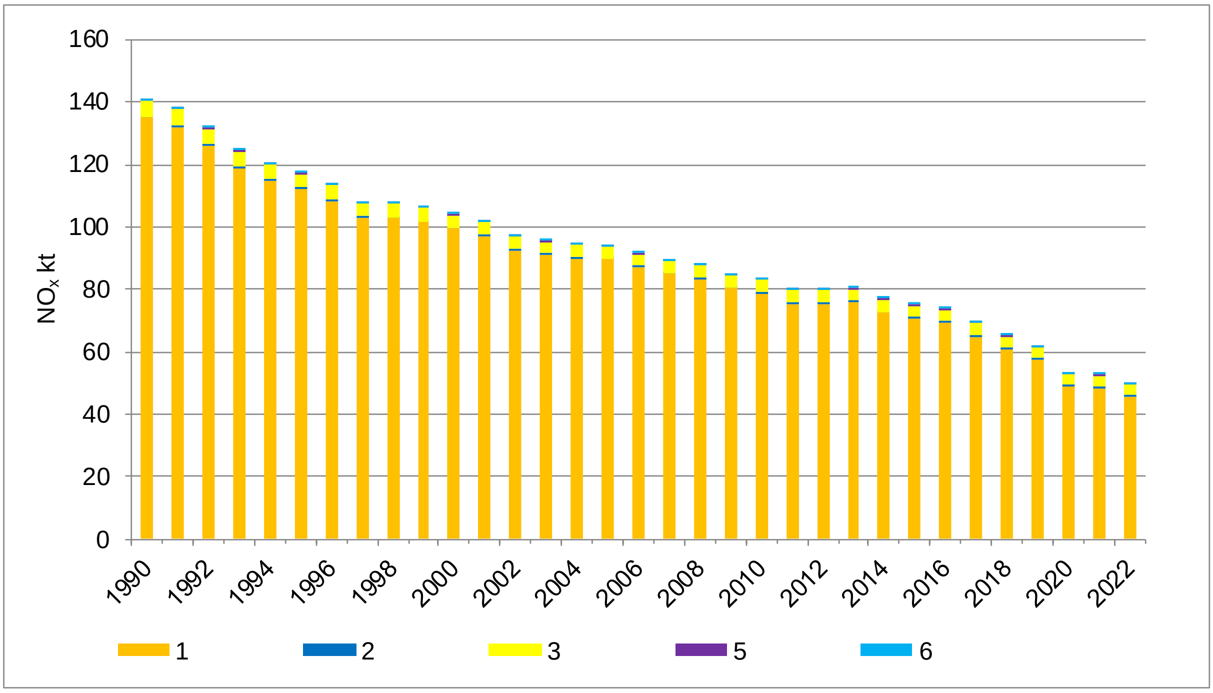


Figure 2-8 Trend of NO_x emissions (kt) in Switzerland by sector.

2.3.2 Trends for NMVOC

Switzerland’s emissions of NMVOC mainly stem from the sectors 2 IPPU, 3 Agriculture and 1 Energy. The trend of NMVOC emissions per sector is given in Table 2-9 and Figure 2-9. The NMVOC emissions have decreased in the time span 1990-2022.

The relevant reductions were achieved in sectors 2 IPPU and 1 Energy:

- In sector 2 IPPU, the emission reduction was more pronounced for the years 1990-2004 than from 2004 onwards. The reduction of 1990-2004 can be mainly attributed to category 2D3d Coating applications, where the paint composition changed from solvent based to water-based paints. In addition, paint consumption in 2D3d decreased for construction (1990-1998) as well as for industrial paint application (2001-2004) which is partly due to substitution of conventional paints by powder coatings.
  Despite population growth and the associated increase in product use (e.g. cosmetics, toiletries, cleaning agents and care products), the general trend of NMVOC emissions from sector 2 IPPU was still decreasing from 2004-2017 (and rather constant values afterwards). This was mainly a result of reduced emissions caused by the ordinance on the VOC incentive tax (enactment of the tax in 2000 and revision in 2012).
- In sector 1 Energy, the emission reduction was mainly influenced from category 1A3b Road transportation, in particular resulting from the higher Euro standards for passenger cars (Euro 1 in 1993, Euro 2 in 1995, Euro 3 in 2000, Euro 4 in 2005, Euro 5 in 2009 and Euro 6 in 2014). Furthermore, the share of diesel oil in fuels used under 1A3b has increased compared to gasoline between 1990 and 2022, which leads to a decrease of NMVOC emissions. In 2020 and 2021, the COVID-19 pandemic led to a reduction of NMVOC emissions from road transportation due to reduced traffic volumes.
  The measures against the pandemic also led to a sharp drop in emissions from 1A3a Aviation in 2020 and 2021, especially international aviation. However, the share of NMVOC emissions from 1A3a Aviation in 1A3 Transport is smaller than that from 1A3b Road transportation, in particular due to the different fuel types (most NMVOC emissions stem from gasoline engines and the system boundaries (only LTO emissions from air traffic are taken into account in the national total, see chapter 3.1.6.1).
- NMVOC emissions of source category 1A4 Other sectors declined in the same period as well due to technical improvements of wood combustion installations and a reduction in the number and energy consumption of emission intensive types of log wood furnaces.

NMVOC emissions from sector 3 Agriculture show a significant increase between 2000 and 2008 and have remained at about constant level since 2014. They depend on the number of livestock, in particular the number of cattle receiving silage feeding. Thus, the emission increase is mainly due to the increase in non-dairy cattle which predominately are fed by silage.

Table 2-9 NMVOC emissions, trends and share per sector as well as the emission ceiling for 2010 from the Gothenburg Protocol (national total for compliance; fuels used).

NMVOC emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	130	44	31	16	-99	-29	-64%	22%
1A Fuel combustion	109	37	26	13	-83	-24	-64%	18%
1A1 Energy industries	0.33	0.32	0.26	0.20	-0.07	-0.12	-37%	0.28%
1A2 Manufacturing industries	2.4	2.1	1.6	0.90	-0.78	-1.2	-56%	1.2%
1A3 Transport	89	23	15	7.4	-74	-16	-68%	10%
1A4 Other sectors	17	12	9.3	4.8	-8.2	-6.8	-59%	6.6%
1A5 Other (Military)	0.16	0.11	0.090	0.064	-0.070	-0.045	-41%	0.09%
1B Fugitive emissions from fuels	21	7.2	5.2	2.4	-16	-4.8	-67%	3.3%
2 IPPU	150	52	48	37	-102	-15	-29%	51%
3 Agriculture	14	16	17	18	2.8	2.1	13%	25%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	1.1	1.0	1.2	1.7	0.041	0.71	69%	2.4%
6 Other	0.20	0.20	0.18	0.17	-0.024	-0.033	-16%	0.23%
National total for compliance	296	113	98	73	-198	-41	-36%	100%
Gothenburg Protocol			2010			Gothenburg Protocol revised		2005-2020
Emission ceiling / reduction			144					-30%

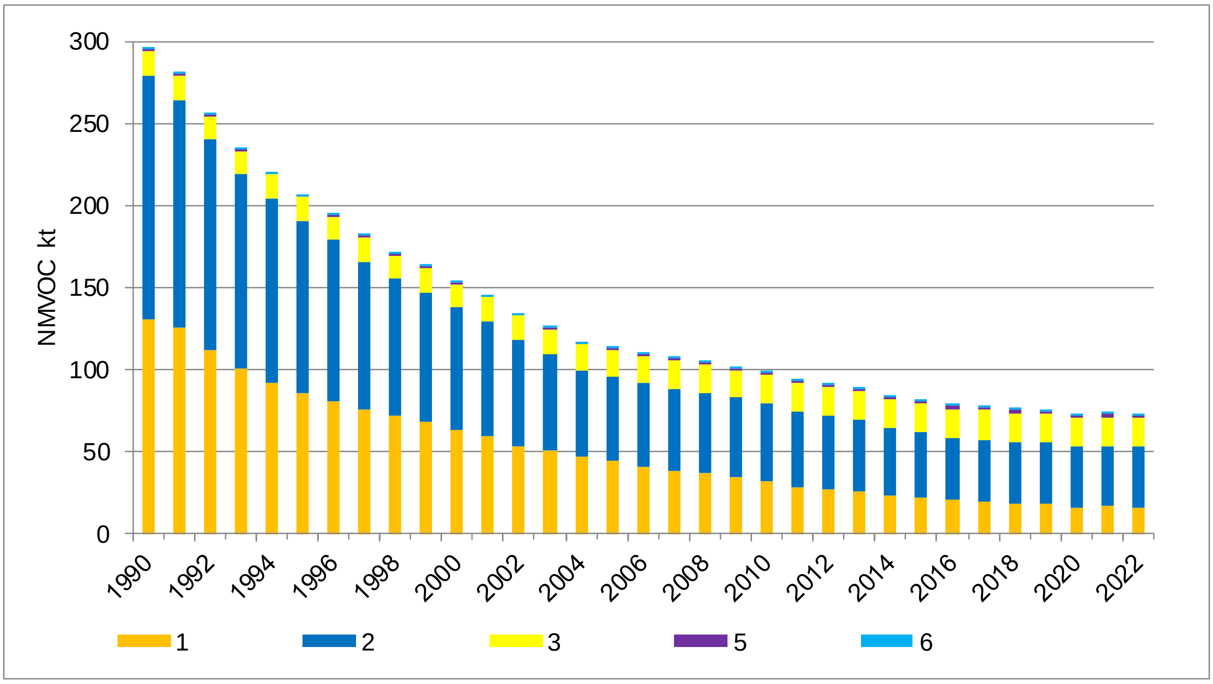


Figure 2-9 Trend of NMVOC emissions (kt) in Switzerland by sector.

2.3.3 Trends for SO_x

Switzerland's emissions of SO_x (sum of SO_2 and SO_3, expressed as SO_2 equivalents) mainly stem from sector 1 Energy. The trend of SO_x emissions per sector is given in Table 2-10 and Figure 2-10. SO_x emissions show a decreasing trend with some fluctuations between 1990 and 2022.

The decrease can be mainly attributed to three measures in Switzerland in the sector Energy:

- First, the Ordinance on Air Pollution Control (Swiss Confederation 1985) introduced a limitation of the sulphur content in liquid fuels, with further stepwise lowering in 1991, 2000, 2005, 2008 and 2009 for liquid fuels (Table 3-28). These stringent measures resulted in a significant decrease of the sulphur oxide emissions from fuel combustion under 1A3 Transport and 1A4 Other sectors (gas oil, diesel oil and gasoline, see Table 3-28).

- Second, a substantial substitution of gas oil with natural gas and eco-grade gas oil (with low sulphur and nitrogen content, from 2006 onwards) under 1A4 Other sectors resulted in further reductions of sulphur emissions (natural gas consumption increased by half from 1990 to 2022).
- Third, a similar substitution of residual fuel oil, coal and gas oil by natural gas has reduced sulphur emissions as well in 1A2 Manufacturing industries (i.e. coal and residual fuel oil from 1990, gas oil from about 2005 onwards).

In addition, SO_x emissions from 2C Metal production declined between 1990 and 2007, mainly following the decrease in aluminium production volume, which was ceased in 2006. SO_x emissions of sector 2B Chemical industry show no clear trend in the period 1990–2022. They stem predominately from the sulphur content of the raw materials of the graphite and silicon carbide production (petroleum coke and other bituminous coal) and reflect, thus, the production volumes.

Table 2-10 SO_x emissions, trends and share per sector as well as the emission ceiling for 2010 from the Gothenburg Protocol (national total for compliance; fuels used).

SO_x emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	37	13	9.2	2.8	-28	-10.3	-79%	88%
1A Fuel combustion	37	13	9.0	2.8	-28	-9.8	-78%	87%
1A1 Energy industries	4.3	1.6	1.7	0.30	-2.6	-1.3	-82%	9.3%
1A2 Manufacturing industries	13	4.2	2.9	1.9	-10	-2.3	-55%	58%
1A3 Transport	4.0	0.18	0.20	0.18	-3.8	-0.005	-3%	5.5%
1A4 Other sectors	15	6.6	4.1	0.44	-11	-6.2	-93%	14%
1A5 Other (Military)	0.078	0.037	0.037	0.033	-0.041	-0.005	-12%	1.0%
1B Fugitive emissions from fuels	0.72	0.51	0.22	0.016	-0.50	-0.50	-97%	0.51%
2 IPPU	1.6	1.0	0.80	0.35	-0.84	-0.68	-66%	11%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.16	0.063	0.063	0.029	-0.10	-0.035	-55%	0.89%
6 Other	0.0092	0.0094	0.0074	0.0072	-0.0017	-0.0021	-23%	0.23%
National total for compliance	39	14	10	3.2	-29	-11	-77%	100%
Gothenburg Protocol			**2010**			Gothenburg Protocol revised		**2005-2020**
Emission ceiling / reduction			26					-21%

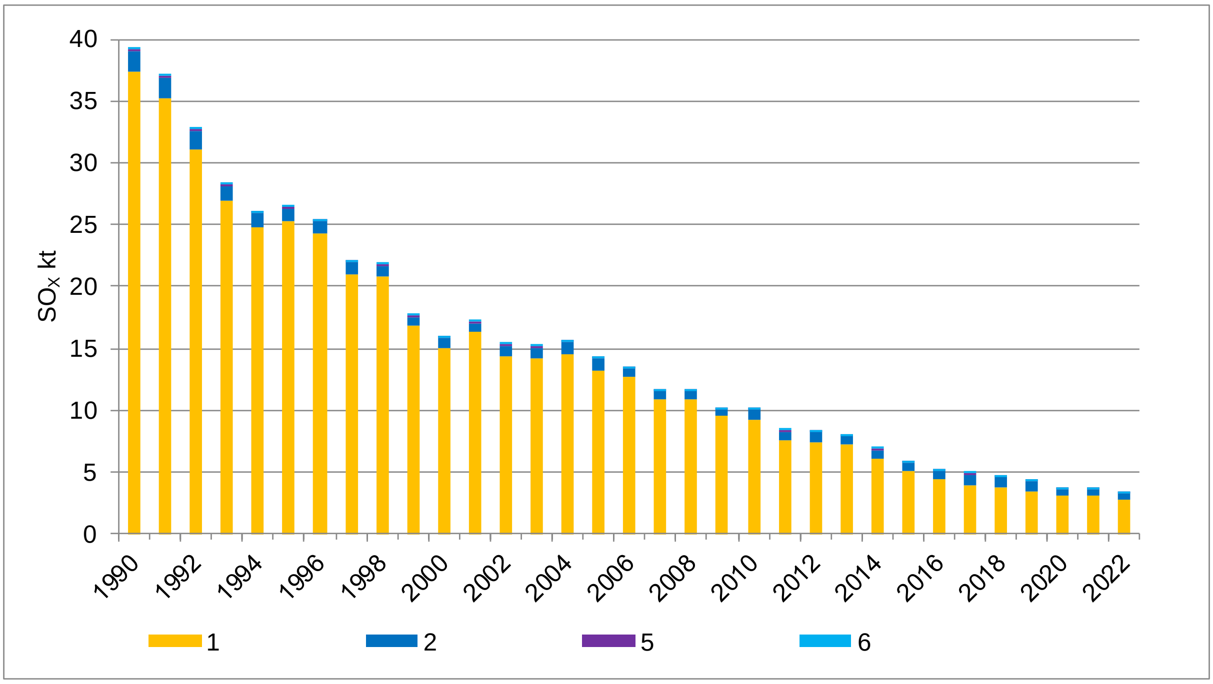


Figure 2-10 Trend of SO_x emissions (kt) in Switzerland by sector (SO_x as sum of SO_2 and SO_3, expressed as SO_2 equivalents).

Emission trends 1980-2022: Trends of main pollutants per gas and sectors - Trends for SOx

2.3.4 Trends for NH_3

Switzerland's emissions of NH_3 mainly stem from sector 3 Agriculture. The trend of NH_3 emissions per sector is given in Table 2-11 and Figure 2-11. NH_3 emissions show a decreasing trend between 1990 and 2022.

Emission reductions (with fluctuations) occurred mainly in source category 3D Crop production and agricultural soils, especially in 3Da2a Animal manure applied to soils, while emissions from source category 3B Manure management slightly increased. In 2022, both categories are about equally important. Agricultural ammonia emissions decreased between 1990 and 2004, followed by a slight increase until 2007 and another decrease since then. This non-monotonic trend results from a combination of changes in animal numbers, introduction of nutrient balance regulations for nitrogen, introduction of new housing systems and more grazing due to developments in animal welfare regulations, increase of animal productivity, changes in production techniques and a considerable decrease of N fertiliser use due to nutrient balance restrictions (Kupper et al. 2015, 2018, 2022). Between 1990 and 2020, N excretions from livestock decreased by 17 % and N excretions of livestock going into the manure stream even by 27 % (Kupper et al. 2022). A further reason for the downward trend of agricultural NH_3 emissions is the growing importance of grazing due to animal welfare incentives. The share of soluble N (TAN) of excretions of livestock going to grazing increased from 8 % in 1990 to 17 % in 2020 (Kupper et al. 2022).

Table 2-11 NH_3 emissions, trends and share per sector as well as the emission ceiling for 2010 from the Gothenburg Protocol (national total for compliance; fuels used).

NH_3 emissions	**1990**	**2005**	**2010**	**2022**	**1990–2010**	**2005–2022**	**2005–2022**	**share in 2022**
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	1.7	3.9	2.7	1.3	1.1	-2.6	-67%	2.4%
1A Fuel combustion	1.7	3.9	2.7	1.3	1.1	-2.6	-67%	2.4%
1A1 Energy industries	0.0049	0.029	0.036	0.037	0.032	0.0081	28%	0.07%
1A2 Manufacturing industries	0.17	0.19	0.24	0.25	0.077	0.051	26%	0.46%
1A3 Transport	1.3	3.5	2.3	0.90	1.0	-2.6	-75%	1.7%
1A4 Other sectors	0.18	0.14	0.14	0.10	-0.038	-0.043	-30%	0.19%
1A5 Other (Military)	0.00004	0.00004	0.00004	0.00004	0.000005	0.000001	3.3%	0.00008%
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	0.37	0.35	0.21	0.15	-0.16	-0.21	-59%	0.27%
3 Agriculture	65	54	53	50	-12	-3.5	-6.5%	94%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.91	0.93	0.89	0.86	-0.024	-0.068	-7.4%	1.6%
6 Other	0.85	0.88	0.92	0.97	0.073	0.094	11%	1.8%
National total for compliance	68	60	58	53	-11	-6.3	-11%	100%
Gothenburg Protocol			**2010**		Gothenburg Protocol revised			**2005-2020**
Emission ceiling / reduction			63					-8.0%

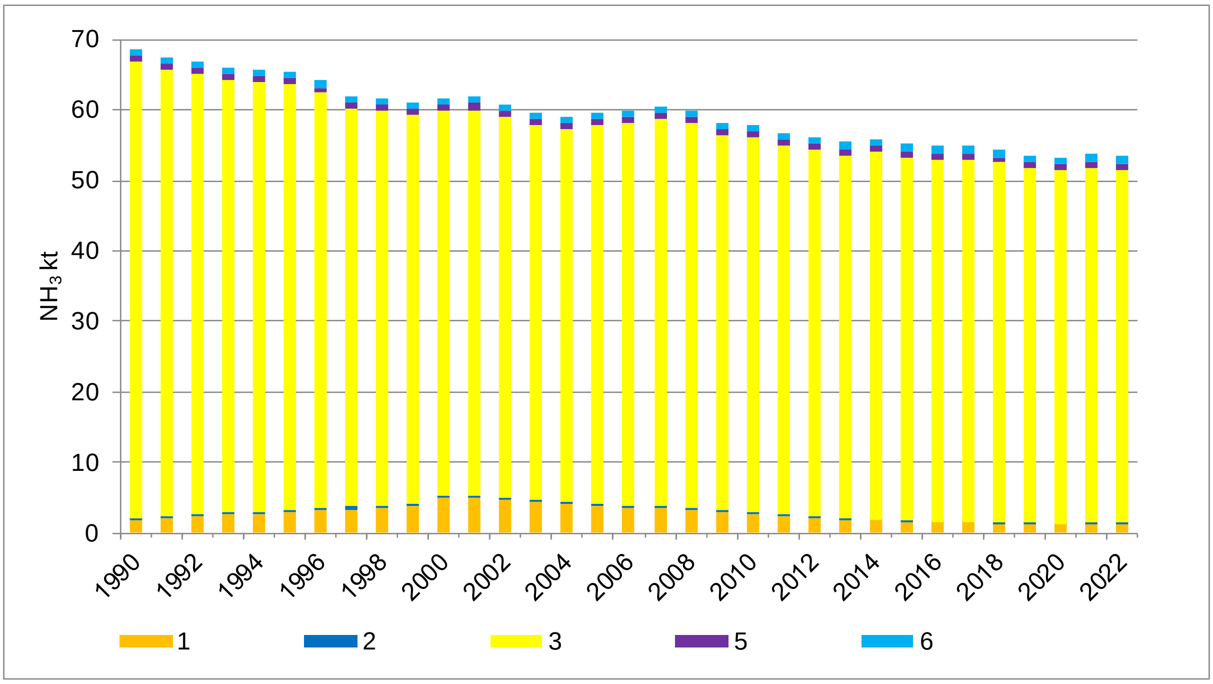


Figure 2-11 Trend of NH_3 emissions (kt) in Switzerland by sector.

2.4 Trends of particulate matter per pollutant

2.4.1 Features commonly holding for all particulate matter fractions PM2.5, PM10, TSP and BC

Switzerland's emissions of particulate matter (PM2.5, PM10, TSP and BC) mainly stem from sector 1 Energy. (For TSP, due to the considerable emission reductions in sector 1 Energy, the emissions from sector 3 Agriculture have gained in importance and have been of comparable size in recent years.) Particulate matter emissions per sector are given in Table 2-12 and Figure 2-12 for PM2.5, in Table 2-13 for PM10, in Table 2-14 to Table 2-16 and Figure 2-13 for TSP and in Table 2-17 for BC. Total particulate matter emissions generally show decreasing trends from 1990 on. The observed reduction of emissions in PM2.5, PM10, TSP and BC were achieved in sectors 1 Energy and 2 IPPU.

In the sector 1 Energy, the decline can be mainly attributed to a reduction of exhaust particulate matter emissions:

- The large reduction of exhaust particulate matter emissions is primarily due to the development of emissions from wood combustion, especially in single-room furnaces and building heating systems (1A4). (Since the latest submission, exhaust particulate matter emissions include not only the filterable fractions, but also the condensable fractions, which are particularly relevant for single-room furnaces and building heating.) This reduction was achieved through technological improvements of the combustion installations and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, wood energy consumption in manually operated furnaces decreased by more than half since 1990. Furthermore, the revision of the Ordinance of Air Pollution (Swiss Confederation 1985) in 2007 introduced more stringent emission limits (2007, 2008 and 2012) for mainly automatic wood combustion installations, which also led to a reduction in emissions from these installations (mainly in 1A1 and 1A2), although their wood energy consumption increased by about a factor of eight since 1990.

- A further reduction of exhaust emissions under 1A3 Transport was caused by the abatement of exhaust emissions from road vehicles. Throughout the years, a continuous reduction of these emissions has been achieved with the stepwise adoption of the Euro standards. New diesel cars must be equipped with diesel particle filters.
- Under category 1A2 Manufacturing industries and construction, a reduction of exhaust emissions resulted from technological improvements in construction machineries (an installation of particle filters for new construction machineries with diesel engines is required by the Ordinance on Air Pollution Control (OAPC) since 2009) and from a fuel switch in stationary combustion (i.e. from coal, residual fuel oil and gas oil to natural gas).
- There is an underlying increasing in non-exhaust particulate matter emissions from growing activity data (annual mileage and machine hours) of mobile sources 1A3 Transport and 1A2gvii Mobile combustion in manufacturing industries and construction which affects larger particle emissions (TSP and PM10) more than PM2.5 (see Table 2-16 and Figure 2-13). This is due to a larger share of non-exhaust emissions with a particle diameter of 10 micrometres and larger. Therefore, the overall decreasing trend in TSP emissions is less pronounced as compared to the decrease in PM2.5 emissions. Note: In 2020 and 2021, despite this underlying increasing trend, the measures against the COVID-19 pandemic led to a reduction of non-exhaust PM10 emissions from road transportation due to reduced traffic volumes.

In sector 2 IPPU, particulate matter emissions strongly decrease in the period 1990-2001 and fluctuate only slightly since then. In 1990, the source categories 2A Mineral products (PM2.5, PM10, TSP), 2C Metal production (PM2.5, PM10, TSP), 2G Other product use (PM2.5), 2H Other (PM2.5) and 2I Wood processing (PM10, TSP) contributed the most to the particulate matter emissions. Since 2001, IPPU emissions (e.g. from cement production, gravel plants and use of fireworks and tobacco, wood processing) became a minor source of total particulate matter emissions. The following measures contribute to the decreasing trend:

- Significant emission reductions up to 1999 occurred in category 2C1 Iron and steel production in two steps. In 1995, two steel production sites were closed down in Switzerland, whereas the drastic drop in emission in 1998/1999 was due to the installation of new filters in the remaining two steel plants.
- For TSP emissions, also the emission reduction in 2I Wood processing between 1990 and 2003 was relevant. On the one hand, this was achieved by refurbishments due to the enforcement of the OAPC (Swiss Confederation 1985), but also by the area-wide introduction of filter systems due to occupational safety regulations (carcinogenic effect of beech wood dust).
- Under category 1A2 Manufacturing industries and construction, a reduction of exhaust emissions resulted from technological improvements in construction machineries (an installation of particle filters for new construction machineries with diesel engines is required by the Ordinance on Air Pollution Control (OAPC) since 2009) and from a fuel switch in stationary combustion (i.e. from coal, residual fuel oil and gas oil to natural gas).

2.4.2 Trends for PM2.5

Switzerland’s emissions of PM2.5 per sector are given in Table 2-12 and Figure 2-12. For explanations regarding the trends, see chp. 2.4.1 for features commonly holding for all particulate matter emissions.

Table 2-12 PM2.5 emissions, trends and share per sector (national total for compliance; fuels used).

PM2.5 emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	24	12	9.3	4.9	-15	-7.1	-59%	74%
1A Fuel combustion	24	12	9.3	4.9	-15	-7.1	-59%	74%
1A1 Energy industries	0.83	0.19	0.20	0.060	-0.64	-0.13	-69%	0.91%
1A2 Manufacturing industries	2.3	1.7	1.2	0.64	-1.1	-1.0	-62%	9.7%
1A3 Transport	3.7	2.8	2.3	1.5	-1.4	-1.4	-49%	22%
1A4 Other sectors	17	7.2	5.6	2.7	-11	-4.6	-63%	41%
1A5 Other (Military)	0.087	0.057	0.050	0.045	-0.037	-0.012	-21%	0.68%
1B Fugitive emissions from fuels	0.00060	0.00066	0.00031	0.000049	-0.0003	-0.0006	-93%	0.00074%
2 IPPU	2.6	1.5	1.5	1.3	-1.1	-0.17	-12%	20%
3 Agriculture	0.12	0.13	0.13	0.15	0.013	0.017	14%	2.2%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.59	0.38	0.36	0.27	-0.22	-0.11	-28%	4.2%
6 Other	0.0044	0.0043	0.0044	0.0048	0.00001	0.0005	11%	0.07%
National total for compliance	27	14	11	6.6	-16	-7.4	-53%	100%
Gothenburg Protocol			2010			Gothenburg Protocol revised		2005-2020
Emission ceiling / reduction			–					-26%

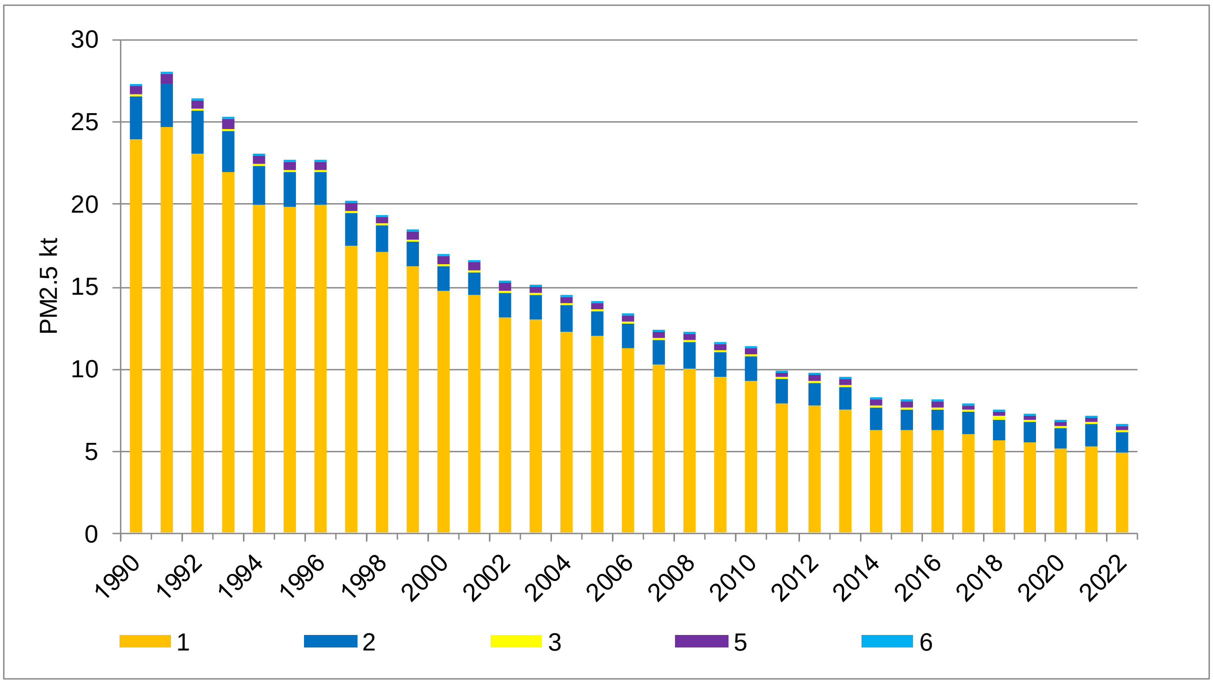


Figure 2-12 Trend of PM2.5 emissions (kt) in Switzerland by sector.

2.4.3 Trends for PM10

Switzerland’s emissions of PM10 per sector are given in Table 2-13. For explanations regarding the trends, see chp. 2.4.1 for features commonly holding for all particulate matter emissions.

Table 2-13 PM10 emissions, trends and share per sector (national total for compliance; fuels used).

PM10 emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	29	17	15	10	-15	-7.0	-41%	70%
1A Fuel combustion	29	17	15	10	-15	-7.0	-41%	70%
1A1 Energy industries	1.1	0.20	0.20	0.061	-0.90	-0.14	-69%	0.42%
1A2 Manufacturing industries	4.2	3.6	3.1	2.6	-1.1	-0.92	-26%	18%
1A3 Transport	5.9	5.4	5.0	4.2	-0.89	-1.1	-21%	29%
1A4 Other sectors	18	7.7	6.0	2.9	-12	-4.8	-63%	20%
1A5 Other (Military)	0.29	0.27	0.27	0.26	-0.018	-0.004	-1.5%	1.8%
1B Fugitive emissions from fuels	0.0020	0.0013	0.0010	0.0005	-0.0011	-0.0008	-63%	0.003%
2 IPPU	4.5	2.3	2.3	2.1	-2.2	-0.18	-8%	15%
3 Agriculture	1.7	1.7	1.7	1.8	0.015	0.13	7.9%	12%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.66	0.42	0.41	0.31	-0.26	-0.12	-28%	2.1%
6 Other	0.23	0.21	0.14	0.12	-0.086	-0.097	-45%	0.8%
National total for compliance	37	22	19	14	-17.4	-7.3	-34%	100%

2.4.4 Trends for TSP

Switzerland’s emissions of TSP per sector are given in Table 2-14 to Table 2-16 and Figure 2-13. In addition to the features commonly holding for all particulate matter emissions mentioned in chp. 2.4.1, the contribution of sector 3 Agriculture to non-exhaust TSP emissions is significant (see Table 2-16). Its dominant emission sources are soil cultivation and crop harvesting reported in 3De Cultivated crops. These emissions remained on a rather constant level since 1990 and account for a high share of TSP emissions. In recent years, the TSP emission shares of the sectors 1 Energy and 3 Agriculture are comparable size. In comparison, non-exhaust PM10 and PM2.5 emissions from the agriculture sector contribute less. Accordingly, the (relative) decreasing trend of TSP is less pronounced than the ones of PM10 and PM2.5.

Table 2-14 Total TSP emissions (sum of exhaust and non-exhaust), trends and share per sector (national total for compliance; fuels used).

TSP total emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	32	19	17	12	-16	-7.2	-37%	42%
1A Fuel combustion	32	19	17	12	-16	-7.2	-37%	42%
1A1 Energy industries	1.1	0.22	0.22	0.064	-0.90	-0.15	-70%	0.23%
1A2 Manufacturing industries	5.5	4.7	4.2	3.8	-1.3	-0.82	-18%	14%
1A3 Transport	6.2	5.8	5.5	4.6	-0.77	-1.1	-19%	16%
1A4 Other sectors	19	8.1	6.3	3.0	-13	-5.1	-63%	11%
1A5 Other (Military)	0.40	0.39	0.40	0.39	-0.0054	0.0008	0.20%	1.4%
1B Fugitive emissions from fuels	0.0045	0.0023	0.0021	0.0012	-0.0024	-0.0011	-49%	0.004%
2 IPPU	10.0	3.4	3.5	3.1	-6.5	-0.25	-7.4%	11%
3 Agriculture	13	13	13	13	-0.33	0.13	1.1%	45%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.81	0.51	0.49	0.37	-0.32	-0.14	-28%	1.3%
6 Other	0.31	0.31	0.23	0.21	-0.083	-0.10	-33%	0.73%
National total for compliance	56	36	33	28	-23	-7.5	-21%	100%

Table 2-15 Exhaust TSP emissions, trends and share per sector (national total for compliance; fuels used).

TSP exhaust emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	26	11.7	8.7	3.6	-17	-8.1	-69%	73%
1A Fuel combustion	26	11.7	8.7	3.6	-17	-8.1	-69%	73%
1A1 Energy industries	1.1	0.22	0.22	0.064	-0.90	-0.15	-70%	1.3%
1A2 Manufacturing industries	2.9	1.6	1.02	0.35	-1.9	-1.3	-78%	7.0%
1A3 Transport	2.9	1.9	1.3	0.31	-1.6	-1.6	-84%	6.3%
1A4 Other sectors	19	8.0	6.2	2.9	-13	-5.1	-64%	59%
1A5 Other (Military)	0.057	0.020	0.012	0.007	-0.044	-0.014	-67%	0.13%
1B Fugitive emissions from fuels	0.0004	NA	NA	NA	–	–	–	–
2 IPPU	2.6	0.84	0.81	0.78	-1.8	-0.06	-7.1%	16%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.81	0.51	0.49	0.37	-0.32	-0.14	-28%	7.4%
6 Other	0.30	0.29	0.21	0.18	-0.096	-0.11	-37%	3.7%
National total for compliance	30	13.3	10.2	5.0	-19	-8.4	-63%	100%

Table 2-16 Non-exhaust TSP emissions, trends and share per sector (national total for compliance; fuels used).

TSP non-exhaust emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	6.4	7.4	7.9	8.3	1.5	0.91	12%	36%
1A Fuel combustion	6.4	7.4	7.9	8.3	1.5	0.91	12%	36%
1A1 Energy industries	NA	NA	NA	NA	–	–	–	–
1A2 Manufacturing industries	2.6	3.0	3.2	3.5	0.61	0.44	14%	15%
1A3 Transport	3.3	3.9	4.2	4.3	0.87	0.48	12%	19%
1A4 Other sectors	0.13	0.12	0.11	0.10	-0.021	-0.017	-14%	0.44%
1A5 Other (Military)	0.34	0.37	0.38	0.38	0.039	0.015	4.0%	1.6%
1B Fugitive emissions from fuels	0.0040	0.0017	0.0019	0.0012	-0.0022	-0.0006	-32%	0.005%
2 IPPU	7.4	2.6	2.7	2.4	-4.7	-0.19	-7.6%	10%
3 Agriculture	13	13	13	13	-0.33	0.134	1.1%	54%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.0034	0.0036	0.0036	0.0036	0.0002	–	–	0.02%
6 Other	0.007	0.017	0.020	0.022	0.013	0.0047	27%	0.09%
National total for compliance	27	22	23	23	-3.5	0.85	3.8%	100%

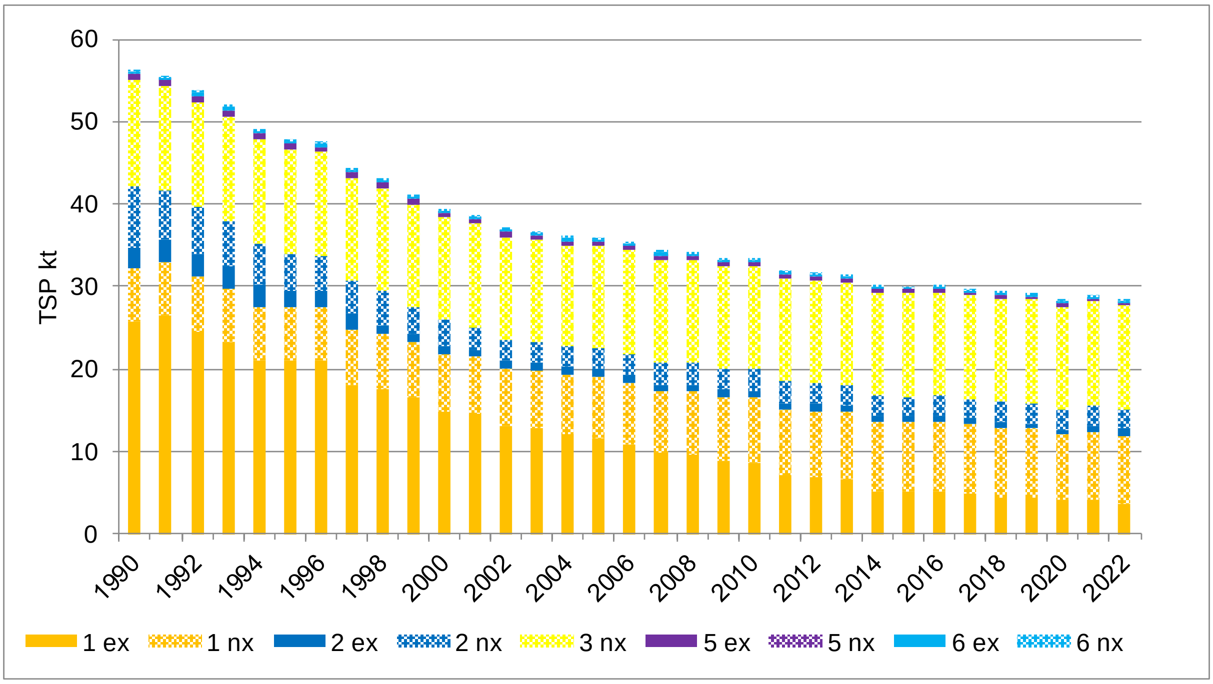


Figure 2-13 Trend of TSP emissions (kt) in Switzerland for sectors 1-6 splitted in exhaust (ex) and non-exhaust (nx) fraction. Non-exhaust emissions cross-hatched.

2.4.5 Trends for BC

Switzerland's emissions of BC mainly stem from sector 1 Energy, especially from stationary combustion in category 1A4bi Residential. The trend of BC emissions per sector is given in Table 2-17. BC emissions have decreased throughout the time period 1990-2022.

Table 2-17 BC emissions, trends and share per sector (national total for compliance; fuels used).

BC emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	5.7	3.5	2.6	0.86	-3.1	-2.7	-76%	98%
1A Fuel combustion	5.7	3.5	2.6	0.86	-3.1	-2.7	-76%	98%
1A1 Energy industries	0.038	0.016	0.016	0.0069	-0.022	-0.0090	-56%	0.78%
1A2 Manufacturing industries	0.42	0.32	0.14	0.034	-0.28	-0.28	-89%	3.9%
1A3 Transport	1.4	1.2	0.88	0.21	-0.51	-1.0	-83%	24%
1A4 Other sectors	3.8	1.9	1.5	0.60	-2.3	-1.3	-69%	69%
1A5 Other (Military)	0.026	0.0099	0.0058	0.0032	-0.020	-0.0067	-67%	0.37%
1B Fugitive emissions from fuels	0.00020	0.00018	0.00010	0.00003	-0.0001	-0.0002	-84%	0.003%
2 IPPU	0.0063	0.0026	0.0016	0.0013	-0.0047	-0.0014	-52%	0.14%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.041	0.027	0.026	0.020	-0.016	-0.007	-27%	2.2%
6 Other	0.00016	0.00015	0.00010	0.00008	-0.00006	-0.00007	-46%	0.009%
National total for compliance	5.7	3.6	2.6	0.88	-3.2	-2.7	-75%	100%

2.5 Trends of other gases

2.5.1 Trends for CO

Switzerland's emissions of CO mainly stem from sector 1 Energy. The trend of CO emissions per sector is given in Table 2-18. The CO emissions have decreased between 1990 and 2022.

The relevant reductions were achieved in sector 1 Energy:

- Reductions of CO emissions in road transportation (1A3b) through the abatement of exhaust emissions from road vehicles (similar as for NMVOC emissions, see chp. 2.3.2). In 2020 and 2021, the COVID-19 pandemic led to a strong reduction of CO emissions from road transportation due to reduced traffic volumes.
- A reduction of CO emissions under 1A4 Other sectors due to technological improvements of wood combustion installations, a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) and a decrease in wood energy consumption in manually operated furnaces by more than half.

Table 2-18 CO emissions, trends and share per sector (national total for compliance; fuels used).

CO emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	741	296	233	136	-509	-160	-54%	95%
1A Fuel combustion	741	296	233	136	-509	-160	-54%	95%
1A1 Energy industries	1.3	1.1	1.1	0.60	-0.25	-0.47	-44%	0.42%
1A2 Manufacturing industries	27	21	20	15	-7.2	-5.4	-26%	11%
1A3 Transport	550	167	119	65	-431	-102	-61%	45%
1A4 Other sectors	162	106	92	55	-70	-52	-49%	38%
1A5 Other (Military)	1.2	0.92	0.87	0.76	-0.34	-0.16	-17%	0.53%
1B Fugitive emissions from fuels	0.048	0.063	0.025	0.0001	-0.022	-0.063	-100%	0.00009%
2 IPPU	11	8.1	7.2	4.9	-3.9	-3.2	-39%	3.5%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	2.8	1.9	1.7	1.4	-1.1	-0.54	-28%	0.97%
6 Other	0.93	0.86	0.57	0.47	-0.35	-0.39	-45%	0.33%
National total for compliance	756	307	242	143	-514	-164	-53%	100%

2.6 Trends of priority heavy metals per pollutant

2.6.1 Lead (Pb)

Switzerland's emissions of Pb mainly stem from sector 1 Energy. Due to significant reductions of Pb emissions in sector 1 Energy, also sectors 6 Other and 5 Waste contribute significantly to emission since 2000 and 2010, respectively. The trend of Pb emissions per sector is given in Table 2-19. Pb emissions have strongly declined between 1990 and 2000 and from then on continued a slightly decreasing trend.

The most relevant reductions were achieved in sectors 1 Energy and 2 IPPU:

- A pronounced decrease of Pb emissions in the energy sector (in particular 1A3b Road transportation) was achieved due to a stepwise reduction of lead content in gasoline, and finally due to the introduction of unleaded gasoline in the OAPC revision of the year 2000 (see Figure 2-1).
- Further measures that resulted in a significant decrease of the emissions under 2C1 Iron and steel production were the closing down of two production sites in 1995 and the installation of new filters in the electric arc furnaces of the remaining secondary steel production plants in 1998/1999.
- Furthermore, a significant reduction was achieved under category 1A1 Energy industries in the period 1990–2003 by equipping municipal solid waste incineration plants with flue gas treatment or by improving the already installed technology.

Since 2000, the emissions further decrease on a lower level. The main reductions in this time period were achieved in the sectors, 1 Energy, 6 Other and 2 IPPU:

- In sector 1 Energy, specifically source category 1A2f Non-metallic minerals (dominated by the emission reduction in container glass production due to reduced lead contamination of the glass cullet and installation of electrofilters in 2011) as well as 1A3b Road transportation due to a higher share of diesel oil in comparison to gasoline (diesel oil has a much lower lead content than gasoline).
- The Pb emissions in sector 6 Other originate from fire damages (6Ad) and their reduction is mainly caused by a decrease in the number of building fires per year.
- In sector 2 IPPU, the ban of Pb in fireworks (2G) in 2003 lead to Pb emission reductions.

Table 2-19 Pb emissions, trends and share per sector (national total for compliance; fuels used).

Pb emissions	**1990**	**2005**	**2010**	**2022**	**1990–2010**	**2005–2022**	**2005–2022**	**share in 2022**
	t	t	t	t	t	t	%	%
1 Energy	275	6.7	5.4	4.4	-269	-2.4	-35%	52%
1A Fuel combustion	271	6.7	5.4	4.4	-266	-2.4	-35%	52%
1A1 Energy industries	30	1.9	1.8	1.7	-28	-0.27	-14%	20%
1A2 Manufacturing industries	6.3	2.7	1.8	1.2	-4.5	-1.5	-54%	14%
1A3 Transport	231	1.2	1.0	0.88	-230	-0.32	-27%	10%
1A4 Other sectors	3.8	0.94	0.90	0.60	-2.9	-0.34	-36%	7.1%
1A5 Other (Military)	0.033	0.00023	0.00024	0.00024	-0.032	0.00001	4.8%	0.003%
1B Fugitive emissions from fuels	3.5	0.0011	0.00043	0.000002	-3.5	-0.0011	-100%	0.00002%
2 IPPU	67	2.1	0.69	0.70	-66	-1.4	-67%	8.3%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	4.3	2.3	2.3	1.6	-2.0	-0.72	-31%	19%
6 Other	7.6	6.8	3.8	1.8	-3.8	-5.1	-74%	21%
National total for compliance	354	18	12	8.4	-342	-9.6	-53%	100%

2.6.2 Cadmium (Cd)

Switzerland's emissions of Cd mainly stem from sector 1 Energy. The trend of Cd emissions per sector is given in Table 2-20. Cd emissions showed a decreasing trend between 1990 and 2003 and remained about constant since then until 2013. After that, emissions slightly decrease.

The decrease 1990-2003 was mainly achieved with the following measures within sectors 1 Energy and 2 IPPU:

- By equipping municipal solid waste incineration plants with flue gas treatment or by improving the already installed technologies, a significant reduction has been achieved in the period 1990–2003 under category 1A1a Public electricity and heat production.
- A significant reduction occurred also in source category 1A2 Manufacturing industries dominated by an emission decrease in the production of mixed goods (1A2f). (Please note that Cd emission measurements are extremely limited and thus these emissions are associated with a high uncertainty.)
- Further measures, resulting in a significant decrease of emissions under 2C1 Iron and steel production, were the closing down of two production sites in 1995 and the installation of new filters in the electric arc furnaces of the remaining secondary steel production plants in 1998/1999.

The slight decrease since 2013 is mainly due to continuous technical improvement in municipal solid waste incineration plants (source category 1A1a Public electricity and heat production), but also in sewage sludge incineration plants (source category 5C1).

Table 2-20 Cd emissions, trends and share per sector (national total for compliance; fuels used).

Cd emissions	**1990**	**2005**	**2010**	**2022**	**1990–2010**	**2005–2022**	**2005–2022**	**share in 2022**
	t	t	t	t	t	t	%	%
1 Energy	2.6	0.43	0.44	0.38	-2.2	-0.053	-12%	81%
1A Fuel combustion	2.6	0.43	0.44	0.38	-2.2	-0.052	-12%	81%
1A1 Energy industries	1.8	0.18	0.20	0.15	-1.6	-0.024	-14%	33%
1A2 Manufacturing industries	0.74	0.10	0.091	0.075	-0.65	-0.028	-27%	16%
1A3 Transport	0.069	0.077	0.083	0.095	0.013	0.018	23%	21%
1A4 Other sectors	0.084	0.068	0.068	0.050	-0.017	-0.018	-26%	11%
1A5 Other (Military)	0.00048	0.00051	0.00054	0.00053	0.00006	0.00001	2.9%	0.11%
1B Fugitive emissions from fuels	0.0011	0.0015	0.00058	0.000003	-0.0006	-0.0015	-100%	0.0006%
2 IPPU	0.56	0.092	0.087	0.079	-0.47	-0.013	-14%	17%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.047	0.021	0.027	0.0086	-0.020	-0.012	-59%	1.8%
6 Other	0.0023	0.0023	0.0017	0.0016	-0.0005	-0.0006	-28%	0.35%
National total for compliance	3.3	0.54	0.56	0.46	-2.7	-0.079	-15%	100%

2.6.3 Mercury (Hg)

Switzerland's emissions of Hg mainly stem from sector 1 Energy. The trend of Hg emissions per sector is shown in Table 2-21. Hg emissions showed a decreasing trend between 1990 and 2003 and from then on a further slightly decreasing trend.

The decrease 1990-2003 was mainly achieved with the following measures within the sectors 1 Energy and 2 IPPU:

- A significant reduction under category 1A1 Energy industries has been achieved in the period 1990–2003 by equipping municipal solid waste incineration plants with flue gas treatment or by improving the already installed technology.

- The closing down of two steel production sites in 1995 and the installation of new filters in the two remaining secondary steel production plants in 1998/1999 were the leading measures in reducing emissions under 2C1.

Since 2003, the decreasing trend continued on a lower level, still dominated by emissions from municipal solid waste incineration (1A1a Public electricity and heat production) and manufacturing industries of non-metallic minerals (1A2f, e.g. cement production).

Table 2-21 Hg emissions, trends and share per sector (national total for compliance; fuels used).

Hg emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	t	t	t	t	t	t	%	%
1 Energy	4.3	0.59	0.59	0.50	-3.7	-0.089	-15%	86%
1A Fuel combustion	4.3	0.59	0.59	0.50	-3.7	-0.089	-15%	86%
1A1 Energy industries	3.9	0.34	0.32	0.29	-3.6	-0.054	-16%	50%
1A2 Manufacturing industries	0.25	0.12	0.14	0.10	-0.11	-0.020	-17%	18%
1A3 Transport	0.034	0.037	0.037	0.033	0.0026	-0.0045	-12%	5.6%
1A4 Other sectors	0.089	0.086	0.094	0.076	0.0048	-0.0095	-11%	13%
1A5 Other (Military)	0.00003	0.00003	0.00003	0.00003	0.000003	0.000001	2.5%	0.005%
1B Fugitive emissions from fuels	0.0002	0.0002	0.0001	0.0000005	-0.0001	-0.0002	-100%	0.0001%
2 IPPU	1.5	0.067	0.066	0.051	-1.4	-0.016	-24%	8.8%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.52	0.077	0.081	0.028	-0.44	-0.049	-64%	4.8%
6 Other	0.0011	0.0011	0.0008	0.0007	-0.0003	-0.0003	-31%	0.13%
National total for compliance	6.3	0.73	0.74	0.58	-5.6	-0.15	-21%	100%

2.7 Trends of POPs

2.7.1 PCDD/PCDF

Switzerland’s emissions of PCDD/PCDF mainly stem from sector 1 Energy. The trend of PCDD/PCDF emissions per sector is given in Table 2-22. PCDD/PCDF emissions were significantly reduced between 1990 and 2003. From then on, the decrease continues on a lower level. Due to the significant reductions in PCDD/PCDF emissions, particularly in sector 1 Energy, sector 5 Waste has also become an important PCDD/PCDF emission source.

The significant decrease between 1990 and 2003 was mainly achieved in category 1A1a Public electricity and heat production by retrofitting municipal solid waste incineration plants with flue gas treatment or by improving the already installed technology. Further reductions between 1990 and 2003 were achieved in source categories 2C1 Iron and steel production (i.e. closing down of two production sites in 1995 and installation of new filters in the electric arc furnaces of the remaining two secondary steel production plants in 1998/1999) and 5C1 Waste incineration (i.e. a continuous reduction of clinical waste incinerated at the hospital sites themselves which ceased in 2002 completely).

In source category 1A4bi Residential: Stationary, a continuous emission reduction occurred over the entire time series (technological improvements of wood combustion installations, reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) and wood energy consumption in manually operated furnaces decreased by more than half).

Since 2003, the slightly decreasing trend is mainly shaped through reductions in categories 1A4bi Residential: Stationary and 1A1a Public electricity and heat production (mainly due to further technical improvements in municipal solid waste incineration plants).

Table 2-22 PCDD/PCDF emissions, trends and share per sector (national total for compliance; fuels used).

PCDD/PCDF emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	%	%
1 Energy	161	23	19	7.9	-142	-15	-66%	63%
1A Fuel combustion	161	23	19	7.9	-142	-15	-66%	63%
1A1 Energy industries	130	5.2	3.4	0.94	-127	-4.3	-82%	7.5%
1A2 Manufacturing industries	8.4	2.8	2.1	1.1	-6.3	-1.7	-61%	8.5%
1A3 Transport	1.6	1.7	1.7	0.45	0.076	-1.3	-74%	3.6%
1A4 Other sectors	20	13	12	5.4	-8.3	-8.0	-59%	43%
1A5 Other (Military)	0.0004	0.0004	0.0004	0.0004	0.00004	0.000009	2.5%	0.003%
1B Fugitive emissions from fuels	0.000006	NA	NA	NA	–	–	–	–
2 IPPU	17	2.1	1.2	0.83	-16	-1.3	-61%	6.6%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	13	4.3	4.0	2.8	-9.2	-1.5	-35%	22%
6 Other	1.6	1.6	1.1	1.0	-0.51	-0.57	-36%	8.0%
National total for compliance	192	31	25	13	-167	-19	-60%	100%

2.7.2 Polycyclic aromatic hydrocarbons (PAHs)

Switzerland's emissions of PAH mainly stem from sector 1 Energy. The trend of PAH emissions per sector is given in Table 2-23. PAH emissions have been reduced continuously between 1990 and 2022, except for 1A3b Road transportation, where PAH emissions increased in parallel with the increase of traffic volumes (except for 2020/2021, where traffic volumes shrank due to the COVID-19 pandemic).

The PAH emissions are dominated by wood energy combustion in single-room furnaces and building heating installations. Their reduction has mainly been achieved in the dominant source category 1A4 Other sectors through technological improvements of wood furnaces and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) as well as a decrease of wood energy consumption by more than half in manually operated furnaces. The superimposed fluctuations in the emission trend reflect the climate variabilities (i.e. warmer or colder winters).

Table 2-23 PAH emissions, trends and share per sector (national total for compliance; fuels used).

PAHs emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	t	t	t	t	t	t	%	%
1 Energy	6.7	4.1	3.7	2.0	-3.0	-2.0	-50%	87%
1A Fuel combustion	6.7	4.1	3.7	2.0	-3.0	-2.0	-50%	87%
1A1 Energy industries	0.0076	0.0085	0.011	0.0058	0.0030	-0.0027	-32%	0.25%
1A2 Manufacturing industries	0.23	0.18	0.16	0.11	-0.075	-0.071	-40%	4.5%
1A3 Transport	0.15	0.17	0.21	0.28	0.061	0.12	70%	12%
1A4 Other sectors	6.3	3.7	3.3	1.6	-3.0	-2.1	-56%	70%
1A5 Other (Military)	0.00071	0.00073	0.00076	0.00068	0.00005	-0.00005	-6.9%	0.029%
1B Fugitive emissions from fuels	0.000002	0.000002	0.0000008	0.000000004	-0.000001	-0.000002	-100%	0.0000002%
2 IPPU	0.95	0.50	0.012	0.012	-0.94	-0.48	-98%	0.51%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.37	0.25	0.21	0.19	-0.16	-0.061	-25%	8.0%
6 Other	0.065	0.086	0.092	0.11	0.027	0.023	27%	4.6%
National total for compliance	8.1	4.9	4.0	2.4	-4.1	-2.6	-52%	100%

2.7.3 HCB

Switzerland's emissions of HCB exclusively stem from sector 1 Energy. The trend of HCB emissions per sector is shown in Table 2-24. HCB emissions have significantly dropped in 1993 and then slightly decreased until 2022.

The decrease of HCB emissions in 1993 occurred in category 1A2b Non-ferrous metals due to the shutdown of the single secondary aluminium production plant. Since then, emissions continue to slightly decrease, in particular in category 1A4 Other sectors due to changes in wood energy combustion (i.e. technological improvements of wood combustion installations, reduction in the number of emission intensive types of wood furnaces and decrease in wood energy consumption in manually operated furnaces by more than half). In contrast, the amount of municipal solid waste incinerated has increased (1A1a Public electricity and heat production), which leads to an increase in HCB emissions in this source category.

Table 2-24 HCB emissions, trends and share per sector (national total for compliance; fuels used).

HCB emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	173	0.44	0.45	0.34	-172	-0.106	-24%	100%
1A Fuel combustion	173	0.44	0.45	0.34	-172	-0.106	-24%	100%
1A1 Energy industries	0.11	0.15	0.17	0.18	0.060	0.027	18%	53%
1A2 Manufacturing industries	172	0.051	0.051	0.038	-172	-0.014	-27%	11%
1A3 Transport	NE	NE	NE	NE	–	–	–	–
1A4 Other sectors	0.38	0.24	0.22	0.12	-0.16	-0.12	-49%	36%
1A5 Other (Military)	NE	NE	NE	NE	–	–	–	–
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	NA	NA	NA	NA	–	–	–	–
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	NA	NA	NA	NA	–	–	–	–
6 Other	NA	NA	NA	NA	–	–	–	–
National total for compliance	173	0.44	0.45	0.34	-172	-0.11	-24%	100%

2.7.4 PCBs

Switzerland's emissions of PCBs mainly stem from sector 2 IPPU, i.e. from source category 2K Usage of PCBs. To a lesser extent, also sectors 5 Waste and 6 Other contribute to PCB emissions. The trend of PCB emissions per sector is shown in Table 2-25. PCB emissions have decreased continuously between 1990 and 2022 with the exception of a sudden sharp increase in 1999.

PCBs were used in Switzerland in transformers, large and small capacitors, anti-corrosive paints and joint sealants between 1946 and 1986, before a total ban was placed on any form of PCB use. The use in so-called open applications, i.e. anti-corrosive paints and joint sealants, was already forbidden in 1972. The emissions from source category 2K Usage of PCBs are dominated by the two open applications and are decreasing since 1975, while still remaining the major source until now (see also Table 1-6 and Figure A - 2).

At the end of the PCB containing products' life cycle, they are disposed of. Some of them undergo priorly a treatment process. Shredding of electronic waste containing PCBs in small capacitors (5E) is the dominant emission source in sector 5 Waste from 1990 onwards and is the cause for the sudden sharp increase in 1999. As a consequence of the legal ban of disposal of combustible waste in landfills a sharp increase in shredding of small capacitors occurred in 1999 although they should have been treated as special waste from 1998 onwards. Between 1999 and 2002, shredding was even the largest emission source of all. Before 1990, 5C1bii Open burning, i. e. burning of PCB contaminated waste oil in outdoor fires (ceased in 1999) dominated the emissions from 5 Waste.

From all PCB usages, PCBs can also be accidentally released by fire or by spilling to soil. Accidental release by fire is dominating the emissions from sector 6 Other which has decreased continuously since 1980.

PCB emissions from 1A1a Municipal solid waste incineration were of somewhat lower importance reaching a maximum in the early 1980s. From 1998 onwards, all PCB containing waste has to be incinerated in special waste incineration plants only.

PCB emissions arise also from combustion of solid and liquid fuels. Like PCDD/PCDF, PCBs are synthesized in the combustion process as by-products involving chloride and organic carbon or are due to incomplete combustion of PCB impurities in the fuel. Please note that these emissions are orders of magnitude smaller than the emissions from former use and subsequent disposal of PCBs.

Table 2-25 PCB emissions, trends and share per sector (national total for compliance; fuels used).

PCB emissions	1990	2005	2010	2022	1990–2010	2005–2022	2005–2022	share in 2022
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	165	1.4	0.55	0.39	-164	-1.0	-73%	0.11%
1A Fuel combustion	165	1.4	0.55	0.39	-164	-1.0	-73%	0.11%
1A1 Energy industries	164	1.1	0.18	0.065	-164	-1.0	-94%	0.02%
1A2 Manufacturing industries	0.50	0.35	0.38	0.33	-0.12	-0.030	-8.3%	0.10%
1A3 Transport	0.0004	0.0004	0.0003	0.00009	-0.00003	-0.0003	-75%	0.00003%
1A4 Other sectors	0.0022	0.0015	0.0013	0.0007	-0.0009	-0.0008	-54%	0.0002%
1A5 Other (Military)	NE	NE	NE	NE	–	–	–	–
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	1'537	922	708	308	-829	-614	-67%	90%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	347	254	56	6.0	-291	-248	-98%	1.7%
6 Other	282	93	62	27	-220	-66	-71%	8.0%
National total for compliance	2'332	1'270	827	341	-1'505	-929	-73%	100%

2.8 Compliance with the Gothenburg Protocol

2.8.1 Emission ceilings 2010

Under the CLRTAP, the 1999 Gothenburg Protocol requires that parties shall reduce and maintain the reduction in annual emissions in accordance with emission ceilings set for 2010 and beyond. Table 2-26 shows the emission ceilings, the reported emissions for 2010 and the respective compliance. Accordingly, Switzerland is in compliance with the Gothenburg Protocol emission ceilings for all pollutants except for NO_x in 2010. All emissions 2022 are in compliance with the emission ceilings for 2010.

Table 2-26 Emission ceilings of the Gothenburg Protocol for 2010 and beyond compared to the reported emissions for 2010 and 2022 of the latest submission (2024).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2024)	Compliance with emission ceilings 2010 in 2010	Emissions 2022 (Subm. 2024)	Compliance with emission ceilings 2010 in 2022
	kt	kt		kt	
SO_x (as SO_2)	26	10	yes	3.2	yes
NO_x (as NO_2)	79	83	no	50	yes
NMVOC	144	98	yes	73	yes
NH_3	63	58	yes	53	yes

2.8.2 Emission reduction commitments 2020

After five years of negotiations, a revised Gothenburg Protocol was successfully finalised on 4 May 2012 at a meeting of the parties to the Convention on Long-range Transboundary Air Pollution (CLRTAP) in Geneva.

The revised protocol specifies emission reduction commitments in terms of percentage reductions from the reference year 2005 to 2020. It has also been extended to cover one additional air pollutant, namely particulate matter (PM2.5), and thereby also black carbon as a component of PM2.5. On 7 October 2019, the amended protocol including the new reduction commitments for 2020 has entered into force.

Table 2-27 shows the emission reduction commitments of the amended Gothenburg protocol and the corresponding emissions in 2022. The emission reduction commitments 2020 are achieved for all the pollutants (SO_x, NO_x, NMVOC, NH_3 and PM2.5).

Table 2-27 Reported emission reductions in 2020 and 2022 versus level of 2005 and reduction commitments per 2020. The Emission commitments 2020 are defined as reductions in percentages from 2005.

Pollutant	**Emission reduction commitments 2020**	**Reduction achieved in 2020**	**Compliance with reduction commitments 2020 in 2020**	**Reduction achieved in 2022**	**Compliance with reduction commitments 2020 in 2022**
	%-reduction of 2005 level	*%-reduction of 2005 level*		*%-reduction of 2005 level*	
SO_x (as SO_2)	21%	74%	yes	77%	yes
NO_x (as NO_2)	41%	43%	yes	47%	yes
NMVOC	30%	36%	yes	36%	yes
NH_3	8%	11%	yes	11%	yes
PM2.5	26%	51%	yes	53%	yes

3 Energy

3.1 Overview of emissions

In this introductory chapter, an overview of emissions separated by most relevant pollutants in sector 1 Energy is presented. In the sector 1 Energy the substances NO_x, NMVOC, PM2.5 and SO_x are the main contributors to air pollution. The following source categories are reported:

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

3.1.1 Overview and trend for NO_x

According to Figure 3-1, emissions from 1A3 Transport contribute most to NO_x emissions in the energy sector for all years. The largest share of 1A3 Transport since 1990 was reached in the year 2015, afterwards the share decreases. Emissions from 1A2 Manufacturing industries and construction and 1A4 Other sectors (commercial/institutional, residential, agriculture/forestry/fishing) are also contributing a noticeable amount. As a consequence of the air pollution ordinance endorsed in 1985 (Swiss Confederation 1985), NO_x emissions steadily decreased ever since. The legislation prescribes clear reduction targets that are mirrored in the trends of most energy related sectors. Various measures led to a total NO_x reduction between 1990 and 2022:

- The reductions in 1A3b Road transportation were triggered by the implementation of new strict emission standards for road vehicles. The first step happened in the late 80’s when Switzerland reduced the standards to a level that required the equipment of three-way catalysts for new passenger cars. Later, when the European Union introduced the first Euro standards in 1993, Switzerland adopted the subsequent reduction path (Euro 2/II in 1995, Euro 3/III in 2000, Euro 4/IV in 2005, Euro V in 2008, Euro 5 in 2009, Euro VI in 2013 and Euro 6 in 2014). However, the reduction of NO_x emissions due to emission standards has not been as pronounced as expected in the years before 2015 because of an increasing share of diesel-powered passenger cars and higher emission factor than expected (the “dieselgate” scandal[3], detected in the year 2015).
- In the years 2020 and 2021, the COVID-19 pandemic led to measures that resulted in a massive reduction in transport activities (1A3). The lower traffic volume led to a strong decrease in NO_x emissions from 1A3b Road transportation and a sharp drop in emissions from 1A3a Aviation, especially international aviation. However, the share of NO_x emissions from 1A3a Aviation in 1A3 Transport is smaller than that from 1A3b Road transportation, in particular due to the system boundaries (only LTO emissions from air traffic are taken into account in the national total, see chapter 3.1.6.1).
- The reductions in 1A2 Manufacturing industries and construction were a result of three main factors: First, there has been a fuel switch from residual fuel oil, coal and gas oil towards natural gas and a reduction in total fuel use since 2008. Second, a reduction has been reached due to an on-going sectoral agreement (from 1998) targeting NO_x emissions of the cement industry. Third, manufacturing plants reduced NO_x emissions through

[3] Dieselgate: «The EPA had found that Volkswagen had intentionally programmed turbocharged direct injection diesel engines to activate certain emissions controls only during laboratory emissions testing. Volkswagen deployed this programming in about eleven million cars worldwide» Source: https://en.wikipedia.org/wiki/Volkswagen_emissions_scandal [25.01.2023]

technical improvements (e.g. DeNO$_x$ technology, selective non-catalytic reduction technology SNCR).

- In the past, the number of buildings and apartments increased, as well as the average floor space per person and workplace. Both phenomena resulted in an increase of the total heated area. On contrary, higher standards were specified for insulation and for combustion equipment efficiency for both new and renovated buildings including low-NO$_x$ standards. Furthermore, a substantial substitution of gas oil by natural gas under 1A4 Other sectors resulted in further reductions of NO$_x$ emissions (i.e. natural gas consumption increased by half from 1990 to 2022). These two effects compensated for the additional heated area, and lead to a reduction of NO$_x$ emissions under category 1A4 Other sectors.

Emissions from 1A1 Energy industries and 1A5 Other (Military) are minor and decreased as well, emissions from 1B Fugitive emissions from fuels are negligible.

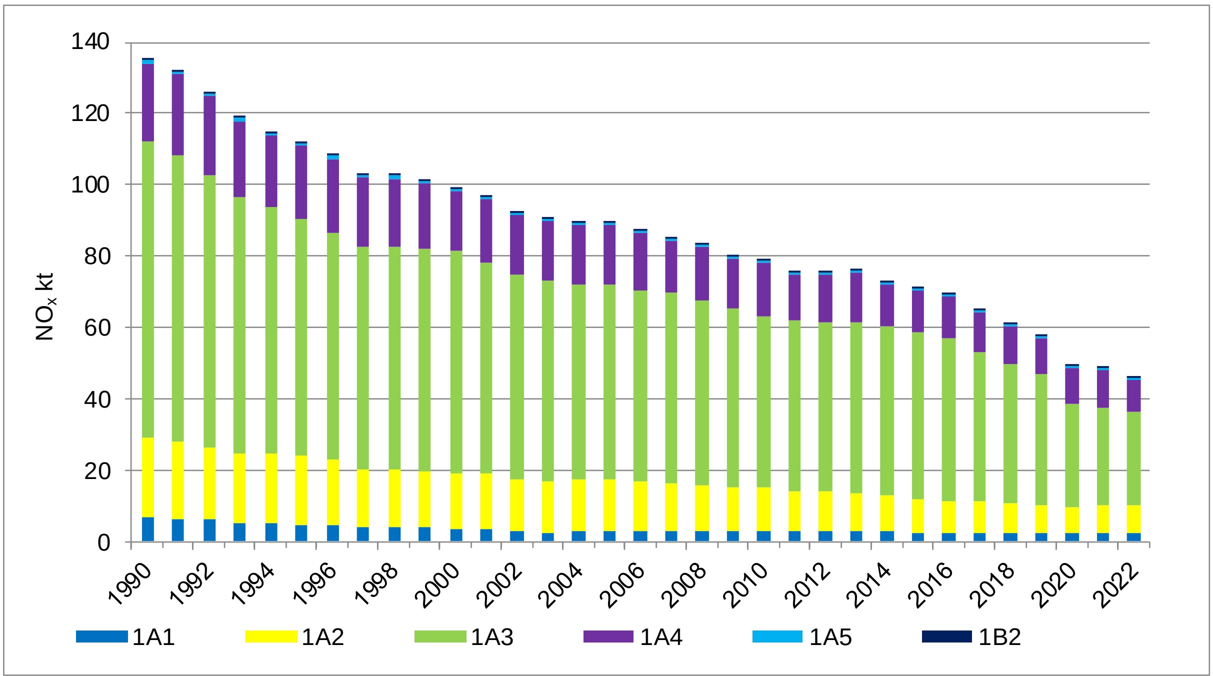


Figure 3-1 Switzerland's NO$_x$ emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2022. The corresponding data can be found in Table 3-1.

Table 3-1 NO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2. The last column in the third part of the table indicates the relative trend.

NOx	1990	1995	2000	2005	2010
	kt				
1A1	6.8	4.8	3.6	3.0	3.1
1A2	23	19	15	14	12
1A3	83	67	62	54	48
1A4	22	20	17	17	15
1A5	0.88	0.71	0.67	0.60	0.54
1B2	0.21	0.31	0.31	0.29	0.11
Sum	135	112	99	89	79

NOx	2013	2014	2015	2016	2017
	kt				
1A1	3.2	3.0	2.5	2.5	2.5
1A2	11	10	9.4	9.2	8.8
1A3	48	48	47	45	42
1A4	14	11	12	12	11
1A5	0.50	0.51	0.49	0.49	0.45
1B2	0.074	0.088	0.050	0.003	0.002
Sum	76	73	71	69	65

NOx	2018	2019	2020	2021	2022	2005–2022
	kt					
1A1	2.5	2.5	2.5	2.5	2.5	-17%
1A2	8.2	7.9	7.3	7.6	7.5	-48%
1A3	39	36	29	27	26	-52%
1A4	10.6	10.5	9.8	10.6	9	-45%
1A5	0.43	0.39	0.40	0.38	0.40	-34%
1B2	0.0024	0.0016	0.0018	0.0013	0.0006	-100%
Sum	61	58	49	48	46	-49%

3.1.2 Overview and trend for NMVOC

Figure 3-2 depicts the NMVOC emissions in energy related sectors since 1990. 1A3 Transport contributes the largest share of total emissions in the period between 1990 and 2022. Due to the decrease of NMVOC emissions from 1A3 Transport, the relative importance of NMVOC emissions from 1A4 Other sectors is increasing.

- In sector 1 Energy, the emission reduction was mainly influenced from category 1A3b Road transportation, in particular resulting from the higher Euro standards for passenger cars (Euro 1 in 1993, Euro 2 in 1995, Euro 3 in 2000, Euro 4 in 2005, Euro 5 in 2009 and Euro 6 in 2014). Furthermore, the share of diesel oil in fuels used under 1A3b has increased compared to gasoline between 1990 and 2022, which leads to a decrease of NMVOC emissions. In 2020 and 2021, the COVID-19 pandemic led to a reduction of NMVOC emissions from road transportation due to reduced traffic volumes.
  The measures against the pandemic also led to a sharp drop in emissions from 1A3a Aviation in 2020 and 2021, especially international aviation. However, the share of NMVOC emissions from 1A3a Aviation in 1A3 Transport is smaller than that from 1A3b Road transportation, in particular due to the different fuel types (most NMVOC emissions stem from gasoline engines and the system boundaries (only LTO emissions from air traffic are taken into account in the national total, see chapter 3.1.6.1).

- NMVOC emissions of source category 1A4 Other sectors declined in the same period as well due to technical improvements of wood combustion installations and a reduction in the number and energy consumption of emission intensive types of log wood furnaces.
- The decline of NMVOC emissions in 1B2 Fugitive emissions from oil and gas is due to technical improvement to reduce fugitive emissions caused by distribution and storage of gasoline.

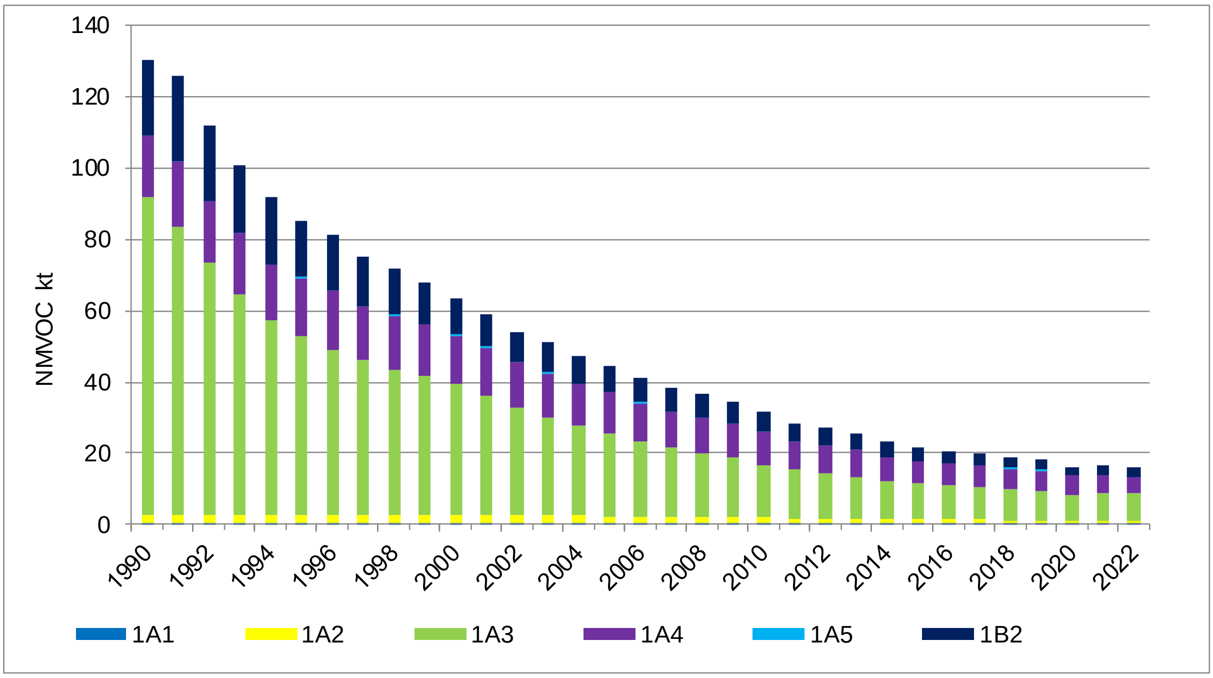


Figure 3-2 Switzerland's NMVOC emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2022. The corresponding data can be found in Table 3-2.

Table 3-2 NMVOC emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2. The last column in the third part of the table indicates the relative trend.

NMVOC total	1990	1995	2000	2005	2010
	kt				
1A1	0.33	0.33	0.35	0.32	0.26
1A2	2.4	2.4	2.3	2.1	1.6
1A3	89	50	37	23	15
1A4	17	16	14	12	9.3
1A5	0.16	0.14	0.13	0.11	0.090
1B2	21	16	10.3	7.2	5.2
Sum	130	85	64	44	31

NMVOC total	2013	2014	2015	2016	2017
	kt				
1A1	0.22	0.21	0.21	0.21	0.21
1A2	1.3	1.2	1.1	1.1	1.1
1A3	12	11	10	9.7	9.2
1A4	7.7	6.3	6.3	6.4	6.1
1A5	0.080	0.079	0.075	0.076	0.070
1B2	4.6	4.4	3.8	3.3	3.1
Sum	26	23	22	21	20

NMVOC total	2018	2019	2020	2021	2022	2005–2022
	kt					
1A1	0.21	0.21	0.21	0.20	0.20	-37%
1A2	1.0	0.98	0.92	0.93	0.90	-56%
1A3	8.9	8.4	7.3	7.4	7.4	-68%
1A4	5.7	5.5	5.2	5.5	4.8	-59%
1A5	0.068	0.062	0.063	0.061	0.064	-41%
1B2	3.0	2.8	2.5	2.4	2.4	-67%
Sum	19	18	16	16	16	-64%

3.1.3 Overview and trend for SO_x

Figure 3-3 depicts the SO_x emissions in energy related sectors since 1990. In 2022, the main contributions from the sector 1 Energy are SO_x emissions from the source categories 1A2 Manufacturing industries and construction and 1A4 Other sectors. SO_x emissions from the other source categories (1A3, 1A5 and 1B2) are comparably small. Overall, there is a decreasing trend since 1990, which is more pronounced between 1990 and 2000. The time series also show some year-to-year fluctuations. These fluctuations are mainly due to annual variations in the number of heating degree days, which causes fluctuations in the SO_x emissions from fossil fuel-based heating systems in sector 1A4 Other sectors.

- First, the Ordinance on Air Pollution Control (Swiss Confederation 1985) introduced a limitation of the sulphur content in fuels, with further stepwise lowering in 1991, 2000, 2005, 2008 and 2009 for liquid fuels (Table 3-28). These stringent measures resulted in a significant decrease of the sulphur oxide emissions from fuel combustion under 1A3 Transport and 1A4 Other sectors (gas oil, diesel oil and gasoline, see Table 3-28).
- Second, a substantial substitution of gas oil with natural gas and eco-grade gas oil (with low sulphur and nitrogen content, from 2006 onwards) under 1A4 Other sectors resulted in further reductions of sulphur emissions (natural gas consumption increased by half from 1990 to 2022).

- Third, a similar substitution of residual fuel oil, coal and gas oil by natural gas has reduced sulphur emissions as well in 1A2 Manufacturing industries (i.e. coal and residual fuel oil from 1990, gas oil from about 2005 onwards).

Additionally, emissions of 1A1 are decreasing caused by substitution of emission intensive fuels (e.g. no more consumption of residual fuel oil since 2011 and no more bituminous coal since 2000) and by the closing of a refinery plant in 2015. The SO_x emissions from 1B2 Fugitive emissions from oil and gas are due to Claus units and flaring in refineries. The decrease between 1990 and 1995 can be explained by the retrofitting of the clause units due to the enactment of the Ordinance on Air Pollution Control in 1985. Further, the emission factors from clause units and flaring decreased over time.

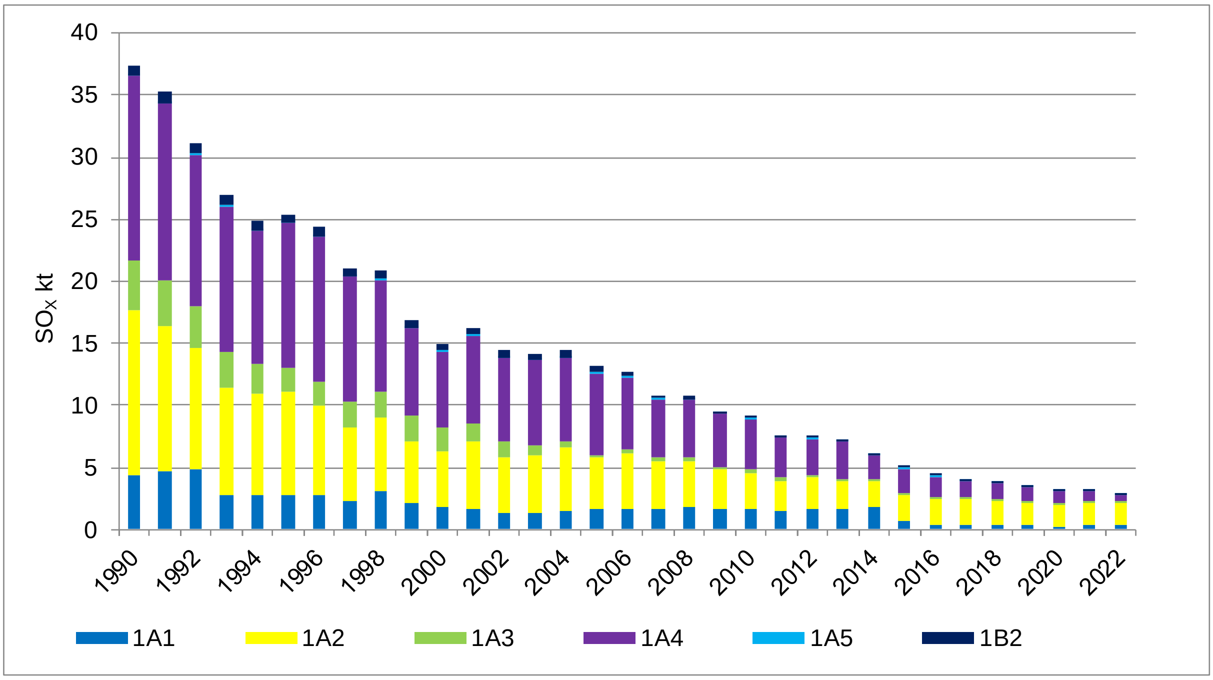


Figure 3-3 Switzerland's SO_x emissions from the energy sector by source category 1A1-1A5 and 1B2 between 1990 and 2022. The corresponding data can be found in Table 3-3.

Table 3-3 SO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2. The last column in the third part of the table indicates the relative trend.

SOx	1990	1995	2000	2005	2010
			kt		
1A1	4.3	2.8	1.8	1.6	1.7
1A2	13	8.2	4.5	4.2	2.9
1A3	4.0	2.1	1.9	0.18	0.20
1A4	15	12	6.1	6.6	4.1
1A5	0.078	0.049	0.045	0.037	0.037
1B2	0.72	0.63	0.59	0.51	0.22
Sum	37	25	15	13	9.2

SOx	2013	2014	2015	2016	2017
			kt		
1A1	1.6	1.7	0.73	0.39	0.39
1A2	2.3	2.1	2.0	2.0	2.0
1A3	0.21	0.21	0.22	0.22	0.22
1A4	3.0	1.9	1.9	1.6	1.3
1A5	0.036	0.037	0.036	0.038	0.034
1B2	0.15	0.16	0.085	0.019	0.018
Sum	7.2	6.1	5.0	4.3	4.0

SOx	2018	2019	2020	2021	2022	2005–2022
			kt			
1A1	0.31	0.29	0.29	0.33	0.30	-82%
1A2	2.0	1.8	1.8	1.8	1.9	-55%
1A3	0.23	0.23	0.11	0.12	0.18	-3%
1A4	1.1	1.1	0.90	0.80	0.44	-93%
1A5	0.034	0.030	0.031	0.030	0.033	-12%
1B2	0.019	0.016	0.017	0.014	0.016	-97%
Sum	3.7	3.5	3.1	3.1	2.8	-79%

3.1.4 Overview and trend for NH_3

Figure 3-4 depicts the NH_3 emissions in energy related sectors since 1990. Note: The contribution of the energy sector is small in comparison to the national total. Therefore, there are no source categories from the energy sector that are key categories for NH_3. For all years, the main contributor among categories of sector 1 Energy is 1A3 Transport. Since 1990, total emissions underwent a twofold trend: Overall emissions increased continuously until 2000. This is mainly attributable to changes of sulphur contents in fuels used in road transportation in combination with three-way catalytic converters: with low sulphur petrol in use, higher NH_3 emissions result (Mejía-Centeno 2007). This effect manifests mainly for car fleets with EURO standards 1, 2 and 3. For cars registered as EURO 2, this effect becomes particularly evident and causes the model to reveal a pronounced jump in emission levels between 1999 and 2000. Afterwards, emissions decreased because the car fleet changes again towards stricter EURO standards, where the sulphur content in fuels has less influence on the NH_3 emissions due to technological improvements in three-way catalytic converters.

In 2020, the COVID-19 pandemic led to measures that resulted in a massive reduction in traffic. The lower traffic volume led to a small but visible decrease in NH_3 emissions from 1A3b Road transportation.

Emissions from the other source categories are comparably small. The NH_3 emissions in 1A2 Manufacturing industries and construction are mainly due to source category 1A2f Manufacturing industries and construction: Non-metallic minerals (especially cement and rock wool production). NH_3 emissions in 1A4 Other sectors stem mainly from residential wood combustions.

There are no NH_3 emissions from source category 1B Fugitive emissions from fuels.

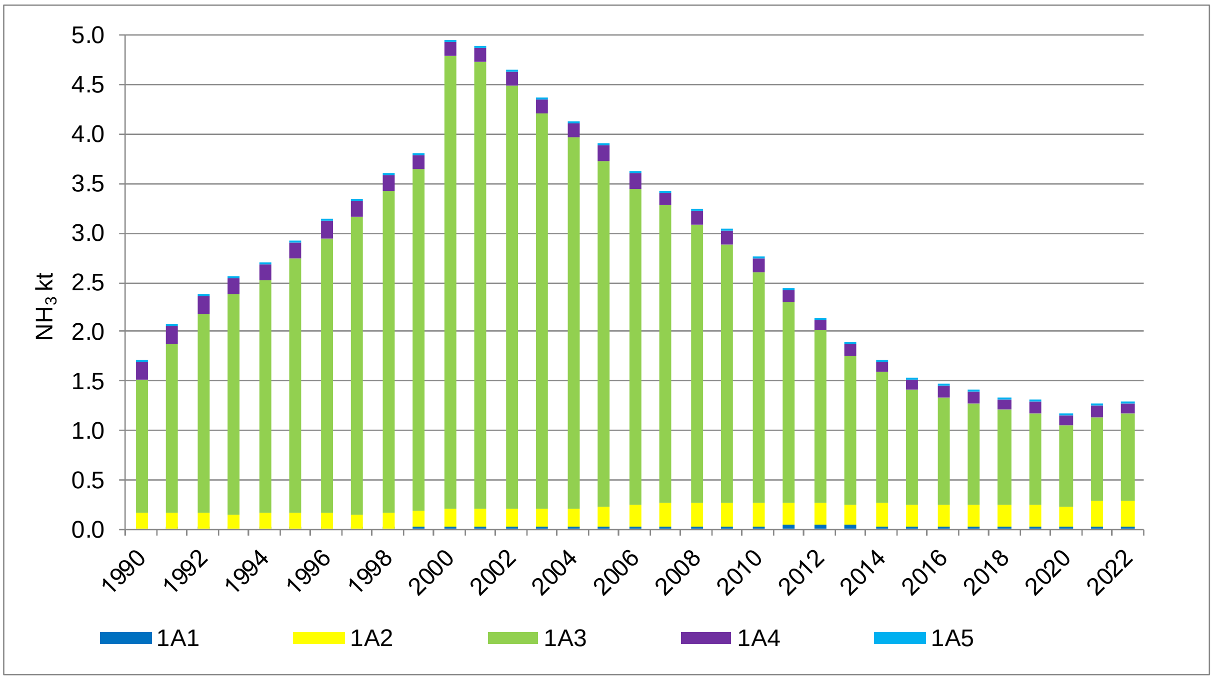


Figure 3-4 Switzerland's NH_3 emissions from the energy sector by source category 1A1-1A5 between 1990 and 2022. There are no emissions from 1B. The corresponding data can be found in Table 3-4.

Table 3-4 NH_3 emissions from sector 1 Energy by source categories 1A1-1A5. The last column in the third part of the table indicates the relative trend.

NH3	1990	1995	2000	2005	2010
	kt				
1A1	0.005	0.011	0.021	0.029	0.036
1A2	0.17	0.15	0.18	0.19	0.24
1A3	1.3	2.6	4.6	3.5	2.3
1A4	0.18	0.17	0.14	0.14	0.14
1A5	0.00004	0.00004	0.00004	0.00004	0.00004
1B	NA	NA	NA	NA	NA
Sum	1.7	2.9	4.9	3.9	2.7

NH3	2013	2014	2015	2016	2017
	kt				
1A1	0.043	0.034	0.032	0.032	0.034
1A2	0.21	0.24	0.21	0.23	0.22
1A3	1.5	1.3	1.2	1.1	1.0
1A4	0.11	0.09	0.10	0.11	0.10
1A5	0.00004	0.00004	0.00004	0.00004	0.00004
1B	NA	NA	NA	NA	NA
Sum	1.9	1.7	1.5	1.4	1.4

NH3	2018	2019	2020	2021	2022	2005–2022
	kt					
1A1	0.033	0.033	0.034	0.037	0.037	28%
1A2	0.21	0.21	0.20	0.24	0.25	26%
1A3	0.98	0.94	0.81	0.85	0.90	-75%
1A4	0.10	0.10	0.10	0.11	0.10	-30%
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	3%
1B	NA	NA	NA	NA	NA	NA
Sum	1.3	1.3	1.1	1.2	1.3	-67%

3.1.5 Overview and trend for PM2.5

Figure 3-5 depicts the PM2.5 emissions in energy related sectors since 1990. The main contributor is source category 1A4 Other sectors, followed by 1A3 Transport and 1A2 Manufacturing industries and construction. Within source category 1A4 Other sectors, mainly wood combustion in small and mid-sized wood furnaces contribute to PM2.5 emissions. Overall emissions declined since 1990. The following effects mainly attributed to the reduction of particulate matter emissions:

- The large reduction of exhaust particulate matter emissions is primarily due to the development of emissions from wood combustion, especially in single-room furnaces and building heating systems (1A4). (Since the latest submission, exhaust particulate matter emissions include not only the filterable fractions, but also the condensable fractions, which are particularly relevant for single-room furnaces and building heating.) This reduction was achieved through technological improvements of the combustion installations and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, wood energy consumption in manually operated furnaces decreased by more than half since 1990. Furthermore, the revision of the Ordinance of Air Pollution (Swiss Confederation 1985) in 2007 introduced more stringent emission limits (2007, 2008 and 2012) for mainly automatic wood combustion installations, which also led to a reduction in emissions from these installations (mainly in 1A1 and 1A2), although their wood energy consumption increased by about a factor of eight since 1990.

- A further reduction of exhaust emissions under 1A3 Transport was caused by the abatement of exhaust emissions from road vehicles. Throughout the years, a continuous reduction of these emissions has been achieved with the stepwise adoption of the Euro standards. New diesel cars must be equipped with diesel particle filters.
- Under category 1A2 Manufacturing industries and construction, a reduction of exhaust emissions resulted from technological improvements in construction machineries (an installation of particle filters for new construction machineries with diesel engines is required by the Ordinance on Air Pollution Control (OAPC) since 2009) and from a fuel switch in stationary combustion (i.e. from coal, residual fuel oil and gas oil to natural gas).
- There is an underlying increasing in non-exhaust particulate matter emissions from growing activity data (annual mileage and machine hours) of mobile sources 1A3 Transport and 1A2gvii Mobile combustion in manufacturing industries and construction which affects larger particle emissions (TSP and PM10) more than PM2.5 (see Table 2-16 and Figure 2-13). This is due to a larger share of non-exhaust emissions with a particle diameter of 10 micrometres and larger. Therefore, the overall decreasing trend in TSP emissions is less pronounced as compared to the decrease in PM2.5 emissions. Note: In 2020 and 2021, despite this underlying increasing trend, the measures against the COVID-19 pandemic led to a reduction of non-exhaust PM10 emissions from road transportation due to reduced traffic volumes.

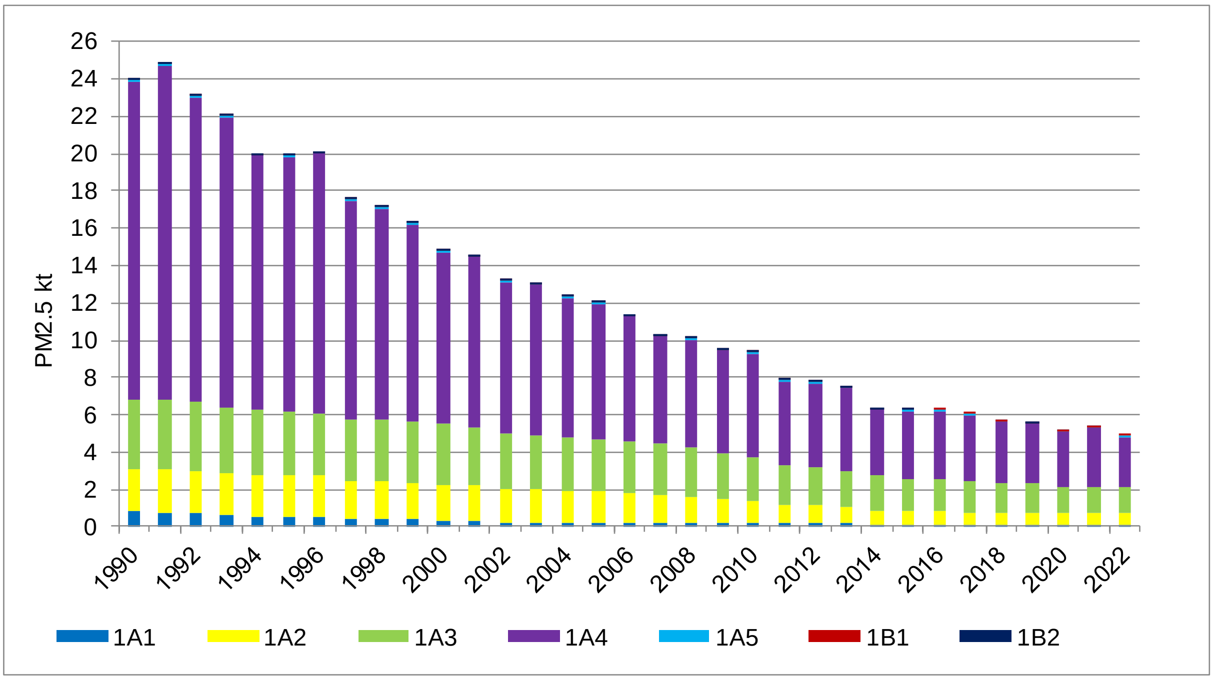


Figure 3-5 Switzerland’s PM2.5 emissions from the energy sector by source categories 1A1-1A5 and 1B1 between 1990 and 2022. The corresponding data can be found in Table 3-5.

Table 3-5 PM2.5 emissions from sector 1 Energy by source categories 1A1-1A5 and 1B1-1B2. The last column in the third part of the table indicates the relative trend.

PM2.5	1990	1995	2000	2005	2010
	kt				
1A1	0.83	0.55	0.35	0.19	0.20
1A2	2.3	2.2	1.9	1.7	1.2
1A3	3.7	3.4	3.3	2.8	2.3
1A4	17.0	13.6	9.2	7.2	5.6
1A5	0.087	0.063	0.062	0.057	0.050
1B1	0.0002	0.0001	0.0001	0.0001	0.0001
1B2	0.0004	0.0007	0.0007	0.0006	0.0002
Sum	24	20	14.8	12.0	9.3

PM2.5	2013	2014	2015	2016	2017
	kt				
1A1	0.16	0.15	0.089	0.069	0.069
1A2	0.88	0.75	0.75	0.73	0.71
1A3	1.9	1.9	1.8	1.7	1.6
1A4	4.5	3.5	3.6	3.7	3.6
1A5	0.048	0.047	0.046	0.046	0.046
1B1	0.00007	0.00007	0.00006	0.00006	0.00006
1B2	0.0002	0.0002	0.0001	0.00001	0.000005
Sum	7.5	6.3	6.3	6.2	6.0

PM2.5	2018	2019	2020	2021	2022	2005–2022
	kt					
1A1	0.065	0.067	0.062	0.065	0.060	-69%
1A2	0.69	0.67	0.65	0.67	0.64	-62%
1A3	1.6	1.6	1.4	1.4	1.5	-49%
1A4	3.3	3.2	3.0	3.1	2.7	-63%
1A5	0.045	0.045	0.045	0.045	0.045	-21%
1B1	0.00005	0.00005	0.00005	0.00005	0.00005	-32%
1B2	0.000005	0.000003	0.000004	0.000003	0.000001	-100%
Sum	5.7	5.6	5.2	5.3	4.9	-59%

3.1.6 General method and disaggregation of energy consumption

3.1.6.1 System boundaries: Differences between CLRTAP and UNFCCC 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 reportings is (almost) the same (NFR), but there are differences concerning the system boundaries. Under the UNFCCC, the national total for assessing compliance is based on fuel sold within the national territory, whereas under the CLRTAP, the national total for assessing compliance is based on fuel used within the territory.

One difference occurs for 1A3b Road transportation as can be seen from Table 3-6, columns “National total” of “CLRTAP / NFR tables” and of “UNFCCC / CRT tables” compared to the column “National total for compliance” of “CLRTAP / NFR tables”. The “National total for compliance” of “CLRTAP / NFR tables” does not contain the amount of fuel sold in Switzerland but consumed abroad, which is called “Fuel tourism and statistical difference”, and which is accounted for in Switzerland’s GHG inventory, but not in the reporting under the CLRTAP. The difference between the two approaches amounts to several percent, with considerable variation from year to year due to fluctuating fuel price differences between Switzerland and its neighboring countries. Note that the fuel tourism and statistical difference from 1A3b Road transportation is reported differently in the tables for the GHG inventory and the ones for the air pollutant inventory. In the air pollutant inventory, fuel tourism is allocated to the source categories 1A3bi-iii in proportion to annual fuel consumption within the respective vehicle categories (see chp. 3.2.6.2.2). In the GHG inventory, the allocation is different for gasoline, diesel oil, gaseous fuels and biomass due to a problem with the CRF reporter (see FOEN 2024, chp. 3.2.9.2.2).

Also, emissions from 1A3a Aviation are accounted for differently under the UNFCCC and the CLRTAP: Only emissions from domestic flights are accounted for in the GHG inventory, while emissions from international flights are reported as aviation bunker, i.e. as a memo item (1D1 International aviation). For the reporting of air pollutants under the CLRTAP, landing and takeoff (LTO) cycle emissions of domestic and international flights are accounted for, while emissions of international and domestic cruise flights are reported as memo items only (see Table 3-6). Note that emissions from overflights without landing in Switzerland are not considered in any of the approaches.

Table 3-6 Accounting rules for emissions from 1A3a Aviation and 1A3b Road transportation for CLRTAP and 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	National total for compliance	Separated information / Memo items	National total	Bunker (1D)
Road transportation (1A3b)	Fuels sold (1A3b)	Fuel used (1A3bi–v)	Yes	Yes	Yes	Yes	No
		Fuel tourism and statistical differences	Yes	No	No	Yes	No
Aviation (1A3a)	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

Emissions generated by road transportation considering fuel used in Switzerland as modelled in the road transportation model described in chp. 3.2.6.2.2 are reported in lines 143-149 in the NFR tables. Emissions generated by road transportation considering the amount of fuel sold in Switzerland are reported in lines 27-33 in the NFR tables.

The following memo items are reported for Switzerland in lines 157-164 in the NFR tables:

- 1A3ai(ii) International aviation cruise (civil) Emission modelling see chp. 3.2.6.2
- 1A3aii(ii) Domestic aviation cruise (civil) Emission modelling see chp. 3.2.6.2
- 1A3di(i) International maritime navigation Emission modelling see chp. 3.2.6.2
- 11B Forest fires Emission modelling see chp. 7.3
- 11C Other natural emissions Emission modelling see chp. 7.4

Recalculations concerning emission estimates of source categories in 1A3 are described in chp. 3.2.6.3, recalculations for 11B in chp. 7.3.3 and for 11C in chp. 7.4.3.

3.1.6.2 Net calorific values (NCV)

Table 3-7 summarizes the net calorific values (NCV) 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 3-7 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 3-8.

Fuel	Year		NCV	Unit	Data sources
			Fossil fuel		
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 (2023)
Petroleum coke	until	1998	35.0	GJ/t	SFOE (2023)
	from	2010	31.8	GJ/t	Cemsuisse (2010a)
Other bituminous coal	until	1998	28.052	GJ/t	SFOE (2023)
	from	2010	25.5	GJ/t	Cemsuisse (2010a)
Lignite	until	1998	20.097	GJ/t	SFOE (2023)
	from	2010	23.6	GJ/t	Cemsuisse (2010a)
			Biofuel		
Biodiesel	from	1990	32.7	GJ/m3	SFOE (2023)
Bioethanol	from	1990	21.1	GJ/m3	SFOE (2023)
Wood	from	1990	8.6-14.6	GJ/t	SFOE (2023b)

Gasoline, jet kerosene, diesel oil and gas oil

For gasoline, jet kerosene, diesel oil and gas oil, 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 2023). 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 2023), is assumed to be constant over the entire reporting period.

Liquefied petroleum gas

The NCV of liquefied petroleum gas is the same as used by the Swiss Federal Office of Energy (SFOE 2023) 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 2023). 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 (see Table 3-8) and also the CO_2 emission factor used in the GHG inventory of natural gas are 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 (2023). 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 (2023i). 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 3-8 Net calorific values of natural gas and biogas for selected years. Years in-between are linearly interpolated. Data source: annual reports of the Swiss Gas and Water Industry Association SGWA, the latest report is SGWA (2023). Spreadsheet to determine national averages: FOEN 2023i.

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

Wood

The net calorific value of wood depends on the type of wood fuel (for e.g. log wood, wood chips, pellets) and is based on the Swiss wood energy statistics (SFOE 2023b).

Table 3-7 illustrates the range of the NCV for 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 2023) and are – as in the Swiss overall energy statistics – constant over the entire reporting period.

3.1.6.3 Swiss energy model and final Swiss energy consumption

3.1.6.3.1 Swiss overall energy statistics

The fundamental data on final energy consumption is provided by the Swiss overall energy statistics (SFOE 2023). However, since Switzerland and Liechtenstein form a customs and monetary union governed by a customs treaty, data regarding liquid fuels in the Swiss overall energy statistics also cover liquid fuel consumption in Liechtenstein. In order to calculate the correct Swiss fuel consumption, Liechtenstein's liquid fossil fuel consumption, given by Liechtenstein's energy statistics (OS 2023), is subtracted from the figures 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 correspond to the energy balance provided in the Swiss overall energy statistics (SFOE 2023). The energy statistics are updated annually and contain all relevant information about primary and final energy consumption. This includes annual aggregated consumption data for various fuels and main consumers such as households, transport, energy industries, industry, and services (see energy balance in Annex 4).

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

- The Swiss organisation for the compulsory stockpiling of oil products – Carbura and Avenergy 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, formerly FCA).
- Data provided by industry associations (GVS, SGWA, Cemsuisse, VSG, VSTB, etc.).
- Swiss electricity statistics (SFOE 2023g).
- Swiss renewable energies statistics (SFOE 2023a).
- Swiss wood energy statistics (SFOE 2023b).
- Swiss statistics on combined heat and power generation (SFOE 2023c).

As can be seen in Figure 3-6, fossil fuels amount to slightly less than half of primary energy consumption. The main end-users of fossil fuels are the transport and the housing sector, as electricity generation is predominantly based on hydro- and nuclear power stations. The most recent energy balance is given in Annex 4.

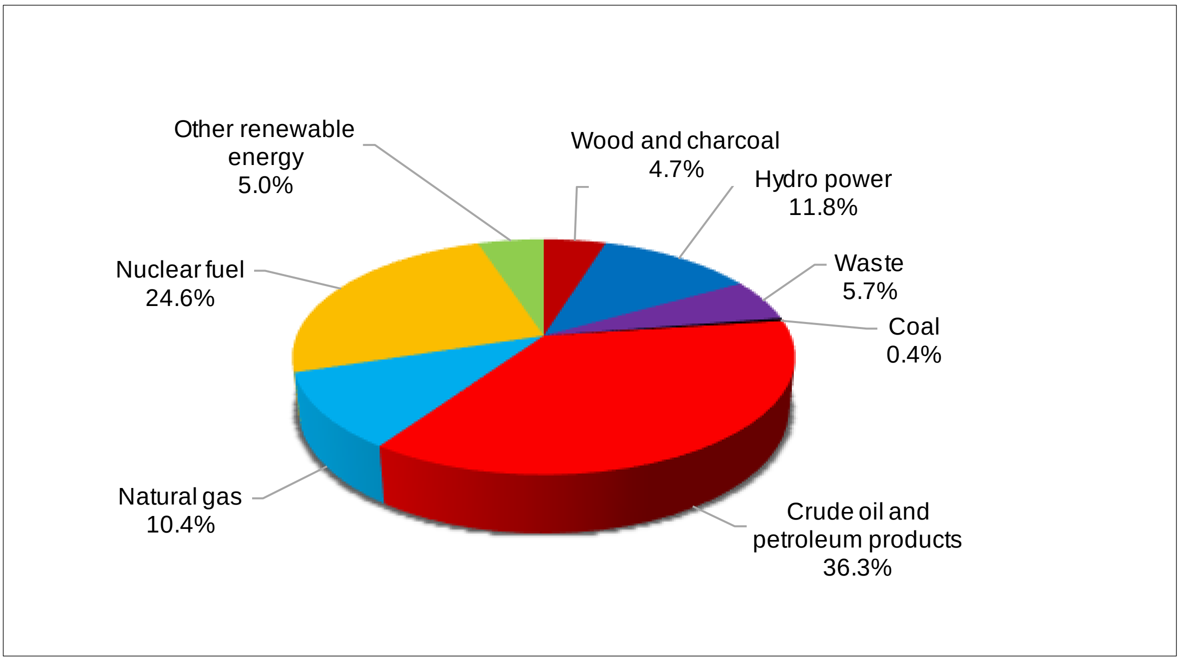


Figure 3-6 Switzerland's primary energy consumption in 2022 by fuel type (see corresponding data and additional information on energy consumption over time in SFOE 2023).

Table 3-9 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 in the residential and industry sector (mainly gas oil) substantially decreased. Overall, liquid fossil fuel consumption changed only little between 1990 and about 2010 but started to decrease thereafter. 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 fossil fuel consumption than in the years before. Particularly, in the transport sector the consumption of gasoline, jet kerosene and diesel oil, does not reach the level of 2019 anymore. Compared to 2021, total fuel consumption declined in 2022. In particular gas oil and natural gas consumption was lower comparted to the previous years due to the warm winter and energy saving measures in response to the looming energy shortage.

Table 3-9 Switzerland's energy consumption by fuel type. Only those fuels are shown that are implemented in the EMIS database (no hydro or nuclear power). The numbers are based on the fuels sold principle; thus, they include gasoline, diesel 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 used for LTO	Jet kerosene used for cruise (memo	Diesel oil	Diesel oil Navigation (memo item)	Gas oil	Residual fuel oil	Refinery gas & Liquefied petroleum gas	Petroleum coke	Solid fuels	Natural gas excl. natural gas losses	Other fuels	Bio fuels	National Total as reported in NFR tables	Total incl. memo items
	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ
1990	155'703	8'059	40'008	46'736	821	218'510	23'342	8'890	1'400	14'901	68'426	19'074	46'826	611'865	652'695
1991	162'063	7'640	38'922	47'417	737	238'602	23'590	12'437	980	12'162	76'724	18'514	48'816	648'945	688'604
1992	168'037	7'803	41'297	45'926	780	236'809	24'170	11'492	315	8'758	80'627	18'931	47'753	650'620	692'697
1993	155'808	7'861	42'915	44'197	781	225'920	17'165	12'388	1'120	7'442	84'574	19'048	48'086	623'607	667'302
1994	155'797	7'911	44'198	46'924	824	207'141	17'860	13'455	1'470	7'632	83'402	19'069	46'036	606'696	651'719
1995	151'094	7'987	46'960	47'865	739	217'523	17'278	12'756	1'260	7'962	91'942	19'588	48'093	623'347	671'046
1996	155'033	8'017	48'736	44'946	651	226'289	15'097	13'939	1'015	5'456	99'530	20'443	51'670	641'436	690'823
1997	161'031	8'320	50'454	46'728	657	212'223	12'581	14'236	280	4'590	96'083	21'498	48'546	626'116	677'227
1998	162'315	8'540	52'728	48'681	528	222'407	15'882	15'259	455	3'960	98'890	23'586	50'153	650'128	703'384
1999	167'815	8'762	56'482	51'626	558	212'349	11'058	15'805	521	4'105	102'415	24'189	50'928	649'575	706'615
2000	168'009	9'074	58'987	55'146	531	196'137	7'923	13'649	551	6'120	101'800	26'294	50'600	635'304	694'822
2001	163'442	8'598	55'610	56'262	447	213'089	9'942	14'069	410	6'233	105'966	26'796	53'877	658'685	714'742
2002	160'276	8'128	51'278	58'389	333	196'655	6'446	15'584	679	5'565	104'007	27'624	53'440	636'793	688'404
2003	159'512	7'327	46'110	61'808	443	208'040	7'061	13'642	202	5'663	109'957	27'361	56'031	656'605	703'159
2004	156'708	6'886	43'555	66'447	446	203'370	7'561	16'429	1'819	5'420	113'459	28'518	56'976	663'594	707'594
2005	151'966	7'020	44'081	72'572	493	205'729	5'805	16'432	2'906	5'940	116'493	28'849	59'148	672'860	717'434
2006	147'344	7'291	46'280	78'606	457	195'926	6'419	18'578	3'324	6'467	113'264	30'846	62'272	670'338	717'074
2007	145'923	7'538	49'627	84'420	465	171'313	5'179	15'587	2'730	7'196	110'252	29'617	61'331	641'086	691'177
2008	142'713	7'773	53'378	92'670	473	178'833	4'581	16'288	3'616	6'562	117'451	30'385	65'531	666'402	720'253
2009	138'883	7'496	51'169	94'143	425	173'219	3'530	16'301	3'254	6'193	112'674	29'296	65'704	650'693	702'288
2010	133'953	7'699	53'921	97'776	471	182'295	2'967	15'463	3'498	6'208	125'846	30'627	70'576	676'908	731'300
2011	128'775	7'970	57'726	100'449	428	143'760	2'292	14'856	2'957	5'792	111'617	30'269	66'255	614'993	673'147
2012	124'229	8'258	59'048	106'611	385	154'448	2'780	12'247	3'148	5'269	122'398	30'555	72'159	642'103	701'536
2013	118'572	8'243	59'825	111'482	342	162'532	1'959	15'053	2'735	5'567	128'912	30'249	75'870	661'173	721'340
2014	113'820	8'282	60'259	114'385	299	122'694	1'581	14'473	3'148	5'704	111'660	30'608	70'270	596'624	657'183
2015	105'540	8'414	62'374	112'808	342	129'349	862	9'822	1'145	5'205	119'314	31'398	73'701	597'558	660'274
2016	102'250	8'577	65'584	114'079	299	132'325	378	9'136	890	4'795	125'355	32'835	79'968	610'590	676'472
2017	99'112	8'581	67'352	113'750	256	123'726	350	8'770	763	4'609	125'602	32'515	83'389	601'168	668'776
2018	97'545	8'756	71'494	115'283	200	111'225	87	8'890	781	4'285	118'931	33'605	83'274	582'663	654'357
2019	96'748	8'587	72'482	115'347	197	108'625	111	8'108	777	3'812	121'941	34'044	85'855	583'953	656'633
2020	85'681	3'930	26'685	109'312	189	97'246	76	7'627	700	3'664	118'782	33'733	85'018	545'767	572'642
2021	87'541	4'203	29'756	110'489	228	107'991	139	7'543	604	3'697	129'321	32'826	91'886	576'239	606'224
2022	85'025	6'779	53'086	110'334	207	86'970	0	9'646	731	3'847	106'250	32'631	88'565	530'780	584'072

3.1.6.3.2 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 2023). 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 2023), the Swiss renewable energy statistics (SFOE 2023a), the Swiss wood energy statistics (SFOE 2023b), the energy consumption statistics in the industry and services sectors (SFOE 2023d), as well as additional information from the industry.

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. 3.2.6.2.2 Road transportation).

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 energy model for wood combustion. A brief overview of each of these models is given below. However, depending on the scope of these sub-models, they are either described in the corresponding source category chapter or in an overarching chapter preceding the detailed description of the individual source categories. In chapter 3.1.6.3.3, the resulting sectoral disaggregation is shown separately for each fuel type.

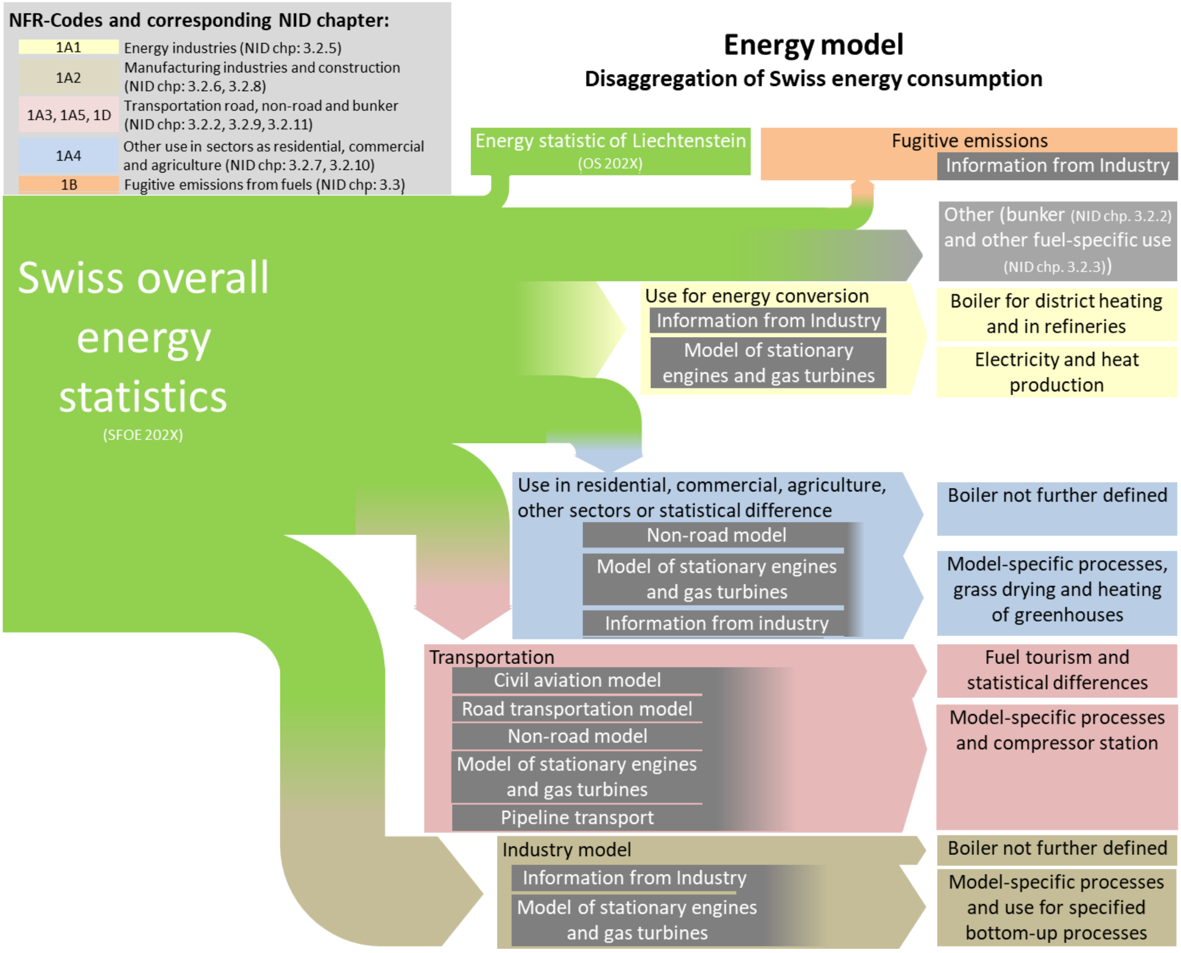


Figure 3-7 Overview of Switzerland's energy model. In the abbreviations SFOE 202X and OS 202X the "X" refers to the latest edition of the respective statistics.

Industry model (Details are given in chp. 3.2.3.2)

The industry model disaggregates the total fuel consumption in the industry sector (SFOE 2023) 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 2023d) 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. 3.2.6.2.1)

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. 3.2.6.2.2)

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

Non-road transportation model (Details are given in chp. 3.2.1.1.1)

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

Energy model for wood combustion (Details are given in chp. 3.2.1.1.2)

Based on the Swiss wood energy statistics (SFOE 2023b), 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.

Energy model of stationary engines and gas turbines (Details are given in chp. 3.2.1.1.3)

The model of stationary engines and gas turbines in 1A Fuel combustion activities is based on a study of the number of engines and gas turbines throughout Switzerland, which was carried out in a survey with the cantonal authorities, from websites and annual reports from industry, as well as from direct enquiries to the operators. This study compiled an inventory of installed capacities, technologies and operating hours. 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.

3.1.6.3.3 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 2023) into the relevant source categories 1A1-1A5 (Figure 3-8). For each fuel type, the disaggregation process of the energy model as shown schematically in Figure 3-7, the interaction between the different sub-models and additional data sources are visualized separately in Figure 3-9 to Figure 3-18.

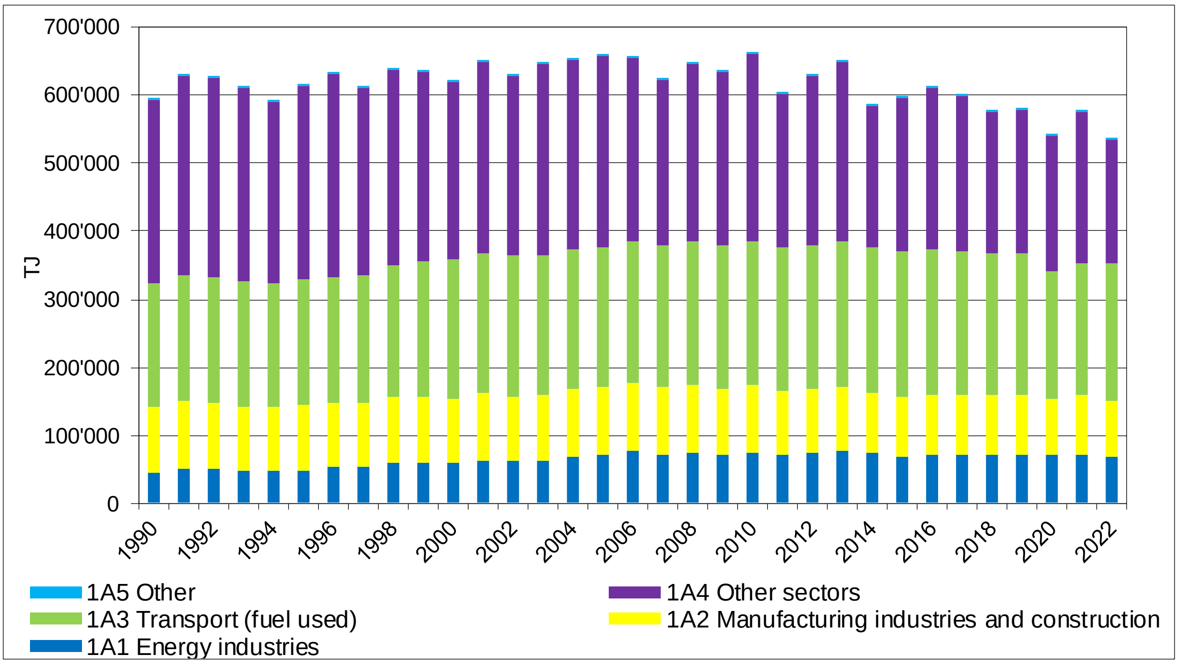


Figure 3-8 Switzerland's energy consumption in the source categories 1A1–1A5 based on the Swiss energy model. Since 1990 population has increased by about one third, industrial production by about three quarters and the motor vehicle fleet by about two thirds (SFOE 2023, table 43)

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 above in chp. 3.1.6.3.2. 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 the heating of greenhouses. The fuel consumption for grass drying is determined 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_2 levy, total energy consumption of all greenhouses within Switzerland is extrapolated. The respective fuel consumption for grass drying and greenhouses is subtracted from the total fuel consumption of 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.

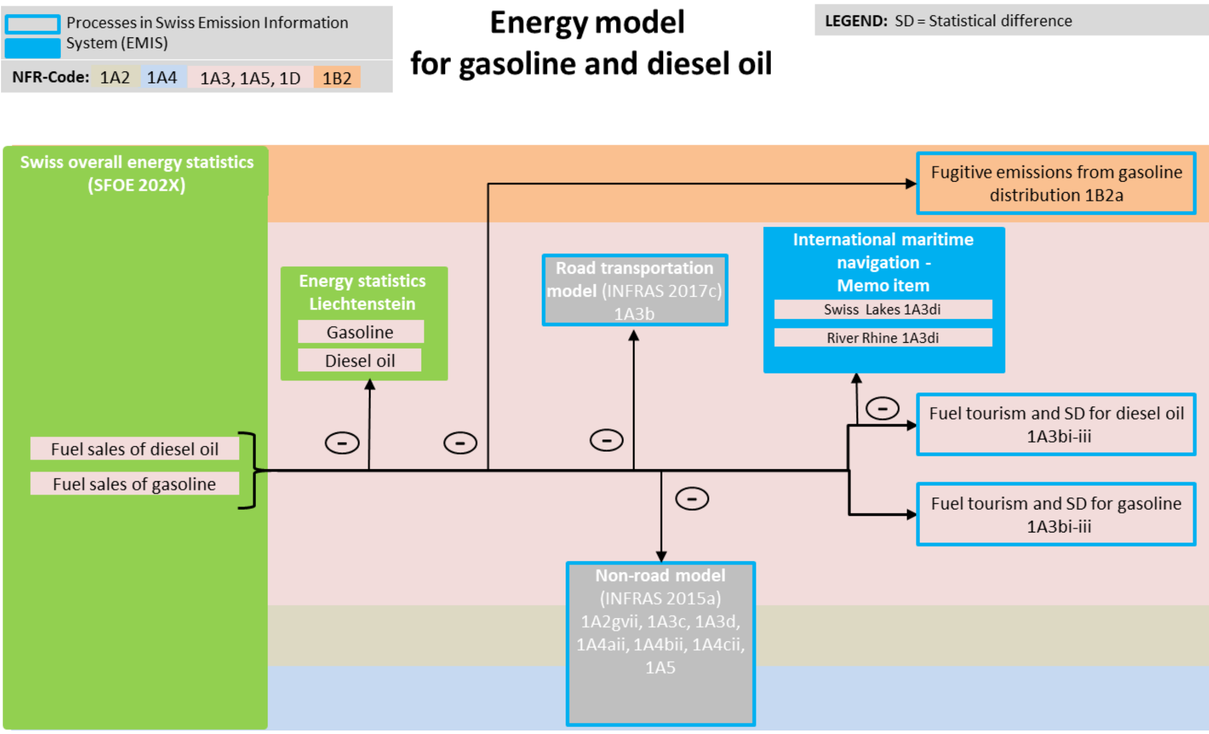


Figure 3-9 Schematic disaggregation of 1A Fuel consumption for gasoline and diesel oil. Marine bunker fuel consumption is based on the national customs statistics (see chapter 3.1.6.1 on memo items)

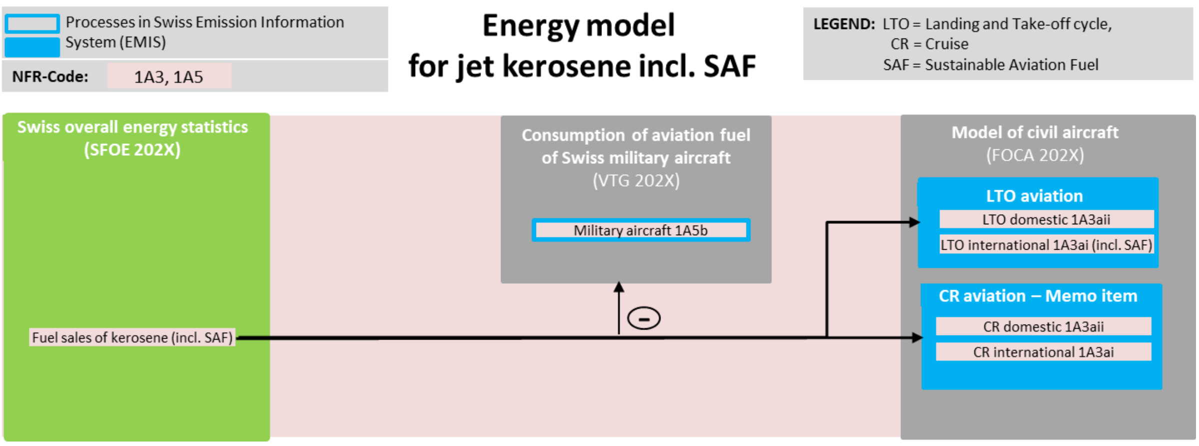


Figure 3-10 Schematic disaggregation of 1A Fuel consumption for jet kerosene. Fuel consumption for military aircraft is provided by the Swiss Air Force (part of the Swiss Armed Forces, VTG). The differentiation between domestic and international aviation as well as between CR and LTO is provided by the civil aviation model (see chp. 3.2.6.2.1)

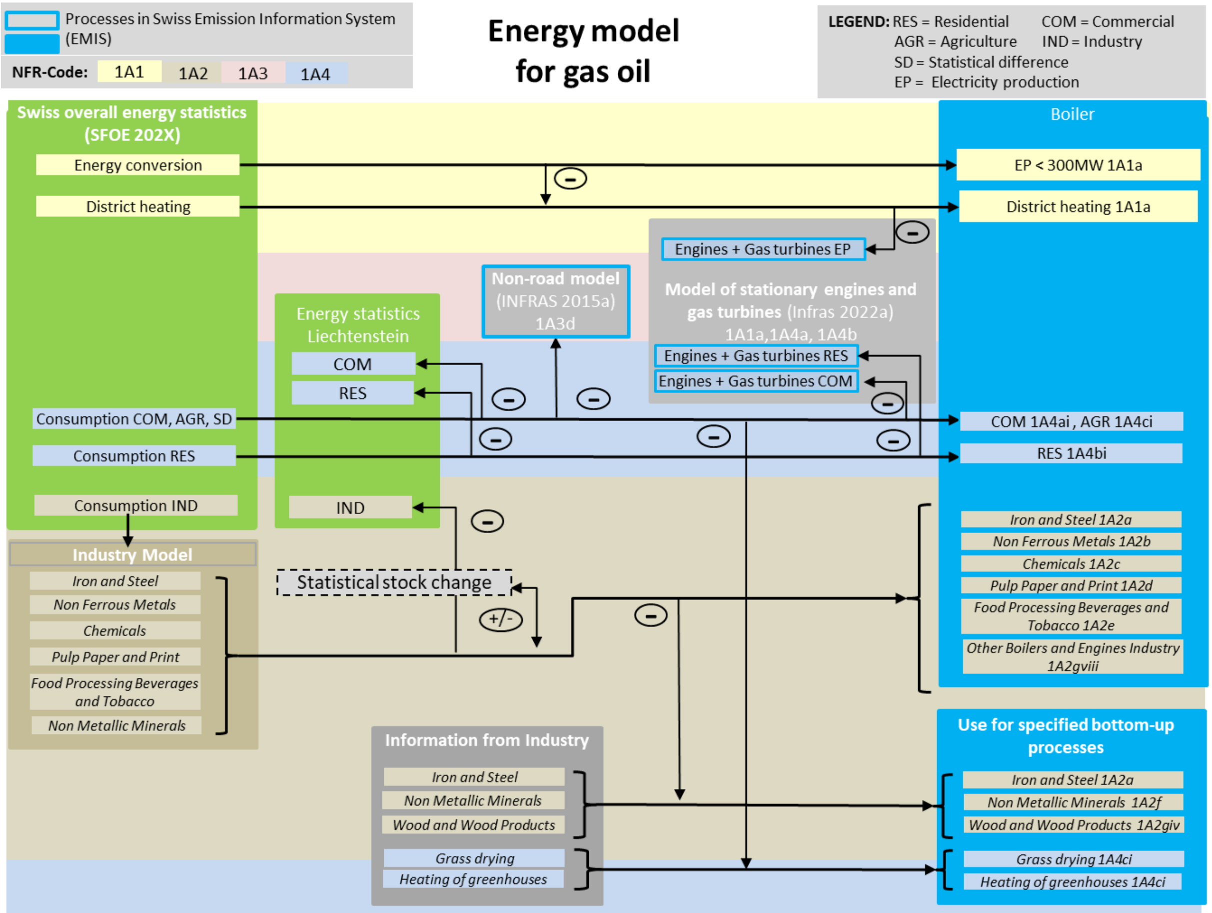


Figure 3-11 Schematic disaggregation of 1A Fuel consumption for gas oil. The Swiss overall energy statistics provide gas oil use for energy conversion and the amount thereof being used for district heating. Based on this information, gas oil use is split into 1A1ai Electricity generation and 1A1aiii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

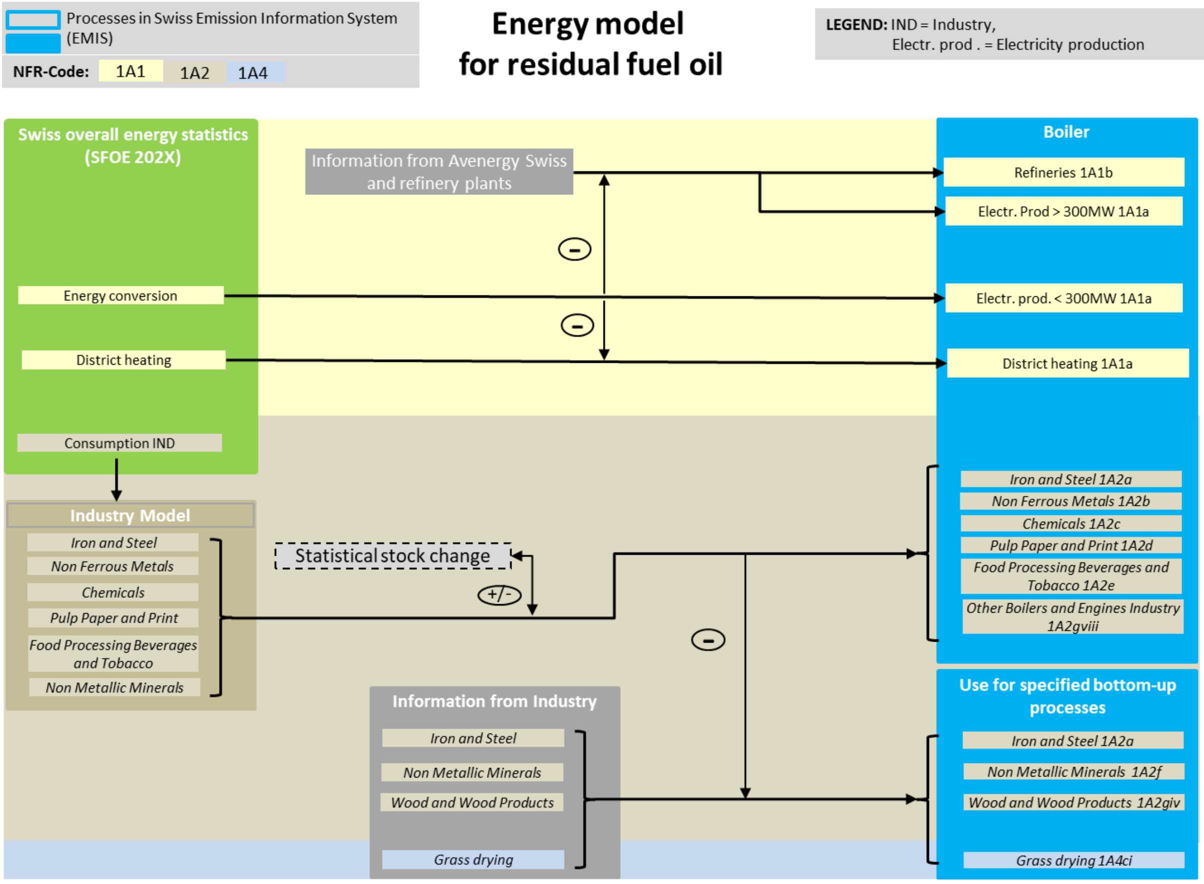


Figure 3-12 Schematic disaggregation of 1A Fuel consumption for residual fuel oil. The Swiss overall energy statistics report residual fuel oil use in energy conversion and the amount thereof consumed in electricity production (one single fossil fuel power station, operational from 1985 to 1994), district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

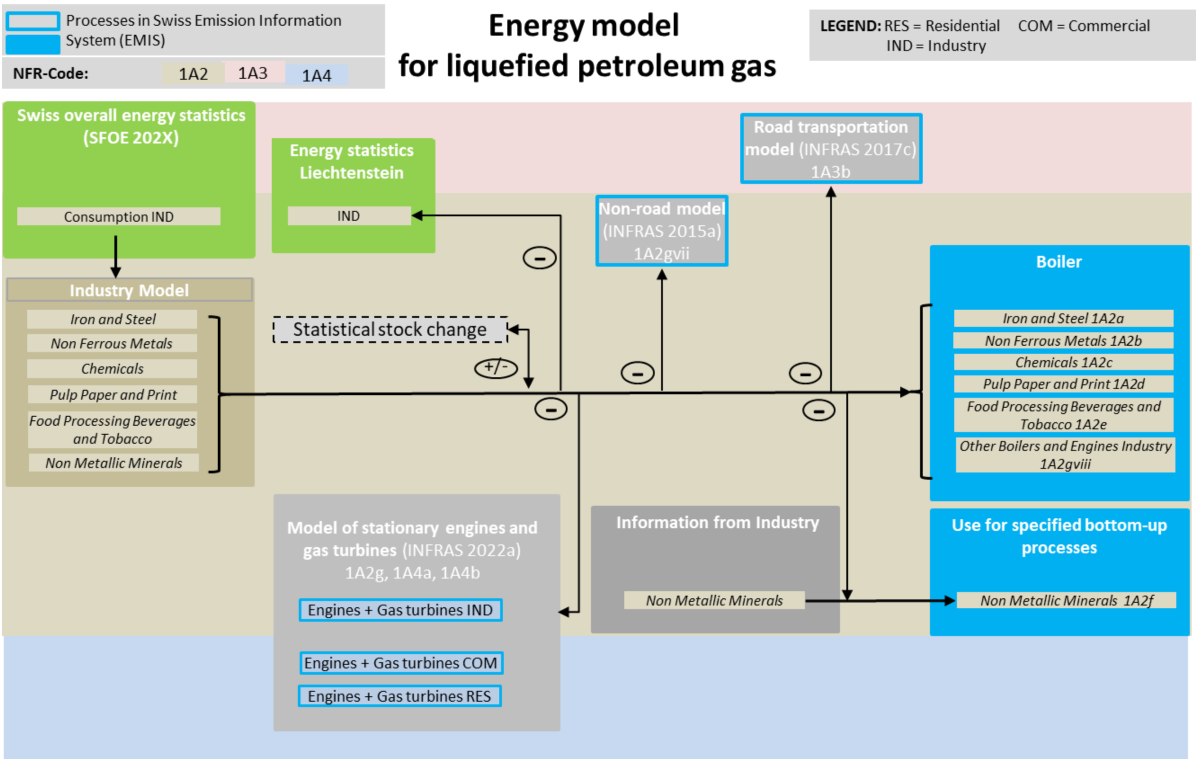


Figure 3-13 Schematic disaggregation of 1A Fuel consumption for liquefied petroleum gas.

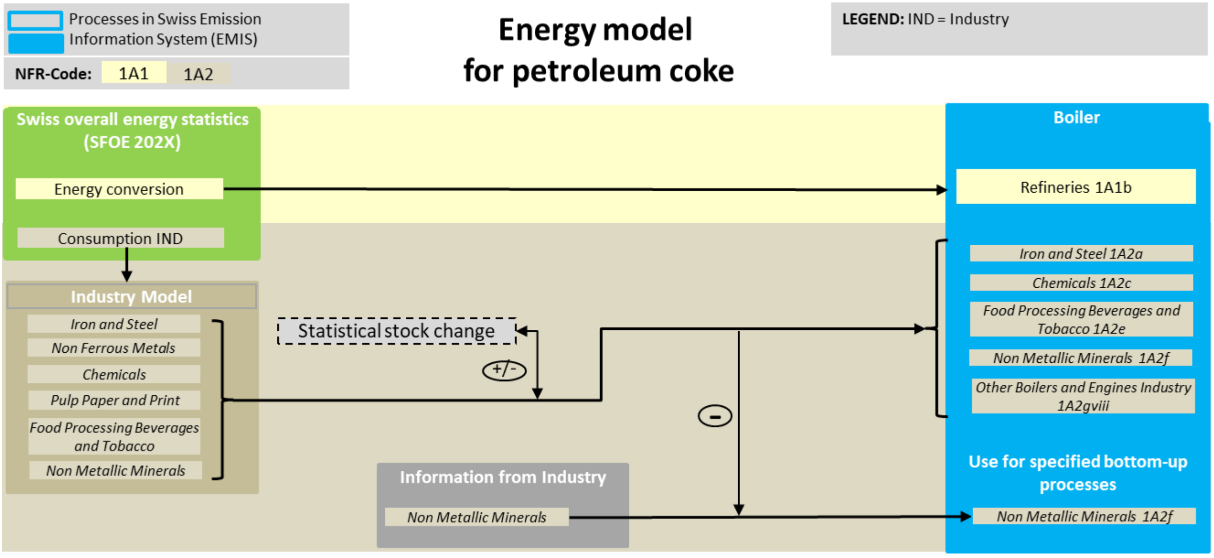


Figure 3-14 Schematic disaggregation of 1A Fuel consumption for petroleum coke.

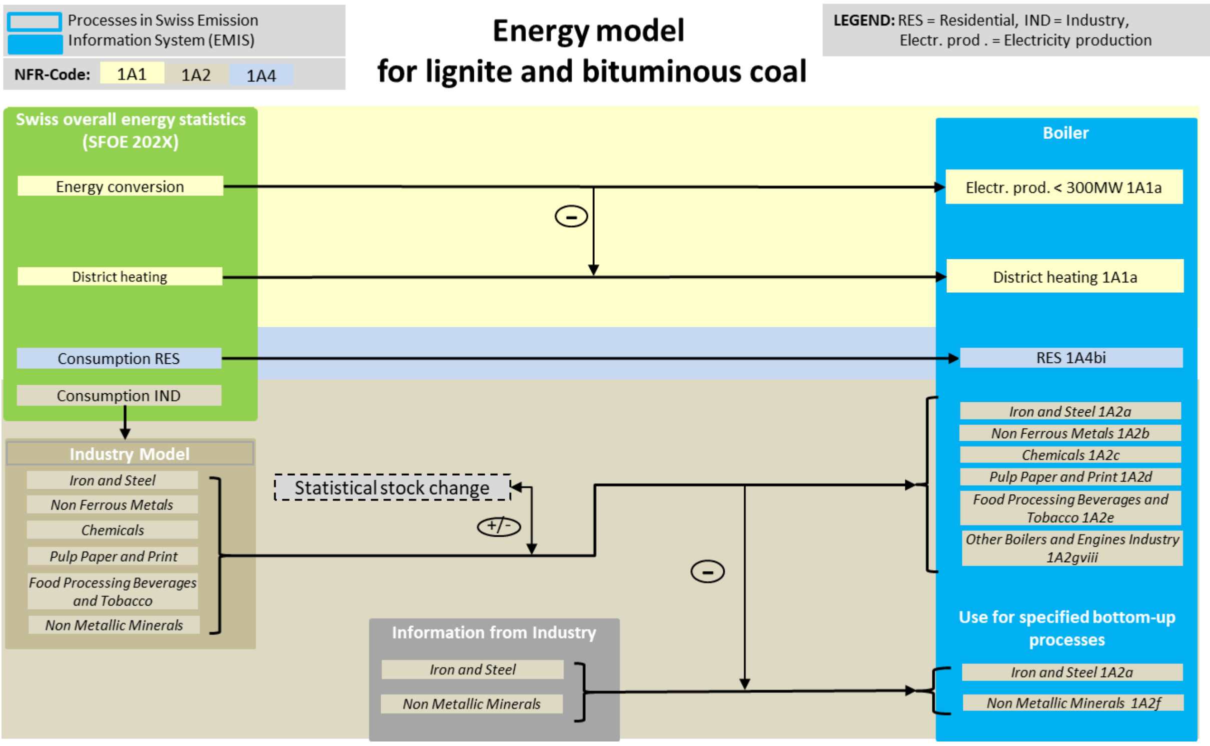


Figure 3-15 Schematic disaggregation of 1A Fuel consumption for lignite and bituminous coal. The Swiss overall energy statistics provide bituminous coal use for energy conversion and the amount thereof being used for district heating. Based on this information, use of bituminous coal in energy industries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

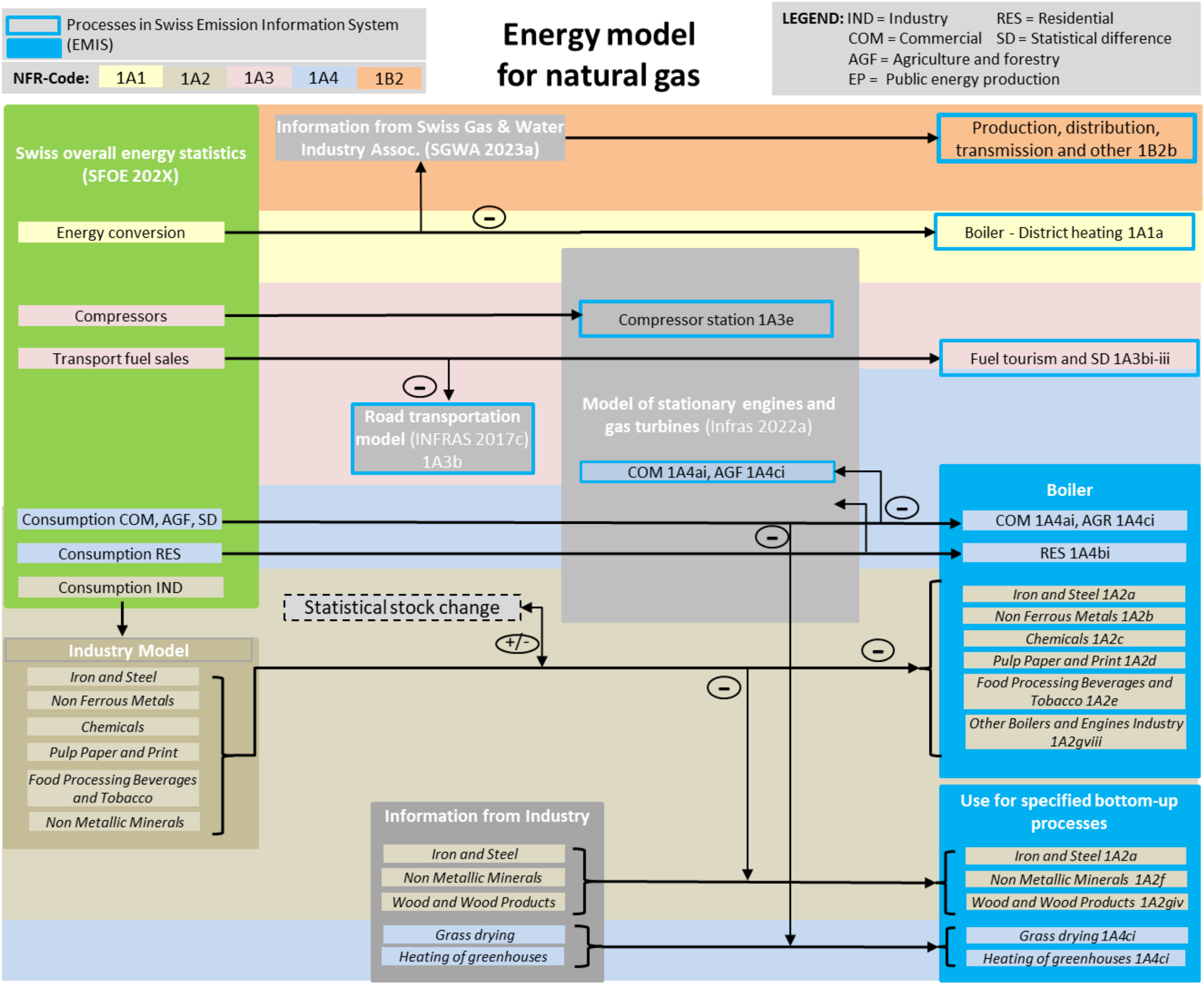


Figure 3-16 Schematic disaggregation of 1A Fuel consumption (and 1B Fugitive emissions from fuels) for natural gas. The Swiss overall energy statistics (SFOE 2023) provide gas use in the transformation sector (energy conversion and distribution losses). Distribution losses as estimated by the Swiss Gas 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 1A1a Public electricity and heat production.

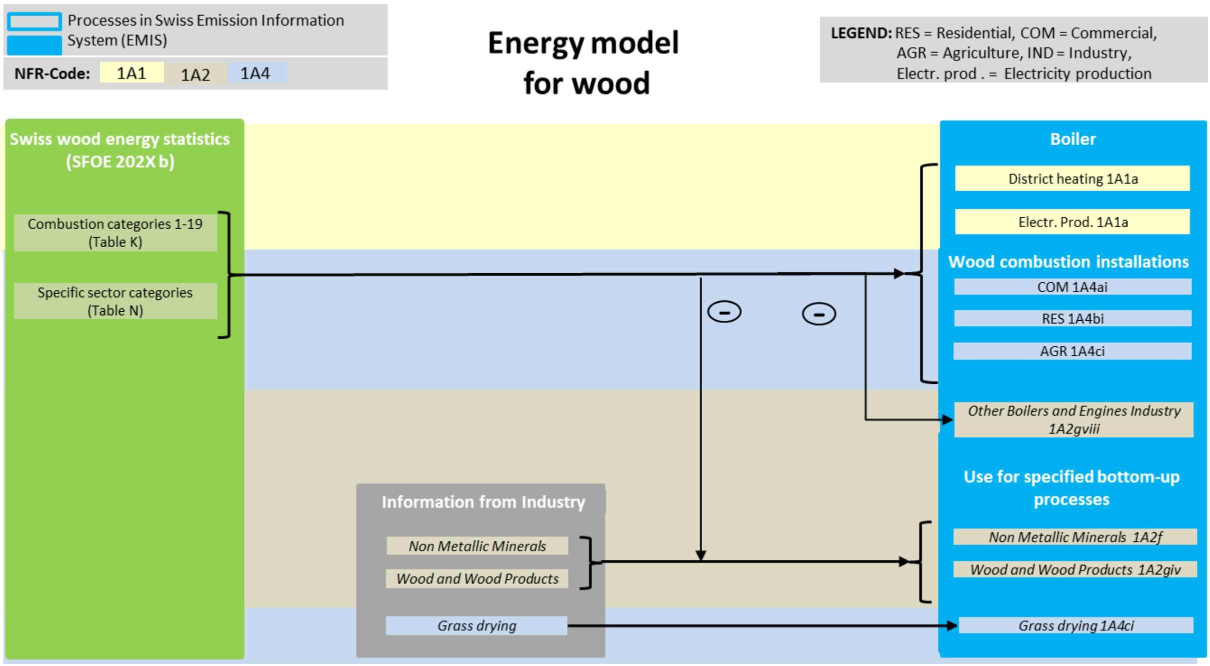


Figure 3-17 Schematic disaggregation of 1A Fuel consumption for wood. For a detailed description of the Energy model for wood combustion, see chapter 3.2.1.1.2.

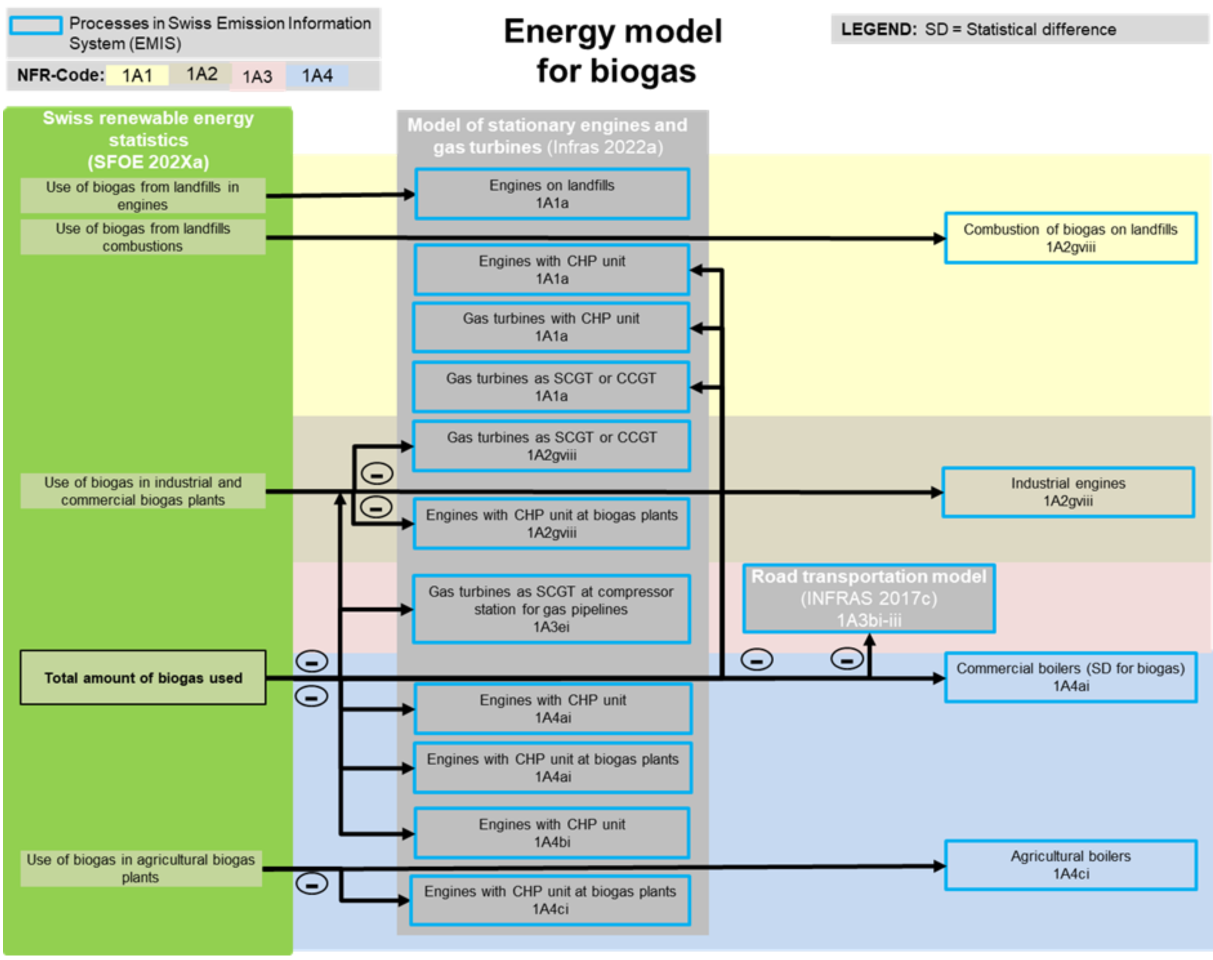


Figure 3-18 Schematic disaggregation of 1A Fuel consumption for biogas.

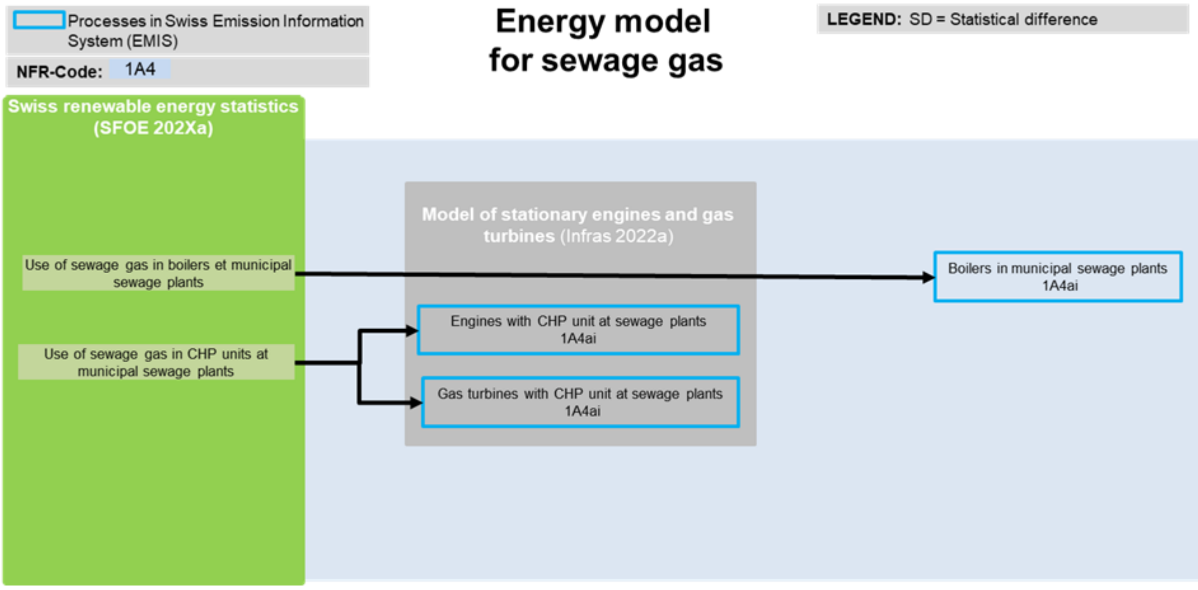


Figure 3-19 Schematic disaggregation of 1A Fuel consumption for sewage gas.

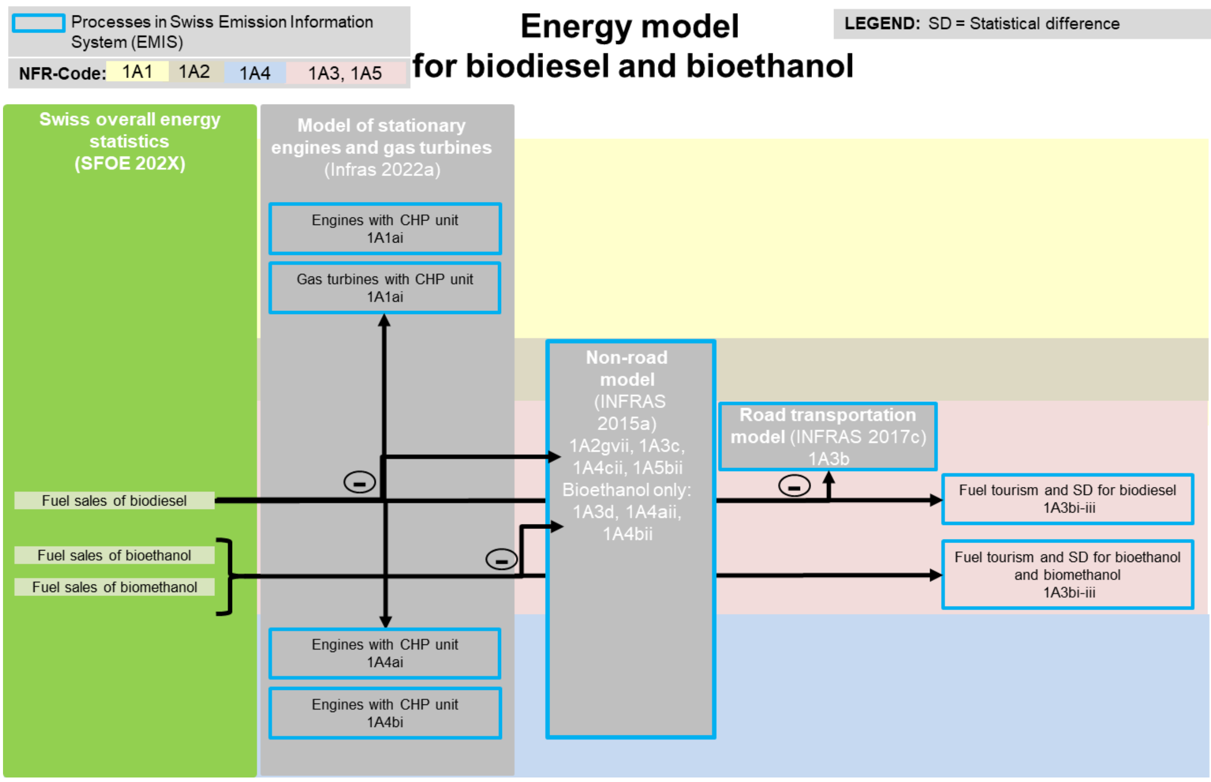


Figure 3-20 Schematic disaggregation of 1A Fuel consumption for biodiesel and bioethanol.

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

3.2 Source category 1A - Fuel combustion activities

3.2.1 Country-specific issues of 1A Fuel combustion

In the following chapter, the general country-specific approach of determining activity data and emission factors is presented. Specific information about each source category is included in the respective chapters 3.2.2 to 3.2.8.

3.2.1.1 Models overlapping more than one source category

3.2.1.1.1 Non-road transportation model (excl. aviation)

Choice of method

For all source categories, for which the non-road transportation model is applied (Table 3-10), the air pollutant emissions are calculated by a Tier 3 method based on the corresponding decision trees given in EMEP/EEA guidebook (EMEP/EEA 2019). The detailed references to the related chapters of the Guidebook are shown in the chps. 3.2.5.2, 3.2.6.2, 3.2.7.2, and 3.2.8.2.

Methodology

The emissions of the non-road sector underwent an extensive revision in 2014/2015. Results are documented in FOEN (2015j). The following non-road categories are considered, all of them including several fuels, technologies, and emission standards.

Table 3-10 Non-road categories (FOEN 2015j) and the corresponding NFR nomenclature (reporting tables).

Non-road categories (by Corinair)	Nomenclature NFR
Construction machinery	1A2gvii Mobile Combustion in manufacturing industries and construction
Industrial machinery	1A2gvii Mobile Combustion in manufacturing industries and construction
Railway machinery	1A3c Railways
Navigation machinery	1A3dii National navigation (shipping)
Garden-care/professional appliances	1A4aii Commercial/institutional: Mobile
Garden-care/hobby appliances	1A4bii Residential: Household and gardening (mobile)
Agricultural machinery	1A4cii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
Forestry machinery	1A4cii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
Military machinery (excl. aviation)	1A5b Other, Mobile (including military, land based)

Within each non-road category, the non-road database (INFRAS 2015a) uses the following classification structure:

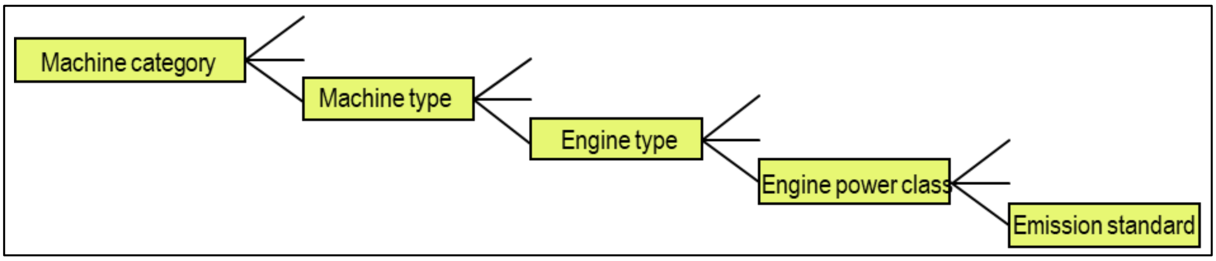


Figure 3-21 Each non-road vehicle is classified by its engine-power class, engine type, machine type, machine category, and emission standard.

The emission modelling is based on activity data and emission factors by means of the following equation, which is implemented at the most disaggregated level (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 by engine type, pollutant or GHG (in g/a)
N	=	number of vehicles (--)
H	=	number of operation hours per year (h/a)
P	=	engine power output (kW)
λ	=	effective load factor (--)
ε	=	emission factor (g/kWh), fuel consumption factor (g/kWh)
CF_1	=	correction factor for the effective load (--)
CF_2	=	correction factor for dynamical engine use (--)
CF_3	=	degradation factor due to aging (--)

The same equation also holds for the calculation of the fuel consumption, where ε is the consumption instead of emission factor (in g/kWh) and *Em* the consumption (in g/a). A more detailed description of the analytical details is given in the Annex of FOEN (2015j).

The total emission and consumption per non-road family is calculated by summing over all classes of the categories included in the families.

The method holds for CO, VOC, NO_x and exhaust particulate matter (PM). For the calculation of emissions of non-regulated air pollutants, the following approaches are applied:

- NMVOC is calculated as a share of VOC dependent on fuel and engine type.
- Further pollutants follow the methodology documented in IFEU (2010) and references therein.

Note that the emissions are only calculated in steps of 5 years from 1980 to 2050. Emissions for the years in between are interpolated linearly.

Emission factors

Emission factors are taken from various sources based on measurements, modelling and literature. SO_x is country-specific, see Table 3-28. For other air pollutants, the main data sources are USEPA (2010), IFEU (2010), EMEP/EEA (2019) and Integer (2013). In general, the following sources are used for the emission factors (if not stated differently in the respective chapters 3.2.5.2, 3.2.6.2, 3.2.7.2 or 3.2.8.2):

- Emission factors for NO_x, VOC/CH_4, CO and exhaust particulate matter (PM) are generally given in FOEN (2015j) and INFRAS (2015a). BC exhaust emission factors stem from Neosys (2013). Considering the measuring procedure and the maximum temperature of 52°C, it can be assumed that PM condensable are also included in the measurements. The installed technology also plays a role in this context (petrol engines with/without catalytic converter, diesel engines with/without particulate filter, etc.).
- Non-exhaust particulate matter (PM) and non-exhaust BC emission factors are based on Carbotech (2000), with some modifications by BUWAL (2001). It should be noted that “PM” in BUWAL (2001) corresponds to total PM, including particles larger than 10 µm. For all non-road mobile machinery sources except rail abrasion, PM10 amounts to 67 % of total PM according to in BUWAL (2001). For rail abrasion, PM10 amounts to 90 % to 100 % of total PM according to in BUWAL (2001). The corresponding factors have been applied in PM10 emission calculation.
- NMVOC is not modelled bottom-up; the NMVOC emissions are calculated as the difference of VOC and CH_4 emissions given in FOEN (2015j) and INFRAS (2015a).
- SO_x emission factors are based upon the sulphur content of fuels (see chp. 3.2.1.2). These are country- and fuel-specific, see implied emission factors in Table 3-28 (column diesel oil, gasoline, natural gas) and in specific tables in the non-road chapters.
- Emission factors for NH_3, priority heavy metals and POPs are generally taken from the EMEP/EEA guidebook (EMEP/EEA 2019). Pb emission factors are estimated based on the Pb content of fuels (according to EMEP/EEA 2019). PCDD/PCDF emissions are taken from Rentz et al. (2008).

Note that all emission factors (in kg/hr) of NO_x, NMVOC, PM (exhaust only; PM2.5 assumed equal to PM10 for combustion particles) and CO can be visualised and downloaded (tables in CSV format) by a query from the online non-road database INFRAS (2015a)[4]. For a detailed description of emission factors and their origin, see tables in the Annex of FOEN (2015j). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels. In Annex A2.1.1 an excerpt of a query is shown to illustrate the results that can be downloaded from the database.

Activity data

Activity data were collected by surveys among producers and several user associations in Switzerland (FOEN 2015j), and by evaluating information from the national database of non-road vehicles (IVZ, formerly MOFIS) run by the Federal Roads Office (FEDRO 2013). In addition, several publications serve as further data source:

- SBV (2013) for construction machinery
- SFSO (2013a) for agricultural machinery
- Jardin Suisse (2012) for garden care /hobby and professional appliances

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[4] https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html [06.02.2023]

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

In Annex A2.1.2 (Table A - 13) the stock numbers and the operating hours of non-road vehicles are summarised for each non-road category.

3.2.1.1.2 Model for wood energy combustion

Choice of method

The emissions from wood combustion in 1A Fuel combustion activities are calculated by a Tier 2 method based on chapter 1A4 Small combustion in the EMEP/EEA guidebook (EMEP/EEA 2019).

Methodology

The Swiss wood energy statistics (SFOE 2023b) distinguish 24 wood combustion installation types (exclusive 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 K, categories 1-19) and the allocations of the installation types to the sectoral consumer categories (table N, household, agriculture/forestry, industry, services, electricity and district heating). This allows for assigning the annual wood consumption at the level of combustion installation categories (Table 3-11) to the source categories 1A1a Public Electricity and Heat Production, 1A2gviii Other, 1A4ai Commercial/Institutional, 1A4bi Residential and 1A4ci Agriculture/Forestry/Fishing. Installation types of the wood energy statistics with the same emission behaviour are grouped into one category in Table 3-11. For information purposes, the category numbers according to the statistics are listed in parentheses.

The combustion of any household waste in wood-burning fireplaces and stoves is prohibited in Switzerland since 1992 (Ordinance on Air Pollution Control, Swiss Confederation 1985). Emissions from illegal domestic incineration of municipal solid waste are reported in source category 5C1a Municipal waste incineration (see chp. 6.4.2)

Table 3-11 Categories of wood combustion installations based on the Swiss wood energy statistics (SFOE 2023b). The category numbers according to the statistics are listed in parentheses.

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

Emission factors

All emission factors are based on a country-specific emission factor model for wood energy that has been completely revised for the entire time series (including projections) by Zotter and Nussbaumer (2022). Emission factor values are modelled for the years 1990, 2008, 2014, 2020 and 2035, i.e. 2008 and 2014 being the update years of the previous models. Years in between are linearly interpolated.

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 guidebook (EMEP/EEA 2019) and takes into account both various technology standards of combustion installations and operating influences.

For single-room furnaces, i.e. open/closed fireplaces and log wood stoves (categories 1-4a, 5) the emission factors of NO_x, VOC, PM exhaust (filterable fraction) and CO are modelled based on literature emission data covering the entire combustion process including the start-up phase and burn-out. A distinction was made between furnaces of conventional and modern technology. In a first step, average emission factors were derived under optimal operating conditions. Optimal operation means that no wet wood is used, the wood is lit from above and the combustion process is not negatively influenced by non-optimal operation. However, in order to be able to represent the emissions as realistically as possible, user impacts such as lighting from below, lighting with newspaper, using wet wood, overloading the combustion chamber as well as reducing the air supply were taken into account by factors. Also based on literature data, factors for the ratio of the emission factors of each disadvantageous operation mode compared to optimal operation were determined. As no literature data on the shares of the respective (disadvantageous) operating modes could be found they were estimated. Shares of 35 % optimal operation, 25 % lighting from below, 10 % lighting with newspaper, 10 % wet wood, 10 % overloaded combustion chamber and 10 % reduced air supply were assumed for a representative mean furnace operation in 2020. By varying these operation shares (user impacts) and the shares of furnace technology (conventional, modern), the emission factors for the past (1990, 2008, 2014) and the future (2035) were modelled as well. As there is no information on the technology of the appliances in the Swiss wood energy statistics (SFOE 2023b), assumptions had to be made. Only a classification into so-called conventional and modern furnaces was made. Conventional includes furnaces with single-stage combustion and those described as old in the literature, while modern comprises multi-stage furnaces and those designated as new or with the eco-label. Assumptions on technology distribution were made for three commissioning periods (1990-1998: 100% conventional, 1999-2008. 50% conventional/50% modern, 2009-2019: 25% conventional/75% modern) yielding a fleet of 56% conventional and 44% modern single-room furnaces in 2020. Compared to other countries (Austria, Denmark, Germany, Norway and Sweden) with values in the range of 20% to 50% this share of conventional furnaces is rather high.

For log boilers (<50 kW, >50 kW, categories 8-9), limited literature data were available for the derivation of emission factors. Only studies that reflect real operation as far as possible were considered, i.e. that cover the entire combustion process or large parts of it (at least including start or burn-out), and for which data on full and partial load were available. It was also not possible to differentiate between different technologies (conventional, modern).

For automatic boilers >50 kW (categories 12-17), combined heat and power plants (category 18) and plants for renewable waste from wood products (category 19), the emission factors of NO_x, VOC, PM exhaust and CO are derived based on the factors of the different operating phases (start, stop, full load, partial load and stand-by) and their effective combustion heat output, taking into account typical shares of the respective phases.

Besides the emission factors for PM exhaust, those for PM condensable were also derived, see Table 3-13. The condensable PM fractions were estimated using the ratio of PM (total particles)/PM exhaust based on literature data, including measurements by Zotter and Nussbaumer (2022) on some installation types relevant for Switzerland. The model differentiates between manually operated single room stoves / central heating boilers and (larger) automatic combustion installations, see Table 3-14. The latest submission of Switzerland's air pollution emission inventory now also includes the emissions of PM condensable.

A mean constant NMVOC to VOC ratio over time of 0.7 is used for all combustion installation types, based on literature emission data for single-room furnaces and central heating systems of different technology, operating conditions and phases. The shares of PM2.5 in TSP and PM10 in TSP are assumed to be 90 % and 95 %, respectively, for all installation types and the entire time series.

For the temporal development of the emission factors of the priority heavy metals Pb and Cd the same relative development was assumed as for PM and for those of the POPs (PCDD/PCDF, PAHs, HCB and PCBs) as for CO. The emission factors of Hg were assumed to be constant over the entire period.

Table 3-12 Emission factors 2022 of pollutants due to wood combustion from source categories 1A1-1A4 (“w/o wood proc. companies.” stands for “without wood processing companies”). PM2.5, PM10 and TSP correspond to PM total particles, which include both the exhaust (filterable) and condensable fractions.

1A Wood combustion	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Open fireplaces	80	257	10	4.9	175	185	195	59	2'933
Closed fireplaces, log wood stoves	85	236	10	4.9	151	161	168	53	2'720
Pellet stoves	85	13	10	2	67	71	75	13	378
Log wood hearths	70	333	10	4.9	348	367	387	125	3'893
Log wood boilers	100	66	10	2	101	106	112	15	1'620
Log wood dual chamber boilers	70	341	10	4.9	348	367	387	130	4'000
Automatic chip boilers < 50 kW	120	39	10	2	155	164	172	16	860
Automatic pellet boilers < 50 kW	70	13	10	2	29	31	32	6.7	314
Automatic chip boilers 50–300 kW w/o wood proc. companies	129	19	3	2	54	57	60	2.7	433
Automatic pellet boilers 50–300 kW	75	6.9	3	2	29	31	32	1.0	162
Automatic chip boilers 50–300 kW within wood proc. companies	139	19	3	2	54	58	61	2.8	443
Automatic chip boilers 300–500 kW w/o wood proc. companies	129	19	3	2	54	57	60	2.7	433
Automatic pellet boilers 300–500 kW	75	6.9	3	2	29	31	32	1.0	162
Automatic chip boilers 300–500 kW within wood proc. companies	139	19	3	2	54	58	61	2.8	443
Automatic chip boilers > 500 kW w/o wood proc. companies	119	6.7	3	2	9	10	10	0.19	135
Automatic pellet boilers > 500 kW	73	2	3	2	5	5	5	0.10	49
Automatic chip boilers > 500 kW within wood proc. companies	119	6.9	3	2	20	21	21	0.46	146
Combined chip heat and power plants	39	0.29	1	2	0.33	0.33	0.33	0.003	9
Plants for renewable waste from wood products	129	1	19	5	1.4	1.4	1.5	0.03	57

1A Wood combustion	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ /GJ	mg/GJ					ng/GJ
Open fireplaces	19	1	2	487	49	49	29	29	0.0049	59
Closed fireplaces, log wood stoves	19	1	2	487	49	49	29	29	0.0049	59
Pellet stoves	19	1	2	49	10	10	3.9	3.9	0.0049	10
Log wood hearths	19	1	2	487	49	49	29	29	0.0049	59
Log wood boilers	19	1	2	243	29	29	14	14	0.0049	19
Log wood dual chamber boilers	20	1	2	500	100	100	60	60	0.005	60
Automatic chip boilers < 50 kW	19	1	2	96	10	10	3.9	3.9	0.0049	19
Automatic pellet boilers < 50 kW	19	1	2	47	10	10	3.9	3.9	0.0049	10
Automatic chip boilers 50–300 kW w/o wood proc. companies	14	1	2	49	4.7	4.7	2.4	2.4	0.0047	10
Automatic pellet boilers 50–300 kW	14	1	2	49	4.7	4.7	2.4	2.4	0.0047	10
Automatic chip boilers 50–300 kW within wood proc. companies	14	1	2	97	4.7	4.7	2.4	2.4	0.0047	10
Automatic chip boilers 300–500 kW w/o wood proc. companies	9	1	2	49	1	1	1	1	0.0047	10
Automatic pellet boilers 300–500 kW	9	1	2	49	1	1	1	1	0.0047	10
Automatic chip boilers 300–500 kW within wood proc. companies	9	1	2	97	1	1	1	1	0.0047	10
Automatic chip boilers > 500 kW w/o wood proc. companies	9	1	2	49	1	1	1	1	0.00096	10
Automatic pellet boilers > 500 kW	9	1	2	49	1	1	1	1	0.00096	10
Automatic chip boilers > 500 kW within wood proc. companies	9	1	2	97	1	1	1	1	0.00096	10
Combined chip heat and power plants	9	1	2	10	0.1	0.1	0.1	0.1	0.00096	10
Plants for renewable waste from wood products	100	2	2	47	1	1	1	1	0.00096	10

Table 3-13 Emission factors 2022 of PM exhaust (filterable) and PM condensable due to wood combustion from source categories 1A1-1A4 (“w/o wood proc. companies.” stands for “without wood processing companies”).

1A Wood combustion	PM2.5		PM10		TSP	
	ex	cond	ex	cond	ex	cond
	g/GJ					
Open fireplaces	88	88	92	92	97	97
Closed fireplaces, log wood stoves	77	74	82	78	86	82
Pellet stoves	35	32	37	34	39	36
Log wood hearths	174	174	184	184	193	193
Log wood boilers	52	49	54	52	57	55
Log wood dual chamber boilers	180	168	190	177	200	187
Automatic chip boilers < 50 kW	80	75	85	80	89	83
Automatic pellet boilers < 50 kW	26	2.9	28	2.9	29	2.9
Automatic chip boilers 50–300 kW w/o wood proc. companies	49	4.6	52	5.5	55	5.5
Automatic pellet boilers 50–300 kW	26	2.9	28	2.9	29	2.9
Automatic chip boilers 50–300 kW within wood proc. companies	50	4.6	53	5.5	55	5.5
Automatic chip boilers 300–500 kW w/o wood proc. companies	49	4.6	52	5.5	55	5.5
Automatic pellet boilers 300–500 kW	26	2.9	28	2.9	29	2.9
Automatic chip boilers 300–500 kW within wood proc. companies	50	4.6	53	5.5	55	5.5
Automatic chip boilers > 500 kW w/o wood proc. companies	8	0.85	9	0.93	9	0.93
Automatic pellet boilers > 500 kW	5	0.47	5	0.47	5	0.47
Automatic chip boilers > 500 kW within wood proc. companies	17	2.7	18	2.7	19	2.7
Combined chip heat and power plants	0.3	0.03	0.3	0.03	0.3	0.03
Plants for renewable waste from wood products	1.3	0.13	1.3	0.13	1.4	0.14

Table 3-14 Ratios of PM(total particles)/PMexhaust for wood combustion installations (model values, Zotter and Nussbaumer (2022))

<table>
<tr><th rowspan="2">1A Wood combustion</th><th>1990</th><th>2008</th><th>2014</th><th>2020</th><th>2035</th></tr>
<tr><th colspan="5">PM(total particles)/PMexhaust</th></tr>
<tr><td>Open fireplaces</td><td rowspan="7">3</td><td rowspan="7" colspan="3">2</td><td>2</td></tr>
<tr><td>Closed fireplaces, log wood stoves</td><td>1.5</td></tr>
<tr><td>Pellet stoves</td><td>1.3</td></tr>
<tr><td>Log wood hearths</td><td>2</td></tr>
<tr><td>Log wood boilers</td><td>1.5</td></tr>
<tr><td>Log wood dual chamber boilers</td><td>2</td></tr>
<tr><td>Automatic chip boilers < 50 kW</td><td>1.5</td></tr>
<tr><td>Automatic pellet boilers < 50 kW</td><td rowspan="12">1.5</td><td rowspan="12" colspan="4">1.1</td></tr>
<tr><td>Automatic chip boilers 50–300 kW w/o wood proc. companies</td></tr>
<tr><td>Automatic pellet boilers 50–300 kW</td></tr>
<tr><td>Automatic chip boilers 50–300 kW within wood proc. companies</td></tr>
<tr><td>Automatic chip boilers 300–500 kW w/o wood proc. companies</td></tr>
<tr><td>Automatic pellet boilers 300–500 kW</td></tr>
<tr><td>Automatic chip boilers 300–500 kW within wood proc. companies</td></tr>
<tr><td>Automatic chip boilers > 500 kW w/o wood proc. companies</td></tr>
<tr><td>Automatic pellet boilers > 500 kW</td></tr>
<tr><td>Automatic chip boilers > 500 kW within wood proc. companies</td></tr>
<tr><td>Combined chip heat and power plants</td></tr>
<tr><td>Plants for renewable waste from wood products</td></tr>
</table>

Activity data

Categories of wood combustion installations and their respective wood energy consumption (see Table 3-15) are based on the Swiss wood energy statistics (SFOE 2023b, table K) as well as the disaggregation into the individual source categories 1A1a Public electricity and heat production, 1A2gviii Manufacturing industries: Other, 1A4ai Commercia/Institutional, 1A4bi Residential and 1A4ci Agriculture/Forestry/Fishing (SFOE 2022b, table N).

In the statistics, the wood energy consumption of single-room furnaces and central heating systems (fireplaces, stoves and boilers <50 kW, categories 1-11b) is not based on sales figures (and estimated amounts of collected wood) but modelled based on the stock of appliances of the individual installation types and their average type-specific wood consumption. The number of new appliances that are annually commissioned are collected based on sales statistics of the associations of manufacturers and importers of wood furnaces and large DIY markets. The stock of appliances is calculated based on the annual number of new appliances commissioned and their respective average service life assuming that they are all decommissioned when they reach the average service life. The average service life is installation type-specific and varies between 15 years for pellets stoves and automatic boilers and 30 years for tiled stoves. The installation-specific wood consumption is derived from the average rated thermal input and the average number of operating hours, also taking into account whether the installations are operated only to a small extent or not at all since the main heating of the building is provided by another heating system (e.g. gas oil, natural gas). The wood energy consumption of automatic boilers >50 kW (categories 12-17) is based on the actual number of these boilers, which is updated annually based on information from the cantons and manufacturing companies, and their installed capacities. The fuel consumption of combined heat and power plants (category 18) and plants for renewable waste from wood products (category 19) are collected individually due to their small number and large outputs.

As additional data source, specific bottom-up information from the industry is used in order to allocate wood combustion emissions directly. Thus, activity data of wood combustion of 1A2f, 1A2gviii and 1A4ci are allocated on the basis of industry information. The information on the specific processes is documented in the respective EMIS database (EMIS 2024/1A Holzfeuerungen). Note that this specific industry data is subtracted from the activity data of the respective combustion installation category in order to avoid double counting within source category 1A2 and 1A4 (see Figure 3-17):

- Wood energy consumption in source categories 1A2f Brick and tile production (2000-2012), 1A2f Cement production (1994-1997 and from 2009 onwards) and 1A2gviii Fibre-board are subtracted from the activity data of 1A2gviii Automatic chip boiler >500 kW without wood processing companies and 1A2gviii Plants for renewable waste from wood products, respectively.
- From 2013 onwards, also the wood energy consumption in 1A4ci Grass drying has been subtracted from the activity data in 1A4ci Automatic chip boiler >500 kW without wood processing companies.

Table 3-15 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	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	TJ									
Total	44'200	37'314	38'920	42'573	43'570	41'149	43'374	42'649	49'732	47'345
Open fireplaces	84	62	64	68	67	62	62	58	59	42
Closed fireplaces, log wood stoves	8'604	6'824	7'446	7'862	7'540	6'926	6'943	6'375	7'280	6'056
Pellet stoves	190	159	181	199	196	186	187	175	198	166
Log wood hearths	1'454	978	1'006	992	900	792	763	675	748	617
Log wood boilers	3'901	2'820	2'970	3'032	2'852	2'597	2'596	2'320	2'523	2'039
Log wood dual chamber boilers	182	125	119	112	88	67	57	42	38	27
Automatic chip boilers < 50 kW	946	739	786	798	742	667	644	559	582	455
Automatic pellet boilers < 50 kW	2'511	2'099	2'376	2'610	2'619	2'538	2'676	2'489	2'909	2'719
Automatic chip boilers 50–300 kW w/o wood proc. companies	3'183	2'645	3'032	3'350	3'372	3'252	3'379	3'241	3'828	3'275
Automatic pellet boilers 50–300 kW	917	857	1'091	1'310	1'451	1'498	1'635	1'659	2'084	1'845
Automatic chip boilers 50–300 kW within wood proc. companies	1'540	1'282	1'400	1'489	1'486	1'426	1'425	1'374	1'543	1'343
Automatic chip boilers 300–500 kW w/o wood proc. companies	1'751	1'436	1'644	1'816	1'820	1'742	1'817	1'744	2'040	1'746
Automatic pellet boilers 300–500 kW	269	239	279	337	355	352	365	352	433	366
Automatic chip boilers 300–500 kW within wood proc. companies	684	570	600	632	623	617	615	596	658	569
Automatic chip boilers > 500 kW w/o wood proc. companies	5'893	5'015	5'843	6'575	6'778	6'525	6'980	7'083	8'325	7'185
Automatic pellet boilers > 500 kW	297	281	317	364	362	346	370	354	423	361
Automatic chip boilers > 500 kW within wood proc. companies	2'905	2'407	2'568	2'653	2'546	2'397	2'425	2'328	2'613	2'285
Combined chip heat and power plants	5'421	5'325	3'830	3'970	4'887	4'696	5'921	6'319	6'795	7'294
Plants for renewable waste from wood products	3'468	3'450	3'367	4'404	4'887	4'463	4'513	4'906	6'653	8'954

3.2.1.1.3 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 chapter 1A1 Energy industries in the EMEP/EEA guidebook (EMEP/EEA 2023).

Methodology

The model for calculating emissions from stationary engines and gas turbines underwent an extensive revision during the years 2021 to 2022 and were finally implemented for the latest data submission 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 to 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 taken from various sources based on measurements, modelling and literature and described in INFRAS (2022a). SO_x is country-specific, see chp. 3.2.1.2, Table 3-30Table 3-28. For other air pollutants, the main data sources are EMEP/EEA (2023), UBA (2020), Norwegian Environment Agency (2020), Ecoinvent (2021), Ebertsch 2021 and Aschmann et al. (2019). The following sources are used for the emission factors of stationary engines and gas turbines, depending on the fuel used:

- Emission factors for NO_x and CO are primarily based on measurements and given in INFRAS 2022a. Exhaust particulate matter (PM) including TSP, PM10 and PM2.5 as well as BC exhaust emission factors stem from tables 3-29, 3-30 and 3-31 (Tier 2) of chapter 1A4 Small combustion of the EMEP/EEA guidebook (EMEP/EEA 2023). Considering the measuring procedure and the recommended sample temperature of 160°C, it can be assumed that PM condensable are not included in the measurements.
- NMVOC emissions are calculated as the difference of VOC and CH_4 emissions given in INFRAS (2022a).
- VOC emission factors stem from tables 3-29, 3-30 and 3-31 (Tier 2) of chapter 1A4 Small combustion of the EMEP/EEA guidebook (EMEP/EEA 2023).
- CH_4 emission factors originate from table 87 of the National Inventory Report for the German Greenhouse Gas Inventory 1990 – 2018, UBA (2020).
- SO_x emission factors are based upon the sulphur content of fuels (see chp. 3.2.1.2). These are country- and fuel-specific, see implied emission factors in Table 3-30 (column diesel oil, gas oil, natural gas) and in specific tables below.
- Emission factors for NH_3 are generally taken from Ecoinvent (2021) and the Norwegian Environment Agency (2020) for all categories, except for installations with SCR catalysts, where the corresponding limit values were taken as defined in the Federal Ordinance on Air Pollution Control OAPC (Swiss Confederation 1985).
- Emission factors for priority heavy metals, PCDD/PCDF, PAHs as well as HCB and PCB stem from tables 3-29, 3-30 and 3-31 (Tier 2) of chapter 1A4 Small combustion of the EMEP/EEA guidebook (EMEP/EEA 2023).

Table 3-16 Emission factors of engines and gas turbines in 1A1 Energy industries.

1A1a Public electricity and heat production (engines and gas turbines)	**NO_x**	**NMVOC**	**SO_x**	**NH_3**	**PM2.5**	**PM10**	**TSP**	**BC**	**CO**
	g/GJ								
Gas turbines as SCGT or CCGT									
Gas oil	83	0.18	2.0	0.10	10	10	10	0.32	2.6
Natural gas	31	1.6	0.18	NA	0.2	0.2	0.2	0.0005	13
Biogas	48	1.6	0.5	NA	0.2	0.2	0.2	0.0005	13
Gas turbines with CHP unit									
Gas oil	83	0.18	2.0	0.10	10	10	10	0.32	2.6
Natural gas	32	1.6	0.18	NA	0.23	0.23	0.23	0.0005	10
Biodiesel	83	0.18	0.31	0.10	9.5	9.5	9.5	0.32	2.6
Biogas	48	1.6	0.5	NA	0.23	0.23	0.23	0.0005	10
Engines with CHP unit									
Gas oil	136	50	2.0	8.9	30	30	30	2.3	136
Natural gas	72	89	0.18	2.4	2.0	2.0	2.0	0.0041	54
Biodiesel	406	50	0.31	3.5	30	30	30	2.3	132
Biogas	97	89	0.5	2.4	2.0	2.0	2.0	0.0041	88
Engines used as emergency generators									
Gas oil	942	50	2.0	0.10	27	27	27	2.3	137
Engines on landfills									
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	101	89	0.5	2.9	2.0	2.0	2.0	0.0040	129
1A1b Petroleum refining (gas turbines)	g/GJ								
Gas turbines as SCGT at refineries									
Refinery gas	NO	NO	NO	NO	NO	NO	NO	NO	NO

1A1a Public electricity and heat production (engines and gas turbines)	**Pb**	**Cd**	**Hg**	**PCDD/ PCDF**	**BaP**	**BbF**	**BkF**	**IcdP**	**HCB**	**PCB**
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Gas turbines as SCGT or CCGT										
Gas oil	0.012	0.001	0.12	1.8	NO	NA	NA	NA	NA	NA
Natural gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Biogas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Gas turbines with CHP unit										
Gas oil	0.012	0.001	0.12	1.8	NA	NA	NA	NA	NA	NA
Natural gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Biodiesel	0.012	0.001	0.12	1.8	NA	NA	NA	NA	NA	NA
Biogas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Engines with CHP unit										
Gas oil	0.15	0.01	0.11	1.0	0.0019	0.015	0.0017	0.0015	220	0.11
Natural gas	0.04	0.003	0.10	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Biodiesel	0.15	0.01	0.11	1.0	0.0019	0.015	0.0017	0.0015	220	0.11
Biogas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Engines used as emergency generators										
Gas oil	0.15	0.01	0.11	1.0	0.0019	0.015	0.0017	0.0015	220	0.11
Engines on landfills										
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
1A1b Petroleum refining (gas turbines)	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Gas turbines as SCGT at refineries										
Refinery gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 3-17 Emission factors of engines and gas turbines in 1A2 Manufacturing industry and construction.

1A2d Pulp, paper and print (gas turbines)	**NO_x**	**NMVOC**	**SO_x**	**NH_3**	**PM2.5**	**PM10**	**TSP**	**BC**	**CO**
	g/GJ								
Gas turbines as SCGT or CCGT									
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2gviii Other (engines and gas turbines)	g/GJ								
Gas turbines as SCGT or CCGT									
Natural gas	95	1.6	0.18	NA	0.2	0.2	0.2	0.0005	9.4
Biogas	48	1.6	0.5	NA	0.2	0.2	0.2	0.0005	9.4
Gas turbines with CHP unit									
Liquefied petroleum gas	48	1.6	0.5	NA	0.2	0.2	0.2	0.0005	4.8
Engines with CHP unit									
Liquefied petroleum gas	135	89	0.5	NA	2.0	2.0	2.0	0.005	56
Engines with CHP unit at biogas plants									
Biogas	101	89	0.5	3.6	2.0	2.0	2.0	0.0040	136

1A2d Pulp, paper and print (gas turbines)	**Pb**	**Cd**	**Hg**	**PCDD/ PCDF**	**BaP**	**BbF**	**BkF**	**IcdP**	**HCB**	**PCB**
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Gas turbines as SCGT or CCGT										
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2gviii Other (engines and gas turbines)	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Gas turbines as SCGT or CCGT										
Natural gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Biogas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Gas turbines with CHP unit										
Liquefied petroleum gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Engines with CHP unit										
Liquefied petroleum gas	0.04	0.003	0.1	0.57	0.0013	0.009	0.0017	0.0018	NA	NA
Engines with CHP unit at biogas plants										
Biogas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA

Table 3-18 Emission factors of engines and gas turbines in 1A3 Transport.

1A3ei Pipeline transport (gas turbines)	**NO_x**	**NMVOC**	**SO_x**	**NH_3**	**PM2.5**	**PM10**	**TSP**	**BC**	**CO**
	g/GJ								
Gas turbines as SCGT at compressor station for gas pipelines									
Natural gas	32	1.6	0.18	NA	0.2	0.2	0.2	0.0005	10
Biogas	48	1.6	0.5	NA	0.2	0.2	0.2	0.0005	10

1A3ei Pipeline transport (gas turbines)	**Pb**	**Cd**	**Hg**	**PCDD/ PCDF**	**BaP**	**BbF**	**BkF**	**IcdP**	**HCB**	**PCB**
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Gas turbines as SCGT at compressor station for gas pipelines										
Natural gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Biogas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA

Table 3-19 Emission factors of engines and gas turbines in 1A4ai Other sectors: commercial/institutional.

1A4ai Other sectors (stationary): Commercial/ institutional (engines and gas turbines)	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Engines with CHP unit									
Gas oil	136	50	2.0	8.9	30	30	30	2.3	136
Natural gas	72	89	0.18	2.4	2.0	2.0	2.0	0.0041	54
Liquefied petroleum gas	135	89	0.5	NA	2.0	2.0	2.0	0.005	56
Biodiesel	406	50	0.31	3.5	30	30	30	2.3	132
Biogas	97	89	0.5	2.4	2.0	2.0	2.0	0.0041	88
Engines with CHP unit at biogas plants									
Liquefied petroleum gas	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biodiesel	156	50	0.31	8.7	30	30	30	2.3	136
Biogas	101	89	0.5	3.6	2.0	2.0	2.0	0.0040	136
Engines used as emergency generators									
Gas oil	915	50	2.0	0.40	14	14	14	2.3	137
Gas turbines at sewage plants									
Natural gas	53	1.6	0.18	NA	0.2	0.2	0.2	0.0005	25
Sewage gas	48	1.6	0.5	NA	0.23	0.23	0.23	0.0005	10
Engines with CHP unit at sewage plants									
Natural gas	310	89	0.18	NA	2.0	2.0	2.0	0.005	76
Sewage gas	103	89	0.5	1.8	2.0	2.0	2.0	0.0043	144

1A4ai Other sectors (stationary): Commercial/ institutional (engines and gas turbines)	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Engines with CHP unit										
Gas oil	0.15	0.01	0.11	0.99	0.0019	0.015	0.0017	0.0015	220	0.11
Natural gas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Liquefied petroleum gas	0.04	0.003	0.1	0.57	0.0013	0.009	0.0017	0.0018	NA	NA
Biodiesel	0.15	0.01	0.11	0.99	0.0019	0.015	0.0017	0.0015	220	0.11
Biogas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Engines with CHP unit at biogas plants										
Liquefied petroleum gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biodiesel	0.15	0.01	0.11	0.99	0.0019	0.015	0.0017	0.0015	220	0.11
Biogas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Engines used as emergency generators										
Gas oil	0.15	0.01	0.11	0.99	0.0019	0.015	0.0017	0.0015	220	0.11
Gas turbines at sewage plants										
Natural gas	0.0015	0.00025	0.1	0.50	0.00056	0.00084	0.00084	0.00084	NA	NA
Sewage gas	0.0015	0.00025	0.1	0.50	0.00056	0.00084	0.00084	0.00084	NA	NA
Engines with CHP unit at sewage plants										
Natural gas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Sewage gas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA

Table 3-20 Emission factors of engines and gas turbines in 1A4bi Other sectors: residential.

1A4bi Other sectors (stationary): Residential (engines)	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Engines with CHP unit									
Gas oil	136	50	2.0	8.9	30	30	30	1.17	136
Natural gas	72	89	0.18	2.4	2.0	2.0	2.0	0.0041	54
Liquefied petroleum gas	135	89	0.5	NA	2.0	2.0	2.0	0.005	56
Biodiesel	406	50	0.31	3.5	30	30	30	2.34	132
Biogas	97	89	0.5	2.4	2.0	2.0	2.0	0.0041	88

1A4bi Other sectors (stationary): Residential (engines)	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Engines with CHP unit										
Gas oil	0.15	0.01	0.11	0.99	0.0019	0.015	0.0017	0.0015	220	0.11
Natural gas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Liquefied petroleum gas	0.04	0.003	0.1	0.57	0.0013	0.009	0.0017	0.0018	NA	NA
Biodiesel	0.15	0.01	0.11	0.99	0.0019	0.015	0.0017	0.0015	220	0.11
Biogas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA

Table 3-21 Emission factors of engines and gas turbines in 1A4ci Other sectors: agriculture/forestry/fishing.

1A4ci Agriculture/forestry/fishing (engines)	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Engines used as emergency generators									
Gas oil	942	50	2.0	0.10	28	28	28	2.3	137
Engines with CHP unit at biogas plants									
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	100	89	0.5	3.0	2.0	2.0	2.0	0.0039	111

1A4ci Agriculture/forestry/fishing (engines)	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Engines used as emergency generators										
Gas oil	0.15	0.01	0.11	0.99	0.0019	0.0150	0.0017	0.0015	220	0.11
Engines with CHP unit at biogas plants										
Natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	0.04	0.003	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA

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 informative 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 are updated annually with newest available information concerning fuel consumption from SFOE 2023a and SFOE 2023, respectively.

Table 3-22 Activity data of engines and gas turbines in 1A1 Energy industries.

1A1a Public electricity and heat production (engines and gas turbines)	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
Total fuel consumption	TJ	421	1'907	2'276	2'377	3'280
Gas turbines as SCGT or CCGT	TJ	28	811	873	1143	2443
Gas oil	TJ	24	33	33	33	33
Natural gas	TJ	3.5	779	840	1'110	2'410
Biogas	TJ	NO	NO	NO	NO	NO
Gas turbines with CHP unit	TJ	73	34	NO	47	47
Gas oil	TJ	6.7	3.6	NO	8.1	3.6
Natural gas	TJ	66	31	NO	39	42
Biodiesel	TJ	NO	NO	NO	0.10	0.64
Biogas	TJ	NO	NO	NO	NO	NO
Engines with CHP unit	TJ	81	451	834	969	726
Gas oil	TJ	7.5	47	179	167	55
Natural gas	TJ	73	405	655	799	661
Biodiesel	TJ	NO	NO	NO	2.1	10
Biogas	TJ	NO	NO	NO	NO	NO
Engines used as emergency generators	TJ	1.4	1.4	1.5	1.5	1.6
Gas oil	TJ	1.4	1.4	1.5	1.5	1.6
Engines on landfill sites	TJ	238	609	568	218	63
Natural gas	TJ	NO	NO	NO	14	14
Biogas	TJ	238	609	568	204	49
1A1b Petroleum refining (gas turbines)	TJ	NO	NO	2'575	2'270	1'808
Gas turbines as SCGT at refineries	TJ	NO	NO	2'575	2'270	1'808
Refinery gas	TJ	NO	NO	2'575	2'270	1'808

1A1a Public electricity and heat production (engines and gas turbines)	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel consumption	TJ	3'044	1741	2921	4709	3748	3643	3649	3566	3577	3718
Gas turbines as SCGT or CCGT	TJ	2'361	1'114	2'339	4'187	3'278	3241	3293	3216	3228	3352
Gas oil	TJ	33	33	33	33	33	33	33	7.2	7.2	7.5
Natural gas	TJ	2'328	1'082	2'306	4'154	3'245	3'208	3'260	3'208	3'083	3'167
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	137	177
Gas turbines with CHP unit	TJ	15	14	13	6.9	3.7	3.4	3.0	3.0	3.0	3.1
Gas oil	TJ	0.70	0.69	0.59	0.29	0.20	0.12	0.16	0.16	0.15	0.15
Natural gas	TJ	14	13	12	6.5	3.5	3.2	2.8	2.7	2.7	2.8
Biodiesel	TJ	0.22	0.22	0.19	0.10	0.065	0.057	0.057	0.055	0.054	0.055
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	0.11	0.12	0.15
Engines with CHP unit	TJ	613	568	546	501	459	391	343	342	341	352
Gas oil	TJ	29	27	25	21	24	14	18	18	17	17
Natural gas	TJ	576	532	513	473	426	370	319	305	304	311
Biodiesel	TJ	8.9	8.8	8.0	7.6	8.0	6.6	6.4	6.3	6.1	6.2
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	13	14	17
Engines used as emergency generators	TJ	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.7	1.8	1.8
Gas oil	TJ	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.7	1.8	1.8
Engines on landfill sites	TJ	53	43	21	12	7	6.0	8.4	4.0	4.0	8.4
Natural gas	TJ	15	11	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	TJ	38	31	21	12	6.5	6.0	8.4	4.0	4.0	8.4
1A1b Petroleum refining (gas turbines)	TJ	1'748	1'879	293	NO	NO	NO	NO	NO	NO	NO
Gas turbines as SCGT at refineries	TJ	1'748	1'879	293	NO	NO	NO	NO	NO	NO	NO
Refinery gas	TJ	1'748	1'879	293	NO	NO	NO	NO	NO	NO	NO

Table 3-23 Activity data of engines and gas turbines in 1A2 Manufacturing industry and construction.

1A2d Pulp, paper and print (gas turbines)	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
Total fuel consumption	TJ	NO	477	808	245	211
Gas turbines as SCGT or CCGT	TJ	NO	477	808	245	211
Natural gas	TJ	NO	477	808	245	211
1A2gviii Other (engines and gas turbines)	TJ	655	821	969	1233	1588
Gas turbines as SCGT or CCGT	TJ	613	721	810	1073	1355
Natural gas	TJ	613	721	810	1073	1355
Biogas	TJ	NO	NO	NO	NO	NO
Gas turbines with CHP unit	TJ	0.68	0.87	NO	1.5	2.3
Liquefied petroleum gas	TJ	0.68	0.87	NO	1.5	2.3
Engines with CHP unit	TJ	0.75	11	33	30	35
Liquefied petroleum gas	TJ	0.75	11	33	30	35
Engines with CHP unit at biogas plants	TJ	41	87	126	128	195
Biogas	TJ	41	87	126	128	195

1A2d Pulp, paper and print (gas turbines)	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel consumption	TJ	289	304	341	NO	NO	NO	NO	NO	NO	NO
Gas turbines with CHP unit	TJ	289	304	341	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	289	304	341	NO	NO	NO	NO	NO	NO	NO
1A2gviii Other (engines and gas turbines)	TJ	1'388	548	429	451	415	353	354	346	359	393
Gas turbines as SCGT or CCGT	TJ	1115	238	145	145	145	145	145	145	145	151
Natural gas	TJ	1'115	238	145	145	145	145	145	145	139	143
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	6.2	8.0
Gas turbines with CHP unit	TJ	0.71	0.79	0.66	0.54	0.12	0.081	0.066	0.064	0.063	0.064
Liquefied petroleum gas	TJ	0.71	0.79	0.66	0.54	0.12	0.081	0.066	0.064	0.063	0.064
Engines with CHP unit	TJ	29	31	28	39	14	9.4	7.4	7.3	7.1	7.2
Liquefied petroleum gas	TJ	29	31	28	39	14	9.4	7.4	7.3	7.1	7.2
Engines with CHP unit at biogas plants	TJ	243	278	256	267	256	199	201	194	206	235
Biogas	TJ	243	278	256	267	256	199	201	194	206	235

Table 3-24 Activity data of engines and gas turbines in 1A3 Transport.

1A3ei Pipeline transport (gas turbines)	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	560	310	340	1070	830
Gas turbines as SCGT at compressor station for gas pipelines	TJ	560	310	340	1'070	830
Natural gas	TJ	560	310	340	1'070	830
Biogas	TJ	NO	NO	NO	NO	NO

1A3ei Pipeline transport (gas turbines)	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total fuel consumption	TJ	410	830	760	340	470	490	600	540	143	430
Gas turbines as SCGT at compressor station for gas pipelines	TJ	410	830	760	340	470	490	600	540	143	430
Natural gas	TJ	410	830	760	340	470	490	600	540	120	400
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	23	30

Table 3-25 Activity data of engines and gas turbines in 1A4a Other sectors: commercial/institutional.

1A4ai Other sectors (stationary): Commercial/institutional (engines and gas turbines)	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	1'572	2973	4524	5062	4603
Engines with CHP unit	TJ	401	1614	2852	3236	2407
Gas oil	TJ	44	171	580	539	178
Natural gas	TJ	355	1'407	2'169	2'596	2'089
Liquefied petroleum gas	TJ	2.4	36	103	95	109
Biodiesel	TJ	NO	NO	NO	6.5	31
Biogas	TJ	NO	NO	NO	NO	NO
Engines with CHP unit at biogas plants	TJ	NO	32	113	144	420
Liquefied petroleum gas	TJ	NO	2.9	5.6	NO	NO
Biodiesel	TJ	NO	NO	26	1.4	26
Biogas	TJ	NO	29	82	143	394
Engines used as emergency generators	TJ	383	383	391	396	405
Gas oil	TJ	383	383	391	396	405
Gas turbines at sewage plants	TJ	179	169	66	NO	18
Natural gas	TJ	NO	0.23	0.073	NO	0.019
Sewage gas	TJ	179	169	66	NO	18
Engines with CHP unit at sewage plants	TJ	610	776	1'102	1'286	1'353
Natural gas	TJ	NO	1.0	1.2	1.4	1.4
Sewage gas	TJ	610	775	1'100	1'284	1'351

1A4ai Other sectors (stationary): Commercial/institutional (engines and gas turbines)	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total fuel consumption	TJ	4'521	4'349	4'260	4'181	4'008	3'813	3'643	3'639	3'621	3'716
Engines with CHP unit	TJ	2'019	1'881	1'784	1'681	1'470	1'244	1'091	1'085	1'082	1'118
Gas oil	TJ	92	88	77	66	76	44	57	55	54	54
Natural gas	TJ	1'809	1'668	1'596	1'469	1'325	1'151	991	948	945	968
Liquefied petroleum gas	TJ	91	97	87	121	44	29	23	23	22	23
Biodiesel	TJ	28	27	25	24	25	21	20	19	19	19
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	39	42	54
Engines with CHP unit at biogas plants	TJ	732	724	762	806	827	843	830	823	804	913
Liquefied petroleum gas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biodiesel	TJ	24	23	24	25	20	24	17	17	16	16
Biogas	TJ	709	701	738	780	807	818	813	807	787	897
Engines used as emergency generators	TJ	410	412	413	415	417	420	421	413	411	409
Gas oil	TJ	410	412	413	415	417	420	421	413	411	409
Gas turbines at sewage plants	TJ	18	25	25	27	26	34	34	34	34	33
Natural gas	TJ	0.020	0.027	0.029	0.25	0.23	0.24	0.23	0.21	0.20	0.19
Sewage gas	TJ	18	25	25	26	26	34	33	34	34	33
Engines with CHP unit at sewage plants	TJ	1'341	1'308	1'276	1'253	1'268	1'272	1'268	1'284	1'290	1'243
Natural gas	TJ	1.5	1.4	1.5	12	11	8.8	8.6	8.0	7.7	7.3
Sewage gas	TJ	1'340	1'306	1'274	1'241	1'257	1'264	1'259	1'276	1'282	1'236

Table 3-26 Activity data of engines and gas turbines in 1A4b Other sectors: residential.

1A4bi Other sectors (stationary): Residential (engines)	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	45	179	317	360	267
Engines with CHP unit	TJ	45	179	317	360	267
Gas oil	TJ	4.9	19	64	60	20
Natural gas	TJ	39	156	241	288	232
Liquefied petroleum gas	TJ	0.26	4.0	11	11	12
Biodiesel	TJ	NO	NO	NO	0.72	3.4
Biogas	TJ	NO	NO	NO	NO	NO

1A4bi Other sectors (stationary): Residential (engines)	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total fuel consumption	TJ	224	209	198	187	163	138	121	121	120	124
Engines with CHP unit	TJ	224	209	198	187	163	138	121	121	120	124
Gas oil	TJ	10	10	8.5	7.4	8.4	4.8	6.4	6.2	6.0	6.0
Natural gas	TJ	201	185	177	163	147	128	110	105	105	108
Liquefied petroleum gas	TJ	10	11	10	14	4.9	3.3	2.6	2.5	2.5	2.5
Biodiesel	TJ	3.1	3.1	2.8	2.6	2.8	2.3	2.2	2.2	2.1	2.2
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	4.3	4.7	6.0

Table 3-27 Activity data of engines and gas turbines in 1A4c Other sectors: agriculture/forestry/fishing.

1A4ci Agriculture/forestry/fishing (engines)	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	61	51	64	130	499
Engines used as emergency generators	TJ	2.1	2.1	2.1	2.1	2.1
Gas oil	TJ	2.1	2.1	2.1	2.1	2.1
Engines with CHP unit at biogas plants	TJ	59	49	62	128	497
Natural gas	TJ	2.7	1.3	2.5	2.3	NO
Biogas	TJ	59	49	62	128	497

1A4ci Agriculture/forestry/fishing (engines)	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total fuel consumption	TJ	814	930	1043	1194	1274	1405	1614	1764	1911	1948
Engines used as emergency generators	TJ	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Gas oil	TJ	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Engines with CHP unit at biogas plants	TJ	812	928	1041	1192	1272	1403	1612	1762	1909	1946
Natural gas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biogas	TJ	812	928	1041	1192	1272	1403	1612	1762	1909	1946

3.2.1.2 Country-specific and fuel-specific default emission factors for 1A Fuel combustion

Methodology

For fossil standard fuels in source category 1A Fuel combustion, we use country-specific and fuel-specific default emission factors, whose values are applicable to several source categories, for SO_2 only. This is appropriate for SO_2 because in many cases, the amount of SO_2 emitted per amount of fuel burned 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_2 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 3-29. 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 3-28. This approach is used in particular for bituminous coal and lignite.

The SO_2 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:

$EF_{SO2,i}$ is the emission factor for SO_2 for a given fuel *i* (g/GJ)

M_{SO2} is the molar mass of SO_2 (g/mol)

M_S is the molar mass of sulphur (g/mol)

$C_{S,i}$ is the measured sulphur content of the given fuel *i* if applicable, otherwise the maximum legal limit for sulphur content (g/t)

NCV_i is the net calorific value for the given fuel *i* (GJ/t)

The obtained country-specific and fuel-specific SO_2 emission factors are reported in Table 3-30.

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 2022b). 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 2023). 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_2/GJ) shown in Table 3-28 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 SO2/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_2 for jet kerosene. Category-specific emission factors are reported in their respective chapters.

Table 3-28 Legal limits for sulphur content per fuel type.

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
2022	10	10	1'000	50	190	10'000	28'000	10'000	30'000

Table 3-29 Measured sulphur content per fuel type.

	Measured sulphur content in fuels				
Fuel	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	788	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	8.6	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	6.2	4.8	551	17	6'567

Table 3-30 Country-specific and fuel-specific default emissions factors for SO_x used within source category 1A Fuel combustion activities, 1990-2022.

	SO_X (as SO_2) country-specific and fuel-specific default emission factors used for Switzerland's emission inventory									
Fuel	Diesel oil, biodiesel (average in 1A3b)	Gasoline, bioethanol (average in 1A3b)	Gas oil (boilers and engines in 1A1a, 1A2, 1A4)	Natural gas (boilers and engines in 1A1, 1A2, 1A4, 1A3e)	Natural gas (for 1A3b only)	Biogas, sewage gas, landfill gas, LPG	Res. fuel oil (boilers in 1A1a, 1A2)	Lignite (boilers in 1A2g)	Bituminous coal (boilers in 1A1a, 1A2g)	Bituminous coal (boilers in 1A4b)
Unit	g/GJ									
1990	69	8.5	72	0.50	NO	0.5	466	500	500	350
1991	61	8.5	64	0.50	NO	0.5	440	500	500	350
1992	54	8.5	55	0.50	NO	0.5	424	500	500	350
1993	41	8.5	55	0.50	NO	0.5	404	500	500	350
1994	28	8.5	55	0.50	NO	0.5	391	500	500	350
1995	18	8.5	58	0.50	NO	0.5	376	500	500	350
1996	17	8.5	56	0.50	NO	0.5	364	500	500	350
1997	18	8.5	52	0.50	NO	0.5	373	500	500	350
1998	19	8.5	44	0.50	NO	0.5	348	500	500	350
1999	17	8.5	35	0.50	NO	0.5	341	500	500	350
2000	15	6.8	34	0.50	NO	0.5	339	500	500	350
2001	12	5.1	36	0.50	0.50	0.5	372	500	500	350
2002	11	3.5	37	0.50	0.50	0.5	393	500	500	350
2003	6.8	1.8	36	0.49	0.49	0.5	383	500	500	350
2004	3.3	0.8	36	0.47	0.47	0.5	377	500	500	350
2005	0.28	0.23	35	0.45	0.45	0.5	381	500	500	350
2006	0.30	0.26	32	0.43	0.43	0.5	395	500	500	350
2007	0.30	0.25	30	0.43	0.43	0.5	413	500	500	350
2008	0.32	0.25	27	0.43	0.43	0.5	430	500	500	350
2009	0.32	0.23	25	0.43	0.43	0.5	435	500	500	350
2010	0.32	0.22	23	0.43	0.43	0.5	438	500	500	350
2011	0.31	0.21	23	0.42	0.42	0.5	435	500	500	350
2012	0.31	0.22	19	0.44	0.44	0.5	437	500	500	350
2013	0.32	0.21	18	0.44	0.44	0.5	431	500	500	350
2014	0.33	0.20	14	0.44	0.44	0.5	416	500	500	350
2015	0.33	0.20	14	0.43	0.43	0.5	396	500	500	350
2016	0.35	0.21	11	0.43	0.43	0.5	448	500	500	350
2017	0.34	0.22	8.8	0.38	0.38	0.5	453	500	500	350
2018	0.33	0.24	8.4	0.38	0.38	0.5	460	500	500	350
2019	0.32	0.24	7.8	0.13	0.13	0.5	356	500	500	350
2020	0.32	0.22	6.8	0.15	0.15	0.5	269	500	500	350
2021	0.31	0.22	4.9	0.039	0.039	0.5	290	500	500	350
2022	0.31	0.22	2.0	0.18	0.18	0.5	297	500	500	350

3.2.2 Source category 1A1 - Energy industries (stationary)

3.2.2.1 Source category description for 1A1 Energy industries (stationary)

The most important source category in Energy industries 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 very small charcoal production activity in traditional and historic trade.

Table 3-31 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 bioegene 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_e; 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

Table 3-32 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1A1, Energy Industries.

NFR code	Source category	Pollutant	Identification criteria
1A1a	Public electricity and heat production	NOx	L1, L2
1A1a	Public electricity and heat production	SOx	L1, L2, T2
1A1a	Public electricity and heat production	PM2.5	T1, T2
1A1a	Public electricity and heat production	PM10	T1

3.2.2.2 Methodological issues for 1A1 Energy industries (stationary)

3.2.2.2.1 Public electricity and heat production (1A1a)

Methodology (1A1a)

Within source category 1A1a Energy industries, heat and electricity production in waste incineration plants cause the largest emissions, as electricity production in Switzerland is dominated by hydroelectric power plants (almost 60 %) and nuclear power stations (more than 30 %). Emissions from industries producing heat and/or power for their own use are included in category 1A2 Manufacturing industries and construction.

Energy recovery from municipal solid waste incineration is mandatory in Switzerland and plants are equipped with energy recovery systems (Schwager 2005). The emissions from municipal solid waste and special waste incineration plants are therefore reported under category 1A1a.

Emissions from fuel combustion in 1A1a Public electricity and heat production are estimated using a Tier 2 method, see decision tree in chapter 1A1 Energy industries in EMEP/EEA guidebook (EMEP/EEA 2019).

Emission factors (1A1a)

Municipal solid waste incineration plants and special waste incineration plants with heat and power generation (reported under "Other fuels"):

Emission factors are expressed in pollutant per energy content of municipal solid waste incinerated. They are all country-specific and based on extensive and repeated emission control measurements according to the Ordinance on Air Pollution Control on municipal solid waste incineration and special waste incineration plants (TBF 2005, TBF 2015, TBF 2021) as well as on expert estimates. The sources are documented in the EMIS database (EMIS 2024/1A1a Kehrichtverbrennungsanlagen and EMIS 2024/1A1a Sonderabfallverbrennungsanlagen). Emission factors are taking into account flue gas cleaning standards in incineration plants. In addition, the burn-out efficiency in modern municipal solid and special waste incineration plants is very high. The PCB emission factors from municipal solid waste and special waste incineration are based on the mass flow and emission model of former use and disposal of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

Until 2003 the same emission factors have been applied for special waste and municipal solid waste incineration plants (TBF 2005). The emission factors have been reevaluated and revised for the two types of installations separately for the years 2013 and 2018 (TBF 2015, TBF 2021). In general, emission factors for sewage sludge incineration plants are considerably higher compared to those for municipal solid waste incineration plants. Regardless, special waste incineration plants meet equal Ordinance on Air Pollution Control emission limit values as municipal solid waste incineration plants.

Wood for combined heat and power generation as well as for heat production:

Emission factors for wood as fuel for combined heat and power generation as well as in plants for renewable waste from wood products are based on a study for wood use in the sector 1A (EMIS 2024/1A Holzfeuerungen) as described in chapter 3.2.1.1.2.

Fossil fuels for heat production and for power generation with boilers not further defined:

Emission factors for NO_x, CO, NMVOC, SO_x and PM2.5/PM10/TSP are country-specific and are documented in SAEFL 2000 (pp. 14 – 27). For NO_x emission factors, expert judgement has been used to estimate the fraction of low-NO_x burners. The emission factors for NO_x and CO for natural gas and gas oil are based on Leupro (2012).

Emission factors for Hg, Pb, Cd, PCDD/PCDF and PAH are taken from the EMEP/EEA guidebook (EMEP/EEA 2019) as follows:

- Gas oil; PAH: chp. 1A4, Tier 1, Table 3.9 liquid fuels
- Gas oil; Pb, Hg, Cd, PCDD/PCDF: chp. 1A4, Table 3.18
- Natural gas; Pb, Hg, Cd, PAH: chp. 1A4, Tier 2, Table 3.13
- Natural gas; PCDD/PCDF: chp. 1A4, Tier 2 Table 3.28

The emission factors of HCB and PCBs are taken from the Danish emission inventory for HCB and PCBs (Nielsen et al. 2013).

Engines and gas turbines

The use of fossil and biogenic fuels in engines and gas turbines is described in the specific model description chp. 3.2.1.1.3.

Table 3-33 Implied emission factors for 1A1a Public electricity and heat production of energy industries for each fuel category in 2022.

1A1a Public electricity and heat production	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ								
Gas oil	41	4.2	2.0	0.37	1.7	1.7	1.7	0.12	12
Residual fuel oil	NO	NO	NO	NO	NO	NO	NO	NO	NO
Petroleum coke	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	26	5.9	0.18	0.113	0.24	0.24	0.24	0.0030	13
Other fuels (MSW)	32	2.4	4.4	0.39	0.69	0.69	0.69	0.0062	6.1
Other fuels (special waste)	38	7.6	1.2	0.82	1.7	1.7	1.7	0.015	12
Biomass (wood and wood waste)	57	0.44	4.6	2.6	0.55	0.55	0.57	0.0084	19
Biogas (engines and gas turbines)	54	13	0.5	0.32	0.42	0.42	0.43	0.00096	24
Biodiesel (engines and gas turbines)	403	50	0.31	3.5	30	30	30	2.3	131

1A1a Public electricity and heat production	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	g/TJ				mg/TJ	
Gas oil	0.018	0.0014	0.12	0.0018	0.0019	0.015	0.0017	0.0015	0.22	0.00011
Residual fuel oil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Petroleum coke	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	0.0033	0.00038	0.1	0.00050	0.00059	0.0012	0.00088	0.00089	NA	NA
Other fuels (MSW)	25	2.5	5.8	0.017	NE	NE	NE	NE	3.8	1.4
Other fuels (special waste)	70	6.3	2.1	0.013	NE	NE	NE	NE	NE	0.49
Biomass (wood and wood waste)	27	1.2	2.0	0.017	0.27	0.27	0.27	0.27	0.96	0.01
Biogas (engines and gas turbines)	0.0064	0.00060	0.1	0.00051	0.00064	0.0019	0.00095	0.0010	NA	NA
Biodiesel (engines and gas turbines)	0.15	0.0099	0.11	0.0010	0.0019	0.015	0.0017	0.0015	0.22	0.00011

Activity data (1A1a)

Municipal solid waste incineration

Activity data for municipal solid waste and special waste incineration are based on annual waste statistics (FOEN 2023h) and provided in the table below.

Table 3-34 Activity data for 1A1a Other fuels: municipal solid waste and special waste incineration plants (with heat and/or power generation).

1A1a Other fuels	Unit	1990	1995	2000	2005	2010
Total Other fuels	kt	2'603	2'433	3'040	3'527	3'968
Municipal solid waste (MSW)	kt	2'470	2'270	2'801	3'297	3'717
Special waste	kt	133	163	239	230	252

1A1a Other fuels	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total Other fuels	kt	4'035	4'066	4'150	4'264	4'248	4'297	4'322	4'312	4'245	4'115
Municipal solid waste (MSW)	kt	3'773	3'817	3'889	4'010	4'011	4'042	4'059	4'072	4'027	3'853
Special waste	kt	262	249	261	254	236	255	262	241	218	261

Engines and gas turbines

The use of fossil and biogenic fuels in engines and gas turbines is described in the specific-model description chp. 3.2.1.1.3.

Other public electricity and heat production

Apart from Other fuels, fuel consumption (TJ) for Public electricity and heat production (1A1a) activity data are extracted from the Swiss overall energy statistics (SFOE 2023; Tables 21, 26, and 28).

Activity data for wood as fuel for combined heat and power generation and for plants for renewable waste from wood products are taken from the Swiss wood energy statistics (SFOE 2023b) as described in chapter 3.2.1.1.2 Energy model for wood combustion.

Table 3-35 Fuel consumption of 1A1a Public electricity and heat production.

1A1a Public electricity and heat production	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	40'379	39'179	49'913	56'976	61'740
Gas oil	TJ	980	554	790	1'300	490
Residual fuel oil	TJ	3'214	1'813	340	290	40
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	530	46	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	4'339	5'422	8'292	9'827	9'926
Other fuels (waste-to-energy, MSW)	TJ	28'158	27'058	34'679	39'994	43'336
Other fuels (waste-to-energy, special waste)	TJ	2'610	3'206	4'692	4'514	4'941
Biomass (wood and wood waste)	TJ	301	466	547	844	2'958
Biogas (engines 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	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total fuel consumption	TJ	63'294	59'316	61'378	65'009	64'744	65'304	66'475	65'548	66'132	63'382
Gas oil	TJ	670	770	660	430	490	380	450	340	420	420
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	8'409	5'032	7'050	8'926	7'907	8'111	8'444	7'501	8'551	6'568
Other fuels (waste-to-energy, MSW)	TJ	43'083	44'275	45'433	47'442	47'675	48'084	48'404	48'526	47'583	45'697
Other fuels (waste-to-energy, special waste)	TJ	5'145	4'886	5'115	4'979	4'641	5'013	5'148	4'722	4'276	5'127
Biomass (wood and wood waste)	TJ	5'949	4'321	3'098	3'218	4'024	3'710	4'022	4'443	5'147	5'366
Biogas (engines and gas turbines)	TJ	39	31	21	13	6.5	6.0	8.4	17	155	203
Biodiesel (engines and gas turbines)	TJ	9.1	9.1	8.1	7.7	8.0	6.7	6.5	6.3	6.2	6.3

3.2.2.2.2 Petroleum refining (1A1b)

In Switzerland, there were originally two petroleum refining plants. 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). Since one of the refineries ceased operation in 2015, the data are considered confidential. Data are available to reviewers on request. In addition, operation was interrupted several times in 2014.

Methodology (1A1b)

Based on the decision tree Fig. 4.1 in chapter 1A1b Petroleum refining of the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from fuel combustion are calculated by a Tier 2 bottom-up approach. The calculations are generally based on measurements and data from individual point sources from the refining industry.

Since 2013, the refineries in Switzerland are participating in the Swiss Emissions Trading Scheme (ETS). Starting from 2013, fuel consumption data are available from annual monitoring reports, which provides plant-specific information on activity data, and an allocation report, which provide plant specific information between 2005 and 2011.

Emission factors (1A1b)

Emission factors are confidential but are available to reviewers on request. Most of the emission factors were derived from SAEFL (2000) or adopted from EMEP/EEA guidebook 2019.

The fraction of BC from PM 2.5 while burning natural gas in boilers of the refineries was set to 8.6 % according to the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1.A.1, table 4-6).

Emission factors for gas turbines with SCGT are described in chp. 3.2.1.1.3.

Activity data (1A1b)

Activity data on fuel combustion for 1A1b Petroleum refining is provided by the Swiss overall energy statistics (SFOE 2023) and the refining 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 2023). As one of the refineries ceased operation in 2015, the data are considered confidential since 2014. Data are available to reviewers on request. The use of refinery gas in gas turbines with SCGT is described in chp. 3.2.1.1.3.

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 is also using petroleum coke as a fuel. Natural gas is used additionally to residual fuel oil and refinery gas since 2017. In 2019, 2020 and 2022, 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 2013-2022 that are required under the Swiss Federal Act and Ordinance on the Reduction of CO_2 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 2023).

Table 3-36 Activity data of 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	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total fuel consumption	TJ	13'834	14'173	7'232	6'355	6'298	6'627	5'911	5'987	5'160	6'575
Residual fuel oil	TJ	1'094	1'330	C	C	C	C	NO	NO	C	NO
Refinery gas	TJ	11'055	10'935	C	C	C	C	C	C	C	C
Petroleum coke	TJ	1'685	1'908	C	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	NO	NO	NO	NO	C	C	C	C	C	C

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

Methodology (1A1c)

Based on the decision tree Figure 5.1 in chapter 1A1c Manufacture of solid fuels and other energy industries of the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions are calculated by a Tier 2 approach. The only activity in this source category is charcoal production and is only of minor importance in Switzerland.

Emission factors (1A1c)

Emission factors for NO_x, NMVOC, CO are based on the revised 1996 IPCC Guidelines (IPCC 1996) and for PM10 exhaust and TSP exhaust based on USEPA (1995, Chapter 10.7 Charcoal). PM2.5 exhaust is supposed to be 95 % from PM10 exhaust (EMIS 2024/1A1c).

Since there is no information available on BC emissions from source category 1A1c Charcoal production (artisanal) its BC factor (%PM2.5) is set to the default Tier 2 value (48 %) of coke manufacture provided in the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A1c Manufacture of solid fuels and other energy industries, Tab. 5-2/5-3). Neither the 1996 IPCC Guidelines nor the EMEP/EEA guidebook provide a SO_x emission factor for charcoal production. The latter one contains data on coke manufacture only which we did not consider as applicable for artisanal charcoal production as the sulphur content of coal is more than one order of magnitude higher than that of wood.

Table 3-37 Emission factors of 1A1c charcoal production in 2022.

1A1c Charcoal	NO_x	NMVOC	SO_x	NH3	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
	kg/TJ								
Charcoal production	10	1'700	NE	NE	3'700	3'900	4'800	1'776	7'000

1A1c Charcoal	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ									
Charcoal production	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Activity data (1A1c)

Activity data on annual charcoal production are provided by the Swiss association of charcoal producers (Köhlerverband Romoos) and individual producers as documented in the EMIS database (EMIS 2024/1A1c).

Table 3-38 Activity data of 1A1c charcoal production.

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

1A1c Charcoal	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Charcoal production	TJ	3.3	4.3	3.8	4.1	3.9	4.3	5.1	3.9	4.0	3.4

3.2.2.3 Category-specific recalculations in 1A1 Energy industries (stationary)

The following recalculations were implemented in submission 2024:

- 1A1: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.
- 1A1a: Activity data of source category 1A1a Combined chip heat and power plants have been revised for 1990-2021 due to recalculations in the Swiss wood energy statistics (SFOE 2023b).
- 1A1a: The emission factors for BC, CO, NO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust for source category 1A1a for combined heat and power generation from landfill gas have been updated for 1990-2021 and are now set equal to emission factors for process 1A4ci Other sectors - Agriculture/forestry/fishing, because the combustible biogas is similar and because the motor types in use are also comparable. Changes range from -99 % for all PM up to +43 % for NO_x.
- 1A1a: The emissions of PM2.5 exhaust, PM10 exhaust and TSP exhaust of wood energy combustion in source category 1A1a Public energy and heat production now also include the condensable particle fractions (1990-2021, PM2.5 (2021): +10 %).
- 1A1a and 1A1b: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails several changes in fuel consumption of fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and of biogenic (biodiesel, biogas and

sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.

- 1A1c: The activity data of sorce category 1A1c Charcoal production was updated for 2021 due to a corrected production quantity of a charcoal burning plant.

3.2.3 Source category 1A2 - Stationary combustion in manufacturing industries and construction

3.2.3.1 Source category description for 1A2 Stationary combustion in manufacturing industries and construction

The source category 1A2 Stationary combustion in 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. Within this category, only activities involving fuel combustion are taken into account. Note that information regarding vehicles and machinery of source category 1A2gvii Mobile combustion in manufacturing industries and construction are provided in chapter 3.2.5.

Table 3-39 Specification of source category 1A2 Stationary combustion in manufacturing industries and construction (stationary without 1A2gvii) in Switzerland.

1A2	Source category	Specification
1A2a	Iron and steel	Fuel combustion in iron and steel industry (cupola furnaces of iron foundries, reheating furnaces in steel plants, boilers)
1A2b	Non-ferrous metals	Fuel combustion in non-ferrous metals industry (non-ferrous metals foundries, aluminium production (ceased in 2006), boilers)
1A2c	Chemicals	Fuel combustion in chemical industry (steam production from cracker by-products, boilers)
1A2d	Pulp, paper and print	Fuel combustion in pulp, paper and print industry (furnaces of cellulose production (ceased in 2008), boilers and gas turbines)
1A2e	Food processing, beverages and tobacco	Fuel combustion in food processing, beverages and tobacco industry (boilers)
1A2f	Non-metallic minerals	Fine ceramics, container glass, tableware glass, glass wool, lime, mineral wool, mixed goods, cement, brick and tile
1A2gviii	Other	Fibreboard production, use of fossil fuel and biomass (wood and biogas) in industrial boilers, engines and gas turbines

Table 3-40 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1A2 Combustion in manufacturing industries and construction (stationary only).

NFR code	Source category	Pollutant	Identification criteria
1A2d	Stationary combustion in manufacturing industries and construction: pulp paper and print	SOx	T1, T2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	L1, L2, T1
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	L1, L2, T1, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	L1, T1, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	L1, L2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	L1

3.2.3.2 Methodological issues for 1A2 Stationary combustion in manufacturing industries and construction

3.2.3.2.1 Methodology (1A2) and industry model

Based on the decision tree Fig. 3.1 in chapter 1A2 Combustion in manufacturing industries and construction of the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions are calculated according to a Tier 2 approach based on country-specific emission factors.

Overview industry model

As a sub-model of the Swiss energy model (see chp. 3.1.6.3.2), the industry model disaggregates for each fuel type, the total fuel consumption in the industry sector provided by the Swiss overall energy statistics (SFOE 2023, see also description in chp. 3.1.6.3) 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 2023d) 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).

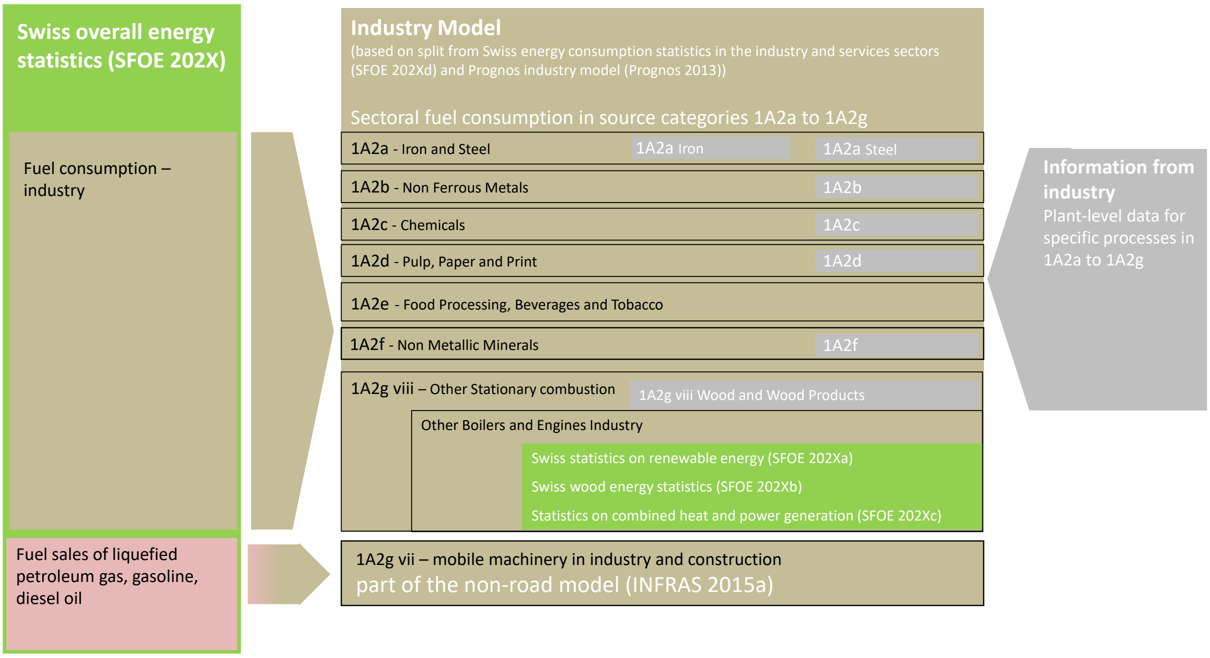

Figure 3-22 Schematic presentation of the data sources used for the industrial sectors 1A2a – 1A2g. The references SFOE 202X, SFOE 202Xa, 202Xb and 202Xc refer to the 2023 edition of the corresponding energy statistics. For each fuel type, the Swiss overall energy statistics provide the total fuel consumption in the industry sector (SFOE 2023). 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 2023d) 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 2023d) 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 standard 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). In brief, the business and enterprise register, which forms the basis for the samples of the surveys, was revised. While previously the business and enterprise register was based on direct surveys with work places, it is now based on annual investigations of registry data (e.g. from the old-age and life 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 1 percent, but also that the differences between the new and the old results for 2013 are not statistically significant (SFOE 2015d). As these statistics are only used for allocation of total energy consumption to different source categories, the impact on the different source categories consists only of a reallocation of the energy consumption and does not affect the total of the sector. Moreover, only consumption of gas oil and natural gas is affected. For all these reasons, the time series consisting of data based on the old (1990-2012) and new (since 2013) survey method are therefore considered consistent.

Modelling of industry categories

As mentioned above, the energy consumption statistics in the industry and services sectors (SFOE 2023d) 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 energy 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 2024/1A2_Sektorgliederung Industrie).

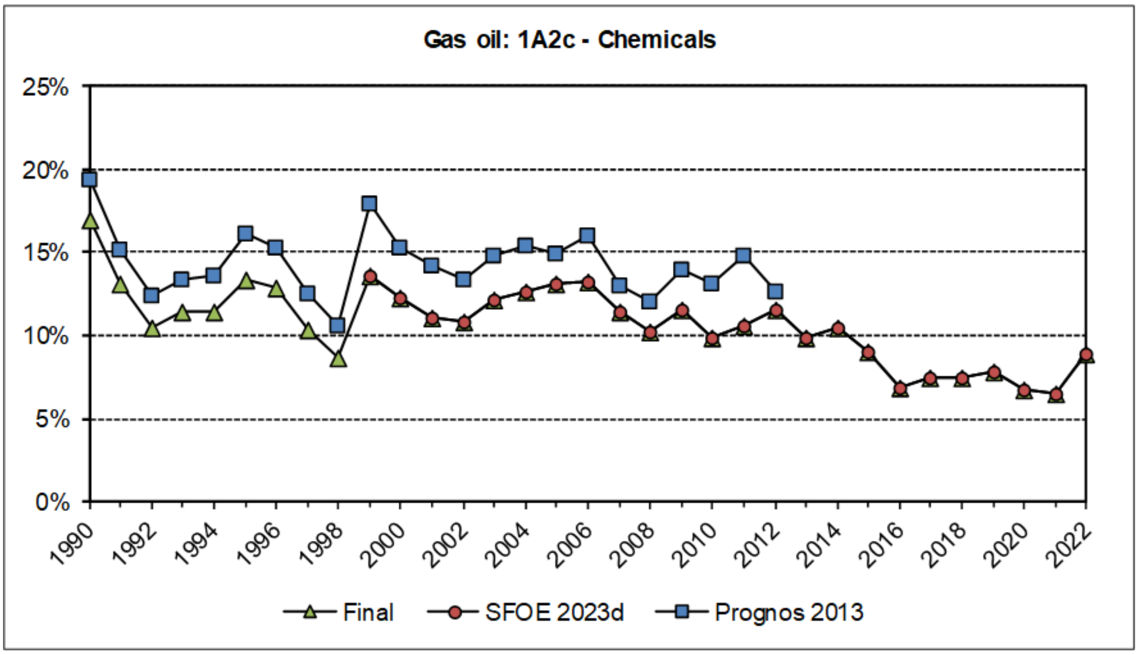

Figure 3-23 Illustrative example for combining time series with consistent overlap according to the 2019 Refinement (IPCC 2019, Volume 1, chp. 5.3.3.1, overlap). The y-axis indicates the share of source category 1A2c in total gas oil consumption in the industry sector. The green triangles correspond 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 2023d, 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 colored boxes in Figure 3-22 represent source categories (i.e. 1A2a-d, 1A2f and 1A2gviii) 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_2 Emissions (Swiss Confederation 2012) and are discussed in depth in the following chapters 3.2.3.2.2 to 3.2.3.2.8.

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 (exclusion principle). This method ensures that the sum of fuel consumptions 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 2023d) and the bottom-up industry model (Prognos 2013).

There is a difference in calculating the emissions 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 and gas turbines developed by INFRAS (2022a) as described in chapter 3.2.1.1.3.

Fuel consumption of wood, wood waste, biogas and sewage gas in manufacturing industries is based on the Swiss wood energy statistics (SFOE 2023b) as well as on data from the Swiss renewable energy statistics (SFOE 2023a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2023c), respectively. Emissions from these sources are reported under 1A2gviii Other due to insufficient information regarding sectoral disaggregation.

Emission factors (1A2)

This chapter describes the emission factors of fossil fuel consumption in boilers. Emission factors are identical for all source categories. Emission factors of bottom-up industry processes and other relevant processes are described in the following chapters for each source category. Emission factors for engines and gas turbines are described in chapter 3.2.1.1.3.

For liquefied petroleum gas and petroleum coke, the same emission factors are assumed for all air pollutants as for natural gas and residual fuel oil, respectively, except for SO_x of liquefied petroleum gas (see chp. 3.2.1.2).

The emission factors of NO_x and CO for natural gas and gas oil are derived from a large number of air pollution control measurements of combustion installations in several Swiss cantons in 1990, 2000 and 2010 (Leupro 2012). The emission factors for residual fuel oil, other bituminous coal and lignite are country-specific and documented in the Handbook on emission factors for stationary sources (SAEFL 2000). The emission factors for NMVOC, NH_3, PM2.5, PM10 and TSP are country-specific and documented in the Handbook on emission factors for stationary sources (SAEFL 2000).

The SO_x emission factors for gas oil, residual fuel oil, liquefied petroleum gas, other bituminous coal, lignite and natural gas are described in chp. 3.2.1.2 and Table 3-30.

Emission factors of BC (% PM2.5), Pb, Cd, Hg, PCDD/PCDF and PAH are taken from the EMEP/EEA guidebook (EMEP/EEA 2019). The emission factors of HCB and PCBs are taken from the Danish emission inventory for HCB and PCBs (Nielsen et al. 2013). There is a difficulty with industrial gas oil burners, as there is a lack of data for non-residential medium-sized boiler in the EMEP/EEA guidebook. Therefore, the emission factors available for the different combustion installations burning gas oil were compared and then the most reasonable and most current data were chosen. The emission factors of BC (% PM2.5), Pb, Cd, Hg and PCDD/PCDF are taken from table 3-18 (EMEP/EEA 2019, Tier 2 Residential plants, boilers burning liquid fuels, chp. 1A4). While the emission factors of PAHs are taken from table 3-9 (EMEP/EEA 2019, Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using liquid fuels) as they represent an average of Tier 2 emission factors for liquid fuel combustion for all technologies.

Table 3-41 Emission factors for fossil fuel boilers of 1A2 Stationary combustion in manufacturing industries and construction in 2022.

1A2 Boiler	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Boiler gas oil	31	2	2.0	0.002	0.2	0.2	0.2	0.0078	5.9
Boiler residual fuel oil	125	4	297	0.002	20	20	23	2	10
Boiler liquefied petroleum gas	18	2	0.5	0.001	0.1	0.1	0.1	0.0054	6.7
Boiler petroleum coke	125	4	297	0.002	20	20	23	2	10
Boiler other bituminous coal	200	10	500	0.003	45	45	50	2.88	100
Boiler lignite	200	10	500	0.003	45	45	50	2.88	100
Boiler natural gas	18	2	0.2	0.001	0.1	0.1	0.1	0.0054	6.7

1A2 Boiler	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Boiler gas oil	0.012	0.001	0.12	1.8	0.0019	0.015	0.0017	0.0015	220	0.11
Boiler residual fuel oil	4.6	1.2	0.34	2.5	0.0045	0.0045	0.0045	0.0069	220	3.2
Boiler liquefied petroleum gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Boiler petroleum coke	4.6	1.2	0.34	2.5	0.0045	0.0045	0.0045	0.0069	220	3.2
Boiler other bituminous coal	167	1	16	40	0.079	1.2	0.85	0.62	620	53
Boiler lignite	167	1	16	40	0.079	1.2	0.85	0.62	620	53
Boiler natural gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA

Activity data (1A2)

Table 3-42 shows the total fuel consumption in 1A2 and Table 3-43 shows fuel consumption in boilers of each source category 1A2a-1A2gviii as described above in the industry model (chp. 3.2.3.2.1). Consumption of other fuels occurs mainly in source category 1A2f, where they refer to fossil waste fuels in cement production. But also, the cracker by-products, i.e. gasolio, heating gas and synthesis gas (from 2018 onwards) used for steam production in a chemical plant in source category 1A2c are included in other fuels of 1A2. There is no fuel consumption in boilers of source category 1A2f Non-metallic minerals since this source category consists of specific bottom-up industry processes only.

Table 3-42 Fuel consumption of 1A2 Stationary combustion in manufacturing industries and construction.

1A2 Manufacturing industries and constr. (stationary sources)	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	88'849	89'256	87'412	90'688	89'351
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	4'350	4'403	5'475	4'171	3'754
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	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total fuel consumption	TJ	85'625	80'165	78'724	79'781	80'236	77'425	77'054	74'229	78'333	73'126
Gas oil	TJ	18'007	12'444	12'725	12'812	11'489	10'871	10'071	8'854	9'074	8'725
Residual fuel oil	TJ	848	231	196	155	123	34	111	76	55	NO
Liquefied petroleum gas	TJ	3'609	3'148	3'215	2'577	3'068	3'009	2'893	2'766	2'910	2'914
Petroleum coke	TJ	1'049	1'240	795	890	763	781	777	700	604	731
Other bituminous coal	TJ	3'910	2'403	1'946	1'517	1'634	1'665	1'450	1'153	1'155	1'331
Lignite	TJ	1'357	3'102	3'060	3'078	2'876	2'520	2'262	2'410	2'442	2'466
Natural gas	TJ	39'710	40'310	39'450	39'960	41'000	39'320	39'560	38'180	39'690	33'100
Other fossil fuels	TJ	4'510	4'558	4'566	5'178	5'085	5'608	5'759	5'815	5'806	5'660
Biomass	TJ	12'624	12'729	12'772	13'613	14'198	13'616	14'171	14'275	16'597	18'197

Table 3-43 Fuel consumption in boilers of 1A2 Stationary combustion in manufacturing industries and construction.

Source (Boilers)	Unit	1990	1995	2000	2005	2010
1A2a Iron and steel	TJ	1'045	1'017	978	1'094	1'657
Gas oil	TJ	480	262	338	401	315
Residual fuel oil	TJ	26	131	20	39	51
Liquefied petroleum gas	TJ	408	193	286	217	219
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	131	431	334	437	1'072
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2b Non-ferrous metals	TJ	2'256	1'969	1'555	973	1'217
Gas oil	TJ	451	336	225	119	108
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
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2c Chemicals	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	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2d Pulp, paper and print	TJ	9'701	11'917	9'108	9'099	6'575
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	6'963	6'141	5'451	5'383
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2e Food processing, beverages and tobacco	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
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2g viii Other	TJ	16'898	20'913	21'380	22'190	22'222
Gas oil	TJ	7'418	11'626	13'484	14'497	12'705
Residual fuel oil	TJ	5'237	3'605	47	5	9
Liquefied petroleum gas	TJ	3'087	3'233	4'011	2'979	2'697
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	186	1'396	3'811	4'233	6'371
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO

Continuation of Table 3-43, fuel consumption in boilers of 1A2 Stationary combustion in manufacturing industries and construction.

Source (Boilers)	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1A2a Iron and steel	TJ	1'435	1'513	1'920	1'892	2'159	2'292	2'143	2'141	1'934	1'754
Gas oil	TJ	139	86	136	134	123	127	97	81	80	59
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	438	388	393	327	368	358	342	327	342	342
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	858	1'039	1'391	1'431	1'669	1'808	1'704	1'732	1'512	1'352
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2b Non-ferrous metals	TJ	1'595	1'919	1'794	1'684	1'642	1'748	1'965	1'815	2'017	1'836
Gas oil	TJ	127	88	77	74	77	53	60	48	64	68
Residual fuel oil	TJ	23	NO	44	NO	3.7	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	11	9.8	9.9	8.3	9.3	9.0	8.6	8.3	8.6	8.6
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	1'434	1'821	1'664	1'602	1'552	1'686	1'897	1'758	1'944	1'759
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2c Chemicals	TJ	14'153	12'155	12'551	14'401	13'834	13'312	11'834	10'956	10'730	9'116
Gas oil	TJ	1'797	1'321	1'167	881	860	825	799	602	593	789
Residual fuel oil	TJ	1.20	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	10	8.9	9.0	7.5	8.4	8.2	7.9	7.5	7.9	7.9
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	12'345	10'824.6	11'375	13'512	12'966	12'479	11'026	10'346	10'130	8'318
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2d Pulp, paper and print	TJ	5'196	4'350	3'321	2'988	2'857	2'077	2'155	2'071	2'267	1'948
Gas oil	TJ	711	297	383	410	288	293	345	284	247	364
Residual fuel oil	TJ	0.018	22	19	9.0	8.8	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	67	60	60	50	57	55	53	50	53	53
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	4'418	3'971	2'859	2'518	2'504	1'729	1'757	1'737	1'968	1'531
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2e Food processing, beverages and tobacco	TJ	13'098	12'463	11'591	10'992	11'231	10'843	11'851	11'928	12'266	10'204
Gas oil	TJ	3'681	2'395	2'522	2'503	2'110	1'925	2'119	2'009	2'298	2'249
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	935	828	838	699	785	763	731	699	731	731
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	8'482	9'241	8'230	7'790	8'337	8'155	9'001	9'220	9'238	7'224
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2g viii Other	TJ	18'695	16'686	17'836	17'665	17'728	16'847	16'606	15'142	16'262	13'854
Gas oil	TJ	10'373	7'050	7'342	7'785	6'912	6'568	5'597	4'831	4'794	4'135
Residual fuel oil	TJ	2.1	0.33	2.8	7.9	4.3	2.2	2.4	3.7	2.8	NO
Liquefied petroleum gas	TJ	2'035	1'809	1'852	1'441	1'798	1'772	1'705	1'635	1'726	1'709
Petroleum coke	TJ	181	108	104	155	113	168	169	65	21	185
Other bituminous coal	TJ	110	105	134	125	102	91	58	101	18	24
Lignite	TJ	75	189	204	197	182	153	141	144	138	135
Natural gas	TJ	5'919	7'425	8'198	7'955	8'617	8'092	8'934	8'362	9'562	7'666
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

3.2.3.2.2 Iron and steel (1A2a)

Methodology (1A2a)

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-41 and Table 3-43, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2a.

Reheating furnaces in steel production

There is no primary iron and steel production in Switzerland. Only secondary steel production using recycled steel scrap occurs. Today, steel is produced in two steel production plants only, after two plants closed down in 1994. The remaining plants use electric arc furnaces (EAF) with carbon electrodes for melting the steel scrap. Therefore, only emissions from the reheating furnaces are reported in source category 1A2a. These furnaces use mainly natural gas for reheating the ingot moulds prior to the rolling mills. Process emissions from steel production are included in source category 2C1 Iron and steel production.

Electric arc furnaces in steel production:

In the electric arc furnaces of secondary steel production also so-called injection coal and petroleum coke for slag formation as well as natural gas are used. Until 2017, the consumption of these fuels has been reported within the respective boilers of source categories 1A2gviii Other (petroleum coke, other bituminous coal) and 1A2a Iron and steel (natural gas). This resulted in a double counting of all air pollutant emissions since the emissions from the electric arc furnaces reported under source category 2C1 Steel production are based on air pollution control measurements at the chimney including emissions from injection coal and coke as well as from natural gas. In order to avoid double counting, these fuel consumptions are subtracted from the respective boilers in source categories 1A2gviii Other (petroleum coke, other bituminous coal) and 1A2a Iron and steel (natural gas) based on plant-specific data from monitoring reports of the Swiss ETS for the years 2005-2011 and from 2013 onwards.

Cupola furnaces in iron foundries

Iron is produced in 14 iron foundries. About 75 % of the iron is processed in induction furnaces and 25 % in cupola furnaces. The share of induction furnaces increased since 1990 with a sharp increase in 2009 based on the closure of at least one cupola furnace. Induction furnaces use electricity for the melting process and therefore only process emissions occur, which are reported in source category 2C1 Iron and steel production.

Emission factors (1A2a)

Reheating furnaces in steel production

For NO_x, PM2.5/PM10, TSP and CO production weighted emission factors are derived from data that are based on various air pollution control measurements under the Ordinance on Air Pollution Control (Swiss Confederation 1985). In years with missing data, emission factors are estimated by interpolation. For NMVOC, SO_x and Hg country-specific emission factors are used. Emission factors for Pb and Cd are available for selected years. Since 1995, emission factors are assumed to be constant. The emission factors of BC (% PM2.5) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil and table 3.16 for natural gas), see EMIS 2024/1A2a Stahl-Produktion Wärmeöfen.

Cupola furnaces in iron foundries

Emission factors of NO_x, NMVOC, SO_x, PM2.5/PM10, TSP, CO, Pb, Cd and PCDD/PCDF are provided by the Swiss foundry association (Schweizerischer Giessereiverband GVS) and are assumed constant. The emission factors of BC (% PM2.5) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp.1A4, Table 3.23). Emission factors of PAH are based on data from literature, see USEPA (1998) and EMIS 2024/1A2a Eisengiessereien Kupolöfen). The Hg emission factor is based on the default value for other bituminous coal of Table 3.23 (chp. 1A4) of EMEP/EEA (2019).

Table 3-44 Emission factors of 1A2a Iron and Steel in 2022.

1A2a Iron and steel	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	g/t								
Iron foundries, cupola	67	40	1'500	NE	60	110	120	3.8	11'000
Steel plants, reheating furnaces	75	2.8	0.71	NE	2.1	2.1	4.1	0.11	0.5

1A2a Iron and steel	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/t			ng I-TEQ/t	mg/t				ng/t	
Iron foundries, cupola	4'800	24	80	1'300	0.13	1.4	1.2	1.6	NE	NE
Steel plants, reheating furnaces	32	3.4	0.071	NE	NE	NE	NE	NE	NA	NA

Activity data (1A2a)

Activity data of iron and steel production that is used to calculate emissions from cupola ovens in iron foundries and reheating furnaces in steel plants is provided by the industry as documented in the EMIS database (EMIS 2024/1A2a).

Reheating furnaces in steel production

Since 1995, steel production increased continuously until 2004 to reach the same production level as 1990. Since then, steel production is constant. Only in 2009, the production was significantly lower due to the economic crisis. One steel producer switched its production to high quality steel and therefore the specific energy use per tonne of steel produced increased between 1995 and 2000. This led to higher natural gas consumption. Data on annual steel production is provided by the steel production plant. Since 2009, activity data refer to monitoring reports of the Swiss ETS.

In steel production, mainly natural gas is used as fuel. Until 1994, the Swiss steel industry also used residual fuel oil in one steel production plant. Due to the closure of two steel production plants in 1994, the amount of fuel used in Swiss steel plants decreased significantly. Fuel consumption is derived from specific energy consumption per tonne of steel or iron and the annual production of steel or iron respectively.

Cupola furnaces in iron foundries

Annual production data are provided by the Swiss foundry association (Schweizerischer Giessereiverband GVS). The use of other bituminous coal decreased significantly due to a switch from cupola furnaces to induction furnaces. Bituminous coal used in cupola furnaces primarily acts as fuel, but also as carburization material and reductant. Therefore, emissions are accounted for in source category 1A2a. This allows to be consistent with the allocation of bituminous coal in the Swiss overall energy statistics (SFOE 2023).

Table 3-45 Activity data from production of iron and steel that is used to calculate bottom-up emissions from sources of 1A2a.

1A2a Iron and steel	Unit	1990	1995	2000	2005	2010
Iron foundries, cupola	kt iron	90	60	55	32	13
Steel plants, reheating furnaces	kt steel	1'108	716	1'022	1'082	1'082

1A2a Iron and steel	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Iron foundries, cupola	kt iron	11	11	9.2	8.6	8.8	8.6	6.0	5.1	5.4	5.8
Steel plants, reheating furnaces	kt steel	1'126	1'176	1'144	1'085	1'138	1'160	1'037	1'031	1'104	1'121

3.2.3.2.3 Non-ferrous metals (1A2b)

Methodology (1A2b)

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-41 and Table 3-43, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2b.

Source category 1A2b Non-ferrous metals includes secondary aluminium production plants as well as non-ferrous metal foundries, producing mainly copper alloys.

Secondary aluminium production plants:

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

Non-ferrous metals smelters and furnaces

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 (GVS).

Emission factors (1A2b)

Emissions from non-ferrous metals smelters and furnaces are derived from the emission factors per tonne of metal as shown in the following table as documented in the EMIS database (EMIS 2024/1A2b Buntmetallgiessereien übriger Betrieb). The emission factors are based on information of the Swiss foundry association (GVS).

Table 3-46 Emission factors of 1A2b Non-ferrous metals in 2022.

1A2b Non-ferrous metals	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/t								
Foundries	7	420	4	NE	160	170	170	6.2	2'100

1A2b Non-ferrous metals	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/t			ng I-TEQ/t	mg/t				ng/t	
Foundries	510	85	NE	4'900	NE	NE	NE	NE	NE	NE

Activity data (1A2b)

The production data for the non-ferrous metal industry is provided by the largest company (Swissmetal, monitoring reports of the Swiss ETS from 2006 onwards) and the annual statistics of the Swiss Foundry Association (GVS). The non-ferrous metal foundries continuously increased their production from 1990 to 2000. Since 2000, the production has strongly decreased. The decrease in production is also reflected in its fuel consumption (Table 3-43).

Activity data of the secondary aluminium production plant (ceased in 1993) were based on data from the Swiss aluminium association (www.alu.ch).

Table 3-47 Activity data from production of Non-ferrous metals that are used to calculate bottom-up emissions from sources of 1A2b.

1A2b Non-ferrous metals	Unit	1990	1995	2000	2005	2010
Aluminium production	kt aluminium	34	NO	NO	NO	NO
Foundries	kt non-ferrous metals	60	56	53	33	20

1A2b Non-ferrous metals	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Aluminium production	kt aluminium	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foundries	kt non-ferrous metals	6.4	9.5	8.9	9.0	8.0	6.8	6.4	5.1	7.5	7.9

3.2.3.2.4 Chemicals (1A2c)

Methodology (1A2c)

In Switzerland, there are more than thirty chemical companies mainly producing fine chemicals and pharmaceuticals. Fossil fuels are mostly used for steam production.

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-41 and Table 3-43, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2c.

Steam production from cracker by-products

There is one large company producing ammonia and ethylene by thermal cracking of liquefied petroleum gas and light virgin naphtha. In addition, thermal cracking also produces so-called heating gas and gasolio as by-products. In 2018 the cracking process and the subsequent integrated production chain were modified yielding synthesis gas as additional by-product. These cracker by-products are used thermally for steam production within the same plant and are accounted for within source category 1A2c as other fossil fuels. Process emissions from ammonia and ethylene production are reported in source category 2B10a Ethylene production.

Emission factors (1A2c)

Since the fuel quality of gasolio and heating gas are of similar quality as residual fuel oil and gas oil, respectively, the same emission factors as of those boilers are assumed for all air pollutants, see Table 3-41. For synthesis gas (about 23 % vol. CO, 77 % vol. H_2) emissions of NO_x and NH_3 are assumed only. Thus, for NO_x and NH_3, the same emission factors as of boilers, natural gas are applied, see Table 3-41.

Activity data (1A2c)

Activity data on gasolio, heating gas and synthesis gas (from 2018 onwards) are provided by the industry. Since 2013, they are based on monitoring reports of the Swiss ETS as documented in the EMIS database (EMIS 2024/1A2c ethylene production). The activity data are confidential but available to reviewers on request.

3.2.3.2.5 Pulp, paper and print (1A2d)

Methodology (1A2d)

Around half a dozen paper producers and several printing facilities exist in Switzerland. The only cellulose production plant was closed in 2008. Thermal energy is mainly used for provision of steam used in the drying process within paper production.

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-41 and Table 3-43, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2d.

Emission factors (1A2d)

For the cellulose production plant, NO_x and SO_x emission factors were derived from air pollution control measurements. The emission factor of BC (% PM2.5) was taken according to the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E) as documented in the EMIS database (EMIS 2024/1A2d Zellulose-Produktion Feuerung). Emission factors for natural gas used in gas turbines as SCGT or CCGT are described in chapter 3.2.1.1.3.

Activity data (1A2d)

Activity data on annual cellulose production are provided by the industry as documented in the EMIS database (EMIS 2024/1A2d Zellulose-Produktion Feuerung). The only plant closed in 2008.

In 2022, natural gas is the most important fuel in this category (see Table 3-43). The use of natural gas in gas turbines as SCGT or CCGT is described in chapter 3.2.1.1.3. Biomass used in paper production is reported in source category 1A2gviii, because no comprehensive data exist to distribute biomass consumption to the specific industries within 1A2.

The overall fuel consumption within the Swiss pulp and paper industry has decreased significantly due to the closure of the cellulose production plant in 2008 and the closure of several paper producers in the last years.

3.2.3.2.6 Food processing, beverages and tobacco (1A2e)

Methodology (1A2e)

In Switzerland, the source category 1A2e Food, beverages and tobacco includes around 200 companies. According to the national food industry association, a 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.

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-41 and Table 3-43, respectively.

In 2022, the fuels used in this category were mainly natural gas as well as gas oil and small amounts of liquefied petroleum gas. All fuel is consumed in boilers. Activity data are provided in Table 3-43.

3.2.3.2.7 Non-metallic minerals (1A2f)

Source category 1A2f Non-metallic minerals includes several large fuel consumers from mineral industry as for example cement, lime or brick and tile, glass and rock wool production (EMIS 2024/1A2f). Emission factors and activity data of some source categories reported under 1A2f Non-metallic minerals are considered confidential and are available to reviewers on request.

Emission factors (1A2f)

The following table provides an overview of the emission factors applied for source category 1A2f. Data sources are described for each process in the following chapters and are documented in the EMIS database (EMIS 2024/1A2f).

Table 3-48 Emission factors for Non-metallic minerals 1A2f in 2022.

1A2f Non-metallic minerals	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	g/t								
Cement	790	67	280	45	3	4	5	0.25	2'600
Lime	C	C	C	NE	C	C	C	C	C
Container glass	C	NA	C	NE	C	C	C	C	C
Glass wool	5'000	14	3.4	NE	342	611	630	18	80
Tableware glass	C	C	C	NE	C	C	C	C	C
Brick and tile	530	140	80	NE	19	29	32	1.0	560
Fine ceramics	C	C	C	NE	C	C	C	C	C
Rock wool	C	IE	C	C	C	C	C	C	C
Mixed goods	10	32	17	NE	1	2.9	3	0.044	85

1A2f Non-metallic minerals	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/t			ng I-TEQ/t	mg/t				ng/t	
Cement	20	2	10	40	0.06	1	0.04	0.3	4'000	103'000
Lime	C	C	C	C	NE	NE	NE	NE	NA	NA
Container glass	C	C	NE	NE	NE	NE	NE	NE	NA	NA
Glass wool	860	90	0.34	NE	NE	NE	NE	NE	NA	NA
Tableware glass	C	C	C	NE	NE	NE	NE	NE	NA	NA
Brick and tile	45	0.7	7	18	NE	NE	NE	NE	NE	NE
Fine ceramics	C	C	C	C	NE	NE	NE	NE	NA	NA
Rock wool	C	C	C	NE	NE	NE	NE	NE	NE	NE
Mixed goods	20	2	2	5	0.04	0.06	0.04	0.04	NE	NE

Activity data (1A2f)

Table 3-49 provides an overview of activity data in source category 1A2f. Data sources are described for each process in the following chapters and are documented in the EMIS database (EMIS 2024/1A2f).

Table 3-49 Activity data for Non-metallic minerals 1A2f.

1A2f Non-metallic minerals	Unit	1990	1995	2000	2005	2010
Cement	kt	4'808	3'706	3'214	3'442	3'642
Lime	kt	C	C	C	C	C
Container glass	kt	C	C	C	C	C
Glass wool	kt	24	24	31	37	36
Tableware glass	kt	C	C	C	C	C
Brick and tile	kt	1'271	1'115	959	1'086	879
Fine ceramics	kt	C	C	C	C	C
Rock wool	kt	C	C	C	C	C
Mixed goods	kt	5'500	4'800	5'170	4'780	5'250

1A2f Non-metallic minerals	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cement	kt	3'415	3'502	3'195	3'296	3'279	3'239	3'227	3'129	3'227	3'155
Lime	kt	C	C	C	C	C	C	C	C	C	C
Container glass	kt	C	C	C	C	C	C	C	C	C	C
Glass wool	kt	33	32	31	32	36	40	47	40	47	45
Tableware glass	kt	C	C	C	C	C	C	C	C	C	C
Brick and tile	kt	785	765	726	660	622	581	554	531	484	521
Fine ceramics	kt	C	C	C	C	C	C	C	C	C	C
Rock wool	kt	C	C	C	C	C	C	C	C	C	C
Mixed goods	kt	4'770	5'260	4'850	4'710	5'260	5'180	5'210	4'910	4'960	4'970

Cement (1A2f)

Methodology

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.

Cement industry emissions stem from incineration of fossil and waste derived fuels used to generate high temperatures needed for the clinker production process. Fossil fuels used in cement industry are coal (lignite and other bituminous coal), petroleum coke and, to a lesser extent, gas oil, residual fuel oil and natural gas. Waste derived fuels can be of fossil or biogenic origin and include for example plastics, waste oil, solvents and residues from distillation or wood waste. The fuels consumed in this category are very diverse and depend on the fuel use within the specific plant (see detailed documentation below).

Emission factors

Table 3-48 shows product-specific emission factors for cement production (EMIS 2024/1A2f Zementwerke Feuerung). Since 2008, emission factors are based on various air pollution control measurements under the Ordinance on Air Pollution Control (Swiss Confederation 1985). A reassessment of emission measurement reports of the years 2013 and 2018 led to changes in emission factors for the years 2009-2012 and from 2013 onwards. Regarding NO_x, industry agreements define an emission reduction path for the years 2016-2021 and 2022-2031, respectively. Emission data for monitoring compliance with the agreement were evaluated and the emission factor for NO_x was computed accordingly. The value for PCB is based on the Tier 2 emission factor in the EMEP/EEA guidebook (EMEP/EEA 2019, chp.1A2, Table 3.24).

Activity data

Activity data of annual clinker production of each cement production plant in Switzerland are provided by the association of the Swiss cement industry (see Table 3-49). Since 2008, activity data are available from monitoring reports of the Swiss ETS.

For information purposes, annual fuel consumption of the cement production plants in Switzerland are shown in Table 3-50. The waste derived fuels can be of fossil or biogenic origin and are accordingly differentiated into so-called other fossil fuels and biomass.

The amount of fuels consumed in the Swiss cement production plants is also provided in the annual monitoring reports of the cement production plants as documented in the respective EMIS 2024/1A2f Zementwerke Feuerung.

Table 3-50 Fuel consumption of cement industry (fossil without waste, fossil waste derived, and biomass waste derived).

Cement industry (part of 1A2f)	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
Total fuel consumption	TJ	17'194	12'774	11'017	11'623	12'388
Cement fossil 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
Cement, waste derived fuel	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

Cement industry (part of 1A2f)	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel consumption	TJ	11'866	12'339	11'348	11'583	11'476	11'524	11'416	11'248	11'609	11'600
Cement fossil without waste	TJ	5'512	5'847	4'917	4'544	4'354	4'015	3'673	3'500	3'617	3'833
Gas oil	TJ	88	75	87	50	56	63	43	54	61	93
Residual fuel oil	TJ	86	58	45	90	59	NO	63	35	52	NO
Petroleum coke	TJ	815	1'052	622	658	574	542	552	591	583	547
Other bituminous coal	TJ	3'203	1'713	1'267	826	938	987	831	528	587	780
Lignite	TJ	1'283	2'912	2'856	2'881	2'694	2'367	2'120	2'266	2'304	2'331
Natural gas	TJ	38	37	41	39	34	56	65	26	28	82
Cement, waste derived fuel	TJ	6'354	6'492	6'431	7'039	7'122	7'509	7'743	7'748	7'992	7'766
Other fossil fuels	TJ	3'923	3'884	3'895	4'486	4'393	4'645	4'885	4'861	4'834	4'722
Industrial waste	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Mix of special waste with saw dust (CSS)	TJ	23	25	20	26	21	20	16	0	0.584	0.67
Other fossil waste fuels	TJ	25	19	12	11	5.7	5.4	NO	NO	13	NO
Plastics	TJ	963	1'016	887	890	1'071	1'319	1'246	1'558	1'688	1'692
Solvents and residues from distillation	TJ	1'345	1'193	1'194	1'397	1'254	1'238	1'456	1'155	1'107	1'265
Waste coke from coke filters	TJ	NO	NO	NO	NO	66	61	48	52	48	30
Waste oil	TJ	848	884	1'083	1'469	1'215	1'239	1'359	1'353	1'253	1'009
Waste tyres	TJ	719	746	699	694	760	763	760	743	726	725
Biomass	TJ	2'432	2'608	2'536	2'553	2'729	2'864	2'858	2'887	3'158	3'044
Agricultural waste	TJ	NO	NO	NO	NO	9.2	NO	NO	NO	NO	NO
Animal meal	TJ	479	457	412	409	470	522	475	441	454	317
Mix of special waste with saw dust (CSS)	TJ	73	78	60	72	57	53	43	0.12	1.58	1.8
Other biomass	TJ	32	21	42	8	5.6	5.4	30.7	36	147	175
Plastics	TJ	336	343	290	281	327	403	381	476	516	517
Sewage sludge (dried)	TJ	418	428	420	479	499	519	512	553	572	578
Solvents and residues from distillation	TJ	70	80	98	137	144	142	167	133	127	145
Waste oil	TJ	27	39	60	98	96	98	107	107	99	79
Waste tyres and rubber	TJ	266	276	259	257	281	282	281	275	269	268
Wood waste	TJ	732	886	896	811	840	840	861	867	973	962

In 2022, the Swiss cement industry used about two-thirds of waste derived fuels (fossil and biogenic) and one-third of standard fossil fuels. Today, fossil fuels used in cement industry are mainly lignite, plastics, waste oil, solvents and residues from distillation whereas waste tyres, petroleum coke and other bituminous coal are less important. Biogenic wastes contain mainly wood waste, sewage sludge, (bio)plastics and animal residues (animal meal). 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 2015 and remained rather constant since then. This is partly due to a decrease in production since 1990 and an increase in energy efficiency. In the period 1990-2019, the fuel mix has changed significantly from mainly standard fossil fuels to the above-mentioned mix of fuels.

Please note that all fossil waste derived fuels are reported as “Other fuels” in the emission reporting templates, whereas the biogenic waste derived fuels belong to “Biomass”.

Container glass (1A2f)

Methodology

Today, there exists only one production plant for container glass in Switzerland. Therefore, emission factors and activity data are considered confidential and are available to reviewers on request.

Emission factors

For container glass production, emission factors of NO_x and PM2.5/PM10/TSP are based on various air pollution control measurements under the Ordinance on Air Pollution Control (EMIS 2024/1A2f Hohlglas Produktion) and partly on information from industry. The SO_x emission factor is based on air pollution control measurements from 2011. The emission factor of BC (% PM2.5) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil and table 3.16 for natural gas).

Emission factors are derived based on air pollution control measurements at the production plants and therefore emission factors include both emission from fuel combustion as well as process emissions. Therefore, emissions from glass production are reported only in source category non-metallic minerals (1A2f). The same holds for tableware glass and glass wool.

Activity data

Activity data consist of annual production data provided by the industry (Table 3-49). Since 2008, activity data are available from monitoring reports of the Swiss ETS.

Since 1990, fuel consumption for container glass has drastically decreased due to reduction in production. Until 2003, only residual fuel oil was used in container glass production. Since 2004, the share of natural gas has increased to reach a stable share between 2006 and 2012. In autumn 2013, the plant has switched its glass kiln completely to natural gas.

Tableware glass (1A2f)

Methodology

Today, there exists only one production plant for tableware glass in Switzerland after the other one ceased production in 2006. Therefore, emission factors and activity data are considered confidential and are available to reviewers on request.

Emission factors

For tableware glass production, emission factors of NO_x and PM2.5/PM10/TSP are based on various air pollution control measurements under the Ordinance on Air Pollution Control whereas those of SO_x, NMVOC, CO are based on information from industry (EMIS 2024/1A2f Glas übrige Produktion). Emission factors of Pb and Cd are assumed proportional to the emissions of TSP. The emission factor of Hg is calculated proportional to the composition of fuels consumed in the production process (liquefied petroleum gas and residual fuel oil until 1995). The emission factors of BC (% PM2.5) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil and table 3.16 for liquefied petroleum gas gas).

Activity data

For tableware glass production, activity data are provided by monitoring reports of the Swiss ETS (Table 3-49). Activity data of tableware glass are considered confidential and are available to reviewers on request.

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

Glass wool (1A2f)

Methodology

In Switzerland, glass wool is produced in two plants.

Emission factors

Table 3-48 shows product-specific emission factors for glass wool production. For glass wool, emission factors of NO_x and PM2.5/PM10/TSP are based on various air pollution control measurements under the Ordinance on Air Pollution Control (EMIS 2024/1A2f Glaswolle Produktion) and partly on information from industry. The emission factor for SO_x is based on measurements and analysis of fuel samples carried out by the Swiss Federal Laboratories for Materials Testing and Research (EMPA 1999). The emission factor of BC (% PM2.5) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.16).

Activity data

Activity data consist of annual production data provided by monitoring reports from the industry (Table 3-49). Currently, fuel consumption for glass wool production includes only natural gas. Production of glass wool has increased since 1990, but the natural gas consumption decreased. This can be explained by an increase in energy efficiency in the production process.

Lime (1A2f)

Methodology

In Switzerland there is only one plant producing lime. Therefore, emission factors and activity data are considered confidential and are available to reviewers on request. Fossil fuels are used for the burning process (calcination) of limestone. The fuel consumption of two sugar plants that auto produce lime is reported in category 1A2e.

Emission factors

For lime production, emission factors of NO_x, SO_x, PM2.5/PM10/TSP and CO are based on various air pollution control measurements under the Ordinance on Air Pollution Control (Swiss Confederation 1985) between 1990 and 2011. Air pollution control measurements in 2017 led to revised emission factors of these pollutants for the natural gas operation of the kiln from 2014 onwards (EMIS 2024/1A2f). The emission factor of BC (% PM2.5) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil, table 3.23 for other bituminous coal and table 3.16 for natural gas), see EMIS 2024/1A2f Kalkproduktion Feuerung.

Activity data

Activity data consist of annual production data provided by the industry. Since 2008, activity data are available from monitoring reports of the Swiss ETS.

Between 1994 and 2012, fuel consumption in lime production was mainly based on residual fuel oil; gas oil was only used to start up the kilns. Up to 1995, also other bituminous coal was used and was the most important fuel (up to 1993). However, in 2013, the kiln was switched to natural gas.

Brick and Tile (1A2f)

Methodology

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

Emission factors

Table 3-48 shows emission factors for brick and tile production. Emission factors of NO_x, NMVOC, SO_x, PM2.5/PM10/TSP, CO, Pb, Cd und Hg are derived from air pollution control measurements as described in the EMIS database (EMIS 2024/1A2f Ziegeleien). The emission factors of BC (% PM2.5) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil, paper pulp and animal fat and table 3.16 for liquefied petroleum gas and natural gas).

Activity data

Activity data consist of annual production data provided by the industry (Table 3-49). Since 2013, for one large plant activity data are available from monitoring reports of the Swiss ETS.

Fuels used in the brick and tile production in 2022 are mainly natural gas as well as small amounts of gas oil and liquefied petroleum gas. Apart from a production recovery in the years around 2004, the production has gradually decreased since 1990, which is also represented in the overall fuel consumption decrease. Regarding the fuels used, there has been a considerable shift from residual fuel oil to natural gas from 1990 onwards as well as a minor shift from gas oil and liquefied petroleum gas to natural gas from 2004 onwards. Paper production residues, wood and animal fat are used since 2000. But the consumption of wood, paper production residues and animal fat is no longer reported in the monitoring reports since 2013, 2018 and 2021, respectively.

Fine Ceramics (1A2f)

Methodology

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

Emission factors

Emission factors of NO_x, NMVOC, SO_x and CO are based on air pollution control measurements from 2001, 2005, 2009 and 2012. The emission factor of PM is based on production weighted air pollution control measurements from 2005 and 2009 and the share of PM2.5/PM10 is assumed 95 % and 60 % of total PM emissions, respectively. Emission factors of Pb and Cd are calculated based on the assumption that they are proportional to the TSP emissions. The emission factor of Hg and SO_x is assumed to be constant. The emission factors of BC (% PM2.5) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil and table 3.16 for natural gas), see EMIS 2024/1A2f Feinkeramik Produktion.

Activity data

Activity data consist of annual production data provided by monitoring reports of the industry. Activity data are considered confidential and are available to reviewers on request.

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

Rock Wool (1A2f)

Methodology

In Switzerland, there is one single producer of rock wool. Therefore, emission factors and activity data are considered confidential and are available to reviewers on request. Fossil fuels are used for the melting of rocks at a temperature of 1500°C in cupola furnaces.

Emission factors

All emission factors (e.g. NO_x, NH_3, SO_x) for rock wool production are based on annual flux analysis from industry – except for the emission factors of BC (% PM2.5), which are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil, table 3.23 for other bituminous coal and table 3.16 for liquefied petroleum gas and natural gas), see EMIS 2024/1A2f Steinwolle Produktion.

Activity data

Activity data consist of annual production data provided by the industry (monitoring reports of the Swiss ETS).

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. Since 1990, there was a decrease in the specific energy consumption of rock wool production.

Mixed Goods (1A2f)

Methodology

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

Emission factors

Table 3-48 shows product-specific emission factors for production of mixed goods. Emission factors of NO_x, NMVOC, CO, PM2.5/PM10/TSP, Pb and Cd are based on air pollution control measurements from the time period between 2001 and 2015. This includes about 150 measurements from 55 out of 110 Swiss producers. As these measurements show no clear trend in the emission factors, a constant country-specific, average emission factor is used from 2001 onwards. Emission factors of SO_x, Hg and PCCD/PCDF are based on data from the industry association (Schweizerische Mischgut-Industrie) (EMIS 2024/1A2f Mischgut Produktion).

Activity data

Activity data consist of annual production data provided by the industry association (Schweizerische Mischgut-Industrie) (Table 3-49).

The main fuel types used are gas oil and natural gas. There has been a fuel switch from gas oil to natural gas in this time period.

3.2.3.2.8 Other (1A2gviii)

Methodology (1A2gviii)

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

In addition, also the emissions from fibreboard production are reported in 1A2gviii. Please note that they are calculated based on fuel consumption and not on production data as for all other bottom-up industry processes. Fibreboard was produced in two plants in Switzerland until 2019, where thermal energy is used for heating and drying processes. Since 2020 only one plant is left.

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

Emission factors (1A2gviii)

Emission factors of fossil fuel consumption in 1A2gviii in boilers and in fibreboard production are determined top-down (see Table 3-41). For animal fat which was used as fuel in the fibreboard production (2001 – 2013) the same emission factors as of residual fuel are assumed for all air pollutants. Emission factors of consumption of wood waste in fibreboard production are documented in Table 3-12.

The emission factors of the individual wood and wood waste combustion installations are described in chp. 3.2.1.1.2 and listed in Table 3-12. The resulting weighted emission factors of wood and wood waste combustion in manufacturing industries and construction are given in Table 3-51.

Table 3-51 Emission factors (weighted average) for 1A2gviii Wood and wood waste combustion in manufacturing industries and construction in 2022.

1A2gviii Other	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Wood and wood waste	110	5.4	10	3.4	13	14	15	0.69	138

1A2gviii Other	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Wood and wood waste	52	1.5	2.0	55	1.5	1.5	1.1	1.1	1'607	10

Emission factors for stationary engines and gas turbines are based on INFRAS (2022a) as described in chp. 3.2.1.1.3.

Activity data (1A2gviii)

Activity data of fossil fuels is derived from the industry model and given in Table 3-43. Fuel consumption of wood and wood waste in in manufacturing industries and construction is based on the Swiss wood energy statistics (SFOE 2023b) (see also chp. 3.2.1.1.2) and is given in Table 3-52. Fuel consumption in stationary engines and gas turbines is as described in chapter 3.2.1.1.3.

Table 3-52 Fuel consumption of 1A2gviii Wood and wood waste combustion in manufacturing industries and construction.

1A2gviii Other	Unit	1990	1995	2000	2005	2010
Wood and wood waste	TJ	3'093	4'057	4'561	5'933	7'680

1A2gviii Other	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wood and wood waste	TJ	7'960	7'884	7'973	8'884	9'368	8'836	9'666	9'715	11'397	13'293

In source category fibreboard production, the fuels currently used are wood waste and natural gas (EMIS 2024/1A2giv). Since 1990, the production of fibreboard and thus the fuel consumption have increased significantly. The fuel mix has strongly shifted between 1990 and 2022 from fossil fuels to biomass (wood waste). Between 2001 and 2013, also animal fat was used

In 2022, fuel consumption of 1A2gviii Other comprises mainly wood/wood waste, natural gas, gas oil and LPG. Overall, there has been a shift in fuel consumption between 1990 and 2022 from liquid and solid fuels to wood/wood waste and natural gas.

3.2.3.3 Category-specific recalculations for 1A2 Stationary combustion in manufacturing industries and construction

The following recalculations were implemented in submission 2024:

- 1A2: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.
- 1A2: The activity data (gas oil) of source category 1A2gviii Boiler - Other have changed for 2021 because the activity data (gas oil) of source category 1A2f Fine ceramics production was revised for 2021 based on plant information.
- 1A2: Due to the revised model of natural gas losses in 1A2b Natural gas, the changes also have an impact on final natural gas consumption and therefore on all source categories in 1A2 for the years 1990-2021.

- 1A2d: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A2f: The incorrect activity data for 2021 of source category 1A2f Glass wool production was corrected.
- 1A2f: The activity data for 1A2f for heating oil consumption in cement production for the year 2019 was erroneously reported and was corrected, resulting in a reduction of the value by 59 %.
- 1A2f: The activity data for 1A2f for consumption of other bituminous coal in cement production for the year 2018 was erroneously reported and was corrected, resulting in a 5 % increase of the value.
- 1A2f: The activity data for 1A2f Cement production, for all biogenic fuels as well as for waste-derived fuels, have changed for the year 2021 due to rounding, resulting in less than 0.1 % change for each value.
- 1A2g: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A2gviii: Activity data of automatic wood combustion installations in source category 1A2gviii have been revised for 1990-2021 due to recalculations in the Swiss wood energy statistics (SFOE 2023b). The biggest changes were in automatic boilers >500 kW and combined chip heat and power plants in 2021.
- 1A2gviii: The activity data of source category 1A2gviii Other for combustion of biogas is now reported in our database directly in GJ instead of GWh and with additional significant digits (see chp. 3.2.1.1.3). In addition, erroneously reported values for the years 1996-1999 have also been corrected, causing emission changes from -9 % up to +10 %. This change affects the following pollutants: NO_x, NMVOC, SO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust, BC, CO, heavy metals, POPs.
- 1A2gviii: The emissions of PM2.5 exhaust, PM10 exhaust and TSP exhaust of wood energy combustion in source category 1A2gviii Stationary combustion - Other now also include the condensable particle fractions (1990-2021, PM2.5 (2021): +16 %).

3.2.4 Source category 1A4 - Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

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

The source category 1A4 Stationary combustion in other sectors comprises all emissions from the combustion of fuels in stationary boilers and cogeneration in facilities within processes in commerce and institutions, households, agriculture and forestry. This includes use of conventional fossil fuels as well as biomass. Within this category, only activities involving fuel combustion are taken into account. Note that information regarding fuel combustion in source category 1A4 Non-road and machinery in other sectors are provided in chapter 3.2.7.

Table 3-53 Specification of source category 1A4 Stationary combustion in 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

Table 3-54 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1A4 Stationary combustion in other sectors.

NFR code	Source category	Pollutant	Identification criteria
1A4ai	Commercial/institutional: stationary	NOx	L1, L2, T1, T2
1A4ai	Commercial/institutional: stationary	SOx	T1, T2
1A4ai	Commercial/institutional: stationary	PM2.5	L1, L2
1A4ai	Commercial/institutional: stationary	PM10	L1, L2
1A4bi	Residential: stationary plants	NOx	L1, L2
1A4bi	Residential: stationary plants	NMVOC	L1, L2
1A4bi	Residential: stationary plants	SOx	L1, L2, T1, T2
1A4bi	Residential: stationary plants	PM2.5	L1, L2, T1, T2
1A4bi	Residential: stationary plants	PM10	L1, L2, T1, T2
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	L1

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

Methodology (1A4 ai/bi/ci stationary)

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. Beside the main energy sources, also the use of other bituminous coal, charcoal use and bonfires are considered in source category 1A4bi. Emissions from 1A4ci originate from fuel combustion for the heating of greenhouses and grass drying, as well as for heating in agriculture and forestry.

The methodology to estimate emissions from stationary combustion in source categories 1A4ai, 1A4bi and 1A4ci, follows a Tier 2 approach according to the decision tree for small combustion, Figure 3-1 in the chapter 1A4 small combustion in the EMEP/EEA guidebook (EMEP/EEA 2019). Emission factors and activity data are specified for different technologies. Direct emission measurements are not available.

Emission factors (1A4 ai/bi/ci stationary)

Table 3-55, Table 3-56 and Table 3-57 present the emission factors applied for source categories 1A4ai, 1A4bi and 1A4ci, respectively. Please note the following additional information:

- For boilers, the emission factors of NO_x and CO for natural gas, biogas and gas oil are based on a study by Leupro (2012). Within this study, measurements from the control of combustion installations in eight Swiss cantons were analysed. Emission factors are thus country specific.
- For boilers, the emission factors for PM10, PM2.5 and TSP for natural gas, biogas and gas oil are based on a study by Leupro (2012).
- For boilers, the emission factors for NMVOC are documented in SAEFL (2000).
- For boilers with natural gas or biogas, the emission factors for Pb, Cd, Hg and PAH are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1.A.4 Small combustion) as follows. 1A4ai: natural gas/biogas boilers table 3-26, 1A4bi: natural gas boilers table 3-16, 1A4ci: natural gas/biogas boilers table 3-26.
- For boilers with gas oil, the emission factors for Pb, Cd and Hg are taken from table 3-18 in the EMEP/EEA guidebook (EMEP/EEA 2019), PAHs are from table 3-31 and 3-9 (Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using liquid fuels), respectively, as stated in the EMEP/EEA guidebook representing average of Tier 2 emission factors for commercial/institutional liquid fuel combustion for all technologies. These PAH emission factor values have been taken since the proposed values in table 3-21 are based on a relatively old reference from 1995 and are rather high compared to other PAH values within the guidebook.
- For boilers with other bituminous coal in 1A4bi, Hg emission factors stem from table 3-23 in the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4) allocated to non-residential sources (automatic boilers) burning coal fuels and not from table 3-15 in the EMEP/EEA guidebook (EMEP/EEA 2019) allocated to residential boilers burning solid fuels. This choice was made because table 3-15 provides for Hg with 6 g/TJ a lower value than table 3-23 with 16 g/TJ for advanced technology.
- For boilers using gaseous and liquid fuels, the HCB emission factors are based on the approach of the Danish Emission Inventory for hexachlorobenzene and polychlorinated biphenyls (Nielsen et al. 2013).
- For boilers with solid and liquid fossil fuels as well as of wood and wood waste combustion, the emission factors of PCB are taken from the Danish emission inventory for HCB and PCBs (Nielsen et al. 2013).
- Emission factors for SO_x are described in chp. 3.2.1.2.
- Wood combustion in1A4ai/bi/ci: The country-specific emission factor model for wood energy is described in chp. 3.2.1.1.2. For mobile pellet combustion installations in source category 1A4ai, the same emission factors are assumed as for the installation category (stationary) automatic pellet boilers 50-300 kW.

- Emission factors for combined heat and power generation in turbines and engines are based on INFRAS (2022a) as described in chapter 3.2.1.1.3.
- Bonfires and use of charcoal (within 1A4bi): Emission factors of NO_x, NMVOC, SO_x, PM2.5/PM10, TSP, CO, Pb, Cd, Hg, PCDD/PCDF, PAH and HCB are taken from EMEP/EEA guidebook, Tier 2 level of source category open fireplaces burning biomass (EMEP/EEA 2019, chp.1A4, Table 3-39) as shown in Table 3-56. The emission factor of NH_3 is based on the revised value in EMEP/EEA 2023 (chp. 1A4, table 3-39). According to the EMEP/EEA guidebook (EMEP/EEA 2019, chp.1A4, Table 3-39), the values for particulate matter correspond to total particles including both filterable and condensable particulate matter. More details are described in EMIS 2024/1A4bi Lagerfeuer and EMIS 2024/1A4bi Holzkohle Verbrauch.
- 1A4ci Emission factors for grass drying are based on air pollution control measurements (NO_x since 2002, NMVOC since 1990, TSP and CO since 2000).

Table 3-55 Emission factors for 1A4ai for 2022. All fuels not listed are "NO".

Source/fuel	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ			g/TJ	kg/TJ				
1A4ai Other sectors (stationary): Commercial/institutional									
Gas oil (weighted average)	46	6.8	2.0	26	0.49	0.49	0.49	0.050	8.2
Gas oil heat only boilers	32	6	2.0	1	0.2	0.2	0.2	0.0078	5.9
Gas oil engines	824	50	2.0	1'391	16	16	16	2.3	137
Natural gas (weighted average)	19	6.6	0.18	126.4	0.20	0.20	0.20	0.0053	11
NG heat only boilers	16	2	0.18	1	0.1	0.1	0.1	0.0054	8.9
NG turbines	53	1.6	0.18	NA	0.2	0.2	0.2	0.0005	25
NG engines	74	89	0.18	2363	2.0	2.0	2.0	0.0041	55
Liquefied petroleum gas (engines)	135	89	0.5	NA	2.0	2.0	2.0	0.005	56
Biomass (weighted average)	107	44	4.4	2517	22	24	25	5.7	431
Biodiesel (engines)	293	50	0.31	5'860	30	30	30	2.3	134
Wood and wood waste (various furnaces)	111	36	5.4	2'580	38	41	42	7.1	507
Biogas (engines and heat only boilers)	101	89	0.5	3'552	1.9	1.9	1.9	0.0040	133
Sewage gas (engines, gas turbines and heat only boilers)	84	69	0.5	1'409	1.5	1.5	1.5	0.0044	112

Source/fuel	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	mg/TJ					
1A4ai Other sectors (stationary): Commercial/institutional										
Gas oil (weighted average)	0.014	0.0012	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil heat only boilers	0.012	0.001	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil engines	0.15	0.01	0.11	0.0010	1.9	15	1.7	1.5	0.22	0.00011
Natural gas (weighted average)	0.0035	0.00039	0.10	0.00050	0.59	1.3	0.89	0.89	NA	NA
NG heat only boilers	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA
NG turbines	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA
NG engines	0.040	0.0030	0.10	0.00057	1.2	8.9	1.7	1.8	NA	NA
Liquefied petroleum gas (engines)	0.040	0.003	0.1	0.00057	1.3	9	1.7	1.8	NA	NA
Biomass (weighted average)	16	0.88	1.6	0.082	5'970	5'971	3'648	3'648	2.2	0.013
Biodiesel (engines)	0.15	0.01	0.11	0.00099	1.9	15	1.7	1.5	0.22	0.00011
Wood and wood waste (various furnaces)	20	1.1	2.0	0.10	7'417	7'417	4'532	4'532	2.7	0.016
Biogas (engines and heat only boilers)	0.040	0.0030	0.1	0.00057	1.2	9.0	1.7	1.8	NA	NA
Sewage gas (engines, gas turbines and heat only boilers)	0.031	0.0024	0.1	0.00055	1.1	7.1	1.5	1.6	NA	NA

Table 3-56 Emission factors for 1A4bi (including charcoal and bonfires) for 2022. All fuels not listed are "NO".

Source/fuel	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ			g/TJ	kg/TJ				
1A4bi Other sectors (stationary): Residential									
Gas oil (weighted average)	33	6.0	2.0	2.04	0.20	0.20	0.20	0.0079	11
Gas oil heat only boilers	33	6	2.0	1	0.2	0.2	0.2	0.0078	11
Gas oil engines	136	50.0	2.0	8'937	30	30	30	1.2	136
Natural gas (weighted average)	15	4.2	0.18	1.0	0.10	0.10	0.10	0.0054	12
NG heat only boilers	15	4.0	0.18	1	0.1	0.1	0.1	0.0054	12
NG engines	72	89	0.18	2'381	2.0	2.0	2.0	0.0041	54
Liquefied petroleum gas (engines)	135	89	0.5	NA	2.0	2.0	2.0	0.005	56
Other bituminous coal	65	100	350	1'600	67	67	97	4.3	1'000
Biomass (weighted average)	94	107	7.8	3'141	71	75	78	24	1311
Biodiesel	406	50	0.31	3'502	30	30	30	2.3	132
Biogas	97	89	0.5	2'380	2.0	2.0	2.0	0.0041	88
Wood and wood waste (various furnaces)	95	92	7.7	2'996	84	89	93	23	1'231
Use of charcoal	50	600	11	8000	820	840	880	57	4000
Wood (bonfires)	50	600	11	8000	820	840	880	57	4000

Source/fuel	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	mg/TJ					
1A4bi Other sectors (stationary): Residential										
Gas oil (weighted average)	0.012	0.0010	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil heat only boilers	0.012	0.001	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil engines	0.15	0.01	0.11	0.0010	1.9	15	1.7	1.5	0.22	0.00011
Natural gas (weighted average)	0.0016	0.00026	0.1	0.0015	0.56	0.86	0.84	0.84	NA	NA
NG heat only boilers	0.0015	0.00025	0.1	0.0015	0.56	0.84	0.84	0.84	NA	NA
NG engines	0.04	0.003	0.1	0.00057	1.2	9	1.7	1.8	NA	NA
Liquefied petroleum gas (engines)	0.04	0.003	0.1	0.00057	1.3	9	1.7	1.8	NA	NA
Other bituminous coal	200	3	16	0.5	270'000	250'000	100'000	90'000	0.62	0.066
Biomass (weighted average)	20	1.4	2.0	0.23	24'089	23'799	12'807	13'646	4.1	0.028
Biodiesel	0.15	0.01	0.11	0.0010	1.9	15	1.7	1.5	0.22	0.00011
Biogas	0.04	0.0030	0.10	0.00057	1.2	9	1.7	1.8	NA	NA
Wood and wood waste (various furnaces)	19	1.0	2	0.21	21'211	21'211	11'942	11'942	4.0	0.027
Use of charcoal	27	13	0.56	0.8	121000	111000	42000	71000	5	0.06
Wood (bonfires)	27	13	0.56	0.8	121000	111000	42000	71000	5.7	0.06

Table 3-57 Emission factors for 1A4ci for 2022. All fuels not listed are "NO".

1A4ci Agriculture/forestry/fishing	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ			g/TJ	kg/TJ				
Drying of grass	73	99	83	NA	284	284	284	13	567
Heating of greenhouses (weighted average)	23	2	0.79	1.3	0.13	0.13	0.13	0.0062	6.4
Gas oil	30.9	2	2.0	2	0.2	0.2	0.2	0.0078	5.9
Natural gas	18.4	2	0.18	1	0.1	0.1	0.1	0.0054	6.7
Other fossil combustion (weighted average)	942	50	2.0	101	28	28	28	2.3	137
Gas oil (engines)	942	50	2.0	101	28	28	28	2.3	137
Natural gas (engines)	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other biomass combustion (weighted average)	101	63	2.3	2'659	18	19	20	1.6	224
Biogas (engines)	100	89	0.5	3'044	2.0	2.0	2.0	0.0039	111
Wood and wood waste (various furnaces)	103	19	5.4	1'980	47	50	52	4.4	424

1A4ci Agriculture/forestry/fishing	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	mg/TJ					
Drying of grass	6.2	1.3	0.64	NE	NE	NE	NE	NE	NE	NE
Heating of greenhouses (weighted average)	0.0051	0.00050	0.11	0.00094	1.0	5.6	1.1	1.1	0.22	0.00011
Gas oil	0.012	0.0010	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Natural gas	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA
Other fossil combustion (weighted average)	0.15	0.01	0.11	0.00099	1.9	15	1.7	1.5	0.22	0.00011
Gas oil (engines)	0.15	0.01	0.11	0.00099	1.9	15	1.7	1.5	0.22	0.00011
Natural gas (engines)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other biomass combustion (weighted average)	6.5	0.35	0.72	0.026	2'143	2'147	1'111	1'111	2.9	0.011
Biogas (engines)	0.04	0.003	0.1	0.00057	1.2	9	1.7	1.8	NA	NA
Wood and wood waste (various furnaces)	18	0.97	1.8	0.071	5'915	5'915	3'064	3'064	2.9	0.011

Activity data (1A4 ai/bi/ci stationary)

Activity data on consumption of gas oil, residual fuel oil, natural gas and biomass are calculated by the energy model (see chp. 3.1.6.3 for further information) and the Energy model for wood combustion (see chp. 3.2.1.1.2). For other energy sources such as other bituminous coal, activity data are provided directly by the Swiss overall energy statistics (SFOE 2023).

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 2023b, chp. 1.4). However, this is not part of the wood energy statistics model.

Charcoal is only used for barbecues. The total charcoal consumption under 1A4bi is very small compared to other fuels used for heating purposes. The activity data are the sum of charcoal production under 1A1c, and net imports provided by the Swiss overall energy statistics (SFOE 2023).

As the Swiss wood energy statistics (SFOE 2023b) 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 2024/1A4bi Lagerfeuer).

Activity data for grass drying in source category 1A4ci are reported by the Swiss association of grass drying plants VSTB (as standard tonne of dried grass, confidential report), see also illustrations Figure 3-12 and Figure 3-16.

Since submission 2015, data on fuel consumption for grass drying are available and used for emission calculations (see EMIS 2024/1A4ci Grastrocknung). The use of gas oil and natural gas for grass drying in 1A4ci is subtracted from boilers in 1A4ai.

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 2024/1A4ci Gewächshäuser).

Table 3-58 Activity data of 1A4ai Commercial/institutional. All fuels not listed are "NO".

1A4ai Other sectors (stationary): Commercial/institutional	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
Total fuel consumption	TJ	73'725	81'713	78'706	85'366	81'751
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	6'156	7'274	9'748
Biodiesel (engines)	TJ	NO	NO	26	7.9	56
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): Commercial/institutional	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel consumption	TJ	79'918	63'561	69'557	72'926	70'414	63'895	64'366	61'620	70'351	57'306
Gas oil	TJ	42'724	32'990	35'151	36'438	34'220	30'877	30'271	27'594	31'347	25'616
Gas oil heat only boilers	TJ	42'223	32'491	34'661	35'957	33'727	30'414	29'793	27'126	30'883	25'154
Gas oil engines	TJ	501	499	490	481	493	463	478	468	465	463
Natural gas	TJ	26'407	20'294	23'161	24'390	24'017	21'222	21'805	21'096	24'175	18'370
NG heat only boilers	TJ	24'596	18'624	21'564	22'909	22'680	20'062	20'806	20'139	23'222	17'394
NG turbines	TJ	0.020	0.027	0.029	0.25	0.23	0.24	0.23	0.21	0.20	0.19
NG engines	TJ	1'810	1'670	1'597	1'481	1'336	1'159	999	956	953	976
Liquefied petroleum gas (engines)	TJ	91	97	87	121	44	29	23	23	22	23
Biomass	TJ	10'697	10'179	11'158	11'976	12'133	11'767	12'267	12'908	14'806	13'298
Biodiesel (engines)	TJ	51	51	49	49	45	45	37	36	35	35
Wood and wood waste (various furnaces)	TJ	8'195	7'720	8'702	9'516	9'642	9'258	9'783	10'375	12'284	10'702
Biogas (engines and heat only boilers)	TJ	711	703	740	783	810	821	816	848	832	954
Sewage gas (engines, gas turbines and heat only boilers)	TJ	1'740	1'706	1'667	1'628	1'636	1'643	1'631	1'648	1'654	1'607

Table 3-59 Activity data of 1A4bi Residential. All fuels not listed are "NO".

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	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	1	3
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**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel consumption	TJ	172'809	135'296	145'010	151'174	145'048	133'301	134'218	124'773	139'974	114'538
Gas oil	TJ	99'373	75'136	79'406	81'340	76'113	67'901	66'642	59'375	66'048	51'247
Gas oil heat only boilers	TJ	99'363	75'126	79'398	81'332	76'104	67'896	66'635	59'369	66'042	51'241
Gas oil engines	TJ	10	10	9	7	8	5	6	6	6	6
Natural gas	TJ	51'162	42'554	46'295	49'026	48'527	46'120	47'781	47'414	53'284	45'494
NG heat only boilers	TJ	50'961	42'369	46'118	48'862	48'380	45'992	47'671	47'309	53'179	45'386
NG engines	TJ	201	185	177	163	147	128	110	105	105	108
Liquefied petroleum gas (engines)	TJ	10	11	10	14	5	3	3	3	2	3
Other bituminous coal	TJ	300	200	200	200	100	100	100	100	100	50
Biomass	TJ	21'964	17'396	19'099	20'595	20'303	19'177	19'692	17'882	20'539	17'745
Biodiesel	TJ	3	3	3	3	3	2	2	2	2	2
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	4	5	6
Wood and wood waste (various furnaces)	TJ	21'457	16'878	18'582	20'099	19'766	18'661	19'205	17'311	20'008	17'223
Charcoal use	TJ	343	354	354	334	374	354	325	404	364	353
Wood (bonfires)	TJ	160	160	160	160	160	160	160	160	160	160

Table 3-60 Activity data of 1A4ci Agriculture / forestry / fishing. All fuels not listed are "NO".

1A4ci Other sectors (stationary): Agriculture/forestry/fishing	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
Total fuel consumption	TJ	6'387	6'110	5'804	5'531	5'656
Drying of grass	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

1A4ci Other sectors (stationary): Agriculture/forestry/fishing	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel consumption	TJ	5'300	4'764	4'937	5'442	5'962	5'488	5'827	5'943	6'371	5'623
Drying of grass	TJ	458	524	431	492	610	545	684	721	630	559
Gas oil	TJ	106	104	89	86	118	116	124	148	94	99
Residual fuel oil	TJ	17	20	22	18	25	13	NO	NO	NO	NO
Natural gas	TJ	220	264	233	279	338	296	427	435	410	347
Biomass (crop residues, fat, wood)	TJ	114	136	88	109	129	120	132	138	126	113
Heating of greenhouses	TJ	3'389	2'800	2'900	2'899	3'238	2'754	2'732	2'537	2'753	2'114
Gas oil	TJ	1'496	1'095	1'165	1'066	1'145	930	916	788	861	717
Natural gas	TJ	1'893	1'705	1'735	1'834	2'093	1'824	1'816	1'749	1'892	1'397
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	1'452	1'438	1'605	2'048	2'112	2'187	2'409	2'683	2'985	2'949
Biogas (engines)	TJ	812	928	1'041	1'192	1'272	1'403	1'612	1'762	1'909	1'946
Wood and wood waste (various furnaces)	TJ	639	510	564	856	840	784	797	921	1'076	1'003

3.2.4.3 Category-specific recalculations for 1A4 Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

The following recalculations were implemented in submission 2024:

- 1A4: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A4: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.
- 1A4: Activity data of automatic wood combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2021 due to recalculations in the Swiss wood energy statistics (SFOE 2023b). The biggest changes were in automatic boilers >50 kW after 2018.
- 1A4: The emissions of PM2.5 exhaust, PM10 exhaust and TSP exhaust of wood energy combustion in source category 1A4ai Commercial/Institutional (stationary), 1A4bi Residential (stationary) and 1A4ci Agriculture/Forestry/Fishing (stationary) now also include the condensable particle fractions (1990-2021, PM2.5 (2021), 1A4ai: +41 %, 1A4bi: +74 % and 1A4ci: +57 %).
- 1A4ai: Source category 1A4ai now 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 fuel consumption is based on information from the Swiss wood energy statistics publication (SFOE 2023b, chp. 1.4), but is not part of the wood energy statistics model.
- 1A4bi: The activity of source category 1A4bi Charcoal consumption was revised for 2021 due to the correction of a typing error in the import figure and an updated value of 1A1c Charcoal production (364 TJ instead of 40 TJ).
- 1A4bi: The NH_3 emission factors of bonfires and use of charcoal were adjusted from 74 g/GJ to 8 g/GJ for the entire time series based on the revised value in EMEP/EEA 2023 (chp. 1A4, table 3-39).
- 1A4bi: Last year's correction of the NMVOC emission factor for single-room furnaces burning logwood was made up for 1A4bi Closed fireplaces.
- 1A4ci: The activity data of source category 1A4ci for combustion of biogas is now reported in our database directly in GJ instead of GWh and with additional significant digits, causing emission changes of less than 0.1 % for the entire time series. This change affects the following pollutants: NO_x, NMVOC, SO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust, BC, CO, heavy metals, POPs.

3.2.5 Source category 1A2 - Mobile Combustion in manufacturing industries and construction

3.2.5.1 Source category description for 1A2 Mobile combustion in manufacturing industries and construction

Table 3-61 Specification of source category 1A2 Mobile combustion in manufacturing industries and construction.

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.

Table 3-62 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1A2 Combustion in manufacturing industries and construction (mobile only).

NFR code	Source category	Pollutant	Identification criteria
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	T1
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	L1, L2, T1, T2
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	L1, L2, T1, T2

3.2.5.2 Methodological issues for 1A2 Mobile combustion in manufacturing industries and construction

Methodology (1A2gvii)

Based on the decision tree Fig. 3.1 in chapter Non-road mobile sources and machinery of the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of industry and construction vehicles and machinery are calculated by a Tier 3 method with the non-road transportation model described in chapter 3.2.1.1.1.

Emission factors (1A2gvii)

The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard-specific emission factors are shown in Table 3-63 to Table 3-66. Implied emission factors for the reporting year are shown in Table 3-67.

Table 3-63 Emission factors for diesel-powered machinery (1A2gvii) per emission standard.

engine power	Pre-EU A	Pre-EU B	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
	g/kWh							
Carbon monoxide (CO)								
<18 kW	6.71	6.71	2.90	2.90	2.90	2.90	2.90	*2.90*
18–37 kW	6.71	6.71	2.76	2.42	2.06	1.76	1.50	*1.50*
37–56 kW	4.68	4.68	1.87	1.63	1.39	1.19	1.01	*1.01*
56–75 kW	4.68	4.68	1.87	1.63	1.39	1.19	1.01	*1.01*
75–130 kW	3.62	3.62	1.28	1.01	0.86	0.73	0.62	*0.62*
130–560 kW	3.62	3.62	1.04	0.91	0.77	0.66	0.50	*0.50*
>560 kW	3.62	3.62	1.04	0.91	0.77	0.66	0.50	*0.50*
Hydrocarbons (HC)								
<18 kW	2.28	2.28	1.60	1.00	0.59	0.59	0.59	*0.53*
18–37 kW	2.41	2.41	0.92	0.56	0.37	0.37	0.37	*0.37*
37–56 kW	1.33	1.33	0.65	0.46	0.33	0.33	0.33	*0.33*
56–75 kW	1.33	1.33	0.65	0.46	0.33	0.13	0.13	*0.13*
75–130 kW	0.91	0.91	0.45	0.35	0.28	0.17	0.17	*0.13*
130–560 kW	0.91	0.91	0.43	0.30	0.22	0.17	0.17	*0.13*
>560 kW	0.91	0.91	0.43	0.30	0.22	0.17	0.17	*0.13*
Nitrogen oxides (NO_X)								
<18 kW	10.31	8.20	5.95	5.95	5.95	5.95	5.95	*5.95*
18–37 kW	10.31	8.20	6.34	6.34	6.34	6.34	6.34	*6.34*
37–56 kW	12.40	9.87	8.95	6.56	3.90	3.90	3.90	*3.90*
56–75 kW	12.40	9.87	8.95	6.56	3.90	3.30	0.40	*0.40*
75–130 kW	12.52	9.96	8.44	5.67	3.32	3.30	0.40	*0.40*
130–560 kW	12.52	9.96	8.19	5.66	3.38	2.00	0.40	*0.40*
>560 kW	12.52	9.96	8.19	5.66	5.66	5.66	5.66	*3.50*
Particulate matter (PM)								
<18 kW	1.51	1.18	1.00	0.80	0.70	0.60	0.60	*0.40*
18–37 kW	1.20	0.94	0.74	0.60	0.54	0.54	0.54	*0.01*
37–56 kW	1.09	0.85	0.47	0.32	0.32	0.03	0.03	*0.01*
56–75 kW	1.09	0.85	0.47	0.32	0.32	0.03	0.03	*0.01*
75–130 kW	0.61	0.47	0.35	0.24	0.24	0.03	0.03	*0.01*
130–560 kW	0.61	0.47	0.22	0.16	0.16	0.03	0.03	*0.01*
>560 kW	0.61	0.47	0.22	0.16	0.16	0.16	0.16	*0.05*
Fuel consumption								
<18 kW	248	248	248	248	248	248	248	*248*
18–37 kW	248	248	248	248	248	248	248	*248*
37–75 kW	248	248	248	248	248	248	248	*248*
75–130 kW	223	223	223	223	223	223	223	*223*
>130 kW	223	223	223	223	223	223	223	*223*

Table 3-64 Emission factors for gasoline-powered machinery (4-stroke engines) (1A2gvii) per emission standard. cc: cubic centimetres

Capacity range	Pre-EU A	Pre-EU B	Pre-EU C	EU I	EU II	EU V
Carbon monoxide (CO)						
<66 cc	470	470	470	467	467	467
66–100 cc	470	470	470	467	467	467
100–225 cc	470	470	470	467	467	467
>225 cc	470	470	470	467	467	467
Hydrocarbons (HC)						
<66 cc	60	60	60	41	41	8
66–100 cc	40	40	40	32	32	8
100–225 cc	20	20	20	12	12	8
>225 cc	20	20	20	10	9	6
Nitrogen oxides (NO_X)						
<66 cc	1.5	2.0	3.0	4.5	4.5	0.9
66–100 cc	1.5	2.0	3.0	3.6	3.6	0.9
100–225 cc	3.5	3.5	3.5	2.8	2.8	0.9
>225 cc	3.5	3.5	3.5	2.2	1.9	0.72
Fuel consumption (FC)						
<66 cc	500	500	500	480	480	460
66–100 cc	480	480	480	470	470	460
100–225 cc	460	460	460	450	450	450
>225 cc	460	460	460	450	450	450
Assumptions regarding introduction of emission stages						
<66 cc	<1996	1996	2000	2004	2005	2019
66–100 cc	<1996	1996	2000	2004	2005	2019
100–225 cc	<1996	1996	2000	2004	2009	2019
>225 cc	<1996	1996	2000	2004	2007	2019

Table 3-65 Emission factors for gasoline-powered machinery (2-stroke engines) (1A2gvii) per emission standard. cc: cubic centimetres

Capacity range	Pre-EU A	Pre-EU B	Pre-EU C	EU I	EU II	EU V
Carbon monoxide (CO)						
<20 cc	650	640	620	600	600	500
20–50 cc	650	640	620	600	600	500
>50 cc	650	640	620	540	540	500
Hydrocarbons (HC)						
<20 cc	260	250	150	100	41	41
20–50 cc	260	250	150	100	41	41
>50 cc	260	250	150	100	58	58
Nitrogen oxides (NO_X)						
<20 cc	1.5	2.0	3.0	4.8	4.5	4.5
20–50 cc	1.5	2.0	3.0	4.8	4.5	4.5
>50 cc	1.5	2.0	3.0	4.8	6.3	6.3
Fuel consumption						
<20 cc	660	650	550	500	440	410
20–50 cc	660	650	550	500	440	410
>50 cc	660	650	550	500	460	410
Assumptions regarding the introduction of emission stages						
<20 cc	<1996	1996	2000	2004	2009	2019
20–50 cc	<1996	1996	2000	2004	2009	2019
>50 cc	<1996	1996	2000	2004	2011	2019

Table 3-66 Emission factors for gas-operated machinery (1A2gvii).

Pollutant	Without catalyst	With oxidation catalysts	50% with 3-way catalysts	100% with 3-way catalysts
	g/kWh			
CO	10	0.2	0.2	0.2
HC	8	0.5	0.5	0.5
NOx	10	10	6	2
PM	0.02	0.01	0.01	0.01
Fuel consumption	450	450	455	460
Assumptions regarding introduction of emission stages				
All capacities		1980	1994	2000

Table 3-67 Implied emission factors for 1A2gvii in 2022.

1A2gvii Non-road vehicles and other machinery	NO_x	NMVOC	SO_X	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	g/GJ					g/h	g/GJ	g/h	g/GJ	g/h	g/GJ	g/h
Gasoline	94	603	0.10	0.089	0.12	2.4	0.12	16	0.12	24	0.0061	0.0030
Diesel oil	185	19	0.31	0.17	4.5	2.4	4.5	16	4.5	24	2.3	0.0030
Liquefied petroleum gas	96	8.7	NA	0.22	0.47	2.4	0.47	16	0.47	24	0.023	0.0030
Biodiesel	158	16	0.31	0.15	3.9	2.4	3.9	16	3.9	24	2.0	0.0030
Bioethanol	42	209	0.22	0.059	0.087	2.4	0.087	16	0.087	24	0.0044	0.0030

1A2gvii Non-road vehicles and other machinery	CO	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/GJ		mg/GJ		ng I-TEQ/GJ	mg/GJ				ng/GJ	
Gasoline	19'700	0.0074	2.3	0.20	2.7	1.0	1.0	0.098	0.30	NE	NE
Diesel oil	93	0.00091	2.2	0.12	1.5	0.66	1.1	0.82	0.19	NE	NE
Liquefied petroleum gas	24	NA	0.23	NA	NA	0.0043	NA	0.0043	0.0043	NE	NE
Biodiesel	79	0.00078	1.9	0.098	1.3	0.56	0.94	0.70	0.16	NE	NE
Bioethanol	12'046	0.00038	1.5	0.13	1.8	0.66	0.66	0.064	0.19	NE	NE

Activity data (1A2gvii)

Table 3-68 shows the activity data of 1A2gvii taken from FOEN (2015j). Diesel oil is the main fuel type consumed in this category. Data on biofuels are provided by the statistics of renewable energies (SFOE 2023a). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-68 Activity data for 1A2gvii.

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	7'106	7'626	8'254
Liquefied petroleum gas	TJ	165	248	294	290	269
Biodiesel	TJ	NO	NO	9.2	28	36
Bioethanol	TJ	NO	NO	NO	NO	0.0047

1A2gvii Non-road vehicles and other machinery	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel consumption	TJ	8'875	8'906	8'938	8'944	8'949	8'955	8'960	8'966	8'991	9'016
Gasoline	TJ	198	191	184	180	177	174	171	168	167	166
Diesel oil	TJ	8'341	8'370	8'399	8'380	8'361	8'342	8'323	8'304	8'296	8'288
Liquefied petroleum gas	TJ	243	235	226	215	203	192	180	168	163	157
Biodiesel	TJ	91	110	128	166	205	243	282	320	360	400
Bioethanol	TJ	0.76	1.02	1.3	2.0	2.7	3.3	4.0	4.7	5.4	6.1

3.2.5.3 Category-specific recalculations for 1A2 Mobile combustion in manufacturing industries and construction

The following recalculations were implemented in submission 2024:

- 1A2gvii: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.

3.2.6 Source category 1A3 - Transport

3.2.6.1 Source category description for 1A3 Transport

The source category 1A3 Transport includes all emissions from fuel combustion in transport processes in the air, on road, on railways, water and pipelines.

Table 3-69 Specification of source category 1A3 Transport.

1A3	Source category	Specification
1A3ai(i)	International aviation LTO (civil)	LTO: Landing/Take-off emissons from international flights
1A3ai(ii)	International aviation CR (civil)	CR: Cruise emissions of international flights Memo item – not to be included in national total
1A3aii(i)	Domestic aviation LTO (civil)	LTO: Landing/Take-off emissions from domestic flights Large (jet, turboprop) & small (piston) aircrafts, helicopters
1A3aii(ii)	Domestic aviation CR (civil)	CR: Cruise emissions from domestic flights Large (jet, turboprop) & small (piston) aircrafts, helicopters Memo item – not to be included in national total
1A3bi	Road transportation: Passenger cars	Emissions from passenger cars
1A3bii	Road transportation: Light duty vehicles	Emissions from light duty vehicles
1A3biii	Road transportation: Heavy duty vehicles and buses	Emissions from heavy duty vehicles, coaches and buses
1A3biv	Road transportation: Mopeds & motorcycles	Emissoins from 2-stroke and 4-stroke motorcycles
1A3bv	Road transportation: Gasoline evaporation	NMVOC emissions from gasoline evaporation
1A3bvi	Road transportation: Automobile tyre and brake wear	Non-exhaust emissions from road transportation
1A3bvii	Road transportation: Automobile road abrasion	Not reported separately but included in non-exhaust emissions reported in 1A3bvi
1A3c	Railways	Diesel locomotives, abrasion by merchandise and person traffic
1A3di(ii)	International maritime navigation	Shipping leaving Switzerland on the river Rhine and on Lake Geneva and Lake Constance Memo item - not to be included in national total
1A3dii	National navigation (shipping)	Passenger ships, motor and sailing boats on the Swiss lakes and the river Rhine
1A3ei	Pipeline transport	Gas turbines at the compressor station in Ruswil (canton Lucerne) for the Swiss gas network.

Note that emissions from cruise in civil aviation (see also Table 3-6; 1A3ai(ii) International aviation CR and 1A3aii(ii) Domestic aviation CR) as well as emissions from international inland waterways are reported under “memo items” and not considered for the national total.

Table 3-70 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1A3, Transport.

NFR code	Source category	Pollutant	Identification criteria
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	NOx	L1, T1, T2
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	SOx	L1, T1, T2
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NOx	L1, L2, T2
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NMVOC	L1, L2, T1, T2
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NOx	L1, L2, T1, T2
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	NOx	L1, L2, T1, T2
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	SOx	T1, T2
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM2.5	T1
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM10	T1
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)	NMVOC	L2, T2
1A3bv(fu)	Road transportation: gasoline evaporation (fuel used)	NMVOC	L1, T1, T2
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM2.5	L1, L2, T1, T2
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM10	L1, L2, T1, T2
1A3c	Railways	PM2.5	L1, T1
1A3c	Railways	PM10	L1, L2, T1, T2
1A3dii	National navigation (shipping)	NOx	T1

3.2.6.2 Methodological issues for 1A3 Transport

3.2.6.2.1 Civil aviation (1A3a)

Methodology (1A3a)

According to the decision tree Figure 3-1 in chapter 1A3a Aviation in the EMEP/EEA guidebook (EMEP/EEA 2019), Switzerland uses a Tier 3 approach because data on start and final destination are available by aircraft type. Emission factors are also used on a detailed level stratified by engine type.

All civil flights from and to Swiss airports are separated into domestic (national, 1A3aii) and international (1A3ai) flights. The Landing/Take-off (LTO) emissions of domestic and international flights are reported under category 1A3a. The emissions of domestic and international cruise are reported as memo item and are therefore not accounted for in the national total.

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, 2005, 2007-2022. The results of the emission modelling have been transmitted from FOCA to FOEN in an aggregated form (FOCA 2006, 2006a, 2007a, 2008-2023). Years in-between are interpolated. Further details of emission modelling are described in Switzerland’s National Inventory Document (FOEN 2024).

Emission factors (1A3a)

The emission factors used are country-specific or taken from the ICAO engine emissions database from the EMEP/EEA guidebook (EMEP/EEA 2019), Swedish Defence Research Agency (FOI) and Swiss FOCA measurements. Emission factors are case sensitive and for that reason separated into emission factors concerning the LTO cycle and cruise phase. Values of emission factors (EF) see Table 3-71.

- NO_x, VOC, CO are differentiated by engine type and by phases of a flight (taxi, take-off etc.)

- NMVOC is calculated as fraction of VOC. For LTO $EF_{NMVOC} = 0.47 * EF_{VOC}$, whereas for cruise $EF_{NMVOC} = EF_{VOC}$ i.e, there is no emission of CH_4 for the cruise phase.
- SO_x is based on the sulphur content of jet kerosene (see Table 3-28).
- PM10 and PM2.5 have been determined by the Federal Office of Civil Aviation (FOCA 2016b). For exhaust emissions, PM10 exhaust = PM2.5 exhaust = PM exhaust is assumed. During the high-power operating state of the engines, PM exhaust is equal to BC, during other operating states PM exhaust also contains volatile compounds. FOCA recommends to set $EF_{PM2.5\ exhaust} = 2 * EF_{BC}$, see also chapter 1.A.3.a, 1.A.5.b * Aviation of the EMEP/EEA guidebook (EMEP/EEA 2019), notes to table 3.11 on p.28.
- For non-exhaust emissions as tyre, break and airstrip abrasion, the findings the FOCA provide the weighted non-exhaust emission factor of 0.1 g per LTO-cycle, which is based on 0.08 g per landing of a short-distant flight and 0.27 g per landing of a long-distant flight.
- EF(Pb) is based on the content of the aviation fuels.

LTO

The Swiss FOCA engine emissions database consists of more than 520 individual engine data sets. Jet engine factors for engines above 26.7 kN thrust (emission certificated) are identical to the ICAO engine emissions database. Emission factors for lower thrust engines, piston engines and helicopters are taken from manufacturers or from own (FOCA) measurements. Emission factors for turboprops could be obtained in collaboration with the Swedish Defence Research Agency (FOI).

Cruise

Aircraft cruise emission factors are dependent on representative flight distances per aircraft type. A load factor of 65 % is assumed. Part of the cruise factors are also taken from former CROSSAIR (FOCA 1991). The whole Airbus fleet (which accounts for a large share of the Swiss inventory) has been modelled on the basis of real operational aircraft data from flight data recorders (FDR) of Swiss International Airlines.

Some of the old or missing aircraft cruise factors had to be modelled on the basis of the ICAO engine emissions database. For piston engine aircraft, FOCA has produced its own data, which were measured under real flight conditions.

Table 3-71 Emission factors for 1A3a Civil aviation, year 2022. (LTO: Landing take-off cycle, CR: cruise.). Sustainable aviation fuels (SAF) are referred to as jet kerosene biogenic.

1A3a Civil aviation	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3a International and domestic aviation, LTO												
1A3ai(i) International aviation, LTO, Jet kerosene fossil	326	23	23	NA	2.4	0.0028	2.4	0.0028	2.4	0.0028	0.96	NA
1A3ai(i) International aviation, LTO, Jet kerosene biogenic	345	21	23	NA	2.3	0.0028	2.3	0.0028	2.3	0.0028	0.83	NA
1A3aii(i) Domestic aviation LTO, Jet kerosene fossil	218	139	19	NA	7.7	0.0019	7.7	0.0019	7.7	0.0019	1.9	NA
1A3a International and domestic aviation, CR												
1A3ai(i) International aviation, CR, Jet kerosene fossil	418	4.1	23	NA	0.76	NA	0.76	NA	0.76	NA	0.76	NA
1A3ai(i) International aviation, CR, Jet kerosene biogenic	441	3.7	23	NA	0.62	NA	0.62	NA	0.62	NA	0.62	NA
1A3aii(i) Domestic aviation CR, Jet kerosene fossil	246	84	22	NA	4.2	NA	4.2	NA	4.2	NA	4.2	NA

1A3a Civil aviation	CO	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ				kg I-TEQ/TJ	kg/TJ					
1A3a International and domestic aviation, LTO											
1A3ai(i) International aviation, LTO, Jet kerosene fossil	269	0.0065	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3ai(i) International aviation, LTO, Jet kerosene biogenic	254	0.0011	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3aii(i) Domestic aviation LTO, Jet kerosene fossil	3'944	3.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3a International and domestic aviation, CR											
1A3ai(i) International aviation, CR, Jet kerosene fossil	46	0.0059	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3ai(i) International aviation, CR, Jet kerosene biogenic	40	0.00059	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3aii(i) Domestic aviation CR, Jet kerosene fossil	656	0.98	NA	NA	NA	NA	NA	NA	NA	NA	NA

Activity data (1A3a)

Activity data are derived from detailed movement statistics by FOCA. The statistics distinguish between scheduled and charter aviation as well as non-scheduled, non-charter and general aviation (including helicopters).

Scheduled and charter aviation

The statistical basis has been extended after 1996. Therefore, the modelling details are not exactly the same for the years 1990/1995 as for the subsequent years. The source for the 1990 and 1995 modelling are the movement statistics, which record for every movement information 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. All annual aircraft movements recorded are split into domestic and international flights.

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

Airports and most of the airfields report individual aircraft data (aircraft registration). FOCA is therefore able to compute also the inventory for small aircraft with a Tier 3 approach. However, for 1990 and 1995, the emissions for non-scheduled, non-charter and general aviation (helicopters etc.) could not be calculated with a Tier 3 approach. Its fuel consumption is estimated to be 10 % of the domestic fuel consumption. Data were taken from two studies by

FOCA (FOCA 1991, FOCA 1991a). Since 2000, all movements from airfields are registered, which allows a more detailed modelling of the emissions.

Helicopter flights which do not take off from an official airport or airfield such as transport flights, flights for lumbering, animal transports, supply of alpine huts, heli-skiing and flight trainings in alpine regions cannot be recorded with the movement data base from airports and airfields. Although these helicopter movements only account for 0.1 % of the total domestic aviation emissions, these emissions are taken into account using the statistics of the Swiss Helicopter Association (Unternehmensstatistik der Schweizer Helikopterunternehmen). These statistics are officially collected by FOCA and updated annually (see FOCA 2004 as illustrative example for all subsequent years). Since 2007, the data of these statistics are included electronically in the data warehouse of the model and undergo first some plausibility checks (E-plaus software). In order to distinguish between single engine helicopters and twin engine helicopters a fix split of 87 % for single engine helicopters and 13 % for twin engine helicopters is applied for the entire commitment period based on investigations in 2004 (FOCA 2004). Note that all emissions from helicopter flights without using an official airport or an official airfield are considered as domestic emissions. There is also a helicopter base in the Principality of Liechtenstein consuming a very small amount of fuel contained in the Swiss statistics. Thus, its consumption leads to domestic instead of international bunker emissions. FOCA and FOEN decided to report these emissions as Swiss-domestic since it is a very small amount and the effort for a separation would be considerable.

Table 3-72 summarises the activity data for civil aviation. Note that the cruise emissions are included in international bunkers and reported as memo items (1A3ai(ii) and 1A3aii(ii). The increase in energy consumption from 1990 to 2019 is due to an increasing number of flights. In 2020 and 2021, the COVID-19 pandemic led to a strong reduction of energy consumption compared to 2019 due to significantly reduced number of flights. In 2022, flight activities and thus the energy consumption increased again. However, the energy consumption remains lower than pre-pandemic level. Since 2021, sustainable aviation fuels (SAF) are reported from Zurich airport and attributed to international flights. The amount is very small compared to the amount of fossil jet fuel.

Table 3-72 Jet kerosene consumption of domestic and international aviation in TJ. Note that domestic and international LTO emissions are reported and included in the national total for the entire territory (based on fuel sold), whereas domestic and international cruise emissions are reported under memo items only. Sustainable aviation fuels (SAF) are referred to as jet kerosene biogenic.

1A3a Civil aviation	1990	1995	2000	2005	2010
	Fuel consumption in TJ				
1A3a International and domestic aviation, LTO	5'326	6'032	7'280	5'396	6'107
1A3ai(i) International aviation, LTO, Jet kerosene fossil	4'277	5'097	6'507	4'878	5'643
1A3ai(i) International aviation, LTO, Jet kerosene biogenic	NO	NO	NO	NO	NO
1A3aii(i) Domestic aviation LTO, Jet kerosene fossil	1'050	935	773	518	464
1A3a International and domestic aviation, CR	40'008	46'960	58'987	44'081	53'921
1A3ai(ii) International aviation, CR, Jet kerosene fossil	37'608	44'821	57'219	42'896	52'691
1A3ai(ii) International aviation, CR, Jet kerosene biogenic	NO	NO	NO	NO	NO
1A3aii(ii) Domestic aviation, CR, Jet kerosene fossil	2'401	2'139	1'768	1'184	1'230
Total 1A3a Civil aviation	45'334	52'993	66'267	49'477	60'028
1990 = 100%	100%	117%	146%	109%	132%

1A3a Civil aviation	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Fuel consumption in TJ									
1A3a International and domestic aviation, LTO	6'702	6'667	6'847	6'950	7'112	7'299	7'284	2'565	2'903	5'356
1A3ai(i) International aviation, LTO, Jet kerosene fossil	6'208	6'142	6'459	6'529	6'728	6'953	6'963	2'395	2'718	5'129
1A3ai(i) International aviation, LTO, Jet kerosene biogenic	NO	NO	NO	NO	NO	NO	NO	NO	2.0	0.029
1A3aii(i) Domestic aviation, LTO, Jet kerosene fossil	494	525	387	421	384	346	321	170	183	227
1A3a International and domestic aviation, CR (memo item)	59'825	60'259	62'374	65'584	67'352	71'494	72'482	26'685	29'780	53'086
1A3ai(ii) International aviation, CR, Jet kerosene fossil	58'501	58'864	60'874	64'073	66'096	70'261	71'233	25'799	29'129	52'369
1A3ai(ii) International aviation, CR, Jet kerosene biogenic	NO	NO	NO	NO	NO	NO	NO	NO	24	0.33
1A3aii(ii) Domestic aviation, CR, Jet kerosene fossil	1'323	1'396	1'500	1'511	1'257	1'234	1'250	886	628	717
Total 1A3a Civil aviation	66'526	66'927	69'220	72'534	74'465	78'793	79'767	29'250	32'683	58'443
1990 = 100%	147%	148%	153%	160%	164%	174%	176%	65%	72%	129%

3.2.6.2.2 Road transportation (1A3b)

Methodology (1A3b)

- The exhaust air pollutant emissions are calculated by a Tier 3 method based on the decision trees Fig. 3.1 in the chapters 1A3bi-iv Road transport 2019 in the EMEP/EEA guidebook (EMEP/EEA 2019).
- The non-exhaust air pollutant emissions are calculated by a Tier 2 method based on the decision trees Fig. 3.1 in the chapters 1A3bi-iv Road transport 2019 in the EMEP/EEA guidebook (EMEP/EEA 2019).

The total emissions are reported in two versions, the first one based on fuel used to account to the national total for compliance assessment and the second version based on fuel sold to be shown in the reporting tables and thereby contributing to the national total (but not for compliance assessment). See also chapter 3.1.6.1 on system boundaries. The difference between fuel sold and fuel used is attributed to fuel tourism (gasoline, bioethanol, diesel oil and biodiesel that are bought in Switzerland and used abroad or the other way round, depending on price differences between Switzerland and neighbouring countries) and statistical differences (difference to Swiss overall energy statistics on fuel sold). Implied emission factors of the territorial road model are used to calculate emissions resulting from fuel tourism. Emissions from fuel used and from fuel tourism and statistical differences add up to emissions from fuel sold. The integration of fuel tourism and statistical difference into the NFR reporting tables to source categories 1A3bi passenger cars, 1A3bii light duty vehicles and 1A3biii heavy duty vehicles and busses was conducted proportionally according to the annual fuel consumption within the respective source categories.

The emission computation is based on emission factors and activity data. For general methods see INFRAS (2017c), updated emission factors see INFRAS (2019a), Matzer et al. (2019) and Notter et al. (2022). Emission factors are expressed as specific emissions in grams per unit, where the unit depends on the set of traffic activity data: vehicle kilometres travelled (hot emissions, evaporation running losses), number of starts/stops and vehicle stock (cold start, evaporation soak and diurnal emissions from gasoline passenger cars, light duty vehicles and motorcycles only) or fuel consumption per vehicle category.

For all years up to 2022, statistical data was used for calculating activity data from 1A3b Road transportation (ex-post). 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 and diurnal NMVOC emissions: $E_{evap,i} = N_{evap,i} \cdot EF_{evap,i}$
- Evaporation running NMVOC losses: $E_{evap-RL} = VKT \cdot EF_{Evap-RL}$

with

- EF_{hot}, EF_{start}, EF_{evap}: Emission factors for ordinary driving conditions (hot engine), cold start and evaporative (VOC) emissions (after stops, running losses, diurnal losses)
- *VKT:* Vehicle km travelled
- N_{start}: Number of starts
- $N_{evap,i}$: Number of stops, or number of vehicles and day. *i* runs over two evaporation categories:
  a) evaporation soak emissions, i.e. emissions after stopping when the engine is still hot; and b) evaporation diurnal emissions, i.e. emissions due to daily air temperature differences. For a) the corresponding activity is number of stops, for b) number of vehicles multiplied by the number of days in the reported period (i.e. 365 for annual emissions).
- Emission factors are differentiated by fuel types: Gasoline (4-stroke), gasoline (2-stroke), diesel oil, liquefied petroleum gas, bioethanol, biodiesel, (compressed) natural gas, biogas, and by emission standard (in terms of percentage of vehicles with evaporation control, average tank and canister size, canister purge rates, and percentage of vehicles with mono- vs. multi-layered tanks).

Emission factors (1A3b)

Emission factors in 1A3b originate from the following sources:

- Emission factors for exhaust pollutants NO_x, NMVOC, NH_3, CO, PM2.5, and PM10 are country-specific and have been derived from "emission functions" determined from a compilation of measurements from various European countries with programs using similar driving cycles (legislative as well as standardized real-world cycles, like "Common Artemis Driving Cycle" (CADC). The method has been developed in 1990-1995 and has been extended and updated in 2000, 2004, 2010, 2017, 2019 and 2022 (INFRAS 2017c, INFRAS 2019a, Notter et al. 2022). These emission factors are compiled in a database called "Handbook of Emission Factors for Road Transport" (INFRAS 2022). Version 4.2 is presented and documented on the website http://www.hbefa.net/. The resulting emission factors are differentiated by so-called “traffic situations”, which represent characteristic patterns of driving behaviour (i.e. speed profiles) and which serve as a key to the disaggregation of the activity data. They are defined by spatial characteristics (urban/rural areas, 7 gradient classes (0, +/-2, +/-4, +/-6%), road type, speed limit) and temporal features (levels of service, i.e. traffic density, from free flow to heavy stop-and-go). The underlying database contains a dynamic fleet compositions model simulating the release of new exhaust technologies and the fading out of old technologies. Corrective factors are provided to account for future technologies. Considering the measuring procedure and the maximum temperature of 52°C, it can be assumed that PM condensables are also included in the measurements. The installed technology also plays a role in this context (petrol engines with/without catalytic converter, diesel engines with/without particulate filter, etc.).

- Emission factors for Pb, Cd exhaust, Zn exhaust, Hg, PCDD/PCDF (except for natural gas engines, see below), PAH and PCB are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chapter 1.A.3.b.i-iv Road transport 2019).
- SO_x emission factors are based upon the sulphur content of fuels and are country- and fuel-specific (see chp. 3.2.1.2).
- Emission factor for PCDD/PCDF emissions from natural gas engines is taken from Rentz et al. (2008).
- Emission factors for BC and Cd stem from the Handbook of Emission Factors for Road Transport as well as non-exhaust emissions of particulate matter (TSP, PM10, PM2.5), which are based on Düring and Schmidt (2016); their integration into the Handbook of Emission Factors for Road Transport is described in INFRAS (2019a). Details to non-exhaust emission factors can be found in EMIS 2023/1A3b-Strassenverkehr.
- Note that there is still no HCB emission factor available in the EMEP/EEA guidebook (EMEP/EEA 2019). Therefore, these emissions are still NE for the years 1990-2022.

For biofuels, the respective air pollutant emission factors of 1A3b for fossil fuels are used as follows: for biodiesel and vegetable/waste oil the ones from diesel oil, for bioethanol the ones from gasoline and for biogas the ones from (compressed) natural gas use. Table 3-73 shows a selection of implied emission factors (emissions divided by specific fuel consumption per source category) for 2022.

Table 3-73 Implied emission factors for road transportation, passenger cars in 2022.

1A3b Road Transportation Gasoline / Bioethanol	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	31	46	0.22	8.9	0.61	5.1	0.61	14	0.61	14	0.094	0.51
1A3bii Light duty vehicles	87	114	0.22	10.3	2.7	6.0	2.7	12	2.7	12	0.46	0.60
1A3biii Heavy duty vehicles	799	482	0.22	0.23	NE	6.0	NE	20	NE	20	NE	0.60
1A3biv Motorcycles	65	263	0.22	1.3	19	3.5	19	6.2	19	6.2	3.9	0.42
1A3bv Gasoline evaporation	NA	23	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	IE	NA	IE	NA	IE	NA	IE
1A3bi Fuel tourism and statistical differences	33	78	0.22	8.6	1.4	5.1	1.4	13	1.4	13	0.25	0.51

1A3b Road Transportation Gasoline / Bioethanol	CO	Pb	Cd ex	Cd nx	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ				mg I-TEQ/TJ	g/TJ				ng/TJ	
1A3bi Passenger cars	555	0.59	0.0045	0.44	0.20	0.0031	0.14	0.16	0.11	0.17	NE	610
1A3bii Light duty vehicles	2'558	0.59	0.0041	0.75	0.19	0.0032	0.12	0.14	0.098	0.15	NE	631
1A3biii Heavy duty vehicles	605	0.59	0.0046	0.81	NE	NE	NE	NE	NE	NE	NE	NE
1A3biv Motorcycles	1'755	0.59	0.0045	0.33	0.19	0.0099	0.19	0.22	0.16	0.24	NE	2'699
1A3bv Gasoline evaporation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	627	0.59	0.0047	0.44	0.20	0.0033	0.14	0.16	0.11	0.17	NE	693

1A3b Road Transportation Diesel / Biodiesel	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	214	3.4	0.31	1.9	1.0	4.4	1.0	12	1.0	12	0.52	0.44
1A3bii Light duty vehicles	246	1.6	0.31	1.4	3.4	4.8	3.4	9.4	3.4	9.4	1.9	0.48
1A3biii Heavy duty vehicles	108	2.4	0.31	1.1	1.4	4.8	1.4	17	1.4	17	0.50	0.48
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	IE	NA	IE	NA	IE	NA	IE
1A3bi Fuel tourism and statistical differences	189	2.9	0.31	1.6	1.5	4.6	1.5	13	1.5	13	0.7	0.46

1A3b Road Transportation Diesel / Biodiesel	CO	Pb	Cd ex	Cd nx	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ				mg I-TEQ/TJ	g/TJ				ng/TJ	
1A3bi Passenger cars	44	0.91	0.0012	0.38	0.12	0.0020	0.64	0.71	0.56	0.59	NE	401
1A3bii Light duty vehicles	49	0.91	0.0012	0.60	0.12	0.0025	0.52	0.59	0.46	0.49	NE	500
1A3biii Heavy duty vehicles	45	0.91	0.0010	0.64	0.21	0.00012	0.082	0.50	0.55	0.13	NE	24
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	45	0.91	0.0012	0.48	0.14	0.0016	0.47	0.63	0.54	0.45	NE	311

1A3b Road Transportation Gas / Biogas	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	25	1.3	0.25	9.0	1.7	5.5	1.7	15	1.7	15	0.26	0.55
1A3bii Light duty vehicles	13	0.59	0.25	7.9	2.4	6.2	2.4	12	2.4	12	0.36	0.62
1A3biii Heavy duty vehicles	112	1.6	0.25	NE	0.41	3.7	0.41	15	0.41	15	0.061	0.37
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	IE	NA	IE	NA	IE	NA	IE
1A3bi Fuel tourism and statistical differences	62	1.4	0.18	5.0	1.2	4.8	1.2	15	1.2	15	0.18	0.48

1A3b Road Transportation Gas / Biogas	CO	Pb	Cd ex	Cd nx	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ				mg I-TEQ/TJ	g/TJ				ng/TJ	
1A3bi Passenger cars	165	NA	NA	0.47	0.19	0.0028	0.15	0.17	0.12	0.18	NE	NA
1A3bii Light duty vehicles	1187	NA	NA	0.77	0.19	0.0023	0.12	0.14	0.10	0.15	NE	NA
1A3biii Heavy duty vehicles	54	NA	NA	0.47	NE	0.0013	0.0034	0.0054	0.0027	0.0020	NE	NA
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	204	NA	NA	0.49	0.11	0.0021	0.083	0.095	0.068	0.10	NE	NA

1A3b Road Transportation Liquefied petroleum gas	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	24	1.8	0.50	7.7	NA	4.4	NA	11.8	NA	11.8	NA	0.44
1A3bii Light duty vehicles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3biii Heavy duty vehicles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bi Fuel tourism and statistical differences	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

1A3b Road Transportation Liquefied petroleum gas	CO	Pb	Cd ex	Cd nx	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ				mg I-TEQ/TJ	g/TJ				ng/TJ	
1A3bi Passenger cars	359	NA	NA	0.38	0.19	NA	0.12	0.14	0.098	0.15	NA	NA
1A3bii Light duty vehicles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3biii Heavy duty vehicles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bi Fuel tourism and statistical differences	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 3-73 continued

1A3b Road Transportation Hydrogen / electricity	NO_X	NMVOC	SO_X	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	NA	NA	NA	NA	NA	15	NA	40	NA	40	NA	1.5
1A3bii Light duty vehicles	NA	NA	NA	NA	NA	12	NA	24	NA	24	NA	1.2
1A3biii Heavy duty vehicles	NA	NA	NA	NA	NA	8.3	NA	37	NA	37	NA	0.83
1A3biv Motorcycles	NA	NA	NA	NA	NA	112	NA	201	NA	201	NA	13
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	IE	NA	IE	NA	IE	NA	IE
1A3bi Fuel tourism and statistical differences	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

1A3b Road Transportation Hydrogen / electricity	CO	Pb	Cd ex	Cd nx	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ				mg I-TEQ/TJ	g/TJ				ng/TJ	
1A3bi Passenger cars	NA	NA	NA	1.3	NA	NA	NA	NA	NA	NA	NA	NA
1A3bii Light duty vehicles	NA	NA	NA	1.5	NA	NA	NA	NA	NA	NA	NA	NA
1A3biii Heavy duty vehicles	NA	NA	NA	1.0	NA	NA	NA	NA	NA	NA	NA	NA
1A3biv Motorcycles	NA	NA	NA	11	NA	NA	NA	NA	NA	NA	NA	NA
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

For fuel tourism and statistical differences of gasoline, bioethanol, diesel oil and biodiesel implied emission factors for all pollutants are derived per fuel type corresponding to mean emission factors for Switzerland (containing weighted average over all vehicle categories). These emission factors are then applied to calculate the emissions resulting from fuel tourism and statistical difference.

Activity data (1A3b)

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 ordinary vehicle stock numbers are published by the Swiss Federal Statistical Office (FSO 2023e). 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 specific mileage per vehicle category is an input from Swiss Federal Statistical Office (FSO 2023e, 2023f). It is based on periodical surveys/Mikrozensus (ARE 2002, ARE/SFSO 2005, ARE/SFSO 2012, ARE/SFSO 2017). By means of the vehicle stock data (see paragraph above), the average specific mileage per vehicle category can be derived (SFOE 2023e, INFRAS 2017). The relative differences in specific mileage between vehicles of different technologies and ages within a vehicle category are based on the odometer readings at periodical technical inspections (PTI), which are recorded in the IVZ database (see above).
- Numbers of starts/stops: Derived from vehicles stock and periodical surveys/Mikrozensus (ARE/SFSO 2005, 2012 and 2017).
- Also, the consumption of biofuels for 1A3b Road transportation is reported. Fuel types involved, emission factors and activity data are summarised in a comment to the EMIS database (EMIS 2023/1A3bi-viii "Strassenverkehr"), Consumption of biofuels is provided by the statistics of renewable energies (SFOE 2023a).

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 factor and which are also available per traffic situation and gradient (see above). 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 detailed 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.

The mileage driven serves as activity data in the national traffic model. Table 3-74 shows the mileage per vehicle category. Numbers hold for the version "fuel used" and represent the vehicle kilometres driven within the Swiss territory.

Table 3-74 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	42'649	41'324	45'613	48'040	52'066
LDV	2'600	2'746	2'957	3'228	3'502
HDV	1'992	2'107	2'273	2'120	2'226
Coaches	108	110	99	106	118
Urban Bus	174	192	200	229	244
2-Wheelers	2'025	1'563	1'700	1'785	1'852
Sum	49'548	48'043	52'841	55'507	60'009
(1990=100%)	100%	97%	107%	112%	121%

Veh. category	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
	million vehicle-km									
PC	54'695	55'641	56'620	57'737	58'735	59'344	59'833	53'371	56'662	59'784
LDV	3'874	3'998	4'129	4'269	4'392	4'530	4'668	4'809	4'947	5'220
HDV	2'243	2'236	2'235	2'235	2'242	2'238	2'226	2'203	2'273	2'278
Coaches	125	128	131	134	136	139	142	131	138	177
Urban Bus	262	267	272	281	281	291	300	294	311	311
2-Wheelers	1'904	1'920	1'937	1'976	2'009	2'046	2'068	2'152	2'209	2'331
Sum	63'102	64'188	65'324	66'631	67'795	68'588	69'238	62'960	66'541	70'100
(1990=100%)	127%	130%	132%	134%	137%	138%	140%	127%	134%	141%

Since 1990, the total mileage has been increasing by about 1 per cent per year on an average. 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. In 2022 total mileages increased again to pre-pandemic levels. The overwhelming part of vehicle kilometres was driven by passenger cars. In the whole reporting period on-road fuel consumption increased less strongly, indicating improved fuel efficiency. This effect is also reflected in Table 3-75 that depicts the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990–2022.

Table 3-75 Specific fuel consumption of road transportation. Data are adopted from the territorial road transportation model. They include excess fuel consumption by cold starts.

Veh. Category	Fuel	1990	1995	2000	2005	2010
		MJ / veh-km				
PC	Gasoline	3.15	3.23	3.29	3.21	3.06
	Diesel oil	3.34	3.16	3.05	2.77	2.79
	Liquefied petroleum gas	NO	NO	NO	NO	NO
	CNG	NO	NO	NO	NO	2.04
LDV	Gasoline	3.85	3.75	3.65	3.62	3.54
	Diesel oil	4.54	4.51	4.33	3.98	3.77
	CNG	NO	NO	NO	NO	2.40
HDV	Gasoline	NO	NO	NO	NO	NO
	Diesel oil	11.3	11.6	11.6	12.2	11.9
	CNG	NO	NO	NO	10.4	13.1
Coach	Diesel oil	12.7	12.6	12.3	12.0	11.5
Urban Bus	Gasoline	NO	NO	NO	NO	NO
	Diesel oil	16.3	16.7	16.8	16.8	16.2
	CNG	NO	NO	NO	NO	16.7
2-Wheeler	Diesel oil	1.49	1.66	1.48	1.59	1.52
Average		3.53	3.66	3.68	3.55	3.38
(1990=100%)		100%	104%	104%	101%	96%

Veh. Category	Fuel	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
		MJ / veh-km									
PC	Gasoline	2.86	2.79	2.72	2.65	2.51	2.45	2.41	2.37	2.32	2.24
	Diesel oil	2.74	2.72	2.68	2.64	2.55	2.52	2.52	2.54	2.56	2.53
	Liquefied petroleum gas	2.94	2.92	2.86	2.84	2.74	2.72	2.71	2.70	2.69	2.64
	CNG	1.88	1.89	1.81	1.84	1.71	1.75	1.70	1.61	1.62	1.64
LDV	Gasoline	3.40	3.35	3.29	3.22	3.04	2.94	2.90	2.85	2.77	2.60
	Diesel oil	3.71	3.69	3.66	3.61	3.41	3.32	3.28	3.24	3.23	3.18
	CNG	2.55	2.55	2.45	2.48	2.29	2.32	2.26	2.14	2.15	1.97
HDV	Gasoline	9.16	9.15	9.11	9.11	8.73	8.70	8.65	8.62	8.56	8.48
	Diesel oil	11.7	11.6	11.5	11.3	11.1	10.8	10.7	10.5	10.5	10.2
	CNG	12.4	12.5	12.1	12.5	11.9	10.5	10.3	8.93	9.60	9.75
Coach	Diesel oil	10.5	10.4	10.3	10.1	9.7	9.46	9.36	9.09	9.13	8.95
Urban Bus	Gasoline	NO	NO	NO	NO	NO	8.82	8.78	8.74	8.68	NO
	Diesel oil	16.0	15.9	15.6	15.4	14.2	14.0	13.9	13.9	13.8	14.0
	CNG	15.8	15.7	15.2	15.6	14.3	14.8	14.6	13.9	14.1	14.6
2-Wheeler	Diesel oil	1.51	1.55	1.59	1.55	1.60	1.62	1.62	1.60	1.55	1.47
Average		3.21	3.16	3.10	3.03	2.90	2.84	2.81	2.82	2.80	2.72
(1990=100%)		91%	90%	88%	86%	82%	81%	80%	80%	79%	77%

For modelling evaporative emissions, the stock, mileage, and numbers of stops of gasoline passenger cars and gasoline light duty vehicles are used. For modelling cold start emissions, numbers of starts of passenger cars and light duty vehicles are used as activity data. The corresponding numbers are summarised in Table 3-76. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific household surveys (ARE/SFSO 2005, 2012, 2017).

Table 3-76 Vehicle stock numbers (gasoline vehicles only – relevant for diurnal evaporation) and average number of starts per vehicle per day (gasoline, diesel oil, and (compressed) natural gas vehicles).

Veh. Category	1990	1995	2000	2005	2010
	stock in 1000 veh. (gasoline/bioeth.)				
PC	2'839	3'049	3'305	3'263	2'957
LDV	167	164	148	112	78
2-Wheelers	764	688	712	746	764
	starts per veh. per day				
PC	2.94	2.68	2.91	2.52	2.56
LDV	1.97	1.97	1.96	1.96	1.96

Veh. Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	stock in 1000 veh. (gasoline/bioeth.)									
PC	2'822	2'774	2'731	2'693	2'693	2'708	2'714	2'762	2'801	2'831
LDV	64	61	59	57	55	53	52	54	53	51
2-Wheelers	789	798	807	814	831	851	856	865	856	859
	starts per veh. per day									
PC	2.54	2.55	2.55	2.56	2.58	2.59	2.59	2.30	2.41	2.54
LDV	1.96	1.96	1.96	1.96	1.96	1.89	2.05	2.03	2.00	2.04

3.2.6.2.3 Railways (1A3c)

Methodology (1A3c)

Based on the decision tree Fig. 3.1 in chapter 1A3c Railways of the EMEP/EEA guidebook (EMEP/EEA 2019), the exhaust emissions of rail vehicles are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.1.1.1.

The entire Swiss railway system is electrified (except for some short feeder tracks to private companies). 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. Their emissions are quantified as exhaust emissions.

The non-exhaust emissions have been estimated with a separate method documented in SBB (2005) and INFRAS (2007). Several concepts have been applied including mass balances e.g. mass loss of break blocks and wheels, measurements on a test bench, ambient PM10 concentration measurements combined with receptor model. The emissions were quantified as a sum of brake, wheel, track and contact wire abrasion and were split into passenger and freight train origins. For projection purposes, the PM10 emissions were divided into emission factors per person-kilometre (passenger rail-transport) and tonne-kilometre (freight rail transport) and corresponding activity data. The share of PM2.5 was estimated to 15 % of the PM10 emissions.

Emission factors (1A3c)

The emission factors are country-specific. The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard specific emission factors are shown in Table 3-77.

- Only diesel oil and biodiesel are used as fuels, therefore all emission factors refer to the use of diesel oil and biodiesel for traffic on railways except for non-exhaust emissions.
- Non-exhaust particulate matter emission factors (PM2.5 and PM10) distinguish passenger and freight transport, i.e. they are based on passenger and tonne kilometres. Emission factors are based on a study from the Swiss Federal Railways Company (SBB 2005). Details concerning non-exhaust emission factors can be found in EMIS 2023/1A3c-Schienenverkehr.

Implied emission factors for the reporting year are shown in Table 3-78.

Table 3-77 Illustration of emission and consumption factors for rail vehicles with diesel engines per emission standard (Pre-EU etc.) and engine power.

engine power	Pre-EU	UIC I	UIC II	EU IIIA	EU IIIB	*EU V*
	g/kWh					
Carbon monoxide (CO)						
<560 kW	4.0	3.0	2.5	2.5	2.5	*2.5*
>560 kW	4.0	3.0	3.0	3.0	3.0	*3.0*
Hydrocarbons (HC)						
<560 kW	1.60	0.80	0.60	0.40	0.17	*0.17*
>560 kW	1.60	0.80	0.80	0.50	0.40	*0.36*
Nitrogen oxides (NO_X)						
<560 kW	13	12	6	3.2	1.8	*1.8*
>560 kW	16	12	9.5	5.4	3.2	*3.2*
Particulate matter (PM)						
<560 kW	0.600	0.500	0.250	0.180	0.025	*0.025*
>560 kW	0.600	0.500	0.250	0.180	0.025	*0.025*
Fuel consumption						
<560 kW	223	223	223	223	223	*223*
>560 kW	223	223	223	223	223	*223*
Assumptions regarding the introduction of EU emission stages						
<560 kW		2000	2003	2006	2012	*2020*
>560 kW		2000	2003	2009	2012	*2020*

Table 3-78 Implied emission factors in 2022 for 1A3c Railways. Data per TJ refer to exhaust emissions (ex), whereas data per km refer to non-exhaust emissions (nx).

1A3c Railways	NO_x	NMVOC	SO_X	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
Fuel	kg/TJ			g/TJ	kg/TJ	g/km	kg/TJ	g/km	kg/TJ	g/km	kg/TJ	g/km
Diesel oil	888	104	0.31	182	5.9	0.017	5.9	0.11	5.9	0.15	1.5	NA
Biodiesel	759	89	0.31	155	5.1	0.017	5.1	0.11	5.1	0.15	1.3	NA

1A3c Railways	CO	Pb	Cd ex	Cd nx	Hg	PCDD/	BaP	BbF	BkF	IcdP	HCB	PCB
Fuel	kg/TJ	g/TJ	g/TJ	g/km	g/TJ	mg I-TEQ/TJ	mg/TJ					
Diesel oil	507	0.91	2.3	NE	0.12	0.0016	823	1'372	1'020	196	NA	NA
Biodiesel	434	0.78	1.9	NE	0.10	0.0014	703	1'172	872	167	NA	NA

Activity data (1A3c)

Table 3-79 shows the activity data of 1A3c taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-79 Activity data for 1A3c Railways is either diesel oil and biodiesel consumption or number of driven km for freight transport as well as number of driven km for passenger transport. Data in TJ refer to exhaust emissions, whereas data in km refer to non-exhaust emissions.

1A3c Railways	Unit	1990	1995	2000	2005	2010
Diesel oil	TJ	390	441	455	472	492
Biodiesel	TJ	NO	NO	0.59	1.7	2.1
Total Railways	TJ	390	441	456	474	494
1990=100%		100%	113%	117%	121%	127%
tonne-kilometers	Mio. km	9'045	8'856	11'080	11'677	11'074
passenger-kilometers	Mio. km	12'978	12'978	12'978	16'210	19'252

1A3c Railways	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Diesel oil	TJ	431	410	390	388	387	385	383	382	380	378
Biodiesel	TJ	4.4	5.2	5.9	7.7	9.4	11	13	15	16	18
Total Railways	TJ	435	416	396	396	396	396	396	396	396	397
1990=100%		112%	107%	102%	102%	102%	102%	102%	102%	102%	102%
tonne-kilometers	Mio. km	11'812	12'313	12'431	12'447	11'665	11'776	11'673	11'500	11'718	11'937
passenger-kilometers	Mio. km	19'525	20'090	20'475	20'894	20'953	20'704	21'831	17'400	17'897	18'394

3.2.6.2.4 *Domestic navigation (1A3d)*

Methodology (1A3d)

Based on the decision tree Fig. 3.1 in the chapter 1A3d Navigation-shipping in the EMEP/EEA guidebook (EMEP/EEA 2019), the air pollutant emissions are calculated by a Tier 3 method Emissions are calculated in line with the non-road transportation model described in chp. 3.2.1.1.1.

There are passenger ships, dredgers, fishing boats, motor and sailing boats on the lakes and rivers of Switzerland.

On the river Rhine and on Lake Geneva and Lake Constance, some of the boats cross the border and go abroad (France, Germany). Fuels bought in Switzerland will therefore become bunker fuel. Accordingly, the amount of bunker diesel oil is reported as a memo item “International maritime navigation”. The emissions are calculated with a Tier 1 approach with implied emission factors from domestic navigation. Only diesel oil is concerned from navigating on the river Rhine (FCA 2015a) and of navigating two border lakes (Lake Constance, Lake Geneva) for which bunker fuel consumption was reported in INFRAS (2011a) after having performed surveys among the shipping companies involved.

Emission factors (1A3d)

The emission factors are country-specific. The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard-specific emission factors are shown in Table 3-80 to Table 3-83 (FOEN 2015j).

Implied emission factors for the reporting year are shown in Table 3-84.

Table 3-80 Emission factors for diesel-powered ships per emission standard.

engine power	Pre-SAV	SAV	EU I	EU II	EU IIIA	*EU V*
	g/kWh					
Carbon monoxide (CO)						
<18 kW	6.7	6.7	6.7	6.7	6.7	6.7
18–37 kW	6.7	6.7	6.7	6.7	6.7	6.7
37–75 kW	5.9	5.9	5.9	4.5	4.5	4.5
75–130 kW	5.0	5.0	4.5	4.5	4.5	4.5
130–300 kW	5.0	5.0	4.5	4.5	4.5	3.15
300–560 kW	5.0	5.0	4.5	4.5	4.5	3.15
>560 kW	5.0	5.0	4.5	4.5	4.5	3.15
Hydrocarbons (HC)						
<18 kW	10	7.2	5.0	3.0	2.0	2.0
18–37 kW	10	7.2	5.0	3.0	2.0	2.0
37–75 kW	10	5.4	1.2	1.2	1.1	0.42
75–130 kW	10	4.1	1.2	0.9	0.8	0.49
130–300 kW	5.0	3.6	1.2	0.9	0.8	0.80
300–560 kW	5.0	3.2	1.2	0.9	0.8	0.17
>560 kW	5.0	2.8	1.2	0.9	0.8	0.17
Nitrogen oxides (NO_X)						
<18 kW	10.3	10.3	10.3	10.3	10.3	10.3
18–37 kW	10.3	10.3	10.3	10.3	10.3	10.3
37–75 kW	12.4	12.4	8.3	6.3	5.7	4.23
75–130 kW	12.5	12.5	8.3	6.3	5.7	4.86
130–300 kW	12.5	12.5	8.3	6.3	5.7	2.10
300–1000 kW	12.5	12.5	8.3	6.3	5.7	1.20
>1000 kW	12.5	12.5	8.3	6.3	5.7	0.40
Particulate matter (PM)						
<18 kW	1.50	1.20	1.00	0.80	0.70	0.70
18–37 kW	1.20	0.90	0.74	0.60	0.54	0.54
37–75 kW	1.10	0.58	0.77	0.36	0.36	0.30
75–130 kW	0.60	0.47	0.63	0.27	0.27	0.14
130–300 kW	0.60	0.47	0.49	0.18	0.18	0.11
300–1000 kW	0.60	0.47	0.49	0.18	0.18	0.02
>1000 kW	0.60	0.47	0.49	0.18	0.18	0.01
Fuel consumption						
<18 kW	248	248	248	248	248	248
18–37 kW	248	248	248	248	248	248
37–75 kW	248	248	248	248	248	248
75–130 kW	223	223	223	223	223	223
>130 kW	223	223	223	223	223	223
Assumptions regarding introduction of emission stages						
All capacities	(<1995)	1995	2003	2008	2009	2019

Table 3-81 Emission factors for diesel-powered boats per emission standard.

engine power	Pre-SAV	SAV	EU I	EU II
	g/kWh			
Carbon monoxide (CO)				
<4.4 kW	6.7	6.7	4.5	4.5
4.4–7.4 kW	6.7	6.7	4.5	4.5
7.4–37 kW	6.7	6.7	4.5	4.5
37–74 kW	5.9	5.9	4.5	4.5
74–100 kW	5.0	5.0	4.5	4.5
>100 kW	5.0	3.6 (6%)	3.6	3.6
Hydrocarbons (HC)				
<4.4 kW	10	10	2.4	2.40
4.4–7.4 kW	10	10	2.1	2.10
7.4–37 kW	10	2.0 (23%)	1.7	1.70
37–74 kW	10	1.4 (23%)	1.4	0.42
74–100 kW	10	1.2 (23%)	1.2	0.52
>100 kW	5	1.2 (30%)	1.2	0.52
Nitrogen oxides (NO_X)				
<4.4 kW	13	11	8.8	8.80
4.4–7.4 kW	13	11 (71%)	8.8	8.80
7.4–37 kW	13	11 (71%)	8.8	8.80
37–74 kW	13	11 (71%)	8.8	4.23
74–100 kW	13	11 (71%)	8.8	5.22
>100 kW	13	11 (73%)	8.8	5.22
Particulate matter (PM)				
<4.4 kW	1.5	1.2	0.9	0.9
4.4–7.4 kW	1.5	1.2	0.9	0.9
7.4–37 kW	1.2	1.1	0.9	0.9
37–74 kW	1.1	1.0	0.9	0.3
74–100 kW	0.9	0.9	0.9	0.15
>100 kW	0.9	0.9	0.9	0.15
Fuel consumption				
<4.4 kW	400	400	400	400
4.4–7.4 kW	400	400	400	400
7.4–37 kW	400	380	380	380
37–74 kW	380	350	350	350
74–100 kW	400	330	330	330
>100 kW	300	300	300	300
Assumptions regarding the introduction of emission stages				
All pow. classes	(<1995)	1995	2007	2015

Table 3-82 Emission factors for gasoline-powered boats per emission standard.

engine power	2-stroke gasloline engines			4-stroke gasoline engines		
	g/kWh					
	Pre-SAV	SAV	SAV/EU	Pre-SAV	SAV	EU
Carbon monoxide (CO)						
<4.4 kW	645	315	315	350	315	315
4.4–7.4 kW	645	200 (79%)	225	350	200 (79%)	225
7.4–37 kW	645	100 (79%)	162	350	100 (79%)	162
37–74 kW	645	65 (79%)	144	350	65 (79%)	144
74–100 kW	645	55 (79%)	141	350	55 (79%)	141
>100 kW	645	45 (73%)	139	350	45 (73%)	139
Hydrocarbons (HC)						
<4.4 kW	260	22	25	25	22	25
4.4–7.4 kW	260	12 (66%)	13	20	12 (66%)	13
7.4–37 kW	260	6.0 (66%)	8	20	6.0 (66%)	8
37–74 kW	260	4.0 (66%)	6	20	4.0 (66%)	6
74–100 kW	260	3.3 (66%)	5	20	3.3 (66%)	5
>100 kW	260	2.1 (52%)	5	20	2.1 (52%)	5
Nitrogen oxides (NO_X)						
<4.4 kW	15	13	13	3.5	13	13
4.4–7.4 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
7.4–37 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
37–74 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
74–100 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
>100 kW	15	9.6 (64%)	9.6	3.5	9.6 (64%)	9.6
Fuel consumption						
<4.4 kW	700	400	400	400	400	400
4.4–7.4 kW	700	400	400	400	400	400
7.4–37 kW	650	380	380	380	380	380
37–74 kW	650	380	380	380	380	380
74–100 kW	650	380	380	380	380	380
>100 kW	650	380	380	380	380	380
Assumptions regarding the introduction of emission stages						
All capacities	(<1995)	1995	2007	(<1995)	1995	2007
Source of consumption factors: SAEFL, 1996a						

Table 3-83 Emission factors for steam-powered vessels per emission standard.

Pollutant	**Steam 1**	**Steam 2**	**Steam 3**	**Steam 4**	**Steam 5**	**Steam 6**	**Steam 7**
	g/kWh						
CO	0.30	0.30	0.30	0.09	0.09	0.09	0.09
HC	0.449	0.449	0.449	0.330	0.330	0.330	0.330
NO_X	2.336	2.336	2.336	1.770	1.558	1.257	1.027
PM2.5	0.033	0.024	0.015	0.009	0.006	0.006	0.006
Fuel cons.	1406	1115	1115	1115	1115	1115	1115
Assumptions regarding the date of introduction of improvements of steamships							
All classes	<1950	1950	1980	1990	1995	2000	2005

Table 3-84 Implied emission factors in 2022 for 1A3d Navigation.

1A3d Navigation	NO_X	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ								
Gasoline	545	418	0.22	0.086	0.049	0.049	0.049	0.0024	8'801
Diesel oil	732	206	0.31	0.18	27	27	27	14	492
Gas oil	27	1.6	2.0	0.042	0.13	0.13	0.13	0.020	6.9
Biodiesel	626	176	0.31	0.16	23	23	23	12	421
Bioethanol	351	258	0.22	0.056	NA	NA	NA	NA	5'574

1A3d Navigation	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	mg/TJ					
Gasoline	0.59	2.2	0.19	0.0026	1'082	1'082	105	287	NA	NE
Diesel oil	0.91	2.3	0.12	0.0016	795	1'325	986	198	NA	NE
Gas oil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NE
Biodiesel	0.78	2.0	0.10	0.0014	679	1'132	842	169	NA	NE
Bioethanol	0.38	1.4	0.12	0.0017	698	698	68	185	NA	NE

Activity data (1A3d)

Table 3-85 shows the activity data of 1A3di taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-85 Activity Data for domestic navigation.

1A3d Domestic navigation	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	1.0	2.9	3.8
Bioethanol	TJ	NO	NO	NO	NO	0.013
Total Navigation	TJ	1'550	1'517	1'556	1'518	1'565
1990 = 100%		100%	98%	100%	98%	101%

1A3d Domestic navigation	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	TJ	522	518	514	512	511	509	508	506	505	503
Diesel oil	TJ	874	876	878	873	867	862	857	851	847	842
Gas oil	TJ	154	153	151	150	149	148	147	146	145	144
Biodiesel	TJ	9.5	11.5	13	17	21	25	29	33	37	40
Bioethanol	TJ	2.3	3.1	3.9	6.3	8.6	11.0	13	16	18	20
Total Navigation	TJ	1'562	1'561	1'560	1'559	1'557	1'556	1'554	1'552	1'551	1'550
1990 = 100%		101%	101%	101%	101%	100%	100%	100%	100%	100%	100%

3.2.6.2.5 Other transportation – pipeline transport (1A3e)

This source category contains only emissions from 1A3ei Pipeline transport of natural gas due to one compressor station of the main gas pipeline.

Methodology (1A3e)

For source 1A3ei Pipeline transport, the emissions of main pollutants, particulate matter, CO, Hg, PCDD/PCDF and PAH from a compressor station located in Ruswil are considered.

The emissions are calculated with a Tier 2 method (note that the EMEP/EEA guidebook (EMEP/EEA 2019) does not contain a decision tree to determine the Tier level specifically). For the main pollutants, TSP, PM2.5 and PM10, country-specific emission factors were used. For all other pollutants (BC, CO, Hg, PCDD/PCDF and PAH), the emission factors stem from the EMEP/EEA guidebook (EMEP/EEA 2019).

Emission factors (1A3e)

The same emission factors are used as for gas turbines (see Table 3-55). The emission factors are described in chapter 3.2.1.1.3.

Table 3-86 Emission factors of 1A3e for 2022.

1A3ei Pipeline transport	NO_X	NMVOC	SO_X	NH_3	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
	g/GJ								
Gas	32	1.6	0.18	NA	0.20	0.20	0.20	0.0005	10
Biogas	48	1.6	0.50	NA	0.20	0.20	0.20	0.0005	10

1A3ei Pipeline transport	Pb	Cd ex	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/TJ	ng/GJ					
Gas	0.0015	0.00025	0.1	0.5	560	840	840	840	NA	NA
Biogas	0.0015	0.00025	0.1	0.5	560	840	840	840	NA	NA

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 2023; Table 17e).

Table 3-87 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	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Natural gas	TJ	410	830	760	340	470	490	600	540	120	400
Biogas	TJ	NO	NO	NO	NO	NO	NO	NO	NO	23	30
1990 = 100%		73%	148%	136%	61%	84%	88%	107%	96%	26%	77%

3.2.6.3 Category-specific recalculations for 1A3 Transport

The following recalculations were implemented in submission 2024:

- 1A3: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.
- 1A3a: Recalculation of non-exhaust PM, PM10 and PM1.5 emissions generated by airplanes during landing in 1A3a Aviation (LTO) for all years 1980-2021.
- 1A3b: Recalculation of activity data in sector 1A3b Road transportation due to new available statistics for activity data (mileage) for the different vehicle categories for all years from 1990-2021.
- 1A3e: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A3c: Small recalculation of the kilometres driven and thus the annual output for abrasion (non-exhaust) emissions for the year 2021. This recalculation results from slightly changed forecast values and interpolation between 2020 and the forecast values 2030.

3.2.7 Source category 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

3.2.7.1 Source category description for 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

The source category 1A4 Non-road and machinery in other sectors comprises all emissions from the combustion of fuels in mobile non-road sources in commerce and institutions, households, agriculture and forestry. This includes use of conventional fossil fuels as well as biofuels. Note that information regarding stationary combustion of source categories 1A4 Stationary combustion in manufacturing industries and construction are provided in chp. 3.2.4.

Table 3-88 Specification of source category 1A4 – Non-road and machinery sources in residential, commercial, agriculture and forestry sectors.

1A4	Source category	Specification
1A4aii	Commercial/Institutional: Mobile	Emissions from mobile machinery and motorised equipment used for professional gardening
1A4bii	Residential: Household and gardening (mobile)	Emissions from mobile machinery and motorised equipment used for hobby gardening
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	Emissions from non-road vehicles and machinery in agriculture and forestry

Table 3-89 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1A4 Non-road and machinery in other sectors (mobile).

NFR code	Source category	Pollutant	Identification criteria
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	L1

3.2.7.2 Methodological issues for 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

Methodology (1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry))

Based on the decision tree Fig. 3.1 in chapter 1A4 of the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of mobile combustion in 1A4 Other sectors are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.1.1.1.

Emission factors (1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard-specific emission factors are shown in Table 3-63 to Table 3-65 (see chp. 3.2.5.2).

To avoid double counting there are no non-exhaust emissions of PM2.5, PM10 and TSP from resuspension caused by non-road vehicles and machinery in agriculture since they are included in the particle emissions from source categories 3Dc Soils operation of cropland and 3Dc Soils operation of grassland, see chp. 5.3.2.

Implied emission factors for the reporting year for all pollutants are shown in Table 3-90.

Table 3-90 Implied emission factors 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry) in 2022.

Source/fuel	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ			g/TJ	kg/TJ	g/h	kg/TJ	g/h	kg/TJ	g/h	kg/TJ	g/h
1A4aii Other sectors (mobile): Commercial/institutional												
Gasoline	171	1'295	0.22	86	NA	NE	NA	NE	NA	NE	NA	NE
Bioethanol	67	400	0.22	61	NA	NE	NA	NE	NA	NE	NA	NE
1A4bii Other sectors (mobile): Residential												
Gasoline	136	822	0.22	92	NA	NE	NA	NE	NA	NE	NA	NE
Bioethanol	77	409	0.22	61	NA	NE	NA	NE	NA	NE	NA	NE
1A4cii Other sectors (mobile): Agriculture/forestry/fishing												
Gasoline	176	1'372	0.22	82	NA	0.10	NA	0.70	NA	1.0	NA	0.0082
Diesel oil	330	38	0.31	160	26	0.10	26	0.70	26	1.0	17	0.0082
Biodiesel	282	33	0.31	137	22	0.10	22	0.70	22	1.0	15	0.0082
Bioethanol	74	508	0.22	56	NA	0.10	NA	0.70	NA	1.0	NA	0.0082

Source/fuel	CO	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ			ng I-TEQ/TJ	mg/TJ					
1A4aii Other sectors (mobile): Commercial/institutional											
Gasoline	26'704	0.59	2.4	0.21	2'843	948	948	92	315	NE	NE
Bioethanol	15'942	0.38	1.5	0.13	1'841	614	614	60	204	NE	NE
1A4bii Other sectors (mobile): Residential											
Gasoline	25'529	0.59	2.4	0.21	2'849	954	954	93	316	NE	NE
Bioethanol	15'945	0.38	1.5	0.13	1'838	616	616	60	204	NE	NE
1A4cii Other sectors (mobile): Agriculture/forestry/fishing											
Gasoline	24'792	0.59	2.2	0.19	2'665	1'037	1'037	101	295	NE	NE
Diesel oil	190	0.91	2.0	0.11	1'402	642	1'070	796	172	NE	NE
Biodiesel	163	0.78	1.7	0.09	1'198	549	915	681	147	NE	NE
Bioethanol	15'176	0.38	1.4	0.12	1'682	694	694	68	186	NE	NE

The Expert Review Team noted during the Stage 3 review in 2016 that the implied emission factors for NMVOC, CO and particulate matter from the non-road sector are much higher compared to other developed countries. Switzerland explained that only garden care and hobby mobile machinery are included in source categories 1A4aii and 1A4bii and they consume gasoline and bioethanol only, and indeed consist mainly of 2-stroke gasoline engines, which explains that the relatively high implied emission factor is justified. (The ERT encouraged the Party to include the explanation of this issue in the IIR.)

Activity data (1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

Table 3-91 shows the activity data of 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry) taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a). In categories 1A4aii and 1A4bii, only gasoline and bioethanol are used as fuel. In category 1A4cii, mainly diesel oil is consumed and only small amounts of gasoline (e.g. chainsaws) and biodiesel.

Table 3-91 Activity Data for 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry).

Source/Fuel	Unit	1990	1995	2000	2005	2010
1A4aii Other sectors (mobile): Commercial/institutional	TJ	191	245	295	295	287
Gasoline	TJ	191	245	295	295	287
Bioethanol	TJ	NO	NO	NO	NO	0.0039
1A4bii Other sectors (mobile): Residential	TJ	142	155	165	166	163
Gasoline	TJ	142	155	165	166	163
Bioethanol	TJ	NO	NO	NO	NO	0.0034
1A4cii Other sectors (mobile): Agriculture/forestry/fishing	TJ	5'429	5'674	5'889	5'642	5'592
Gasoline	TJ	1'160	1'070	963	824	689
Diesel oil	TJ	4'269	4'604	4'920	4'802	4'882
Biodiesel	TJ	NO	NO	6.4	17	21
Bioethanol	TJ	NO	NO	NO	NO	0.012

Source/Fuel	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1A4aii Other sectors (mobile): Commercial/institutional	TJ	267	261	254	253	252	252	251	250	249	247
Gasoline	TJ	266	260	253	251	250	248	247	245	243	241
Bioethanol	TJ	0.72	0.95	1.2	1.9	2.6	3.3	4.0	4.7	5.4	6.1
1A4bii Other sectors (mobile): Residential	TJ	160	159	157	157	157	156	156	155	155	155
Gasoline	TJ	159	158	156	155	154	153	152	151	150	149
Bioethanol	TJ	0.64	0.85	1.1	1.7	2.3	2.9	3.6	4.2	4.8	5.4
1A4cii Other sectors (mobile): Agriculture/forestry/fishing	TJ	5'535	5'517	5'498	5'487	5'477	5'466	5'456	5'445	5'433	5'420
Gasoline	TJ	616	592	568	551	535	519	503	486	473	459
Diesel oil	TJ	4'864	4'859	4'853	4'835	4'817	4'800	4'782	4'764	4'742	4'721
Biodiesel	TJ	53	63	74	96	118	140	162	184	205	227
Bioethanol	TJ	2.0	2.6	3.3	4.8	6.4	8.0	9.6	11	12	13

3.2.7.3 Category-specific recalculations for 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

- 1A4a/b/cii: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.

3.2.8 Source category 1A5b - Other, mobile (Military)

3.2.8.1 Source category description for 1A5b Other, mobile (Military)

The source category 1A5b Other includes emissions from fuel combustion in military aircraft and military non-road activities.

Table 3-92 Specification of source category 1A5 Other, mobile (Military)

1A5	Source category	Specification
1A5b	Other mobile (including military, land based and recreational boats)	Emissions from military aircrafts and machines like power generators, tanks, bulldozers, boats etc.

Table 3-93 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1A5 Other, mobile.

NFR code	Source category	Pollutant	Identification criteria
1A5b	Other mobile (including military land-based and recreational boats)	PM10	L1

3.2.8.2 Methodological issues for 1A5b Other, mobile (Military)

1A5bi military aviation

To calculate the emissions from military aviation, a Tier 2 method is used.

1A5bii military non-road vehicles and machines

Based on the decision tree Fig. 3.1 in chapter 1A4 Non-road mobile sources and machinery of the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of military non-road vehicles and machines are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.1.1.1.

Emission factors (1A5b)

Emission factors 1A5bi military aviation

- NO_x, NMVOC, CO: average emission factors for military aircraft are calculated by the Federal Office of Civil Aviation (FOCA) based on information from the Federal Department of Defence, Civil Protection and Sport (DDPS) concerning fuel consumption per aircraft type in the year 2017-2018 (DDPS 2020). These emission factors stay constant for the whole time series from 1990 onwards.
- SO_x: the SO_x emission factor is taken from the EMEP/EEA guidebook (EMEP/EEA 2019, Table 3.11, row “Switzerland/CCD”) and is assumed to be constant over the period 1990–2022. CCD means climb/cruise/descent.
- TSP, PM10, PM2.5 exhaust: emission factors for TSP, PM10, and PM2.5 exhaust are assumed to be equal. The implied emission factor from territorial processes (means all flights only in Swiss territory) are taken for the years 1990 (15.5 g/GJ), 1995 (7.8 g/GJ), 2000 (4.5 g/GJ) and linearly interpolated in between. From 2015 onwards an average emission factor (3.4 g/GJ) could be calculated by FOCA based on information from DDPS the same way as for NO_x, NMVOC, CO (see explanation above).

- TSP, PM10, PM2.5 non-exhaust: emission factors for TSP, PM10, PM2.5 non-exhaust are assumed to be equal. The implied emission factor (0.0016 g/GJ) from territorial processes (means all flights only in Swiss territory) in the year 1990 are taken for the whole time period (FOCA 2016b).
- BC exhaust: the BC-factor of 48 % from PM2.5 exhaust is the same as for civil aviation and constant over the period 1990-2022.
- Implied emission factors for the reporting year are shown in Table 3-94.

Emission factors of military non-road vehicles and machines

The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Implied emission factors for the reporting year are shown in Table 3-94.

Table 3-94 Emission factors for 1A5b Other (Military, mobile) in 2022.

1A5b Other: Military (mobile)	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
Military aviation	kg/TJ											
Jet kerosene	231	33	23	NA	3.4	0.0016	3.4	0.0016	3.4	0.0016	1.6	NA
Military non-road	kg/TJ					g/h	kg/TJ	g/h	kg/TJ	g/h	kg/TJ	g/h
Gasoline	120	688	0.20	0.092	NA	NA	NA	NA	NA	NA	NA	NA
Diesel oil	272	25	0.31	0.16	7.3	10	7.3	67	7.3	101	3.6	NA
Biodiesel	232	22	0.31	0.13	6.2	10	6.2	67	6.2	101	3.1	NA
Bioethanol	60	267	0.22	0.061	NA	NA	NA	NA	NA	NA	NA	NA

1A5b Other: Military (mobile)	CO	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
Military aviation	kg/TJ	g/TJ			mg I-TEQ/TJ	mg/TJ					
Jet kerosene	235	NA	NA	NA	NA	NA	NA	NA	NA	NE	NE
Military non-road	kg/TJ	g/TJ			mg I-TEQ/TJ	mg/TJ					
Gasoline	24'765	0.59	2.4	0.21	0.0028	959	959	93	315	NE	NE
Diesel oil	127	0.91	1.9	0.10	0.0014	612	1'021	759	167	NE	NE
Biodiesel	108	0.78	1.7	0.088	0.0012	523	872	649	143	NE	NE
Bioethanol	15'702	0.38	1.5	0.13	0.0018	619	619	60	203	NE	NE

Activity data (1A5b)

The fuel consumption of 1A5bi Military aviation is copied from the logbooks of the military aircrafts and summed up yearly by the Swiss Air Force (part of the Swiss Armed Forces, VTG) and provided to FOEN (VTG 2011, VTG 2023).

The fuel consumption of 1A5bii military non-road vehicles and machines is based on activity data provided by DDPS (DDPS 2014a) and calculated bottom-up by the non-road transportation model (chp. 3.2.1.1.1). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-95 shows activity data of both categories 1A5bi and 1A5bii.

Table 3-95 Activity data (fuel consumption) for 1A5b Other (Military, mobile).

1A5b Other: Military (mobile)	Unit	1990	1995	2000	2005	2010
Military aviation						
Jet kerosene	TJ	2'733	1'955	1'794	1'624	1'592
Military non-road		239	248	252	257	275
Gasoline	TJ	19	19	19	19	18
Diesel oil	TJ	220	228	233	238	256
Biodiesel	TJ	NO	NO	0.30	0.86	1.1
Bioethanol	TJ	NO	NO	NO	NO	0.00038

1A5b Other: Military (mobile)	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Military aviation											
Jet kerosene	TJ	1'542	1'615	1'567	1'627	1'469	1'457	1'303	1'365	1'301	1'423
Military non-road		275	275	275	274	273	272	271	270	269	269
Gasoline	TJ	17	17	17	17	16	16	16	16	16	16
Diesel oil	TJ	255	254	254	252	250	248	246	244	243	241
Biodiesel	TJ	2.8	3.3	3.9	5.0	6.1	7.2	8.3	9.4	10.5	12
Bioethanol	TJ	0.069	0.092	0.11	0.18	0.25	0.31	0.38	0.45	0.51	0.58

3.2.8.3 Category-specific recalculations for 1A5b Other, mobile (Military)

- 1A5b: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.

3.3 Source category 1B - Fugitive emissions from fuels

3.3.1 Source category 1B1 - Fugitive emissions from solid fuels

3.3.1.1 Source category description for 1B1 – Fugitive emissions from solid fuels

The source category 1B1 Fugitive emissions from solid fuels includes non-exhaust emissions from coal handling only. There is no production of solid fuels in Switzerland.

Table 3-96 Specification of source category 1B1a Coal mining and handling.

1B1	Source category	Specification
1B1a	Fugitive emission from solid fuels: Coal mining and handling	Only particulate matter emissions from handling of coal

Table 3-97 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1B1 Fugitive emissions from solid fuels

Source category 1B1 Fugitive emission from solid fuels is not a key category.

3.3.1.2 Methodological issues for 1B1 – Fugitive emissions from solid fuels

Methodology (1B1)

There is no coal mining in Switzerland and therefore only non-exhaust particulate matter emissions from coal handling occur.

Based on the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from coal handling are determined by a Tier 2 method using technology-specific activity data and emission factors.

Emission factors (1B1)

Emission factors for TSP, PM10 and PM2.5 are based on the EMEP/EEA guidebook (EMEP/EEA 2019, table 3-6). No BC emission factors are available from literature for coal turnover. It is assumed that coal persists of 60 % of carbon and that the share is equal independent of its size.

Table 3-98 Emission factors in 1B1 Fugitive emissions from solid fuels in 2022.

1B1 Fugitive emissions attributed to solid fuels	Per amount of	Unit	PM2.5 nx	PM10 nx	TSP nx	BC nx
1B1a Coal handling	Other bituminous coal imported	g/t	0.3	3.0	7.5	0.18

Activity data (1B1)

Activity data are provided by the energy model as described in chapter 3.1.6.3 and are based on the total amount of other bituminous coal imported as published in Swiss overall energy statistics (SFOE 2023).

Table 3-99 Activity data in 1B1 Fugitive emissions from solid fuels.

1B1 Fugitive emissions attributed to solid fuels	Amount of	Unit	1990	1995	2000	2005	2010
1B1a Coal handling	Other bituminous coal imported	t	534'938	286'007	210'347	232'974	248'060

1B1 Fugitive emissions attributed to solid fuels	Amount of	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	1990 to 2022
1B1a Coal handling	Other bituminous coal imported	t	222'598	233'487	213'788	197'752	189'824	176'005	156'612	151'282	152'699	158'665	-70%

3.3.1.3 Category-specific recalculations for 1B1 Fugitive emissions from solid fuels

There were no recalculations implemented in submission 2024.

3.3.2 Source category 1B2a - Fugitive emissions from oil

3.3.2.1 Source category description for 1B2a

In Switzerland, oil production is not occurring. Fugitive emissions from oil industry in Switzerland 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 and there is only one refinery left. 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 3-100 Specification of source category 1B2a – Oil.

1B2a	Source category	Specification
1B2ai	Fugitive emissions oil: Exploration, production, transport	Oil production is not occurring in Switzerland. Emissions only stem from pipeline transport
1B2aiv	Fugitive emissions oil: Refining and storage	SO2 emissions from Claus-units in refineries
1B2av	Distribution of oil products	Fugitive emissions caused by distribution and storage of gasoline and storage of kerosene

Table 3-101 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1B2a fugitive emissions from oil.

NFR code	Source category	Pollutant	Identification criteria
1B2av	Distribution of oil products	NMVOC	L1, T1, T2

3.3.2.2 Methodological issues for 1B2a

Methodology (1B2a)

1B2ai Exploration, production, transport of oil – pipeline transport: Following the decision tree, Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions reported under 1B2ai are estimated using a Tier 3 approach where emission estimates are based on information from experts (Canton of Neuchâtel 2019).

1B2aiv Refining and storage - leakage and emissions from Claus-units in refineries: Following the decision tree, Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), NMVOC emissions due to leakage reported under 1B2aiv are estimated using a Tier 2 approach where technology-specific activity data and emission factors are available. This source category also encompasses the SO_x emissions from Claus-units. An analogous Tier 2 method with country-specific emission factors is used to calculate these emissions.

1B2av Distribution of oil products - emissions from gasoline stations: According to the decision tree in Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), the methodology to estimate emissions from gasoline stations follows a Tier 2 approach using technology specific activity data and emission factors. A bottom-up model was developed to estimate and sum up the emissions from each individual source that could cause emissions: (a) gasoline delivery from the main storage tank to the gasoline station, (b) underfloor storage tank filling at the gasoline station, (c) storage in underfloor tank and finally (d) the refuelling process. The model is also based on information from several gasoline station operators, technicians and Swiss cantons. This information entails emission measurements as well as details regarding the number of gasoline stations which are equipped with petrol pumps with vapour recovery systems.

1B2av Distribution of oil products - gasoline and jet kerosene storage tank facilities: According to the decision tree in Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), the methodology to estimate emissions from gasoline and jet kerosene storage tanks follows a tier 3 methodology using facility-specific emission estimates available on a yearly basis since 2017. These estimates are used for a model validation. The model extrapolates backwards for previous years using currently available databases on numbers of storage tanks and their respective equipment.

Emission factors (1B2a)

1B2ai Exploration, production, transport of oil – pipeline transport of crude oil: In Switzerland crude oil is transported by underground pipelines only. According to expert information from oil industry, 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^3 air saturated with VOC are emitted per week and pig trap. This leads to negligible NMVOC emissions of 10-20 kg per year.

1B2aiv, NMVOC from leakage in refineries: The emission factor of NMVOC for 1B2aiv, leakage in refineries is country-specific and is documented in the EMIS database (EMIS 2024/1B2aiv_Raffinerie, Leckverluste). It is delineated from an emission estimation project in one of the refineries in 1992 called CRISTAL (Raffinerie de Cressier 1992). The estimation from the other refinery is assumed to be twice as high, because the technology of the plant is older. Then a weighted mean based on the quantity of crude oil used in both refineries was calculated (for further details see the internal documentation of the EMIS database, EMIS 2024/1B2aiv). This emission factor is used for all the years until 1995. For the years 2007-2019 total NMVOC emissions from 1A1b, 1B2aiv and 1B2c correspond to those reported in the Swiss PRTR database (PRTR 2021), including data for the years up to 2019 from the two refineries. Therefore, emission factors in 1B2aiv are adapted to reach the total NMVOC emission reported in Swiss PRTR. Between the years 1995 and 2007 the emission factors are interpolated linearly.

1B2aiv, SO_x emission factors from Claus units: For emissions from Claus units, the emission factors per tonne of crude oil are based on values from the project CRISTAL (Raffinerie de Cressier 1992) for the years 1990 and 1995 as well as on estimates from experts from the refinery for the year 2015 (years between 1990-1995 and 1995-2015 are interpolated, from 2015 on the value is kept constant).

1B2av Distribution of oil products - gasoline stations: The emission factors of NMVOC from 1B2av are country-specific and based on a bottom-up model (Luftkollektiv 2023) 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, 2020 and 2030 and the respective emission factors were determined. In between, the emission factors are linearly interpolated. The Pb emission factor is based on the lead content of gasoline. Pb emissions only occurred until 1999. Since 2000, only unleaded gasoline is sold.

1B2av Distribution of oil products – gasoline and jet kerosene storage tank facilities: 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. For gasoline storage tanks, detailed information is available for all historical reporting 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 3-102 NMVOC and SO_x emission factors in 1B2a – Oil, for 2022. All other emission factors including Pb (where emissions occurred from 1990 to 1999 only) are not applicable for this source category.

1B2a Fugitive emissions attributed to oil	**Per amount of**	**Unit**	**NMVOC**	**SO_X**
1B2ai Crude oil transport by pipelines	Number of refineries	g/no.	10'000	NA
1B2aiv Refinery leackage	Crude oil imported	g/t	75	NA
1B2aiv Refinery claus units	Crude oil imported	g/t	NA	5
1B2av Gasoline storage tank	Gasoline sold	g/GJ	1.2	NA
1B2av Gasoline station	Gasoline sold	g/GJ	22	NA
1B2av Jet kerosene storage tanks	Jet kerosene imported and produced	g/GJ	0.082	NA

Activity data (1B2a)

As crude oil is transported per pipeline to the refineries in Switzerland, activity data for 1B2ai reflect the number of pipelines, which is equal to the number of pipelines and number of pig traps. Activity data for 1B2aiv refining and storage are the amount of crude oil imported. These data are provided by Avenergy Suisse (Avenergy 2023) in their annual statistics and also reported in the Swiss overall energy statistics (SFOE 2023).

The activity data for 1B2av concerning fugitive emissions from gasoline stations and storage tanks is the amount of gasoline sold based on the Swiss overall energy statistics (SFOE 2023), corrected for consumption of Liechtenstein.

The activity data for 1B2av fugitive emissions from jet kerosene storage tanks is the sum of total amount of jet kerosene imported and produced in Swiss refineries. The amount of jet kerosene production in Swiss refineries has decreased steadily since 2005 and is zero in the year 2021.

Table 3-103 Activity data of 1B2a – Oil.

1B2a Fugitive emissions attributed to oil	**Amount of**	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
1B2ai Transport of crude oil by pipelines	Refineries	Number	2	2	2	2	2
1B2aiv Refining and storage	Crude oil	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 Fugitive emissions attributed to oil	**Amount of**	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**1990 to 2022**
1B2ai Transport of crude oil by pipelines	Refineries	Number	2	2	1	1	1	1	1	1	1	1	-50%
1B2aiv Refining and storage	Crude oil	kt	4'935	4'975	2'836	3'006	2'889	3'076	2'789	2'857	2'339	3'102	-1%
1B2av Gasoline distribution	Gasoline sold	TJ	118'717	113'956	105'664	102'367	99'223	97'654	96'850	85'769	87'628	85'110	-46%
1B2av Jet kerosene distribution	Jet kerosene imported and produced	TJ	69'248	68'219	70'857	73'853	75'027	80'262	83'698	34'816	31'736	54'264	13%

3.3.2.3 Category-specific recalculations for 1B2a - Oil

- 1B2a: The emission factors for NMVOC from gasoline losses and evaporation at petrol stations have changed due to corrections in the model for all reported years.

3.3.3 Source category 1B2b - Fugitive emissions from natural gas

3.3.3.1 Source category description for 1B2b

Emissions from natural gas production 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 and distribution.

Table 3-104 Specification of source category 1B2b – Natural gas.

1B2b	Source category	Specification
1B2b	Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other)	Emissions from gas "distribution and transit" network Production of natural gas (only relevant for 1990-1994)

Table 3-105: Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1B2b – Natural gas

Source category 1B2b – Natural gas is not a key category.

3.3.3.2 Methodological issues for 1B2b

Methodology (1B2b)

In source category 1B2b Fugitive emissions from natural gas, fugitive emissions from production and from pipeline transport of natural gas are reported. Therefore, only NMVOC emissions occur in this source category.

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 production of natural gas and a Tier 2 approach for fugitive emissions attributed to transmission and distribution of natural gas. As source category 1B2 is not a key category and as the contribution from production of natural gas 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 and distribution form 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 greenhouse gases CO_2 and CH_4 and the air pollutant NMVOC. The same country-specific properties are used to estimate fugitive emissions from natural gas production as there are no other data available.

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 and distribution, 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 NMVOC are calculated by multiplying the losses (activity data) with the country-specific composition of the gas (emission factor).

Emission factors (1B2b)

Production of natural gas

For natural gas production NMVOC default emission factors are taken from the 2006 IPCC Guidelines (IPCC 2006) as documented in the internal emission database documentation (EMIS 2024/1B2b 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. As gas production only occurred until 1994, there is no emission factor reported in Table 3-106.

Transport of natural gas

For natural gas transmission and distribution, the emission factors represent the composition of the gas lost and are based on the country-specific gas properties as mentioned above.

Table 3-106 Emission factors in 1B2b – Natural gas, for 2022.

1B2b Fugitive emissions attributed to natural gas	Per amount of	Unit	NMVOC
1B2biv Transmission, losses	Natural gas	g/GJ	2'233
1B2bv Distribution, losses	Natural gas	g/GJ	2'233
1B2bvi Other Leakage, losses	Natural gas	g/GJ	NO

Activity data (1B2b)

Production of natural gas

Note that production of natural gas only occurred until 1994 in Switzerland. Activity data are based on Swiss overall energy statistics (SFOE 2023).

Transport of natural gas

For gas transmission and distribution, the activity data represent the amount of natural gas lost from the gas network. All the details are documented in SGWA (2023a) and EMIS 2024/1B2b Diffuse Emissionen.

The key points within 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 distribution are as follows:

- **Leakage:** The methodology is based on the actual amount of leaks per kilometre for the years since 2017 (gas statistics from SGWA). For 1990, the amount 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 Maintenanc**e: 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 3-107 Activity data of 1B2b Fugitive emissions – Natural gas.

1B2b Fugitive emissions attributed to 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
1B2bvi Other Leakage, losses	Natural gas	GJ	NO	NO	NO	NO	NO

1B2b Fugitive emissions attributed to natural gas	Amount of	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	1990 to 2022
1B2bii Production	Natural gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-
1B2biv Transmission, losses	Natural gas	GJ	11'029	12'304	11'641	10'381	18'062	11'269	11'105	14'367	7'910	8'970	-25%
1B2bv Distribution, losses	Natural gas	GJ	103'515	98'328	94'441	90'580	88'134	82'119	78'760	74'659	76'401	75'485	-53%
1B2bvi Other Leakage, losses	Natural gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-

3.3.3.3 Category-specific recalculations for 1B2b

- Fugitive emissions from 1B2b – Natural gas: A new country-specific methodology has been established, completely revising the hitherto applied methodology by Quantis (2014). The main changes are:
  - Where applicable, outdated emission factors from Battelle (1989) are now replaced by emission factors from DVGW (2022) or actual measurements. This applies in particular to components, appliances, house installations, industrial networks, gas stoves, etc.
  - The number of actual leakages and third-party damages are now used, combined with emissions per leakage according to DVGW (2022).
  - Actual losses from the operation and maintenance of the transit pipeline based on annual data provided by the operator (for the years since 2016) are considered. Therewith, mitigation measures such as reducing the pressure within the pipelines before maintenance can now be reflected.
  - For the compressor station, the actual average compressor power is now used instead of the installed power.
  - Permeation through polyethylene pipelines is newly considered based on DVGW (2022).
  - Emissions from the handling of liquefied natural gas is newly considered under 1B2bv Distribution.
  - Emissions previously reported under 1B2bvi Other, Leakage are now included under Transmission (relevant for the years 2010 and 2011).

3.3.4 Source category 1B2c - Fugitive emissions from venting and flaring

3.3.4.1 Source category description for 1B2c

This source category contains venting and flaring caused by two types of activities: oil production and refining and gas production. 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 gas torches caused by oil refining, which were operational at the two refineries. Since 2015, there is only one refinery in operation. In addition, CO_2 emissions from H_2 production in one of the two refineries since 2005 are also reported under 1B2c.

Table 3-108 Specification of source category 1B2c – Venting and flaring.

1B2c	Source category	Specification
1B2c	Venting and flaring (oil, gas, combined oil and gas)	The release/combustion of excess gas at the oil refinery Flaring of gas at gas production facility (only relevant for 1990-1994)

Table 3-109: Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 1B2c - Fugitive emissions from venting and flaring (oil, gas, combined oil and gas).

NFR code	Source category	Pollutant	Identification criteria
1B2c	Venting and flaring (oil gas combined oil and gas)	NOx	T2

3.3.4.2 Methodological issues for 1B2c

Methodology (1B2c)

Following the decision tree, Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions reported under 1B2c are estimated using a Tier 3 approach where plant-specific activity data are available. In Switzerland, flaring only occurs in refineries and there is no venting. One of the two refineries in Switzerland ceased its operation at the beginning of 2015. Between 1990-1994, there was a gas production facility in Switzerland, where gas was flared.

Emission factors (1B2c)

Emission factors of 1B2c Venting and flaring are based on the following data:

- NO_x, NMVOC, SO_x and CO emission factors are provided from the refining industry as documented in the EMIS database (EMIS 2024/1B2c Raffinerie Abfackelung). Since 2005 (with the exception of 2012), the refining industry provides annual data on the CO_2 emissions from flaring under the Federal Act on the Reduction of CO_2 Emissions (Swiss Confederation 2011) based on daily measurements of CO_2 emission factors of the flared gases. From these data, annual CO_2 emission factors are derived. Since 2005, the evolution of the other emission factors (NO_x, NMVOC, SO_x, CO) is assumed to be proportional to the CO_2 emission factor. Emission factors for 2022 are considered confidential and are available to reviewers upon request. The NMVOC emissions from flaring in the gas production facility (only occurring from 1990-1994) are calculated based on default emission factors provided in the 2006 IPCC Guidelines.
- PM/TSP exhaust, BC exhaust, heavy metals and PAH emission factors concerning gas venting and flaring for gas production and for oil refining stem from the EMEP/EEA guidebook (EMEP/EEA 2019). For the emission factors applicable at oil refineries, the values from EMEP/EEA (2019), originally in the unit of ton of gas burned, are recalculated per quantity of oil processed for the Swiss inventory. Since the quantity of gas burned per oil processed at refinery is confidential, therefore, the emission factor shown in Table 3-110 is confidential as well.
- The PCDD/PCDF emission factor for venting and flaring at gas production stems from Norway's Informative Inventory Report 2021 (Norwegian Environment Agency 2021). This emission factor is used from 1985 until 1994, when gas production stopped in Switzerland.

Table 3-110 Emission factors in 1B2c – Venting and flaring, for 2022.

1B2c Fugitive emissions attributed to venting and flaring	Per amount of	Unit	NO_x	NMVOC	SO_X	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
1B2ci Flaring oil	Crude oil imported	g/t	C	C	C	C	C	C	C	C
1B2cii Flaring gas	Natural gas produced	g/t	NO	NO	NO	NO	NO	NO	NO	NO

1B2c Fugitive emissions attributed to venting and flaring	Per amount of	Unit	Pb	Cd	Hg	BaP	BbF	BkF	IcdP
1B2ci Flaring oil	Crude oil imported	ng/t	C	C	C	C	C	C	C
1B2cii Flaring gas	Natural gas produced	ng/t	NO	NO	NO	NO	NO	NO	NO

Activity data (1B2c)

1B2c Fugitive emissions from venting and flaring

Before 2005, the amount of flared gas in oil refineries (1B2ci) is assumed to be proportional to the amount of crude oil processed in the refineries. Since 2005, the industry provides bottom-up data on the amount of gas flared in the refineries. Activity data since 2014 are considered confidential and are available to reviewers on request.

For gas venting and flaring associated with gas production (only occurring from 1990-1994), the amount of gas flared under category 1B2cii is estimated based on the amount of gas produced.

Table 3-111 Activity data of 1B2c – Venting and flaring.

1B2c Fugitive emissions attributed to venting and flaring	Amount of	Unit	1990	1995	2000	2005	2010
1B2ci Flaring oil	Crude oil imported	kt	C	C	C	C	C
1B2cii Flaring gas	Natural gas produced	GJ	130'000	NO	NO	NO	NO

1B2c Fugitive emissions attributed to venting and flaring	Amount of	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	1990 to 2022
1B2ci Flaring oil	Crude oil imported	kt	C	C	C	C	C	C	C	C	C	C	C
1B2cii Flaring gas	Natural gas produced	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-

3.3.4.3 Category-specific recalculations for 1B2c

- 1B2c: Small recalculations for all pollutants in 1B2c Flaring oil due to the use of more precise values (more significant decimal places) for the emission factors of these pollutants for the years 2005-2021.

4 Industrial processes and product use

4.1 Overview of emissions

This introductory chapter gives an overview of major emissions from sector 2 Industrial processes and product use between 1990 and 2022 and comprises process emissions only. All emissions from fuel combustion in industry are reported in sector 1 Energy. Regarding main pollutants, industrial processes and product use are the main emission source of NMVOC and contribute to a lesser extent to the emissions of SO_x and particulate matter. Industrial processes and product use are also relevant sources for emissions of priority heavy metals and dominate the PCB emissions.

The following source categories are reported:

- 2A Mineral products
- 2B Chemical industry
- 2C Metal production
- 2D, 2G Other solvent and product use
- 2H Other
- 2I Wood processing
- 2K Consumption of POPs and heavy metals
- 2L Other production, consumption, storage, transportation or handling of bulk products

4.1.1 Overview and trend for NMVOC

According to Figure 4-1 and Table 4-1, total NMVOC emissions from 2 Industrial processes and product use show a considerable decrease between 1990 and 2004 with a weaker decreasing trend until 2017 and rather constant values afterwards. The trend until 2004 is mainly due to reductions in 2D Other solvent and product use and to a lesser extent to reductions in 2G Other product use. For the entire time series, the NMVOC emissions are dominated by the emissions from 2D. Relevant emissions stem from 2G Other product use and 2H Other as well.

In 1990, source categories 2D3d Coating applications and 2D3g Chemical products contribute to more than half of the NMVOC emissions of source category 2D whereas all the other source categories account for the rest. In 2022, the largest shares in source category 2D come from 2D3d Coating applications and 2D3a Domestic solvent use including fungicides while the shares of 2D3b Road paving with asphalt, 2D3c Asphalt roofing, 2D3e Degreasing, 2D3f Dry cleaning, 2D3g Chemical products, 2D3h Printing and 2D3i Other solvent use account for the rest.

The reduction in 2D3d Coating applications is due to changes in the paint composition, i.e. from solvent-based to water-based paints. Accordingly, emission factors for all commercial and industrial applications show a significant decrease between 1990 and 2004. This trend is induced and driven by the EU directive (EC 2004) on the limitation of emissions of volatile organic compounds from the solvents used in certain paints and varnishes and vehicle refinishing products. In addition, noticeable decreases in paint consumption in construction (1990–1998) and industrial paint application (2001–2004) are superposed. The latter resulted from structural changes within the industrial sector and replacing of conventional paints by powder coatings. In 1990, the NMVOC emissions from 2D3d Coating applications are dominated by the emissions from industrial paint application and paint application in construction whereas in 2022, by emissions from paint application on wood and in construction.

The NMVOC emissions from the most important single source category 2D3a Household cleaning agents, cosmetics and toiletries increase between 1990 and 1996 then they drop until 2000 and since then they show a weaker decline until 2016. From 2017 onwards, the emissions are again increasing. Factors contributing to this trend are changes in the range of product used, product-specific NMVOC contents and population growth.

Within source category 2D, a significant reduction in emissions from 2D3g Chemical products and 2D3h Printing between 1990 and 2022 is observed. The reduction in source category 2D3h Printing as well as in industry and services in general is mainly a result of the ordinance on the VOC incentive tax (Swiss Confederation 1997) with enactment of the tax in 2000 and structural changes within the respective industry and service sectors.

Also process optimizations (production of acetic acid and PVC), closing down of production, e.g. PVC production in 1996 (2B Chemical industry) and the production decrease in the iron foundries (2C Metal production) contribute to the observed decrease in NMVOC emissions. The NMVOC emissions from 2H Other with main contributions from source category 2H2 Bread production slightly decline as well in the period 1990–2022. In addition, general technological improvements and post-combustion installations contribute to further emission reductions.

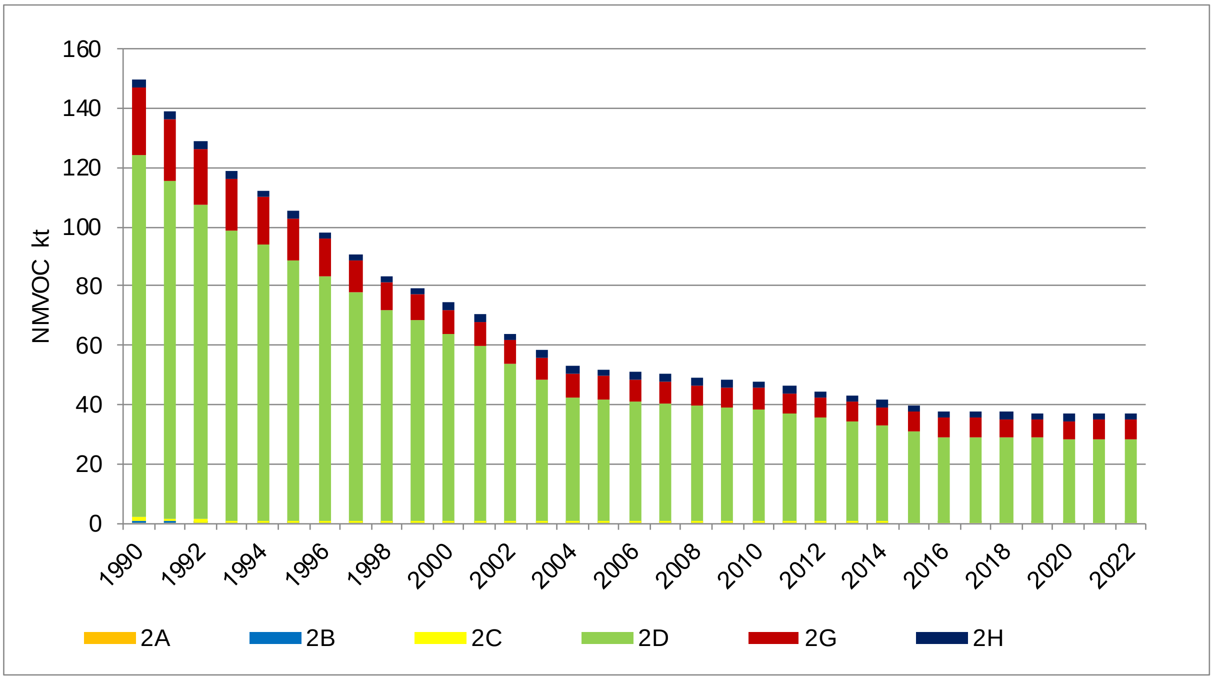

Figure 4-1 Switzerland’s NMVOC emissions from industrial processes and product use by source categories 2A-2D and 2G-2H between 1990 and 2022. The corresponding data can be found in Table 4-1.

Table 4-1 NMVOC emissions from sector 2 Industrial processes and product use by source categories 2A-2D, 2G and 2H. The last column in the third part of the table indicates the relative trend.

NMVOC total	1990	1995	2000	2005	2010
	kt				
2A	0.047	0.037	0.032	0.035	0.037
2B	0.61	0.18	0.025	0.028	0.037
2C	1.1	0.76	0.71	0.45	0.35
2D	123	88	63	41	38
2G	22	14	8.2	7.6	6.9
2H	2.7	2.6	2.4	2.4	2.5
Sum	150	106	75	52	48

NMVOC total	2013	2014	2015	2016	2017
	kt				
2A	0.033	0.033	0.030	0.031	0.031
2B	0.025	0.023	0.020	0.016	0.013
2C	0.31	0.31	0.29	0.27	0.28
2D	34	32	30	29	29
2G	6.8	6.7	6.6	6.5	6.4
2H	2.4	2.4	2.4	2.3	2.3
Sum	43	42	40	38	38

NMVOC total	2018	2019	2020	2021	2022	2005–2022
	kt					
2A	0.031	0.030	0.029	0.030	0.029	-17%
2B	0.015	0.016	0.015	0.016	0.015	-45%
2C	0.28	0.22	0.20	0.22	0.22	-51%
2D	28	28	28	28	28	-32%
2G	6.3	6.3	6.3	6.3	6.3	-17%
2H	2.3	2.3	2.2	2.3	2.3	-5%
Sum	37	37	37	37	37	-29%

4.1.2 Overview and trend for SO_x

According to Figure 4-2 and Table 4-2, total SO_x emissions from 2 Industrial processes and product use show an intermittent decrease of almost 70 % in the period 1990-2009. From 2010 to 2018, there is again an increase in SO_x emissions followed by a decrease 2019-2022. In 1990, source categories 2C Metal production and 2B Chemical industry show the largest contributions (around 50 % each) to the total SO_x emissions. In 2022, the emissions are dominated by 2B Chemical industry. The emissions from 2A Mineral products are negligible over the entire time period and there are no emissions from 2D. The highly fluctuating SO_x emissions from 2B Chemical industry stem mainly from the graphite and silicon carbide production, i.e. the raw materials used (petroleum coke and other bituminous coal) and reflect both the production volume and the sulphur content of raw materials between 1990 and 2022. In 2022, it is by far the largest emission source within sector 2. The SO_x emissions from 2C Metal production originate predominately from the consumption of electrodes (anodes) in the aluminium production and follow thus the aluminium production volume in Switzerland (the only primary aluminium smelter was closed down in 2006). The small amount of SO_x emissions from 2G Other product use stems from the use of fireworks.

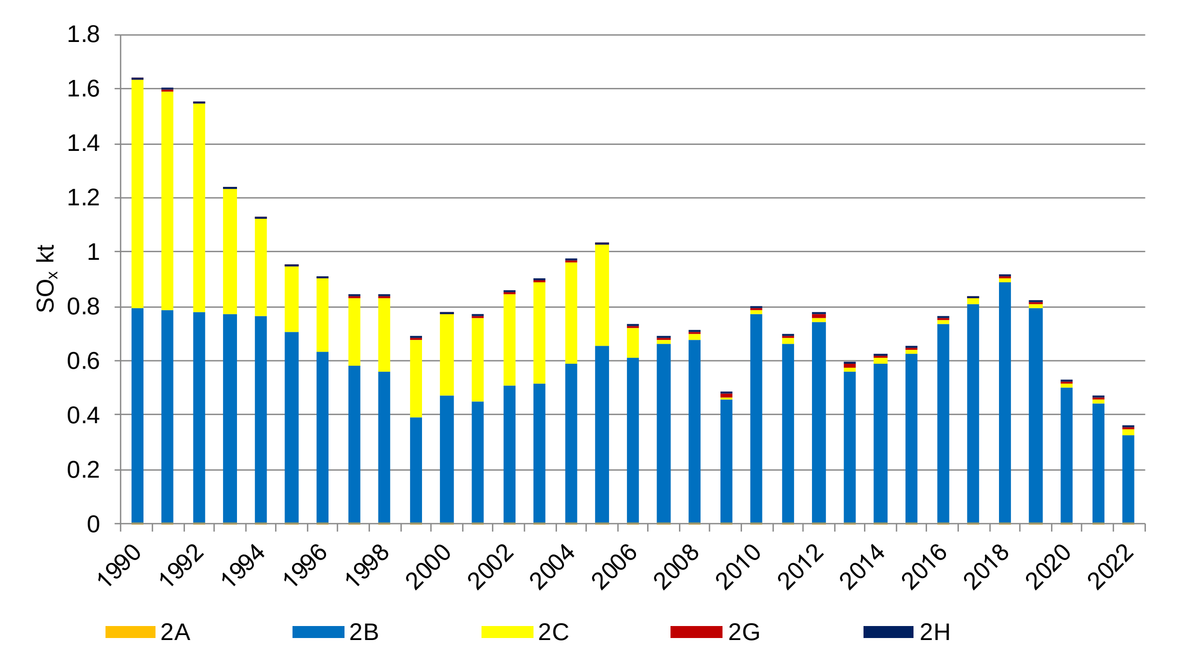

Figure 4-2 Switzerland's SO_x emissions from industrial processes and product use by source categories 2A–2C and 2G-2H between 1990 and 2022. The corresponding data can be found in Table 4-2.

Table 4-2 SO_x emissions from sector 2 Industrial processes and product use by source categories 2A-2C and 2G-2H. The last column in the third part of the table indicates the relative trend.

SOx	1990	1995	2000	2005	2010
	kt				
2A	0.0008	0.0006	0.0005	0.0006	0.0006
2B	0.79	0.71	0.47	0.65	0.77
2C	0.84	0.24	0.30	0.37	0.017
2G	0.003	0.004	0.006	0.006	0.007
2H	0.001	0.0007	0.0009	0.0004	0.001
Sum	1.6	0.95	0.78	1.0	0.80

SOx	2013	2014	2015	2016	2017
	kt				
2A	0.0006	0.0006	0.0005	0.0005	0.0005
2B	0.56	0.59	0.62	0.73	0.81
2C	0.017	0.018	0.018	0.017	0.018
2G	0.010	0.007	0.007	0.005	0.007
2H	0.001	0.001	0.001	0.0003	0.0004
Sum	0.59	0.62	0.65	0.76	0.83

SOx	2018	2019	2020	2021	2022	2005–2022
	kt					
2A	0.0005	0.0005	0.0005	0.0005	0.0005	-17%
2B	0.89	0.79	0.50	0.44	0.33	-50%
2C	0.018	0.016	0.016	0.018	0.017	-95%
2G	0.007	0.004	0.004	0.006	0.008	38%
2H	0.0004	0.0003	0.0003	0.0003	0.0003	-18%
Sum	0.91	0.81	0.52	0.47	0.35	-66%

4.1.3 Overview and trend for PM2.5

According to Figure 4-3 and Table 4-3, total PM2.5 emissions from sector 2 Industrial processes and product use show a decrease of about 40 % in the period 1990-1999. The emissions are fluctuating with again a decreasing trend since 2008. In 1990, the source categories 2C Metal production, 2A Mineral products, 2G Other product use and 2H Other contribute the most to the total PM2.5 emissions.

In 2022, the highest contribution to the total PM2.5 emissions is due to the source categories 2A, 2G and 2H whereas the other source categories are of minor importance. PM2.5 emissions from 2A Mineral products with main contributions from blasting operations in 2A1 Cement production and from 2A5a Quarrying and mining of minerals other than coal are more or less constant over the entire time period. On the other hand, PM2.5 emissions from 2C Metal production, which are dominated by the emissions from 2C1 Iron and steel production, show a strong decrease between 1994 and 1999 and are almost exclusively responsible for the total PM2.5 emission reduction in this source category between 1990 and 2022. The reason for the initial emission reduction in 1995 is the closing down of two steel production sites, whereas the drastic emission drop in 1998/1999 is due to the installation of new filters in the remaining two steel plants. The PM2.5 emissions from 2G Other product use, i.e. from the use of fireworks and tobacco, remained about constant between 1990 and 2013 and has decreased since then. In 1990, 2G emissions were dominated by tobacco use. In 2022, tobacco use is still the major emission source but also the use of fireworks contributes considerable amounts. The emissions in 2H Other remain about constant since 1990 but with a slight decline since 2008. In this source category, the main contributions arise from 2H1 Chipboard and fibreboard production.

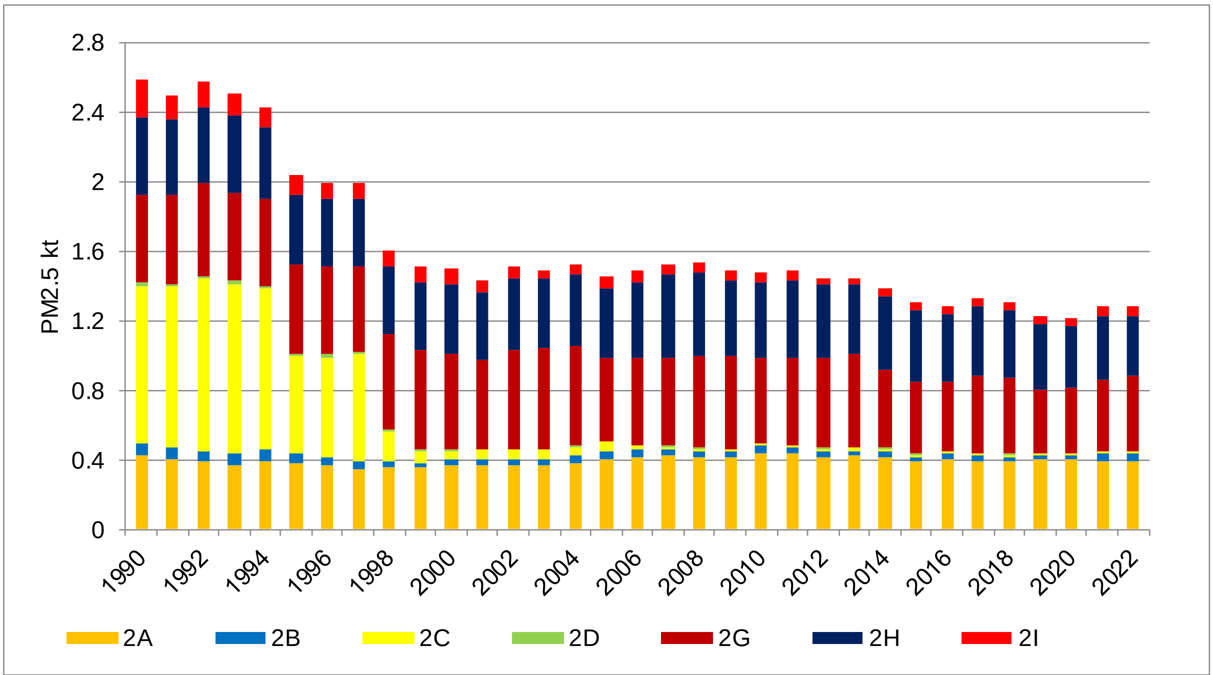

Figure 4-3 Switzerland's PM2.5 emissions from industrial processes and product use by source categories 2A-2D and 2G-2I between 1990 and 2022. The corresponding data can be found in Table 4-3.

Table 4-3 PM2.5 emissions from sector 2 Industrial processes and product use by source categories 2A-2D and 2G-2I. The last column in the third part of the table indicates the relative trend.

PM2.5	1990	1995	2000	2005	2010
	kt				
2A	0.43	0.39	0.37	0.41	0.44
2B	0.069	0.058	0.033	0.040	0.039
2C	0.90	0.56	0.051	0.055	0.014
2D	0.016	0.015	0.007	0.002	0.003
2G	0.51	0.52	0.55	0.48	0.49
2H	0.44	0.39	0.40	0.41	0.44
2I	0.22	0.12	0.090	0.063	0.057
Sum	2.6	2.0	1.5	1.5	1.5

PM2.5	2013	2014	2015	2016	2017
	kt				
2A	0.43	0.42	0.39	0.40	0.40
2B	0.031	0.033	0.029	0.031	0.029
2C	0.012	0.013	0.012	0.012	0.012
2D	0.004	0.004	0.004	0.004	0.004
2G	0.54	0.45	0.42	0.40	0.44
2H	0.40	0.43	0.41	0.39	0.41
2I	0.042	0.047	0.046	0.046	0.043
Sum	1.5	1.4	1.3	1.3	1.3

PM2.5	2018	2019	2020	2021	2022	2005–2022
	kt					
2A	0.39	0.41	0.40	0.40	0.39	-5%
2B	0.029	0.023	0.030	0.038	0.045	14%
2C	0.012	0.010	0.010	0.011	0.011	-81%
2D	0.004	0.004	0.004	0.004	0.004	57%
2G	0.44	0.36	0.38	0.41	0.43	-10%
2H	0.39	0.38	0.35	0.37	0.35	-13%
2I	0.044	0.044	0.046	0.049	0.049	-22%
Sum	1.3	1.2	1.2	1.3	1.3	-12%

4.2 Source category 2A – Mineral products

4.2.1 Source category description of 2A Mineral products

Table 4-4 Specification of source category 2A Mineral products in Switzerland.

2A	Source category	Specification
2A1	Cement production	Blasting operations of the cement production, Process emissions from calcination are reported in 1A2f
2A2	Lime production	Blasting operations of the lime production, Process emissions from calcination are reported in 1A2f
2A3	Glass production	Process emissions from glass production are reported in 1A2f
2A5a	Quarrying and mining of minerals other than coal	Gravel plants and blasting operations of the plaster production

Table 4-5 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 2A Mineral Products.

NFR code	Source category	Pollutant	Identification criteria
2A1	Cement production	PM2.5	L2, T2
2A1	Cement production	PM10	L2
2A5a	Quarrying and mining of minerals other than coal	PM2.5	L1, L2, T1, T2
2A5a	Quarrying and mining of minerals other than coal	PM10	L1, L2, T2

4.2.2 Methodological issues of 2A Mineral products

4.2.2.1 Cement production (2A1)

Methodology (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.

According to the EMEP/EEA guidebook (EMEP/EEA 2019), source category 2A1 Cement production comprises all emissions from operations other than pyroprocessing (kiln). Based on the decision tree Fig. 3.1 in chapter 2A1 Cement production of EMEP/EEA (2019), the emissions resulting from blasting operations during the digging of limestone are determined by a Tier 2 method using country-specific emission factors documented in EMIS 2024/2A1. The reported emissions of non-exhaust particulate matter contain fugitive emissions of particulate matter of the production sites including storage and handling as well.

Pollutants released from the raw material during the calcination process in the kiln are reported in source category 1A2f Cement production together with the emissions from fuel combustion.

Emission factors (2A1)

Blasting: Emission factors per tonne of clinker are derived from the 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) and the EMIS database. They are assumed to be constant over the entire time period. The emission factor of BC (% of PM2.5 exh.) is taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.A.1, table 3.1).

Table 4-6 Emission factors for blasting operations of 2A1 Cement production in 2022.

2A1 Cement production	Unit	NOx	NMVOC	SO_X
Blasting operations	g/t clinker	3.3	8.6	0.14

2A1 Cement production	Unit	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO
Blasting operations	g/t clinker	0.51	50	0.86	77	0.86	110	0.015	3.3

Activity data (2A1)

Since 1990, data on annual clinker production are provided by the industry association (Cemsuisse) as documented in the EMIS database (EMIS 2024/2A1_Zementwerke übriger Betrieb). From 2008 onwards, they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Table 4-7 Activity data of 2A1 Cement production.

2A1 Cement production	Unit	1990	1995	2000	2005	2010
Clinker	kt	4'808	3'706	3'214	3'442	3'642

2A1 Cement production	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Clinker	kt	3'415	3'502	3'195	3'296	3'279	3'239	3'227	3'129	3'227	3'155

4.2.2.2 Lime production (2A2)

Methodology (2A2)

There is only one producer of burnt lime in Switzerland. Based on the decision tree Fig. 3.1 in chapter 2A2 Lime production of the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from blasting operations in the quarry are determined by a Tier 2 method using country-specific emission factors (EMIS 2024/2A2). The reported emissions of non-exhaust particulate matter contain fugitive emissions of particulate matter of the production site including storage and handling as well.

Pollutants released from the raw material during the calcination process in the kiln are reported in source category 1A2f Lime production together with the emissions from fuel combustion.

Emission factors (2A2)

The emission factors (NO_x, NMVOC, SO_x, PM2.5, PM10, TSP and CO) per tonne of lime produced are confidential but available to reviewers on request. They are assumed to be constant over the entire time period. The emission factor of BC (% PM2.5) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.A.2, table 3.1).

Activity data (2A2)

Activity data on annual lime production is based on data from the only lime producer in Switzerland and is confidential but available to reviewers on request. From 2008 onwards, they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

4.2.2.3 Glass production (2A3)

Process emissions from glass production in Switzerland, i.e. container and tableware glass as well as glass wool are reported together with the combustion emissions in source category 1A2f according to EMEP/EEA guidebook (EMEP/EEA 2019), since it is not straightforward to separate them. Therefore, emissions of NO_x, SO_x, PM2.5/PM10/TSP, BC, CO, Pb, Cd and Hg are reported as “included elsewhere” (IE).

4.2.2.4 Quarrying and mining of minerals other than coal (2A5a)

Methodology (2A5a)

In this source category there are two production processes occurring in Switzerland: Gravel plants and plaster production. In August 2020, one of the two plaster production plants was closed. The emissions stem mainly from blasting operations and crushing of stones either in plaster production or gravel plants.

Based on the EMEP/EEA guidebook (EMEP/EEA 2016), emissions from blasting operations as well as emissions of particulates from crushing and grinding work are determined by a Tier 2 method using country-specific emission factors (EMIS 2024/2A5a). Emissions from storage and handling are also accounted for.

Emission factors (2A5a)

The emission factors per tonne of gravel and rocks are country-specific. For plaster production, the emission factors are confidential from 2021 onwards but available to reviewers on request.

Table 4-8 Emission factors of 2A5a Gravel plants and Plaster production in 2022.

2A5a Quarrying and mining of minerals other than coal	Unit	NOx	NMVOC	SO_X
Gravel plants	g/t gravel	NA	NA	NA
Plaster production	g/t rocks	C	C	C

2A5a Quarrying and mining of minerals other than coal	Unit	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO
Gravel plants	g/t gravel	NA	4	NA	8	NA	16	NA	NA
Plaster production	g/t rocks	C	C	C	C	C	C	NE	C

Activity data (2A5a)

Activity data for gravel plants and plaster production is based on industry data. For plaster production, plant-specific data are available for 1990, 2001 and from 2004 onwards. For the missing years in between the activity data are linearly interpolated. From 2021 onwards, activity data are confidential but available to reviewers on request.

Data on gravel production is provided annually by the Swiss association of gravel and concrete industry (Fachverband der Schweizerischen Kies- und Betonindustrie, FSKB). But the latest data available is always one year delayed with respect to the latest year of the submission.

Table 4-9 Activity data of 2A5a Gravel plants and Plaster production.

2A5a Quarrying and mining of minerals other than coal	Unit	1990	1995	2000	2005	2010
Gravel plants	kt gravel	33'798	36'791	39'785	44'960	50'540
Plaster production	kt rocks	319	304	288	327	335

2A5a Quarrying and mining of minerals other than coal	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gravel plants	kt gravel	53'940	53'090	50'610	52'750	51'480	49'880	54'060	54'570	53'580	53'404
Plaster production	kt rocks	213	166	140	148	146	152	149	122	C	C

4.2.2.5 Construction and demolition (2A5b)

The emissions (from resuspension) of particulate matter (PM2.5, PM10 and TSP) from construction machinery are reported in source category 1A2gvii Mobile combustion in manufacturing industries and construction. Therefore, these emissions are indicated in the reporting tables as "IE".

4.2.3 Category-specific recalculations in 2A Mineral products

The following recalculations were implemented in submission 2024:

- 2A5a: The last year's extrapolated activity data of 2A5a Gravel plants for 2021 was revised based on effective production data from the industry association.

4.3 Source category 2B – Chemical industry

4.3.1 Source category description of 2B Chemical industry

Table 4-10 Specification of source category 2B Chemical industry in Switzerland.

2B	Source category	Specification
2B1	Ammonia production	Production of ammonia
2B2	Nitric acid production	Production of nitric acid (ceased in 2018)
2B5	Carbide production	Production of silicon carbide and graphite
2B10a	Chemical industry: Other	Production of acetic acid, ammonium nitrate (ceased in 2018), chlorine gas, ethylene, niacin, PVC (ceased in 1996) and sulfuric acid

Table 4-11 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 2B Chemical Industry.

NFR code	Source category	Pollutant	Identification criteria
2B5	Carbide production	SOx	L1, L2, T1, T2

4.3.2 Methodological Issues of 2B Chemical industry

4.3.2.1 Ammonia production (2B1)

Methodology (2B1)

In Switzerland, ammonia is produced in one single plant by catalytic reaction of nitrogen and synthetic hydrogen. Ammonia is not produced in an isolated reaction plant but is part of an integrated production chain. Starting process of this production chain is the thermal cracking of liquefied petroleum gas and light virgin naphtha yielding ethylene and a series of by-products such as e.g. synthetic hydrogen, which are used as educts in further production steps. According to the producer it is not possible to split and allocate the NMVOC emissions of the cracking process to each single product (ethylene, ammonia, cyanic acid etc.) within the integrated production chain. Therefore, the NMVOC emissions of the cracking process are allocated completely to the primary product ethylene (source category 2B10a). The only emissions reported under 2B1 Ammonia production are NH_3 emissions escaping from the flue gas scrubber.

Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions from 2B1 Ammonia production are calculated by a Tier 2 method using plant-specific emission factors documented in EMIS 2024/2B1.

Emission factors (2B1)

The NH_3 emission factor per tonne of ammonia produced is confidential but available to reviewers on request. From 1990 to 2001, a constant emission factor based on measurements is applied. In 2002, the scrubber was replaced. For 2011 and since 2013 the emission factor is determined based on measurements provided by the plant. For the years 2002 – 2010 and 2012 the average value of the years 2011 and 2013 – 2017 is applied.

Table 4-12 Emission factor for 2B1 Ammonia production in 2022.

2B1 Ammonia production	Unit	NMVOC	NH_3
	g/t ammonia	IE	C

Activity data (2B1)

Plant-specific activity data on annual ammonia production is provided by the single plant that exists in Switzerland for the entire time period 1990-2022. Since 2013, activity data are taken from annual monitoring reports from the Swiss Emissions Trading Scheme (ETS). Activity data are confidential, and information is available to reviewers on request.

4.3.2.2 Nitric acid production (2B2)

Methodology (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°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.

Thus, there resulted also some nitrogen oxide (NO_x) as an unintentional by-product. 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.

Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), NH_3 and NO_x emissions from 2B2 Nitric acid production are calculated by a Tier 2 method using plant-specific emission factors (see EMIS 2024/2B2).

Emission factors (2B2)

The emission factors for NO_x and NH_3 per tonne of nitric acid (100 %) are confidential but available to reviewers upon request. The emission factor values for NO_x and NH_3 are mean values based on measurements on site in 2005, 2009 and 2012, and 2007, 2009 and 2012, respectively. They are assumed to be constant between 1990 and 2012 since no modifications in the production process has been made in this period.

In 2013, a new catalyst was installed in the production line along with a measurement device for NH_3 slip in order to regulate ammonia dosage in the DeNOx plant. Moreover, in 2013 the volume of the DeNOx plant was duplicated. Consequently, the NH_3 emissions could be reduced significantly. Also, a slight reduction of NO_x occurred. From 2013 to 2018, emission factors were based on measurements provided by the plant.

Activity data (2B2)

Activity data on annual nitric acid (100 %) production was provided for the years 1990 to 2018 by the single production plant in Switzerland and is therefore considered as confidential. However, this information is available to reviewers. From 2013 to 2018, activity data were taken from annual monitoring reports from the Swiss Emission Trading Scheme (ETS).

4.3.2.3 Carbide production (2B5)

Methodology (2B5)

In Switzerland, only silicon carbide is produced in a single plant. It is produced together with graphite in a coupled process in an electric furnace at temperatures above 2000ºC using the Acheson process. Therefore, emissions include those from the production of both silicon carbide and graphite. Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of SO_x, particulate matter and CO from 2B5 Silicon carbide production are calculated by a Tier 2 method using plant-specific emission factors (EMIS 2024/2B5).

Emission factors (2B5)

The emission factors of SO_x, particulate matter and CO are based on data from the production plant. The SO_x emission factor is derived from the sulphur content of the feedstocks, i.e. petroleum coke and anthracite. The CO emission factor is calculated based on the carbon mass balance of the production process and exhaust measurements. The emission factors are expressed in g/t carbide but comprise the (unsplit) emissions from the coupled production process of silicon carbide and graphite. They are confidential but available to reviewers on request.

Table 4-13 Emission factor for 2B5 Carbide production in 2022.

2B5 Carbide production	Unit	SO_X	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
Silicon carbide	g/t carbide	C	C	C	C	NE	C

Activity data (2B5)

Activity data on annual production of silicon carbide (and graphite) is provided by the production plant from 1995 onwards. For 1990–1994 they are estimates based on industry data. The activity data are considered confidential. However, this information is available to reviewers on request.

4.3.2.4 Chemical industry: Other (2B10a)

Methodology (2B10a)

Source category 2B10a Chemical industry: Other comprises emissions from production of acetic acid, ammonium nitrate (ceased in 2018), chlorine gas, ethylene, niacin, PVC (ceased in 1996) as well as sulphuric acid. Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from 2B10a Chemical industry are calculated by a Tier 2 method using plant-specific emission factors (EMIS 2024/2B10a).

Acetic acid production (2B10a)

In Switzerland there is only one plant producing acetic acid (CH_3COOH) remaining after the other one stopped its production by the end of 2012. The still existing plant emits NMVOC only whereas from the latter one also emissions of CO have occurred.

Emission factors

The emission factors for NMVOC and CO (up to 2012) from acetic acid production in Switzerland are based on measurement data from industry and expert estimates documented in EMIS 2024/2B10 Essigsäure-Produktion. From 2013 onwards, the only relevant pollutant from acetic acid production is NMVOC. Since 2013 the emission factor is confidential but available to reviewers on request.

During normal operation the process emissions in the plant, which stopped its production in the end of 2012, had been treated in a flue gas incineration. Thus, the reported emissions of NMVOC and CO only occurred in case of malfunction resulting in strongly fluctuating plant-specific emission factors. In addition, the resulting implied emission factors based on the emissions of both plants were modulated by considerable production fluctuations of one of the plants from 2000 onwards.

Table 4-14 Emission factors of 2B10a Chemical industry: Other in 2022.

2B10a Chemical industry: Other	Unit	NO_x	NMVOC	SO_X	CO
Acetic acid production	g/t acid	NA	C	NA	NA
Ethylene production	g/t ethylene	NA	C	NA	NA
Niacin production	g/t niacin	C	NA	NA	C
Sulfuric acid production	g/t acid	NA	NA	C	NA

Activity data

The annual amount of produced acetic acid is based on data from industry and from the Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries) documented in EMIS 2023/2B10 Essigsäure-Produktion. The data for acetic acid production are confidential since 2013 (only one manufacturer remaining) but available for reviewers on request.

Table 4-15 Activity data of 2B10a Chemical industry: Other.

2B10a Chemical industry: Other	Unit	1990	1995	2000	2005	2010	2015	2019–2022
Ammonium nitrate production	kt	C	C	C	C	C	C	NO
Chlorine gas production	kt	C	C	C	C	C	C	C
Acetic acid production	kt	30	27	24	8.4	20	C	C
Ethylene production	kt	C	C	C	C	C	C	C
Sulfuric acid production	kt	C	C	C	C	C	C	C
Niacin production	kt	C	C	C	C	C	C	C
PVC production	kt	43	43	NO	NO	NO	NO	NO

Ammonium nitrate production (2B10a)

In Switzerland there was only one plant producing ammonium nitrate; it stopped production in 2018. In the production process emissions of NH_3 and particulate matter occurred.

Emission factors

The emission factors for NH_3 and for particulate matter from ammonium nitrate production in Switzerland are plant-specific and based on measurement data from industry and expert estimates, which are available for 2009, 2012, 2013 and 2016 as documented in EMIS 2024/2B10 Ammoniumnitrat Produktion. From 1990-2013 average emission factors are applied based on the measurements from 2009, 2012 and 2013. The emission factors are confidential but available to reviewers on request.

Activity data

The annual amount of ammonium nitrate (pure NH_4NO_3) produced was based on data from industry for 1990 and from 1997 to 2018 as documented in EMIS 2024/2B10 Ammoniumnitrat Produktion. The activity data for ammonium nitrate production are confidential but available to reviewers on request.

Chlorine gas production (2B10a)

In Switzerland there is only one plant producing chlorine gas. Chlorine gas was produced by chlorinealkaline electrolysis in a mercury-cell process until 2016. In the course of 2016, the production was switched to mercury-free membrane process technology. Thus, from 2017 onwards, there are no more Hg emissions.

Emission factors

The emission factor for Hg from chlorine gas production by chlorinealkaline electrolysis in a mercury-cell process between 1990 and 2016 in Switzerland is plant-specific and based on measurement data from industry and expert estimates documented in EMIS 2024/2B10 Chlorgas-Produktion. The emission factor is confidential but available to reviewers on request.

Activity data

The annual amount of chlorine gas produced is based on data from industry and data from the Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries) as documented in EMIS 2024/2B10 Chlorgas-Produktion. The activity data for chlorine gas production are confidential but available to reviewers on request.

Ethylene production (2B10a)

As described above in source category 2B1 Ammonia production, ethylene is produced within an integrated production chain and results as primary product of the first step, i.e. the cracking process. Since the NMVOC emissions of the cracking process cannot be split and allocated separately to the various chemical products, they are assigned completely to the production of ethylene and are reported here under source category 2B10a.

Emission factors

The emission factor for NMVOC from ethylene production in Switzerland is plant-specific and based on measurement data from industry documented in EMIS 2024/2B10 ethylene production. The emission factor is confidential but available to reviewers on request.

Activity data

The annual amount of ethylene produced is based on data from the industry as documented in EMIS 2024/2B10 ethylene production. They refer to annual monitoring reports from the Swiss Emissions Trading Scheme (ETS). The activity data for ethylene production are confidential but available to reviewers on request.

Niacin production (2B10a)

In Switzerland, there is one plant producing niacin that emits NO_x and CO. In the production process of niacin, 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 (incl. 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.

Emission factors

The emission factors for NO_x and CO from niacin production in Switzerland are plant-specific. They are based on measurement data from industry in 2017, 2018 and 2021 as documented in EMIS 2024/2B10 Niacin Produktion. The emission factors are confidential but available to reviewers on request.

Activity data

Activity data of annual niacin production were provided by the Swiss production plant for the entire time period as documented in EMIS 2024/2B10 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.

Sulphuric acid production (2B10a)

Sulphuric acid (H_2SO_4) is produced by one plant only in Switzerland. From this production process SO_x is emitted.

Emission factors

The emission factor for SO_x from sulphuric acid production in Switzerland is plant-specific. Since 2009, the emission factor is based on annual measurement data from industry documented in EMIS 2024/2B10 Schwefelsäure-Produktion. Between 1990 and 2008 the mean value is applied. The SO_x emission factor is confidential but available to reviewers on request.

Activity data

The annual amount of sulphuric acid produced is based on data from industry and data from Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries) as documented in EMIS 2024/2B10 Schwefelsäure-Produktion. The activity data for sulphuric acid production are confidential but available to reviewers on request.

PVC (2B10a)

Until 1996 PVC was produced in Switzerland. From this production process NMVOC emissions were released.

Emission factors

For PVC production the NMVOC emission factor is based on industry information and expert estimates as documented in the EMIS database (EMIS 2024/2B10 PVC-Produktion).

Activity data

The annual amount of PVC produced is based on data from industry and expert estimates documented in EMIS 2024/2B10 PVC-Produktion (see Table 4-15).

4.3.3 Category-specific recalculations in 2B Chemical industry

There were no recalculations in submission 2024.

4.4 Source category 2C – Metal production

4.4.1 Source category description of 2C Metal production

Table 4-16 Specification of source category 2C Metal production in Switzerland.

2C	Source category	Specification
2C1	Iron and steel production	Secondary steel production, iron foundries
2C3	Aluminium production	Production of aluminium (ceased in 2006)
2C7a	Copper production	Non-ferrous metal foundries
2C7c	Other metal production	Battery recycling, galvanizing plants

Table 4-17 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 2C Metal Production.

NFR code	Source category	Pollutant	Identification criteria
2C1	Iron and steel production	SOx	L2
2C1	Iron and steel production	PM2.5	T1, T2
2C1	Iron and steel production	PM10	T1, T2

4.4.2 Methodological issues of 2C Metal production

4.4.2.1 Iron and steel production (2C1)

Methodology (2C1)

In Switzerland only secondary steel production from recycled steel scrap occurs. After closing of two steel plants in 1994 another two plants remain. Both plants use electric arc furnaces (EAF) with carbon electrodes for melting the steel scrap. The PCB emissions are modelled within the disposal category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2. The PCB emission value of the air pollution control measurements in 2014 were included in the model.

Iron is processed in foundries only. There is no production of pig iron. Today, 14 iron foundries exist in Switzerland. About 75 % of the iron is processed in induction furnaces and 25 % in cupola furnaces.

Based on the decision tree Fig. 3.1 in chapter 2C1 in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions from 2C1 Iron and steel production are calculated by a Tier 2 method using country-specific emission factors (EMIS 2024/2C1).

Emission factors (2C1)

Emission factors for the pollutants emitted from steel production are based on air pollution control measurements of the steel plants. Emission factors of NO_x, NMVOC, SO_x, PM2.5/PM10/TSP, CO, Pb, Cd, PCDD/PCDF and PAH are 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 PCB emission factor comes from the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2. There was a significant decrease in the PM2.5/PM10/TSP, Pb, Cd and Hg emission factors due to the installation of new filters in 1998/1999 at the two remaining production sites.

The emission factors from iron production in foundries are provided by the Swiss foundry association (GVS) and are assumed to be constant for the entire time period. NMVOC is mainly emitted in the finishing process of the cast iron. The NH_3 emission factor is taken from the Handbook on emission factors for stationary sources (SAEFL 2000).

The emission factor of BC (% PM2.5) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.C.1, table 3.1).

Table 4-18 Emission factors 2C1 Iron and steel production in 2022. Unit of PCDD/PCDF is in I-TEQ.

2C1 Iron and steel production	Unit	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO
Iron production,													
electric melting furnace	g/t iron	NA	33	NA	NA	7	NA	10	NA	13	NA	0.025	93
other processes	g/t iron	10	4'000	NA	70	NA	50	NA	130	NA	150	NA	4'000
Steel production,													
electric arc furnace	g/t steel	140	70	14	NA	6	NA	8	NA	9	NA	0.022	700
rolling mill	g/t steel	NA	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

2C1 Iron and steel production	Unit	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	PCB
Iron production,										
electric melting furnace	mg/t iron	320	1.3	NA	0.00013	NA	NA	NA	NA	NA
other processes	mg/t iron	NA	NA	NA	0.0013	NA	NA	NA	NA	NA
Steel production,										
electric arc furnace	mg/t steel	200	4	40	0.00011	0.8	3.4	0.9	2.2	1.3
rolling mill	mg/t steel	NA	NA	NA	NA	NA	NA	NA	NA	NA

Activity data (2C1)

For the steel production, annual activity data is provided by the Swiss steel producers (1990 – 1994 four plants, since 1995 two plants). Since 2009, activity data refer to monitoring reports of the Swiss ETS.

Annual activity data on iron production is provided by the Swiss foundry association for the entire time period.

The steel production decreased between 1994 and 1995 significantly due to the closing of two steel production sites in Switzerland. In 2009, there was a remarkable reduction in activity data within the metal industry due to the effects of the financial crisis.

Table 4-19 Activity data for 2C1 Iron and steel production.

2C1 Iron and steel production	Unit	1990	1995	2000	2005	2010
Iron production,						
electric melting furnace	kt	80	70	65	35	40
other processes	kt	170	130	120	67	53
Steel production,						
electric arc furnace	kt	1'108	716	1'022	1'159	1'218
other processes	kt	1'108	716	NO	NO	NO
rolling mill	kt	1'108	716	1'022	1'082	1'082

2C1 Iron and steel production	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Iron production,											
electric melting furnace	kt	34	33	28	26	27	26	18	15	16	17
other processes	kt	45	43	37	34	35	34	24	20	22	23
Steel production,											
electric arc furnace	kt	1'231	1'315	1'296	1'238	1'270	1'291	1'130	1'125	1'294	1'208
other processes	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
rolling mill	kt	1'126	1'176	1'144	1'085	1'138	1'160	1'037	1'031	1'104	1'121

4.4.2.2 Aluminium production (2C3)

Methodology (2C3)

Today, there is no more primary aluminium production as the last production site closed in April 2006. Based on the decision tree Fig. 3.1 in chapter 2C3 in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from source category 2C3 are calculated by a Tier 2 method using country-specific emission factors (EMIS 2024/2C3).

Emission factors (2C3)

The emission factors are based on air pollution control measurements and data from the aluminium industry association (Aluminium – Verband Schweiz), literature and expert estimates documented in the EMIS database. Since production stopped in 2006, there are no emission factors to be reported for 2022.

Activity data (2C3)

From 1995 to 2006 data on aluminium production is based on data published regularly by the Swiss Aluminium Association (www.alu.ch). For earlier years, the data was provided directly by the aluminium industry. In April 2006, the last site of primary aluminium production (electrolysis) in Switzerland closed down.

Table 4-20 Activity data for the 2C3 Aluminium production.

2C3 Aluminium production	Unit	1990	1995	2000	2005	2006	2007–2022
	kt	87	21	36	45	12	NO

4.4.2.3 Copper production (2C7a)

Methodology (2C7a)

Source category 2C7a Copper production comprises one large and several small non-ferrous metal foundries, which are organized within the Swiss foundry association (GVS). In Switzerland, only casting and no primary production of non-ferrous metals occur.

Based on the decision tree Fig. 3.1 in chapter 2C7a in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from source category 2C7a are calculated by a Tier 2 method (EMIS 2024/2C7a) using country-specific emission factors.

Emission factors (2C7a)

The emission factors from non-ferrous metal foundries are based on expert estimates and data from the industry as documented in the EMIS database. They are assumed to be constant over the entire time period.

Table 4-21 Emission factors for 2C7a Foundries of non-ferrous metals in 2022. Unit of PCDD/PCDF is in I-TEQ.

2C7a Copper production	Unit	NMVOC	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO	Pb	Cd	PCDD/ PCDF
Foundries of non-ferrous metals	g/t metal	50	95	100	100	0.095	240	0.30	0.05	0.00003

Activity data (2C7a)

Activity data on annual non-ferrous metal production is based on data from industry (1990 and monitoring reports of the Swiss ETS from 2006 onwards) and the Swiss foundry association (GVS, since 1996) as documented in the EMIS database.

Table 4-22 Activity data for 2C7a Foundries of non-ferrous metals.

2C7a Copper production	Unit	1990	1995	2000	2005	2010
Foundries of non-ferrous metals	kt	60	56	53	33	20

2C7a Copper production	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Foundries of non-ferrous metals	kt	6.4	9.5	8.9	9.0	8.0	6.8	6.4	5.1	7.5	7.9

4.4.2.4 Other metal production (2C7c)

Methodology (2C7c)

Source category 2C7c Other metal production comprises emissions from battery recycling and galvanizing plants. In Switzerland, there is one plant recycling batteries by applying the Sumitomo-process which started operation in 1992 and about a dozen of galvanizing plants. Based on chapter 2C7c in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from source category 2C7c are calculated by a Tier 2 approach (EMIS 2024/2C7c) using country-specific emission factors.

Emission factors (2C7c)

The emission factors for battery recycling between 1992 and 2003 are based on measurements in 2000 (TSP, Hg) and 2003 (NO_x, SO_x, CO, Pb, Cd, PCDD/PCDF) as well as mass balances of the single recycling site. Emission factors are assumed constant between 1990 and 2002.

Since 2003 emission factors of NO_x, SO_x, TSP, CO, Pb, Cd, Hg and PCDD/PCDF are assumed constant based on air pollution control measurements from 2003 and 2012.

Emission factors of NMVOC and NH_3 are also based on air pollution control measurements from 2003 and 2012. Emission factors are assumed constant for the entire time period.

All emission factors of battery recycling are confidential. These data are available to reviewers on request.

The emission factors of galvanizing plants are based on data from the Swiss galvanizing association and expert estimates documented in the EMIS database. They are assumed to be constant over the entire time period.

Table 4-23 Emission factors for 2C7c Other metal production: Battery recycling and Galvanizing in 2022. Unit of PCDD/PCDF is in I-TEQ.

2C7c Other metal production	Unit	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO
Galvanazing plants	g/t metal	NA	NA	NA	90	NA	15	NA	30	NA	37	NA	NA
Battery recycling	g/t battery	C	C	C	C	C	NA	C	NA	C	NA	NE	C

2C7c Other metal production	Unit	Pb	Cd	Hg	PCDD/ PCDF
Galvanazing plants	g/t metal	NA	2.5	NA	0.0007
Battery recycling	g/t battery	C	C	C	C

Activity data (2C7c)

Annual activity data on the amount of metal processed is based on data from the only battery recycling site in Switzerland which started operation in 1992 and from the Swiss galvanizing association, as documented in the EMIS database (EMIS 2024/2C7c_Batterie-Recycling, EMIS 2024/2C7c_Verzinkereien).

Activity data of battery recycling are confidential. These data are available to reviewers on request.

Table 4-24 Activity data for 2C7c Other metal production: Battery recycling and Galvanizing.

2C7c Other metal production	Unit	1990	1995	2000	2005	2010
Galvanazing plants	kt	102	84	99	88	93
Battery recycling	kt	NO	C	C	C	C

2C7c Other metal production	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Galvanazing plants	kt	92	92	92	91	91	91	91	91	91	91
Battery recycling	kt	C	C	C	C	C	C	C	C	C	C

4.4.3 Category-specific recalculations in 2C Metal production

There were no recalculations in submission 2024.

4.5 Source category 2D3 – Other solvent use

4.5.1 Source category description of 2D3 Other solvent use

Source category 2D3 comprises mainly NMVOC emissions from about 40 different solvent applications. From 2D3c Asphalt roofing and 2D3i Fat, edible and non-edible oil extraction (ceased in 2000) also particulate matter and CO and particulate matter, respectively, are emitted.

Table 4-25 Specification of source category 2D Other solvent use in Switzerland.

2D	Source category	Specification
2D3a	Domestic solvent use including fungicides	Domestic use of cleaning agents, solvents, cosmetics and toiletries; use of pharmaceutical products in households
2D3b	Road paving with asphalt	Road paving
2D3c	Asphalt roofing	Asphalt roofing
2D3d	Coating applications	Paint application in households, industry, construction and car repairing and on wood
2D3e	Degreasing	Metal degreasing and cleaning; cleaning of electronic components; other industrial cleaning
2D3f	Dry cleaning	Dry cleaning
2D3g	Chemical products	Handling and storage of solvents; production of fine chemicals, pharmaceuticals; manufacturing of paint, inks, glues, adhesive tape (ceased in 1994); processing of rubber, PVC, polystyrene foam, polyurethane and polyester; tanning of leather (ceased in 2015)
2D3h	Printing	Package printing, other printing industry
2D3i	Other solvent use	Removal of paint and lacquer; vehicles dewaxing (ceased in 2001); production of perfume/aroma and cosmetics, paper and paper board, tobacco products, textile products; scientific laboratories; not attributable solvent emissions; extraction of oil and fats (ceased in 2000)

Table 4-26 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 2D Other Solvent Use.

NFR code	Source category	Pollutant	Identification criteria
2D3a	Domestic solvent use including fungicides	NMVOC	L1, L2, T1, T2
2D3b	Road paving with asphalt	NMVOC	L1, L2, T1, T2
2D3d	Coating applications	NMVOC	L1, L2, T1
2D3e	Degreasing	NMVOC	T1, T2
2D3g	Chemical products	NMVOC	L1, L2, T1, T2
2D3h	Printing	NMVOC	L1, L2, T1
2D3i	Other solvent use	NMVOC	L1, L2, T2

4.5.2 Methodological issues of 2D Other solvent use

4.5.2.1 Domestic solvent use including fungicides (2D3a)

Methodology (2D3a)

The source category 2D3a Domestic solvent use including fungicides comprises mainly the use of cleaning agents and solvents in private households for building and furniture cleaning and cosmetics and toiletries but also the use of pharmaceuticals. These products contain solvents, which evaporate during use or after the application. Up to submission 2022, propellant emissions from the use of spray cans in the household sector were reported as a separate source category. An in-depth discussion with a long-standing expert from the largest contract manufacturer in Switzerland revealed that the aerosol in many spray applications has the function of both propellant and solvent, and a clear distinction is usually not even possible or meaningful. Therefore, the source category 2D3a Domestic use of aerosol cans was removed and its NMVOC emissions were integrated into the respective application sources, also into the two source categories 2D3a Use of cleaning agents and 2D3a Domestic use of pharmaceuticals. Among the numerous NMVOC emission sources, the use of household cleaning agents, cosmetics and toiletries is the largest single source in source category 2D3.

Based on the decision tree Fig. 3.1 in chapter 2D3a in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions are calculated by a Tier 2 method (EMIS 2024/2D3a) using country-specific emission factors. All emissions related to domestic solvent use are calculated proportional to the Swiss population.

Emission factors (2D3a)

Household cleaning agents

The source category 2D3a Use of cleaning agents comprises the use of cosmetics, toiletries, cleaning agents and care products including spray cans (aerosol). Its resulting emission factor bases thus on a multitude of products, their consumption figures, NMVOC contents and emission fractions. Currently, about 85 % of the NMVOC emissions stem from the use of cosmetics and toiletries whereas the rest arises from the use of cleaning agents and care products. The most important product classes are hair styling and deodorants with emission shares of about 30 % and just under 20 %, respectively, followed by air refresheners, perfumes and eaux de toilette, nail care and waterproofing sprays with shares between 10 % and 5 %.

Available data sources consist of surveys of the use of household cleaning agents, cosmetics and toiletries in Switzerland (1990) and in Germany (1996 and 2000).

For the current values, a comprehensive study was conducted based on detailed sales figures of the years 2017-2020, NMVOC contents and application-specific emission factors. The sales figures mainly come from a market research institute covering a large part of the Swiss retail trade, while information on product class-specific NMVOC contents were provided by a large retailer, production companies and a contract manufacturer and are based on the European aerosol statistics as well.

Domestic use of pharmaceutical products

Emission factors of domestic use of pharmaceutical products are available from surveys in Switzerland (1990) and Germany (1998) and from the Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries) for 2011, as documented in the EMIS database. For years with no survey data, emission factors are interpolated.

Table 4-27 Emission factors of 2D3a Domestic solvent use including fungicides in 2022.

2D3a Domestic solvent use	Unit	NMVOC
Household cleaning agents	g/inhabitant	700
Domestic use of pharmaceutical products	g/inhabitant	32

Activity data (2D3a)

As described in the methodology chapter, the activity data used for calculating the NMVOC emissions in 2D3a Domestic solvent use corresponds to the Swiss population (FSO 2023c).

Table 4-28 Activity data of 2D3a Domestic solvent use including fungicides.

2D3a Domestic solvent use	Unit	1990	1995	2000	2005	2010
	inhabitants	6'712'000	7'041'000	7'184'000	7'437'000	7'825'000

2D3a Domestic solvent use	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	inhabitants	8'089'000	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

4.5.2.2 Road paving with asphalt (2D3b)

Methodology (2D3b)

Based on the decision tree Fig. 3.1 in chapter 2D3b in the EMEP/EEA guidebook (EMEP/EEA 2019), 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 2024/2D3b. Other pollutants are not considered.

Emission factors (2D3b)

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. Emissions of particulate matter are not estimated so far.

Table 4-29 Emission factors of 2D3b Road paving with asphalt in 2022.

2D3b Road paving with asphalt	Unit	NMVOC	PM2.5 ex	PM10 ex	TSP ex	BC ex
Asphalt concrete	kg/t	0.54	NE	NE	NE	NE

Activity data (2D3b)

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 in between.

Table 4-30 Activity data of 2D3b Road paving with asphalt.

2D3b Road paving with asphalt	Unit	1990	1995	2000	2005	2010
Asphalt concrete	kt	5'500	4'800	5'170	4'780	5'250

2D3b Road paving with asphalt	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Asphalt concrete	kt	4'770	5'260	4'850	4'710	5'260	5'180	5'210	4'910	4'960	4'970

4.5.2.3 Asphalt roofing (2D3c)

Methodology (2D3c)

In Switzerland there are three main producers of asphalt roofing material. Based on the decision tree Fig. 3.1 in chapter 2D3c in in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of NMVOC from Asphalt roofing are determined by a Tier 2 method based on country-specific emission factors as documented in EMIS 2024/2D3c. Emissions of PM2.5, PM10, TSP, BC and CO from the manufacture of asphalt sheeting are determined based on a Tier 1 method using default emission factors (EMEP/EEA 2019). In the past, four processes related to asphalt roofing were differentiated, i.e. production of sheeting, production of prime coat, laying of sheeting and use of prime coat. For submission 2018, these processes were aggregated and revised resulting in an implied emission factor for the entire asphalt roofing process.

Emission factors (2D3c)

The NMVOC emission factors from Asphalt roofing are based on information from the industry association, literature and expert estimates as documented in the EMIS database. Tier 1 emission factors of PM2.5, PM10, TSP, BC (% PM2.5) and CO from the manufacture of asphalt sheeting are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.D.3.c, table 3.1).

Table 4-31 Emission factors of 2D3c Asphalt roofing in 2022.

2D3c Asphalt roofing	Unit	NMVOC	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
Asphalt roofing	kg/t sheeting	4.8	0.049	0.25	1.0	0.000005	0.0059

Activity data (2D3c)

Activity data is based on data from industry and expert estimates as documented in the EMIS database. From 2012 onwards, they are extrapolated on the basis of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020).

Table 4-32 Activity data of 2D3c Asphalt roofing.

2D3c Asphalt roofing	Unit	1990	1995	2000	2005	2010
Asphalt roofing	kt sheeting	54	56	58	51	68

2D3c Asphalt roofing	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Asphalt roofing	kt sheeting	75	75	75	76	76	76	77	77	77	77

4.5.2.4 Coating applications (2D3d)

Methodology (2D3d)

This source category comprises emissions from paint application in construction, households, industry, wood and car repair. Industrial application also includes commercial applications such as corrosion protection and road marking. A comprehensive assessment of all coating applications and paint production was carried out in 2018-2020. Based on the decision tree Fig. 3.1 in chapter 2D3d in the EMEP/EEA guidebook (EMEP/EEA 2019), for 2D3d Coating applications a bottom-up Tier 2 method based on the consumption of paints, lacquers, glazes, thinners and related materials and their solvent content. Country-specific emission factors are used. In 2022, the most important emission sources are 2D3d Paint application, wood and 2D3d Paint application in construction and to a lesser extent 2D3d Paint application, industrial.

Emission factors (2D3d)

Emission factors for NMVOC are derived from the solvent contents of the paints and thinners based on data from the Swiss association for coating and paint applications (VSLF), the biggest industrial users (incl. surveys of VOC balances), paint producers, and all major Swiss DIY (do it yourself) companies as documented in the EMIS database (EMIS 2024/2D3d). The emission factors for all commercial and industrial coating applications declined significantly between 1990 and 2004 as a result of both a reduction of the solvent content and replacing of solvent-based paint by water-based paint due to increasingly strict NMVOC regulations by the EU directive (EC 2004). In addition, powder coatings, which are far more efficient, replaced in this time period the conventional paint (rough estimate: 1 t of powder coating replaces 3 t of conventional paint). Since 2004, the mean solvent content of paint applied in construction and on wood has remained about constant with some fluctuations whereas a decrease has been observed for paints in industrial applications. For paint application in car repair, even a slight increase in solvent content has been observed in the last few years. Source category 2D3d Paint application, households is based on a comprehensive study including all major Swiss DIY companies and also covers the paint spray aerosols.

Table 4-33 Emission factors of 2D3d Coating applications in 2022.

2D3d Coating applications	Unit	NMVOC
Paint application, construction	kg/t paint	61
Paint application, households	kg/t paint	85
Paint application, industrial	kg/t paint	180
Paint application, wood	kg/t paint	314
Paint application, car repair	kg/t paint	550

Activity data (2D3d)

The activity data correspond to the annual consumption of paints which are estimated according to data and information from VSLF, the biggest industrial users (incl. VOC balances), Swiss paint producers, foreign trade statistics and all major Swiss DIY companies for paint applications in households (EMIS 2024/2D3d). Between 1990 and 1998, the total consumption of paint decreased considerably, increased continuously from 2004 onwards and dropped again after 2013. This trend results from the opposing trends in the different source categories:

- 2D3d Paint application, construction: The paint consumption in construction shows a substantial reduction compared to 1990 levels. The increasing tendency in paint application between 2001 and 2010, the drop thereafter and the slight increase from 2020 onwards can be explained to a certain extent by the development of construction activity in Switzerland. Before 2001, there was a decline in construction activity, which explains the decreasing tendency in paint application.
- 2D3d Paint application, wood: The paint consumption for applications on wood increased moderately between 1990 and 1998. But from 2001 onwards it shows a comparable development as the paint application in construction.
- 2D3d Paint application, industrial Between 1990 and 2016, the activity of industrial paint application decreased significantly. There was a clear decrease between 2001 and 2004 due to structural changes in the industrial sectors and a widespread application of powder coatings from 2004 onwards. Since 2007, the activity data show a moderate decrease.

Table 4-34 Activity data of 2D3d Coating application.

2D3d Coating applications	Unit	1990	1995	2000	2005	2010
Paint application, construction	kt	60	43	33	42	54
Paint application, households	kt	12	13	13	12	11
Paint application, industrial	kt	20	21	21	8.8	8.3
Paint application, wood	kt	8.7	8.7	8.5	9.2	13
Paint application, car repair	kt	2.7	2.2	2.0	1.9	1.7

2D3d Coating applications	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Paint application, construction	kt	50	49	49	47	46	46	45	45	46	46
Paint application, households	kt	11	10	10	10	10	10	10	10	10	10
Paint application, industrial	kt	7.9	7.8	7.6	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Paint application, wood	kt	13	11	10	9.5	9.3	9.2	9.0	9.0	9.0	9.0
Paint application, car repair	kt	1.2	1.1	0.97	0.85	0.85	0.85	0.85	0.85	0.85	0.85

4.5.2.5 Degreasing (2D3e)

Methodology (2D3e)

Source category 2D3e comprises emissions from degreasing of electronic components, metal and other industrial cleaning. It covers also the emissions from the use of spray cans in the field of industry, technical products and automotive applications without coating. Based on the decision tree Fig. 3.1 in chapter 2D3e in the EMEP/EEA guidebook (EMEP/EEA 2019), the NMVOC emissions from 2D3e Degreasing are calculated by a Tier 2 method (EMIS 2024/2D3e) using country-specific emission factors.

Emission factors (2D3e)

Emission factors for NMVOC are estimated based on data from industry surveys by swissmem (including VOC balance evaluations in 2004, 2007, 2012 and 2018) and expert estimates as documented in the EMIS database. For the use of spray cans the values are based on an (unpublished) propellant gas statistics, data from the Swiss aerosol association and statistics data of the European aerosol federation (FEA) for the years 1990, 1998 and 2019/2020, respectively.

Table 4-35 Emission factors of 2D3e Degreasing in 2022.

2D3e Degreasing	Unit	NMVOC
Cleaning of electronic components	kg/t solvent	478
Degreasing of metal	kg/t solvent	541
Other industrial cleaning	kg/t solvent	543

Activity data (2D3e)

Activity data correspond to the annual consumption of solvents for degreasing and cleaning. They are based on survey data from the association of Swiss mechanical and electric engineering industries (swissmem) in 2004, 2007, 2012 and 2018, VOC balances of the most important companies, import statistics and expert estimates, documented in the EMIS database (EMIS 2024/2D3e). For the use of spray cans the data are based on an (unpublished) propellant gas statistics, data of the Swiss aerosol association and statistics data of the European aerosol federation (FEA) for the years 1990, 1998 and 2019/2020, respectively.

In 1990 metal degreasing showed by far the highest activity data, i.e. consumption of solvents and NMVOC emissions but with a subsequent sharp decline until around 2004. Since then, other industrial cleaning and metal degreasing are of similar importance.

Table 4-36 Activity data of 2D3e Degreasing (solvent consumption).

2D3e Degreasing	Unit	1990	1995	2000	2005	2010
Cleaning of electronic components	kt	1.7	1.5	1.3	1.1	0.84
Degreasing of metal	kt	13	9.1	6.2	2.7	2.3
Other industrial cleaning	kt	2.9	2.5	2.0	1.8	1.4

2D3e Degreasing	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cleaning of electronic components	kt	0.69	0.59	0.49	0.38	0.28	0.18	0.18	0.18	0.18	0.18
Degreasing of metal	kt	1.9	1.8	1.6	1.4	1.3	1.1	1.1	1.1	1.1	1.1
Other industrial cleaning	kt	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6

4.5.2.6 Dry cleaning (2D3f)

Methodology (2D3f)

Based on the decision tree Fig. 3.1 in chapter 2D3f in the EMEP/EEA guidebook (EMEP/EEA 2019), the NMVOC emissions from 2D3f Dry cleaning are calculated by a Tier 2 method (EMIS 2024/2D3f) using country-specific emission factors.

Emission factors (2D3f)

Emission factors for NMVOC are estimated based on information from the emission control authority and analysis of about 170 VKTS inspection protocols from the four biggest Swiss cantons (AG, BE, VD and ZH) of 2017 as documented in the EMIS database.

Table 4-37 Emission factors of 2D3f Dry cleaning in 2022.

2D3f Dry cleaning	Unit	NMVOC
	kg/t solvent	900

Activity data (2D3f)

For dry cleaning, activity data is the amount of tetrachloroethylene (PER) and non-halogenated solvents used. The activity data from 2001 onwards has been calculated based on the (annual) number of dry-cleaning facilities in Switzerland according to VKTS and FSO (business census) and the mean solvent consumption per facility based on an analysis of about 170 VKTS inspection protocols from the four biggest Swiss cantons (AG, BE, VD and ZH) of 2017. Activity data for 1990 are based on net imports of PER. For the years in between, data are interpolated linearly.

Table 4-38 Activity data of 2D3f Dry cleaning.

2D3f Dry cleaning	Unit	1990	1995	2000	2005	2010
Solvent	kt	1.3	0.77	0.23	0.097	0.081

2D3f Dry cleaning	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Solvent	kt	0.072	0.072	0.071	0.071	0.070	0.070	0.069	0.069	0.068	0.068

4.5.2.7 Chemical products (2D3g)

Methodology (2D3g)

Based on the decision tree Fig. 3.1 in chapter 2D3g in the EMEP/EEA guidebook (EMEP/EEA 2019), for source category 2D3g Chemical products a Tier 2 method using country-specific emission factors is used for calculating the NMVOC emissions (EMIS 2024/2D3g).

Although asphalt roofing materials are produced in Switzerland, there is no bitumen blowing. According to information from both manufacturers, all bitumen (including very small amounts of oxidized bitumen) used for the production of polymer-bitumen sealing sheeting is imported. The emissions from the coating machines of the production of polymer-bitumen sheeting and the thinner production are reported in source category 2D3c Asphalt roofing.

Emission factors (2D3g)

Emission factors for NMVOC in the period 1990 to approximately 2010 were mainly provided by industry associations, i.e. for

- fine chemicals production, pharmaceutical production and handling and storing of solvents: Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries)
- paint and ink production: Swiss association for coating and paint applications (VSLF) and the Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV)
- polyurethane processing: Swiss plastics association
- polyester processing: Swiss polyester association
- tanning of leather (ceased production in 2015): Swiss leather tanning association.

For the period from around 2010 and the other processes in source category 2D3g, data are based on information from individual industrial companies (e.g. ink and paint production), surveys of VOC balances (e.g. ink production), emission control authorities (e.g. polystyrene processing) and expert estimates as documented in the EMIS database.

Table 4-39 Emission factors of 2D3g Chemical products in 2022.

2D3g Chemical products	Unit	NMVOC
Fine chemicals production	t/production index	3.4
Glue production	kg/t glue	0.51
Handling and storing of solvents	t/production index	1.5
Ink production	kg/t ink	5.0
Paint production	kg/t paint	3.0
Pharmaceutical production	kg/t pharmaceuticals	7.1
Polyester processing	kg/t polyester	70
Polystyrene processing	kg/t polystyrene	31
Polyurethane processing	kg/t polyurethane	3.0
PVC processing	kg/t PVC	4.0
Rubber processing	kg/tyres	0.14

Activity data (2D3g)

The activity data are mainly production or consumption data provided by the Swiss Federal Office of Statistics, Swiss foreign trade statistics and industry associations, i.e. for

- fine chemicals production and handling and storing of solvents: Swiss Federal Office of Statistics
- pharmaceutical production: Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries)
- paint and ink production: Swiss association for coating and paint applications (VSLF) and Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV)
- polyurethane processing: Swiss plastics association
- polyester processing: Swiss polyester association
- polystyrene processing: Swiss foreign trade statistics (annual net import figures)
- tanning of leather: Swiss leather tanning association.

In addition, and for the other processes in source category 2D3g, data are based on information from individual industrial companies and expert estimates as documented in the EMIS database. Activity data on handling and storage of solvents, production of fine chemicals and pharmaceuticals as well as production of inks, are extrapolated on the basis of the

Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) from 2012 and 2017, respectively, onwards. Since 1994 no production of adhesive tape is occurring in Switzerland anymore. The last Swiss tannery ceased production in 2015.

Table 4-40 Activity data of 2D3g Chemical products.

2D3g Chemical products	Unit	1990	1995	2000	2005	2010
Fine chemicals production	prod. index	70	100	163	224	314
Glue production	kt	19	39	58	72	82
Handling and storing of solvents	prod. index	70	100	163	224	314
Ink production	kt	20	29	36	55	65
Paint production	kt	88	78	72	77	78
Pharmaceutical production	kt	16	21	20	28	30
Polyester processing	kt	11	7.0	6.5	6.9	3.4
Polystyrene processing	kt	20	19	19	24	35
Polyurethane processing	kt	17	35	45	54	54
Production of adhesive tape	kt	1.5	NO	NO	NO	NO
PVC processing	kt	94	94	78	64	52
Rubber processing	tyres	120'000	119'375	103'667	67'000	77'500
Tanning of leather	employees	110	108	102	88	65

2D3g Chemical products	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Fine chemicals production	prod. index	295	293	291	289	286	284	282	280	278	276
Glue production	kt	91	94	97	99	102	105	106	107	108	109
Handling and storing of solvents	prod. index	295	293	291	289	286	284	282	280	278	276
Ink production	kt	60	52	43	35	36	36	37	37	38	39
Paint production	kt	69	66	63	60	60	60	60	60	60	60
Pharmaceutical production	kt	30	29	29	29	29	29	28	28	28	28
Polyester processing	kt	3.6	3.6	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.4
Polystyrene processing	kt	30	29	27	23	24	22	23	23	24	24
Polyurethane processing	kt	38	38	37	37	36	36	35	35	35	35
Production of adhesive tape	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PVC processing	kt	38	37	36	35	34	32	31	30	30	30
Rubber processing	tyres	81'000	82'000	83'000	84'000	85'000	86'000	87'000	88'000	88'533	89'067
Tanning of leather	employees	33	22	11	NO	NO	NO	NO	NO	NO	NO

4.5.2.8 Printing (2D3h)

Methodology (2D3h)

The source category 2D3h Printing is differentiated into package printing and other printing industry. Based on the decision tree Fig. 3.1 in chapter 2D3g in the EMEP/EEA guidebook (EMEP/EEA 2019), a Tier 2 method using country-specific emission factors is used for calculating the NMVOC emissions from the ink applications (EMIS 2024/2D3h).

Emission factors (2D3h)

Emission factors for NMVOC are based on data from industry associations (Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV), Swiss organisation for the print and media industry (viscom)), surveys on the VOC balances, emission control authorities, German studies on NMVOC emissions from solvent use (Theloke 2005) and expert estimates, as documented in the EMIS database.

Table 4-41 Emission factors of 2D3h Printing in 2022.

2D3h Printing	Unit	NMVOC
Package printing	kg/t ink	280
Other printing	kg/t ink	130

Activity data (2D3h)

The activity data correspond to the consumption of printing ink. These data stem from industry associations (SOLV, viscom), surveys on the VOC balances, Swiss Federal Office of Statistics, emission control authorities and expert estimates, documented in the EMIS database. Activity data are extrapolated on the basis of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) from 2017 onwards.

Table 4-42 Activity data of 2D3h Printing (ink consumption).

2D3h Printing	Unit	1990	1995	2000	2005	2010
Package printing	kt	5.9	5.9	5.5	9.1	13
Other printing	kt	13	13	14	12	8.3

2D3h Printing	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Package printing	kt	13	13	13	13	13	13	13	13	12	12
Other printing	kt	8.0	7.8	7.7	7.5	7.5	7.4	7.4	7.3	7.3	7.3

4.5.2.9 Other solvent use (2D3i)

Methodology (2D3i)

Source category 2D3i Other solvent use consists of a number of solvent uses in various production processes and services. Based on the decision tree Fig. 3.1 in chapter 2D3i in the EMEP/EEA guidebook (EMEP/EEA 2019), a Tier 2 method using country-specific emission factors is applied for calculating the NMVOC emissions from the different solvent applications in source category 2D3i Other solvent use (EMIS 2024/2D3i). For the source category 2D3i Not-attributable solvent emissions, so-called direct emission data is available only.

Emission factors (2D3i)

Emission factors for NMVOC are based on data from industry and services, industry associations, retail trade, German studies on NMVOC emissions from solvent use (Theloke et al. 2000 and Theloke 2005), VOC balances and expert estimates, as documented in the EMIS database.

Table 4-43 Emission factors of 2D3i Other solvent use in 2022.

2D3i Other solvent use	Unit	NMVOC
Production of cosmetics	kg/employee	62
Production of paper and paperboard	g/t	13
Production of flavours and	kg/employee	30
Production of textiles	kg/t solvent	178
Production of tobacoo	kg/employee	12
Removal of paint and lacquer	kg/t removal agent	350
Scientific laboratories	kg/employee	15

Activity data (2D3i)

For some production processes and services – such as production of perfume and flavour and scientific laboratories – the activity data correspond to the number of employees in the respective industrial sectors (FSO 2023d). The quantity of NMVOC emission per employee originates from the bottom-up approach in these industrial sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are referred to the number of employees in order to calculate the Swiss total.

For production of paper and paperboard and fat, edible and non-edible oil extraction, the activity data are based on production volumes. Annual production volumes of paper and paperboard are provided by the Swiss association of pulp, paper and paperboard industry

(ZPK) and the Swiss association of paper, cardboard and foil manufacturers (SPKF) for the years 1997 – 2011 and from 2016 onwards, respectively. For the production of textiles, the activity data is the solvent consumption based on VOC balances and industry data. For the removal of paint and lacquer, the activity data correspond to the amount of removal agent based on information from producers and retail trade.

Table 4-44 Activity data of 2D3i Other solvent use.

2D3i Other solvent use	Unit	1990	1995	2000	2005	2010
Fat, edible and non-edible oil extraction	kt	40	38	12	NO	NO
Production of cosmetics	employees	2'200	2'200	2'267	2'100	2'100
Production of paper and paperboard	kt	1'510	1'560	1'780	1'750	1'540
Production of flavours and fragrances	employees	2'200	2'325	2'567	3'200	3'475
Production of textiles	t solvent	600	498	396	294	192
Production of tobacoo	employees	3'300	2'988	2'733	2'700	3'200
Removal of paint and lacquer	t	700	600	502	405	307
Scientific laboratories	employees	10'194	18'604	23'217	23'000	23'000
Vehicles dewaxing	employees	200'000	166'250	72'667	NO	NO

2D3i Other solvent use	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Fat, edible and non-edible oil extraction	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Production of cosmetics	employees	2'100	2'100	2'100	2'100	2'100	2'100	2'100	2'100	2'100	2'100
Production of paper and paperboard	kt	1'386	1'390	1'393	1'396	1'362	1'056	1'034	967	1'024	1'061
Production of flavours and fragrances	employees	3'360	3'290	3'220	3'150	3'080	3'010	2'940	2'870	2'800	2'800
Production of textiles	t solvent	206	210	215	219	224	223	221	220	219	217
Production of tobacoo	employees	3'200	3'200	3'200	3'200	3'200	3'200	3'200	3'200	3'200	3'200
Removal of paint and lacquer	t	249	229	210	190	190	190	190	190	190	190
Scientific laboratories	employees	23'167	23'250	23'333	23'417	23'500	23'583	23'667	23'750	23'833	23'917
Vehicles dewaxing	employees	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

4.5.3 Category-specific recalculations in 2D Other solvent use

The following recalculations were implemented in submission 2024:

- 2D3g: The NMVOC emission factor and activity data of source category 2D3g Glue production were revised for the years 1999-2017 and 1991-2017, respectively.
- 2D3g: The NMVOC emission factor and the activity data of source category 2D3g Polyester processing were updated for 2019. The emission factors for the years 2001 to 2012 were also revised, which resulted in recalculated emission factor values and activity data for 1999-2021 and 2013-2021, respectively.

4.6 Source category 2G – Other product use

4.6.1 Source category description of 2G Other product use

Source category 2G Other product use includes about 20 sources releasing NMVOC. In addition, there are also emissions of NO_x, SO_x, NH_3, particulate matter, BC, CO, Pb, Cd, Hg, PCDD/PCDF and PAH from use of fireworks and tobacco as well as from renovation of corrosion inhibiting coatings.

Table 4-45 Specification of source category 2G Other product use in Switzerland.

2G	Source category	Specification
2G	Other product use	Use of spray cans in industry (commercial insecticide application only), antifreeze agents in vehicles, concrete additives, cooling and other lubricants, pesticides, tobacco and fireworks; car underbody sealant; de-icing of airplanes and airport surfaces (ceased in 2011); glass and mineral wool enduction; application of glues and adhesives; house cleaning industry/craft/services; hairdressers; cosmetic institutions; preservation of wood; medical practitioners; other health care institutions; other use of gases; renovation of corrosion inhibiting coatings

Table 4-46 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 2G Other product use.

NFR code	Source category	Pollutant	Identification criteria
2G	Other product use	NMVOC	L1, L2, T2
2G	Other product use	PM2.5	L1, L2, T1, T2
2G	Other product use	PM10	L1, L2, T1, T2

4.6.2 Methodological issues of 2G Other product use

4.6.2.1 Other product use (2G)

Methodology (2G)

Within source category 2G Other product use, the major NMVOC emission sources in 2022 are 2G Commercial and industrial use of cleaning agents and 2G Health care, other.

Based on the decision tree Fig. 3.1 in chapter 2G in the EMEP/EEA guidebook (EMEP/EEA 2019), for source category 2G Other product use Tier 2 methods using country-specific emission factors are applied for calculating the emissions from the different product applications and the use of fireworks and tobacco (EMIS 2024/2G).

For the source categories 2G Renovation of corrosion inhibiting coatings and 2G Use of aerosol cans in commerce and industry so-called direct emission data is available only. An in-depth discussion with a long-standing expert from the largest contract manufacturer in Switzerland revealed that the aerosol in many spray applications has the function of both propellant and solvent, and a clear distinction is usually not even possible or meaningful. Therefore, the aerosol emissions from the use of spray cans, with the exception of a residual batch of commercial insecticide application, were integrated into the respective application sources, e.g. the use of spray cans in the field of industry and technical products and automotive without paints into 2D3e Degreasing and the disinfectant sprays in 2G Health care other and 2G Medical practices.

Emission factors (2G)

Emission factors for NMVOC are based on data from individual industrial companies, services and Swiss airports, industry associations, survey on co-formulants in pesticides, German studies on NMVOC emissions from solvent use (Theloke et al. 2000 and Theloke 2005), VOC balances, post-combustion plants, statistics (aerosol) and expert estimates, as documented in the EMIS database.

Table 4-47 Emission factors of 2G Other product use in 2022.

2G Other product use	Unit	NMVOC
Application of glues and adhesives	kg/t solvent	385
Commercial and industrial use of cleaning agents	g/employee	400
Cosmetic institutions	kg/employee	28
De-icing of airplanes	kg/t de-icing agent	54
Glass wool enduction	g/t glass wool	129
Hairdressers	kg/employee	2.1
Health care, other	kg/employee	9.1
Medical practices	kg/employee	8.2
Preservation of wood	kg/t preservative	30
Rock wool enduction	g/t rock wool	C
Underseal treatment and conservation of vehicles	kg/t underseal agent	450
Use of antifreeze agents in vehicles	kg/Mio vehicle km	8.0
Use of concrete additives	g/t additive	740
Use of cooling lubricants	kg/t lubricant	6.0
Use of lubricants	kg/t lubricant	120
Use of pesticides	kg/t pesticide	116
Use of tobacco	kg/Mio cigarette eq.	4.8

Emission factors for pollutants other than NMVOC from 2G Use of fireworks and tobacco (EMIS 2024/2G) are displayed in Table 4-48. Emission factors of fireworks are documented in FOEN (2014p). Emission factors for use of tobacco are according to the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.D.3.i, 2.G, table 3-15). The emission factor for PCDD/PCDF is according to the UK National Atmospheric Emissions Inventory (UK NAEI 2019).

Table 4-48 Emission factors of all pollutants other than NMVOC from 2G Other product use in 2022. Unit of PCDD/PCDF is in I-TEQ.

2G	Unit	NO_x	SO_X	NH_3	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
Fireworks	kg/t fireworks	0.26	4.1	NA	90	180	180	NE	7.4
Use of tobacco	kg/Mio cigarette eq.	1.8	NE	4.2	27	27	27	0.12	55

2G	Unit	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP
Fireworks	g/t fireworks	130	3.0	0.1	NE	NE	NE	NE	NE
Use of tobacco	g/Mio cigarette eq.	NE	5.4	NE	0.0000001	0.11	0.045	0.045	0.045

Activity data (2G)

For the production processes, such as enduction of glass and rock wool and part of the applications in services or agriculture, such as preservation of wood, pesticides and application of glues and adhesives the activity data are based on production volume or employed agents. For the other part of applications in services, such as house cleaning in services, commerce and industry and medical practices the activity data correspond to the respective number of employees. The quantity of NMVOC emission per employee originates from the bottom-up approach in these service sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are referenced to the number of employees in order to calculate the Swiss total.

The activity data stem from individual industrial companies, services, Swiss airports (since 2011 no VOC-containing agents are used for de-icing of airport surfaces anymore), industry associations, Swiss Federal Statistical Office, Swiss Federal Office for Agriculture (sales statistics of pesticides), VOC balances, foreign trade statistics and expert estimates. They are documented in the EMIS database. Activity data for annual tobacco consumption and the annual firework sales are provided by the Swiss addiction prevention foundation (“Sucht Schweiz”) and the statistics of the Swiss federal office for police (FEDPOL 2023), respectively. Activity data for concrete additives are extrapolated from 2017 onwards, based on the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020).

Table 4-49 Activity data of 2G Other product use.

2G Other product use	Unit	1990	1995	2000	2005	2010
Application of glues and adhesives	kt solvent	4.8	4.0	3.2	2.7	2.5
Commercial and industrial use of cleaning agents	employees	3'950'000	3'867'500	3'954'667	4'133'667	4'404'000
Cosmetic institutions	employees	2'600	3'100	3'533	3'800	4'800
De-icing of airplanes	kt	1.2	2.4	1.8	2.5	3.3
De-icing of airport surfaces	kt	0.34	0.39	0.32	0.41	0.018
Fireworks	kt	0.84	1.0	1.5	1.4	1.7
Glass wool enduction	kt	24	24	31	37	36
Hairdressers	employees	20'553	22'826	23'530	22'200	26'761
Health care, other	employees	113'000	129'250	145'667	161'667	163'000
Medical practices	employees	27'625	42'047	50'833	55'357	58'700
Preservation of wood	kt	4.8	6.5	7.8	6.6	0.97
Rock wool enduction	kt	C	C	C	C	C
Underseal treatment and conservation of vehicles	kt	0.060	0.060	0.076	0.12	0.16
Use of antifreeze agents in vehicles	Mio vehicle km	47'523	46'479	51'142	53'723	57'039
Use of concrete additives	kt	24	25	29	36	41
Use of cooling lubricants	kt	5.0	5.2	5.8	7.8	7.0
Use of lubricants	kt	1.3	1.3	1.3	4.4	2.4
Use of pesticides	kt	2.4	2.4	2.3	2.3	2.1
Use of tobacco	Mio cigarette eq.	16'192	15'774	15'328	13'256	12'360

2G Other product use	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Application of glues and adhesives	kt solvent	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Commercial and industrial use of cleaning agents	employees	4'192'000	4'236'000	4'280'000	4'324'000	4'368'000	4'412'000	4'456'000	4'500'000	4'500'000	4'500'000
Cosmetic institutions	employees	5'222	5'333	5'444	5'556	5'667	5'778	5'889	6'000	6'100	6'200
De-icing of airplanes	kt	3.1	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5
De-icing of airport surfaces	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fireworks	kt	2.3	1.8	1.6	1.2	1.7	1.8	1.0	1.0	1.5	1.9
Glass wool enduction	kt	33	32	31	32	36	40	47	40	47	45
Hairdressers	employees	29'079	29'297	29'516	29'735	29'954	30'172	30'391	30'610	30'836	31'062
Health care, other	employees	163'000	163'000	163'000	163'000	163'000	163'000	163'000	163'000	163'000	163'000
Medical practices	employees	58'700	58'700	58'700	58'700	58'700	58'700	58'700	58'700	58'700	58'700
Preservation of wood	kt	0.94	0.57	0.62	0.68	0.70	0.49	0.60	0.60	0.60	0.60
Rock wool enduction	kt	C	C	C	C	C	C	C	C	C	C
Underseal treatment and conservation of vehicles	kt	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Use of antifreeze agents in vehicles	Mio vehicle km	59'944	60'913	61'881	62'260	62'638	63'017	63'395	63'774	64'259	64'744
Use of concrete additives	kt	38	39	39	39	39	40	40	40	40	40
Use of cooling lubricants	kt	7.2	7.4	7.5	7.7	7.8	8.0	8.1	8.1	8.2	8.2
Use of lubricants	kt	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8	1.8
Use of pesticides	kt	2.3	2.2	2.2	2.2	2.0	2.1	2.1	2.2	2.2	2.2
Use of tobacco	Mio cigarette eq.	12'162	10'628	10'284	10'702	10'702	10'318	10'030	10'414	10'222	9'742

4.6.3 Category-specific recalculations in 2G Other product use

The following recalculations were implemented in submission 2024:

- 2G: The incorrect activity data for 2021 of source category 2G Glass wool enduction was corrected.
- 2G: The activity data of source category 2G Fireworks has been updated for the year 2021 due to newly available statistics data. This results in an emission change of +30 %.

4.7 Source categories 2H – Other

4.7.1 Source category description of 2H Other

Table 4-50 Specification of source category 2H Other in Switzerland.

2H	Source category	Specification
2H1	Pulp and paper industry	Production of fibreboards, chipboards and cellulose (ceased in 2008)
2H2	Food and beverages industry	Production of beer, spirits, wine, bread, sugar, smoked and roasted meat and mills
2H3	Other industrial processes	Blasting and shooting

Table 4-51 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 2H Other.

NFR code	Source category	Pollutant	Identification criteria
2H1	Pulp and paper industry	PM2.5	L1, L2, T1, T2
2H2	Food and beverages industry	NMVOC	L1, L2, T1, T2
2H2	Food and beverages industry	PM2.5	L2, T2
2H2	Food and beverages industry	PM10	L1, L2, T2

4.7.2 Methodological issues of 2H Other

4.7.2.1 Pulp and paper industry (2H1)

Methodology (2H1)

Today, the production of chipboard and fibreboard are the relevant industrial processes in the source category 2H1 Pulp and paper industry. 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.

Based on the decision tree Fig. 3.1 in chapter 2H1 in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions are calculated by a Tier 2 method using country-specific emission factors (EMIS 2024/2H1).

Emission factors (2H1)

Emission factors are based on measurements of the chipboard production plant whereas constant emission factors are assumed for the fibreboard production, documented in the EMIS database. They are confidential but available to reviewers on request.

Table 4-52 Emission factors for 2H1 Pulp and paper industry in 2022. Unit of PCDD/PCDF is in I-TEQ.

2H1 Pulp and paper industry	Unit	NO_x	NMVOC	SO_X	PM2.5 nx	PM10 nx	TSP nx	BC nx	CO	PCDD/ PCDF
Fibreboard production	g/t fibreboard	NE	C	NE	C	C	C	NE	NE	NA
Chipboard production	g/t chipboard	NE	C	NE	C	C	C	NE	NE	C

Activity data (2H1)

Activity data on annual chipboard production has been provided by the industry since 2005 and between 1990 and 2003 annual data are based on the annual statistics on forest and wood (SFSO/BUWAL 2004) as documented in the EMIS database.

Activity data on annual fibreboard production are provided by monitoring reports of the industry since 1996 as documented in the EMIS database.

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 4-53 Activity data of 2H1 Pulp and paper industry.

2H1 Pulp and paper industry	Unit	1990	1995	2000	2005	2010
Sum of chipboard, fibreboard and cellulose production	kt	604	593	641	693	602

2H1 Pulp and paper industry	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Sum of chipboard, fibreboard and cellulose production	kt	510	516	519	503	507	502	460	C	C	C

4.7.2.2 Food and beverages industry (2H2)

Methodology (2H2)

Based on the decision tree Fig. 3.1 in chapter 2H2 in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions from the source category 2H2 Food and beverages industry, are calculated by a Tier 2 method using country-specific emission factors (EMIS 2024/2H2).

Emission factors (2H2)

Emission factors are based on measurements, data from industry and expert estimates as well as data from a study on emissions of volatile organic compounds (VOCs) from the food and drink industries of the European Community (Passant et al., 1993), documented in the EMIS database. For bread production, the emission factor is derived from the arithmetic mean of different studies and information provided by some of the Swiss bread producers as documented in the EMIS database (EMIS 2024/2H2 Brot Produktion).

Table 4-54 Emission factors for 2H2 Food and beverages industry in 2022. Unit of PCDD/PCDF is in I-TEQ.

2H2 Food and beverages	Unit	NMVOC	NH_3
Breweries	g/m^3 beer	250	NA
Spirits production	g/m^3 alcohol	10'000	NA
Bread production	g/t bread	4'500	NA
Meat smokehouses	g/t meat	1'300	NA
Roasting facilities	g/t coffee	30	NA
Milling companies	g/t flour	NA	NA
Wine production	g/m^3 wine	580	NA
Sugar production	g/t sugar	195	251

2H2 Food and beverages industry	Unit	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO	PCDD/ PCDF
Breweries	g/m^3 beer	NA	NA	NA	NE	NA	NA	NA	NA	NA
Spirits production	g/m^3 alcohol	NA	NA	NA	NE	NA	NA	NA	NA	NA
Bread production	g/t bread	NA	NA	NA	NE	NA	NA	NA	NA	NA
Meat smokehouses	g/t meat	350	NA	350	NE	350	NA	NA	250	0.000003
Roasting facilities	g/t coffee	NA	30	NA	60	NA	60	NA	NA	NA
Milling companies	g/t flour	NA	50	NA	100	NA	160	NA	NA	NA
Wine production	g/m^3 wine	NA	NA	NA	NE	NA	NA	NA	NA	NA
Sugar production	g/t sugar	NA	260	NA	520	NA	600	NA	NA	NA

Activity data (2H2)

Activity data on annual production have been provided by industry, by the Federal Office for Customs and Border Security (FOCBS), the Swiss farmers' union (SBV), the Swiss Fatstock and Meat Suppliers Cooperative (Schweiz. Genossenschaft für Schlachtvieh- und Fleischversorgung (GSF)), the Swiss Federal Office for Agriculture and the Swiss Alcohol Board as documented in the EMIS database. Activity data on annual bread production are derived from the number of inhabitants (FSO 2023c) and the annual bread consumption per inhabitant provided by the Swiss bread statistics (Schweizerische Brotinformation, SBI) for the time period between 1990 and 2010. A value for 2017 per capita bread consumption has been provided by the Swiss Bread Association as documented in the EMIS database (EMIS 2024/2H2 Brot Produktion).

Table 4-55 Activity data of 2H2 Food and beverages industry.

2H2 Food and beverages industry	Unit	1990	1995	2000	2005	2010
Breweries	m^3	414'300	367'100	354'100	341'600	353'800
Spirits production	m^3	4'158	3'271	2'179	2'266	1'945
Bread production	kt	336	352	359	372	386
Meat smokehouses	kt	66	64	60	62	66
Roasting facilities	kt	56	50	58	78	102
Milling companies	kt	1'644	1'519	1'603	1'425	1'602
Wine production	m^3	120'000	111'693	123'073	108'526	108'319
Sugar production	kt	147	129	219	197	241

2H2 Food and beverages industry	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Breweries	m^3	336'900	343'100	342'700	341'900	346'300	365'900	367'500	340'400	338'200	368'600
Spirits production	m^3	1'158	1'150	1'636	1'211	1'010	961	1'624	1'224	1'233	744
Bread production	kt	380	378	376	373	370	373	376	378	381	383
Meat smokehouses	kt	66	67	67	67	67	67	66	66	68	68
Roasting facilities	kt	120	119	125	127	131	141	148	161	172	177
Milling companies	kt	1'602	1'625	1'645	1'663	1'626	1'629	1'617	1'589	1'658	1'613
Wine production	m^3	108'564	99'556	99'859	90'174	88'116	90'404	95'742	96'107	91'458	88'813
Sugar production	kt	245	344	261	240	299	246	273	226	199	223

4.7.2.3 Other industrial processes (2H3)

Methodology (2H3)

Source category 2H3 Other industrial processes encompasses the emissions from blasting and shooting only. An analogous Tier 2 method with country-specific emission factors is used to calculate the emissions.

Emission factors (2H3)

Emission factors per tonne of explosive are derived from the 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) and the EMIS database. They are assumed to be constant over the entire time period.

Table 4-56 Emission factors for 2H3 Other industrial processes in 2022.

2H3 Other industrial processes	Unit	NO_x	NMVOC	SO_X	NH_3	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO	Pb
Blasting and shooting	kg/t exp	35	60	0.5	0.4	6	6	6	NE	310	0.00001

Activity data (2H3)

Activity data for blasting and shooting is taken from federal statistics on explosives (FEDPOL 2023).

Table 4-57 Activity data of 2H3 Other industrial processes.

2H3 Other industrial processes	Unit	1990	1995	2000	2005	2010
Blasting and shooting	kt explosive	2.6	1.3	1.9	0.79	2.4

2H3 Other industrial processes	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Blasting and shooting	kt explosive	2.2	2.1	2.1	0.67	0.73	0.81	0.67	0.63	0.61	0.65

4.7.3 Category-specific recalculations in 2H Other

The following recalculations were implemented in submission 2024:

- 2H2: The activity data of source category 2H2 Production of beer has been updated for the years 1990-2016 due to newly available statistics on beer production published by FOCBS. This results in emission changes ranging from -13 % to +1 %.
- 2H2: The activity data of source category 2H2 Production of smoked meat and fish has been updated for the years 2020 and 2021 due to an update in the underlying statistics, resulting in changes in emissions of -0.7 % for 2020 and +0.5 % for 2021.
- 2H2: The activity data of source category 2H2 Production of flour has been updated for the years 2020 and 2021 due to an update in the underlying statistics, resulting in changes in emissions of +1.9 % for 2020 and -0.3 % for 2021.

4.8 Source categories 2I – Wood processing, 2K – Consumption of POPs and heavy metals and 2L – Other production, consumption, storage, transportation or handling of bulk products

4.8.1 Source category description of 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products

Table 4-58 Specification of source category 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products in Switzerland.

2I, 2K, 2L	Source category	Specification
2I	Wood processing	Wood processing
2K	Consumption of POPs and heavy metals	Emissions of PCBs from usage of PCBs in transformers, large and small capacitors, anti-corrosive paints and joint sealants as well as from demolition/renovation of PCB containing anti-corrosive paints and joint-sealants
2L	Other production, consumption, storage, transportation or handling of bulk products	Ammonia emissions from freezers (filling and storage)

Table 4-59 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products.

NFR code	Source category	Pollutant	Identification criteria
2I	Wood processing	PM2.5	L2
2I	Wood processing	PM10	L2, T2

4.8.2 Methodological issues of 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products

4.8.2.1 Wood processing (2I)

Methodology (2I)

Source category 2I includes particulate emissions of wood processing. Emissions from charcoal production are reported in 1A1c Manufacture of solid fuels and other energy industries. According to chapter 2I in the EMEP/EEA guidebook (EMEP/EEA 2019), the calculation of emissions is based on a Tier 1 method based on country-specific emission factors (EMIS 2024/2I Holzbearbeitung).

Emission factors (2I)

Emission factors of wood processing are based on an industry survey (EMPA 2004b).

Table 4-60 Emission factors for 2I Wood processing in 2022.

2I Wood processing	Unit	PM2.5 nx	PM10 nx	TSP nx
Wood processing	g/t sawnwood	74	294	735

Activity data (2I)

Activity data of wood processing are the annual amount of sawnwood based on the yearbook forest and wood (FOEN 2023f).

Table 4-61 Activity data of 2I Wood processing.

2I Wood processing	Unit	1990	1995	2000	2005	2010
Wood processing	kt sawnwood	1'168	827	901	853	774

2I Wood processing	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wood processing	kt sawnwood	564	634	626	622	578	597	598	623	664	667

4.8.2.2 Usage of PCBs (2K)

Methodology (2K)

Source category 2K includes PCB emissions from use of polychlorinated biphenyls (PCBs) in transformers, small and large capacitors, anti-corrosive paints and joint sealants in Switzerland between 1946 and 1986. In 1986, a total ban was placed on any form of PCB use. The use in so-called open systems, i.e. anti-corrosive paints and joint sealants, was allowed until 1972 only. For the time being, anti-corrosive paints and joint sealants are the predominant PCB emission sources. Emissions from demolition/renovation of steel constructions and buildings containing PCBs in anti-corrosive paints and joint sealants, respectively, are also reported in source category 2K.

A dynamic mass flow model was developed for the usage of PCBs in Switzerland for the time period 1930 to 2100 (Glüge et al. 2017). The model takes into account the entire life cycle, i.e. import, usage, export, treatment, disposal and accidental release of PCBs. A description of the model is given in Annex A2.2.

The emissions are calculated by multiplying the annual mass of PCBs involved in a source (e.g. tonnes of PCBs in use in joint sealants) with a source-specific emission factor (e.g. tonnes of PCBs emitted/tonnes of PCBs in use). This country-specific approach corresponds to a Tier 2 method according to the EMEP/EEA guidebook (EMEP/EEA 2019).

Emission factors (2K)

The PCB emission factors from the use of PCBs in transformers, small and large capacitors, anti-corrosive paints and joint sealants are expressed in units per tonnes of PCBs available in the respective application, see Table 4-62. The PCB emission factors for demolition/renovation of steel constructions and buildings containing PCBs in anti-corrosive paints and joint sealants are expressed in units per tonnes of PCBs demolished or renovated.

Table 4-62 Emission factors for 2K Usage of PCBs in 2022.

2K Usage of PCBs	Unit	PCB
Transformers	kg/t PCB	0.0022
Large capacitors	kg/t PCB	0.47
Small capacitors	kg/t PCB	0.47
Anti-corrosive paints	kg/t PCB	2.5
Joint sealants	kg/t PCB	2.5
Demolition and renovation	kg/t PCB	2.5

Activity data (2K)

The five usage categories are PCB stocks, which means that PCBs are stored in these applications and passed on through the system with a temporal delay (lifetime). In these cases, the activity data are the amounts of PCBs stored in the stock. The treatment category demolition and renovation is an instantaneous category. In this case, the activity data corresponds to the amount of PCBs treated in the respective year.

Table 4-63 Activity data for 2K Usage of PCBs.

2K Usage of PCBs	Unit	1990	1995	2000	2005	2010
Transformers	t PCB	1'257	840	501	265	123
Large capacitors	t PCB	356	235	139	73	33
Small capacitors	t PCB	361	213	108	47	17
Anti-corrosive paints	t PCB	209	196	178	156	128
Joint sealants	t PCB	209	196	178	156	129
Demolition and renovation	t PCB	2.4	4.0	6.2	8.5	10

2K Usage of PCBs	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Transformers	t PCB	73	60	50	41	33	27	22	18	14	11
Large capacitors	t PCB	20	16	13	11	9.0	7.3	5.8	4.7	3.7	2.9
Small capacitors	t PCB	8.6	6.7	5.2	4.0	3.1	2.4	1.8	1.3	1.0	0.75
Anti-corrosive paints	t PCB	110	104	98	92	86	80	73	68	62	56
Joint sealants	t PCB	110	104	98	92	86	80	73	68	62	56
Demolition and renovation	t PCB	11	11	11	11	11	11	11	11	10	10

4.8.2.3 Use of ammonia as cooling agent (2L)

Methodology (2L)

Ammonia is used as a cooling agent in various applications in the industry and services sector. The most important sources are ice rinks and cold storage facilities. Other relevant sources are breweries, nuclear power plants and chemical industries. An analogous Tier 2 method with country-specific emission factors is used to calculate the emissions.

Emission factors (2L)

Emission factors are expressed as share of losses from storage and from filling and recovery. Emission factors are based on expert judgement as documented in the EMIS database (EMIS 2024/2 F_2 L_NH3 aus Kühlanlagen). Emission factors are assumed constant over the entire time period (see Table 4-64).

Table 4-64 Emission factors for 2L Ammonia in freezers in 2022.

2L Ammonia from freezers	Unit	NH_3
Freezers filling	kg/t	1
Freezers storage	kg/t	2

Activity data (2L)

Activity data are based on data from the industry. They are calculated by multiplying the number of plants and installations that use ammonia for cooling by an average amount of ammonia consumed by the corresponding process. This includes the number of breweries, ice rinks, nuclear power plants, cold storage facilities, chemical industries, large scale heat pumps and air conditioners. Data on average ammonia consumption of each of these processes is provided by a Swiss company for cooling devices (EMIS 2024/2 F_2 L_NH3 aus Kühlanlagen) (see Table 4-65).

Table 4-65 Activity data of 2L Ammonia in freezers.

2L Ammonia from freezers	Unit	1990	1995	2000	2005	2010
Freezers filling	t	178	201	224	246	269
Freezers storage	t	1'100	1'100	1'200	1'200	1'200

2L Ammonia from freezers	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Freezers filling	t	283	287	292	295	298	301	304	307	310	313
Freezers storage	t	1'436	1'515	1'593	1'616	1'638	1'661	1'683	1'706	1'728	1'751

4.8.3 Category-specific recalculations in 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products

There were no recalculations implemented in submission 2024.

5 Agriculture

5.1 Overview of emissions

This introductory chapter contains an overview of emissions from sector 3 Agriculture. NO_x, NMVOC, NH_3, PM2.5, PM10 and TSP are the reported air pollutants for this sector.

The following source categories are reported:

- 3B Manure management
- 3D Crop production and agricultural soils

Note that emissions from burning of agricultural residues is reported in sector Waste (chp. 6.4, category 5C Waste incineration and open burning of waste), since there is no field burning of crop residues, as this is prohibited in Switzerland. Even in case of diseases the fruit trees are felled, cut up and burned on piles. This usually occurs on the field, but after chopping and stacking (not as standing trees).

5.1.1 Overview and trend for NO_x

NO_x emissions from agriculture are of minor importance for the national total NO_x emissions (see Table 2-8). They show a decreasing trend over the whole period 1990-2022 (see Figure 5-1 and Table 5-1). The trend was more pronounced between 1990 and 2004, and since then continues on a lower level with some fluctuations. Main source is category 3D Crop production and agricultural soils, where 3Da2a Animal manure applied to soils is the most relevant emission source. Accordingly, the development of NO_x emissions in category 3D depends on the development of livestock numbers and thus N excretions, which decreased by 17 % between 1990 and 2020 (Kupper et al. 2022) with a similar pattern as overall NO_x emissions from the agriculture sector. The decrease in inorganic N-fertiliser use (3Da1) additionally contributed to the reduction of NO_x emissions (N applied between 1990 and 2020 was reduced by 38 %; Kupper et al. 2022).

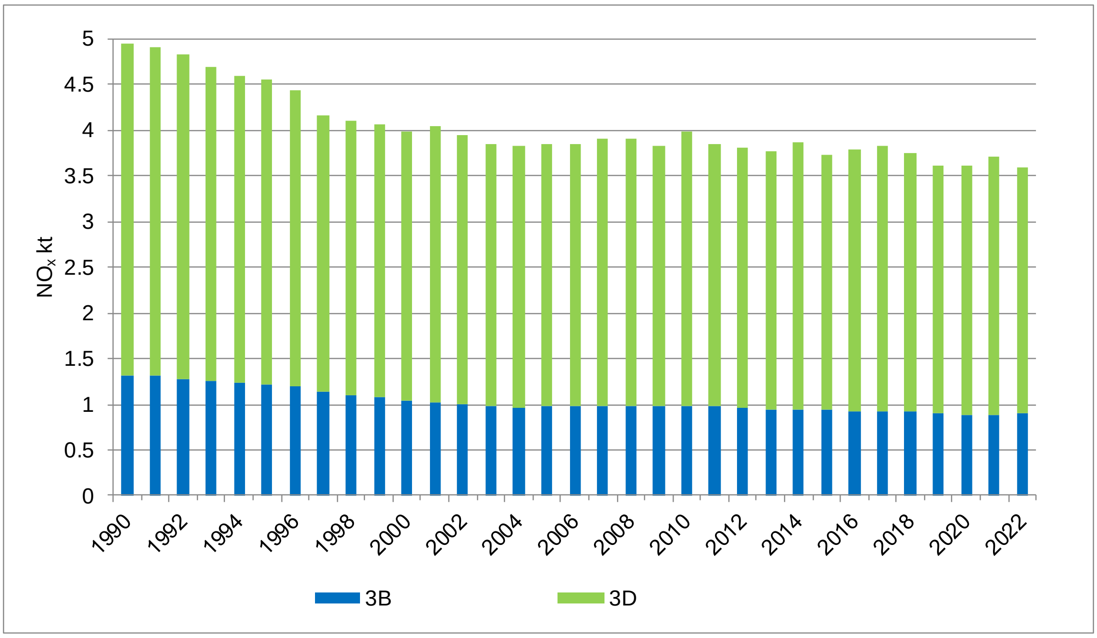

Figure 5-1 Switzerland's NO_x emissions from agriculture by source categories 3B and 3D. The corresponding data can be found in Table 5-1.

Table 5-1 NO_x emissions from Sector 3 Agriculture by source categories 3B and 3D. The last column in the third part of the table indicates the relative trend.

NOx	1990	1995	2000	2005	2010
	kt				
3B	1.3	1.2	1.0	0.97	0.99
3D	3.6	3.3	3.0	2.9	3.0
Sum	4.9	4.6	4.0	3.8	4.0

NOx	2013	2014	2015	2016	2017
	kt				
3B	0.95	0.95	0.93	0.93	0.92
3D	2.8	2.9	2.8	2.9	2.9
Sum	3.8	3.9	3.7	3.8	3.8

NOx	2018	2019	2020	2021	2022	2005–2022
	kt					
3B	0.91	0.90	0.89	0.89	0.90	-8%
3D	2.8	2.7	2.7	2.8	2.7	-6%
Sum	3.7	3.6	3.6	3.7	3.6	-6%

5.1.2 Overview and trend for NMVOC

NMVOC emissions from animal husbandry are the main reason why the emissions from sector agriculture provide a significant contribution to the national total of NMVOC emissions (see Table 2-9). The trend of NMVOC emissions within agriculture is depicted in Figure 5-2 and Table 5-2. The emissions are dominated by source category 3B Manure management, where emissions stem from cattle husbandry fed by silage, as dominant emission source. Emissions were stable between 1990 and 2000, before an increasing trend started between 2000 and 2008 due to a significant increase in the number of non-dairy cattle which predominately are fed by silage. Since 2014, the emissions have remained at about constant level.

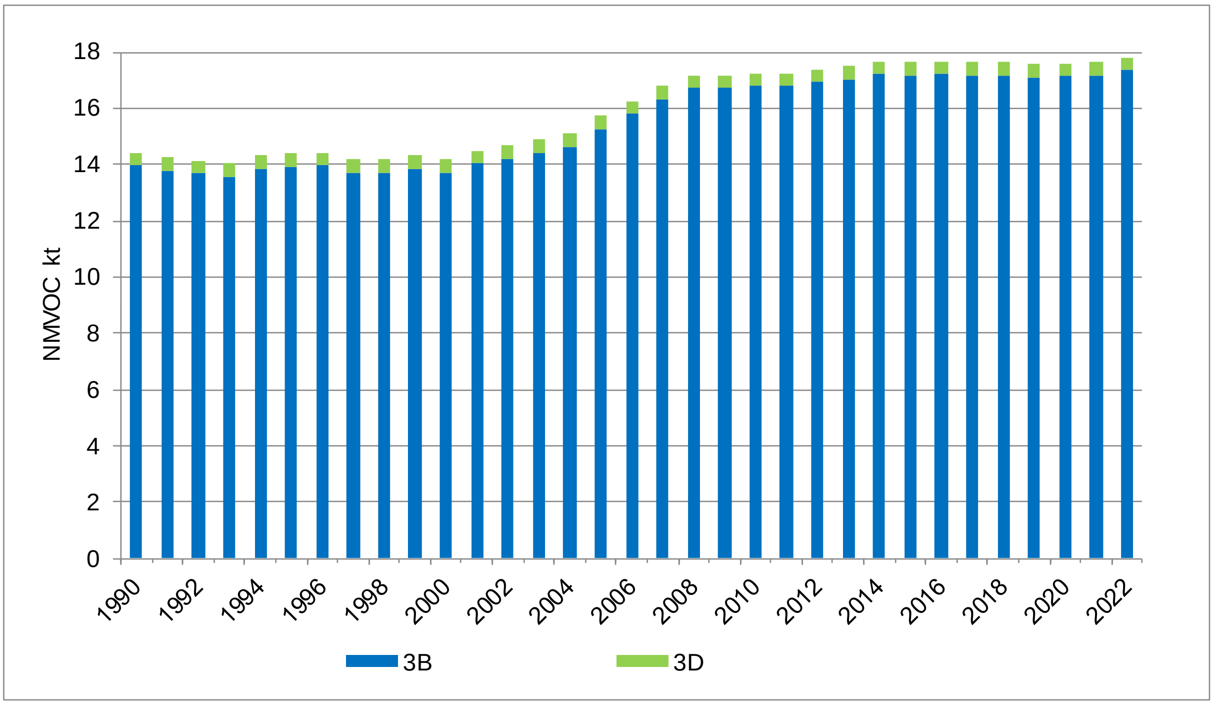

Figure 5-2 Switzerland's NMVOC emissions from agriculture by source categories 3B and 3D. The corresponding data can be found in Table 5-2.

Table 5-2 NMVOC emissions from Sector 3 Agriculture by source category 3B and 3D. The last column in the third part of the table indicates the relative trend.

NMVOC total	1990	1995	2000	2005	2010
	kt				
3B	14	14	14	15	17
3D	0.48	0.48	0.47	0.47	0.46
Sum	14	14	14	16	17

NMVOC total	2013	2014	2015	2016	2017
	kt				
3B	17	17	17	17	17
3D	0.46	0.46	0.46	0.46	0.46
Sum	17	18	18	18	18

NMVOC total	2018	2019	2020	2021	2022	2005–2022
	kt					
3B	17	17	17	17	17	14%
3D	0.46	0.46	0.46	0.46	0.45	-3%
Sum	18	18	18	18	18	13%

5.1.3 Overview and trend for NH_3

Agriculture is by far the most important source of NH_3 emissions in Switzerland (see Table 2-11). The trend of NH_3 emissions within agriculture is depicted in Figure 5-3 and Table 5-3. While source category 3B Manure management slightly increased in the period 1990-2022, category 3D Crop production and agricultural soils shows a fluctuating and decreasing trend. Both categories are about equally important in the year 2022. Agricultural ammonia emissions decreased between 1990 and 2004, followed by a slight increase until 2007 and another decrease since then. This non-monotonic trend results from a combination of changes in animal numbers, introduction of nutrient balance regulations for nitrogen, introduction of new housing systems and more grazing due to developments in animal welfare regulations, increase of animal productivity, changes in production techniques and a considerable decrease of N fertiliser use due to nutrient balance restrictions (Kupper et al. 2015, Kupper et al. 2018, Kupper et al. 2022). Between 1990 and 2020, N excretions from livestock decreased by 17 % and N excretions of livestock going into the manure stream even by 27 % (Kupper et al. 2022). A further reason for the downward trend of agricultural NH_3 emissions is the growing importance of grazing due to animal welfare incentives. The share of soluble N (TAN) of excretions of livestock going to grazing increased from 8 % in 1990 to 17 % in 2020 (Kupper et al. 2022).

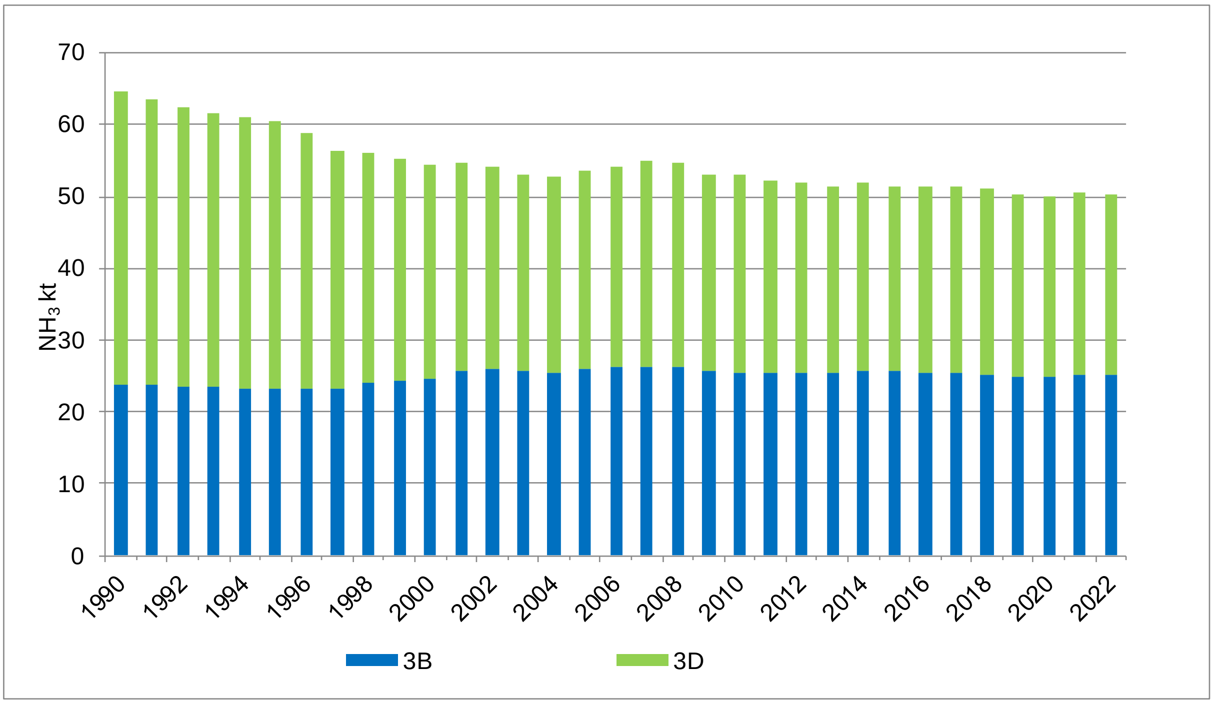

Figure 5-3 Switzerland's NH_3 emissions from agriculture by source categories 3B and 3D. The corresponding data can be found in Table 5-3.

Table 5-3 NH_3 emissions from Sector 3 Agriculture by source categories 3B and 3D. The last column in the third part of the table indicates the relative trend.

NH3	1990	1995	2000	2005	2010
	kt				
3B	24	23	25	26	26
3D	41	37	30	28	27
Sum	65	61	54	54	53

NH3	2013	2014	2015	2016	2017
	kt				
3B	25	26	26	26	25
3D	26	26	26	26	26
Sum	51	52	52	51	51

NH3	2018	2019	2020	2021	2022	2005–2022
	kt					
3B	25	25	25	25	25	-3%
3D	26	25	25	25	25	-10%
Sum	51	50	50	50	50	-7%

5.2 Source category 3B – Manure management

5.2.1 Source category description of 3B Manure management

This chapter contains emissions stemming from animal husbandry. It includes emissions of NO_x and NH_3 from animal manure (except categories 3Da2a Animal manure applied to soils and 3Da3 Urine and dung deposited by grazing animals). Also, NMVOC emissions from animal husbandry are reported in the inventory with silage feeding as important emission source besides manure management. Emissions from physical activities of the animals (PM from abrasion and resuspension of dust) are included in source category 3B as well.

Table 5-4 Specification of source category 3B Manure Management.

3B	Source category	Specification
3B1a	Manure management - Dairy cattle	Mature dairy cattle, water buffalos
3B1b	Manure management - Non-dairy cattle	Other mature cattle and growing cattle: fattening calves, pre-weaned calves, breeding cattle 1st, 2nd, 3rd year, fattening cattle
3B2	Manure management - Sheep	
3B3	Manure management - Swine	Dry sows, nursing sows, boars, fattening pigs, piglets
3B4a	Manure management - Buffalo	IE (included in 3B1a)
3B4d	Manure management - Goats	
3B4e	Manure management - Horses	
3B4f	Manure management - Mules and asses	
3B4gi	Manure mangement - Laying hens	
3B4gii	Manure mangement - Broilers	
3B4giii	Manure mangement - Turkeys	
3B4giv	Manure management - Other poultry	Growers, other poultry (geese, ducks, ostriches, quails)
3B4h	Manure management - Other animals	Camels and llamas (3B4b), deer (3B4c), rabbits (3B4hi), bisons (3B4hii)

Table 5-5 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 3B, Manure Management.

NFR code	Source category	Pollutant	Identification criteria
3B1a	Manure management - Dairy cattle	NMVOC	L1, L2, T1, T2
3B1a	Manure management - Dairy cattle	NH3	L1, L2, T1, T2
3B1b	Manure management - Non-dairy cattle	NMVOC	L1, L2, T1, T2
3B1b	Manure management - Non-dairy cattle	NH3	L1, L2, T1, T2
3B3	Manure management - Swine	NMVOC	T2
3B3	Manure management - Swine	NH3	L1, L2, T2
3B4gi	Manure management - Laying hens	PM10	L2
3B4gii	Manure management - Broilers	NMVOC	L2, T2
3B4gii	Manure management - Broilers	NH3	L2, T2
3B4gii	Manure management - Broilers	PM10	L2, T2

5.2.2 Methodological issues of 3B Manure management

Methodology (3B)

For calculating the ammonia emissions caused by manure management a country-specific approach is used according to the Tier 3 detailed methodology described in chapter 3B Manure management of the EMEP/EEA guidebook (EMEP/EEA 2019).

An internet-based model called AGRAMMON was developed in Switzerland allowing the calculation of ammonia emissions for single farms and for regions (https://agrammon.ch/). The model simulates the nitrogen flow from animal feeding to excretion (in housing systems and during grazing), to manure storage and to manure application. In the 2018 revision of the model (Kupper et al. 2018) it was extended to cover not only NH_3 emissions but all nitrogen flows (including N_2O, NO_x and N_2).

AGRAMMON considers important parameters on farm and manure management influencing the emissions of ammonia at the different levels of farm management. The Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL) collected data on farm and manure management at farm-level with a detailed representative questionnaire in 2002, 2007, 2010, 2015 and 2019. Each survey consisted of a representative stratified random sample covering approximately 2000 to 3000 farms (in total, in 2020 there were about 49’000 farms in Switzerland). The strata cover five different farm types, three regions of Switzerland and three altitude classes (valley zone, hill zone, mountain zone). The questionnaire contained detailed questions on livestock housing, feeding and grazing for different livestock categories, as well as manure storage and spreading, and use of mineral fertiliser. For each farm in the survey, farm-specific emission calculations were done with AGRAMMON. These results were then used to calculate livestock-category specific average emission factors for each strata group and the five respective survey years. For the national extrapolation of the emission data, the weighted average (according to share of the total livestock population of the respective livestock categories) input data on production of the different strata group was used. The emission time series from 2002 to 2019 was established with the calculated emission factors (2002, 2007, 2010, 2015, 2019), with interpolated emission factors for the years 2003-2006, 2008-2009, 2011-2014 and 2016-2018, and the known development of the number of animals in different livestock categories (activity data). Emission factors beyond 2019 are kept constant until new survey results are available (expected in 2025). The experience gained from the detailed surveys between 2002 and 2019 and from the extrapolation of the single farm data to the totality of farms in Switzerland was used, together with expert assumptions and available statistical data on farm management, to calculate the emissions between 1990 and 2002. The procedure is described in Kupper et al. (2022).

A comparison of the country-specifically calculated Tier 3 results (using the AGRAMMON version 2018) for N flows and NH_3 emissions from animal husbandry (3B Manure management, 3Da2a Animal manure applied to soils and 3Da3 Urine and dung deposited by grazing animals) with the results of the Tier 2 calculations based on the TFEIP N flow tool was performed for 2015 (at the time the last year with a representative survey on farm management). The comparison and discussion of the results are given in Annex A2.3. In the framework of the Stage 3 in-depth review of emission inventories in summer 2020, Switzerland provided detailed information on the development of the nitrogen (N) flow distribution to liquid and solid manure depending on management technique modelled within AGRAMMON.

For nitrogen flux calculations, AGRAMMON uses nitrogen excretions of different livestock categories according to the values valid in the respective reference years of the “Principles of Agricultural Crop Fertilisation in Switzerland” (Richner and Sinaj 2017). The values have partly changed over time depending on the development of production technology (especially breeding, feeding) and have been adjusted accordingly (Kupper et al. 2018, Kupper et al. 2022). To take into account the varying milk yield level of dairy cattle, a linear correction factor given in Richner and Sinaj (2017) was applied. The TAN proportions in the excreta of the animal categories which are used in AGRAMMON are as follows: Dairy cattle and other cattle categories: 55 %; swine: 70 %; poultry: 60 %; horses and other equids as well as sheeps, goats and all other animals are assumed to have 40 % TAN (Kupper et al. 2018, Kupper et al. 2022). N-excretion values and the proportion of TAN therein is based on models which employed experimental data obtained from dairy cattle and fattening swines. The proportion of TAN has been extrapolated from the values to the other cattle and swine categories. For poultry, horses and other equids, sheeps, goats and other animals it is based on expert judgments. The proportion of TAN is equated with urine N, ‘Documentation on the Technical Parameters’ in AGRAMMON 2018 describes how the values were derived.

Table 5-6 shows that the share of the total N exretions from all agricultural livestock that went into the slurry flow decreased from 64 % to 56 % from 1990 to 2019. Table 5-7 shows that this was not the case for the N excretions of cattle (all categories together) that remained almost constant around 60 %. This probably was because an increase in grazing – which reduced the share of N collected in the housing area – compensated the increase of the share of N going to slurry in the housing area. The share of total N excretions of all livestock going to pasture, range and paddock (Table 5-6) roughly doubled because of animal welfare incentives and the considerable decrease of pig production. The share going to digesters increased from 0.6 % to 6.9 % and the share going to deep litter and poultry manure rose from 5.4 % to 8.4 % due to a strong growth of poultry production. The share going to solid manure decreased by nearly halve, mainly because of the shift from tied to loose housing systems for cattle. Table 5-8 shows the share of N excretions going to the liquid manure flow (including digesters) for the different livestock categories. The shares strongly increase for the cattle categories. For swine, which produce only liquid manure and for equids (horse, mules and asses), sheep, goats and poultry which produce only solid manure the values logically remained constant.

Table 5-6 Development of the share of the total N excretions from livestock (incl. cattle) going to the paths liquid slurry / solid manure / other (deep litter / poultry manure) / digesters / pasture, range and paddock in Switzerland from 1990 to 2019 (in % of total N excretions). Data based on representative surveys on farm management technique in 2002, 2007, 2010, 2015 and 2019; for 1990 and 1995 based on expert assumptions (Kupper et al. 2022).

Distribution of N excretion [%]	**1990**	**1995**	**2002**	**2007**	**2010**	**2015**	**2019**
Liquid / Slurry	63.8%	64.0%	58.7%	59.4%	58.7%	58.7%	55.6%
Solid manure	21.4%	20.3%	16.5%	13.9%	13.3%	11.6%	10.8%
Other (deep litter, poultry manure)	5.4%	5.2%	5.8%	6.8%	7.7%	7.5%	8.4%
Digesters	0.6%	0.5%	0.6%	1.6%	2.3%	4.4%	6.9%
Pasture, range and paddock	8.9%	9.9%	18.5%	18.2%	18.0%	17.9%	18.3%

Table 5-7 Development of the share of the N excretions from cattle (sum of all three categories) going to the paths liquid slurry / solid manure / other (deep litter) / digesters / pasture, range and paddock in Switzerland from 1990 to 2019 (in % of total N excretions). Data based on representative surveys on farm management technique in 2002, 2007, 2010, 2015 and 2019; for 1990 and 1995 based on expert assumptions (Kupper et al. 2022).

Distribution of N excretion [%]	**1990**	**1995**	**2002**	**2007**	**2010**	**2015**	**2019**
Liquid / Slurry	60.5%	61.8%	58.7%	61.6%	61.6%	62.9%	60.8%
Solid manure	26.9%	24.7%	18.7%	15.4%	14.4%	12.0%	11.2%
Other (deep litter)	1.3%	1.3%	1.3%	1.2%	1.4%	1.2%	1.2%
Digesters	0.5%	0.4%	0.6%	1.5%	2.2%	4.1%	6.4%
Pasture, range and paddock	10.7%	11.8%	20.7%	20.3%	20.4%	19.8%	20.4%

Table 5-8 Development of the share of N excretions going to the liquid phase of manure (including digestate) for the different livestock categories in Switzerland from 1990 to 2019 (in % of total N excretions of the respective category). Data based on representative surveys on farm management technique in 2002, 2007, 2010, 2015 and 2019; for 1990 and 1995 based on expert assumptions (Kupper et al. 2022).

% N excretion going to liquid phase	**1990**	**1995**	**2002**	**2007**	**2010**	**2015**	**2019**
Dairy cattle	66.2%	67.9%	66.0%	69.6%	70.8%	73.6%	74.4%
Non-dairy cattle	41.6%	39.0%	43.8%	55.2%	55.9%	58.5%	55.9%
Young cattle	50.0%	50.4%	45.8%	50.1%	50.7%	54.8%	55.7%
Sheep	0%	0%	0%	0%	0%	0%	0%
Swine	100%	100%	98.7%	99.0%	99.5%	99.8%	99.9%
Goats	0%	0%	0%	0%	0%	0%	0%
Horses	0%	0%	0%	0%	0%	0%	0%
Mules and asses	0%	0%	0%	0%	0%	0%	0%
Poultry (layers, broilers, turkey, growers)	0%	0%	0%	0%	0%	0%	0%

Additionally, a larger survey – but less detailed with respect to ammonia relevant farm data – was carried out in 2013 by the Swiss Federal Statistical Office at the national level covering a sample of about 17’000 farms. This allowed a plausibility check of the AGRAMMON data, which showed a good compatibility of the resulting national emissions between the two surveys. The difference in overall national emissions was about 1 %, although there were higher differences at the process- or farm-level, but these cancelled each other out (Kupper et al. 2018).

For the volatilisation of NO_x, which is also integrated in the AGRAMMON model, a Tier 2 approach based on emission factors from van Bruggen et al. (2014) was used.

The calculation of non-methane volatile organic compounds (NMVOC) and particulate matter (PM, except for all cattle categories) emissions was conducted with a Tier 1 approach using country specific and default Tier 1 emission factors from the EMEP/EEA guidebook (EMEP/EEA 2019). The PM emissions from all cattle categories (3B1) are calculated by a

Tier 2 method using country specific emission factors based on literature data and expert judgement (Bühler and Kupper 2018).

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 the derived emission factors differ widely. The studies cited in the EMEP/EEA guidebook at that time (EMEP/EEA 2016, unchanged in EMEP/EEA 2019) showed several inconsistencies that could affect significantly the emission factors. It also remains 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 dairy housing during summer, winter and transitional season and to derive emission factors that are representative for cattle husbandry in Switzerland (Schrade et al. 2024). However, it should be noted that the time the animals spend on pasture is not taken into account in this study and NMVOC emissions are thus probably rather overestimated.

Please note that we are aware that Tier 2 methodologies are in principle required for emission calculations of key categories. But due to lack of data, this was not possible to implement for all categories (e.g. NMVOC (3B) and PM (3B4gii)).

Emission factors (3B)

The consideration of structural and management parameters based on representative stratified surveys on farm management practice for the calculation of the ammonia emissions with the nitrogen flow model AGRAMMON results in livestock category specific emission factors reflecting the changes of such parameters over the assessed time period (Kupper et al. 2015, Kupper et al. 2018, Kupper et al. 2022). National standard N excretion rates are used (Richner and Sinaj 2017), considering animal category specific correction factors as also described under methodology.

For the volatilisation of NO_x, which is also integrated in the AGRAMMON model, default 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, respectively, are lost to the atmosphere in the form of NO_x. These values are considerably higher than the ones based on the EMEP/EEA guidebook (Table 3.10 and A1.8; EMEP/EEA 2019), especially for liquid/slurry systems which in 2020 account for about 70 % of the total N flow through manure storage (Kupper et al. 2022). In this context the management systems “anaerobic digestion” is treated as liquid/slurry system.

The resulting NH_3 and NO_x emission factors for the livestock categories are listed in Table 5-9 and Table 5-10. Each emission factor reflects the sum of the emissions from animal housing and manure storage. The emissions resulting from the application of manure to soils and from grazing are reported separately under category 3Da2a and 3Da3 and are not included in the emission factors listed in Table 5-9 and Table 5-10, but are given in the tables of chp. 5.3.2.

Table 5-9 Time series of NH_3 Emission factors for livestock categories. Note that the emissions from grazing and for the application of manure are not included in these emission factors (see chp. 5.3.2).

NH_3 emission factors		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	kg/animal	11.9	12.6	15.9	17.5	17.5
3B1b	Non-dairy cattle	kg/animal	11.8	12.9	14.4	16.2	16.1
3B1c	Young cattle	kg/animal	4.8	5.0	5.3	5.6	5.7
3B2	Sheep	kg/animal	1.3	1.3	1.1	1.0	1.2
3B3	Swine	kg/animal	3.5	3.7	3.9	3.8	3.4
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	NO	NO	2.1	1.8	2.0
3B4c	Deer	kg/animal	3.4	3.7	3.3	3.1	3.6
3B4d	Goats	kg/animal	2.3	2.3	2.1	1.9	1.9
3B4e	Horses	kg/animal	9.1	9.1	8.3	8.0	8.1
3B4f	Mules and asses	kg/animal	3.3	3.3	3.2	3.0	2.9
3B4gi	Layers	kg/animal	0.32	0.31	0.27	0.26	0.22
3B4gii	Broilers	kg/animal	0.09	0.086	0.084	0.088	0.080
3B4giii	Turkey	kg/animal	0.31	0.31	0.29	0.30	0.28
3B4giv	Growers	kg/animal	0.17	0.16	0.13	0.11	0.083
3B4giv	Other poultry	kg/animal	0.17	0.17	0.17	0.17	0.17
3B4hi	Rabbits	kg/animal	0.23	0.23	0.23	0.23	0.23
3B4hii	Bisons	kg/animal	NO	6.8	7.0	6.4	6.3

NH_3 emission factors		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3B1a	Dairy cattle	kg/animal	18.1	18.3	18.5	18.6	18.8	18.9	19.1	19.1	19.1	19.1
3B1b	Non-dairy cattle	kg/animal	16.3	16.4	16.5	16.3	16.1	15.9	15.7	15.7	15.7	15.7
3B1c	Young cattle	kg/animal	5.9	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9
3B2	Sheep	kg/animal	1.2	1.2	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2
3B3	Swine	kg/animal	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	1.9	1.9	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9
3B4c	Deer	kg/animal	3.5	3.4	3.3	3.4	3.4	3.5	3.5	3.5	3.5	3.6
3B4d	Goats	kg/animal	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.8	1.7
3B4e	Horses	kg/animal	8.2	8.2	8.3	8.3	8.2	8.2	8.2	8.2	8.2	8.2
3B4f	Mules and asses	kg/animal	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
3B4gi	Layers	kg/animal	0.20	0.20	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18
3B4gii	Broilers	kg/animal	0.070	0.067	0.063	0.063	0.064	0.064	0.064	0.064	0.064	0.064
3B4giii	Turkey	kg/animal	0.30	0.31	0.32	0.30	0.29	0.28	0.26	0.26	0.26	0.26
3B4giv	Growers	kg/animal	0.079	0.077	0.076	0.074	0.073	0.072	0.070	0.070	0.070	0.070
3B4giv	Other poultry	kg/animal	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16
3B4hi	Rabbits	kg/animal	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
3B4hii	Bisons	kg/animal	6.2	6.1	6.1	6.1	6.0	7.9	7.8	7.7	7.7	7.7

Table 5-10 Time series of NO_x emission factors for livestock categories.

NO_x emisson factors		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	g/animal	859	829	773	742	730
3B1b	Non-dairy cattle	g/animal	635	657	558	535	518
3B1c	Young cattle	g/animal	318	317	282	267	268
3B2	Sheep	g/animal	171	174	150	142	170
3B3	Swine	g/animal	94	92	73	63	61
3B4a	Buffalos	g/animal	IE	IE	IE	IE	IE
3B4b	Camels and llamas	g/animal	NO	NO	260	227	254
3B4c	Deer	g/animal	423	463	411	388	453
3B4d	Goats	g/animal	317	314	280	264	265
3B4e	Horses	g/animal	624	623	569	547	546
3B4f	Mules and asses	g/animal	229	229	223	209	202
3B4gi	Layers	g/animal	2.3	2.3	2.2	2.4	2.4
3B4gii	Broilers	g/animal	1.3	1.3	1.3	1.4	1.5
3B4giii	Turkey	g/animal	4.6	4.6	4.5	4.5	4.5
3B4giv	Growers	g/animal	1.1	1.1	1.1	1.0	1.0
3B4giv	Other poultry	g/animal	1.8	1.8	1.8	1.8	1.8
3B4hi	Rabbits	g/animal	16	16	16	16	16
3B4hii	Bisons	g/animal	NO	433	446	407	399

NO_x emisson factors		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3B1a	Dairy cattle	g/animal	723	720	717	715	713	711	707	705	704	703
3B1b	Non-dairy cattle	g/animal	506	502	498	498	497	497	496	494	493	492
3B1c	Young cattle	g/animal	262	260	259	257	255	253	251	250	248	248
3B2	Sheep	g/animal	161	156	152	153	156	157	159	159	159	159
3B3	Swine	g/animal	60	60	60	60	60	60	60	60	60	60
3B4a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	g/animal	243	236	229	228	230	230	233	234	233	233
3B4c	Deer	g/animal	434	423	412	419	424	431	436	437	437	441
3B4d	Goats	g/animal	272	274	269	263	258	253	248	248	248	248
3B4e	Horses	g/animal	556	560	565	562	558	555	552	552	553	552
3B4f	Mules and asses	g/animal	204	204	205	206	208	210	211	211	211	211
3B4gi	Layers	g/animal	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
3B4gii	Broilers	g/animal	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3B4giii	Turkey	g/animal	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
3B4giv	Growers	g/animal	0.98	0.98	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96
3B4giv	Other poultry	g/animal	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
3B4hi	Rabbits	g/animal	16	16	16	16	16	16	16	16	16	16
3B4hii	Bisons	g/animal	393	386	385	387	383	505	495	492	490	490

For all cattle categories country specific NMVOC emission factors are used based on a comprehensive study in which emission measurements were carried out in an experimental dairy housing (Schrade et al. 2024). NMVOC emissions from dairy cattle with and without silage feeding were measured during summer, winter and transitional season. For a representative determination of emissions from silage, measurements were carried out with three different silage rations. Based on these measurements, NMVOC emission factors were derived for dairy cattle with and without silage for the lowlands and mountain area, respectively, see Table 5-11. A distinction was also made between the summer and winter feeding period, as there are clear differences between the proportions of dairy cows with and without silage feeding in the two feeding periods. For silage feeding, emission factors (weighted for feeding periods) of 24.0 kg/animal and 21.9 kg/animal resulted for dairy cattle in the lowlands and the mountain area, respectively. The values are higher than the default Tier 1 emission factor of 17.937 provided in the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 3B Manure management, Table 3.4). It should be noted that the weight of Swiss dairy cattle (660 kg, Richner and Sinaj 2017) is higher than the one of dairy cattle in EMEP/EEA (2019) (600 kg, chp. 3B, Table A1.6). On the other hand, the emission factors without silage feeding (weighted for feeding periods) of 1.1 kg/animal and 0.9 kg/animal for the lowlands and the mountain area, respectively, are considerably lower than the one given in EMEP/EEA (2019) (8.047 kg/animal). For non-dairy cattle the same emission factors are assumed whereas for young cattle categories, the emission factors were scaled with the ratio of the gross energy intake of the respective categories related to the one of dairy cattle. For the calculation of NMVOC emissions, the proportion of animals kept in the lowlands and mountain area as well as their proportion with and without silage feeding were taken into account, see Table 5-12. The proportions are derived from the on-farm surveys on farm and manure management conducted by HAFL (2002, 2007, 2010, 2015 and 2019) in connection with the AGRAMMON model (Kupper and Häni 2022). The relatively high proportion of dairy cattle that is fed without silage in Switzerland is due to the fact that unpasteurised milk is used for hard cheese production and that farms producing milk for hard cheese production are not allowed to produce and use silage for all cattle. Between 1990 and 2019, the share of dairy cattle receiving silage increased almost continuously, e.g. in the lowlands from 37 % to 61 %. For all livestock categories other than cattle, the NMVOC emission factors are based on default Tier 1 emission factors (EMEP/EEA 2019, chp. 3B Manure management, Table 3.4). As the livestock category swine comprises of five categories, namely boars, dry sows, nursing sows (including suckling piglets), fattening pigs and weaned piglets, the NMVOC emission factor is an implied factor based on the default Tier 1 emission factors for swine (sows) and swine (finishing pigs) and also takes into account the empty periods for fattening pigs. The resulting NMVOC emission factors for cattle categories and swine as well as the default emission factors for all other animal categories are given in Table 5-13.

Table 5-11 NMVOC emission factors of dairy cattle with and without silage feeding derived by Schrade et al. 2024 for the Swiss lowlands and mountain area.

3B1 Dairy cattle	**Silage**	**w/o Silage**
NMVOC emission factors	kg/animal	kg/animal
Lowlands, summer feeding	26.5	1.3
Lowlands, winter feeding	20.6	0.8
Lowlands, weighted for feeding periods	24.0	1.1
Mountain area, summer feeding	24.5	1.1
Mountain area, winter feeding	19.3	0.7
Mountain area, weighted for feeding periods	21.9	0.9

Table 5-12 Time series of the share of cattle categories kept in the lowlands as well as of animals receiving silage feeding in the lowlands and mountain area, respectively.

	1990	1995	2000	2005	2010
3B1a Dairy cattle					
Lowlands	62%	61%	60%	60%	60%
Silage feeding, lowlands	37%	41%	45%	53%	56%
Silage feeding, mountain area	30%	31%	33%	38%	39%
3B1b Non-dairy cattle					
Lowlands	62%	61%	58%	58%	58%
Silage feeding, lowlands	95%	95%	95%	95%	95%
Silage feeding, mountain area	95%	95%	95%	95%	95%
3B1c Young cattle					
Lowlands	51%	51%	55%	56%	56%
Silage feeding, lowlands	48%	52%	56%	64%	70%
Silage feeding, mountain area	43%	46%	43%	47%	58%

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3B1a Dairy cattle										
Lowlands	60%	60%	60%	60%	60%	60%	59%	59%	59%	59%
Silage feeding, lowlands	56%	56%	56%	57%	59%	60%	61%	61%	61%	61%
Silage feeding, mountain area	41%	42%	43%	42%	41%	41%	40%	40%	40%	40%
3B1b Non-dairy cattle										
Lowlands	57%	57%	57%	56%	56%	56%	56%	56%	56%	56%
Silage feeding, lowlands	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Silage feeding, mountain area	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
3B1c Young cattle										
Lowlands	56%	57%	57%	57%	57%	57%	57%	57%	57%	57%
Silage feeding, lowlands	72%	73%	73%	73%	73%	73%	73%	73%	73%	73%
Silage feeding, mountain area	59%	60%	60%	59%	59%	59%	59%	59%	59%	59%

Table 5-13 Time series of NMVOC emission factors for livestock categories.

NMVOC emission factors		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	kg/animal	8.2	8.8	9.6	11	12
3B1b	Non-dairy cattle	kg/animal	22	22	22	22	22
3B1c	Young cattle	kg/animal	4.6	4.7	4.6	4.8	5.2
3B2	Sheep	kg/animal	0.17	0.17	0.17	0.17	0.17
3B3	Swine	kg/animal	0.57	0.57	0.55	0.55	0.55
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	NO	NO	0.27	0.27	0.27
3B4c	Deer	kg/animal	0.045	0.045	0.045	0.045	0.045
3B4d	Goats	kg/animal	0.54	0.54	0.54	0.54	0.54
3B4e	Horses	kg/animal	4.3	4.3	4.3	4.3	4.3
3B4f	Mules and asses	kg/animal	1.5	1.5	1.5	1.5	1.5
3B4gi	Layers	kg/animal	0.17	0.17	0.17	0.17	0.17
3B4gii	Broilers	kg/animal	0.11	0.11	0.11	0.11	0.11
3B4giii	Turkey	kg/animal	0.49	0.49	0.49	0.49	0.49
3B4giv	Growers	kg/animal	0.17	0.17	0.17	0.17	0.17
3B4giv	Other poultry	kg/animal	0.49	0.49	0.49	0.49	0.49
3B4hi	Rabbits	kg/animal	0.059	0.059	0.059	0.059	0.059
3B4hii	Bisons	kg/animal	NO	3.6	3.6	3.6	3.6

NMVOC emission factors		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3B1a	Dairy cattle	kg/animal	12	12	12	12	12	12	12	12	12	12
3B1b	Non-dairy cattle	kg/animal	22	22	22	22	22	22	22	22	22	22
3B1c	Young cattle	kg/animal	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.1	5.2
3B2	Sheep	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
3B3	Swine	kg/animal	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.54	0.55	0.55
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
3B4c	Deer	kg/animal	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
3B4d	Goats	kg/animal	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
3B4e	Horses	kg/animal	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
3B4f	Mules and asses	kg/animal	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3B4gi	Layers	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
3B4gii	Broilers	kg/animal	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
3B4giii	Turkey	kg/animal	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
3B4giv	Growers	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
3B4giv	Other poultry	kg/animal	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
3B4hi	Rabbits	kg/animal	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
3B4hii	Bisons	kg/animal	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6

The particulate matter emission factors (PM2.5, PM10, and TSP) are listed in Table 5-14. They are based on a comprehensive literature study by Bühler and Kupper (2018). The emission factors of all cattle categories were derived from literature data and expert judgment distinguishing loose- and tied-housing systems. For dairy cattle, the emission factors are based on PM10 emission measurements in a loose-housing system in Switzerland (Schrade 2009). For all livestock categories other than cattle, except for fattening pigs (TSP) and sheeps and goats (PM2.5 and PM10) default Tier 1 emission factors from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 3B, Table 3.5) are used. For the mentioned exceptions other literature values are assumed. For camels/llamas, deer and bisons the same emission factors as for goats are assumed whereas for rabbits the emission factors of fur animals are applied. All these emission factors are kept constant over the entire time series, except for the emission factors of the aggregated category swine. For the animals outside agriculture, i.e. sheeps, goats, horses, mules and asses the same emission factors as for the corresponding agricultural animals are applied (see chp. 7.2.2).

Table 5-14 Emission factors of PM2.5, PM10 and TSP for livestock categories in year 2022 (based on measurements in Switzerland, literature data and EMEP/EEA 2019).

Emmission factors		Unit	PM2.5	PM10	TSP
3B1a	Dairy cattle	g/animal	43	177	609
3B1b	Non-dairy cattle	g/animal	22	92	314
3B1c	Young cattle	g/animal	22	91	313
3B2	Sheep	g/animal	2	50	140
3B3	Swine	g/animal	4.5	101	439
3B4a	Buffalos	g/animal	IE	IE	IE
3B4b	Camels and llamas	g/animal	2	50	140
3B4c	Deer	g/animal	2	50	140
3B4d	Goats	g/animal	2	50	140
3B4e	Horses	g/animal	140	220	480
3B4f	Mules and asses	g/animal	100	160	340
3B4gi	Layers	g/animal	3	40	190
3B4gii	Broilers	g/animal	2	20	40
3B4giii	Turkey	g/animal	20	110	110
3B4giv	Growers	g/animal	2	20	40
3B4giv	Other poultry	g/animal	25	190	190
3B4hi	Rabbits	g/animal	4	8	18
3B4hii	Bisons	g/animal	2	50	140

Activity data (3B)

The number of animals in the different livestock categories (SBV 2023, FSO 2023a) for the time period 1990 to 2022 is shown in Table 5-15. The figures represent harmonised livestock numbers coming from various sources since 1990. The methodology of the harmonisation, which was a joint effort of the Agroscope Reckenholz Tänikon Research Station (ART) and the Swiss College of Agriculture (SHL) in 2011 for the 1990-2010 time series, is documented in ART/SHL (2012). The livestock category swine comprises the five categories boars, dry sows, nursing sows (including suckling piglets), fattening pigs (> 25 kg) and weaned piglets (up to 25 kg). Because the official livestock census statistics are based on a key date (1st May until 2014, 1st January since 2015), the Federal Office of Statistics provided a dataset with average livestock numbers over the whole year, as suggested by the EMEP/EEA guidebook (EMEP/EEA 2019). Thus, for fattening pigs over 25 kg and broilers also empty periods were taken into account. Data for horses, mules and asses were derived from background data of the gross nutrient balance of the Swiss Federal Statistical Office (FSO 2023b).

Table 5-15 Time series of animal numbers for livestock categories (in thousand animals).

Activity data 3B		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	1'000 animals	783	740	669	621	589
3B1b	Non-dairy cattle	1'000 animals	12	23	45	78	111
3B1c	Young cattle	1'000 animals	1'060	986	874	856	891
3B2	Sheep	1'000 animals	395	387	421	446	434
3B3	Swine	1'000 animals	1'965	1'739	1'670	1'744	1'750
3B4a	Buffalos	1'000 animals	IE	IE	IE	IE	IE
3B4b	Camels and llamas	1'000 animals	NO	NO	1.0	3.1	6.1
3B4c	Deer	1'000 animals	0.17	1.4	2.8	3.8	5.5
3B4d	Goats	1'000 animals	68	53	62	74	83
3B4e	Horses	1'000 animals	28	41	50	55	62
3B4f	Mules and asses	1'000 animals	5.9	7.6	12	16	20
3B4gi	Layers	1'000 animals	3'083	2'118	2'150	2'189	2'438
3B4gii	Broilers	1'000 animals	3'392	3'637	3'985	5'711	7'184
3B4giii	Turkey	1'000 animals	95	170	173	132	58
3B4giv	Growers	1'000 animals	719	714	832	868	926
3B4giv	Other poultry	1'000 animals	22	17	21	11	23
3B4hi	Rabbits	1'000 animals	61	41	28	25	35
3B4hii	Bisons	1'000 animals	NO	0.10	0.26	0.37	0.51

Activity data 3B		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3B1a	Dairy cattle	1'000 animals	587	587	583	576	569	564	555	546	546	543
3B1b	Non-dairy cattle	1'000 animals	117	118	118	121	123	125	128	131	135	138
3B1c	Young cattle	1'000 animals	854	857	853	859	852	854	842	837	833	845
3B2	Sheep	1'000 animals	409	403	395	397	398	403	400	398	398	403
3B3	Swine	1'000 animals	1'615	1'631	1'605	1'553	1'546	1'501	1'447	1'449	1'470	1'475
3B4a	Buffalos	1'000 animals	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	1'000 animals	5.9	6.1	6.4	6.5	6.6	6.7	6.6	6.5	6.5	6.7
3B4c	Deer	1'000 animals	5.7	5.7	6.0	6.0	6.0	6.4	6.6	6.6	6.6	6.7
3B4d	Goats	1'000 animals	85	85	84	85	88	91	92	90	91	92
3B4e	Horses	1'000 animals	57	57	55	56	56	46	47	47	47	48
3B4f	Mules and asses	1'000 animals	20	20	20	20	21	34	34	33	33	33
3B4gi	Layers	1'000 animals	2'589	2'665	2'822	3'056	3'174	3'371	3'486	3'854	3'867	3'893
3B4gii	Broilers	1'000 animals	8'126	8'506	8'614	9'064	8'857	9'430	9'593	10'097	10'470	10'672
3B4giii	Turkey	1'000 animals	55	57	49	71	77	84	75	88	83	82
3B4giv	Growers	1'000 animals	1'055	1'196	1'033	959	1'084	1'078	1'242	1'150	1'177	1'300
3B4giv	Other poultry	1'000 animals	20	22	23	30	16	20	21	24	25	28
3B4hi	Rabbits	1'000 animals	28	27	25	25	22	22	21	19	17	16
3B4hii	Bisons	1'000 animals	0.50	0.53	0.56	0.56	0.57	0.54	0.46	0.46	0.43	0.40

5.2.3 Category-specific recalculations 3B Manure management

- 3B1: The NMVOC emission factors were revised for all cattle categories for the years 1990–2021. A distinction is now made between the summer and winter feeding periods, as the proportions of animals fed silage are different in the two periods.

5.3 Source category 3D – Crop production and agricultural soils

5.3.1 Source category description of 3D Crop production and agricultural soils

This chapter contains direct and indirect emissions from agricultural soils, from all fertilisers (mineral (inorganic N-) fertiliser, sewage sludge, compost and other residue fertilisers) and animal manure applied on these soils as well as excretions during grazing.

Note that the application of HCB as a fungicide is prohibited in Switzerland since 1972 and its application as a seed-dressing agent since 1978 (LUBW 1995). Emissions due to potential HCB impurities or by-products in certain pesticides (3Df) are not estimated.

Table 5-16 Specification of source category 3D Agricultural Soils.

3D	Source category	Specification
3Da1	Inorganic N-fertilizers	Application of urea-containing fertilizers and other inorganic fertilizers
3Da2a	Livestock manure applied to soils	Application of livestock manure (incl. digestate from agricultural biogas plants) to soils (dairy cattle, non-dairy cattle, sheep, swine, buffalos, goats, horses, mules/asses, laying hens, broilers, turkeys, growers, other poultry, other animals)
3Da2b	Sewage sludge applied to soils	Application of sewage sludge to soils (NO after 2009)
3Da2c	Other organic fertilisers applied to soils (including compost)	Application of compost derived from organic residues (incl. liquid and solid digestate from non-agricultural biogas plants)
3Da3	Urine and dung deposited by grazing livestock	Deposition of urine and dung by grazing livestock
3De	Cultivated crops	For particulate matter emissions: Soil cultivation and crop harvesting (operation of tractors and machinery). For NMVOC emissions: Crop production, differentiated for cropland, grassland and summering pastures

Table 5-17 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 3D Agricultural Soils.

NFR code	Source category	Pollutant	Identification criteria
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	L2, T2
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	L2, T1, T2
3Da2a	Animal manure applied to soils	NOx	L2, T1, T2
3Da2a	Animal manure applied to soils	NH3	L1, L2, T1, T2
3Da2b	Sewage sludge applied to soils	NH3	T1
3Da2c	Other organic fertilisers applied to soils (including compost)	NOx	T2
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	T1, T2
3Da3	Urine and dung deposited by grazing animals	NOx	L2, T2
3Da3	Urine and dung deposited by grazing animals	NH3	L2, T1, T2
3De	Cultivated crops	PM10	L1, L2, T1, T2

5.3.2 Methodological issues of 3D Crop production and agricultural soils

Methodology (3D)

The emissions are calculated by Tier 3 (3Da2a, 3Da3 (NH_3)), Tier 2 (3Da1, 3De) and Tier 1 (3Da2b, 3Da2c, 3Da3 (NO_x)) methods based on the decision tree in Fig. 3.1 in chapter 3D Crop production and agricultural soils of the EMEP/EEA guidebook (EMEP/EEA 2019).

- 3Da1: For the application of nitrogen containing inorganic fertilisers the Tier 2 method and NH_3 emission factors according to the EMEP/EEA guidebook (EMEP/EEA 2019) were used. In 3Da1 only the agricultural use of inorganic fertilisers is reported, while private use is reported under 6Ac.
- 3Da2a: As described in chapter 5.2.2, emissions from livestock manure management are calculated with livestock specific emission factors multiplied by the number of livestock. Both the emission factors for 3B and 3D are generated from stratified samples considering different farm types, regions, height above sea level and application techniques (Tier 3). This category also includes emissions from digestate originating from agricultural biogas plants (at least 80 % of the substrate is livestock manure).
- 3Da2b/3Da2c: NH_3 and NO_x emissions from field application of sewage sludge and compost (including solid and liquid digestate from non-agricultural sources) derived from or-

ganic residues are included in this category (Tier 1 except for NH_3 from 3Da2c). For NH_3 emissions from 3Da2c, a Tier 2 method based on Kupper et al. (2022) is used. In Switzerland, the application of sewage sludge as fertiliser is prohibited since 2006 (with some exceptions in certain cantons until the end of 2008).

- 3Da3: NH_3 emission from urine and dung deposited by grazing livestock are determined by multiplying animal specific emission factors (see chapter 5.2.2) with the number of animals. For NO_x emissions, the Tier 1 method and emission factors described in the EMEP/EEA guidebook (EMEP/EEA 2019) were used.
- 3De: In this source category, NMVOC and particulate matter (PM2.5, PM10 and TSP) emissions from agricultural soils are reported based on a study by Bühler and Kupper (2018). The NMVOC emissions from agricultural soils are estimated with a Tier 2 approach according to the EMEP/EEA guidebook (EMEP/EEA 2016, unchanged in EMEP/EEA 2019) differentiating three agricultural areas, i.e. cropland, grassland and summering pastures. The particulate matter emissions from soil cultivation and crop harvesting originate at the sites at which the tractors and other machinery operate and are thought to consist of a mixture of organic fragments from the crop and soil mineral and organic matter. There is considerable settling of dust close to the sources and washing out of fine particles by large particles. Field operations may also lead to the resuspension of dust that has already settled (reentrainment). For the emission calculation it was differentiated between cropland and grassland.

Emission factors (3Da)

For fertiliser, default Tier 2 NH_3 emission factors from the EMEP/EEA guidebook (EMEP/EEA 2019, 3D Crop production and agricultural soils, Table 3.2) were used for the whole time series. The climate zone for Switzerland is "cool". Based on official fertiliser trade statistics (Agricura 2022) and an assessment of soil pH based on the Swiss agricultural soil use capability map (Frei et al. 1980), 54 % of fertilisers are used on soils with pH > 7.0 and 46 % on soils with pH > 7.0.

NH_3-emission factors for 3Da2c are based on Kupper et al. (2022; chp. 7.4.2). The emission factors used were 60 % of TAN for liquid residues and 80 % of TAN for solid residues.

Table 5-18 shows NH_3 and NO_x emission factors for nitrogen containing fertiliser, sewage sludge and compost applied to soils. For other synthetic N fertilisers, they are weighted mean factors. A fertiliser-induced emission (FIE) value of 0.55 % from Stehfest and Bouwman (2006) is used for NO_x emission factors, both for mineral and organic fertiliser. This means that 0.0055/14*46 kg NO_x (as NO_2) is emitted per ton of nitrogen applied.

Table 5-18 NH_3 and NO_x emission factors 2022 for nitrogen containing fertiliser.

Emission factors		Unit	NO_x	NH_3
3Da1	Urea containing fertiliser	kg / tN	18	159
3Da1	Other synthetic N-fertiliser	kg / tN	18	35
3Da2c	Other organic fertiliser	kg / tN	18	151

Emission factors for the application of animal manure are displayed in Table 5-19 and Table 5-20. They are based on the livestock category specific N flow calculations with AGRAMMON (see chapter 5.2.2).

Table 5-19 Time series of NH_3 emission factors for the application of animal manure to soils (3Da2a).

NH_3 emission factors		Unit	1990	1995	2000	2005	2010
3Da2a1a	Dairy cattle	kg/animal	26.0	25.7	23.1	23.0	22.6
3Da2a1b	Non-dairy cattle	kg/animal	13.4	12.7	11.4	12.0	12.3
3Da2a1c	Young cattle	kg/animal	6.6	6.5	5.6	5.4	5.3
3Da2a2	Sheep	kg/animal	0.22	0.23	0.19	0.20	0.25
3Da2a3	Swine	kg/animal	3.3	3.1	2.0	1.6	1.4
3Da2a4a	Buffalos	kg/animal	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	kg/animal	NO	NO	0.23	0.19	0.23
3Da2a4c	Deer	kg/animal	0.38	0.41	0.36	0.33	0.40
3Da2a4d	Goats	kg/animal	0.44	0.44	0.33	0.50	0.41
3Da2a4e	Horses	kg/animal	1.8	1.8	1.6	1.5	1.5
3Da2a4f	Mules and asses	kg/animal	0.65	0.65	0.62	0.61	0.65
3Da2a4gi	Layers	kg/animal	0.059	0.061	0.067	0.075	0.087
3Da2a4gii	Broilers	kg/animal	0.063	0.064	0.053	0.054	0.063
3Da2a4giii	Turkey	kg/animal	0.22	0.22	0.21	0.18	0.17
3Da2a4giv	Growers	kg/animal	0.023	0.027	0.032	0.032	0.035
3Da2a4giv	Other poultry	kg/animal	0.075	0.075	0.070	0.054	0.077
3Da2a4hi	Rabbits	kg/animal	0.037	0.037	0.036	0.035	0.035
3Da2a4hii	Bisons	kg/animal	NO	0.84	0.83	0.75	0.73

NH_3 emission factors		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3Da2a1a	Dairy cattle	kg/animal	21.8	21.5	21.3	21.3	21.2	21.2	21.2	21.2	21.2	21.2
3Da2a1b	Non-dairy cattle	kg/animal	12.0	11.9	11.8	11.7	11.6	11.5	11.5	11.5	11.5	11.5
3Da2a1c	Young cattle	kg/animal	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
3Da2a2	Sheep	kg/animal	0.22	0.21	0.20	0.20	0.21	0.21	0.22	0.22	0.22	0.22
3Da2a3	Swine	kg/animal	1.4	1.4	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4
3Da2a4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	kg/animal	0.21	0.21	0.20	0.20	0.20	0.19	0.19	0.20	0.19	0.19
3Da2a4c	Deer	kg/animal	0.38	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.37
3Da2a4d	Goats	kg/animal	0.43	0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.44
3Da2a4e	Horses	kg/animal	1.5	1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5
3Da2a4f	Mules and asses	kg/animal	0.62	0.61	0.60	0.62	0.64	0.65	0.67	0.67	0.67	0.67
3Da2a4gi	Layers	kg/animal	0.093	0.095	0.096	0.096	0.095	0.094	0.094	0.094	0.094	0.094
3Da2a4gii	Broilers	kg/animal	0.054	0.051	0.048	0.049	0.049	0.049	0.050	0.050	0.050	0.050
3Da2a4giii	Turkey	kg/animal	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15
3Da2a4giv	Growers	kg/animal	0.038	0.039	0.040	0.037	0.033	0.030	0.027	0.027	0.027	0.027
3Da2a4giv	Other poultry	kg/animal	0.069	0.067	0.064	0.064	0.064	0.064	0.065	0.065	0.065	0.065
3Da2a4hi	Rabbits	kg/animal	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
3Da2a4hii	Bisons	kg/animal	0.72	0.71	0.70	0.71	0.70	0.92	0.90	0.90	0.89	0.89

Table 5-20 Time series of NO_x emission factors for the application of animal manure to soils (3Da2a).

NO_x emission factors		Unit	1990	1995	2000	2005	2010
3Da2a1a	Dairy cattle	g/animal	1443	1427	1322	1305	1347
3Da2a1b	Non-dairy cattle	g/animal	875	859	761	785	818
3Da2a1c	Young cattle	g/animal	416	414	360	341	347
3Da2a2	Sheep	g/animal	68	69	60	57	68
3Da2a3	Swine	g/animal	200	192	136	110	112
3Da2a4a	Buffalos	g/animal	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	g/animal	NO	NO	102	89	100
3Da2a4c	Deer	g/animal	166	181	161	152	178
3Da2a4d	Goats	g/animal	127	126	112	107	107
3Da2a4e	Horses	g/animal	527	526	481	462	460
3Da2a4f	Mules and asses	g/animal	194	194	189	178	171
3Da2a4gi	Layers	g/animal	7.8	7.8	8.0	8.8	9.9
3Da2a4gii	Broilers	g/animal	5.7	5.7	5.7	6.2	6.7
3Da2a4giii	Turkey	g/animal	20	20	20	20	20
3Da2a4giv	Growers	g/animal	3.5	3.6	4.0	3.9	4.1
3Da2a4giv	Other poultry	g/animal	7.4	7.4	7.1	7.1	7.1
3Da2a4hi	Rabbits	g/animal	13	13	13	13	13
3Da2a4hii	Bisons	g/animal	NO	359	369	337	330

NO_x emission factors		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3Da2a1a	Dairy cattle	g/animal	1354	1356	1359	1357	1355	1353	1351	1351	1351	1351
3Da2a1b	Non-dairy cattle	g/animal	815	814	813	810	806	803	799	799	799	799
3Da2a1c	Young cattle	g/animal	351	352	352	350	348	347	346	345	344	343
3Da2a2	Sheep	g/animal	65	63	61	61	62	63	64	64	64	64
3Da2a3	Swine	g/animal	110	110	110	111	110	110	111	111	111	111
3Da2a4a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	g/animal	96	93	90	89	90	90	91	92	91	91
3Da2a4c	Deer	g/animal	170	166	162	164	166	169	171	171	171	172
3Da2a4d	Goats	g/animal	110	111	109	107	105	103	101	101	101	101
3Da2a4e	Horses	g/animal	468	471	476	473	470	467	464	464	465	464
3Da2a4f	Mules and asses	g/animal	172	172	173	174	176	178	179	179	179	179
3Da2a4gi	Layers	g/animal	10	10	10	10	10	10	10	10	10	10
3Da2a4gii	Broilers	g/animal	5.9	5.6	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3
3Da2a4giii	Turkey	g/animal	19	19	19	19	20	20	20	20	20	20
3Da2a4giv	Growers	g/animal	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
3Da2a4giv	Other poultry	g/animal	7.0	7.0	7.0	7.0	7.1	7.1	7.1	7.1	7.1	7.1
3Da2a4hi	Rabbits	g/animal	13	13	13	13	13	13	13	13	13	13
3Da2a4hii	Bisons	g/animal	325	320	319	320	317	418	410	408	405	405

In the following, Table 5-21 and Table 5-22 list the emission factors for NH_3 and NO_x for N excretion on pasture and paddock during grazing. They are based on the livestock category specific N flow calculations with AGRAMMON (see chapter 5.2.2). The considerable increase between 1990 and 2010 (e.g. dairy cattle, young cattle (calves), sheep, goats, horses) was a consequence of a strong increase of grazing linked to animal welfare incentives.

Table 5-21 Time series of NH_3 emission factors for N excretion during grazing (3Da3) for different of livestock categories.

NH_3 emission factors		**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
3Da31a	Dairy cattle	kg/animal	0.47	0.55	0.87	1.0	1.1
3Da31b	Non-dairy cattle	kg/animal	1.4	1.4	1.6	1.5	1.4
3Da31c	Young cattle	kg/animal	0.29	0.29	0.44	0.47	0.45
3Da32	Sheep	kg/animal	0.14	0.14	0.21	0.23	0.20
3Da33	Swine	kg/animal	NO	NO	0.004	0.010	0.0046
3Da34a	Buffalos	kg/animal	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	kg/animal	NO	NO	0.38	0.36	0.29
3Da34c	Deer	kg/animal	0.43	0.47	0.59	0.61	0.52
3Da34d	Goats	kg/animal	0.092	0.091	0.17	0.19	0.19
3Da34e	Horses	kg/animal	0.34	0.34	0.54	0.63	0.64
3Da34f	Mules and asses	kg/animal	0.12	0.12	0.15	0.20	0.22
3Da34gi	Layers	kg/animal	NO	0.002	0.014	0.024	0.028
3Da34gii	Broilers	kg/animal	NO	0.00080	0.0012	0.0021	0.0010
3Da34giii	Turkey	kg/animal	NO	0.0028	0.016	0.017	0.014
3Da34giv	Growers	kg/animal	NO	0.0010	0.0010	0.0015	0.0029
3Da34giv	Other poultry	kg/animal	NO	NO	0.0063	0.0046	0.0057
3Da34hi	Rabbits	kg/animal	NO	NO	NO	NO	NO
3Da34hii	Bisons	kg/animal	NO	0.66	0.84	0.85	0.79

NH_3 emission factors		**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
3Da31a	Dairy cattle	kg/animal	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3Da31b	Non-dairy cattle	kg/animal	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5
3Da31c	Young cattle	kg/animal	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
3Da32	Sheep	kg/animal	0.22	0.23	0.23	0.23	0.23	0.22	0.22	0.22	0.22	0.22
3Da33	Swine	kg/animal	0.0027	0.0021	0.0015	0.0013	0.0012	0.0010	0.00087	0.00087	0.00087	0.00087
3Da34a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	kg/animal	0.33	0.34	0.35	0.34	0.34	0.34	0.33	0.34	0.33	0.33
3Da34c	Deer	kg/animal	0.59	0.61	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
3Da34d	Goats	kg/animal	0.20	0.20	0.20	0.21	0.21	0.22	0.23	0.23	0.23	0.23
3Da34e	Horses	kg/animal	0.60	0.59	0.57	0.59	0.60	0.61	0.62	0.62	0.62	0.62
3Da34f	Mules and asses	kg/animal	0.22	0.22	0.21	0.21	0.20	0.20	0.19	0.19	0.19	0.19
3Da34gi	Layers	kg/animal	0.028	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
3Da34gii	Broilers	kg/animal	0.00072	0.00064	0.00055	0.00065	0.00075	0.00084	0.00094	0.00094	0.00094	0.00094
3Da34giii	Turkey	kg/animal	0.019	0.020	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
3Da34giv	Growers	kg/animal	0.0025	0.0023	0.0022	0.0026	0.0030	0.0034	0.0038	0.0038	0.0038	0.0038
3Da34giv	Other poultry	kg/animal	0.0072	0.0077	0.0082	0.0084	0.0085	0.0086	0.0088	0.0088	0.0088	0.0088
3Da34hi	Rabbits	kg/animal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da34hii	Bisons	kg/animal	0.79	0.78	0.79	0.78	0.76	0.99	0.96	0.95	0.95	0.95

Table 5-22 Time series of NO_x emission factors for N excretion during grazing (3Da3) for different livestock categories.

NO_x emission factors		Unit	1990	1995	2000	2005	2010
3Da31a	Dairy Cattle	g/animal	150	176	280	333	342
3Da31b	Non dairy Cattle	g/animal	455	455	532	482	451
3Da31c	Young Cattle	g/animal	94	95	144	152	146
3Da32	Sheep	g/animal	41	41	63	69	59
3Da33	Swine	g/animal	NO	NO	0.38	1.1	0.49
3Da34a	Buffalos	g/animal	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	g/animal	NO	NO	112	107	87
3Da34c	Deer	g/animal	129	141	177	183	155
3Da34d	Goats	g/animal	27	27	49	56	57
3Da34e	Horses	g/animal	101	100	162	187	189
3Da34f	Mules and Asses	g/animal	37	37	44	59	67
3Da34gi	Layers	g/animal	NO	0.076	0.51	0.86	1.00
3Da34gii	Broilers	g/animal	NO	0.028	0.043	0.076	0.035
3Da34giii	Turkey	g/animal	NO	0.099	0.56	0.61	0.48
3Da34giv	Growers	g/animal	NO	0.036	0.034	0.053	0.104
3Da34giv	Other poultry	g/animal	NO	NO	0.22	0.16	0.20
3Da34hi	Rabbits	g/animal	NO	NO	NO	NO	NO
3Da34hii	Bisons	g/animal	NO	196	252	252	236

NO_x emission factors		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3Da31a	Dairy Cattle	g/animal	335	333	331	333	334	335	337	337	337	337
3Da31b	Non dairy Cattle	g/animal	450	449	449	456	462	469	476	476	476	476
3Da31c	Young Cattle	g/animal	146	145	144	144	145	144	144	143	144	143
3Da32	Sheep	g/animal	66	67	69	68	68	67	66	66	66	66
3Da33	Swine	g/animal	0.29	0.22	0.16	0.14	0.12	0.11	0.093	0.092	0.092	0.092
3Da34a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	g/animal	99	102	104	102	101	100	99	100	100	99
3Da34c	Deer	g/animal	177	182	188	188	187	187	186	186	187	188
3Da34d	Goats	g/animal	59	59	58	61	64	67	69	69	69	69
3Da34e	Horses	g/animal	179	176	171	175	178	182	186	185	185	185
3Da34f	Mules and Asses	g/animal	65	64	64	62	60	58	57	57	57	57
3Da34gi	Layers	g/animal	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3Da34gii	Broilers	g/animal	0.026	0.023	0.020	0.023	0.026	0.030	0.033	0.033	0.033	0.033
3Da34giii	Turkey	g/animal	0.66	0.72	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
3Da34giv	Growers	g/animal	0.088	0.083	0.078	0.092	0.106	0.121	0.135	0.135	0.135	0.135
3Da34giv	Other poultry	g/animal	0.26	0.27	0.29	0.30	0.30	0.31	0.31	0.31	0.31	0.31
3Da34hi	Rabbits	g/animal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da34hii	Bisons	g/animal	236	233	234	232	227	295	285	284	282	282

Emission factors (3De)

For the calculation of the NMVOC emissions from crop production and agricultural soils three types of agricultural areas are differentiated, i.e. cropland, grassland and summering pastures. The NMVOC emission factors for cropland and grassland are based on the values for wheat and grass (15°C), respectively, of Table 3.3 of the EMEP/EEA guidebook (EMEP/EEA 2019) taking into account country-specific values for the mean dry matter yield (Richner and Sinaj 2017). For summering pastures, the same NMVOC emission value as of 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 and are given in Table 5-23.

The particulate matter emission factors consist of an operation-specific emission factor for soil cultivation or harvesting and a factor for the annual number of the respective agricultural operation. The crop- and operation-specific emission factors are based on the Tier 2 emission factors for wet conditions of the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 3D, Tables 3.5 and 3.7). The factors for the annual number of agricultural operations are country-specific and are based mainly on expert judgements (Bühler and Kupper 2018). Only for the number of grass harvests literature values are available (Richner and Sinaj 2017) for five different altitude classes. In order to derive the emission factors of the aggregated source categories cropland and grassland, the emissions from the cultivation of each single type of crop and of grassland have to be calculated, summed up and then divided by the total area of the respective crop and grassland types. Since the relative shares of grassland in the valley and the alpine area remain about constant over the entire time period constant (aggregated) emission factors result for grassland.

Unfortunately, the guidebook provides emission factors for PM10 and PM2.5 only. A couple of European countries assume for TSP the same values as of PM10. But this assumption is not reasonable since particulate matter emissions from soil cultivation and harvesting have a large mass fraction in the coarse fraction. Therefore, the TSP emission factors have been estimated according to the Danish emission inventory (Danish Informative Inventory Report 2018) with a fraction of PM10/TSP of 10 %. The particulate matter emission factors are also given in Table 5-23.

Table 5-23 NMVOC and PM2.5 emission factors of 2022 for 3De Crop production and agricultural soils.

Emission factors		Unit	NMVOC	PM2.5	PM10	TSP
3De	Cropland	g/ha	376	40	757	7'566
3De	Grassland	g/ha	397	47	1'100	11'000
3De	Summering pastures	g/ha	141	NA	NA	NA

Activity data (3Da)

The nitrogen amount applied with urea-containing and other synthetic fertilisers (SBV 2023, Agricura 2022, AGRAMMON 2018) as well as the amount applied with sewage sludge and compost (including solid and liquid digestate) derived from organic residues are shown in Table 5-24.

Activity data for emissions from N excretion resulting from the application of animal manure to soils (3Da2a) and from grazing (3Da3) are the livestock numbers for source category 3B. Manure management which are given in Table 5-15. The application of sewage sludge to soils has been prohibited (too high heavy metal content), therefore the activity data is NO from 2009 onwards.

The underlying data for compost and digestate (liquid and solid) from non agricultural biogas plants are based on a study from the year 2017 (Schleiss 2017, covering the period from 1990 to 2015 and subsequent annual update) and on data from the statistics of renewable energies (SFOE 2023a), respectively, see description in chp. 6.3.2. Schleiss (2017) differentiates so-called back yard and industrial composting. The compost applied to soil as fertiliser in agriculture is part of the industrial compost.

Note that for this submission, the conversion factor from wet to dry matter of compost has changed in sector 5B as documented in chp. 6.3.2. For estimates in sector 3Da2c and for this submission only, the data reported in the previous submission in chp. 6.3.2, have still been applied for scheduling reasons.

Table 5-24 Time series of nitrogen amount applied on agricultural soils: synthetic N-fertilisers (urea-containing and other N-containing synthetic fertilisers), sewage sludge and compost (derived from organic residues in t N). Additionally, agricultural areas (in ha; cropland, grassland, summering pastures) are displayed.

Activity data of agricultural soils		Unit	1990	1995	2000	2005	2010
3Da1	Urea containing fertiliser	tN	16'284	10'707	7'631	6'605	7'101
3Da1	Other synthetic N-fertiliser	tN	50'390	47'652	43'042	43'478	45'985
3Da2b	Sewage sludge	tN	4'815	4'942	3'356	1'054	NO
3Da2c	Other organic fertiliser	tN	817	1'286	1'829	2'169	3'281
3De	Cropland	ha	312'398	307'754	289'939	283'003	269'390
3De	Grassland	ha	724'556	735'408	743'756	742'379	741'775
3De	Summering pastures	ha	538'676	499'774	496'667	487'956	486'382

Activity data of agricultural soils		Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3Da1	Urea containing fertiliser	tN	5'793	7'942	7'223	8'872	9'250	8'324	7'752	7'397	8'100	6'915
3Da1	Other synthetic N-fertiliser	tN	37'924	41'393	36'521	37'531	40'113	37'432	32'400	33'694	37'265	31'531
3Da2b	Sewage sludge	tN	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da2c	Other organic fertiliser	tN	4'670	4'709	4'908	5'435	5'542	5'668	6'211	6'357	6'548	6'575
3De	Cropland	ha	268'743	267'809	268'449	267'702	268'563	269'701	265'917	267'854	270'043	269'671
3De	Grassland	ha	739'470	740'002	737'403	736'429	732'101	729'044	731'265	728'787	729'460	724'886
3De	Summering pastures	ha	479'745	475'690	474'575	472'465	472'618	470'837	469'280	466'163	463'443	465'709

Activity data (3De)

As activity data of source category 3De Crop production and agricultural soils two different types of agricultural areas were considered, i.e. cropland and grassland. They consist of aggregated agricultural areas based on the (annual) farm structure survey of the Swiss Federal Statistical Office (FSO 2023i). In addition, for NMVOC emissions also the emissions from summering pastures (FSO 2023b) are included where no agricultural crop operations take place. The activity data of these agricultural areas are also given in Table 5-24. While cropland and grassland are part of the agricultural farms (farmland), summering pastures are alpine land (usually at an altitude of more than 1000-2500 m) which is grazed for around 100 days per year by dairy cows (for mountain cheese production), heifers, sheep and goats.

5.3.3 Category-specific recalculations for 3D Crop production and agricultural soils

- 3Da1: The activity data of source categories 3Da1 Urea and 3Da1 Other synthetic fertiliser were revised for 2021 due to adjusted values in the AGRAMMON model resulting in a revised NH_3 emission factor of 3Da1 Other synthetic fertiliser as well.
- 3Da2c: The activity data of source category 3Da2c Other organic fertilisers was revised for the year 2021 due to updated values for the provisional amount of compost and biogas digestate applied to agricultural soils.
- 3De: The individual cropland and grassland areas were updated for 1990-2021, resulting in minimal adjustments to the total cropland and grassland areas as well as to the PM2.5, PM10 and TSP emission factors of cropland.

5.4 Source category 3F – Field burning of agricultural residuals

Burning of crop residues in fields is prohibited in Switzerland. Only the burning of branches and twigs is allowed under certain conditions. These emissions are reported in source category 5C2 Open burning of agricultural waste.

6 Waste

6.1 Overview of emissions

In this introductory chapter, an overview of emissions, separated according to the most relevant pollutants, is presented. Trends and changes for individual source categories in the period between 1990 and 2022 are analysed and discussed. In absolute figures, processes in sector 5 Waste emit mainly NMVOC and NH_3. The contributions of PM2.5, heavy metals (Pb and Hg) and PCDD/F are smaller in absolute terms, but larger relative to total national emissions.

The following source categories are reported:

- 5A Biological treatment of waste - Solid waste disposal on land
- 5B Biological treatment of waste - Composting and anaerobic digestion
- 5C Waste incineration and open burning of waste
- 5D Wastewater handling
- 5E Other waste

Please note that according to EMEP/EEA guidebook (EMEP/EEA 2019) **all emissions from waste-to-energy, where waste material is used directly as fuel or converted into a fuel, are reported under the sector 1A Fuel combustion**. Therefore, the largest share of waste-related emissions in Switzerland is not reported in sector 5 Waste but in sector 1 Energy.

6.1.1 Overview and trend for NMVOC

Figure 6-1 depicts the NMVOC emissions in the waste related sectors since 1990. A clear and increasing trend of total NMVOC emissions from 2006 to 2021 can be observed. This is mainly explained by the continuous positive trend for category 5B Biological treatment of waste - Composting and anaerobic digestion, which is a key category according to the trend assessment. The contribution of the waste sector still remains small in comparison to the national total. Therefore, there are no source categories from the waste sector that are key categories for NMVOC according to the level assessment.

The main sources of NMVOC emissions are 5B Biological treatment of solid waste and 5C Incineration and open burning of waste. Nowadays the bulk emissions in this sector originate from 5B Biological treatment of solid waste. The reason for this development is the increase in industrial and commercial composting activities, particularly the digestion of organic waste. The latter has become economically more beneficial due to cost covering feed-in tariffs for electricity and due to additional revenues as CO_2 compensation projects. The increase in digested quantities is also linked to population growth. 5A Solid waste disposal shows a decreasing trend.

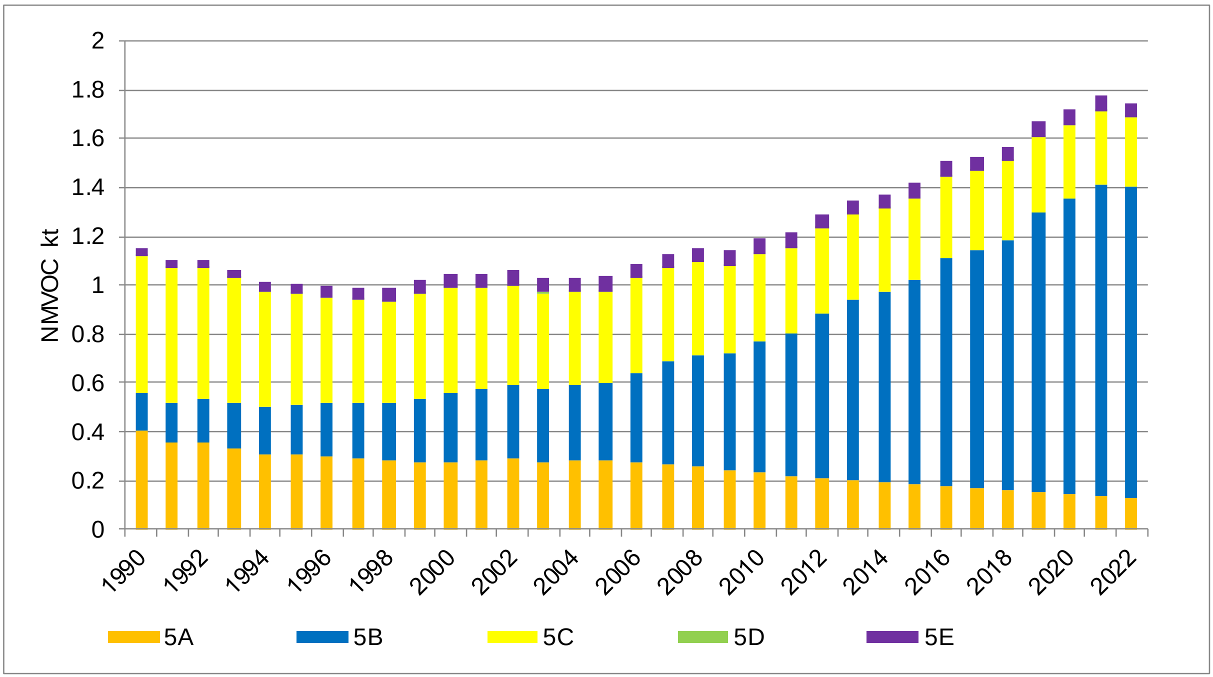

Figure 6-1 Switzerland's NMVOC emissions from the waste sector by source categories 5A-5E. The corresponding data can be found in Table 6-1.

Table 6-1 NMVOC emissions from sector 5 Waste by source categories 5A-5E. The last column in the third part of the table indicates the relative trend.

NMVOC total	1990	1995	2000	2005	2010
	kt				
5A	0.41	0.30	0.28	0.28	0.23
5B	0.15	0.21	0.28	0.32	0.54
5C	0.56	0.45	0.43	0.37	0.36
5D	0.0005	0.0004	0.0003	0.0001	0.0001
5E	0.028	0.045	0.060	0.060	0.060
Sum	1.15	1.01	1.05	1.04	1.19

NMVOC total	2013	2014	2015	2016	2017
	kt				
5A	0.20	0.19	0.19	0.18	0.17
5B	0.74	0.78	0.83	0.93	0.97
5C	0.35	0.34	0.34	0.34	0.33
5D	0.0001	0.0001	0.0001	0.0001	0.0001
5E	0.060	0.060	0.060	0.060	0.060
Sum	1.35	1.37	1.42	1.51	1.53

NMVOC total	2018	2019	2020	2021	2022	2005–2022
	kt					%
5A	0.16	0.15	0.14	0.14	0.13	-54%
5B	1.03	1.1	1.2	1.3	1.3	293%
5C	0.32	0.31	0.31	0.30	0.29	-23%
5D	0.0001	0.0001	0.0001	0.0001	0.0001	20%
5E	0.060	0.060	0.060	0.060	0.060	0%
Sum	1.57	1.67	1.72	1.78	1.75	69%

6.1.2 Overview and trend for PM2.5

Figure 6-2 depicts the PM2.5 emissions in the waste related sectors since 1990. 5C Incineration and open burning of waste is significantly contributing to total PM2.5 emissions from the waste sector over the entire reporting period and thus is key category.

Between 1990 and 2022 a continuous decrease of total PM2.5 emissions occurred that largely can be affiliated with the emission reductions achieved in 5C Waste incineration. This is mainly due to emission reductions from sewage sludge incineration, refurbishment of crematoriums, the cessation of burning cable insulation in 1995 as well as clinical waste incineration in 2002 as well as due to an overall decreasing trend in the open burning of natural residues in agriculture and households.

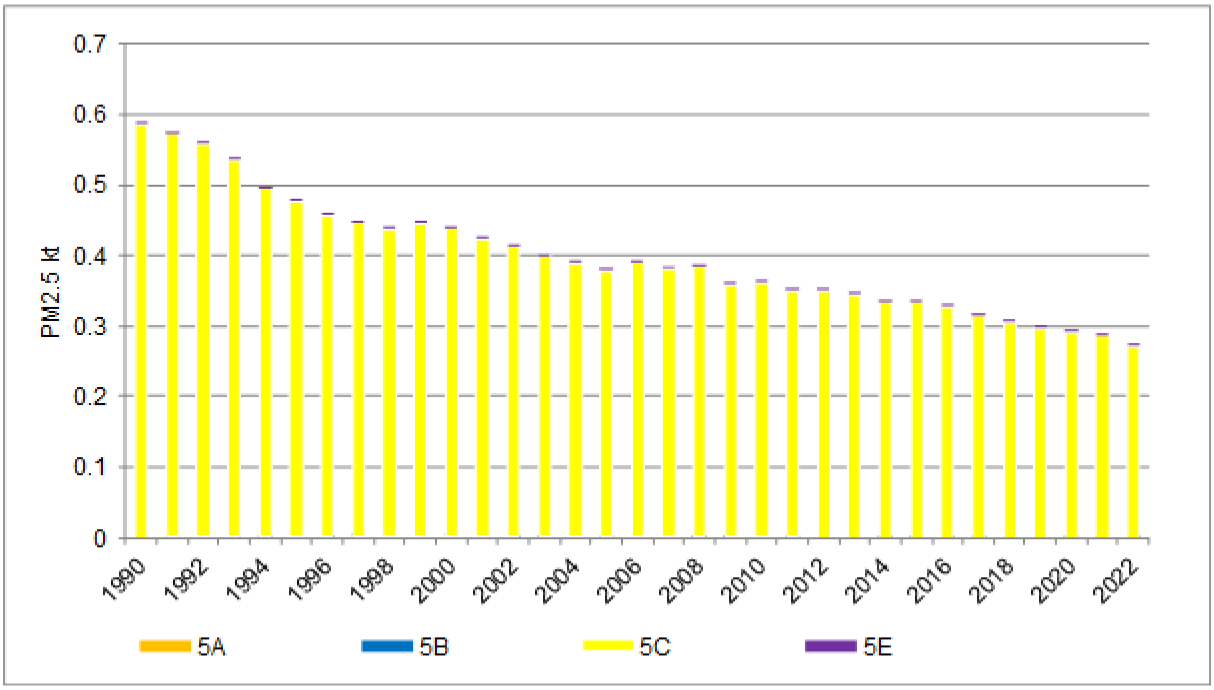

Figure 6-2 Switzerland’s PM2.5 emissions from the waste sector by source categories 5 A-5C and 5E. Note that PM2.5 emissions from 5D are not occurring. The corresponding data can be found in Table 6-2.

Table 6-2 PM2.5 emissions from sector 5 Waste by source categories 5A-5C and 5E. The last column in the third part of the table indicates the relative trend.

PM2.5 total	1990	1995	2000	2005	2010
	kt				
5A	0.0007	0.002	0.002	0.001	0.001
5B	NA	0.000001	0.000004	0.00001	0.00002
5C	0.59	0.48	0.44	0.38	0.36
5E	0.001	0.002	0.002	0.002	0.002
Sum	0.59	0.48	0.44	0.38	0.36

PM2.5 total	2013	2014	2015	2016	2017
	kt				
5A	0.0006	0.0005	0.0005	0.0005	0.0005
5B	0.00004	0.00004	0.00004	0.00005	0.00005
5C	0.34	0.34	0.33	0.33	0.31
5E	0.002	0.002	0.002	0.002	0.002
Sum	0.35	0.34	0.34	0.33	0.32

PM2.5 total	2018	2019	2020	2021	2022	2005–2022
	kt					%
5A	0.0005	0.0005	0.0005	0.0005	0.0005	-62%
5B	0.00005	0.00005	0.00005	0.00005	0.00005	710%
5C	0.31	0.30	0.29	0.29	0.27	-28%
5E	0.002	0.002	0.002	0.002	0.002	0%
Sum	0.31	0.30	0.29	0.29	0.27	-28%

6.2 Source category 5A – Biological treatment of waste - Solid waste disposal on land

6.2.1 Source category description of 5A Biological treatment of waste - Solid waste disposal on land

The source category 5A Biological treatment of waste - Solid waste disposal on land includes all emissions from solid waste handling on landfill sites. Since 1987 all deposited waste in Switzerland has been deposited on managed landfill sites.

In Switzerland, managed active landfill sites where organic material is degraded in biological processes are equipped to recover landfill gas (SFOE 2023a). The landfill gas is generally used in combined heat and power plants for the production of electricity and heat (reported under 1A Fuel combustion). A fraction of landfill gas is used to generate heat only. A very small fraction of the landfill gas is flared (reported under 5A).

Methane emissions are estimated by using a First Order Decay (FOD) model compliant with the 2006 IPCC Guidelines (IPCC 2006; see below). Following legal requirements and regulations it is assumed that open burning ceased after 1990 (Consaba 2016).

Table 6-3 Specification of source category 5A Biological treatment of waste - Solid waste disposal on land.

5A	Source category	Specification
5A	Solid waste disposal on land	Emissions from handling of solid waste on landfill sites

Table 6-4 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 5A Biological treatment of waste - Solid waste disposal on land.

Source category 5A Biological treatment of waste - Solid waste disposal on land is not a key category.

6.2.2 Methodological issues of 5A Biological treatment of waste - Solid waste disposal on land

Methodology (5A)

The emission modelling corresponds to a Tier 2 approach. See decision tree in chapter 5A Biological treatment of waste – Solid waste disposal on land of the EMEP/EEA guidebook (EMEP/EEA 2019).

The main emission from landfills is the greenhouse gas CH_4, which is not relevant for the CLRTAP Inventory. However, methane is used for combined heat and power generation, or it is flared. Thereby, other pollutants are produced and emitted. They are reported in the CLRTAP Inventory. Emissions from combined heat and power generation are reported in the energy sector (1A1a Public electricity and heat production), emissions from flaring in the waste sector.

The emissions of CH_4 are calculated in several steps, the details are described in Switzerland's National Inventory Report (FOEN 2023):

1. CH_4 emissions are modelled with the FOD model according to the 2006 IPCC Guidelines (IPCC 2006).
2. The amount of CH_4 that is recovered and used as fuel for combined heat and power generation as well as for flaring is subtracted from the total CH_4 generated in landfills.
3. Emissions of air pollutants from burning methane in engines and torches are calculated. Their amount is proportional to the CH_4 burnt.

The PCB emissions from landfills are modelled within the disposal category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

Emission factors (5A)

Emission factors are country-specific based on measurements and expert estimates, documented in EMIS (EMIS 2024/1A1a & 5A), see Table 6-5. The PCB emission factor expressed in units per tonnes of PCBs stored in landfills is based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2. Emission factors for open burning of waste are not shown because open burning on solid waste disposal sites is assumed not to occur anymore in Switzerland since 1990.

Table 6-5 Emission factors 2022 for 5A Biological treatment of waste - Solid waste disposal on land.

5A1 Solid waste disposal on land	Unit	NOx	NMVOC	NH_3	PM2.5 ex	PM10 ex	TSP ex	CO	PCB
Flaring	kg/t CH_4 produced	1	0.082	NA	0.4	0.4	0.4	17	NA
Direct emission	kg/t CH_4	NA	13	20	NA	NA	NA	NA	NA
Direct emission	g/t PCB	NA	NA	NA	NA	NA	NA	NA	10

Activity data (5A)

The main activity data for 5A Biological treatment of waste - Solid waste disposal on land are the waste quantities disposed on landfills that are used for calculating the amount of methane produced. Activity data are taken from EMIS 2024/1A1a & 5A. Table 6-6 documents the decrease of municipal solid waste, construction waste and sewage sludge disposed in landfill sites in the reporting period. The reason for this is that incineration of combustible waste is mandatory in Switzerland since the year 2000 and therefore amounts deposited have dropped to zero in the following years.

Table 6-6 Activity data for 5A Biological treatment of waste - Solid waste disposal on land (source EMIS 2023/1A1a & 5A).

5A1 Solid waste disposal on land	Unit	1990	1995	2000	2005	2010
Total waste quantity	kt	860	628	350	16	NO
Municipal solid waste (MSW)	kt	650	540	292	14	NO
Construction waste (CW)	kt	150	60	54	1.4	NO
Sewage sludge (SS)	kt (dry)	60	28	4.2	0.98	NO
Open burned waste	kt	NO	NO	NO	NO	NO

5A1 Solid waste disposal on land	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total waste quantity	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Municipal solid waste (MSW)	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Construction waste (CW)	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge (SS)	kt (dry)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Open burned waste	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

The resulting set of activity data for 5A Biological treatment of waste - Solid waste disposal on land is the amount of CH_4 flared (see Table 6-7). The quantity of CH_4 flared on Swiss landfill sites was assessed in 2015 and is documented in a separate report (Consaba 2016). For PCB emissions, the activity data is the amount of PCBs stored in landfills based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 6-7 Activity data of 5A Biological treatment of waste - Solid waste disposal on land (data source: Consaba 2016).

5A1 Solid waste disposal on land	Unit	1990	1995	2000	2005	2010
CH_4 flared	kt	1.8	5.3	5.6	3.4	2.4
PCB quantity available	kt	0.40	0.37	0.35	0.33	0.32

5A1 Solid waste disposal on land	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4 flared	kt	1.6	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3
PCB quantity available	kt	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30

The emissions from using methane as fuel for combined heat and power generation in engines are reported under 1A1a Energy industries.

6.2.3 Category-specific recalculations in 5A Biological treatment of waste - Solid waste disposal on land

There were no recalculations implemented in submission 2024.

6.3 Source category 5B - Biological treatment of waste - Composting and anaerobic digestion at biogas facilities

6.3.1 Source category description of 5B Biological treatment of waste - Composting and anaerobic digestion at biogas facilities

The source category 5B Biological treatment of waste comprises the emissions from 5B1 Composting and from 5B2 Anaerobic digestion at biogas facilities. Emissions from combined heat and power generation using biogas from digestion are reported under 1A2gviii Other and 1A4a Commercial/Institutional.

5B1 Composting distinguishes between industrial composting and backyard composting. Industrial composting covers 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 common practice in Switzerland. Activity data and emission factors for industrial and backyard composting have been thoroughly reassessed in 2017, new data were gained and EMIS 2024/5B1 Kompostierung has been revised accordingly.

Within 5B2 Anaerobic digestion at biogas facilities two plant types are distinguished: (1) industrial biogas plants and (2) agricultural biogas plants. Biogas upgrading is treated as a separate process covered in this source category; however, this only induces methane emissions due to leakage and is therefore not relevant for the CLRTAP Inventory. The digestion of organic waste takes place under anaerobic conditions. The digestate (solid and liquid output after completion of a process of anaerobic microbial degradation of organic matter) is composted or directly used as fertiliser, respectively. The biogas generated during the digestion process is used for combined heat and power generation or upgraded and used as fuel for cars or fed into the natural gas grid.

Table 6-8 Specification of source category 5B Biological treatment of waste - Composting and anaerobic digestion at biogas facilities.

5B	Source category	Specification
5B1	Composting	Emissions from composting activities
5B2	Anaerobic digestion at biogas facilities	Emissions from digesting of organic waste at biogas facilities

Table 6-9 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 5B Biological treatment of waste – Composting and anaerobic digestion at biogas facilities

NFR code	Source category	Pollutant	Identification criteria
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NMVOC	T1

6.3.2 Methodological issues of 5B Biological treatment of waste - Composting and anaerobic digestion at biogas facilities

Methodology (5B)

A Tier 2 method is applied to estimate emissions from 5B1 Composting (see decision tree in chapter 5B1 Biological treatment of waste – Composting of the EMEP/EEA guidebook (EMEP/EEA 2019).

Emissions from 5B2 Anaerobic digestion are estimated by applying a Tier 2 method (see decision tree in chapter 5B2 Biological treatment of waste – Anaerobic digestion at biogas facilities of the EMEP/EEA guidebook (EMEP/EEA 2019).

Figure 6-3 depicts a schematic design of an industrial biogas plant. Six emission-relevant process steps are taken into account. For each process step separate activity data and emission factors are used:

- P1: Emissions from the storage of organic waste
- P2: Emissions from fermentation
- P3: Emissions from the interim storage of liquid digestate
- P4: Emissions from on site aerobic after treatment of solid digestate
- P5: Emissions from the utilisation of biogas in combined heat and power generation units
- P6: Emissions from flaring of biogas

P5 as energy-related emissions are reported in sector 1 Energy source category 1A2gviii Other.

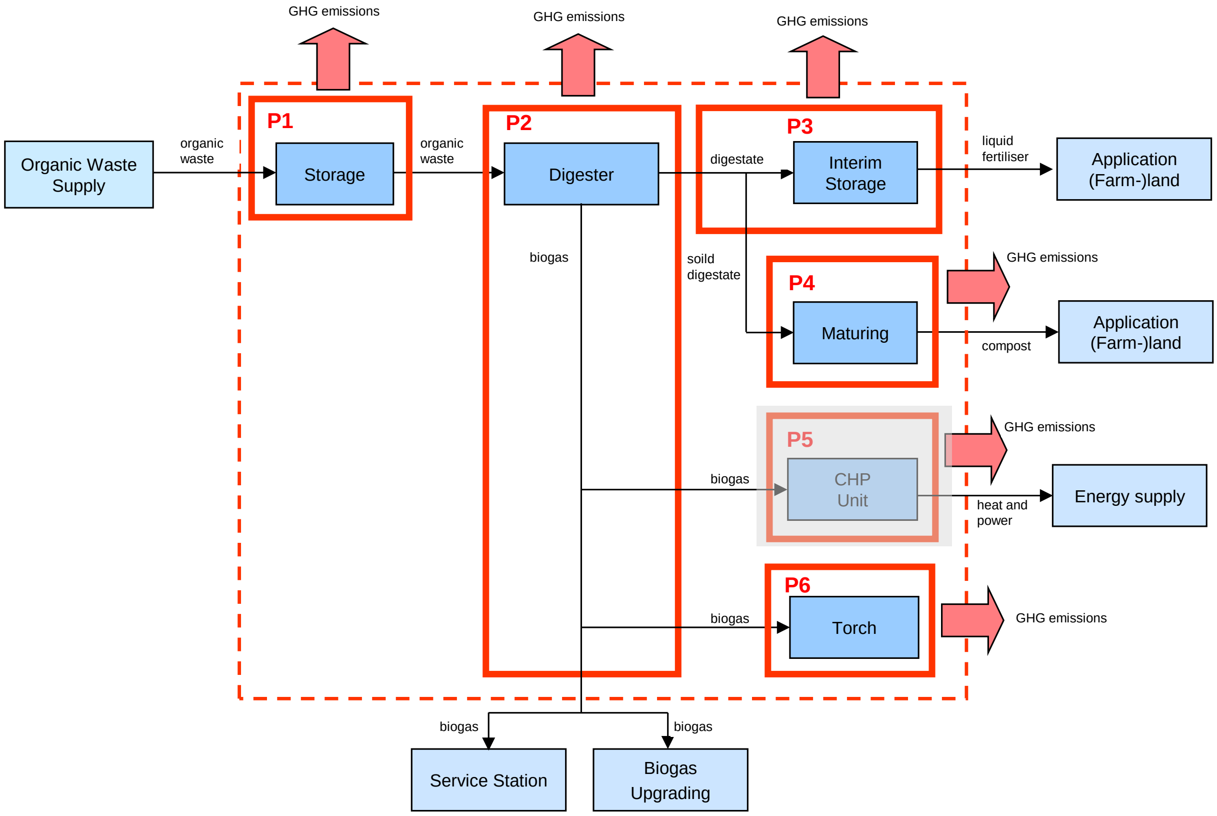

Figure 6-3 Schematic design of an industrial biogas plant.

Figure 6-4 depicts a schematic design of an agricultural biogas plant. It is very similar to the scheme of the industrial biogas plant described above. Seven process steps are distinguished where emissions might occur. For each process step separate activity data and emission factors are used:

- P1: Emissions from the intermediate storage of the waste from animal husbandry (liquid and solid manure) and the additional co-substrate.
- P2: Losses due to leakage from the fermenter, gas piping and overproduction
- P3: Emissions from the storage of liquid digestate
- P4: Emissions from aerobic after treatment of solid digestate
- P5: Emissions from the utilisation of biogas in combined heat and power generation units
- P6: Emissions from the utilisation of biogas in the gas boiler
- P7: Emissions from flaring of biogas

Emissions from P1 are reported in sector 3 Agriculture, and emissions from P5 and P6 are reported in sector 1 Energy source category 1A4ai Commercial/Institutional.

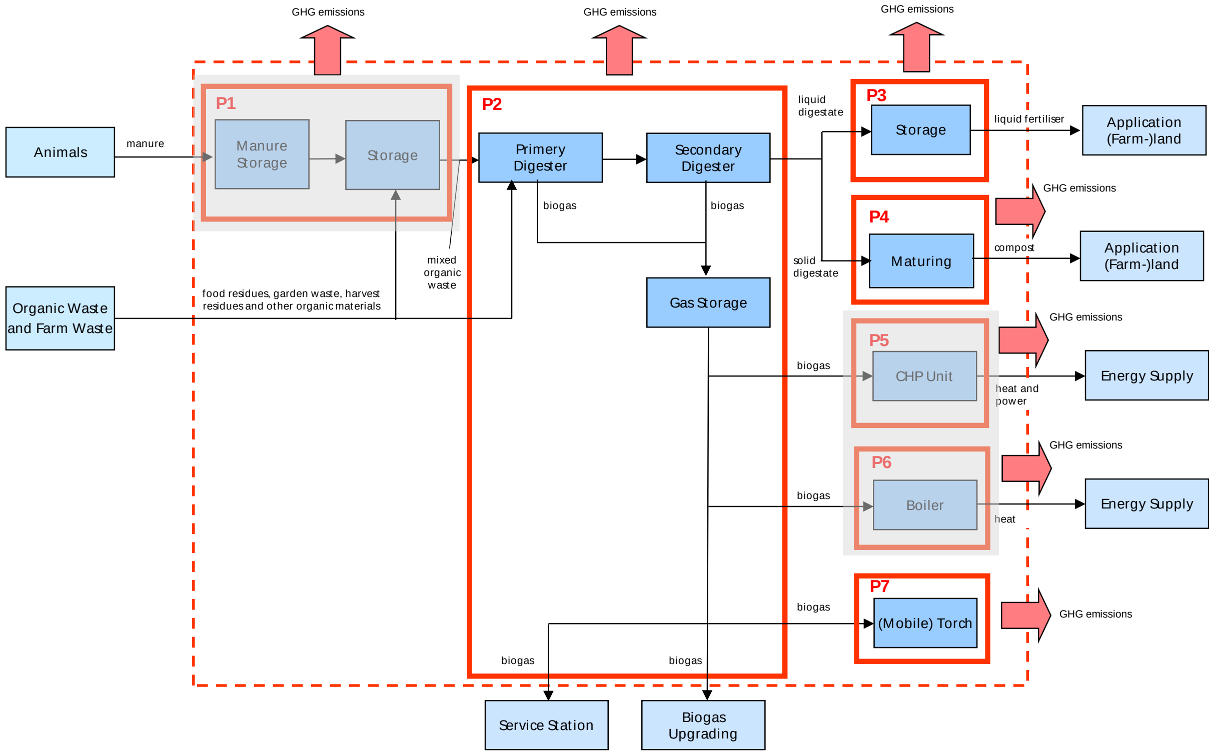

Figure 6-4 Schematic design of an agricultural biogas plant.

Emission factors (5B)

Emission factors for 5B1 Composting are country-specific based on measurements and expert estimates (EMIS 2024/5B1 Kompostierung). Emission factors are assumed to remain constant over the reporting period.

Emission factors for 5B2 Anaerobic digestion are country-specific based on measurements according to Edelmann and Schleiss (1999), Butz (2003) and Cuhls et al. (2010) as documented in comments to the database (EMIS 2024/1A2g and 5B2 Vergärung IG and EMIS 2024/1A4a and 5B2 Vergärung LW). Table 6-10 presents the emission factors used in 5B.

Table 6-10 Emission factors of 5B Biological treatment of waste - Composting and anaerobic digestion at biogas facilities in 2022.

5B Composting and anaerobic digestion at biogas facilities	Unit	NOx	NMVOC	SO_x	NH_3	PM2.5 ex	PM10 ex	TSP ex	CO
Composting (industrial)	g/t composted waste	NA	750	NA	1'250	NA	NA	NA	NA
Composting (backyard)	g/t composted waste	NA	750	NA	1'250	NA	NA	NA	NA
Digestion (ind., digestable waste / storage)	g/t digestable waste	NA	70	NA	5.6	NA	NA	NA	NA
Digestion (ind., digested waste liquid / storage)	g/t digested waste (liquid)	NA	400	NA	80	NA	NA	NA	NA
Digestion (ind., digested waste solid / rotting)	g/t digested waste (solid)	NA	230	NA	104	NA	NA	NA	NA
Digestion (ind., flaring, CH_4)	g/t CH_4	4'066	82	616	NA	37	37	37	2'054
Digestion (agr., digested waste liquid / process water)	g/t digested waste (liquid)	NA	400	NA	80	NA	NA	NA	NA
Digestion (agr., digested waste solid / rotting)	g/t digested waste (solid)	NA	230	NA	104	NA	NA	NA	NA
Digestion (agr., flaring, CH_4)	g/t CH_4	4'066	82	616	NA	37	37	37	2'054

Activity data (5B)

Activity data for 5B Biological treatment of waste are extracted from EMIS 2024/5B1 Kompostierung, EMIS 2024/1A1a and 5B2 Vergärung IG and EMIS 2024/1A1a and 5B2 Vergärung LW. Activity data for digestion are based on reliable statistical data from the statistics of renewable energies (SFOE 2023a). Activity data for industrial and backyard composting are based on a study by Schleiss (2017) using data of the years 1989, 1993, 2000 and 2013, supplied by plant operators. From 2014 onwards, 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). As of 2012, activity data for backyard composting are assumed to be constant as recommended by Schleiss (2017). Data on the amount of waste is provided in tonnes of wet matter. In order to comply with UNFCCC reporting guidelines, a factor 0.40 (Baier 2023) is applied for the conversion of wet substance to dry substance.

There is a continuous increase of organic material composted until the year 2000 and afterwards a strong increase of organic material digested.

Table 6-11 Activity data of 5B Biological treatment of waste.

5B Composting and anaerobic digestion at biogas facilities	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 (ind., digestable waste / storage)	kt wet	NO	27	60	108	289
Digestion (ind., digested waste liquid / storage)	kt wet	NO	15	33	60	161
Digestion (ind., digested waste solid / rotting)	kt wet	NO	9.4	20	37	99
Digestion (ind., flaring, CH_4)	kt	NO	0.037	0.10	0.18	0.51
Digestion (agr., digested waste liquid / process water)	kt wet	120	100	125	181	569
Digestion (agr., digested waste solid / rotting)	kt wet	6.3	5.2	6.5	10	30
Digestion (agr., flaring, CH_4)	kt	NO	NO	NO	NO	0.12

5B Composting and anaerobic digestion at biogas facilities	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Composting (industrial)	kt dry	214	191	172	201	196	190	218	209	219	194
Composting (backyard)	kt dry	40	40	40	40	40	40	40	40	40	40
Digestion (ind., digestable waste / storage)	kt wet	561	590	650	695	712	729	770	792	792	794
Digestion (ind., digested waste liquid / storage)	kt wet	313	329	362	387	397	406	429	441	441	442
Digestion (ind., digested waste solid / rotting)	kt wet	192	201	222	237	243	249	263	270	270	271
Digestion (ind., flaring, CH_4)	kt	0.91	0.90	0.95	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Digestion (agr., digested waste liquid / process water)	kt wet	829	940	1053	1201	1290	1416	1619	1767	1914	1949
Digestion (agr., digested waste solid / rotting)	kt wet	44	50	55	63	68	75	85	93	101	103
Digestion (agr., flaring, CH_4)	kt	0.20	0.23	0.26	0.29	0.31	0.34	0.40	0.43	0.47	0.48

6.3.3 Category-specific recalculations in 5B Biological treatment of waste - Anaerobic digestion at biogas facilities

The following recalculations were implemented in submission 2024.

- 5B Biological Treatment of Solid Waste: All input activity data for 1990-2021 have been updated because of harmonisation of rounding. This may cause changes in emissions of up to 10 %.
- 5B1 - Composting (industrial and backyard): The unit of activity data and emission factors are reported as weight dry mass according to the Guidelines reference for reporting tables (CRT). A new transfer factor from wet to dry mass of 40.0 % has been suggested by

Baier (2023) instead of the previously applied factor 54.5 % as stated in CVIS (2019). Thus, activity data for the years 1990-2021 have decreased by 26 % while emission factors for NH_3 and NMVOC have increased by 36 %. This leads to changes in emissions from 5B1 Composting of <1 % due to rounding.

6.4 Source category 5C – Waste incineration and open burning of waste

6.4.1 Source category description of 5C Waste incineration and open burning of waste

There is a long tradition in Switzerland for waste to be incinerated. 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. It is a requirement that waste heat generated during the incineration in installations has to be recovered if technically and economically feasible. In accordance with the 2006 IPCC Guidelines provisions (IPCC 2006), emissions from the combustion of waste-to-energy activities are reported within 1A Fuel combustion activities. The sources included in source category 5C are given in Table 6-12.

Table 6-12 Specification of source category 5C Waste incineration and open burning of waste.

5C	Source category	Specification
5C1a	Municipal waste incineration	Emissions from illegal incineration of municipal solid wastes at home; Emissions from waste incineration at construction sites (open burning)
5C1bi	Industrial waste incineration	Emissions from incinerating cable insulation materials
5C1bii	Hazardous waste incineration	PCB emissions from combustion of PCB contaminated waste oil (transformers and large capacitors, ceased in 1999)
5C1biii	Clinical waste incineration	Emissions from incinerating hospital waste in hospital incinerators (ceased in 2002)
5C1biv	Sewage sludge incineration	Emissions from sewage sludge incineration plants
5C1bv	Cremation	Emissions from the burning of dead bodies
5C2	Open burning of waste	Emissions from field burning of agricultural waste. Burning of gardening residues from private households is also integrated (small contribution compared to agriculture).

Table 6-13 gives an overview of other waste incineration sources in Switzerland and the source category, where respective emissions are reported in the national inventory.

Table 6-13 Overview of other waste incineration activities in Switzerland and indication of source categories where the waste incineration activity is reported in the national inventory.

Waste incineration	Specification	Source category
Paper and pulp industries	Emissions from incineration of residues and sludge from industrial waste water treatment plants as fuel for paper/pulp production	1A2d Biomass
Municipal solid waste incineration plants	Emissions from waste incineration in municipal solid waste incineration plants	1A1a Public electricity and heat production
Waste in cement plants	Emissions from waste incineration as alternative fuels in cement kilns	1A2fi Non-metallic minerals
Special waste	Emissions from incinerating industrial and hazardous wastes	1A1a Public electricity and heat production

Table 6-14 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 5C Waste incineration and open burning of waste.

NFR code	Source category	Pollutant	Identification criteria
5C1a	Municipal waste incineration	PM2.5	L1, L2
5C1a	Municipal waste incineration	PM10	L1

6.4.2 Methodological issues of 5C Waste incineration and open burning of waste

Methodology (5C)

For the calculation of the emissions from municipal waste incineration (illegal burning of municipal waste) a Tier 2 method is used (see decision tree in chapter 5C1a Municipal waste incineration, EMEP/EEA 2019).

For the calculation of the emissions from the incineration of insulation materials from cables a Tier 2 method is used (see decision tree in chapter 5C1b Industrial waste incineration including special waste and sewage sludge, EMEP/EEA 2019).

Until 1999, also PCB emissions from so-called open burning of PCB contaminated waste oil in outdoor fires (i.e. outside of a container) occurred in Switzerland. They are modelled within the disposal category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

For the calculation of the emissions from clinical waste incineration a Tier 2 method is used (see decision tree in chapter 5C1biii Clinical waste incineration, EMEP/EEA 2019).

For the calculation of the emissions from sewage sludge incineration plants a Tier 2 method is used (see decision tree in chapter 5C1b Industrial waste incineration including special waste and sewage sludge, EMEP/EEA 2019).

For the calculation of the emissions from cremation a Tier 2 method is used (see decision tree in chapter 5C1bv Cremation, EMEP/EEA 2019).

For the calculation of the emissions from burning of agricultural and private gardening waste a country-specific Tier 2 method is used (see decision tree in chapter 5C2 Open burning of waste, EMEP/EEA 2019).

Emission factors (5C)

Emission factors are country-specific based on measurements and expert estimates as documented in the EMIS database (EMIS 2024/5C1 Abfallverbrennung illegal, EMIS 2024/5C1 Kabelbrand, EMIS 2024/5C1 Spitalabfallverbrennung, EMIS 2024/5C1 Krematorien, EMIS 2024/5C1 Klärschlammverbrennung, EMIS 2024/5C2 Abfallverbrennung Land- und Forstwirtschaft).

The emission factor of dioxine for 5C1 Illegal waste incineration in particular is defined based on Wevers et al. (2004) and Lemieux et al. (2003). Emission factors for the other pollutants of 5C1 Illegal waste incineration are based on SAEFL (2000) and USEPA (1995, Chapter 2.5 Open Burning).

Emission factors for 5C2 Open burning of agricultural and private gardening waste were, upon recommendation by INFRAS (2014) taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 5.C.2, table 3-2). INFRAS (2014) concluded, that Tier 2 default emission factor for incineration of natural residues in forestry would best account for emission factors for incineration of natural residues in agriculture and private gardens as well, except for NH_3 (EMEP/EEA 2002), Hg (Sigler et al. 2003) and IcdP (USEPA 1998, Table 4.10.5-1 Open burning of Municipal Refuse).

The emission factors for 5C1b Sewage sludge incineration for the year 1990 are taken from SAEFL (2000). The emission factors for the year 2002 are based on emission declarations of plants in the region of Basel (accounting for about 1/3 of the national total quantities). Emission factors for 2015 have been re-investigated based on emission declarations of the same plants in the region of Basel. Based on 27 air pollution control measurement reports under the Ordinance on Air Pollution Control of 11 different sewage sludge incineration plants, emission factors have again been estimated for 2018 (TBF 2021). For documentation see EMIS 2024/5C1 (5C1biv UNECE) Klärschlammverbrennung. From 1990 to 2002 from 2002 to 2015 and from 2015 to 2018 emission factors are interpolated linearly. From 2018 onwards the emission factors are assumed to be constant.

The following Table 6-15 depicts the emission factors used in 5C.

Table 6-15 Emission factors for 5C Waste incineration and open burning of waste in 2022. Unit of PCDD/PCDF is in I-TEQ.

5C Incineration and open burning of waste	Unit	NOx	NMVOC	SO_X	NH3	PM2.5 ex	PM10 ex	TSP ex	CO
Clinical waste incineration	g/t waste	1'500	300	1'300	NA	1'100	1'600	2'200	1'400
Illegal waste incineration	g/t waste	2'500	16'000	750	NA	14'400	16'000	20'000	50'000
Insulation material from cables	g/t cable	1'300	500	6'000	NA	62	410	510	2'500
Sewage sludge incineration	g/t sludge	400	189	162	19	28	40	40	97
Open burning of natural residues in agriculture	g/t wood	1'380	1'470	30	800	3'760	4'130	4'310	48'790
Open burning of natural residues in private households	g/t wood	1'380	1'470	30	800	3'760	4'130	4'310	48'790
Cremation	g/cremation	210	5.9	NA	NA	13	13	15	38

5C Incineration and open burning of waste	Unit	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP
Clinical waste incineration	mg/t waste	25'000	1'100	16'000	0.46	NA	NA	NA	NA
Illegal waste incineration	mg/t waste	100'000	200	100	0.16	0.34	0.2	0.27	0.1
Insulation material from cables	mg/t cable	80'000	1'900	200	0.017	NA	NA	NA	NA
Sewage sludge incineration	mg/t sludge	280	33	200	0.00014	NA	NA	NA	NA
Open burning of natural residues in agriculture	mg/t wood	320	130	60	0.01	3'150	6'450	5'150	1'700
Open burning of natural residues in private households	mg/t wood	320	130	60	0.01	3'150	6'450	5'150	1'700
Cremation	mg/cremation	47	NA	91	0.0005	NA	NA	NA	NA

Activity data (5C)

The clinical waste incineration quantities are based on rough expert estimates (EMIS 2024/5C1 Spitalabfallverbrennung).

Emissions from illegal waste incineration are based on the amount of municipal solid waste and waste from construction work burned in Switzerland. Due to the illegal nature of the process, there is a lack of reliable data. Thus, it is estimated that in 1990 1 % and in 2035 0.25 % of this amount is burned illegally (expert judgment). The shares for the years in between are interpolated. In order to estimate the quantity of illegal waste, the percentage quotation is multiplied by the total amount of municipal solid waste and waste from construction work (EMIS 2024/5C1 Abfallverbrennung illegal).

The sewage sludge quantity for 1990, 1994 and 1999 are taken from Külling and Stadelmann (2002). The total amount of sewage sludge produced in Switzerland as of 2000 is calculated by multiplying the per capita sludge production per person and year as reported by VBSA (2017) with the total population (FSO 2023c). The per capita sewage sludge production for 2000, 2004, 2008, 2012, 2016 and 2017 as reported in VBSA 2017 have been derived by compiling the respective amounts of sewage sludge incinerated in municipal solid waste incineration plant, 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. The total amount of sewage sludge incinerated is then calculated using the total amount generated minus the sewage sludge burnt in municipal solid waste incineration plants and sewage sludge used as alternative fuel in cement plants.

The activity data for burning of agricultural residues (see Table 6-16) is decreasing because legal burning is more strongly restricted since a revision of the corresponding article in the Swiss Federal Ordinance on Air Pollution Control in the year 2009 (EMIS 2024/5C2 Abfallverbrennung Land- und Forstwirtschaft). As a consequence of the greenhouse gas inventory UNFCC in-country review 2016, greenhouse gas emissions from open burning of natural residues in forestry (5C2ii) were moved to sector 4V in the greenhouse gas inventory. The corresponding air pollutant emissions have been moved to 11B Forest fires within the informative inventory report (chp. 7.3).

Table 6-16 Activity data for the various emission sources within source category 5C Waste incineration and open burning of waste.

5C Incineration and open burning of waste	Unit	1990	1995	2000	2005	2010
Total	kt	134	105	109	132	124
Clinical waste incineration	kt	15	8.8	2.5	NO	NO
Illegal waste incineration	kt	32	26	25	22	21
Insulation material from cables	kt	7.5	NO	NO	NO	NO
Open burning of PCB	kt	0.0011	0.00020	NO	NO	NO
Sewage sludge incineration	kt dry	57	50	64	95	90
Open burning of natural residues in agriculture	kt	16	15	14	13	12
Open burning of natural residues in private households	kt	6.1	4.9	3.6	2.4	1.2
Cremation	Numb.	37'513	40'968	44'821	48'169	52'813

5C Incineration and open burning of waste	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total	kt	126	124	129	130	132	128	129	126	125	124
Clinical waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Illegal waste incineration	kt	20	19	19	19	18	18	17	17	17	16
Insulation material from cables	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Open burning of PCB	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge incineration	kt dry	94	93	97	99	102	98	100	97	96	97
Open burning of natural residues in agriculture	kt	11	11	11	11	11	11	10	10	10	10
Open burning of natural residues in private households	kt	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Cremation	Numb.	53'205	55'616	59'664	54'634	57'694	54'842	57'746	68'148	64'106	65'688

Note that since 2002, all specific clinical waste incineration plants have ceased operation and all hospital waste is incinerated in municipal solid waste incineration plants (accounted for in 1A1 Energy industry). All burning of insulation material cables (industrial waste incineration in the table above) has ceased as well since 1995.

6.4.3 Category-specific recalculations in 5C Waste incineration and open burning of waste

The following recalculations were implemented in submission 2024.

- 5C1 incineration of waste / sewage sludge: Activity data of the amount of sewage sludge incineration has changed in 2016 and 2021 by -1 t and 100 t, respectively. This leads to changes in emissions of NO_x, CO, NMVOC, NH_3, SO_x, PM10, PM2.5, TSP, Pb, Cd, Hg, and PCDD/PCDF by <1 % (2016 and 2021).
- 5C1a Illegal waste incineration: For practical reason, the activity data for illegal waste incineration in tons is now reported separately for the fossil and biogenic fractions, for the entire time series. The sum of the fossil and biogenic fractions has changed by less than 1 % compared to the previous values due to rounding issues.

6.5 Source category 5D – Wastewater handling

6.5.1 Source category description of 5D Wastewater handling

Source category 5D1 Domestic wastewater handling comprises all emissions from liquid waste handling and sludge from housing and commercial sources (including grey water and night soil). In Switzerland, municipal wastewater treatment plants treat wastewater from either individual cities or several cities and/or municipalities together. Wastewater in general is treated in three consecutive steps: 1. mechanical treatment, 2. biological treatment, and 3. chemical treatment. The treated wastewater flows into a receiving system (lake, river or stream). The wastewater treatment infrastructure in Switzerland is now virtually complete (FOEN 2017l). The vast majority of wastewater treatment plants apply anaerobic sludge treatment with sewage gas recovery and use the sewage gas for combined heat and power production.

The source category 5D2 Industrial wastewater handling includes all emissions from liquid wastes and sludge from industrial processes such as food processing, textiles, car-washing places and electroplating plants as well as pulp and paper production. These processes may result in effluents with a high load of organics. Depending on the contaminants, an on-site pre-treatment is necessary in order to reduce the load of pollutants in the wastewater to meet the regulatory standards (which are in place to preclude disruptions of the municipal 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 combined heat and power production. The pre-treated wastewater is discharged to the domestic sewage systems, where the industrial wastewater is further treated, together with domestic wastewater in municipal wastewater treatment plants.

Table 6-17 Specification of source category 5D Wastewater handling.

5D	Source category	Specification
5D1	Domestic wastewater handling	Emissions from liquid waste handling and sludge from housing and commercial sources
5D2	Industrial wastewater handling	Emissions from handling of liquid wastes and sludge from industrial processes

Table 6-18 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 5D Wastewater handling

Source category 5D Wastewater handling is not a key category.

The emissions related to wastewater treatment fall under various categories as laid out in Figure 6-5 below. The system boundaries of category 5D contain all emissions from direct wastewater handling, some emissions from sewage sludge drying and no emissions from sewage sludge use or disposal. The discharge of sewage sludge on agricultural soils has been phased out since 2003 and is generally forbidden since 2008, therefore this process is crossed out in the figure below. The same applies to solid waste disposal on land (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).

The emissions from the use of sewage gas for combined heat and power generation as well as in boilers are reported in sector 1 Energy in source category 1A2gviii Other.

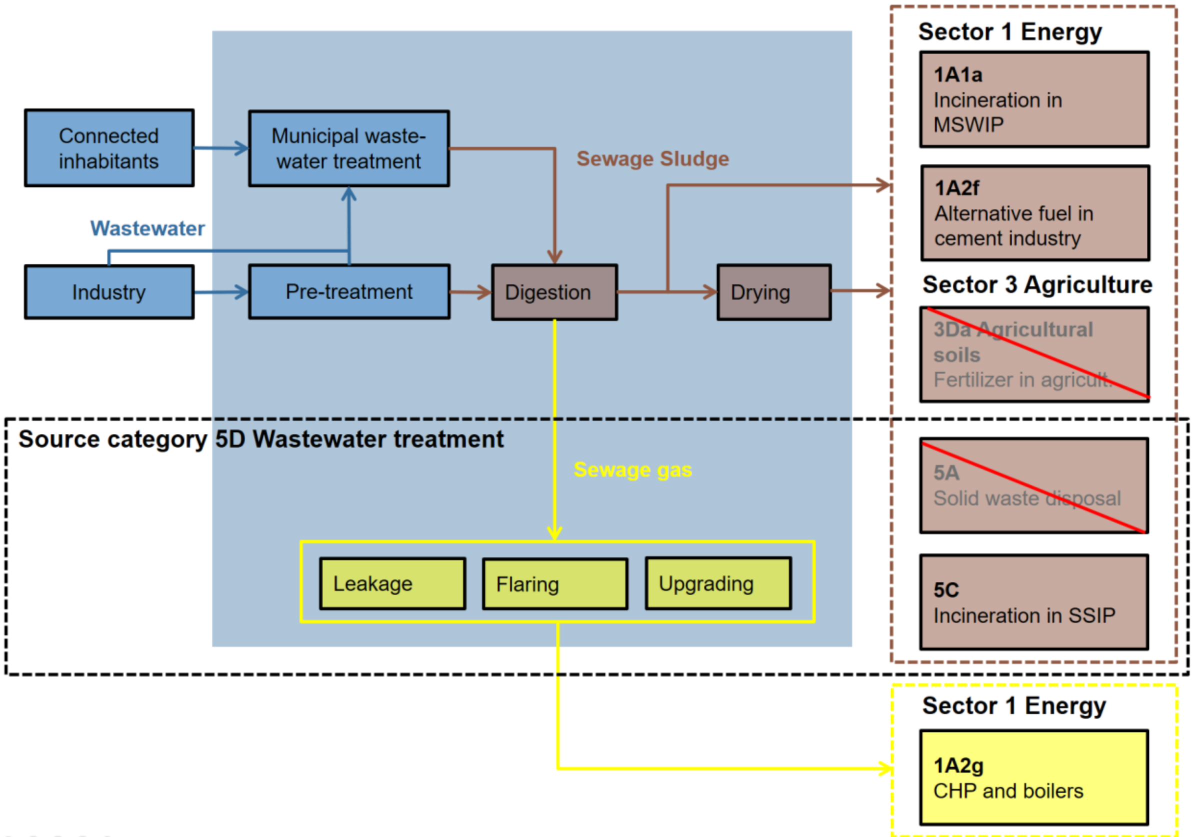

Figure 6-5 System boundaries of emissions related to wastewater handling. Abbreviations: CHP Combined Heat and Power Generation, MSWIP municipal solid waste incineration plant, SSIP sewage sludge incineration plant.

6.5.2 Methodological issues of 5D Wastewater handling

Methodology (5D)

For 5D1 Domestic wastewater handling and 5D2 Industrial wastewater handling, a Tier 2 method is used (see decision tree in chapter 5D Wastewater handling, EMEP/EEA 2019).

For 5D1 Domestic wastewater handling emission factors are calculated on the basis of the total emissions divided by the number of inhabitants (Swiss population, FSO 2023c). This number is not equivalent to the number of inhabitants connected to the wastewater system.

Emission factors (5D)

Emission factors are country-specific based on measurements and expert estimates, documented in the EMIS database (EMIS 2024/5D1, EMIS 2024/5D2), see Table 6-19.

Table 6-19 Emission factors for 5D Wastewater handling in 2022.

5D Wastewater handling	Unit	NO_x	NMVOC	SO_x	NH_3	CO
5D1 Domestic wastewater handling	g/person	0.59	0.012	0.0030	14	0.29
5D2 Industrial wastewater handling	g/person	0.15	0.0029	0.00073	NA	0.073

Activity data (5D)

Activity data for 5D1 Domestic wastewater handling and 5D2 Industrial wastewater handling are the total number of inhabitants extracted from FSO (2023c). The number of inhabitants connected to the system is the product of the number of inhabitants and the service level. The fraction and number of persons connected to wastewater systems are indicated below for informational reason.

Table 6-20: Activity data in 5D Wastewater handling: Population and fraction connected to wastewater treatment plants.

5D Wastewater handling	Unit	1990	1995	2000	2005	2010
Inhabitants	persons in 1000	6'712	7'041	7'184	7'437	7'825
Fraction connected to waste water treatment plants	%	90.0	93.7	95.4	96.8	97.2
Inhabitants connected	persons in 1000	6'041	6'597	6'854	7'199	7'606

5D Wastewater handling	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Inhabitants	persons in 1000	8'089	8'189	8'282	8'373	8'452	8'514	8'575	8'638	8'705	8'739
Fraction connected to waste water treatment plants	%	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3
Inhabitants connected	persons in 1000	7'871	7'968	8'058	8'147	8'224	8'284	8'343	8'405	8'470	8'503

6.5.3 Category-specific recalculations in 5D Wastewater handling

There were no recalculations implemented in submission 2024.

6.6 Source category 5E – Other waste, shredding

6.6.1 Source category description of 5E Other waste, shredding

In source category 5E only shredding of cars and electronic waste containing PCBs in small capacitors is considered.

Sewage sludge spreading is a drying process not occurring in Switzerland: In Swiss wastewater treatment plants, sewage sludge, after anaerobic digestion and generation of biogas, is stored in sludge tanks and in a first step, chemical and mechanical means are applied to dehydrate the sludge. Of the dehydrated sewage sludge, 70 – 80 % is incinerated in municipal solid waste incineration plants or in dedicated sewage sludge incineration plants. The remaining 20 – 30 % is used as alternative fuel in the cement industry (1A2f). For this purpose, the water content of the sludge has to be reduced to 10 %, which requires thermal drying processes. However in Switzerland, due to restrictions in available space, sludge spreading is not applied as a method for drying. The thermal drying predominantly occurs in large thermal drying plants equipped with flue gas treatment systems. Hence emission from sludge spreading (5E) is a process not applicable.

Table 6-21 Specification of source category 5E Other waste, shredding

5E	Source category	Specification
5E	Other waste	Emissions from car shredding plants; PCB emissions from shredding of electronic waste containing small capacitors

Table 6-22 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 5E Other waste, shredding

Source category 5E Other waste, shredding is not a key category.

6.6.2 Methodological issues of 5E Other waste, shredding

Methodology (5E)

For the emissions from car shredding a Tier 2 method is used (see decision tree in chapter 5E Other, EMEP/EEA 2019). Emissions are calculated by multiplying the quantity of scrap by respective emission factors. The PCB emissions from shredding of electronic waste containing PCBs in small capacitors are modelled within the treatment category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

Emission factors (5E)

For the emissions from car shredding country-specific emission factors are used (SAEFL 2000 and EMIS 2024/5E Shredder Anlagen). For all years, emission factors are considered to remain constant. The PCB emission factor expressed in units per tonnes of PCBs shredded is based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 6-23 Emission factors for 5E Other waste, car shredding and shredder in 2022. Unit of PCDD/PCDF is in I-TEQ.

5E Other waste	Unit	NMVOC	PM2.5 nx	PM10 nx	TSP nx	CO	Pb	Cd	PCDD/ PCDF	PCB
Car shredding	g/t scrap	200	5	10	12	5	0.022	0.0025	0.0000004	NA
Shredder	t/t PCB	NA	NA	NA	NA	NA	NA	NA	NA	0.071

Activity data (5E)

The quantities of shredded cars from 1990 are data provided by the Swiss shredder association. The data from 2003 and 2007 are taken from Swiss waste statistics. Data for the years in between is interpolated. From 2007 onwards the quantities are assumed to remain constant due to the lack of data (EMIS 2024/5E Shredder Anlagen). For PCB emissions, the activity data is the amount of PCBs shredded based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2. As a consequence of the legal ban of disposal of combustible waste in landfills, a sharp increase in shredding of small capacitors occurred in 1999 although they should have been treated as special waste from 1998 onwards.

Table 6-24 Activity data for car shredding (source EMIS 2024/5E Shredder Anlagen)

5E Other waste	Unit	1990	1995	2000	2005	2010
Car shredding	kt	280	300	300	300	300
Shredder	t PCB	3.0	3.3	10	3.5	0.71

5E Other waste	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Car shredding	kt	300	300	300	300	300	300	300	300	300	300
Shredder	t PCB	0.39	0.31	0.25	0.20	0.15	0.12	0.092	0.070	0.053	0.040

6.6.3 Category-specific recalculations in 5E Other waste, car shredding

There were no recalculations implemented in submission 2024.

7 Other and natural emissions

7.1 Overview of emissions

In this introductory chapter, an overview of emissions separated according to the most relevant pollutants is presented. Trends and changes for individual source categories in the period between 1990 and 2022 are analysed and discussed. In sectors 6 Other and 11 Natural emissions NH_3, NO_x, PM2.5 and NMVOC are the most relevant pollutants.

The following source categories are reported:

- 6Aa Humans
- 6Ab Pets
- 6Ac Fertilisers (private use)
- 6Ad Fire damages buildings and motor vehicles
- 11B Forest fires and open burning of residues in forestry
- 11C Other natural emissions (NMVOC from forest stands)

There are no emissions reported under memo item 6B Other.

Active volcanoes (11A) do not occur in Switzerland.

7.1.1 Overview and trend for NH_3

Figure 7-1 shows the trend of NH_3 emissions in sector 6 Other since 1990. The source category 6A Other sources is a key category for NH_3. Total emissions fluctuate and have continuously slightly increased within the reporting period. Emissions from source category 6Ab Pets, which includes cats, dogs and livestock outside agriculture (i.e. asses, goats, horses and sheep) as well as zoo animals, contributes the largest share to total emissions. The emissions fluctuate due to the variability in the animal numbers. The emissions from 6Aa Humans show an increasing trend in line with the population growth, while the ones of 6Ac Fertilisers almost halved between 1990 and 1999 and have remained roughly constant since then. There is no ammonia emission from category 6Ad Fire damages.

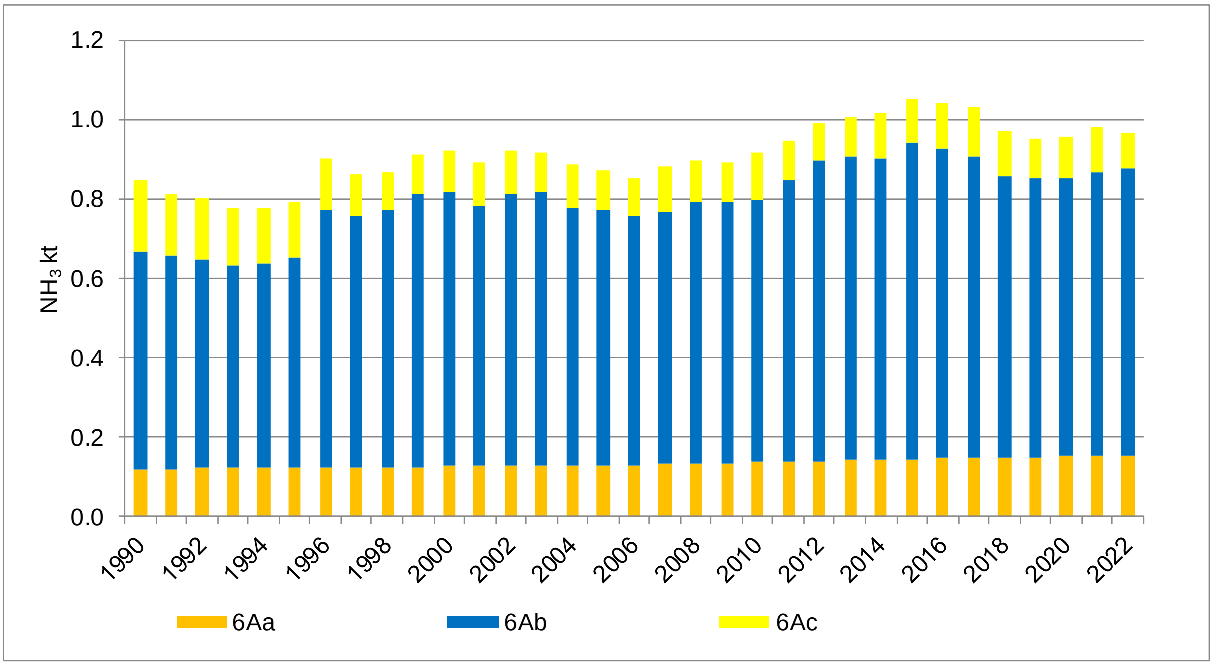

Figure 7-1 Switzerland's NH_3 emissions from sector 6 Other and natural emissions by source categories 6Aa, 6Ab and 6Ac. The corresponding data can be found in Table 7-1.

Table 7-1 NH_3 emissions from sector 6 Other by source categories 6Aa-6Ac. The last column in the third part of the table indicates the relative trend.

NH3	1990	1995	2000	2005	2010
	kt				
6Aa	0.12	0.12	0.13	0.13	0.14
6Ab	0.55	0.53	0.69	0.64	0.66
6Ac	0.18	0.14	0.11	0.10	0.12
Sum	0.85	0.79	0.92	0.88	0.92

NH3	2013	2014	2015	2016	2017
	kt				
6Aa	0.14	0.14	0.15	0.15	0.15
6Ab	0.76	0.76	0.80	0.78	0.76
6Ac	0.10	0.12	0.11	0.11	0.12
Sum	1.0	1.0	1.1	1.0	1.0

NH3	2018	2019	2020	2021	2022	2005–2022
	kt					
6Aa	0.15	0.15	0.15	0.15	0.15	18%
6Ab	0.71	0.70	0.70	0.72	0.72	13%
6Ac	0.11	0.10	0.10	0.11	0.09	-13%
Sum	0.97	0.95	0.96	0.98	0.97	11%

7.1.2 Overview and trend for NO_x

NO_x emissions from the source categories 6Ab Pets, 6Ac Fertilisers and 6Ad Fire damages buildings and motor vehicles between 1990 and 2022 are summarised in Figure 7-2. The contribution of sector 6A is very small in comparison to the national total and is not a key category for NO_x. The overall emissions fluctuate due to changes in the number of livestock outside agriculture (6Ab), but remain at about the same (low) level within the reporting period. For all years, 6Ab Pets and 6Ac Fertilisers contribute the most to total emissions. Emissions from 6Ac Fertilisers and 6Ad Fire damages buildings and motor vehicles show a slight decrease during the reporting period.

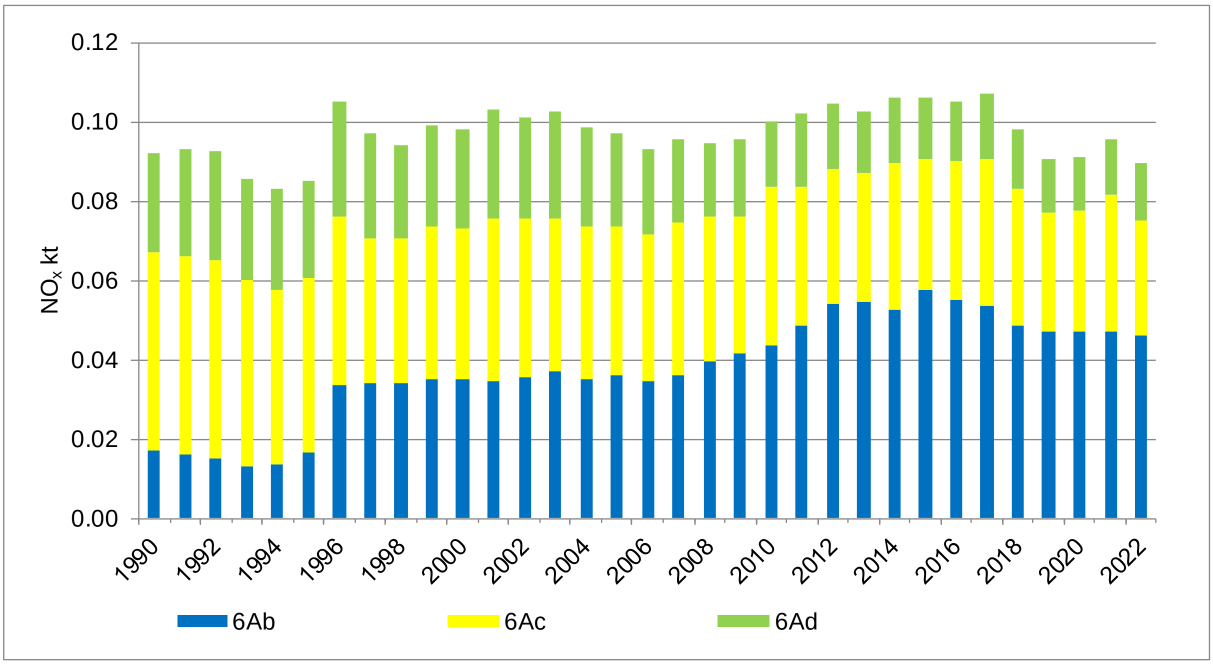

Figure 7-2 Switzerland's NO_x emissions from the sector 6 Other and natural emissions by source categories 6Ab, 6Ac and 6Ad. The corresponding data can be found in Table 7-2.

Table 7-2 NO_x emissions from sector 6 Other by source categories 6Ab-6Ad. The last column in the third part of the table indicates the relative trend.

NOx	1990	1995	2000	2005	2010
	kt				
6Ab	0.017	0.017	0.035	0.036	0.043
6Ac	0.050	0.044	0.038	0.038	0.040
6Ad	0.025	0.024	0.025	0.023	0.016
Sum	0.092	0.085	0.098	0.097	0.10

NOx	2013	2014	2015	2016	2017
	kt				
6Ab	0.054	0.053	0.058	0.055	0.054
6Ac	0.033	0.037	0.033	0.035	0.037
6Ad	0.015	0.017	0.015	0.015	0.017
Sum	0.10	0.11	0.11	0.11	0.11

NOx	2018	2019	2020	2021	2022	2005–2022
	kt					
6Ab	0.048	0.047	0.047	0.047	0.046	29%
6Ac	0.034	0.030	0.031	0.034	0.029	-23%
6Ad	0.015	0.013	0.013	0.014	0.014	-39%
Sum	0.098	0.091	0.091	0.096	0.090	-7.9%

7.1.3 Overview and trend for PM2.5

Figure 7-3 depicts the trend of PM2.5 emissions in sector 6 Other since 1990. The contribution of sector 6A is very small in comparison to the national total and is not a key category for PM2.5. Emissions from source category 6Ab Pets originate from livestock outside agriculture. They fluctuate due to changes in animal numbers and show an increasing trend from 2008 to 2015. Emissions from 6Ad Fire damages buildings and motor vehicles have a decreasing trend over the entire time period because the number of building fires is decreasing.

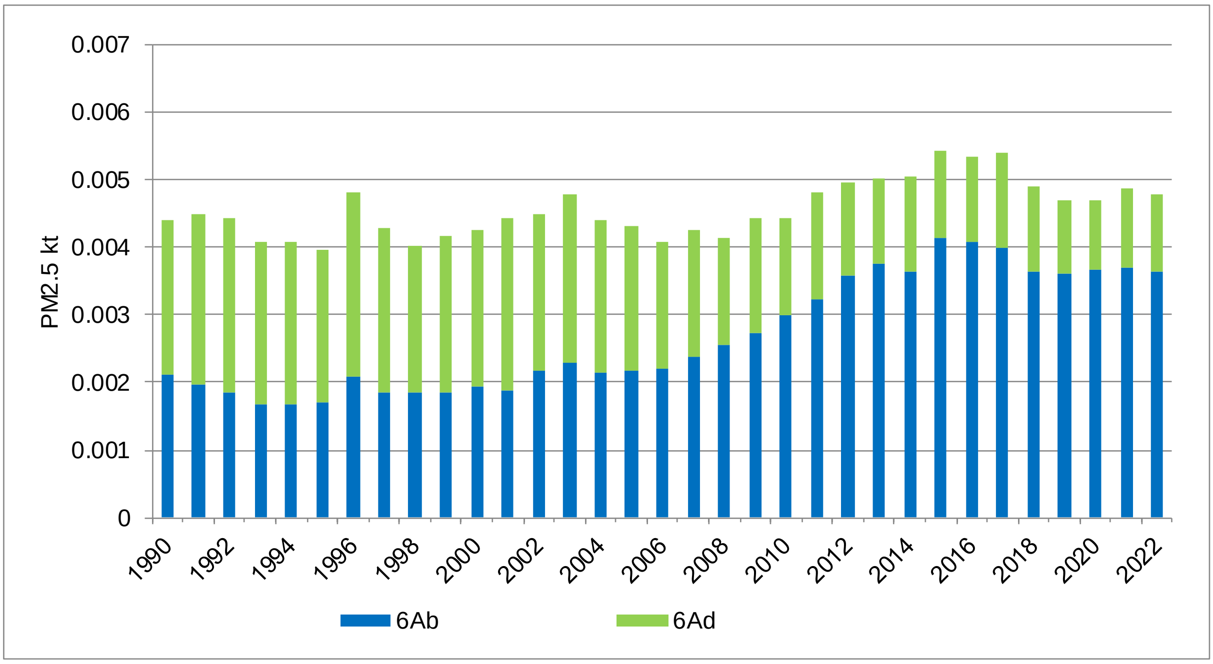

Figure 7-3 Switzerland's PM2.5 emissions from the sector 6 Other emissions. The corresponding data can be found in Table 7-3.

Table 7-3 PM2.5 emissions from sector 6 Other by source categories 6Ab and 6Ad. The last column in the third part of the table indicates the relative trend.

PM2.5	1990	1995	2000	2005	2010
	kt				
6Ab	0.0021	0.0017	0.0019	0.0022	0.0030
6Ad	0.0023	0.0023	0.0023	0.0021	0.0014
Sum	0.0044	0.0040	0.0042	0.0043	0.0044

PM2.5	2013	2014	2015	2016	2017
	kt				
6Ab	0.0038	0.0036	0.0042	0.0041	0.0040
6Ad	0.0013	0.0014	0.0013	0.0013	0.0014
Sum	0.0050	0.0050	0.0054	0.0053	0.0054

PM2.5	2018	2019	2020	2021	2022	2005–2022
	kt					
6Ab	0.0036	0.0036	0.0037	0.0037	0.0036	66%
6Ad	0.0013	0.0011	0.0010	0.0012	0.0011	-46%
Sum	0.0049	0.0047	0.0047	0.0049	0.0048	11%

7.1.4 Overview and trend for NMVOC from Forests

Figure 7-4 depicts the trend of NMVOC emissions in the sector 11C Other natural emissions since 1990 for various tree species. The emissions stem predominantly from Norway spruce, fir and oak stands. They are considerably high in comparison to the national total of NMVOC emissions. However, sector 11C is reported as a memo item only and is therefore not a key category for NMVOC. Total emissions in 1990 were 60.8 kt; they are increasing on average by 0.34 % per year. The annual fluctuations are due to the meteorological conditions, which influence the emission rates of the trees.

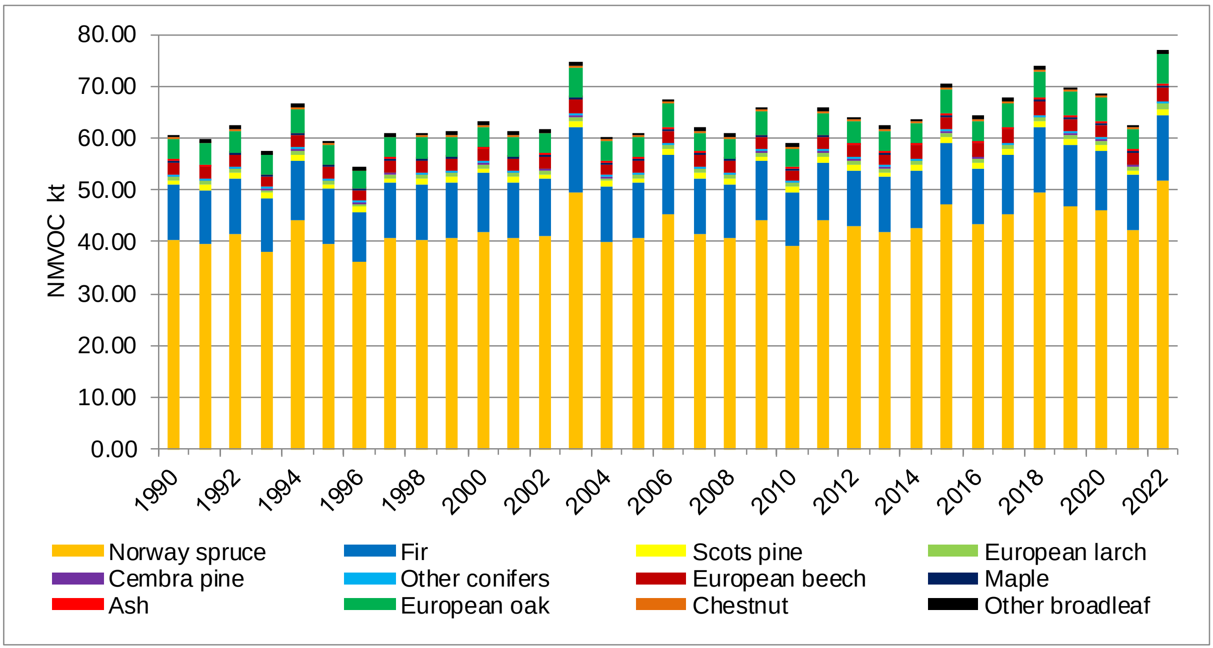

Figure 7-4 Switzerland's NMVOC emissions from the sector 11C Other natural emissions (forest stands).

7.2 Source category 6 - Other emissions

7.2.1 Source category description of 6 Other emissions

Within the sector 6 Other emissions, emissions from the sources as shown in Table 7-4 are considered.

Table 7-4 Specification of sector 6 Other emissions.

6A	Source category	Specification
6Aa	Human emissions	NH3 emissions from respiration and transpiration and diapers
6Ab	Pets and livestock outside agriculture	NOx, NMVOC, NH3, PM2.5, PM10 and TSP emissions of domestic and zoo animals and of livestock not included in sector 3 Agriculture
6Ac	Private application of synthetic fertilizer and urea	NOx and NH3 emissions
6Ad	Fire damages and accidential PCB release	Emissions from fires in buildings and emissions from fires and fire damage in motor vehicles Emissions from accidential PCB releases by fire and to soil

Table 7-5 Key categories, approaches 1 and 2, level assessment 2022 (L1, L2) and trend assessment 1990-2022 (T1, T2) for source category 6A Other emissions.

NFR code	Source category	Pollutant	Identification criteria
6A	Other sources	NH3	L2, T2

7.2.2 Methodological issues of 6 Other emissions

Methodology (6A)

Human emissions (6Aa)

Ammonia emissions of human respiration and transpiration and of diapers are considered.

Emissions from pets and livestock outside agriculture (6Ab)

Ammonia emissions of domestic animals such as cats and dogs as well as of zoo animals are considered.

Emissions of NO_x, NMVOC, NH_3 and particulate matter (PM2.5, PM10 and TSP) from manure management of so-called livestock outside agriculture (i.e. asses, goats, horses and sheep) are considered. This livestock is not covered by the agricultural census as it consists of animals 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. The methodology is the same as for animal husbandry in agriculture (see chp. 5.2.2).

Emissions from private fertiliser use (6Ac)

The methodology for calculating emissions of NO_x and NH_3 from private use of inorganic N-fertiliser is the same as for fertilisers used in the agricultural sector (see chp. 5.3.2). The methodology for calculating NH_3 emissions from application of inorganic fertilisers in agriculture (source category 3Da1) is a Tier 2 approach of the EMEP/EEA guidebook (EMEP/EEA 2019) taking into account the specified list of fertilisers, climate zone and pH. Emission factors and activity data are given in Table 7-6 and Table 7-9, respectively.

Emissions from fire damage buildings and motor vehicles and emissions from accidental release of PCBs by fire and to soil (6Ad)

Activity data for 6Ad Fire damage buildings 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 2024/6A), multiplied by the burnt material (400 kg) per fire incident. The resulting value of 9 kt burnt goods is used for the year 1990.

Activity data for 6Ad Fire damage motor vehicles are estimated yearly based on the vehicle number published annually by the Federal Statistical Office FSO (EMIS 2024/6A). 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 amount of material burnt can be calculated from the total number of cars in Switzerland.

From all PCB usage in transformers, large and small capacitors, anti-corrosive paints and joint-sealants, PCBs can be accidentally released by fire or spilling to soil. These PCB emissions are modelled within the accidental release category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

Emission factors (6A)

The emission factors for the source categories 6Aa to 6Ac are depicted in Table 7-6. Emission factors for fertiliser see also Table 5-18.

Ammonia emissions (6Aa-6Ac)

Emission factors for human ammonia emissions are extracted from Sutton et al. (2000). Emission factors for pet (cats, dogs and zoo animals) ammonia emissions are retrieved from Reidy and Menzi (2005). The ammonia emission factors for livestock outside agriculture are derived from source category 3B – Manure management (see chp. 5.2.2).

NOx, NMVOC, PM2.5, PM10 and TSP non-exhaust (6Ab)

The emission factors for NOx, NMVOC, PM2.5, PM10 and TSP from livestock outside agriculture are implied values based on emission factors of the respective animal categories (asses, goats, horses and sheep) in source categories 3B Manure management and 3D Crop production and agricultural soils (see chp. 5.2.2 and chp. 5.3.2).

Table 7-6 Emission factors for the year 2022 in sector 6 Other emissions (source EMIS 2024/6A).

6 Other emissions	Unit	NOx	NMVOC	NH_3	PM2.5 nx	PM10 nx	TSP nx
6Aa Human emissions							
Human respiration	g/person	NA	NA	3	NA	NA	NA
Human transpiration	g/person	NA	NA	14	NA	NA	NA
Children <1y	g/person	NA	NA	12	NA	NA	NA
Children 1–3y	g/person	NA	NA	15	NA	NA	NA
Aged inhabitants	g/person	NA	NA	42	NA	NA	NA
6Ab Pets and livestock outside agriculture							
Livestock, outside agriculture	g/animal	459	991	3'304	36	90	218
Cats	g/animal	NA	NA	90	NA	NA	NA
Dogs	g/animal	NA	NA	400	NA	NA	NA
Zoo animals	g/t	NA	NA	41'400	NA	NA	NA
6Ac Private application of synthetic fertilizer and urea							
Fertilizer, outside agriculture	kg/t	18	NA	57	NA	NA	NA

Fire damages (6Ad)

Fire damages buildings (EMIS 2024/6A Immobilienbraende): Emission factors for CO, NO_x and SO_x are country-specific based on measurements and expert estimates originally derived for illegal waste incineration. It is assumed that emissions are similar in fire damage in buildings. The emission factors for Cd and Hg are country-specific and based on measurements from a study about a cable recycling company in Switzerland (Graf 1990). For Pb, the emission factor is updated yearly and derived from a bottom-up estimation based on estimation of the fraction of new or renovated buildings (therefore without lead-containing paint) and a rough inventory of lead-containing items within a building. For Pb, the emission factor decreases gradually from 1990 until the reporting year, due to the progressive ban of lead in construction items and consumption goods, as enforced by the Chemical Risk Reduction Ordinance ORRChem. It is assumed that the PCDD/PCDF emission factor is the same as for illegal waste incineration. The emission factor for B(a)P is taken from USEPA 1998 (Table 4.10.5-1 Open burning of municipal refuse).

Fire damage motor vehicles (EMIS 2024/6A Fahrzeugbraende): The following emission factors are constant over the reporting period and derived from three scientific publications reporting estimations based on real car fire experiments:

- CO and NO_x (ADEME 2013, INERIS 2019)
- Heavy metals As, Cd, Cr, Cu, Hg, Ni, Se, Zn (Lönnermark and Blomqvist 2006 and ADEME 2013)
- PCB and PCDD/PCDF (INERIS 2019)

For Pb, the emission factor reported by Lönnermark and Blomqvist 2006 (820 g/t, car model from 1998) is significantly higher than the one reported in ADEME 2013 (31 g/t, car model between 2008 and 2013). This reported discrepancy may be explained by additional legal measures to decrease lead content in cars over the years. One such measure in Switzerland is the ban of lead as weel weight that entered into force in 2005. We therefore use for Pb an emission factor that is yearly updated and computed as an average of the two published values, weighted by the fraction of cars in service since 2005.

The emission factor for NMVOC, PM10, PM2.5 and SO_x are country-specific and based on measurements and expert estimates originally derived for wire burn off. The emission factors for PAH are determined by USEPA 1998 (chp. 4.10.2 Open burning of scrap tires). It is assumed that the emission factor for B(a)P is slightly higher than the study-based emission factor for B(a)P of car scrap due to higher B(a)P emission factor values of car tires.

Table 7-7 presents the emission factors used for the reporting year.

Table 7-7 Emission factors for fires reported under 6Ad Fire damages buildings and motor vehicles in 2022 as kg/t burned good and g/t burned good, respectively. Unit of PCDD/PCDF is in I-TEQ.

6Ad Fire damages	Unit	NO_x	NMVOC	SO_X	PM10	TSP	CO
Fire damage buildings	kg / t burned good	3	16	0.75	25	30	100
Fire damage motor vehicles	kg / t burned good	4.5	2	5	1	70	52

6Ad Fire damages	Unit	Pb	Cd	Hg	PCDD/F	BaP	BbF	BkF	IcdP
Fire damage buildings	g / t burned good	398	0.2	0.1	0.0002	0.00034	0.0002	0.00027	0.0001
Fire damage motor vehicles	g / t burned good	107	0.96	0.38	0.0004	50	30	40	15

Emissions from accidental release of PCBs (6Ad)

The PCB emission factors from accidental release of PCBs by fire and to soil are expressed in units per tonnes of PCBs incinerated and stored in soil, respectively, see Table 7-8. They are based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 7-8 PCB emission factors for accidental release of PCB by fire and to soil, respectively, reported under 6Ad Other emissions in 2022 as kg/t released PCB.

6Ad Accidential release of PCB	Unit	PCB
by fire	kg/t released PCB	100
to soil	kg/t released PCB	0.37

Activity data (6A)

Human emissions (6Aa)

Activity data for human ammonia emissions is retrieved from the Swiss Federal Statistical Office and consists of the number of inhabitants for the processes respiration and transpiration, whereas for the emissions from diapers the number of children younger than 1 year and 3 years respectively, are taken into account as well as the number of residents in nursing homes.

Pets and livestock outside agriculture (6Ab)

Activity data for pet ammonia as well as NO_x, NMVOC, PM2.5, PM10 and TSP emissions (for livestock outside agriculture) are the number of domestic animals and the total live weight of zoo animals, respectively. For domestic animals, different publications are used as a source. The number of the most important category of dogs and cats is provided by the Swiss Association for pet food[5].

Emissions from private fertiliser use (6Ac)

For 6Ac only mineral fertilisers (no urea-based fertilisers) are used for private applications outside agriculture.

Table 7-9 Activity data causing N emissions in sector 6 Other emissions.

6 Other emissions	Unit	1990	1995	2000	2005	2010
6Aa Human emissions						
Human respiration	person	6'712'000	7'041'000	7'184'000	7'437'000	7'825'000
Human transpiration	person	6'712'000	7'041'000	7'184'000	7'437'000	7'825'000
Children <1y	person	83'939	82'203	78'458	72'903	80'290
Children 1–3y	person	238'030	253'652	237'941	217'302	229'471
Aged inhabitants	person	9'000	9'752	10'504	11'029	17'357
6Ab Pets and livestock outside agriculture						
Livestock, outside agriculture	animals	16'326	18'649	88'285	89'276	95'332
Cats	animals	1'164'786	1'205'000	1'379'000	1'417'000	1'507'000
Dogs	animals	456'015	438'000	513'000	487'000	445'000
Zoo animals	t	140	140	140	140	140
6Ac Private application of synthetic fertilizer and urea						
Fertilizer, outside agriculture	t	2'778	2'432	2'111	2'087	2'212

6 Other emissions	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
6Aa Human emissions											
Human respiration	person	8'089'000	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
Human transpiration	person	8'089'000	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
Children <1y	person	82'731	85'287	86'559	87'883	87'381	87'851	86'172	85'914	89'644	82'371
Children 1–3y	person	243'262	245'703	250'182	254'577	259'729	261'823	263'115	261'404	259'937	261'730
Aged inhabitants	person	18'389	18'679	19'278	19'244	19'793	20'337	20'661	19'827	19'946	20'957
6Ab Pets and livestock outside agriculture											
Livestock, outside agriculture	animals	111'397	108'866	120'094	113'379	109'783	107'715	103'135	102'173	102'912	100'749
Cats	animals	1'543'317	1'618'406	1'655'951	1'655'951	1'645'096	1'634'240	1'678'277	1'722'313	1'788'036	1'853'759
Dogs	animals	511'297	518'360	521'891	521'891	513'816	505'740	504'375	503'009	523'734	544'459
Zoo animals	t	140	140	140	140	140	140	140	140	140	140
6Ac Private application of synthetic fertilizer and urea											
Fertilizer, outside agriculture	t	1'822	2'056	1'823	1'933	2'057	1'907	1'673	1'712	1'890	1'602

Fire damages and accidental release of PCBs (6Ad)

Activity data for source category fire damages and accidental release of PCBs (6Ad) are given in Table 7-10. For accidental release of PCBs by fire and to soil, the activity data are the

[5] Verband für Heimtiernahrung VHN (http://www.vhn.ch/)

amounts of PCBs incinerated and stored in soil, respectively, based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 7-10 Activity data in source category 6Ad Fire damages: Burnt goods (source EMIS 2024/6A).

6Ad Fire damages	**Unit**	**1990**	**1995**	**2000**	**2005**	**2010**
Fire damage buildings	kt	9.0	8.8	9.0	8.2	5.4
Fire damage motor vehicles	kt	0.48	0.52	0.58	0.64	0.68
6Ad Accidential release of PCB						
by fire	t	2.4	1.7	1.1	0.70	0.43
to soil	t	39	41	41	41	41

6Ad Fire damages	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Fire damage buildings	kt	4.8	5.3	4.8	4.7	5.3	4.8	4.0	3.8	4.3	4.3
Fire damage motor vehicles	kt	0.72	0.73	0.75	0.76	0.77	0.77	0.78	0.79	0.80	0.81
6Ad Accidential release of PCB											
by fire	t	0.32	0.29	0.26	0.24	0.22	0.20	0.18	0.16	0.14	0.13
to soil	t	41	41	40	40	40	40	40	40	40	39

7.2.3 Recalculations in 6 Other emissions

The following recalculations were implemented in submission 2024:

- 6Aa Human emissions (NH_3): The activity data “number adults wearing diapers” in 2021 has increased by 0.36 % (+67 people), due to changes in the underlying statistics by the FSO.
- 6Ab Pets and livestock outside agriculture (NH_3): The activity data "Number of pet cats" in 2021 has decreased by 3.7 %, due to changes in the underlying statistics.
- 6Ab Pets and livestock outside agriculture (NH_3): The activity data "Number of pet dogs" in 2021 has decreased by 4 %, due to changes in the underlying statistics.
- 6Ab: The NO_x emission factors of source category 6Ab Livestock outside agriculture were revised for the years 1995-2021.
- 6Ac: The activity data and the NH_3 emission factor of source category 6Ac Other synthetic fertiliser were updated for 2020 and 2021 due to adjusted values in the AGRAMMON model.
- 6Ad Fire damages buildings (EMEP Guidebook 5 E Other): The emission factors for Cd exhaust, Hg, Zn exhaust, SO_x, NO_x, PCDD/PCDF, and all PAH were erroneously reported and have been corrected, resulting in major emission changes, from 1’000 times less up to 25 % more. For Pb, a new estimation for the time period 1990-2021 has been established. While its emission factor remains the same for 1990, it decreases gradually until the reporting year, due to limitation of lead in construction items and consumption goods.
- 6Ad Fire damages buildings: The activity data for the number of building fires has been reassessed for the time period 1990-2021. The activity data is now based on the number of fires per year instead of the total costs of fires. Once the total costs of fire have been corrected for inflation, both the number of fires and total costs follow a similar decreasing trend over the time 1990-2021. This reassessment causes emissions changes from +10 % in 1990 to -45 % in 2021, for all reported pollutants: SO_x, NO_x, NMVOCs, CO, BC, PM, heavy metals, PCDD/PCDF, PAK.
- 6Ad Fire damages motor vehicles: The emission factor for source category 6Ad Other for pollutants emitted during accidental car fires has been reassessed for NO_x, CO, PM exhaust, heavy metals, PCB, PCDD/PCDF. It is now based on the average of several car fire experiments reported in the literature. This causes changes in emissions for the time period 1990-2021 by up to several orders of magnitude.

7.3 Source category 11B - Forest fires

7.3.1 Source category description of 11B Forest fires

Within 11B Forest fires, emissions of NO_x, NMVOC, SO_x, NH_3, particulate matter, CO, Pb, Cd, Hg, PCDD/PCDF and PAH are reported.

Table 7-11 Specification of source category 11B Forest fires in Switzerland.

11B	Source category	Specification
11B	Forest fires	Emissions from natural wildfires on forest land and grassland; Emissions from open burning of natural residues in forestry

Note that emissions are reported under 11B Natural emissions but are not accounted for in the national totals and are reported as memo item only. In the greenhouse gas inventory, wildfires are reported in sector 4V.

As a consequence of the greenhouse gas inventory UNFCC in-country review 2016, greenhouse gas emissions from open burning of natural residues in forestry (5C2ii) was moved from sector 5C to sector 4VA1. The corresponding air pollutant emissions are reported here within source category 11B.

7.3.2 Methodology of 11B Forest fires

For calculating the emissions of forest fires a country-specific Tier 2 method is used (see decision tree in chapter 11B Forest fires in the EMEP/EEA guidebook (EMEP/EEA 2019). Emissions of wildfires are calculated by multiplying the annual area of forest and grassland burnt by the appropriate emission factors.

For the calculation of the emissions from burning of silvicultural residues a country-specific Tier 2 method is used (see decision tree in chapter 5C2 Open burning of waste, EMEP/EEA 2019).

Emission factors (11B)

Emission factors for forest and grassland fires are specified in the EMIS database (EMIS 2024/4VA1-11B-NFR_Waldbrände). Between 1900 and 1990, the available fuel on forest land, i.e. the mean biomass stocks, increased by a factor of 2.3 (Kurz et al. 1998). This information was used to calculate time series of the emission factors for most pollutants. For burnt grassland, the emission factors remain constant.

Emission factors for open burning of natural residues in forestry are taken from EMEP guidebook (EMEP/EEA 2019, chp. 5.C.2, table 3-2) and USEPA as documented in EMIS 2024/5C2 Abfallverbrennung Land- und Forstwirtschaft.

Table 7-12 Emission factors 2022 of 11B Forest fires, grassland fires and open burning of natural residues in forestry. Unit of PCDD/PCDF is in I-TEQ.

11B Forest fires	Unit	NO_x	NMVOC	SO_X	NH3	PM2.5	PM10	TSP	CO
Forest fires	kg/ha	87	500	43	43	1'000	1'200	1'800	2'280
Burning grassland	kg/ha	13	34	3	3	110	140	210	373
Open burning of natural residues in forestry	g/t	1'380	1'470	30	800	3'760	4'130	4'310	48'790

11B Forest fires	Unit	Pb	Cd	Hg	PCDD/F	BaP	BbF	BkF	IcdP
Forest fires	kg/ha	NE	NE	0.0014	0.0000004	0.08	0.14	0.14	0.18
Burning grassland	kg/ha	NE	NE	0.0014	0.0000004	0.08	0.14	0.14	0.18
Open burning of natural residues in forestry	g/t	0.32	0.13	0.06	0.00001	3.2	6.5	5.2	1.7

Activity data (11B)

The area of forest land and grassland burnt is provided by swissfire, a database of wildfires managed by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) as documented in the EMIS database (EMIS 2024/4VA1-11B-NFR_Waldbrände). For the years since 1990, the swissfire database is also used in the GHGI (FOEN 2024). Burnt grassland areas also include woody grassland.

The activity data for burning of silvicultural residues is decreasing since 1990 since legal burning is more strongly restricted, especially since the last revision of the corresponding article in the Swiss Federal Ordinance on Air Pollution Control in the year 2009 (Swiss Confederation 1985 as of 1 January 2009). Activity data are documented in EMIS 2024/5C2 Abfallverbrennung Land- und Forstwirtschaft.

Table 7-13 Activity data of 11B Forest fires, grassland fires and open burning of natural residues in forestry.

11B Forest fires	Unit	1990	1995	2000	2005	2010
Forest fires	ha	1'067	363	47	41	26
Burning grassland	ha	637	82	22	20	1.3
Open burning of natural residues in forestry	kt	29	25	20	16	12

11B Forest fires	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Forest fires	ha	24	43	45	256	106	55	16	11	26	267
Burning grassland	ha	4	3	8.0	212.3	38.2	29	16	30	10	63
Open burning of natural residues in forestry	kt	11	11	11	11	11	11	10	10	10	10

7.3.3 Recalculations in 11B Forest fires

The following recalculations were implemented in submission 2024:

- 11B: The time series of wildfires were recalculated with updated activity data from the Swissfire database in the years 2015 and 2021 on forest land.

7.4 Category 11C – Other natural emissions

7.4.1 Category description of 11C Other natural emissions

Within 11C Other natural emissions, NMVOC emissions of Swiss forest stands are reported for different tree species. 11C also includes NMVOC emissions from natural grassland.

Note that emissions are reported under Natural emissions (11C) but are not accounted for in the national totals and are reported as memo item only.

Table 7-14 Specification of source category 11C Other natural emissions in Switzerland.

11C	Source category	Specification
11C	Other natural emissions	Natural NMVOC emissions from forest trees; NMVOC emissions from natural grassland

7.4.2 Methodology of 11C Other natural emissions

The biogenic NMVOC emissions from forests 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, EMIS 2024/11C Wald). This corresponds to the simplified method according to chapter 11C in the EMEP/EEA guidebook (EMEP/EEA 2019) which represents a Tier 2 approach. With the method used, the emissions for iso-prene, monoterpene and OVOC (Oxygenated VOC) could be modelled for each month with a spatial resolution of 100 x 100 m.

The NMVOC emission of natural grassland is 0.51 kt yr^{-1} for all years according to SAEFL (1996a).

Emission factors (11C)

Emission factors for NMVOC emissions of different tree species are specified in the EMIS database (Table 7-15). They represent annual implied emission factors derived from the monthly emission maps. The values after 2022 are interpolated between the modelled years 2020 and 2050.

Table 7-15 Implied emission factors 2022 of 11C NMVOC for different tree species.

11C Tree species	Unit	NMVOC
Norway spruce	g/ha	88'585
Fir	g/ha	91'083
Scots pine	g/ha	23'079
European larch	g/ha	11'221
Cembra pine	g/ha	15'176
Other conifers	g/ha	123'253
European beech	g/ha	11'605
Maple	g/ha	22'877
Ash	g/ha	8'446
European oak	g/ha	221'679
Chestnut	g/ha	13'160
Other broadleaf	g/ha	11'495

Figure 7-5 shows the time series of emission factors for a coniferous species and a broadleaf species. The interannual variation is due to the monthly climatic data used in the model (Meteotest 2019a, EMIS 2024/11C Wald).

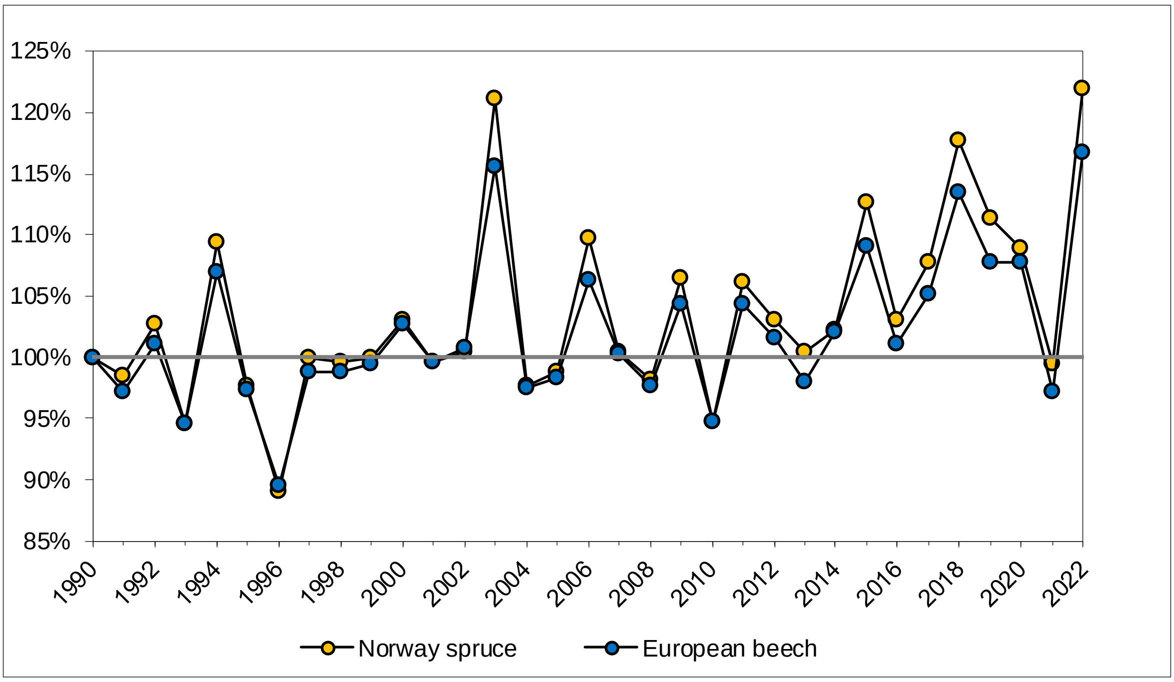

Figure 7-5 Relative trends of the (implied) NMVOC emission factors for two selected tree species 1990-2022.

Activity data (11C)

On the basis of several forest and area statistics, the area proportions of the various tree species and their temporal change over the years could be determined (Meteotest 2019a) as shown in Table 7-16.

Table 7-16 Activity data of 11C; forest areas covered by the twelve main tree species.

11C Tree species	Unit	1990	1995	2000	2005	2010
Total	ha	1'211'651	1'220'183	1'229'051	1'237'835	1'247'057
Total coniferous	ha	829'570	835'789	842'127	848'438	855'920
Norway spruce	ha	554'168	558'151	562'292	566'457	571'778
Fir	ha	138'196	138'374	138'497	138'634	138'930
Scots pine	ha	49'503	49'823	50'136	50'400	50'688
European larch	ha	73'421	74'919	76'432	77'933	79'282
Cembra pine	ha	11'025	11'261	11'502	11'745	11'964
Other conifers	ha	3'257	3'261	3'268	3'269	3'278
Total non-coniferous	ha	382'081	384'394	386'924	389'397	391'137
European beech	ha	226'751	227'722	228'738	229'799	230'716
Maple	ha	15'325	15'461	15'614	15'729	15'857
Ash	ha	28'555	28'655	28'782	28'911	28'991
European oak	ha	24'911	24'919	24'978	25'023	25'027
Chestnut	ha	26'877	27'097	27'353	27'578	27'674
Other broadleaf	ha	59'662	60'540	61'459	62'357	62'872

11C Tree species	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total	ha	1'252'632	1'254'489	1'256'307	1'258'136	1'260'026	1'261'840	1'263'687	1'265'518	1'267'457	1'269'355
Total coniferous	ha	860'557	862'131	863'641	865'167	866'724	868'212	869'778	871'331	872'989	874'584
Norway spruce	ha	575'109	576'243	577'328	578'465	579'544	580'618	581'777	582'896	584'087	585'229
Fir	ha	139'149	139'220	139'295	139'380	139'463	139'535	139'606	139'670	139'725	139'793
Scots pine	ha	50'870	50'939	51'002	51'056	51'119	51'163	51'219	51'269	51'343	51'418
European larch	ha	80'032	80'282	80'532	80'733	81'007	81'244	81'478	81'748	82'013	82'274
Cembra pine	ha	12'114	12'161	12'196	12'241	12'296	12'353	12'395	12'442	12'505	12'552
Other conifers	ha	3'283	3'286	3'288	3'292	3'295	3'299	3'303	3'306	3'316	3'318
Total non-coniferous	ha	392'075	392'358	392'666	392'969	393'302	393'628	393'909	394'187	394'468	394'771
European beech	ha	231'256	231'422	231'609	231'780	231'974	232'161	232'314	232'462	232'615	232'790
Maple	ha	15'953	15'982	16'007	16'039	16'067	16'095	16'125	16'158	16'180	16'210
Ash	ha	29'025	29'037	29'047	29'062	29'082	29'095	29'109	29'128	29'154	29'167
European oak	ha	25'035	25'039	25'040	25'041	25'043	25'047	25'051	25'052	25'055	25'058
Chestnut	ha	27'687	27'693	27'700	27'706	27'715	27'724	27'731	27'739	27'741	27'750
Other broadleaf	ha	63'119	63'185	63'263	63'341	63'421	63'506	63'579	63'648	63'723	63'796

7.4.3 Recalculations in 11C Other natural emissions

The following recalculations were implemented in submission 2024:

- 11C Natural emissions from forest trees: Emissions in 2021 (and 2022) were modelled on the basis of monthly meteorological data. They replace the extrapolated values of the previous submission.

8 Recalculations and improvements

8.1 Explanations and justifications for recalculation

Several recalculations had to be carried out due to improvements in several sectors. They are listed sorted by sector in the following enumerations. Improvements realised for this submission and leading to recalculations are described in chp. 1.4.1.

8.1.1 1 Energy

8.1.1.1 Category specific recalculations for 1A1 Energy industries (stationary)

- 1A1: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.
- 1A1a: Activity data of source category 1A1a Combined chip heat and power plants have been revised for 1990-2021 due to recalculations in the Swiss wood energy statistics (SFOE 2023b).
- 1A1a: The emission factors for BC, CO, NO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust for source category 1A1a for combined heat and power generation from landfill gas have been updated for 1990-2021 and are now set equal to emission factors for process 1A4ci Other sectors - Agriculture/forestry/fishing, because the combustible biogas is similar and because the motor types in use are also comparable. Changes range from -99 % for all PM up to +43 % for NO_x.
- 1A1a: The emissions of PM2.5 exhaust, PM10 exhaust and TSP exhaust of wood energy combustion in source category 1A1a Public energy and heat production now also include the condensable particle fractions (1990-2021, PM2.5 (2021): +10 %).
- 1A1a and 1A1b: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails several changes in fuel consumption of fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and of biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A1c: The activity data of source category 1A1c Charcoal production was updated for 2021 due to a corrected production quantity of a charcoal burning plant.

8.1.1.2 Category-specific recalculations for 1A2 Stationary combustion in manufacturing industries and construction

- 1A2: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.
- 1A2: The activity data (gas oil) of source category 1A2gviii Boiler - Other have changed for 2021 because the activity data (gas oil) of source category 1A2f Fine ceramics production was revised for 2021 based on plant information.

- 1A2: Due to the revised model of natural gas losses in 1A2b Natural gas, the changes also have an impact on final natural gas consumption and therefore on all source categories in 1A2 for the years 1990-2021.
- 1A2d: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A2f: The incorrect activity data for 2021 of source category 1A2f Glass wool production was corrected.
- 1A2f: The activity data for 1A2f for heating oil consumption in cement production for the year 2019 was erroneously reported and was corrected, resulting in a reduction of the value by 59 %.
- 1A2f: The activity data for 1A2f for consumption of other bituminous coal in cement production for the year 2018 was erroneously reported and was corrected, resulting in a 5 % increase of the value.
- 1A2f: The activity data for 1A2f Cement production, for all biogenic fuels as well as for waste-derived fuels, have changed for the year 2021 due to rounding, resulting in less than 0.1 % change for each value.
- 1A2g: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A2gviii: Activity data of automatic wood combustion installations in source category 1A2gviii have been revised for 1990-2021 due to recalculations in the Swiss wood energy statistics (SFOE 2023b). The biggest changes were in automatic boilers >500 kW and combined chip heat and power plants in 2021.
- 1A2gviii: The activity data of source category 1A2gviii Other for combustion of biogas is now reported in our database directly in GJ instead of GWh and with additional significant digits (see chp. 3.2.1.1.3). In addition, erroneously reported values for the years 1996-1999 have also been corrected, causing emission changes from -9 % up to +10 %. This change affects the following pollutants: NO_x, NMVOC, SO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust, BC, CO, heavy metals, POPs.
- 1A2gviii: The emissions of PM2.5 exhaust, PM10 exhaust and TSP exhaust of wood energy combustion in source category 1A2gviii Stationary combustion - Other now also include the condensable particle fractions (1990-2021, PM2.5 (2021): +16 %).

8.1.1.3 Category-specific recalculations for 1A4 Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

- 1A4: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.

- 1A4: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.
- 1A4: Activity data of automatic wood combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2021 due to recalculations in the Swiss wood energy statistics (SFOE 2023b). The biggest changes were in automatic boilers >50 kW after 2018.
- 1A4: The emissions of PM2.5 exhaust, PM10 exhaust and TSP exhaust of wood energy combustion in source category 1A4ai Commercial/Institutional (stationary), 1A4bi Residential (stationary) and 1A4ci Agriculture/Forestry/Fishing (stationary) now also include the condensable particle fractions (1990-2021, PM2.5 (2021), 1A4ai: +41 %, 1A4bi: +74 % and 1A4ci: +57 %).
- 1A4ai: Source category 1A4ai now 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 fuel consumption is based on information from the Swiss wood energy statistics publication (SFOE 2023b, chp. 1.4), but is not part of the wood energy statistics model.
- 1A4bi: The activity of source category 1A4bi Charcoal consumption was revised for 2021 due to the correction of a typing error in the import figure and an updated value of 1A1c Charcoal production (364 TJ instead of 40 TJ).
- 1A4bi: The NH_3 emission factors of bonfires and use of charcoal were adjusted from 74 g/GJ to 8 g/GJ for the entire time series based on the revised value in EMEP/EEA 2023 (chp. 1A4, table 3-39).
- 1A4bi: Last year's correction of the NMVOC emission factor for single-room furnaces burning logwood was made up for 1A4bi Closed fireplaces.
- 1A4ci: The activity data of source category 1A4ci for combustion of biogas is now reported in our database directly in GJ instead of GWh and with additional significant digits, causing emission changes of less than 0.1 % for the entire time series. This change affects the following pollutants: NO_x, NMVOC, SO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust, BC, CO, heavy metals, POPs.

8.1.1.4 Category-specific recalculations for 1A2 Mobile combustion in manufacturing industry and construction (1A2gvii)

- 1A2gvii: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.

8.1.1.5 Category-specific recalculations for 1A3 Transport

- 1A3: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.

- 1A3a: Recalculation of non-exhaust PM, PM10 and PM1.5 emissions generated by airplanes during landing in 1A3a Aviation (LTO) for all years 1980-2021.
- 1A3b: Recalculation of activity data in sector 1A3b Road transportation due to new available statistics for activity data (mileage) for the different vehicle categories for all years from 1990-2021.
- 1A3e: A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- 1A3c: Small recalculation of the kilometres driven and thus the annual output for abrasion (non-exhaust) emissions for the year 2021. This recalculation results from slightly changed forecast values and interpolation between 2020 and the forecast values 2030.

8.1.1.6 Category-specific recalculations for 1A4 Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

- 1A4a/b/cii: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.

8.1.1.7 Category-specific recalculations for 1A5b Other, mobile (Military)

- 1A5b: The SO_2 emission factors for diesel, gasoline, gas oil, residual fuel oil, natural gas, bioethanol, biodiesel, gasolio and heating gas have been updated for all years 1980-2021 based on newly available measurement data. This affects several fuel combustion processes within sector 1A, see chp. 3.2.1.2 for details.

8.1.1.8 Category-specific recalculations for 1B Fugitive emissions from fuels

- 1B2a: The emission factors for NMVOC from gasoline losses and evaporation at petrol stations have changed due to corrections in the model for all reported years.
- Fugitive emissions from 1B2b – Natural gas: A new country-specific methodology has been established, completely revising the hitherto applied methodology by Quantis (2014). The main changes are:
  - Where applicable, outdated emission factors from Battelle (1989) are now replaced by emission factors from DVGW (2022) or actual measurements. This applies in particular to components, appliances, house installations, industrial networks, gas stoves, etc.
  - The number of actual leakages and third-party damages are now used, combined with emissions per leakage according to DVGW (2022).
  - Actual losses from the operation and maintenance of the transit pipeline based on annual data provided by the operator (for the years since 2016) are considered. Therewith, mitigation measures such as reducing the pressure within the pipelines before maintenance can now be reflected.

  - For the compressor station, the actual average compressor power is now used instead of the installed power.
  - Permeation through polyethylene pipelines is newly considered based on DVGW (2022).
  - Emissions from the handling of liquefied natural gas is newly considered under 1B2bv Distribution.
  - Emissions previously reported under 1B2bvi Other, Leakage are now included under Transmission (relevant for the years 2010 and 2011).
- 1B2c: Small recalculations for all pollutants in 1B2c Flaring oil due to the use of more precise values (more significant decimal places) for the emission factors of these pollutants for the years 2005-2021.

8.1.2 2 Industrial processes and product use

8.1.2.1 Category-specific recalculations in 2A Mineral products

- 2A5a: The last year's extrapolated activity data of 2A5a Gravel plants for 2021 was revised based on effective production data from the industry association.

8.1.2.2 Category-specific recalculations in 2B Chemical industry

There were no recalculations in submission 2024.

8.1.2.3 Category-specific recalculations in 2C Metal production

There were no recalculations in submission 2024.

8.1.2.4 Category-specific recalculations in 2D Other solvent use

- 2D3g: The NMVOC emission factor and activity data of source category 2D3g Glue production were revised for the years 1999-2017 and 1991-2017, respectively.
- 2D3g: The NMVOC emission factor and the activity data of source category 2D3g Polyester processing were updated for 2019. The emission factors for the years 2001 to 2012 were also revised, which resulted in recalculated emission factor values and activity data for 1999-2021 and 2013-2021, respectively.

8.1.2.5 Category-specific recalculations in 2G Other product use

- 2G: The incorrect activity data for 2021 of source category 2G Glass wool enduction was corrected.
- 2G: The activity data of source category 2G Fireworks has been updated for the year 2021 due to newly available statistics data. This results in an emission change of +30 %.

8.1.2.6 Category-specific recalculations in 2H Other industry production

- 2H2: The activity data of source category 2H2 Production of beer has been updated for the years 1990-2016 due to newly available statistics on beer production published by FOCBS. This results in emission changes ranging from -13 % to +1 %.
- 2H2: The activity data of source category 2H2 Production of smoked meat and fish has been updated for the years 2020 and 2021 due to an update in the underlying statistics, resulting in changes in emissions of -0.7 % for 2020 and +0.5 % for 2021.
- 2H2: The activity data of source category 2H2 Production of flour has been updated for the years 2020 and 2021 due to an update in the underlying statistics, resulting in changes in emissions of +1.9 % for 2020 and -0.3 % for 2021.

8.1.2.7 Category-specific recalculations in 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products

There were no recalculations implemented in submission 2024.

8.1.3 3 Agriculture

8.1.3.1 Category-specific recalculations in 3B Manure management

- 3B1: The NMVOC emission factors were revised for all cattle categories for the years 1990–2021. A distinction is now made between the summer and winter feeding periods, as the proportions of animals fed silage are different in the two periods.

8.1.3.2 Category-specific recalculations in 3D Crop production and agricultural soils

- 3Da1: The activity data of source categories 3Da1 Urea and 3Da1 Other synthetic fertiliser were revised for 2021 due to adjusted values in the AGRAMMON model resulting in a revised NH_3 emission factor of 3Da1 Other synthetic fertiliser as well.
- 3Da2c: The activity data of source category 3Da2c Other organic fertilisers was revised for the year 2021 due to updated values for the provisional amount of compost and biogas digestate applied to agricultural soils.
- 3De: The individual cropland and grassland areas were updated for 1990-2021, resulting in minimal adjustments to the total cropland and grassland areas as well as to the PM2.5, PM10 and TSP emission factors of cropland.

8.1.4 5 Waste

8.1.4.1 Category-specific recalculations in 5A Biological treatment of waste - Solid waste disposal on land

There were no recalculations implemented in submission 2024.

8.1.4.2 Category-specific recalculations in 5B Biological treatment of waste – Composting and anaerobic digestion at biogas facilities

- 5B Biological Treatment of Solid Waste: All input activity data for 1990-2021 have been updated because of harmonisation of rounding. This may cause changes in emissions of up to 10 %.
- 5B1 - Composting (industrial and backyard): The unit of activity data and emission factors are reported as weight dry mass according to the Guidelines reference for reporting tables (CRT). A new transfer factor from wet to dry mass of 40.0 % has been suggested by Baier (2023) instead of the previously applied factor 54.5 % as stated in CVIS (2019). Thus, activity data for the years 1990-2021 have decreased by 26 % while emission factors for NH_3 and NMVOC have increased by 36 %. This leads to changes in emissions from 5B1 Composting of <1 % due to rounding.

8.1.4.3 Category-specific recalculations in 5C Waste incineration and open burning of waste

- 5C1 incineration of waste / sewage sludge: Activity data of the amount of sewage sludge incineration has changed in 2016 and 2021 by -1 t and 100 t, respectively. This leads to changes in emissions of NO_x, CO, NMVOC, NH_3, SO_x, PM10, PM2.5, TSP, Pb, Cd, Hg, and PCDD/PCDF by <1 % (2016 and 2021).
- 5C1a Illegal waste incineration: For practical reason, the activity data for illegal waste incineration in tons is now reported separately for the fossil and biogenic fractions, for the entire time series. The sum of the fossil and biogenic fractions has changed by less than 1 % compared to the previous values due to rounding issues.

8.1.4.4 Category-specific recalculations in 5D Wastewater handling

There were no recalculations implemented in submission 2024.

8.1.4.5 Category-specific recalculations in 5E Other waste, car shredding

There were no recalculations implemented in submission 2024.

8.1.5 6 Other

8.1.5.1 Recalculations in 6 Other emissions

- 6Aa Human emissions (NH_3): The activity data “number adults wearing diapers” in 2021 has increased by 0.36 % (+67 people), due to changes in the underlying statistics by the FSO.
- 6Ab Pets and livestock outside agriculture (NH_3): The activity data "Number of pet cats" in 2021 has decreased by 3.7 %, due to changes in the underlying statistics.
- 6Ab Pets and livestock outside agriculture (NH_3): The activity data "Number of pet dogs" in 2021 has decreased by 4 %, due to changes in the underlying statistics.
- 6Ab: The NO_x emission factors of source category 6Ab Livestock outside agriculture were revised for the years 1995-2021.

- 6Ac: The activity data and the NH_3 emission factor of source category 6Ac Other synthetic fertiliser were updated for 2020 and 2021 due to adjusted values in the AGRAMMON model.
- 6Ad Fire damages buildings (EMEP Guidebook 5 E Other): The emission factors for Cd exhaust, Hg, Zn exhaust, SO_x, NO_x, PCDD/PCDF, and all PAH were erroneously reported and have been corrected, resulting in major emission changes, from 1'000 times less up to 25 % more. For Pb, a new estimation for the time period 1990-2021 has been established. While its emission factor remains the same for 1990, it decreases gradually until the reporting year, due to limitation of lead in construction items and consumption goods.
- 6Ad Fire damages buildings: The activity data for the number of building fires has been reassessed for the time period 1990-2021. The activity data is now based on the number of fires per year instead of the total costs of fires. Once the total costs of fire have been corrected for inflation, both the number of fires and total costs follow a similar decreasing trend over the time 1990-2021. This reassessment causes emissions changes from +10 % in 1990 to -45 % in 2021, for all reported pollutants: SO_x, NO_x, NMVOCs, CO, BC, PM, heavy metals, PCDD/PCDF, PAK.
- 6Ad Fire damages motor vehicles: The emission factor for source category 6Ad Other for pollutants emitted during accidental car fires has been reassessed for NO_x, CO, PM exhaust, heavy metals, PCB, PCDD/PCDF. It is now based on the average of several car fire experiments reported in the literature. This causes changes in emissions for the time period 1990-2021 by up to several orders of magnitude.

8.1.5.2 Recalculations in 11B Forest fires

- 11B: The time series of wildfires were recalculated with updated activity data from the Swissfire database in the years 2015 and 2021 on forest land.

8.1.5.3 Recalculations in 11C Other natural emissions

- 11C Natural emissions from forest trees: Emissions in 2021 (and 2022) were modelled on the basis of monthly meteorological data. They replace the extrapolated values of the previous submission.

8.1.6 Implications of recalculation for emission levels

Table 8-1 shows the effect of recalculations on the emission levels 2021 and 1990, based on the previous (2023) and latest (2024) submission.

In 2021, the recalculations cause a higher emission level between 23°% and 4°% for PM2.5, PM10, TSP and PAH. A decrease due to recalculations between 37°% and 4 % is observed for Pb, Cd, Hg, PCDD/PCDF and SO_x. For all other pollutants, the difference in emissions due to recalculations for 2021 does not exceed 2.1 %.

In 1990, the recalculations cause a higher emission level between 64°% and 6°% for PM2.5, PM10, TSP and SO_x. A decrease due to recalculations of 5°% is observed for Cd. For all other pollutants, the difference in emissions due to recalculations for 1990 does not exceed 1.3 %.

Table 8-1 Recalculations: Implications for the emission levels 2021 and 1990. The values refer to the NFR submission 2023 (previous) and 2024 (latest). Differences are given in absolute and relative numbers for all pollutants.

Pollutant	**Units**	**2021**			
		previous subm. 2023	**latest** subm. 2024	**difference (abs.)**	**difference (rel.)** previous = 100%
NO_x	kt	51	51	0.11	0.2%
NMVOC	kt	75	74	-1.0	-1.4%
SO_x	kt	3.8	3.6	-0.21	-5.6%
NH_3	kt	54	54	-0.0092	0.0%
PM2.5	kt	5.8	7.1	1.3	22.8%
PM10	kt	14	15	1.2	8.6%
TSP	kt	27	29	1.3	4.8%
BC	kt	1.0	1.0	0.021	2.1%
CO	kt	152	153	1.8	1.2%
Pb	t	14	8.5	-5.0	-37.2%
Cd	t	0.63	0.46	-0.17	-26.4%
Hg	t	0.68	0.60	-0.077	-11.3%
PCDD/PCDF	g I-TEQ	15	14	-1.3	-8.7%
PAH (total)	t	2.6	2.7	0.11	4.3%
HCB	kg	0.37	0.37	0.0040	1.1%
PCB	kg	374	374	0.000048	0.0%

Pollutant	**Units**	**1990**			
		previous subm. 2023	**latest** subm. 2024	**difference (abs.)**	**difference (rel.)** previous = 100%
NO_x	kt	144	145	0.16	0.1%
NMVOC	kt	302	305	3.1	1.0%
SO_x	kt	37	39	2.3	6.2%
NH_3	kt	69	69	-0.031	0.0%
PM2.5	kt	17	27	11	64.1%
PM10	kt	25	37	11	44.4%
TSP	kt	44	56	12	26.8%
BC	kt	5.7	5.7	0.0020	0.0%
CO	kt	818	817	-0.47	-0.1%
Pb	t	381	381	0.40	0.1%
Cd	t	3.4	3.3	-0.17	-5.0%
Hg	t	6.4	6.3	-0.081	-1.3%
PCDD/PCDF	g I-TEQ	194	193	-0.97	-0.5%
PAH (total)	t	8.1	8.1	-0.0073	-0.1%
HCB	kg	173	173	0.000038	0.0%
PCB	kg	2'332	2'332	0.000013	0.0%

The source categories with the most important recalculations implemented for main pollutants and PM2.5 in submission 2024 in terms of absolute emissions are listed in Table 8-2 and Table 8-3 for the years 2021 and 1990, respectively. The most important recalculations for 1990 and the last year reported in both submissions and each main pollutant are the following:

NO_x

There are mainly small recalculations for NO_x in the source categories of sector 1A Energy combustion that are mainly induced by the newly implemented model for stationary engines and gas turbines and small adjustments to the road transportation model. The associated redistribution of fuel consumption from one combustion technology to another or to a different source category has influence on the NO_x emissions. The corresponding main recalculations are described as follows:

- A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The respective recalculations are most relevant for source category 1A4 Stationary combustion in other sectors, 1A2gviii Other and 1A3e Pipeline transport. The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- In source category 1A3b Road transportation, activity data was recalculated due to new available statistics for activity data (mileage) for the different vehicle categories for all years from 1990-2021.

NMVOC

The most important recalculation regarding NMVOC emissions occurred in source category 3B Manure management. Other recalculations are induced by revised emission factors for fugitive emissions of gasoline distribution in 1B2a and redistribution of fuel consumption from one combustion technology to another or to a different source category due to the implementation of a new model of stationary engines and gas turbines. The corresponding main recalculations are described as follows:

- In source category 3B Manure management the NMVOC emission factors were revised for all cattle categories for the years 1990–2021. A distinction is now made between the summer and winter feeding periods, as the proportions of animals fed silage are different in the two periods.
- In source category 1B2av Gasoline distribution (especially in 1990), the emission factors for NMVOC from gasoline losses and evaporation at petrol stations have changed due to corrections in the model for all years 1990-2021.
- A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in small recalculations for all years 1980-2021.

SO_x

Recalculations for SO_x are mainly due to recalculated emission factors related to newly available measurement data of the sulphur content in fuels of sector 1 Energy. The corresponding main recalculations are described as follows:

- The SO_x emission factors for diesel, gasoline, gas oil, residual fuel oil, Gasolio, heating gas, natural gas, bioethanol and biodiesel have been updated based on newly available measurement data. This affects especially source categories 1A2gvii Mobile combustion in manufacturing industries and construction, 1A3b Road transportation and 1A4 Stationary combustion in other sectors.

NH_3

The most important recalculation for NH_3 emissions occurred in the year 2021 for source category 6A Other emissions. Recalculations of NH_3 emissions in sector 1 Energy for the years 1990-2021 are induced by a correction of NH_3 emission factors from bonfires and use of charcoal, the newly implemented model for stationary engines and gas turbines and small adjustments to the road transportation model. In 2021 the activity data of source category 3Da2c Other organic fertilisers was revised as well as the activity data in 5B and leads to recalculations of NH_3 emissions, too. The corresponding main recalculations are described as follows:

- The activity data and the NH_3 emission factor of source category 6Ac Other synthetic fertiliser were updated for 2020 and 2021 due to adjusted values in the AGRAMMON model.
- The correction of two emission factors in source category 1A4b Stationary combustion in other sectors (residential) had an impact on NH_3 emissions 1990-2021. The NH_3 emission factors of bonfires and use of charcoal were adjusted from 74 g/GJ to 8 g/GJ for the entire time series based on the revised value in EMEP/EEA 2023 (chp. 1A4, table 3-39).
- A new model of stationary engines and gas turbines was implemented (INFRAS 2022a). The respective recalculations are most relevant for source category 1A4 Stationary combustion in other sectors. The new allocation of the engines and gas turbines surveyed to the various source categories entails various changes in fuel consumption for fossil (diesel oil, gas oil, natural gas and liquefied gas in refineries) and biogenic (biodiesel, biogas and sewage gas) fuels in source categories 1A1a, 1A1b, 1A2d, 1A2gviii, 1A3e and 1A4ai/bi/ci. All emission factors for these engines and gas turbines were also revised in the model. This results in recalculations for all years 1980-2021.
- In source category 1A3b Road transportation, the activity data was recalculated due to new available statistics for activity data (mileage) for the different vehicle categories for all years from 1990-2021.
- The activity data of source category 3Da2c Other organic fertilisers was revised for the year 2021 due to updated values for the provisional amount of compost and biogas digestate applied to agricultural soils.
- 5B Biological Treatment of Solid Waste: All input activity data for 1990-2021 have been updated because of harmonisation of rounding. This may cause changes in emissions of up to 10 %.

PM2.5

For PM2.5 the most relevant recalculations are due to the newly included emission factors for the condensable fractions of PM emissions from wood combustion (1A), which are particularly important for manually operated single-room furnaces and building heating installations (1A4ai and 1A4bi). Previously, only the filterable fractions were reported. The corresponding main recalculations are described as follows:

- Emission factors of PM2.5 for wood combustion newly also include the condensable particle fractions. This concerns all wood energy combustion processes in source categories 1A1, 1A2 and 1A4.
- For source category 2G Other product the activity data of fireworks has been updated for the year 2021 due to newly available statistics data.

Table 8-2 NFR categories with most important implications of recalculations on emission levels in 2021 in terms of absolute differences for the main pollutants and PM2.5. The values refer to the NFR submission 2023 and 2024. The list is ranked for each pollutant in terms of the absolute difference in emission levels due to recalculations.

NO_x (as NO_2)	kt	NMVOC	kt	SO_x (as SO_2)	kt	NH_3	kt	$PM_{2.5}$	kt
1 A 4 a i_ Commercial/ Institutional: Stationary	0.66	3 B 1 b_Manure management - Non-dairy cattle	-1.0	1 A 2 c_Stationary combustion in manufacturing industries and construction: Chemicals	-0.072	6 A_Other (included in national total for entire territory)	-0.014	1 A 4 b i_Residential: Stationary	1.0
1 A 3 b iii_Road transport: Heavy duty vehicles and buses	-0.49	1 B 2 b_Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other)	-0.42	1 A 4 b i_Residential: Stationary	-0.068	1 A 4 b i_Residential: Stationary	-0.010	1 A 4 a i_ Commercial/ Institutional: Stationary	0.17
1 A 3 b i_Road transport: Passenger cars	-0.20	3 B 1 a_Manure management - Dairy cattle	-0.38	1 A 4 a i_ Commercial/ Institutional: Stationary	-0.031	1 A 4 a i_ Commercial/ Institutional: Stationary	0.0087	2 G _Other product use	0.042
1 A 4 c i_ Agriculture/Forestry/ Fishing: Stationary	0.16	1 A 4 a i_ Commercial/ Institutional: Stationary	0.30	1 A 2 g viii_Stationary combustion in manufacturing industries and construction: Other	-0.017	1 A 4 c i_ Agriculture/Forestry/ Fishing: Stationary	0.0055	1 A 2 g viii_Stationary combustion in manufacturing industries and construction: Other	0.030
1 A 3 b ii_Road transport: Light duty vehicles	-0.10	1 A 4 b i_Residential: Stationary	0.22	1 A 2 e_Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	-0.0058	3 D a 2 c_Other organic fertilisers applied to soils (including compost)	0.0031	1 A 4 c i_ Agriculture/Forestry/ Fishing: Stationary	0.027

Table 8-3 NFR categories with most important implications of recalculations on emission levels in 1990 in terms of absolute differences for the main pollutants and PM2.5. The values refer to the NFR submission 2023 and 2024. The list is ranked for each pollutant in terms of the absolute difference in emission levels due to recalculations.

NO_x (as NO_2)	kt	NMVOC	kt	SO_x (as SO_2)	kt	NH_3	kt	$PM_{2.5}$	kt
1 A 4 a i_ Commercial/ Institutional: Stationary	0.44	1 B 2 a v_Distribution of oil products	4.7	1 A 4 b i_Residential: Stationary	1.1	1 A 4 b i_Residential: Stationary	-0.031	1 A 4 b i_Residential: Stationary	9.3
1 A 2 g viii_Stationary combustion in manufacturing industries and construction: Other	-0.16	1 B 2 b_Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other)	-0.73	1 A 4 a i_ Commercial/ Institutional: Stationary	0.44	1 A 3 b i_Road transport: Passenger cars	-0.0015	1 A 4 a i_ Commercial/ Institutional: Stationary	0.85
1 A 3 e i_Pipeline transport	-0.13	3 B 1 a_Manure management - Dairy cattle	-0.66	1 A 2 g viii_Stationary combustion in manufacturing industries and construction: Other	0.22	1 A 4 a i_ Commercial/ Institutional: Stationary	0.00073	1 A 2 g viii_Stationary combustion in manufacturing industries and construction: Other	0.33
1 A 1 a_Public electricity and heat production	0.044	3 B 1 b_Manure management - Non-dairy cattle	-0.25	1 A 2 d_Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	0.15	5 B 2_Biological treatment of waste - Anaerobic digestion at biogas facilities	0.00065	1 A 4 c i_ Agriculture/Forestry/ Fishing: Stationary	0.16
1 A 3 b iii_Road transport: Heavy duty vehicles and buses	-0.039	1 A 4 a i_ Commercial/ Institutional: Stationary	0.10	1 A 3 b i_Road transport: Passenger cars	-0.11	1 A 3 b iii_Road transport: Heavy duty vehicles and buses	-0.00033	1 A 1 a_Public electricity and heat production	0.0093

8.1.7 Implications of recalculation for emission trends of main pollutants and PM2.5

The emission trends 1990–2021 of the main pollutants are only slightly affected through the recalculations in the latest submission (difference of maximal 1 percentage point). A significant change in the trend occurred for PM2.5, where the trend is around 9 percentage points stronger than in the previous submission. This is due to the inclusion of condensable PM fractions from wood combustion energy in the inventory.

Table 8-4 Recalculations: Implications for the emission trends between 1990 and 2021 for the main pollutants. The values refer to the NFR submission 2023 and 2024.

Pollutant	**Trend 1990-2021 (1990 = 100%)**	
	previous subm. 2023 %	**latest subm. 2024** %
NO_x	36	36
NMVOC	25	24
SO_x	10	9
NH_3	78	78
PM2.5	35	26

8.2 Planned improvements

The following improvements are planned for the submission 2025. Improvements for source categories which are key categories are, as much as possible, given priority.

General (not sector specific)

As the new EMEP Guidebook (EMEP/EEA 2023) is available since the end of 2023, all emission factors used from EMEP/EEA 2019 have to be verified with the corresponding ones in the newest Guidebook (EME/EEA 2023) and adapted, if necessary, in future submissions.

Energy (stationary)

- 1A: The NO_x and CO emission factors of boilers (gas oil, natural gas) will be updated based on a large number of air pollution control measurements of combustion installations in several Swiss cantons (later than submission 2025). Source categories 1A1a, 1A2gviii, 1A4ai and 1A4bi are key categories for NO_x.

Energy (mobile)

- 1A3bi-vii: With reference to the recommendation in paragraph 88 of the last report from the stage 3 in-depth review of Switzerland's emission inventory in 2020, it is planned to report the non-exhaust emissions in these two categories separately in a later submission. Modelling work for the determination of traffic situation-dependent emission factors for brake and tyre abrasion is in progress and could subsequently be integrated into the HBEFA database and thus also into the Swiss road traffic model. Source categories 1A3bi, 1A3biii and 1A3bvi are key categories for PM2.5 and PM10.

Energy (fugitive emissions) no planned improvements

IPPU

- 2D3 and 2G: A comprehensive update of all NMVOC emissions from solvent and product use is on-going. These two source categories are both key categories for NMVOC.

Agriculture

- 3B1: Since cattle also spend a part of their time on pasture and this has not yet been taken into account in the calculation of NMVOC emissions, emission measurements in the experimental dairy housing during grazing are being planned (later than submission 2025). Source categories 3B1a and 3B1b are both key categories for NMVOC.
-

Waste no planned improvements

Other and Natural no planned improvements

9 Emission projections 2023–2035

9.1 Comments on projections

The emission projections of air pollutants in Switzerland have been fully revised in the course of submission 2022. The activity data for the sectors energy, IPPU and waste are in accordance with the base scenario of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). The base scenario called in German “Weiter wie bisher” (WWB), which means as much as to continue with the existing policy measure at that time, bases on the reference year 2017 and is reported as “With Measures” (WM) scenario in the reporting tables of the latest submission. Other scenarios elaborated in the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) have the focus on how to get to net zero greenhouse gas emissions in the year 2050 and beyond, which future developments in the emission sources will contribute and which further measures are necessary to achieve this goal. As these net zero greenhouse gas emissions scenarios do not include any “additional (technological and legal) measures” aimed at reducing air pollution, none of these scenarios were implemented in the database of air pollutant emissions so far. Therefore, the air pollutant emissions in chps. 9.3 to 9.6 are shown for the “With Measures” (WM) scenario only. Note further that:

- due to lack of detailed data for all sectors with non-road vehicles and machineries (mobile sources under 1A2gvii, 1A3c/d, 1A4aii/bii/cii), the projections for these source categories are based on the previous energy scenarios (Prognos 2012a) instead of the new Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). However, total fuel consumption corresponds to the new Swiss Energy Perspectives 2050+.
- for activity data based on population size the latest perspectives for Switzerland’s inhabitants are used (SFSO 2020p).
- for the agricultural sector, independent scenarios were developed according to the agricultural policy 2018-2021 (Swiss Confederation 2017).

Note also that emission data published in the submission table for the projections (“Annex IV WM”) refer to the “national total” assessment based on the fuel sold principle for road transportation. All tables and figures in this chapter refer to the “national total for compliance” assessment based on fuel used principle (for details see chapter 1.4.2 and 3.1.6.1).

In the IIR at hand,

9.2 Assumptions for projections for the WM scenario

9.2.1 Emission factors

Emission factors for the sector 1 Energy are mainly based on available emission measurements, EMEP/EEA guidebook (EMEP/EEA 2019 and EMEP/EEA 2023), expert estimates as described in chapter 3 and assumptions about their future development. Where no such assumptions can be made, the emission factors are kept constant.

Table 9-1 Overview of sources and references for emission factors in the WM scenario.

Sector	Sources and references for emission factors
1 Energy	Fuel combustion / heating systems: Internal emission database (EMIS 2024)
	Wood energy combustion: Zotter and Nussbaumer (2022)
	Road transportation: EMEP/EEA guidebook (EMEP/EEA 2019), INFRAS (2022)
	Domestic aviation: EMEP/EEA guidebook (EMEP/EEA 2019), FOCA (2006, 2006a, 2007a, 2008-2023)
	Stationary engines and gas turbines: INFRAS (2022a)
	Non-road vehicles: EMEP/EEA guidebook (EMEP/EEA 2019), FOEN (2015j), INFRAS (2015a)
2 IPPU	Emission measurements, industry data and factors from the EMEP/EEA guidebook (EMEP/EEA 2019) as described in chapter 4 and assumptions about their future development. Where no assumption can be made, emission factors are kept constant.
3 Agriculture	AGRAMMON model (Kupper et al. 2022), EMEP/EEA guidebook (EMEP/EEA 2019) and country-specific studies (Bühler and Kupper 2018, Schrade et al. 2024). Emission factors are kept constant as in 2019 due to uncertain assumptions about the evolution of production parameters (according to Kupper et al. 2022). See chapter 5 for further information.
5 Waste	Various literature sources and EMEP/EEA guidebook 2019 (EMEP/EEA 2019), see chapter 6.
6 Other	Various literature sources and EMEP/EEA guidebook 2019 (EMEP/EEA 2019), see chapter 7.

9.2.2 Activity data

As described in chapter 9.1 and Table 9-2, activity data base mainly on the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) and the agricultural policy 2018-2021 (Swiss Confederation 2017). Due to the lack of detailed, disaggregated data elaborated in the Swiss Energy Perspectives 2050+ for the non-road model, projected developments from earlier projections (Prognos 2012a) are used. The total amount of fuel used in non-road sectors is then subtracted from the projected overall fuel consumption in the Swiss Energy Perspectives 2050+, which has some influence on the allocation of fuel consumption to the different source categories, whereas the overall fuel consumption remains the same as projected in the Swiss Energy Perspectives 2050+.

The Swiss Energy Perspectives 2050+ base on the reference year 2017 for the energy consumption in the different source categories and other statistics. Energy consumption data from the year 2017 was used to develop the future scenarios. The base scenario is the scenario “WWB” called in German “Weiter wie bisher”, which means as much as a continuation with the so far implemented energy and climate policy measures). To avoid unplausible leaps from the latest submission year to the first projected year, projections of the Swiss Energy Perspectives 2050+ are used for the years 2025 and later and data in between are linearly interpolated. Except for 1A3b Road transportation, model data was already calculated for the Swiss Energy Perspectives 2050+ with an annual resolution and for the detailed activity data.

Table 9-2 provides an overview of the respective sectoral references. A detailed description of the WM scenario can be found in Switzerland’s 8th National Communication under the UNFCCC – therein named as “With Existing Measures (WEM)” (FOEN 2022d).

Table 9-2 Overview of sectoral underlying detailed scenarios in the WM scenario of the latest submission.

Sector	Scenario	Sectoral scenario	Reference
1 Energy	WM	Swiss Energy Perspectives 2050+ scenario "WWB" (continutation with measures implemented up to base year 2017) updated with new national reference scenario for popoulation ("A-00-2020"). Activity data for road transportation and stationary engines and gas turbines are modelled based on assumptions in the Swiss energy perspectives 2050+. Activity data in the nonroad sectors still base on assumptions of Prognos (2012a).	Prognos/INFRAS/TEP/Ecoplan 2020 INFRAS 2022 and 2022a SFSO 2020p Prognos 2012a
2 IPPU	WM	Scenario based on key parameters of the Swiss Energy Perspectives 2050+ but updated with new national reference scenario for popoulation ("A-00-2020")	Prognos/INFRAS/TEP/Ecoplan 2020 SFSO 2020p
3 Agriculture	WM	Continuation of Agricultural policy 2018-2021	Swiss Confederation 2017 Mack and Möhring 2021
5 Waste	WM	Scenario based on key parameters of the Swiss Energy Perspectives 2050+ but updated with new national reference scenario for popoulation ("A-00-2020")	Prognos/INFRAS/TEP/Ecoplan 2020 SFSO 2020p

Table 9-3 lists the key factors underlying the WM scenario of the latest submission and their assumed development until 2035.

Table 9-3 Trend of underlying key factors of the WM scenario between 2010 and 2035 (FSO 2022c and SFSO 2020p for population, INFRAS 2017 for vehicle km, and Prognos/INFRAS/TEP/Ecoplan 2020 for the rest).

Indicator	2010	2015	2020	2025	2030	2035	2010-2035
Population (million)	7.83	8.28	8.64	9.02	9.39	9.73	24%
GDP (prices 2017, billion CHF)	603	648	713	760	805	851	41%
Oil price (prices 2017, USD/barrel)	88	-	75	88	96	105	19%
Gas price (prices 2017, CHF/MWh)	28	-	24	27	28	29	4%
Heating degree days	3'586	3'075	3'182	3'135	3'089	3'042	-15%
Cooling degree days	153	263	177	188	199	213	39%
Energy reference area (million m^2)	706	744	782	816	847	874	24%
Passenger cars (million vehicle km)	52'066	56'620	53'371	61'749	63'691	65'335	25%

Please note that the population data in the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) do not match the official statistics used within the air pollutant (and greenhouse gas) inventory (SFSO 2020p).

For each sector, further specific methods and respective assumptions apply that are described below in more detail:

Sector 1 Energy

As mentioned above, energy consumption is based on the scenario “WWB” of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). Main measures and underlying assumptions in the energy scenario “WWB” and the different source categories are described in detail in Prognos/INFRAS/TEP/Ecoplan (2020). The projections are based on an aggregation of various bottom-up models. Energy demand is determined using separate models for private households, industry, transportation, services/agriculture and electricity supply. Figure 9-1 depicts the total fuel consumption in recent years and as projected up to 2035 for each source category in the energy sector. In source category 1A3, the electricity consumption of the electric vehicles is also included. The electricity production of the existing Swiss power plant park is projected with a bottom-up approach, taking into account the lifetime of the power plants.

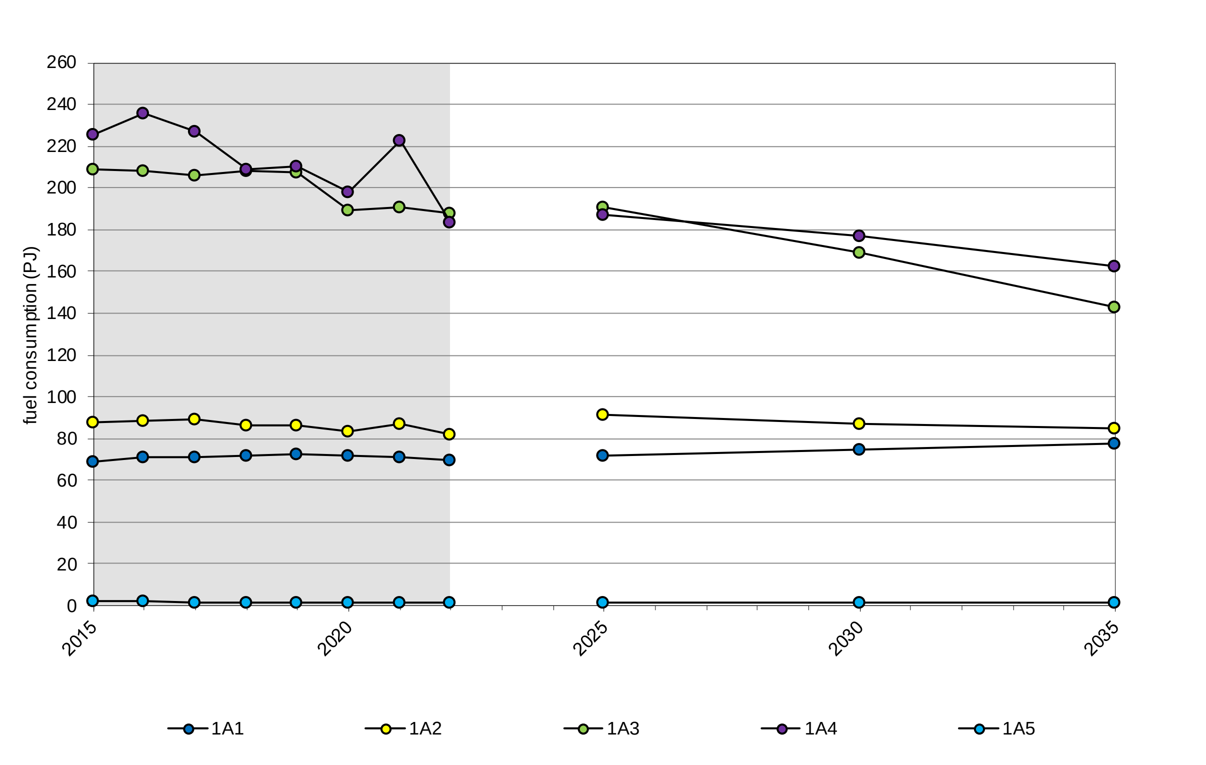

Figure 9-1 Fuel consumption in Switzerland as projected in the WM scenario in source categories 1A1 – 1A5 of the source category 1A Fuel combustion.

The growing fuel consumption in 1A1 Energy industries is mainly driven by source category 1A1a Public electricity and heat production that includes waste incineration depending on the population growth. While the amount of waste per capita is assumed to remain at the current level, the amount of waste is increasing due to population growth and therefore leading to growing fuel consumption. An increasing use of biogas in gas turbines as SCGT or CCGT and of natural gas in boilers for district heating is considered, too. The amount of wood consumption is considered to increase only slightly compared to natural gas, biogas and waste in this source category. The amounts of fuels used in 1A1b Petroleum refining is hold constant for projected years based on the amount reported in the latest submission year, assuming that the only refinery in Switzerland will maintain operations in the future at the same level as they do today. Source category 1A1c Manufacture of Solid Fuel and Other only contains a little amount of charcoal production which is considered to stay constant at the level of the latest submission year.

Fuel consumption in 1A2 Manufacturing industries and construction is modelled for the main fuel types based on a large number of industrial production processes, broken down by the most important industrial sectors, including a residual sector for all other industrial sectors. Fuel consumption is then projected based on activity data for the sectors and specific energy use per process.

For the source category 1A3 Transport, parameters such as tonne-kilometres, passenger-kilometres, vehicle-kilometres, specific energy use and substitution effects were determined on the basis of model estimations. For more detailed information see section below.

In source category 1A4ai Commercial/Institutional: Stationary, the energy demand from commercial and institutional buildings is based on energy use for heating, hot water, air conditioning, lighting, office appliances, engines and other uses, split for different energy sources, trades and services. Projections are then driven by gross value-creating activity, number of employees, energy reference area and technical standards. Also considered are the use of biogas and sewage gas in boilers, engines and gas turbines.

In source category 1A4bi Residential: Stationary, the energy demand in households is modelled based on energy use for heating, hot water, household appliances, lighting and other electrical equipment. The model consists of a dynamic building stock in various classes. The projection is then based on population growth, average floor space per person, average household size as well as technological developments of old and new buildings. Also considered is the use of biogas in engines.

The use of these bottom-up models allows to reproduce past developments and to derive the key drivers for particular segments of energy demand. Future energy demand is projected based on assumptions on the evolution of the key drivers. The energy demand is then assigned to the relevant categories.

Source category 1A3 Transport

Activity data from transport activities are based on the same model as the one used to derive energy demand for the energy scenarios (see above). The main measures and underlying assumptions are:

- Implementation of measures such as efficiency targets set for light duty vehicles, energy efficiency labelling, as well as economic incentives for low-emission vehicles.
- Road transportation: Projections of the mileage by vehicle categories and of fuel consumption factors are given by the Swiss Federal Office of Statistics and are represented in Prognos/INFRAS/TEP/Ecoplan (2020) and Swiss Confederation (2021).
- Non-road source categories: Projections of vehicle fleets, operating hours and expected fuel consumption (see Annex A2.1.2) serve as input for projecting the fuel consumption of non-road vehicles (FOEN 2015j, INFRAS 2015a, Prognos 2012a). In addition, (compressed) natural gas in non-road has been replaced with liquefied petroleum gas, which is a more accurate reflection of the situation in Switzerland.

Sector 2 Industrial processes and product use

Activity data of sector 2 Industrial processes and product use are inferred from the sectoral production data that were used in the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). In particular, sectoral indices of production volumes for clinker, cement, iron and steel, non-iron metals, glass, food, construction, and so-called other industry have been used. For other processes, such as production of basic chemicals of source category 2B Chemical industry, the provided production index scenario is not consistent with the more or less stable production volumes of the past twenty years. Therefore, constant activity data at the level of the recent years have been assumed for these source categories. Furthermore, a few activity data are only scaled with population growth (SFSO 2020p). However, the Energy Perspectives 2050+ provide no appropriate key parameters or measures for a number of source categories mainly within solvent and product use. For these source categories, projections are thus estimates based on information from industry, industry associations or expert judgement.

Sector 3 Agriculture

The basis of the WM scenario is the continuation of the agricultural policy 2018–2021 (Swiss Confederation 2017). The new agricultural policy (AP22+) should have become effective in 2022 but it was rejected by the parliament. Thus, central elements of the policy will be implemented through a parliamentary initiative. Their effects were modelled by Mack and Möhring (2021) and they elaborated respective projections of animal populations, milk yields, cropping areas and fertiliser use. As the ordinances under the parliamentary initiative have not yet passed legislation, the reference scenario of Mack and Möhring (2021) was used as basis for the calculations of the WM scenario. Projections are thus based on data and information available by 2021 on (i) the development of the macroeconomical variables (gross domestic product, population, crop yields), (ii) the expected development of the domestic producer prices and (iii) the actual agricultural policy with the respective subsidy system. The main measures and underlying assumptions are:

- Livestock populations: Direct payments have been decoupled to a certain degree from cropping area and particularly from the number of animals living on the farms reducing incentives for intensification that would lead to negative environmental impacts (Swiss Confederation 2009). Consequently, the animal population numbers are more directly dependent on price levels. The cattle population is projected to decline slightly, whereas the number of swine and poultry remains more or less constant. Dairy cows are projected to exhibit a further increase in milk yield. Beyond 2027, constant population numbers were assumed for all animal categories due to the lack of further projections.
- Manure management: the shares of manure excreted during grazing as well as the shares of the individual manure management systems cannot be predicted satisfactorily and are thus left constant since 2019 together with all other parameters affecting manure management.
- Crops: Important aspects of the further development of direct payments that influence the development of the crop cultures are an improved targeting of direct payments, particularly for the promotion of common goods and the securing of a socially acceptable development (Swiss Confederation 2009, FOAG 2011). In general, arable crop production is projected to slightly decline whereas feed production from grasslands will remain more or less constant. Beyond 2027, constant yields and areas were assumed due to the lack of further projections.
- Fertilisers and fertiliser management: Use of commercial fertilisers is projected to decrease slightly until 2027 (Mack and Möhring 2021). Beyond 2027, constant fertiliser use was assumed due to the lack of further projections.

Sector 5 Waste

Per capita waste generation is assumed to remain at the level of 2018 in the projections up to 2035. However, in agreement with the energy scenarios, digestion of organic waste is increasing according to the use of biogas and sewage gas in the energy scenarios. Landfilling of combustible waste is prohibited in Switzerland, and it is assumed that this will also be the case in the future.

9.3 Main pollutants and CO for the WM scenario

According to the projections, total NO_x and CO emissions will continue to decrease significantly between 2025 and 2035, while total emissions of NMVOC, SO_x and NH_3 will remain at more or less constant levels. The gap in Figure 9-2 between the latest reporting year and 2025 symbolises the fact that most of the scenarios used to calculate emissions projections for the individual sectors and source categories cover the period from 2025 onwards. Accordingly, the emissions in between are interpolated linearly.

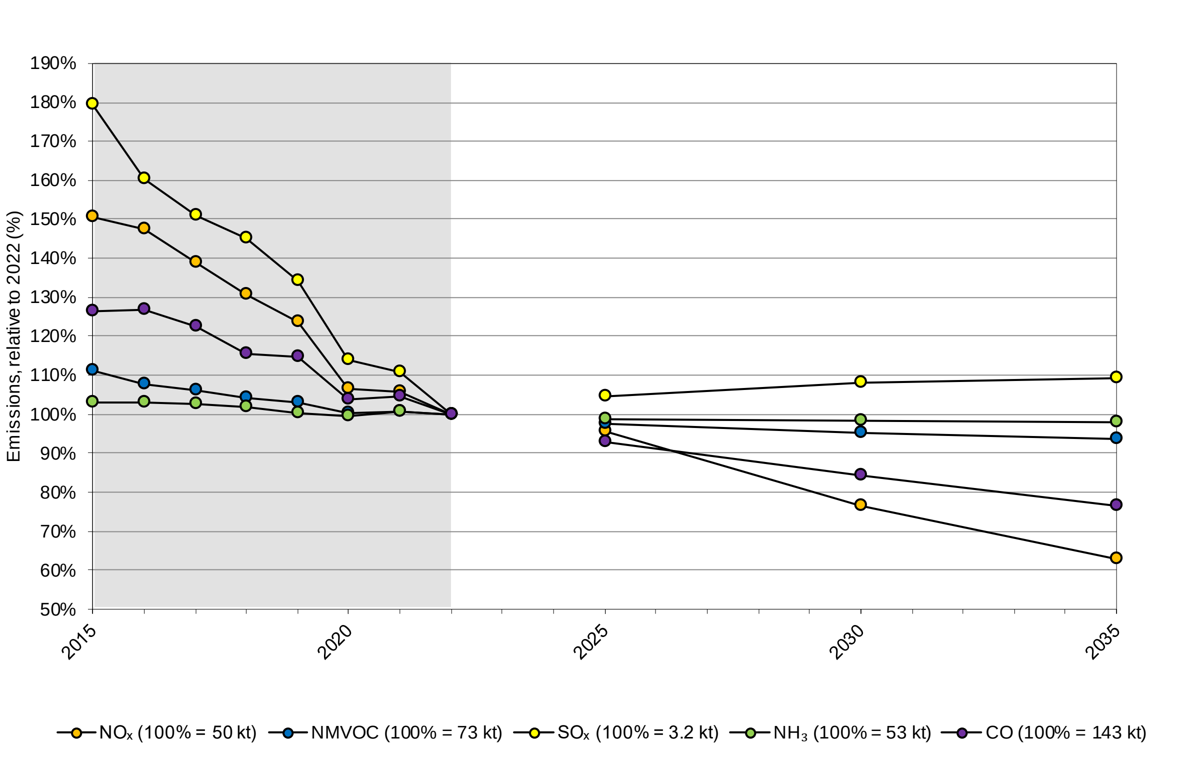

Figure 9-2 Relative trends for the total emissions of main air pollutants and CO in Switzerland as projected in the WM scenario. 100 % corresponds to levels of the latest reporting year.

Table 9-4 Main air pollutants and CO: Total emissions of the WM projections until 2035 in kt.

Year	NO_x	NMVOC	SO_x	NH_3	CO
	kt	kt	kt	kt	kt
2005	94	113	14	60	307
2010	83	98	10	58	242
2015	75	81	5.8	55	180
2020	53	73	3.7	53	148
2022	50	73	3.2	53	143
2025	48	71	3.4	53	133
2030	38	69	3.5	52	120
2035	31	68	3.5	52	109
2035 vs. 2022 (%)	-37%	-6%	9%	-2%	-24%
2035 vs. 2005 (%)	-67%	-40%	-75%	-12%	-64%
Gothenburg protocol, emission reduction (2020 vs 2005)					
	-41%	-30%	-21%	-8%	–

9.3.1 Projections for NO_x

NO_x emissions are projected to continue to decrease until 2035 (see Figure 9-2 and Table 9-5). The most significant reductions are projected for source category 1A3 Transport, which will also remain the main source of NO_x emissions in 2035, as in the latest reporting year. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A3 Transport: Emissions are projected to be reduced especially in 1A3b Road Transportation due to improvements in emission abatement technology, improved in-use compliance under real driving conditions for road vehicles (triggered by the Euro 6/VI standards) and a reduction of fuel consumption due to the increase of electromobility (see Figure 9-1).

- 1A4 Other sectors: A reduction of emissions is projected due to measures related to domestic and commercial heating such as better insulation of buildings and increasing use of heat pumps.
- 1A2 Manufacturing industry and construction: Emission reductions are expected due to the so-called NO_x industry agreement with the cement industry (1A2f), which includes a reduction path for the NO_x emission limit value by 2032 as well as a projected decline in the use of wood waste (1A2gviii).
- 3 Agriculture: NO_x emissions from agriculture are projected to remain about constant between 2025-2035. Similar as in the latest reporting year, source category 3D Agricultural soils (in particular 3Da2 Use of organic nitrogen ferilisers) is expected to contribute the largest share of NO_x emissions in 2035.

Table 9-5 WM projections: Trends of NO_x emissions per sector.

NO_x emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	46	44	34	27	92%	87%	-19
1A Fuel combustion	46	44	34	27	92%	87%	-19
1A1 Energy industries	2.5	2.6	2.7	2.7	5.0%	8.7%	0.22
1A2 Manufacturing industries and constr.	7.5	7.3	6.2	5.6	15%	18%	-1.9
1A3 Transport	26	25	17	12	53%	38%	-15
1A4 Other sectors	9.1	8.6	7.7	6.8	18%	22%	-2.3
1A5 Other (Military)	0.40	0.39	0.38	0.37	0.80%	1.2%	-0.031
1B Fugitive emissions from fuels	0.0006	0.0006	0.0006	0.0006	0.001%	0.002%	-0.00004
2 IPPU	0.22	0.24	0.25	0.25	0.45%	0.79%	0.026
3 Agriculture	3.6	3.6	3.6	3.6	7.2%	11%	-0.034
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.12	0.13	0.13	0.11	0.24%	0.36%	-0.0076
6 Other	0.090	0.092	0.091	0.091	0.18%	0.29%	0.0012
National total	50	48	38	31	100%	100%	-19

9.3.2 Projections for NMVOC

NMVOC emissions are projected to remain almost constant between 2025 and 2035 (see Figure 9-2 and Table 9-6). On the one hand, a decrease of NMVOC emissions is expected in source categories 1A3 Transport and 1A4 Other sectors. On the other hand, an increase in the sector 2 IPPU is projected. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 2 IPPU: Population growth and, to some extent, the stagnation of the effects of the VOC incentive tax (Swiss Confederation 1997) are projected to lead to a slight increase of NMVOC emissions.
- 3 Agriculture: Slight reductions of emissions are projected due to the expected development of cattle population.
- 1A3 Transport: Emissions are projected to be reduced especially in 1A3b Road Transportation due to improvements in emission abatement technology, improved in-use compliance under real driving conditions for road vehicles (triggered by the Euro 6/VI standards) and a reduction of fuel consumption due to the increase of electromobility (see Figure 9-1).

- 1A4 Other sectors: A decline of overall fuel consumption, but in particular of log wood in manually operated furnaces, is expected to lead to a reduction of NMVOC emissions (see Figure 9-1).

Table 9-6 WM projections: Trends of NMVOC emissions per sector.

NMVOC emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	16	14	12	11	22%	16%	-5.0
1A Fuel combustion	13	12	10	9.3	18%	14%	-4.1
1A1 Energy industries	0.20	0.21	0.21	0.22	0.28%	0.32%	0.014
1A2 Manufacturing industries and constr.	0.90	0.89	0.86	0.84	1.2%	1.2%	-0.065
1A3 Transport	7.4	6.3	5.3	4.7	10%	6.9%	-2.7
1A4 Other sectors	4.8	4.4	3.9	3.5	6.6%	5.1%	-1.3
1A5 Other (Military)	0.064	0.063	0.062	0.061	0.09%	0.09%	-0.0031
1B Fugitive emissions from fuels	2.4	2.1	1.7	1.5	3.3%	2.2%	-0.90
2 IPPU	37	37	38	38	51%	56%	1.0
3 Agriculture	18	17	17	17	25%	25%	-0.55
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	1.7	1.8	1.8	1.8	2.4%	2.6%	0.037
6 Other	0.17	0.17	0.17	0.16	0.23%	0.24%	-0.0052
National total	73	71	69	68	100%	100%	-4.6

9.3.3 Projections for SO_x

SO_x emissions are projected to remain almost constant between 2025 and 2035 (see Figure 9-2 and Table 9-7). In Figure 9-2 (relative trends), a slight increase of SO_x emissions is visible – however, this increase is very small in absolute numbers. On the one hand, an increase is expected in sector 2 IPPU and source category 1A1 Energy industries. An emission reduction is mainly expected in source categories 1A2 Manufacturing industries and construction and 1A4 Other sectors. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A2 Manufacturing industries and construction: A reduction of emissions between 2025 and 2035 is mainly expected due to a projected decline in production volumes and a change in the fuel mix in the non-metallic minerals processing industry (rock wool, cement, brick and tile, glass, 1A2f) as well as in the use of wood waste (1A2gviii).
- 2 IPPU: An increase of the production volume of silicon carbide and graphite (2B5) and thus of the use of sulphur-containing feedstocks is expected.
- 1A1 Energy industries: A slight increase of emissions is expected due to an increase in the use of residual fuel oil in 1A1b Petroleum refining.
- 1A4 Other sectors: The projected decrease is mainly due to an expected reduced use of gas oil because of better insulation of buildings, a higher share of heat pumps as well as a fuel switch to natural gas (revised CO_2 law, Swiss Confederation 2011).
- 1A3 Transport: The slight increase of SO_x emissions between 2025 and 2035 is mainly due to an expected increase of international flights up to 2030 (i.e. landing and take-off cycles). In contrast, SO_x emissions from source category 1A3b Road transportation are expected to slightly decrease between 2025 and 2035 as fuel consumption (especially diesel oil) decreases due to the increase of electromobility (see Figure 9-1). Note that the increase of jet kerosene use in source category 1A3a Civil Aviation between 2022 and 2025 is due to the interpolation between reported data (latest reported year) and the emission modelling for the projections from 2025 onwards.

Table 9-7 WM projections: Trends of SO_x emissions per sector.

SO_x emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	2.8	2.9	2.9	2.8	88%	80%	-0.030
1A Fuel combustion	2.8	2.9	2.9	2.8	87%	79%	-0.029
1A1 Energy industries	0.30	0.34	0.42	0.42	9.3%	12%	0.12
1A2 Manufacturing industries and constr.	1.9	1.9	1.8	1.8	58%	51%	-0.088
1A3 Transport	0.18	0.25	0.27	0.26	5.5%	7.5%	0.087
1A4 Other sectors	0.44	0.33	0.31	0.28	14%	8.1%	-0.15
1A5 Other (Military)	0.033	0.033	0.033	0.033	1.0%	0.93%	0.000008
1B Fugitive emissions from fuels	0.016	0.016	0.015	0.015	0.51%	0.43%	-0.0011
2 IPPU	0.35	0.43	0.55	0.69	11%	20%	0.33
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.029	0.030	0.033	0.027	0.89%	0.77%	-0.0015
6 Other	0.0072	0.0072	0.0072	0.0072	0.23%	0.21%	-0.00001
National total	3.2	3.4	3.5	3.5	100%	100%	0.30

9.3.4 Projections for NH_3

NH_3 emissions are projected to remain almost constant between 2025 and 2035 (see Figure 9-2 and Table 9-4). Emission projections for NH_3 are highly dependent on sector 3 Agriculture. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 3 Agriculture: Emissions are highly dependent on livestock numbers, particularly cattle. A slight reduction of livestock numbers for cattle until 2027 is expected. Furthermore, the application of existing programs with incentives to introduce low-emission techniques or animal welfare programs is expected to reduce NH_3 emissions.
  Note: The emission projections for the sector 3 Agriculture up to 2035 are based on Swiss modelling studies covering the expected development of livestock numbers under specified economic and regulatory conditions (Mack and Möhring 2021). Projections are calculated with unchanged emission factors (except for dairy cattle, see chapter 9.2), which resulted for different livestock categories on the basis of the detailed farm survey carried out in 2019 (see chapter 5.2.2). This is a conservative approach that does not include any further changes in housing systems and manure management techniques. Emission factors on the aggregated reporting level may change slightly due to changes in the projected animal numbers on lower disaggregated levels, as for example in the source category 3B3 Manure Management - Swine consisting of animal categories piglets, fattening pig, dry sows, nursing sows and boars with constant emission factors for each.
- 6 Other: A slight increase in source category 6Aa Human emissions is expected due to population growth.
- 5 Waste: An increase of the use of biogas is expected, which leads to an increase of NH_3 emissions of 5B2 Anaerobic digestion at biogas facilities.

Table 9-8 WM projections: Trends of NH_3 emissions per sector.

NH_3 emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	1.3	1.2	1.2	1.2	2.4%	2.2%	-0.11
1A Fuel combustion	1.3	1.2	1.2	1.2	2.4%	2.2%	-0.11
1A1 Energy industries	0.037	0.040	0.046	0.047	0.07%	0.09%	0.010
1A2 Manufacturing industries and constr.	0.25	0.24	0.23	0.22	0.46%	0.42%	-0.026
1A3 Transport	0.90	0.86	0.84	0.80	1.7%	1.5%	-0.093
1A4 Other sectors	0.10	0.10	0.102	0.099	0.19%	0.19%	-0.0030
1A5 Other (Military)	0.00004	0.00004	0.00004	0.00004	0.00008%	0.00008%	-0.0000006
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–
2 IPPU	0.15	0.14	0.13	0.11	0.27%	0.21%	-0.036
3 Agriculture	50	49	49	49	94%	94%	-0.91
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.86	0.85	0.84	0.86	1.6%	1.6%	0.0044
6 Other	0.97	0.99	1.0	1.0	1.8%	1.9%	0.032
National total	53	53	52	52	100%	100%	-1.02

9.3.5 Projections for CO

CO emissions are projected to continue to decrease until 2035 (see Figure 9-2 and Table 9-9). Similar to NO_x, the most significant reductions are expected to happen in source category 1A3 Transport and 1A4 Other sectors, which will also remain the main sources of CO emissions in 2035. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A4 Other sectors: Emission reductions are expected due to measures related to domestic heating such as better insulation of buildings, higher share of heat pumps, both continuous technological improvements of wood combustion installations and decrease in wood energy consumption in manually operated furnaces as well as further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves).
- 1A3 Transport: Further improvements in emission abatement technology (triggered by the Euro 6/VI standards) and a reduction of fuel consumption due to the increase of electromobility (see Figure 9-1) are expected to lead to emission reductions.
- 1A2 Manufacturing industries and construction: A minor reduction between 2025 and 2035 is expected due to an expected higher proportion of modern wood combustion plants with lower proportions of non-optimal operating phases and a projected decline of the use of wood waste (1A2gviii) as well as of the production volumes in the non-metallic minerals processing industry (1A2f).
- 2 IPPU: Emissions are projected to slightly increase between 2025 and 2035, especially due to an expected increase of the production volume of silicon carbide and graphite (2B5).

Table 9-9 WM projections: Trends of CO emissions per sector.

CO emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	136	126	112	101	95%	92%	-35
1A Fuel combustion	136	126	112	101	95%	92%	-35
1A1 Energy industries	0.60	0.63	0.66	0.66	0.42%	0.60%	0.053
1A2 Manufacturing industries and constr.	15	16	15	15	11%	13%	-0.69
1A3 Transport	65	57	48	42	45%	38%	-23
1A4 Other sectors	55	52	48	43	38%	39%	-12
1A5 Other (Military)	0.76	0.76	0.75	0.75	0.53%	0.69%	-0.013
1B Fugitive emissions from fuels	0.0001	0.0001	0.0001	0.0001	0.00009%	0.0001%	-0.000009
2 IPPU	4.9	5.5	6.2	7.1	3.5%	6.5%	2.1
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	1.4	1.4	1.5	1.1	0.97%	1.0%	-0.31
6 Other	0.47	0.45	0.42	0.41	0.33%	0.38%	-0.057
National total	143	133	120	109	100%	100%	-34

9.4 Suspended particulate matter

According to the projections, exhaust and non-exhaust suspended particulate matter emissions are expected to develop differently between 2025 and 2035. While non-exhaust emissions of all fractions increase, exhaust emissions decrease (see Figure 9-3, Table 9-10 and Table 9-11). Overall, this leads to a decrease of the smaller fractions of suspended particulate matter (PM2.5) and BC between 2025 and 2035 (see Figure 9-4 and Table 9-12). In contrast, the larger PM fractions (PM10, TSP) are expected to remain at more or less constant levels. The gaps in Figure 9-3 and Figure 9-4 between the latest reporting year and 2025 symbolise the fact that most of the scenarios used to calculate emissions projections for the individual sectors and source categories cover the period from 2025 onwards. Accordingly, the emissions in between are interpolated linearly.

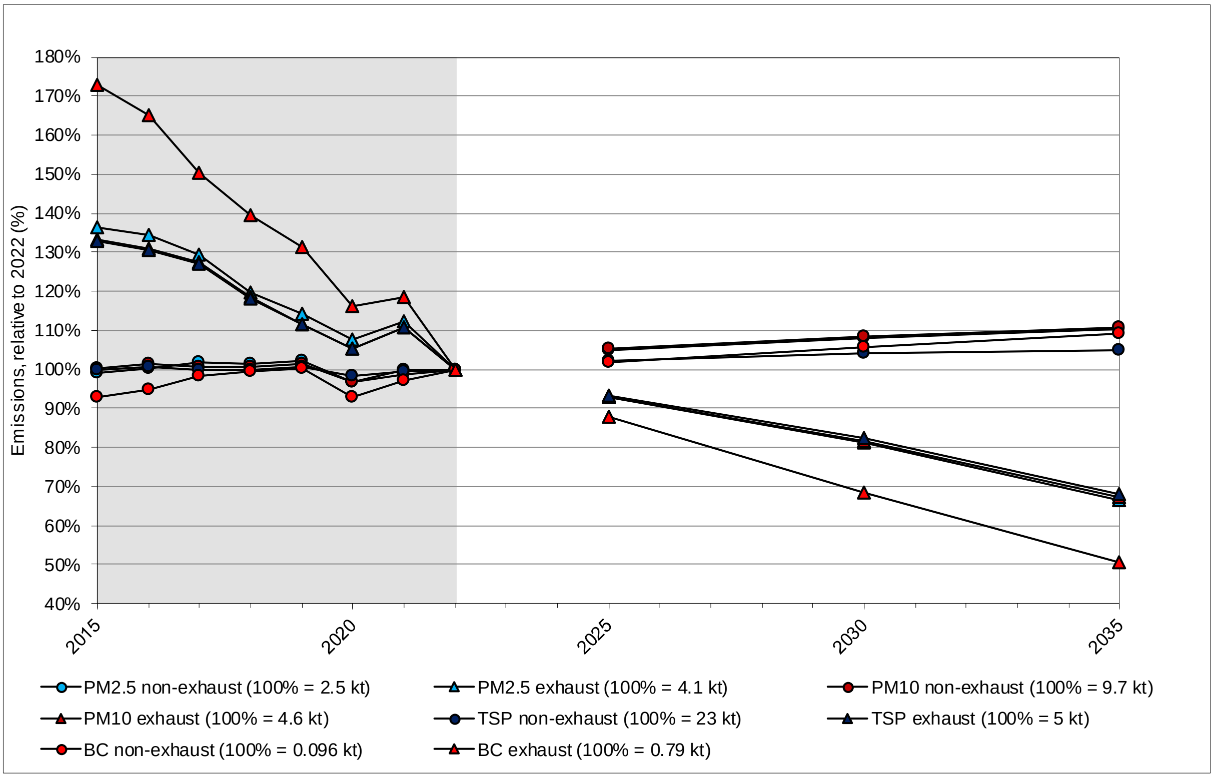

Figure 9-3 Projection of exhaust and non-exhaust emissions of suspended particulate matter PM2.5, PM10, TSP and BC in Switzerland of the WM scenario. 100 % corresponds to levels of the latest reporting year.

Table 9-10 Suspended particulate matter: Total exhaust emissions of the WM projections until 2035 in kt.

Year	PM2.5 ex	PM10 ex	TSP ex	BC ex
	kt	kt	kt	kt
2005	12	13	13	3.5
2010	8.9	9.6	10	2.5
2015	5.6	6.2	6.6	1.4
2020	4.4	4.9	5.2	0.91
2022	4.1	4.6	5.0	0.79
2025	3.8	4.3	4.6	0.69
2030	3.3	3.8	4.1	0.54
2035	2.7	3.1	3.4	0.40
2035 vs. 2022 (%)	-34%	-33%	-32%	-49%

Table 9-11 Suspended particulate matter: Total non-exhaust emissions of the WM projections until 2035 in kt.

Year	PM2.5 nx	PM10 nx	TSP nx	BC nx
	kt	kt	kt	kt
2005	2.3	9.0	22	0.078
2010	2.4	9.5	23	0.083
2015	2.4	9.8	23	0.089
2020	2.4	9.4	23	0.089
2022	2.5	9.7	23	0.096
2025	2.6	10	24	0.098
2030	2.7	11	24	0.10
2035	2.7	11	25	0.10
2035 vs. 2022 (%)	10%	11%	5%	9%

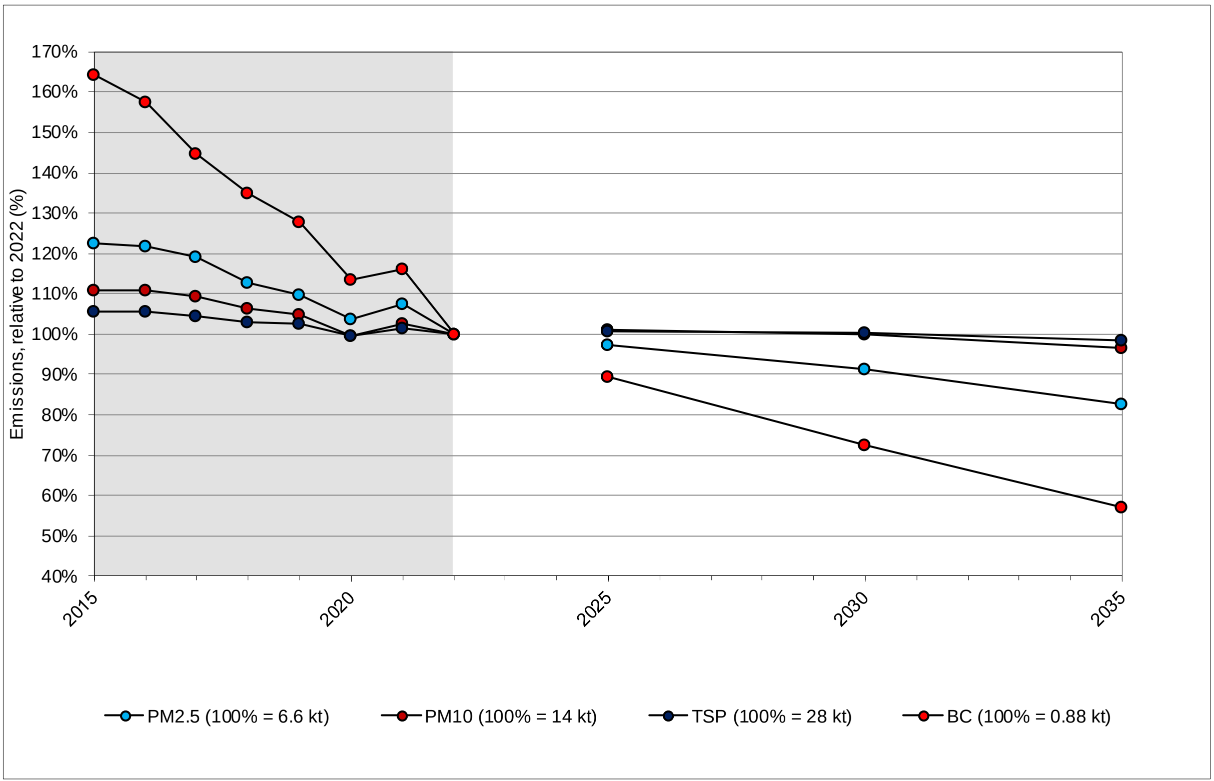

Figure 9-4 Projection of total emissions of suspended particulate matter PM2.5, PM10, TSP and BC in Switzerland of the WM (WEM) scenario. 100 % corresponds to levels of the latest reporting year. The figure shows the sum of exhaust and non-exhaust particles.

Table 9-12 Suspended particulate matter: Total emissions of the WM projections until 2035 in kt.

Year	PM2.5	PM10	TSP	BC
	kt	kt	kt	kt
2005	14	22	36	3.6
2010	11	19	33	2.6
2015	8.1	16	30	1.4
2020	6.8	14	28	1.0
2022	6.6	14	28	0.88
2025	6.4	15	29	0.79
2030	6.0	14	28	0.64
2035	5.4	14	28	0.50
2035 vs. 2022 (%)	-17%	-3%	-1%	-43%
2035 vs. 2005 (%)	-61%	-36%	-22%	-86%
Gothenburg protocol, emission reduction (2020 vs 2005)				
	-26%	–	–	–

9.4.1 Projections for PM2.5

PM2.5 emissions are projected to continue to decrease until 2035 (see Figure 9-4 and Table 9-13). The most significant reductions are expected in source category 1A4 Other sectors. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A4 Other sectors: Continuous technological improvements of small wood combustion installations (due to compliance with stricter air pollution control requirements from 2007 onwards) and a further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) lead to projected emission reductions. Furthermore, a decrease in wood energy consumption in manually operated furnaces is expected.
- 1A3 Transport: Emissions are expected to remain about constant between 2025 and 2035. In source category 1A3b Road transportation, the ongoing replacement of older vehicles with vehicles with stricter emission standards (Euro 6/VI for diesel engine vehicles, EU stage V for non-road vehicles) and a reduction of fuel consumption (see Figure 9-1) will lead to reduced PM2.5 exhaust emissions. However, at the same time non-exhaust emissions are expected to increase with increasing activity (vehicle kilometres), which partially compensates the decrease of exhaust emissions. This effect is more relevant for the larger particles (TSP, PM10) and less for smaller fractions.
- 2 IPPU: The main contributors to PM2.5 emissions are source categories 2A Mineral industry (especially 2A1 Cement production and 2A4 Other process use of carbonates), 2G Other product manufacture and use and 2H Other (especially 2H1 Pulp and paper and 2H2 Food and beverages industry). The emissions of all of these source categories are expected to remain about constant between 2025 and 2035.
- 1A2 Manufacturing industries and construction: An emission reduction is projected due to the expected higher proportion of modern wood combustion plants with lower proportions of non-optimal operating phases (1A2gviii Other boilers and engines industry).

Table 9-13 WM projections: Trends of PM2.5 emissions per sector.

PM2.5 emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	4.9	4.6	4.2	3.7	74%	69%	-1.1
1A Fuel combustion	4.9	4.6	4.2	3.7	74%	69%	-1.1
1A1 Energy industries	0.060	0.065	0.073	0.074	0.91%	1.4%	0.014
1A2 Manufacturing industries and constr.	0.64	0.61	0.58	0.54	9.7%	10%	-0.092
1A3 Transport	1.5	1.5	1.5	1.5	22%	27%	0.0096
1A4 Other sectors	2.7	2.4	2.0	1.6	41%	30%	-1.1
1A5 Other (Military)	0.045	0.045	0.045	0.044	0.68%	0.81%	-0.0007
1B Fugitive emissions from fuels	0.00005	0.00005	0.00005	0.00005	0.0007%	0.0009%	-0.000001
2 IPPU	1.3	1.4	1.4	1.4	20%	25%	0.079
3 Agriculture	0.15	0.14	0.14	0.14	2.2%	2.6%	-0.0022
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.27	0.29	0.31	0.19	4.2%	3.4%	-0.086
6 Other	0.0048	0.0049	0.0049	0.0048	0.07%	0.09%	0.00005
National total	6.6	6.4	6.0	5.4	100%	100%	-1.1

9.4.2 Projections for PM10

PM10 emissions are projected to remain about constant between 2025-2035 (see Figure 9-4 and Table 9-14). A decrease is expected in source category 1A4 Other sectors. On the opposite, an increase is expected in source category 1A3 Transport. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A3 Transport: Despite of a reduction of exhaust emissions due to a reduction of fuel consumption and the ongoing replacement of older vehicles with vehicles with tightened emission standards (Euro 6/VI for diesel engine vehicles, EU stage V for non-road vehicles), the projected increase of vehicle kilometres and thereby increase of non-exhaust emissions leads to an overall increase in PM10 emissions.
- 1A2 Manufacturing industries and construction: As for PM2.5, there is an emission reduction projected for wood energy combustion (higher proportion of modern combustion plants with lower proportions of non-optimal operating phases, 1A2gviii). However, this will be offset by an increase in non-exhaust PM10 emissions from the re-suspension of construction machinery (1A2gvii), the dominant PM emission source within 1A2, due to a predicted increase in activity.
- 2 IPPU: Similar to PM2.5, the main contributors to PM10 emissions are source categories 2A Mineral industry (especially 2A1 Cement production and 2A4 Other process use of carbonates), 2G Other product manufacture and use and 2H Other (especially 2H1 Pulp and paper and 2H2 Food and beverages industry). In addition, also source category 2I Wood processing is relevant for PM10 emissions. The emissions of all of these source categories are expected to remain about constant between 2025 and 2035.
- 3 Agriculture: PM10 emissions originate from source categories 3De Cultivated crops and 3B Manure management (especially 3B4g Poultry, due to high livestock numbers) and are assumed to remain about constant until 2035.
- 1A4 Other sectors: As for PM2.5, continuous technological improvements of small wood combustion installations (due to compliance with stricter air pollution control requirements from 2007 onwards) and a further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) lead to the projected emission reductions. Furthermore, a decrease in wood energy consumption in manually operated furnaces is expected.

Table 9-14 WM projections: Trends of PM10 emissions per sector.

PM10 emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	10	10	9.9	9.6	70%	69%	-0.43
1A Fuel combustion	10	10	9.9	9.6	70%	69%	-0.43
1A1 Energy industries	0.061	0.066	0.074	0.075	0.42%	0.54%	0.014
1A2 Manufacturing industries and constr.	2.6	2.7	2.7	2.7	18%	19%	0.011
1A3 Transport	4.2	4.6	4.8	4.9	29%	35%	0.67
1A4 Other sectors	2.9	2.6	2.2	1.7	20%	13%	-1.1
1A5 Other (Military)	0.26	0.26	0.26	0.26	1.8%	1.9%	-0.0017
1B Fugitive emissions from fuels	0.0005	0.0005	0.0005	0.0005	0.003%	0.003%	-0.00001
2 IPPU	2.1	2.2	2.2	2.2	15%	16%	0.076
3 Agriculture	1.8	1.8	1.8	1.8	12%	13%	-0.019
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.31	0.32	0.34	0.21	2.1%	1.5%	-0.10
6 Other	0.12	0.11	0.10	0.10	0.8%	0.7%	-0.015
National total	14	15	14	14	100%	100%	-0.48

9.4.3 Projections for TSP

The opposing trend of exhaust and non-exhaust emissions is best visible for the largest fractions of particulate matter: exhaust emissions are expected to decrease, whereas non-exhaust emissions increase. Overall, TSP emissions are projected to remain about constant between 2025-2035 (see Figure 9-4 and Table 9-15, Table 9-16, Table 9-17). An important source of TSP, where emissions are expected to remain constant, is sector 5 Agriculture. An increase of TSP emissions is expected in source category 1A3 Transport and a decrease in source category 1A4 Other sectors and sector 5 Waste. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 3 Agriculture: The sector contributes considerably to total TSP emissions. They are dominated by non-exhaust TSP emissions from source category 3De Cultivated crops (field and arable tillage) that are assumed to remain about constant until 2035. Thus, the relative share of agriculture sector on total TSP emissions is in-creasing over time (since exhaust TSP emissions from the energy sector are generally de-creasing). Considering both non-exhaust and total TSP emissions, agriculture even is and remains the predominating emission source.
- 1A3 Transport: Despite a reduction of exhaust emissions due to reduced fuel consumption and the ongoing replacement of older vehicles with vehicles with tightened emission standards (Euro 6/VI for diesel engine vehicles, EU stage V for non-road vehicles), the projected increase of vehicle kilometres and thereby increase of non-exhaust emissions leads to an overall increase in TSP emissions.
- 1A2 Manufacturing industries and construction: As for PM10, an emission reduction is projected for wood energy combustion (higher proportion of modern combustion plants with lower proportions of non-optimal operating phases, 1A2gviii), which will be offset by an increase in non-exhaust PM emissions from the re-suspension of construction machinery (1A2gvii), the dominant PM emission source within 1A2, due to a predicted increase in activity.
- 2 IPPU: Similar to PM2.5, the main contributors to TSP emissions are source categories 2A Mineral industry (especially 2A1 Cement production and 2A4 Other process use of carbonates), 2G Other product manufacture and use and 2H Other (especially 2H1 Pulp and paper and 2H2 Food and beverages industry). In addition, similar as for PM10, also source category 2I Wood processing is relevant for TSP emissions. The emissions of all of these source categories are expected to remain about constant between 2025 and 2035.

- 1A4 Other sectors: Continuous technological improvements of small wood combustion installations (due to compliance with stricter air pollution control requirements from 2007 onwards) and a further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) lead to projected emission reductions. Furthermore, a decrease in wood energy consumption in manually operated furnaces is expected.
- 5 Waste: The projected reduction of TSP emissions is mainly due to an assumed reduction of illegal waste incineration (in source category 5C1a).

Table 9-15 WM projections: Trends of total TSP emissions per sector.

TSP emissions	**2022**	**2025**	**2030**	**2035**	**share in 2022**	**share in 2035**	**2022-2035**
	kt	**kt**	**kt**	**kt**			**kt**
1 Energy	12	12	12	12	42%	42%	-0.32
1A Fuel combustion	12	12	12	12	42%	42%	-0.32
1A1 Energy industries	0.064	0.070	0.079	0.080	0.23%	0.29%	0.016
1A2 Manufacturing industries and constr.	3.8	3.9	3.9	3.9	14%	14%	0.071
1A3 Transport	4.6	5.0	5.3	5.4	16%	19%	0.77
1A4 Other sectors	3.0	2.7	2.3	1.8	11%	6.6%	-1.2
1A5 Other (Military)	0.39	0.39	0.39	0.39	1.4%	1.4%	-0.0023
1B Fugitive emissions from fuels	0.0012	0.0013	0.0012	0.0012	0.0042%	0.0042%	-0.00002
2 IPPU	3.1	3.3	3.2	3.2	11%	12%	0.09
3 Agriculture	13	13	13	13	45%	45%	-0.033
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.37	0.39	0.42	0.25	1.3%	0.90%	-0.12
6 Other	0.21	0.20	0.20	0.19	0.73%	0.70%	-0.012
National total	28	29	28	28	100%	100%	-0.39

Table 9-16 WM projections: Trends of TSP exhaust emissions per sector.

TSP exhaust emissions	**2022**	**2025**	**2030**	**2035**	**share in 2022**	**share in 2035**	**2022-2035**
	kt	**kt**	**kt**	**kt**			**kt**
1 Energy	3.6	3.3	2.8	2.2	73%	66%	-1.4
1A Fuel combustion	3.6	3.3	2.8	2.2	73%	66%	-1.4
1A1 Energy industries	0.064	0.070	0.079	0.080	1.3%	2.4%	0.016
1A2 Manufacturing industries and constr.	0.35	0.32	0.27	0.22	7.0%	6.6%	-0.13
1A3 Transport	0.31	0.30	0.23	0.19	6.3%	5.5%	-0.13
1A4 Other sectors	2.9	2.6	2.2	1.7	59%	51%	-1.16
1A5 Other (Military)	0.0067	0.0065	0.0063	0.0061	0.13%	0.18%	-0.0006
1B Fugitive emissions from fuels	0.000001	0.000001	0.000001	0.000001	0.00002%	0.00003%	-0.00000008
2 IPPU	0.78	0.76	0.73	0.73	16%	22%	-0.045
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.37	0.39	0.42	0.25	7.4%	7.3%	-0.12
6 Other	0.18	0.18	0.17	0.17	3.7%	5.1%	-0.012
National total	5.0	4.6	4.1	3.4	100%	100%	-1.6

Table 9-17 WM projections: Trends of TSP non-exhaust emissions per sector.

TSP non-exhaust emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	8.3	8.8	9.2	9.4	36%	38%	1.1
1A Fuel combustion	8.3	8.8	9.2	9.4	36%	38%	1.1
1A1 Energy industries	NA	NA	NA	NA	–	–	–
1A2 Manufacturing industries and constr.	3.5	3.5	3.6	3.7	15%	15%	0.20
1A3 Transport	4.3	4.7	5.1	5.2	19%	21%	0.89
1A4 Other sectors	0.10	0.10	0.098	0.096	0.44%	0.39%	-0.0068
1A5 Other (Military)	0.38	0.38	0.38	0.38	1.6%	1.6%	-0.0017
1B Fugitive emissions from fuels	0.0012	0.0013	0.0012	0.0012	0.005%	0.005%	-0.00002
2 IPPU	2.4	2.5	2.5	2.5	10%	10%	0.13
3 Agriculture	13	13	13	13	54%	51%	-0.033
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.0036	0.0036	0.0036	0.0036	0.02%	0.01%	–
6 Other	0.022	0.023	0.022	0.022	0.09%	0.09%	0.0005
National total	23	24	24	25	100%	100%	1.2

9.4.4 Projections for BC

The decreasing trend of emissions from PM2.5 and PM10 is also reflected in the trends of BC emissions and is even more pronounced since the reduction measures mainly focus on combustion particles which largely consists of BC (see Figure 9-4 and Table 9-18). The decrease is mainly expected in source categories 1A4 Other sectors and 1A3 Transport. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A4 Other sectors: Continuous technological improvements of small wood combustion installations (due to compliance with stricter air pollution control requirements from 2007 onwards) and a further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) lead to projected emission reductions. Furthermore, a decrease in wood energy consumption in manually operated furnaces is expected.
- 1A3 Transport: Emissions are expected slightly decline between 2025 and 2035. In source category 1A3b Road transportation, the Euro 6/VI standard and a reduction of fuel consumption (see Figure 9-1) will lead to reduced BC emissions.

Table 9-18 WM projections: Trends of BC emissions per sector.

BC emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kt	kt	kt	kt			kt
1 Energy	0.86	0.77	0.61	0.49	98%	97%	-0.37
1A Fuel combustion	0.86	0.77	0.61	0.49	98%	97%	-0.37
1A1 Energy industries	0.0069	0.0075	0.0083	0.0083	0.78%	1.7%	0.0014
1A2 Manufacturing industries and constr.	0.034	0.023	0.015	0.012	3.9%	2.4%	-0.022
1A3 Transport	0.21	0.20	0.16	0.15	24%	30%	-0.063
1A4 Other sectors	0.60	0.53	0.42	0.32	69%	63%	-0.29
1A5 Other (Military)	0.0032	0.0031	0.0030	0.0029	0.37%	0.58%	-0.0003
1B Fugitive emissions from fuels	0.00003	0.00003	0.00003	0.00003	0.003%	0.006%	-0.0000004
2 IPPU	0.0013	0.0013	0.0013	0.0013	0.14%	0.26%	0.00003
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.020	0.021	0.022	0.014	2.2%	2.7%	-0.0060
6 Other	0.00008	0.00008	0.00007	0.00007	0.009%	0.01%	-0.00001
National total	0.88	0.79	0.64	0.50	100%	100%	-0.38

9.5 Priority heavy metals

According to the projections, total Pb emissions will decrease between 2025 and 2035 whereas total Cd and Hg emissions are remaining about constant. The gap in Figure 9-5 between the latest reporting year and 2025 symbolises the fact that most of the scenarios used to calculate emissions projections for the individual sectors and source categories cover the period from 2025 onwards. Accordingly, the emissions in between are interpolated linearly.

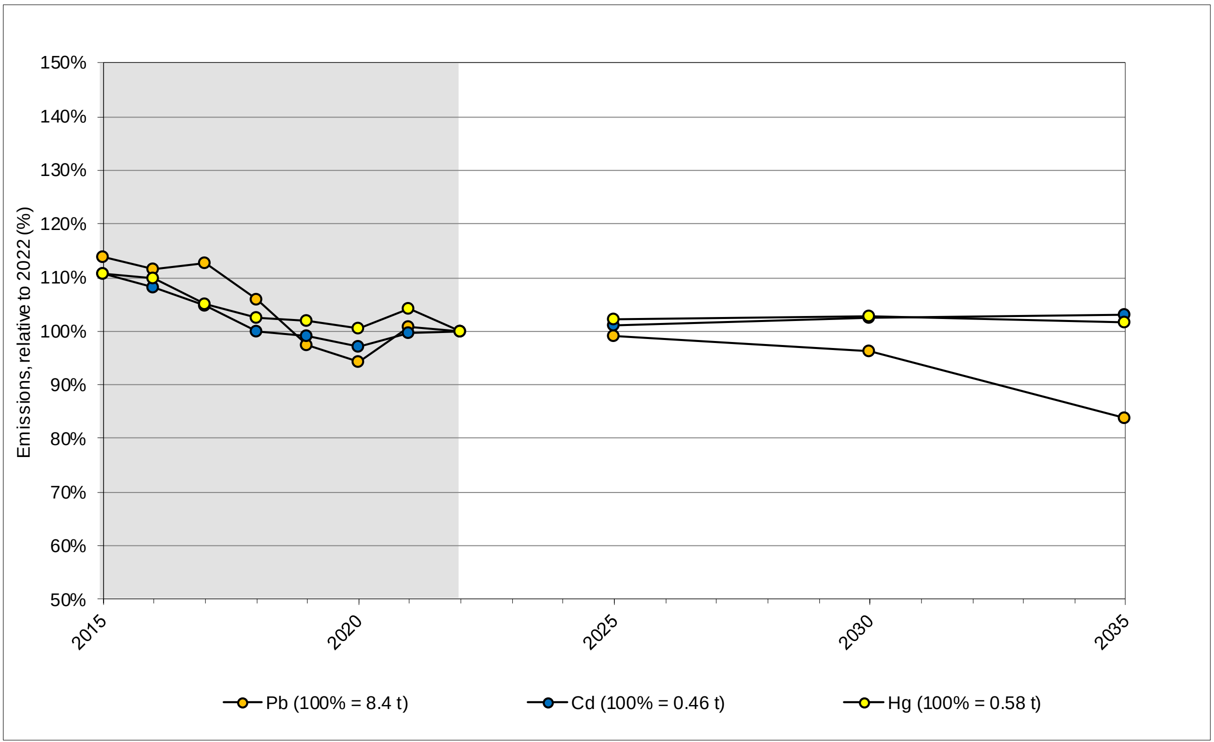

Figure 9-5 Relative trends for the total emissions of priority heavy metals in Switzerland as projected in the WM scenario. 100 % corresponds to levels of the latest reporting year.

Table 9-19 Priority heavy metals: Total emissions of the WM projections until 2035 in t.

Year	Pb	Cd	Hg
	t	t	t
2005	18	0.54	0.73
2010	12	0.56	0.74
2015	9.6	0.51	0.64
2020	8.0	0.45	0.58
2022	8.4	0.46	0.58
2025	8.4	0.47	0.59
2030	8.1	0.48	0.59
2035	7.1	0.48	0.59
2035 vs. 2022 (%)	-16%	3%	2%

9.5.1 Projections for lead (Pb)

Pb emissions are projected to continue to decrease until 2035 (see Table 9-20 and Figure 9-5). The most significant reductions are expected in sectors 5 Waste and 6 Other as well as smaller ones in source categories 1A2 Manufacturing industries and construction and 1A4

Other sectors. In return, an increase is projected in source category 1A1 Energy industries. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A1 Energy industries: Pb emissions are expected to increase due to growing amounts of waste and wood waste incinerated.
- 6 Other: It is assumed that the number of fires in buildings (under the source category 6Ad Fire damage buildings and motor vehicles) will continue to decrease between 2025 and 2035 due to improvement in safety. In parallel, we expect newly constructed and renovated buildings to contain much less lead due to a continuous increase in the ban of lead in many products, as enforced by the Chemical Risk Reduction Ordinance ORRChem (Swiss Confederation 2005).
- 5 Waste: The projected reduction of Pb emissions is mainly due to an assumed reduction of illegal waste incineration (in source category 5C1a).
- 1A2 Manufacturing industries and construction: A reduction between 2025 and 2035 is mainly expected due to a projected decline of the use of wood waste (1A2gviii) as well as of the production volumes in the non-metallic minerals processing industry (1A2f).
- 1A3 Transport: Emissions are dominated by source category 1A3a Civil aviation and are projected to slightly decrease.
- 2 IPPU: The main contributors to Pb emissions are source categories 2C1 Iron and steel production and 2G Other product use. The emissions from these source categories are projected to remain about constant between 2025 and 2035.
- 1A4 Other sectors: A reduction of emissions is expected through continuous technological improvements in small wood combustion installations, a further reduction in the number of emission intensive types of wood furnaces and in the combustion of wood in manually operated furnaces and wood waste in commercial installations (source category 1A4ai).

Table 9-20 WM projections: Trends of Pb emissions per sector.

Pb emissions	**2022**	**2025**	**2030**	**2035**	**share in 2022**	**share in 2035**	**2022-2035**
	t	t	t	t			t
1 Energy	4.4	4.4	4.2	4.1	52%	58%	-0.29
1A Fuel combustion	4.4	4.4	4.2	4.1	52%	58%	-0.29
1A1 Energy industries	1.7	1.7	1.8	1.8	20%	26%	0.15
1A2 Manufacturing industries and constr.	1.2	1.2	1.0	1.0	14%	14%	-0.22
1A3 Transport	0.88	0.88	0.87	0.85	10%	12%	-0.027
1A4 Other sectors	0.60	0.56	0.50	0.41	7.1%	5.8%	-0.19
1A5 Other (Military)	0.0002	0.0002	0.0002	0.0002	0.003%	0.003%	-0.000004
1B Fugitive emissions from fuels	0.000002	0.000002	0.000002	0.000002	0.00002%	0.00003%	-0.0000001
2 IPPU	0.70	0.70	0.67	0.67	8.3%	10%	-0.023
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	1.6	1.7	1.8	1.0	19%	14%	-0.59
6 Other	1.8	1.6	1.4	1.3	21%	19%	-0.47
National total	8.4	8.4	8.1	7.1	100%	100%	-1.4

9.5.2 Projections for cadmium (Cd)

Cadmium emissions are expected to remain about constant until 2035 (see Table 9-21 and Figure 9-5). Only marginal changes of cadmium emission levels are projected for any sector. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A1 Energy industries: A slight increase is projected due to population growth and thereby increased amount of waste incinerated as well as an increase in consumption of wood and wood waste.
- 1A3 Transport: An increase of traffic volumes is projected to also lead to a slight increase of Cd emissions from tyre abrasion.
- 2 IPPU: The main contributor to Cd emissions is source category 2G Other product use (tobacco consumption and fireworks use), where emissions are projected to remain about constant.
- 1A2 Manufacturing industries and construction: The emission reduction is mainly related to an expected decline of the use of wood waste (1A2gviii) as well as of the production volumes in the non-metallic minerals processing industry (1A2f). In addition, relevant source categories are 1A2gvii Mobile combustion in manufacturing industries and construction (non-road vehicles and machinery), where emissions are expected to slightly increase due to increased activity.

Table 9-21 WM projections: Trends of Cd emissions per sector.

Cd emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	t	t	t	t			kt
1 Energy	0.38	0.38	0.39	0.39	81%	81%	0.014
1A Fuel combustion	0.38	0.38	0.39	0.39	81%	81%	0.014
1A1 Energy industries	0.15	0.16	0.16	0.17	33%	35%	0.014
1A2 Manufacturing industries and constr.	0.075	0.074	0.070	0.070	16%	15%	-0.0054
1A3 Transport	0.095	0.097	0.10	0.10	21%	22%	0.0081
1A4 Other sectors	0.050	0.050	0.050	0.047	11%	9.9%	-0.0027
1A5 Other (Military)	0.0005	0.0005	0.0005	0.0005	0.11%	0.11%	-0.000008
1B Fugitive emissions from fuels	0.000003	0.000003	0.000003	0.000003	0.0006%	0.0006%	-0.0000002
2 IPPU	0.079	0.079	0.079	0.080	17%	17%	0.0009
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.0086	0.0089	0.0095	0.0079	1.8%	1.7%	-0.0006
6 Other	0.0016	0.0016	0.0016	0.0016	0.35%	0.33%	-0.00004
National total	0.46	0.47	0.48	0.48	100%	100%	0.014

9.5.3 Projections for mercury (Hg)

Mercury emissions are expected to remain about constant until 2035 (see Table 9-22 and Figure 9-5). Only marginal changes of mercury emission levels are projected for any sector. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A1 Energy industries: An increase is projected as a result of an increase in the amounts of waste, wood and wood waste incinerated.
- 1A2 Manufacturing industries and construction: The emission reduction is mainly related to an expected decline of the use of wood waste (1A2gviii) as well as of the production volumes in the non-metallic minerals processing industry (1A2f). In addition, relevant source categories are 1A2gvii Mobile combustion in manufacturing industries and construction (non-road vehicles and machinery), where emissions are expected to slightly increase due to increased activity.
- 1A4 Other sectors: A reduction of emissions is expected in stationary combustion. This reduction is due to the projected general decrease in the combustion of wood, gas oil and wood waste.

- 2 IPPU: The main contributor to Hg emissions is source category 2C1 Iron and steel production, where emissions are expected to remain about constant due to projected roughly constant production volumes in secondary steel production.

Table 9-22 WM projections: Trends of Hg emissions per sector.

Hg emissions	**2022**	**2025**	**2030**	**2035**	**share in 2022**	**share in 2035**	**2022-2035**
	t	**t**	**t**	**t**			**t**
1 Energy	0.50	0.51	0.51	0.51	86%	86%	0.0073
1A Fuel combustion	0.50	0.51	0.51	0.51	86%	86%	0.0073
1A1 Energy industries	0.29	0.30	0.31	0.32	50%	54%	0.028
1A2 Manufacturing industries and constr.	0.10	0.10	0.098	0.094	18%	16%	-0.0072
1A3 Transport	0.033	0.032	0.029	0.026	5.6%	4.3%	-0.0070
1A4 Other sectors	0.076	0.076	0.075	0.069	13%	12%	-0.0070
1A5 Other (Military)	0.00003	0.00003	0.00003	0.00003	0.005%	0.005%	-0.0000005
1B Fugitive emissions from fuels	0.0000005	0.0000005	0.0000004	0.0000004	0.00008%	0.00008%	-0.00000003
2 IPPU	0.051	0.054	0.054	0.054	8.8%	9.2%	0.0031
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.028	0.028	0.028	0.027	4.8%	4.5%	-0.0011
6 Other	0.0007	0.0007	0.0007	0.0007	0.13%	0.12%	-0.00003
National total	0.58	0.59	0.59	0.59	100%	100%	0.0093

9.6 Persistent organic pollutants (POPs)

According to the projections, total emissions of all persistent organic pollutants (POPs) will decrease between 2025 and 2035. The decrease is most significant for PCB and less for the other POPs (PCDD/PCDF, PAH, HCB). The gap in Figure 9-6 between the latest reporting year and 2025 symbolises the fact that most of the scenarios used to calculate emissions projections for the individual sectors and source categories cover the period from 2025 onwards. Accordingly, the emissions in between are interpolated linearly.

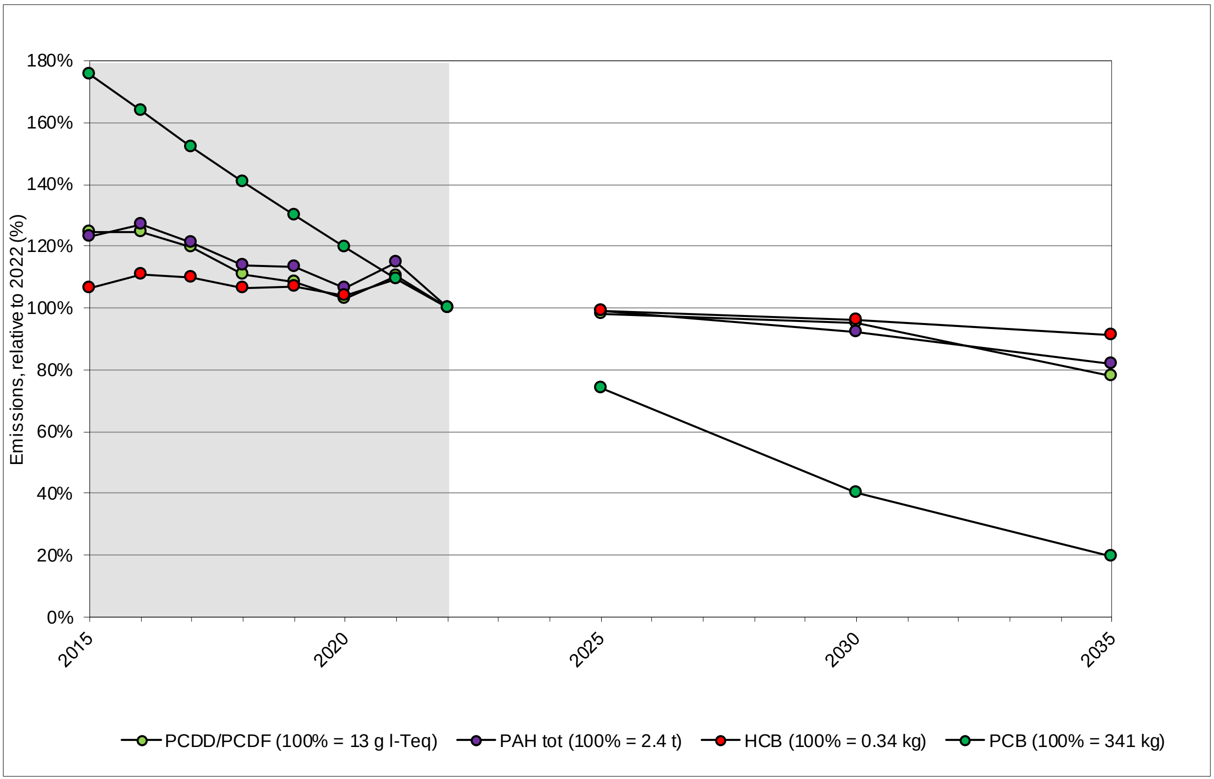

Figure 9-6 Relative trends for the total emissions of POPs: PCDD/PCDF, PAH (as the sum of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene), and HCB in Switzerland in the WM scenario. 100 % corresponds to levels of the latest reporting year.

Table 9-23 Persistent organic pollutants (POPs): Total emissions of the WM projections until 2035 (please take note of the different units).

Year	PCDD/ PCDF	BaP	BbF	BkF	IcdP	PAH tot	HCB	PCB
	g I-Teq	t	t	t	t	t	kg	kg
2005	31	1.4	1.6	1.0	0.82	4.9	0.44	1'270
2010	25	1.2	1.3	0.77	0.70	4.0	0.45	827
2015	16	0.88	0.93	0.57	0.51	2.9	0.36	600
2020	13	0.76	0.80	0.50	0.45	2.5	0.35	408
2022	13	0.70	0.75	0.48	0.42	2.4	0.34	341
2025	12	0.70	0.75	0.47	0.41	2.3	0.33	252
2030	12	0.65	0.70	0.44	0.37	2.2	0.33	138
2035	9.8	0.58	0.63	0.39	0.33	1.9	0.31	66
2035 vs. 2022 (%)	-22%	-18%	-16%	-17%	-22%	-18%	-9%	-81%

9.6.1 Projections for PCDD/PCDF

PCDD/PCDF emissions are projected to continue to decrease until 2035 (see Table 9-24 and Figure 9-6). The most significant (approximately equal) reductions are expected in source category 1A4 Other sectors, which is also the main source of PCDD/PCDF emissions in 2035, and in sector 5 Waste. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A4 Other sectors: The emission reduction is projected to result from a continuous improvement in wood combustion installations, a continued decrease in wood energy consumption in manually operated furnaces as well as further reductions in the number of emission intensive types of wood furnaces (e.g. cooking stoves).
- 5 Waste: Emission reductions are projected due to a reduction of illegally incinerated waste under source category 5C1a.
- 1A1 Energy industries: Emissions are expected to increase due to the projected increase in volumes in waste incineration plants.
- 6 Other: It is assumed that the number of fires in buildings (under source category 6Ad Fire damage buildings and motor vehicles) will continue to decrease between 2025 and 2035 due to improvement in safety.
- 2 IPPU: The main contributors to PCDD/PCDF emissions are source categories 2C Metal industry (especially 2C1 Secondary steel production and 2C7a Non-ferrous metal foundries) and 2H Other (2H1 chipboard production and 2H2 Meat smokehouses). The emissions of all of these source categories are expected to remain about constant between 2025 and 2035 due to projected roughly constant production volumes.
- 1A2 Manufacturing industries and construction: A reduction is mainly due to a projected decline of the use of wood waste and an expected higher proportion of modern wood combustion plants with lower proportions of non-optimal operating phases (1A2gviii Other boilers and engines industry).

Table 9-24 WM projections: Trends of PCDD/PCDF emissions per sector.

PCDD/PCDF emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	g I-Teq	g I-Teq	g I-Teq	g I-Teq			g I-Teq
1 Energy	7.9	7.5	6.9	6.2	63%	63%	-1.7
1A Fuel combustion	7.9	7.5	6.9	6.2	63%	63%	-1.7
1A1 Energy industries	0.94	0.97	1.0	1.0	7.5%	10%	0.088
1A2 Manufacturing industries and constr.	1.1	1.0	0.89	0.81	8.5%	8.3%	-0.25
1A3 Transport	0.45	0.39	0.30	0.26	3.6%	2.6%	-0.19
1A4 Other sectors	5.4	5.2	4.7	4.1	43%	42%	-1.4
1A5 Other (Military)	0.0004	0.0004	0.0004	0.0004	0.003%	0.004%	-0.000006
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–
2 IPPU	0.83	0.84	0.85	0.86	6.6%	8.8%	0.033
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	2.8	2.9	3.2	1.8	22%	18%	-0.98
6 Other	1.0	0.98	0.94	0.94	8.0%	9.6%	-0.063
National total	13	12	12	9.8	100%	100%	-2.7

9.6.2 Projections for polycyclic aromatic hydrocarbons (PAH)

PAH emissions are projected to continue to decrease until 2035 (see Table 9-25 and Figure 9-6). The most significant reduction is expected in source category 1A4 Other sectors, which is also the main source of PAH emissions in 2035. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A4 Other sectors: The emission reduction is projected to result from a continuous improvement in wood combustion installations, a continued decrease in wood energy consumption in manually operated furnaces as well as further reductions in the number of emission intensive types of wood furnaces (e.g. cooking stoves).
- 1A3 Transport: Emissions from 1A3 Transport are expected to remain about constant between 2025-2035. The main contributor to PAH emissions is diesel consumption from passenger cars (1A3bi). The mileage of passenger cars fuelled with diesel is expected to remain about constant between 2025 and 2035. As the PAH emission factors from the EMEP/EEA Guidebook (EMEP/EEA 2019) are used (constant over time, in g/km). Accordingly, the emission projection is correlated with mileage of diesel vehicles and is also expected to remain about constant.
- 5 Waste: PAH emissions are dominated by field burning of agricultural waste (5C2 Open burning of waste), which is expected to remain about constant.
- 1A2 Manufacturing industries and construction: PAH emissions are expected to decrease between 2025 and 2035 mainly due to a projected decline of the use of wood waste and an expected higher proportion of modern wood combustion plants with lower proportions of non-optimal operating phases. (Note that the increase 2022-2035 in Table 9-25 is related to the interpolation between the latest reporting year and the first year of the projections (2025).
- 6 Other: PAH emissions are dominated by vehicles fires and are expected to slightly increase between 2025 and 2035 due to an increase in the number of fires (source category 6Adb).

Table 9-25 WM projections: Trends of PAHs emissions per sector.

PAHs emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	t	t	t	t			t
1 Energy	2.0	2.0	1.8	1.6	87%	83%	-0.43
1A Fuel combustion	2.0	2.0	1.8	1.6	87%	83%	-0.43
1A1 Energy industries	0.0058	0.0065	0.0074	0.0063	0.25%	0.33%	0.0005
1A2 Manufacturing industries and constr.	0.11	0.16	0.14	0.13	4.5%	7.0%	0.028
1A3 Transport	0.28	0.30	0.30	0.30	12%	15%	0.015
1A4 Other sectors	1.6	1.5	1.4	1.2	70%	61%	-0.48
1A5 Other (Military)	0.0007	0.0007	0.0007	0.0007	0.03%	0.03%	-0.00002
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–
2 IPPU	0.012	0.012	0.012	0.012	0.51%	0.64%	0.0005
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	0.19	0.19	0.19	0.19	8.0%	9.8%	-0.000005
6 Other	0.11	0.11	0.12	0.12	4.6%	6.3%	0.012
National total	2.4	2.3	2.2	1.9	100%	100%	-0.42

9.6.3 Projections for hexachlorobenzene (HCB)

HCB emissions are projected to continue to decrease until 2035 (see Table 9-26 and Figure 9-6). The most significant reductions are expected in source category 1A4 Other sectors. On the opposite, an increase is projected for source category 1A1 Energy industries, which is the main source of HCB emissions in 2035. It should be noted that emissions from mobile sources (1A3, 1A2gvii, and 1A4aii/bii/cii) are not estimated in the inventory. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 1A1 Energy industries: Emissions are expected to increase due to the projected increase in volumes in waste incineration plants.
- 1A4 Other sectors: The emission reduction is projected to result from a continuous improvement in wood combustion installations a continued decrease in wood energy consumption in manually operated furnaces as well as further reductions in the number of emission intensive types of wood furnaces (e.g. cooking stoves).
- 1A2 Manufacturing and constructing industries: The emission reduction is mainly due to a projected decline of the use of wood waste and an expected higher proportion of modern wood combustion plants with lower proportions of non-optimal operating phases in source category 1A2gviii Stationary combustion in manufacturing industries and construction: Other. In addition, cement production (1A2f) is a relevant source category, where emissions are expected to decrease only minimally as production volumes are projected to remain almost the same.

Table 9-26 WM projections: Trends of HCB emissions per sector.

HCB emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kg	kg	kg	kg			kg
1 Energy	0.34	0.33	0.33	0.31	100%	100%	-0.030
1A Fuel combustion	0.34	0.33	0.33	0.31	100%	100%	-0.030
1A1 Energy industries	0.18	0.18	0.19	0.19	53%	63%	0.015
1A2 Manufacturing industries and constr.	0.038	0.036	0.033	0.030	11%	9.6%	-0.0080
1A3 Transport	NE	NE	NE	NE	–	–	–
1A4 Other sectors	0.12	0.11	0.10	0.085	36%	27%	-0.037
1A5 Other (Military)	NE	NE	NE	NE	–	–	–
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–
2 IPPU	NA	NA	NA	NA	–	–	–
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	NA	NA	NA	NA	–	–	–
6 Other	NA	NA	NA	NA	–	–	–
National total	0.34	0.33	0.33	0.31	100%	100%	-0.030

9.6.4 Projections for polychlorinated biphenyl (PCBs)

PCB emissions are projected to decrease considerably until 2035 (see Table 9-27 and Figure 9-6). The main reduction is expected in sector 2 IPPU, which remains the main emission source in 2035. The most important source categories in the future and the reasons for their emission trends are briefly described below, in order of the emissions shares in 2035:

- 2 IPPU: Also in future, the main relevant PCB emission sources remain anti-corrosive paints and joint sealants (2K) which were applied on steel and in window frames, respectively, prior to the ban of PCBs in so-called open application in 1972.
- 6 Other: To a lesser extent than the emissions of 2K, also accidental releases of PCB by fire and from soil due to former PCB spillages (6Ad) contribute to future PCB emissions. These are also expected to decline between 2025 and 2035.

Table 9-27 WM projections: Trends of PCB emissions per sector.

PCB emissions	2022	2025	2030	2035	share in 2022	share in 2035	2022-2035
	kg	kg	kg	kg			kg
1 Energy	0.39	0.39	0.37	0.35	0.11%	0.53%	-0.042
1A Fuel combustion	0.39	0.39	0.37	0.35	0.11%	0.53%	-0.042
1A1 Energy industries	0.065	0.053	0.033	0.017	0.02%	0.03%	-0.048
1A2 Manufacturing industries and constr.	0.33	0.34	0.34	0.33	0.10%	0.50%	0.0062
1A3 Transport	0.00009	0.00008	0.00006	0.00005	0.00003%	0.00008%	-0.00004
1A4 Other sectors	0.0007	0.0007	0.0006	0.0005	0.0002%	0.0008%	-0.0001
1A5 Other (Military)	NE	NE	NE	NE	–	–	–
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–
2 IPPU	308	225	118	51	90%	77%	-257
3 Agriculture	NA	NA	NA	NA	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–
5 Waste	6.0	3.8	2.2	1.5	1.7%	2.3%	-4.5
6 Other	27	23	17	13	8.0%	20%	-14
National total	341	252	138	66	100%	100%	-275

10 Reporting of gridded emissions and LPS

Paragraph 28 of the “Guidelines for Reporting Emissions and Projections Data under the CLRTAP” requires that “Emission data calculated by Parties within the geographic scope of EMEP shall be spatially allocated in the EMEP grid as defined in paragraph 14 of these Guidelines” (ECE 2023). This chapter describes how Switzerland implemented these requirements.

10.1 EMEP grid

Definition of the EMEP grid

The EMEP grid is based on a latitude-longitude coordinate system: 0.1° × 0.1° latitude-longitude projection in the geographic coordinate World Geodetic System latest revision, WGS 84. The domain is therefore described in degrees and not in km^2. It extends in south-north direction from 30°N-82°N latitude and in west-east direction from 30°W-90°E longitude.

The grid fulfils the following requirements:

- It allows assessing globally dispersed pollutants on a hemispheric/global scale (Assessment Report, HTAP 2010).
- It allows to consider wider spatial scales in order to deal with tasks related to climate change and its effect on air pollution.
- Pollution levels can be assessed at a finer spatial resolution in order to provide more detailed information on pollution levels within territories of parties of the convention.

Figure 10-1 shows the EMEP grid domain.

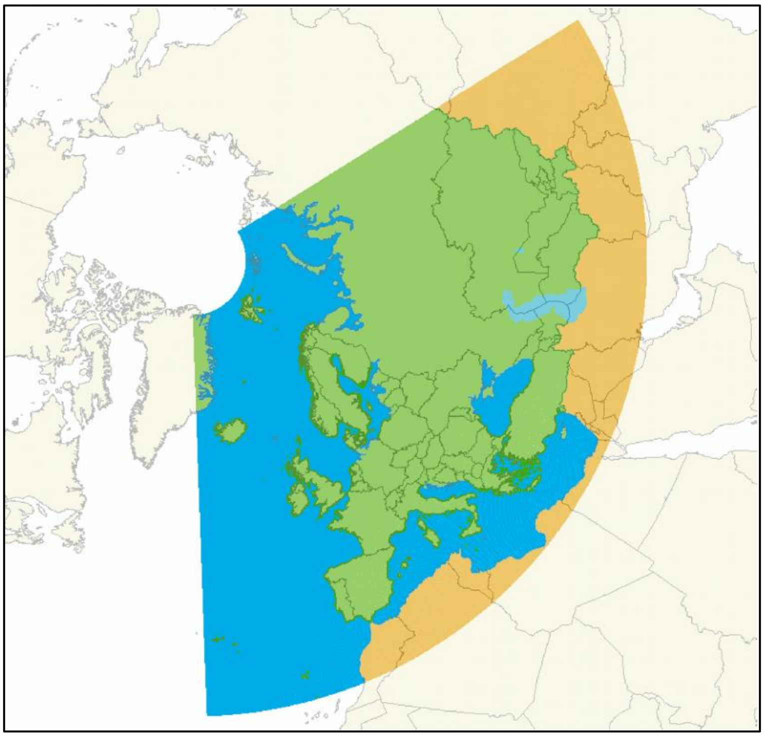

Figure 10-1 EMEP domain in the latitude-longitude projection (30°N-82°N, 30°W-90°E) (EMEP 2012a, https://www.emep.int/grid/lonlatgrid.pdf).

The EMEP domain on regional-scale

In accordance with the requirements described above, grid resolution for standard EMEP regional simulations can be chosen in the range of 0.5° x 0.5° to 0.2° x 0.2° (EMEP 2012a). This means, for instance, that in a 0.2°-based EMEP grid the cell size at 40°N (Italy) is 17 x 22 km^2 whereas at 60°N (Scandinavia) the cell size is 11 x 22 km^2. In total, a 0.2° x 0.2° resolution results in 156’000 grid cells.

EMEP domain on local-scale

For a more detailed assessment of air pollution levels, spatial resolution needs to be further refined. Several studies have shown that the EMEP modelling centres can provide more accurate results if refined resolution with more detailed input data is applied (EMEP 2012a). Therefore, a spatial resolution for national/local levels is defined at 0.1° x 0.1°. This results in a spatial resolution at 40°N (Italy) of 9 x 11 km^2 and 6 x 11 km^2 at 60°N (Scandinavia). Figure 10-2 illustrates the EMEP grid resolution for Europe as used on local scales. In total, approximately 624’000 grid cells exist within the local EMEP domain.

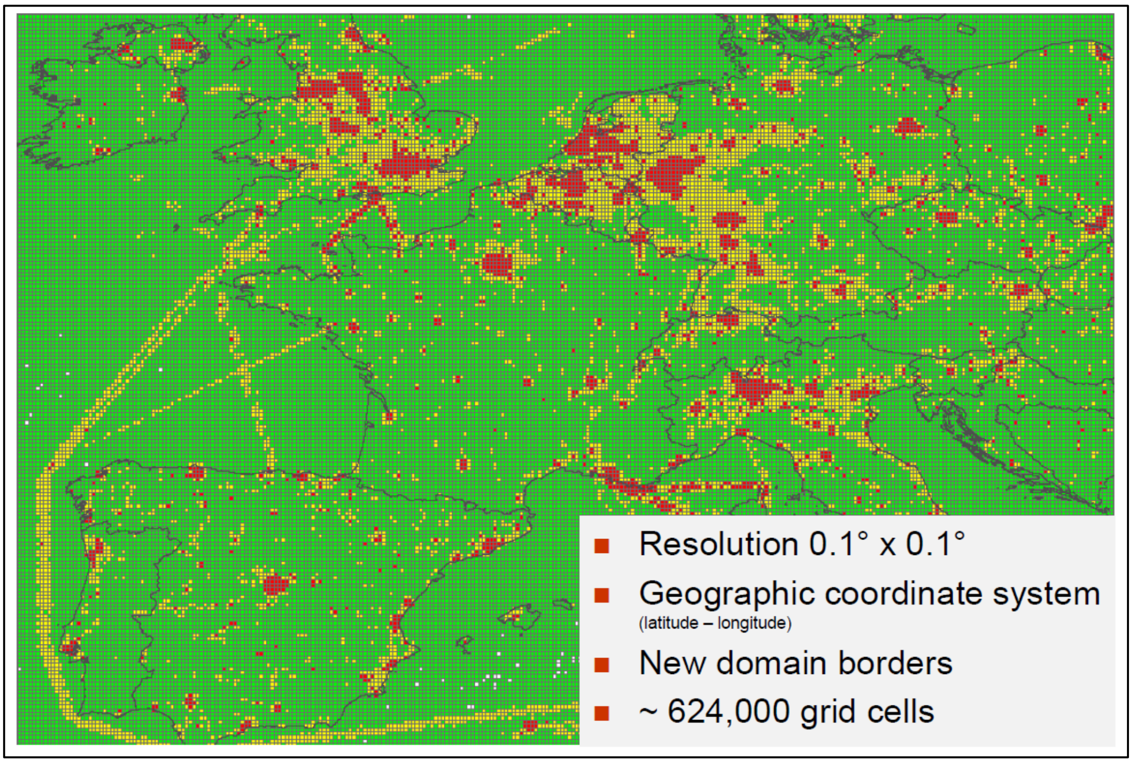

Figure 10-2 Resolution of the EMEP grid for Europe (EMEP 2012b).

In Switzerland’s air pollution inventory of the latest submission 2024, the EMEP grid on local scale (0.1° x 0.1°) is applied (see chapter 10.3) and contains 580 different grid cells. This includes also cells covering Lake of Constance. For grid cells outside Swiss borders no emissions are reported (see Figure 10-3).

The challenge in modelling on local scale (0.1° x 0.1°) is the accurate allocation of emissions from the national total of emissions. Accordingly, emissions form national total should be processed to a resolution that is at least as fine as the resolution of the local-based EMEP grid. To achieve that, a separate study has been carried out which provides the allocation of the emissions sources within the local-scale EMEP grid (see Meteotest 2013 and 2021a).

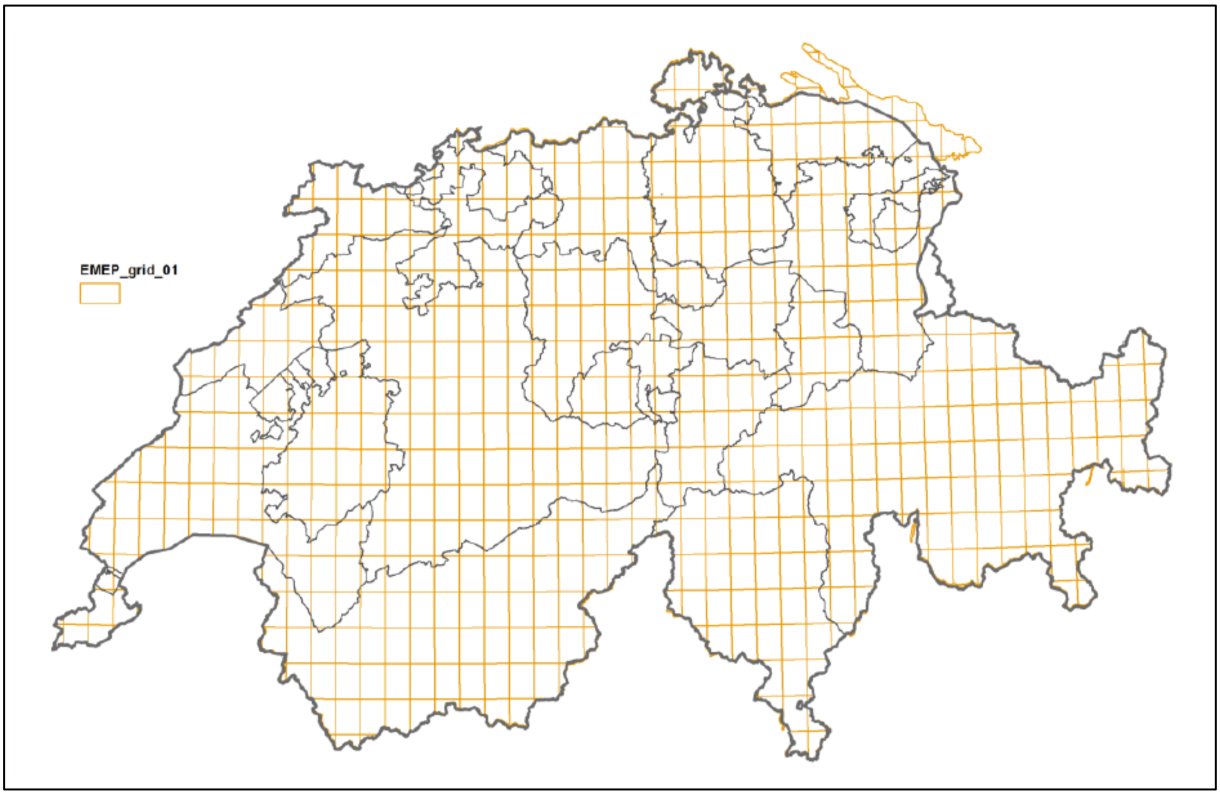

Figure 10-3 EMEP grid in Switzerland with 0.1° x 0.1° spatial resolution (from Meteotest 2013, downloaded from EMEP).

10.2 Gridding of emissions

10.2.1 Switzerland’s emissions according to the GNFR-Code

As described above, the emissions of the Swiss national inventory have to be allocated to the EMEP grid. Therefore, the source categories according to the NFR (Nomenclature for Reporting) code need to be aggregated to the GNFR categories (NFR Aggregation for Gridding according to annexes V (GNFR) of ECE 2023a). Table 10-1 shows the relative shares of the GNFR categories of Switzerland’s total emissions (national total) in 2022 for all main air pollutants including PM2.5 and CO.

Table 10-1 GNFR categories and their part (%) of total emissions in 2022 (national total) for the main air pollutants, PM2.5 and CO.

GNFR aggregated sectors	NO_x	NMVOC	SO_x	NH_3	PM2.5	CO
A_PublicPower	4.4%	0.27%	7.3%	0.069%	0.70%	0.37%
B_Industry	13%	8.6%	71%	0.59%	17%	11%
C_OtherStatComb	15%	4.9%	14%	0.19%	39%	22%
D_Fugitive	0.0012%	3.3%	0.51%	NA	0.00075%	0.000092%
E_Solvents	0.037%	43%	0.24%	0.14%	6.6%	0.38%
F_RoadTransport	45%	9.6%	1.6%	1.7%	18%	40%
G_Shipping	1.9%	0.55%	0.021%	0.00040%	0.36%	3.5%
H_Aviation	3.6%	0.21%	3.8%	NA	0.22%	1.6%
I_Offroad	8.6%	2.2%	1.2%	0.0047%	12%	20%
J_Waste	0.25%	2.4%	0.89%	1.6%	4.2%	0.96%
K_AgriLivestock	1.9%	24%	NA	47%	1.5%	NA
L_AgriOther	5.6%	0.63%	NA	47%	0.69%	NA
M_Other	0.19%	0.23%	0.23%	1.8%	0.073%	0.33%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

10.2.2 Data availability for emission allocation

In order to allocate the emissions of each GNFR category, an adequate allocation key has to be determined. Numerous GNFR categories overlap with various source categories thus it is not possible to apply a single approach. Depending on the properties of each GNFR category, evaluation and identification of an appropriate allocation key is required. This ensures the adequate allocation of total emissions in the EMEP grid. For allocation purposes only relative shares of the national total emissions are relevant. Details of this work can be found in Meteotest 2013 and 2021a.

For the latest submission 2024, Switzerland calculated gridded emissions for the entire time series 1980-2022. For the allocation process of the emissions various data sources were applied for the time intervals 1980-1989, 1990-1999, 2000-2009, 2010-2015, 2016-2019 and >2020. Table 10-2 illustrates the data source applied for each time interval.

Table 10-2 Applied data sources for gridded emission time series 1980-1989, 1990-1999, 2000-2009, 2010-2015, 2016-2019 and >2020 (Meteotest 2013 and 2021a).

Data source	Distribution pattern	Applied data source for gridded emission time series					
		1980-89	1990-99	2000-09	2010-15	2016-19	> 2020
Population data	1990, 2000, annually from 2010	1990	1990	2000	2013	2017	2020
Census of enterprises sector 1	1996, 2000, 2005, 2008, annually from 2011	1996	1996	2005	2013	2017	2018
Census of enterprises sector 2+3	1995, 2000, 2001, 2005, 2008, annually from 2011	1995	1995	2005	2013	2017	2018
Land use statistics	1979/85, 1992/97, 2004/09, 2013/18	1979/85	1992/97	2004/09	2013/18	2013/18	2013/18
NO_X emission maps	1990, 2000, 2005, 2010, 2015	2005	2005	2005	2015	2015	2015
PM10 emission maps	2005, 2010, 2015	2005	2005	2005	2015	2015	2015
NH_3 emission maps	1990, 2000, 2007, 2010 (manure management)	1990	2000	2007	2010	2010	2010
Aviation	annual passenger numbers	1985	1995	2005	2013	2017	2019
Refineries	number of refineries	2	2	2	2	1	1
Cement production	number of cement plants (1990, 1998, 2006, 2013)	1990	1998	2006	2013	2013	2013

Population Density

At first sight, most emissions originate where people live and occur proportional to population density in an area. Therefore, population density is one of the main factors to allocate emissions in the EMEP grid. Geo-referenced population data is available annually by the Federal Statistical Office. The most populated area in Switzerland is the Swiss Plateau and the largest cities with their agglomerations in particular (see Figure 10-4).

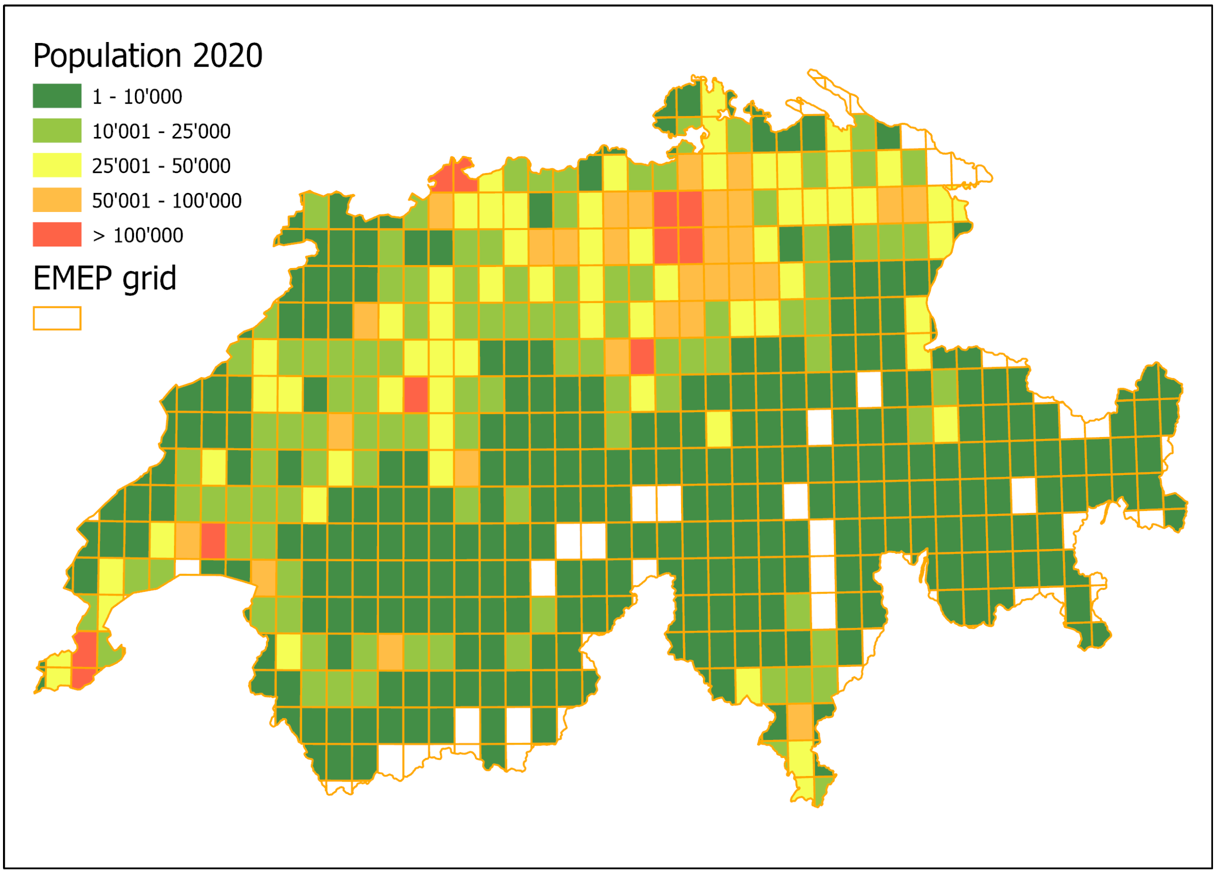

Figure 10-4 Population number per EMEP grid cell in Switzerland in 2020.

Census of enterprises/number of employees by economic sectors

Statistical surveys exist for enterprises, from which information about the specific economic use per hectare (100x100 m^2) is derived. This data is provided annually by the Federal Statistical Office. For several GNFR categories covering industrial production, the number of employees per economic branch and per hectare combined with the information on the economic use per hectare is used for the allocation of the emissions in the EMEP grid.

Land Use Statistics

Switzerland's Land Use Statistics allows determining specific land use characteristics on a hectare-scale (100x100 m^2). According to the Land Use Statistics by the Federal Statistical Office 74 categories are available. They are aggregated to 9 main land use categories to apply them to the EMEP grid (Meteotest 2013). The 9 main land use categories are:

- Wooded areas
- Industrial buildings

- Industrial grounds
- Residential buildings
- Surroundings of residential buildings
- Agricultural buildings
- Agricultural areas
- Unspecified buildings
- Wastewater treatment plants

Air pollution modelling data

The results of specific emissions models are used as additional data for allocation purposes. These specific emission models are described in detail in the associated documentations (FOEN 2011b, FOEN 2013a, Meteotest 2020a and Meteotest 2019b) Based on these models maps of selected emissions can be applied for allocation. For the following air pollutants and source categories, appropriate emission maps are available:

- NO_x: Emissions of road traffic (FOEN 2011b, Meteotest 2020a)
- NO_x: Emissions of navigation (FOEN 2011b, Meteotest 2020a)
- NO_x: Emissions of construction machinery (FOEN 2011b, Meteotest 2020a)
- NO_x: Emissions of industrial vehicles (FOEN 2011b, Meteotest 2020a)
- PM10: Emissions of rail traffic (FOEN 2013a, Meteotest 2020a)
- NH_3: Emissions of manure management - farming of animals without pasture (Meteotest 2019b)

10.2.3 Switzerland's allocation of emissions for the EMEP grid

Method

The data sets described in 10.2.2 are available for the allocation of total emissions to the EMEP grid. The application of those data sets results in various spatial patterns of national emissions in each GNFR category. The attribution of GNFR categories to the patterns is given in the Table 10-3. This allocation method is applied for every pollutant (Meteotest 2014, 2015a).

Example of a GNFR category allocation in the EMEP grid in a case where the emission is attributed to the pattern "population" that means that the emission per hectare is proportional to its population:

$$Emission_{gs} = \frac{Population_g}{Total\ population\ of\ Switzerland} \times Emission_{tot_s}$$

$Emission_{gs}$: Emission of air pollutant (s) of a GNFR category in EMEP grid cell (g)

$Population_g$: Population of grid cell (g)

$Emission_{tots}$: Total emission of Switzerland of air pollutant (s) within the GNFR category with:

$$\sum_{g=0}^{n_g} Emisson_{g_s} = Emission_{tot_s}$$

GNFR categories include by definition also Large Point Sources (LPS). The LPS for 2022 are described under chp. 10.4 and illustrated in Figure 10-11.

Allocation rules and emission shares

The GNFR categories including their shares of emissions (main air pollutants, PM10 and PM2.5) and their allocation rules are presented in Meteotest (2013) and Meteotest (2021a).

Table 10-3 GNFR categories and their allocation indicators.

GFNR category	Allocation indicators
A_PublicPower	proportional to the population density and employees in economic sector 2
B_Industry	proportional to the number of employees in economic sector 2
C_OtherStatComb	proportional to the number of employees in sector 3 (1A4ai), sector 1 (1A4ci) and the population density (1A4bi)
D_Fugitive	proportional to the number of employees in sector 2 and restricted to land use category industrial buildings, industrial grounds, residential buildings and unspecified buildings
E_Solvents	proportional to the number of employees in sector 2, to the population density and the land use categories industrial buildings, industrial grounds, residential buildings and unspecified buildings
F_RoadTransport	based on specific air pollution modelling data (NOx emission map for road transport)
G_Shipping	based on specific air pollution modelling data (NOx emission map of navigation)
H_Aviation	based on the annual statistics of flight passengers of the six largest airports in Switzerland (excluding Basel since it lies on French territory)
I_OffRoad	based on selected land use categories, proportional to the number of employees in economic sector 2 and specific air pollution modelling data (NO_x emission map of construction machinery and industrial vehicles, PM10 emission map of rail transport). Emissions from military activities were uniformly distributed on areas below 1500 meters above sea level.
J_Waste	proportional to the population density, the land use categories industrial buildings, industrial grounds, residential buildings and unspecified buildings, to the number of employees in sector 2 and to the waste water treatment plants
K_AgriLivestock	based on specific air pollution modelling data (NH_3 emission map of manure management – farming of animals without pasture)
L_AgriOther	based on the land use categories agricultural areas
M_Other	proportional to the population density

Emissions not included in national total emissions

The following GNFR categories are not part of the national total emissions for the EMEP grid domain. These emissions are, therefore, not allocated to the EMEP grid cells.

Table 10-4 GNFR categories not included in the EMEP grid domain (according to Meteotest 2013).

GNFR	NFR Code	Longname
K_CivilAviCruise	1 A 3 a ii (ii)	1 A 3 a ii (ii) Civil Aviation (Domestic Cruise)
T_IntAviCruise	1 A 3 a i (ii)	1 A 3 a i (ii) Civil Aviation (International Cruise)
z_memo	1 A 3 d i (i)	1 A 3 d i (i) International maritime Navigation
	1 A 3	Transport (fuel used)
	7 B	Other (not included in National Total for Entire Territory)
S_Natural	11 A	11 (11 08 Volcanoes)
	11 B	Forest fires
	11 C	Other natural emissions

10.3 EMEP grid results (visualizations)

10.3.1 Spatial distribution of Switzerland's NO_x emissions 2022

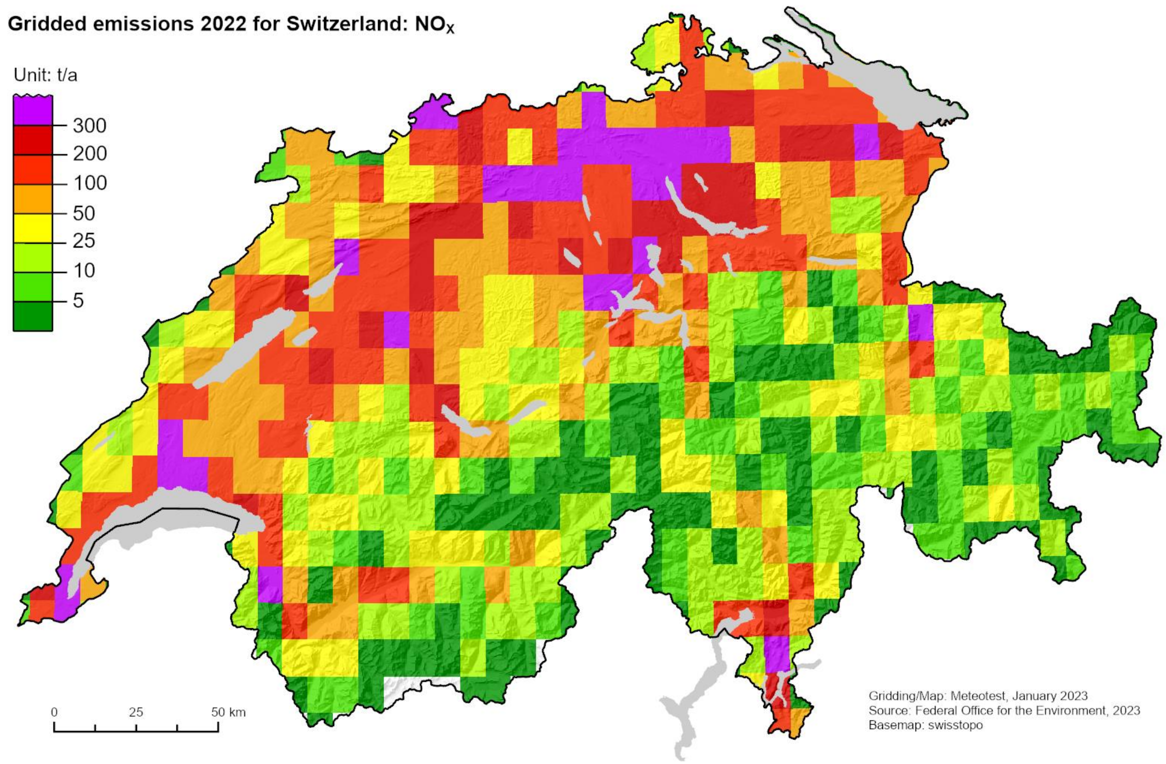

Figure 10-5 Spatial distribution of the NO_x emissions in Switzerland.

10.3.2 Spatial distribution of Switzerland's NMVOC emissions 2022

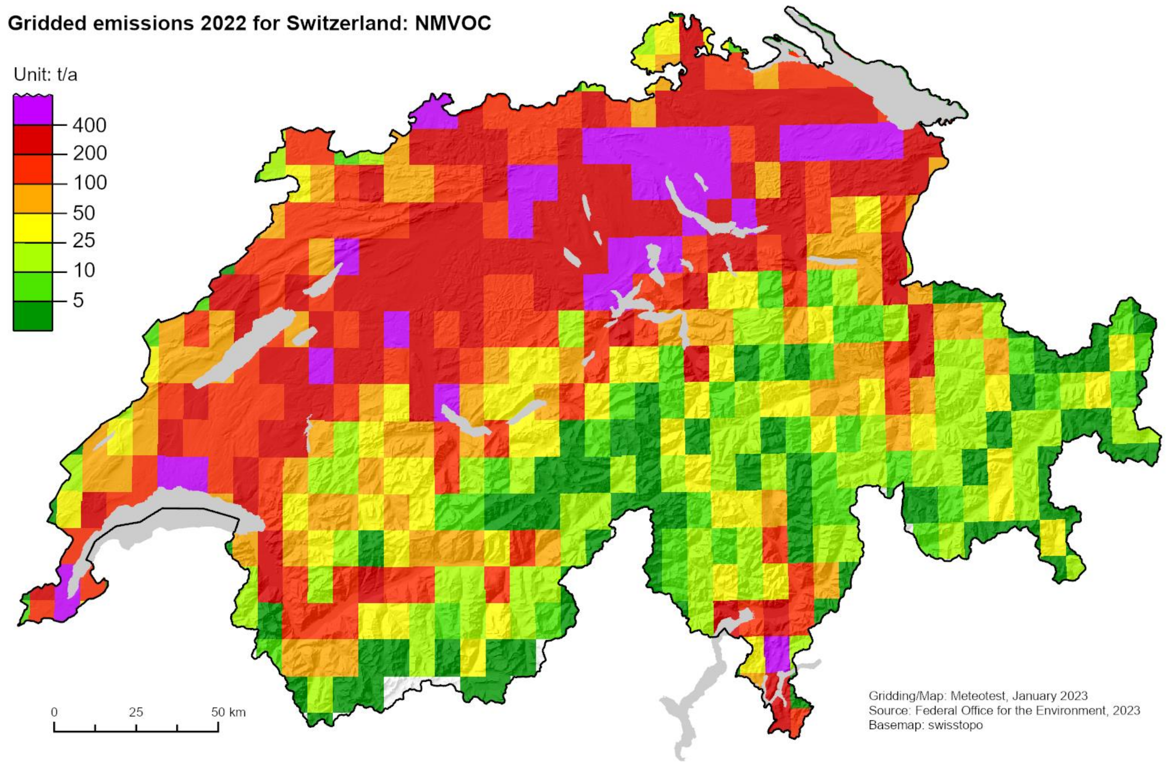

Figure 10-6 Spatial distribution of the NMVOC emissions in Switzerland.

10.3.3 Spatial distribution of Switzerland's SO_x emissions 2022

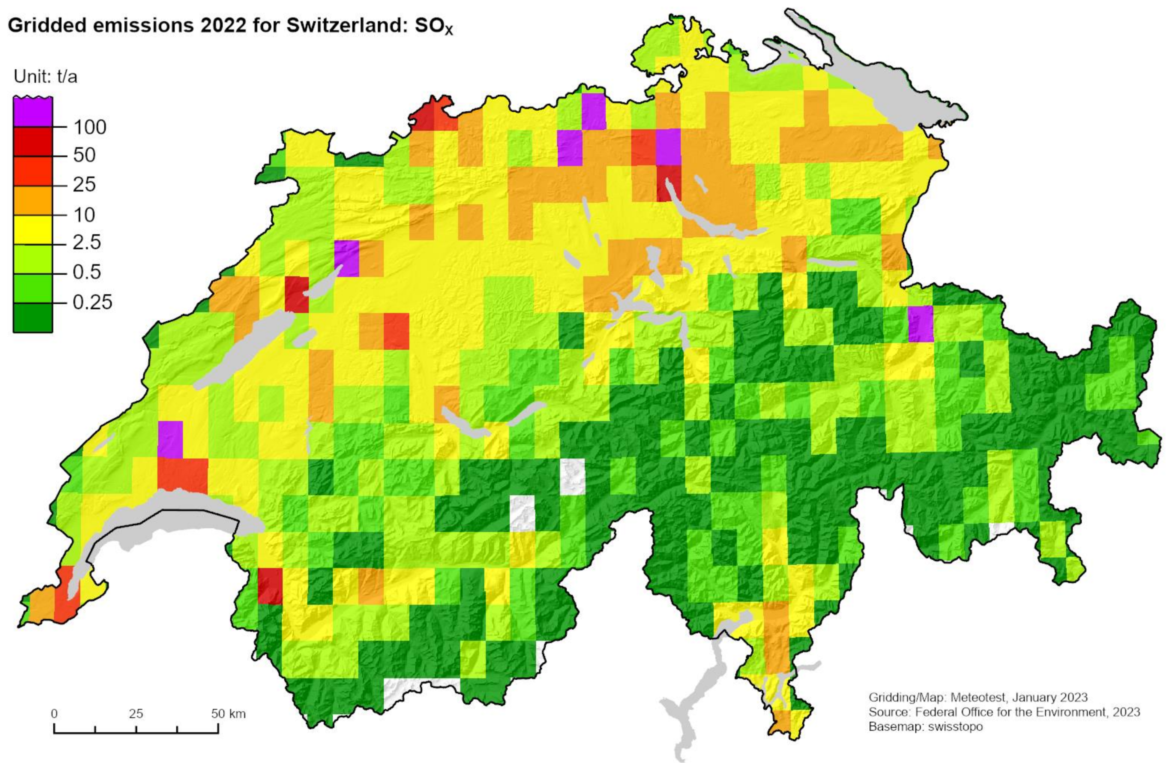

Figure 10-7 Spatial distribution of the SO_x emissions in Switzerland.

10.3.4 Spatial distribution of Switzerland's NH_3 emissions 2022

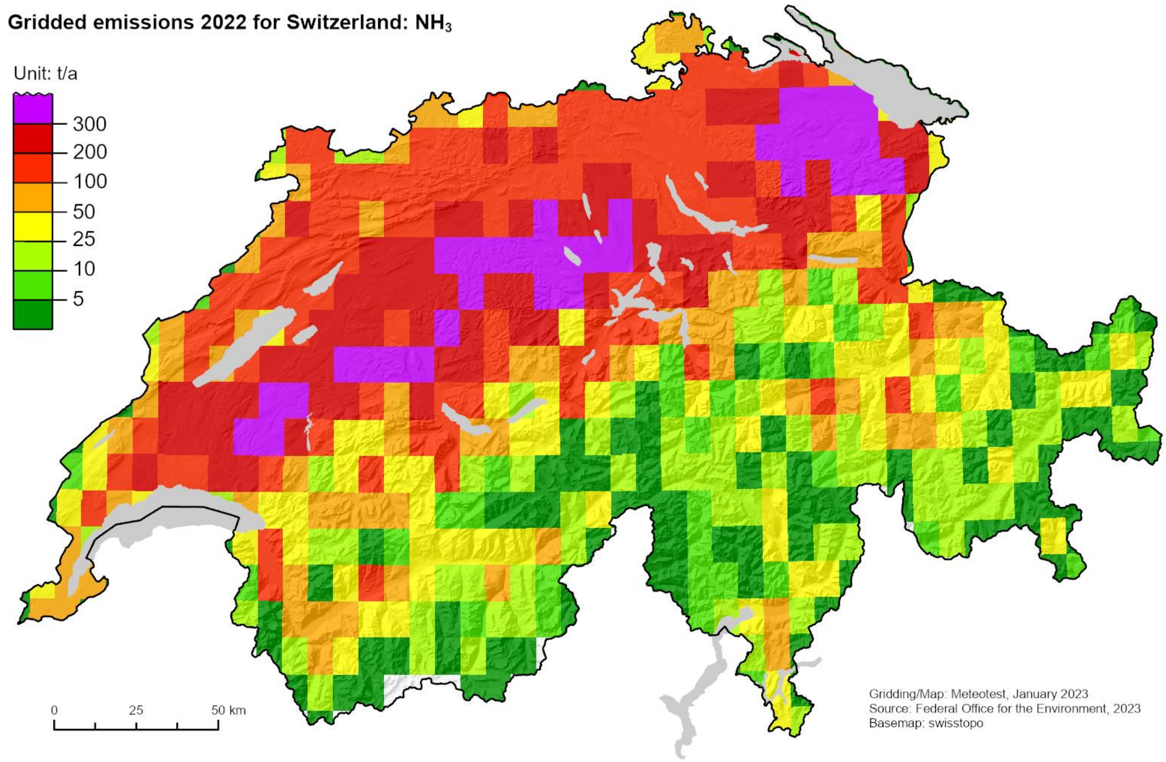

Figure 10-8 Spatial distribution of the NH_3 emissions in Switzerland.

10.3.5 Spatial distribution of Switzerland's PM2.5 emissions 2022

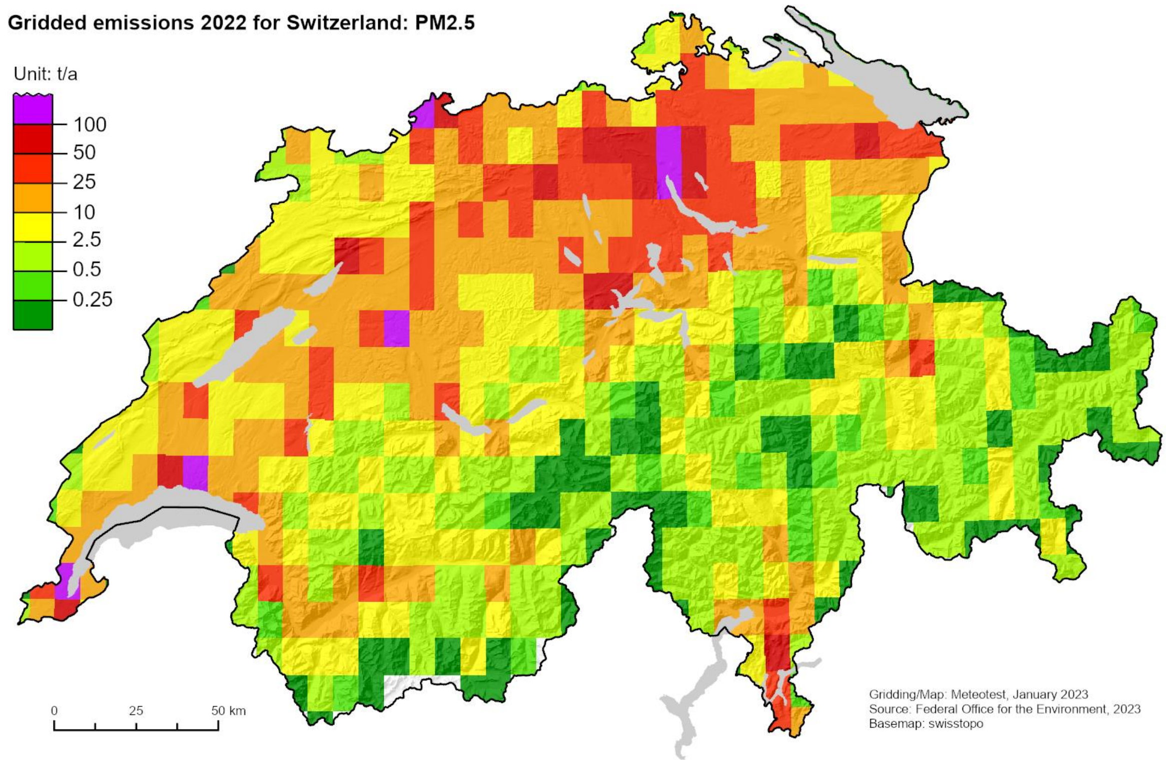

Figure 10-9 Spatial distribution of the PM2.5 emissions in Switzerland.

10.3.6 Spatial distribution of Switzerland's CO emissions 2022

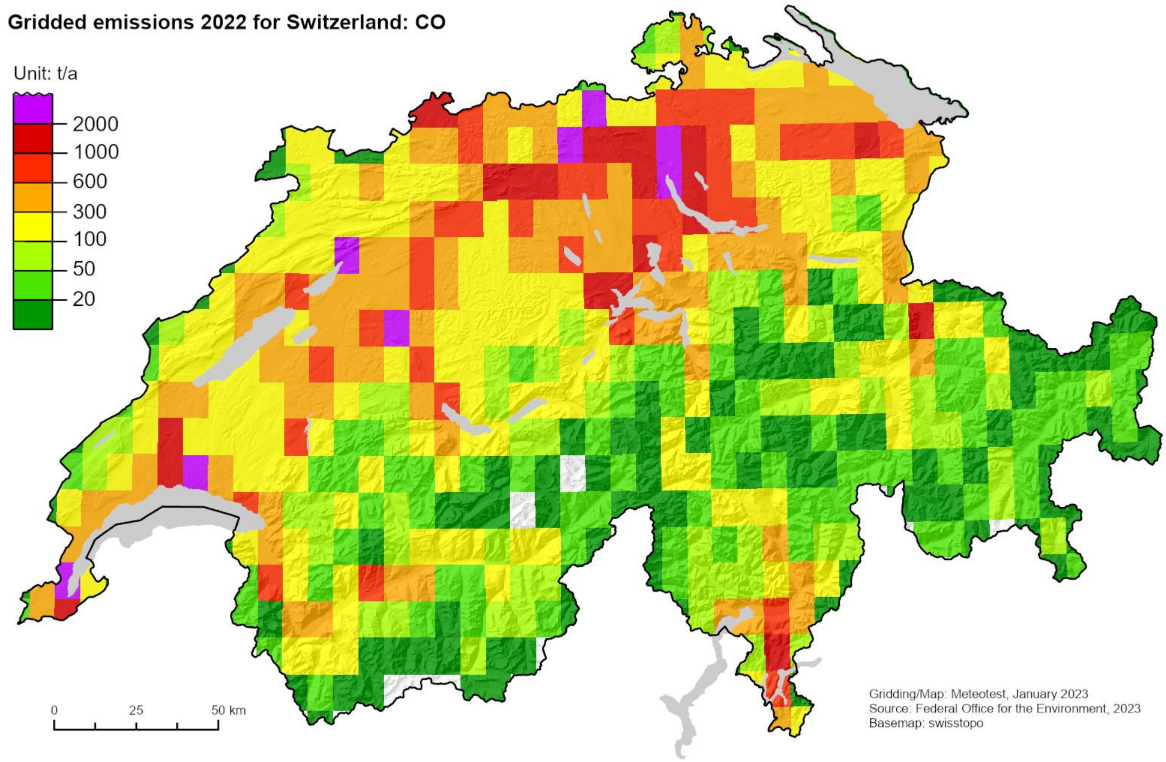

Figure 10-10 Spatial distribution of the CO emissions in Switzerland.

10.4 Large point sources (LPS)

Large Point Sources (LPS) are reported according to the definitions of the ECE Guidelines (ECE 2023). LPS are defined as facilities or installations whose emissions of at least one of 14 pollutants exceed the threshold value given in Table 1 of the ECE Guidelines (ECE 2023).

Facility designations, locations and emissions of Switzerland's LPS of the years 2007-2022 are reported based on the most recent data of the Swiss Pollution Release and Transfer Register (PRTR 2024). Data concerning air pollution release are reported annually by the facility operators and may be calculated based on periodic measurements, fuel consumption or other methods.

In 2022, the list of Switzerland's LPS includes 29 facilities, in particular of the industrial and waste sectors. As in previous years, most significant LPS are cement production plants and municipal solid waste incineration plants, followed by different facilities of the manufacturing industry such as steel production and chemicals (see Figure 10-11).

Information concerning the physical height of stack is reported as stack height class and the locations of the LPS are given in WGS 84 decimal coordinates, recalculated from Swiss grid coordinates (CH1903) as given in the Swiss PRTR.

The reported E-Swiss PRTR facility IDs correspond to the BER-Code (Business and Enterprise Register) of the Swiss Federal Statistical Office.

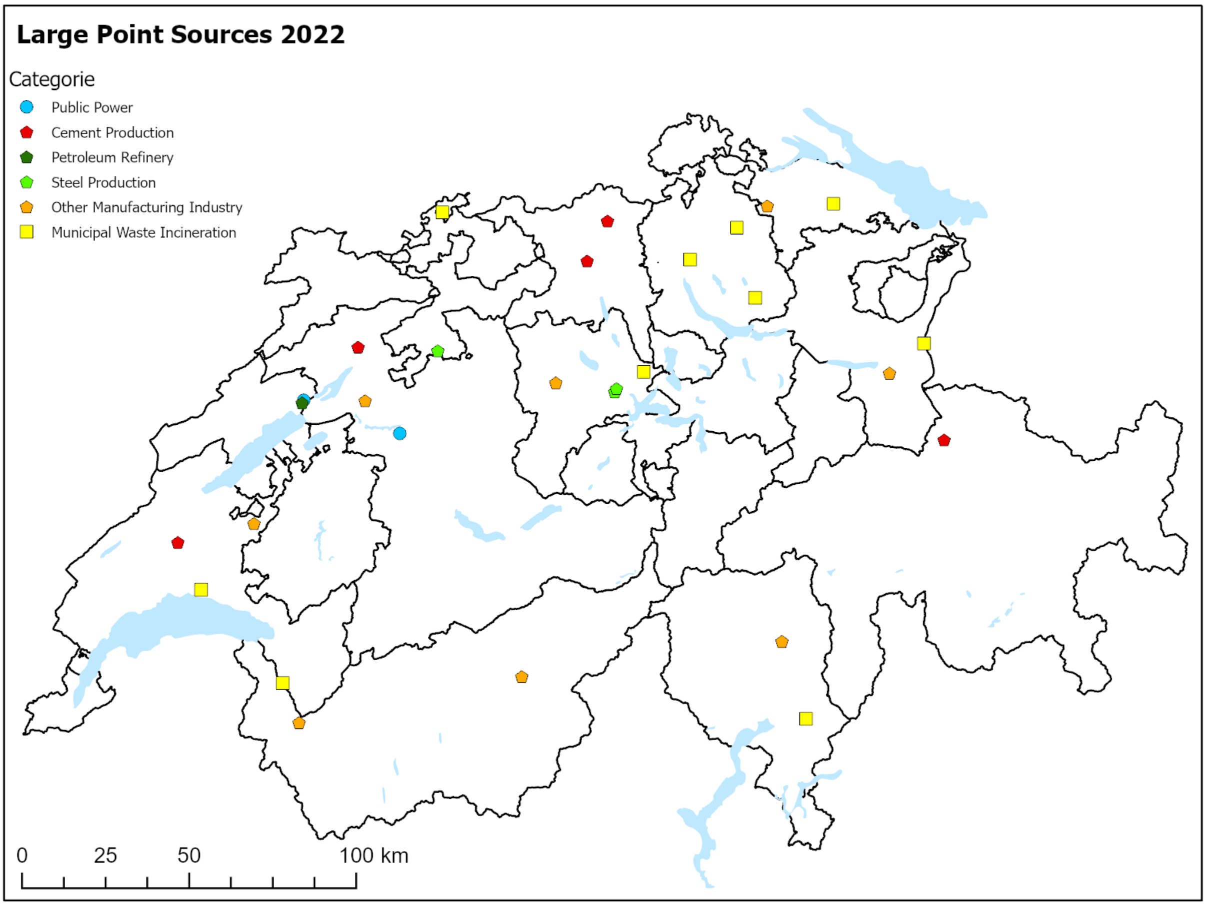

Figure 10-11 Spatial distribution of Switzerland's LPS in 2022. Note, that this figure only shows the LPS that exceed the limit values of emissions as defined in ECE (2023) and not all existing plants in Switzerland of the categories listed.

11 Adjustments

There are no adjustments in Switzerland’s air pollutant emission inventory.

12 References and assignments to EMIS categories

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12.2 Assignment of EMIS categories to NFR code

Table 12-1 Assignments of NFR Code to titles of EMIS database comments. For the CLRTAP Inventory the Code in [violet] are relevant.

NFR Code CRF [UNECE]	EMIS Title	NFR Code CRF [UNECE]	EMIS Title
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 2016)	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 Wärmeöfen**	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 uebrige**
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	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-viii	Strassenverkehr	2 G 4 [2 D 3 i]	Textilien-Produktion**
1 A 3 c	Schienenverkehr	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]	Coiffeursalons
1 A 4 c i	Gewächshäuser**	2 G 4 [2 G]	Fahrzeug-Unterbodenschutz**
1 A 4 c i	Grastrocknung**	2 G 4 [2 G]	Feuerwerke
1 A 4 c i & 5 B 2	Vergärung LW (landwirtschaftlich)	2 G 4 [2 G]	Flaechenenteisung Flughaefen
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 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 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 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 [2 B 10 a]	Ammoniumnitrat-Produktion*	2 H 1	Spanplatten Produktion*
2 B 10 [2 B 10 a]	Chlorgas-Produktion*	2 H 2	Bierbrauereien
2 B 10 [2 B 10 a]	Essigsäure-Produktion* (ab 2013)	2 H 2	Branntwein Produktion
2 B 10 [2 B 10 a]	*Formaldehyd-Produktion*	2 H 2	Brot Produktion
2 B 10 [2 B 10 a]	PVC-Produktion	2 H 2	Fleischräuchereien
2 B 10 [2 B 10 a]	*Salzsäure-Produktion**	2 H 2	Kaffeeröstereien
2 B 10 [2 B 10 a]	Schwefelsäure-Produktion*	2 H 2	Müllereien
2 B 10	Kalksteingrube*	2 H 2	Wein Produktion
2 B 10	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 & 6Ad	Emissions due to former PCB usage
2 C 1	Eisengiessereien Elektroschmelzöfen	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 V 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 [5 C 1 a]	Abfallverbrennung illegal
2 D 1	Schmiermittel-Verbrauch B2T	5 C 1 [5 C 1 b i]	Kabelabbrand
2 D 2	Paraffinwachs-Anwendung	5 C 1 [5 C 1 b iii]	Spitalabfallverbrennung
2 D 3 a [2 D 3 d]	Farben-Anwendung Bau	5 C 1 [5 C 1 b iv]	Klärschlammverbrennung
2 D 3 a [2 D 3 d]	Farben-Anwendung andere	5 C 1 [5 C 1 b v]	Krematorien
2 D 3 a [2 D 3 d]	Farben-Anwendung Haushalte**	5 C 2 / 4 V A 1 (Forstwirtschaft)	Abfallverbrennung Land- und Forstwirtschaft und Private
2 D 3 a [2 D 3 d]	Farben-Anwendung Holz	5 D 1 [5 D]	Kläranlagen kommunal (Luftschadstoffe)
2 D 3 a [2 D 3 d]	Farben-Anwendung Autoreparatur**	5 D 2 [5 D]	Kläranlagen industriell (Luftschadstoffe)
2 D 3 a [2 D 3 e]	Elektronik-Reinigung**	5 D 1 / 5 D 2 [5 D]	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 d	Brand- und Feuerschäden Immobilien
2 D 3 a [2 D 3 f]	Chemische Reinigung**	6 A d	Brand- und Feuerschäden Motorfahrzeuge
2 D 3 a [2 D 3 g]	Druckfarben Produktion**	[11 C]	NMVOC 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.

Annexes

Annex 1 Key category analysis (KCA)

A1.1 Overview

The following table provides an overview over the level (1990 and 2022) and trend (1990-2022) assessments based on approach 1 and approach 2 of the key category analysis. Note that the key category analysis is performed based on the approach “fuels used” (in contrast to “fuels sold”; for differentiation of the two approaches see chapter 3.1.6.1). Columns A to D in the following two tables are labelled according to Table 2-6 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 2, “Key category analysis and methodological choice 2019”.

Table A - 1 Summary of Switzerland's key category analysis, for the main pollutants, PM2.5 and PM10. L: level assessment (2022); T: trend assessment (1990-2022); 1: KCA approach 1; 2: KCA approach 2. Note that categories which are key for the level assessment for the base year only are not reported in this table.

SUMMARIES TO IDENTIFY KEY CATEGORIES							
A	B	C & D					
NFR Code	Source category	NOx	NMVOC	SOx	NH3	PM2.5	PM10
1A1a	Public electricity and heat production	L1, L2		L1, L2, T2		T1, T2	T1
1A2d	Stationary combustion in manufacturing industries and construction: pulp paper and print			T1, T2			
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	L1, L2, T1		L1, L2, T1, T2			
1A2gvii	Mobile combustion in manufacturing industries and construction	T1				L1, L2, T1, T2	L1, L2, T1, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	L1, T1, T2		L1, L2		L1	
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	L1, T1, T2		L1, T1, T2			
1A3bi(fu)	Road transportation: passenger cars (fuel used)	L1, L2, T2	L1, L2, T1, T2				
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	L1, L2, T1, T2					
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	L1, L2, T1, T2		T1, T2		T1	T1
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)		L2, T2				
1A3bv(fu)	Road transportation: gasoline evaporation (fuel used)		L1, T1, T2				
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)					L1, L2, T1, T2	L1, L2, T1, T2
1A3c	Railways					L1, T1	L1, L2, T1, T2
1A3dii	National navigation (shipping)	T1					
1A4ai	Commercial/institutional: stationary	L1, L2, T1, T2		T1, T2		L1, L2	L1, L2
1A4bi	Residential: stationary plants	L1, L2	L1, L2	L1, L2, T1, T2		L1, L2, T1, T2	L1, L2, T1, T2
1A4ci	Agriculture/forestry/fishing: stationary					L1	
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	L1					
1A5b	Other mobile (including military land-based and recreational boats)						L1
1B2av	Distribution of oil products		L1, T1, T2				
1B2c	Venting and flaring (oil gas combined oil and gas)	T2					
2A1	Cement production					L2, T2	L2
2A5a	Quarrying and mining of minerals other than coal					L1, L2, T1, T2	L1, L2, T2
2B5	Carbide production			L1, L2, T1, T2			
2C1	Iron and steel production			L2		T1, T2	T1, T2
2D3a	Domestic solvent use including fungicides		L1, L2, T1, T2				
2D3b	Road paving with asphalt		L1, L2, T1, T2				
2D3d	Coating applications		L1, L2, T1				
2D3e	Degreasing		T1, T2				
2D3g	Chemical products		L1, L2, T1, T2				
2D3h	Printing		L1, L2, T1				
2D3i	Other solvent use		L1, L2, T2				
2G	Other product use		L1, L2, T2			L1, L2, T1, T2	L1, L2, T1, T2
2H1	Pulp and paper industry					L1, L2, T1, T2	
2H2	Food and beverages industry		L1, L2, T1, T2			L2, T2	L1, L2, T2
2I	Wood processing					L2	L2, T2
3B1a	Manure management - Dairy cattle		L1, L2, T1, T2		L1, L2, T1, T2		
3B1b	Manure management - Non-dairy cattle		L1, L2, T1, T2		L1, L2, T1, T2		
3B3	Manure management - Swine		T2		L1, L2, T2		
3B4gi	Manure management - Laying hens						L2
3B4gii	Manure management - Broilers		L2, T2		L2, T2		L2, T2
3Da1	Inorganic N-fertilizers (includes also urea application)	L2, T2			L2, T1, T2		
3Da2a	Animal manure applied to soils	L2, T1, T2			L1, L2, T1, T2		
3Da2b	Sewage sludge applied to soils				T1		
3Da2c	Other organic fertilisers applied to soils (including compost)	T2			T1, T2		
3Da3	Urine and dung deposited by grazing animals	L2, T2			L2, T1, T2		
3De	Cultivated crops						L1, L2, T1, T2
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities		T1				
5C1a	Municipal waste incineration					L1, L2	L1
6A	Other sources				L2, T2		

Table A - 2 Summary of Switzerland's key category analysis, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. L: level assessment (2022); T: trend assessment (1990-2022); 1: KCA approach 1. No approach 2 analysis was conducted. Note that categories which are key for the level assessment for the base year only are not reported in this table.

SUMMARIES TO IDENTIFY KEY CATEGORIES											
A	B	C & D									
NFR Code	Source category	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCB
1A1a	Public electricity and heat production				L1, T1	L1, T1	L1, T1	L1, T1		L1, T1	T1
1A2b	Stationary combustion in manufacturing industries and construction: non-ferrous metals									T1	
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	T1		L1, T1		L1, T1	L1, T1				
1A2gvii	Mobile combustion in manufacturing industries and construction	L1, T1	T1								
1A2gviii	Stationary combustion in manufacturing industries and construction: other				L1, T1	L1, T1	L1, T1	L1			
1A3aii(i)	Civil aviation (domestic cruise)				L1						
1A3bi(fu)	Road transportation: passenger cars (fuel used)		L1	L1, T1	T1				L1, T1		
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)			T1							
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	T1	T1								
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)			L1							
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	L1, T1	L1, T1			L1, T1					
1A3c	Railways	L1, T1									
1A3dii	National navigation (shipping)			L1							
1A4ai	Commercial/institutional: stationary		L1, T1	L1, T1			T1	L1, T1	L1, T1	L1	
1A4aii	Commercial/institutional: mobile			L1, T1							
1A4bi	Residential: stationary plants	L1, T1	L1, T1	L1, T1		L1	L1, T1	L1, T1	L1, T1	L1, T1	
1A4bii	Residential: household and gardening (mobile)			T1							
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery		L1, T1	L1, T1							
2A5a	Quarrying and mining of minerals other than coal	L1, T1									
2B10a	Chemical industry: other						T1				
2C1	Iron and steel production	T1			T1	T1	L1, T1				
2C3	Aluminium production								T1		
2G	Other product use	L1			L1	L1, T1					
2I	Wood processing	T1									
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)										L1, T1
3B3	Manure management - Swine	L1									
3B4gi	Manure management - Laying hens	L1									
3De	Cultivated crops	L1, T1									
5C1a	Municipal waste incineration				L1, T1			L1, T1			
5C2	Open burning of waste								L1		
5E	Other waste										T1
6A	Other sources				L1, T1			L1, T1	T1		

A1.2 Detailed results of approach 1 assessment

The following tables report the detailed results for the key category analysis, approach 1, level and trend assessments, for the reporting year 2022 and the base year 1990. Columns labelled A to F for the level assessments correspond exactly to columns A to F from Table 2-1 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 2, “Key category analysis and methodological choice 2019”. For the table reporting the trend assessment, columns labelled A to G correspond exactly to columns A to G from Table 2-5 from the same guidelines. Equations referenced hereafter are also from the same guidelines.

Explanations of headers for tables in this Annex are:

- $E_{x, t}$: emission estimate for the reporting year.
- $E_{x, 0}$: emission estimate for the base year.
- $L_{x, t}$: level assessment for the reporting year (EMEP/EAA guidebook part A, chp. 2, equ. 1 for approach 1).
- $L_{x, 0}$: level assessment for the base year (EMEP/EAA guidebook part A, chp. 2, equ. 1 for approach 1).
- Trend assessment: computed according to EMEP/EAA guidebook part A, chp. 2, equ. 2 for approach 1.

Table A - 3 Switzerland's key categories according to approach 1 level assessment for the year 2022, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 2022					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, t (t)	Lx, t (%)	Cumu-lative Total (%)
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NOx	15'856	31.8	31.8
1A4bi	Residential: stationary plants	NOx	4'009	8.0	39.8
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NOx	3'956	7.9	47.7
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	NOx	3'269	6.5	54.3
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	3'203	6.4	60.7
1A4ai	Commercial/institutional: stationary	NOx	2'957	5.9	66.6
1A1a	Public electricity and heat production	NOx	2'151	4.3	70.9
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	2'068	4.1	75.1
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	1'703	3.4	78.5
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	NOx	1'671	3.3	81.8
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	1'629	3.3	85.1
2D3d	Coating applications	NMVOC	8'283	11.4	11.4
3B1b	Manure management - Non-dairy cattle	NMVOC	7'399	10.2	21.6
3B1a	Manure management - Dairy cattle	NMVOC	6'716	9.3	30.9
2D3a	Domestic solvent use including fungicides	NMVOC	6'397	8.8	39.7
2G	Other product use	NMVOC	6'306	8.7	48.4
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NMVOC	3'862	5.3	53.7
2D3h	Printing	NMVOC	3'642	5.0	58.8
2D3g	Chemical products	NMVOC	3'188	4.4	63.2
2D3b	Road paving with asphalt	NMVOC	2'684	3.7	66.9
1A4bi	Residential: stationary plants	NMVOC	2'406	3.3	70.2
2H2	Food and beverages industry	NMVOC	2'011	2.8	72.9
1B2av	Distribution of oil products	NMVOC	1'992	2.7	75.7
2D3i	Other solvent use	NMVOC	1'932	2.7	78.4
1A3bv(fu)	Road transportation: gasoline evaporation (fuel used)	NMVOC	1'913	2.6	81.0
2D3e	Degreasing	NMVOC	1'566	2.2	83.2
3B4gii	Manure management - Broilers	NMVOC	1'153	1.6	84.7
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NMVOC	1'098	1.5	86.3
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	1'467	45.6	45.6
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	314	9.8	55.4
2B5	Carbide production	SOx	289	9.0	64.4
1A4bi	Residential: stationary plants	SOx	267	8.3	72.7
1A1a	Public electricity and heat production	SOx	234	7.3	80.0
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	SOx	119	3.7	83.7
1A4ai	Commercial/institutional: stationary	SOx	113	3.5	87.2
3Da2a	Animal manure applied to soils	NH3	20'447	38.3	38.3
3B1a	Manure management - Dairy cattle	NH3	10'346	19.4	57.6
3B1b	Manure management - Non-dairy cattle	NH3	7'151	13.4	71.0
3B3	Manure management - Swine	NH3	4'974	9.3	80.3
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	2'193	4.1	84.4
3Da3	Urine and dung deposited by grazing animals	NH3	1'421	2.7	87.1
1A4bi	Residential: stationary plants	PM2.5	1'888	28.7	28.7
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM2.5	945	14.4	43.1
2G	Other product use	PM2.5	432	6.6	49.6
1A4ai	Commercial/institutional: stationary	PM2.5	430	6.5	56.2
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	387	5.9	62.1
2A5a	Quarrying and mining of minerals other than coal	PM2.5	226	3.4	65.5
5C1a	Municipal waste incineration	PM2.5	225	3.4	68.9
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	214	3.3	72.2
1A3c	Railways	PM2.5	203	3.1	75.2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	191	2.9	78.2
2H1	Pulp and paper industry	PM2.5	180	2.7	80.9
2H2	Food and beverages industry	PM2.5	168	2.6	83.5
2A1	Cement production	PM2.5	158	2.4	85.8
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM10	2'577	18.0	18.0
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2'359	16.4	34.4
1A4bi	Residential: stationary plants	PM10	1'987	13.8	48.2
1A3c	Railways	PM10	1'323	9.2	57.5
3De	Cultivated crops	PM10	1'001	7.0	64.4
2G	Other product use	PM10	601	4.2	68.6
1A4ai	Commercial/institutional: stationary	PM10	457	3.2	71.8
2A5a	Quarrying and mining of minerals other than coal	PM10	451	3.1	75.0
2H2	Food and beverages industry	PM10	312	2.2	77.1
1A5b	Other mobile (including military land-based and recreational boats)	PM10	262	1.8	78.9
5C1a	Municipal waste incineration	PM10	250	1.7	80.7
2A1	Cement production	PM10	246	1.7	82.4
1A4ci	Agriculture/forestry/fishing: stationary	PM10	217	1.5	83.9
3B4gii	Manure management - Broilers	PM10	213	1.5	85.4

Table A - 4 Switzerland's key categories according to approach 1 level assessment for the year 1990, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. 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
NFR code	Source category	Pollutant	Ex, 0 (t)	Lx, 0 (%)	Cumu-lative Total (%)
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NOx	43'772	31.1	31.1
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	NOx	29'658	21.1	52.2
1A4bi	Residential: stationary plants	NOx	11'636	8.3	60.4
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	10'535	7.5	67.9
1A1a	Public electricity and heat production	NOx	6'338	4.5	72.4
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	6'334	4.5	76.9
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NOx	6'197	4.4	81.3
1A4ai	Commercial/institutional: stationary	NOx	5'132	3.6	84.9
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	4'358	3.1	88.0
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NMVOC	55'938	18.9	18.9
2D3d	Coating applications	NMVOC	40'731	13.8	32.7
2D3g	Chemical products	NMVOC	27'504	9.3	42.0
2G	Other product use	NMVOC	22'432	7.6	49.6
2D3h	Printing	NMVOC	20'354	6.9	56.5
1B2av	Distribution of oil products	NMVOC	19'127	6.5	62.9
1A3bv(fu)	Road transportation: gasoline evaporation (fuel used)	NMVOC	16'981	5.7	68.7
2D3e	Degreasing	NMVOC	11'731	4.0	72.6
1A4bi	Residential: stationary plants	NMVOC	10'056	3.4	76.0
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	3.0	79.0
3B1a	Manure management - Dairy cattle	NMVOC	6'413	2.2	81.2
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)	NMVOC	5'733	1.9	83.1
2D3i	Other solvent use	NMVOC	5'470	1.8	85.0
3B1b	Manure management - Non-dairy cattle	NMVOC	5'122	1.7	86.7
1A4bi	Residential: stationary plants	SOx	10'355	26.4	26.4
1A4ai	Commercial/institutional: stationary	SOx	3'870	9.9	36.3
1A1a	Public electricity and heat production	SOx	3'679	9.4	45.7
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	3'534	9.0	54.7
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	9.0	63.7
1A2d	Stationary combustion in manufacturing industries and construction: pulp paper and print	SOx	3'238	8.3	72.0
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	SOx	1'838	4.7	76.7
1A3bi(fu)	Road transportation: passenger cars (fuel used)	SOx	1'613	4.1	80.8
1A2c	Stationary combustion in manufacturing industries and construction: chemicals	SOx	1'187	3.0	83.9
1A2e	Stationary combustion in manufacturing industries and construction: food processing beverages and tobacco	SOx	1'078	2.8	86.6
3Da2a	Animal manure applied to soils	NH3	34'567	50.5	50.5
3B1a	Manure management - Dairy cattle	NH3	9'337	13.6	64.1
3B3	Manure management - Swine	NH3	6'965	10.2	74.3
3B1b	Manure management - Non-dairy cattle	NH3	5'191	7.6	81.8
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4'258	6.2	88.1
1A4bi	Residential: stationary plants	PM2.5	14'536	53.3	53.3
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM2.5	1'588	5.8	59.1
1A4ai	Commercial/institutional: stationary	PM2.5	1'354	5.0	64.1
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	873	3.2	67.3
2C1	Iron and steel production	PM2.5	818	3.0	70.3
1A1a	Public electricity and heat production	PM2.5	782	2.9	73.1
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	729	2.7	75.8
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	697	2.6	78.4
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM2.5	689	2.5	80.9
1A3bi(fu)	Road transportation: passenger cars (fuel used)	PM2.5	578	2.1	83.0
2G	Other product use	PM2.5	513	1.9	84.9
5C1a	Municipal waste incineration	PM2.5	465	1.7	86.6
1A4bi	Residential: stationary plants	PM10	15'326	41.9	41.9
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2'173	5.9	47.8
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM10	2'050	5.6	53.4
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM10	1'588	4.3	57.8
2C1	Iron and steel production	PM10	1'485	4.1	61.9
1A4ai	Commercial/institutional: stationary	PM10	1'428	3.9	65.8
3De	Cultivated crops	PM10	1'054	2.9	68.6
1A1a	Public electricity and heat production	PM10	1'045	2.9	71.5
1A3c	Railways	PM10	983	2.7	74.2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM10	913	2.5	76.7
2I	Wood processing	PM10	864	2.4	79.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	2.3	81.3
1A4ci	Agriculture/forestry/fishing: stationary	PM10	710	1.9	83.3
2G	Other product use	PM10	588	1.6	84.9
1A3bi(fu)	Road transportation: passenger cars (fuel used)	PM10	578	1.6	86.4

Table A - 5 Switzerland's key categories according to approach 1 trend assessment for 1990-2022, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in orange have increased emissions in 2022 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 1 TREND ASSESSMENT 1990 - 2022							
A	B	C	D	E	F	G	H
NFR code	Source category	Pollutant	Ex, 0 (t)	Ex, t (t)	Trend Assess-ment	Contri-bution to trend assess. (%)	Cumu-lative Total (%)
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	NOx	29'658	3'269	0.051	38.6	38.6
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NOx	6'197	3'956	0.012	9.4	48.0
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	2'182	2'068	0.009	6.9	54.8
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	NOx	1'214	1'671	0.009	6.6	61.5
1A4ai	Commercial/institutional: stationary	NOx	5'132	2'957	0.008	6.1	67.5
3Da2a	Animal manure applied to soils	NOx	2'075	1'466	0.005	3.9	71.4
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	6'334	1'629	0.004	3.3	74.7
1A3dii	National navigation (shipping)	NOx	1'055	927	0.004	2.9	77.6
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	10'535	3'203	0.004	2.8	80.5
1A2d	Stationary combustion in manufacturing industries and construction: pulp paper and print	NOx	1'262	40	0.003	2.2	82.6
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NOx	43'772	15'856	0.002	1.8	84.4
3Da3	Urine and dung deposited by grazing animals	NOx	243	420	0.002	1.8	86.2
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NMVOC	55'938	3'862	0.033	18.8	18.8
3B1b	Manure management - Non-dairy cattle	NMVOC	5'122	7'399	0.021	11.7	30.6
3B1a	Manure management - Dairy cattle	NMVOC	6'413	6'716	0.017	9.8	40.4
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	6'397	0.014	8.1	48.5
2D3g	Chemical products	NMVOC	27'504	3'188	0.012	6.8	55.3
1B2av	Distribution of oil products	NMVOC	19'127	1'992	0.009	5.2	60.4
1A3bv(fu)	Road transportation: gasoline evaporation (fuel used)	NMVOC	16'981	1'913	0.008	4.3	64.7
2D3d	Coating applications	NMVOC	40'731	8'283	0.006	3.3	68.0
2H2	Food and beverages industry	NMVOC	1'950	2'011	0.005	2.9	70.9
2D3b	Road paving with asphalt	NMVOC	4'895	2'684	0.005	2.8	73.8
2D3h	Printing	NMVOC	20'354	3'642	0.005	2.6	76.3
2D3e	Degreasing	NMVOC	11'731	1'566	0.004	2.5	78.8
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NMVOC	50	1'098	0.004	2.1	80.9
3B4gii	Manure management - Broilers	NMVOC	366	1'153	0.004	2.0	82.9
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NMVOC	4'920	150	0.004	2.0	85.0
2G	Other product use	NMVOC	22'432	6'306	0.003	1.5	86.5
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	1'467	0.030	35.0	35.0
1A4bi	Residential: stationary plants	SOx	10'355	267	0.015	17.3	52.4
1A2d	Stationary combustion in manufacturing industries and construction: pulp paper and print	SOx	3'238	1	0.007	7.9	60.2
2B5	Carbide production	SOx	625	289	0.006	7.1	67.3
1A4ai	Commercial/institutional: stationary	SOx	3'870	113	0.005	6.1	73.4
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	SOx	1'838	9	0.004	4.2	77.6
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	SOx	100	119	0.003	3.3	80.9
1A3bi(fu)	Road transportation: passenger cars (fuel used)	SOx	1'613	37	0.002	2.8	83.7
1A2e	Stationary combustion in manufacturing industries and construction: food processing beverages and tobacco	SOx	1'078	6	0.002	2.4	86.2
3Da2a	Animal manure applied to soils	NH3	34'567	20'447	0.095	33.2	33.2
3B1b	Manure management - Non-dairy cattle	NH3	5'191	7'151	0.045	15.8	49.0
3B1a	Manure management - Dairy cattle	NH3	9'337	10'346	0.045	15.6	64.6
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4'258	2'193	0.016	5.8	70.4
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	34	990	0.014	4.9	75.3
3Da2b	Sewage sludge applied to soils	NH3	1'169	0	0.013	4.6	79.9
3Da3	Urine and dung deposited by grazing animals	NH3	761	1'421	0.012	4.2	84.1
3B3	Manure management - Swine	NH3	6'965	4'974	0.007	2.3	86.5
1A4bi	Residential: stationary plants	PM2.5	14'536	1'888	0.059	32.0	32.0
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM2.5	689	945	0.029	15.4	47.5
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM2.5	1'588	41	0.013	6.8	54.2
2G	Other product use	PM2.5	513	432	0.011	6.1	60.3
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	729	387	0.008	4.2	64.5
2C1	Iron and steel production	PM2.5	818	9	0.007	3.7	68.3
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	226	0.007	3.6	71.9
1A3c	Railways	PM2.5	174	203	0.006	3.2	75.1
1A1a	Public electricity and heat production	PM2.5	782	46	0.005	2.8	77.9
2H1	Pulp and paper industry	PM2.5	236	180	0.005	2.4	80.3
2H2	Food and beverages industry	PM2.5	188	168	0.004	2.4	82.8
5C1a	Municipal waste incineration	PM2.5	465	225	0.004	2.2	85.0
1A4ai	Commercial/institutional: stationary	PM2.5	1'354	430	0.004	2.0	87.0
1A4bi	Residential: stationary plants	PM10	15'326	1'987	0.110	30.1	30.1
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM10	2'050	2'577	0.048	13.2	43.3
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2'173	2'359	0.041	11.2	54.5
1A3c	Railways	PM10	983	1'323	0.026	7.0	61.5
3De	Cultivated crops	PM10	1'054	1'001	0.016	4.4	65.9
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM10	1'588	41	0.016	4.3	70.3
2C1	Iron and steel production	PM10	1'485	13	0.016	4.3	74.5
2G	Other product use	PM10	588	601	0.010	2.8	77.3
1A1a	Public electricity and heat production	PM10	1'045	46	0.010	2.7	80.0
2A5a	Quarrying and mining of minerals other than coal	PM10	367	451	0.008	2.3	82.3
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	78	0.007	1.9	84.2
2H2	Food and beverages industry	PM10	310	312	0.005	1.4	85.6

Table A - 6 Switzerland's key categories according to approach 1 level assessment for the year 2022, sorted by decreasing contribution, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 2022					
A	B	C	D	E	F
NFR code	Source category	Pollutant (unit)	Ex, t	Lx, t (%)	Cumu-lative Total (%)
3De	Cultivated crops	TSP (t)	10'014	35.4	35.4
1A2gvii	Mobile combustion in manufacturing industries and construction	TSP (t)	3'519	12.4	47.8
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	TSP (t)	2'577	9.1	56.9
1A4bi	Residential: stationary plants	TSP (t)	2'081	7.4	64.3
1A3c	Railways	TSP (t)	1'758	6.2	70.5
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	890	3.1	73.6
3B4gi	Manure management - Laying hens	TSP (t)	740	2.6	76.2
3B3	Manure management - Swine	TSP (t)	648	2.3	78.5
2G	Other product use	TSP (t)	601	2.1	80.6
2I	Wood processing	TSP (t)	490	1.7	82.4
1A4ai	Commercial/institutional: stationary	TSP (t)	475	1.7	84.1
3B4gii	Manure management - Broilers	TSP (t)	427	1.5	85.6
1A4bi	Residential: stationary plants	BC (t)	429	48.7	48.7
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	BC (t)	95	10.7	59.4
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	86	9.7	69.1
1A4ai	Commercial/institutional: stationary	BC (t)	78	8.8	77.9
1A3bi(fu)	Road transportation: passenger cars (fuel used)	BC (t)	40	4.5	82.4
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	BC (t)	31	3.5	85.9
1A3bi(fu)	Road transportation: passenger cars (fuel used)	CO (t)	46'788	32.7	32.7
1A4bi	Residential: stationary plants	CO (t)	24'406	17.1	49.8
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	12'522	8.8	58.6
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	CO (t)	8'972	6.3	64.8
1A4aii	Commercial/institutional: mobile	CO (t)	6'534	4.6	69.4
1A4ai	Commercial/institutional: stationary	CO (t)	6'155	4.3	73.7
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)	CO (t)	5'627	3.9	77.6
1A3dii	National navigation (shipping)	CO (t)	4'976	3.5	81.1
1A2gvii	Mobile combustion in manufacturing industries and construction	CO (t)	4'142	2.9	84.0
1A4bii	Residential: household and gardening (mobile)	CO (t)	3'894	2.7	86.7
6A	Other sources	Pb (kg)	1'784	21.1	21.1
1A1a	Public electricity and heat production	Pb (kg)	1'664	19.7	40.8
5C1a	Municipal waste incineration	Pb (kg)	1'561	18.5	59.3
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Pb (kg)	884	10.5	69.8
1A3aii(i)	Civil aviation (domestic cruise)	Pb (kg)	697	8.3	78.0
2G	Other product use	Pb (kg)	444	5.3	83.3
1A4bi	Residential: stationary plants	Pb (kg)	359	4.3	87.5
1A1a	Public electricity and heat production	Cd (kg)	154	33.2	33.2
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	Cd (kg)	91	19.5	52.8
2G	Other product use	Cd (kg)	73	15.8	68.5
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Cd (kg)	28	6.0	74.6
1A4bi	Residential: stationary plants	Cd (kg)	25	5.3	79.9
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Cd (kg)	23	5.0	84.9
1A2gvii	Mobile combustion in manufacturing industries and construction	Cd (kg)	19	4.1	89.0
1A1a	Public electricity and heat production	Hg (kg)	288	49.8	49.8
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Hg (kg)	63	11.0	60.8
2C1	Iron and steel production	Hg (kg)	48	8.4	69.2
1A4bi	Residential: stationary plants	Hg (kg)	46	8.0	77.2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Hg (kg)	34	5.9	83.0
1A4ai	Commercial/institutional: stationary	Hg (kg)	27	4.6	87.6
1A4bi	Residential: stationary plants	PCDD/PCDF (mg I-TEQ)	4'209	33.7	33.7
5C1a	Municipal waste incineration	PCDD/PCDF (mg I-TEQ)	2'497	20.0	53.6
1A4ai	Commercial/institutional: stationary	PCDD/PCDF (mg I-TEQ)	1'142	9.1	62.7
6A	Other sources	PCDD/PCDF (mg I-TEQ)	1'002	8.0	70.8
1A1a	Public electricity and heat production	PCDD/PCDF (mg I-TEQ)	934	7.5	78.2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PCDD/PCDF (mg I-TEQ)	821	6.6	84.8
1A3bi(fu)	Road transportation: passenger cars (fuel used)	PCDD/PCDF (mg I-TEQ)	369	2.9	87.7
1A4bi	Residential: stationary plants	PAHs total (kg)	1'356	57.6	57.6
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	256	10.9	68.5
1A3bi(fu)	Road transportation: passenger cars (fuel used)	PAHs total (kg)	202	8.6	77.2
5C2	Open burning of waste	PAHs total (kg)	189	8.0	85.2
1A1a	Public electricity and heat production	HCB (g)	179	53.0	53.0
1A4bi	Residential: stationary plants	HCB (g)	84	24.7	77.7
1A4ai	Commercial/institutional: stationary	HCB (g)	35	10.3	87.9
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCB (g)	306'244	89.7	89.7

Table A - 7 Switzerland's key categories according to approach 1 level assessment for the year 1990, sorted by decreasing contribution, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. 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
NFR code	Source category	Pollutant (unit)	Ex, 0	Lx, 0 (%)	Cumu-lative Total (%)
1A4bi	Residential: stationary plants	TSP (t)	16'162	28.8	28.8
3De	Cultivated crops	TSP (t)	10'536	18.8	47.5
2I	Wood processing	TSP (t)	4'322	7.7	55.2
1A2gvii	Mobile combustion in manufacturing industries and construction	TSP (t)	3'023	5.4	60.6
2C1	Iron and steel production	TSP (t)	2'686	4.8	65.4
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	TSP (t)	2'050	3.6	69.0
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	TSP (t)	1'588	2.8	71.8
1A4ai	Commercial/institutional: stationary	TSP (t)	1'501	2.7	74.5
1A3c	Railways	TSP (t)	1'298	2.3	76.8
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	TSP (t)	1'227	2.2	79.0
1A1a	Public electricity and heat production	TSP (t)	1'059	1.9	80.9
1A2gviii	Stationary combustion in manufacturing industries and construction: other	TSP (t)	972	1.7	82.6
3B3	Manure management - Swine	TSP (t)	915	1.6	84.3
1A4ci	Agriculture/forestry/fishing: stationary	TSP (t)	724	1.3	85.5
1A4bi	Residential: stationary plants	BC (t)	3'220	56.2	56.2
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	BC (t)	794	13.9	70.0
1A4ai	Commercial/institutional: stationary	BC (t)	301	5.2	75.3
1A2gvii	Mobile combustion in manufacturing industries and construction	BC (t)	256	4.5	79.7
1A3bi(fu)	Road transportation: passenger cars (fuel used)	BC (t)	242	4.2	84.0
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	232	4.1	88.0
1A3bi(fu)	Road transportation: passenger cars (fuel used)	CO (t)	425'322	56.2	56.2
1A4bi	Residential: stationary plants	CO (t)	111'881	14.8	71.0
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	CO (t)	72'490	9.6	80.6
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	28'368	3.8	84.4
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)	CO (t)	24'680	3.3	87.6
1A3bi(fu)	Road transportation: passenger cars (fuel used)	Pb (kg)	211'229	59.7	59.7
2C1	Iron and steel production	Pb (kg)	59'858	16.9	76.6
1A1a	Public electricity and heat production	Pb (kg)	29'818	8.4	85.0
1A1a	Public electricity and heat production	Cd (kg)	1'754	53.9	53.9
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Cd (kg)	665	20.4	74.3
2C1	Iron and steel production	Cd (kg)	443	13.6	88.0
1A1a	Public electricity and heat production	Hg (kg)	3'915	62.1	62.1
2C1	Iron and steel production	Hg (kg)	1'108	17.6	79.6
2B10a	Chemical industry: other	Hg (kg)	384	6.1	85.7
1A1a	Public electricity and heat production	PCDD/PCDF (mg I-TEQ)	130'484	67.8	67.8
1A4bi	Residential: stationary plants	PCDD/PCDF (mg I-TEQ)	17'674	9.2	77.0
2C1	Iron and steel production	PCDD/PCDF (mg I-TEQ)	12'419	6.5	83.4
5C1biii	Clinical waste incineration	PCDD/PCDF (mg I-TEQ)	6'900	3.6	87.0
1A4bi	Residential: stationary plants	PAHs total (kg)	5'698	70.2	70.2
2C3	Aluminium production	PAHs total (kg)	940	11.6	81.8
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	516	6.4	88.1
1A2b	Stationary combustion in manufacturing industries and construction: non-ferrous metals	HCB (g)	172'000	99.7	99.7
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCB (g)	1'525'788	65.4	65.4
6A	Other sources	PCB (g)	281'955	12.1	77.5
5E	Other waste	PCB (g)	215'511	9.2	86.8

Table A - 8 Switzerland's key categories according to approach 1 trend assessment for 1990-2022, sorted by decreasing contribution, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Categories in orange have increased emissions in 2022 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 1 TREND ASSESSMENT 1990 - 2022							
A	B	C	D	E	F	G	H
NFR code	Source category	Pollutant (unit)	Ex, 0	Ex, t	Trend Assess-ment	Contri-bution to trend assess. (%)	Cumu-lative Total (%)
1A4bi	Residential: stationary plants	TSP (t)	16'162	2'081	0.108	24.5	24.5
3De	Cultivated crops	TSP (t)	10'536	10'014	0.084	19.1	43.6
1A2gvii	Mobile combustion in manufacturing industries and construction	TSP (t)	3'023	3'519	0.036	8.1	51.7
2I	Wood processing	TSP (t)	4'322	490	0.030	6.8	58.5
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	TSP (t)	2'050	2'577	0.027	6.3	64.8
2C1	Iron and steel production	TSP (t)	2'686	15	0.024	5.4	70.2
1A3c	Railways	TSP (t)	1'298	1'758	0.020	4.5	74.7
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	TSP (t)	1'588	41	0.014	3.1	77.7
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	685	890	0.010	2.2	79.9
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	TSP (t)	1'227	89	0.009	2.1	82.1
1A1a	Public electricity and heat production	TSP (t)	1'059	46	0.009	2.0	84.1
3B4gi	Manure management - Laying hens	TSP (t)	586	740	0.008	1.8	85.9
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	BC (t)	794	15	0.019	24.9	24.9
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	BC (t)	69	95	0.015	19.6	44.5
1A4bi	Residential: stationary plants	BC (t)	3'220	429	0.012	15.5	60.0
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	232	86	0.009	11.6	71.6
1A4ai	Commercial/institutional: stationary	BC (t)	301	78	0.005	7.3	78.9
1A2gvii	Mobile combustion in manufacturing industries and construction	BC (t)	256	21	0.003	4.4	83.3
5C1a	Municipal waste incineration	BC (t)	33	16	0.002	2.5	85.8
1A3bi(fu)	Road transportation: passenger cars (fuel used)	CO (t)	425'322	46'788	0.044	37.4	37.4
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	CO (t)	72'490	3'600	0.013	11.2	48.6
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	28'368	12'522	0.009	8.0	56.6
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	CO (t)	13'126	8'972	0.009	7.2	63.8
1A4aii	Commercial/institutional: mobile	CO (t)	4'117	6'534	0.008	6.4	70.2
1A4ai	Commercial/institutional: stationary	CO (t)	11'349	6'155	0.005	4.5	74.7
1A4bii	Residential: household and gardening (mobile)	CO (t)	3'271	3'894	0.004	3.6	78.3
1A4bi	Residential: stationary plants	CO (t)	111'881	24'406	0.004	3.6	81.9
1A2gvii	Mobile combustion in manufacturing industries and construction	CO (t)	7'253	4'142	0.004	3.1	85.0
1A3bi(fu)	Road transportation: passenger cars (fuel used)	Pb (kg)	211'229	104	0.014	36.9	36.9
6A	Other sources	Pb (kg)	7'612	1'784	0.005	12.0	48.8
5C1a	Municipal waste incineration	Pb (kg)	3'230	1'561	0.004	11.1	59.9
2C1	Iron and steel production	Pb (kg)	59'858	247	0.003	8.8	68.7
1A1a	Public electricity and heat production	Pb (kg)	29'818	1'664	0.003	7.1	75.8
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Pb (kg)	975	884	0.002	6.4	82.3
1A3aii(i)	Civil aviation (domestic cruise)	Pb (kg)	2'027	697	0.002	4.8	87.1
1A1a	Public electricity and heat production	Cd (kg)	1'754	154	0.030	21.0	21.0
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	Cd (kg)	65	91	0.025	17.8	38.8
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Cd (kg)	665	28	0.021	14.6	53.4
2G	Other product use	Cd (kg)	102	73	0.018	12.8	66.3
2C1	Iron and steel production	Cd (kg)	443	5	0.018	12.8	79.1
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Cd (kg)	31	23	0.006	4.1	83.2
1A2gvii	Mobile combustion in manufacturing industries and construction	Cd (kg)	12	19	0.005	3.8	87.0
1A1a	Public electricity and heat production	Hg (kg)	3'915	288	0.011	19.5	19.5
2C1	Iron and steel production	Hg (kg)	1'108	48	0.008	14.7	34.2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Hg (kg)	226	63	0.007	11.8	46.0
1A4bi	Residential: stationary plants	Hg (kg)	72	46	0.006	10.9	56.9
2B10a	Chemical industry: other	Hg (kg)	384	0	0.006	9.7	66.6
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Hg (kg)	13	34	0.005	9.0	75.6
1A4ai	Commercial/institutional: stationary	Hg (kg)	14	27	0.004	7.0	82.5
5C1biii	Clinical waste incineration	Hg (kg)	240	0	0.003	6.1	88.6
1A1a	Public electricity and heat production	PCDD/PCDF (mg I-TEQ)	130'484	934	0.039	41.4	41.4
1A4bi	Residential: stationary plants	PCDD/PCDF (mg I-TEQ)	17'674	4'209	0.016	16.8	58.2
5C1a	Municipal waste incineration	PCDD/PCDF (mg I-TEQ)	5'168	2'497	0.011	11.9	70.1
1A4ai	Commercial/institutional: stationary	PCDD/PCDF (mg I-TEQ)	2'112	1'142	0.005	5.5	75.6
6A	Other sources	PCDD/PCDF (mg I-TEQ)	1'633	1'002	0.005	4.9	80.5
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PCDD/PCDF (mg I-TEQ)	1'947	821	0.004	3.8	84.4
2C1	Iron and steel production	PCDD/PCDF (mg I-TEQ)	12'419	165	0.003	3.5	87.9
1A4bi	Residential: stationary plants	PAHs total (kg)	5'698	1'356	0.036	25.5	25.5
2C3	Aluminium production	PAHs total (kg)	940	0	0.034	23.5	49.0
1A3bi(fu)	Road transportation: passenger cars (fuel used)	PAHs total (kg)	103	202	0.021	14.9	63.9
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	516	256	0.013	9.2	73.2
6A	Other sources	PAHs total (kg)	65	109	0.011	7.8	81.0
5C2	Open burning of waste	PAHs total (kg)	371	189	0.010	7.0	88.0
1A2b	Stationary combustion in manufacturing industries and construction: non-ferrous metals	HCB (g)	172'000	0	0.002	50.0	50.0
1A1a	Public electricity and heat production	HCB (g)	114	179	0.001	26.5	76.5
1A4bi	Residential: stationary plants	HCB (g)	322	84	0.000	12.3	88.8
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCB (g)	1'525'788	306'244	0.036	49.7	49.7
5E	Other waste	PCB (g)	215'511	2'857	0.012	17.2	67.0
1A1a	Public electricity and heat production	PCB (g)	164'493	65	0.010	14.4	81.4
5C1bii	Hazardous waste incineration	PCB (g)	111'813	0	0.007	9.8	91.2

A1.3 Detailed results of approach 2 assessment

The following tables report the detailed results for the key category analysis, approach 2, level and trend assessments, for the reporting year 2022 and the base year 1990. Columns labelled A to F for the level assessments correspond exactly to columns A to F from Table 2-1 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 2, “Key category analysis and methodological choice 2019”. For the table reporting the trend assessment, columns labelled A to G correspond exactly to columns A to G from Table 2-5 from the same guidelines. Equations referenced hereafter are also from the same guidelines.

Explanations of headers for tables in this Annex are:

- $E_{x,t}$: emission estimate for the reporting year.
- $E_{x,0}$: emission estimate for the base year.
- $L_{x,t}$: level assessment for the reporting year (EMEP/EAA guidebook part A, chp. 2, equ. 3 for approach 2).
- $L_{x,0}$: level assessment for the base year (EMEP/EAA guidebook part A, chp. 2, equ. 3 for approach 2).
- Trend assessment: computed according to the EMEP/EAA guidebook part A, chp. 2, equ. 4 for approach 2.

Table A - 9 Switzerland's key categories according to approach 2 level assessment for the year 2022, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, LEVEL ASSESSMENT FOR 2022					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, t (t)	Lx, t (%)	Cumu-lative Total (%)
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NOx	15'856	42.0	42.0
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NOx	3'956	8.8	50.8
3Da2a	Animal manure applied to soils	NOx	1'466	5.1	56.0
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	695	4.8	60.8
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	NOx	3'269	4.1	64.9
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	3'203	3.8	68.7
1A4bi	Residential: stationary plants	NOx	4'009	3.8	72.4
1A4ai	Commercial/institutional: stationary	NOx	2'957	3.3	75.7
1A1a	Public electricity and heat production	NOx	2'151	3.2	78.9
3Da3	Urine and dung deposited by grazing animals	NOx	420	2.9	81.9
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	2'068	2.5	84.3
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	NOx	1'671	2.3	86.6
2G	Other product use	NMVOC	6'306	17.2	17.2
3B1b	Manure management - Non-dairy cattle	NMVOC	7'399	9.3	26.5
3B1a	Manure management - Dairy cattle	NMVOC	6'716	7.2	33.7
2D3d	Coating applications	NMVOC	8'283	6.6	40.3
2D3a	Domestic solvent use including fungicides	NMVOC	6'397	5.7	46.1
2D3g	Chemical products	NMVOC	3'188	5.5	51.5
2D3i	Other solvent use	NMVOC	1'932	4.9	56.5
2D3b	Road paving with asphalt	NMVOC	2'684	4.4	60.9
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)	NMVOC	843	3.7	64.6
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NMVOC	3'862	3.6	68.2
2H2	Food and beverages industry	NMVOC	2'011	3.3	71.5
3B4gii	Manure management - Broilers	NMVOC	1'153	3.1	74.6
1A4bi	Residential: stationary plants	NMVOC	2'406	2.9	77.5
2D3h	Printing	NMVOC	3'642	2.9	80.4
3B3	Manure management - Swine	NMVOC	807	2.2	82.6
2D3e	Degreasing	NMVOC	1'566	1.8	84.4
3B4gi	Manure management - Laying hens	NMVOC	642	1.7	86.2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	1'467	45.1	45.1
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	314	9.7	54.8
2B5	Carbide production	SOx	289	9.4	64.1
1A1a	Public electricity and heat production	SOx	234	9.1	73.2
1A4bi	Residential: stationary plants	SOx	267	4.6	77.8
2C1	Iron and steel production	SOx	17	2.5	80.3
2B10a	Chemical industry: other	SOx	38	2.5	82.8
1A4ci	Agriculture/forestry/fishing: stationary	SOx	55	2.4	85.2
3Da2a	Animal manure applied to soils	NH3	20'447	24.2	24.2
3B1a	Manure management - Dairy cattle	NH3	10'346	16.6	40.8
3B3	Manure management - Swine	NH3	4'974	10.9	51.6
3B1b	Manure management - Non-dairy cattle	NH3	7'151	10.7	62.3
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	2'193	5.9	68.3
6A	Other sources	NH3	969	5.5	73.8
3Da3	Urine and dung deposited by grazing animals	NH3	1'421	4.8	78.6
3B4gii	Manure management - Broilers	NH3	685	3.2	81.8
3B4gi	Manure management - Laying hens	NH3	683	3.0	84.8
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	990	2.9	87.7
1A4bi	Residential: stationary plants	PM2.5	1'888	24.6	24.6
2A5a	Quarrying and mining of minerals other than coal	PM2.5	226	10.5	35.2
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM2.5	945	8.1	43.3
2H2	Food and beverages industry	PM2.5	168	7.9	51.2
2G	Other product use	PM2.5	432	7.0	58.2
1A4ai	Commercial/institutional: stationary	PM2.5	430	5.7	63.9
2H1	Pulp and paper industry	PM2.5	180	4.8	68.7
2A1	Cement production	PM2.5	158	4.1	72.8
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	387	3.3	76.1
2I	Wood processing	PM2.5	49	2.3	78.4
5C1a	Municipal waste incineration	PM2.5	225	2.2	80.7
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	191	2.1	82.8
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	139	1.9	84.7
1A3c	Railways	PM2.5	203	1.7	86.5
3De	Cultivated crops	PM10	1'001	11.5	11.5
1A4bi	Residential: stationary plants	PM10	1'987	11.4	23.0
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM10	2'577	9.7	32.7
2A5a	Quarrying and mining of minerals other than coal	PM10	451	9.4	42.1
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2'359	8.9	51.0
2H2	Food and beverages industry	PM10	312	6.5	57.5
1A3c	Railways	PM10	1'323	5.0	62.5
2G	Other product use	PM10	601	4.3	66.8
2I	Wood processing	PM10	196	4.1	70.9
3B4gii	Manure management - Broilers	PM10	213	3.3	74.1
2A1	Cement production	PM10	246	2.8	77.0
1A4ai	Commercial/institutional: stationary	PM10	457	2.7	79.7
3B4gi	Manure management - Laying hens	PM10	156	2.4	82.0
3B3	Manure management - Swine	PM10	150	2.3	84.4
2H1	Pulp and paper industry	PM10	186	2.2	86.5

Table A - 10 Switzerland's key categories according to approach 2 level assessment for the year 1990, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, LEVEL ASSESSMENT FOR 1990					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, 0 (t)	Lx, 0 (%)	Cumu-lative Total (%)
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NOx	43'772	45.2	45.2
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	NOx	29'658	14.5	59.7
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NOx	6'197	5.4	65.1
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	10'535	4.9	70.0
1A4bi	Residential: stationary plants	NOx	11'636	4.3	74.2
1A1a	Public electricity and heat production	NOx	6'338	3.7	77.9
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1'205	3.3	81.2
3Da2a	Animal manure applied to soils	NOx	2'075	2.8	84.0
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	6'334	2.2	86.2
2G	Other product use	NMVOC	22'432	16.6	16.6
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NMVOC	55'938	14.1	30.6
2D3g	Chemical products	NMVOC	27'504	12.7	43.3
2D3d	Coating applications	NMVOC	40'731	8.8	52.1
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)	NMVOC	5'733	6.8	58.9
2D3h	Printing	NMVOC	20'354	4.4	63.3
2D3i	Other solvent use	NMVOC	5'470	3.8	67.1
1B2av	Distribution of oil products	NMVOC	19'127	3.6	70.7
2D3e	Degreasing	NMVOC	11'731	3.6	74.3
1A4bi	Residential: stationary plants	NMVOC	10'056	3.3	77.7
1A3bv(fu)	Road transportation: gasoline evaporation (fuel used)	NMVOC	16'981	3.3	80.9
2D3b	Road paving with asphalt	NMVOC	4'895	2.2	83.1
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	2.1	85.2
1A4bi	Residential: stationary plants	SOx	10'355	15.7	15.7
2C3	Aluminium production	SOx	696	15.0	30.7
1A1a	Public electricity and heat production	SOx	3'679	12.6	43.4
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	3'534	9.6	53.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	9.6	62.6
1A2d	Stationary combustion in manufacturing industries and construction: pulp paper and print	SOx	3'238	6.5	69.1
1A4ai	Commercial/institutional: stationary	SOx	3'870	5.6	74.6
1B2aiv	Fugitive emissions oil: refining / storage	SOx	419	3.3	78.0
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	SOx	1'838	2.6	80.6
1A3bi(fu)	Road transportation: passenger cars (fuel used)	SOx	1'613	2.3	82.9
1A2c	Stationary combustion in manufacturing industries and construction: chemicals	SOx	1'187	1.9	84.8
2C1	Iron and steel production	SOx	144	1.9	86.7
3Da2a	Animal manure applied to soils	NH3	34'567	33.8	33.8
3B3	Manure management - Swine	NH3	6'965	12.6	46.4
3B1a	Manure management - Dairy cattle	NH3	9'337	12.4	58.8
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4'258	9.5	68.3
3B1b	Manure management - Non-dairy cattle	NH3	5'191	6.4	74.8
6A	Other sources	NH3	846	4.0	78.7
3B4gi	Manure management - Laying hens	NH3	979	3.6	82.3
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NH3	1'325	3.0	85.3
1A4bi	Residential: stationary plants	PM2.5	14'536	53.0	53.0
1A4ai	Commercial/institutional: stationary	PM2.5	1'354	5.1	58.1
2C1	Iron and steel production	PM2.5	818	4.3	62.4
2I	Wood processing	PM2.5	216	2.8	65.2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	873	2.7	68.0
1A1a	Public electricity and heat production	PM2.5	782	2.7	70.7
2H2	Food and beverages industry	PM2.5	188	2.5	73.1
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	2.4	75.5
2G	Other product use	PM2.5	513	2.3	77.9
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM2.5	1'588	2.1	79.9
2A1	Cement production	PM2.5	240	1.8	81.7
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	729	1.7	83.4
2H1	Pulp and paper industry	PM2.5	236	1.7	85.1
1A4bi	Residential: stationary plants	PM10	15'326	38.0	38.0
2I	Wood processing	PM10	864	7.7	45.8
2C1	Iron and steel production	PM10	1'485	5.3	51.1
3De	Cultivated crops	PM10	1'054	5.2	56.3
1A4ai	Commercial/institutional: stationary	PM10	1'428	3.6	60.0
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2'173	3.6	63.5
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM10	2'050	3.3	66.8
2A5a	Quarrying and mining of minerals other than coal	PM10	367	3.3	70.1
2H2	Food and beverages industry	PM10	310	2.8	72.9
1A1a	Public electricity and heat production	PM10	1'045	2.5	75.4
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM10	913	1.9	77.3
2A1	Cement production	PM10	374	1.9	79.2
2G	Other product use	PM10	588	1.8	81.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	1.8	82.8
1A3c	Railways	PM10	983	1.6	84.4
3B3	Manure management - Swine	PM10	213	1.4	85.8

Table A - 11 Switzerland's key categories according to approach 2 trend assessment for 1990-2022, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in orange have increased emissions in 2022 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, TREND ASSESSMENT 1990 - 2022							
A	B	C	D	E	F	G	H
NFR code	Source category	Pollutant	Ex, 0 (t)	Ex, t (t)	Trend Assess-ment	Contri-bution to trend assess. (%)	Cumu-lative Total (%)
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	NOx	29'658	3'269	6.962	27.3	27.3
1A3bii(fu)	Road transportation: light duty vehicles (fuel used)	NOx	6'197	3'956	3.021	11.8	39.2
3Da2a	Animal manure applied to soils	NOx	2'075	1'466	1.969	7.7	46.9
3Da3	Urine and dung deposited by grazing animals	NOx	243	420	1.778	7.0	53.9
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1'205	695	1.428	5.6	59.5
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	NOx	1'214	1'671	1.328	5.2	64.7
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	2'182	2'068	1.183	4.6	69.3
1A4ai	Commercial/institutional: stationary	NOx	5'132	2'957	0.973	3.8	73.1
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NOx	43'772	15'856	0.693	2.7	75.8
3Da2c	Other organic fertilisers applied to soils (including compost)	NOx	15	119	0.622	2.4	78.3
1B2c	Venting and flaring (oil gas combined oil and gas)	NOx	211	1	0.605	2.4	80.7
1A4ci	Agriculture/forestry/fishing: stationary	NOx	398	398	0.503	2.0	82.6
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	10'535	3'203	0.483	1.9	84.5
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	6'334	1'629	0.429	1.7	86.2
1A3bi(fu)	Road transportation: passenger cars (fuel used)	NMVOC	55'938	3'862	9.833	14.3	14.3
3B1b	Manure management - Non-dairy cattle	NMVOC	5'122	7'399	8.257	12.0	26.3
2D3g	Chemical products	NMVOC	27'504	3'188	6.515	9.5	35.7
3B1a	Manure management - Dairy cattle	NMVOC	6'413	6'716	5.936	8.6	44.3
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	6'397	4.032	5.9	50.2
3B4gii	Manure management - Broilers	NMVOC	366	1'153	3.085	4.5	54.7
2H2	Food and beverages industry	NMVOC	1'950	2'011	2.705	3.9	58.6
1A3biv(fu)	Road transportation: mopeds and motorcycles (fuel used)	NMVOC	5'733	843	2.635	3.8	62.4
2D3b	Road paving with asphalt	NMVOC	4'895	2'684	2.611	3.8	66.2
2G	Other product use	NMVOC	22'432	6'306	2.348	3.4	69.6
1B2av	Distribution of oil products	NMVOC	19'127	1'992	2.038	3.0	72.6
1A3bv(fu)	Road transportation: gasoline evaporation (fuel used)	NMVOC	16'981	1'913	1.723	2.5	75.1
2D3i	Other solvent use	NMVOC	5'470	1'932	1.616	2.3	77.4
2D3e	Degreasing	NMVOC	11'731	1'566	1.597	2.3	79.7
3B3	Manure management - Swine	NMVOC	1'126	807	1.539	2.2	82.0
3B4gi	Manure management - Laying hens	NMVOC	509	642	1.507	2.2	84.1
2D3d	Coating applications	NMVOC	40'731	8'283	1.460	2.1	86.3
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	1'467	6.683	41.4	41.4
1A4bi	Residential: stationary plants	SOx	10'355	267	1.850	11.4	52.8
2B5	Carbide production	SOx	625	289	1.420	8.8	61.6
1A2d	Stationary combustion in manufacturing industries and construction: pulp paper and print	SOx	3'238	1	1.113	6.9	68.5
1A4ai	Commercial/institutional: stationary	SOx	3'870	113	0.615	3.8	72.3
1A1a	Public electricity and heat production	SOx	3'679	234	0.490	3.0	75.3
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	SOx	1'838	9	0.425	2.6	78.0
1A3ai(i)	Civil aviation (domestic landing/take-off (LTO))	SOx	100	119	0.332	2.1	80.0
1B2aiv	Fugitive emissions oil: refining / storage	SOx	419	16	0.313	1.9	81.9
1A2e	Stationary combustion in manufacturing industries and construction: food processing beverages and tobacco	SOx	1'078	6	0.298	1.8	83.8
2B10a	Chemical industry: other	SOx	168	38	0.291	1.8	85.6
3Da2a	Animal manure applied to soils	NH3	34'567	20'447	7.281	20.7	20.7
3B1a	Manure management - Dairy cattle	NH3	9'337	10'346	4.636	13.2	33.9
3B1b	Manure management - Non-dairy cattle	NH3	5'191	7'151	4.389	12.5	46.3
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4'258	2'193	2.884	8.2	54.5
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	34	990	2.651	7.5	62.1
3Da3	Urine and dung deposited by grazing animals	NH3	761	1'421	2.635	7.5	69.6
3B4gii	Manure management - Broilers	NH3	305	685	1.964	5.6	75.2
6A	Other sources	NH3	846	969	1.665	4.7	79.9
3B3	Manure management - Swine	NH3	6'965	4'974	0.950	2.7	82.6
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NH3	10	235	0.900	2.6	85.1
1A4bi	Residential: stationary plants	PM2.5	14'536	1'888	24.366	28.5	28.5
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	226	9.780	11.4	39.9
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM2.5	689	945	7.703	9.0	48.9
2H2	Food and beverages industry	PM2.5	188	168	6.672	7.8	56.7
2G	Other product use	PM2.5	513	432	5.764	6.7	63.5
2C1	Iron and steel production	PM2.5	818	9	4.098	4.8	68.3
2H1	Pulp and paper industry	PM2.5	236	180	3.757	4.4	72.7
2A1	Cement production	PM2.5	240	158	3.008	3.5	76.2
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	729	387	2.092	2.4	78.6
1A1a	Public electricity and heat production	PM2.5	782	46	2.036	2.4	81.0
1A3biii(fu)	Road transportation: heavy duty vehicles and buses (fuel used)	PM2.5	1'588	41	1.828	2.1	83.1
1A3c	Railways	PM2.5	174	203	1.595	1.9	85.0
1A4bi	Residential: stationary plants	PM10	15'326	1'987	22.836	26.9	26.9
3De	Cultivated crops	PM10	1'054	1'001	6.681	7.9	34.8
1A3bvi(fu)	Road transportation: automobile tyre and brake wear (fuel used)	PM10	2'050	2'577	6.612	7.8	42.6
2A5a	Quarrying and mining of minerals other than coal	PM10	367	451	6.295	7.4	50.0
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2'173	2'359	5.630	6.6	56.7
2C1	Iron and steel production	PM10	1'485	13	4.651	5.5	62.2
2H2	Food and beverages industry	PM10	310	312	3.888	4.6	66.8
1A3c	Railways	PM10	983	1'323	3.505	4.1	70.9
2I	Wood processing	PM10	864	196	2.920	3.4	74.3
3B4gii	Manure management - Broilers	PM10	68	213	2.823	3.3	77.7
2G	Other product use	PM10	588	601	2.610	3.1	80.7
1A1a	Public electricity and heat production	PM10	1'045	46	1.954	2.3	83.0
3B4gi	Manure management - Laying hens	PM10	123	156	1.629	1.9	85.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	78	1.208	1.4	86.4

Annex 2 Other detailed methodological descriptions for individual source categories

A2.1 Sector Energy: non-road vehicles

A2.1.1 Emission and fuel consumption factors for non-road vehicles

As mentioned in chp. 3.2.1.1.1 (non-road transportation model), emission factors and activity data can be downloaded by query from the non-road database INFRAS (2015a[6]), which is the data pool of FOEN (2015j). They can be queried by year, non-road family (see categories in Table A - 13), machine type, engine type (diesel, gasoline/2-/4-stroke, liquefied petroleum gas, gas oil), engine capacity (power class) and emission concept (standard), pollutant either at aggregated or disaggregated levels. The following table illustrates a query for the family 'construction machinery'.

Table A - 12 Excerpt of the non-road database INFRAS (2015a).

Construction machinery, 2010								
Machine type	Engine type	Engine capacity	Emission concept	Poll.	Op. hrs. (h/a)	EF (kg/h)	EF [w/o PF] (kg/h)	EF [100% PF] (kg/h)
Road finishing machines	diesel	18-37 kW	Nonr D PreEUB	PM	112.7	0.0074	0.0074	0.0007
Road finishing machines	diesel	18-37 kW	Nonr D EU2	PM	259.9	0.0045	0.0045	0.0005
Road finishing machines	diesel	18-37 kW	Nonr D EU3A	PM	305.8	0.0006	0.0046	0.0005
Road finishing machines	diesel	37-75 kW	Nonr D PreEUB	PM	130.1	0.0133	0.0133	0.0013
Road finishing machines	diesel	37-75 kW	Nonr D EU1	PM	248.6	0.0073	0.0073	0.0007
Road finishing machines	diesel	37-75 kW	Nonr D EU2	PM	327.8	0.0014	0.0047	0.0005
Road finishing machines	diesel	37-75 kW	Nonr D EU3A	PM	357.7	0.0005	0.0053	0.0005
Road finishing machines	diesel	75-130 kW	Nonr D PreEUB	PM	138.8	0.0129	0.0129	0.0013
Road finishing machines	diesel	75-130 kW	Nonr D EU1	PM	239.4	0.0096	0.0096	0.001
Road finishing machines	diesel	75-130 kW	Nonr D EU2	PM	332.7	0.0031	0.0062	0.0006
Road finishing machines	diesel	75-130 kW	Nonr D EU3A	PM	376.4	0.0007	0.007	0.0007
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D PreEUB	PM	131.7	0.0104	0.0104	0.001
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D EU1	PM	227.2	0.0077	0.0077	0.0008
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D EU2	PM	315.7	0.0025	0.005	0.0005
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D EU3A	PM	357.2	0.0005	0.0048	0.0005
Rolling mill engines of all types	diesel	<18 kW	Nonr D PreEUB	PM	130.9	0.005	0.005	0.0005
Rolling mill engines of all types	diesel	<18 kW	Nonr D EU1	PM	250.1	0.0042	0.0042	0.0004
Rolling mill engines of all types	diesel	<18 kW	Nonr D EU2	PM	329.7	0.0032	0.0032	0.0003
Rolling mill engines of all types	diesel	<18 kW	Nonr D EU3A	PM	359.8	0.0029	0.0032	0.0003
Rolling mill engines of all types	diesel	18-37 kW	Nonr D PreEUB	PM	148.3	0.0077	0.0077	0.0008
Rolling mill engines of all types	diesel	18-37 kW	Nonr D EU2	PM	341.8	0.0046	0.0046	0.0005
Rolling mill engines of all types	diesel	18-37 kW	Nonr D EU3A	PM	402.3	0.0006	0.0047	0.0005
Rolling mill engines of all types	diesel	37-75 kW	Nonr D PreEUB	PM	168.8	0.0138	0.0138	0.0014
Rolling mill engines of all types	diesel	37-75 kW	Nonr D EU1	PM	322.6	0.0076	0.0076	0.0008
Rolling mill engines of all types	diesel	37-75 kW	Nonr D EU2	PM	425.3	0.0014	0.0048	0.0005
Rolling mill engines of all types	diesel	37-75 kW	Nonr D EU3A	PM	464.1	0.0005	0.0054	0.0005
Rolling mill engines of all types	diesel	75-130 kW	Nonr D PreEUB	PM	174.5	0.0133	0.0133	0.0013
Rolling mill engines of all types	diesel	75-130 kW	Nonr D EU1	PM	301	0.0099	0.0099	0.001
Rolling mill engines of all types	diesel	75-130 kW	Nonr D EU2	PM	418.3	0.0032	0.0064	0.0006
Rolling mill engines of all types	diesel	75-130 kW	Nonr D EU3A	PM	473.2	0.0007	0.0071	0.0007
Rolling mill engines of all types	diesel	130-300 kW	Nonr D PreEUB	PM	174.5	0.0279	0.0279	0.0028
Rolling mill engines of all types	diesel	130-300 kW	Nonr D EU2	PM	387.1	0.0068	0.0094	0.0009
Rolling mill engines of all types	diesel	130-300 kW	Nonr D EU3A	PM	467.7	0.001	0.0104	0.001
Mechanical vibrators	diesel	18-37 kW	Nonr D PreEUB	PM	100.6	0.0059	0.0059	0.0006
Mechanical vibrators	diesel	18-37 kW	Nonr D EU2	PM	232	0.0036	0.0036	0.0004
Mechanical vibrators	diesel	18-37 kW	Nonr D EU3A	PM	273	0.0004	0.0031	0.0003
Mechanical vibrators	diesel	37-75 kW	Nonr D PreEUB	PM	131.3	0.0108	0.0108	0.0011
Mechanical vibrators	diesel	37-75 kW	Nonr D EU1	PM	250.9	0.0059	0.0059	0.0006
Mechanical vibrators	diesel	37-75 kW	Nonr D EU2	PM	330.7	0.0011	0.0038	0.0004
Mechanical vibrators	diesel	37-75 kW	Nonr D EU3A	PM	361	0.0004	0.0036	0.0004
Mechanical vibrators	diesel	75-130 kW	Nonr D PreEUB	PM	140	0.0105	0.0105	0.0011
Mechanical vibrators	diesel	75-130 kW	Nonr D EU1	PM	241.6	0.0078	0.0078	0.0008
Mechanical vibrators	diesel	75-130 kW	Nonr D EU2	PM	335.8	0.0025	0.0051	0.0005
Mechanical vibrators	diesel	75-130 kW	Nonr D EU3A	PM	379.8	0.0005	0.0048	0.0005

[6] https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html [06.02.2024]

A2.1.2 Activity data non-road vehicles

The following table gives an overview on the stock and the operating hours of non-road vehicles (FOEN 2015j).

Table A - 13 Number of vehicles, specific operating hours per year and total operating hours per year for all non-road families/categories (FOEN 2015j).

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
Total	**1'701'994**	**2'098'151**	**2'528'136**	**2'889'193**	**3'026'135**	**3'060'441**

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
Total	**95**	**121**	**155**	**261**	**301**	**311**

A2.2 Emissions due to former usage (2K) and subsequent disposal of polychlorinated biphenyls (1A1a, 2C1, 5A, 5C1, 5E, 6A)

A2.2.1 Mass flow and emission model of former use and disposal of PCBs

Polychlorinated biphenyls (PCBs) were used in Switzerland between 1946 and 1986. In 1986, a total ban was placed on any form of PCB use. The use in so-called 'open applications' was allowed until 1972. Open applications include joint (elastic) sealants, anti-corrosion coatings, paints and varnishes. All other uses were allowed until 1986.

An emission inventory based on a dynamic mass flow model was developed for PCBs for Switzerland for the time period 1930 to 2100. The model takes into account the import, usage, export, treatment, disposal and accidental release of PCBs, see Figure A - 1. PCB emissions to the environment occur from all stages of their lifecycle. A detailed documentation of the emission inventory is available in Glüge et al. 2017. Additionally, the underlying model is available in Microsoft Excel/VBA and can be downloaded.

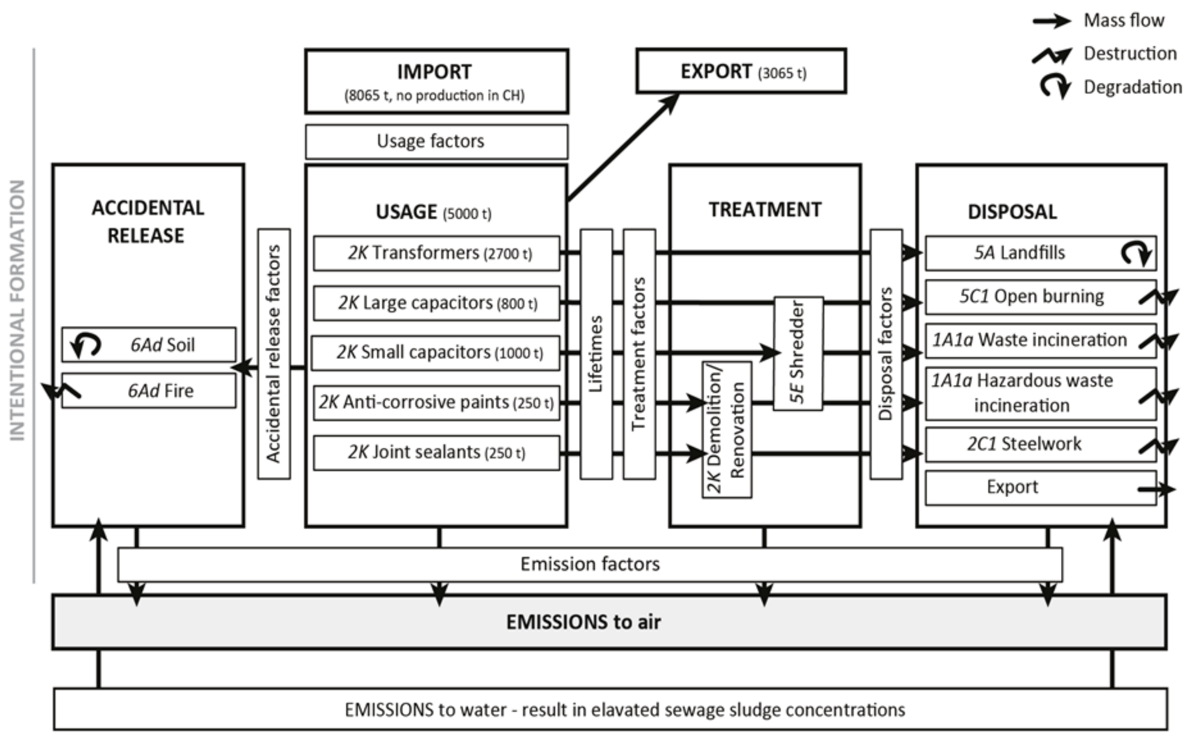

Figure A - 1 Model setup for the dynamic mass flow and emissions of PCBs taking into account the import, usage, export, treatment, disposal and accidental release. Emissions to air occur from usage, treatment, disposal, and accidental release. (Waste and hazardous waste incineration correspond to municipal solid waste and special waste incineration, respectively.)

Besides this intentional usage of PCBs, PCBs can also be emitted by unintentional formation, e.g. in combustion processes. Emissions from unintentional formation are not part of this mass flow model but are included in the air pollutant emission inventory for stationary combustion of solid and liquid fossil fuels as well as of wood and wood waste, see chapters 3.2.2 – 3.2.4.

Import and usage

PCBs have not been produced in Switzerland. Therefore, the chemicals enter the system solely through import (Figure A - 1, top part). The imported amounts are then distributed to the usage categories according to usage factors (Figure A - 1, middle part). The imported amounts, as well as the usage factors, vary over time. In this study, five usage categories that were identified to be important for Switzerland are included: transformers, large capacitors (> 1 kg), small capacitors (< 1 kg), anti-corrosive paints on steel and joint sealants. Other uses, such as PCBs in hydraulic oils (used in mining), plastics, or insecticides are considered as being of minor importance in Switzerland and are thus, not included in the model. For the time being, anti-corrosive paints and joint sealants are the predominant PCB emission sources (see Figure A - 2). The emissions from the five usage categories are reported in source category 2K Consumption of POPs and heavy metals.

Export

The exported amounts to other countries could have been estimated only roughly. PCBs were mainly exported in disposed PCB-containing transformers and capacitors and electronic waste, but also in old installations, such as for example hydraulic turbines with PCB-containing paints.

Disposal

When a PCB-containing product reaches its end of life it is disposed of. In the model, six disposal categories that have been relevant in Switzerland are included: landfills (5A), open burning (5C1), municipal waste incineration (1A1a), special waste incineration (1A1a), steelworks (2C1), and export (Figure A - 1, right part). For all usage categories, specific disposal factors, which vary over time, are applied to the six disposal categories and export. Here, open burning refers to combustion of PCB contaminated waste oil in outdoor fires (i.e. outside of a container). Open burning was ceased in 1999. Steelworks represent scrap metal that is melted in electric arc furnaces of secondary steel production plants. Thereby PCB-containing paint residues are combusted at temperatures of around 1600°C. Landfills are disposal sites where the waste is dumped. Since 2000, the incineration of combustible waste is mandatory in Switzerland, therefore, disposing of to landfills stopped. In landfills, PCBs are partly stored and partly degraded. When waste is exported, its emissions abroad are not included in the Swiss emission inventory. When combusted, PCBs are partly destroyed by high temperatures and partly emitted to the environment.

Treatment

Before disposal, some usage categories undergo specific treatment processes (Figure A - 1, right part). Two treatment categories are included in the model: Demolition/renovation of steel constructions and buildings containing PCBs in anti-corrosive paints and joint sealants, respectively (2K), as well as Shredding of electronic waste containing PCBs in small capacitors (5E).

Demolition/renovation can induce elevated emissions to the environment, as has been observed for buildings. Shredding of electronic waste occurs at fast rotation velocity that leads to increased temperature and dust production. As a consequence of the legal ban of disposal of combustible waste in landfills, a sharp increase in shredding of small capacitors occurred in 1999 although they should have been treated as special waste from 1998 onwards (see Figure A - 2Figure A - 3). Shearing of steel constructions (heavy scrap), otherwise, is supposed to produce little dust and yield no evaporation of the substances in the coating. Therefore, no emissions to air from the shearing of steel constructions were assumed.

Accidental release

From each usage category, PCBs can be accidentally released (Figure A - 1, left part). The model includes two release categories: soil and fire (6Ad). When released to soil, PCBs are partly stored and partly degraded. In the case of fire, PCBs are partly destroyed by high temperatures and partly emitted to the environment.

Release to water

The release of PCBs to water bodies is only partly included in this model. Release to water bodies is important for anti-corrosive paints and to a smaller degree also for leachate from landfills. The measured PCB concentrations in sewage sludge and the total amount of produced sewage sludge per year was used to determine the mass of PCBs released to water. This approach overlooks emissions to natural water bodies, but it captures emissions to wastewater.

A2.2.2 Emission methodology

Emissions to air occur from the entire system: usage, treatment, disposal and accidental release. The emissions are calculated by multiplying the annual mass of PCBs involved in a source category (e.g. tonnes of PCBs in use in joint sealants) with a source-specific emission factor (e.g. tonnes of PCBs emitted/tonnes of PCBs in use). This country-specific approach corresponds to a Tier 2 method according to EMEP/EEA (2019).

The five usage categories as well as landfills and soils are PCB stocks, which means that PCBs are stored in these categories and passed on through the system with a temporal delay according to their lifetime or residence time. In these cases, the activity data are the amounts of PCBs stored in the stock. The treatment categories of renovation and shredder and all incineration categories (including fire) are instantaneous categories, where PCBs are not stored. In these cases, the activity data correspond to the amount of PCBs treated or incinerated in the respective year.

PCB emissions are sometimes reported as sum of the so-called indicator PCBs (iPCBs, i.e. PCB congeners 28, 52, 101, 138, 153, and 180), sometimes as sum of the dioxin-like PCBs (dl-PCBs, i.e. PCB congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189) and sometimes as sum of all 209 congeners. The emission model is run for all congeners, so emission numbers are available for all three sums. Where data such as typically emission factors are not available for all congeners, estimates are derived from the iPCBs using the chlorination degrees of the congeners. Please note that the PCB emissions reported in Switzerland's air pollutant emission inventory comprise the sum of all 209 congeners.

Figure A - 3Figure A - 2 shows the resulting PCB emissions from all stages of the life cycle of PCB applications, i.e. usage, treatment, disposal and accidental release. Anti-corrosive paints and joint sealants are the predominant PCB emission sources for most of the time. Between 1975 and 1985 and around 2000, open burning and the above-mentioned shredding of small capacitors, respectively, were the dominant PCB sources. Only after 2040, emissions from soil due to former accidental releases to soil become the most important emission source. Mainly in the seventies and eighties, accidental release by fire, small and large capacitors and waste incineration were important emission sources as well.

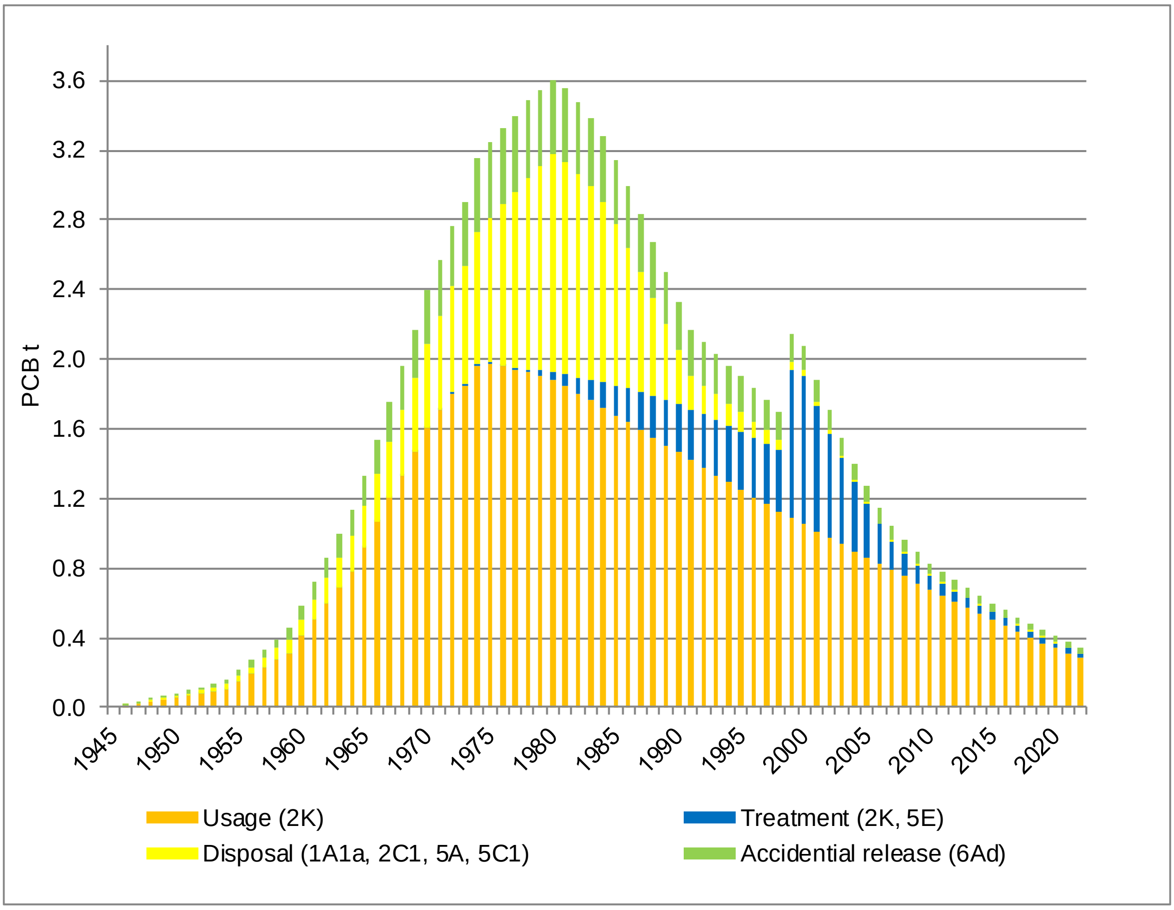

Figure A - 2 PCB emissions from usage (2K Transformers, large and small condensators, anti-corrosive paints and joint sealants), treatment (2K Demoition and renovation, 5E Shredder), disposal (1A1a Municipal solid waste and special waste incineration, 2C1 Secondary steel production, 5A Landfills, 5C1 Open burning (until 1999)) and accidental release (6Ad Accidental release by fire and from soil).

A2.3 Comparison of the country-specifically calculated Tier 3 results for N flows and NH_3 emissions from animal husbandry with the results of the Tier 2 calculations using the TFEIP N-flow tool (3B, 3Da2a, 3Da3)

In the report of the Stage 3 in-depth review in summer 2020 it was recommended “To present more details regarding the country-specific emission factors as well as a comparison of the national emission factors and the Guidebook emission factors with a rationale of the discrepancies.” Because it is not only the emission factors that have a strong influence on the emission inventory calculations but also other assumptions like N excretions, length of housed period or percentage of TAN in the manure, it was decided to not only compare the emission factors but rather the total N flows and NH_3 emissions resulting from the calculations with the model AGRAMMON (see chp. 5.2.2) and the TFEIP N flow tool (downloaded from https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/4-agriculture/manure-management-n-flow-tool/view, version Jan 2021). The comparison was made for the year 2015, which at the time was the last year with data from a representative survey on farm and manure management, using the previous version of the AGRAMMON model (Kupper et al. 2018). The procedure and the results are summarised in an internal memo (Menzi 2022). An overview of the results is shown in Tables A-14 to A-16. The main results can be summarised as follows:

N excretions

- Total N excretions from livestock production shown for the livestock categories used in the N flow tool were 4 % lower in the N flow tool than according to the Swiss AGRAMMON tool (Swiss reporting). The lower total N excretion was mainly due to cattle and swine which contributed over 75 % and over 10 %, respectively, of the N excretions from agricultural livestock.
- For dairy cows the value used in the N flow tool is 6 % lower than in the Swiss reporting. This can be explained by the average weight assumed. In the N flow tool, it is 600 kg while it is 660 kg in Switzerland (according to Swiss Fertiliser Guidelines). With a correction to 660 kg N the N flow tool shows excretions of 113.9 kg N per dairy cow place and year, which is 1.8 % more than the Swiss value.
- For all main livestock categories except small ruminants and equids the difference of N excretion between the two approaches was less than 10 %.

NH_3 emissions livestock

- Total NH_3 emissions from livestock and manure management differ less than 10 % between the two approaches, the N flow tool being a bit lower than the Swiss reporting. This holds for both 3B (housing and manure storage) and 3D (manure application and grazing) emission categories and is also true for cattle, which contribute about three fourths of the NH_3 emissions from livestock and manure management. For the cattle categories the relative difference is in the same proportion as the difference for N excretion. Total emissions from pig production were well comparable between the two approaches (N flow tool 4 % lower than Swiss reporting). Pig production in 2015 was responsible for around 15 % of the emissions from livestock and manure management. According to the N flow tool the values for the category 3B were nearly 20 % lower than according to the Swiss reporting and those for the category 3D about 25 % higher. This can mainly be explained by the high importance of animal friendly housing system in Switzerland, which cannot be considered in the N flow tool.

<u>Distribution of NH_3 emissions to the stages of the manure management chain</u>

- The distribution of NH_3 emissions to housing, storage, application and grazing the N-flow tool has a lower share for housing and a higher share for grazing as compared to the Swiss reporting. Housing emissions (including yards) were 22 % lower in the N flow tool compared to the Swiss reporting because of the assumptions on grazing and housing and the high importance of special animal friendly housing systems which cannot be considered in the N flow tool.
- In spite of the lower N flow through the manure cascade (because of assumption about grazing) emissions from manure storage were 21 % higher in the N flow tool than in the Swiss reporting (slurry +37 %, solid manure -12 %), probably mainly because of the high share of covered slurry stores (89 %; not considered in the N flow tool) and the importance of liquid and solid manure (Switzerland 2015 share N flow going to storage: 74 % slurry, 26 % solid manure).
- Emissions from manure application were 19 % lower in the N flow tool than in the Swiss reporting, probably mainly because of the lower N flow through the manure cascade and the importance of low emission spreading technique in Switzerland (2015 38 % of the slurry) which cannot be considered in the N flow tool.
- Emissions from grazing were nearly fourfold as high in the N low tool as compared to the Swiss reporting because of the assumptions about housing and grazing.
- The distribution of emissions from livestock and manure management to the Guidebook categories 3B (housing, manure storage) and 3D (Manure application, grazing) agreed well between the two approaches (share 3B: N flow tool 54 %, Swiss reporting 55 %). However, within the category 3B the distribution to housing and manure storage differed quite a bit (N flow tool 58 %/42 %, Swiss reporting 68 %/32 %). For the category 3D the distribution to manure application and grazing was 77 %/23 % for the N flow tool and 94 %/6 % for the Swiss reporting. Looking at the distribution of total emissions to housing/manure storage/manure application/grazing the distribution was 31 %/23 %/36 %/10 % for the N flow tool and 37 %/17 %/43 %/3 % for the Swiss reporting.

A direct comparison of N flows or emission factors is impeded in various places by the differences between the models in the allocation of N flows. Important examples are:

a) The N-flow tool differentiates between emission factors for liquid and solid manure in the housing area while AGRAMMON has only one emission factor for housing because a clear allocation of excreta and soiled surfaces to liquid and solid manure is not possible.

b) For slurry storage, the emission factors are in percent of TAN in the N flow model and in g per m^2 slurry surface and day in AGRAMMON.

c) AGRAMMON takes into account a different allocation of TAN excretions to liquid and solid manure. As urine (containing soluble N, which is potentially emitted) is primarily collected in the liquid manure, the emissions are higher than for a comparable N flow in the form of faeces, which primarily contain organic N and mostly go into solid manure.

d) AGRAMMON takes into account the immobilisation of TAN and the release of TAN from the degradation of organic N in housing and during manure storage, which is not considered in the N flow tool.

The comparison of the two approaches shows that the Tier 2 approach can hardly cope with farm management conditions that differ strongly from the assumption in the N-flow tool and can only be transferred to the input variables with difficulty. If such detailed farm management data is available, it is more reliable and maybe even easier to use a country-specific Tier 3 approach.

Table A - 14 N excretions of livestock in Switzerland according to the Swiss reporting (AGRAMMON model, Tier 3 methodology) and the N flow tool (Tier 2 methodology) for the year 2015.

Swiss reporting (Tier 3) AGRAMMON Model		**dairy cows**	**non-d. cattle**	**calves**	**catttle exc DC**	**cattle total**	**finishing pigs**	**sows**	**pigs total**	**sheep**	**goats**	**small ruminants**	**horses**	**mules+asses**	**equids**	**laying hens**	**broilers**	**turkeys**	**poultry total**	**total**
N excretion housing & yard	kt N	54.74	25.63	3.18	28.80	83.55	11.43	3.59	15.02	2.10	0.84	2.94	1.91	0.24	2.16	2.41	3.09	0.07	5.57	109.24
N excretion grazing	kt N	10.38	8.81	0.67	9.49	19.86	0.002	0.002	0.003	1.23	0.11	1.34	0.52	0.07	0.59	0.16	0.01	0.002	0.17	21.96
N excretion total	kt N	65.12	34.44	3.85	38.29	103.41	11.44	3.59	15.02	3.33	0.95	4.29	2.43	0.31	2.75	2.57	3.10	0.07	5.74	131.21
% category of total		49.6%	26.2%	2.9%	29.2%	78.8%	8.7%	2.7%	11.5%	2.5%	0.7%	3.3%	1.9%	0.2%	2.1%	2.0%	2.4%	0.1%	4.4%	100%
% during grazing		16%	26%	17%	25%	19%	0.02%	0.05%	0.02%	37%	12%	31%	21%	22%	21%	6%	0.2%	3%	9%	17%

N flow tool (Tier 2)		**dairy cows**	**non-d. cattle**	**calves**	**cattle exc DC**	**cattle total**	**finishing pigs**	**sows**	**pigs total**	**sheep**	**goats**	**small ruminants**	**horses**	**mules+asses**	**equids**	**laying hens**	**broilers**	**turkeys**	**poultry total**	**total**
N excretion housing & yard	kt N	38.01	17.31	1.90	19.22	57.22	9.44	4.23	13.67	0.54	0.14	0.68	1.30	0.32	1.62	2.97	2.77	0.09	5.83	79.02
N excretion grazing	kt N	23.31	14.52	1.60	16.12	39.43	-	-	-	4.84	1.53	6.37	1.33	0.33	1.67	-	-	-	-	47.46
N excretion total	kt N	61.31	31.83	3.50	35.33	96.65	9.44	4.23	13.67	5.38	1.66	7.05	2.63	0.65	3.29	2.97	2.77	0.09	5.83	126.48
% category of total		48.5%	25.2%	2.8%	27.9%	76.4%	7.5%	3.3%	10.8%	4.3%	1.3%	5.6%	2.1%	0.5%	2.6%	2.3%	2.2%	0.1%	4.6%	100.0%
% during grazing		38%	46%	46%	46%	41%	-	-	-	90%	92%	90%	51%	51%	51%	-	-	-	-	38%

Table A - 15 NH_3 emissions from livestock and manure management in Switzerland according to the Swiss reporting (AGRAMMON model) for the different livestock categories and steps of the manure cascade for the year 2015.

Swiss reporting (Tier 3) AGRAMMON Model		dairy cows	non-d. cattle	calves	catttle exc DC	cattle total	finishing pigs	sows	pigs total	sheep	goats	small ruminants	horses	mules+ asses	equids	laying hens	broilers	turkeys	poultry total	total
N excretion housing & yard	kt N	54.74	25.63	3.18	28.80	83.55	11.43	3.59	15.02	2.10	0.84	2.94	1.91	0.24	2.16	2.41	3.09	0.07	5.57	109.24
N excretion grazing	kt N	10.38	8.81	0.67	9.49	19.86	0.00	0.00	0.00	1.23	0.11	1.34	0.52	0.07	0.59	0.16	0.01	0.00	0.17	21.96
N excretion total	kt N	65.12	34.44	3.85	38.29	103.41	11.44	3.59	15.02	3.33	0.95	4.29	2.43	0.31	2.75	2.57	3.10	0.07	5.74	131.21
% category of total		49.6%	26.2%	2.9%	29.2%	78.8%	8.7%	2.7%	11.5%	2.5%	0.7%	3.3%	1.9%	0.2%	2.1%	2.0%	2.4%	0.1%	4.4%	100%
% during grazing		16%	26%	17%	25%	19%	0.02%	0.05%	0.02%	37%	12%	31%	21%	22%	21%	6%	0%	3%	9%	17%
emissions housing	kt N	4.34	2.14	0.31	2.45	6.79	2.78	0.93	3.72	0.25	0.10	0.35	0.14	0.01	0.15	0.37	0.38	0.01	0.76	11.77
emissions yard	kt N	1.55	1.33	0.10	1.43	2.98	-	-	-	-	-	-	0.11	0.02	0.13	-	-	-	-	3.11
emissions housing & yard	kt N	5.89	3.47	0.41	3.88	9.77	2.78	0.93	3.72	0.25	0.10	0.35	0.25	0.03	0.28	0.37	0.38	0.01	0.76	14.88
emissions storage liq.	kt N	2.72	1.19	0.08	1.28	4.00	0.47	0.16	0.63	-	-	-	-	-	-	-	-	-	-	4.63
storage solid	kt N	0.80	0.70	0.19	0.89	1.69	-	-	-	0.17	0.06	0.22	0.14	0.02	0.16	0.12	0.065	0.00	0.19	2.27
storage total	kt N	3.53	1.89	0.27	2.16	5.69	0.47	0.16	0.63	0.17	0.06	0.22	0.14	0.02	0.16	0.12	0.06	0.00	0.19	6.89
application liquid	kt N	8.58	3.14	0.23	3.36	11.95	1.44	0.42	1.86	-	-	-	-	-	-	-	-	-	-	13.80
application solid	kt N	1.16	1.02	0.25	1.27	2.44	-	-	-	0.07	0.04	0.11	0.08	0.01	0.08	0.26	0.34	0.01	0.61	3.24
application total	kt N	9.75	4.16	0.48	4.64	14.38	1.44	0.42	1.86	0.07	0.04	0.11	0.08	0.01	0.08	0.26	0.34	0.01	0.61	17.05
emissions grazing	kt N	0.48	0.40	0.03	0.43	0.91	0.0002	0.0002	0.001	0.06	0.01	0.07	0.03	0.00	0.03	0.07	0.003	0.001	0.07	1.08
% of grazing emissions		44.2%	37.4%	2.9%	40.3%	84.5%	0.02%	0.02%	0.05%	5.7%	0.5%	6.2%	2.4%	0.3%	2.7%	6.1%	0.3%	0.1%	6.5%	100%
% of total emissions		1.2%	1.0%	0.1%	1.1%	2.3%	0.001%	0.001%	0.001%	0.2%	0.0%	0.2%	0.06%	0.01%	0.1%	0.2%	0.01%	0.002%	0.2%	2.7%
3B total	kt N	9.41	5.37	0.68	6.05	15.46	3.25	1.09	4.34	0.42	0.16	0.58	0.39	0.05	0.44	0.49	0.45	0.01	0.95	21.77
% category of total		43.2%	24.6%	3.1%	27.8%	71.0%	14.9%	5.0%	20.0%	1.9%	0.7%	2.7%	1.8%	0.2%	2.0%	2.3%	2.0%	0.1%	4.4%	100%
3D total (manure)	kt N	10.22	4.56	0.51	5.07	15.29	1.44	0.42	1.86	0.14	0.04	0.18	0.10	0.01	0.11	0.33	0.35	0.01	0.68	18.12
% category of total		56.4%	25.2%	2.8%	28.0%	84.4%	7.9%	2.3%	10.3%	0.7%	0.2%	1.0%	0.6%	0.1%	0.6%	1.8%	1.9%	0.0%	3.8%	100%
Emissions manure tot.	kt N	19.64	9.93	1.19	11.11	30.75	4.69	1.51	6.20	0.55	0.20	0.75	0.49	0.06	0.56	0.82	0.79	0.02	1.63	39.90
% category of total		49.2%	24.9%	3.0%	27.9%	77.1%	11.8%	3.8%	15.5%	1.4%	0.5%	1.9%	1.2%	0.2%	1.4%	2.0%	2.0%	0.1%	4.1%	100%
% of N excretion		30.2%	28.8%	30.8%	29.0%	29.7%	41.0%	42.1%	41.3%	16.6%	21.0%	17.6%	20.3%	20.1%	20.2%	31.8%	25.6%	29.5%	28.4%	30.4%

Table A - 16 NH_3 emissions from livestock and manure management in Switzerland according to the N flow tool for the different livestock categories and steps of the manure cascade for the year 2015.

N flow tool (Tier 2)		dairy cows	non-d cattle	calves	catttle exc DC	cattle total	finishing pigs	sows	pigs total	sheep	goats	small ruminants	horses	mules+ asses	equids	laying hens	broilers	turkeys	poultry total	total
N excretion housing & yard	kt N	38.01	17.31	1.90	19.22	57.22	9.44	4.23	13.67	0.54	0.14	0.68	1.30	0.32	1.62	2.97	2.77	0.09	5.83	79.02
N excretion grazing	kt N	23.31	14.52	1.60	16.12	39.43	-	-	-	4.84	1.53	6.37	1.33	0.33	1.67	-	-	-	-	47.46
N excretion total	kt N	61.31	31.83	3.50	35.33	96.65	9.44	4.23	13.67	5.38	1.66	7.05	2.63	0.65	3.29	2.97	2.77	0.09	5.83	126.48
% category of total		48.5%	25.2%	2.8%	27.9%	76.4%	7.5%	3.3%	10.8%	4.3%	1.3%	5.6%	2.1%	0.5%	2.6%	2.3%	2.2%	0.1%	4.6%	100%
% during grazing		38%	46%	46%	46%	41%	0%	0%	0%	90%	92%	90%	51%	51%	51%	0%	0%	0%	0%	38%
emissions housing	kt N	2.08	1.49	0.14	1.63	3.71	1.78	1.04	2.82	0.05	0.02	0.06	0.17	0.04	0.21	0.42	0.41	0.02	0.85	7.65
emissions yards	kt N	2.76	1.01	0.11	1.12	3.88	-	-	-	0.04	-		-	-	-	-	-	-	-	3.92
emissions housing & yard	kt N	4.84	2.50	0.25	2.75	7.59	1.78	1.04	2.82	0.09	0.02	0.10	0.17	0.04	0.21	0.42	0.41	0.02	0.85	11.57
storage liquid	kt N	4.14	1.30	0.11	1.41	5.55	0.56	0.23	0.79	-	-	-	-	-	-	-	-	-	-	6.34
storage solid	kt N	0.46	0.67	0.04	0.71	1.17	-	-	-	0.04	0.01	0.05	0.15	0.03	0.18	0.13	0.46	0.01	0.60	2.00
storage total	kt N	4.60	1.97	0.15	2.12	6.72	0.56	0.23	0.79	0.04	0.01	0.05	0.15	0.03	0.18	0.13	0.46	0.01	0.60	8.34
application liquid	kt N	6.73	2.11	0.18	2.29	9.03	1.81	0.53	2.34	-	-	-	-	-	-	-	-	-	-	11.37
application solid	kt N	0.34	0.50	0.03	0.53	0.87	-	-	-	0.04	0.02	0.05	0.12	0.02	0.15	0.46	0.23	0.01	0.69	1.76
application total	kt N	7.08	2.61	0.21	2.82	9.90	1.81	0.53	2.34	0.04	0.02	0.05	0.12	0.02	0.15	0.46	0.23	0.01	0.69	13.13
grazing	kt N	1.96	1.22	0.13	1.35	3.31	-	-	-	0.22	0.07	0.29	0.28	0.07	0.35	-	-	-	-	3.95
% of grazing emissions		49.6%	30.9%	3.4%	34.3%	83.9%	-	-	-	5.5%	1.7%	7.3%	7.1%	1.8%	8.9%	-	-	-	-	100%
% of total emissions		5.3%	3.3%	0.4%	3.7%	9.0%	-	-	-	0.6%	0.2%	0.8%	0.8%	0.2%	0.9%	-	-	-	-	10.7%
3B total	kt N	9.44	4.47	0.40	4.87	14.32	2.35	1.26	3.61	0.13	0.03	0.15	0.32	0.07	0.39	0.55	0.87	0.03	1.45	19.92
% category of total		47.4%	22.4%	2.0%	24.5%	71.9%	11.8%	6.3%	18.1%	0.6%	0.1%	0.8%	1.6%	0.4%	2.0%	2.8%	4.4%	0.2%	7.3%	100%
3D total (manure)	kt N	9.03	3.83	0.35	4.18	13.21	1.81	0.53	2.34	0.26	0.08	0.34	0.40	0.09	0.50	0.46	0.23	0.01	0.69	17.08
% category of total		52.9%	22.4%	2.0%	24.5%	77.4%	10.6%	3.1%	13.7%	1.5%	0.5%	2.0%	2.4%	0.6%	2.9%	2.7%	1.3%	0.1%	4.0%	100%
Emissions manure tot.	kt N	18.48	8.30	0.75	9.05	27.53	4.16	1.79	5.95	0.38	0.11	0.50	0.72	0.17	0.89	1.00	1.09	0.04	2.14	36.99
% category of total		49.9%	22.4%	2.0%	24.5%	74.4%	11.2%	4.8%	16.1%	1.0%	0.3%	1.3%	1.9%	0.4%	2.4%	2.7%	3.0%	0.1%	5.8%	100%
% of N excretion		30.1%	26.1%	21.4%	25.6%	28.5%	44.0%	42.3%	43.5%	7.1%	6.7%	7.0%	27.4%	25.4%	27.0%	33.8%	39.4%	46.4%	36.7%	29.2%

Annex 3 Additional information and explanations concerning the NFR tables

Table A - 17 Explanation of the NE notation key in the NFR tables from the latest submission.

NFR code	Substance(s)	Reason for notation key NE
all	As, Cr, Cu, Ni, Se, Zn	Lack of data
1A (Nonroad)	HCB, PCBs	Lack of data
1A (mobile)	HCB, PCBs	Lack of data (for the years 1980-1989)
1A1c	SO_x, NH_3, Pb, Cd, Hg, POPs	Lack of data
1A3b	HCB	no EF available
1A3di(i)	TSP, PM_{10}, $PM_{2.5}$, BC, Pb, Cd, Hg, PCDD/PCDF, PAHs, PCBs	no EF available
1A3dii	PCBs	no EF available
2A5a	BC	no EF available
2B5	BC	no EF available
2C3	Pb, Hg, PCDD/PCDF, HCB, PCBs	no EF available (production only from 1980 to 2006)
2C7c	BC	no EF available
2D3b	$PM_{2.5}$, PM_{10}, TSP, BC	Lack of data
2H1	NO_x, SO_x, BC, CO	no EF available
2H2	BC	no EF available
2H3	BC	no EF available
3Df	HCB	Lack of data
11B	BC, PCBs	no EF available

Table A - 18 Explanation of the IE Notation key in the NFR tables from the latest submission.

NFR code	Substance(s)	Included in NFR code
1A1b	Activity Data "Gaseous Fuels"	1A1b - Activity Data "Liquid Fuels" (for the years 2017 onwards)
1A3bvii	TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Activity Data "Other activity"	1A3bvi
1A4ciii	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, Activity Data "Liquid Fuels", "Biomass", "Other activity"	1A3dii
2A3	NO_x, SO_x, $PM_{2.5}$, PM_{10}, TSP, BC, CO, Pb, Cd, Hg	1A2f
2A5b	$PM_{2.5}$, PM_{10}, TSP	1A2gvii
2B1	NMVOC	2B10a
2D3c	NMVOC	2D3i (for the years 1980-1989)
2D3e	NMVOC	2D3i (for the years 1980-1989)
2D3f	NMVOC	2D3i (for the years 1980-1989)
2D3g	NMVOC	2D3i (for the years 1980-1989)
2D3h	NMVOC	2D3i (for the years 1980-1989)
3B4a	NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, TSP, Activity Data "Other activity"	3B1a
5D2	NO_x, NMVOC, SO_x, NH_3, CO, Activity Data "Other activity"	5D1 (for the years 1980-1989)

Table A - 19 List of sub-sources accounted for in reporting codes "other" in the NFR tables from the latest submission.

NFR code	Substance(s) reported	Sub-source description
1A2gviii	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, HCB, PCB	Industrial combustion of wood and wood waste, other boilers and engines in industry, fibreboard production
1A3eii	-	NO
1A5a	-	NO
1A5b	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs	Military mobile only (aviation and nonroad)
1B1c	-	NO
1B2d	-	NO
2A6	-	NO
2B10a	NO_x, NMVOC, SO_x, CO, Hg (until 2016)	Acetic acid, ammonium nitrate (until 2018), chlorine gas, ehtylene, formaldehyde (until 1989), PVC (until 1996), niacin and sulphuric acid
2C7c	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO, Pb, Cd, Hg, PCDD/PCDF	Battery recycling, galvanizing plants, silicium production (until 1988)
2D3i	NMVOC	Removal of paint and lacquer, vehicles dewaxing (until 2001), production of perfume/arome, cosmetics, paper/paper board, tobacco products and textiles, extraction of oil and fat (until 2000) and scientific laboratories, unspecified commercial and industrial solvent emissions
2G	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs	Application of glues and adhesives, commercial and industrial use of cleaning agents, cosmetic institutions, de-icing of airplanes and air-port surfaces (until 2011), glass wool enduction, hairdressers, health care other, medical practices, preservation of wood, renovation of anti-corrosive coatings, rock wool enduction, underseal treatment and conservation of vehicles and use of concrete additives, cooling lubricants, fireworks, lubricants and pesticides
2H3	NO, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO, Pb	Blasting and shooting
2L	NH_3	Use of NH_3 as refrigerant
3B4h	NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, TSP	Camels and Llamas (3B4b), Deer (3B4c), Rabbits (3B4hi), Bisons (3B4hii)
3I	-	NO
5C1bvi	-	NO
5D3	-	NO
5E	NMVOC, $PM_{2.5}$, PM_{10}, TSP, CO, Pb, Cd, PCDD/F, PCBs	Car shredding
6A	NO_x, NMVOC, SO_x, NH3, $PM_{2.5}$, PM_{10}, TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, PCB	Human ammonia emissions (breath, transpiration, napkin), pet ammonia emissions, pet PM emissions (keeping of horses, sheep, goats and donkeys outside agriculture), domestic use of fertilizers, fire damages estates and motor vehicles
6B	-	NO
11C	NMVOC	Natural NMVOC emissions from forest and grassland.

Table A - 20 Basis for estimating emissions from mobile sources in the NFR tables from the latest submission.

NFR code	Description	Fuel sold	Fuel used	Comment
1 A 3 a i (i)	International Aviation (LTO)	X		
1 A 3 a i (ii)	International Aviation (Cruise)	X		
1 A 3 a ii (i)	1 A 3 a ii Civil Aviation (Domestic, LTO)	X		
1 A 3 a ii (ii)	1 A 3 a ii Civil Aviation (Domestic, Cruise)	X		
1A3b	Road transport	(X)	X	"NATIONAL TOTAL" reported as "fuel sold", "COMPLIANCE TOTAL (CLRTAP)" as "fuel used"
1A3c	Railways		X	
1A3di (i)	International maritime Navigation	X		
1A3di (ii)	International inland waterways			NO
1A3dii	National Navigation	X		
1A4ci	Agriculture; stationary		X	
1A4cii	Off-road Vehicles and Other Machinery		X	
1A4ciii	National Fishing		IE	IE in 1A3dii
1 A 5 b	Other, Mobile (Including military)		X	

Annex 4 National energy balance

Swiss energy flow

The diagrams show a summary of the Swiss energy flow 2022 and 1990 in TJ as published by the Swiss Federal Office of Energy (SFOE 2023, SFOE 1991) in German and French.

Fig. 5 Detailliertes Energieflussdiagramm der Schweiz 2022 (in TJ)
Flux énergétique détaillé de la Suisse en 2022 (en TJ)

BFE, Schweizerische Gesamtenergiestatistik 2022 (Fig. 5)
OFEN, Statistique globale suisse de l'énergie 2022 (fig. 5)

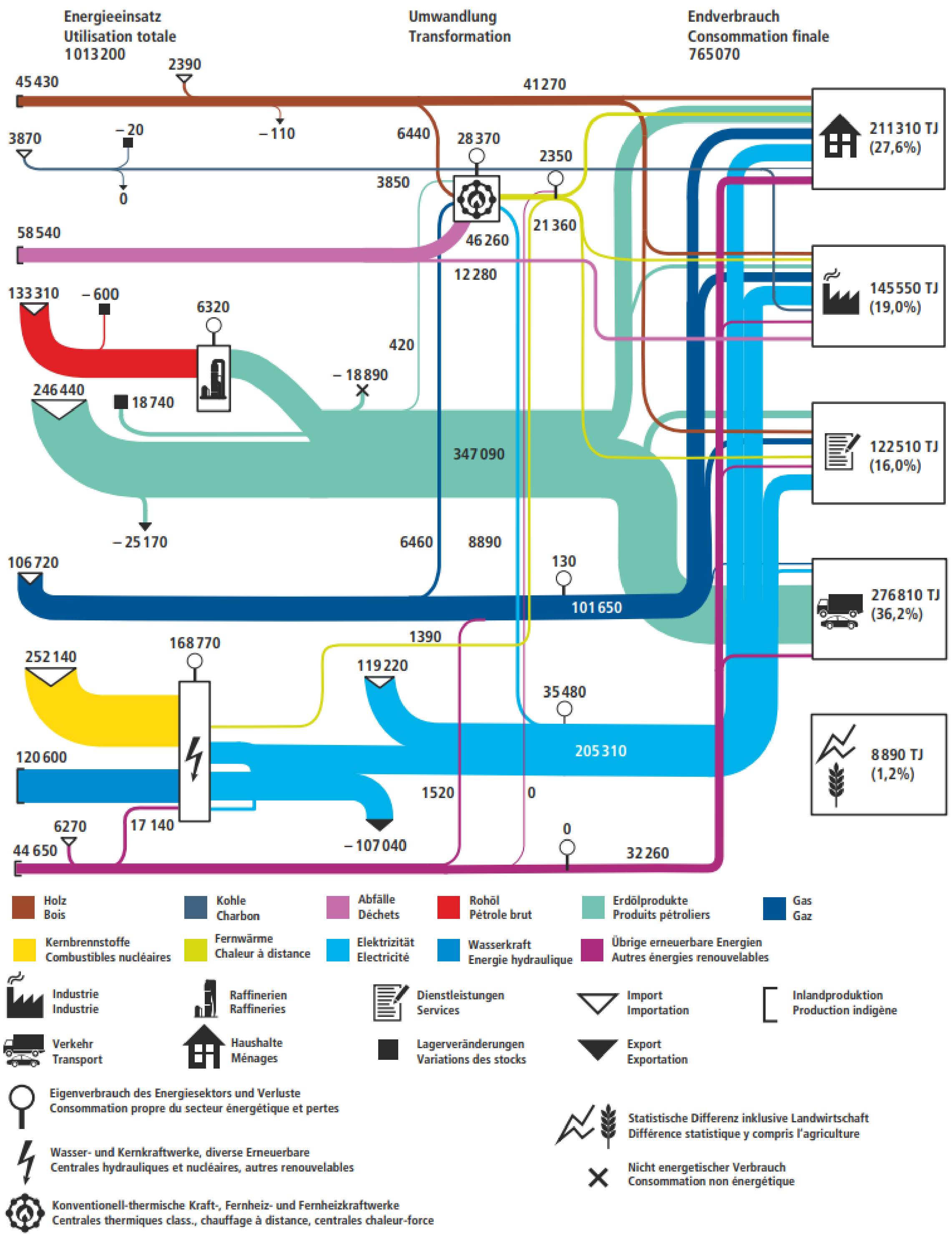

Figure A - 3 Energy flow in Switzerland 2022 (SFOE 2023, figure 5). Depicted values are in TJ.

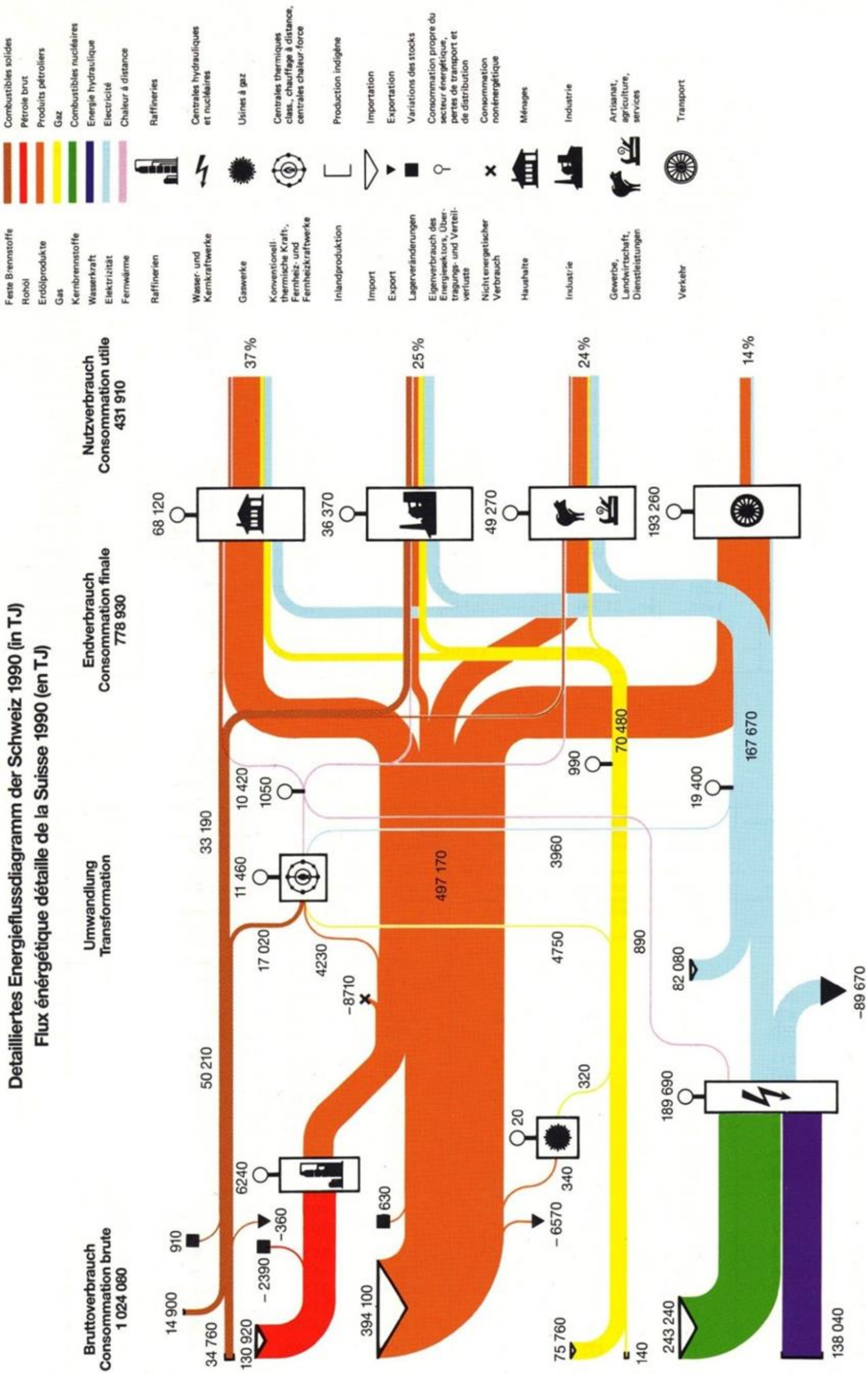

Figure A - 4 Energy flow in Switzerland 1990 (SFOE 1991). Depicted values are in TJ.

Table A - 21 Energy balance for Switzerland 2022 (table 4, Swiss overall energy statistics, SFOE 2023) in TJ.[7].

Tab. 4 Energiebilanz der Schweiz für das Jahr 2022 (in TJ)
Bilan énergétique de la Suisse pour 2022 (en TJ)

		Holzenergie	Kohle	Müll und Industrie-abfälle	Rohöl	Erdöl-produkte	Gas	Wasserkraft	Kernbrenn-stoffe	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)	45 430	–	58 540	0	–	–	120 600	–	44 650	–	–	269 220	Production indigène
+ Import	(b)	2 390	3 870	–	133 310	246 440	106 720	–	252 140	6 270	119 220	–	870 360	+ Importation
+ Export	(c)	–110	–	–	0	–25 170	–	–	–	–	–107 040	–	–132 320	+ Exportation
+ Lagerveränderung[1]	(d)	–	–20	–	–600	18 740	–	–	–	–	–	–	18 120	+ Variation de stock[1]
= Bruttoverbrauch	(e)	47 710	3 850	58 540	132 710	240 010	106 720	120 600	252 140	50 920	12 180	–	1 025 380	= Consommation brute
+ Energieumwandlung:														+ Transformation d'énergie:
- Wasserkraftwerke	(f)	–	–	–	–	–	–	–120 600	–	–	120 600	–	0	- Centrales hydrauliques
- Kernkraftwerke	(g)	–	–	–	–	–	–	–	–252 140	–	83 210	1 390	–167 540	- Centrales nucléaires
- konventionell-thermische Kraft-, Fernheiz- und Fernheizkraftwerke	(h)	–3 720	0	–46 260	–	–420	–6460	–	–	–	7 060	22 320	–27 480	- Centrales thermiques class., chauffage à distance, centrales chaleur-force
- Gaswerke	(i)	–	–	–	–	–	0	–	–	–	–	–	0	- Usines à gaz
- Raffinerien	(j)	–	–	–	–132 710	132 710	–	–	–	–	–	–	0	- Raffineries
- Diverse Erneuerbare	(k)	–2 720	–	–	–	–	1 520	–	–	–18 660	17 740	–	–2 120	- Renouvelables div.
+ Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherungen	(l)	–	–	–	–	–6 320	–130	–	–	–	–35 480	–2 350	–44 280	+ Consommation propre du secteur énergétique, pertes de réseau, pompage d'accumulation
+ Nichtenergetischer Verbrauch	(m)	–	–	–	–	–18 890	–	–	–	–	–	–	–18 890	+ Consommation non énergétique
= Endverbrauch	(n)	41 270	3 850	12 280	–	347 090	101 650	–	–	32 260	205 310	21 360	765 070	= Consommation finale
Haushalte	(o)	17 140	50	–	–	51 320	45 550	–	–	19 050	69 680	8 520	211 310	Ménages
Industrie	(p)	12 920	3 800	12 010	–	11 610	33 100	–	–	2 030	62 310	7 770	145 550	Industrie
Dienstleistungen	(q)	10 230	0	270	–	25 730	20 250	–	–	3 920	57 040	5 070	122 510	Services
Verkehr	(r)	–	–	–	–	256 310	920	–	–	6 730	12 850	–	276 810	Transport
Statistische Differenz inkl. Landwirtschaft	(s)	980	0	0	–	2 120	1 830	–	–	530	3 430	0	8 890	Différence statistique, y compris l'agriculture

[1] + Lagerabnahme
– Lagerzunahme

[1] + diminution de stock
– augmentation de stock

BFE, Schweizerische Gesamtenergiestatistik 2022 (Tab. 4)
OFEN, Statistique globale suisse de l'énergie 2022 (tabl. 4)

[7] Note that Liechtenstein's consumption of liquid fuels is included in these numbers (see chp. 3.1.6.3).

Annex 5 Additional information concerning uncertainties

The tables in the following chapters provide information about the level and trend uncertainty analysis of all relevant air pollutant emissions in 1990 and 2022. Input data used for the uncertainty estimation are the same for approach 1 (uncertainty propagation) and approach 2 (Monte Carlo simulations) and listed in Annex A5.1. Uncertainty estimates obtained by approach 1 are given in the tables in Annex A5.2 and uncertainty estimates obtained by approach 2 are given in the tables in Annex A5.3.

Categories for which no emission is quantified for neither the base year nor the reporting year are not listed in the tables.

For tables reporting input uncertainties in Annex A5.1 and results from approach 1 in Annex A5.2, columns labelled A to M correspond exactly to columns A to M from Table 5-1 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 5, "Uncertainties 2019", or Table 3.2, chp. 3, from the 2006 IPCC Guidelines (IPCC 2006).

For tables reporting uncertainty results from approach 2, columns labelled A to J correspond exactly to columns A to J from Table 3.3, chp. 3, from the 2006 IPCC Guidelines (IPCC 2006).

A5.1 Uncertainty estimations: input data

Bibliographic references for tables of Annex A5.1:

EMEP/EEA 2019: Default values of EMEP/EEA 2019 and associated uncertainty ranges (activity data and emission factors).

EMIS: Uncertainties that are implemented in the EMIS database (activity data and emission factors).

GHGI: Uncertainty analysis of Switzerland's greenhouse gas inventory (FOEN 2024); mainly activity data.

France/Sweden: Uncertainties from France's or Sweden's Informative Inventory Reports (Citepa 2012, SEPA 2010); mainly emission factors.

UBA: Uncertainties for mobile sources from IFEU/INFRAS (2010), in which uncertainties are evaluated for road and non-road vehicles via Monte Carlo simulations (for emission factors).

UBA/INFRAS: PM10 emission factor uncertainties derived from raw data of IFEU/INFRAS (2010).

Kupper 2012: see References (chp. 12.1).

INFRAS 2017b: see References (chp. 12.1).

INFRAS 2021: see References (chp. 12.1).

Schleiss 2017: see References (chp. 12.1).

Schrade et al. 2024: see References (chp. 12.1).

Table A - 22 Input uncertainties for NO_x for the year 2022, assigned to activity data (col. E) and emissions factors (col. F). For normal and gamma distributions, the given uncertainty is the standard deviation with a coverage factor of 2, expressed in percentage of the mean.

A	B	E				F			
NFR code	Pollutant	Activity data uncertainty year 2022				Emission factor uncertainty year 2022			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	NOx (as NO2)	normal	10	no	GHGI	normal	19	yes	EMIS
1A1b	NOx (as NO2)	normal	1	no	GHGI	normal	20	yes	EMIS
1A1c	NOx (as NO2)	normal	5	no	EMIS	normal	20	yes	EMEP/EEA 2019
1A2a	NOx (as NO2)	normal	2	no	GHGI	normal	27	yes	EMIS
1A2b	NOx (as NO2)	normal	2	no	GHGI	normal	20	yes	EMIS
1A2c	NOx (as NO2)	normal	2	no	GHGI	normal	10	yes	EMIS
1A2d	NOx (as NO2)	normal	2	no	GHGI	normal	10	yes	EMIS
1A2e	NOx (as NO2)	normal	2	no	GHGI	normal	10	yes	EMIS
1A2f	NOx (as NO2)	normal	2	no	GHGI	normal	17	yes	EMIS
1A2gvii	NOx (as NO2)	normal	1	no	GHGI	normal	13	yes	UBA
1A2gviii	NOx (as NO2)	normal	2	no	GHGI	normal	17	yes	EMIS
1A3ai(i)	NOx (as NO2)	normal	1	no	GHGI	normal	20	yes	EMEP/EEA 2019
1A3aii(i)	NOx (as NO2)	normal	1	no	GHGI	normal	20	yes	EMEP/EEA 2019
1A3bi(fu)	NOx (as NO2)	normal	1	no	GHGI	normal	38	yes	UBA
1A3bii(fu)	NOx (as NO2)	normal	1	no	GHGI	normal	32	yes	UBA
1A3biii(fu)	NOx (as NO2)	normal	1	no	GHGI	normal	18	yes	UBA
1A3biv(fu)	NOx (as NO2)	normal	1	no	GHGI	normal	36	yes	UBA
1A3c	NOx (as NO2)	normal	1	no	GHGI	normal	13	yes	UBA
1A3dii	NOx (as NO2)	normal	1	no	GHGI	normal	13	yes	UBA
1A3ei	NOx (as NO2)	normal	2	no	GHGI	normal	50	yes	EMEP/EEA 2019
1A4ai	NOx (as NO2)	normal	2	no	GHGI	normal	16	yes	EMIS
1A4aii	NOx (as NO2)	normal	1	no	GHGI	normal	13	yes	UBA
1A4bi	NOx (as NO2)	normal	4	no	GHGI	normal	13	yes	EMIS
1A4bii	NOx (as NO2)	normal	1	no	GHGI	normal	30	yes	EMIS
1A4ci	NOx (as NO2)	normal	21	no	GHGI	normal	30	yes	EMIS
1A4cii	NOx (as NO2)	normal	1	no	GHGI	normal	13	yes	UBA
1A5b	NOx (as NO2)	normal	1	no	GHGI	normal	13	yes	UBA
1B2c	NOx (as NO2)	normal	22	no	EMIS	gamma	200	yes	EMIS
2A1	NOx (as NO2)	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2A2	NOx (as NO2)	normal	2	no	GHGI	gamma	500	yes	EMEP/EEA 2019
2A5a	NOx (as NO2)	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2B2	NOx (as NO2)	normal	2	no	GHGI	normal	10	yes	EMEP/EEA 2019
2B10a	NOx (as NO2)	normal	2	no	GHGI	normal	60	yes	EMEP/EEA 2019
2C1	NOx (as NO2)	normal	2	no	GHGI	normal	50	yes	EMEP/EEA 2019
2C3	NOx (as NO2)	normal	5	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7c	NOx (as NO2)	normal	5	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2G	NOx (as NO2)	normal	25	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2H3	NOx (as NO2)	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
3B1a	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B1b	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B2	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B3	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4d	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4e	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4f	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4gi	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4gii	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4giii	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4giv	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4h	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3Da1	NOx (as NO2)	normal	5	no	GHGI	normal	100	yes	EMEP/EEA 2019
3Da2a	NOx (as NO2)	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3Da2b	NOx (as NO2)	normal	6	no	GHGI	normal	100	yes	EMEP/EEA 2019
3Da2c	NOx (as NO2)	normal	20	no	Schleiss 2017	normal	100	yes	EMEP/EEA 2019
3Da3	NOx (as NO2)	normal	6	no	GHGI	normal	100	yes	EMEP/EEA 2019
5A	NOx (as NO2)	normal	10	no	GHGI	normal	50	yes	EMIS
5B2	NOx (as NO2)	normal	20	no	EMIS	normal	100	yes	EMEP/EEA 2019
5C1a	NOx (as NO2)	normal	50	no	EMIS	normal	40	yes	EMIS
5C1bi	NOx (as NO2)	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biii	NOx (as NO2)	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biv	NOx (as NO2)	normal	20	no	EMIS	normal	50	yes	EMIS
5C1bv	NOx (as NO2)	normal	5	no	EMIS	normal	30	yes	EMIS
5C2	NOx (as NO2)	normal	48	no	EMIS	gamma	156	yes	EMIS
5D1	NOx (as NO2)	normal	1	no	EMIS	normal	10	yes	EMIS
5D2	NOx (as NO2)	normal	10	no	EMIS	normal	10	yes	EMIS
6A	NOx (as NO2)	normal	30	no	EMIS	normal	50	yes	EMIS

Table A - 23 Input uncertainties for NMVOC for the year 2022, assigned to activity data (col. E) and emissions factors (col. F). For normal and gamma distributions, the given uncertainty is the standard deviation with a coverage factor of 2, expressed in percentage of the mean.

A	B	E				F			
NFR code	Pollutant	Activity data uncertainty year 2022				Emission factor uncertainty year 2022			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	NMVOC	normal	10	no	GHGI	normal	32	yes	EMIS
1A1b	NMVOC	normal	1	no	GHGI	normal	20	yes	EMIS
1A1c	NMVOC	normal	5	no	EMIS	normal	20	yes	EMEP/EEA 2019
1A2a	NMVOC	normal	2	no	GHGI	normal	18	yes	EMIS
1A2b	NMVOC	normal	2	no	GHGI	normal	19	yes	EMIS
1A2c	NMVOC	normal	2	no	GHGI	normal	10	yes	EMIS
1A2d	NMVOC	normal	2	no	GHGI	normal	10	yes	EMIS
1A2e	NMVOC	normal	2	no	GHGI	normal	10	yes	EMIS
1A2f	NMVOC	normal	2	no	GHGI	normal	30	yes	EMIS
1A2gvii	NMVOC	normal	1	no	GHGI	normal	34	yes	UBA
1A2gviii	NMVOC	normal	2	no	GHGI	normal	30	yes	EMIS
1A3ai(i)	NMVOC	normal	1	no	GHGI	normal	50	yes	EMEP/EEA 2019
1A3aii(i)	NMVOC	normal	1	no	GHGI	normal	50	yes	EMEP/EEA 2019
1A3bi(fu)	NMVOC	normal	1	no	GHGI	normal	52	yes	UBA
1A3bii(fu)	NMVOC	normal	1	no	GHGI	normal	46	yes	UBA
1A3biii(fu)	NMVOC	normal	1	no	GHGI	normal	22	yes	UBA
1A3biv(fu)	NMVOC	normal	1	no	GHGI	gamma	400	yes	UBA
1A3bv(fu)	NMVOC	normal	1	no	GHGI	normal	40	yes	UBA
1A3c	NMVOC	normal	1	no	GHGI	normal	34	yes	UBA
1A3dii	NMVOC	normal	1	no	GHGI	normal	34	yes	UBA
1A3ei	NMVOC	normal	2	no	GHGI	normal	50	yes	EMEP/EEA 2019
1A4ai	NMVOC	normal	2	no	GHGI	normal	56	yes	EMIS
1A4aii	NMVOC	normal	1	no	GHGI	normal	75	yes	Sweden
1A4bi	NMVOC	normal	4	no	GHGI	normal	68	yes	EMIS
1A4bii	NMVOC	normal	1	no	GHGI	normal	75	yes	Sweden
1A4ci	NMVOC	normal	21	no	GHGI	normal	75	yes	EMIS
1A4cii	NMVOC	normal	1	no	GHGI	normal	75	yes	Sweden
1A5b	NMVOC	normal	1	no	GHGI	normal	34	yes	UBA
1B2ai	NMVOC	normal	30	no	EMIS	normal	50	yes	EMEP/EEA 2019
1B2aiv	NMVOC	normal	30	no	EMEP/EEA 2019	normal	47	yes	EMIS
1B2av	NMVOC	normal	1	no	EMEP/EEA 2019	gamma	40	yes	EMIS
1B2b	NMVOC	normal	22	no	EMIS	normal	50	yes	EMEP/EEA 2019
1B2c	NMVOC	normal	22	no	EMIS	gamma	100	yes	EMIS
2A1	NMVOC	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2A2	NMVOC	normal	2	no	GHGI	gamma	500	yes	EMEP/EEA 2019
2A5a	NMVOC	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2B10a	NMVOC	normal	2	no	GHGI	normal	40	yes	EMEP/EEA 2019
2C1	NMVOC	normal	2	no	GHGI	gamma	100	yes	EMEP/EEA 2019
2C3	NMVOC	normal	5	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7a	NMVOC	normal	5	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2C7c	NMVOC	normal	5	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2D3a	NMVOC	normal	1	no	EMIS	normal	50	no	EMIS
2D3b	NMVOC	normal	5	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2D3c	NMVOC	normal	20	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2D3d	NMVOC	normal	20	no	EMIS	normal	40	yes	EMEP/EEA 2019
2D3e	NMVOC	normal	40	no	EMIS	normal	50	yes	EMEP/EEA 2019
2D3f	NMVOC	normal	20	no	EMIS	normal	40	yes	EMEP/EEA 2019
2D3g	NMVOC	normal	30	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2D3h	NMVOC	normal	20	no	EMIS	normal	40	yes	EMEP/EEA 2019
2D3i	NMVOC	normal	30	no	EMEP/EEA 2019	gamma	180	yes	EMEP/EEA 2019
2G	NMVOC	normal	25	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2H1	NMVOC	normal	30	no	EMEP/EEA 2019	gamma	200	yes	EMEP/EEA 2019
2H2	NMVOC	normal	10	no	EMEP/EEA 2019	gamma	100	yes	EMEP/EEA 2019
2H3	NMVOC	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
3B1a	NMVOC	normal	6	no	GHGI	normal	60	yes	Schrade 2024
3B1b	NMVOC	normal	6	no	GHGI	normal	70	yes	Schrade 2024
3B2	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B3	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4d	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4e	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4f	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4gi	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4gii	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4giii	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4giv	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3B4h	NMVOC	normal	6	no	GHGI	gamma	200	yes	EMEP/EEA 2019
3De	NMVOC	normal	5	no	GHGI (LULUCF)	gamma	200	yes	EMEP/EEA 2019
5A	NMVOC	normal	10	no	GHGI	normal	50	yes	EMIS
5B1	NMVOC	normal	20	no	Schleiss 2017	normal	100	yes	EMIS
5B2	NMVOC	normal	20	no	EMIS	normal	30	yes	EMIS
5C1a	NMVOC	normal	50	no	EMIS	normal	50	yes	EMIS
5C1bi	NMVOC	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biii	NMVOC	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biv	NMVOC	normal	20	no	EMIS	normal	20	yes	EMIS
5C1bv	NMVOC	normal	5	no	EMIS	normal	30	yes	EMIS
5C2	NMVOC	normal	48	no	EMIS	gamma	156	yes	EMIS
5D1	NMVOC	normal	1	no	EMIS	normal	27	yes	EMIS
5D2	NMVOC	normal	10	no	EMIS	normal	20	yes	EMIS
5E	NMVOC	normal	20	no	EMIS	normal	24	yes	EMIS
6A	NMVOC	normal	30	no	EMIS	normal	50	yes	EMIS

Table A - 24 Input uncertainties for SO_x for the year 2022, assigned to activity data (col. E) and emissions factors (col. F). For normal and gamma distributions, the given uncertainty is the standard deviation with a coverage factor of 2, expressed in percentage of the mean.

A	B	E				F			
NFR code	Pollutant	Activity data uncertainty year 2022				Emission factor uncertainty year 2022			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	SOx (as SO2)	normal	10	no	GHGI	normal	22	yes	EMIS
1A1b	SOx (as SO2)	normal	1	no	GHGI	normal	20	yes	EMIS
1A2a	SOx (as SO2)	normal	2	no	GHGI	normal	15	yes	EMIS
1A2b	SOx (as SO2)	normal	2	no	GHGI	normal	10	yes	EMIS
1A2c	SOx (as SO2)	normal	2	no	GHGI	normal	11	yes	EMIS
1A2d	SOx (as SO2)	normal	2	no	GHGI	normal	14	yes	EMIS
1A2e	SOx (as SO2)	normal	2	no	GHGI	normal	12	yes	EMIS
1A2f	SOx (as SO2)	normal	2	no	GHGI	normal	19	yes	EMIS
1A2gvii	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A2gviii	SOx (as SO2)	normal	2	no	GHGI	normal	19	yes	EMIS
1A3ai(i)	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3aii(i)	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3bi(fu)	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3bii(fu)	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3biii(fu)	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3biv(fu)	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3c	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3dii	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3ei	SOx (as SO2)	normal	2	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A4ai	SOx (as SO2)	normal	2	no	GHGI	normal	10	yes	EMIS
1A4aii	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A4bi	SOx (as SO2)	normal	4	no	GHGI	normal	10	yes	EMIS
1A4bii	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A4ci	SOx (as SO2)	normal	21	no	GHGI	normal	18	yes	EMIS
1A4cii	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A5b	SOx (as SO2)	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1B2aiv	SOx (as SO2)	normal	30	no	EMEP/EEA 2019	normal	47	yes	EMIS
1B2c	SOx (as SO2)	normal	22	no	EMIS	normal	31	yes	EMIS
2A1	SOx (as SO2)	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2A2	SOx (as SO2)	normal	2	no	GHGI	gamma	500	yes	EMEP/EEA 2019
2A5a	SOx (as SO2)	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2B5	SOx (as SO2)	normal	2	no	GHGI	normal	20	yes	EMEP/EEA 2019
2B10a	SOx (as SO2)	normal	2	no	GHGI	normal	40	yes	EMEP/EEA 2019
2C1	SOx (as SO2)	normal	2	no	GHGI	gamma	100	yes	EMEP/EEA 2019
2C3	SOx (as SO2)	normal	5	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7c	SOx (as SO2)	normal	5	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2G	SOx (as SO2)	normal	25	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2H3	SOx (as SO2)	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
5B2	SOx (as SO2)	normal	20	no	EMIS	normal	100	yes	EMIS
5C1a	SOx (as SO2)	normal	50	no	EMIS	normal	40	yes	EMIS
5C1bi	SOx (as SO2)	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biii	SOx (as SO2)	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biv	SOx (as SO2)	normal	20	no	EMIS	normal	30	yes	EMIS
5C2	SOx (as SO2)	normal	48	no	EMIS	gamma	133	yes	EMIS
5D1	SOx (as SO2)	normal	1	no	EMIS	normal	37	yes	EMIS
5D2	SOx (as SO2)	normal	10	no	EMIS	normal	20	yes	EMIS
6A	SOx (as SO2)	normal	30	no	EMIS	normal	50	yes	EMIS

Table A - 25 Input uncertainties for NH_3 for the year 2022, assigned to activity data (col. E) and emissions factors (col. F). For normal and gamma distributions, the given uncertainty is the standard deviation with a coverage factor of 2, expressed in percentage of the mean.

A	B	E				F			
NFR code	Pollutant	Activity data uncertainty year 2022				Emission factor uncertainty year 2022			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	NH3	normal	10	no	GHGI	normal	20	yes	EMIS
1A1b	NH3	normal	1	no	GHGI	normal	10	yes	EMIS
1A2a	NH3	normal	2	no	GHGI	normal	10	yes	EMIS
1A2b	NH3	normal	2	no	GHGI	normal	10	yes	EMIS
1A2c	NH3	normal	2	no	GHGI	normal	10	yes	EMIS
1A2d	NH3	normal	2	no	GHGI	normal	10	yes	EMIS
1A2e	NH3	normal	2	no	GHGI	normal	10	yes	EMIS
1A2f	NH3	normal	2	no	GHGI	normal	9	yes	EMIS
1A2gvii	NH3	normal	1	no	GHGI	normal	50	yes	France
1A2gviii	NH3	normal	2	no	GHGI	normal	9	yes	EMIS
1A3bi(fu)	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3bii(fu)	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3biii(fu)	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3biv(fu)	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3c	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3dii	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3ei	NH3	normal	2	no	GHGI	normal	50	yes	France
1A4ai	NH3	normal	2	no	GHGI	normal	10	yes	EMIS
1A4aii	NH3	normal	1	no	GHGI	normal	10	yes	EMIS
1A4bi	NH3	normal	4	no	GHGI	normal	10	yes	EMIS
1A4bii	NH3	normal	1	no	GHGI	normal	10	yes	EMIS
1A4ci	NH3	normal	21	no	GHGI	normal	10	yes	EMIS
1A4cii	NH3	normal	1	no	GHGI	normal	50	yes	France
1A5b	NH3	normal	1	no	GHGI	normal	50	yes	France
2B1	NH3	normal	2	no	GHGI	normal	10	yes	EMEP/EEA 2019
2B2	NH3	normal	2	no	GHGI	normal	10	yes	EMEP/EEA 2019
2B10a	NH3	normal	2	no	GHGI	normal	40	yes	EMEP/EEA 2019
2C1	NH3	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7c	NH3	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2G	NH3	normal	25	no	EMIS	normal	40	yes	EMEP/EEA 2019
2H2	NH3	normal	10	no	EMEP/EEA 2019	gamma	500	yes	EMEP/EEA 2019
2H3	NH3	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2L	NH3	normal	25	no	EMIS	normal	100	yes	EMEP/EEA 2019
3B1a	NH3	normal	6	no	GHGI	normal	29	yes	INFRAS 2021
3B1b	NH3	normal	6	no	GHGI	normal	27	yes	INFRAS 2021
3B2	NH3	normal	6	no	GHGI	normal	87	yes	INFRAS 2021
3B3	NH3	normal	6	no	GHGI	normal	40	yes	INFRAS 2021
3B4d	NH3	normal	6	no	GHGI	normal	65	yes	INFRAS 2021
3B4e	NH3	normal	6	no	GHGI	normal	52	yes	INFRAS 2021
3B4f	NH3	normal	6	no	GHGI	normal	68	yes	INFRAS 2021
3B4gi	NH3	normal	6	no	GHGI	normal	82	yes	INFRAS 2021
3B4gii	NH3	normal	6	no	GHGI	normal	86	yes	INFRAS 2021
3B4giii	NH3	normal	6	no	GHGI	normal	93	yes	INFRAS 2021
3B4giv	NH3	normal	6	no	GHGI	normal	85	yes	INFRAS 2021
3B4h	NH3	normal	6	no	GHGI	normal	50	yes	INFRAS 2021
3Da1	NH3	normal	5	no	GHGI	normal	50	yes	Kupper 2012
3Da2a	NH3	normal	6	no	GHGI	normal	21	yes	INFRAS 2021
3Da2b	NH3	normal	6	no	GHGI	normal	50	yes	Kupper 2012
3Da2c	NH3	normal	20	no	Schleiss 2017	normal	50	yes	Kupper 2012
3Da3	NH3	normal	6	no	GHGI	normal	62	yes	INFRAS 2021
5A	NH3	normal	10	no	GHGI	normal	50	yes	EMIS
5B1	NH3	normal	20	no	Schleiss 2017	normal	100	yes	EMIS
5B2	NH3	normal	20	no	EMIS	normal	75	yes	INFRAS 2014
5C1biv	NH3	normal	20	no	EMIS	normal	50	yes	EMIS
5C2	NH3	normal	48	no	EMIS	normal	25	yes	EMIS
5D1	NH3	normal	1	no	EMIS	normal	50	yes	EMIS
6A	NH3	normal	30	no	EMIS	normal	100	yes	EMEP/EEA 2019

Table A - 26 Input uncertainties for PM2.5 for the year 2022, assigned to activity data (col. E) and emissions factors (col. F). For normal and gamma distributions, the given uncertainty is the standard deviation with a coverage factor of 2, expressed in percentage of the mean.

A	B	E				F			
NFR code	Pollutant	Activity data uncertainty year 2022				Emission factor uncertainty year 2022			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	PM2.5	normal	10	no	GHGI	normal	71	yes	EMIS
1A1b	PM2.5	normal	1	no	GHGI	normal	20	yes	EMIS
1A1c	PM2.5	normal	5	no	EMIS	normal	20	yes	EMEP/EEA 2019
1A2a	PM2.5	normal	2	no	GHGI	normal	28	yes	EMIS
1A2b	PM2.5	normal	2	no	GHGI	normal	30	yes	EMIS
1A2c	PM2.5	normal	2	no	GHGI	normal	10	yes	EMIS
1A2d	PM2.5	normal	2	no	GHGI	normal	33	yes	EMIS
1A2e	PM2.5	normal	2	no	GHGI	normal	10	yes	EMIS
1A2f	PM2.5	normal	2	no	GHGI	normal	65	yes	EMIS
1A2gvii	PM2.5	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A2gviii	PM2.5	normal	2	no	GHGI	normal	65	yes	EMIS
1A3ai(i)	PM2.5	normal	1	no	GHGI	normal	30	yes	UBA/INFRAS
1A3aii(i)	PM2.5	normal	1	no	GHGI	normal	30	yes	UBA/INFRAS
1A3bi(fu)	PM2.5	normal	1	no	GHGI	normal	57	yes	UBA/INFRAS
1A3bii(fu)	PM2.5	normal	1	no	GHGI	normal	48	yes	UBA/INFRAS
1A3biii(fu)	PM2.5	normal	1	no	GHGI	normal	27	yes	UBA/INFRAS
1A3biv(fu)	PM2.5	normal	1	no	GHGI	normal	54	yes	UBA/INFRAS
1A3bvi(fu)	PM2.5	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A3c	PM2.5	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A3dii	PM2.5	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A3ei	PM2.5	normal	2	no	GHGI	normal	27	yes	UBA/INFRAS
1A4ai	PM2.5	normal	2	no	GHGI	normal	78	yes	EMIS
1A4bi	PM2.5	normal	4	no	GHGI	normal	76	yes	EMIS
1A4ci	PM2.5	normal	21	no	GHGI	normal	39	yes	EMIS
1A4cii	PM2.5	normal	1	no	GHGI	normal	80	yes	EMIS
1A5b	PM2.5	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1B1a	PM2.5	normal	30	no	EMEP/EEA 2019	normal	40	yes	EMIS
1B2c	PM2.5	normal	22	no	EMIS	gamma	237	yes	EMEP/EEA 2019
2A1	PM2.5	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2A2	PM2.5	normal	2	no	GHGI	gamma	500	yes	EMEP/EEA 2019
2A5a	PM2.5	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2B5	PM2.5	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2B10a	PM2.5	normal	2	no	GHGI	normal	40	yes	EMEP/EEA 2019
2C1	PM2.5	normal	2	no	GHGI	gamma	125	yes	EMEP/EEA 2019
2C3	PM2.5	normal	5	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7a	PM2.5	normal	5	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2C7c	PM2.5	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2D3c	PM2.5	normal	20	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2D3i	PM2.5	normal	30	no	EMEP/EEA 2019	gamma	500	yes	EMEP/EEA 2019
2G	PM2.5	normal	25	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2H1	PM2.5	normal	30	no	EMEP/EEA 2019	gamma	200	yes	EMEP/EEA 2019
2H2	PM2.5	normal	10	no	EMEP/EEA 2019	gamma	500	yes	EMEP/EEA 2019
2H3	PM2.5	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2I	PM2.5	normal	10	no	EMEP/EEA 2019	gamma	500	yes	EMEP/EEA 2019
3B1a	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B1b	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B2	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B3	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4d	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4e	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4f	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4gi	PM2.5	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4gii	PM2.5	normal	6	no	GHGI	gamma	300	yes	none
3B4giii	PM2.5	normal	6	no	GHGI	gamma	300	yes	none
3B4giv	PM2.5	normal	6	no	GHGI	gamma	300	yes	none
3B4h	PM2.5	normal	6	no	GHGI	gamma	300	yes	none
3De	PM2.5	normal	5	no	GHGI (LULUCF)	gamma	200	yes	EMEP/EEA 2019
5A	PM2.5	normal	10	no	GHGI	normal	30	yes	EMIS
5B2	PM2.5	normal	20	no	EMIS	normal	100	yes	EMIS
5C1a	PM2.5	normal	50	no	EMIS	normal	30	yes	EMIS
5C1bi	PM2.5	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biii	PM2.5	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biv	PM2.5	normal	20	no	EMIS	normal	34	yes	EMIS
5C1bv	PM2.5	normal	5	no	EMIS	normal	33	yes	EMIS
5C2	PM2.5	normal	48	no	EMIS	gamma	156	yes	EMIS
5E	PM2.5	normal	20	no	EMIS	normal	30	yes	EMIS
6A	PM2.5	normal	30	no	EMIS	normal	40	yes	EMIS

Table A - 27 Input uncertainties for PM10 for the year 2022, assigned to activity data (col. E) and emissions factors (col. F). For normal and gamma distributions, the given uncertainty is the standard deviation with a coverage factor of 2, expressed in percentage of the mean.

A	B	E				F			
NFR code	Pollutant	Activity data uncertainty year 2022				Emission factor uncertainty year 2022			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	PM10	normal	10	no	GHGI	normal	71	yes	EMIS
1A1b	PM10	normal	1	no	GHGI	normal	20	yes	EMIS
1A1c	PM10	normal	5	no	EMIS	normal	20	yes	EMEP/EEA 2019
1A2a	PM10	normal	2	no	GHGI	normal	28	yes	EMIS
1A2b	PM10	normal	2	no	GHGI	normal	30	yes	EMIS
1A2c	PM10	normal	2	no	GHGI	normal	10	yes	EMIS
1A2d	PM10	normal	2	no	GHGI	normal	33	yes	EMIS
1A2e	PM10	normal	2	no	GHGI	normal	10	yes	EMIS
1A2f	PM10	normal	2	no	GHGI	normal	65	yes	EMIS
1A2gvii	PM10	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A2gviii	PM10	normal	2	no	GHGI	normal	65	yes	EMIS
1A3ai(i)	PM10	normal	1	no	GHGI	normal	30	yes	UBA/INFRAS
1A3aii(i)	PM10	normal	1	no	GHGI	normal	30	yes	UBA/INFRAS
1A3bi(fu)	PM10	normal	1	no	GHGI	normal	57	yes	UBA/INFRAS
1A3bii(fu)	PM10	normal	1	no	GHGI	normal	48	yes	UBA/INFRAS
1A3biii(fu)	PM10	normal	1	no	GHGI	normal	27	yes	UBA/INFRAS
1A3biv(fu)	PM10	normal	1	no	GHGI	normal	54	yes	UBA/INFRAS
1A3bvi(fu)	PM10	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A3c	PM10	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A3dii	PM10	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1A3ei	PM10	normal	2	no	GHGI	normal	27	yes	UBA/INFRAS
1A4ai	PM10	normal	2	no	GHGI	normal	78	yes	EMIS
1A4bi	PM10	normal	4	no	GHGI	normal	76	yes	EMIS
1A4ci	PM10	normal	21	no	GHGI	normal	39	yes	EMIS
1A4cii	PM10	normal	1	no	GHGI	normal	80	yes	EMIS
1A5b	PM10	normal	1	no	GHGI	normal	50	yes	UBA/INFRAS
1B1a	PM10	normal	30	no	EMEP/EEA 2019	normal	40	yes	EMIS
1B2c	PM10	normal	22	no	EMIS	gamma	237	yes	EMEP/EEA 2019
2A1	PM10	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2A2	PM10	normal	2	no	GHGI	gamma	500	yes	EMEP/EEA 2019
2A5a	PM10	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2B5	PM10	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2B10a	PM10	normal	2	no	GHGI	normal	40	yes	EMEP/EEA 2019
2C1	PM10	normal	2	no	GHGI	gamma	125	yes	EMEP/EEA 2019
2C3	PM10	normal	5	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7a	PM10	normal	5	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2C7c	PM10	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2D3c	PM10	normal	20	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2D3i	PM10	normal	30	no	EMEP/EEA 2019	gamma	500	yes	EMEP/EEA 2019
2G	PM10	normal	25	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2H1	PM10	normal	30	no	EMEP/EEA 2019	gamma	200	yes	EMEP/EEA 2019
2H2	PM10	normal	10	no	EMEP/EEA 2019	gamma	500	yes	EMEP/EEA 2019
2H3	PM10	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
2I	PM10	normal	10	no	EMEP/EEA 2019	gamma	500	yes	EMEP/EEA 2019
3B1a	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B1b	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B2	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B3	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4d	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4e	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4f	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4gi	PM10	normal	6	no	GHGI	gamma	300	yes	EMIS
3B4gii	PM10	normal	6	no	GHGI	gamma	300	yes	None
3B4giii	PM10	normal	6	no	GHGI	gamma	300	yes	None
3B4giv	PM10	normal	6	no	GHGI	gamma	300	yes	None
3B4h	PM10	normal	6	no	GHGI	gamma	300	yes	None
3De	PM10	normal	5	no	GHGI (LULUCF)	gamma	200	yes	EMEP/EEA 2019
5A	PM10	normal	10	no	GHGI	normal	30	yes	EMIS
5B2	PM10	normal	20	no	EMIS	normal	100	yes	EMIS
5C1a	PM10	normal	50	no	EMIS	normal	50	yes	EMIS
5C1bi	PM10	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biii	PM10	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biv	PM10	normal	20	no	EMIS	normal	35	yes	EMIS
5C1bv	PM10	normal	5	no	EMIS	normal	33	yes	EMIS
5C2	PM10	normal	48	no	EMIS	gamma	156	yes	EMIS
5E	PM10	normal	20	no	EMIS	normal	30	yes	EMIS
6A	PM10	normal	30	no	EMIS	normal	40	yes	EMIS

A5.2 Uncertainty estimations: results from approach 1

Table A - 28 Uncertainty analysis of NO_x emissions, approach 1, for 2022 and for the trend 1990-2022. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
NFR	Pollutant	Emissions 1990	Emissions 2022	Emission combined uncertainty 2022		Category contribution to inventory variance 2022		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	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1A1a	NOx (as NO2)	6'337.60	2'150.66	21	21	0.856	0.856	0.001	0.015	0.216	0.216	0.013	0.013	0.047	0.047
1A1b	NOx (as NO2)	494.17	361.20	20	20	0.021	0.021	0.001	0.003	0.005	0.005	0.026	0.026	0.001	0.001
1A1c	NOx (as NO2)	0.01	0.03	21	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2a	NOx (as NO2)	279.07	117.53	27	27	0.004	0.004	0.000	0.001	0.002	0.002	0.004	0.004	0.000	0.000
1A2b	NOx (as NO2)	127.53	34.74	20	20	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
1A2c	NOx (as NO2)	1'050.42	225.04	10	10	0.002	0.002	0.001	0.002	0.005	0.005	0.010	0.010	0.000	0.000
1A2d	NOx (as NO2)	1'261.91	40.44	10	10	0.000	0.000	0.003	0.000	0.001	0.001	0.029	0.029	0.001	0.001
1A2e	NOx (as NO2)	743.69	216.06	10	10	0.002	0.002	0.000	0.002	0.004	0.004	0.003	0.003	0.000	0.000
1A2f	NOx (as NO2)	10'534.54	3'203.25	17	17	1.207	1.207	0.004	0.023	0.064	0.064	0.064	0.064	0.008	0.008
1A2gvii	NOx (as NO2)	6'333.94	1'629.49	13	13	0.182	0.182	0.004	0.012	0.021	0.021	0.057	0.057	0.004	0.004
1A2gviii	NOx (as NO2)	2'181.62	2'067.94	17	17	0.503	0.503	0.009	0.015	0.043	0.043	0.156	0.156	0.026	0.026
1A3ai(i)	NOx (as NO2)	1'214.30	1'671.30	20	20	0.450	0.450	0.009	0.012	0.022	0.022	0.176	0.176	0.032	0.032
1A3aii(i)	NOx (as NO2)	153.76	49.45	20	20	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
1A3bi(fu)	NOx (as NO2)	43'771.53	15'855.80	38	38	147.612	147.612	0.002	0.113	0.205	0.205	0.092	0.092	0.051	0.051
1A3bii(fu)	NOx (as NO2)	6'196.89	3'956.48	32	32	6.527	6.527	0.012	0.028	0.051	0.051	0.402	0.402	0.164	0.164
1A3biii(fu)	NOx (as NO2)	29'657.53	3'268.82	18	18	1.397	1.397	0.051	0.023	0.042	0.042	0.924	0.924	0.856	0.856
1A3biv(fu)	NOx (as NO2)	308.61	208.72	36	36	0.023	0.023	0.001	0.001	0.003	0.003	0.025	0.025	0.001	0.001
1A3c	NOx (as NO2)	595.50	349.85	13	13	0.008	0.008	0.001	0.002	0.005	0.005	0.013	0.013	0.000	0.000
1A3dii	NOx (as NO2)	1'054.73	926.98	13	13	0.059	0.059	0.004	0.007	0.012	0.012	0.051	0.051	0.003	0.003
1A3ei	NOx (as NO2)	19.41	14.15	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A4ai	NOx (as NO2)	5'132.30	2'956.73	16	16	0.907	0.907	0.008	0.021	0.047	0.047	0.129	0.129	0.019	0.019
1A4aii	NOx (as NO2)	16.28	41.71	13	13	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.003	0.000	0.000
1A4bi	NOx (as NO2)	11'636.07	4'009.36	14	14	1.180	1.180	0.001	0.028	0.150	0.150	0.011	0.011	0.023	0.023
1A4bii	NOx (as NO2)	18.76	20.71	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A4ci	NOx (as NO2)	398.34	398.41	37	37	0.086	0.086	0.002	0.003	0.085	0.085	0.055	0.055	0.010	0.010
1A4cii	NOx (as NO2)	4'357.53	1'702.53	13	13	0.199	0.199	0.001	0.012	0.022	0.022	0.015	0.015	0.001	0.001
1A5b	NOx (as NO2)	882.99	399.52	13	13	0.011	0.011	0.001	0.003	0.005	0.005	0.008	0.008	0.000	0.000
1B2c	NOx (as NO2)	211.21	0.59	100	276	0.000	0.000	0.001	0.000	0.000	0.000	0.052	0.145	0.003	0.021
2A1	NOx (as NO2)	15.87	10.41	98	275	0.000	0.003	0.000	0.000	0.000	0.000	0.003	0.009	0.000	0.000
2A2	NOx (as NO2)	0.27	0.27	100	740	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
2A5a	NOx (as NO2)	1.79	0.44	100	741	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
2B2	NOx (as NO2)	82.78	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B10a	NOx (as NO2)	8.93	0.62	60	60	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2C1	NOx (as NO2)	245.46	169.38	50	50	0.029	0.029	0.001	0.001	0.003	0.003	0.029	0.029	0.001	0.001
2C3	NOx (as NO2)	17.41	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7c	NOx (as NO2)	NA	1.36	74	122	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2G	NOx (as NO2)	29.36	18.02	78	125	0.001	0.002	0.000	0.000	0.005	0.005	0.004	0.007	0.000	0.000
2H3	NOx (as NO2)	91.00	22.82	98	275	0.002	0.016	0.000	0.000	0.001	0.001	0.007	0.018	0.000	0.000
3B1a	NOx (as NO2)	672.34	381.80	50	50	0.149	0.149	0.001	0.003	0.025	0.025	0.051	0.051	0.003	0.003
3B1b	NOx (as NO2)	344.32	277.29	50	50	0.078	0.078	0.001	0.002	0.018	0.018	0.055	0.055	0.003	0.003
3B2	NOx (as NO2)	67.60	64.25	50	50	0.004	0.004	0.000	0.000	0.004	0.004	0.014	0.014	0.000	0.000
3B3	NOx (as NO2)	185.29	88.39	50	50	0.008	0.008	0.000	0.001	0.006	0.006	0.008	0.008	0.000	0.000
3B4d	NOx (as NO2)	21.62	22.73	50	50	0.001	0.001	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.000
3B4e	NOx (as NO2)	17.58	26.27	50	50	0.001	0.001	0.000	0.000	0.002	0.002	0.007	0.007	0.000	0.000
3B4f	NOx (as NO2)	1.35	7.06	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
3B4gi	NOx (as NO2)	7.19	9.51	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
3B4gii	NOx (as NO2)	4.46	12.56	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000
3B4giii	NOx (as NO2)	0.44	0.37	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3B4giv	NOx (as NO2)	0.84	1.30	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3B4h	NOx (as NO2)	1.03	4.95	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
3Da1	NOx (as NO2)	1'204.90	694.77	100	100	1.943	1.943	0.002	0.005	0.035	0.035	0.190	0.190	0.037	0.037
3Da2a	NOx (as NO2)	2'075.01	1'466.31	50	50	2.194	2.194	0.005	0.010	0.095	0.095	0.259	0.259	0.076	0.076
3Da2b	NOx (as NO2)	87.01	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3Da2c	NOx (as NO2)	14.76	118.82	102	102	0.059	0.059	0.001	0.001	0.024	0.024	0.081	0.081	0.007	0.007
3Da3	NOx (as NO2)	243.41	419.61	100	100	0.710	0.710	0.002	0.003	0.027	0.027	0.237	0.237	0.057	0.057
5A	NOx (as NO2)	1.83	1.28	51	51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5B2	NOx (as NO2)	NA	6.03	102	102	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000
5C1a	NOx (as NO2)	80.75	39.02	64	64	0.003	0.003	0.000	0.000	0.020	0.020	0.003	0.003	0.000	0.000
5C1bi	NOx (as NO2)	9.75	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biii	NOx (as NO2)	22.50	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biv	NOx (as NO2)	114.00	38.75	54	54	0.002	0.002	0.000	0.000	0.008	0.008	0.001	0.001	0.000	0.000
5C1bv	NOx (as NO2)	11.25	13.79	30	30	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
5C2	NOx (as NO2)	31.10	15.83	104	211	0.001	0.004	0.000	0.000	0.008	0.008	0.003	0.007	0.000	0.000
5D1	NOx (as NO2)	25.35	5.14	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5D2	NOx (as NO2)	0.25	1.27	14	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6A	NOx (as NO2)	92.04	89.55	58	58	0.011	0.011	0.000	0.001	0.027	0.027	0.020	0.020	0.001	0.001
Total						166.4	166.5							1.4	1.5
Total		140'801	49'907	Emissions 2022 uncertainty (%):		12.9	12.9			Trend uncertainty (%):				1.2	1.2

Table A - 29 Uncertainty analysis of NMVOC emissions, approach 1, for 2022 and for the trend 1990-2022. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
NFR	Pollutant	Emissions 1990	Emissions 2022	Emission combined uncertainty 2022		Category contribution to inventory variance 2022		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	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1A1a	NMVOC	320.80	193.02	34	34	0.008	0.008	0.000	0.001	0.009	0.009	0.012	0.012	0.000	0.000
1A1b	NMVOC	6.95	2.72	20	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A1c	NMVOC	2.13	5.86	21	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2a	NMVOC	8.95	6.88	18	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2b	NMVOC	53.62	6.99	19	19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2c	NMVOC	34.22	20.40	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2d	NMVOC	29.90	3.90	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2e	NMVOC	22.05	20.41	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A2f	NMVOC	596.56	452.61	30	30	0.035	0.035	0.001	0.002	0.004	0.004	0.031	0.031	0.001	0.001
1A2gvii	NMVOC	1'331.50	264.61	34	34	0.015	0.015	0.000	0.001	0.002	0.002	0.007	0.007	0.000	0.000
1A2gviii	NMVOC	294.30	124.82	30	30	0.003	0.003	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.000
1A3ai(i)	NMVOC	247.46	118.42	50	50	0.007	0.007	0.000	0.000	0.001	0.001	0.010	0.010	0.000	0.000
1A3aii(i)	NMVOC	58.81	31.54	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A3bi(fu)	NMVOC	55'937.77	3'862.01	52	52	7.740	7.740	0.033	0.013	0.024	0.024	1.737	1.737	3.018	3.018
1A3bii(fu)	NMVOC	4'919.59	149.88	46	46	0.009	0.009	0.004	0.001	0.001	0.001	0.163	0.163	0.027	0.027
1A3biii(fu)	NMVOC	3'419.18	80.66	22	22	0.001	0.001	0.003	0.000	0.000	0.000	0.056	0.056	0.003	0.003
1A3biv(fu)	NMVOC	5'733.49	842.76	100	599	1.351	48.439	0.002	0.003	0.005	0.005	0.190	1.140	0.036	1.301
1A3bv(fu)	NMVOC	16'980.67	1'912.73	40	40	1.114	1.114	0.008	0.006	0.012	0.012	0.304	0.304	0.093	0.093
1A3c	NMVOC	83.76	40.92	34	34	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
1A3dii	NMVOC	1'640.55	396.59	34	34	0.035	0.035	0.000	0.001	0.002	0.002	0.001	0.001	0.000	0.000
1A3ei	NMVOC	0.90	0.69	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	NMVOC	1'329.00	876.67	56	56	0.459	0.459	0.002	0.003	0.007	0.007	0.104	0.104	0.011	0.011
1A4aii	NMVOC	1'091.65	314.67	75	75	0.106	0.106	0.000	0.001	0.002	0.002	0.012	0.012	0.000	0.000
1A4bi	NMVOC	10'056.33	2'405.77	68	68	5.105	5.105	0.000	0.008	0.043	0.043	0.014	0.014	0.002	0.002
1A4bii	NMVOC	398.23	124.81	75	75	0.017	0.017	0.000	0.000	0.001	0.001	0.007	0.007	0.000	0.000
1A4ci	NMVOC	235.07	253.44	78	78	0.074	0.074	0.001	0.001	0.026	0.026	0.050	0.050	0.003	0.003
1A4cii	NMVOC	4'369.08	823.64	75	75	0.726	0.726	0.001	0.003	0.005	0.005	0.063	0.063	0.004	0.004
1A5b	NMVOC	160.25	64.20	34	34	0.001	0.001	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1B2ai	NMVOC	0.02	0.01	58	58	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1B2aiv	NMVOC	1'344.61	232.65	56	56	0.032	0.032	0.000	0.001	0.033	0.033	0.015	0.015	0.001	0.001
1B2av	NMVOC	19'127.24	1'992.18	36	44	0.975	1.448	0.009	0.007	0.012	0.012	0.328	0.399	0.107	0.160
1B2b	NMVOC	323.52	188.57	55	55	0.020	0.020	0.000	0.001	0.020	0.020	0.018	0.018	0.001	0.001
1B2c	NMVOC	13.72	0.04	77	124	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2A1	NMVOC	41.25	27.07	98	275	0.001	0.011	0.000	0.000	0.000	0.000	0.006	0.016	0.000	0.000
2A2	NMVOC	0.69	0.69	100	740	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
2A5a	NMVOC	4.59	1.14	100	741	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B10a	NMVOC	608.61	15.39	40	40	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.018	0.000	0.000
2C1	NMVOC	1'053.60	222.26	74	122	0.051	0.140	0.000	0.001	0.002	0.002	0.009	0.015	0.000	0.000
2C3	NMVOC	56.57	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7a	NMVOC	2.98	0.39	98	275	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7c	NMVOC	NA	0.44	74	122	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2D3a	NMVOC	8'866.55	6'396.95	50	50	19.463	19.463	0.014	0.022	0.031	0.031	1.530	1.530	2.341	2.341
2D3b	NMVOC	4'895.00	2'683.80	74	122	7.474	20.421	0.005	0.009	0.064	0.064	0.370	0.612	0.141	0.379
2D3c	NMVOC	2'430.00	373.01	76	124	0.154	0.404	0.001	0.001	0.036	0.036	0.056	0.092	0.004	0.010
2D3d	NMVOC	40'731.00	8'283.08	45	45	26.095	26.095	0.006	0.028	0.792	0.792	0.230	0.230	0.681	0.681
2D3e	NMVOC	11'731.23	1'566.25	64	64	1.913	1.913	0.004	0.005	0.300	0.300	0.222	0.222	0.139	0.139
2D3f	NMVOC	910.00	61.00	45	45	0.001	0.001	0.001	0.000	0.006	0.006	0.022	0.022	0.001	0.001
2D3g	NMVOC	27'503.97	3'188.49	80	126	12.241	30.515	0.012	0.011	0.457	0.457	0.885	1.466	0.993	2.358
2D3h	NMVOC	20'353.80	3'642.07	45	45	5.045	5.045	0.005	0.012	0.348	0.348	0.182	0.182	0.155	0.155
2D3i	NMVOC	5'470.21	1'931.66	100	245	7.159	42.597	0.002	0.007	0.277	0.277	0.191	0.485	0.113	0.312
2G	NMVOC	22'431.61	6'305.80	101	277	77.021	578.127	0.003	0.021	0.754	0.754	0.266	0.749	0.639	1.130
2H1	NMVOC	554.99	216.67	102	277	0.093	0.685	0.000	0.001	0.031	0.031	0.027	0.075	0.002	0.007
2H2	NMVOC	1'950.03	2'010.81	74	122	4.253	11.521	0.005	0.007	0.096	0.096	0.382	0.632	0.155	0.409
2H3	NMVOC	156.00	39.12	98	275	0.003	0.022	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000
3B1a	NMVOC	6'412.83	6'715.83	60	60	31.234	31.234	0.017	0.023	0.207	0.207	1.043	1.043	1.131	1.131
3B1b	NMVOC	5'121.56	7'399.49	70	70	51.453	51.453	0.021	0.025	0.228	0.228	1.454	1.454	2.166	2.166
3B2	NMVOC	66.79	68.15	98	275	0.008	0.067	0.000	0.000	0.002	0.002	0.017	0.048	0.000	0.002
3B3	NMVOC	1'126.15	807.34	98	275	1.190	9.404	0.002	0.003	0.025	0.025	0.176	0.495	0.031	0.245
3B4d	NMVOC	37.02	49.74	98	275	0.005	0.036	0.000	0.000	0.002	0.002	0.013	0.038	0.000	0.001
3B4e	NMVOC	120.39	203.34	98	275	0.075	0.597	0.001	0.001	0.006	0.006	0.057	0.162	0.003	0.026
3B4f	NMVOC	8.64	49.08	98	275	0.004	0.035	0.000	0.000	0.002	0.002	0.016	0.044	0.000	0.002
3B4gi	NMVOC	508.70	642.42	98	275	0.754	5.955	0.002	0.002	0.020	0.020	0.171	0.482	0.030	0.233
3B4gii	NMVOC	366.34	1'152.54	98	275	2.426	19.166	0.004	0.004	0.035	0.035	0.351	0.990	0.125	0.981
3B4giii	NMVOC	46.28	40.14	98	275	0.003	0.023	0.000	0.000	0.001	0.001	0.010	0.027	0.000	0.001
3B4giv	NMVOC	129.27	228.30	98	275	0.095	0.752	0.001	0.001	0.007	0.007	0.065	0.183	0.004	0.034
3B4h	NMVOC	3.60	4.52	98	275	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.000	0.000
3De	NMVOC	481.06	454.84	98	275	0.377	2.984	0.001	0.002	0.011	0.011	0.111	0.314	0.013	0.099
5A	NMVOC	405.68	129.24	51	51	0.008	0.008	0.000	0.000	0.006	0.006	0.005	0.005	0.000	0.000
5B1	NMVOC	105.05	175.20	102	102	0.061	0.061	0.001	0.001	0.017	0.017	0.051	0.051	0.003	0.003
5B2	NMVOC	49.57	1'098.06	36	36	0.298	0.298	0.004	0.004	0.105	0.105	0.110	0.110	0.023	0.023
5C1a	NMVOC	516.80	249.74	71	71	0.059	0.059	0.000	0.001	0.060	0.060	0.021	0.021	0.004	0.004
5C1bi	NMVOC	3.75	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biii	NMVOC	4.50	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biv	NMVOC	0.46	18.31	28	28	0.000	0.000	0.000	0.000	0.002	0.002	0.001	0.001	0.000	0.000
5C1bv	NMVOC	1.20	0.39	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C2	NMVOC	33.13	16.86	104	211	0.001	0.002	0.000	0.000	0.004	0.004	0.003	0.006	0.000	0.000
5D1	NMVOC	0.51	0.10	27	27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5D2	NMVOC	0.01	0.03	22	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5E	NMVOC	28.00	60.00	31	31	0.001	0.001	0.000	0.000	0.006	0.006	0.004	0.004	0.000	0.000
6A	NMVOC	202.98	169.69	58	58	0.019	0.019	0.000	0.001	0.024	0.024	0.020	0.020	0.001	0.001
Total						266.9	924.5							12.2	17.5
Total		295'705	72'515	Emissions 2022 uncertainty (%):		16.3	30.4			Trend uncertainty (%):				3.5	4.2

Table A - 30 Uncertainty analysis of SO_x emissions, approach 1, for 2022 and for the trend 1990-2022. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
NFR	Pollutant	Emissions 1990	Emissions 2022	Emission combined uncertainty 2022		Category contribution to inventory variance 2022		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	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1A1a	SOx (as SO2)	3'679.11	233.66	24	24	3.087	3.087	0.002	0.006	0.084	0.084	0.038	0.038	0.009	0.009
1A1b	SOx (as SO2)	660.41	65.22	20	20	0.165	0.165	0.000	0.002	0.003	0.003	0.006	0.006	0.000	0.000
1A2a	SOx (as SO2)	362.55	9.97	15	15	0.002	0.002	0.001	0.000	0.001	0.001	0.008	0.008	0.000	0.000
1A2b	SOx (as SO2)	67.34	0.48	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A2c	SOx (as SO2)	1'187.10	64.21	11	11	0.050	0.050	0.001	0.002	0.005	0.005	0.009	0.009	0.000	0.000
1A2d	SOx (as SO2)	3'238.01	1.02	14	14	0.000	0.000	0.007	0.000	0.000	0.000	0.095	0.095	0.009	0.009
1A2e	SOx (as SO2)	1'077.50	6.10	12	12	0.001	0.001	0.002	0.000	0.000	0.000	0.025	0.025	0.001	0.001
1A2f	SOx (as SO2)	3'530.25	1'466.65	19	19	76.019	76.019	0.030	0.037	0.106	0.106	0.570	0.570	0.337	0.337
1A2gvii	SOx (as SO2)	370.66	2.68	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.007	0.007	0.000	0.000
1A2gviii	SOx (as SO2)	3'533.86	313.58	19	19	3.477	3.477	0.001	0.008	0.023	0.023	0.011	0.011	0.001	0.001
1A3ai(i)	SOx (as SO2)	99.68	118.92	10	10	0.139	0.139	0.003	0.003	0.006	0.006	0.028	0.028	0.001	0.001
1A3aii(i)	SOx (as SO2)	24.94	4.38	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3bi(fu)	SOx (as SO2)	1'612.51	37.12	10	10	0.014	0.014	0.002	0.001	0.002	0.002	0.024	0.024	0.001	0.001
1A3bii(fu)	SOx (as SO2)	291.09	5.08	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.000	0.000
1A3biii(fu)	SOx (as SO2)	1'837.87	9.25	10	10	0.001	0.001	0.004	0.000	0.000	0.000	0.036	0.036	0.001	0.001
1A3biv(fu)	SOx (as SO2)	25.47	0.72	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A3c	SOx (as SO2)	26.92	0.12	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3dii	SOx (as SO2)	64.88	0.67	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3ei	SOx (as SO2)	0.28	0.08	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	SOx (as SO2)	3'869.92	112.91	10	10	0.126	0.126	0.005	0.003	0.006	0.006	0.052	0.052	0.003	0.003
1A4aii	SOx (as SO2)	1.61	0.05	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4bi	SOx (as SO2)	10'354.85	266.52	11	11	0.783	0.783	0.015	0.007	0.036	0.036	0.148	0.148	0.023	0.023
1A4bii	SOx (as SO2)	1.20	0.03	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ci	SOx (as SO2)	335.80	54.67	28	28	0.224	0.224	0.001	0.001	0.042	0.042	0.012	0.012	0.002	0.002
1A4cii	SOx (as SO2)	304.60	1.62	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.006	0.006	0.000	0.000
1A5b	SOx (as SO2)	78.17	32.80	10	10	0.011	0.011	0.001	0.001	0.002	0.002	0.007	0.007	0.000	0.000
1B2aiv	SOx (as SO2)	419.02	15.51	56	56	0.072	0.072	0.000	0.000	0.017	0.017	0.023	0.023	0.001	0.001
1B2c	SOx (as SO2)	300.98	0.85	38	38	0.000	0.000	0.001	0.000	0.001	0.001	0.019	0.019	0.000	0.000
2A1	SOx (as SO2)	0.69	0.45	98	275	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.003	0.000	0.000
2A2	SOx (as SO2)	0.01	0.01	100	740	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2A5a	SOx (as SO2)	0.08	0.02	100	741	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B5	SOx (as SO2)	625.20	289.32	20	20	3.274	3.274	0.006	0.007	0.021	0.021	0.122	0.122	0.015	0.015
2B10a	SOx (as SO2)	168.00	38.15	40	40	0.226	0.226	0.001	0.001	0.003	0.003	0.025	0.025	0.001	0.001
2C1	SOx (as SO2)	144.04	16.91	74	122	0.151	0.412	0.000	0.000	0.001	0.001	0.010	0.016	0.000	0.000
2C3	SOx (as SO2)	696.30	NO	NO	NO	NO	NO	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7c	SOx (as SO2)	NA	0.02	74	122	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2G	SOx (as SO2)	3.44	7.69	78	125	0.035	0.089	0.000	0.000	0.007	0.007	0.014	0.023	0.000	0.001
2H3	SOx (as SO2)	1.30	0.33	98	275	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
5B2	SOx (as SO2)	NA	0.91	102	102	0.001	0.001	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
5C1a	SOx (as SO2)	24.23	11.71	64	64	0.054	0.054	0.000	0.000	0.021	0.021	0.010	0.010	0.001	0.001
5C1bi	SOx (as SO2)	45.00	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biii	SOx (as SO2)	19.50	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biv	SOx (as SO2)	74.10	15.69	36	36	0.031	0.031	0.000	0.000	0.011	0.011	0.007	0.007	0.000	0.000
5C2	SOx (as SO2)	0.68	0.34	99	177	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
5D1	SOx (as SO2)	0.13	0.03	37	37	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5D2	SOx (as SO2)	0.00	0.01	22	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6A	SOx (as SO2)	9.17	7.25	58	58	0.017	0.017	0.000	0.000	0.008	0.008	0.008	0.008	0.000	0.000
Total						88.0	88.3							0.4	0.4
Total		39'168	3'214	Emissions 2022 uncertainty (%):		9.4	9.4			Trend uncertainty (%):				0.6	0.6

Table A - 31 Uncertainty analysis of NH_3 emissions, approach 1, for 2022 and for the trend 1990-2022. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
NFR	Pollutant	Emissions 1990	Emissions 2022	Emission combined uncertainty 2022		Category contribution to inventory variance 2022		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	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1A1a	NH3	4.85	36.83	22	22	0.000	0.000	0.000	0.001	0.008	0.008	0.010	0.010	0.000	0.000
1A1b	NH3	0.01	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2a	NH3	0.00	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2b	NH3	0.11	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2c	NH3	0.02	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2d	NH3	0.02	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2e	NH3	0.02	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2f	NH3	147.02	189.84	9	9	0.001	0.001	0.001	0.003	0.008	0.008	0.010	0.010	0.000	0.000
1A2gvii	NH3	1.00	1.55	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A2gviii	NH3	17.00	54.00	9	9	0.000	0.000	0.001	0.001	0.002	0.002	0.005	0.005	0.000	0.000
1A3bi(fu)	NH3	1'324.97	823.61	50	50	0.594	0.594	0.003	0.012	0.022	0.022	0.153	0.153	0.024	0.024
1A3bii(fu)	NH3	8.57	33.92	50	50	0.001	0.001	0.000	0.000	0.001	0.001	0.020	0.020	0.000	0.000
1A3biii(fu)	NH3	4.55	34.44	50	50	0.001	0.001	0.000	0.001	0.001	0.001	0.023	0.023	0.001	0.001
1A3biv(fu)	NH3	3.26	4.03	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3c	NH3	0.07	0.07	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A3dii	NH3	0.20	0.21	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	NH3	19.80	36.46	10	10	0.000	0.000	0.000	0.001	0.001	0.001	0.003	0.003	0.000	0.000
1A4aii	NH3	0.01	0.02	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4bi	NH3	153.12	56.22	11	11	0.000	0.000	0.001	0.001	0.004	0.004	0.009	0.009	0.000	0.000
1A4bii	NH3	0.01	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ci	NH3	2.88	8.11	23	23	0.000	0.000	0.000	0.000	0.004	0.004	0.001	0.001	0.000	0.000
1A4cii	NH3	0.76	0.83	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A5b	NH3	0.04	0.04	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B1	NH3	0.07	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B2	NH3	0.73	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B10a	NH3	7.73	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C1	NH3	11.90	1.61	98	275	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.031	0.000	0.001
2C7c	NH3	9.19	8.17	100	741	0.000	0.013	0.000	0.000	0.001	0.001	0.001	0.011	0.000	0.000
2G	NH3	203.15	75.63	47	47	0.004	0.004	0.001	0.001	0.039	0.039	0.048	0.048	0.004	0.004
2H2	NH3	132.33	56.06	100	741	0.011	0.603	0.001	0.001	0.012	0.012	0.069	0.510	0.005	0.260
2H3	NH3	1.04	0.26	98	275	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
2L	NH3	2.38	3.81	103	103	0.000	0.000	0.000	0.000	0.002	0.002	0.003	0.003	0.000	0.000
3B1a	NH3	9'337.10	10'346.42	30	30	33.084	33.084	0.045	0.151	1.376	1.376	1.295	1.295	3.569	3.569
3B1b	NH3	5'190.92	7'150.78	28	28	13.797	13.797	0.045	0.104	0.951	0.951	1.222	1.222	2.396	2.396
3B2	NH3	509.75	479.32	87	87	0.612	0.612	0.001	0.007	0.064	0.064	0.104	0.104	0.015	0.015
3B3	NH3	6'965.04	4'973.57	41	41	14.220	14.220	0.007	0.073	0.661	0.661	0.268	0.268	0.509	0.509
3B4d	NH3	158.13	160.48	65	65	0.038	0.038	0.001	0.002	0.021	0.021	0.035	0.035	0.002	0.002
3B4e	NH3	256.31	389.90	52	52	0.146	0.146	0.003	0.006	0.052	0.052	0.144	0.144	0.023	0.023
3B4f	NH3	19.65	101.23	68	68	0.017	0.017	0.001	0.001	0.013	0.013	0.085	0.085	0.007	0.007
3B4gi	NH3	978.79	682.91	82	82	1.105	1.105	0.001	0.010	0.091	0.091	0.097	0.097	0.018	0.018
3B4gii	NH3	304.87	685.29	86	86	1.223	1.223	0.007	0.010	0.091	0.091	0.562	0.562	0.324	0.324
3B4giii	NH3	29.77	21.54	93	93	0.001	0.001	0.000	0.000	0.003	0.003	0.002	0.002	0.000	0.000
3B4giv	NH3	124.46	95.73	85	85	0.023	0.023	0.000	0.001	0.013	0.013	0.002	0.002	0.000	0.000
3B4h	NH3	14.55	43.21	50	50	0.002	0.002	0.000	0.001	0.006	0.006	0.023	0.023	0.001	0.001
3Da1	NH3	4'258.33	2'192.59	50	50	4.251	4.251	0.016	0.032	0.226	0.226	0.824	0.824	0.730	0.730
3Da2a	NH3	34'567.08	20'447.23	22	22	70.644	70.644	0.095	0.299	2.719	2.719	1.989	1.989	11.348	11.348
3Da2b	NH3	1'169.36	NO	NO	NO	NO	NO	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3Da2c	NH3	34.00	990.33	54	54	0.996	0.996	0.014	0.014	0.409	0.409	0.704	0.704	0.662	0.662
3Da3	NH3	760.92	1'420.53	62	62	2.746	2.746	0.012	0.021	0.189	0.189	0.748	0.748	0.596	0.596
5A	NH3	615.79	196.08	51	51	0.035	0.035	0.004	0.003	0.040	0.040	0.208	0.208	0.045	0.045
5B1	NH3	175.08	292.01	102	102	0.311	0.311	0.002	0.004	0.121	0.121	0.227	0.227	0.066	0.066
5B2	NH3	10.28	234.59	78	78	0.116	0.116	0.003	0.003	0.097	0.097	0.248	0.248	0.071	0.071
5C1biv	NH3	5.70	1.84	54	54	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
5C2	NH3	18.03	9.18	54	54	0.000	0.000	0.000	0.000	0.009	0.009	0.002	0.002	0.000	0.000
5D1	NH3	89.98	126.65	50	50	0.014	0.014	0.001	0.002	0.003	0.003	0.041	0.041	0.002	0.002
6A	NH3	845.54	969.02	104	104	3.584	3.584	0.005	0.014	0.600	0.600	0.452	0.452	0.564	0.564
Total						147.6	148.2							21.0	21.2
Total		68'496	53'436	Emissions 2022 uncertainty (%):		12.1	12.2			Trend uncertainty (%):				4.6	4.6

Table A - 32 Uncertainty analysis of PM2.5 emissions, approach 1, for 2022 and for the trend 1990-2022. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
NFR	Pollutant	Emissions 1990	Emissions 2022	Emission combined uncertainty 2022		Category contribution to inventory variance 2022		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	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1A1a	PM2.5	781.83	45.71	72	72	0.248	0.248	0.005	0.002	0.024	0.024	0.372	0.372	0.139	0.139
1A1b	PM2.5	47.66	1.64	20	20	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.007	0.000	0.000
1A1c	PM2.5	4.64	12.76	21	21	0.002	0.002	0.000	0.000	0.003	0.003	0.009	0.009	0.000	0.000
1A2a	PM2.5	14.81	2.88	28	28	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A2b	PM2.5	20.39	1.45	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
1A2c	PM2.5	40.77	5.16	10	10	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
1A2d	PM2.5	149.62	0.23	33	33	0.000	0.000	0.001	0.000	0.000	0.000	0.043	0.043	0.002	0.002
1A2e	PM2.5	25.68	1.25	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
1A2f	PM2.5	437.58	46.37	65	65	0.210	0.210	0.002	0.002	0.005	0.005	0.141	0.141	0.020	0.020
1A2gvii	PM2.5	728.86	387.04	50	50	8.663	8.663	0.008	0.014	0.026	0.026	0.387	0.387	0.151	0.151
1A2gviii	PM2.5	872.51	191.39	65	65	3.581	3.581	0.001	0.007	0.020	0.020	0.045	0.045	0.002	0.002
1A3ai(i)	PM2.5	92.39	12.49	30	30	0.003	0.003	0.000	0.000	0.001	0.001	0.011	0.011	0.000	0.000
1A3aii(i)	PM2.5	22.67	1.74	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
1A3bi(fu)	PM2.5	577.66	112.38	57	57	0.960	0.960	0.001	0.004	0.008	0.008	0.057	0.057	0.003	0.003
1A3bii(fu)	PM2.5	327.15	56.07	48	48	0.170	0.170	0.001	0.002	0.004	0.004	0.040	0.040	0.002	0.002
1A3biii(fu)	PM2.5	1'587.90	40.87	27	27	0.028	0.028	0.013	0.001	0.003	0.003	0.338	0.338	0.115	0.115
1A3biv(fu)	PM2.5	208.81	62.30	54	54	0.262	0.262	0.000	0.002	0.004	0.004	0.024	0.024	0.001	0.001
1A3bvi(fu)	PM2.5	689.15	944.64	50	50	51.604	51.604	0.029	0.035	0.063	0.063	1.427	1.427	2.039	2.039
1A3c	PM2.5	174.35	203.08	50	50	2.385	2.385	0.006	0.007	0.014	0.014	0.295	0.295	0.087	0.087
1A3dii	PM2.5	59.09	23.64	50	50	0.032	0.032	0.000	0.001	0.002	0.002	0.017	0.017	0.000	0.000
1A3ei	PM2.5	0.11	0.09	27	27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	PM2.5	1'354.47	429.78	78	78	25.988	25.988	0.004	0.016	0.035	0.035	0.295	0.295	0.088	0.088
1A4bi	PM2.5	14'535.91	1'888.35	76	76	477.259	477.259	0.059	0.069	0.364	0.364	4.481	4.481	20.216	20.216
1A4ci	PM2.5	696.98	214.03	44	44	2.087	2.087	0.002	0.008	0.235	0.235	0.066	0.066	0.060	0.060
1A4cii	PM2.5	435.10	139.20	80	80	2.867	2.867	0.001	0.005	0.009	0.009	0.101	0.101	0.010	0.010
1A5b	PM2.5	86.95	44.90	50	50	0.117	0.117	0.001	0.002	0.003	0.003	0.044	0.044	0.002	0.002
1B1a	PM2.5	0.16	0.05	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1B2c	PM2.5	0.44	0.00	102	337	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
2A1	PM2.5	240.48	157.80	98	275	5.505	43.648	0.004	0.006	0.016	0.016	0.358	1.008	0.128	1.015
2A2	PM2.5	7.21	7.25	100	740	0.012	0.666	0.000	0.000	0.001	0.001	0.020	0.150	0.000	0.022
2A5a	PM2.5	183.33	225.55	100	741	11.789	644.836	0.007	0.008	0.058	0.058	0.665	4.923	0.445	24.238
2B5	PM2.5	61.20	44.96	98	275	0.447	3.544	0.001	0.002	0.005	0.005	0.108	0.305	0.012	0.093
2B10a	PM2.5	7.86	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C1	PM2.5	817.90	8.52	84	158	0.012	0.042	0.007	0.000	0.001	0.001	0.579	1.094	0.335	1.197
2C3	PM2.5	78.33	NO	NO	NO	NO	NO	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7a	PM2.5	5.66	0.75	98	275	0.000	0.001	0.000	0.000	0.000	0.000	0.002	0.006	0.000	0.000
2C7c	PM2.5	1.53	1.40	100	741	0.000	0.025	0.000	0.000	0.000	0.000	0.004	0.028	0.000	0.001
2D3c	PM2.5	4.00	3.80	100	276	0.003	0.025	0.000	0.000	0.004	0.004	0.010	0.029	0.000	0.001
2D3i	PM2.5	12.00	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2G	PM2.5	512.78	431.87	78	125	26.112	66.864	0.011	0.016	0.560	0.560	0.833	1.378	1.007	2.213
2H1	PM2.5	235.77	180.31	102	277	7.862	57.666	0.005	0.007	0.280	0.280	0.443	1.246	0.275	1.632
2H2	PM2.5	187.99	167.87	100	741	6.579	357.248	0.004	0.006	0.087	0.087	0.449	3.326	0.209	11.073
2H3	PM2.5	15.60	3.91	98	275	0.003	0.027	0.000	0.000	0.001	0.001	0.001	0.002	0.000	0.000
2I	PM2.5	216.08	49.33	100	741	0.568	30.849	0.000	0.002	0.026	0.026	0.010	0.075	0.001	0.006
3B1a	PM2.5	20.61	23.50	100	440	0.128	2.473	0.001	0.001	0.008	0.008	0.068	0.299	0.005	0.089
3B1b	PM2.5	18.26	21.86	100	440	0.111	2.138	0.001	0.001	0.007	0.007	0.064	0.282	0.004	0.079
3B2	PM2.5	0.79	0.81	100	440	0.000	0.003	0.000	0.000	0.000	0.000	0.002	0.010	0.000	0.000
3B3	PM2.5	9.57	6.66	100	440	0.010	0.199	0.000	0.000	0.002	0.002	0.016	0.070	0.000	0.005
3B4d	PM2.5	0.14	0.18	100	440	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
3B4e	PM2.5	3.94	6.66	100	440	0.010	0.198	0.000	0.000	0.002	0.002	0.021	0.092	0.000	0.008
3B4f	PM2.5	0.59	3.34	100	440	0.003	0.050	0.000	0.000	0.001	0.001	0.012	0.052	0.000	0.003
3B4gi	PM2.5	9.25	11.68	100	440	0.032	0.611	0.000	0.000	0.004	0.004	0.035	0.152	0.001	0.023
3B4gii	PM2.5	6.78	21.34	100	440	0.106	2.039	0.001	0.001	0.007	0.007	0.072	0.318	0.005	0.101
3B4giii	PM2.5	1.89	1.64	100	440	0.001	0.012	0.000	0.000	0.001	0.001	0.004	0.019	0.000	0.000
3B4giv	PM2.5	1.98	3.31	100	440	0.003	0.049	0.000	0.000	0.001	0.001	0.010	0.046	0.000	0.002
3B4h	PM2.5	0.24	0.09	100	440	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
3De	PM2.5	47.48	44.96	98	275	0.448	3.545	0.001	0.002	0.012	0.012	0.120	0.338	0.015	0.115
5A	PM2.5	0.73	0.51	32	32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5B2	PM2.5	NA	0.05	102	102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1a	PM2.5	465.12	224.77	58	58	3.971	3.971	0.004	0.008	0.583	0.583	0.124	0.124	0.355	0.355
5C1bi	PM2.5	0.47	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biii	PM2.5	16.50	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biv	PM2.5	14.25	2.71	39	39	0.000	0.000	0.000	0.000	0.003	0.003	0.001	0.001	0.000	0.000
5C1bv	PM2.5	4.39	0.88	33	33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C2	PM2.5	84.75	43.12	104	211	0.463	1.911	0.001	0.002	0.107	0.107	0.077	0.171	0.017	0.041
5E	PM2.5	1.40	1.50	36	36	0.000	0.000	0.000	0.000	0.002	0.002	0.001	0.001	0.000	0.000
6A	PM2.5	4.42	4.78	50	50	0.001	0.001	0.000	0.000	0.007	0.007	0.005	0.005	0.000	0.000
Total						640.6	1'799.1							25.8	65.3
Total		27'275	6'577	Emissions 2022 uncertainty (%):		25.3	42.4			Trend uncertainty (%):				5.1	8.1

Table A - 33 Uncertainty analysis of PM10 emissions, approach 1, for 2022 and for the trend 1990-2022. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
NFR	Pollutant	Emissions 1990	Emissions 2022	Emission combined uncertainty 2022		Category contribution to inventory variance 2022		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	
				(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1A1a	PM10	1'044.54	45.71	72	72	0.052	0.052	0.010	0.001	0.018	0.018	0.707	0.707	0.500	0.500
1A1b	PM10	47.66	1.64	20	20	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.009	0.000	0.000
1A1c	PM10	4.89	13.45	21	21	0.000	0.000	0.000	0.000	0.003	0.003	0.006	0.006	0.000	0.000
1A2a	PM10	20.53	3.17	28	28	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
1A2b	PM10	29.24	1.53	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.000	0.000
1A2c	PM10	40.77	5.16	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A2d	PM10	166.58	0.23	33	33	0.000	0.000	0.002	0.000	0.000	0.000	0.059	0.059	0.003	0.003
1A2e	PM10	25.68	1.25	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
1A2f	PM10	832.63	77.89	65	65	0.125	0.125	0.007	0.002	0.006	0.006	0.442	0.442	0.195	0.195
1A2gvii	PM10	2'173.23	2'358.75	50	50	67.587	67.587	0.041	0.064	0.118	0.118	2.058	2.058	4.248	4.248
1A2gviii	PM10	913.14	201.95	65	65	0.838	0.838	0.004	0.006	0.016	0.016	0.278	0.278	0.077	0.077
1A3ai(i)	PM10	102.65	12.49	30	30	0.001	0.001	0.001	0.000	0.001	0.001	0.023	0.023	0.001	0.001
1A3aii(i)	PM10	25.19	1.74	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.007	0.000	0.000
1A3bi(fu)	PM10	577.66	112.38	57	57	0.202	0.202	0.003	0.003	0.006	0.006	0.179	0.179	0.032	0.032
1A3bii(fu)	PM10	327.15	56.07	48	48	0.036	0.036	0.002	0.002	0.003	0.003	0.095	0.095	0.009	0.009
1A3biii(fu)	PM10	1'587.90	40.87	27	27	0.006	0.006	0.016	0.001	0.002	0.002	0.430	0.430	0.185	0.185
1A3biv(fu)	PM10	208.81	62.30	54	54	0.055	0.055	0.001	0.002	0.003	0.003	0.029	0.029	0.001	0.001
1A3bvi(fu)	PM10	2'049.68	2'577.31	50	50	80.692	80.692	0.048	0.070	0.128	0.128	2.423	2.423	5.885	5.885
1A3c	PM10	982.81	1'322.59	50	50	21.250	21.250	0.026	0.036	0.066	0.066	1.281	1.281	1.644	1.644
1A3dii	PM10	59.09	23.64	50	50	0.007	0.007	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.000
1A3ei	PM10	0.11	0.09	27	27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	PM10	1'427.63	457.04	78	78	6.174	6.174	0.003	0.012	0.028	0.028	0.220	0.220	0.049	0.049
1A4bi	PM10	15'325.72	1'987.14	76	76	111.018	111.018	0.110	0.054	0.286	0.286	8.331	8.331	69.486	69.486
1A4ci	PM10	710.36	217.30	44	44	0.452	0.452	0.002	0.006	0.178	0.178	0.065	0.065	0.036	0.036
1A4cii	PM10	511.19	197.68	80	80	1.215	1.215	0.000	0.005	0.010	0.010	0.006	0.006	0.000	0.000
1A5b	PM10	286.52	261.52	50	50	0.831	0.831	0.004	0.007	0.013	0.013	0.204	0.204	0.042	0.042
1B1a	PM10	1.60	0.48	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
1B2c	PM10	0.44	0.00	102	337	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000
2A1	PM10	374.35	245.64	98	275	2.802	22.219	0.003	0.007	0.019	0.019	0.264	0.743	0.070	0.553
2A2	PM10	14.41	14.48	100	740	0.010	0.558	0.000	0.000	0.001	0.001	0.024	0.179	0.001	0.032
2A5a	PM10	366.54	451.07	100	741	9.905	541.753	0.008	0.012	0.087	0.087	0.840	6.220	0.713	38.695
2B5	PM10	73.80	53.76	98	275	0.134	1.064	0.001	0.001	0.004	0.004	0.066	0.187	0.004	0.035
2B10a	PM10	17.07	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C1	PM10	1'485.46	12.84	84	158	0.006	0.020	0.016	0.000	0.001	0.001	1.304	2.464	1.701	6.073
2C3	PM10	113.15	NO	NO	NO	NO	NO	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7a	PM10	5.96	0.79	98	275	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.012	0.000	0.000
2C7c	PM10	3.06	2.78	100	741	0.000	0.021	0.000	0.000	0.001	0.001	0.004	0.032	0.000	0.001
2D3c	PM10	19.98	19.01	100	276	0.017	0.134	0.000	0.001	0.015	0.015	0.030	0.084	0.001	0.007
2D3i	PM10	24.00	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2G	PM10	588.38	600.71	78	125	10.612	27.175	0.010	0.016	0.581	0.581	0.745	1.233	0.892	1.859
2H1	PM10	243.80	186.43	102	277	1.765	12.950	0.002	0.005	0.216	0.216	0.243	0.683	0.106	0.514
2H2	PM10	310.39	311.95	100	741	4.773	259.143	0.005	0.009	0.121	0.121	0.520	3.850	0.285	14.834
2H3	PM10	15.60	3.91	98	275	0.001	0.006	0.000	0.000	0.000	0.000	0.006	0.017	0.000	0.000
2I	PM10	864.32	195.98	100	741	1.884	102.285	0.004	0.005	0.076	0.076	0.391	2.897	0.159	8.400
3B1a	PM10	84.47	96.33	100	440	0.452	8.724	0.002	0.003	0.024	0.024	0.173	0.760	0.030	0.578
3B1b	PM10	74.85	89.58	100	440	0.391	7.544	0.002	0.002	0.022	0.022	0.165	0.724	0.028	0.525
3B2	PM10	19.76	20.16	100	440	0.020	0.382	0.000	0.001	0.005	0.005	0.034	0.149	0.001	0.022
3B3	PM10	213.16	149.51	100	440	1.089	21.015	0.002	0.004	0.037	0.037	0.180	0.792	0.034	0.629
3B4d	PM10	3.42	4.59	100	440	0.001	0.020	0.000	0.000	0.001	0.001	0.009	0.039	0.000	0.002
3B4e	PM10	6.20	10.46	100	440	0.005	0.103	0.000	0.000	0.003	0.003	0.022	0.097	0.000	0.009
3B4f	PM10	0.94	5.34	100	440	0.001	0.027	0.000	0.000	0.001	0.001	0.014	0.060	0.000	0.004
3B4gi	PM10	123.32	155.74	100	440	1.182	22.802	0.003	0.004	0.039	0.039	0.293	1.291	0.088	1.669
3B4gii	PM10	67.84	213.43	100	440	2.220	42.827	0.005	0.006	0.053	0.053	0.511	2.247	0.264	5.053
3B4giii	PM10	10.41	9.03	100	440	0.004	0.077	0.000	0.000	0.002	0.002	0.014	0.059	0.000	0.004
3B4giv	PM10	18.52	31.37	100	440	0.048	0.925	0.001	0.001	0.008	0.008	0.066	0.290	0.004	0.084
3B4h	PM10	0.50	0.82	100	440	0.000	0.001	0.000	0.000	0.000	0.000	0.002	0.008	0.000	0.000
3De	PM10	1'053.57	1'001.42	98	275	46.678	369.380	0.016	0.027	0.194	0.194	1.572	4.426	2.507	19.627
5A	PM10	0.73	0.51	32	32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5B2	PM10	NA	0.05	102	102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1a	PM10	516.80	249.74	71	71	1.514	1.514	0.001	0.007	0.483	0.483	0.064	0.064	0.237	0.237
5C1bi	PM10	3.08	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biii	PM10	24.00	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biv	PM10	19.95	3.88	40	40	0.000	0.000	0.000	0.000	0.003	0.003	0.004	0.004	0.000	0.000
5C1bv	PM10	4.39	0.88	33	33	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
5C2	PM10	93.09	47.37	104	211	0.117	0.484	0.000	0.001	0.088	0.088	0.027	0.061	0.008	0.011
5E	PM10	2.80	3.00	36	36	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.000	0.000
6A	PM10	229.38	116.54	50	50	0.165	0.165	0.001	0.003	0.135	0.135	0.029	0.029	0.019	0.019
Total						376.3	1'733.9							89.5	181.9
Total		36'575	14'350	Emissions 2022 uncertainty (%):		19.4	41.6			Trend uncertainty (%):				9.5	13.5

A5.3 Uncertainty estimations: results from approach 2

Numeric results of the uncertainty estimations using Monte Carlo simulations are summarised in the tables in Annex A5.3.1. In these tables, columns labelled A to J correspond exactly to columns A to J from Table 3.3, chp. 3, from the 2006 IPCC Guidelines (IPCC 2006).

Results of the sensitivity analysis between input emissions from each category and inventory emission are depicted by tornado plots in the figures in Annex A5.3.2 (see also discussion in chp. 1.7.3).

Distributions of inventory emissions obtained from the 500’000 Monte Carlo simulations are shown as histograms, for each pollutant, for the base year, the reporting year and the trend, in the figures in Annex A5.3.3.

A5.3.1 Uncertainty estimations, approach 2, numeric results

Table A - 34 Uncertainty analysis of NO_x emissions, approach 2, for 2022 and for the trend 1990-2022. Monte Carlo simulations were run 500’000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J	
NFR	Pollutant	Emissions 1990	Emissions 2022	Activity data uncertainty 2022		Emission factor uncertainty 2022		Emission combined uncertainty 2022		Emission contri-bution to variance 2022	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	NOx (as NO2)	6'337.60	2'150.66	10	10	19	19	21	22	0.005	-2.984	0.835	0.785
1A1b	NOx (as NO2)	494.17	361.20	1	1	20	20	20	20	0.000	-0.095	0.023	0.023
1A1c	NOx (as NO2)	0.01	0.03	5	5	20	20	20	21	0.000	0.000	0.000	0.000
1A2a	NOx (as NO2)	279.07	117.53	2	2	27	27	27	27	0.000	-0.115	0.035	0.034
1A2b	NOx (as NO2)	127.53	34.74	2	2	20	20	20	20	0.000	-0.066	0.016	0.016
1A2c	NOx (as NO2)	1'050.42	225.04	2	2	10	10	10	10	0.000	-0.589	0.100	0.094
1A2d	NOx (as NO2)	1'261.91	40.44	2	2	10	10	10	10	0.000	-0.871	0.145	0.140
1A2e	NOx (as NO2)	743.69	216.06	2	2	10	10	10	10	0.000	-0.376	0.063	0.061
1A2f	NOx (as NO2)	10'534.54	3'203.25	2	2	17	17	17	17	0.007	-5.225	1.091	1.051
1A2gvii	NOx (as NO2)	6'333.94	1'629.49	1	1	13	13	13	13	0.001	-3.355	0.615	0.593
1A2gviii	NOx (as NO2)	2'181.62	2'067.94	2	2	17	17	17	17	0.003	-0.081	0.048	0.047
1A3ai(i)	NOx (as NO2)	1'214.30	1'671.30	1	1	20	20	20	20	0.003	0.326	0.078	0.081
1A3aii(i)	NOx (as NO2)	153.76	49.45	1	1	20	20	20	20	0.000	-0.074	0.018	0.018
1A3bi(fu)	NOx (as NO2)	43'771.53	15'855.80	1	1	38	38	38	39	0.886	-19.678	5.220	5.487
1A3bii(fu)	NOx (as NO2)	6'196.89	3'956.48	1	1	32	33	32	32	0.039	-1.596	0.542	0.533
1A3biii(fu)	NOx (as NO2)	29'657.53	3'268.82	1	1	18	18	18	18	0.008	-18.786	3.554	3.528
1A3biv(fu)	NOx (as NO2)	308.61	208.72	1	1	36	36	36	36	0.000	-0.071	0.028	0.027
1A3c	NOx (as NO2)	595.50	349.85	1	1	13	13	13	13	0.000	-0.175	0.033	0.032
1A3dii	NOx (as NO2)	1'054.73	926.98	1	1	13	13	13	13	0.000	-0.091	0.021	0.021
1A3ei	NOx (as NO2)	19.41	14.15	2	2	50	50	50	50	0.000	-0.004	0.002	0.002
1A4ai	NOx (as NO2)	5'132.30	2'956.73	2	2	16	16	16	16	0.005	-1.551	0.324	0.313
1A4aii	NOx (as NO2)	16.28	41.71	1	1	13	13	13	13	0.000	0.018	0.003	0.003
1A4bi	NOx (as NO2)	11'636.07	4'009.36	4	4	13	13	14	13	0.007	-5.439	1.023	0.983
1A4bii	NOx (as NO2)	18.76	20.71	1	1	30	30	30	30	0.000	0.001	0.001	0.001
1A4ci	NOx (as NO2)	398.34	398.41	21	21	30	30	36	37	0.001	0.000	0.088	0.087
1A4cii	NOx (as NO2)	4'357.53	1'702.53	1	1	13	13	13	13	0.001	-1.893	0.350	0.337
1A5b	NOx (as NO2)	882.99	399.52	1	1	13	13	13	13	0.000	-0.345	0.065	0.062
1B2c	NOx (as NO2)	211.21	0.59	22	22	100	204	100	206	0.000	-0.150	0.309	0.150
2A1	NOx (as NO2)	15.87	10.41	2	2	100	204	100	204	0.000	-0.004	0.008	0.004
2A2	NOx (as NO2)	0.27	0.27	2	2	100	448	100	447	0.000	0.000	0.000	0.000
2A5a	NOx (as NO2)	1.79	0.44	5	5	100	447	100	447	0.000	-0.001	0.004	0.001
2B2	NOx (as NO2)	82.78	NO	NO	NO	NO	NO	NO	NO	0.000	-0.059	0.010	0.009
2B10a	NOx (as NO2)	8.93	0.62	2	2	61	59	60	60	0.000	-0.006	0.004	0.004
2C1	NOx (as NO2)	245.46	169.38	2	2	50	50	50	50	0.000	-0.054	0.028	0.028
2C3	NOx (as NO2)	17.41	NO	NO	NO	NO	NO	NO	NO	0.000	-0.012	0.026	0.012
2C7c	NOx (as NO2)	NA	1.36	5	5	84	100	84	100	0.000	0.001	0.001	0.001
2G	NOx (as NO2)	29.36	18.02	25	25	83	101	85	104	0.000	-0.008	0.011	0.008
2H3	NOx (as NO2)	91.00	22.82	3	3	100	204	100	204	0.000	-0.049	0.100	0.049
3B1a	NOx (as NO2)	672.34	381.80	6	6	50	50	50	51	0.001	-0.207	0.114	0.112
3B1b	NOx (as NO2)	344.32	277.29	6	6	50	50	50	51	0.000	-0.048	0.033	0.030
3B2	NOx (as NO2)	67.60	64.25	6	6	50	50	50	51	0.000	-0.002	0.005	0.004
3B3	NOx (as NO2)	185.29	88.39	6	6	50	50	50	51	0.000	-0.069	0.038	0.036
3B4d	NOx (as NO2)	21.62	22.73	6	6	49	51	50	51	0.000	0.001	0.002	0.002
3B4e	NOx (as NO2)	17.58	26.27	6	6	51	49	50	51	0.000	0.006	0.003	0.004
3B4f	NOx (as NO2)	1.35	7.06	6	6	50	50	50	51	0.000	0.004	0.002	0.002
3B4gi	NOx (as NO2)	7.19	9.51	6	6	50	50	50	51	0.000	0.002	0.001	0.001
3B4gii	NOx (as NO2)	4.46	12.56	6	6	50	50	50	51	0.000	0.006	0.003	0.003
3B4giii	NOx (as NO2)	0.44	0.37	6	6	50	50	51	50	0.000	0.000	0.000	0.000
3B4giv	NOx (as NO2)	0.84	1.30	6	6	50	50	50	51	0.000	0.000	0.000	0.000
3B4h	NOx (as NO2)	1.03	4.95	6	6	50	50	51	50	0.000	0.003	0.001	0.001
3Da1	NOx (as NO2)	1'204.90	694.77	5	5	100	100	99	101	0.012	-0.363	0.374	0.366
3Da2a	NOx (as NO2)	2'075.01	1'466.31	6	6	50	50	50	51	0.013	-0.434	0.259	0.242
3Da2b	NOx (as NO2)	87.01	NO	NO	NO	NO	NO	NO	NO	0.000	-0.062	0.063	0.063
3Da2c	NOx (as NO2)	14.76	118.82	20	20	99	101	102	104	0.000	0.074	0.077	0.078
3Da3	NOx (as NO2)	243.41	419.61	6	6	100	99	100	100	0.004	0.126	0.129	0.130
5A	NOx (as NO2)	1.83	1.28	10	10	50	50	51	51	0.000	0.000	0.000	0.000
5B2	NOx (as NO2)	NA	6.03	20	20	99	101	101	105	0.000	0.004	0.004	0.005
5C1a	NOx (as NO2)	80.75	39.02	50	50	40	40	60	67	0.000	-0.030	0.037	0.033
5C1bi	NOx (as NO2)	9.75	NO	NO	NO	NO	NO	NO	NO	0.000	-0.007	0.003	0.003
5C1biii	NOx (as NO2)	22.50	NO	NO	NO	NO	NO	NO	NO	0.000	-0.016	0.007	0.007
5C1biv	NOx (as NO2)	114.00	38.75	20	20	50	50	53	55	0.000	-0.054	0.034	0.032
5C1bv	NOx (as NO2)	11.25	13.79	5	5	30	30	30	30	0.000	0.002	0.001	0.001
5C2	NOx (as NO2)	31.10	15.83	48	48	100	156	100	168	0.000	-0.011	0.025	0.014
5D1	NOx (as NO2)	25.35	5.14	1	1	10	10	10	10	0.000	-0.014	0.002	0.002
5D2	NOx (as NO2)	0.25	1.27	10	10	10	10	14	14	0.000	0.001	0.000	0.000
6A	NOx (as NO2)	92.04	89.55	30	30	50	50	56	60	0.000	-0.002	0.030	0.029
Total, Monte Carlo simulations		140'809	49'911					12.7	13.1	1.0	-64.5	1.2	1.2
Total, inventory		140'801	49'907								-64.6		

Table A - 35 Uncertainty analysis of NMVOC emissions, approach 2, for 2022 and for the trend 1990-2022. Monte Carlo simulations were run 500’000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J	
NFR	Pollutant	Emissions 1990	Emissions 2022	Activity data uncertainty 2022		Emission factor uncertainty 2022		Emission combined uncertainty 2022		Emission contri-bution to variance 2022	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	NMVOC	320.80	193.02	10	10	32	32	33	34	0.000	-0.044	0.022	0.021
1A1b	NMVOC	6.95	2.72	1	1	20	20	20	20	0.000	-0.001	0.000	0.000
1A1c	NMVOC	2.13	5.86	5	5	20	20	21	21	0.000	0.001	0.000	0.000
1A2a	NMVOC	8.95	6.88	2	2	18	18	18	18	0.000	-0.001	0.000	0.000
1A2b	NMVOC	53.62	6.99	2	2	19	19	19	19	0.000	-0.016	0.005	0.005
1A2c	NMVOC	34.22	20.40	2	2	10	10	10	10	0.000	-0.005	0.001	0.001
1A2d	NMVOC	29.90	3.90	2	2	10	10	10	10	0.000	-0.009	0.002	0.002
1A2e	NMVOC	22.05	20.41	2	2	10	10	10	10	0.000	-0.001	0.000	0.000
1A2f	NMVOC	596.56	452.61	2	2	30	30	30	30	0.000	-0.049	0.020	0.019
1A2gvii	NMVOC	1'331.50	264.61	1	1	34	34	34	34	0.000	-0.366	0.154	0.147
1A2gviii	NMVOC	294.30	124.82	2	2	29	31	30	30	0.000	-0.058	0.022	0.022
1A3ai(i)	NMVOC	247.46	118.42	1	1	50	50	50	50	0.000	-0.044	0.025	0.024
1A3aii(i)	NMVOC	58.81	31.54	1	1	50	50	50	50	0.000	-0.009	0.005	0.005
1A3bi(fu)	NMVOC	55'937.77	3'862.01	1	1	53	52	53	52	0.013	-17.621	8.370	8.470
1A3bii(fu)	NMVOC	4'919.59	149.88	1	1	46	45	46	46	0.000	-1.635	0.838	0.822
1A3biii(fu)	NMVOC	3'419.18	80.66	1	1	22	22	22	22	0.000	-1.145	0.369	0.361
1A3biv(fu)	NMVOC	5'733.49	842.76	1	1	100	390	100	390	0.037	-1.559	6.070	1.559
1A3bv(fu)	NMVOC	16'980.67	1'912.73	1	1	40	40	40	40	0.002	-5.159	2.307	2.275
1A3c	NMVOC	83.76	40.92	1	1	34	34	34	34	0.000	-0.015	0.006	0.006
1A3dii	NMVOC	1'640.55	396.59	1	1	34	34	34	34	0.000	-0.427	0.180	0.171
1A3ei	NMVOC	0.90	0.69	2	2	50	50	51	50	0.000	0.000	0.000	0.000
1A4ai	NMVOC	1'329.00	876.67	2	2	56	56	57	55	0.001	-0.155	0.096	0.093
1A4aii	NMVOC	1'091.65	314.67	1	1	76	74	76	74	0.000	-0.266	0.216	0.204
1A4bi	NMVOC	10'056.33	2'405.77	4	4	68	69	68	68	0.009	-2.612	1.863	1.838
1A4bii	NMVOC	398.23	124.81	1	1	75	74	74	75	0.000	-0.094	0.075	0.073
1A4ci	NMVOC	235.07	253.44	21	21	75	74	76	81	0.000	0.006	0.028	0.030
1A4cii	NMVOC	4'369.08	823.64	1	1	74	75	75	75	0.001	-1.214	0.961	0.935
1A5b	NMVOC	160.25	64.20	1	1	34	34	34	34	0.000	-0.033	0.014	0.013
1B2ai	NMVOC	0.02	0.01	30	30	49	51	57	59	0.000	0.000	0.000	0.000
1B2aiv	NMVOC	1'344.61	232.65	30	30	47	47	54	57	0.000	-0.381	0.252	0.232
1B2av	NMVOC	19'127.24	1'992.18	1	1	38	41	38	41	0.002	-5.859	2.605	2.469
1B2b	NMVOC	323.52	188.57	22	22	50	50	54	55	0.000	-0.046	0.040	0.035
1B2c	NMVOC	13.72	0.04	22	22	84	100	85	103	0.000	-0.005	0.005	0.004
2A1	NMVOC	41.25	27.07	2	2	100	204	100	204	0.000	-0.005	0.010	0.005
2A2	NMVOC	0.69	0.69	2	2	100	450	100	450	0.000	0.000	0.000	0.000
2A5a	NMVOC	4.59	1.14	5	5	100	447	100	448	0.000	-0.001	0.005	0.001
2B10a	NMVOC	608.61	15.39	2	2	40	40	40	40	0.000	-0.203	0.095	0.093
2C1	NMVOC	1'053.60	222.26	2	2	83	101	84	100	0.000	-0.285	0.294	0.240
2C3	NMVOC	56.57	NO	NO	NO	NO	NO	NO	NO	0.000	-0.019	0.040	0.019
2C7a	NMVOC	2.98	0.39	5	5	100	204	100	204	0.000	-0.001	0.002	0.001
2C7c	NMVOC	NA	0.44	5	5	83	101	84	100	0.000	0.000	0.000	0.000
2D3a	NMVOC	8'866.55	6'396.95	1	1	50	50	50	50	0.034	-0.841	1.895	1.897
2D3b	NMVOC	4'895.00	2'683.80	5	5	84	100	83	101	0.024	-0.755	0.773	0.639
2D3c	NMVOC	2'430.00	373.01	20	20	83	101	84	103	0.000	-0.703	0.751	0.595
2D3d	NMVOC	40'731.00	8'283.08	20	20	40	40	44	46	0.046	-11.045	5.326	5.050
2D3e	NMVOC	11'731.23	1'566.25	40	40	51	50	62	66	0.003	-3.472	2.522	2.292
2D3f	NMVOC	910.00	61.00	20	20	40	40	44	46	0.000	-0.291	0.150	0.145
2D3g	NMVOC	27'503.97	3'188.49	30	30	83	102	85	107	0.038	-8.128	8.036	6.683
2D3h	NMVOC	20'353.80	3'642.07	20	20	40	40	44	46	0.009	-5.708	2.911	2.743
2D3i	NMVOC	5'470.21	1'931.66	30	30	100	183	100	186	0.042	-1.195	2.280	1.195
2G	NMVOC	22'431.61	6'305.80	25	25	100	203	100	205	0.543	-5.137	9.640	5.137
2H1	NMVOC	554.99	216.67	30	30	100	205	100	208	0.001	-0.116	0.251	0.116
2H2	NMVOC	1'950.03	2'010.81	10	10	83	101	84	101	0.014	0.021	0.110	0.124
2H3	NMVOC	156.00	39.12	3	3	100	204	100	204	0.000	-0.040	0.083	0.040
3B1a	NMVOC	6'412.83	6'715.83	6	6	60	60	60	61	0.054	0.104	0.217	0.242
3B1b	NMVOC	5'121.56	7'399.49	6	6	71	69	71	70	0.089	0.779	0.580	0.632
3B2	NMVOC	66.79	68.15	6	6	100	204	100	204	0.000	0.000	0.003	0.004
3B3	NMVOC	1'126.15	807.34	6	6	100	203	100	203	0.009	-0.109	0.225	0.109
3B4d	NMVOC	37.02	49.74	6	6	100	204	100	205	0.000	0.004	0.004	0.009
3B4e	NMVOC	120.39	203.34	6	6	100	204	100	204	0.001	0.028	0.028	0.059
3B4f	NMVOC	8.64	49.08	6	6	100	204	100	204	0.000	0.014	0.014	0.029
3B4gi	NMVOC	508.70	642.42	6	6	100	204	100	205	0.006	0.046	0.046	0.097
3B4gii	NMVOC	366.34	1'152.54	6	6	100	204	100	204	0.018	0.269	0.269	0.554
3B4giii	NMVOC	46.28	40.14	6	6	100	204	100	204	0.000	-0.002	0.005	0.002
3B4giv	NMVOC	129.27	228.30	6	6	100	203	100	203	0.001	0.034	0.034	0.070
3B4h	NMVOC	3.60	4.52	7	6	100	204	100	204	0.000	0.000	0.000	0.001
3De	NMVOC	481.06	454.84	5	5	100	204	100	204	0.003	-0.009	0.027	0.013
5A	NMVOC	405.68	129.24	10	10	50	51	51	52	0.000	-0.095	0.056	0.053
5B1	NMVOC	105.05	175.20	20	20	99	101	102	104	0.000	0.024	0.026	0.031
5B2	NMVOC	49.57	1'098.06	20	20	30	30	35	37	0.001	0.360	0.149	0.162
5C1a	NMVOC	516.80	249.74	50	50	50	50	68	73	0.000	-0.092	0.119	0.107
5C1bi	NMVOC	3.75	NO	NO	NO	NO	NO	NO	NO	0.000	-0.001	0.001	0.001
5C1biii	NMVOC	4.50	NO	NO	NO	NO	NO	NO	NO	0.000	-0.002	0.001	0.001
5C1biv	NMVOC	0.46	18.31	20	20	20	20	27	29	0.000	0.006	0.002	0.002
5C1bv	NMVOC	1.20	0.39	5	5	30	30	30	31	0.000	0.000	0.000	0.000
5C2	NMVOC	33.13	16.86	48	48	100	156	100	168	0.000	-0.006	0.013	0.007
5D1	NMVOC	0.51	0.10	1	1	27	27	27	27	0.000	0.000	0.000	0.000
5D2	NMVOC	0.01	0.03	10	10	20	20	22	22	0.000	0.000	0.000	0.000
5E	NMVOC	28.00	60.00	20	20	23	24	30	32	0.000	0.011	0.006	0.006
6A	NMVOC	202.98	169.69	30	30	50	50	56	60	0.000	-0.011	0.031	0.028
Total, Monte Carlo simulations		295'753	72'523					22.1	24.8	1.0	-75.4	3.8	3.9
Total, inventory		295'705	72'515								-75.5		

Table A - 36 Uncertainty analysis of SO_x emissions, approach 2, for 2022 and for the trend 1990-2022. Monte Carlo simulations were run 500'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J	
NFR	Pollutant	Emissions 1990	Emissions 2022	Activity data uncertainty 2022		Emission factor uncertainty 2022		Emission combined uncertainty 2022		Emission contri-bution to variance 2022	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	SOx (as SO2)	3'679.11	233.66	10	10	22	22	24	24	0.035	-8.788	2.008	2.005
1A1b	SOx (as SO2)	660.41	65.22	1	1	20	20	20	20	0.002	-1.521	0.314	0.311
1A2a	SOx (as SO2)	362.55	9.97	2	2	15	15	15	15	0.000	-0.901	0.144	0.146
1A2b	SOx (as SO2)	67.34	0.48	2	2	10	10	10	10	0.000	-0.171	0.020	0.020
1A2c	SOx (as SO2)	1'187.10	64.21	2	2	11	11	11	11	0.001	-2.869	0.356	0.355
1A2d	SOx (as SO2)	3'238.01	1.02	2	2	14	14	14	14	0.000	-8.267	1.178	1.175
1A2e	SOx (as SO2)	1'077.50	6.10	2	2	12	12	12	12	0.000	-2.738	0.366	0.359
1A2f	SOx (as SO2)	3'530.25	1'466.65	2	2	19	19	19	19	0.863	-5.268	0.977	0.976
1A2gvii	SOx (as SO2)	370.66	2.68	1	1	10	10	10	10	0.000	-0.940	0.109	0.108
1A2gviii	SOx (as SO2)	3'533.86	313.58	2	2	19	19	19	19	0.040	-8.222	1.513	1.501
1A3ai(i)	SOx (as SO2)	99.68	118.92	1	1	10	10	10	10	0.002	0.049	0.008	0.008
1A3aii(i)	SOx (as SO2)	24.94	4.38	1	1	10	10	10	10	0.000	-0.053	0.006	0.006
1A3bi(fu)	SOx (as SO2)	1'612.51	37.12	1	1	10	10	10	10	0.000	-4.026	0.454	0.459
1A3bii(fu)	SOx (as SO2)	291.09	5.08	1	1	10	10	10	10	0.000	-0.731	0.085	0.085
1A3biii(fu)	SOx (as SO2)	1'837.87	9.25	1	1	10	10	10	10	0.000	-4.672	0.530	0.525
1A3biv(fu)	SOx (as SO2)	25.47	0.72	1	1	10	10	10	10	0.000	-0.063	0.007	0.007
1A3c	SOx (as SO2)	26.92	0.12	1	1	10	10	10	10	0.000	-0.068	0.008	0.008
1A3dii	SOx (as SO2)	64.88	0.67	1	1	10	10	10	10	0.000	-0.164	0.019	0.019
1A3ei	SOx (as SO2)	0.28	0.08	2	2	10	10	10	10	0.000	0.000	0.000	0.000
1A4ai	SOx (as SO2)	3'869.92	112.91	2	2	10	10	10	10	0.001	-9.599	1.044	1.041
1A4aii	SOx (as SO2)	1.61	0.05	1	1	10	10	10	10	0.000	-0.004	0.000	0.000
1A4bi	SOx (as SO2)	10'354.85	266.52	4	4	10	10	11	11	0.009	-25.760	2.448	2.422
1A4bii	SOx (as SO2)	1.20	0.03	1	1	10	10	10	10	0.000	-0.003	0.000	0.000
1A4ci	SOx (as SO2)	335.80	54.67	21	21	18	18	27	28	0.003	-0.719	0.230	0.225
1A4cii	SOx (as SO2)	304.60	1.62	1	1	10	10	10	10	0.000	-0.774	0.090	0.090
1A5b	SOx (as SO2)	78.17	32.80	1	1	10	10	10	10	0.000	-0.116	0.014	0.014
1B2aiv	SOx (as SO2)	419.02	15.51	30	30	47	47	54	58	0.001	-1.030	0.592	0.564
1B2c	SOx (as SO2)	300.98	0.85	22	22	31	31	37	39	0.000	-0.766	0.301	0.284
2A1	SOx (as SO2)	0.69	0.45	2	2	100	204	100	204	0.000	-0.001	0.001	0.001
2A2	SOx (as SO2)	0.01	0.01	2	2	100	449	100	449	0.000	0.000	0.000	0.000
2A5a	SOx (as SO2)	0.08	0.02	5	5	100	448	100	448	0.000	0.000	0.001	0.000
2B5	SOx (as SO2)	625.20	289.32	2	2	20	20	20	20	0.037	-0.858	0.182	0.178
2B10a	SOx (as SO2)	168.00	38.15	2	2	40	40	40	40	0.003	-0.332	0.135	0.133
2C1	SOx (as SO2)	144.04	16.91	2	2	83	101	83	101	0.003	-0.325	0.325	0.271
2C3	SOx (as SO2)	696.30	NO	NO	NO	NO	NO	NO	NO	0.000	-1.751	3.474	1.751
2C7c	SOx (as SO2)	NA	0.02	5	5	83	101	83	101	0.000	0.000	0.000	0.000
2G	SOx (as SO2)	3.44	7.69	25	25	83	101	84	104	0.001	0.011	0.010	0.013
2H3	SOx (as SO2)	1.30	0.33	3	3	100	203	100	204	0.000	-0.002	0.005	0.002
5B2	SOx (as SO2)	NA	0.91	20	20	101	98	102	103	0.000	0.002	0.002	0.002
5C1a	SOx (as SO2)	24.23	11.71	51	49	40	40	62	65	0.001	-0.032	0.039	0.036
5C1bi	SOx (as SO2)	45.00	NO	NO	NO	NO	NO	NO	NO	0.000	-0.115	0.050	0.048
5C1biii	SOx (as SO2)	19.50	NO	NO	NO	NO	NO	NO	NO	0.000	-0.050	0.022	0.021
5C1biv	SOx (as SO2)	74.10	15.69	20	20	30	30	36	36	0.000	-0.149	0.061	0.058
5C2	SOx (as SO2)	0.68	0.34	48	48	96	133	98	145	0.000	-0.001	0.002	0.001
5D1	SOx (as SO2)	0.13	0.03	1	1	37	37	37	37	0.000	0.000	0.000	0.000
5D2	SOx (as SO2)	0.00	0.01	10	10	20	20	22	22	0.000	0.000	0.000	0.000
6A	SOx (as SO2)	9.17	7.25	30	30	50	50	56	60	0.000	-0.005	0.010	0.009
Total, Monte Carlo simulations		39'167	3'213					9.3	9.4	1.0	-91.8	0.7	0.7
Total, inventory		39'168	3'214								-91.8		

Table A - 37 Uncertainty analysis of NH_3 emissions, approach 2, for 2022 and for the trend 1990-2022. Monte Carlo simulations were run 500'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J	
NFR	Pollutant	Emissions 1990	Emissions 2022	Activity data uncertainty 2022		Emission factor uncertainty 2022		Emission combined uncertainty 2022		Emission contri-bution to variance 2022	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	NH3	4.85	36.83	10	10	20	20	22	22	0.000	0.047	0.012	0.013
1A1b	NH3	0.01	0.01	1	1	10	10	10	10	0.000	0.000	0.000	0.000
1A2a	NH3	0.00	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000
1A2b	NH3	0.11	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000
1A2c	NH3	0.02	0.01	2	2	10	10	10	10	0.000	0.000	0.000	0.000
1A2d	NH3	0.02	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000
1A2e	NH3	0.02	0.01	2	2	10	10	10	10	0.000	0.000	0.000	0.000
1A2f	NH3	147.02	189.84	2	2	9	9	9	9	0.000	0.063	0.012	0.013
1A2gvii	NH3	1.00	1.55	1	1	51	49	50	50	0.000	0.001	0.000	0.000
1A2gviii	NH3	17.00	54.00	2	2	9	9	9	9	0.000	0.054	0.009	0.009
1A3bi(fu)	NH3	1'324.97	823.61	1	1	50	50	50	50	0.004	-0.735	0.379	0.374
1A3bii(fu)	NH3	8.57	33.92	1	1	50	50	50	50	0.000	0.037	0.019	0.019
1A3biii(fu)	NH3	4.55	34.44	1	1	50	51	50	50	0.000	0.044	0.023	0.023
1A3biv(fu)	NH3	3.26	4.03	1	1	50	50	50	50	0.000	0.001	0.001	0.001
1A3c	NH3	0.07	0.07	1	1	50	50	50	50	0.000	0.000	0.000	0.000
1A3dii	NH3	0.20	0.21	1	1	50	50	51	49	0.000	0.000	0.000	0.000
1A3ei	NH3	NA	0.00	0	0	0	0	0	0	0.000	0.000	0.000	0.000
1A4ai	NH3	19.80	36.46	2	2	10	10	10	10	0.000	0.024	0.004	0.004
1A4aii	NH3	0.01	0.02	1	1	10	10	10	10	0.000	0.000	0.000	0.000
1A4bi	NH3	153.12	56.22	4	4	10	10	11	11	0.000	-0.142	0.026	0.025
1A4bii	NH3	0.01	0.01	1	1	10	10	10	10	0.000	0.000	0.000	0.000
1A4ci	NH3	2.88	8.11	21	21	10	10	23	24	0.000	0.008	0.003	0.003
1A4cii	NH3	0.76	0.83	1	1	50	50	50	50	0.000	0.000	0.000	0.000
1A5b	NH3	0.04	0.04	1	1	50	50	50	50	0.000	0.000	0.000	0.000
2B1	NH3	0.07	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000
2B2	NH3	0.73	NO	NO	NO	NO	NO	NO	NO	0.000	-0.001	0.000	0.000
2B10a	NH3	7.73	NA	NA	NA	NA	NA	NA	NA	0.000	-0.011	0.005	0.005
2C1	NH3	11.90	1.61	2	2	100	204	100	204	0.000	-0.015	0.031	0.015
2C7c	NH3	9.19	8.17	5	5	100	446	100	446	0.000	-0.001	0.007	0.001
2G	NH3	203.15	75.63	25	25	40	40	46	48	0.000	-0.187	0.114	0.107
2H2	NH3	132.33	56.06	10	10	100	452	100	450	0.002	-0.110	0.498	0.110
2H3	NH3	1.04	0.26	3	3	100	203	100	203	0.000	-0.001	0.002	0.001
2L	NH3	2.38	3.81	25	25	102	98	102	106	0.000	0.002	0.002	0.003
3B1a	NH3	9'337.10	10'346.42	6	7	29	29	29	30	0.223	1.478	1.359	1.443
3B1b	NH3	5'190.92	7'150.78	6	6	27	27	28	28	0.093	2.870	1.141	1.193
3B2	NH3	509.75	479.32	6	6	87	87	88	87	0.004	-0.045	0.090	0.073
3B3	NH3	6'965.04	4'973.57	6	6	40	40	40	41	0.096	-2.909	1.385	1.341
3B4d	NH3	158.13	160.48	6	6	65	65	65	66	0.000	0.003	0.023	0.024
3B4e	NH3	256.31	389.90	6	6	52	52	53	52	0.001	0.196	0.111	0.118
3B4f	NH3	19.65	101.23	6	6	68	68	69	68	0.000	0.120	0.084	0.084
3B4gi	NH3	978.79	682.91	6	6	82	82	82	82	0.007	-0.433	0.388	0.366
3B4gii	NH3	304.87	685.29	7	6	85	87	85	87	0.008	0.558	0.483	0.500
3B4giii	NH3	29.77	21.54	6	6	93	93	93	93	0.000	-0.012	0.012	0.012
3B4giv	NH3	124.46	95.73	6	6	85	85	86	84	0.000	-0.042	0.041	0.038
3B4h	NH3	14.55	43.21	6	6	51	49	51	50	0.000	0.042	0.022	0.023
3Da1	NH3	4'258.33	2'192.59	5	5	50	50	50	50	0.029	-3.018	1.515	1.520
3Da2a	NH3	34'567.08	20'447.23	6	6	21	21	22	22	0.478	-20.559	4.104	4.226
3Da2b	NH3	1'169.36	NO	NO	NO	NO	NO	NO	NO	0.000	-1.714	0.889	0.877
3Da2c	NH3	34.00	990.33	20	20	50	50	53	55	0.007	1.402	0.763	0.807
3Da3	NH3	760.92	1'420.53	6	6	62	62	63	63	0.019	0.965	0.622	0.637
5A	NH3	615.79	196.08	10	10	50	50	51	51	0.000	-0.616	0.340	0.322
5B1	NH3	175.08	292.01	20	20	100	100	101	104	0.002	0.172	0.186	0.217
5B2	NH3	10.28	234.59	20	20	75	75	77	79	0.001	0.329	0.259	0.264
5C1biv	NH3	5.70	1.84	20	20	50	50	53	55	0.000	-0.006	0.004	0.003
5C2	NH3	18.03	9.18	48	48	25	25	53	56	0.000	-0.013	0.015	0.015
5D1	NH3	89.98	126.65	1	1	50	50	50	51	0.000	0.054	0.028	0.028
6A	NH3	845.54	969.02	30	30	99	101	103	109	0.025	0.181	0.633	0.747
Total, Monte Carlo simulations		68'491	53'431					12.1	12.2	1.0	-21.9	4.8	4.9
Total, inventory		68'496	53'436								-22.0		

Table A - 38 Uncertainty analysis of PM2.5 emissions, approach 2, for 2022 and for the trend 1990-2022. Monte Carlo simulations were run 500'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J	
NFR	Pollutant	Emissions 1990	Emissions 2022	Activity data uncertainty 2022		Emission factor uncertainty 2022		Emission combined uncertainty 2022		Emission contri-bution to variance 2022	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	PM2.5	781.83	45.71	10	10	72	71	73	71	0.000	-2.833	2.498	2.311
1A1b	PM2.5	47.66	1.64	1	1	20	20	20	20	0.000	-0.178	0.094	0.077
1A1c	PM2.5	4.64	12.76	5	5	20	20	21	21	0.000	0.031	0.014	0.017
1A2a	PM2.5	14.81	2.88	2	2	28	28	28	28	0.000	-0.046	0.026	0.022
1A2b	PM2.5	20.39	1.45	2	2	30	30	30	30	0.000	-0.073	0.043	0.035
1A2c	PM2.5	40.77	5.16	2	2	10	10	10	10	0.000	-0.138	0.069	0.054
1A2d	PM2.5	149.62	0.23	2	2	33	33	33	33	0.000	-0.577	0.346	0.291
1A2e	PM2.5	25.68	1.25	2	2	10	10	10	10	0.000	-0.094	0.047	0.037
1A2f	PM2.5	437.58	46.37	2	2	65	65	65	66	0.000	-1.508	1.274	1.133
1A2gvii	PM2.5	728.86	387.04	1	1	50	50	50	50	0.007	-1.319	0.940	0.823
1A2gviii	PM2.5	872.51	191.39	2	2	65	65	65	65	0.003	-2.620	2.150	1.985
1A3ai(i)	PM2.5	92.39	12.49	1	1	30	30	30	30	0.000	-0.309	0.179	0.151
1A3aii(i)	PM2.5	22.67	1.74	1	1	31	29	30	30	0.000	-0.081	0.047	0.039
1A3bi(fu)	PM2.5	577.66	112.38	1	1	57	57	57	57	0.001	-1.793	1.379	1.233
1A3bii(fu)	PM2.5	327.15	56.07	1	1	48	48	49	48	0.000	-1.046	0.733	0.645
1A3biii(fu)	PM2.5	1'587.90	40.87	1	1	27	27	27	27	0.000	-5.972	3.320	2.760
1A3biv(fu)	PM2.5	208.81	62.30	1	1	54	53	54	53	0.000	-0.566	0.421	0.379
1A3bvi(fu)	PM2.5	689.15	944.64	1	1	50	50	50	50	0.044	0.985	0.621	0.700
1A3c	PM2.5	174.35	203.08	1	1	50	50	50	50	0.002	0.111	0.071	0.081
1A3dii	PM2.5	59.09	23.64	1	1	50	50	50	50	0.000	-0.137	0.100	0.086
1A3ei	PM2.5	0.11	0.09	2	2	27	27	27	27	0.000	0.000	0.000	0.000
1A4ai	PM2.5	1'354.47	429.78	2	2	78	78	78	78	0.022	-3.542	3.307	3.026
1A4bi	PM2.5	14'535.91	1'888.35	4	4	75	77	76	76	0.409	-44.435	16.951	20.439
1A4ci	PM2.5	696.98	214.03	21	21	39	39	44	45	0.002	-1.862	1.320	1.130
1A4cii	PM2.5	435.10	139.20	1	1	80	80	81	79	0.002	-1.140	1.122	0.996
1A5b	PM2.5	86.95	44.90	1	1	50	50	50	50	0.000	-0.162	0.117	0.102
1B1a	PM2.5	0.16	0.05	30	30	40	40	49	51	0.000	0.000	0.000	0.000
1B2c	PM2.5	0.44	0.00	22	22	100	245	100	246	0.000	-0.002	0.004	0.002
2A1	PM2.5	240.48	157.80	2	2	100	204	100	204	0.020	-0.316	0.660	0.316
2A2	PM2.5	7.21	7.25	2	2	100	448	100	448	0.000	0.000	0.001	0.002
2A5a	PM2.5	183.33	225.55	5	5	100	444	100	444	0.254	0.156	0.156	0.694
2B5	PM2.5	61.20	44.96	2	2	100	205	100	205	0.002	-0.063	0.132	0.063
2B10a	PM2.5	7.86	NA	NA	NA	NA	NA	NA	NA	0.000	-0.030	0.020	0.017
2C1	PM2.5	817.90	8.52	2	2	94	125	94	125	0.000	-3.085	4.008	2.947
2C3	PM2.5	78.33	NO	NO	NO	NO	NO	NO	NO	0.000	-0.302	0.634	0.302
2C7a	PM2.5	5.66	0.75	5	5	100	203	100	204	0.000	-0.019	0.040	0.019
2C7c	PM2.5	1.53	1.40	5	5	100	446	100	446	0.000	0.000	0.002	0.001
2D3c	PM2.5	4.00	3.80	20	20	100	205	100	206	0.000	-0.001	0.007	0.006
2D3i	PM2.5	12.00	NA	NA	NA	NA	NA	NA	NA	0.000	-0.046	0.203	0.046
2G	PM2.5	512.78	431.87	25	25	83	101	84	105	0.040	-0.311	0.914	0.725
2H1	PM2.5	235.77	180.31	30	30	100	204	100	207	0.027	-0.212	0.757	0.400
2H2	PM2.5	187.99	167.87	10	10	100	449	100	450	0.141	-0.074	0.390	0.113
2H3	PM2.5	15.60	3.91	3	3	100	203	100	203	0.000	-0.045	0.095	0.045
2I	PM2.5	216.08	49.33	10	10	100	447	100	447	0.012	-0.613	2.763	0.613
3B1a	PM2.5	20.61	23.50	6	6	100	306	100	306	0.001	0.011	0.011	0.036
3B1b	PM2.5	18.26	21.86	6	6	100	305	100	306	0.001	0.014	0.014	0.043
3B2	PM2.5	0.79	0.81	6	6	100	306	100	306	0.000	0.000	0.000	0.001
3B3	PM2.5	9.57	6.66	6	6	100	308	100	308	0.000	-0.011	0.035	0.011
3B4d	PM2.5	0.14	0.18	6	6	100	304	100	305	0.000	0.000	0.000	0.001
3B4e	PM2.5	3.94	6.66	7	6	100	307	100	307	0.000	0.010	0.010	0.032
3B4f	PM2.5	0.59	3.34	6	6	100	307	100	307	0.000	0.011	0.011	0.033
3B4gi	PM2.5	9.25	11.68	6	7	100	307	100	307	0.000	0.009	0.009	0.029
3B4gii	PM2.5	6.78	21.34	7	6	100	306	100	307	0.001	0.056	0.056	0.173
3B4giii	PM2.5	1.89	1.64	7	6	100	306	100	306	0.000	-0.001	0.003	0.001
3B4giv	PM2.5	1.98	3.31	6	6	100	305	100	305	0.000	0.005	0.005	0.016
3B4h	PM2.5	0.24	0.09	6	6	100	306	100	306	0.000	-0.001	0.002	0.001
3De	PM2.5	47.48	44.96	5	5	100	204	100	204	0.002	-0.010	0.030	0.015
5A	PM2.5	0.73	0.51	10	10	30	30	32	32	0.000	-0.001	0.001	0.001
5B2	PM2.5	NA	0.05	20	20	100	100	101	104	0.000	0.000	0.000	0.000
5C1a	PM2.5	465.12	224.77	50	50	30	30	57	60	0.003	-0.927	1.203	1.089
5C1bi	PM2.5	0.47	NO	NO	NO	NO	NO	NO	NO	0.000	-0.002	0.001	0.001
5C1biii	PM2.5	16.50	NO	NO	NO	NO	NO	NO	NO	0.000	-0.064	0.042	0.035
5C1biv	PM2.5	14.25	2.71	20	20	34	34	39	40	0.000	-0.045	0.030	0.024
5C1bv	PM2.5	4.39	0.88	5	5	33	33	33	33	0.000	-0.014	0.008	0.007
5C2	PM2.5	84.75	43.12	48	48	100	156	100	167	0.001	-0.161	0.387	0.201
5E	PM2.5	1.40	1.50	20	20	30	30	36	36	0.000	0.000	0.002	0.002
6A	PM2.5	4.42	4.78	30	30	40	40	49	51	0.000	0.001	0.008	0.008
Total, Monte Carlo simulations		27'268	6'577					32.6	33.7	1.0	-75.4	5.9	7.4
Total, inventory		27'275	6'577								-75.9		

Table A - 39 Uncertainty analysis of PM10 emissions, approach 2, for 2022 and for the trend 1990-2022. Monte Carlo simulations were run 500'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J	
NFR	Pollutant	Emissions 1990	Emissions 2022	Activity data uncertainty 2022		Emission factor uncertainty 2022		Emission combined uncertainty 2022		Emission contri-bution to variance 2022	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	PM10	1'044.54	45.71	10	10	71	71	73	71	0.000	-2.820	2.364	2.187
1A1b	PM10	47.66	1.64	1	1	20	20	20	20	0.000	-0.131	0.059	0.052
1A1c	PM10	4.89	13.45	5	5	20	20	21	21	0.000	0.024	0.010	0.011
1A2a	PM10	20.53	3.17	2	2	28	28	28	28	0.000	-0.049	0.025	0.021
1A2b	PM10	29.24	1.53	2	2	30	30	30	30	0.000	-0.079	0.040	0.035
1A2c	PM10	40.77	5.16	2	2	10	10	10	10	0.000	-0.101	0.042	0.036
1A2d	PM10	166.58	0.23	2	2	33	33	33	33	0.000	-0.472	0.248	0.222
1A2e	PM10	25.68	1.25	2	2	10	10	10	10	0.000	-0.069	0.029	0.024
1A2f	PM10	832.63	77.89	2	2	65	65	65	65	0.000	-2.134	1.652	1.551
1A2gvii	PM10	2'173.23	2'358.75	1	1	50	50	50	50	0.069	0.524	0.320	0.355
1A2gviii	PM10	913.14	201.95	2	2	65	65	65	65	0.001	-2.012	1.587	1.439
1A3ai(i)	PM10	102.65	12.49	1	1	30	30	30	30	0.000	-0.256	0.130	0.116
1A3aii(i)	PM10	25.19	1.74	1	1	30	30	30	30	0.000	-0.067	0.034	0.030
1A3bi(fu)	PM10	577.66	112.38	1	1	58	57	58	57	0.000	-1.318	0.945	0.866
1A3bii(fu)	PM10	327.15	56.07	1	1	48	48	48	48	0.000	-0.768	0.495	0.447
1A3biii(fu)	PM10	1'587.90	40.87	1	1	27	27	27	27	0.000	-4.384	2.119	1.867
1A3biv(fu)	PM10	208.81	62.30	1	1	55	53	54	54	0.000	-0.415	0.287	0.263
1A3bvi(fu)	PM10	2'049.68	2'577.31	1	1	50	50	50	50	0.082	1.490	0.874	0.951
1A3c	PM10	982.81	1'322.59	1	1	50	50	50	50	0.022	0.962	0.564	0.637
1A3dii	PM10	59.09	23.64	1	1	50	50	50	50	0.000	-0.100	0.066	0.060
1A3ei	PM10	0.11	0.09	2	2	28	27	27	28	0.000	0.000	0.000	0.000
1A4ai	PM10	1'427.63	457.04	2	2	77	79	78	79	0.006	-2.735	2.411	2.290
1A4bi	PM10	15'325.72	1'987.14	4	4	77	75	76	76	0.113	-35.240	16.661	19.385
1A4ci	PM10	710.36	217.30	22	21	39	39	43	45	0.000	-1.397	0.922	0.796
1A4cii	PM10	511.19	197.68	1	1	81	79	80	81	0.001	-0.886	0.811	0.776
1A5b	PM10	286.52	261.52	1	1	50	50	50	50	0.001	-0.071	0.050	0.044
1B1a	PM10	1.60	0.48	30	30	40	40	48	51	0.000	-0.003	0.002	0.002
1B2c	PM10	0.44	0.00	22	22	100	243	100	245	0.000	-0.001	0.003	0.001
2A1	PM10	374.35	245.64	2	2	100	204	100	204	0.012	-0.362	0.746	0.362
2A2	PM10	14.41	14.48	2	2	100	448	100	447	0.000	0.000	0.002	0.003
2A5a	PM10	366.54	451.07	5	5	100	449	100	449	0.249	0.224	0.224	1.013
2B5	PM10	73.80	53.76	2	2	100	203	100	203	0.001	-0.057	0.118	0.057
2B10a	PM10	17.07	NA	NA	NA	NA	NA	NA	NA	0.000	-0.048	0.028	0.025
2C1	PM10	1'485.46	12.84	2	2	94	125	94	124	0.000	-4.105	5.130	3.889
2C3	PM10	113.15	NO	NO	NO	NO	NO	NO	NO	0.000	-0.319	0.665	0.319
2C7a	PM10	5.96	0.79	5	5	100	204	100	204	0.000	-0.015	0.031	0.015
2C7c	PM10	3.06	2.78	5	5	100	449	100	449	0.000	-0.001	0.004	0.001
2D3c	PM10	19.98	19.01	20	20	100	203	100	205	0.000	-0.003	0.027	0.022
2D3i	PM10	24.00	NA	NA	NA	NA	NA	NA	NA	0.000	-0.068	0.302	0.068
2G	PM10	588.38	600.71	25	25	84	100	84	105	0.019	0.035	0.712	0.728
2H1	PM10	243.80	186.43	30	30	100	204	100	207	0.007	-0.161	0.572	0.310
2H2	PM10	310.39	311.95	10	10	100	448	100	448	0.121	0.005	0.249	0.263
2H3	PM10	15.60	3.91	3	3	100	203	100	203	0.000	-0.033	0.069	0.033
2I	PM10	864.32	195.98	10	10	100	447	100	447	0.048	-1.653	7.610	1.653
3B1a	PM10	84.47	96.33	7	6	100	306	100	307	0.004	0.033	0.034	0.108
3B1b	PM10	74.85	89.58	6	6	100	305	100	306	0.004	0.042	0.042	0.130
3B2	PM10	19.76	20.16	6	6	100	306	100	306	0.000	0.001	0.008	0.011
3B3	PM10	213.16	149.51	6	6	100	306	100	307	0.010	-0.178	0.549	0.178
3B4d	PM10	3.42	4.59	6	6	100	306	100	305	0.000	0.003	0.003	0.010
3B4e	PM10	6.20	10.46	6	6	100	305	100	305	0.000	0.012	0.012	0.037
3B4f	PM10	0.94	5.34	6	6	100	307	100	307	0.000	0.013	0.013	0.039
3B4gi	PM10	123.32	155.74	6	6	100	306	100	306	0.011	0.091	0.091	0.284
3B4gii	PM10	67.84	213.43	6	6	100	305	100	305	0.020	0.411	0.411	1.259
3B4giii	PM10	10.41	9.03	6	6	100	307	100	307	0.000	-0.004	0.013	0.004
3B4giv	PM10	18.52	31.37	6	6	100	306	100	306	0.000	0.036	0.036	0.112
3B4h	PM10	0.50	0.82	7	6	100	306	100	306	0.000	0.001	0.001	0.003
3De	PM10	1'053.57	1'001.42	5	5	100	204	100	204	0.198	-0.143	0.451	0.235
5A	PM10	0.73	0.51	10	10	30	30	31	32	0.000	-0.001	0.000	0.000
5B2	PM10	NA	0.05	20	20	100	100	101	104	0.000	0.000	0.000	0.000
5C1a	PM10	516.80	249.74	50	50	50	50	68	73	0.002	-0.755	1.044	0.871
5C1bi	PM10	3.08	NO	NO	NO	NO	NO	NO	NO	0.000	-0.009	0.005	0.005
5C1biii	PM10	24.00	NO	NO	NO	NO	NO	NO	NO	0.000	-0.068	0.041	0.035
5C1biv	PM10	19.95	3.88	20	20	36	34	40	41	0.000	-0.046	0.027	0.024
5C1bv	PM10	4.39	0.88	5	5	33	33	33	33	0.000	-0.010	0.005	0.005
5C2	PM10	93.09	47.37	47	49	100	156	100	168	0.000	-0.129	0.309	0.163
5E	PM10	2.80	3.00	20	20	30	30	35	37	0.000	0.001	0.002	0.003
6A	PM10	229.38	116.54	30	30	40	40	49	51	0.000	-0.320	0.297	0.262
Total, Monte Carlo simulations		36'564	14'346					28.7	32.0	1.0	-60.1	10.7	12.5
Total, inventory		36'575	14'350								-60.8		

A5.3.2 Uncertainty estimations, approach 2, sensitivity results

Results for the sensitivity analysis between emissions from each category and inventory emission are given as tornado plots, in Figure A - 5 to Figure A - 10.

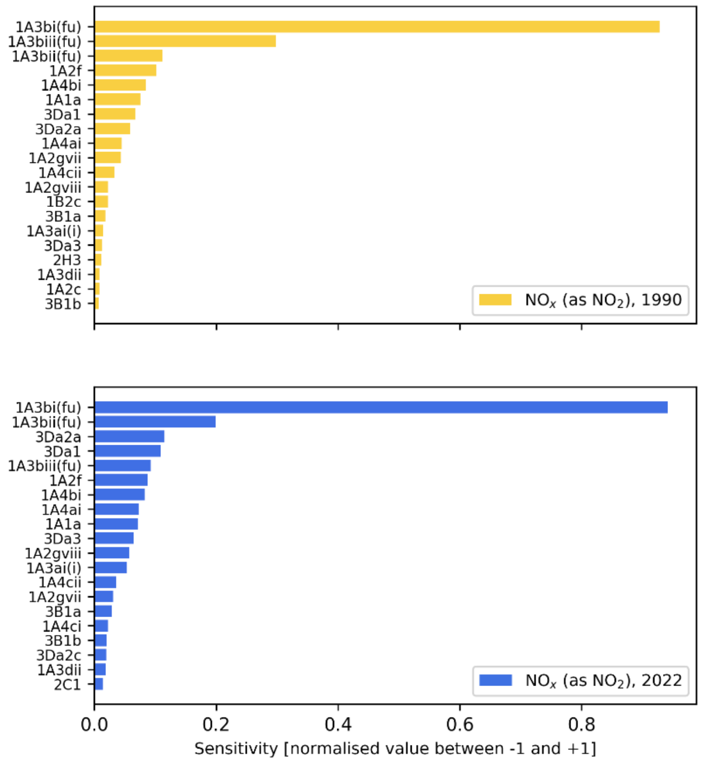

Figure A - 5 Results of the sensitivity analysis between emissions from each category and inventory emissions for NO_x, for the base year 1990 and the reporting year 2022. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

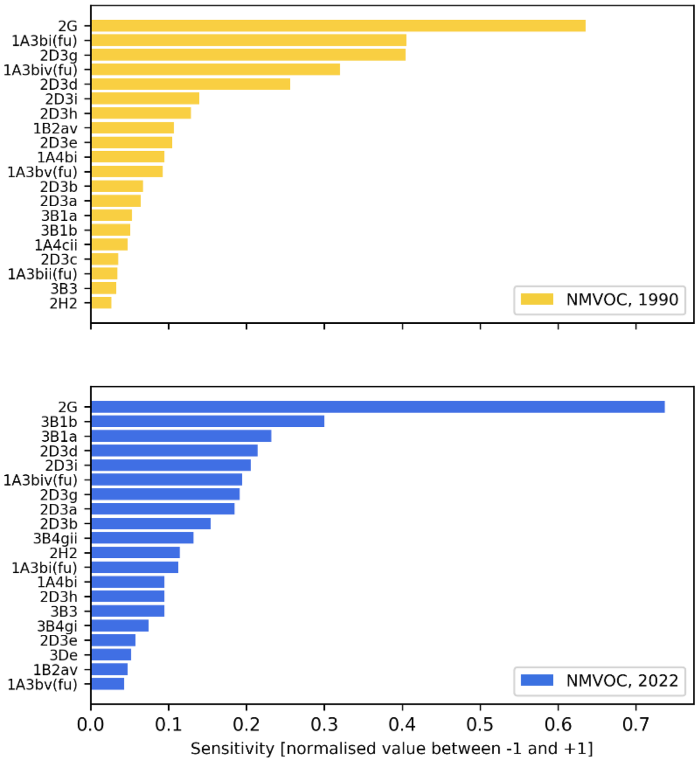

Figure A - 6 Results of the sensitivity analysis between emissions from each category and inventory emissions for NMVOC, for the base year 1990 and the reporting year 2022. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

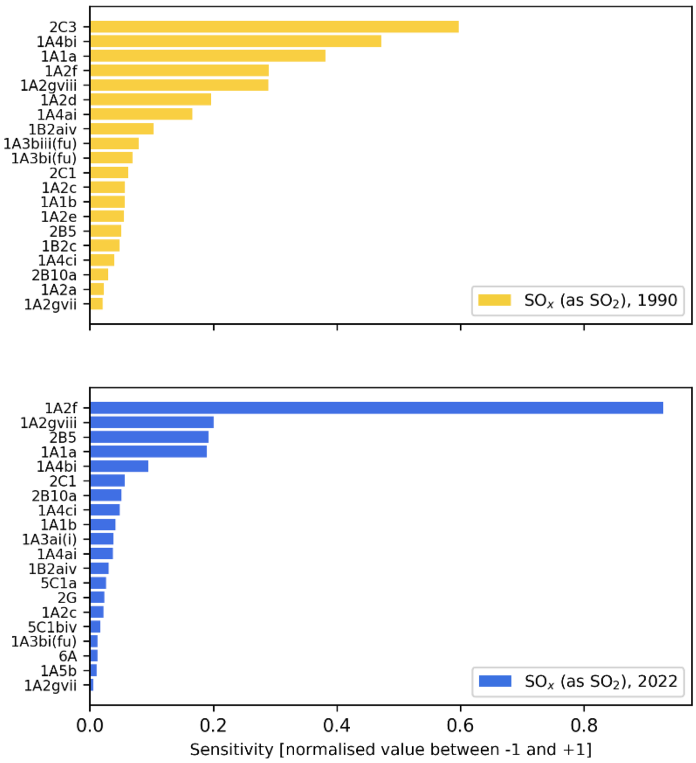

Figure A - 7 Results of the sensitivity analysis between emissions from each category and inventory emissions for SO_x (expressed as SO_2 equivalents), for the base year 1990 and the reporting year 2022. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

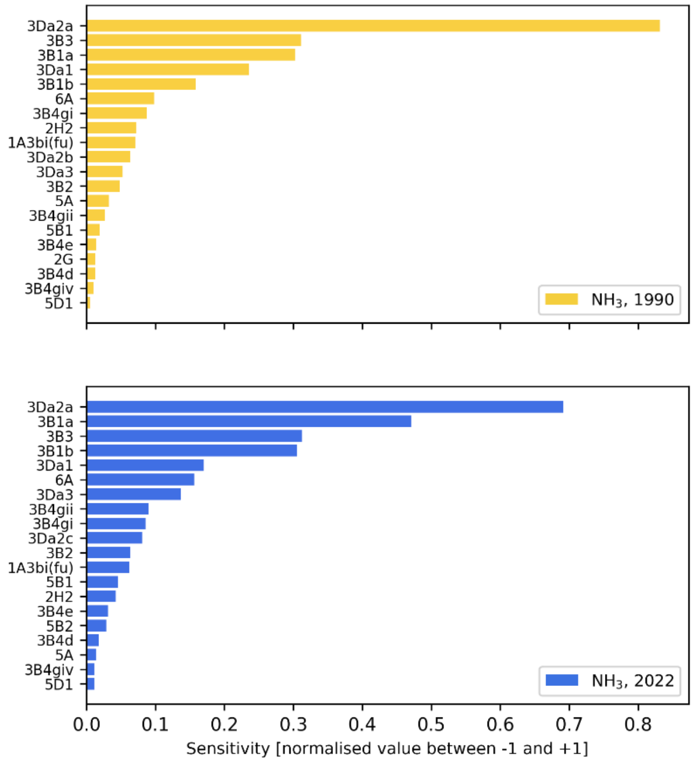

Figure A - 8 Results of the sensitivity analysis between emissions from each category and inventory emissions for NH_3, for the base year 1990 and the reporting year 2022. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

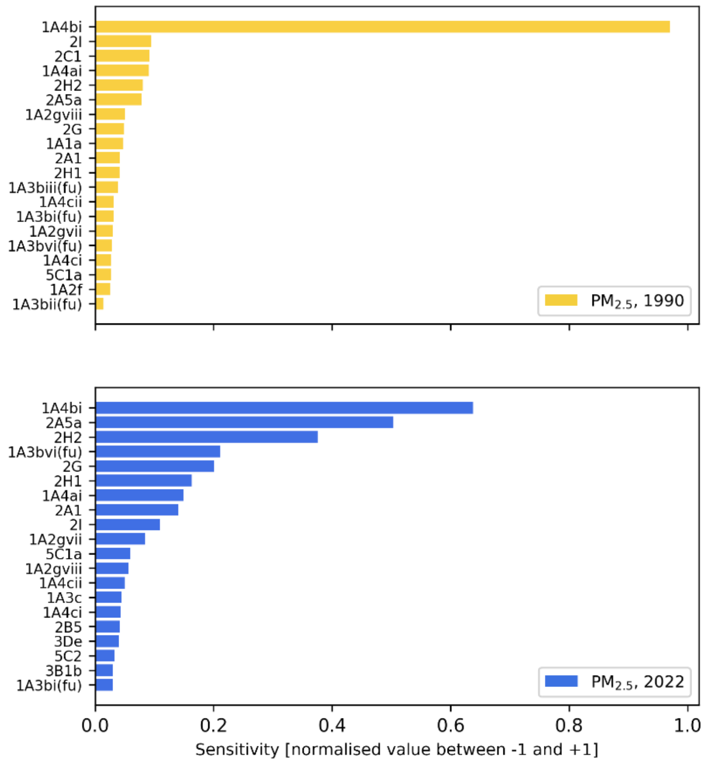

Figure A - 9 Results of the sensitivity analysis between emissions from each category and inventory emissions for PM2.5, for the base year 1990 and the reporting year 2022. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

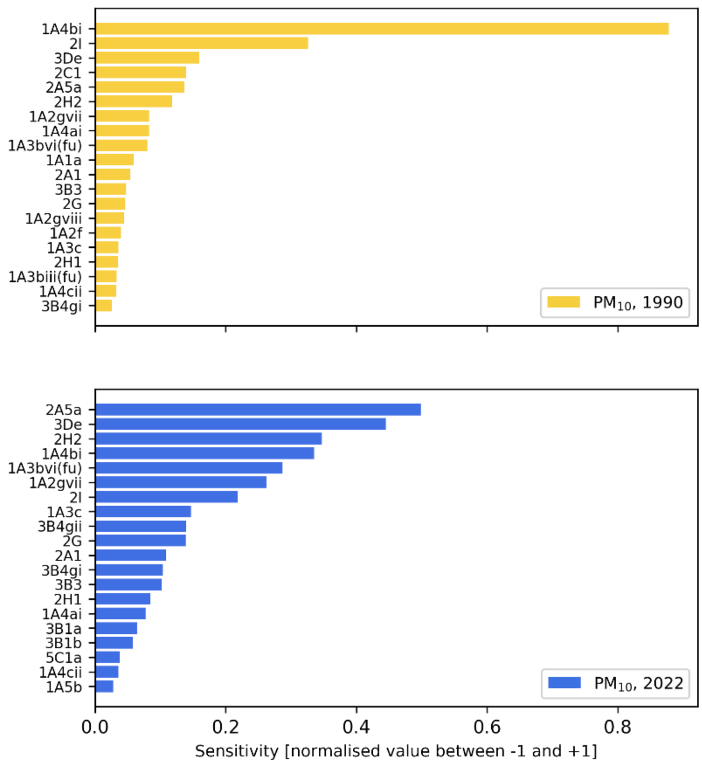

Figure A - 10 Results of the sensitivity analysis between emissions from each category and inventory emissions for PM10, for the base year 1990 and the reporting year 2022. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

A5.3.3 Uncertainty estimations, approach 2, generated distributions for inventory emissions

The following figures present the probability distributions generated by Monte Carlo simulations for each pollutant, for the base year, the reporting year and the trend. Each distribution is fitted using a continuous, normal probability density function, whose integral (or total area) has a value of one, by definition. Therefore, for variables with a large uncertainty, the probability values, depicted on the y-axis, can be very low.

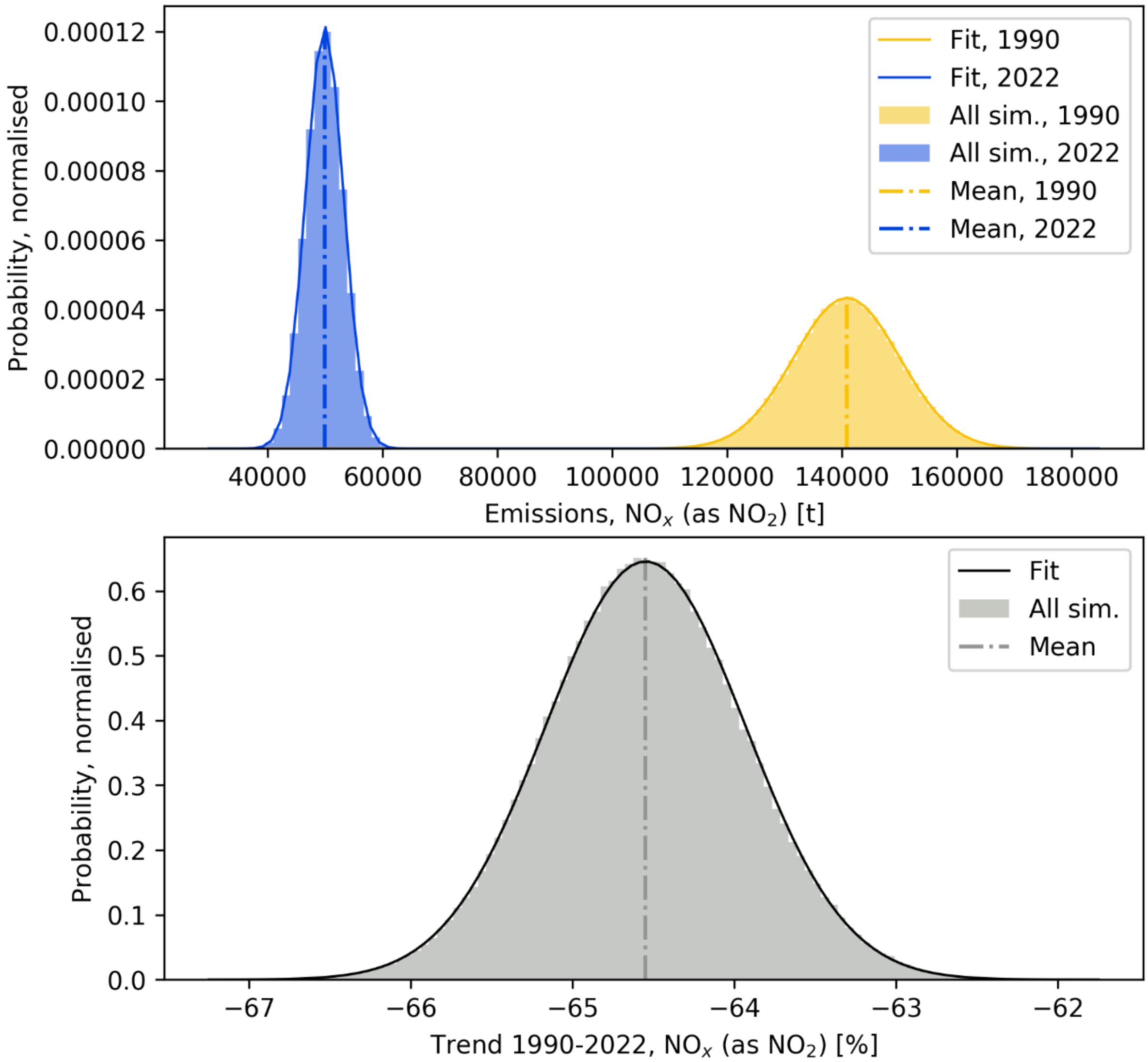

Figure A - 11 Monte Carlo simulations: Distributions obtained for the inventory mean emission for NO_x, for the base year 1990 (top panel, yellow), the reporting year 2022 (top panel, blue) and the trend 1990-2022 (bottom panel, grey). All sim.: all simulations (500’000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

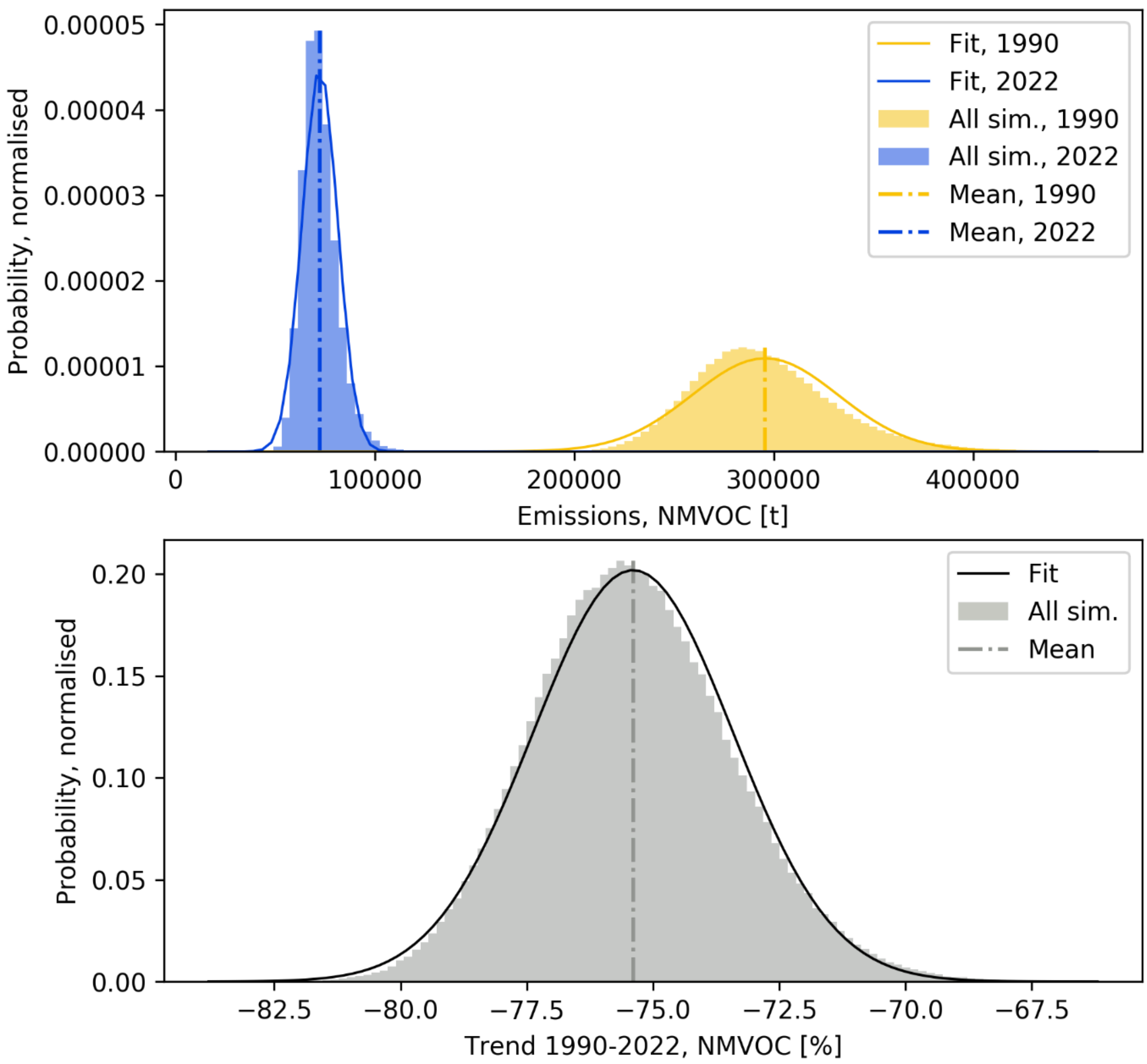

Figure A - 12 Monte Carlo simulations: Distributions obtained for the inventory mean emission for NMVOC, for the base year 1990 (top panel, yellow), the reporting year 2022 (top panel, blue) and the trend 1990-2022 (bottom panel, grey). All sim: all simulations (500'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

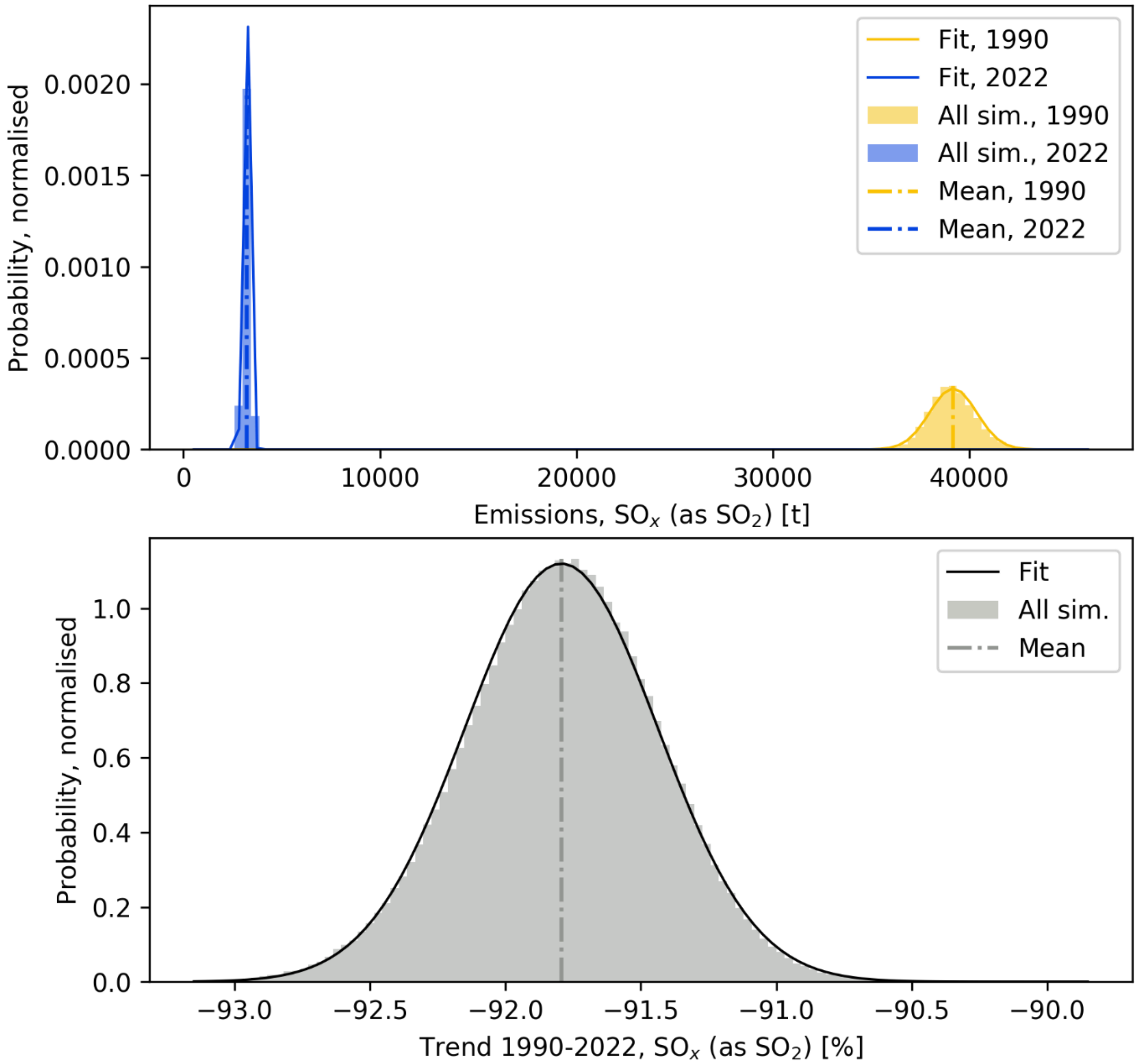

Figure A - 13 Monte Carlo simulations: Distributions obtained for the inventory mean emission for SO_x, for the base year 1990 (top panel, yellow), the reporting year 2022 (top panel, blue) and the trend 1990-2022 (bottom panel, grey). All sim: all simulations (500'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

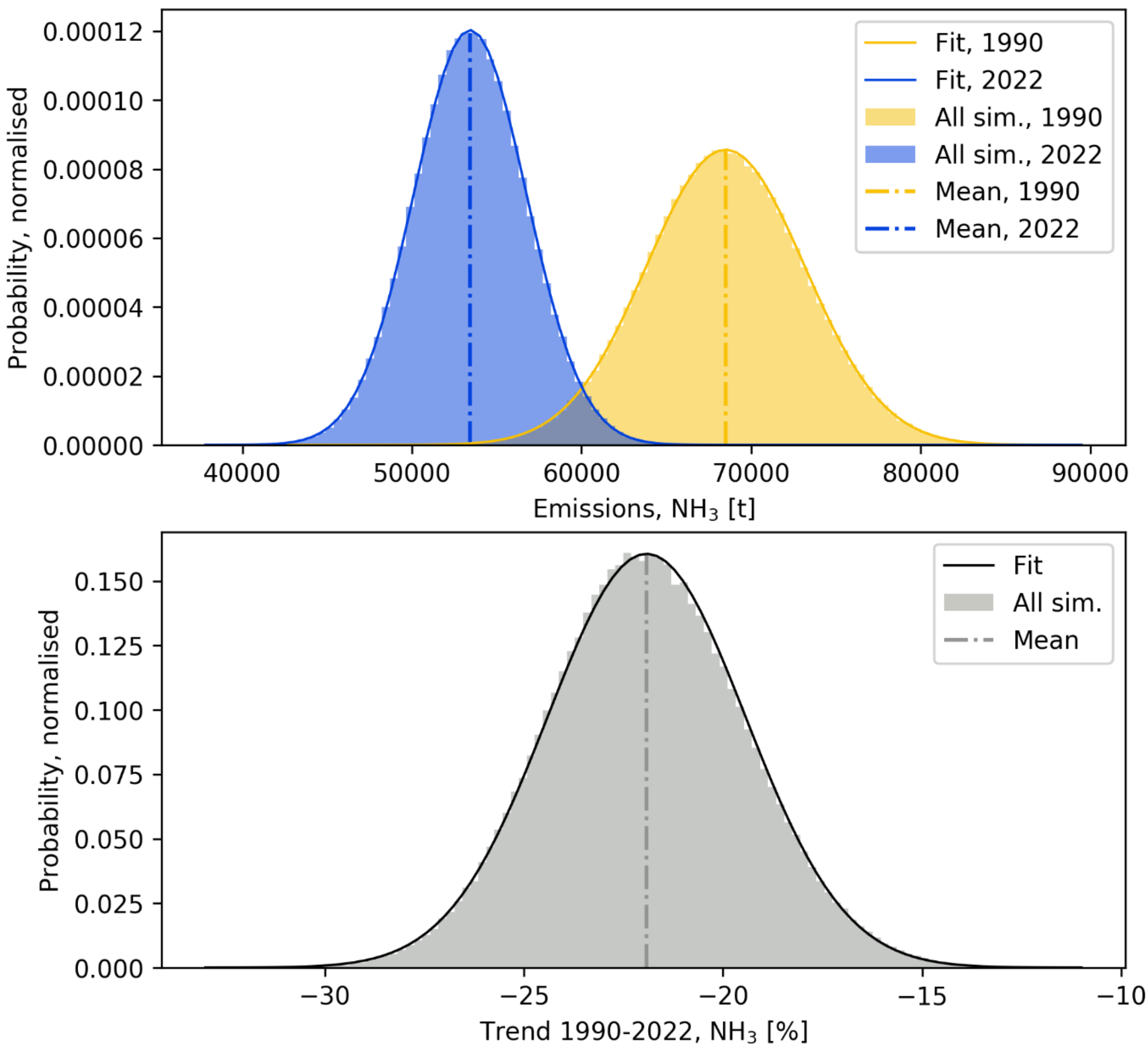

Figure A - 14 Monte Carlo simulations: Distributions obtained for the inventory mean emission for NH_3, for the base year 1990 (top panel, yellow), the reporting year 2022 (top panel, blue) and the trend 1990-2022 (bottom panel, grey). All sim: all simulations (500’000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

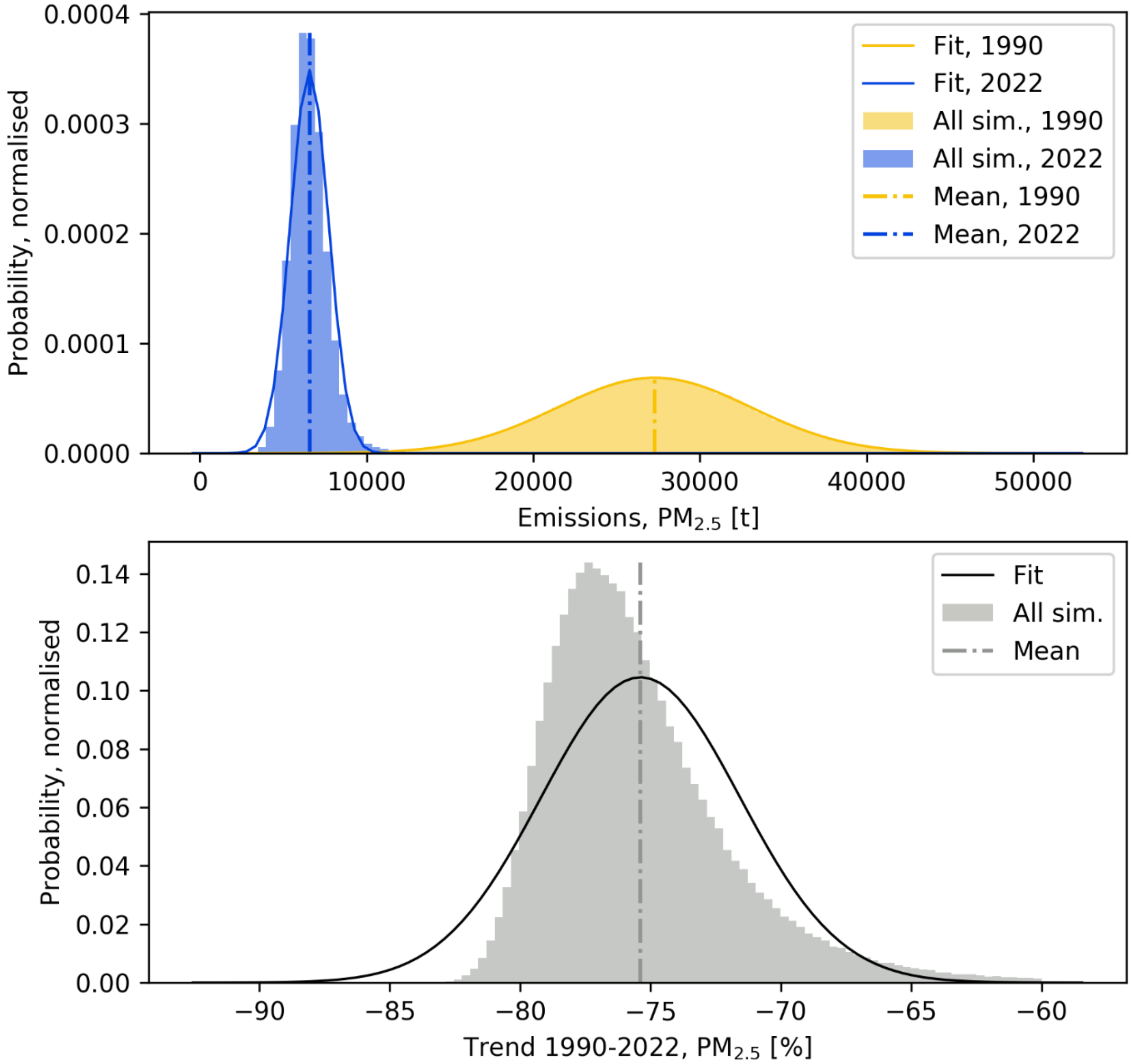

Figure A - 15 Monte Carlo simulations: Distributions obtained for the inventory mean emission for PM2.5, for the base year 1990 (top panel, yellow), the reporting year 2022 (top panel, blue) and the trend 1990-2022 (bottom panel, grey). All sim: all simulations (500'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

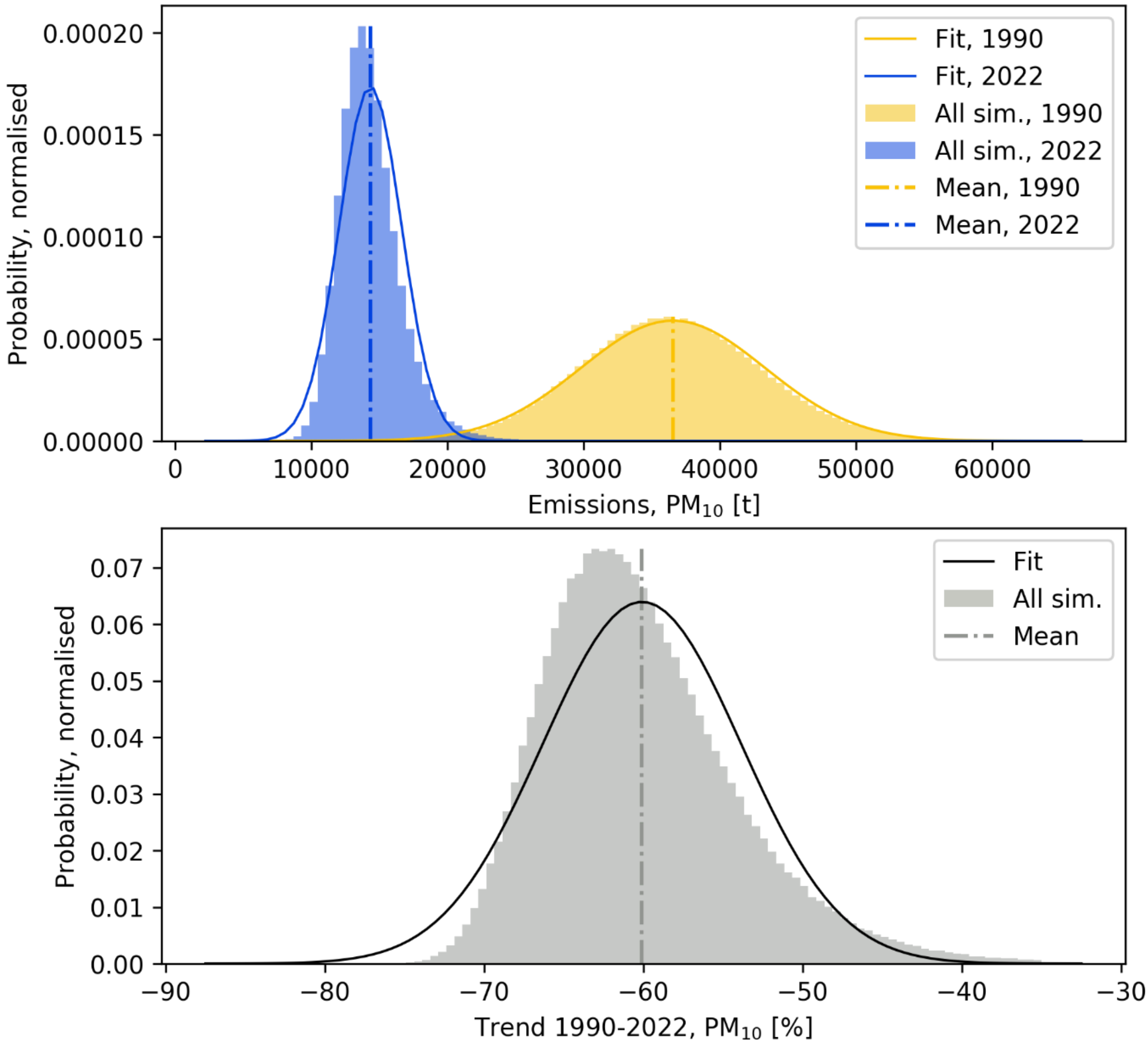

Figure A - 16 Monte Carlo simulations: Distributions obtained for the inventory mean emission for PM10, for the base year 1990 (top panel, yellow), the reporting year 2022 (top panel, blue) and the trend 1990-2022 (bottom panel, grey). All sim: all simulations (500'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

Annex 6 Summary information on condensables in PM

Table A - 40 Inclusion/exclusion of the condensable component from PM10 and PM2.5 emission factors.

NFR codes	Source/sector name	PM emissions: the condensable		Emission factor reference and comments
		included	excluded	
1	Energy		X	With the exception of the source categories listed below, no condensables are included in the reported PM emissions.
1A1a, 1A2gviii, 1A4ai/bi/ci	Wood energy combustion	X		The emission factors of particulate matter from wood energy combustion comprise both the filterable and condensable fractions.
1A2gvii, 1A3b-d, 1A4aii/bii/cii, 1A5	Road transportation, Nonroad machinery and vehicles	X		Considering the measuring procedure and the maximum temperature of 52°C, it can be assumed that PM condesables are also included in the measurements. The installed technology also plays a role in this context (gasoline engines with/without catalytic converter, diesel engines with/without particulate filter, etc.).
1A4bi	Charcoal use, Bonfire	X		The emission factor of particulate matter of these two source categories are based on default Tier-2 emission factor of the EMEP/EEA Guidebook 2019 (chp. 1A4, Table 3-39). These emission factor values correspond to total particles which include both filterable and condensable PM.
2	IPPU		X	
3	Agriculture	NA	NA	
5	Waste		X	
6	Other		X	

Annex 7 Emission time series of main air pollutants, PM2.5 and BC for 1990–2022 by pollutant and aggregated sectors

A7.1 NO_x emission time series

Table A - 41 NO_x emissions by sector. The last column in the third part of the table indicates the relative trend.

NOx	1990	1995	2000	2005	2010
	kt				
1	135	112	99	89	79
2	0.49	0.32	0.35	0.32	0.38
3	4.9	4.6	4.0	3.8	4.0
5	0.30	0.22	0.18	0.16	0.15
6	0.092	0.085	0.098	0.097	0.10
Sum	141	117	104	94	83

NOx	2013	2014	2015	2016	2017
	kt				
1	76	73	71	69	65
2	0.34	0.36	0.33	0.29	0.30
3	3.8	3.9	3.7	3.8	3.8
5	0.15	0.15	0.15	0.14	0.14
6	0.10	0.11	0.11	0.11	0.11
Sum	80	77	75	74	69

NOx	2018	2019	2020	2021	2022	2005–2022
	kt					
1	61	58	49	48	46	-49%
2	0.27	0.23	0.23	0.25	0.22	-29%
3	3.7	3.6	3.6	3.7	3.6	-6%
5	0.12	0.12	0.12	0.12	0.12	-25%
6	0.10	0.091	0.091	0.096	0.090	-8%
Sum	65	62	53	53	50	-47%

A7.2 NMVOC emission time series

Table A - 42 NMVOC emissions by sector. The last column in the third part of the table indicates the relative trend.

NMVOC total	1990	1995	2000	2005	2010
	kt				
1	130	85	64	44	31
2	150	106	75	52	48
3	14	14	14	16	17
5	1.1	1.0	1.0	1.0	1.2
6	0.20	0.19	0.21	0.20	0.18
Sum	296	207	154	113	98

NMVOC total	2013	2014	2015	2016	2017
	kt				
1	26	23	22	21	20
2	43	42	40	38	38
3	17	18	18	18	18
5	1.3	1.4	1.4	1.5	1.5
6	0.19	0.20	0.20	0.20	0.21
Sum	88	84	81	78	77

NMVOC total	2018	2019	2020	2021	2022	2005–2022
	kt					
1	19	18	16	16	16	-64%
2	37	37	37	37	37	-29%
3	18	18	18	18	18	13%
5	1.6	1.7	1.7	1.8	1.7	69%
6	0.18	0.17	0.16	0.17	0.17	-16%
Sum	76	75	73	73	73	-36%

A7.3 SO_x emission time series

Table A - 43 SO_x emissions by sector. The last column in the third part of the table indicates the relative trend.

SOx	1990	1995	2000	2005	2010
	kt				
1	37	25	15	13	9.2
2	1.6	0.95	0.78	1.0	0.80
3	NA	NA	NA	NA	NA
5	0.16	0.080	0.062	0.063	0.063
6	0.009	0.009	0.010	0.009	0.007
Sum	39	26	16	14	10

SOx	2013	2014	2015	2016	2017
	kt				
1	7.2	6.1	5.0	4.3	4.0
2	0.59	0.62	0.65	0.76	0.83
3	NA	NA	NA	NA	NA
5	0.067	0.066	0.070	0.058	0.045
6	0.007	0.008	0.007	0.007	0.008
Sum	7.9	6.8	5.8	5.2	4.9

SOx	2018	2019	2020	2021	2022	2005–2022
	kt					
1	3.7	3.5	3.1	3.1	2.8	-79%
2	0.91	0.81	0.52	0.47	0.35	-66%
3	NA	NA	NA	NA	NA	NA
5	0.031	0.031	0.030	0.029	0.029	-55%
6	0.007	0.007	0.007	0.007	0.007	-23%
Sum	4.7	4.3	3.7	3.6	3.2	-77%

A7.4 NH_3 emission time series

Table A - 44 NH_3 emissions by sector. The last column in the third part of the table indicates the relative trend.

NH3	1990	1995	2000	2005	2010
	kt				
1	1.7	2.9	4.9	3.9	2.7
2	0.37	0.32	0.40	0.35	0.21
3	65	61	54	54	53
5	0.91	0.85	0.91	0.93	0.89
6	0.85	0.79	0.92	0.88	0.92
Sum	68	65	62	60	58

NH3	2013	2014	2015	2016	2017
	kt				
1	1.9	1.7	1.5	1.4	1.4
2	0.18	0.20	0.17	0.16	0.18
3	51	52	52	51	51
5	0.89	0.87	0.85	0.88	0.86
6	1.0	1.0	1.1	1.0	1.0
Sum	55	56	55	55	55

NH3	2018	2019	2020	2021	2022	2005–2022
	kt					
1	1.3	1.3	1.1	1.2	1.3	-67%
2	0.17	0.17	0.15	0.15	0.15	-59%
3	51	50	50	50	50	-7%
5	0.85	0.89	0.88	0.90	0.86	-7%
6	0.97	0.95	0.96	0.98	0.97	11%
Sum	54	54	53	54	53	-11%

A7.5 PM2.5 emission time series

Table A - 45 PM2.5 emissions by sector. The last column in the third part of the table indicates the relative trend.

PM2.5 total	1990	1995	2000	2005	2010
	kt				
1	24	20	14.8	12.0	9.3
2	2.6	2.0	1.5	1.5	1.5
3	0.12	0.12	0.12	0.13	0.13
5	0.59	0.48	0.44	0.38	0.36
6	0.004	0.004	0.004	0.004	0.004
Sum	27	23	17	14	11.3

PM2.5 total	2013	2014	2015	2016	2017
	kt				
1	7.5	6.3	6.3	6.2	6.0
2	1.5	1.4	1.3	1.3	1.3
3	0.14	0.14	0.14	0.14	0.14
5	0.35	0.34	0.34	0.33	0.32
6	0.005	0.005	0.005	0.005	0.005
Sum	9.4	8.2	8.1	8.0	7.8

PM2.5 total	2018	2019	2020	2021	2022	2005–2022
	kt					
1	5.7	5.6	5.2	5.3	4.9	-59%
2	1.3	1.2	1.2	1.3	1.3	-12%
3	0.14	0.14	0.14	0.15	0.15	14%
5	0.31	0.30	0.29	0.29	0.27	-28%
6	0.005	0.005	0.005	0.005	0.005	11%
Sum	7.4	7.2	6.8	7.1	6.6	-53%

A7.6 BC emission time series

Table A - 46 BC emissions by sector. The last column in the third part of the table indicates the relative trend.

BC total	1990	1995	2000	2005	2010
	kt				
1	5.7	5.1	4.1	3.5	2.6
2	0.006	0.004	0.003	0.003	0.002
3	NA	NA	NA	NA	NA
5	0.041	0.034	0.031	0.027	0.026
6	0.0002	0.0002	0.0002	0.0001	0.0001
Sum	5.7	5.1	4.1	3.6	2.6

BC total	2013	2014	2015	2016	2017
	kt				
1	1.8	1.5	1.4	1.4	1.3
2	0.002	0.001	0.001	0.001	0.001
3	NA	NA	NA	NA	NA
5	0.024	0.024	0.024	0.023	0.023
6	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	1.9	1.5	1.4	1.4	1.3

BC total	2018	2019	2020	2021	2022	2005–2022
	kt					
1	1.2	1.1	1.0	1.0	0.9	-76%
2	0.001	0.001	0.001	0.001	0.001	-52%
3	NA	NA	NA	NA	NA	NA
5	0.022	0.022	0.021	0.021	0.020	-27%
6	0.0001	0.0001	0.0001	0.0001	0.0001	-46%
Sum	1.2	1.1	1.0	1.0	0.9	-75%