Switzerland’s Informative Inventory Report 2023 (IIR)

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

Submission of March 2023
to the United Nations ECE Secretariat

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

Published and distributed by:
Federal Office for the Environment FOEN
Air Pollution Control and Chemicals Division
3003 Bern, Switzerland
www.bafu.admin.ch

Bern, March 2023

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IIR_CHE_2023

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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
CEIP	EMEP Centre on Emission Inventories and Projections
Cd	Cadmium (CLRTAP: priority heavy metal)
Cemsuisse	Association of the Swiss cement industry
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
CO_2	Carbon dioxide
CRF	Common Reporting Format (UNFCCC)
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 ex, PM10 ex, TSP ex, BC ex or Cd ex)) 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”)
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
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
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
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 2014 for Estimating and Reporting Emission Data under the Convention on Long Range Transboundary Air Pollution (ECE 2014) and in the EMEP/EEA Air Pollutant Emission Inventory Guidebook, editions 2016 and 2019 (EMEP/EEA 2016, 2019). 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 1990–2021 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 sixteenth 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) and 2020 (UNECE 2020a). 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

Key category analyses were conducted according to approaches 1 and 2. For both approaches, level assessments were conducted for the years 2021 and 1990 and a trend assessment for 1990-2021. The most relevant source categories originate from sectors 1 Energy, 2 IPPU and 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.

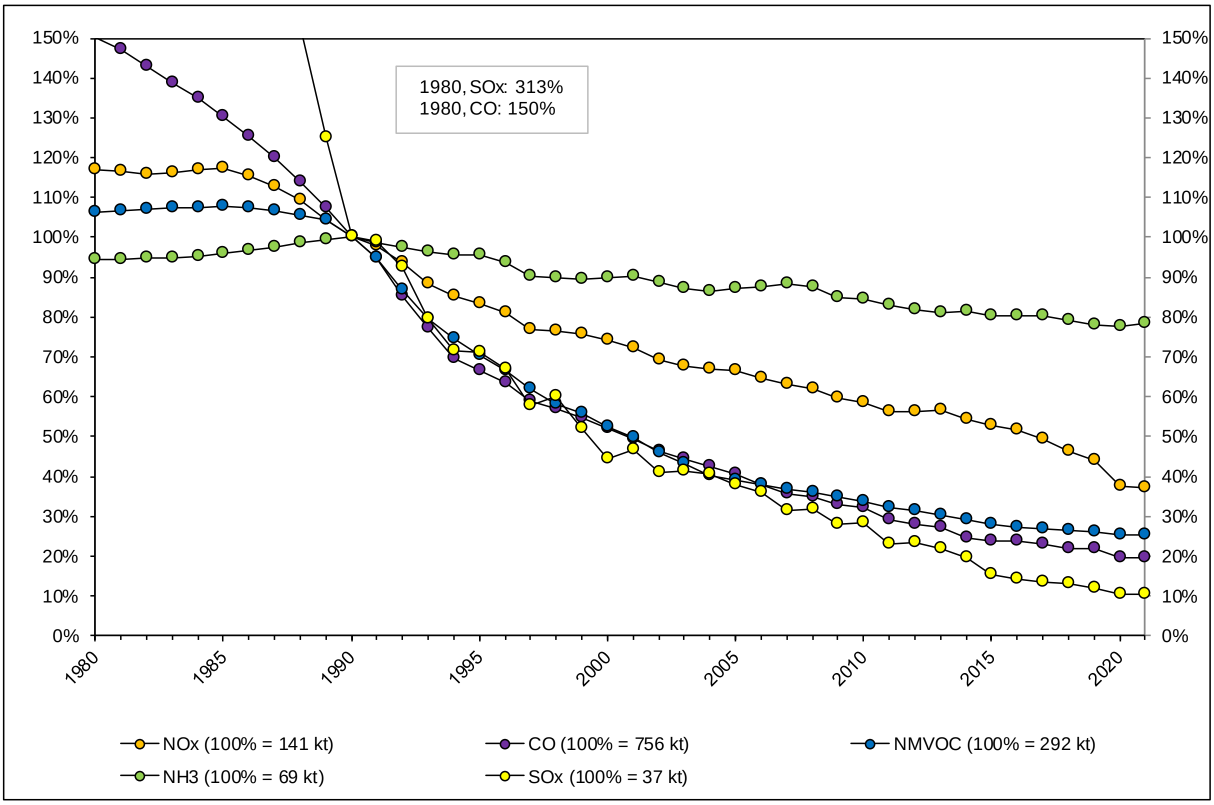
The uncertainty analysis has been carried out for level emissions for the years 1990 and 2021 and for the trend 1990-2021. Level uncertainty estimations from approach 2 for the reporting year range from 8 % to 33 %, trend uncertainties from 0.7 % to 11 %. Results from approach 1 are similar. The level uncertainty estimations remain similar for all pollutants (change below 1 percentage point) as compared to the values of the previous submission for the year 2020, except for NMVOC, for which the inventory uncertainty decreased (see discussion in chp. 1.7.3).

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 last submission.

Emission trends 1980-2021



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. 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 2021 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, Pb 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) as well as SO_x 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.
- 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 and NH_3. NMVOC emissions are mainly caused by 5B Biological treatment of solid waste, while NH_3 is emitted mainly by composting activities and solid waste disposal. Regarding total emissions, sector 5 Waste is also a relevant source of heavy metals (Pb, Hg), PCDD/PCDF and PAH emissions, mainly from 5C Incineration and open burning of waste. Emissions in sector 5 Waste have declined since 1990, with the exception of NMVOC (increase), and NH_3, which is about the same as in 1990.
- 6 Other: In this sector, mainly emissions from human and pet ammonia, private application of synthetic fertiliser as well as fire damages in estates and in motor vehicles are reported. This sector is an important source of heavy metals (Pb, Cd, Hg), PCDD/PCDF and PCB as well as of PAH mainly due to 6Ad fire damage. Regarding the main pollutants however, emissions from sector 6 Other are minor when compared to sectors 1 to 5. Overall, emissions are fluctuating without any significant trends.

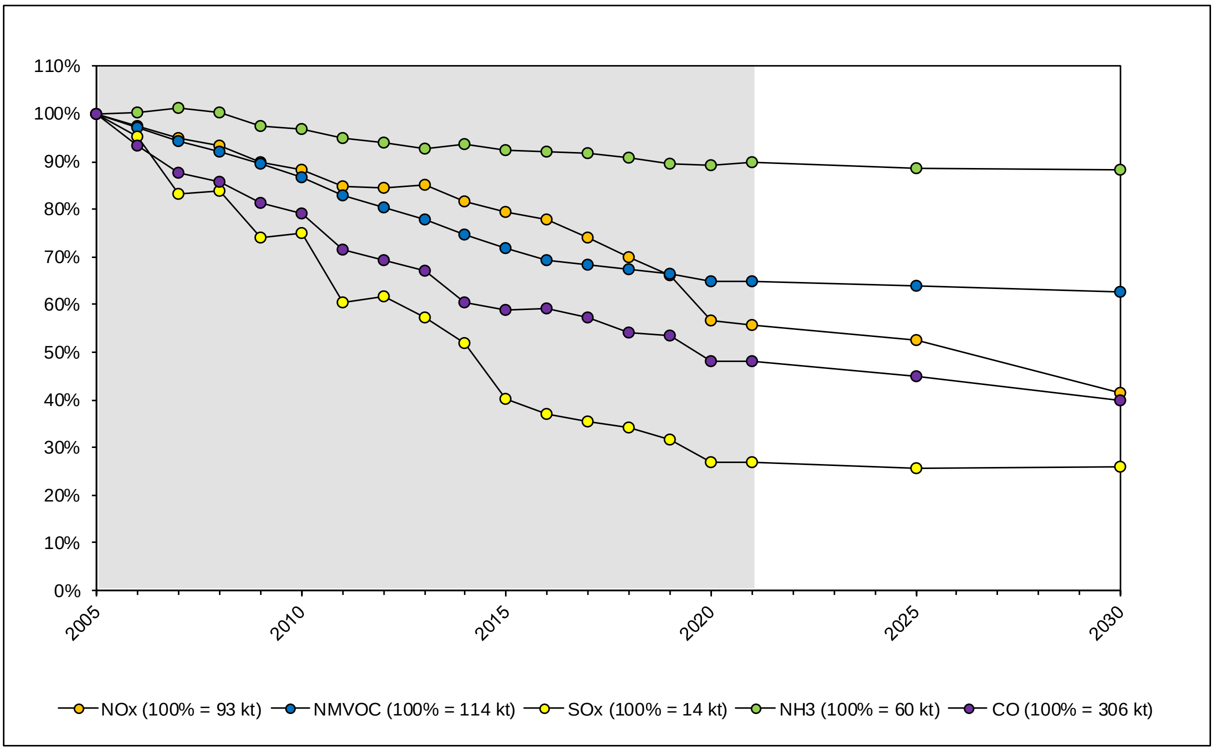
Projections for emissions until 2030

The emission projections of air pollutants in Switzerland have been fully revised in the course of submission 2022 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 2005-2021 and the projected emissions until 2030 for main air pollutants relative to 2005 levels under the WM scenario.



ES Figure 1.2 Relative trends for the total emissions from 2005-2021 (grey area) and the projected emissions until 2030 for main pollutants and CO in the WM scenario. 100 % corresponds to 2005 levels (base year of the revised Gothenburg Protocol).

Total emissions of the main air pollutants are expected to develop differently from the reporting year onwards until 2030. Overall projections of the emissions of main pollutants NO_x, NMVOC, SO_x and CO indicate a decline between 2005 and 2030. NH_3 emissions are projected to be slightly below 2005 levels in 2030. For NO_x, CO and SO_x, the drop in 2020/2021 due to reduced traffic volumes in the COVID-19 pandemic led to a less pronounced decrease between 2021 and 2030 compared to earlier submissions. Forecasts for suspended primary particulate matter predict a declining trend in PM2.5 and BC emissions but a slight increase of PM10 and TSP emissions due to the drop of emissions in 2020/2021 caused by reduced traffic volumes during the COVID-19 pandemic and an increase of non-exhaust emissions due to the overall increasing trend of traffic. Concerning heavy metals, emissions of Pb are expected to slightly decrease, emissions of Cd to slightly increase and Hg emissions to remain about constant.

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 2021 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 2021 of the latest submission (2023).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2023)	Compliance with emission ceilings 2010 in 2010	Emissions 2021 (Subm. 2023)	Compliance with emission ceilings 2010 in 2021
	kt	kt		kt	
SO_x (as SO_2)	26	10	yes	3.8	yes
NO_x (as NO_2)	79	83	no	52	yes
NMVOC	144	99	yes	74	yes
NH_3	63	58	yes	54	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 2021. The emission reduction commitments 2020 are achieved for all pollutants.

ES Table 1.2 Reported emission reductions 2020 and 2021 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 2021	Compliance with reduction commitments 2020 in 2021
	%-reduction of 2005 level	*%-reduction of 2005 level*		*%-reduction of 2005 level*	
SO_x (as SO_2)	21%	73%	yes	73%	yes
NO_x (as NO_2)	41%	43%	yes	44%	yes
NMVOC	30%	35%	yes	35%	yes
NH_3	8%	11%	yes	10%	yes
PM2.5	26%	45%	yes	46%	yes

Recalculations and improvements

In 2020, recalculations have a minor effect on the emission levels compared to previous submissions except for Pb emissions (-9.8 %). The recalculations cause a higher emission level between 3 % and 1 % for Cd, PCDD/PCDF and Hg emissions. A decrease due to recalculations between 10 % and 1 % is observed for Pb, BC, NMVOC and NO_x. For all other pollutants, the difference in emissions due to recalculations for 2020 does not exceed 0.6 %.

In 1990, recalculations do not cause an increase or a decrease of more than 1 % for any pollutant. The largest differences occur for SO_x (+0.5 %) and BC (-0.4 %) emissions, whereas the change for all other pollutants does not exceed 0.2 %.

In the latest submission 2023, several improvements were conducted and a number of further planned improvements are identified. The following improvements, which were announced in the previous submission, were conducted in submission 2023 had a relevant impact on the inventory:

- 1B2av Distribution of oil products: Results from a new study concerning fugitive NMVOC emissions from gasoline handling in fuel stations replace the existing emission estimates. In addition, NMVOC emissions from kerosene storage tanks were estimated and included in the database, too. NMVOC emissions from 1B2av are a key category (see chp. 1.5).
- 2D3 Other solvent use (which includes seven key categories for NMVOCs, see chp. 1.5) and 2G Other product use (which is a key category for NMVOCs, see chp. 1.5): A comprehensive update of all NMVOC emissions from solvent and product use was conducted.

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 2023, Switzerland provides for the sixteenth 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 2014, ECE 2014a), the EMEP/EEA guidebook (EMEP/EEA 2019) 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 2023/(*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.

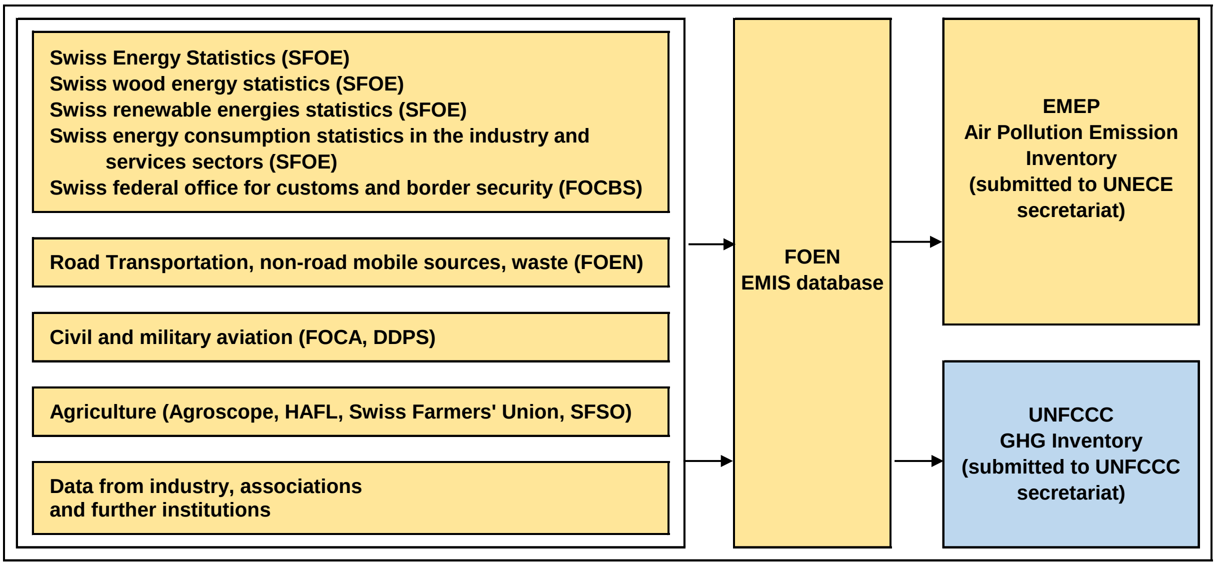


Figure 1-1 Data collection for EMIS database and CLRTAP air pollution emission inventory (GHG: Greenhouse Gas).

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 2023) 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 2022). Additionally, three in-depth Stage 3 reviews took place in 2010, 2016 and 2020, documented in UNECE (2010, 2016, 2020a). 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. Publicly available material will be published after submission on the website owned by the FOEN (www.climatereporting.ch).

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 2022 in chp. 8.2 (FOEN 2022b). 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:

- *Uncertainty estimations: The code developed in Python to compute the uncertainty estimations, for approaches 1 and 2, is available on the Github public platform with the repository name <inventory_uncertainty_UNFCCC_CLRTAP>.*
  Current state: Done.
- *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 will be implemented in the 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: In progress.
- *1B2av Distribution of oil products: Results from a new study concerning fugitive NMVOC emissions from gasoline handling in fuel stations replace the existing emission estimates. In addition NMVOC emissions from kerosene storage tanks were estimated and included in the database, too. This source category is a key category for NMVOCs.*
  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.

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 Estimating and Reporting Emission Data under the Convention on Long Range Transboundary Air Pollution, Edition 2014 (ECE 2014).
- EMEP/EEA air pollutant emission inventory guidebook — version 2019 (EMEP/EEA 2019), 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 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.” (ECE 2014)

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 3-1 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 2014).

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, 14–19 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	Avenergy 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	ecolot	Solvents and product use							x				
20	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 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 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, 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 2021 (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 38 % of emissions. Its trend for 1990-2021 is decreasing.
- Almost all NH_3 emissions originate from Sector 3 Agriculture, particularly from 3Da2a Animal manure applied to soils and 3B Manure management. The trend 1990-2021 for 3Da2a is negative.
- For PM2.5 the main source is category 1A4bi Residential: stationary plants, 21 % of emissions, followed by 1A3bvi Road transportation: automobile tyre and brake wear (16 %, note that this category contains only non-exhaust emissions) and 1A2gvii Mobile combustion in manufacturing industries and construction (7 %). The trend 1990-2021 for category 1A3bvi is positive whereas it is negative for 1A4bi and 1A2gvii.
- The main source of PM10 emissions is category 1A3bvi Road transportation: automobile tyre and brake wear, representing 19 % of emissions, followed by categories 1A2gvii Mobile combustion in manufacturing industries and construction (17 %) and 1A3c Railways (9 %). As for PM2.5, the trend 1990-2021 for category 1A3bvi is positive.

A few categories, which were not key for the year 2020 (for any of the approaches, level or trend) became key categories for the year 2021 according to at least one criterion:

- Category 1A3ai(i) Civil aviation (domestic, landing/take-off) is a new key category for NOx for the trend, approach1 (T1) and 2 (T2), because of a pronounced negative trend. For T1 and T2, it is the last key category with a minor contribution. Note that for the year 2019 (Submission 2021), this category was already a key category for T1 and T2, but because of a marked positive trend. This change from positive to negative trend can likely be attributed to the economic consequences of the Covid-19 pandemic.
- Category 1A3bi Road transportation: passenger cars is a new key category for PM10 for the trend, approach 1 (T1), because of a negative trend. It is the last key category with a minor contribution.
- Category 1A3bii Road transportation: light-duty vehicles is a new key category for NMVOC for the trend, approach 1 (T1), because of a pronounced negative trend for this category. Emissions have strongly decreased since 1990. It is the last key category with a minor contribution.
- 2H1 Pulp and paper industry is a new key category for PM10, for the emission level for the year 2021, approach 2 (L2). It is the penultimate key category for this approach. This change is likely due to an emission increase for the year 2021 compared to the year 2020.
- 3B3 Manure management - Swine is a new key category for NMVOC for the trend, approach 2 (T2), because of a negative trend for this category. It is the last key category for this approach with a minor contribution. It was already a key category for NMVOC for the year 2019, also for the trend, approach 2.

The following categories were key for the year 2020, for at least one of the criteria, but are not key anymore for the year 2021:

- 1A4cii Agriculture/forestry/fishing: off-road vehicles and other machinery was a key category for PM2.5 for the year 2020 (submission 2022) for the emission level according to approach 2 (L2). It was then the penultimate key category for this approach. Emissions for the year 2021 have decreased and may explain why it is not anymore a key category.
- 3B3 Manure management - Swine is not anymore a key category for PM10 for the emission level, approach 2 (L2), likely because category 2H1 Pulp and paper industry became a key category instead. For the previous submission, 3B3 Manure management - Swine was the last key category for this approach with a minor contribution.

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 summarized in Table 1-3 for the year 1990 and in Table 1-4 for the year 2021 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		9.7		4.6	4.1	22.9
1A2d			8.4				8.4
1A2f	7.5		9.6		2.6	3.3	23.0
1A2gvii	4.5				4.4	8.6	17.5
1A2gviii			9.0		3.3	2.2	14.5
1A3bi	31.1	19.1	4.6		3.5	2.3	60.6
1A3bii	4.4						4.4
1A3biii	21.1		4.7		9.5	6.3	41.7
1A3bv		5.8					5.8
1A3bvi					4.1	8.1	12.2
1A3c						3.9	3.9
1A4ai			9.3		3.0	2.1	14.4
1A4bi	8.3	3.4	25.0		31.4	21.7	89.9
1A4ci					3.2	2.1	5.4
1B2av		4.9					4.9
2C1					4.9	5.9	10.8
2D3a		3.0					3.0
2D3d		13.9					13.9
2D3e		4.0					4.0
2D3g		9.4					9.4
2D3h		7.0					7.0
2G		7.7			3.1	2.3	13.1
2I						3.4	3.4
3B1a		2.4		13.6			16.0
3B1b				7.6			7.6
3B3				10.2			10.2
3Da2a				50.4			50.4
3De						4.2	4.2
5C1a					2.8		2.8
Fraction of total, %	81.4	80.7	80.3	81.8	80.7	80.5	

Table 1-4 List of Switzerland's approach 1 level key categories 2021, 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 2021						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a	4.1		6.6				10.6
1A2f	6.2		38.0				44.3
1A2gvii					6.8	17.3	24.1
1A2gviii	3.7		6.8		3.3		13.8
1A3bi	32.0	5.1					37.1
1A3bii	8.4						8.4
1A3biii	8.2						8.2
1A3bv		2.6					2.6
1A3bvi					15.5	19.4	34.9
1A3c					3.4	9.5	12.9
1A4ai	5.3		6.7		6.2	2.8	20.9
1A4bi	9.3	3.6	15.6		21.1	9.5	59.2
1A4ci					3.5		3.5
1A4cii	3.4						3.4
1A5b						1.9	1.9
1B2av		2.8					2.8
2A1						1.9	1.9
2A5a					4.0	3.4	7.4
2B5			10.1				10.1
2D3a		8.6					8.6
2D3b		3.6					3.6
2D3d		11.2					11.2
2D3g		4.2					4.2
2D3h		5.0					5.0
2D3i		2.6					2.6
2G		8.5			6.4	3.4	18.4
2H1					3.6		3.6
2H2		2.7			2.8	2.2	7.8
3B1a		9.6		19.3			29.0
3B1b		11.2		13.1			24.3
3B3				9.2			9.2
3Da1				4.9			4.9
3Da2a				38.0			38.0
3De						7.4	7.4
5C1a					4.2	2.0	6.2
Fraction of total, %	80.7	81.3	83.8	84.6	80.9	80.7	

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	PCBs	
1A1a	2.4			8.4	51.2	61.3	67.5				190.8
1A2b									99.7		99.7
1A2f	2.8				19.4						22.2
1A2gvii	6.8	4.5									11.3
1A3bi		4.2	56.3	59.8							120.3
1A3bii			9.6								9.6
1A3biii	3.6	13.9									17.4
1A3bvi	4.6										4.6
1A3c	2.9										2.9
1A4ai		5.2									5.2
1A4bi	13.1	56.2	14.8				9.1	70.1			163.4
2A5a	1.5										1.5
2B10a						6.0					6.0
2C1	6.1			16.9	12.9	17.3	6.4				59.7
2C3								11.6			11.6
2I	9.8										9.8
2K										65.4	65.4
3B3	2.1										2.1
3De	23.8										23.8
5C1a	1.5										1.5
5E										9.2	9.2
6A										12.1	12.1
Fraction of total, %	80.9	84.0	80.6	85.2	83.6	84.7	83.0	81.7	99.7	86.8	

Table 1-6 List of Switzerland's approach 1 level key categories 2021, 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 2021										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCBs	
1A1a				12.2	24.5	43.9	6.3		51.0		138.0
1A2f			6.2		4.6	9.4					20.2
1A2gvii	12.8										12.8
1A3aii(i)				5.6							5.6
1A3bi		4.7	30.2					7.5			42.4
1A3biv			4.1								4.1
1A3bvi	9.6	8.9			13.6						32.1
1A3c	6.2										6.2
1A3dii			3.4								3.4
1A4ai		9.4	4.7				8.9	11.9	10.8		45.7
1A4aii			4.5								4.5
1A4bi	4.9	50.6	19.1			8.0	31.7	59.5	26.7		200.5
1A4cii		9.3	8.7								18.0
2A5a	3.3										3.3
2C1						7.6					7.6
2G					11.7						11.7
2I	1.8										1.8
2K										89.8	89.8
3B3	2.4										2.4
3B4gi	2.7										2.7
3De	36.5										36.5
5C1a				12.3			17.7				30.0
5C2								7.3			7.3
6A				51.3	27.7	11.6	17.3				107.9
Fraction of total, %	80.1	83.0	80.8	81.5	82.0	80.6	81.9	86.1	88.5	89.8	

1.5.2.2 Trend key category analysis (approach 1)

The results of the KCA according to approach 1, trend, for 1990-2021 are summarized in Table 1-7 and Table 1-8.

Table 1-7 List of Switzerland's approach 1 key categories for the trend 1990-2021, 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 - 2021						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a			3.7		5.5	4.7	13.9
1A2d			9.7				9.7
1A2f	3.6		33.1		2.6	3.4	42.7
1A2gvii	3.5				3.4	11.1	17.9
1A2gviii	5.8		2.6				8.4
1A3ai(i)	2.5						2.5
1A3bi	2.5	19.4	4.2			1.8	27.9
1A3bii	11.4	2.0					13.4
1A3biii	37.2		5.2		12.2	7.4	62.0
1A3bv		4.4					4.4
1A3bvi					16.0	14.2	30.2
1A3c					3.4	7.1	10.5
1A3dii	3.1						3.1
1A4ai	5.6		3.0		4.4		13.1
1A4bi	3.1		10.9		14.5	15.5	44.0
1B2av		3.0					3.0
2A5a					4.1	2.5	6.5
2B5			9.8				9.8
2C1					6.7	7.3	14.0
2D3a		7.7					7.7
2D3b		2.7					2.7
2D3d		3.8					3.8
2D3e		2.6					2.6
2D3g		7.2					7.2
2D3h		2.8					2.8
2G					4.7		4.7
2H1					3.1		3.1
2H2		2.8					2.8
2I						2.5	2.5
3B1a		10.0		15.9			25.9
3B1b		13.0		15.4			28.4
3Da1				3.6			3.6
3Da2a	3.8			34.7			38.5
3Da2b				4.7			4.7
3Da2c				4.9			4.9
3Da3				4.2			4.2
3De						4.1	4.1
Fraction of total, %	82.1	81.4	82.2	83.4	80.4	81.5	

Table 1-8 List of Switzerland's approach 1 key categories for the trend 1990-2021, 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 - 2021										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCBs	
1A1a	3.1				24.2	23.2	41.4		25.6	14.4	131.8
1A2b									50.0		50.0
1A2f	3.4		6.6		13.5	7.9					31.4
1A2gvii	8.4	4.4									12.8
1A2gviii						5.8					5.8
1A3bi			38.6	36.4				13.8			88.9
1A3bii			10.4								10.4
1A3biii	4.8	26.5									31.3
1A3bvi	7.0	17.3			10.6						34.9
1A3c	4.7										4.7
1A4ai		9.4	4.8				5.3	12.2			31.7
1A4aii			5.8								5.8
1A4bi	11.6	12.6	6.3			9.2	15.3	23.6	13.3		91.9
1A4bii			3.3								3.3
1A4cii		11.9	7.3								19.2
2B10a						8.0					8.0
2C1	8.5			9.3	11.0	13.0					41.6
2C3								25.6			25.6
2G					7.9						7.9
2I	11.2										11.2
2K										49.8	49.8
3De	17.9										17.9
5C1a				7.0			10.2				17.2
5E										16.8	16.8
6A				30.5	20.5	13.8	10.8	7.9			83.4
Fraction of total, %	80.5	82.1	83.2	83.2	87.6	80.8	83.0	83.0	88.9	81.0	

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 summarized in Table 1-9 for the year 1990 and in Table 1-10 for the year 2021.

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		12.9		4.3	3.3	24.2
1A2d			6.5				6.5
1A2f	4.9		10.0			2.4	17.3
1A2gvii					2.8	4.9	7.7
1A2gviii			9.4		2.8		12.1
1A3bi	45.2	14.0					59.2
1A3bii	5.4						5.4
1A3biii	14.5		2.6		3.3	1.9	22.3
1A3biv		6.8					6.8
1A3bv		3.3					3.3
1A3bvi					2.7	4.6	7.3
1A3c						2.2	2.2
1A4ai			5.1		3.1	1.9	10.1
1A4bi	4.3	3.3	14.5		30.9	18.8	71.8
1A4cii					2.7		2.7
1B2aiv			3.4				3.4
2A1					2.9	2.6	5.4
2A5a					3.9	4.6	8.5
2C1					7.0	7.4	14.4
2C3			15.8				15.8
2D3a		3.9					3.9
2D3d		8.7					8.7
2D3e		3.6					3.6
2D3g		12.7					12.7
2D3h		4.4					4.4
2D3i		3.8					3.8
2G		16.6			3.8	2.5	22.8
2H1					2.8		2.8
2H2					4.1	3.9	7.9
2I					4.7	10.8	15.5
3B1a				12.4			12.4
3B1b				6.4			6.4
3B3				12.6		2.0	14.6
3B4gi				3.6			3.6
3Da1	3.3			9.5			12.8
3Da2a				33.9			33.9
3De						7.3	7.3
6A				4.0			4.0
Fraction of total, %	81.1	80.9	80.1	82.3	81.8	81.0	

Table 1-10 List of Switzerland's approach 2 level key categories 2021, 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 2021						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a	3.0		8.6				11.7
1A2f	3.7		39.6				43.3
1A2gvii					3.7	9.3	13.0
1A2gviii			7.1		2.4		9.4
1A3bi	42.4	3.3					45.7
1A3bii	9.3						9.3
1A3biii	5.1						5.1
1A3biv		3.3					3.3
1A3bvi					8.5	10.4	18.9
1A3c						5.1	5.1
1A4ai	2.9		3.7		5.3		11.9
1A4bi	4.4	3.1	9.1		17.6	7.7	41.9
2A1					4.7	3.0	7.7
2A5a					12.1	10.1	22.2
2B5			11.1				11.1
2B10a			3.4				3.4
2D3a		9.9					9.9
2D3b		4.2					4.2
2D3d		6.2					6.2
2D3g		5.1					5.1
2D3h		2.8					2.8
2D3i		4.7					4.7
2G		16.3			6.7	3.5	26.5
2H1					6.1	2.6	8.7
2H2		3.1			8.7	6.7	18.4
2I					2.6	4.3	6.9
3B1a		7.2		16.5			23.7
3B1b		9.8		10.4			20.3
3B3				10.7			10.7
3B4gi						2.5	2.5
3B4gii		2.9		3.1		3.4	9.4
3Da1	5.4			7.1			12.6
3Da2a	4.9			23.9			28.8
3Da3				4.7			4.7
3De						12.1	12.1
5C1a					2.7		2.7
6A				5.6			5.6
Fraction of total, %	81.2	81.9	82.6	82.1	81.1	80.8	

1.5.3.2 Trend key category analysis (approach 2)

The results of the KCA according to approach 2, trend assessment, for 1990-2021 are summarized in Table 1-11.

Table 1-11 List of Switzerland's approach 2 key categories for the trend 1990-2021, 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 - 2021						% sum of category
	NOx	NMVOC	SOx	NH3	PM2.5	PM10	
1A1a			5.2		4.6	4.0	13.9
1A2d			8.0				8.0
1A2f	2.4		37.1			2.6	42.0
1A2gvii						6.5	6.5
1A2gviii	3.8		2.9				6.7
1A3ai(i)	1.9						1.9
1A3bi	3.7	14.1					17.8
1A3bii	13.9						13.9
1A3biii	25.4		3.1		3.9		32.4
1A3biv		4.3					4.3
1A3bv		2.4					2.4
1A3bvi					9.4	8.4	17.8
1A3c						4.2	4.2
1A4ai	3.4				4.0		7.5
1A4bi			6.8		13.0	13.8	33.7
1B2aiv			3.1				3.1
1B2c	2.5						2.5
2A1					3.4		3.4
2A5a					13.3	8.0	21.3
2B5			11.6				11.6
2B10a			3.0				3.0
2C1					8.7	9.4	18.1
2D3a		9.9					9.9
2D3b		3.5					3.5
2D3d		2.4					2.4
2D3e		2.3					2.3
2D3g		9.5					9.5
2G		2.4			5.3		7.7
2H1					5.6		5.6
2H2		3.6			7.9	4.2	15.7
2I					2.0	8.2	10.2
3B1a		8.4		13.5			21.9
3B1b		12.7		12.2			24.9
3B3		2.1		3.0			5.1
3B4gii		4.1		5.5		3.9	13.5
3Da1	7.8			5.1			12.9
3Da2a	7.3			21.8			29.1
3Da2c	2.4			7.6			10.0
3Da3	6.9			7.5			14.4
3De						7.3	7.3
6A				5.2			5.2
Fraction of total, %	81.4	81.7	80.9	81.4	81.0	80.5	

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 (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 2023a) 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 automated checks implemented in the database in order to identify incorrect internal aggregation processes.

Recalculations are compiled in a document and made available to the data compilers and the 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 2023).
- 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 are 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 2021 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 summarized 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, 1’000’000 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 1'000'000 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 1990-2021 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 2021, 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	Base year (1990)			Reporting year (2021)			Trend (1990-2021)		
	Emissions, t	U(-) %	U(+) %	Emissions, t	U(-) %	U(+) %	Trend, %	U(-) %	U(+) %
Monte Carlo simulations (approach 2)									
NOx	140'600	13	12	52'214	13	13	-63	1.2	1.2
NMVOC	292'448	22	25	74'040	22	25	-75	4.0	4.1
SOx	36'863	5.8	6.1	3'775	8.0	7.9	-90	0.74	0.73
NH3	68'526	13	13	53'745	12	12	-22	4.7	4.8
PM2.5	16'621	28	28	5'747	30	33	-65	6.4	7.5
PM10	25'311	27	29	13'555	28	32	-46	11	11
Uncertainty propagation (approach 1)									
NOx	140'600	13	13	52'214	13	13	-63	1.2	1.2
NMVOC	292'448	17	30	74'040	17	31	-75	3.5	3.5
SOx	36'863	4.8	4.8	3'775	8.1	8.1	-90	0.64	0.64
NH3	68'526	13	13	53'745	12	12	-22	4.5	4.5
PM2.5	16'621	26	31	5'747	21	44	-65	4.6	4.6
PM10	25'311	20	38	13'555	19	43	-46	7.8	7.8

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).

Uncertainty estimations can be summarized as follow:

- For the base year, the estimations range from 5 % to 38 % for approach 1 and from 6 % to 29 % for approach 2.
- For the reporting year, the estimations range from 8 % to 44 % for approach 1 and from 8 % to 33 % for approach 2.
- For the trend, the estimations range from 0.6 % to 8 % for approach 1 and from 0.7 % to 11 % for approach 2.

The level and trend uncertainty estimations for the latest submission remained similar for all pollutants as the values of the previous submission 2022, except for the following cases:

- For NMVOCs, the input uncertainty estimates were the same as for the previous submission. The small reduction of the overall uncertainty for NMVOCs obtained by Monte Carlo simulations can therefore only be attributed to emission changes, and in particular to an emission reduction in source category 2D3a Domestic solvent use including fungicides. This source category has a large assigned uncertainty compared to the inventory uncertainty for NMVOCs (see also recalculations in chp. 4.5.3).

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 1980-2021

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 decreasing in the period 1980-2021 (see Table 2-1). 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	2021	1980-2021	1990-2021	2005-2021
NO_x	kt	165	141	93	52	-68%	-63%	-44%
NMVOC	kt	311	292	114	74	-76%	-75%	-35%
SO_2	kt	115	37	14	3.8	-97%	-90%	-73%
NH_3	kt	65	69	60	54	-17%	-22%	-10%
PM2.5 total	kt	19	17	11	5.7	-70%	-65%	-46%
PM2.5 exhaust	kt	17	14	8.4	3.3	-81%	-77%	-60%
PM2.5 non-exhaust	kt	2.3	2.4	2.3	2.4	6%	-1%	6%
PM10 total	kt	29	25	18	14	-54%	-46%	-25%
PM10 exhaust	kt	20	16	9.1	3.8	-81%	-76%	-58%
PM10 non-exhaust	kt	9.5	9.5	9.0	9.8	3%	3%	8%
TSP total	kt	53	44	32	27	-49%	-38%	-15%
TSP exhaust	kt	26	18	9.6	4.1	-84%	-77%	-58%
TSP non-exhaust	kt	28	27	22	23	-16%	-12%	4%
BC total	kt	4.9	5.7	3.5	1.0	-79%	-83%	-72%
BC exhaust	kt	4.9	5.7	3.5	0.91	-81%	-84%	-74%
BC non-exhaust	kt	0.026	0.071	0.078	0.091	251%	28%	17%
CO	kt	1'135	756	306	148	-87%	-80%	-52%
Pb	t	1'326	353	19	14	-99%	-96%	-29%
Cd	t	5.4	3.4	0.74	0.63	-88%	-82%	-15%
Hg	t	7.6	6.4	0.82	0.68	-91%	-89%	-17%
PCDD/PCDF	g I-Teq	444	193	32	15	-97%	-92%	-53%
BaP	t	2.3	2.3	1.4	0.78	-67%	-67%	-46%
BbF	t	2.6	2.7	1.6	0.83	-68%	-69%	-49%
BkF	t	1.6	1.7	1.0	0.52	-67%	-70%	-50%
IcdP	t	1.2	1.4	0.83	0.46	-61%	-67%	-45%
PAH tot	t	7.7	8.1	4.9	2.6	-66%	-68%	-48%
HCB	kg	97	173	0.44	0.37	-100%	-100%	-17%
PCB	t	3.6	2.3	1.3	0.37	-90%	-84%	-71%

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.

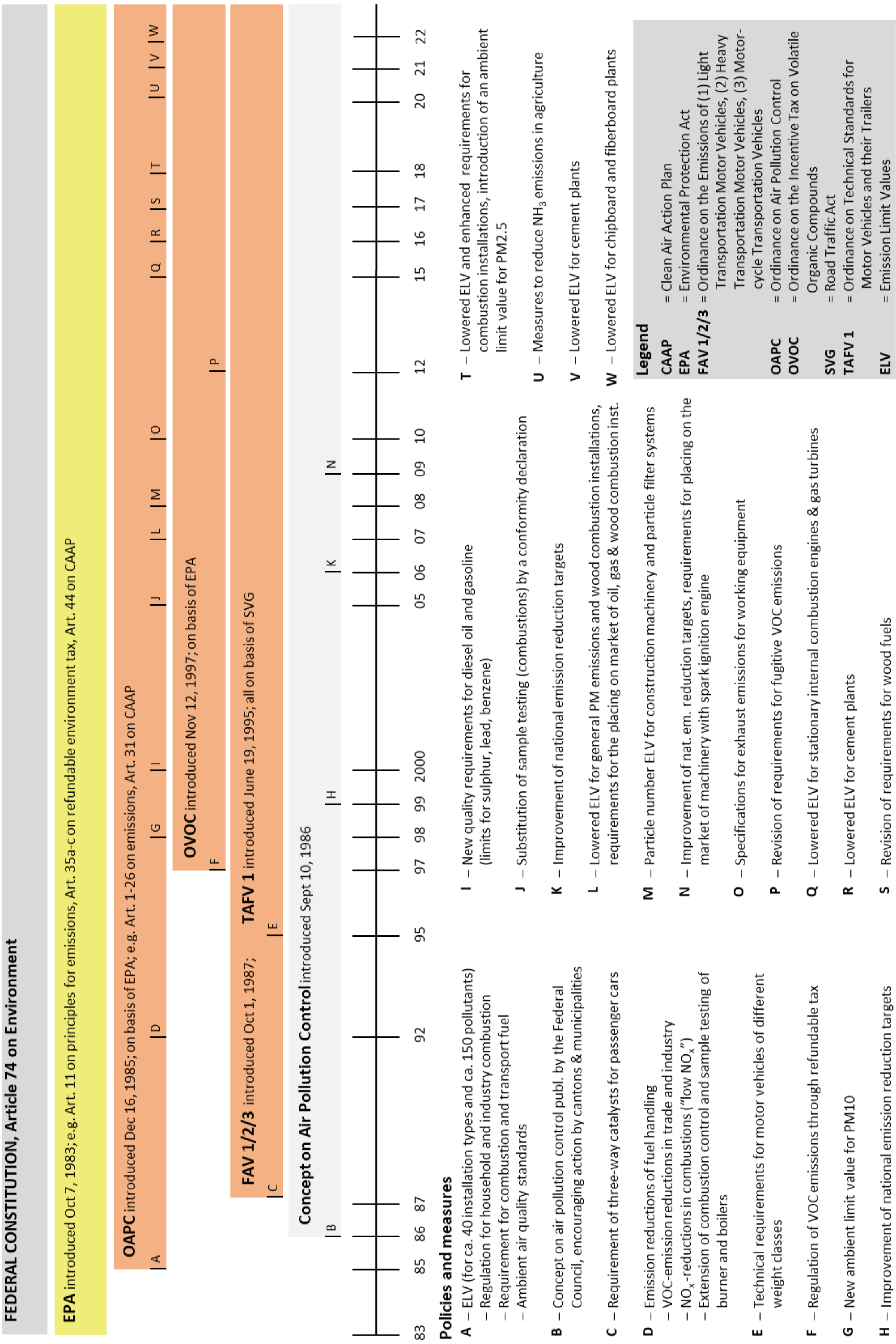


Figure 2-1 Overview of the OAPC Revisions in Switzerland. The Concept on Air Pollution Control is also referred to as the Air Pollution Control Strategy.

For further information on legislation on the abatement of air pollution, see https://www.bafu.admin.ch/bafu/en/home/topics/air/law.html [03.02.2023].

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 almost complete disappearance of residual fuel oil. As a result, NO_x, NMVOC and CO emissions clearly declined between 1980 and 2021.

Furthermore, due to legal restrictions of the sulphur content in liquid fuels, a decrease in coal consumption (roughly until 2000) and a shift from liquid fuels to natural gas in industry and residential heating, a decreasing trend can also be observed for SO_x emissions. The lowering of the maximum sulphur content in liquid fuels is shown in Table 3-9, whereas the time series of Switzerland's decreasing coal consumption is given in Table 3-4. Both trends resulted in a considerable reduction of the SO_x emissions. 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 in the past 40 years 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 years 2020 and 2021, the drop of NO_x and CO emissions is mainly due to the COVID-19 pandemic. This pandemic resulted in strongly reduced traffic volumes in Switzerland. Therefore, a reduction of overall emissions in 2020 and 2021 compared to 2019 is visible for pollutants which are emitted by a large share from the transport sector (in particular 1A3b Road transportation).

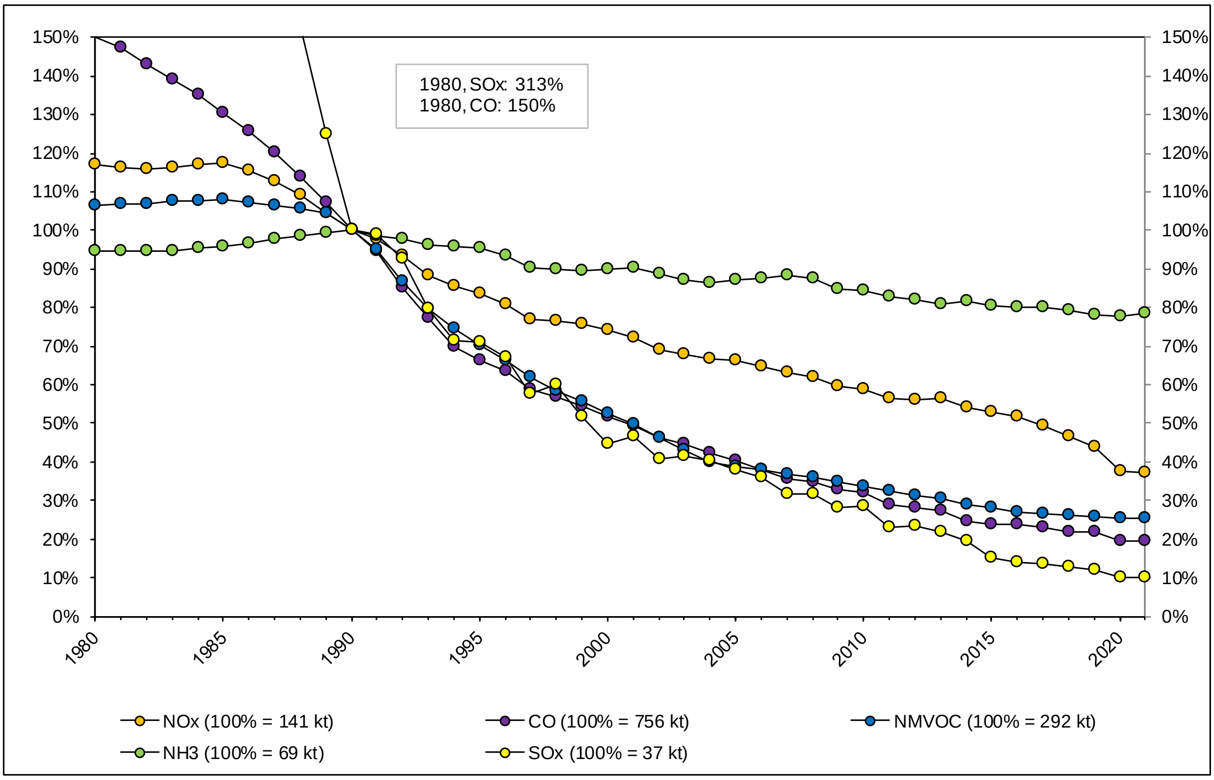


Figure 2-2 Relative trends for the total emissions of main air pollutants and CO in Switzerland 1980–2021 in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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	311	115	65	1'135
1985	165	316	74	66	985
1990	141	292	37	69	756
1995	117	205	26	65	503
2000	104	154	16	62	392
2005	93	114	14	60	306
2010	83	99	10	58	242
2012	79	92	8.6	56	212
2013	79	89	8.0	55	206
2014	76	85	7.2	56	185
2015	74	82	5.6	55	180
2016	73	79	5.2	55	181
2017	69	78	5.0	55	175
2018	65	77	4.8	54	165
2019	62	76	4.4	54	164
2020	53	74	3.8	53	148
2021	52	74	3.8	54	148
2021 vs. 2005 (%)	-44%	-35%	-73%	-10%	-52%

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 2005 (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, 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).

Condensables are included in PM emissions of road transportation (1A3b-1A3d), non-road vehicles and machinery (1A2gvii, 1A4aii/bii/cii and 1A5b) as well as of bonfires (1A4bi) and charcoal use (1A4bi); see respective sections in chp. 3. In all other source categories, also small wood combustion (1A4ai/bi/ci) they are not included. For details see table Table A - 40 in Annex 6. However, Annex A6.1 describes the derivation of the condensables of all wood combustion categories and lists the emission factors and emissions of the PM2.5 condensables.

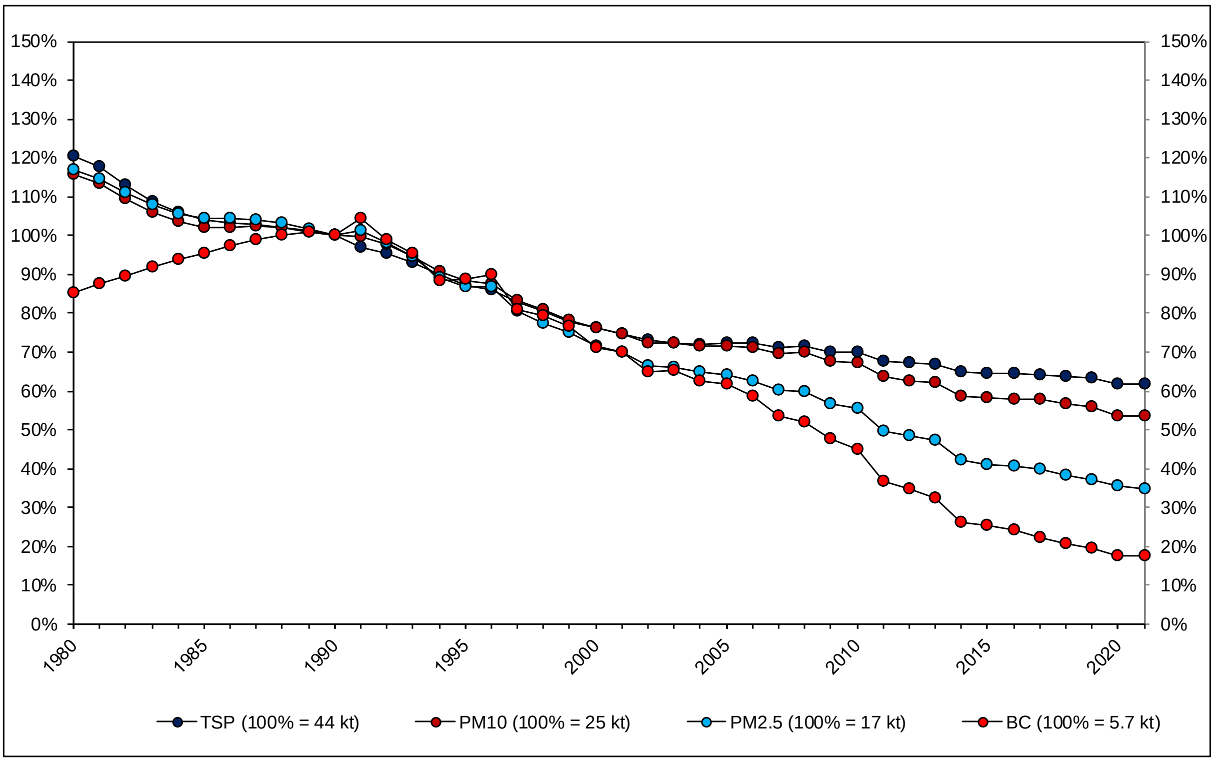


Figure 2-3 Total emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2021 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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	19	29	53	4.9
1985	17	26	46	5.5
1990	17	25	44	5.7
1995	14	22	39	5.1
2000	12	19	34	4.1
2005	11	18	32	3.5
2010	9.2	17	31	2.6
2012	8.1	16	30	2.0
2013	7.8	16	30	1.9
2014	7.0	15	29	1.5
2015	6.8	15	29	1.4
2016	6.8	15	29	1.4
2017	6.6	15	28	1.3
2018	6.4	14	28	1.2
2019	6.2	14	28	1.1
2020	5.9	14	27	1.0
2021	5.7	14	27	1.0
2021 vs. 2005 (%)	-46%	-25%	-15%	-72%

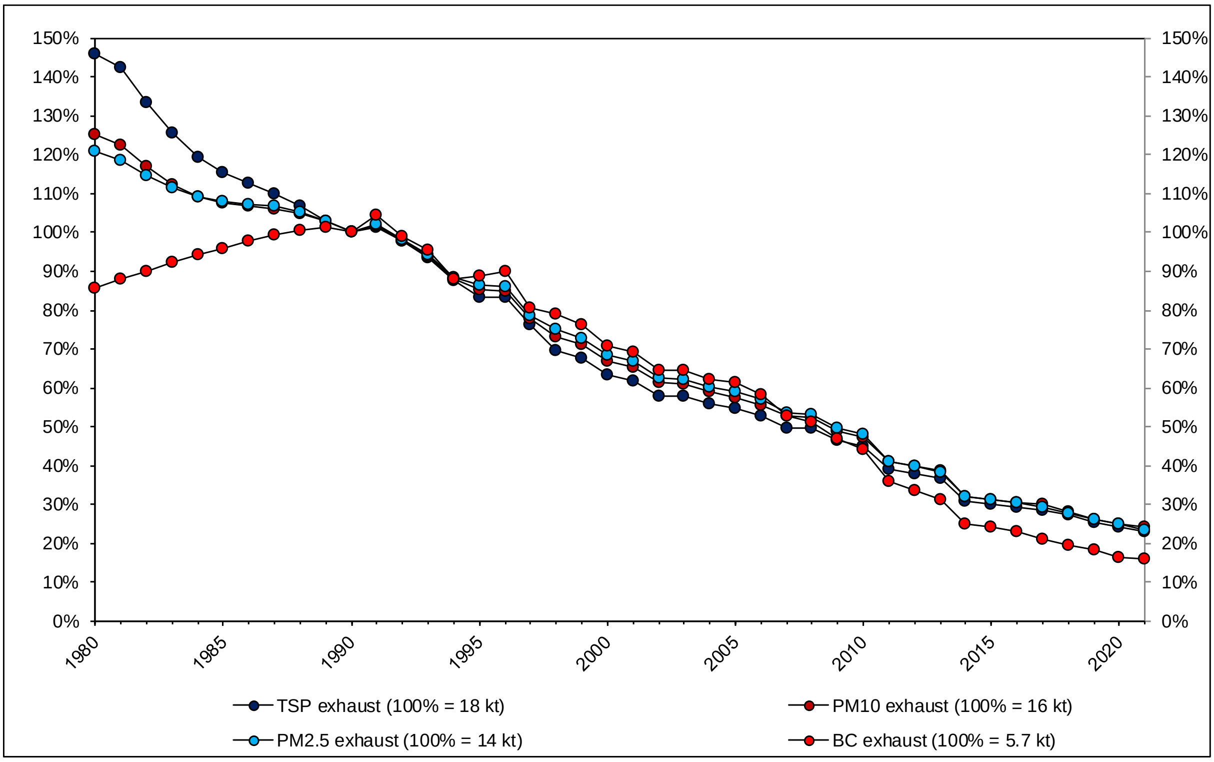


Figure 2-4 Exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2021 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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	17	20	26	4.9
1985	15	17	20	5.4
1990	14	16	18	5.7
1995	12	13	15	5.0
2000	9.7	11	11	4.0
2005	8.4	9.1	9.6	3.5
2010	6.8	7.5	7.9	2.5
2012	5.7	6.3	6.7	1.9
2013	5.4	6.1	6.5	1.8
2014	4.5	5.1	5.4	1.4
2015	4.4	5.0	5.3	1.4
2016	4.3	4.8	5.1	1.3
2017	4.2	4.7	5.0	1.2
2018	3.9	4.5	4.8	1.1
2019	3.7	4.2	4.4	1.0
2020	3.5	4.0	4.3	0.91
2021	3.3	3.8	4.1	0.91
2021 vs. 2005 (%)	-60%	-58%	-58%	-74%

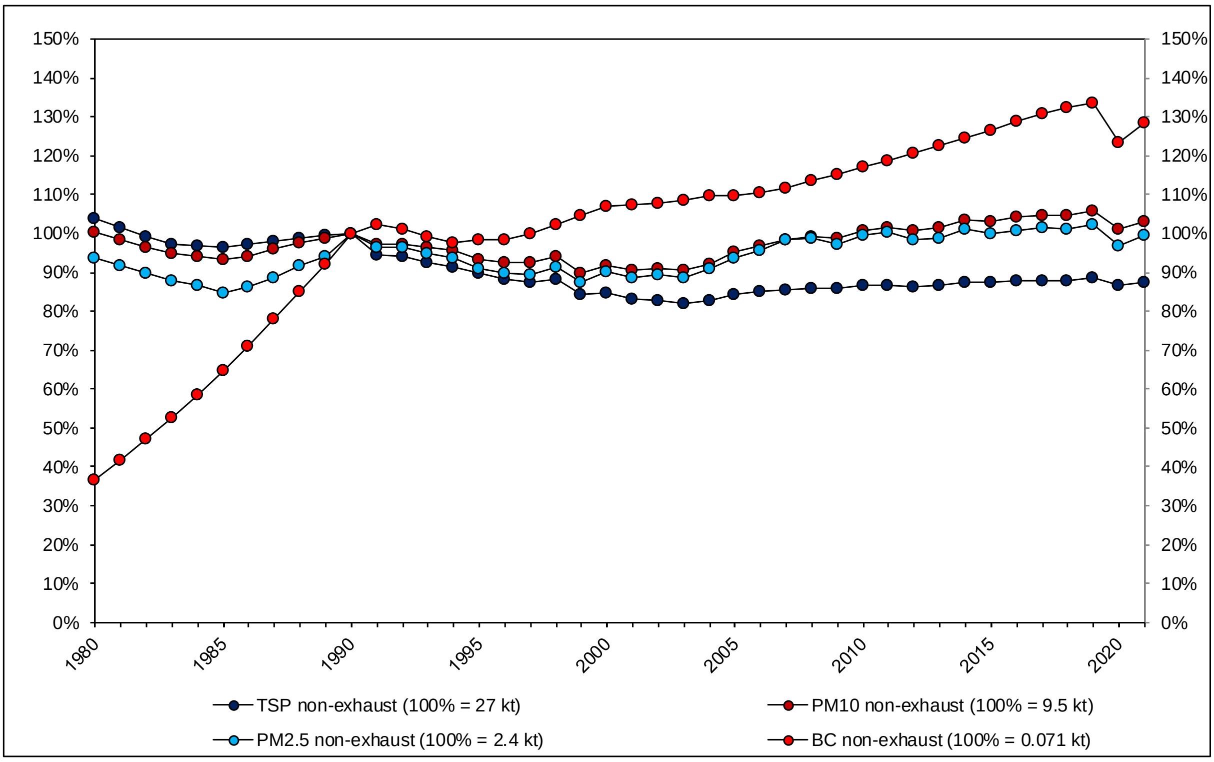


Figure 2-5 Non-exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2021 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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
2012	2.4	9.5	23	0.085
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	9.9	23	0.092
2018	2.5	9.9	23	0.093
2019	2.5	10.0	24	0.094
2020	2.4	9.6	23	0.087
2021	2.4	9.8	23	0.091
2021 vs. 2005 (%)	6.3%	8.4%	3.8%	16.9%

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.

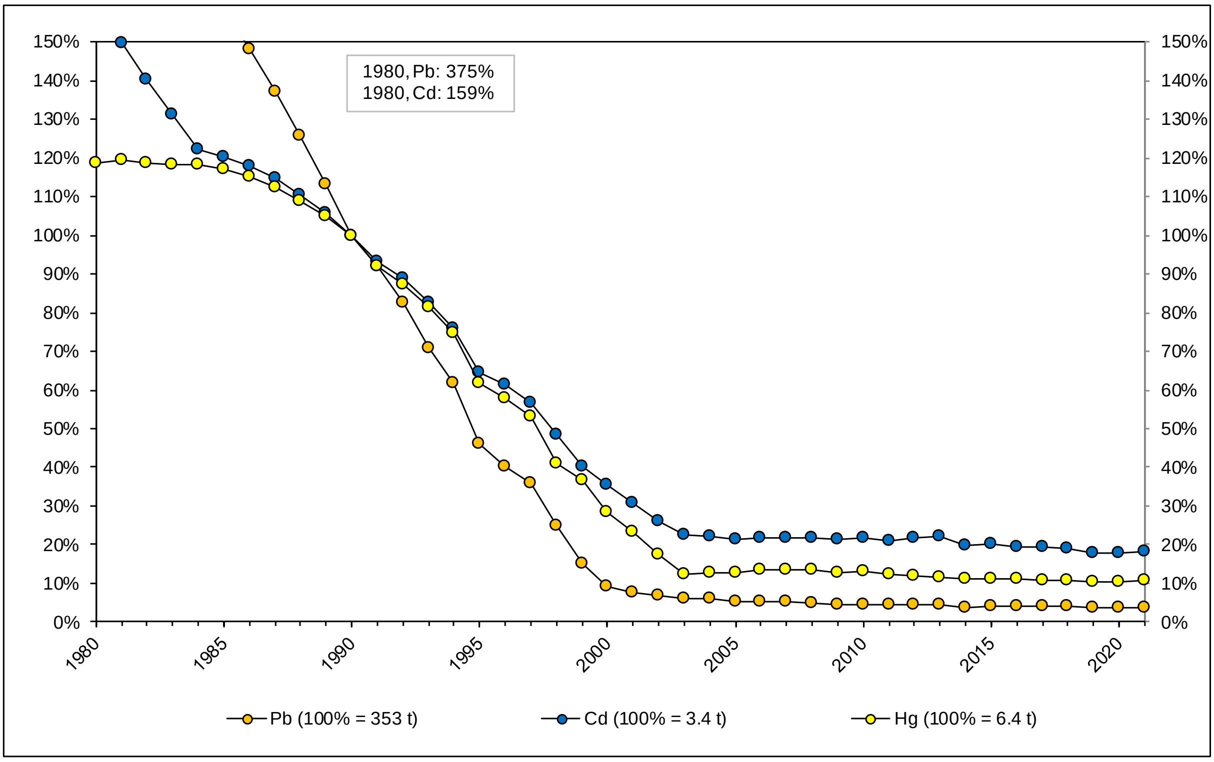


Figure 2-6 Emissions of priority heavy metals in Switzerland 1980–2021 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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	5.4	7.6
1985	560	4.1	7.5
1990	353	3.4	6.4
1995	163	2.2	3.9
2000	33	1.2	1.8
2005	19	0.74	0.82
2010	16	0.74	0.83
2012	15	0.74	0.75
2013	16	0.75	0.74
2014	14	0.68	0.71
2015	14	0.69	0.72
2016	14	0.67	0.71
2017	14	0.66	0.69
2018	14	0.65	0.68
2019	13	0.62	0.66
2020	13	0.60	0.65
2021	14	0.63	0.68
2021 vs. 2005 (%)	-29%	-15%	-17%

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 1980-1989, 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 and increased by about a factor of eight in manually operated furnaces and automatic combustion installations, respectively, 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.

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.

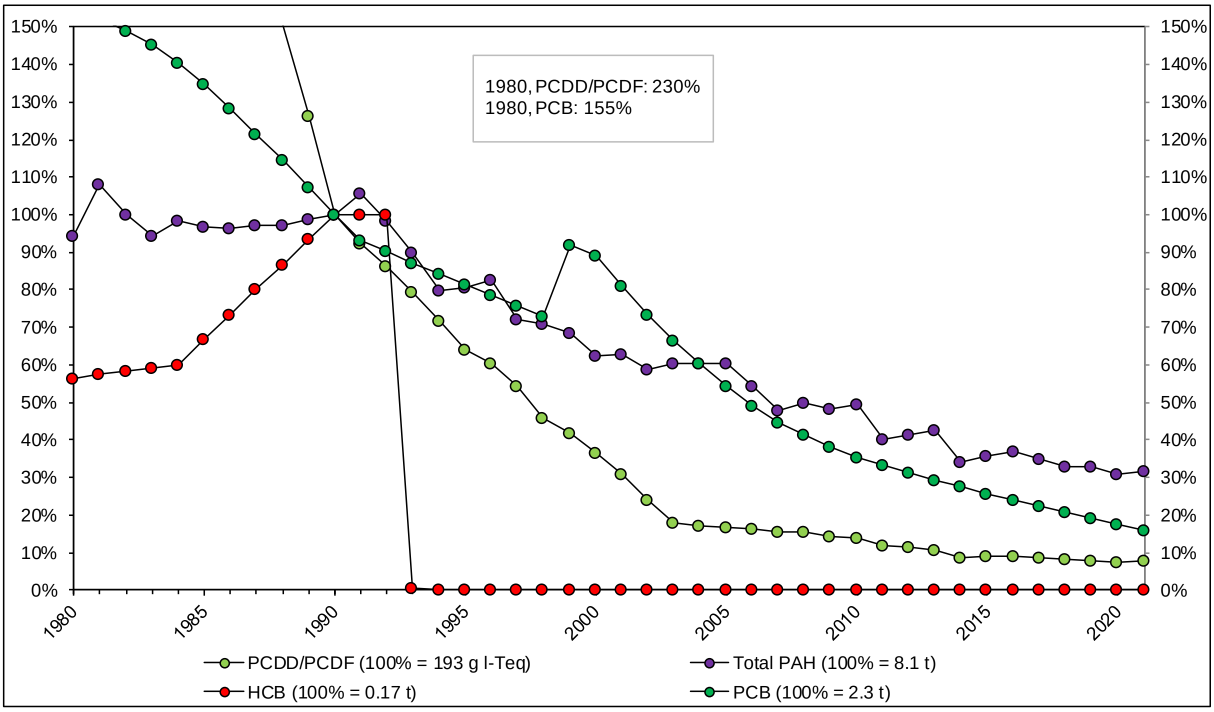


Figure 2-7 Emissions of POPs Annex III[1]: PAH – as the sum of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene – PCDD/PCDF, HCB and PCB in Switzerland 1980–2021. Note that values for PCDD/PCDF before 1989 are not displayed here but illustrated in the table below. Potential 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	t
1980	444	2.3	2.6	1.6	1.2	7.7	97	3.6
1985	398	2.3	2.6	1.7	1.3	7.9	115	3.1
1990	193	2.3	2.7	1.7	1.4	8.1	173	2.3
1995	124	2.0	2.1	1.3	1.2	6.5	0.49	1.9
2000	70	1.5	1.6	1.1	0.87	5.1	0.43	2.1
2005	32	1.4	1.6	1.0	0.83	4.9	0.44	1.3
2010	27	1.3	1.3	0.77	0.70	4.0	0.45	0.83
2012	22	1.0	1.1	0.65	0.59	3.4	0.40	0.73
2013	21	1.1	1.1	0.67	0.60	3.4	0.40	0.69
2014	17	0.84	0.89	0.55	0.48	2.8	0.35	0.64
2015	17	0.89	0.93	0.57	0.51	2.9	0.36	0.60
2016	17	0.91	0.96	0.59	0.53	3.0	0.38	0.56
2017	16	0.86	0.91	0.57	0.51	2.9	0.37	0.52
2018	16	0.81	0.86	0.54	0.48	2.7	0.36	0.48
2019	15	0.80	0.85	0.53	0.47	2.7	0.36	0.44
2020	14	0.76	0.80	0.50	0.45	2.5	0.35	0.41
2021	15	0.78	0.83	0.52	0.46	2.6	0.37	0.37
2021 vs. 2005 (%)	-53%	-46%	-49%	-50%	-45%	-48%	-17%	-71%

[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 2021.

The decline has mainly occurred due to emission reductions in the energy sector. Within the energy sector, in particular categories 1A3 Transport, 1A2 Manufacturing industries and 1A4 Other sectors are relevant for NO_x emissions. 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 2020, the COVID-19 pandemic led to measures that resulted in a massive reduction in traffic. The lower traffic volume led to a strong decrease in NO_x emissions from 1A3b Road transportation. These measures also led to 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 effects on emissions due to the measures taken in the context of the pandemic are still visible in the year 2021.
- 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 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 almost doubled from 1990 to 2021). These two effects compensated for the addition-

[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]

al heated area, and lead to a reduction of NO_x emissions under category 1A4 Other sectors.

- NO_x emissions from Agriculture decrease quite strongly, especially between 1990 and 2005. This was mainly due to a reduction and thus N excretions of livestock (-17 % between 1990 and 2020) and a strong decrease of N fertilizer 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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	135	89	78	48	-57	-41	-46%	92%
1A Fuel combustion	135	89	78	48	-57	-41	-46%	92%
1A1 Energy industries	6.8	2.9	3.0	2.4	-3.8	-0.51	-17%	4.6%
1A2 Manufacturing industries	23	14	12	7.6	-11	-6.8	-47%	15%
1A3 Transport	83	55	48	28	-35	-27	-49%	53%
1A4 Other sectors	21	16	14	9.8	-6.9	-6.6	-40%	19%
1A5 Other (Military)	0.88	0.60	0.54	0.38	-0.34	-0.23	-37%	0.72%
1B Fugitive emissions from fuels	0.21	0.29	0.11	0.0014	-0.099	-0.29	-100%	0.0027%
2 IPPU	0.49	0.32	0.38	0.25	-0.11	-0.068	-22%	0.47%
3 Agriculture	4.9	3.8	4.0	3.7	-0.97	-0.13	-3.5%	7.1%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.30	0.16	0.15	0.12	-0.15	-0.039	-24.3%	0.24%
6 Other	0.084	0.093	0.102	0.099	0.018	0.0055	5.9%	0.19%
National total for compliance	141	93	83	52	-58	-41	-44%	100%
Gothenburg Protocol			2010			Gothenburg Protocol revised		2005-2020
Emission ceiling / reduction			79					-41%

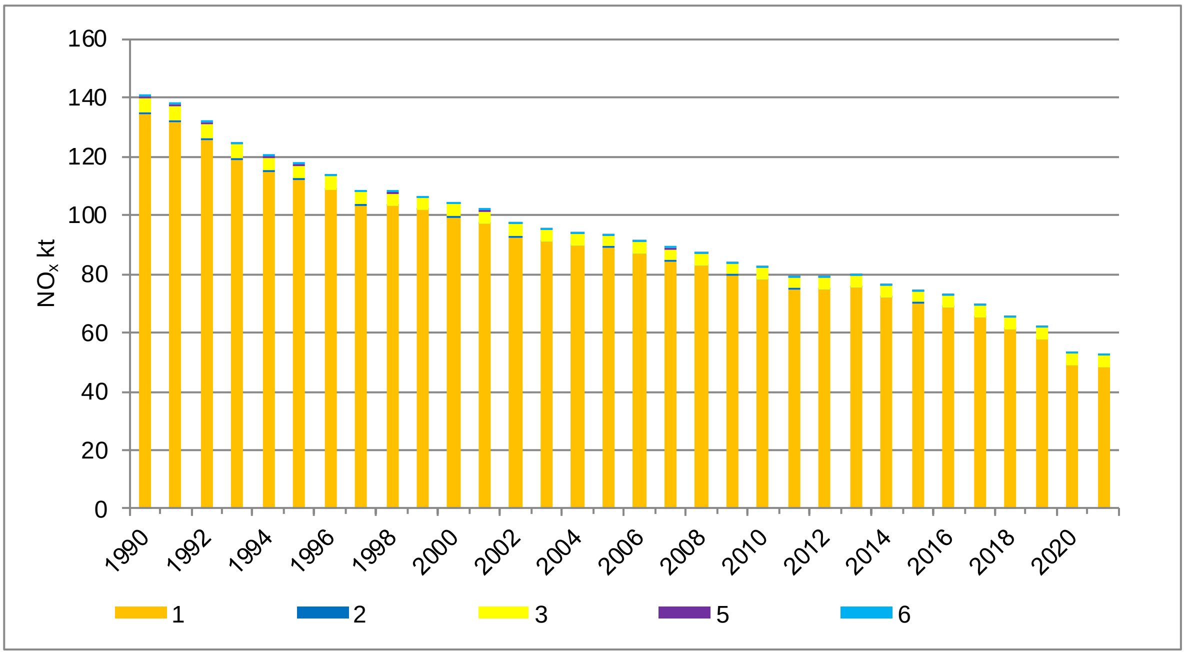


Figure 2-8 Trend of NO_x emissions (kt) in Switzerland by sector.

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 1990-2021.

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 slightly decreasing from 2004-2021. 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 2021, which leads to a decrease of NMVOC emissions. In 2020, the COVID-19 pandemic led to a reduction of NMVOC emissions from road transportation due to reduced traffic volumes. Effects of the pandemic on emissions are still visible in the year 2021.
- In 2020, the COVID-19 pandemic led to measures that resulted in a massive reduction in traffic. The lower traffic volume led to a strong decrease in NMVOC emissions from 1A3b Road transportation. These measures also led to a sharp drop in emissions from 1A3a Aviation, 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).The effects on emissions due to the measures taken in the context of the pandemic are still visible in the year 2021.
- 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 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**	**2021**	**1990-2010**	**2005-2021**	**2005-2021**	**share in 2021**
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	126	44	31	16	-95	-28	-63%	22%
1A Fuel combustion	109	37	26	13	-84	-23	-64%	18%
1A1 Energy industries	0.30	0.22	0.20	0.18	-0.11	-0.046	-21%	0.24%
1A2 Manufacturing industries	2.4	2.1	1.6	0.91	-0.80	-1.1	-56%	1.2%
1A3 Transport	89	23	15	7.3	-74	-16	-68%	10%
1A4 Other sectors	17	11	8.8	4.8	-8.6	-6.3	-57%	6.5%
1A5 Other (Military)	0.16	0.11	0.090	0.061	-0.070	-0.049	-44%	0.082%
1B Fugitive emissions from fuels	17	7.4	5.1	2.8	-12	-4.6	-62%	3.8%
2 IPPU	150	52	48	37	-102	-15	-29%	50%
3 Agriculture	15	17	19	19	3.3	2.1	12%	26%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	1.1	1.0	1.2	1.8	0.044	0.74	71%	2.4%
6 Other	0.19	0.22	0.23	0.23	0.043	0.013	6.2%	0.31%
National total for compliance	292	114	99	74	-194	-40	-35%	100%
Gothenburg Protocol			**2010**			Gothenburg Protocol revised		**2005-2020**
Emission ceiling / reduction			144					-30%

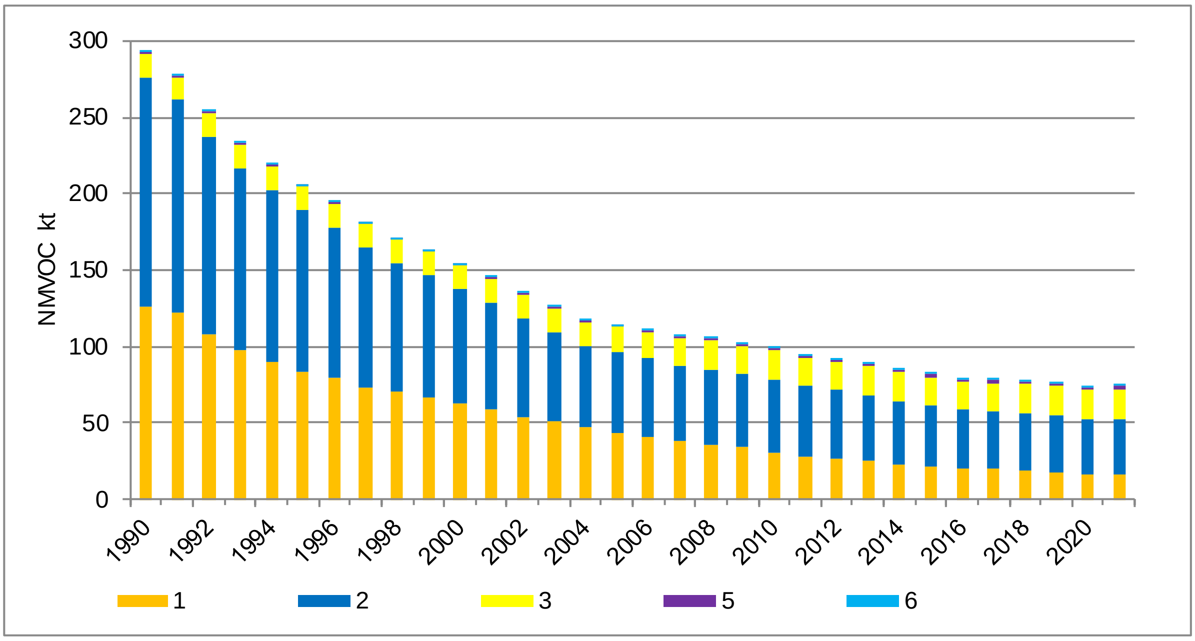


Figure 2-9 Trend of NMVOC emissions (kt) in Switzerland by sector.

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 2021.

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 fuels, with further stepwise lowering in 1991, 2000, 2005, 2008 and 2009 for liquid fuels (Table 3-9). These stringent measures resulted in a significant decrease of the sulphur oxide emissions from fuel combustible under 1A3 Transport and 1A4 Other sectors (gas oil, diesel oil and gasoline, see Table 3-9).
- 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 almost doubled from 1990 to 2021).
- 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 strongly 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 1990–2021. 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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	35	13	9.6	3.3	-25	-9.6	-75%	87%
1A Fuel combustion	34	12	9.4	3.3	-25	-9.1	-74%	86%
1A1 Energy industries	4.2	1.7	1.7	0.33	-2.5	-1.3	-80%	8.8%
1A2 Manufacturing industries	13	4.1	2.9	1.9	-9.9	-2.2	-55%	49%
1A3 Transport	4.0	0.21	0.22	0.12	-3.8	-0.087	-41%	3.3%
1A4 Other sectors	13	6.3	4.5	0.90	-8.8	-5.4	-86%	24%
1A5 Other (Military)	0.077	0.037	0.037	0.030	-0.041	-0.0075	-20%	0.80%
1B Fugitive emissions from fuels	0.72	0.51	0.22	0.014	-0.50	-0.50	-97%	0.36%
2 IPPU	1.6	1.0	0.80	0.47	-0.84	-0.57	-55%	12%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.16	0.063	0.063	0.029	-0.10	-0.034	-54%	0.78%
6 Other	0.011	0.012	0.012	0.012	0.00158	-0.00040	-3.3%	0.32%
National total for compliance	37	14	10	3.8	-26	-10	-73%	100%
Gothenburg Protocol			**2010**			Gothenburg Protocol revised		**2005-2020**
Emission ceiling / reduction			26					-21%

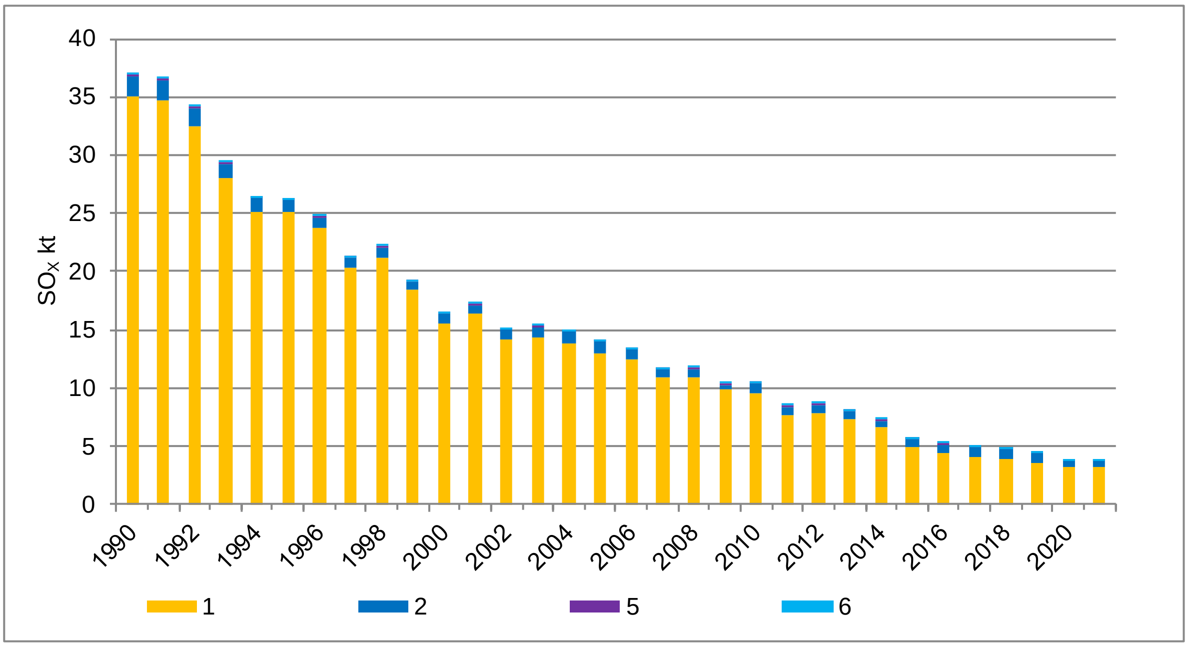


Figure 2-10 Trend of SO_x emissions (kt) in Switzerland by sector (SO_x as sum of SO_2 and SO_3, expressed as SO_2 equivalents).

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 2021.

Emission reductions (with fluctuations) occurred mainly in source category 3D Crop production and agricultural soils, especially in 3Da2a Animal manure applied to soils, while source category 3B Manure management was only subject to minor fluctuations. In 2021, 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 fertilizer 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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	1.7	3.9	2.8	1.2	1.1	-2.7	-68%	2.3%
1A Fuel combustion	1.7	3.9	2.8	1.2	1.1	-2.7	-68%	2.3%
1A1 Energy industries	0.0046	0.026	0.035	0.036	0.030	0.0099	38%	0.066%
1A2 Manufacturing industries	0.17	0.19	0.24	0.24	0.076	0.049	25%	0.45%
1A3 Transport	1.3	3.5	2.3	0.85	1.0	-2.7	-76%	1.6%
1A4 Other sectors	0.21	0.16	0.16	0.11	-0.043	-0.054	-33%	0.21%
1A5 Other (Military)	0.000037	0.000039	0.000042	0.000041	0.0000048	0.0000013	3.4%	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	-58%	0.27%
3 Agriculture	65	54	53	50	-12	-3.2	-6.0%	94%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.91	0.93	0.89	0.90	-0.023	-0.030	-3.2%	1.7%
6 Other	0.85	0.88	0.92	1.0	0.073	0.12	14%	1.9%
National total for compliance	69	60	58	54	-11	-6.0	-10%	100%
Gothenburg Protocol			2010		Gothenburg Protocol revised			2005-2020
Emission ceiling / reduction			63					-8.0%

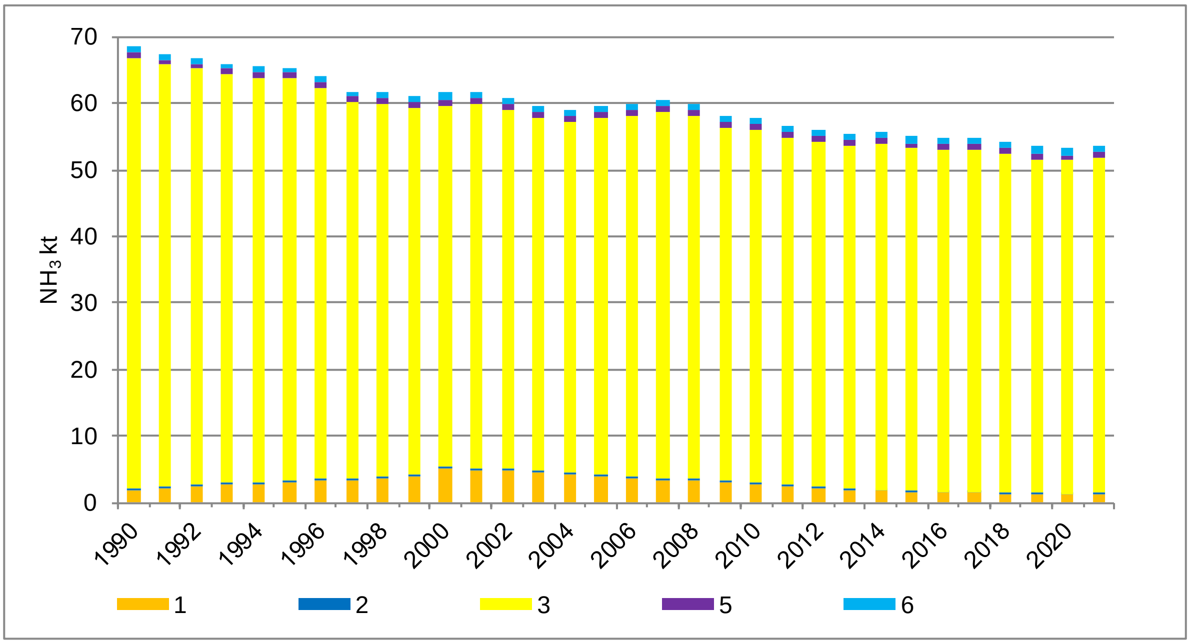


Figure 2-11 Trend of NH_3 emissions (kt) in Switzerland by sector.

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. Switzerland's 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 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 energy sector, the decline can be mainly attributed to a reduction of exhaust particulate matter emissions. The following measures contributed to the reduction of particulate matter emissions:

- A reduction of exhaust emissions under 1A4 Other sectors was due to technological improvements of wood combustion installations and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, the wood energy consumption decreased by more than half and increased by about a factor of eight in manually operated furnaces and automatic combustion installations (mainly in 1A1, 1A2), respectively. 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.
- 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.
- Particulate matter emissions from sector 2 Industrial processes and product use strongly decrease in the period 1990-1999 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. 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 renovations 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). Afterwards, 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.
- 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. In addition to the main trends mentioned in chp. 2.4.1, there is an underlying increasing trend of non-exhaust particulate emissions mainly driven by non-exhaust emissions from passenger cars (1A3bi) and non-road vehicles and machines in manufacturing industry and construction (1A2gvii). This increase in absolute values is more distinctive for TSP and PM10 than for PM2.5 (see chp. 2.4.4). In 2020 and 2021, despite this underlying increasing trend, the COVID-19 pandemic led to a reduction of non-exhaust PM2.5 emissions from road transportation due to reduced traffic volumes.

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

PM2.5 emissions	1990	2005	2010	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	13	8.7	7.2	4.1	-6.1	-4.6	-53%	71%
1A Fuel combustion	13	8.7	7.2	4.1	-6.1	-4.6	-53%	71%
1A1 Energy industries	0.82	0.18	0.19	0.062	-0.64	-0.12	-66%	1.1%
1A2 Manufacturing industries	2.0	1.5	1.1	0.64	-0.86	-0.88	-58%	11%
1A3 Transport	3.7	2.8	2.3	1.4	-1.4	-1.4	-51%	24%
1A4 Other sectors	6.7	4.1	3.6	1.9	-3.1	-2.2	-53%	33%
1A5 Other (Military)	0.087	0.057	0.050	0.045	-0.037	-0.012	-21%	0.78%
1B Fugitive emissions from fuels	0.00060	0.00066	0.00031	0.000048	-0.00029	-0.00061	-93%	0.0008%
2 IPPU	2.6	1.5	1.5	1.2	-1.1	-0.21	-14%	22%
3 Agriculture	0.12	0.13	0.13	0.14	0.013	0.016	13%	2.5%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.59	0.38	0.36	0.29	-0.22	-0.092	-24%	5.0%
6 Other	0.0042	0.0045	0.0053	0.0058	0.0011	0.0012	28%	0.10%
National total for compliance	17	11	9.2	5.7	-7.4	-4.9	-46%	100%
Gothenburg Protocol			**2010**		Gothenburg Protocol revised			**2005-2020**
Emission ceiling / reduction			–					-26%

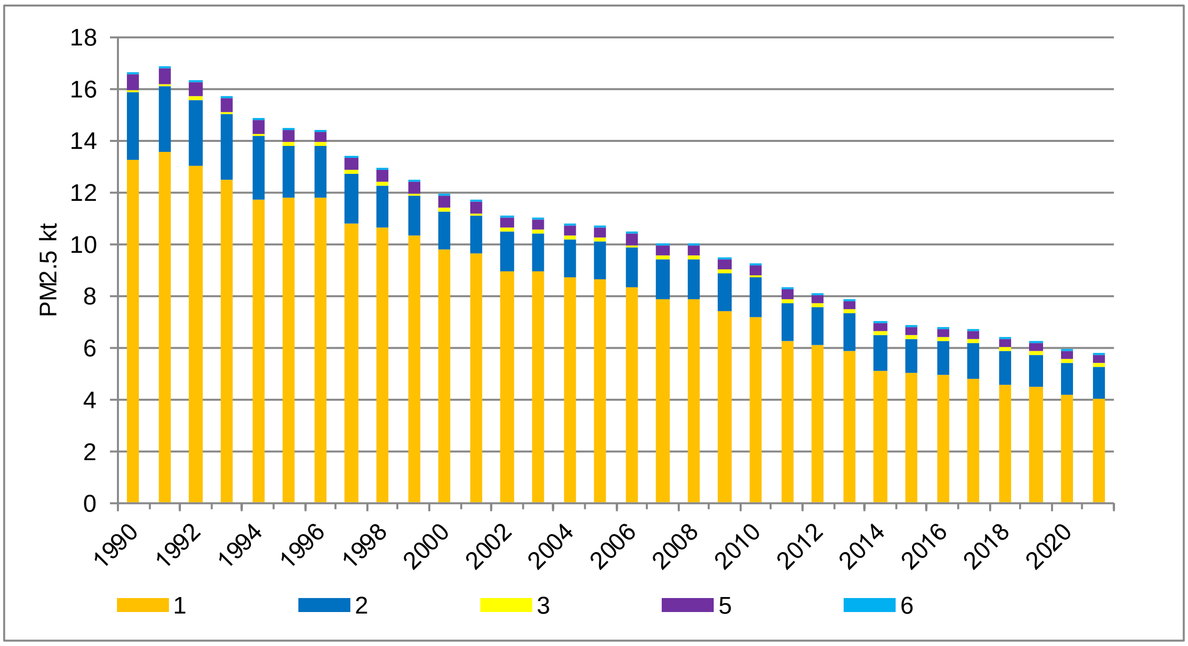


Figure 2-12 Trend of PM2.5 emissions (kt) in Switzerland by sector.

2.4.3 Trends for PM10

Switzerland's emissions of PM10 per sector are given in Table 2-13. In addition to the main trends mentioned in chp. 2.4.1, there is an underlying increasing trend of non-exhaust particulate emissions (more distinctive in absolute values for TSP and PM10 and less for PM2.5; see chp. 2.4.4). In 2020 and 2021, despite this underlying increasing trend, the COVID-19 pandemic led to a reduction of non-exhaust PM10 emissions from road transportation due to reduced traffic volumes.

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

PM10 emissions	1990	2005	2010	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	18	14	12	9.3	-5.9	-4.3	-32%	68%
1A Fuel combustion	18	14	12	9.3	-5.9	-4.3	-32%	68%
1A1 Energy industries	1.1	0.19	0.19	0.062	-0.89	-0.12	-66%	0.46%
1A2 Manufacturing industries	3.9	3.4	3.0	2.6	-0.84	-0.76	-22%	19%
1A3 Transport	5.9	5.4	5.0	4.2	-0.89	-1.1	-21%	31%
1A4 Other sectors	7.1	4.3	3.8	2.1	-3.2	-2.3	-52%	15%
1A5 Other (Military)	0.29	0.27	0.27	0.26	-0.018	-0.0044	-1.7%	1.9%
1B Fugitive emissions from fuels	0.0020	0.0013	0.00098	0.00046	-0.0011	-0.00083	-64%	0.0034%
2 IPPU	4.5	2.3	2.3	2.0	-2.2	-0.29	-13%	15%
3 Agriculture	1.7	1.7	1.7	1.8	0.015	0.12	7.2%	13%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.66	0.42	0.41	0.32	-0.26	-0.10	-24%	2.4%
6 Other	0.21	0.23	0.23	0.21	0.019	-0.027	-12%	1.5%
National total for compliance	25	18	17	14	-8.3	-4.6	-25%	100%

2.4.4 Trends for TSP

Switzerland's emissions of TSP per sector are given in Table 2-14. In addition to the main (mostly) decreasing trends mentioned in chp. 2.4.1, there is an underlying increasing trend in TSP due to non-exhaust particulate emissions from growing activity data (annual mileage and machine hours) of mobile sources 1A3 and 1A2gvii 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. An additional factor to be considered when comparing the decreasing trend of TSP with PM10 and PM2.5 is the contribution of sector 3 Agriculture to non-exhaust TSP emissions. 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 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. In 2020 and 2021, despite this underlying increasing trend, the COVID-19 pandemic led to a reduction of non-exhaust PM emissions from road transportation due to reduced traffic volumes.

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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	20	15	14	11	-6.2	-4.3	-28%	41%
1A Fuel combustion	20	15	14	11	-6.1	-4.3	-28%	40%
1A1 Energy industries	1.1	0.20	0.21	0.066	-0.90	-0.14	-67%	0.24%
1A2 Manufacturing industries	5.2	4.5	4.1	3.8	-1.0	-0.66	-15%	14%
1A3 Transport	6.2	5.8	5.5	4.6	-0.77	-1.11	-19%	17%
1A4 Other sectors	7.5	4.6	4.1	2.2	-3.4	-2.4	-52%	8.0%
1A5 Other (Military)	0.40	0.39	0.40	0.39	-0.0054	0.00044	0.11%	1.4%
1B Fugitive emissions from fuels	0.0045	0.0023	0.0021	0.0011	-0.0024	-0.0012	-51%	0.0042%
2 IPPU	10.0	3.4	3.5	3.1	-6.5	-0.35	-10%	11%
3 Agriculture	13	13	13	13	-0.33	0.098	0.78%	46%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.81	0.52	0.49	0.39	-0.32	-0.12	-24%	1.4%
6 Other	0.26	0.29	0.29	0.26	0.031	-0.030	-10%	0.96%
National total for compliance	44	32	31	27	-13	-4.7	-15%	100%

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

TSP exhaust emissions	1990	2005	2010	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	14	8.0	6.4	2.8	-7.6	-5.2	-65%	69%
1A Fuel combustion	14	8.0	6.4	2.8	-7.6	-5.2	-65%	69%
1A1 Energy industries	1.1	0.20	0.21	0.066	-0.90	-0.14	-67%	1.6%
1A2 Manufacturing industries	2.6	1.4	0.93	0.35	-1.7	-1.1	-75%	8.7%
1A3 Transport	2.9	1.9	1.3	0.31	-1.6	-1.6	-84%	7.6%
1A4 Other sectors	7.3	4.5	3.9	2.1	-3.4	-2.4	-53%	51%
1A5 Other (Military)	0.057	0.020	0.012	0.0063	-0.044	-0.014	-69%	0.15%
1B Fugitive emissions from fuels	0.00044	NA	NA	NA	–	–	–	–
2 IPPU	2.6	0.84	0.81	0.63	-1.8	-0.20	-24%	15%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.81	0.51	0.49	0.39	-0.32	-0.12	-24%	9.5%
6 Other	0.25	0.28	0.27	0.24	0.018	-0.035	-13%	5.9%
National total for compliance	18	9.6	7.9	4.1	-9.7	-5.5	-58%	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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	6.4	7.4	7.9	8.3	1.5	0.89	12%	36%
1A Fuel combustion	6.4	7.4	7.9	8.3	1.5	0.89	12%	36%
1A1 Energy industries	NA	NA	NA	NA	–	–	–	–
1A2 Manufacturing industries	2.6	3.0	3.2	3.5	0.61	0.42	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%	0.45%
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	0.0011	-0.0022	-0.00060	-34%	0.0049%
2 IPPU	7.4	2.6	2.7	2.4	-4.7	-0.15	-5.7%	10%
3 Agriculture	13	13	13	13	-0.33	0.098	0.78%	54%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.0034	0.0036	0.0036	0.0036	0.00024	0.0	0.0%	0.015%
6 Other	0.0072	0.017	0.020	0.022	0.013	0.0052	30%	0.096%
National total for compliance	27	22	23	23	-3.5	0.85	3.8%	100%

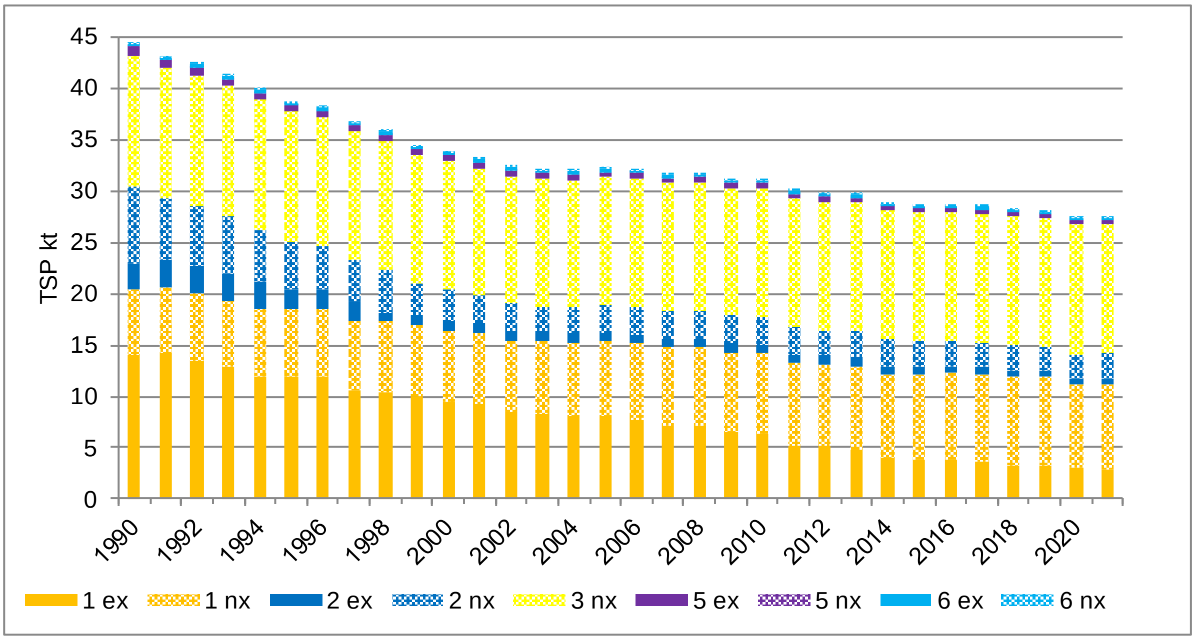


Figure 2-13 Trend of TSP emissions (kt) in Switzerland for sectors 1-6 splitted in exhaust (ex) and non-exhaust (nx) fraction. Non-exhaust emissions cross-hatched.

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 1990-2021.

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

BC emissions	1990	2005	2010	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	5.7	3.5	2.6	1.0	-3.1	-2.5	-72%	98%
1A Fuel combustion	5.7	3.5	2.6	0.98	-3.1	-2.5	-72%	98%
1A1 Energy industries	0.038	0.016	0.016	0.0073	-0.022	-0.0084	-53%	0.73%
1A2 Manufacturing industries	0.42	0.32	0.14	0.040	-0.28	-0.28	-87%	4.0%
1A3 Transport	1.4	1.2	0.88	0.22	-0.51	-1.0	-82%	22%
1A4 Other sectors	3.8	1.9	1.5	0.71	-2.3	-1.2	-63%	71%
1A5 Other (Military)	0.026	0.0099	0.0058	0.0031	-0.020	-0.0068	-69%	0.31%
1B Fugitive emissions from fuels	0.00020	0.00018	0.00010	0.000028	-0.00010	-0.00016	-85%	0.0028%
2 IPPU	0.0063	0.0026	0.0016	0.0013	-0.0047	-0.0013	-50%	0.13%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.041	0.027	0.026	0.021	-0.016	-0.0064	-23%	2.1%
6 Other	0.00015	0.00016	0.00016	0.00014	0.000011	-0.000020	-12%	0.014%
National total for compliance	5.7	3.5	2.6	1.0	-3.2	-2.5	-72%	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 in the time span 1990-2021.

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 half.

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

CO emissions	1990	2005	2010	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	741	295	232	140	-509	-156	-53%	95%
1A Fuel combustion	741	295	232	140	-509	-156	-53%	95%
1A1 Energy industries	1.3	0.96	0.95	0.59	-0.34	-0.38	-39%	0.40%
1A2 Manufacturing industries	27	21	20	16	-7.2	-5.0	-24%	11%
1A3 Transport	550	167	119	63	-431	-104	-62%	43%
1A4 Other sectors	161	106	91	59	-70	-46	-44%	40%
1A5 Other (Military)	1.2	0.92	0.87	0.74	-0.34	-0.18	-20%	0.50%
1B Fugitive emissions from fuels	0.048	0.063	0.027	0.00023	-0.020	-0.063	-100%	0.00016%
2 IPPU	11	8.1	7.2	5.7	-3.9	-2.47	-30.4%	3.8%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	2.8	1.9	1.7	1.4	-1.1	-0.48	-25%	0.97%
6 Other	0.82	0.91	0.88	0.79	0.06	-0.12	-13%	0.54%
National total for compliance	756	306	242	148	-514	-159	-52%	100%

2.6 Trends of priority heavy metals per pollutant

2.6.1 Lead (Pb)

Switzerland's emissions of Pb mainly stem from the sectors 1 Energy and 6 Other (from 2000 onwards). 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 2 IPPU (i.e. ban of Pb in fireworks (2G) in 2003) and 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).

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

Pb emissions	1990	2005	2010	2021	1990-2010	2005-2021	2005-2021	share in 2021
	t	t	t	t	t	t	%	%
1 Energy	275	6.7	5.4	4.3	-269	-2.5	-37%	32%
1A Fuel combustion	271	6.7	5.4	4.3	-266	-2.5	-37%	32%
1A1 Energy industries	30	1.9	1.8	1.7	-28	-0.28	-14%	12%
1A2 Manufacturing industries	6.3	2.7	1.8	1.0	-4.5	-1.7	-62%	7.4%
1A3 Transport	231	1.2	1.0	0.93	-230	-0.27	-22%	6.9%
1A4 Other sectors	3.8	0.94	0.90	0.68	-2.9	-0.25	-27%	5.0%
1A5 Other (Military)	0.033	0.00023	0.00024	0.00024	-0.032	0.000011	4.9%	0.0018%
1B Fugitive emissions from fuels	3.5	0.0011	0.00043	0.0000049	-3.536	-0.001068	-100%	0.000036%
2 IPPU	67	2.1	0.69	0.61	-66	-1.5	-71%	4.5%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	4.3	2.3	2.3	1.7	-2.0	-0.61	-26%	13%
6 Other	6.9	7.8	7.6	7.0	0.62	-0.83	-11%	51%
National total for compliance	353	19	16	14	-337	-5.4	-29%	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. In contrast, since 2003, emissions from 1A1a and 1A3b increased due to the increase of municipal solid waste incineration and of mileage (exhaust emissions from vehicles), respectively.
- 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 2015 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), but also in sewage sludge incineration plants (source category 5C1). Also the (fluctuating) Cd emissions from 6Ad Fire damages have declined since 2013.

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

Cd emissions	**1990**	**2005**	**2010**	**2021**	**1990-2010**	**2005-2021**	**2005-2021**	**share in 2021**
	t	t	t	t	t	t	%	%
1 Energy	2.6	0.43	0.44	0.37	-2.2	-0.062	-15%	58%
1A Fuel combustion	2.6	0.43	0.44	0.37	-2.2	-0.061	-14%	58%
1A1 Energy industries	1.8	0.18	0.20	0.15	-1.6	-0.024	-14%	25%
1A2 Manufacturing industries	0.74	0.10	0.091	0.072	-0.65	-0.031	-30%	11%
1A3 Transport	0.069	0.077	0.083	0.090	0.013	0.013	17%	14%
1A4 Other sectors	0.084	0.068	0.067	0.050	-0.017	-0.018	-26%	8.0%
1A5 Other (Military)	0.00048	0.00051	0.00054	0.00053	0.000058	0.000015	3.0%	0.084%
1B Fugitive emissions from fuels	0.0011	0.0015	0.00058	0.0000066	-0.00056	-0.0015	-100%	0.0011%
2 IPPU	0.56	0.092	0.087	0.079	-0.47	-0.013	-14%	13%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.047	0.021	0.027	0.0088	-0.020	-0.012	-58%	1.4%
6 Other	0.17	0.19	0.19	0.17	0.016	-0.021	-11%	28%
National total for compliance	3.4	0.74	0.74	0.63	-2.7	-0.11	-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 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 production sites in 2015 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) 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).

	t	t	t	t	t	t	%	%
1 Energy	4.3	0.59	0.59	0.52	-3.7	-0.070	-12%	76%
1A Fuel combustion	4.3	0.59	0.59	0.52	-3.7	-0.070	-12%	76%
1A1 Energy industries	3.9	0.34	0.32	0.30	-3.6	-0.045	-13%	44%
1A2 Manufacturing industries	0.25	0.12	0.14	0.10	-0.11	-0.022	-18%	15%
1A3 Transport	0.034	0.037	0.036	0.032	0.0024	-0.0054	-14%	4.7%
1A4 Other sectors	0.089	0.085	0.093	0.088	0.0046	0.0028	3.2%	13%
1A5 Other (Military)	0.000027	0.000028	0.000030	0.000029	0.0000030	0.00000074	2.6%	0.0043%
1B Fugitive emissions from fuels	0.00020	0.00025	0.00010	0.0000011	-0.00010	-0.00025	-100%	0.0002%
2 IPPU	1.5	0.067	0.066	0.054	-1.4	-0.012	-19%	8.0%
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%	4.1%
6 Other	0.082	0.091	0.088	0.079	0.0058	-0.012	-13%	12%
National total for compliance	6.4	0.82	0.83	0.68	-5.6	-0.14	-17%	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.

The significant decrease between 1990 and 2003 was mainly achieved in category 1A1a 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 5C1 Waste incineration (i.e. a continuous reduction of clinical waste incinerated at the hospital sites themselves which ceased in 2002 completely) and 2C1 Iron and steel production (i.e. closing down of two production sites in 2015 and installation of new filters in the electric arc furnaces of the remaining secondary steel production plants in 1998/1999).

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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	%	%
1 Energy	161	23	19	8.7	-142	-14	-62%	58%
1A Fuel combustion	161	23	19	8.7	-142	-14	-62%	58%
1A1 Energy industries	130	5.2	3.4	0.96	-127	-4.3	-82%	6.4%
1A2 Manufacturing industries	8.4	2.8	2.1	1.1	-6.3	-1.7	-62%	7.0%
1A3 Transport	1.6	1.7	1.7	0.46	0.076	-1.3	-73%	3.1%
1A4 Other sectors	20	13	12	6.2	-8.3	-7.2	-53%	41%
1A5 Other (Military)	0.00036	0.00038	0.00040	0.00039	0.000040	0.000010	2.5%	0.0026%
1B Fugitive emissions from fuels	0.00001	NA	NA	NA	–	–	–	–
2 IPPU	17	2.1	1.2	0.83	-16	-1.3	-61%	5.5%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	13	4.3	4.0	3.0	-9.2	-1.3	-31%	20%
6 Other	2.6	2.9	2.8	2.6	0.23	-0.31	-11%	17%
National total for compliance	193	32	27	15	-166	-17	-53%	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 2021, 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 and their reduction has mainly been achieved in the dominant source category 1A4, through technological improvements of wood furnaces and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, the wood energy consumption decreased by more than half and increased by about a factor of eight in manually operated furnaces and automatic combustion installations (1A1 and 1A2, respectively). The superimposed fluctuations in the emission trend reflect the climate variabilities (i.e. warm or cold winters).

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

PAHs emissions	1990	2005	2010	2021	1990-2010	2005-2021	2005-2021	share in 2021
	t	t	t	t	t	t	%	%
1 Energy	6.7	4.1	3.7	2.3	-3.0	-1.8	-44%	88%
1A Fuel combustion	6.7	4.1	3.7	2.3	-3.0	-1.8	-44%	88%
1A1 Energy industries	0.0076	0.0085	0.011	0.0060	0.0030	-0.0025	-29%	0.23%
1A2 Manufacturing industries	0.23	0.18	0.16	0.11	-0.075	-0.070	-39%	4.2%
1A3 Transport	0.15	0.17	0.21	0.27	0.061	0.10	63%	10%
1A4 Other sectors	6.3	3.7	3.3	1.9	-3.0	-1.8	-50%	73%
1A5 Other (Military)	0.00071	0.00073	0.00076	0.00068	0.000051	-0.000048	-6.6%	0.026%
1B Fugitive emissions from fuels	0.0000015	0.0000020	0.00000081	0.000000009	-0.00000070	-0.0000020	-100%	0.0000004%
2 IPPU	0.95	0.50	0.012	0.013	-0.94	-0.48	-97%	0.49%
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%	7.3%
6 Other	0.072	0.095	0.10	0.12	0.028	0.021	22%	4.5%
National total for compliance	8.1	4.9	4.0	2.6	-4.1	-2.3	-48%	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 2021.

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 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 half). In contrast, the amount of municipal solid waste incinerated has increased (1A1a), 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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	173	0.44	0.45	0.37	-172	-0.078	-17%	100%
1A Fuel combustion	173	0.44	0.45	0.37	-172	-0.078	-17%	100%
1A1 Energy industries	0.11	0.15	0.17	0.19	0.060	0.035	23%	51%
1A2 Manufacturing industries	172	0.051	0.051	0.038	-172	-0.013	-26%	10%
1A3 Transport	NE	NE	NE	NE	–	–	–	–
1A4 Other sectors	0.38	0.24	0.22	0.14	-0.16	-0.10	-41%	39%
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	0.37	-172	-0.078	-17%	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 2021 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 at 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	2021	1990-2010	2005-2021	2005-2021	share in 2021
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	165	1.4	0.55	0.40	-164	-1.0	-72%	0.11%
1A Fuel combustion	165	1.4	0.55	0.40	-164	-1.0	-72%	0.11%
1A1 Energy industries	164	1.1	0.18	0.070	-164	-1.0	-94%	0.019%
1A2 Manufacturing industries	0.50	0.35	0.38	0.33	-0.12	-0.022	-6.3%	0.089%
1A3 Transport	0.00037	0.00037	0.00034	0.000094	-0.000026	-0.00027	-74%	0.00003%
1A4 Other sectors	0.0022	0.0015	0.0013	0.00079	-0.00093	-0.00070	-47%	0.0002%
1A5 Other (Military)	NE	NE	NE	NE	–	–	–	–
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	1'537	922	708	338	-829	-584	-63%	90%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	347	254	56	7.1	-291	-247	-97%	1.9%
6 Other	282	93	62	29	-220	-64	-69%	7.7%
National total for compliance	2'332	1'270	827	374	-1'505	-896	-71%	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 2021 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 2021 of the latest submission (2023).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2023)	Compliance with emission ceilings 2010 in 2010	Emissions 2021 (Subm. 2023)	Compliance with emission ceilings 2010 in 2021
	kt	kt		kt	
SO_x (as SO_2)	26	10	yes	3.8	yes
NO_x (as NO_2)	79	83	no	52	yes
NMVOC	144	99	yes	74	yes
NH_3	63	58	yes	54	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 2021. 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 2021 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 2021**	**Compliance with reduction commitments 2020 in 2021**
	%-reduction of 2005 level	*%-reduction of 2005 level*		*%-reduction of 2005 level*	
SO_x (as SO_2)	21%	73%	yes	73%	yes
NO_x (as NO_2)	41%	43%	yes	44%	yes
NMVOC	30%	35%	yes	35%	yes
NH_3	8%	11%	yes	10%	yes
PM2.5	26%	45%	yes	46%	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 2021:

- 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 2020, the COVID-19 pandemic led to measures that resulted in a massive reduction in traffic. The lower traffic volume led to a strong decrease in NO_x emissions from 1A3b Road transportation. These measures also led to 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 effects on emissions due to the measures taken in the context of the pandemic are still visible in the year 2021.
- 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 almost doubled from 1990 to 2021). 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.

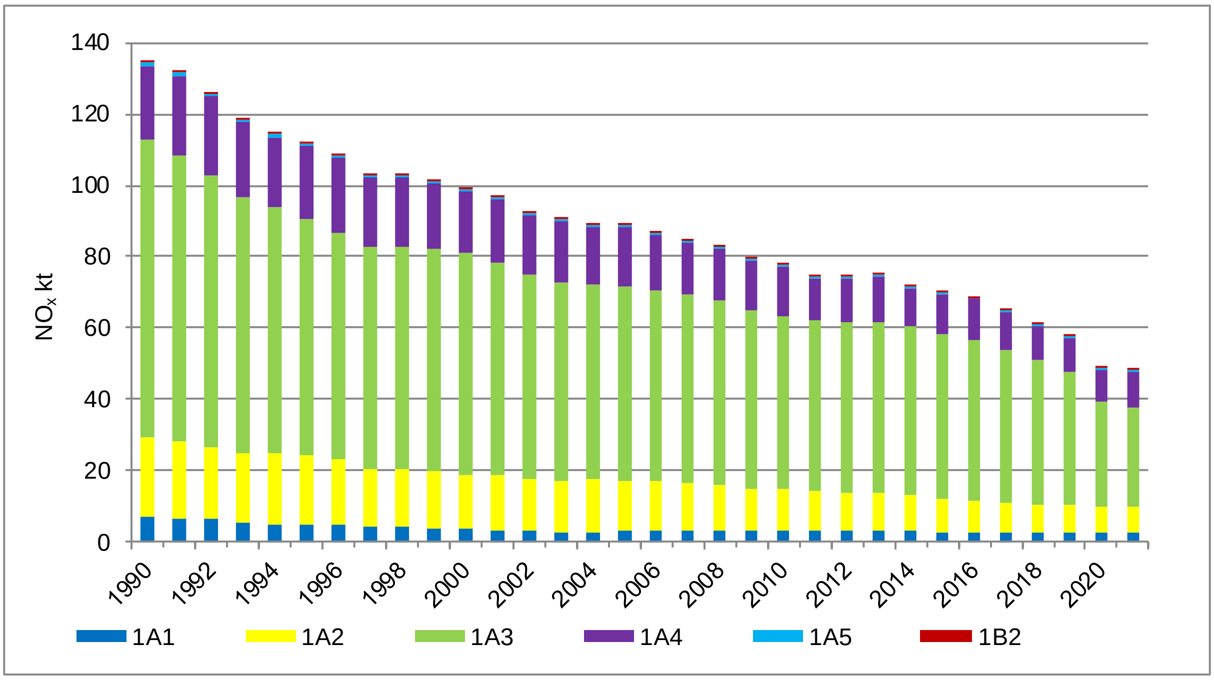


Figure 3-1 Switzerland's NO_x emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2021. The corresponding data table can be found in Annex A7.2.

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 2021. 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 2021, which leads to a decrease of NMVOC emissions.

- In 2020, the COVID-19 pandemic led to measures that resulted in a massive reduction in traffic. The lower traffic volume led to a decrease in NMVOC emissions from 1A3b Road transportation. These measures also led to a drop in emissions from 1A3a Aviation, 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).The effects on emissions due to the measures taken in the context of the pandemic are still visible in the year 2021.
- 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.

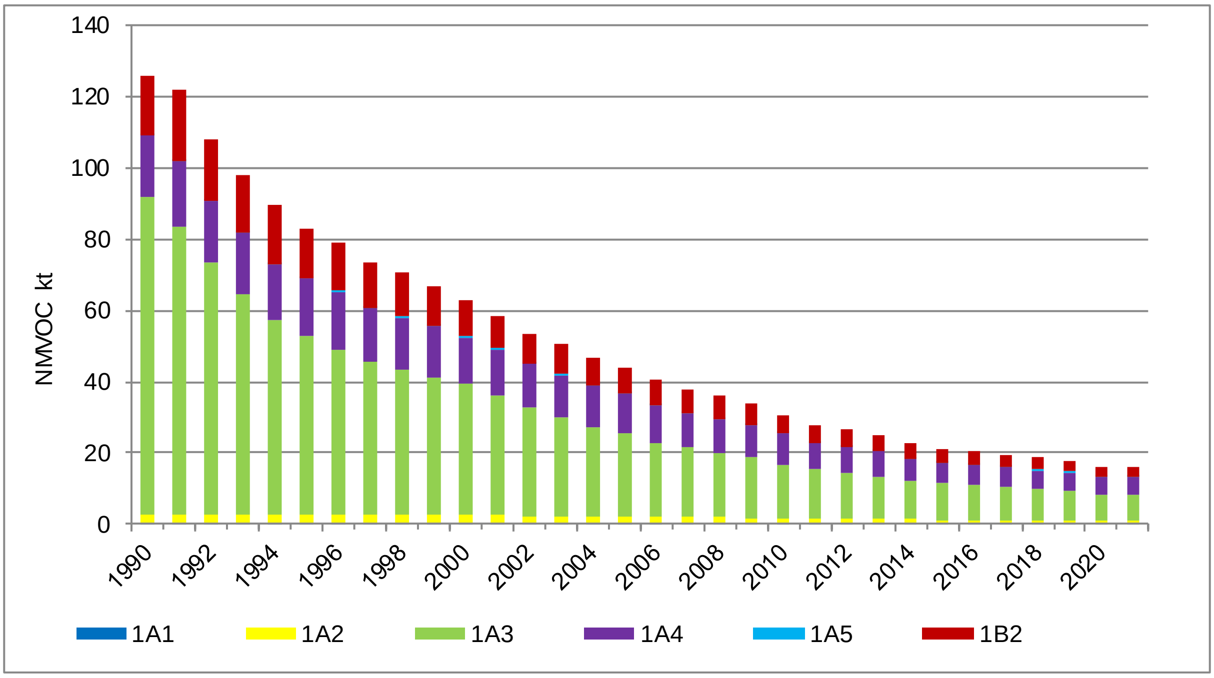


Figure 3-2 Switzerland’s NMVOC emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2021. The corresponding data table can be found in Annex A7.2.

3.1.3 Overview and trend for SO_x

Figure 3-3 depicts the SO_x emissions in energy related sectors since 1990. In 2021, 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, a limitation of the sulphur content in fuels (stepwise lowering in 1991, 2000, 2005, 2008 and 2009 for liquid fuels led to a massive reduction between 1990 and 2021, see

Table 3-9) by the Ordinance on Air Pollution Control (Swiss Confederation 1985) 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 3-9).

- 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 almost doubled from 1990 to 2021).
- 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 retrofittings 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.

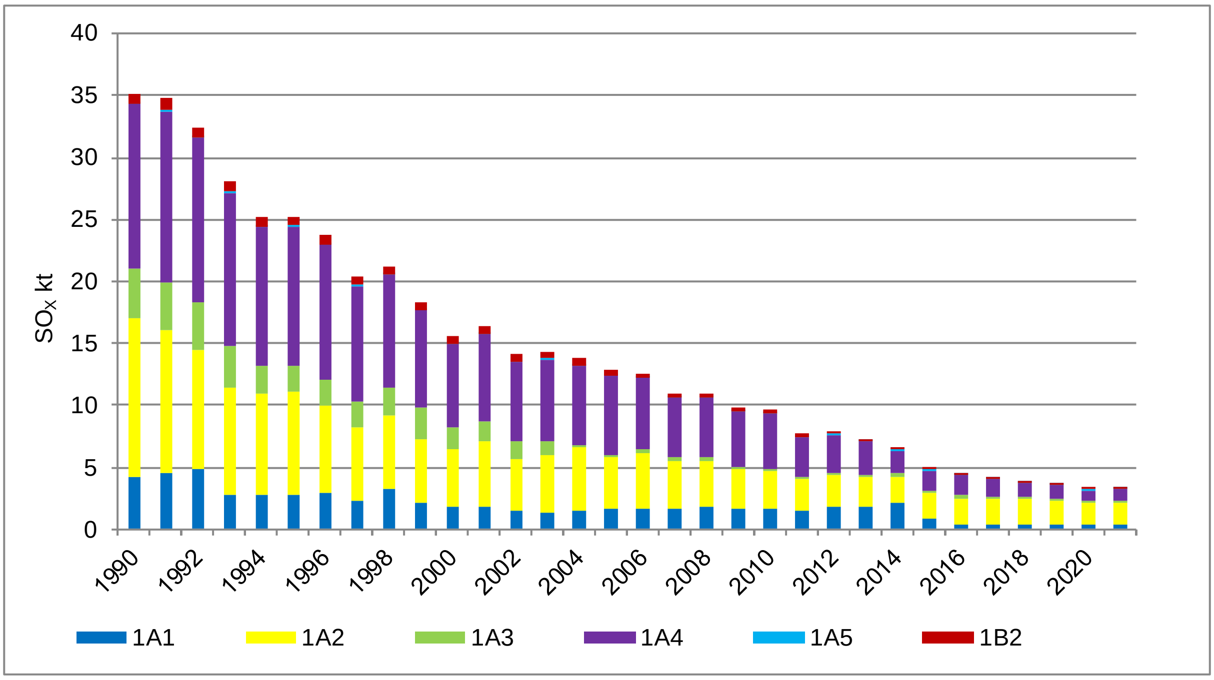


Figure 3-3 Switzerland's SO_x emissions from the energy sector by source category 1A1-1A5 and 1B2 between 1990 and 2021. The detailed corresponding data table can be found in Annex A7.2.

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 emissions from source category 1B Fugitive emissions from fuels.

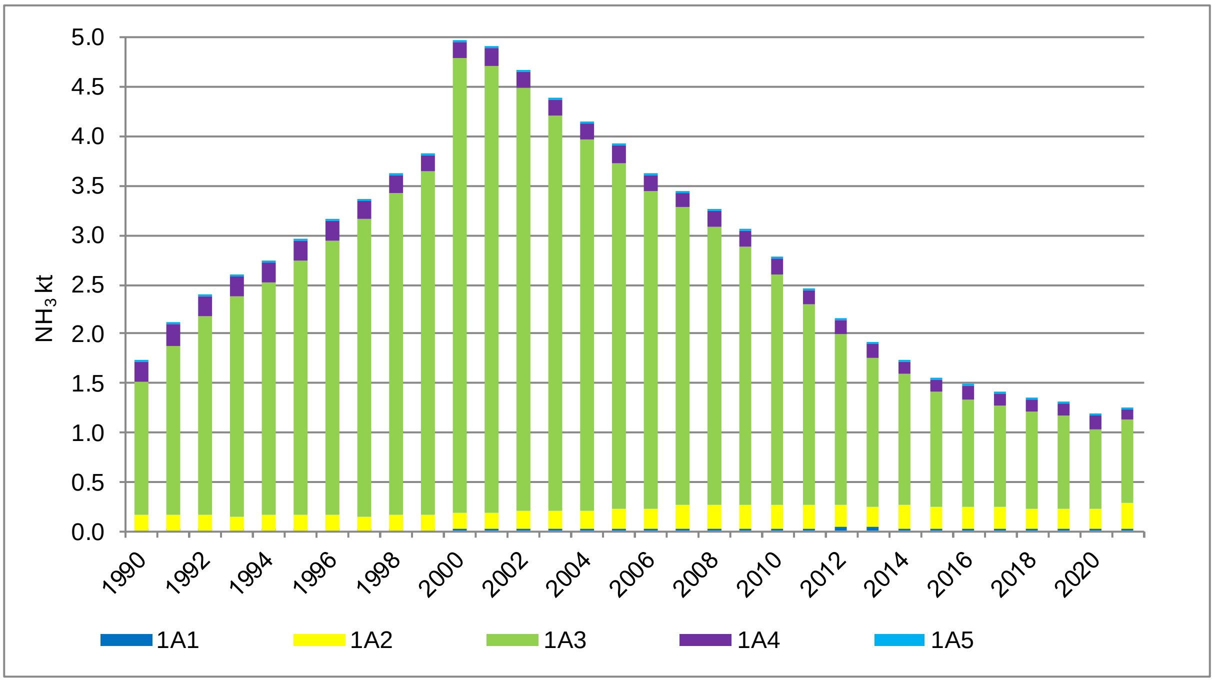


Figure 3-4 Switzerland's NH_3 emissions from the energy sector by source category 1A1-1A5 between 1990 and 2021. There are no emissions from 1B. The detailed corresponding data table can be found in Annex A7.2.

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:

- A reduction of exhaust emissions under 1A4 Other sectors was due to technological improvements of wood combustion installations and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, the wood energy consumption decreased by more than half and increased by almost a factor of eight in manually operated furnaces and automatic combustion installations (mainly in 1A1, 1A2), respectively. Furthermore, the revision of the Ordinance of Air Pollution (Swiss Confederation 1985) in 2007 with more stringent emission limits (2007, 2008 and 2012) for mainly automatic wood combustion installations led to emission reductions.

- 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.
- In 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).

Note that there is an underlying increasing trend of non-exhaust particulate emissions (see Figure 2-13) mainly driven by non-exhaust emissions from passenger cars (1A3bi) and non-road vehicles and machines in manufacturing industry and construction (1A2gvii). This increase in absolute values is more distinctive for TSP and PM10 and less for PM2.5 (see chp. 2.4.4). In 2020, the COVID-19 pandemic led to measures that resulted in a massive reduction in traffic. The lower traffic volume caused a pronounced decrease in total PM2.5 emissions from 1A3b Road transportation. The effects on emissions due to the measures taken in the context of the pandemic are still visible in the year 2021.

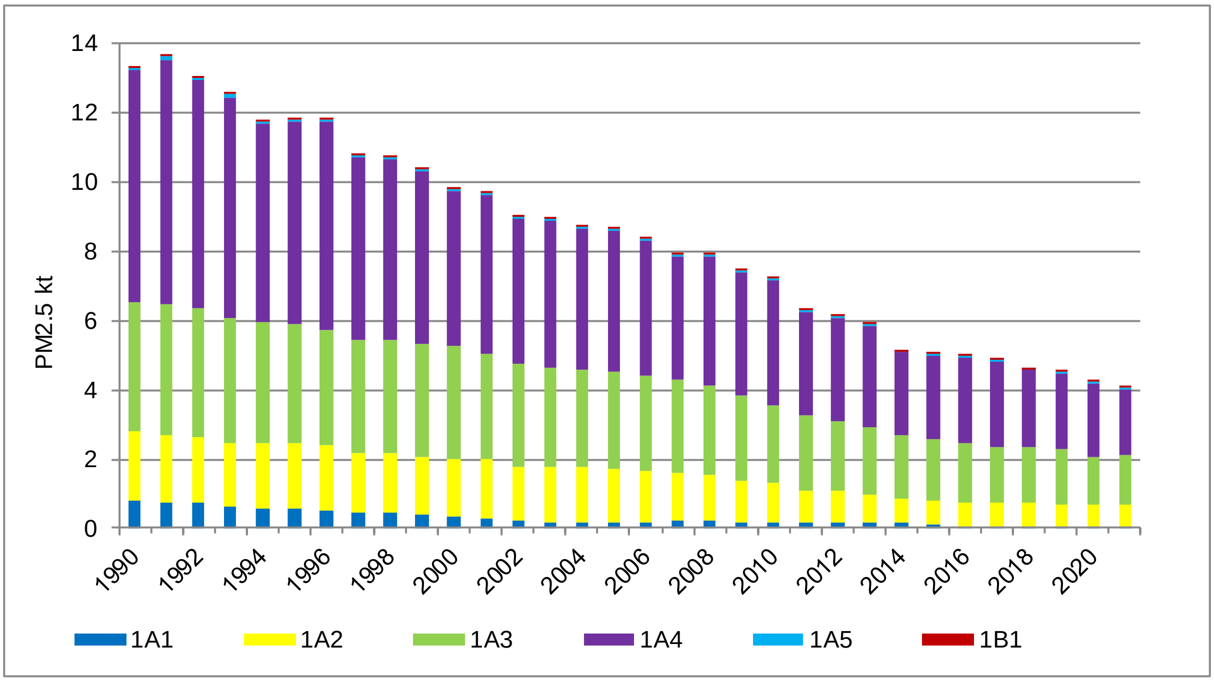


Figure 3-5 Switzerland's PM2.5 emissions from the energy sector by source categories 1A1-1A5 and 1B1 between 1990 and 2021. The corresponding data table can be found in Annex A7.2.

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 3-1, columns CLRTAP / NFR tables “national total” and UNFCCC / CRF tables “national total” compared to CLRTAP / NFR tables “national total for compliance”. The CLRTAP / NFR tables “national total for compliance” 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 2023, 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, as a memo item (1D1 International aviation). For the reporting of air pollutant under the CLRTAP, landing and takeoff (LTO) emissions of domestic and international flights are accounted for, while emissions of international and domestic cruise flights are reported under memo items only (see Table 3-1). Note that emissions from overflights without landing in Switzerland are not considered in any of the approaches.

Table 3-1 Accounting rules for emissions from 1A3a Aviation and 1A3b Road transportation for CLRTAP and UNFCCC.

<table>
<tr><td colspan="3" rowspan="3">Differences between reporting under CLRTAP and UNFCCC concerning the accounting to the national total</td><td colspan="3">CLRTAP / NFR tables</td><td colspan="2">UNFCCC / CRF tables</td></tr>
<tr><td colspan="5">accounted to</td></tr>
<tr><td>National total</td><td>National total for compliance</td><td>Separated information / Memo items</td><td>National total</td><td>Bunker (1D)</td></tr>
<tr><td rowspan="2">Road transportation (1A3b)</td><td rowspan="2">Fuels sold (1A3b)</td><td>Fuel used (1A3bi-v)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td>Fuel tourism and statistical differences</td><td>Yes</td><td>No</td><td>No</td><td>Yes</td><td>No</td></tr>
<tr><td rowspan="4">Aviation (1A3a)</td><td rowspan="2">Civil and domestic aviation</td><td>Landing and Take-Off (LTO)</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td></tr>
<tr><td>Cruise</td><td>No</td><td>No</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td rowspan="2">International aviation</td><td>Landing and Take-Off (LTO)</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>Yes</td></tr>
<tr><td>Cruise</td><td>No</td><td>No</td><td>Yes</td><td>No</td><td>Yes</td></tr>
</table>

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 3-2 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 3-2 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 3-3.

Fuel	**Data sources**	**NCV [GJ/t]**
Gasoline	EMPA (1999), SFOE/FOEN (2014)	42.5 (1998), 42.6 (2013)
Jet kerosene	EMPA (1999), SFOE/FOEN (2014)	43.0 (1998), 43.2 (2013)
Diesel oil	EMPA (1999), SFOE/FOEN (2014)	42.8 (1998), 43.0 (2013)
Gas oil	EMPA (1999), SFOE/FOEN (2014)	42.6 (1998), 42.9 (2013)
Residual fuel oil	EMPA (1999)	41.2
Liquefied petroleum gas	SFOE (2022)	46.0
Petroleum coke	SFOE (2022), Cemsuisse (2010a)	35.0 (1998), 31.8 (2010)
Other bituminous coal	SFOE (2022), Cemsuisse (2010a)	28.052 (1998), 25.5 (2010)
Lignite	SFOE (2022), Cemsuisse (2010a)	20.097 (1998), 23.6 (2010)
Natural gas	SGWA	*see caption*
Biofuel	**Data sources**	
Biodiesel	SFOE (2022)	38.0
Bioethanol	SFOE (2022)	26.5
Biogas	*assumed equal to natural gas*	*see caption*
Wood	SFOE (2022b)	8.6-14.6

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 2022). 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 2022), 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 2022) 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 2022). For these fuels, the Swiss overall energy statistics contains NCVs for the years 1998 and 2010. Values in between are interpolated, before the first and after the last year of available data values are 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 3-3) 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 (2022). 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 (2022i). The NCV of biogas is assumed to be equal to the NCV of natural gas since the raw biogas is treated to become the same quality level including its energetic properties as natural gas.

Table 3-3 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 (2022). Spreadsheet to determine national averages: FOEN 2022i.

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

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 2022b).

Table 3-2 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 2022) 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 2022). 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 2022), 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 2022). 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 2022g).
- Swiss renewable energies statistics (SFOE 2022a).
- Swiss wood energy statistics (SFOE 2022b).
- Swiss statistics on combined heat and power generation (SFOE 2022c).

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.

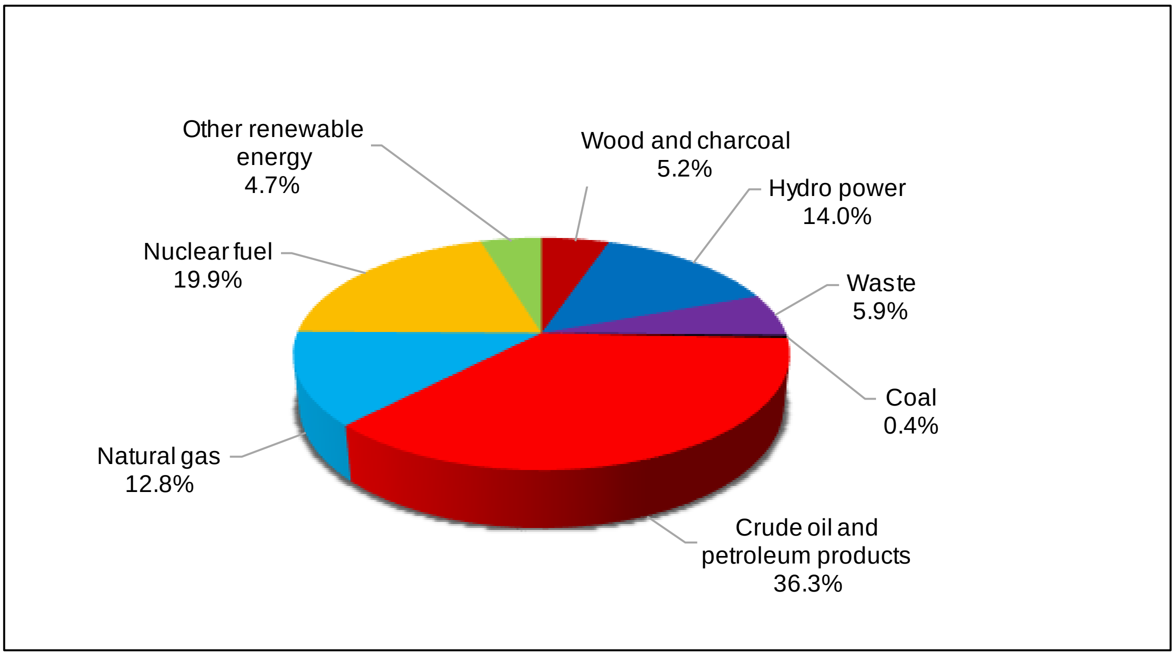


Figure 3-6 Switzerland's primary energy consumption in 2021 by fuel type (see corresponding data and additional information on energy consumption over time in SFOE 2022).

Table 3-4 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 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 fuel consumption, especially in the transport sector.

Table 3-4 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 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**	**Kerosene** used for LTO	**Kerosene** used for cruise (memo item)	**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	155'904	8'059	40'008	46'736	821	218'510	23'342	8'890	1'400	14'901	67'861	19'074	46'820	611'496	652'326
1991	162'255	7'640	38'922	47'417	737	238'602	23'590	12'437	980	12'162	76'114	18'514	48'809	648'520	688'178
1992	168'219	7'803	41'297	45'926	780	236'809	24'170	11'492	315	8'758	79'984	18'931	47'766	650'172	692'249
1993	155'960	7'861	42'915	44'197	781	225'920	17'165	12'388	1'120	7'442	83'911	19'048	48'102	623'112	666'808
1994	155'934	7'911	44'198	46'924	824	207'141	17'860	13'455	1'470	7'632	82'737	19'069	46'054	606'185	651'208
1995	151'210	7'987	46'960	47'865	739	217'523	17'278	12'756	1'260	7'962	91'275	19'588	48'130	622'834	670'534
1996	155'136	8'017	48'736	44'946	651	226'289	15'097	13'939	1'015	5'456	98'876	20'443	51'674	640'889	690'276
1997	161'121	8'320	50'454	46'728	657	212'223	12'581	14'236	280	4'590	95'453	21'498	48'552	625'583	676'694
1998	162'390	8'540	52'728	48'681	528	222'407	15'882	15'259	455	3'960	98'301	23'586	50'159	649'619	702'875
1999	167'874	8'762	56'482	51'626	558	212'349	11'058	15'805	521	4'105	101'863	24'189	50'920	649'074	706'114
2000	168'051	9'074	58'987	55'146	531	196'137	7'923	13'649	551	6'120	101'282	26'294	50'597	634'825	694'342
2001	163'466	8'598	55'610	56'262	447	213'089	9'942	14'069	410	6'233	105'478	26'796	53'832	658'177	714'234
2002	160'283	8'128	51'278	58'389	333	196'655	6'446	15'584	679	5'565	103'548	27'624	53'398	636'298	687'909
2003	159'521	7'327	46'110	61'808	443	208'040	7'061	13'642	202	5'663	109'522	27'361	56'010	656'158	702'711
2004	156'718	6'886	43'555	66'447	446	203'370	7'561	16'429	1'819	5'420	113'047	28'518	56'954	663'170	707'170
2005	151'978	7'020	44'081	72'572	493	205'729	5'805	16'432	2'906	5'940	116'100	28'849	59'124	672'455	717'028
2006	147'357	7'291	46'280	78'606	457	195'926	6'419	18'578	3'324	6'467	112'887	30'846	62'248	669'949	716'686
2007	145'938	7'538	49'627	84'420	465	171'313	5'179	15'587	2'730	7'196	109'874	29'617	61'310	640'701	690'793
2008	142'729	7'773	53'378	92'670	473	178'833	4'581	16'288	3'616	6'562	117'083	30'385	65'486	666'005	719'856
2009	138'900	7'496	51'169	94'143	425	173'219	3'530	16'301	3'254	6'193	112'313	29'296	65'656	650'301	701'896
2010	133'972	7'699	53'921	97'776	471	182'295	2'967	15'463	3'498	6'208	125'494	30'627	70'511	676'510	730'901
2011	128'791	7'970	57'726	100'449	428	143'760	2'292	14'856	2'957	5'792	111'269	30'269	66'197	614'602	672'757
2012	124'243	8'258	59'048	106'611	385	154'448	2'780	12'247	3'148	5'269	122'051	30'555	72'128	641'738	701'171
2013	118'583	8'243	59'825	111'482	342	162'532	1'959	15'053	2'735	5'567	128'592	30'249	75'829	660'823	720'989
2014	113'830	8'282	60'259	114'385	299	122'694	1'581	14'473	3'148	5'704	111'346	30'608	70'266	596'316	656'874
2015	105'548	8'414	62'374	112'808	342	129'349	862	9'822	1'145	5'205	118'996	31'398	73'670	597'217	659'933
2016	102'256	8'577	65'584	114'079	299	132'325	378	9'136	890	4'795	125'030	32'835	79'949	610'251	676'134
2017	99'116	8'581	67'352	113'750	256	123'726	350	8'770	763	4'609	125'289	32'515	83'292	600'763	668'371
2018	97'548	8'756	71'494	115'283	200	111'225	87	8'890	781	4'285	118'611	33'605	83'168	582'239	653'933
2019	96'750	8'587	72'482	115'347	197	108'625	111	8'108	777	3'812	121'618	34'044	85'700	583'477	656'156
2020	85'682	3'930	26'685	109'312	189	97'246	76	7'627	700	3'664	118'461	33'733	84'512	544'941	571'815
2021	87'542	4'203	29'756	110'489	228	107'991	139	7'543	604	3'697	128'997	32'826	90'683	574'714	604'698

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 2022). 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 2022), the Swiss renewable energy statistics (SFOE 2022a), the Swiss wood energy statistics (SFOE 2022b), the energy consumption statistics in the industry and services sectors (SFOE 2022d), 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.

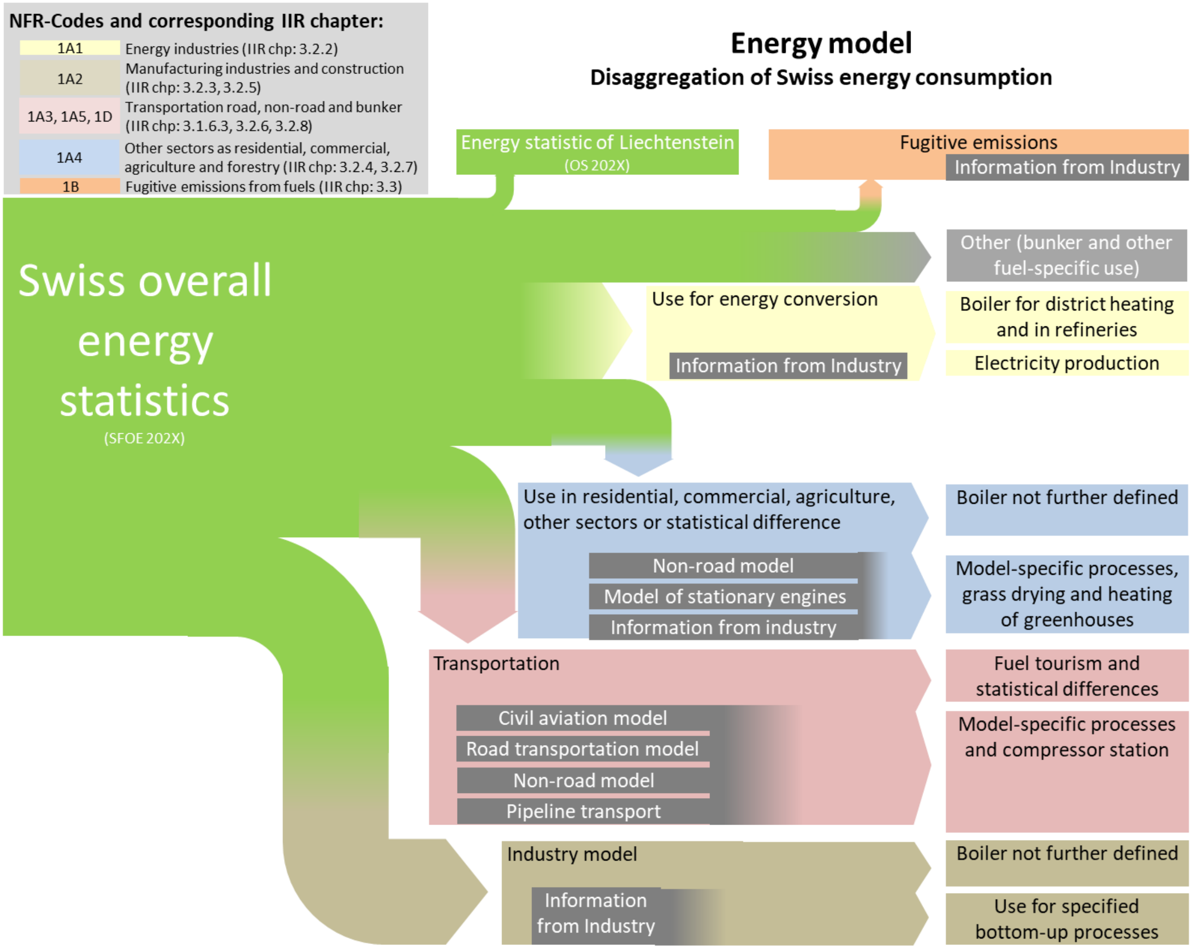


Figure 3-7 Overview of Switzerland's energy model. In the abbreviations SFOE 202X and OS 202X the "X" refers to the latest edition of the respective statistics.

Industry model (Details are given in chp. 3.2.3.2)

The industry model disaggregates the total fuel consumption in the industry sector (SFOE 2022) 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 2022d) 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 2022b), total wood consumption is disaggregated into source categories (public electricity and heat production, industry, commercial/institutional, residential, agriculture/forestry/fisheries) and into 24 different combustion installations (ranging from open fireplaces to large-scale automatic boiler or heat and power plants). Where available, industry data on wood combustion is taken into account to allocate parts of the wood consumption as given by the Swiss wood energy statistics to a specific source category.

3.1.6.3.3 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 2022) 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.

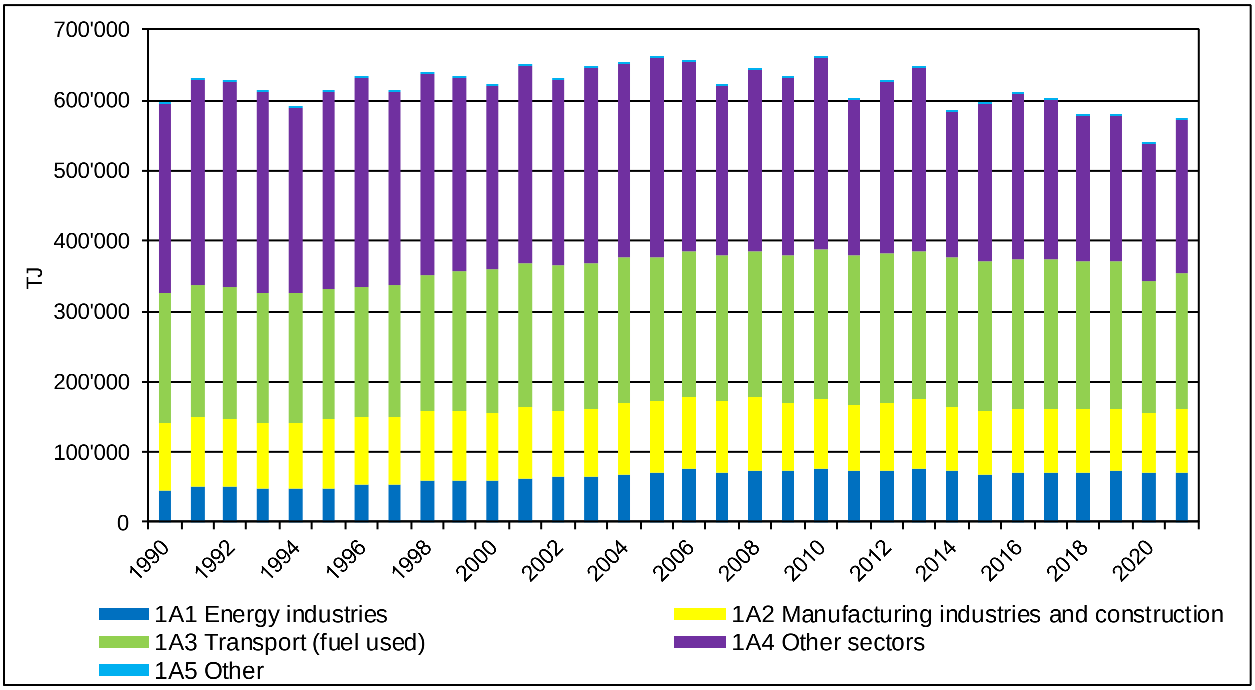


Figure 3-8 Switzerland's energy consumption in the source categories 1A1–1A5 based on the Swiss energy model. Since 1990 population has increased by about one third, industrial production by about three quarters and the motor vehicle fleet by about two thirds (SFOE 2022, table 43)

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:

- Within source categories 1A4ai and 1A4bi, the amount of used gas oil and natural gas for co-generation in turbines and engines is derived from a model of stationary engines developed by Eicher + Pauli (Kaufmann 2015) for the statistics on combined heat and power generation (SFOE 2014c). The residual energy is then assigned to boilers which are not further specified.
- 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.

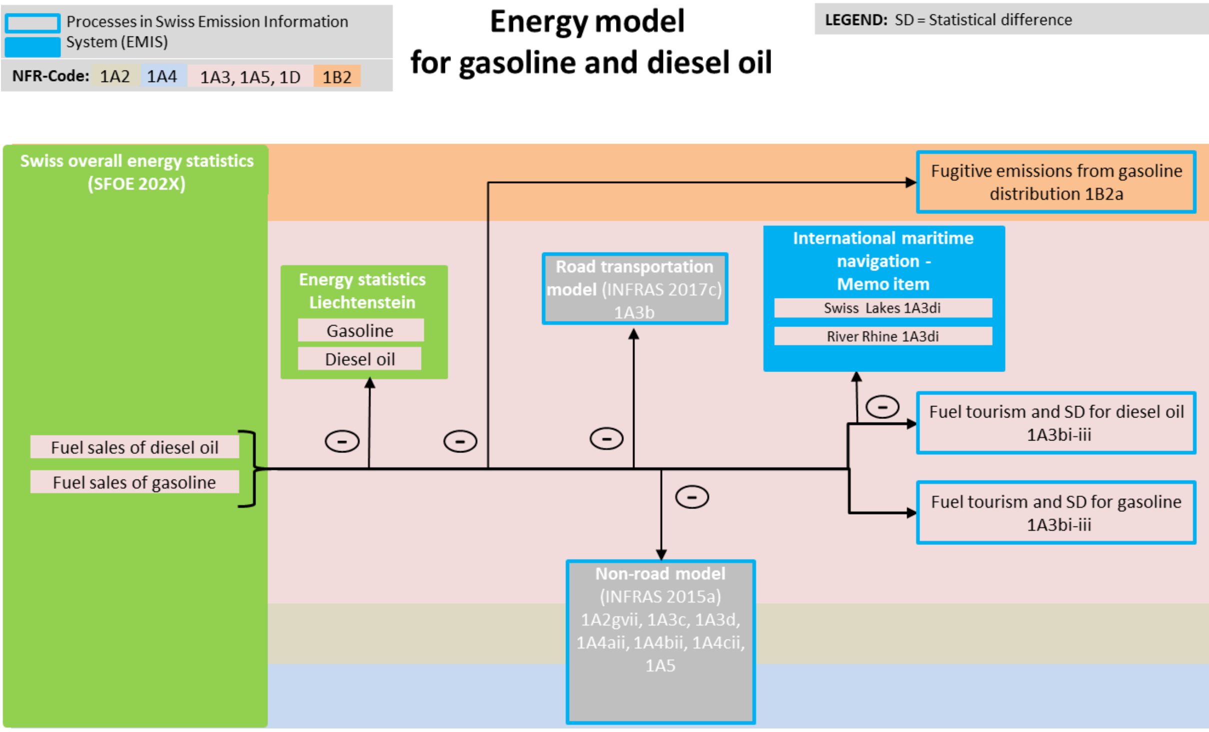


Figure 3-9 Schematic disaggregation of 1A Fuel consumption for gasoline and diesel oil. Marine bunker fuel consumption is based on the national customs statistics (see chapter 3.1.6.1 on memo items)

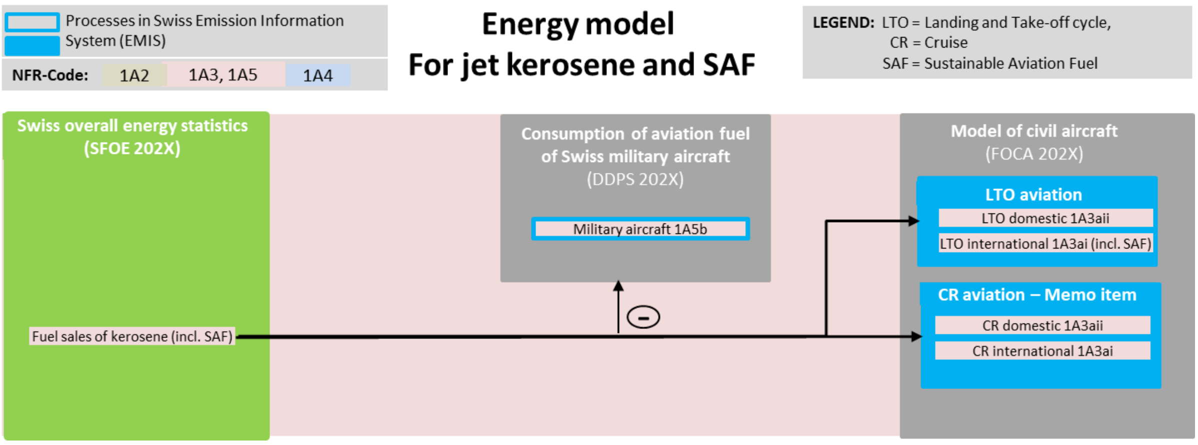


Figure 3-10 Schematic disaggregation of 1A Fuel consumption for kerosene. Fuel consumption for military aircraft is provided by the Federal Department of Defence, Civil Protection and Sport (DDPS). The differentiation between domestic and international aviation as well as between CR and LTO is provided by the civil aviation model (see chp. 3.2.6.2.1)

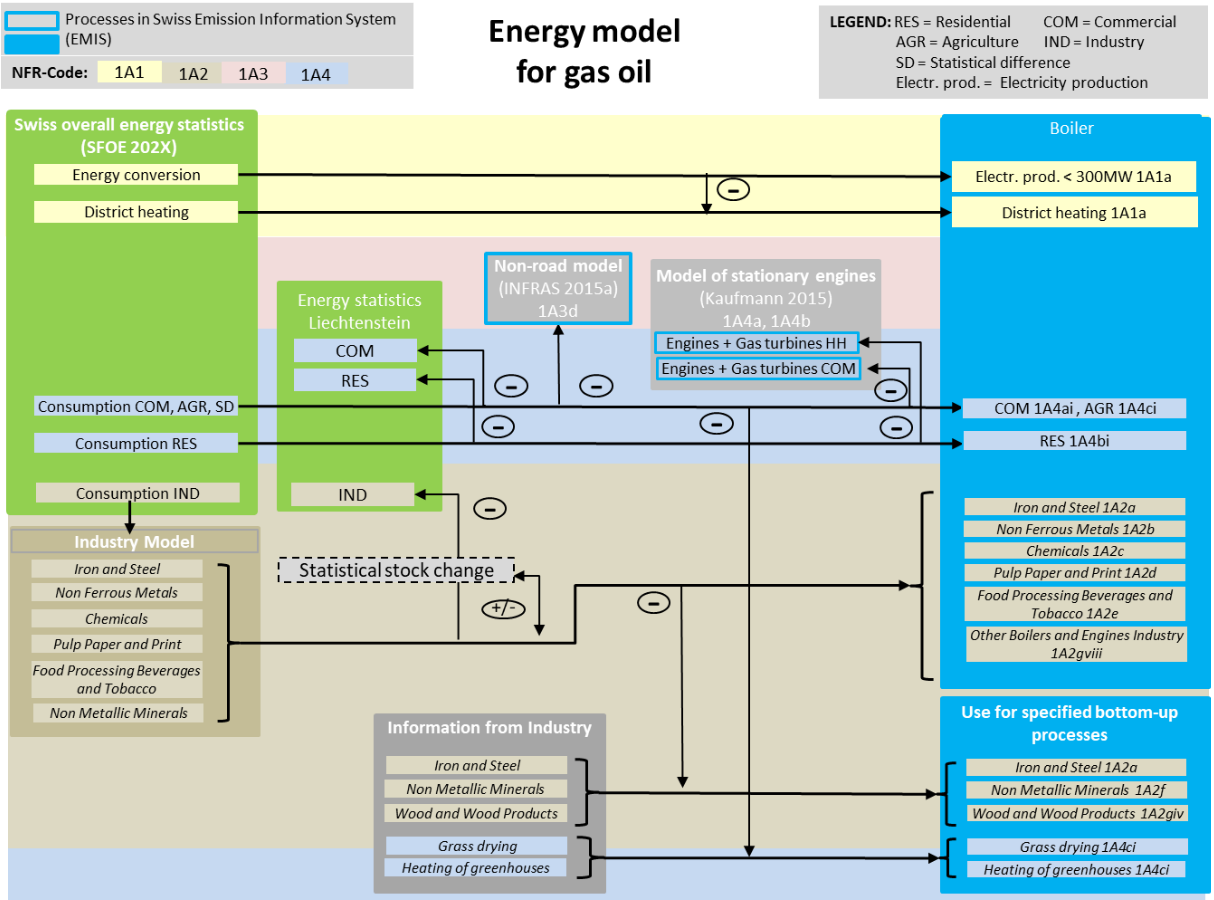


Figure 3-11 Schematic disaggregation of 1A Fuel consumption for gas oil. The Swiss overall energy statistics provide gas oil use for energy conversion and the amount thereof being used for district heating. Based on this information, gas oil use is split into 1A1ai Electricity generation and 1A1aiii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

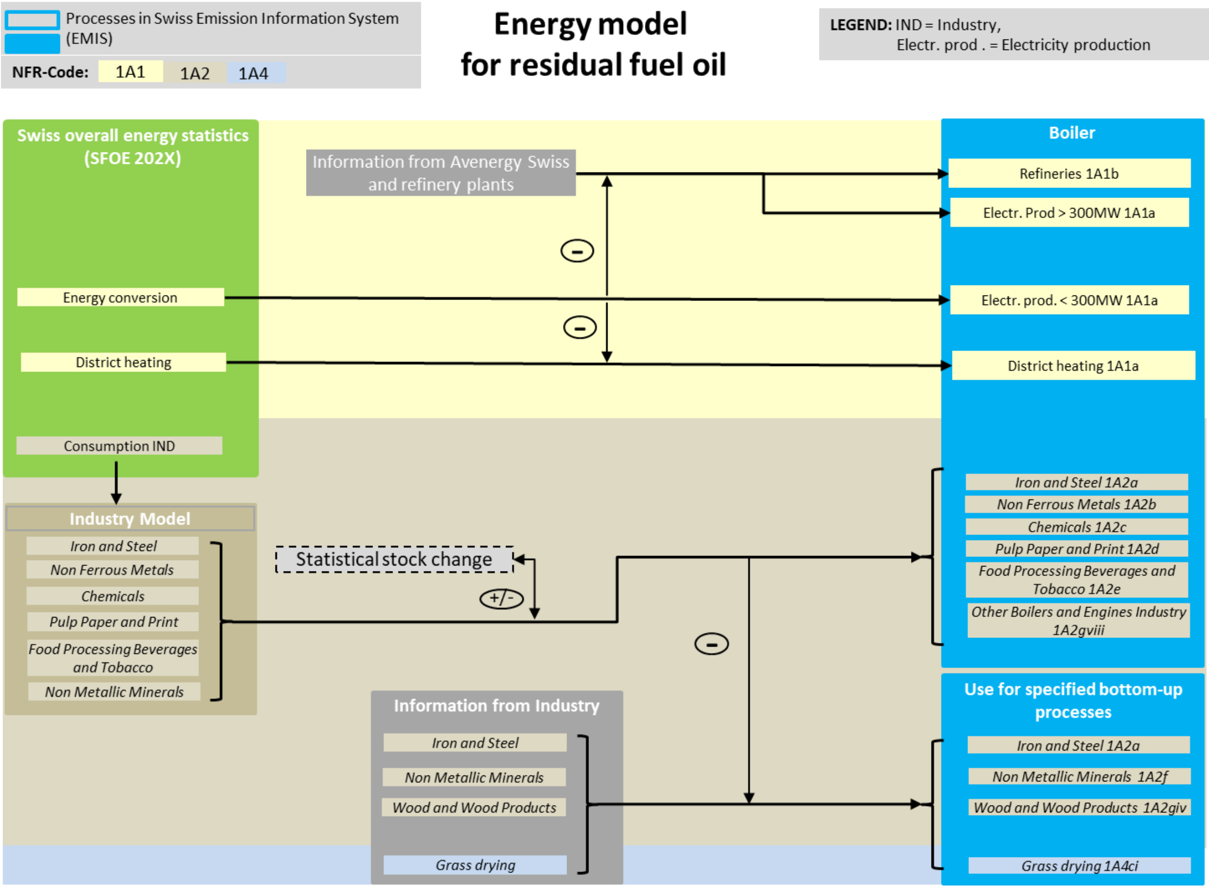


Figure 3-12 Schematic disaggregation of 1A Fuel consumption for residual fuel oil. The Swiss overall energy statistics report residual fuel oil use in energy conversion and the amount thereof consumed in electricity production (one single fossil fuel power station, operational from 1985 to 1994), district 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.

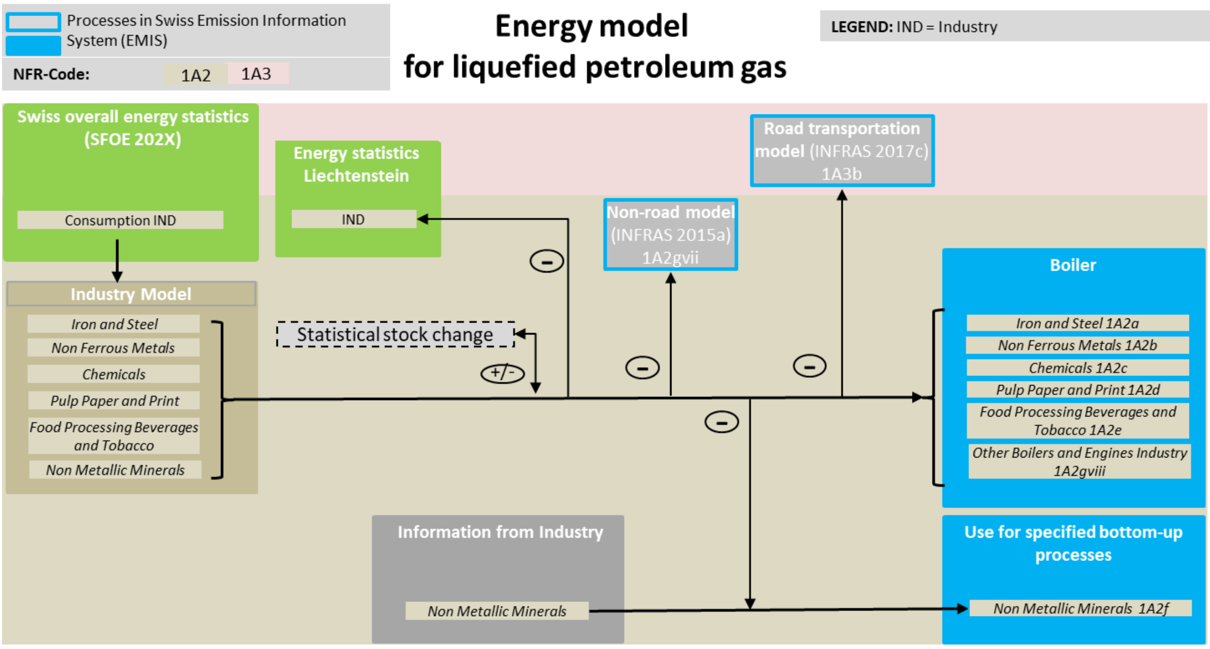


Figure 3-13 Schematic disaggregation of 1A Fuel consumption for liquefied petroleum gas.

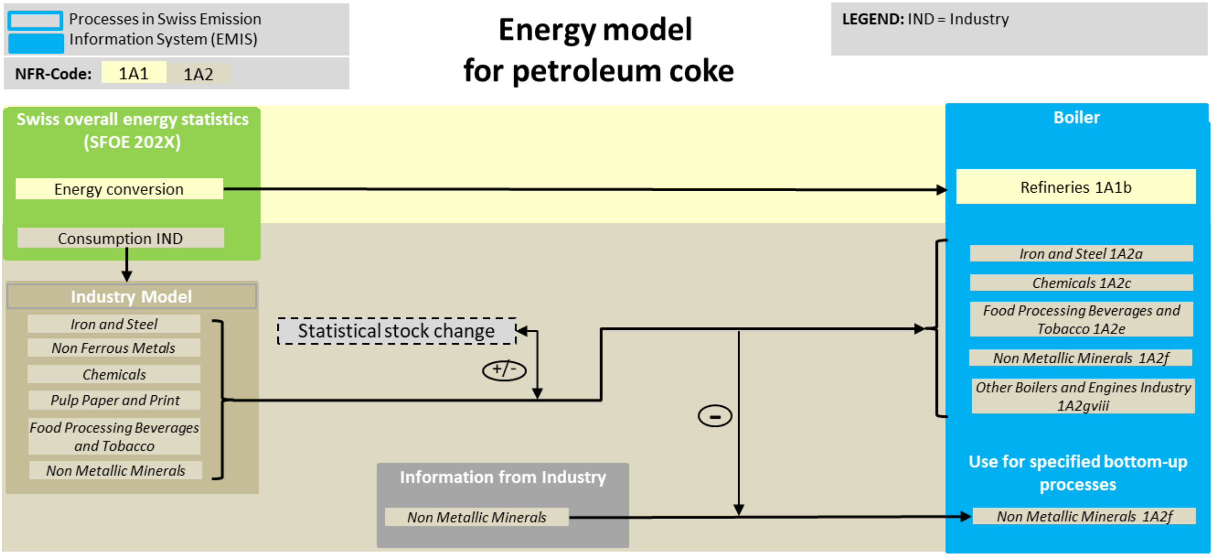


Figure 3-14 Schematic disaggregation of 1A Fuel consumption for petroleum coke.

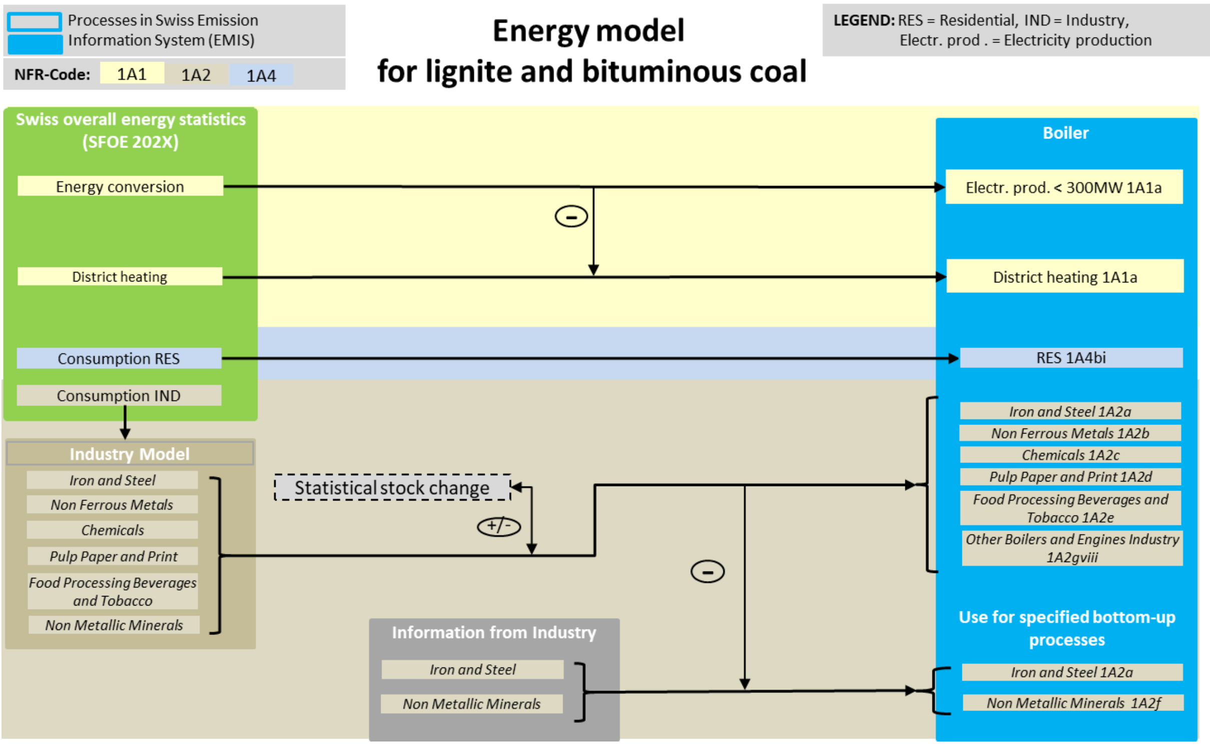


Figure 3-15 Schematic disaggregation of 1A Fuel consumption for lignite and bituminous coal. The Swiss overall energy statistics provide bituminous coal use for energy conversion and the amount thereof being used for district heating. Based on this information, use of bituminous coal in energy industries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

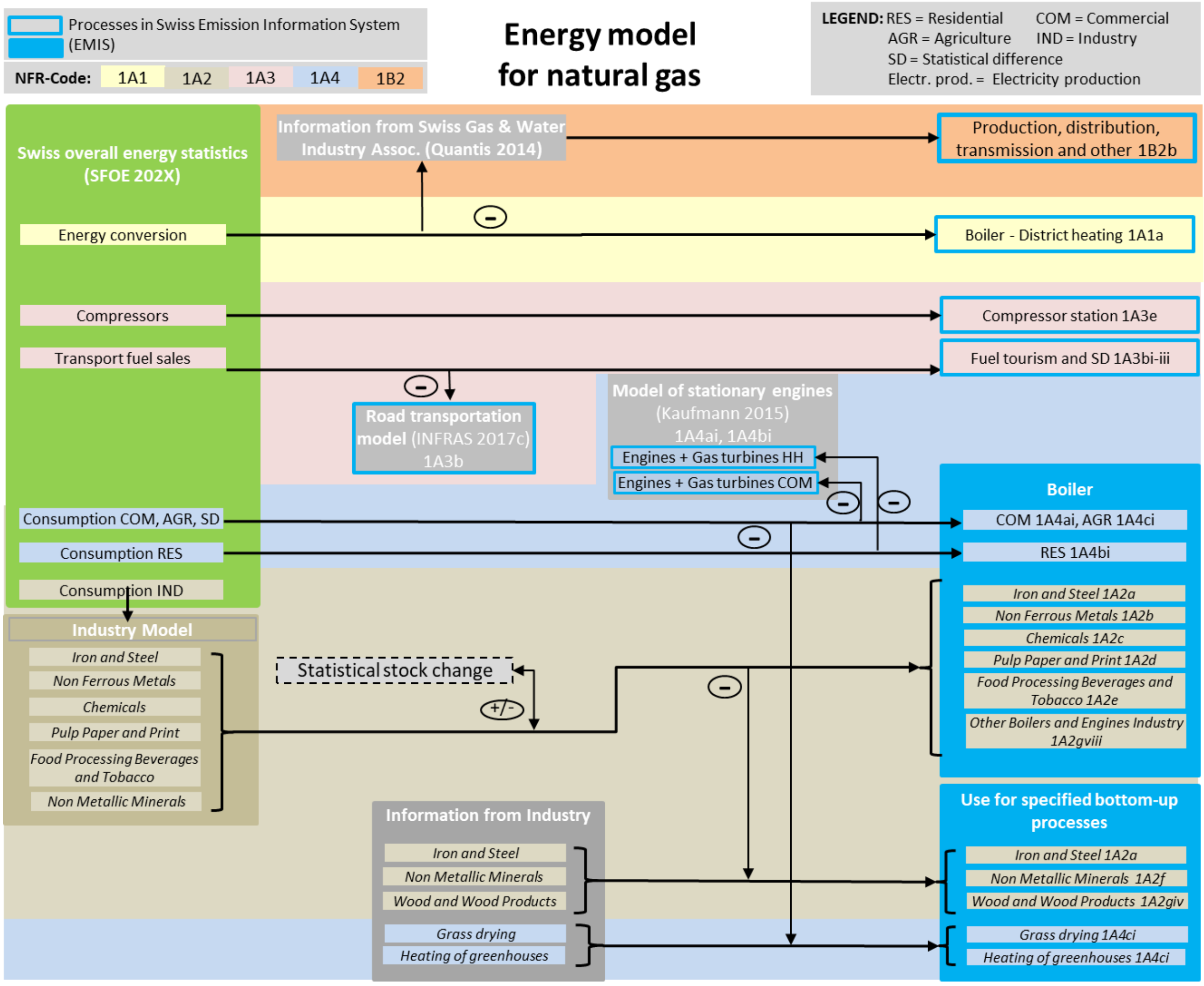


Figure 3-16 Schematic disaggregation of 1A Fuel consumption (and 1B Fugitive emissions from fuels) for natural gas. The Swiss overall energy statistics (SFOE 2022) provide gas use in the transformation sector (energy conversion and distribution losses). Distribution losses as estimated by the Swiss Gas 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.

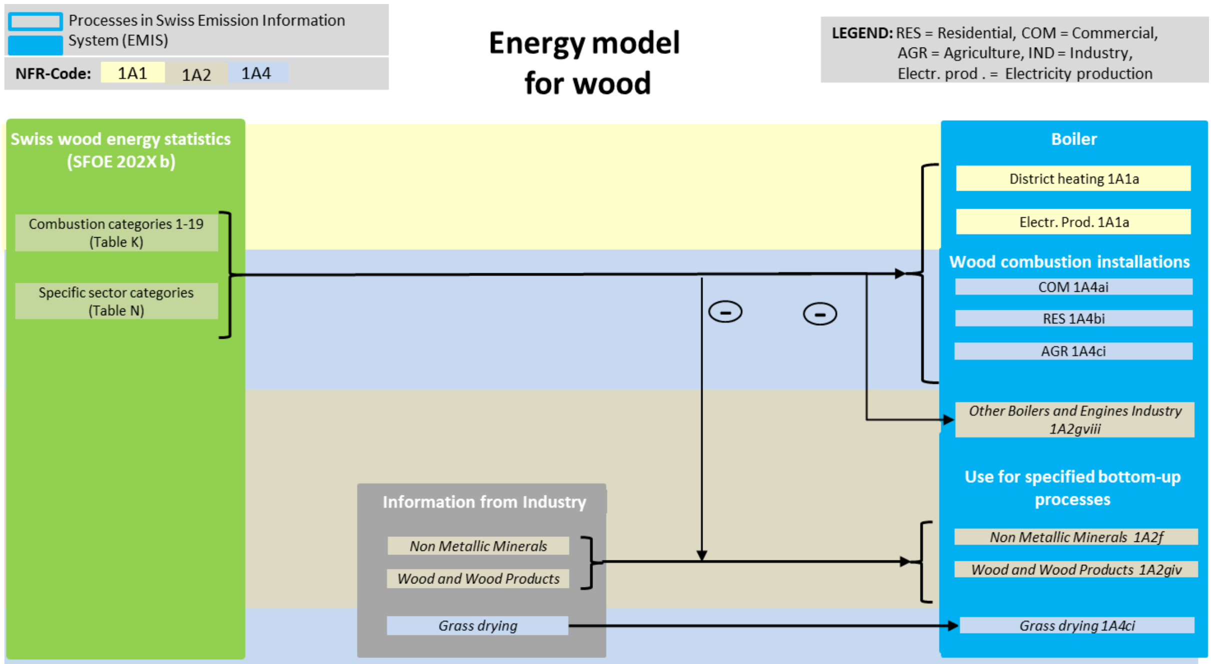


Figure 3-17 Schematic disaggregation of 1A Fuel consumption for wood. For a detailed description of the Energy model for wood combustion, see chapter 3.2.1.1.2.

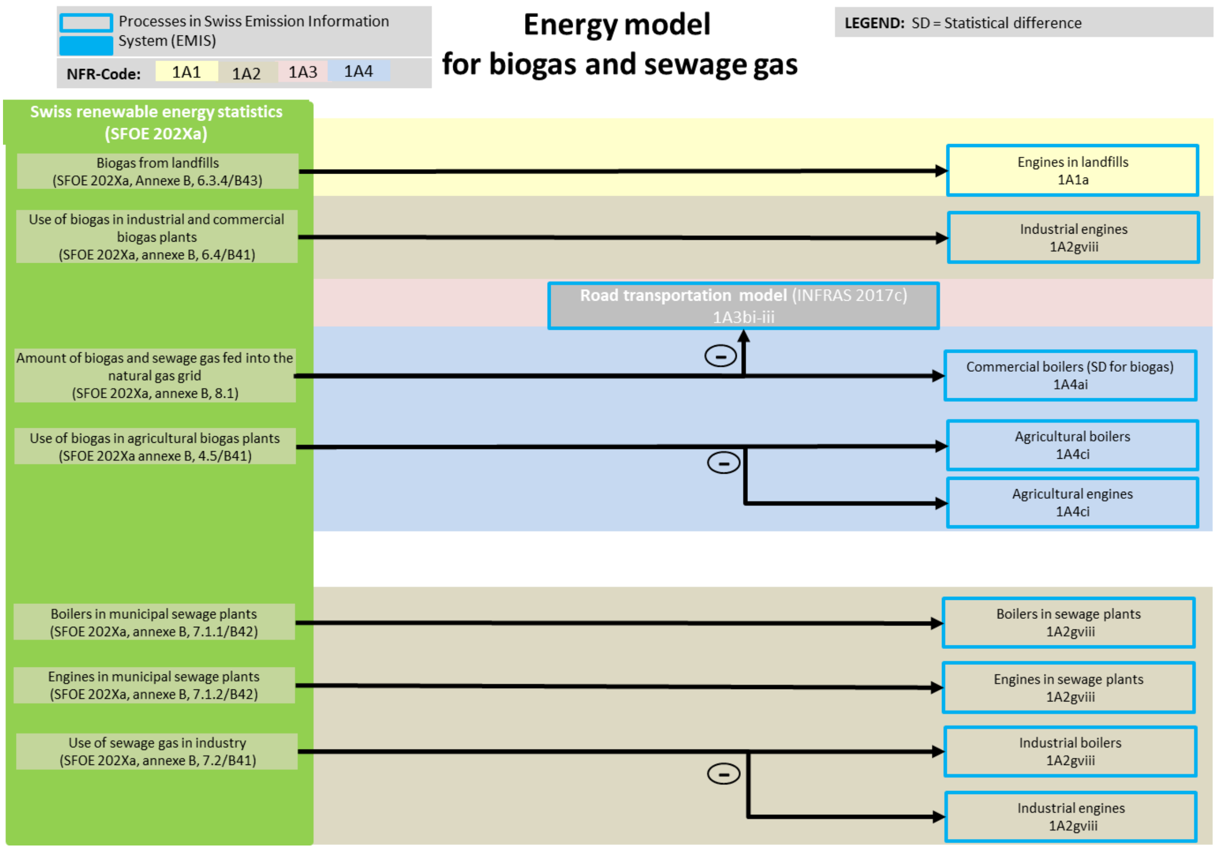


Figure 3-18 Schematic disaggregation of 1A Fuel consumption for biogas and sewage gas.

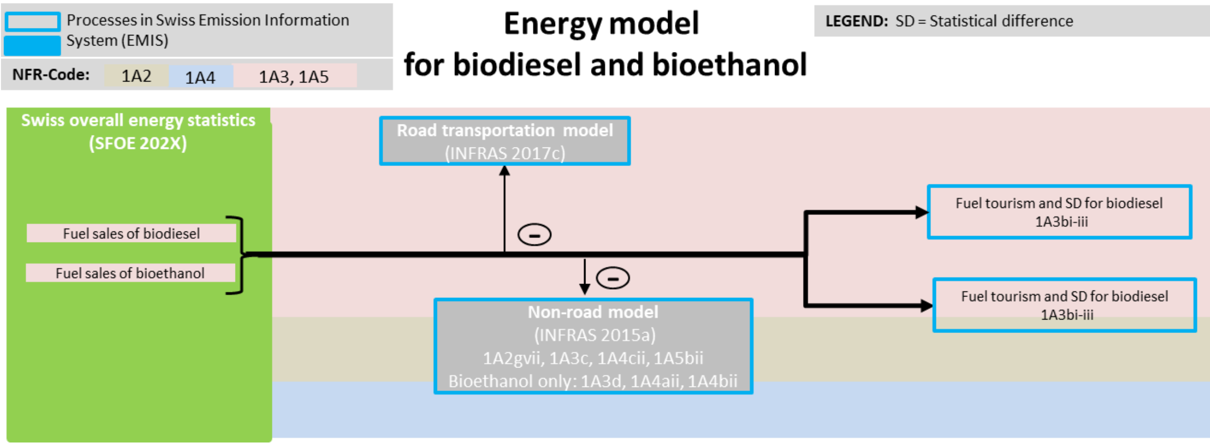


Figure 3-19 Schematic disaggregation of 1A Fuel consumption for biodiesel and bioethanol.

Statistical stock change

In a few years the quantity of a fuel sold in a year according to total energy statistics may be less 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 to 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 in the years 2008-2010, 2014, 2015 and used in the years 2011, 2012, 2016-2021.
- For petroleum coke stock was build in the years 2007, 2018 and used in the years 2008, 2019.
- For other bituminous coal stock was build 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 3-5), 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 3-5 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:

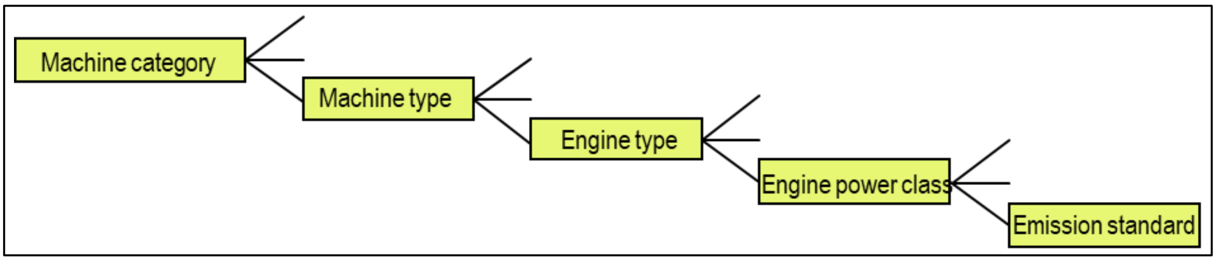


Figure 3-20 Each non-road vehicle is classified by its engine-power class, engine type, machine type, machine category, and emission standard.

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 3-20):

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

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 3-9. 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 condesables 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 3-9 (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
- 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).

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

Methodology

The Swiss wood energy statistics (SFOE 2022b) 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 3-6) 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 3-6. 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 3-6 Categories of wood combustion installations based on SFOE 2022b (category numbers 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 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 2022b), 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, TSP 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.

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 3-7 Emission factors 2021 of pollutants due to wood combustion from source categories 1A1-1A4 ("w/o wood proc. companies." stands for "without wood processing companies").

1A Wood combustion	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Open fireplaces	80	264	10	4.9	89	94	99	59	2'967
Closed fireplaces, log wood stoves	85	243	10	4.9	79	84	88	55	2'760
Pellet stoves	85	14	10	2	35	37	39	14	384
Log wood hearths	70	342	10	4.9	177	187	197	127	3'947
Log wood boilers	100	68	10	2	53	56	59	16	1'660
Log wood dual chamber boilers	70	345	10	4.9	180	190	200	130	4'000
Automatic chip boilers < 50 kW	120	39	10	2	80	85	89	16	880
Automatic pellet boilers < 50 kW	70	13	10	2	27	29	30	6.9	322
Automatic chip boilers 50-300 kW w/o wood proc. companies	129	20	3	2	52	54	57	2.9	441
Automatic pellet boilers 50-300 kW	75	6.9	3	2	26	28	29	1.0	166
Automatic chip boilers 50-300 kW within wood proc. companies	139	20	3	2	52	55	58	2.9	451
Automatic chip boilers 300-500 kW w/o wood proc. companies	129	20	3	2	52	54	57	2.9	441
Automatic pellet boilers 300-500 kW	75	6.9	3	2	26	28	29	1.0	166
Automatic chip boilers 300-500 kW within wood proc. companies	139	20	3	2	52	55	58	2.9	451
Automatic chip boilers > 500 kW w/o wood proc. companies	119	6.9	3	2	9	10	10	0.19	137
Automatic pellet boilers > 500 kW	74	2	3	2	5	5	5	0.10	49
Automatic chip boilers > 500 kW within wood proc. companies	119	6.9	3	2	17	18	19	0.48	148
Combined chip heat and power plants	40	0.29	1	2	0.3	0.3	0.3	0.003	10
Plants for renewable waste from wood products	129	1	20	5	1.3	1.3	1.4	0.03	59

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	20	1	2	493	49	49	29	29	0.0049	59
Closed fireplaces, log wood stoves	20	1	2	493	49	49	29	29	0.0049	59
Pellet stoves	20	1	2	49	10	10	3.9	3.9	0.0049	10
Log wood hearths	20	1	2	493	49	49	29	29	0.0049	59
Log wood boilers	20	1	2	247	29	29	15	15	0.0049	19
Log wood dual chamber boilers	20	1	2	500	100	100	60	60	0.005	60
Automatic chip boilers < 50 kW	20	1	2	98	10	10	3.9	3.9	0.0049	19
Automatic pellet boilers < 50 kW	20	1	2	49	10	10	3.9	3.9	0.0049	10
Automatic chip boilers 50-300 kW w/o wood proc. companies	14	1	2	49	4.9	4.9	2.5	2.5	0.0049	10
Automatic pellet boilers 50-300 kW	14	1	2	49	4.9	4.9	2.5	2.5	0.0049	10
Automatic chip boilers 50-300 kW within wood proc. companies	14	1	2	99	4.9	4.9	2.5	2.5	0.0049	10
Automatic chip boilers 300-500 kW w/o wood proc. companies	10	1	2	49	1	1	1	1	0.0049	10
Automatic pellet boilers 300-500 kW	10	1	2	49	1	1	1	1	0.0049	10
Automatic chip boilers 300-500 kW within wood proc. companies	10	1	2	99	1	1	1	1	0.0049	10
Automatic chip boilers > 500 kW w/o wood proc. companies	10	1	2	49	1	1	1	1	0.00098	10
Automatic pellet boilers > 500 kW	10	1	2	49	1	1	1	1	0.00098	10
Automatic chip boilers > 500 kW within wood proc. companies	10	1	2	99	1	1	1	1	0.00098	10
Combined chip heat and power plants	10	1	2	10	0.1	0.1	0.1	0.1	0.00098	10
Plants for renewable waste from wood products	100	2	2	49	1	1	1	1	0.00098	10

Activity data

Categories of wood combustion installations and their respective wood energy consumption (see Table 3-8) are based on the Swiss wood energy statistics (SFOE 2022b, 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 2023/1A 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 Fibreboard are subtracted from the activity data of 1A2gviii Automatic chip boiler >500 kW without wood processing companies and 1A2gviii Plants for renewable waste from wood products, respectively.
- 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 3-8 Wood energy consumption in 1A Fuel combustion.

1A Wood combustion	**1990**	**1995**	**2000**	**2005**	**2010**
	TJ				
Total	28'215	29'693	27'419	31'386	40'073
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	461	854	1'158	1'859	2'723
Automatic pellet boilers 50-300 kW	NO	NO	3.0	113	596
Automatic chip boilers 50-300 kW within wood proc. companies	895	1'186	1'216	1'364	1'531
Automatic chip boilers 300-500 kW w/o wood proc. companies	237	521	713	998	1'496
Automatic pellet boilers 300-500 kW	NO	NO	NO	19	195
Automatic chip boilers 300-500 kW within wood proc. companies	412	570	586	630	670
Automatic chip boilers > 500 kW w/o wood proc. companies	314	1'084	1'705	2'355	4'423
Automatic pellet boilers > 500 kW	NO	NO	NO	9.0	186
Automatic chip boilers > 500 kW within wood proc. companies	1'388	2'188	2'393	2'795	2'988
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	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
	TJ									
Total	40'007	44'161	37'312	38'892	42'556	43'540	41'141	43'316	42'312	49'260
Open fireplaces	84	84	62	64	68	67	62	62	58	59
Closed fireplaces, log wood stoves	7'787	8'604	6'824	7'446	7'862	7'540	6'926	6'943	6'375	7'281
Pellet stoves	163	190	159	181	199	196	186	187	175	198
Log wood hearths	1'567	1'454	978	1'006	992	900	792	763	675	748
Log wood boilers	3'823	3'901	2'820	2'970	3'032	2'852	2'597	2'596	2'320	2'523
Log wood dual chamber boilers	190	182	125	119	112	88	67	57	42	38
Automatic chip boilers < 50 kW	867	946	739	786	798	742	667	644	559	582
Automatic pellet boilers < 50 kW	2'151	2'511	2'099	2'376	2'610	2'619	2'538	2'676	2'489	2'909
Automatic chip boilers 50-300 kW w/o wood proc. companies	2'762	3'164	2'628	3'012	3'328	3'351	3'227	3'347	3'199	3'752
Automatic pellet boilers 50-300 kW	733	906	845	1'077	1'295	1'436	1'478	1'604	1'610	1'971
Automatic chip boilers 50-300 kW within wood proc. companies	1'427	1'538	1'280	1'398	1'486	1'483	1'421	1'418	1'367	1'534
Automatic chip boilers 300-500 kW w/o wood proc. companies	1'548	1'744	1'430	1'635	1'806	1'811	1'728	1'797	1'726	1'992
Automatic pellet boilers 300-500 kW	246	269	239	279	337	355	352	365	350	427
Automatic chip boilers 300-500 kW within wood proc. companies	633	680	567	597	629	619	613	611	592	654
Automatic chip boilers > 500 kW w/o wood proc. companies	4'973	5'828	4'963	5'810	6'548	6'736	6'481	6'895	6'919	8'104
Automatic pellet boilers > 500 kW	258	297	281	317	364	362	346	370	354	408
Automatic chip boilers > 500 kW within wood proc. companies	2'780	2'974	2'497	2'659	2'750	2'641	2'501	2'547	2'445	2'749
Combined chip heat and power plants	5'010	5'421	5'325	3'792	3'936	4'856	4'696	5'920	6'151	6'678
Plants for renewable waste from wood products	3'005	3'468	3'450	3'367	4'404	4'887	4'463	4'513	4'906	6'653

3.2.1.2 Emission factors for 1A Fuel combustion

There are no so-called general emission factors for all sources belonging to source category 1A Fuel combustion except for SO_x. Table 3-9 shows sulphur contents and SO_x emission factors per fuel type. Explanations:

- For liquid and solid fuels, the SO_x emission factors are determined by the sulphur content. The upper table depicts the maximum values as defined in the Federal Ordinance on Air Pollution Control OAPC (Swiss Confederation 1985).
- The middle table contains the effective sulphur contents. They are based on measurements: Summary and annual reports of Avenergy, reports by the Federal Office for Customs and Border Security (FOCBS) since 2000, as well as their measurement project 'Schwerpunktaktion Brenn und Treibstoffe'. For diesel oil and gasoline, the measurement project 'Tankstellensurvey', arranged by the FOEN, is a central data source.
- The lower table shows the emission factors in kg/TJ. They are calculated from the effective sulphur content S, the net calorific value NCV and the quotient of the molar masses of S and SO_x.

$$EF_{SO_x} = \frac{M_{SO_x}}{M_S} * \frac{S}{NCV} = 2\frac{S}{NCV}$$

- Gas oil: starting from 1990 and for each fifth subsequent year up to and including 2015 the values for the SO_x emission factors are based on five-year averages (eg. the value for 1995 is based on an average of the years 1993-1997). 1990 is the exception: for this year, the value is based on an average of the three years 1990-1992. The values for all other years are linear interpolations between the two nearest five-year averages as described above. Furthermore, 2006 saw the introduction to the market of low-sulphur eco-grade gas oil with a maximum legal sulphur limit of 50 ppm. From this year onwards, FOCBS measurements include both standard Euro- and eco-grade gas oil. For each year, the two grades are weighted by the respective total annual fuel consumption. Additionally, as of 2018, heating gas is also classified as gas oil.
- Coal: 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 kg SO_x/TJ) shown in Table 3-9 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 kg SO_x/TJ).
- Residual fuel oil: OAPC Annex 5, §11, lit.2 sets 2.8 % for the legal limit (denoted as class B in the upper table). Simultaneously, OAPC dispenses from emission control measurements if residual fuel oil of class A is used with sulphur content of maximum 1 % (see OAPC Annex 3, §421, lit.2, Swiss Confederation 1985), which holds for most combustion plants. The emission factors are based on five-year averages in the case of 1995, 2000 and 2015. 1990 is based on an average of the years 1990-1992 because no non-interpolated data is available for 1988 and 1989. Similarly, because the emission factors of the years 2006-2008 are not available, the average of 2005 is based on the years 2003-2005 and that of 2010 on 2009-2012. The values for all other years are linear interpolations between the two nearest five-year averages as described above.
- Natural gas: OAPC Annex 5, §42 sets 190 ppm as the legal limit for natural gas.

Table 3-9 Sulphur contents and SO_x emissions factors. For explanation see text.

Year	Maximum legal limit of sulphur content						
	Diesel oil ppm	Gasoline ppm	Gas oil (Euro) ppm	Natural gas ppm	Res. fuel oil Class A, %	Res. fuel oil Class B, %	Coal %
1990	1400	200	2000	190	1.0	2.8	1-3
1991	1300	200	2000	190	1.0	2.8	1-3
1992	1200	200	2000	190	1.0	2.8	1-3
1993	1000	200	2000	190	1.0	2.8	1-3
1994	500	200	2000	190	1.0	2.8	1-3
2000	350	150	2000	190	1.0	2.8	1-3
2005	50	50	2000	190	1.0	2.8	1-3
2008	50	50	1000	190	1.0	2.8	1-3
2009	10	50	1000	190	1.0	2.8	1-3
2010-2021	10	10	1000	190	1.0	2.8	1-3

Year	Effective sulphur content				
	Diesel oil ppm	Gasoline ppm	Gas oil (Euro) ppm	Gas oil (Oeko) ppm	Res. fuel oil %
1990	1400	200	1600	NO	0.97
1991	1300	200	1300	NO	0.89
1992	1200	200	1200	NO	0.86
1993	1000	200	1000	NO	0.87
1994	434	200	1350	NO	0.77
1995	341	200	1170	NO	0.78
1996	372	200	1160	NO	0.78
1997	353	200	1250	NO	0.70
1998	402	200	926	NO	0.83
1999	443	200	650	NO	0.62
2000	272	142	680	NO	0.66
2001	250	121	830	NO	0.82
2002	235	101	798	NO	0.82
2003	200	81	700	NO	0.79
2004	10	8.0	700	NO	0.76
2005	10	8.0	800	NO	0.78
2006	10	8.0	740	NO	0.74
2007	10	8.0	680	NO	0.71
2008	10	8.0	620	NO	0.67
2009	7.6	5.3	549	NO	0.92
2010	6.7	4.7	519	NO	0.88
2011	6.6	5.0	417	NO	0.90
2012	7.0	5.3	503	NO	0.91
2013	7.1	4.8	224	NO	0.90
2014	6.8	4.8	516	14	1.11
2015	7.7	4.5	516	14	1.93
2016	7.0	4.6	246	10	1.92
2017	7.7	5.2	248	19	0.98
2018	7.2	4.4	486	5	0.91
2019	No measurements in the year 2019				
2020	6.2	Not measured	319	18	0.55
2021	Not measured	Not measured	337	19	0.56

Year	SO_x emission factor used for Switzerland's emission inventory								
	Diesel oil (average in 1A3b)	Gasoline (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)	Res. fuel oil (boilers in 1A1a, 1A2) *	Lignite (boilers in 1A2g)	Bituminous coal (boilers in 1A4b)	Kerosene (average)
	kg/TJ								
1990	65	9.4	64			440			23.2
1991	61	9.4	62			428			23.2
1992	56	9.4	61			416			23.2
1993	47	9.4	59			404			23.3
1994	20	9.4	58			392			23.3
1995	16	9.4	56		NO	380			23.3
1996	17	9.4	52			376			23.3
1997	16	9.4	48			372	NO		23.3
1998	19	9.4	45			368			23.2
1999	21	9.4	41			364			23.2
2000	13	6.6	37			360			23.2
2001	12	5.7	36		0.27	364			23.2
2002	11	4.8	35		0.27	368			23.2
2003	9.3	3.8	35		0.27	372			23.2
2004	0.47	0.38	34		0.27	376			23.2
2005	0.46	0.37	33	0.5	0.27	380		350	23.2
2006	0.44	0.36	31		0.27	392			23.1
2007	0.43	0.35	30		0.27	404			23.2
2008	0.42	0.34	28		0.27	416			23.2
2009	0.41	0.33	27		0.27	428			23.2
2010	0.40	0.32	25		0.28	440			23.2
2011	0.39	0.31	22		0.27	480			23.2
2012	0.38	0.30	19		0.27	520			23.2
2013	0.37	0.29	17		0.28	560	500		23.1
2014	0.36	0.28	14		0.28	600			23.1
2015	0.35	0.27	11		0.28	640			23.1
2016	0.34	0.26	10		0.28	633			23.1
2017	0.33	0.26	9.2		0.28	626			23.1
2018	0.33	0.26	8.3		0.28	619			23.2
2019	0.33	0.26	7.4		0.28	612			23.2
2020	0.33	0.26	6.5		0.27	605			23.1
2021	0.33	0.26	5.6		0.27	598			23.1

** blue cells = interpolation*

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 3-10 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 fuels) and public district heating systems, including a small fraction of combined heat and power. 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
1A1c	Manufacture of solid fuels and other energy industries	Emissions from charcoal production

Table 3-11 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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, T1, L2, T2
1A1a	Public electricity and heat production	PM2.5	T1, T2
1A1a	Public electricity and heat production	PM10	T1, T2

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 2023/1A1a Kehrichtverbrennungsanlagen and EMIS 2023/1A1a 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.

Biogas for combined heat and power generation:

Emission factors for combined heat and power generation with landfill gas are considered to be the same as for natural gas engines in commercial and institutional buildings or stem from the Clearinghouse for Inventories and Emissions Factors (CHIEF) by USEPA (NO_x, NMVOC, SO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust, CO) (EMIS 2023/1A1a Kehrichtdeponien).

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 2023/1A Holzfeuerungen) as described in chapter 3.2.1.1.2.

Fossil fuels for heat production and for power generation:

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).

Between 1992 and 1993 the emission factor for SO_x is reduced according to a strong decline of using residual fuel oil as fuel for district heating systems and for electricity production. Furthermore, compared to other countries, the Swiss emission factors for SO_x are low for the following two reasons: first, there is only little use of residual fuel oil in factories, of which a very big one shut down in 2000. Second, a compulsory limitation of sulphur content in liquid fuels (extra-light, medium and residual fuel oil) leads to a significant reduction in SO_x emissions since 1985.

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).

Table 3-12 Emission factors for 1A1a Public electricity and heat production of energy industries in 2021.

1A1a Public electricity and heat production	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ								
Gas oil	32	2	5.6	0.002	0.2	0.2	0.2	0.0078	5.9
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	17	2	0.5	0.001	0.1	0.1	0.1	0.0054	9
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, renewable waste)	59	0.45	5.1	2.7	0.52	0.52	0.54	0.0090	21
Biogas (co-generation from landfills)	119	1	0.5	NA	22	22	22	0.54	198

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	0.012	0.001	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	0.0015	0.00025	0.1	0.00050	0.00056	0.0008	0.00084	0.00084	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	2.1	0.013	NE	NE	NE	NE	NE	0.64
Biomass (wood, renewable waste)	30	1.2	2	0.019	0.29	0.29	0.29	0.29	0.98	0.010
Biogas (co-generation from landfills)	0.0015	0.00025	0.1	0.00057	0.0012	0.009	0.0017	0.0018	NA	NA

Activity data (1A1a)

Municipal solid waste incineration

Activity data for municipal solid waste and special waste incineration are based on annual waste statistics (FOEN 2022h) and provided in the table below.

Table 3-13 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total Other fuels	kt	4'104	4'035	4'066	4'150	4'264	4'248	4'297	4'322	4'312	4'245
Municipal solid waste (MSW)	kt	3'841	3'773	3'817	3'889	4'010	4'011	4'042	4'059	4'072	4'027
Special waste	kt	263	262	249	261	254	236	255	262	241	218

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 2022; Tables 21, 26, and 28).

Activity data for combined heat and power generation from landfill gas are taken from the Swiss renewable energies statistics (SFOE 2022a). 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 2022b) as described in chapter 3.2.1.1.2 Energy model for wood combustion.

Table 3-14 Activity data of 1A1a Public electricity/heat.

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)	TJ	30'768	30'264	39'371	44'508	48'277
Biomass (wood, renewable waste)	TJ	301	466	547	844	2'958
Biogas (co-generation from landfills)	TJ	247	614	573	207	49

1A1a Public electricity and heat production	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	63'402	63'294	59'316	61'351	64'986	64'723	65'304	66'475	65'436	65'912
Gas oil	TJ	800	670	770	660	430	490	380	450	340	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	8'213	8'409	5'032	7'050	8'926	7'907	8'111	8'444	7'501	8'551
Other fuels (waste-to-energy)	TJ	49'313	48'228	49'161	50'548	52'422	52'316	53'097	53'552	53'248	51'859
Biomass (wood, renewable waste)	TJ	5'032	5'949	4'321	3'071	3'195	4'003	3'710	4'021	4'343	5'078
Biogas (co-generation from landfills)	TJ	44	39	31	21	13	6.5	6.0	8.4	4.0	4.0

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).

Activity data (1A1b)

Activity data on fuel combustion for 1A1b Petroleum refining is provided by the Swiss overall energy statistics (SFOE 2022) 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 2022). As one of the refineries ceased operation in 2015, the data are considered confidential since 2014. Data are available to reviewers on request.

Refinery gas is the most important fuel used in source category 1A1b. Energy consumption, in particular use of refinery gas has increased substantially since 1990 because one of the two Swiss Refineries operated at reduced capacity in 1990 and resumed full production in later years. In 2012, one of the refineries was closed over six months due to insolvency and the search for a new buyer (EV 2014). Between 2004 and 2015, one of the Swiss refineries is also using petroleum coke as a fuel. Natural gas is used additionally to residual fuel oil and refinery gas since 2017. In 2019 and 2020, 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 2013-2021 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 2022).

Table 3-15 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	11'242	13'834	14'173	7'232	6'355	6'298	6'627	5'911	5'987	5'160
Residual fuel oil	TJ	1'212	1'094	1'330	C	C	C	C	NO	NO	C
Refinery gas	TJ	8'249	11'055	10'935	C	C	C	C	C	C	C
Petroleum coke	TJ	1'781	1'685	1'908	C	NO	NO	NO	NO	NO	NO
Natural gas	TJ	NO	NO	NO	NO	NO	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 2023/1A1c). 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 3-16 Emission factors of 1A1c charcoal production in 2021.

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 2023/1A1c).

Table 3-17 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Charcoal production	TJ	4.1	3.3	4.3	3.8	4.1	3.9	4.3	5.1	3.9	3.7

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

The following recalculations were implemented in submission 2023:

- 1A1a: According to the Swiss energy statistic there was a reallocation of natural gas use from source category 1A1a Public electricity and heat production to 1A4a Commercial/institutional in the years 2013 to 2020. This does not lead to a change in total gas consumption.
- 1A1a: Activity data (wood, wood waste) of combustion installations in source category 1A1a have been revised for 1990-2020 due to recalculations in the Swiss wood energy statistics (SFOE 2022b).
- 1A1c: Since there is no information available on BC emissions from source category 1A1c Charcoal production (artisanal) its BC factor (%PM2.5) was set to the default Tier 2 value (48 %) of coke manufacture provided in the EMEP/EEA guidebook - 2019 (chap. 1A1c Manufacture of solid fuels and other energy industries, Tab. 5-2/5-3), yielding revised BC emission factors for the entire time series.

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 3-18 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)
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, biogas and sewage gas) in industrial boilers and engines

Table 3-19 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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, T1, L2, T2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	L1, T1, L2, T2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM2.5	T1
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	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, T1, L2, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	L1, L2

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 2022, 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 3-21, the industry model is based on two pillars. First, the energy consumption statistics in the industry and services sectors (SFOE 2022d) 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).

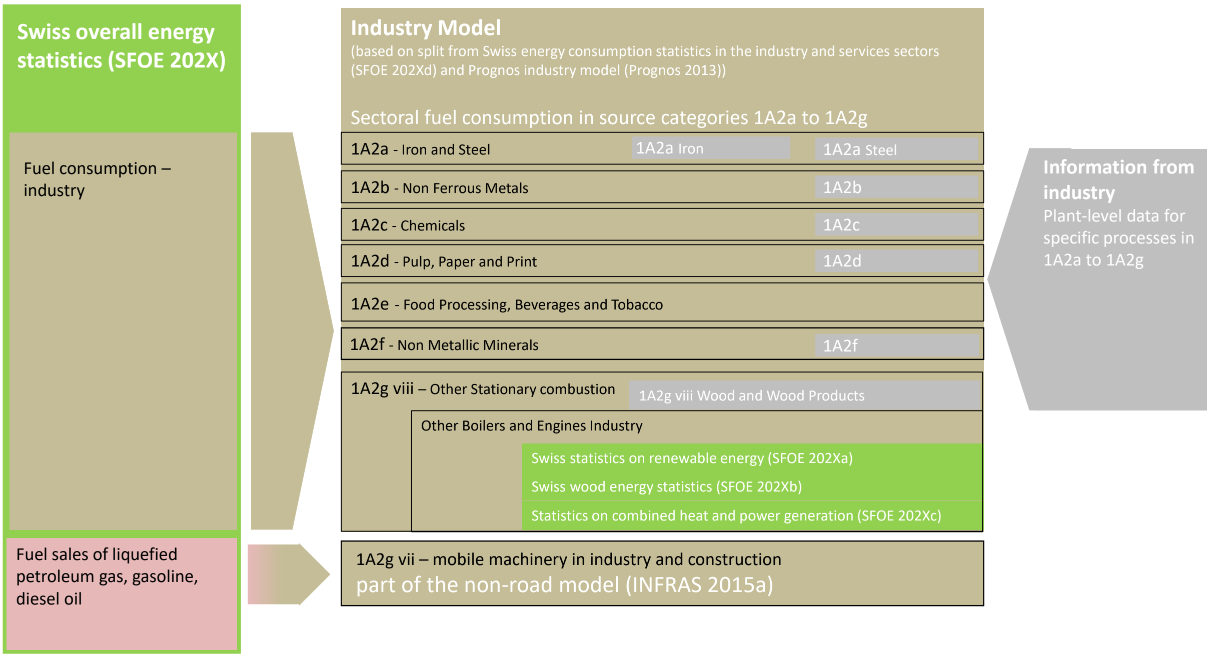


Figure 3-21 Schematic presentation of the data sources used for the industrial sectors 1A2a – 1A2g. The references SFOE 202X, SFOE 202Xa, 202Xb and 202Xc refer to the 2022 edition of the corresponding energy statistics. For each fuel type, the Swiss overall energy statistics provide the total fuel consumption in the industry sector (SFOE 2022). 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 2022d) 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 2022d) 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 2022d) 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 3-22. 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 2023/1A2_Sektorgliederung Industrie).

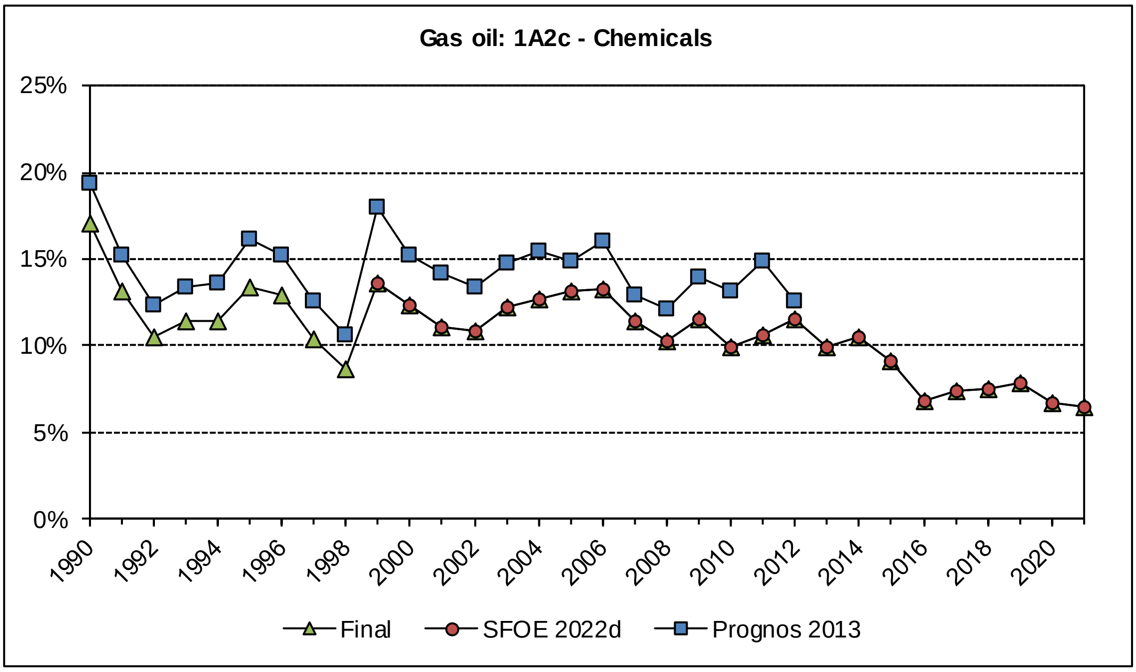


Figure 3-22 Illustrative example for combining time series with consistent overlap according to the 2019 Refinement (IPCC 2019, Volume 1, chp. 5.3.3.1, overlap). The y-axis indicates the share of source category 1A2c in total gas oil consumption in the industry sector. The green triangles correspond 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 2022d, 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 3-21 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 2022d) 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 developed by Eicher + Pauli (Kaufmann 2015) for the statistics on combined heat and power generation (SFOE 2022c).

Fuel consumption of wood, wood waste, biogas and sewage gas in manufacturing industries is based on the Swiss wood energy statistics (SFOE 2022b) as well as on data from the Swiss renewable energy statistics (SFOE 2022a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2022c), 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.

For liquefied petroleum gas and petroleum coke the same emission factors as of natural gas and residual fuel oil, respectively, are assumed for all air pollutants.

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, SO_x (except for gas oil and residual fuel oil), NH_3, PM2.5, PM10 and TSP are country-specific and documented in the Handbook on emission factors for stationary sources (SAEFL 2000). Since submission 2019, the emission factors of SO_x for gas oil and residual fuel oil are based on five-year averages of the annual sulphur analysis by the Swiss Federal Laboratories for Materials Science and Techology (EMPA, up to 2000) and Federal Office for Customs and Border Security (FOCBS), see also description in chp. 3.2.1.2.

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 3-20 Emission factors for boilers of 1A2 Stationary combustion in manufacturing industries and construction in 2021.

1A2 Boiler	NO_x	NMVOC	SO_x	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Boiler gas oil	31	2	5.6	0.002	0.2	0.2	0.2	0.0078	5.9
Boiler residual fuel oil	125	4	598	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	6.9
Boiler petroleum coke	125	4	598	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	0.5	0.001	0.1	0.1	0.1	0.0054	6.9

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 3-21 shows the total fuel consumption in 1A2 and Table 3-22 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 3-21 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	89'953	90'573	89'111	92'570	91'580
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	4'354	4'458	5'627	4'309	3'912
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	19'450	28'500	31'850	34'760	38'330
Other fossil fuels	TJ	2'469	2'718	3'812	4'138	4'625
Biomass	TJ	6'759	8'031	9'715	12'800	14'238

1A2 Manufacturing industries and constr. (stationary sources)	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	86'536	88'151	82'665	81'213	82'325	82'699	79'896	79'499	76'633	80'738
Gas oil	TJ	17'575	18'007	12'444	12'725	12'812	11'489	10'871	10'071	8'854	9'074
Residual fuel oil	TJ	1'568	848	231	196	155	123	34	111	76	55
Liquefied petroleum gas	TJ	3'731	3'740	3'288	3'340	2'752	3'131	3'051	2'925	2'797	2'941
Petroleum coke	TJ	1'367	1'049	1'240	795	890	763	781	777	700	604
Other bituminous coal	TJ	3'794	3'910	2'403	1'946	1'517	1'634	1'665	1'450	1'153	1'155
Lignite	TJ	1'175	1'357	3'102	3'060	3'078	2'876	2'520	2'262	2'410	2'442
Natural gas	TJ	38'280	39'630	40'220	39'370	39'880	40'920	39'240	39'480	38'100	39'620
Other fossil fuels	TJ	4'292	4'510	4'558	4'566	5'178	5'085	5'608	5'759	5'815	5'806
Biomass	TJ	14'753	15'100	15'179	15'217	16'062	16'679	16'126	16'663	16'727	19'041

Table 3-22 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	1'031	1'005	966	1'085	1'649
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	118	419	322	429	1'065
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2b Non-ferrous metals	TJ	2'242	1'958	1'549	971	1'214
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	1'764	1'605	1'309	845	1'098
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2c Chemicals	TJ	14'431	15'158	13'497	15'477	11'814
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	9'039	11'138	10'017	12'086	9'637
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2d Pulp, paper and print	TJ	9'675	12'343	9'883	9'326	6'773
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	3'151	7'389	6'916	5'678	5'581
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2e Food processing, beverages and tobacco	TJ	9'858	8'784	10'437	10'239	13'161
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	1'085	2'500	4'250	5'635	8'723
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2g viii Other	TJ	17'990	22'164	22'823	23'874	24'242
Gas oil	TJ	7'418	11'626	13'484	14'497	12'705
Residual fuel oil	TJ	5'237	3'605	47	4.9	9.3
Liquefied petroleum gas	TJ	3'091	3'288	4'164	3'116	2'855
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	781	2'088	4'588	5'281	7'703
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass (biogas, sewage gas, woo	TJ	493	504	513	499	529

Continuation of Table 3-22, fuel consumption in boilers of 1A2 Stationary combustion in manufacturing industries and construction.

Source (Boilers)	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A2a Iron and steel	TJ	1'455	1'429	1'506	1'913	1'885	2'152	2'284	2'136	2'133	1'936
Gas oil	TJ	172	139	86	136	134	123	127	97	81	80
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	438	438	388	393	327	368	358	342	327	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	845	852	1'032	1'384	1'424	1'661	1'800	1'697	1'724	1'514
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	1'745	1'592	1'915	1'791	1'681	1'639	1'745	1'961	1'811	2'018
Gas oil	TJ	152	127	88	77	74	77	53	60	48	64
Residual fuel oil	TJ	0.78	23	NO	44	NO	3.7	NO	NO	NO	NO
Liquefied petroleum gas	TJ	11	11	10	9.9	8.3	9.3	9.0	8.6	8.3	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	1'581	1'431	1'817	1'660	1'599	1'549	1'682	1'893	1'755	1'945
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	13'909	14'128	12'131	12'528	14'374	13'809	13'286	11'811	10'935	10'813
Gas oil	TJ	2'055	1'797	1'321	1'167	881	860	825	799	602	597
Residual fuel oil	TJ	0.16	1.2	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	10	10	8.9	9.0	7.5	8.4	8.2	7.9	7.5	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	11'845	12'320	10'800	11'352	13'485	12'941	12'454	11'004	10'325	10'208
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	5'374	5'475	4'645	3'656	2'983	2'852	2'074	2'151	2'068	2'337
Gas oil	TJ	623	711	297	383	410	288	293	345	284	244
Residual fuel oil	TJ	2.8	0.018	22	19	9.0	8.8	NO	NO	NO	NO
Liquefied petroleum gas	TJ	67	67	60	60	50	57	55	53	50	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	4'681	4'697	4'266	3'194	2'513	2'499	1'726	1'754	1'734	2'041
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	11'310	13'081	12'442	11'574	10'976	11'214	10'826	11'833	11'909	12'067
Gas oil	TJ	3'237	3'681	2'395	2'522	2'503	2'110	1'925	2'119	2'009	2'301
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	935	935	828	838	699	785	763	731	699	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	7'138	8'465	9'220	8'214	7'774	8'320	8'139	8'983	9'201	9'035
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	21'341	20'461	17'593	18'612	18'492	18'430	17'524	17'158	15'753	16'875
Gas oil	TJ	10'239	10'373	7'050	7'342	7'785	6'912	6'568	5'534	4'831	4'791
Residual fuel oil	TJ	0.26	2.1	0.33	2.8	7.9	4.3	2.2	2.4	3.7	2.8
Liquefied petroleum gas	TJ	2'162	2'165	1'949	1'977	1'615	1'860	1'814	1'738	1'667	1'758
Petroleum coke	TJ	405	181	108	104	155	113	168	169	65	21
Other bituminous coal	TJ	50	110	105	134	125	102	140	58	101	18
Lignite	TJ	95	75	189	204	197	182	153	141	144	138
Natural gas	TJ	7'824	7'015	7'638	8'319	8'078	8'739	8'213	9'054	8'482	9'679
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	567	540	553	530	530	518	464	462	458	468

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 3-20 and Table 3-22, 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 2023/1A2a 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 2023/1A2a Eisengiessereien Kupolöfen). The Hg emission factor is based on the default value for other bitumonius coal of Table 3.23 (chp. 1A4) of EMEP/EEA (2019).

Table 3-23 Emission factors of 1A2a Iron and Steel in 2021.

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 2023/1A2a).

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 2022).

Table 3-24 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Iron foundries, cupola	kt iron	11	11	11	9.2	8.6	8.8	8.6	6.0	5.1	5.4
Steel plants, reheating furnaces	kt steel	1'162	1'126	1'176	1'144	1'085	1'138	1'160	1'037	1'031	1'104

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 3-20 and Table 3-22, 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 2023/1A2b Buntmetallgiessereien übriger Betrieb). The emission factors are based on information of the Swiss foundry association (GVS).

Table 3-25 Emission factors of 1A2b Non-ferrous metals in 2021.

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 3-22).

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

Table 3-26 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Aluminium production	kt aluminium	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foundries	kt non-ferrous metals	6.6	6.4	9.5	8.9	9.0	8.0	6.8	6.4	5.1	7.5

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 3-20 and Table 3-22, 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 3-20. 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 3-20.

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 2023/1A2c 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 3-20 and Table 3-22, 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 2023/1A2d Zellulose-Produktion Feuerung).

Activity data (1A2d)

Activity data on annual cellulose production are provided by the industry as documented in the EMIS database (EMIS 2023/1A2d Zellulose-Produktion Feuerung). The only plant closed in 2008.

In 2021, natural gas is the most important fuel in this category (see Table 3-22). 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 3-20 and Table 3-22, respectively.

In 2021, 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 3-22.

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 2023/1A2f). 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 2023/1A2f).

Table 3-27 Emission factors for Non-metallic minerals 1A2f in 2021.

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 3-28 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 2023/1A2f).

Table 3-28 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cement	kt	3'368	3'415	3'502	3'195	3'296	3'279	3'239	3'227	3'129	3'227
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	39	33	32	31	32	36	40	47	40	49
Tableware glass	kt	C	C	C	C	C	C	C	C	C	C
Brick and tile	kt	792	785	765	726	660	622	581	554	531	484
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	4'770	5'260	4'850	4'710	5'260	5'180	5'210	4'910	4'960

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 3-27 shows product-specific emission factors for cement production (EMIS 2023/1A2f 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, an industry agreement defines an emission reduction path for the years 2016-2021. 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 3-28). 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 3-29. 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 2023/1A2f Zementwerke Feuerung.

Table 3-29 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	11'462	11'866	12'339	11'348	11'583	11'476	11'474	11'478	11'248	11'609
Cement fossil without waste	TJ	5'406	5'512	5'847	4'917	4'544	4'354	3'965	3'736	3'500	3'617
Gas oil	TJ	0.10	88	75	87	50	56	63	106	54	61
Residual fuel oil	TJ	297	86	58	45	90	59	NO	63	35	52
Petroleum coke	TJ	920	815	1'052	622	658	574	542	552	591	583
Other bituminous coal	TJ	3'097	3'203	1'713	1'267	826	938	938	831	528	587
Lignite	TJ	1'081	1'283	2'912	2'856	2'881	2'694	2'367	2'120	2'266	2'304
Natural gas	TJ	11	38	37	41	39	34	56	65	26	28
Cement, waste derived fuel	TJ	6'056	6'354	6'492	6'431	7'039	7'122	7'509	7'743	7'748	7'992
Other fossil fuels	TJ	3'635	3'923	3'884	3'895	4'486	4'393	4'645	4'885	4'861	4'834
Industrial waste	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Mix of special waste with saw dust (CSS)	TJ	23	23	25	20	26	21	20	16	0.043	0.58
Other fossil waste fuels	TJ	36	25	19	12	11	5.7	5.4	NO	NO	13
Plastics	TJ	803	963	1'016	887	890	1'071	1'319	1'246	1'558	1'688
Solvents and residues from distillation	TJ	1'247	1'345	1'193	1'194	1'397	1'254	1'238	1'456	1'155	1'107
Waste coke from coke filters	TJ	NO	NO	NO	NO	NO	66	61	48	52	48
Waste oil	TJ	822	848	884	1'083	1'469	1'215	1'239	1'359	1'353	1'253
Waste tyres	TJ	704	719	746	699	694	760	763	760	743	726
Biomass	TJ	2'421	2'432	2'608	2'536	2'553	2'729	2'864	2'858	2'887	3'158
Agricultural waste	TJ	28	NO	NO	NO	NO	9.2	NO	NO	NO	NO
Animal meal	TJ	572	479	457	412	409	470	522	475	441	454
Mix of special waste with saw dust (CSS)	TJ	77	73	78	60	72	57	53	43	0.12	1.6
Other biomass	TJ	17	32	21	42	7.9	5.6	5.4	31	36	147
Plastics	TJ	289	336	343	290	281	327	403	381	476	516
Sewage sludge (dried)	TJ	527	418	428	420	479	499	519	512	553	572
Solvents and residues from distillation	TJ	46	70	80	98	137	144	142	167	133	127
Waste oil	TJ	18	27	39	60	98	96	98	107	107	99
Waste tyres and rubber	TJ	260	266	276	259	257	281	282	281	275	269
Wood waste	TJ	586	732	886	896	811	840	840	861	867	973

In 2021, 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 2021. This is partly due to a decrease in production since 1990 and an increase in energy efficiency. In the same period, the fuel mix has changed significantly from mainly standard fossil fuels to the above-mentioned mix of fuels.

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 2023/1A2f 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 3-28). 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 2023/1A2f 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 3-28). 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 3-27 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 2023/1A2f 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 3-28). 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 2023/1A2f). 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 2023/1A2f 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 3-27 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 2023/1A2f 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 3-28). 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 2021 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 2023/1A2f 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 2023/1A2f 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 3-27 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 2023/1A2f Mischgut Produktion).

Activity data

Activity data consist of annual production data provided by the industry association (Schweizerische Mischgut-Industrie) (Table 3-28).

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, biogas and sewage gas in all manufacturing industries. For more detailed descriptions on methodologies of biogas and sewage gas, see source categories 5B Biological treatment of waste (chp. 6.3) and 5D Wastewater handling (chp. 6.5), respectively.

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 3-20). 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 3-7.

For wood combustion in 1A2gviii in both, installations and fibreboard production, the emission factors are described in chp. 3.2.1.1.2. They are shown in Table 3-7.

Emission factors of biogas and sewage gas are assumed to be the same as for natural gas. For boilers the emission factors are thus the same as documented above in chapter 3.2.3.2 Emission factors 1A2. For engines the emission factors of NO_x, NMVOC, SO_x, NH_3, PM2.5, PM10, TSP and CO are documented in the Handbook on emission factors for stationary sources (SAEFL 2000) whereas those of BC (% PM2.5), Pb, Cd, Hg, PCDD/PCDF and PAH are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, Table 3.26 and Table 3.30).

Table 3-30 Emission factors in 2021 for 1A2gviii

1A2gviii Other	NO_x	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Boiler industrial sewage gas	18	2	0.5	0.001	0.1	0.1	0.1	0.0054	6.9
Boiler municipal sewage gas	18	2	0.5	0.001	0.1	0.1	0.1	0.0054	6.9
Engines biogas	20	1	0.5	NE	0.1	0.1	0.1	0.0025	55
Engines sewage gas	15	1	0.5	NE	0.1	0.1	0.1	0.0025	45

1A2gviii Other	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/GJ	mg/GJ				ng/GJ	
Boiler industrial sewage gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Boiler municipal sewage gas	0.0015	0.00025	0.1	0.5	0.00056	0.00084	0.00084	0.00084	NA	NA
Engines biogas	0.0015	0.00025	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA
Engines sewage gas	0.0015	0.00025	0.1	0.57	0.0012	0.009	0.0017	0.0018	NA	NA

Activity data (1A2gviii)

In 2015, fuel consumption of 1A2gviii Other comprises mainly biomass, gas oil and natural gas. Overall, there has been a shift in fuel consumption between 1990 and 2021 from liquid and solid fuels to liquid fuels, biomass and natural gas. Activity data of fossil fuels is derived from the industry model and given in Table 3-22. Fuel consumption of wood, wood waste, biogas and sewage gas in this source category is based on the Swiss wood energy statistics (SFOE 2022b) as well as on data from the Swiss renewable energy statistics (SFOE 2022a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2022c) (see also chp. 3.2.1.1.2).

In source category fibreboard production, the main fuels currently used are wood waste and natural gas. Since 1990, the production of fibreboard and thus the fuel consumption have increased significantly. The fuel mix has strongly shifted between 1990 and 2021 from fossil fuels to biomass (wood waste). Between 2001 and 2013, also animal fat was used for fibreboard production. Since 2012, data on annual fibreboard production is taken from monitoring reports of the industry as documented in the EMIS database (EMIS 2023/1A2giv).

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

The following recalculations were implemented in submission 2023:

- 1A2: Revised amount of natural gas use in the Swiss energy statistics for the years 2013-2021 leads to recalculations for natural gas in all source-categories with stationary combustion of 1A2 Manufacturing industry and construction for these years, too.
- 1A2a–g: Recalculation in all source categories 1A2a to 1A2gviii due to reallocations of gas and gas oil use in these sub-categories of 1A2 Manufacturing industries and construction in the year 2020. The reason is that during the surveys for the most recent year, the reports from the previous year are reviewed again and, if necessary, adjusted retroactively. This does not affect the total amount of gas and gas oil used in 1A2 Manufacturing industries and construction for that year.
- 1A2f: In 1A2f Cement production, the activity data of the waste derived combustibles were reorganised in order for Biomass to contain only biogenic fuels and for Other fuels to contain only fossil fuels. All years are affected. Total emissions are affected by less than 5 % (due to rounding issues).
- 1A2gviii: Activity data (wood, wood waste) of combustion installations in source category 1A2gviii have been revised for 1990-2020 due to recalculations in the Swiss wood energy statistics (SFOE 2022b). The biggest changes were in automatic boilers >50 kW after 2015.

- 1A2gviii: An error in the country-specific emission factor model for wood energy combustion was corrected resulting in revised NMVOC emission factors of log wood dual chamber boilers for the entire time series.
- 1A2gviii: Since more residual fuel oil was consumed in the years 2020 and 2021 according to direct bottom-up information from the industry than was declared in total sales in the same year, stock transfers must be made. This leads to additional stockpiling in 2008-2010 and therefore to changes for residual fuel oil used in not further defined boilers in 1A2gviii Other. Stockpiling can only be performed in the years in which more residual fuel oil was sold according to total energy statistics than was consumed according to bottom-up information. Therefore, the years 2008-2010 were chosen to add residual fuel oil to stocks to cover the additional bottom-up consumption in the years 2020 and 2021.
- 1A2gviii: Due to revised activity data of liquefied petroleum gas in source category 1A3bi Passenger cars, also the statistical difference and not further defined use of liquefied petroleum gas in boilers of source category 1A2gviii Other changed for the years 2011 to 2020.

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 3-31 Specification of source category 1A4 Stationary combustion in other sectors.

1A4	Source category	Specification
1A4ai	Commercial/institutional: Stationary	Emissions from stationary combustion in commercial and institutional buildings as different wood combustions, boilers, engines and turbines
1A4bi	Residential: Stationary	Emissions from stationary fuel combustion in households as different wood combustions, boilers, engines and turbines
1A4ci	Agriculture/Forestry/Fishing: Stationary	Emissions from stationary fuel combustion in agriculture as different wood combustions, engines with biogas, heating of greenhouses and grass drying

Table 3-32 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 1A4 Stationary combustion in other sectors.

NFR code	Source category	Pollutant	Identification criteria
1A4ai	Commercial/institutional: stationary	NOx	L1, T1, L2, T2
1A4ai	Commercial/institutional: stationary	SOx	L1, T1, L2
1A4ai	Commercial/institutional: stationary	PM2.5	L1, T1, L2, T2
1A4ai	Commercial/institutional: stationary	PM10	L1
1A4bi	Residential: stationary plants	NOx	L1, T1, L2
1A4bi	Residential: stationary plants	NMVOC	L1, L2
1A4bi	Residential: stationary plants	SOx	L1, T1, L2, T2
1A4bi	Residential: stationary plants	PM2.5	L1, T1, L2, T2
1A4bi	Residential: stationary plants	PM10	L1, T1, L2, 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. Beside the main energy sources, also 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 from wood combustion 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 3-33, Table 3-34 and Table 3-35 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.
- The emission factors for PM10, PM2.5 and TSP for natural gas, biogas and gas oil are based on a study by Leupro (2012).
- Emission factors for NO_x and NMVOC for combined heat and power generation in turbines and engines are based on measurements documented in the Handbook on emission factors for stationary sources (SAEFL 2000).
- 1A4ai: The emission factor for NH_3 with a development from 0 g/TJ to 500 g/TJ (gas turbines with catalysator) from 1990 to 2021 was taken from SAEFL 2000.
- 1A4ai and 1A4bi: The CO emission factor of gas turbines from 1990 to 2010 stem from SAEFL 2000. The development from 50 kg/TJ to 10 kg/TJ was adjusted slightly. From the year 2015 on forward the emission factor of 4.8 kg/TJ from the EMEP guidebook

(EMEP/EEA 2019, chp. 1A4, table 3-28) is taken. This corresponds to measurements in the years 2013-2017 from the only Swiss compressor station.

- Emission factors for NMVOC for combustion boilers, turbines and engines in the residential, commercial institutional and agricultural sectors are documented in SAEFL (2000).
- Emission factors for SO_x of gas oil are based on five-year averages of the annual sulphur analysis by the Swiss Federal Laboratories for Materials Science and Technology (EMPA, up to 2000) and Federal Office for Customs and Border Security (FOCBS) (see chp. 3.2.1.2).
- The emission factor for SO_x of natural gas and biogas is based on the legal limit of 190 ppm (see chp. 3.2.1.2).
- The emission factor for SO_x of coal is based on 1 % sulphur content which holds for heat capacities below 1 MW (see chp. 3.2.1.2).
- Emission factors for Pb, Cd, Hg and PAH for natural gas and biogas are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1.A.4 Small combustion) as follows. 1A4ai: natural gas turbines table 3-28, natural gas/biogas boilers table 3-26, natural gas engines table 3-26 (HM) and table 3-30 (PAH). 1A4bi: natural gas boilers table 3-16, natural gas engines table 3-26 (HM) and table 3-30 (PAH). 1A4ci: natural gas/biogas boilers table 3-26, biogas engines table 3-26 (HM) and table 3-30 (PAH).
- 1A4ai/bi gas oil engines: Emission factors are from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1.A.4 Small combustion, table 3-31).
- 1A4ai/bi/ci gas oil boiler Pb/Cd/Hg: emission factors are taken from table 3-18 in the EMEP/EEA guidebook (EMEP/EEA 2019), but 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.
- Wood combustion in1A4ai/bi/ci: The country-specific emission factor model for wood energy is described in chp. 3.2.1.1.2.
- 1A4bi Hg emission factors for other bituminous coal 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.
- 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).
- HCB emission factors of boilers, stationary engines, turbines and CCGT-plants (combined cycle gas turbines) using gaseous and liquid fuels are based on the approach of the Danish Emission Inventory for hexachlorobenzene and polychlorinated biphenyls (Nielsen et al. 2013).
- Emission factors of PCB for stationary combustion (1A4ai, 1A4bi and 14Aci) of solid and liquid fossil fuels as well as of wood and wood waste are taken from the Danish emission inventory for HCB and PCBs (Nielsen et al. 2013).
- Bonfires and use of charcoal (within 1A4bi): Emission factors of NO_x, NMVOC, SO_x, PM2.5/PM10, TSP, CO, NH_3, 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 3-34. 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 2023/1A4bi Lagerfeuer and EMIS 2023/1A4bi Holzkohle Verbrauch.

Table 3-33 Emission factors for 1A4ai for 2021. 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)	32	6.0	5.6	2.6	0.25	0.25	0.25	0.010	6.0
Gas oil heat only boilers	32	6	5.6	1	0.2	0.2	0.2	0.0078	5.9
Gas oil engines	40	8	5.6	600	20	20	20	0.78	30
Natural gas (weighted average)	18	1.9	0.5	1.1	0.1	0.1	0.1	0.0052	12
NG heat only boilers	16	2	0.5	1	0.1	0.1	0.1	0.0054	8.9
NG turbines	19	0.1	0.5	490	0.1	0.1	0.1	0.0025	4.8
NG engines	50	1	0.5	NA	0.1	0.1	0.1	0.0025	55
Biomass (weighted average)	112	39	5.4	2'614	29	31	32	7.9	545
Biomass (wood)	112	39	5.4	2'615	29	31	32	7.9	545
Biomass (biogas)	16	2	0.5	1	0.1	0.1	0.1	0.0054	8.9

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)	0.012	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)	0.0015	0.00025	0.1	0.00050	0.60	1.3	0.89	0.90	NA	NA
NG heat only boilers	0.0015	0.00025	0.1	0.0005	0.6	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	0.0015	0.00025	0.1	0.00057	1.2	9	1.7	1.8	NA	NA
Biomass (weighted average)	20	1.1	2	0.11	7'964	7'964	4'895	4'895	2.8	0.016
Biomass (wood)	20	1.1	2	0.11	7'965	7'965	4'895	4'895	2.8	0.016
Biomass (biogas)	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA

Table 3-34 Emission factors for 1A4bi (including charcoal and bonfires) for 2021. 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	5.6	1.2	0.21	0.21	0.21	0.0081	11
Gas oil heat only boilers	33	6.0	5.6	1	0.2	0.2	0.2	0.0078	11
Gas oil engines	40	8.0	5.6	600	20	20	20	0.78	30
Natural gas (weighted average)	15	4.0	0.5	0.99	0.1	0.1	0.1	0.0054	12
NG heat only boilers	15	4	0.5	1	0.1	0.1	0.1	0.0054	12
NG engines	29	1	0.5	NA	0.1	0.1	0.1	0.0025	55
Other bituminous coal	65	100	350	1'600	69	69	99	4.4	1'000
Biomass	95	104	7.8	3'774	59	63	66	25	1'331
Wood	96	99	7.8	3'068	52	55	57	25	1'304
Use of charcoal	50	600	11	74'000	820	840	880	57	4'000
Bonfires	50	600	11	74'000	820	840	880	57	4'000

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)	0.0015	0.00025	0.1	0.0015	0.57	0.91	0.85	0.85	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	0.0015	0.00025	0.1	0.00057	1.2	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	20	1.2	2.0	0.23	23'372	23'272	12'997	13'286	4.2	0.028
Wood	20	1.0	2	0.22	22'389	22'389	12'706	12'706	4.1	0.028
Use of charcoal	27	13	0.56	0.8	121'000	111'000	42'000	71'000	5	0.06
Bonfires	27	13	0.56	0.8	121'000	111'000	42'000	71'000	5.7	0.06

Table 3-35 Emission factors for 1A4ci for 2021. 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	65	88	73	NA	251	251	251	12	501
Heating of greenhouses (weighted average)	22	2	2.1	1.3	0.13	0.13	0.13	0.0062	6.6
Gas oil	30.9	2	5.6	2	0.2	0.2	0.2	0.0078	5.9
Natural gas	18.5	2	0.5	1	0.1	0.1	0.1	0.0054	6.9
Other biomass combustion (weighted average)	51	8.7	2.5	1'968	13	14	15	2.0	218
Biogas heat only boilers	16	2	0.5	1	0.1	0.1	0.1	0.0054	8.9
Biogas engines	20	1	0.5	NA	0.1	0.1	0.1	0.0025	55
Wood combustion	103	21	5.7	1'995	35	37	39	5.3	487

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	5.5	1.1	0.6	NE	NE	NE	NE	NE	NE	NE
Heating of greenhouses (weighted average)	0.005	0.00048	0.11	0.00091	0.56	5.3	1.11	1.0464	0.22	0.00011
Gas oil	0.012	0.001	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Natural gas	0.0015	0.00025	0.10	0.0005	0.56	0.84	0.84	0.84	NA	NA
Other biomass combustion (weighted average)	7.1	0.4	0.7	0.029	2'615	2'619	1'325	1'325	3.2	0.01
Biogas heat only boilers	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.8400	NA	NA
Biogas engines	0.0015	0.00025	0.1	0.0006	1.20	9.0	1.7	1.8000	NA	NA
Wood combustion	19	0.97	1.81	0.08	6'905	6'905	3'497	3'497	3.2	0.01

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 2022).

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 2022).

As the Swiss wood energy statistics (SFOE 2022b) 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 2023/1A4bi 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 2023/1A4ci 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 2023/1A4ci Gewächshäuser).

Table 3-36 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	72'354	80'123	76'795	83'379	79'430
Gas oil	TJ	52'977	54'379	48'777	51'197	46'525
Gas oil heat only boilers	TJ	52'953	54'204	48'426	50'880	46'406
Gas oil engines	TJ	24	175	351	318	119
Natural gas	TJ	16'399	21'843	23'552	26'732	25'307
NG heat only boilers	TJ	16'123	20'672	21'815	24'699	23'602
NG turbines	TJ	85	78	NO	28	23
NG engines	TJ	192	1'093	1'737	2'004	1'681
Biomass (total)	TJ	2'978	3'901	4'466	5'450	7'599
Biomass (wood)	TJ	2'939	3'869	4'438	5'403	7'495
Biogas (heat only boilers)	TJ	39	32	27	46	104

1A4ai Other sectors (stationary): Commercial/institutional	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	71'902	77'299	60'985	66'966	70'299	67'761	61'196	61'675	58'792	67'362
Gas oil	TJ	39'750	42'727	32'993	35'153	36'440	34'222	30'879	30'273	27'596	31'349
Gas oil heat only boilers	TJ	39'656	42'640	32'910	35'071	36'358	34'140	30'797	30'191	27'514	31'267
Gas oil engines	TJ	94	86	82	82	82	82	82	82	82	82
Natural gas	TJ	24'733	26'351	20'247	23'112	24'336	23'967	21'176	21'759	21'054	24'120
NG heat only boilers	TJ	23'180	24'854	18'811	21'676	22'900	22'531	19'740	20'323	19'618	22'684
NG turbines	TJ	5	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
NG engines	TJ	1'548	1'490	1'429	1'429	1'429	1'429	1'429	1'429	1'429	1'429
Biomass (total)	TJ	7'420	8'221	7'745	8'701	9'522	9'572	9'141	9'643	10'142	11'892
Biomass (wood)	TJ	7'344	8'162	7'698	8'679	9'498	9'548	9'128	9'628	10'127	11'877
Biogas (heat only boilers)	TJ	76	59	47	21	24	24	13	14	15	16

Table 3-37 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	185'308	189'291	170'485	186'056	182'062
Gas oil	TJ	136'887	133'548	116'295	124'024	111'731
Gas oil heat only boilers	TJ	136'887	133'544	116'242	123'961	111'695
Gas oil engines	TJ	0.59	4.5	53	63	36
Natural gas	TJ	25'864	34'088	36'261	42'633	48'229
NG heat only boilers	TJ	25'804	33'830	35'822	42'103	47'723
NG turbines	TJ	NO	NO	NO	NO	NO
NG engines	TJ	60	258	439	530	506
Other bituminous coal	TJ	630	460	130	400	400
Biomass (wood, charcoal, bonfires)	TJ	21'926	21'195	17'799	19'000	21'702
Wood	TJ	21'455	20'744	17'347	18'526	21'198
Use of charcoal	TJ	311	291	292	313	344
Bonfires	TJ	160	160	160	160	160

1A4bi Other sectors (stationary): Residential	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	161'282	172'581	135'085	144'791	150'953	144'838	133'078	133'971	124'475	139'280
Gas oil	TJ	94'103	99'373	75'136	79'406	81'340	76'113	67'901	66'642	59'375	66'048
Gas oil heat only boilers	TJ	94'072	99'344	75'109	79'379	81'312	76'085	67'874	66'615	59'348	66'021
Gas oil engines	TJ	32	29	27	27	27	27	27	27	27	27
Natural gas	TJ	47'043	50'977	42'377	46'106	48'835	48'345	45'925	47'585	47'215	53'086
NG heat only boilers	TJ	46'577	50'529	41'947	45'676	48'405	47'915	45'496	47'155	46'786	52'656
NG turbines	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NG engines	TJ	466	448	430	430	430	430	430	430	430	430
Other bituminous coal	TJ	300	300	200	200	200	100	100	100	100	100
Biomass (wood, charcoal, bonfires)	TJ	19'836	21'931	17'372	19'079	20'579	20'281	19'151	19'645	17'785	20'045
Wood	TJ	19'331	21'428	16'858	18'565	20'084	19'747	18'637	19'159	17'221	19'846
Use of charcoal	TJ	344	343	354	354	334	374	354	325	404	40
Bonfires	TJ	160	160	160	160	160	160	160	160	160	160

Table 3-38 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	6'378	6'103	5'798	5'524	5'650
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	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 biomass combustion	TJ	484	559	575	795	1'235
Biogas heat only boilers	TJ	39	32	27	46	104
Biogas engines	TJ	16	15	35	82	394
Wood combustion	TJ	428	513	513	666	738

1A4ci Other sectors (stationary): Agriculture/forestry/fishing	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	5'803	5'294	4'758	4'933	5'438	5'957	5'483	5'819	5'928	6'347
Drying of grass	TJ	685	458	524	431	492	610	545	684	721	630
Gas oil	TJ	418	106	104	89	86	118	116	124	148	94
Residual fuel oil	TJ	NO	17	20	22	18	25	13	NO	NO	NO
Natural gas	TJ	267	220	264	233	279	338	296	427	435	410
Biomass	TJ	NO	114	136	88	109	129	120	132	138	126
Heating of greenhouses	TJ	3'671	3'389	2'800	2'900	2'899	3'238	2'754	2'732	2'537	2'753
Gas oil	TJ	1'647	1'496	1'095	1'165	1'066	1'145	930	916	788	861
Natural gas	TJ	2'025	1'893	1'705	1'735	1'834	2'093	1'824	1'816	1'749	1'892
Other biomass combustion	TJ	1'447	1'448	1'435	1'602	2'046	2'109	2'184	2'403	2'670	2'963
Biogas heat only boilers	TJ	76	59	47	21	24	24	13	14	15	16
Biogas engines	TJ	599	754	880	1'020	1'168	1'248	1'390	1'597	1'747	1'893
Wood combustion	TJ	772	635	507	562	854	837	781	792	909	1'055

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 2023:

- 1A4: An error in the country-specific emission factor model for wood energy combustion was corrected resulting in revised NMVOC emission factors of log wood single-room furnaces and dual chamber boilers for the entire time series.
- 1A4a: According to the Swiss energy statistic there was a reallocation of natural gas use from source category 1A1a Public electricity and heat production to 1A4a Commercial/institutional in the years 2013 to 2020. This leads not to a change in total gas consumption.
- 1A4ai, 1A4bi, 1A4ci: Activity data (wood, wood waste) of combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2020 due to recalculations in the Swiss wood energy statistics (SFOE 2022b). The biggest changes were in automatic boilers >50 kW after 2015.

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 3-39 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 3-40 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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, T1, L2
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	L1, T1, L2, 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 3-41 to Table 3-44. Implied emission factors 2021 are shown in Table 3-45.

Table 3-41 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 3-42 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 3-43 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 3-44 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 3-45 Implied emission factors for 1A2gvii in 2021.

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	100	617	0.26	0.09	0.12	2.4	0.12	16	0.12	24	0.0059	0.0030
Diesel oil	196	19	0.33	0.17	5.1	2.4	5.1	16	5.1	24	2.8	0.0030
Liquefied petroleum gas	96	8.8	NA	0.22	0.47	2.4	0.47	16	0.47	24	0.023	0.0030
Biodiesel	168	17	0.28	0.15	4.3	2.4	4.3	16	4.3	24	2.4	0.0030
Bioethanol	46	220	0.17	0.059	0.086	2.4	0.086	16	0.086	24	0.0043	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	19'716	0.007	2.3	0.20	2.7	1.0	1.0	0.10	0.30	NE	NE
Diesel oil	97	0.001	2.2	0.12	1.5	0.66	1.1	0.82	0.19	NE	NE
Liquefied petroleum gas	24	NA	0.2	NA	NA	0.0043	NA	0.0043	0.0043	NE	NE
Biodiesel	83	0.001	1.9	0.10	1.3	0.56	0.94	0.70	0.16	NE	NE
Bioethanol	12'058	0.000	1.5	0.13	1.8	0.65	0.65	0.064	0.19	NE	NE

Activity data (1A2gvii)

Table 3-46 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 2022a). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-46 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total fuel consumption	TJ	8'843	8'875	8'906	8'938	8'944	8'949	8'955	8'960	8'966	8'991
Gasoline	TJ	206	198	191	184	180	177	174	171	168	167
Diesel oil	TJ	8'312	8'341	8'370	8'399	8'380	8'361	8'342	8'323	8'304	8'296
Liquefied petroleum gas	TJ	252	243	235	226	215	203	192	180	168	163
Biodiesel	TJ	73	91	110	128	166	205	243	282	320	360
Bioethanol	TJ	0.51	0.76	1.02	1.3	2.0	2.7	3.3	4.0	4.7	5.4

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

The following recalculations were implemented in submission 2023:

- 1A2gvii: Emission factors of Pb and SO_2 in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii and 1A5b as well as those in 1A3b Road transportation were revised for the years 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).

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 3-47 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	Emissions from the one compressor station in Ruswil (canton Lucerne)

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

Table 3-48 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 1A3, Transport.

NFR code	Source category	Pollutant	Identification criteria
1A3ai(i)	Civil aviation (domestic, landing/take-off (LTO))	NOx	T1, T2
1A3bi	Road transportation: passenger cars	NOx	L1, T1, L2, T2
1A3bi	Road transportation: passenger cars	NMVOC	L1, T1, L2, T2
1A3bi	Road transportation: passenger cars	SOx	T1
1A3bi	Road transportation: passenger cars	PM10	T1
1A3bii	Road transportation: light-duty vehicles	NOx	L1, T1, L2, T2
1A3bii	Road transportation: light-duty vehicles	NMVOC	T1
1A3biii	Road transportation: heavy-duty vehicles and buses	NOx	L1, T1, L2, T2
1A3biii	Road transportation: heavy-duty vehicles and buses	SOx	T1, T2
1A3biii	Road transportation: heavy-duty vehicles and buses	PM2.5	T1, T2
1A3biii	Road transportation: heavy-duty vehicles and buses	PM10	T1
1A3biv	Road transportation: mopeds and motorcycles	NMVOC	L2, T2
1A3bv	Road transportation: gasoline evaporation	NMVOC	L1, T1, T2
1A3bvi	Road transportation: automobile tyre and brake wear	PM2.5	L1, T1, L2, T2
1A3bvi	Road transportation: automobile tyre and brake wear	PM10	L1, T1, L2, T2
1A3c	Railways	PM2.5	L1, T1
1A3c	Railways	PM10	L1, T1, L2, 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, 2007-2021. The results of the emission modelling have been transmitted from FOCA to FOEN in an aggregated form (FOCA 2006, 2006a, 2007a, 2008-2022). Years in-between are interpolated. Further details of emission modelling are described in Switzerland's National Inventory Document (FOEN 2023).

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 3-49.

- 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 kerosene (see Table 3-9).
- 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 3-49 Emission factors for 1A3a Civil aviation, year 2021. (LTO: Landing take-off cycle, CR: cruise.). Sustainable aviation fuels (SAF) are referred to as kerosene biogenic.

1A3a Civil aviation	NO_x	NMVOC	SO_x	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSM ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3a International and domestic aviation, LTO												
1A3ai(i) International aviation, LTO, Kerosene fossil	332	26	23	NA	2.5	0.0030	2.5	0.0030	2.5	0.0030	1.0	NA
1A3ai(i) International aviation, LTO, Kerosene biogenic	358	23	23	NA	2.4	0.0027	2.4	0.0027	2.4	0.0027	0.89	NA
1A3aii(i) Domestic aviation LTO, Kerosene fossil	208	175	18	NA	9.4	0.0044	9.4	0.0044	9.4	0.0044	2.4	NA
1A3a International and domestic aviation, CR												
1A3ai(i) International aviation, CR, Kerosene fossil	427	4.2	23	NA	0.8	NA	0.83	NA	0.83	NA	0.83	NA
1A3ai(i) International aviation, CR, Kerosene biogenic	454	3.7	23	NA	0.71	NA	0.71	NA	0.71	NA	0.71	NA
1A3aii(i) Domestic aviation CR, Kerosene fossil	252	85	22	NA	4.5	NA	4.5	NA	4.5	NA	4.5	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, Kerosene fossil	280	0.0089	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3ai(i) International aviation, LTO, Kerosene biogenic	258	0.0020	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3aii(i) Domestic aviation LTO, Kerosene fossil	5'254	4.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3a International and domestic aviation, CR											
1A3ai(i) International aviation, CR, Kerosene fossil	47	0.0076	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3ai(i) International aviation, CR, Kerosene biogenic	41	0.0012	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3aii(i) Domestic aviation CR, Kerosene fossil	832	1.2	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 3-50 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. 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 3-50 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 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, Kerosene fossil	4'277	5'097	6'507	4'878	5'643
1A3ai(i) International aviation, LTO, Kerosene biogenic	NO	NO	NO	NO	NO
1A3aii(i) Domestic aviation LTO, 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 Kerosene fossil	37'608	44'821	57'219	42'896	52'691
1A3ai(ii) International aviation, CR Kerosene biogenic	NO	NO	NO	NO	NO
1A3aii(ii) Domestic aviation, CR 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	Fuel consumption in TJ									
1A3a International and domestic aviation, LTO	6'730	6'702	6'667	6'847	6'950	7'112	7'299	7'284	2'565	2'903
1A3ai(i) International aviation, LTO, Kerosene fossil	6'226	6'208	6'142	6'459	6'529	6'728	6'953	6'963	2'395	2'718
1A3ai(i) International aviation, LTO, Kerosene biogenic	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.0
1A3aii(i) Domestic aviation, LTO, Kerosene fossil	504	494	525	387	421	384	346	321	170	183
1A3a International and domestic aviation, CR (memo item)	59'048	59'825	60'259	62'374	65'584	67'352	71'494	72'482	26'685	29'780
1A3ai(ii) International aviation, CR Kerosene fossil	57'677	58'501	58'864	60'874	64'073	66'096	70'261	71'233	25'799	29'129
1A3ai(ii) International aviation, CR Kerosene biogenic	NO	NO	NO	NO	NO	NO	NO	NO	NO	24
1A3aii(ii) Domestic aviation, CR Kerosene fossil	1'371	1'323	1'396	1'500	1'511	1'257	1'234	1'250	886	628
Total 1A3a Civil aviation	65'778	66'526	66'927	69'220	72'534	74'465	78'793	79'767	29'250	32'683
1990 = 100%	145%	147%	148%	153%	160%	164%	174%	176%	65%	72%

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 2021, 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. *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.
- 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, four gradient classes, 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 1990-2021.

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 3-51 shows a selection of implied emission factors (emissions divided by specific fuel consumption per source category) for 2021.

Table 3-51 Implied emission factors for road transportation, passenger cars in 2021.

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	32	46	0.26	8.8	0.62	5.0	0.62	13	0.62	13	0.10	0.50
1A3bii Light duty vehicles	86	121	0.26	9.0	2.7	5.5	2.7	11	2.7	11	0.45	0.55
1A3biii Heavy duty vehicles	781	552	0.26	0.22	0.00076	6.0	0.00076	27	0.00076	27	0.00011	0.60
1A3biv Motorcycles	73	248	0.26	1.2	13	3.2	13	5.7	13	5.7	2.5	0.38
1A3bv Gasoline evaporation	NA	24	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	35	80	0.26	8.5	1.1	4.9	1.1	13	1.1	13	0.20	0.50

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	545	0.59	0.0044	0.42	0.20	0.0030	0.13	0.15	0.11	0.16	NE	594
1A3bii Light duty vehicles	2'535	0.59	0.0037	0.68	0.19	0.0029	0.11	0.13	0.088	0.14	NE	582
1A3biii Heavy duty vehicles	666	0.59	0.0044	0.77	NE	NE	NE	NE	NE	NE	NE	NE
1A3biv Motorcycles	1'911	0.59	0.0045	0.31	0.20	0.010	0.18	0.21	0.15	0.23	NE	2757
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	0.42	0.20	0.0032	0.14	0.15	0.11	0.17	NE	679

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	239	3.7	0.33	1.7	1.2	4.5	1.2	12	1.2	12	0.66	0.45
1A3bii Light duty vehicles	281	1.7	0.33	1.2	3.8	4.4	3.8	9.2	3.8	9.2	2.4	0.44
1A3biii Heavy duty vehicles	137	2.6	0.33	1.1	1.7	4.6	1.7	21	1.7	21	0.66	0.46
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	210	3.0	0.33	1.4	1.7	4.4	1.7	14	1.7	14	0.9	0.44

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	46	0.92	0.0012	0.38	0.12	0.0024	0.64	0.72	0.57	0.60	NE	491
1A3bii Light duty vehicles	47	0.92	0.0012	0.57	0.12	0.0030	0.50	0.56	0.44	0.47	NE	597
1A3biii Heavy duty vehicles	55	0.92	0.0010	0.60	0.21	0.0002	0.078	0.47	0.52	0.12	NE	30
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	48	0.91	0.0012	0.46	0.14	0.0018	0.45	0.61	0.52	0.43	NE	363

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	27	1.3	0.28	8.8	1.8	5.3	1.8	14	1.8	14	0.27	0.53
1A3bii Light duty vehicles	14	0.62	0.27	7.3	2.5	5.2	2.5	11	2.5	11	0.37	0.52
1A3biii Heavy duty vehicles	207	2.2	0.28	NE	0.39	3.4	0.39	19	0.39	19	0.059	0.34
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	103	1.6	0.27	4.9	1.3	4.5	1.3	16	1.3	16	0.19	0.45

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	167	NA	NA	0.44	0.19	0.0027	0.14	0.16	0.12	0.17	NE	NA
1A3bii Light duty vehicles	1283	NA	NA	0.66	0.19	0.0020	0.11	0.12	0.086	0.13	NE	NA
1A3biii Heavy duty vehicles	64	NA	NA	0.42	NE	0.0011	0.0030	0.0048	0.0024	0.0018	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	232	NA	NA	0.45	0.11	0.0019	0.079	0.090	0.064	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	NA	7.1	NA	4.3	NA	12	NA	12	NA	0.43
1A3bii Light duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biii Heavy duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biv Motorcycles	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	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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	327	NA	NA	0.36	0.19	NA	0.11	0.13	0.093	0.14	NA	NA
1A3bii Light duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biii Heavy duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biv Motorcycles	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	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 3-51 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	0.07	NA	NA	15	NA	39	NA	39	NA	1.5
1A3bii Light duty vehicles	NA	NA	0.000036	NA	NA	11	NA	22	NA	22	NA	1.1
1A3biii Heavy duty vehicles	NA	NA	NA	NA	NA	7.5	NA	43	NA	43	NA	0.75
1A3biv Motorcycles	NA	NA	NA	NA	NA	128	NA	240	NA	240	NA	15
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	0.18	NA	1.2	NA	NA	NA	NA	NA	NA	NA	NA
1A3bii Light duty vehicles	NA	0.000077	NA	1.4	NA	NA	NA	NA	NA	NA	NA	NA
1A3biii Heavy duty vehicles	NA	NA	NA	0.91	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 2022e). 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 2022e). 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 specific mileage per vehicle category can be derived (SFOE 2022e, INFRAS 2017).
- 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 2022a).

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 2016). The traffic model is based on an origin-destination matrix that is assigned to a network of about 20’000 road segments. The model is calibrated partly bottom-up and partly top-down:

bottom-up by a number of traffic counts from the national traffic-counter network, and top-down by the total of the mileage per vehicle category. The assignment of traffic situations 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 3-52 shows the mileage per vehicle category. Numbers hold for the version “fuel used” and represent the vehicle kilometres driven within the Swiss territory.

Table 3-52 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	million vehicle-km									
PC	53'721	54'695	55'641	56'620	57'737	58'735	59'344	59'833	52'840	56'057
LDV	3'776	3'874	3'998	4'129	4'269	4'392	4'530	4'668	4'809	4'809
HDV	2'229	2'243	2'236	2'235	2'235	2'242	2'238	2'226	2'203	2'248
Coaches	124	125	128	131	134	136	139	142	131	135
Urban Bus	254	262	267	272	281	280	291	300	295	300
2-Wheelers	1'899	1'904	1'920	1'937	1'976	2'008	2'046	2'068	2'152	2'152
Sum	62'004	63'102	64'188	65'324	66'631	67'793	68'588	69'237	62'430	65'701
(1990=100%)	125%	127%	130%	132%	134%	137%	138%	140%	126%	133%

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 2021 total mileages increased again compared to 2020 but were still lower than before 2020. 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 3-53 that depicts the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990–2021.

Table 3-53 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	3.07
	Diesel oil	3.34	3.16	3.05	2.75	2.72
	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	10.5	13.2
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	3.37
(1990=100%)		100%	104%	104%	101%	96%

Veh. Category	Fuel	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
		MJ / veh-km									
PC	Gasoline	2.95	2.88	2.81	2.73	2.65	2.57	2.50	2.44	2.39	2.33
	Diesel oil	2.70	2.68	2.66	2.62	2.58	2.53	2.49	2.49	2.50	2.52
	Liquefied petroleum gas	2.96	2.95	2.93	2.86	2.84	2.82	2.82	2.81	2.81	2.79
	CNG	1.97	1.88	1.89	1.81	1.84	1.76	1.80	1.75	1.65	1.66
LDV	Gasoline	3.45	3.40	3.35	3.29	3.23	3.15	3.05	3.01	2.96	2.89
	Diesel oil	3.71	3.71	3.69	3.66	3.61	3.53	3.43	3.40	3.36	3.36
	CNG	2.69	2.55	2.56	2.45	2.48	2.38	2.40	2.34	2.22	2.24
HDV	Gasoline	9.15	9.16	9.15	9.10	9.10	9.07	9.04	8.99	8.95	8.89
	Diesel oil	11.8	11.7	11.6	11.5	11.4	11.1	10.9	10.8	10.8	10.8
	CNG	13.0	12.5	12.7	12.3	12.7	12.2	10.9	10.7	9.4	10.2
Coach	Diesel oil	10.6	10.5	10.4	10.3	10.1	9.92	9.67	9.64	9.43	9.54
Urban Bus	Gasoline	NO	NO	NO	NO	NO	NO	9.4	9.39	9.38	9.34
	Diesel oil	16.1	16.0	15.9	15.6	15.4	15.0	14.9	14.8	14.8	14.7
	CNG	16.4	15.8	15.7	15.2	15.6	15.2	15.8	15.6	14.9	15.2
2-Wheeler	Diesel oil	1.55	1.53	1.58	1.62	1.59	1.59	1.61	1.62	1.61	1.57
Average		3.26	3.21	3.15	3.08	3.02	2.94	2.87	2.84	2.85	2.81
(1990=100%)		92%	91%	89%	87%	85%	83%	81%	80%	81%	80%

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 3-54. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific household surveys (ARE/SFSO 2005, 2012, 2017).

Table 3-54 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	2'956
LDV	167	164	148	112	77
2-Wheelers	764	688	712	746	765
	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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	stock in 1000 veh. (gasoline/bioeth.)									
PC	2'873	2'831	2'782	2'738	2'688	2'687	2'701	2'706	2'767	2'791
LDV	69	64	61	58	56	54	51	52	54	52
2-Wheelers	779	792	801	812	820	839	860	866	879	870
	starts per veh. per day									
PC	2.53	2.54	2.55	2.55	2.56	2.58	2.59	2.59	2.27	2.40
LDV	1.96	1.96	1.96	1.96	1.96	1.96	1.94	2.05	2.03	1.95

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 3-55.

- 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 2021 are shown in Table 3-56.

Table 3-55 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 3-56 Implied emission factors in 2021 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	937	110	0.33	182	6.7	0.017	6.7	0.11	6.7	0.15	1.9	NA
Biodiesel	801	94	0.28	155	5.7	0.017	5.7	0.11	5.7	0.15	1.6	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	520	0.91	2.3	NE	0.12	0.0016	833	1389	1034	195	NA	NA
Biodiesel	445	0.78	1.9	NE	0.10	0.0014	712	1187	883	167	NA	NA

Activity data (1A3c)

Table 3-57 shows the activity data of 1A3c taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-57 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel oil	TJ	451	431	410	390	388	387	385	383	382	380
Biodiesel	TJ	3.7	4.4	5.2	5.9	7.7	9.4	11	13	15	16
Total Railways	TJ	455	435	416	396	396	396	396	396	396	396
1990=100%		117%	112%	107%	102%	102%	102%	102%	102%	102%	102%
tonne-kilometers	Mio. km	11'061	11'812	12'313	12'431	12'447	11'665	11'776	11'673	11'500	11'696
passenger-kilometers	Mio. km	19'340	19'525	20'090	20'475	20'894	20'953	20'704	21'831	17'400	17'843

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 3-58 to Table 3-61 (FOEN 2015j).

Implied emission factors 2021 are shown in Table 3-62.

Table 3-58 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 3-59 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 3-60 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 3-61 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 3-62 Implied emission factors in 2021 for 1A3d Navigation.

1A3d Navigation	NO_X	NMVOC	SO_X	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ								
Gasoline	545	416	0.26	0.086	0.064	0.064	0.064	0.0032	8'751
Diesel oil	764	216	0.33	0.18	29	29	29	15	498
Gas oil	26	1.6	4.7	0.042	0.13	0.13	0.13	0.020	6.9
Biodiesel	653	185	0.28	0.16	25	25	25	13	426
Bioethanol	351	256	0.17	0.056	NA	NA	NA	NA	5'540

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	1'080	1'080	105	287	NA	NE
Diesel oil	0.91	2.3	0.12	0.0016	793	1'322	984	198	NA	NE
Gas oil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NE
Biodiesel	0.78	2.0	0.10	0.0014	678	1'130	841	169	NA	NE
Bioethanol	0.38	1.4	0.12	0.0017	696	696	68	185	NA	NE

Activity data (1A3d)

Table 3-63 shows the activity data of 1A3di taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-63 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	TJ	526	522	518	514	512	511	509	508	506	505
Diesel oil	TJ	872	874	876	878	873	867	862	857	851	847
Gas oil	TJ	156	154	153	151	150	149	148	147	146	145
Biodiesel	TJ	7.6	9.5	11	13	17	21	25	29	33	37
Bioethanol	TJ	1.6	2.3	3.1	3.9	6.3	8.6	11	13	16	18
Total Navigation	TJ	1'563	1'562	1'561	1'560	1'559	1'557	1'556	1'554	1'552	1'551
1990 = 100%		101%	101%	101%	101%	101%	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 3-33) and are based on different sources.

- For NO_x, the emission factor stems from the Factsheet Emission Factors Furnaces (FOEN 2015k).
- For the other main pollutants (NMVOC, SO_x, NH_3), the emission factors stem from the section “Gasturbinen; Erdgas” of SAEFL (2000). For NMVOC, it is assumed that NMVOC amount to 5 % of total VOC (i.e. CH_4 amounts to 95 % of total VOC).
- For PM2.5, PM10 and TSP, emission factors stem from Leupro 2012.
- For all the other pollutants, the emission factors are taken from the EMEP/EEA Guidebook (EMEP/EEA 2019, Table 3.28). The BC exhaust emission factor corresponds to 2.5 % of the PM2.5 emission factor.

Table 3-64 Emission factors of 1A3e for 2021.

1A3ei Pipeline transport	NO_X	NMVOC	SO_X	NH_3	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
	g/GJ								
Gas	19	0.10	0.50	0.60	0.10	0.10	0.10	0.0025	4.8

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	0.10	0.50	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 2022; Table 17e).

Table 3-65 Activity data of 1A3e.

1A3ei Pipeline transport	Unit	1990	1995	2000	2005	2010
Natural gas	TJ	560	310	340	1'070	830
1990=100%		100%	55%	61%	191%	148%

1A3ei Pipeline transport	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Natural gas	TJ	810	410	830	760	340	470	490	600	540	120
1990=100%		145%	73%	148%	136%	61%	84%	88%	107%	96%	21%

3.2.6.3 Category-specific recalculations for 1A3 Transport

- 1A3a/Memo item: An update of activity data in 1A3ai Domestic aviation and 1A3aii International aviation for the year 2020 leads to a recalculation of emissions of all pollutants for the year 2020.
- 1A3a/Memo item: Due to incorrect references in the calculation spreadsheets the emission factor of BC was wrong for 1A3a Domestic International Aviation in previous submissions and was corrected in this submission. This leads to a recalculation of BC emissions for the years 1980-2020.
- 1A3a: The calculations of non-exhaust (TSP, PM10, and PM2.5) emission factors was corrected. This leads to a recalculation of TSP, PM10 and PM2.5 non-exhaust emissions in category 1A3ai/aii Domestic aviation for the years 1980-2020.
- 1A3b: Based on newest available statistics updates in the activity data (mileage) for different vehicle categories have been done. This recalculation leads to changes for all pollutants for the years 1990-2020.
- 1A3b: The revision of the model for determining NMVOC emissions at gasoline stations in 1B2a Fugitive emissions from oil distribution leads to changes in total gasoline losses as the NMVOC lost are equivalent to gasoline losses. This amount of gasoline lost is part of the total amount of gasoline consumption reported in the Swiss overall energy statis-

tics. To keep consistency with this total amount of gasoline consumption a respective adjustment of activity data of gasoline consumption in 1A3b Road transportation was required.

- 1A3b: The emission factors in 1A3b Road transportation were adjusted to the HBEFA version 4.2 published in February 2022. This leads to a recalculation of emissions of all pollutants for the years 1990-2020.
- 1A3b: The emission factors for PCB in each subcategory of 1A3b Road transportation were set equal to the value of 1990 for all years prior to 1990. Previously, the emission factors for the years prior to 1990 were zero. This recalculation leads to changes in PCB emissions for the years 1980 to 1989.
- 1A3b/c/d: Emission factors of Pb and SO_x in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii, 1A5b as well as those in 1A3b Road transportation were revised for the years 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).
- 1A3d/Memo item: Recalculation in the reported amount of diesel oil consumption for international shipping on the river Rhine for the years 1997, 2001-2003, 2005, 2008, 2010, 2012.

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 3-66 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 3-67 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 3-41 to Table 3-43 (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 2021 for all pollutants are shown in Table 3-68.

Table 3-68 Implied emission factors 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry) in 2021.

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	178	1'317	0.26	86	NA	NE	NA	NE	NA	NE	NA	NE
Bioethanol	75	434	0.17	61	NA	NE	NA	NE	NA	NE	NA	NE
1A4bii Other sectors (mobile): Residential												
Gasoline	146	852	0.26	92	NA	NE	NA	NE	NA	NE	NA	NE
Bioethanol	85	432	0.17	61	NA	NE	NA	NE	NA	NE	NA	NE
1A4cii Other sectors (mobile): Agriculture/forestry/fishing												
Gasoline	177	1'379	0.26	82	NA	0.10	NA	0.70	NA	1.05	NA	0.0082
Diesel oil	348	40	0.33	160	29	0.10	29	0.70	29	1.05	19	0.0082
Biodiesel	298	34	0.28	137	24	0.10	24	0.70	24	1.05	16	0.0082
Bioethanol	76	529	0.17	56	NA	0.10	NA	0.70	NA	1.05	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	26'732	0.59	2.4	0.21	2'840	947	947	92	315	NE	NE
Bioethanol	15'853	0.38	1.5	0.13	1'838	613	613	60	204	NE	NE
1A4bii Other sectors (mobile): Residential											
Gasoline	25'475	0.59	2.4	0.21	2'843	953	953	93	315	NE	NE
Bioethanol	15'867	0.38	1.5	0.13	1'834	615	615	60	203	NE	NE
1A4cii Other sectors (mobile): Agriculture/forestry/fishing											
Gasoline	24'656	0.59	2.2	0.19	2'650	1'043	1'043	102	294	NE	NE
Diesel oil	201	0.91	2.0	0.11	1'403	647	1'079	803	172	NE	NE
Biodiesel	172	0.78	1.7	0.09	1'199	553	922	686	147	NE	NE
Bioethanol	15'083	0.38	1.4	0.12	1'668	698	698	68	185	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 3-69 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 3-69 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A4aii Other sectors (mobile): Commercial/institutional	TJ	274	267	261	254	253	252	252	251	250	249
Gasoline	TJ	273	266	260	253	251	250	248	247	245	243
Bioethanol	TJ	0.48	0.72	0.95	1.19	1.9	2.6	3.3	4.0	4.7	5.4
1A4bii Other sectors (mobile): Residential	TJ	161	160	159	157	157	157	156	156	155	155
Gasoline	TJ	160	159	158	156	155	154	153	152	151	150
Bioethanol	TJ	0.43	0.64	0.85	1.06	1.7	2.3	2.9	3.6	4.2	4.8
1A4cii Other sectors (mobile): Agriculture/forestry/fishing	TJ	5'554	5'535	5'517	5'498	5'487	5'477	5'466	5'456	5'445	5'433
Gasoline	TJ	641	616	592	568	551	535	519	503	486	473
Diesel oil	TJ	4'870	4'864	4'859	4'853	4'835	4'817	4'800	4'782	4'764	4'742
Biodiesel	TJ	42	53	63	74	96	118	140	162	184	205
Bioethanol	TJ	1.31	2.0	2.6	3.3	4.8	6.4	8.0	9.6	11	12

3.2.7.3 Category-specific recalculations for 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

- 1A4a/b/cii: Emission factors of Pb and SO_x in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii, 1A5b as well as those in 1A3b Road transportation were revised for the years 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).

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 3-70 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 3-71 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 1990–2021. 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 pro-

cesses (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 1990-2021.
- Implied emission factors 2021 are shown in Table 3-72.

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 2021 are shown in Table 3-72.

Table 3-72 Emission factors for 1A5b Other (Military, mobile) in 2021.

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	126	701	0.26	0.092	NA	NA	NA	NA	NA	NA	NA	NA
Diesel oil	289	26	0.33	0.16	7.5	10	7.5	67	7.5	101	3.7	NA
Biodiesel	247	22	0.28	0.13	6.4	10	6.4	67	6.4	101	3.2	NA
Bioethanol	65	279	0.17	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	24'654	0.59	2.4	0.21	0.0028	957	957	93	314	NE	NE
Diesel oil	133	0.91	1.9	0.10	0.0014	614	1'023	761	167	NE	NE
Biodiesel	113	0.78	1.7	0.088	0.0012	525	875	651	143	NE	NE
Bioethanol	15'629	0.38	1.5	0.13	0.0018	618	618	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 DDPS and provided to FOEN (VTG 2011, DDPS 2022).

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 3-73 shows activity data of both categories 1A5bi and 1A5bii.

Table 3-73 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Military aviation											
Jet kerosene	TJ	1'527	1'542	1'615	1'567	1'627	1'469	1'457	1'303	1'365	1'301
Military non-road		275	275	275	275	274	273	272	271	270	269
Gasoline	TJ	18	17	17	17	17	16	16	16	16	16
Diesel oil	TJ	255	255	254	254	252	250	248	246	244	243
Biodiesel	TJ	2.2	2.8	3.3	3.9	5.0	6.1	7.2	8.3	9.4	11
Bioethanol	TJ	0.046	0.069	0.092	0.11	0.18	0.25	0.31	0.38	0.45	0.51

3.2.8.3 Category-specific recalculations for 1A5b Other, mobile (Military)

- 1A5b: Emission factors of Pb and SO_x in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii, 1A5b as well as those in 1A3b Road transportation were revised for the year 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).

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 nonexhaust emissions from coal handling only. There is no production of solid fuels in Switzerland.

Table 3-74 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 3-75 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 nonexhaust 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 literature BC-factors are available for coal turnover. It is assumed that coal persists of 60 % of carbon and that the share is equal independent of its size.

Table 3-76 Emission factors in 1B1 Fugitive emissions from solid fuels in 2021.

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 2022).

Table 3-77 Activity data in 1B1 Fugitive emissions from solid fuels.

Amount of	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

Amount of	Amount of	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	1990 to 2021
1B1a Coal handling	Other bituminous coal imported	t	206'436	222'598	233'487	213'788	197'752	189'824	176'005	156'612	151'282	152'699	-71%

3.3.1.3 Category-specific recalculations for 1B1 Fugitive emissions from solid fuels

- There are no category-specific recalculations for 1B1 Fugitive emissions from solid fuels.

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. Crude oil is imported by underground pipelines only. Fugitive emissions from oil industry in Switzerland result exclusively from the refineries transforming crude oil into liquid fuels and the several gasoline handling stations and storage tanks. At the beginning of 2015, one of the two refineries ceased operation and there is only one refinery left.

Table 3-78 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 3-79 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 1B2a fugitive emissions from oil.

NFR code	Source category	Pollutant	Identification criteria
1B2aiv	Fugitive emissions oil: refining / storage	SOx	T2
1B2av	Distribution of oil products	NMVOC	L1, T1

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) storage tank filling at the gasoline station and finally (c) the refuelling process. The model is also based on information from several gasoline station operators and Swiss cantons. This information entails a large number of 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 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 kerosene storage tanks follows a tier 3 methodology using facility-specific emission estimates available on a yearly basis since 2017. These estimates are extrapolated 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 2023/1B2aiv_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 2023/1B2aiv). This emission factor is used for all the years until 1995. For the years 2007-2017 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 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 kerosene storage tank facilities: Emission factors for storage tanks are estimated by Carbura based on two studies, one for gasoline storage tanks (Carbura 2021) and one for kerosene storage tanks (Carbura 2022). 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 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 kerosene causes significantly lower NMVOC emissions than gasoline due to the significantly lower vapour pressure.

Table 3-80 NMVOC and SO_x emission factors in 1B2a – Oil, for 2021. 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	0.83	NA
1B2av Gasoline station	Gasoline sold	g/GJ	22	NA
1B2av Kerosene storage tanks	Kerosene imported and produced	g/GJ	0.12	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 2022) in their annual statistics and also reported in the Swiss overall energy statistics (SFOE 2022).

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 2022), corrected for consumption of Liechtenstein.

The activity data for 1B2av fugitive emissions from kerosene storage tanks is the sum of total amount of kerosene imported and produced in Swiss refineries. The amount of kerosene production in Swiss refineries has decreased steadily since 2005 and is zero in the year 2021.

Table 3-81 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 Kerosene distribution	Kerosene imported and produced	TJ	48'160	54'739	68'310	51'004	61'815

1B2a Fugitive emissions attributed to oil	Amount of	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	1990 to 2021
1B2ai Transport of crude oil by pipelines	Refineries	Number	2	2	2	1	1	1	1	1	1	1	-50%
1B2aiv Refining and storage	Crude oil	kt	3'455	4'935	4'975	2'836	3'006	2'889	3'076	2'789	2'857	2'339	-25%
1B2av Gasoline distribution	Gasoline sold	TJ	124'386	118'717	113'956	105'664	102'367	99'223	97'654	96'850	85'769	87'628	-44%
1B2av Kerosene distribution	Kerosene imported and produced	TJ	67'513	69'248	68'219	70'857	73'853	75'027	80'262	83'698	34'816	31'736	-34%

3.3.2.3 Category-specific recalculations for 1B2a - Oil

- 1B2av: The model for determining NMVOC emission factors at gasoline stations in 1B2a Fugitive emissions from oil distribution was completely revised. New emission factors were determined for the years 1980, 1990, 2002, 2010, 2020 and forecasts. This leads to slightly lower NMVOC emissions in 1990 (around 0.3kt) and to higher emissions from

1993 onwards. In 2020, the difference amounts +1.1kt, which corresponds to approx. 1% of total NMVOC emissions.

- 1B2av: Based on a new study (Carbura 2022), NMVOC emissions from storage tanks for jet kerosene were determined and modelled for the entire time series 1990-2050. The emissions are significantly smaller compared to those from gasoline storage tanks or gasoline stations.

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 are only occurring for the years of operation of the single production plant in Switzerland from 1985–1994. Other emissions in this source category occur from natural gas transmission and distribution.

Table 3-82 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 3-83: Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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.

Production of natural gas

Emissions from natural gas production occur only between 1985 and 1994 because the only production site was closed in 1994. According to the decision tree in the EMEP/EEA guidebook (EMEP/EEA 2019), for 1B2ai and 1B2b (Fugitive emissions - Exploration production transport) emissions resulting from natural gas production under 1B2b Natural gas may be estimated using a Tier 2 approach where technology specific activity data and specific emission factors are available (i.e., onshore facility producing natural gas only). However, since NMVOC emissions are also relevant for greenhouse gas emission reporting, it was decided to choose the highest estimate available, which is the upper value of the 2006 IPCC Guidelines Tier 1 emission factor for fugitive emissions from gas production in developed countries (Table 4.2.4 in Chap. 4 of IPCC 2006).

Transport of natural gas

For emission calculations concerning natural gas transport (including transmission, distribution and other leakage), country-specific emission factors and activity data are available. Emissions are calculated with a country-specific method which first assesses the losses of natural gas in the gas network including pipelines, fittings and gas devices, as these data represent the activity data. Based on the gas losses, NMVOC emissions are calculated with country-specific emission factors which reflect the composition of the gas lost.

Source category 1B2b covers emissions from gas transport and includes emissions from transport in pipelines including the transit pipeline and the single compressor station. Emissions comprise leakages from gas pipelines, small-scale damages, maintenance work and leakages of pipeline fittings. Gas storages are considered as components of the distribution network and the respective emissions are included in this source category. Emissions from the gas distribution pipelines and network components (e.g. control units, fittings and gas meters) as well as fugitive emissions at the end users are also included. Emission calculations for the gas distribution network are based on the length, material and pressure of the gas pipelines. Fugitive emissions at the end users arise from on-site and indoor pipelines and the permanent leakiness of the different gas appliances in households, industry and natural gas fuelling stations. In the calculations, the number and kind of end users and connected gas appliances are considered.

This method follows a Tier 2 approach according to the decision tree in the EMEP/EEA guidebook (EMEP/EEA 2019). Emissions are provided by Quantis (2014) based on data from accident reports and emission reports from the gas pipeline operators. This method follows a Tier 2 approach according to the decision tree in the EMEP/EEA guidebook (EMEP/EEA 2019).

Note that losses from consumption in households and industry are already included in the losses from gas transmission reported in source category 1A.

Emission factors (1B2b)

Production of natural gas

For natural gas production occurring in the years 1985-1994, NMVOC default emission factors are taken from the 2006 IPCC Guidelines (IPCC 2006) as documented in the internal emission database documentation (EMIS 2023/1B2b Gasproduktion).

Transport of natural gas

Emission factors of NMVOC for gas transport (transmission and distribution) as well as emissions from accidents in the gas pipeline are based on a study by Quantis (2014). They are calculated based on the average NMVOC concentrations of natural gas and its average net calorific value in Switzerland as described in Quantis (2014) and in the EMIS database (EMIS 2023/1B2b Diffuse Emissionen Erdgas).

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

Since Submission 2017, the net calorific value of natural gas in Switzerland is evaluated annually by the Swiss Gas and Water Industry Association (SGWA).

Table 3-84 Emission factors in 1B2b – Natural gas, for 2021.

1B2b Fugitive emissions attributed to natural gas	Per amount of	Unit	NMVOC
1B2biv Transmission, losses	Natural gas	g/GJ	1'409
1B2bv Distribution, losses	Natural gas	g/GJ	1'409
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 2022)

Transport of natural gas

For gas transmission, distribution and other leakage, the activity data have been reassessed in a study by Quantis (2014) and are documented in the EMIS database (EMIS 2023/1B2b Diffuse Emissionen Erdgas). The activity data represent the amount of natural gas lost from the gas network.

Information regarding the gas transport and distribution network from the Swiss Gas and Water Industry Association (SGWA) is used to derive the activity data (see Quantis 2014 and EMIS 2023/1B2b Diffuse Emissionen Erdgas).

The calculation of losses from distribution network follows a detailed country-specific approach that considers losses from the pipeline network as well as losses at the end users.

- The calculated gas losses from the pipeline network depend on the length, material and pressure of the pipelines. Gas losses due to permanent leakiness, small-scale damages, network maintenance and the network components are evaluated separately. As no applicable loss rates are available for the network compounds in Switzerland (installed control units, fittings, storage systems and gas meters), a fixed percentage is applied to the permanent gas losses. This amount is added to the permanent gas losses.
- Regarding the end users, gas losses from on-site and indoor pipelines as well as gas losses due to the permanent leakiness of gas appliances are evaluated. Pipeline loss rates apply to the number of households, industrial users and gas fuelling stations separately. Regarding the gas appliances, different loss rates are assigned to the number of gas heating systems, gas cooking stoves and gas fuelling stations.
- For some (earlier) years in the time series, sufficient input data are not available to calculate the gas losses. For these years, polynomial interpolations are applied to assess the activity data. Depending on the process, a second, third or fourth order polynomial interpolation is applied.

For significant emission events due to accidents the Swiss Pollutant Release and Transfer Register (PRTR) is considered. So far, two events have been reported by the transit pipeline operator, one in 2010 and one in 2011.

Table 3-85 Activity data of 1B2b – 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	28'226	30'874	32'571	33'491	34'595
1B2bv Distribution, losses	Natural gas	GJ	710'246	817'028	655'267	512'036	449'418
1B2bvi Other Leakage, losses	Natural gas	GJ	NO	NO	NO	NO	35'444

1B2b Fugitive emissions attributed to natural gas	Amount of	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	1990 to 2021
1B2bii Production	Natural gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-
1B2biv Transmission, losses	Natural gas	GJ	34'483	34'852	35'125	35'468	35'743	35'884	35'809	36'096	36'007	35'784	27%
1B2bv Distribution, losses	Natural gas	GJ	435'545	399'993	389'310	388'251	390'185	383'203	377'827	376'657	374'028	371'708	-48%
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

- 1B2b: Small recalculation, as fewer decimal places were used for activity rate and emission factors of NMVOC to calculate fugitive emissions from natural gas distribution network for all years.

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 3-86 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 3-87: Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 2023/1B2c 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 2020 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 3-88 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 3-88 Emission factors in 1B2c – Venting and flaring, for 2021.

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 3-89 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	1990 to 2021
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 recalculation due to rounding of emission factors for 1B2c Flaring oil for the years 2016-2020.
- 1B2c: Recalculation for CO emission factor for 1B2c Flaring Oil due to a mistake in previous submission.

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 2021 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 important sources for Cd and Hg emissions 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, total NMVOC emissions from 2 Industrial processes and product use show a considerable decrease between 1990 and 2004 with a weaker decreasing trend 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 2021, 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 2D3d 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 2021, by emissions from paint application in construction and on wood.

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 2021 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 1990–2021. In addition, general technological improvements and post-combustion installations contribute to further emission reductions.

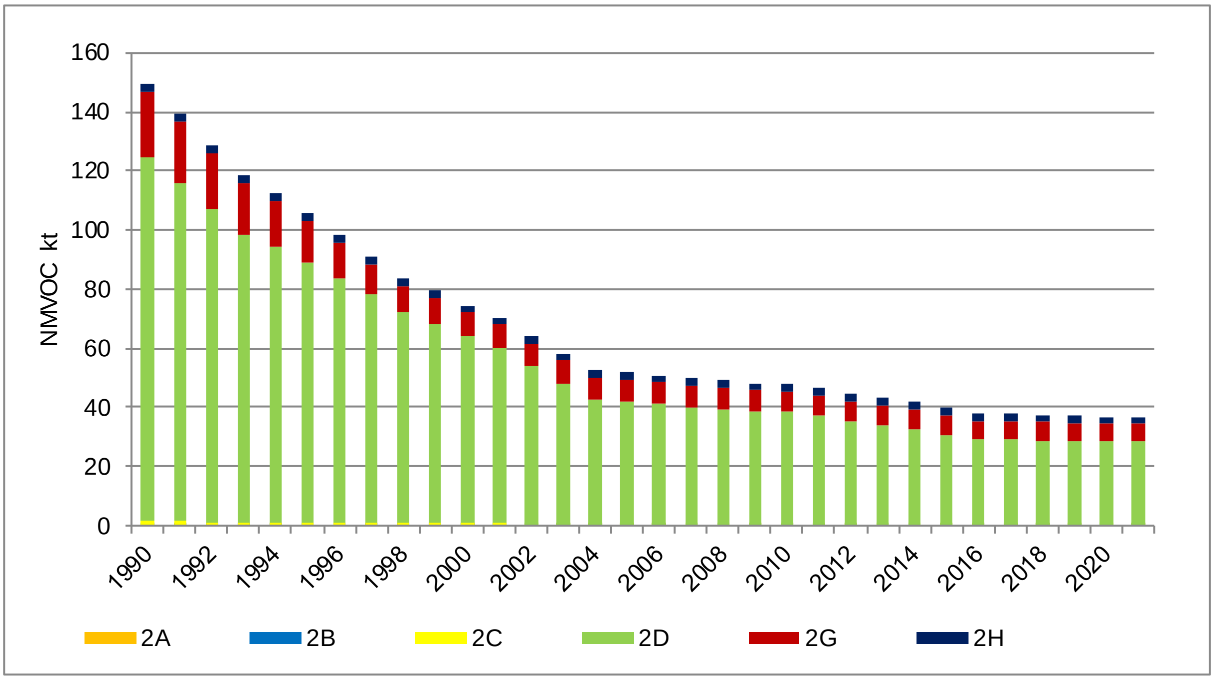


Figure 4-1 Switzerland’s NMVOC emissions from industrial processes and product use by source categories 2A-2D and 2G-2H between 1990 and 2021. The corresponding data table can be found in Annex A7.3.

4.1.2 Overview and trend for SO_x

According to Figure 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 2019-2021. 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 2021, 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 2021. In 2021, 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.

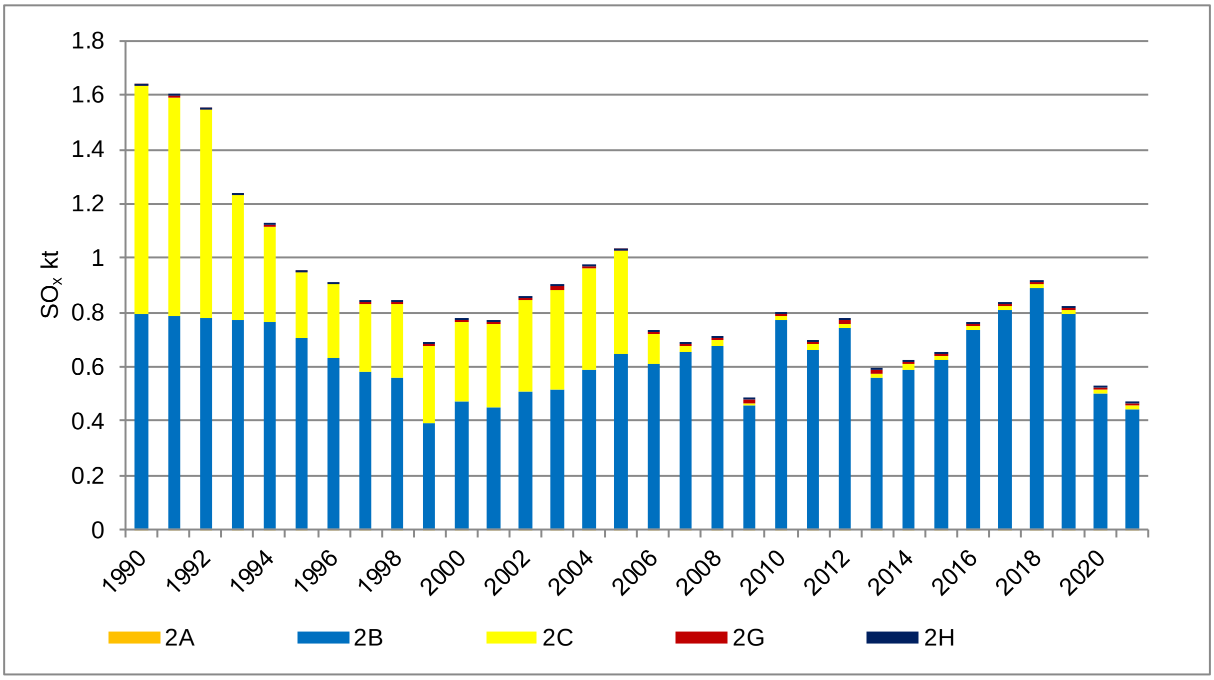


Figure 4-2 Switzerland's SO_x emissions from industrial processes and product use by source categories 2A–2C and 2G-2H between 1990 and 2021. The corresponding data table can be found in Annex A7.3.

4.1.3 Overview and trend for PM2.5

According to Figure 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 2021, 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 2021. 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 show a decreasing trend since then. In 1990, 2G emissions were dominated by tobacco use. In 2021, tobacco use is still the major emission source but also the use of fireworks contributed 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.

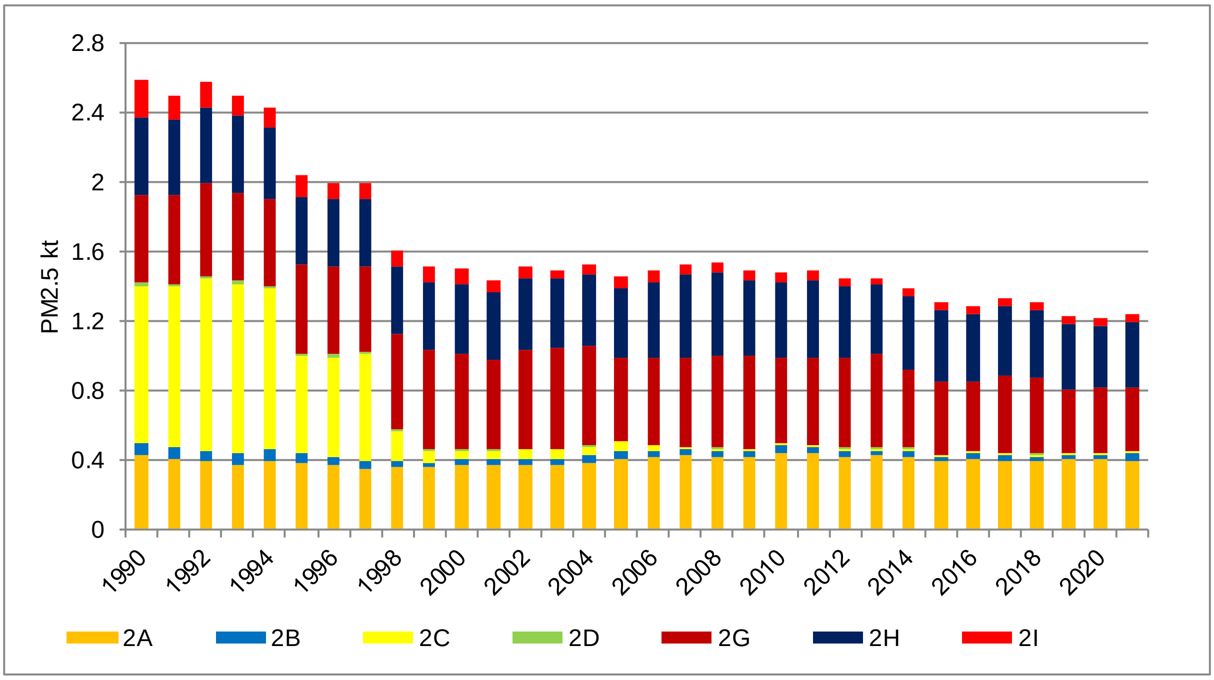


Figure 4-3 Switzerland's PM2.5 emissions from industrial processes and product use by source categories 2A-2D and 2G-2I between 1990 and 2021. The corresponding data table can be found in Annex A7.3.

4.2 Source category 2A – Mineral products

4.2.1 Source category description of 2A Mineral products

Table 4-1 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 4-2 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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	L1, L2
2A5a	Quarrying and mining of minerals other than coal	PM2.5	L1, T1, L2, T2
2A5a	Quarrying and mining of minerals other than coal	PM10	L1, T1, 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 2023/2A1. 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 4-3 Emission factors for blasting operations of 2A1 Cement production in 2021.

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 2023/2A1_Zementwerke übriger Betrieb). From 2008 onwards, they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Table 4-4 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Clinker	kt	3'368	3'415	3'502	3'195	3'296	3'279	3'239	3'227	3'129	3'227

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 2023/2A2). 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 2023/2A5a). 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 4-5 Emission factors of 2A5a Gravel plants and Plaster production in 2021.

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 4-6 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gravel plants	kt gravel	49'780	53'940	53'090	50'610	52'750	51'480	49'880	54'060	54'570	54'313
Plaster production	kt rocks	271	213	166	140	148	146	152	149	122	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 2023:

- 2A5a: The last year's extrapolated activity data of 2A5a Gravel plants for 2020 has been 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 4-7 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 4-8 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 2B Chemical Industry.

NFR code	Source category	Pollutant	Identification criteria
2B5	Carbide production	SOx	L1, T1, L2, T2
2B10a	Chemical industry: other	SOx	L2, 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 2023/2B1.

Emission factors (2B1)

The NH_3 emission factor per tonne of ammonia produced is confidential but available to re-viewers 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 4-9 Emission factor for 2B1 Ammonia production in 2021.

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 1990-2021. 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 2023/2B2).

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 2023/2B5).

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 4-10 Emission factor for 2B5 Carbide production in 2021.

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 2023/2B10a).

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 2023/2B10 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 4-11 Emission factors of 2B10a Chemical industry: Other in 2021.

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 4-12 Activity data of 2B10a Chemical industry: Other.

2B10a Chemical industry: Other	Unit	1990	1995	2000	2005	2010
Ammonium nitrate production	kt	C	C	C	C	C
Chlorine gas production	kt	C	C	C	C	C
Acetic acid production	kt	30	27	24	8.4	20
Ethylene production	kt	C	C	C	C	C
Sulfuric acid production	kt	C	C	C	C	C
Niacin production	kt	C	C	C	C	C
PVC production	kt	43	43	NO	NO	NO

2B10a Chemical industry: Other	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Ammonium nitrate production	kt	C	C	C	C	C	C	C	NO	NO	NO
Chlorine gas production	kt	C	C	C	C	C	C	C	C	C	C
Acetic acid production	kt	12	C	C	C	C	C	C	C	C	C
Ethylene production	kt	C	C	C	C	C	C	C	C	C	C
Sulfuric acid production	kt	C	C	C	C	C	C	C	C	C	C
Niacin production	kt	C	C	C	C	C	C	C	C	C	C
PVC production	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 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 2023/2B10 PVC-Produktion).

Activity data

The annual amount of PVC produced is based on data from industry and expert estimates documented in EMIS 2023/2B10 PVC-Produktion (see Table 4-12).

4.3.3 Category-specific recalculations in 2B Chemical industry

The following recalculations were implemented in submission 2023:

- 2B5: The emission factors for SO_x, PM2.5, PM10 and TSP of source category 2B5 Silicon carbide production were updated for 1990–2012, 1990–2020 and 1990–2008, 2011, 2020, respectively, based on industry data and information.

4.4 Source category 2C – Metal production

4.4.1 Source category description of 2C Metal production

Table 4-13 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 4-14 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 2C Metal Production.

NFR code	Source category	Pollutant	Identification criteria
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 2023/2C1).

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 4-15 Emission factors 2C1 Iron and steel production in 2021. 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 4-16 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Iron production,											
electric melting furnace	kt	34	34	33	28	26	27	26	18	15	16
other processes	kt	46	45	43	37	34	35	34	24	20	22
Steel production,											
electric arc furnace	kt	1'252	1'231	1'315	1'296	1'238	1'270	1'291	1'130	1'125	1'294
other processes	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
rolling mill	kt	1'162	1'126	1'176	1'144	1'085	1'138	1'160	1'037	1'031	1'104

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 2023/2C3).

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 2021.

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 4-17 Activity data for the 2C3 Aluminium production.

2C3 Aluminium production	Unit	1990	1995	2000	2005	2010
	kt	87	21	36	45	NO

2C3 Aluminium production	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	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 2023/2C7a) 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 4-18 Emission factors for 2C7a Foundries of non-ferrous metals in 2021. 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 4-19 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Foundries of non-ferrous metals	kt	6.6	6.4	9.5	8.9	9.0	8.0	6.8	6.4	5.1	7.5

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 2023/2C7c) 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 4-20 Emission factors for 2C7c Other metal production: Battery recycling and Galvanizing in 2021. 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 2023/2C7c_Batterie-Recycling, EMIS 2023/2C7c_Verzinkereien).

Activity data of battery recycling are confidential. These data are available to reviewers on request.

Table 4-21 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Galvanazing plants	kt	92	92	92	92	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

The following recalculations were implemented in submission 2023:

- 2C7c: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of source category 2C7c Galvanizing plants have changed from 2013 onwards.

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 4-22 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 wood and car repairing
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 4-23 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 2D Other Solvent Use.

NFR code	Source category	Pollutant	Identification criteria
2D3a	Domestic solvent use including fungicides	NMVOC	L1, T1, L2, T2
2D3b	Road paving with asphalt	NMVOC	L1, T1, L2, T2
2D3d	Coating applications	NMVOC	L1, T1, L2, T2
2D3e	Degreasing	NMVOC	T1, T2
2D3g	Chemical products	NMVOC	L1, T1, L2, T2
2D3h	Printing	NMVOC	L1, T1, L2
2D3i	Other solvent use	NMVOC	L1, L2

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 and including the previous submission, 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 2023/2D3a) 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 is 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 4-24 Emission factors of 2D3a Domestic solvent use including fungicides in 2021.

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 2022c).

Table 4-25 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	inhabitants	7'997'000	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

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 2023/2D3b. 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 4-26 Emission factors of 2D3b Road paving with asphalt in 2021.

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 4-27 Activity data of 2D3b Road paving with asphalt.

2D3b Road paving with asphal	Unit	1990	1995	2000	2005	2010
Asphalt concrete	kt	5'500	4'800	5'170	4'780	5'250

2D3b Road paving with asphal	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Asphalt concrete	kt	4'770	4'770	5'260	4'850	4'710	5'260	5'180	5'210	4'910	4'960

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 2023/2D3c. 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 4-28 Emission factors of 2D3c Asphalt roofing in 2021.

2D3c Asphalt roofing	Unit	NMVOC	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
Asphalt roofing	kg/t sheeting	4.9	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 4-29 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Asphalt roofing	kt sheeting	74	75	75	75	76	76	76	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. 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 2021, 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 2023/2D3d). 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 4-30 Emission factors of 2D3d Coating applications in 2021.

2D3d Coating applications	Unit	NMVOC
Paint application, construction	kg/t paint	61
Paint application, households	kg/t paint	86
Paint application, industrial	kg/t paint	180
Paint application, wood	kg/t paint	315
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 2023/2D3d). 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: As a consequence of the comprehensive assessment of all coating applications and the paint production in the course of the previous and the latest submission, the amount of paint applied in construction was adjusted considerably downwards. It seemed that also plasters have been included in the activity data of 1990 so far. Still, the paint consumption in construction shows a substantial reduction compared to 1990 levels. The increasing tendency in paint application between 2001 and 2010 and the drop afterwards can be explained to a certain extent by the evolution in the 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 4-31 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Paint application, construction	kt	52	50	49	49	47	46	46	45	45	46
Paint application, households	kt	11	11	10	10	10	10	10	10	10	10
Paint application, industrial	kt	8.0	7.9	7.8	7.6	7.5	7.5	7.5	7.5	7.5	7.5
Paint application, wood	kt	13	13	11	10	9.5	9.3	9.2	9.0	9.0	9.0
Paint application, car repair	kt	1.4	1.2	1.1	0.97	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. From the latest submission onwards, 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 2023/2D3e) 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 4-32 Emission factors of 2D3e Degreasing in 2021.

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 2023/2D3e). 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 4-33 Activity data of 2D3e Degreasing.

2D3e Degreasing	Unit	1990	1995	2000	2005	2010
Cleaning of electronic componen	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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cleaning of electronic componen	kt	0.79	0.69	0.59	0.49	0.38	0.28	0.18	0.18	0.18	0.18
Degreasing of metal	kt	2.1	1.9	1.8	1.6	1.4	1.3	1.1	1.1	1.1	1.1
Other industrial cleaning	kt	1.3	1.4	1.4	1.5	1.5	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 2023/2D3f) 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 4-34 Emission factors of 2D3f Dry cleaning in 2021.

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 4-35 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Solvent	kt	0.074	0.072	0.072	0.071	0.071	0.070	0.070	0.069	0.069	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 2023/2D3g).

Although asphalt roofing materials are produced in Switzerland, there is no asphalt 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 are mainly provided by industry associations, i.e. for

- fine chemicals production, pharmaceutical production and handling and storing of solvents: Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries)
- paint and ink production: Swiss association for coating and paint applications (VSLF) and the Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV)
- polyurethane processing: Swiss plastics association
- polyester processing: Swiss polyester association
- tanning of leather (ceased production in 2015): Swiss leather tanning association.

For the other processes in source category 2D3g, data are based on information from the industry (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 4-36 Emission factors of 2D3g Chemical products in 2021.

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	7.2
Polyester processing	kg/t polyester	50
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 industry associations, the Swiss Federal Office of Statistics and Swiss foreign trade statistics, i.e. for

- fine chemicals production and handling and storing of solvents: Swiss Federal Office of Statistics
- pharmaceutical production: Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries)
- paint and ink production: Swiss association for coating and paint applications (VSLF) and Swiss Organisation for the Solvent Recovery of Industrial Enterprises in the Packaging Sector (SOLV)
- polyurethane processing: Swiss plastics association
- polyester processing: Swiss polyester association
- polystyrene processing: Swiss foreign trade statistics (annual net import figures)
- tanning of leather: Swiss leather tanning association.

For the other processes in source category 2D3g data are based on information from the industry 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 4-37 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	36	54	70	83
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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fine chemicals production	prod. index	297	295	293	291	289	286	284	282	280	278
Glue production	kt	89	91	94	97	100	102	105	106	107	108
Handling and storing of solvents	prod. index	297	295	293	291	289	286	284	282	280	278
Ink production	kt	62	60	52	43	35	36	36	37	37	38
Paint production	kt	72	69	66	63	60	60	60	60	60	60
Pharmaceutical production	kt	30	30	29	29	29	29	29	29	28	28	28
Polyester processing	kt	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Polystyrene processing	kt	34	30	29	27	23	24	22	23	23	24
Polyurethane processing	kt	40	38	38	37	37	36	36	35	35	35
Production of adhesive tape	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PVC processing	kt	40	38	37	36	35	34	32	31	30	30
Rubber processing	tyres	80'000	81'000	82'000	83'000	84'000	85'000	86'000	87'000	88'000	88'533
Tanning of leather	employees	44	33	22	11	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 2023/2D3h).

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 4-38 Emission factors of 2D3h Printing in 2021.

2D3h Printing	Unit	NMVOC
Package printing	kg/t ink	130
Other printing	kg/t ink	280

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 4-39 Activity data of 2D3h Printing.

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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Package printing	kt	13	13	13	13	13	13	13	13	13	12
Other printing	kt	8.1	8.0	7.8	7.7	7.5	7.5	7.4	7.4	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 2023/2D3i). 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 4-40 Emission factors of 2D3i Other solvent use in 2021.

2D3i Other solvent use	Unit	NMVOC
Production of cosmetics	kg/employee	63
Production of paper and paperboard	g/t	14
Production of flavours and fragrances	kg/employee	30
Production of textiles	kg/t solvent	177
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 2022d). 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 4-41 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
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	1'383	1'386	1'390	1'393	1'396	1'362	1'056	1'034	967	1'024
Production of flavours and fragrances	employees	3'430	3'360	3'290	3'220	3'150	3'080	3'010	2'940	2'870	2'800
Production of textiles	t solvent	201	206	210	215	219	224	223	221	220	219
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	268	249	229	210	190	190	190	190	190	190
Scientific laboratories	employees	23'083	23'167	23'250	23'333	23'417	23'500	23'583	23'667	23'750	23'833
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 2023:

- 2D3a: Since in many spray applications the aerosol has both the function of the propellant and the solvent, a clear differentiation is often not possible at all. Therefore, the source category 2D3a Domestic use of spray cans was removed and its NMVOC emissions were integrated in the respective application sources, among other things, also in the two sources 2D3a Use of cleaning agents and 2D3a Domestic use of pharmaceuticals.
- 2D3a: Source category 2D3a Domestic use of cleaning agents, which includes also the use of cosmetics, toiletries and care products, was updated based on detailed sales figures for special cleaning and care products, waterproofing sprays and air refresheners from 2017–2020 and NMVOC contents, especially of aerosol cans, based on information from the largest contract manufacturer in Switzerland, resulting in revised NMVOC emission factor values from 2001 onwards.
- 2D3c: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of source category 2D3c Asphalt roofing have changed from 2012 onwards.
- 2D3d: The NMVOC emission factor values of source category 2D3d Coating application, household were revised for 1999–2020 as the propellants of the paint spray cans were now also considered for 2016.
- 2D3e: Due to the removal of the source category 2G Use of aerosol cans in commerce and industry (except for a residual batch of the commercial insecticide application), the aerosol of the spray applications of the categories "industry and technical products" as well as "automotive applications without coating" were now also taken into account in the three source categories of 2D3e Degreasing resulting in revised activity data and NMVOC emission factors for the entire time series.

- 2D3g: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of fine chemicals production, pharmaceutical production and handling and storage of solvents have changed from 2012 onwards as well as of ink production from 2017 onwards.
- 2D3h: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of package printing and other printing have changed from 2017 onwards.
- 2D3i: Activity data and NMVOC emission factor of source category 2D3i Production of paper and paperboard were updated for the years 2016–2021 and 2020, respectively, based on production figures and a survey of the association of Swiss paper, cardboard and foil manufacturers yielding revised activity data and emission factors for 2012–2020 and for 2008–2020, respectively.
- 2D3i: Activity data and NMVOC emission factor of source category 2D3i Production of flavours and fragrances were updated for the year 2021, based on industry information and VOC balances yielding revised activity data and emission factors from 2012 onwards.

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 4-42 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 4-43 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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, T1, L2, T2
2G	Other product use	PM10	L1, L2

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 2021 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 2023/2G).

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, for the latest submission, 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 industry, 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 4-44 Emission factors of 2G Other product use in 2021.

2G Other product use	Unit	NMVOC
Application of glues and adhesives	kg/t solvent	384
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	126
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	105
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 2023/2G) are displayed in Table 4-45. 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 4-45 Emission factors of all pollutants other than NMVOC from 2G Other product use in 2021. 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 industry, 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 2022), respectively. Activity data for concrete additives are extrapolated from 2017 onwards, based on the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020).

Table 4-46 Activity data of 2G Other product use.

2G Other product use	Unit	1990	1995	2000	2005	2010
Application of glues and adhesiv	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	38	40	51	46	56
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	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 cigarett	16'192	15'774	15'328	13'256	12'360

2G Other product use	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Application of glues and adhesiv	kt solvent	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3
Commercial and industrial use of cleaning agents	employees	4'262'667	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
Cosmetic institutions	employees	5'111	5'222	5'333	5'444	5'556	5'667	5'778	5'889	6'000	6'100
De-icing of airplanes	kt	3.8	3.1	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.5
De-icing of airport surfaces	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fireworks	kt	1.9	2.3	1.8	1.6	1.2	1.7	1.8	1.0	1.0	1.0
Glass wool enduction	kt	39	33	32	31	32	36	40	47	40	49
Hairdressers	employees	28'860	29'079	29'297	29'516	29'735	29'954	30'172	30'391	30'610	30'836
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	0.85	0.94	0.57	0.62	0.68	0.70	0.49	0.60	0.60	0.60
Rock wool enduction	kt	57	54	53	47	52	52	57	51	47	58
Underseal treatment and conservation of vehicles	kt	0.18	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	58'976	59'944	60'913	61'881	62'260	62'638	63'017	63'395	63'774	64'259
Use of concrete additives	kt	38	38	39	39	39	39	40	40	40	40
Use of cooling lubricants	kt	7.1	7.2	7.4	7.5	7.7	7.8	8.0	8.1	8.1	8.2
Use of lubricants	kt	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8
Use of pesticides	kt	2.2	2.3	2.2	2.2	2.2	2.0	2.1	2.1	2.2	2.2
Use of tobacco	Mio	12'705	12'162	10'628	10'284	10'702	10'702	10'318	10'030	10'414	10'222

4.6.3 Category-specific recalculations in 2G Other product use

The following recalculations were implemented in submission 2023:

- 2G: The activity data of source category 2G Use of concrete additives was updated for 2020 based on manufacturer data yielding revised values for the years 2013–2020.
- 2G: Due to the removal of the source category 2G Use of aerosol cans in commerce and industry (except for a residual batch of the commercial insecticide application), the aerosols of disinfection sprays were now also taken into account in the source categories 2G Health care other and 2G Medical practices resulting in revised activity data and NMVOC emission factors for the entire time series.
- 2G: The activity data and NMVOC emission factor values of source category 2G Hairdressers were revised completely based on enquiries and information from the largest contract manufacturer of aerosol cans in Switzerland and the European aerosol association.
- 2G: Since in many spray applications the aerosol has both the function of the propellant and the solvent, a clear differentiation is often not possible at all. Therefore, the NMVOC emissions of source category 2G Use of aerosol cans in commerce and industry (except for a residual batch of the commercial insecticide application) were integrated in the respective commercial and industrial application sources.

- 2G: Activity data and NMVOC emission factors of source categories 2G Use of cooling lubricants and 2G Use of lubricants were updated for the years 2003–2020, based on statistics of the association of the lubricants industry and data of the foreign trade statistics yielding revised activity data and emission factors from 2003 onwards.

4.7 Source categories 2H – Other

4.7.1 Source category description of 2H Other

Table 4-47 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 4-48 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 2H Other.

NFR code	Source category	Pollutant	Identification criteria
2H1	Pulp and paper industry	PM2.5	L1, T1, L2, T2
2H1	Pulp and paper industry	PM10	L2
2H2	Food and beverages industry	NMVOC	L1, T1, L2, T2
2H2	Food and beverages industry	PM2.5	L1, 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 2023/2H1).

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 4-49 Emission factors for 2H1 Pulp and paper industry in 2021. 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 4-50 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Sum of chipboard, fibreboard and cellulose production	kt	533	510	516	519	503	507	502	460	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 2023/2H2).

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 2023/2H2 Brot Produktion).

Table 4-51 Emission factors for 2H2 Food and beverages industry in 2021. Unit of PCDD/PCDF is in I-TEQ.

2H2 Food and beverages industry	Unit	NMVOC	NH_3
Breweries	g/m³ beer	250	NA
Spirits production	g/m³ 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/m³ wine	580	NA
Sugar production	g/t sugar	195	263

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/m³ beer	NA	NA	NA	NE	NA	NA	NA	NA	NA
Spirits production	g/m³ 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/m³ 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, 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 2022c) 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 2023/2H2 Brot Produktion).

Table 4-52 Activity data of 2H2 Food and beverages industry.

2H2 Food and beverages industry	Unit	1990	1995	2000	2005	2010
Breweries	m³	436'814	401'555	366'956	342'085	357'435
Spirits production	m³	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	m³	120'000	111'693	123'073	108'526	108'319
Sugar production	kt	147	129	219	197	241

2H2 Food and beverages industry	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Breweries	m³	354'293	339'348	345'861	346'214	348'171	346'300	365'900	367'500	340'400	338'200
Spirits production	m³	1'989	1'158	1'150	1'636	1'211	1'010	961	1'624	1'224	1'233
Bread production	kt	382	380	378	376	373	370	373	376	378	381
Meat smokehouses	kt	65	66	67	67	67	67	67	66	67	67
Roasting facilities	kt	110	120	119	125	127	131	141	148	161	172
Milling companies	kt	1'648	1'602	1'625	1'645	1'663	1'626	1'629	1'617	1'560	1'663
Wine production	m³	98'621	108'564	99'556	99'859	90'174	88'116	90'404	95'742	96'107	91'458
Sugar production	kt	286	245	344	261	240	299	246	273	226	199

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 4-53 Emission factors for 2H3 Other industrial processes in 2021.

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 explosive	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 2022).

Table 4-54 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Blasting and shooting	kt explosive	2.3	2.2	2.1	2.1	0.67	0.73	0.81	0.67	0.63	0.61

4.7.3 Category-specific recalculations in 2H Other

The following recalculations were implemented in submission 2023:

- 2H2 Meat smokehouses: Activity data have decreased by 0.37% (-241 t) in 2019 and increased by 0.36% (241 t) in 2020, respectively, due to changes in the underlying statistics for annual per capita meat consumption by the FSO.

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 4-55 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 4-56 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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, T2
2I	Wood processing	PM10	T1, 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 2023/2I Holzbearbeitung).

Emission factors (2I)

Emission factors of wood processing are based on an industry survey (EMPA 2004b).

Table 4-57 Emission factors for 2I Wood processing in 2021.

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 2022f).

Table 4-58 Activity data of 2I Wood processing.

2I Wood processing	Unit	1990	1995	2000	2005	2010
Wood processing	kt sawnwoo	1'168	827	901	853	774

2I Wood processing	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Wood processing	kt sawnwoo	606	564	634	626	622	578	597	598	623	664

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 Switzer-land 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 4-59. The PCB emission factors for demoli-tion/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 4-59 Emission factors for 2K Usage of PCBs in 2021.

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 4-60 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Transformers	t PCB	87	73	60	50	41	33	27	22	18	14
Large capacitors	t PCB	24	20	16	13	11	9.0	7.3	5.8	4.7	3.7
Small capacitors	t PCB	11	8.6	6.7	5.2	4.0	3.1	2.4	1.8	1.3	1.0
Anti-corrosive paints	t PCB	117	110	104	98	92	86	80	73	68	62
Joint sealants	t PCB	117	110	104	98	92	86	80	73	68	62
Demolition and renovation	t PCB	11	11	11	11	11	11	11	11	11	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 2023/2 F_2 L_NH3 aus Kühlanlagen). Emission factors are assumed constant over the entire time period (seeTable 4-61).

Table 4-61 Emission factors for 2L Ammonia in freezers in 2021.

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 2023/2 F_2 L_NH3 aus Kühlanlagen) (seeTable 4-62).

Table 4-62 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Freezers filling	t	278	283	287	292	295	298	301	304	307	310
Freezers storage	t	1'357	1'436	1'515	1'593	1'616	1'638	1'661	1'683	1'706	1'728

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 2023.

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 1990-2021 (see Figure 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-fertilizer 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).

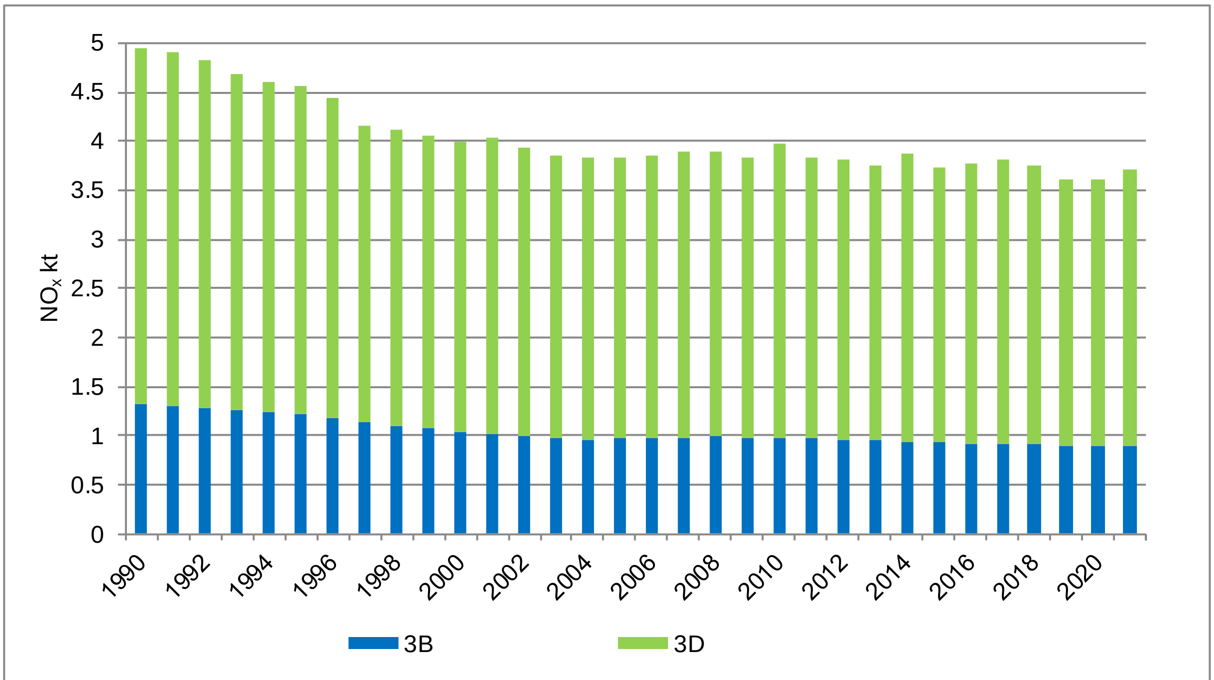


Figure 5-1 Switzerland's NO_x emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.1.

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. 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.

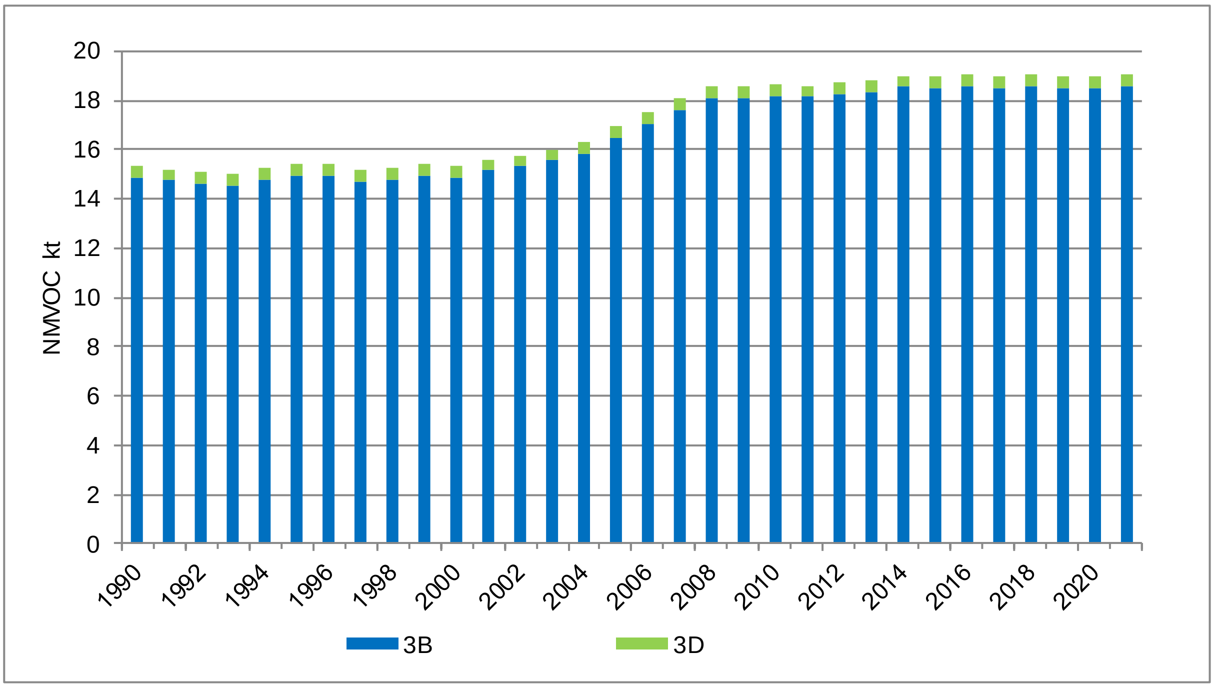


Figure 5-2 Switzerland's NMVOC emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.2.

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. While source category 3B Manure management is subject to little variation throughout the period 1990-2021, category 3D Crop production and agricultural soils shows a fluctuating and decreasing trend. Both categories are about equally important in the year 2021. 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 fertilizer 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).

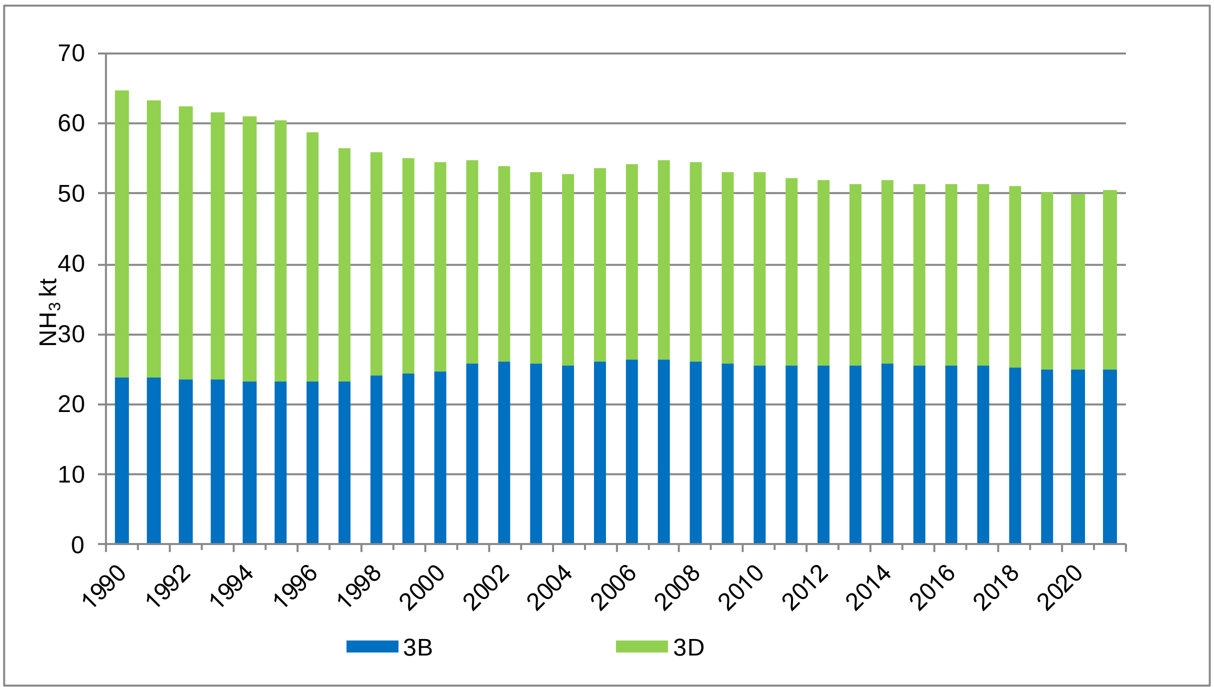


Figure 5-3 Switzerland's NH_3 emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.4.

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 5-1 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 5-2 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 3B, Manure Management.

NFR code	Source category	Pollutant	Identification criteria
3B1a	Manure management - Dairy cattle	NMVOC	L1, T1, L2, T2
3B1a	Manure management - Dairy cattle	NH3	L1, T1, L2, T2
3B1b	Manure management - Non-dairy cattle	NMVOC	L1, T1, L2, T2
3B1b	Manure management - Non-dairy cattle	NH3	L1, T1, L2, 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).

For nitrogen flux calculations, AGRAMMON uses nitrogen excretions of different livestock categories according to the Swiss fertiliser guidelines (Richner and Sinaj 2017). To take into account the varying milk yield level of dairy cattle, a linear correction factor also given in Richner and Sinaj (2017) was applied. 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 fertilization. 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. (2018, 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.

Table 5-3 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 5-4 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 5-3) roughly doubled because of animal welfare incentives and the considerable decrease of pig production. The share going to digesters increased from 0.6 % to 6.6 % 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 5-5 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 5-3 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 5-4 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 5-5 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 on which the emission factors in the EMEP/EEA guidebook (EMEP/EEA 2016, unchanged in EMEP/EEA 2019) are based show 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. 2023). 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. Emission measurements in the experimental dairy housing while the animals are grazing are being planned.

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 for various feeding strategies as well as for milk yield of dairy cows (Kupper et al. 2022).

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 5-6 and Table 5-7. 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 5-6 and Table 5-7, but are given in the tables of chp. 5.3.2.

Table 5-6 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**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
3B1a	Dairy cattle	kg/animal	17.9	18.1	18.3	18.5	18.6	18.8	18.9	19.1	19.1	19.1
3B1b	Non-dairy cattle	kg/animal	16.3	16.3	16.4	16.5	16.3	16.1	15.9	15.7	15.7	15.7
3B1c	Young cattle	kg/animal	5.8	5.9	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9
3B2	Sheep	kg/animal	1.2	1.2	1.2	1.1	1.1	1.2	1.2	1.2	1.2	1.2
3B3	Swine	kg/animal	3.3	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	2.0	1.9	1.9	1.8	1.8	1.8	1.9	1.9	1.9	1.9
3B4c	Deer	kg/animal	3.5	3.5	3.4	3.3	3.4	3.4	3.5	3.5	3.5	3.5
3B4d	Goats	kg/animal	2.0	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.8
3B4e	Horses	kg/animal	8.2	8.2	8.2	8.3	8.3	8.2	8.2	8.2	8.2	8.2
3B4f	Mules and asses	kg/animal	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
3B4gi	Layers	kg/animal	0.21	0.20	0.20	0.19	0.19	0.18	0.18	0.18	0.18	0.18
3B4gii	Broilers	kg/animal	0.073	0.070	0.067	0.063	0.063	0.064	0.064	0.064	0.064	0.064
3B4giii	Turkey	kg/animal	0.30	0.30	0.31	0.32	0.30	0.29	0.28	0.26	0.26	0.26
3B4giv	Growers	kg/animal	0.080	0.079	0.077	0.076	0.074	0.073	0.072	0.070	0.070	0.070
3B4giv	Other poultry	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	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	6.2	6.1	6.1	6.1	6.0	7.9	7.8	7.7	7.7

Table 5-7 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3B1a	Dairy cattle	g/animal	726	723	720	717	715	713	711	707	705	704
3B1b	Non-dairy cattle	g/animal	511	506	502	498	498	497	497	496	494	493
3B1c	Young cattle	g/animal	264	262	260	259	257	255	253	251	250	248
3B2	Sheep	g/animal	164	161	156	152	153	156	157	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	247	243	236	229	228	230	230	233	234	233
3B4c	Deer	g/animal	436	434	423	412	419	424	431	436	437	437
3B4d	Goats	g/animal	272	272	274	269	263	258	253	248	248	248
3B4e	Horses	g/animal	552	556	560	565	562	558	555	552	552	553
3B4f	Mules and asses	g/animal	203	204	204	205	206	208	210	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	1.4	1.3	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	1.0	1.0	0.98	0.97	0.97	0.97	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	393	386	385	387	383	505	495	492	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. 2023). 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. For silage feeding, emission factors of 25 kg/animal and 21 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 of 1.5 kg/animal and 1.3 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 5-8. 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 2020, 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). The resulting NMVOC emission factors for cattle categories and the default emission factors for all other animal categories are given in Table 5-9.

Table 5-8 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%

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3B1a Dairy cattle										
Lowlands	60%	60%	60%	60%	60%	60%	60%	59%	59%	59%
Silage feeding, lowlands	56%	56%	56%	56%	57%	59%	60%	61%	61%	61%
Silage feeding, mountain area	40%	41%	42%	43%	42%	41%	41%	40%	40%	40%
3B1b Non-dairy cattle										
Lowlands	58%	57%	57%	57%	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%	56%	57%	57%	57%	57%	57%	57%	57%	57%
Silage feeding, lowlands	72%	72%	73%	73%	73%	73%	73%	73%	73%	73%
Silage feeding, mountain area	59%	59%	60%	60%	59%	59%	59%	59%	59%	59%

Table 5-9 Time series of NMVOC emission factors for livestock categories.

NMVOC emission factors		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	kg/animal	9	10	10	12	12
3B1b	Non-dairy cattle	kg/animal	23	23	23	23	23
3B1c	Young cattle	kg/animal	4.8	5.1	5.2	5.6	6.2
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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3B1a	Dairy cattle	kg/animal	13	13	13	13	13	13	13	13	13	13
3B1b	Non-dairy cattle	kg/animal	23	23	23	23	23	23	23	23	23	23
3B1c	Young cattle	kg/animal	6.4	6.4	6.4	6.4	6.4	6.4	6.3	6.3	6.3	6.2
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	0.55	0.54	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 5-10. 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 5-10 Emission factors of PM2.5, PM10 and TSP for livestock categories in year 2021 (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 2022, FSO 2022a) for the time period 1990 to 2021 is shown in Table 5-11. 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). Because the official livestock census statistics are based on a key date (1^{st} May until 2014, 1^{st} 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 2022b).

Table 5-11 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3B1a	Dairy cattle	1'000 animals	591	587	587	583	576	569	564	555	546	546
3B1b	Non-dairy cattle	1'000 animals	114	117	118	118	121	123	125	128	131	135
3B1c	Young cattle	1'000 animals	859	854	857	853	859	852	854	842	837	833
3B2	Sheep	1'000 animals	417	409	403	395	397	398	403	400	398	398
3B3	Swine	1'000 animals	1'678	1'615	1'631	1'605	1'553	1'546	1'501	1'447	1'449	1'470
3B4a	Buffalos	1'000 animals	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	1'000 animals	5.8	5.9	6.1	6.4	6.5	6.6	6.7	6.6	6.5	6.5
3B4c	Deer	1'000 animals	5.7	5.7	5.7	6.0	6.0	6.0	6.4	6.6	6.6	6.6
3B4d	Goats	1'000 animals	85	85	85	84	85	88	91	92	90	91
3B4e	Horses	1'000 animals	58	57	57	55	56	56	46	47	47	47
3B4f	Mules and asses	1'000 animals	20	20	20	20	20	21	34	34	33	33
3B4gi	Layers	1'000 animals	2'521	2'589	2'665	2'822	3'056	3'174	3'371	3'486	3'854	3'867
3B4gii	Broilers	1'000 animals	7'737	8'126	8'506	8'614	9'064	8'857	9'430	9'593	10'097	10'470
3B4giii	Turkey	1'000 animals	51	55	57	49	71	77	84	75	88	83
3B4giv	Growers	1'000 animals	1'076	1'055	1'196	1'033	959	1'084	1'078	1'242	1'150	1'177
3B4giv	Other poultry	1'000 animals	25	20	22	23	30	16	20	21	24	25
3B4hi	Rabbits	1'000 animals	28	28	27	25	25	22	22	21	19	17
3B4hii	Bisons	1'000 animals	0.52	0.50	0.53	0.56	0.56	0.57	0.54	0.46	0.46	0.43

5.2.3 Category-specific recalculations 3B Manure management

- 3B1: The emission factors of PM2.5, PM10 and TSP were revised for all cattle categories for the years 1996–2020 due to updated data for the fractions of animals kept in tied housing (Kupper et. al. 2022).
- 3B1: Some adjustments were made in the allocation of manure to the various storage systems. The elimination of volatile solids (VS) has been revised (digestibility (DE%) and update VS), which resulted in changes in NO_x emission factors of all cattle categories for the whole time series.
- 3B3: The activity data of source category 3B3 Manure management - Swine were revised for the years 1990-2016, since the animal population statistics were adjusted due to an error correction in the accounting of suckling piglets. These revised animal numbers also resulted in recalculated implied emission factors of all pollutants (NO_x, NMVOC, NH_3, PM2.5, PM10, TSP).
- 3B3, 3B4gii: The animal numbers of fattening pigs and broilers of source categories 3B3 Manure management - Swine and 3B4gii Manure management - Broilers were revised for 2020, since provisional animal population statistics from background data of the FSO were updated. The revised numbers of fattening pigs also resulted in recalculated implied emission factors of all pollutants (NO_x, NMVOC, NH_3, PM2.5, PM10, TSP) of 3B3 Manure management - Swine.

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 5-12 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 5-13 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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	L1, T1, L2, T2
3Da2a	Animal manure applied to soils	NOx	T1, L2, T2
3Da2a	Animal manure applied to soils	NH3	L1, T1, L2, 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	T2
3Da3	Urine and dung deposited by grazing animals	NH3	T1, L2, T2
3De	Cultivated crops	PM10	L1, T1, L2, 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 organic 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. (2018) 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 2021) 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 5-14 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 5-14 NH_3 and NO_x emission factors 2021 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	37
3Da2c	Organic compost	kg / tN	18	151

Emission factors for the application of animal manure are displayed in Table 5-15 and Table 5-16. They are based on the livestock category specific N flow calculations with AGRAMMON (see chapter 5.2.2).

Table 5-15 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3Da2a1a	Dairy cattle	kg/animal	22.0	21.8	21.5	21.3	21.3	21.2	21.2	21.2	21.2	21.2
3Da2a1b	Non-dairy cattle	kg/animal	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.5	11.5	11.5
3Da2a1c	Young cattle	kg/animal	5.2	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0
3Da2a2	Sheep	kg/animal	0.23	0.22	0.21	0.20	0.20	0.21	0.21	0.22	0.22	0.22
3Da2a3	Swine	kg/animal	1.4	1.4	1.4	1.3	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	0.22	0.21	0.21	0.20	0.20	0.20	0.19	0.19	0.20	0.19
3Da2a4c	Deer	kg/animal	0.38	0.38	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.36
3Da2a4d	Goats	kg/animal	0.42	0.43	0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.44
3Da2a4e	Horses	kg/animal	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.5
3Da2a4f	Mules and asses	kg/animal	0.63	0.62	0.61	0.60	0.62	0.64	0.65	0.67	0.67	0.67
3Da2a4gi	Layers	kg/animal	0.091	0.093	0.095	0.096	0.096	0.095	0.094	0.094	0.094	0.094
3Da2a4gii	Broilers	kg/animal	0.057	0.054	0.051	0.048	0.049	0.049	0.049	0.050	0.050	0.050
3Da2a4giii	Turkey	kg/animal	0.17	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15
3Da2a4giv	Growers	kg/animal	0.037	0.038	0.039	0.040	0.037	0.033	0.030	0.027	0.027	0.027
3Da2a4giv	Other poultry	kg/animal	0.072	0.069	0.067	0.064	0.064	0.064	0.064	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	0.72	0.71	0.70	0.71	0.70	0.92	0.90	0.90	0.89

Table 5-16 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3Da2a1a	Dairy cattle	g/animal	1351	1354	1356	1359	1357	1355	1353	1351	1351	1351
3Da2a1b	Non-dairy cattle	g/animal	816	815	814	813	810	806	803	799	799	799
3Da2a1c	Young cattle	g/animal	350	351	352	352	350	348	347	346	345	344
3Da2a2	Sheep	g/animal	66	65	63	61	61	62	63	64	64	64
3Da2a3	Swine	g/animal	110	110	110	110	111	110	110	111	111	111
3Da2a4a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	g/animal	97	96	93	90	89	90	90	91	92	91
3Da2a4c	Deer	g/animal	171	170	166	162	164	166	169	171	171	171
3Da2a4d	Goats	g/animal	110	110	111	109	107	105	103	101	101	101
3Da2a4e	Horses	g/animal	465	468	471	476	473	470	467	464	464	465
3Da2a4f	Mules and asses	g/animal	172	172	172	173	174	176	178	179	179	179
3Da2a4gi	Layers	g/animal	10.0	10	10	10	10	10	10	10	10	10
3Da2a4gii	Broilers	g/animal	6.2	5.9	5.6	5.4	5.4	5.4	5.3	5.3	5.3	5.3
3Da2a4giii	Turkey	g/animal	20	19	19	19	19	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	7.1	7.0	7.0	7.0	7.0	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	325	320	319	320	317	418	410	408	405

In the following, Table 5-17 and Table 5-18 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 5-17 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	0.005
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	0.001	0.001	0.002	0.001
3Da34giii	Turkey	kg/animal	NO	0.003	0.016	0.017	0.014
3Da34giv	Growers	kg/animal	NO	0.001	0.001	0.001	0.003
3Da34giv	Other poultry	kg/animal	NO	NO	0.006	0.005	0.006
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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
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	1.4	1.5	1.5	1.5
3Da31c	Young cattle	kg/animal	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.44
3Da32	Sheep	kg/animal	0.21	0.22	0.23	0.23	0.23	0.23	0.22	0.22	0.22	0.22
3Da33	Swine	kg/animal	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3Da34a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	kg/animal	0.32	0.33	0.34	0.35	0.34	0.34	0.34	0.33	0.34	0.33
3Da34c	Deer	kg/animal	0.56	0.59	0.61	0.63	0.63	0.63	0.63	0.63	0.63	0.63
3Da34d	Goats	kg/animal	0.20	0.20	0.20	0.20	0.21	0.21	0.22	0.23	0.23	0.23
3Da34e	Horses	kg/animal	0.61	0.60	0.59	0.57	0.59	0.60	0.61	0.62	0.62	0.62
3Da34f	Mules and asses	kg/animal	0.22	0.22	0.22	0.21	0.21	0.20	0.20	0.19	0.19	0.19
3Da34gi	Layers	kg/animal	0.028	0.028	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
3Da34gii	Broilers	kg/animal	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3Da34giii	Turkey	kg/animal	0.017	0.019	0.020	0.022	0.022	0.022	0.022	0.022	0.022	0.022
3Da34giv	Growers	kg/animal	0.003	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004
3Da34giv	Other poultry	kg/animal	0.007	0.007	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.009
3Da34hi	Rabbits	kg/animal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da34hii	Bisons	kg/animal	0.79	0.79	0.78	0.79	0.78	0.76	0.99	0.96	0.95	0.95

Table 5-18 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3Da31a	Dairy Cattle	g/animal	338	335	333	331	333	334	335	337	337	337
3Da31b	Non dairy Cattle	g/animal	450	450	449	449	456	462	469	476	476	476
3Da31c	Young Cattle	g/animal	147	146	145	144	144	145	144	144	143	144
3Da32	Sheep	g/animal	64	66	67	69	68	68	67	66	66	66
3Da33	Swine	g/animal	0.35	0.29	0.22	0.155	0.141	0.125	0.108	0.093	0.092	0.092
3Da34a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	g/animal	95	99	102	104	102	101	100	99	100	100
3Da34c	Deer	g/animal	168	177	182	188	188	187	187	186	186	187
3Da34d	Goats	g/animal	59	59	59	58	61	64	67	69	69	69
3Da34e	Horses	g/animal	183	179	176	171	175	178	182	186	185	185
3Da34f	Mules and Asses	g/animal	66	65	64	64	62	60	58	57	57	57
3Da34gi	Layers	g/animal	1.00	1.01	1.01	1.02	1.0	1.0	1.0	1.0	1.0	1.0
3Da34gii	Broilers	g/animal	0.029	0.026	0.023	0.020	0.023	0.026	0.030	0.033	0.033	0.033
3Da34giii	Turkey	g/animal	0.60	0.66	0.72	0.78	0.78	0.78	0.78	0.78	0.78	0.78
3Da34giv	Growers	g/animal	0.094	0.088	0.083	0.078	0.092	0.106	0.121	0.135	0.135	0.135
3Da34giv	Other poultry	g/animal	0.24	0.26	0.27	0.29	0.30	0.30	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	235	236	233	234	232	227	295	285	284	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 5-19.

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 5-19.

Table 5-19 NMVOC and PM2.5 emission factors of 2021 for 3De Crop production and agricultural soils.

Emission factors		Unit	NMVOC	PM2.5	PM10	TSP
3De	Cropland	g/ha	376	40	758	7'577
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 2022, Agricura 2021, 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 5-20.

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 5-11. 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 2022a), 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.

Table 5-20 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	Organic compost	tN	817	1'286	1'829	2'169	3'281
3De	Cropland	ha	313'247	308'284	290'954	283'802	270'371
3De	Grassland	ha	724'556	737'229	743'849	742'474	741'837
3De	Summering pastures	ha	538'676	499'774	496'667	487'956	486'382

Activity data of agricultural soils		Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3Da1	Urea containing fertiliser	tN	5'377	5'793	7'942	7'223	8'872	9'250	8'324	7'752	7'397	8'101
3Da1	Other synthetic N-fertiliser	tN	39'771	37'924	41'393	36'521	37'531	40'113	37'432	32'400	33'694	37'269
3Da2b	Sewage sludge	tN	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da2c	Organic compost	tN	4'345	4'670	4'709	4'908	5'435	5'542	5'668	6'211	6'357	6'472
3De	Cropland	ha	267'531	269'820	269'337	270'092	269'536	270'557	270'146	266'207	267'462	266'686
3De	Grassland	ha	743'594	739'588	740'097	737'463	736'455	732'125	729'073	731'287	726'210	726'210
3De	Summering pastures	ha	481'379	479'745	475'690	474'575	472'465	472'618	470'837	469'280	466'163	463'443

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 2022i). In addition, for NMVOC emissions also the emissions from summering pastures (FSO 2022b) are included where no agricultural crop operations take place. The activity data of these agricultural areas are also given in Table 5-20. 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

- 3Da: The activity data for swine in source categories 3Da2a Animal manure applied to soils and 3Da3 Urine and dung deposited by grazing animals were revised for the years 1990-2016, since the animal populations statistics were adjusted due to an error correction in the accounting of suckling piglets. These revised animal numbers also resulted in recalculated implied emission factors of NH_3.
- 3Da: The activity data for fattening pigs and broilers in source categories 3Da2a Animal manure applied to soils and 3Da3 Urine and dung deposited by grazing animals were revised for 2020, since provisional animal populations statistics from background data of the FSO were updated. The revised numbers of fattening pigs also resulted in recalculated implied emission factors of NH_3 for 3B3 Manure management - Swine.
- 3Da: Some adjustments were made in the allocation of manure to the various storage systems. The elimination of VS has been revised (DE% and update VS), which resulted in changes in NO_x emission factors of all cattle categories for the whole time series.
- 3Da1: The activity data of source category 3Da1 Inorganic N-fertilizers were revised for the whole time series due to updated values for inorganic fertilizers used in Liechtenstein that were subtracted from amounts applied in Switzerland. The impact on overall emissions is negligible.
- 3Da2c: The activity data and the weighted mean NH_3 emission factor of source category 3Da2c Other organic fertilizers were revised for the year 2020 due to updated values for the amount of compost applied to agricultural soils.
- 3De: The activity data for grassland of source category 3De Cultivated crops was revised for 2019 and 2020 based on updated FSO data (farm structure survey).
- 3De: The emission factors of particulate matter from of source category 3De Cultivated crops (cropland) were revised for 2020 based on updated FSO data (farm structure survey).

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 2021 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 continuous increasing trend of total NMVOC emissions from 2006 to 2021 can be observed. The contribution of the waste sector is small in comparison to the national total. Therefore, there are no source categories from the waste sector that are key categories for NMVOC.

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.

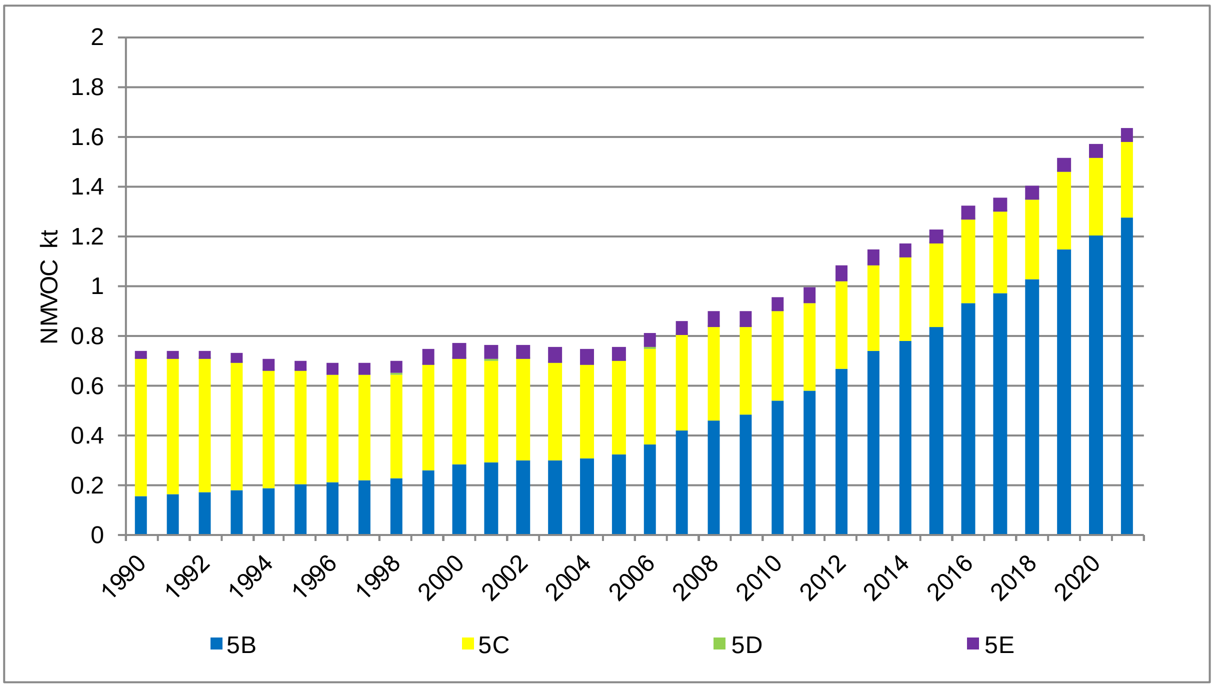


Figure 6-1 Switzerland's NMVOC emissions from the waste sector by source categories 5B-5E. The corresponding data table can be found in Annex A7.5.

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 2020 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.

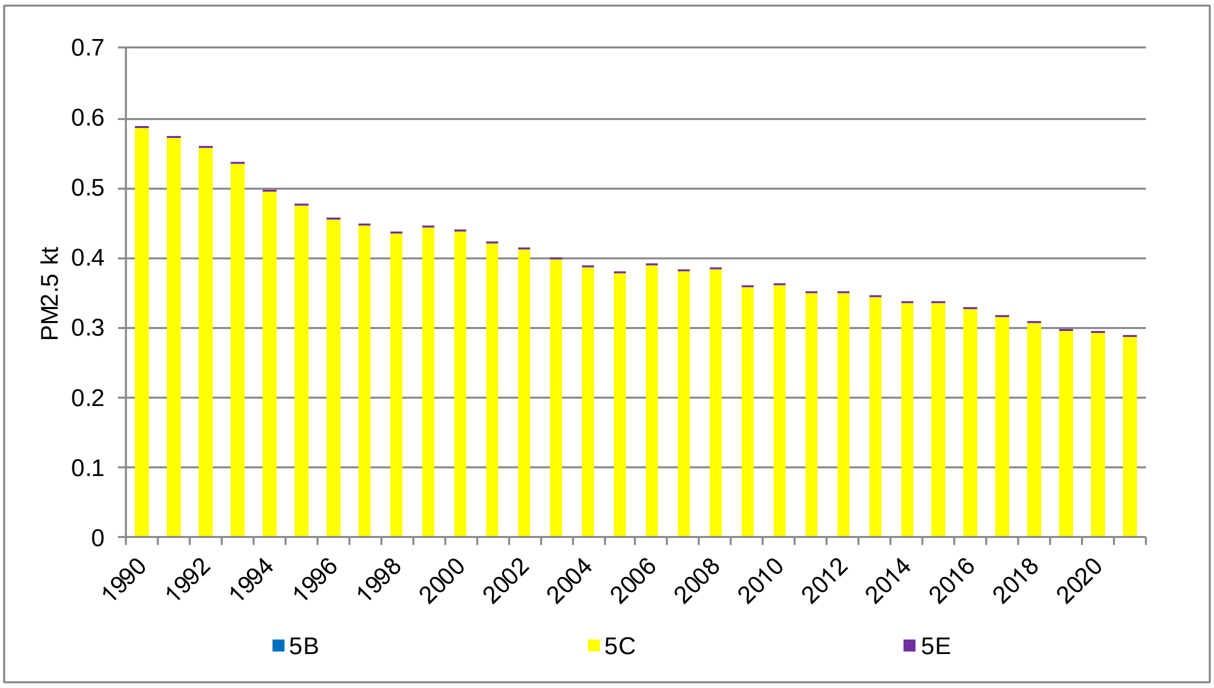


Figure 6-2 Switzerland's PM2.5 emissions from the waste sector by source categories 5B, 5C and 5E. Note that PM2.5 emissions from 5D are not occurring. The corresponding data table can be found in Annex A7.5.

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 2022a). 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 6-1 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 6-2 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 2022):

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 2023/1A1a & 5A), see Table 6-3. 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 6-3 Emission factors 2021 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	11

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 2023/1A1a & 5A. Table 6-4 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 6-4 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
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 6-5). 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 6-5 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CH_4 flared	kt	1.8	1.6	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3
PCB quantity available	kt	0.32	0.31	0.31	0.31	0.31	0.31	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 2023.

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 2023/5B1 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 6-6 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 6-7 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (T1, T2) for source category 5B Biological treatment of waste – Composting and anaerobic digestion at biogas facilities

Source category 5B Biological treatment of waste – Composting and anaerobic digestion at biogas facilities is not a key category.

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.

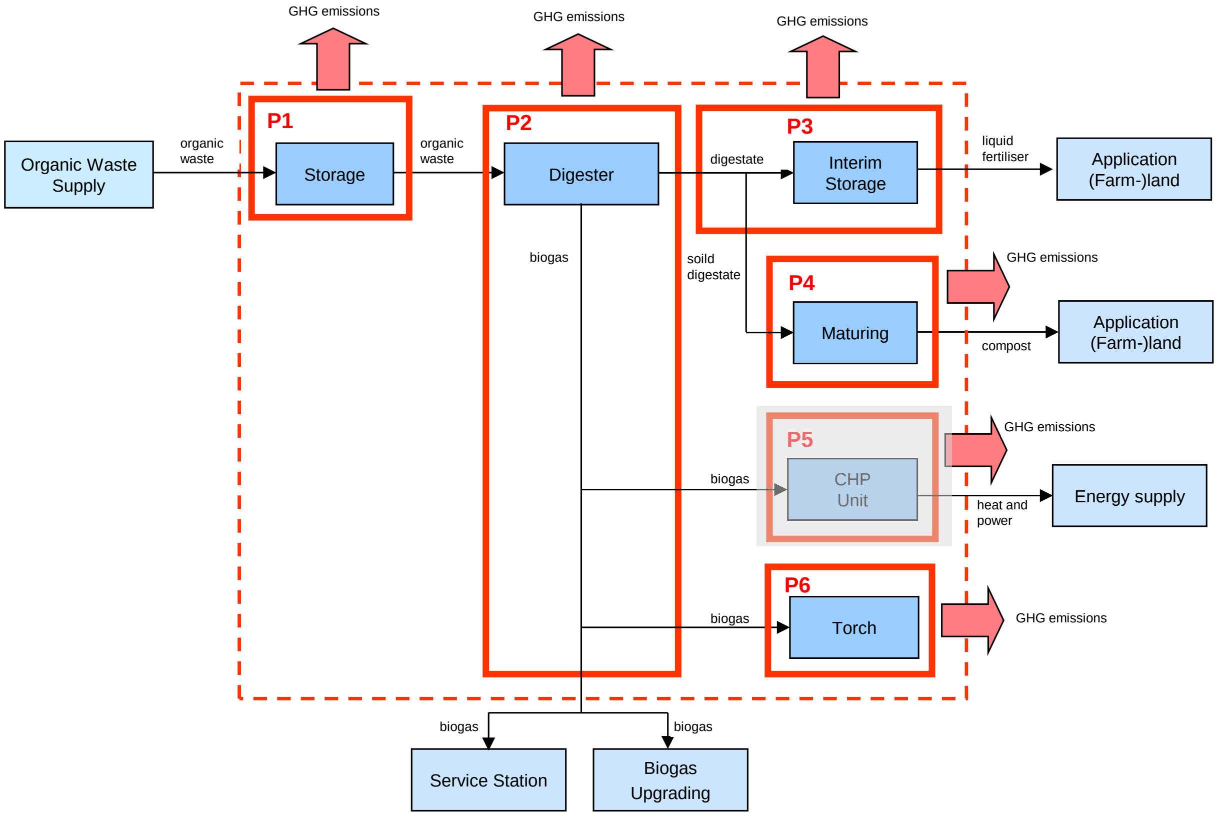


Figure 6-3 Schematic design of an industrial biogas plant.

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.

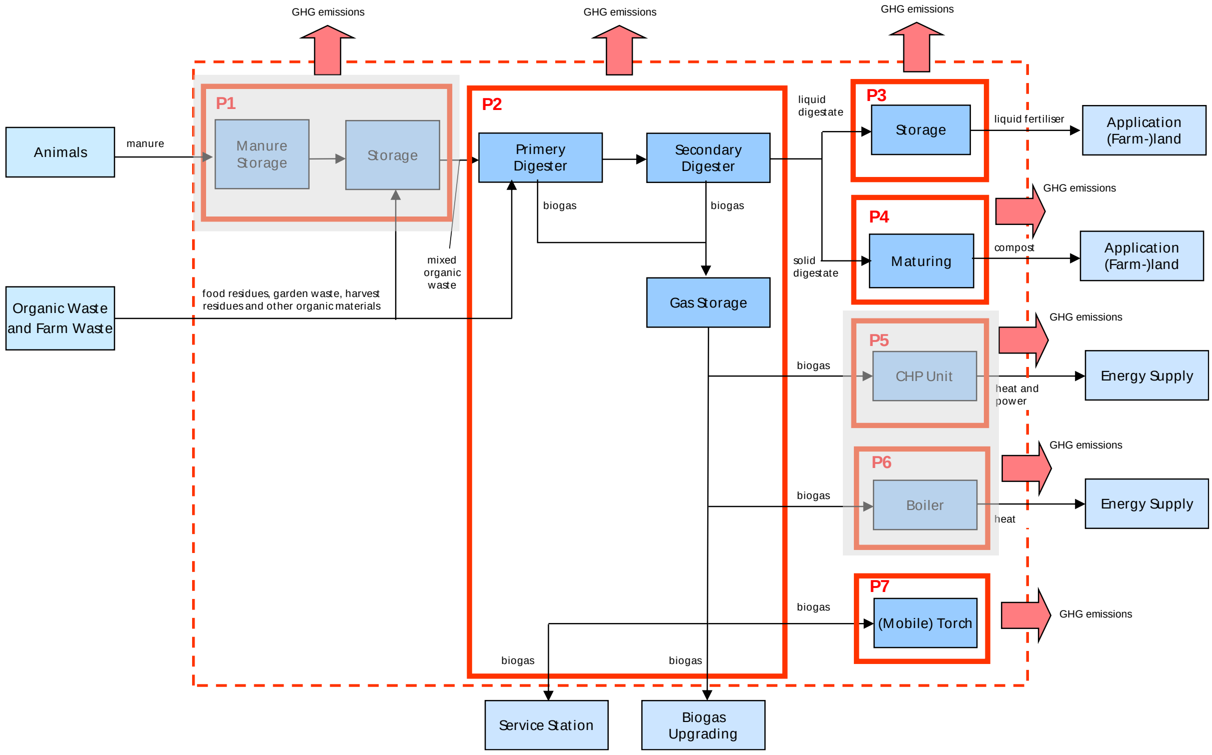


Figure 6-4 Schematic design of an agricultural biogas plant.

Emission factors (5B)

Emission factors for 5B1 Composting are country-specific based on measurements and expert estimates (EMIS 2023/5B1 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 2023/1A2g and 5B2 Vergärung IG and EMIS 2023/1A4a and 5B2 Vergärung LW). Table 6-8 presents the emission factors used in 5B.

Table 6-8 Emission factors of 5B Biological treatment of waste - Composting and anaerobic digestion at biogas facilities in 2021.

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	550	NA	917	NA	NA	NA	NA
Composting (backyard)	g/t composted waste	NA	550	NA	917	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	4066	82	616	NA	37	37	37	2054
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	4066	82	616	NA	37	37	37	2054

Activity data (5B)

Activity data for 5B Biological treatment of waste are extracted from EMIS 2023/5B1 Kompostierung, EMIS 2023/1A1a and 5B2 Vergärung IG and EMIS 2023/1A1a and 5B2

Vergärung LW. Activity data for digestion are based on reliable statistical data from the statistics of renewable energies (SFOE 2022a). 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 0.545 (CVIS 2019) 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 6-9 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	131	196	283	287	289
Composting (backyard)	kt dry	60	84	98	93	65
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	113	94	125	181	569
Digestion (agr., digested waste solid / rotting)	kt wet	5.9	4.9	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**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Composting (industrial)	kt dry	291	292	261	234	274	267	259	296	285	298
Composting (backyard)	kt dry	55	55	55	55	55	55	55	55	55	55
Digestion (ind., digestable waste / storage)	kt wet	508	561	590	650	695	712	729	770	792	792
Digestion (ind., digested waste liquid / storage)	kt wet	283	313	329	362	387	397	406	429	441	441
Digestion (ind., digested waste solid / rotting)	kt wet	174	192	201	222	237	243	249	263	270	270
Digestion (ind., flaring, CH_4)	kt	0.84	0.91	0.90	0.95	1.00	1.0	1.0	1.0	1.0	1.0
Digestion (agr., digested waste liquid / process water)	kt wet	711	829	940	1053	1201	1290	1416	1619	1767	1914
Digestion (agr., digested waste solid / rotting)	kt wet	37	44	50	55	63	68	75	85	93	101
Digestion (agr., flaring, CH_4)	kt	0.16	0.20	0.23	0.26	0.29	0.31	0.34	0.40	0.43	0.47

6.3.3 Category-specific recalculations in 5B Biological treatment of waste - Anaerobic digestion at biogas facilities

There were no recalculations implemented in submission 2023.

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 6-10.

Table 6-10 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 6-11 gives an overview of other waste incineration sources in Switzerland and the source category, where respective emissions are reported in the national inventory.

Table 6-11 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 6-12 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 2023/5C1 Abfallverbrennung illegal, EMIS 2023/5C1 Kabelbrand, EMIS 2023/5C1 Spitalabfallverbrennung, EMIS 2023/5C1 Krematorien, EMIS 2023/5C1 Klärschlammverbrennung, EMIS 2023/5C2 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 2023/5C1 (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 6-13 depicts the emission factors used in 5C.

Table 6-13 Emission factors for 5C Waste incineration and open burning of waste in 2021. 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	14	14	16	40

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	49	NA	95	0.0006	NA	NA	NA	NA

Activity data (5C)

The clinical waste incineration quantities are based on rough expert estimates (EMIS 2023/5C1 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 2023/5C1 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 2022c). 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 6-14) 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 2023/5C2 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 6-14 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	kt	108	126	124	129	130	132	128	129	126	125
Clinical waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Illegal waste incineration	kt	20	20	19	19	19	18	18	17	17	17
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	75	94	93	97	99	102	98	100	97	96
Open burning of natural residues in agriculture	kt	11	11	11	11	11	11	11	10	10	10
Open burning of natural residues in private households	kt	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1
Cremation	Numb.	50'567	53'205	55'616	59'664	54'634	57'694	54'842	57'746	68'148	64'106

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

There were no recalculations implemented in submission 2023.

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 6-15 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 6-16 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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.

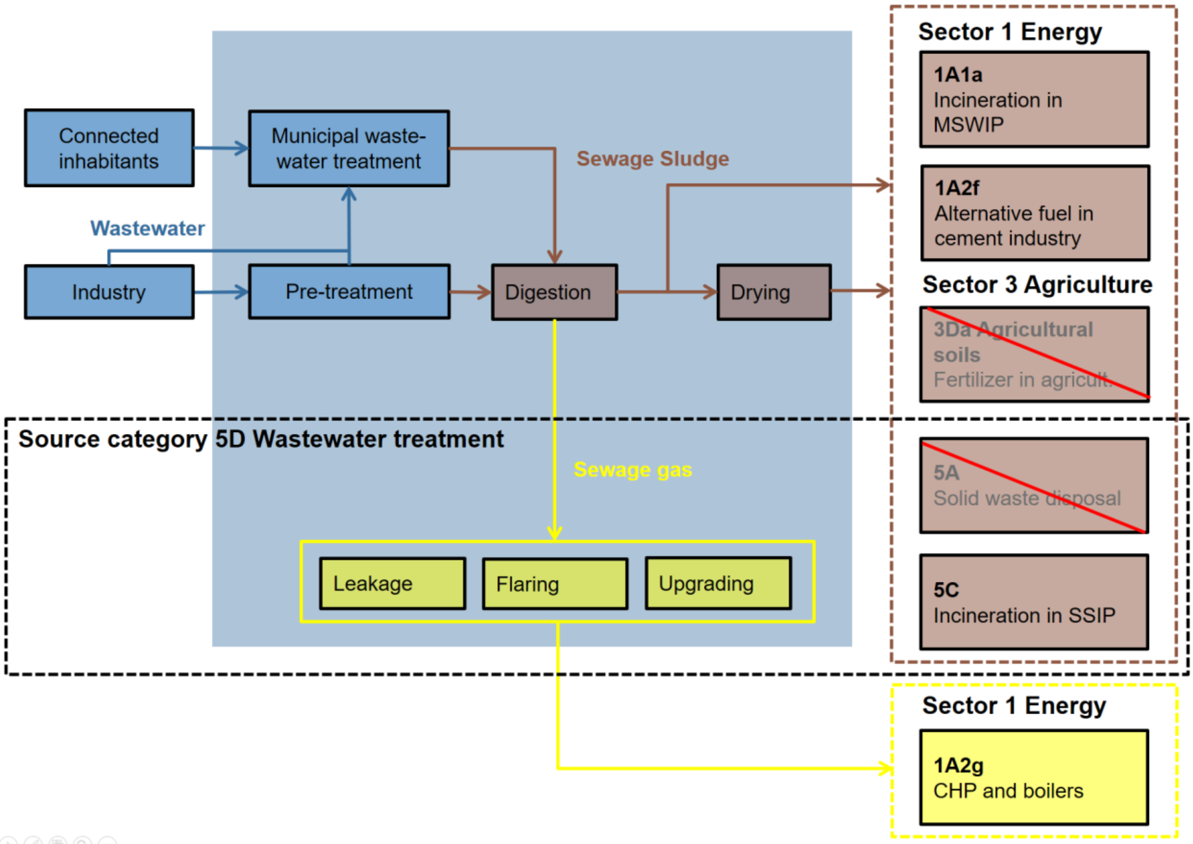


Figure 6-5 System boundaries of emissions related to wastewater handling. Abbreviations: CHP Combined Heat and Power Generation, MSWIP municipal solid waste incineration plant, SSIP sewage sludge incineration plant.

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 2022c). 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 2023/5D1, EMIS 2023/5D2), see Table 6-17.

Table 6-17 Emission factors for 5D Wastewater handling in 2021.

5D Wastewater handling	Unit	NO_x	NMVOC	SO_X	NH_3	CO
5D1 Domestic wastewater handling	g/person	0.55	0.011	0.0028	14	0.28
5D2 Industrial wastewater handling	g/person	0.13	0.0026	0.00065	NA	0.064

Activity data (5D)

Activity data for 5D1 Domestic wastewater handling and 5D2 Industrial wastewater handling are the total number of inhabitants extracted from FSO (2022c). 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 6-18: 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Inhabitants	persons in 1000	7'997	8'089	8'189	8'282	8'373	8'452	8'514	8'575	8'638	8'705
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	7'781	7'871	7'968	8'058	8'147	8'224	8'284	8'343	8'405	8'470

6.5.3 Category-specific recalculations in 5D Wastewater handling

The following recalculations were implemented in submission 2023:

- 5D1 Domestic wastewater treatment: The emission factor for NH_3 has decreased by <1 % over the period 1990–2020 due to a change in the underlying data source (number of persons with centralised wastewater treatment).

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 6-19 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 6-20 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 2023/5E 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 6-21 Emission factors for 5E Other waste, car shredding and shredder in 2021. 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 2023/5E 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 6-22 Activity data for car shredding (source EMIS 2023/5E 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Car shredding	kt	300	300	300	300	300	300	300	300	300	300
Shredder	t PCB	0.48	0.39	0.31	0.25	0.20	0.15	0.12	0.09	0.070	0.053

6.6.3 Category-specific recalculations in 5E Other waste, car shredding

There were no recalculations implemented in submission 2023.

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 2021 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 estates and motor vehicles
- 11B Forest fires and open burning of residues in forestry
- 11C Other natural emissions (NMVOC from forest stands)

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.

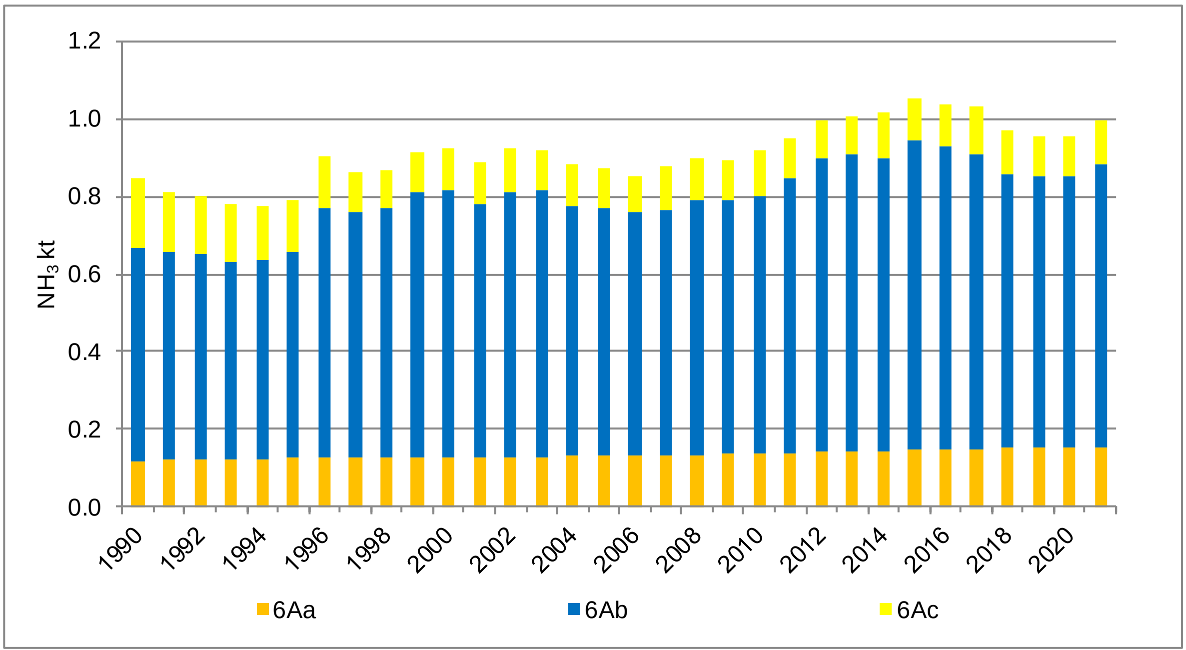


Figure 7-1 Switzerland’s NH_3 emissions from sector 6 Other and natural emissions by source categories 6Aa, 6Ab and 6Ac. The corresponding data table can be found in Annex A7.6.

7.1.2 Overview and trend for NO_x

NO_x emissions from the source categories 6Ab Pets, 6Ac Fertilisers and 6Ad Fire damages estates and motor vehicles between 1990 and 2021 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 bulk to total emissions. Emissions from 6Ac Fertilizers show a slight decrease during the reporting period. Emissions from 6Ad Fire damages estates and motor vehicles remained stable.

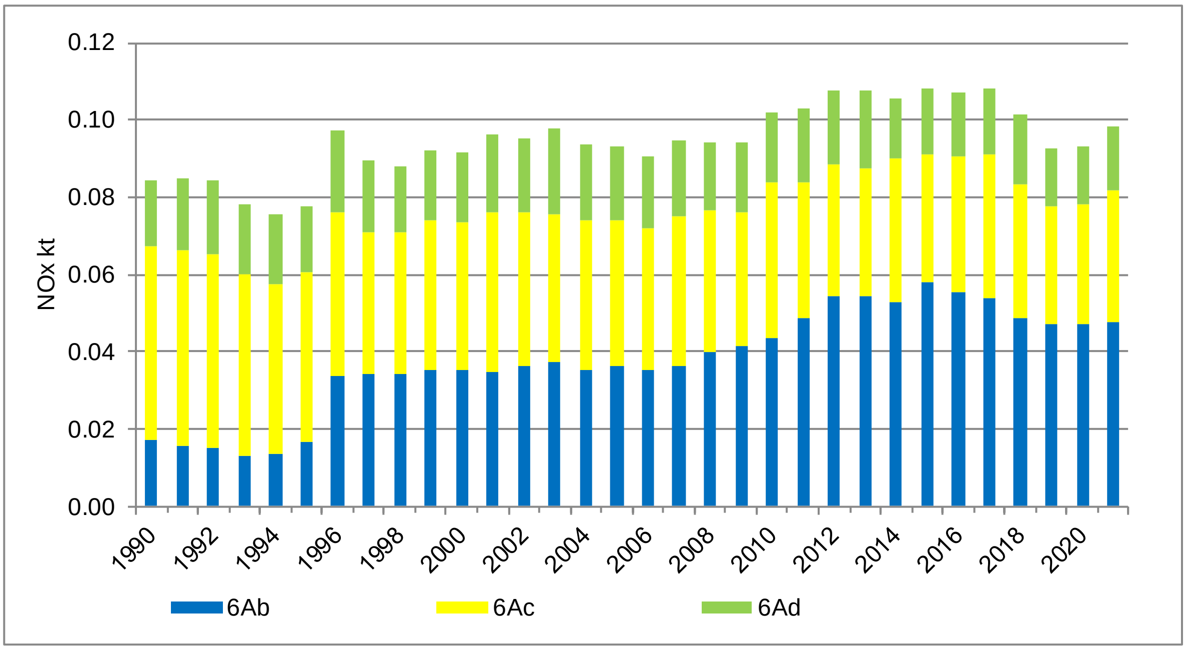


Figure 7-2 Switzerland's NO_x emissions from the sector 6 Other and natural emissions by source categories 6Ab, 6Ac and 6Ad. The corresponding data table can be found in Annex A7.6.

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 estates and motor vehicles, the other source category; are relatively stable over the entire time period.

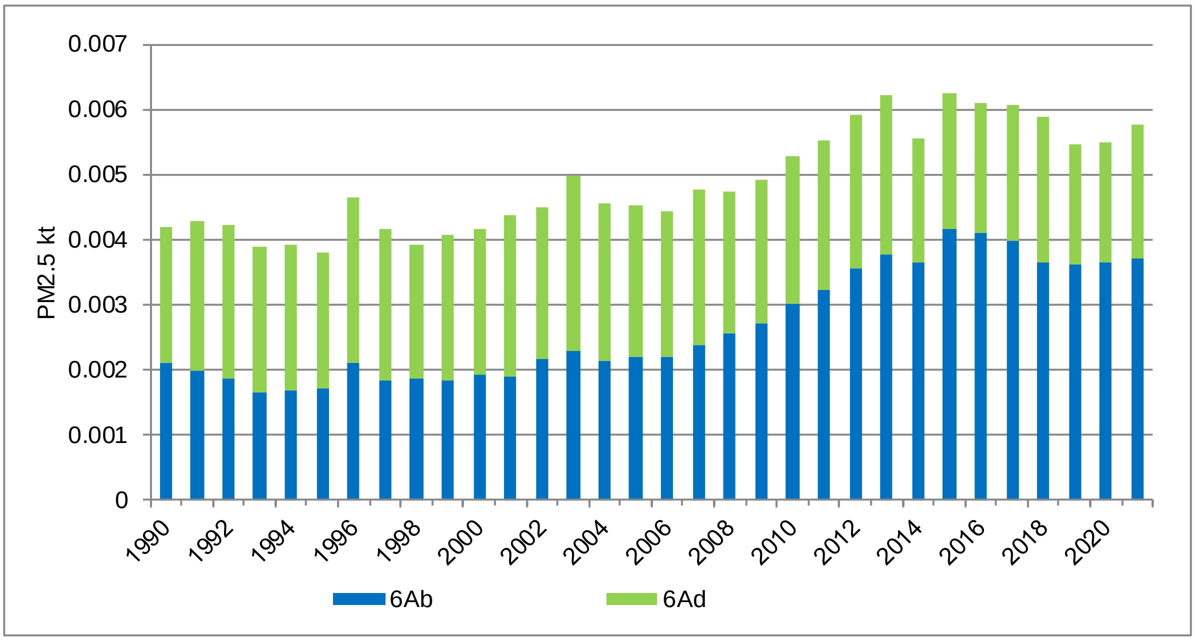


Figure 7-3 Switzerland's PM2.5 emissions from the sector 6 Other emissions. The corresponding data table can be found in Annex A7.6.

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.

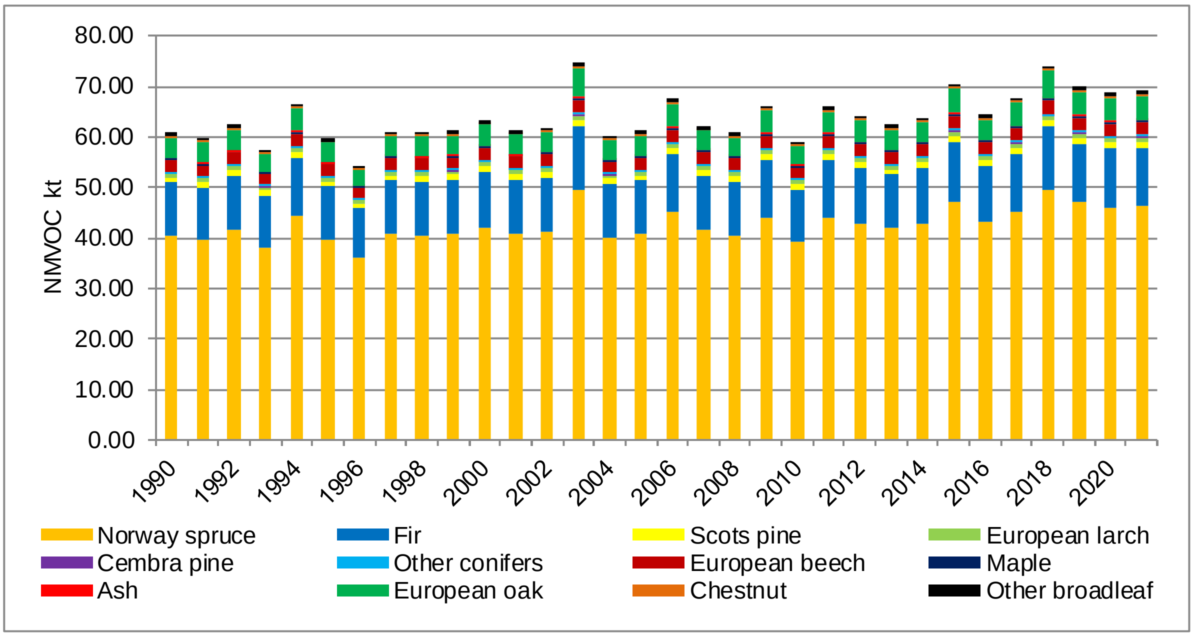


Figure 7-4 Switzerland's NMVOC emissions from the sector 11C Other natural emissions (forest stands).

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 7-1 are considered.

Table 7-1 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 7-2 Key categories, approaches 1 and 2, level assessment 2021 (L1, L2) and trend assessment 1990-2021 (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 7-3 and Table 7-6, respectively.

Emissions from fire damage estates and motor vehicles and emissions from accidental release of PCBs by fire and to soil (6Ad)

Emissions from fire damage in estates are calculated as follows: The fire insurance association of the cantons (Vereinigung kantonaler Feuerversicherungen, VKF) publishes the number of fire incidents in buildings each year and the total sum of monetary damage. Data from 1990 to 2001 show that the average damage sum per fire incident in buildings amounts to approximately CHF 20’000. It is assumed that this corresponds to 780 kg of flammable material per case. It is further assumed that in average only 50 % of the material actually burns down during an incident because of the interference of the fire brigade. Thus, an amount of 400 kg of burnt material per fire case is estimated. With these assumptions, the amount of burnt material for each year can be calculated from the total sum of monetary damage published by VKF (EMIS 2023/6A).

Emissions from fire damage of motor vehicles are calculated based on data from a Swiss car insurance company with 25 % market share in 2002. The number of reported cases of fire damage from this company was extrapolated to the total vehicle number in Switzerland. It was estimated that one fire case per 790 vehicles occurs per year, remaining constant within the reporting period. Applying this ratio to the actual annual vehicle number, which is published by the Swiss Federal Statistical Office, the total number of fire incidents with vehicles in Switzerland is obtained for each year (EMIS 2023/6A). 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 7-3. Emission factors for fertiliser see also Table 5-14.

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 7-3 Emission factors for the year 2021 in sector 6 Other emissions (source EMIS 2023/6A).

6 Other emissions	Unit	NOx	NMVOC	NH_3	PM2.5 non-exh.	PM10 non-exh.	TSP non-exh.
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	462	991	3'305	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	58	NA	NA	NA

Fire damages (6Ad)

Fire damages estates: 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 estates (EMIS 2023/6A “Brand- und Feuerschäden Immobilien”). The emission factors of Pb, Cd, and Hg are country-specific based on measurements of a study about a cable recycling company in Switzerland (Graf 1990). 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: Emission factors for CO, NO_x and SO_x are country-specific based on measurements and expert estimates originally derived for wire burn off, documented in EMIS 2023/6A Brand- und Feuerschäden Motorfahrzeuge”. The PCDD/PCDF emission factors for fire damage of motor vehicles 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 7-4 presents the emission factors used.

Table 7-4 Emission factors for fires reported under 6Ad Fire damages estates and motor vehicles in 2021 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 estates	kg / t burned good	2	16	1	25	30	100
Fire damage motor vehicles	kg / t burned good	1.3	2	5	1	5	2

6Ad Fire damages	Unit	Pb	Cd	Hg	Zn	PCDD/F	BaP	BbF	BkF	IcdP
Fire damage estates	g / t burned good	800	20	10	350	0.0003	0.34	0.2	0.27	0.1
Fire damage motor vehicles	g / t burned good	800	20	0.05	350	0.0003	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 7-5. They are based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 7-5 PCB emission factors for accidental release of PCB by fire and to soil, respectively, reported under 6Ad Other emissions in 2021 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.

[5]Verband für Heimtiernahrung VHN (http://www.vhn.ch/)

Table 7-6 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
6Aa Human emissions											
Human respiration	person	7'997'000	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
Human transpiration	person	7'997'000	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
Children <1y	person	82'164	82'731	85'287	86'559	87'883	87'381	87'851	86'172	85'914	89'644
Children 1-3y	person	239'384	243'262	245'703	250'182	254'577	259'729	261'823	263'115	261'404	259'937
Aged inhabitants	person	17'972	18'389	18'679	19'278	19'244	19'793	20'337	20'661	19'827	19'879
6Ab Pets and livestock outside agriculture											
Livestock, outside agriculture	animals	113'853	111'397	108'866	120'094	113'379	109'783	107'715	103'135	102'173	102'912
Cats	animals	1'487'000	1'543'317	1'618'406	1'655'951	1'655'951	1'645'096	1'634'240	1'678'277	1'722'313	1'853'759
Dogs	animals	506'000	511'297	518'360	521'891	521'891	513'816	505'740	504'375	503'009	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	1'881	1'822	2'056	1'823	1'933	2'057	1'907	1'673	1'712	1'890

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 7-7. For accidental release of PCBs by fire and to soil, the activity data are the 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 7-7 Activity data in source category 6Ad Fire damages: Burnt goods (source EMIS 2023/6A).

6Ad Fire damages	Unit	1990	1995	2000	2005	2010
Fire damage estates	kt	8.2	8.3	8.7	9.1	8.8
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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fire damage estates	kt	9.1	9.5	7.4	8.1	7.7	8.0	8.7	7.1	7.0	7.9
Fire damage motor vehicles	kt	0.71	0.72	0.73	0.75	0.76	0.77	0.77	0.78	0.79	0.80
6Ad Accidential release of PCB											
by fire	t	0.35	0.32	0.29	0.26	0.24	0.22	0.20	0.18	0.16	0.14
to soil	t	41	41	41	40	40	40	40	40	40	40

7.2.3 Recalculations in 6 Other emissions

The following recalculations were implemented in submission 2023:

- 6Aa Human emissions (NH_3): The activity data "number adults wearing diapers" in 2020 has increased by 0.11% (23 people), due to changes in the underlying statistics by the FSO.
- 6Ab Livestock outside agriculture: Some adjustments were made in the allocation of manure to the various storage systems. The elimination of volatile solids (VS) has been revised (digestibility (DE%) and update VS), which resulted in changes of NO_x emission factors from grazing of livestock outside agriculture for the years 1995–2020.
- 6Ac Private application of synthetic fertilizer and urea: The activity data and the weighted mean NH_3 emission factor were revised for the whole time series due to updated values

for fertilizers used in Liechtenstein that are subtracted from amounts applied in Switzerland.

- 6Ad Fire damages estates: Activity data for the years 1990–1995 (amount of burnt material) have been recalculated based on newly available data from the fire insurance association of the cantons (Vereinigung kantonaler Feuerversicherungen, VKF). Activity data for the years 1996–2020 (amount of burnt material) increased by 20 % (1’442 t) on average (11–38 %, 710 t to 2’584 t), due to a change in the underlying statistics by VKF.

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 7-8 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 incountry 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 2023/4VA1-11B-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 2023/5C2 Abfallverbrennung Land- und Forstwirtschaft.

Table 7-9 Emission factors 2021 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 2021) as documented in the EMIS database (EMIS 2023/4VA1-11B-NFR_Waldbrände). For the years since 1990, the swissfire database is also used in the GHGI (FOEN 2021). 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 2023/5C2 Abfallverbrennung Land- und Forstwirtschaft.

Table 7-10 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Forest fires	ha	26	24	43	43	256	106	55	16	11	25
Burning grassland	ha	14	4	2.6	8.0	212.3	38	29	16	30	10
Open burning of natural residues in forestry	kt	11	11	11	11	11	11	11	10	10	10

7.3.3 Recalculations in 11B Forest fires

The following recalculations were implemented in submission 2023:

- 11B: The time series of wildfires were recalculated with updated activity data from the Swissfire database in the years 2016, 2018, 2019 and 2020 on forest land and in the year 2018 on grassland.

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 7-11 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 1900-2020 and 2050 on the basis of monthly maps for the parameters temperature, vegetation period and for 12 different tree species (Meteotest 2019a, EMIS 2023/11C 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 isoprene, 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 7-12). They represent annual implied emission factors derived from the monthly emission maps. The values after 2020 are interpolated between the modelled years 2020 and 2050.

Table 7-12 Implied emission factors 2021 of 11C NMVOC for different tree species.

11C Tree species	Unit	NMVOC
Norway spruce	g/ha	79'235
Fir	g/ha	83'731
Scots pine	g/ha	21'258
European larch	g/ha	10'247
Cembra pine	g/ha	13'980
Other conifers	g/ha	110'806
European beech	g/ha	10'734
Maple	g/ha	21'184
Ash	g/ha	7'811
European oak	g/ha	182'870
Chestnut	g/ha	12'334
Other broadleaf	g/ha	10'654

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 2023/11C Wald).

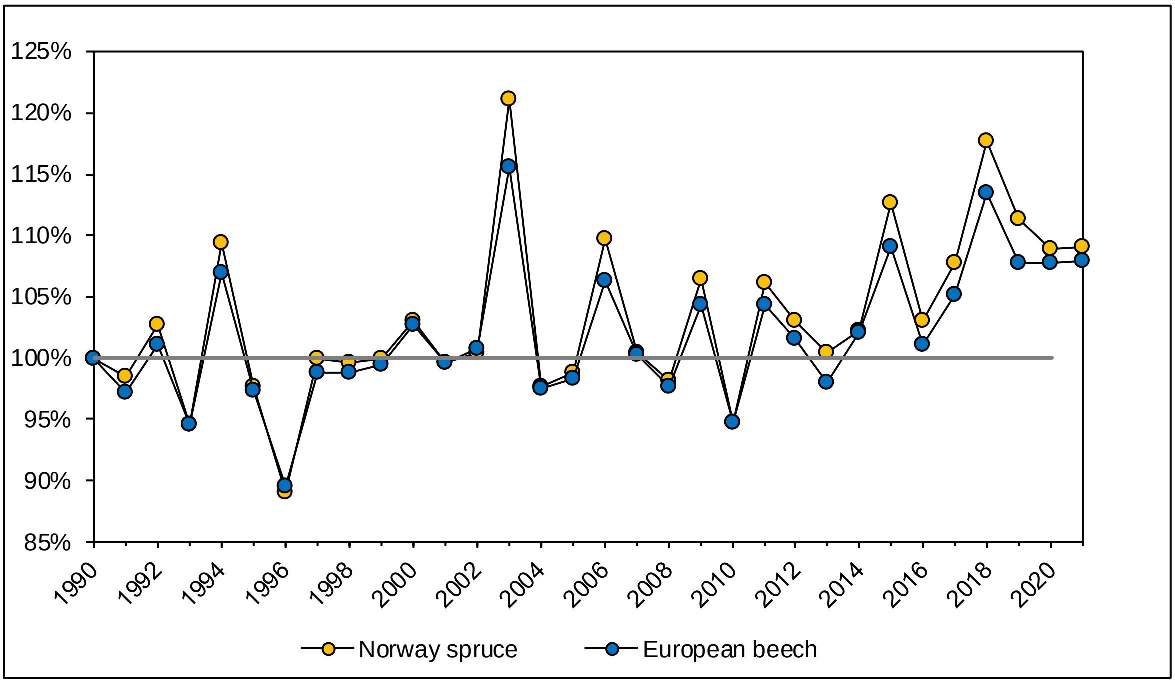


Figure 7-5 Relative trends of the (implied) NMVOC emission factors for two selected tree species 1990-2021.

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 7-13.

Table 7-13 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	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	ha	1'250'769	1'252'632	1'254'489	1'256'307	1'258'136	1'260'026	1'261'840	1'263'687	1'265'518	1'266'319
Total coniferous	ha	859'020	860'557	862'131	863'641	865'167	866'724	868'212	869'778	871'331	871'999
Norway spruce	ha	574'022	575'109	576'243	577'328	578'465	579'544	580'618	581'777	582'896	583'380
Fir	ha	139'075	139'149	139'220	139'295	139'380	139'463	139'535	139'606	139'670	139'700
Scots pine	ha	50'820	50'870	50'939	51'002	51'056	51'119	51'163	51'219	51'269	51'294
European larch	ha	79'758	80'032	80'282	80'532	80'733	81'007	81'244	81'478	81'748	81'855
Cembra pine	ha	12'062	12'114	12'161	12'196	12'241	12'296	12'353	12'395	12'442	12'463
Other conifers	ha	3'283	3'283	3'286	3'288	3'292	3'295	3'299	3'303	3'306	3'307
Total non-coniferous	ha	391'749	392'075	392'358	392'666	392'969	393'302	393'628	393'909	394'187	394'320
European beech	ha	231'063	231'256	231'422	231'609	231'780	231'974	232'161	232'314	232'462	232'539
Maple	ha	15'926	15'953	15'982	16'007	16'039	16'067	16'095	16'125	16'158	16'170
Ash	ha	29'010	29'025	29'037	29'047	29'062	29'082	29'095	29'109	29'128	29'134
European oak	ha	25'031	25'035	25'039	25'040	25'041	25'043	25'047	25'051	25'052	25'053
Chestnut	ha	27'681	27'687	27'693	27'700	27'706	27'715	27'724	27'731	27'739	27'742
Other broadleaf	ha	63'038	63'119	63'185	63'263	63'341	63'421	63'506	63'579	63'648	63'680

7.4.3 Recalculations in 11C Other natural emissions

There were no recalculations implemented in submission 2023.

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)

- 1A1a: According to the Swiss energy statistic there was a reallocation of natural gas use from source category 1A1a Public electricity and heat production to 1A4a Commercial/institutional in the years 2013 to 2020. This does not lead to a change in total gas consumption.
- 1A1a: Activity data (wood, wood waste) of combustion installations in source category 1A1a have been revised for 1990-2020 due to recalculations in the Swiss wood energy statistics (SFOE 2022b).
- 1A1c: Since there is no information available on BC emissions from source category 1A1c Charcoal production (artisanal) its BC factor (%PM2.5) was set to the default Tier 2 value (48 %) of coke manufacture provided in the EMEP/EEA guidebook - 2019 (chap. 1A1c Manufacture of solid fuels and other energy industries, Tab. 5-2/5-3), yielding revised BC emission factors for the entire time series.

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

- 1A2: Revised amount of natural gas use in the Swiss energy statistics for the years 2013-2021 leads to recalculations for natural gas in all source-categories with stationary combustion of 1A2 Manufacturing industry and construction for these years, too.
- 1A2a–g: Recalculation in all source categories 1A2a to 1A2gviii due to reallocations of gas and gas oil use in these sub-categories of 1A2 Manufacturing industries and construction in the year 2020. The reason is that during the surveys for the most recent year, the reports from the previous year are reviewed again and, if necessary, adjusted retroactively. This does not affect the total amount of gas and gas oil used in 1A2 Manufacturing industries and construction for that year.
- 1A2f: In 1A2f Cement production, the activity data of the waste derived combustibles were reorganised in order for Biomass to contain only biogenic fuels and for Other fuels to contain only fossil fuels. All years are affected. Total emissions are affected by less than 5 % (due to rounding issues).
- 1A2gviii: Activity data (wood, wood waste) of combustion installations in source category 1A2gviii have been revised for 1990-2020 due to recalculations in the Swiss wood energy statistics (SFOE 2022b). The biggest changes were in automatic boilers >50 kW after 2015.
- 1A2gviii: An error in the country-specific emission factor model for wood energy combustion was corrected resulting in revised NMVOC emission factors of log wood dual chamber boilers for the entire time series.
- 1A2gviii: Since more residual fuel oil was consumed in the years 2020 and 2021 according to direct bottom-up information from the industry than was declared in total sales in

the same year, stock transfers must be made. This leads to additional stockpiling in 2008-2010 and therefore to changes for residual fuel oil used in not further defined boilers in 1A2gviii Other. Stockpiling can only be performed in the years in which more residual fuel oil was sold according to total energy statistics than was consumed according to bottom-up information. Therefore, the years 2008-2010 were chosen to add residual fuel oil to stocks to cover the additional bottom-up consumption in the years 2020 and 2021.

- 1A2gviii: Due to revised activity data of liquefied petroleum gas in source category 1A3bi Passenger cars, also the statistical difference and not further defined use of liquefied petroleum gas in boilers of source category 1A2gviii Other changed for the years 2011 to 2020.

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

- 1A4: An error in the country-specific emission factor model for wood energy combustion was corrected resulting in revised NMVOC emission factors of log wood single-room furnaces and dual chamber boilers for the entire time series.
- 1A4a: According to the Swiss energy statistic there was a reallocation of natural gas use from source category 1A1a Public electricity and heat production to 1A4a Commercial/institutional in the years 2013 to 2020. This leads not to a change in total gas consumption.
- 1A4ai, 1A4bi, 1A4ci: Activity data (wood, wood waste) of combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2020 due to recalculations in the Swiss wood energy statistics (SFOE 2022b). The biggest changes were in automatic boilers >50 kW after 2015.

8.1.1.4 Category-specific recalculations for 1A2 Mobile combustion in manufacturing industry and construction (1A2gvii)

- 1A2gvii: Emission factors of Pb and SO_2 in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii and 1A5b as well as those in 1A3b Road transportation were revised for the years 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).

8.1.1.5 Category-specific recalculations for 1A3 Transport

- 1A3a/Memo item: An update of activity data in 1A3ai Domestic aviation and 1A3aii International aviation for the year 2020 leads to a recalculation of emissions of all pollutants for the year 2020.
- 1A3a/Memo item: Due to incorrect references in the calculation spreadsheets the emission factor of BC was wrong for 1A3a Domestic International Aviation in previous submissions and was corrected in this submission. This leads to a recalculation of BC emissions for the years 1980-2020.
- 1A3a: The calculations of non-exhaust (TSP, PM10, and PM2.5) emission factors was corrected. This leads to a recalculation of TSP, PM10 and PM2.5 non-exhaust emissions in category 1A3ai/aii Domestic aviation for the years 1980-2020.

- 1A3b: Based on newest available statistics updates in the activity data (mileage) for different vehicle categories have been done. This recalculation leads to changes for all pollutants for the years 1990-2020.
- 1A3b: The revision of the model for determining NMVOC emissions at gasoline stations in 1B2a Fugitive emissions from oil distribution leads to changes in total gasoline losses as the NMVOC lost are equivalent to gasoline losses. This amount of gasoline lost is part of the total amount of gasoline consumption reported in the Swiss overall energy statistics. To keep consistency with this total amount of gasoline consumption a respective adjustment of activity data of gasoline consumption in 1A3b Road transportation was required.
- 1A3b: The emission factors in 1A3b Road transportation were adjusted to the HBEFA version 4.2 published in February 2022. This leads to a recalculation of emissions of all pollutants for the years 1990-2020.
- 1A3b: The emission factors for PCB in each subcategory of 1A3b Road transportation were set equal to the value of 1990 for all years prior to 1990. Previously, the emission factors for the years prior to 1990 were zero. This recalculation leads to changes in PCB emissions for the years 1980 to 1989.
- 1A3b/c/d: Emission factors of Pb and SO_x in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii, 1A5b as well as those in 1A3b Road transportation were revised for the years 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).
- 1A3d/Memo item: Recalculation in the reported amount of diesel oil consumption for international shipping on the river Rhine for the years 1997, 2001-2003, 2005, 2008, 2010, 2012.

8.1.1.6 Category-specific recalculations for 1A4 Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

- 1A4a/b/cii: Emission factors of Pb and SO_x in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii, 1A5b as well as those in 1A3b Road transportation were revised for the years 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).

8.1.1.7 Category-specific recalculations for 1A5b Other, mobile (Military)

- 1A5b: Emission factors of Pb and SO_x in all non-road sectors 1A2gvii, 1A3c/d, 1A4a/b/cii, 1A5b as well as those in 1A3b Road transportation were revised for the year 1980-2050. This revision is based on measurements of S-content in gasoline and diesel oil samples and on official information concerning the S-content in natural gas used in Switzerland (see chp. 3.2.1.2). For Pb the tier 1 emission factors as published in the EMEP/EEA guidebook (EMEP/EEA 2019) are used in this submission. The recalculation results in 98% lower Pb emissions from gasoline use since 2001 and higher emissions from diesel oil use (emission factor for diesel was zero in previous submissions).

8.1.1.8 Category-specific recalculations for 1B Fugitive emissions from fuels

- There are no category-specific recalculations for 1B1 Fugitive emissions from solid fuels.
- 1B2av: The model for determining NMVOC emission factors at gasoline stations in 1B2a Fugitive emissions from oil distribution was completely revised. New emission factors were determined for the years 1980, 1990, 2002, 2010, 2020 and forecasts. This leads to slightly lower NMVOC emissions in 1990 (around 0.3kt) and to higher emissions from 1993 onwards. In 2020, the difference amounts +1.1kt, which corresponds to approx. 1% of total NMVOC emissions.
- 1B2av: Based on a new study (Carbura 2022), NMVOC emissions from storage tanks for jet kerosene were determined and modelled for the entire time series 1990-2050. The emissions are significantly smaller compared to those from gasoline storage tanks or gasoline stations.
- 1B2b: Small recalculation, as fewer decimal places were used for activity rate and emission factors of NMVOC to calculate fugitive emissions from natural gas distribution network for all years.
- 1B2c: Small recalculation due to rounding of emission factors for 1B2c Flaring oil for the years 2016-2020.
- 1B2c: Recalculation for CO emission factor for 1B2c Flaring Oil due to a mistake in previous submission.

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 2020 has been revised based on effective production data from the industry association.
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8.1.2.2 Category-specific recalculations in 2B Chemical industry

- 2B5: The emission factors for SO_x, PM2.5, PM10 and TSP of source category 2B5 Silicon carbide production were updated for 1990–2012, 1990–2020 and 1990–2008, 2011, 2020, respectively, based on industry data and information.

8.1.2.3 Category-specific recalculations in 2C Metal production

- 2C7c: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of source category 2C7c Galvanizing plants have changed from 2013 onwards.

8.1.2.4 Category-specific recalculations in 2D Other solvent use

- 2D3a: Since in many spray applications the aerosol has both the function of the propellant and the solvent, a clear differentiation is often not possible at all. Therefore, the source category 2D3a Domestic use of spray cans was removed and its NMVOC emissions were integrated in the respective application sources, among other things, also in the two sources 2D3a Use of cleaning agents and 2D3a Domestic use of pharmaceuticals.

- 2D3a: Source category 2D3a Domestic use of cleaning agents, which includes also the use of cosmetics, toiletries and care products, was updated based on detailed sales figures for special cleaning and care products, waterproofing sprays and air refresheners from 2017–2020 and NMVOC contents, especially of aerosol cans, based on information from the largest contract manufacturer in Switzerland, resulting in revised NMVOC emission factor values from 2001 onwards.
- 2D3c: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of source category 2D3c Asphalt roofing have changed from 2012 onwards.
- 2D3d: The NMVOC emission factor values of source category 2D3d Coating application, household were revised for 1999–2020 as the propellants of the paint spray cans were now also considered for 2016.
- 2D3e: Due to the removal of the source category 2G Use of aerosol cans in commerce and industry (except for a residual batch of the commercial insecticide application), the aerosol of the spray applications of the categories "industry and technical products" as well as "automotive applications without coating" were now also taken into account in the three source categories of 2D3e Degreasing resulting in revised activity data and NMVOC emission factors for the entire time series.
- 2D3g: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of fine chemicals production, pharmaceutical production and handling and storage of solvents have changed from 2012 onwards as well as of ink production from 2017 onwards.
- 2D3h: Due to new projection figures for 2025 (EP2050+), the interpolated activity data of package printing and other printing have changed from 2017 onwards.
- 2D3i: Activity data and NMVOC emission factor of source category 2D3i Production of paper and paperboard were updated for the years 2016–2021 and 2020, respectively, based on production figures and a survey of the association of Swiss paper, cardboard and foil manufacturers yielding revised activity data and emission factors for 2012–2020 and for 2008–2020, respectively.
- 2D3i: Activity data and NMVOC emission factor of source category 2D3i Production of flavours and fragrances were updated for the year 2021, based on industry information and VOC balances yielding revised activity data and emission factors from 2012 onwards.

8.1.2.5 Category-specific recalculations in 2G Other product use

- 2G: The activity data of source category 2G Use of concrete additives was updated for 2020 based on manufacturer data yielding revised values for the years 2013–2020.
- 2G: Due to the removal of the source category 2G Use of aerosol cans in commerce and industry (except for a residual batch of the commercial insecticide application), the aerosols of disinfection sprays were now also taken into account in the source categories 2G Health care other and 2G Medical practices resulting in revised activity data and NMVOC emission factors for the entire time series.
- 2G: The activity data and NMVOC emission factor values of source category 2G Hairdressers were revised completely based on enquiries and information from the largest contract manufacturer of aerosol cans in Switzerland and the European aerosol association.
- 2G: Since in many spray applications the aerosol has both the function of the propellant and the solvent, a clear differentiation is often not possible at all. Therefore, the NMVOC emissions of source category 2G Use of aerosol cans in commerce and industry (except for a residual batch of the commercial insecticide application) were integrated in the respective commercial and industrial application sources.

- 2G: Activity data and NMVOC emission factors of source categories 2G Use of cooling lubricants and 2G Use of lubricants were updated for the years 2003–2020, based on statistics of the association of the lubricants industry and data of the foreign trade statistics yielding revised activity data and emission factors from 2003 onwards.

8.1.2.6 Category-specific recalculations in 2H Other industry production

- 2H2 Meat smokehouses: Activity data have decreased by 0.37% (-241 t) in 2019 and increased by 0.36% (241 t) in 2020, respectively, due to changes in the underlying statistics for annual per capita meat consumption by the FSO.

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 2023.

8.1.3 3 Agriculture

8.1.3.1 Category-specific recalculations in 3B Manure management

- 3B1: The emission factors of PM2.5, PM10 and TSP were revised for all cattle categories for the years 1996–2020 due to updated data for the fractions of animals kept in tied housing (Kupper et. al. 2022).
- 3B1: Some adjustments were made in the allocation of manure to the various storage systems. The elimination of volatile solids (VS) has been revised (digestibility (DE%) and update VS), which resulted in changes in NO_x emission factors of all cattle categories for the whole time series.
- 3B3: The activity data of source category 3B3 Manure management - Swine were revised for the years 1990-2016, since the animal population statistics were adjusted due to an error correction in the accounting of suckling piglets. These revised animal numbers also resulted in recalculated implied emission factors of all pollutants (NO_x, NMVOC, NH_3, PM2.5, PM10, TSP).
- 3B3, 3B4gii: The animal numbers of fattening pigs and broilers of source categories 3B3 Manure management - Swine and 3B4gii Manure management - Broilers were revised for 2020, since provisional animal population statistics from background data of the FSO were updated. The revised numbers of fattening pigs also resulted in recalculated implied emission factors of all pollutants (NO_x, NMVOC, NH_3, PM2.5, PM10, TSP) of 3B3 Manure management - Swine.

8.1.3.2 Category-specific recalculations in 3D Crop production and agricultural soils

- 3Da: The activity data for swine in source categories 3Da2a Animal manure applied to soils and 3Da3 Urine and dung deposited by grazing animals were revised for the years 1990-2016, since the animal populations statistics were adjusted due to an error correction in the accounting of suckling piglets. These revised animal numbers also resulted in recalculated implied emission factors of NH_3.
- 3Da: The activity data for fattening pigs and broilers in source categories 3Da2a Animal manure applied to soils and 3Da3 Urine and dung deposited by grazing animals were re-

vised for 2020, since provisional animal populations statistics from background data of the FSO were updated. The revised numbers of fattening pigs also resulted in recalculated implied emission factors of NH_3 for 3B3 Manure management - Swine.

- 3Da: Some adjustments were made in the allocation of manure to the various storage systems. The elimination of VS has been revised (DE% and update VS), which resulted in changes in NO_x emission factors of all cattle categories for the whole time series.
- 3Da1: The activity data of source category 3Da1 Inorganic N-fertilizers were revised for the whole time series due to updated values for inorganic fertilizers used in Liechtenstein that were subtracted from amounts applied in Switzerland. The impact on overall emissions is negligible.
- 3Da2c: The activity data and the weighted mean NH_3 emission factor of source category 3Da2c Other organic fertilizers were revised for the year 2020 due to updated values for the amount of compost applied to agricultural soils.
- 3De: The activity data for grassland of source category 3De Cultivated crops was revised for 2019 and 2020 based on updated FSO data (farm structure survey).
- 3De: The emission factors of particulate matter from of source category 3De Cultivated crops (cropland) were revised for 2020 based on updated FSO data (farm structure survey).

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 2023.

8.1.4.2 Category-specific recalculations in 5B Biological treatment of waste – Composting and anaerobic digestion at biogas facilities

There were no recalculations implemented in submission 2023.

8.1.4.3 Category-specific recalculations in 5C Waste incineration and open burning of waste

There were no recalculations implemented in submission 2023.

8.1.4.4 Category-specific recalculations in 5D Wastewater handling

- 5D1 Domestic wastewater treatment: The emission factor for NH_3 has decreased by <1 % over the period 1990–2020 due to a change in the underlying data source (number of persons with centralised wastewater treatment).

8.1.4.5 Category-specific recalculations in 5E Other waste, car shredding

There were no recalculations implemented in submission 2023.

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 2020 has increased by 0.11% (23 people), due to changes in the underlying statistics by the FSO.
- 6Ab Livestock outside agriculture: Some adjustments were made in the allocation of manure to the various storage systems. The elimination of volatile solids (VS) has been revised (digestibility (DE%) and update VS), which resulted in changes of NO_x emission factors from grazing of livestock outside agriculture for the years 1995–2020.
- 6Ac Private application of synthetic fertilizer and urea: The activity data and the weighted mean NH_3 emission factor were revised for the whole time series due to updated values for fertilizers used in Liechtenstein that are subtracted from amounts applied in Switzerland.
- 6Ad Fire damages estates: Activity data for the years 1990–1995 (amount of burnt material) have been recalculated based on newly available data from the fire insurance association of the cantons (Vereinigung kantonaler Feuerversicherungen, VKF). Activity data for the years 1996–2020 (amount of burnt material) increased by 20 % (1’442 t) on average (11–38 %, 710 t to 2’584 t), due to a change in the underlying statistics by VKF.

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 2016, 2018, 2019 and 2020 on forest land and in the year 2018 on grassland.

8.1.5.3 Recalculations in 11C Other natural emissions

There were no recalculations implemented in submission 2023.

8.1.6 Implications of recalculation for emission levels

Table 8-1 shows the effect of recalculations on the emission levels 2020 and 1990, based on the previous (2022) and latest (2023) submission.

In 2020, recalculations have a minor effect on the emission levels compared to previous submissions except for Pb emissions (-9.8 %). The recalculations cause a higher emission level between 3°% and 1°% for Cd, PCDD/PCDF and Hg. A decrease due to recalculations between 10°% and 1 % is observed for Pb, BC, NMVOC and NO_x. For all other pollutants, the difference in emissions due to recalculations for 2020 does not exceed 0.6 %.

In 1990, recalculations do not cause an increase or a decrease of more than 1 % for any pollutant. The largest differences occur for SO_x (+0.5°%) and BC (-0.4°%) emissions, whereas the change for all other pollutants does not exceed 0.2 %.

Table 8-1 Recalculations: Implications for the emission levels 2020 and 1990. The values refer to the NFR submission 2022 (previous) and 2023 (latest). Differences are given in absolute and relative numbers for all pollutants.

Pollutant	Units	2020			
		previous subm. 2022	latest subm. 2023	difference (abs.)	difference (rel.) previous = 100%
NO_x	kt	53	53	-0.71	-1.3%
NMVOC	kt	76	74	-1.6	-2.1%
SO_x	kt	3.8	3.8	-0.024	-0.6%
NH_3	kt	53	53	-0.075	-0.1%
PM2.5	kt	5.9	5.9	-0.019	-0.3%
PM10	kt	14	14	0.019	0.1%
TSP	kt	27	27	-0.0058	0.0%
BC	kt	1.0	1.0	-0.030	-2.9%
CO	kt	152	152	0.15	0.1%
Pb	t	14	13	-1.4	-9.8%
Cd	t	0.59	0.61	0.015	2.6%
Hg	t	0.64	0.65	0.0079	1.2%
PCDD/PCDF	g I-TEQ	14	14	0.18	1.3%
PAH (total)	t	2.5	2.5	-0.0031	-0.1%
HCB	kg	0.35	0.35	0.00087	0.2%
PCB	kg	408	408	-0.0000067	0.0%

Pollutant	Units	1990			
		previous subm. 2022	latest subm. 2023	difference (abs.)	difference (rel.) previous = 100%
NO_x	kt	145	144	-0.074	-0.1%
NMVOC	kt	302	302	0.031	0.0%
SO_x	kt	37	37	0.18	0.5%
NH_3	kt	69	69	0.0062	0.0%
PM2.5	kt	17	17	0.028	0.2%
PM10	kt	25	25	0.038	0.2%
TSP	kt	44	44	0.041	0.1%
BC	kt	6	5.7	-0.023	-0.4%
CO	kt	817	818	0.13	0.0%
Pb	t	380	381	0.15	0.0%
Cd	t	3	3.4	0.0040	0.1%
Hg	t	6	6.4	0.0020	0.0%
PCDD/PCDF	g I-TEQ	194	194	0.058	0.0%
PAH (total)	t	8	8.1	0.00055	0.0%
HCB	kg	173	173	-0.0000012	0.0%
PCB	kg	2'332	2'332	0.000000029	0.0%

The source categories with the most important recalculations implemented for main pollutants and PM2.5 in submission 2023 in terms of absolute emissions are listed in Table 8-2 and Table 8-3 for the years 2020 and 1990, respectively. The most important recalculations for each year and each pollutant are the following:

NO_x

- For the whole time series, the most important recalculation concerning NO_x emissions occurs in category 1A3b Road transportation. On one hand, the activity data (mileage) for different vehicle categories have been updated. On the other hand, the emission factors were adjusted to the newest version of HBEFA (4.2). The effect differs for different vehicle categories. For passenger cars (1A3bi), emissions decreased, mainly because software updates for diesel-powered passenger cars were considered in HBEFA 4.2 (for Euro V standard vehicles). For heavy duty vehicles and buses (1A3biii), the overall increase of NO_x emissions is mainly due to inclusion of updated ageing functions of these vehicles.

NMVOC

- The most important recalculation in the year 2020 and a relevant one in 1990 concerns category 2D3a Domestic solvent use including fungicides. Firstly, under 2D3a, the source category domestic use of spray cans (propellant emissions) was removed for the entire time series, as it is often not possible to distinguish between the propellant and solvent function in aerosol cans. Their NMVOC emissions were reallocated to the respective application source categories (i.e. 2D3a Domestic use of cleaning agents, 2D3d Coating applications, household, 2G Hairdressers and 2D3a Domestic use of pharmaceutical products). Secondly, the domestic use of cleaning agents, which includes also the use of cosmetics, toiletries and care products, was updated based on detailed sales figures for special cleaning and care products, waterproofing sprays and air refresheners as well as their NMVOC content, especially of aerosol cans based on information from the largest contract manufacturer in Switzerland.
- The most important recalculation in 1990 and a relevant one in 2020 concerns 2G Other product use. Analogously to the domestic use of spray cans (2D3a) also the source category 2G Use of aerosol cans in commerce and industry was removed (except for a residual batch of the commercial insecticide application) and their NMVOC emissions were reallocated to the respective application source categories (i.e. 2D3e Degreasing, 2G Healthcare and other and 2G Medical practices). In addition, source category 2G Hairdressers was completely revised based on enquiries and information from the largest contract manufacturer of aerosol cans in Switzerland and the European aerosol association for the entire time series.
- Also of importance in 1990 is the recalculation of NMVOC emissions in source category 1A4bi Residential: Stationary. An error in the country-specific emission factor model for wood energy combustion was corrected resulting in revised NMVOC emission factors of log wood single-room furnaces and dual chamber boilers for the entire time series in 1A4 Small combustion.
- Other important recalculations in 2020 and 1990 concern source category 1B2av Distribution of oil products. The model for determining NMVOC emission factors at gasoline stations was completely revised and new emission factors were determined for the entire time series.

SO_x

- The most important recalculation for SO_x emissions in 2020 stems from source category 1A3b Road transportation. The changes in emission levels of 1A3b are also visible in the year 1990. First, SO_x emission factors were revised for 1A3b for the whole time series (based on measurements of S-content in gasoline and diesel oil samples and an official information concerning the S-content in natural gas used in Switzerland). Second, the activity data (mileage) for different vehicle categories have been updated and third, the emission factors were adjusted to the newest version of HBEFA (4.2).
- The most important recalculation for the year 1990 concerns source category 2B5 Carbide production. The emission factor for SO_x for silicon carbide (and graphite) production was updated for 1990-2012 based on industry data and information.

NH_3

- The most important recalculation of NH_3 emissions in 2020 and 1990 concern emissions from category 1A3b Road transportation. On one hand, the activity data (mileage) for different vehicle categories have been updated. On the other hand, the emission factors were adjusted to the newest version of HBEFA (4.2).

PM2.5

- The most important recalculation of PM2.5 emissions in 2020 concern emissions from category 1A3b Road transportation. On one hand, the activity data (mileage) for different vehicle categories have been updated. On the other hand, the emission factors were adjusted to the newest version of HBEFA (4.2). These recalculations also lead to changes in emission levels 1990.
- The most important recalculation in 1990 stems from category 2B5 Carbide production. The emission factor for PM2.5 for silicon carbide (and graphite) production was updated for 1990-2020 based on industry data and information.

Table 8-2 NFR categories with most important implications of recalculations on emission levels in 2020 in terms of absolute differences for the main pollutants and PM2.5. The values refer to the NFR submission 2022 and 2023. The list is ranked for each pollutant in terms of the absolute difference in emission levels due to recalculations.

NO_x (as NO_2)		NMVOC		SO_x (as SO_2)		NH_3		$PM_{2.5}$	
	kt		kt		kt		kt		kt
1A3bi_Road transport: Passenger cars	-1.2	2D3a_Domestic solvent use including fungicides	-2.7	1A3bi_Road transport: Passenger cars	-0.019	1A3bi_Road transport: Passenger cars	-0.074	1A3bi_Road transport: Passenger cars	-0.021
1A3biii_Road transport: Heavy duty vehicles and buses	0.42	1B2av_Distribution of oil products	1.2	1A3biii_Road transport: Heavy duty vehicles and buses	-0.0032	1A3bii_Road transport: Light duty vehicles	-0.0031	1A3bii_Road transport: Light duty vehicles	-0.015
1A3biv_Road transport: Mopeds & motorcycles	0.027	2G_Other product use	-0.55	1A3bii_Road transport: Light duty vehicles	-0.0025	3Da2c_Other organic fertilisers applied to soils (including compost)	-0.0027	1A3bvi_Road transport: Automobile tyre and brake wear	0.011
1A4ai_Commercial/Institutional: Stationary	0.021	2D3e_Degreasing	0.25	1A2gvii_Mobile combustion in manufacturing industries and construction	-0.0012	1A3biii_Road transport: Heavy duty vehicles and buses	0.0011	1A3biii_Road transport: Heavy duty vehicles and buses	-0.011
1A3ai(i)_International aviation LTO (civil)	0.015	2D3d_Coating applications	0.22	1A3ai(i)_International aviation LTO (civil)	0.0010	3Da2a_Animal manure applied to soils	0.00096	1A3biv_Road transport: Mopeds & motorcycles	0.0037

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 2022 and 2023. 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
1A3biii_Road transport: Heavy duty vehicles and buses	-0.19	2G_Other product use	-1.3	2B5_Carbide production	0.18	1A3bi_Road transport: Passenger cars	0.0068	2B5_Carbide production	0.018
1A3bi_Road transport: Passenger cars	0.11	1A4bi_Residential: Stationary	1.2	1A3biii_Road transport: Heavy duty vehicles and buses	-0.0079	5D1_Domestic wastewater handling	-0.00063	1A3bi_Road transport: Passenger cars	0.0061
1A3bii_Road transport: Light duty vehicles	0.0086	2D3e_Degreasing	0.57	1A3bi_Road transport: Passenger cars	0.0076	1A3bii_Road transport: Light duty vehicles	0.000058	1A3biii_Road transport: Heavy duty vehicles and buses	0.0032
1A2gviii_Stationary combustion in manufacturing industries and construction: Other	-0.00042	2D3a_Domestic solvent use including fungicides	-0.33	1B2c_Venting and flaring (oil, gas, combined oil and gas)	-0.00078	3Da1_Inorganic N-fertilizers (includes also urea application)	-0.000036	1A3bvi_Road transport: Automobile tyre and brake wear	0.00064
6A_Other (included in national total for entire territory)	0.00039	1B2av_Distribution of oil products	-0.27	1A3bii_Road transport: Light duty vehicles	0.00062	1A2gviii_Stationary combustion in manufacturing industries and construction: Other	-0.000017	1A3bii_Road transport: Light duty vehicles	0.00050

8.1.7 Implications of recalculation for emission trends of main pollutants and PM2.5

The emission trends 1990–2020 are only slightly affected through the recalculations in the latest submission. The most significant change occurred for the trend of NO_x and NMVOC emissions, where the decreasing trend is around 0.5 % weaker in the latest compared to the previous submission. For all other pollutants, the change in trend is negligible (difference of maximum 0.2 %).

Table 8-4 Recalculations: Implications for the emission trends between 1990 and 2020 for the main pollutants. The values refer to the NFR submission 2022 and 2023.

Pollutant	**Trend 1990-2020 (1990 = 100%)**	
	previous subm. 2022	**latest subm. 2023**
	%	%
NO_x	37	36
NMVOC	25	25
SO_x	10	10
NH_3	78	78
PM2.5	36	36

8.2 Planned improvements

The following improvements are planned for the submission 2023. Improvements for source categories which are key categories are, as much as possible, given priority.

General (not sector specific) no planned improvements.

Energy (stationary)

- 1A stationary engines and gas turbines: based on a new data collection and model emissions from stationary engines and gas turbines were reestimated for all the years and will be implemented in the inventory. Within source category 1A4, several sub-categories are key categories for the main pollutants NO_x, NMVOC, SO_x, PM2.5 and PM10.

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.
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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. Source categories 3B1a and 3B1b are both key categories for NMVOC.
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Waste no planned improvements

Other and Natural no planned improvements

9 Emission projections 2022–2030

9.1 Comments on projections

The emission projections of air pollutants in Switzerland have been fully revised in the course of submission 2022 and a new “With Measures” (WM) scenario was elaborated. The activity data for the sectors energy, IPPU and waste are in accordance with the base scenario called “WWB” (which means “with existing measures”) of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). Note 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, the air pollutant emissions in chps. 9.3 to 9.6 are shown for the “With Measures” (WM) scenario only. A “With additional Measures” (WaM) scenario was not elaborated for the latest submission.

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), 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 2023)
	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, 2008-2022)
	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. 2023). 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). The base scenario called “WWB” (German for “Weiter wie bisher” meaning a continuation of existing energy and climate policy measures) of the Swiss Energy Perspectives 2050+ is calculated on energy consumption data from 2017 onwards. The measures taken during the COVID-19 pandemic situation in the years 2020-2021 had an impact on road transportation and aviation activities lead to exceptional low fuel consumption and activity data. Therefore, an increasing trend in energy consumption after the latest submission year (2021) to the first displayed projection year (2025) can be observed especially in 1A3 Transportation. In general, from 2025 onwards, the actual projections of the Swiss Energy Perspectives 2050+ are used and data from 2022 to 2024 is linearly interpolated between past statistical data 2021 and projected data 2025. Due to the strong decline in air traffic by the pandemic situation in 2020 and 2021, projections for the year 2025 are used for 1A3a Aviation and linearly interpolated in between (2021-2024). For 1A3b Road transportation, model data based on the Swiss Energy Perspectives 2050+ with an annual resolution is implemented. Due to the lack of detailed, disaggregated data in the Swiss Energy Perspectives 2050+ for processes in all non-road sectors, model data from the previous projections (Prognos 2012a) is 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+.

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.

Sector	Sectoral scenario	Reference
1 Energy	Swiss Energy Perspectives 2050+ scenario "WWB" (with existing measures) updated with new national reference scenario for popoulation ("A-00-2020"). Activity data in the nonroad sectors still base on assumptions of Prognos (2012a).	Prognos/INFRAS/TEP/Ecoplan 2020 SFSO 2020p Prognos 2012a
2 IPPU	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	Continuation of Agricultural policy 2018-2021	Swiss Confederation 2017 Mack and Möhring 2021
5 Waste	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 and their assumed development between 2010 and 2030.

Table 9-3 Trend of underlying key factors of the WM scenario between 2010 and 2030 (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	2010-2030
Population (million)	7.83	8.28	8.64	9.02	9.39	20%
GDP (prices 2017, billion CHF)	603	648	713	760	805	33%
Oil price (prices 2017, USD/barrel)	88	-	75	88	96	9%
Gas price (prices 2017, CHF/MWh)	28	-	24	27	28	0%
Heating degree days	3'586	3'075	3'182	3'135	3'089	-14%
Cooling degree days	153	263	177	188	199	30%
Energy reference area (million m^2)	706	744	782	816	847	20%
Passenger cars (million vehicle km)	52'066	56'620	52'840	61'749	63'691	22%

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 2030 for each source category in the energy sector. In source category 1A3, the electricity consumption of the electric vehicles is also included.

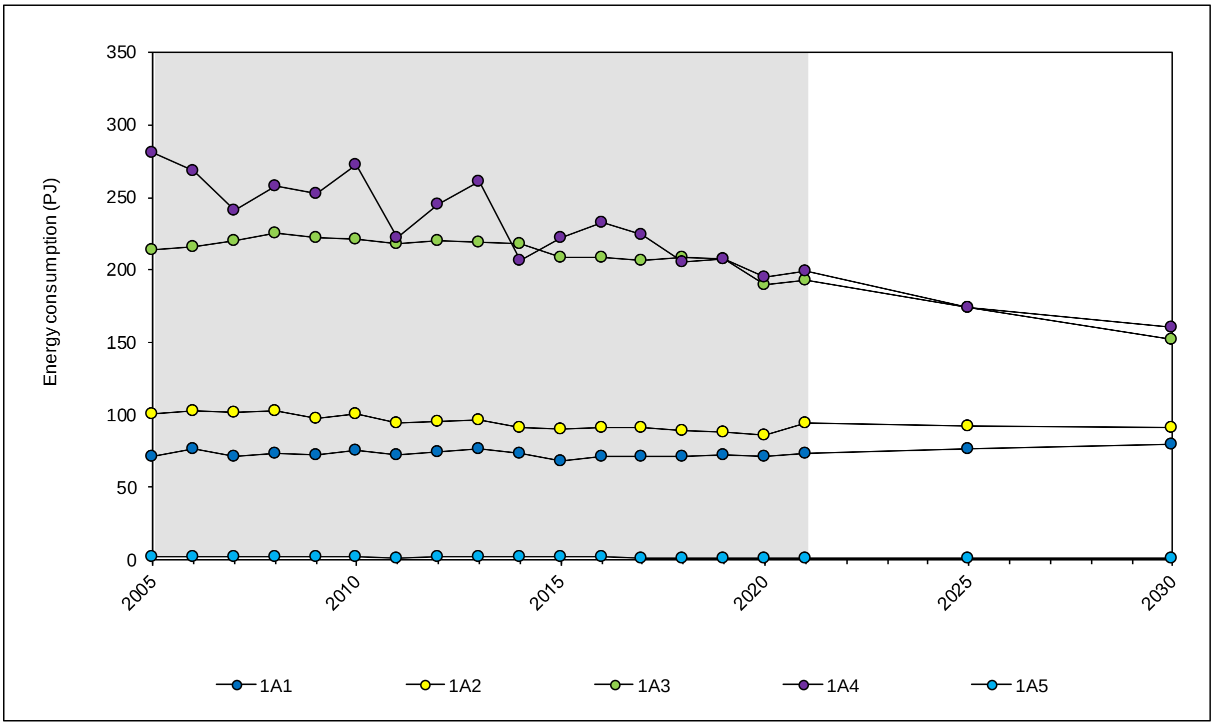

Figure 9-1 Fuel consumption in Switzerland as projected in the WM scenario in source categories 1A1 – 1A5 of the source category 1A Fuel combustion. 1A3 also includes the electricity consumption of the electric vehicles.

Fuel consumption in 1A1 Energy industries is mainly caused by waste incineration depending on the population growth. It is assumed to remain at the current levels per capita. Due to population growth, the amount of waste is increasing, leading to growing fuel consumption in this source category based on waste incineration.

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. Also considered are the respective building and facility management processes as well as the use of biogas and sewage gas in boilers and engines. Fuel consumption is then projected based on activity data for the sectors and specific energy use per process.

For the transport sector, parameters such as tonne-kilometres, passenger-kilometres, vehicle-kilometres, specific energy use and substitution effects were determined on the basis of model estimations.

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.

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.

Finally, the electricity production of the existing power plant park is projected with a bottom-up approach, taking into account the life-time of the power plants.

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 2030. 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

Overall projections of the emissions for NO_x, NMVOC, SO_x and CO indicate a significant decline between 2005 and 2030 while it is much weaker for NH_3 (Figure 9-2).

Note that the projected development trend between 2021 and 2025 particularly for NO_x, SO_x and CO is influenced by the drop of emissions in 2020/2021 due to reduced traffic volumes caused by the COVID-19 pandemic situation.

The following developments are expected for the time period 2021-2030:

- NO_x emission reductions are projected to continue their decrease until 2030. The reductions are mainly projected to happen in source category 1A Fuel combustion. For 1A3b Road transportation, improved emission abatement technology, in-use compliance under real driving conditions and increase of electromobility are the relevant drivers. For 1A2 Manufacturing industry and construction and 1A4 Other sectors, reduced emissions from domestic and commercial heating, higher shares of heat pumps and increased use of eco-grade gas oil (mandatory for combustion installations <5 MW from summer 2023) are expected.
- NMVOC emissions are projected to decrease very slightly compared to the current levels. The main driver for a decrease is in source category 1A Fuel combustion caused by improved emission abatement technology for road and non-road vehicles and machineries and an overall reduction of fuel consumption, in particular of log wood. Population growth and, to some extent, the stagnation of the effects of the VOC incentive tax (Swiss Confederation 1997) will lead to a slight increase of NMVOC emissions in sector 2 IPPU. In

sector 5 Waste, an increase is based on the assumption that the production of biogas is likely to increase, in particular anaerobic digestion at biogas facilities under 5B2.

- The SO_x emissions are projected to remain low, which is mainly due to the revision of the Ordinance on Air Pollution Control (Swiss Confederation 1985) in 2018, which included that eco-grade gas oil (with low sulphur content) is only allowed to be used in installations of a rated thermal input of less than 5 MW from summer 2023 onwards.
- NH_3 emissions are projected to remain more or less on constant, but on a slightly lower level than in 2021 (mainly depending on animal numbers, which are projected to decrease slightly up to 2027 and remain constant afterwards).
- Concerning CO emissions, a continuous decreasing trend is projected mainly in 1A3b Road transportation and 1A4 Other sectors driven by improved emission abatement technology for road vehicles, an increase in electromobility, lower fuel consumption for heating because of better insulation of buildings and a higher share of heat pumps.

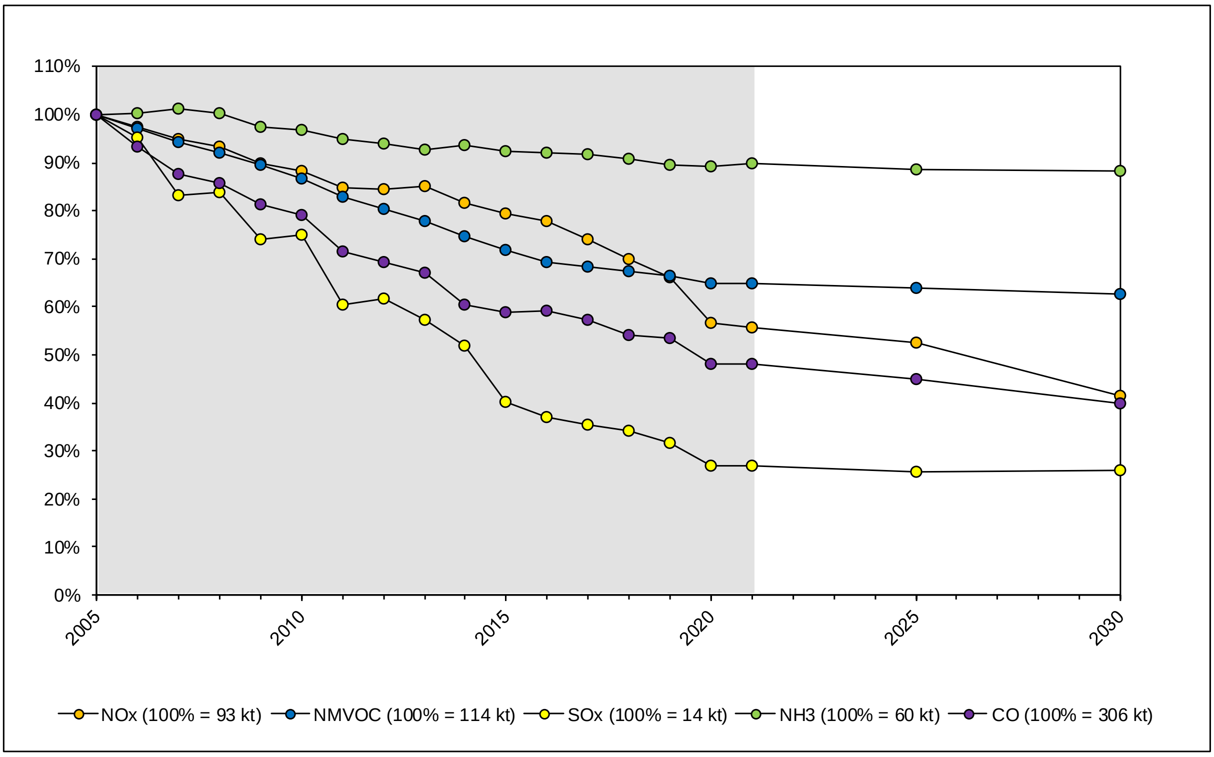

Figure 9-2 Relative trends for the total emissions of main air pollutants and CO in Switzerland as projected in the WM scenario. 100 % corresponds to the 2005 levels (base year of the Gothenburg Protocol).

Table 9-4 Main air pollutants and CO: Total emissions of the WM projections until 2030 in kt.

Year	NO_x	NMVOC	SO_X	NH_3	CO
	kt	kt	kt	kt	kt
2005	93	114	14	60	306
2010	83	99	10	58	242
2012	79	92	8.6	56	212
2013	79	89	8.0	55	206
2014	76	85	7.2	56	185
2015	74	82	5.6	55	180
2016	73	79	5.2	55	181
2017	69	78	5.0	55	175
2018	65	77	4.8	54	165
2019	62	76	4.4	54	164
2020	53	74	3.8	53	148
2021	52	74	3.8	54	148
2025	49	73	3.6	53	138
2030	39	71	3.6	53	122
2030 vs. 2021 (%)	-26%	-4%	-4%	-2%	-17%

9.3.1 Projections for NO_X

The decreasing trend for NO_x emissions which is visible since 2005 is expected to continue until 2030 (see Figure 9-3 and Table 9-5). The most significant reductions happen in source category 1A Fuel combustion – especially in 1A3b Road transportation with the largest absolute contribution and the strongest relative decrease – but also in source categories 1A2 Manufacturing industry and construction and 1A4 Other sectors.

Reductions under 1A Fuel combustion are expected to be achieved by improved emission abatement technology and by improved in-use compliance under real driving conditions for road vehicles in source category 1A3b Road transportation (triggered by the Euro 6/VI standards and a reduction of fuel consumption due to the increase of electromobility (see Figure 9-1)) as well as by measures related to domestic and commercial heating in source category 1A4 Other sectors such as better insulation of buildings, higher share of heat pumps or increased use of eco-grade gas oil (with low sulphur and nitrogen content). In source category 1A2 Manufacturing industry and construction, reductions of production volumes (e.g. cement industry and other non-metallic minerals) also contribute to the overall projected emission reduction until 2030. The slight emission increase of 1A1 is caused by growing amount of waste incinerated due to population growth. Compared to the energy sector, the other sectors are less relevant for the development of NO_x emissions. In sector 2 Industrial processes and product use, emissions in 2030 are projected to be lower than in the base year 2005 but to increase compared to the current (low) level in 2021. In sector 3 Agriculture, emissions are expected to be lower in 2030 than in 2005, but to remain constant on current levels. In sector 5 Waste, a decrease in emissions is expected until 2025 compared to 2005. From 2025 onwards, the trend levels off. In sector 6 Other, emissions are on a very low level and are expected to slightly increase until 2030 compared to 2005.

Table 9-5 WM projections: Relative trends of NO_x emissions per sector (2005 represents 100 %).

NO_x emissions	**2005**	**2021**	**2025**	**2030**
	kt	%	%	
1 Energy	89	54%	51%	39%
1A Fuel combustion	89	54%	51%	39%
1A1 Energy industries	2.9	83%	87%	92%
1A2 Manufacturing industries and constr.	14	53%	50%	43%
1A3 Transport	55	51%	49%	34%
1A4 Other sectors	16	60%	52%	43%
1A5 Other (Military)	0.60	63%	59%	58%
1B Fugitive emissions from fuels	0.29	0.5%	0.5%	0.5%
2 IPPU	0.32	78%	78%	83%
3 Agriculture	3.8	96%	93%	93%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.16	76%	76%	76%
6 Other	0.093	106%	103%	102%
National total	93	56%	53%	41%

9.3.2 Projections for NMVOC

The bulk of NMVOC emission reductions has been achieved until 2016, and a minor decrease of emissions is expected from 2021 up to 2030 (see Figure 9-3, Table 9-4 and Table 9-6). Although an increase is projected in sector 2 IPPU, the most important source for NMVOC emissions, a reduction in the energy sector leads to the overall reduction.

NMVOC emission reductions are projected to happen in 1A Fuel combustion. A substantial reduction will take place in 1A3b Road transportation caused by a reduction of gasoline-powered vehicles and a reduction of overall fuel consumption, in particular of log wood (see Figure 9-1). In sector 2 IPPU, a slight increase is expected due to population growth and, to some extent, due to stagnating effects of the VOC incentive tax in 2000 (Swiss Confederation 1997). In sector 3 Agriculture, emissions are expected to slightly decrease (mainly due to the development of cattle population). The increase in the waste sector is based on the assumption that the production of biogas is likely to increase, in particular anaerobic digestion at biogas facilities under 5B2. In sector 6 Other, emissions have increased between 2005 and 2015, but have stabilized afterwards on a very low level and are expected to slightly increase until 2030.

Table 9-6 WM projections: Relative trends of NMVOC emissions per sector (2005 represents 100 %).

NMVOC emissions	2005	2021	2025	2030
	kt	%	%	
1 Energy	44	37%	32%	27%
1A Fuel combustion	37	36%	32%	27%
1A1 Energy industries	0.22	79%	80%	82%
1A2 Manufacturing industries and constr.	2.1	44%	44%	42%
1A3 Transport	23	32%	28%	23%
1A4 Other sectors	11	43%	37%	30%
1A5 Other (Military)	0.11	56%	54%	53%
1B Fugitive emissions from fuels	7.4	38%	33%	28%
2 IPPU	52	71%	72%	73%
3 Agriculture	17	112%	111%	110%
4 LULUCF	NR	NR	NR	NR
5 Waste	1.0	171%	216%	273%
6 Other	0.22	106%	107%	107%
National total	114	65%	64%	63%

9.3.3 Projections for SO_x

The decreasing trend of SO_x emissions is expected to continue until 2025, thereafter emissions remain about constant (see Figure 9-3, Table 9-4 and Table 9-7). The highest contributions to SO_x emissions stem from source categories 1A2 Manufacturing industries and construction and 1A4 Other sectors.

The projected decrease is mainly due to the revision of the Ordinance on Air Pollution Control (Swiss Confederation 1985) in 2018, which included that eco-grade gas oil (with low sulphur content) is only allowed to be used in installations of a rated thermal input of less than 5 MW from summer 2023 onwards and a 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). After 2025, SO_x emissions from source category 1A1 and sector 2 slightly increase due to a projected increase in the use of residual fuel oil in 1A1b Petroleum refining and production volume in 2B5 Silicon carbide (and graphite) production, respectively. Only marginal emission reductions or stable levels are projected for all other source categories.

Table 9-7 WM projections: Relative trends of SO_x emissions per sector (2005 represents 100 %).

SO_x emissions	2005	2021	2025	2030
	kt	%	%	
1 Energy	13	25%	23%	23%
1A Fuel combustion	12	26%	24%	23%
1A1 Energy industries	1.7	20%	22%	26%
1A2 Manufacturing industries and constr.	4.1	45%	44%	43%
1A3 Transport	0.21	59%	114%	122%
1A4 Other sectors	6.3	14%	8.0%	6.7%
1A5 Other (Military)	0.037	80%	80%	80%
1B Fugitive emissions from fuels	0.51	2.7%	2.7%	2.8%
2 IPPU	1.0	45%	53%	65%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.063	46%	46%	46%
6 Other	0.012	97%	97%	97%
National total	14	27%	26%	26%

9.3.4 Projections for NH_3

Emission projections for NH_3 are highly dependent on sector 3 Agriculture. Overall, NH_3 emissions are expected to decrease slightly between 2021 and 2030 (see Figure 9-3 and Table 9-4).

The emission projections for the sector 3 Agriculture up to 2030 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. Nonetheless, changes are expected to occur due to the further application of existing programs with incentives to introduce low-emission techniques or animal welfare programs. Agricultural NH_3 emissions between 2021 and 2030 are expected to decline very slightly due to the projected development of livestock numbers for cattle until 2027.

Ammonia emissions from all other sectors are of minor relevance in comparison with the agriculture sector. NH_3 emissions show slightly decreasing trends 2021-2030 for sectors 1 Energy (due to new low emission vehicles and machinery) and 2 Industrial processes and product use. An increase compared to 2005 levels is expected to occur in sector 5 Waste due to a growing population. In sector 6 Other, emissions have increased between 2005 and 2015, but have stabilized afterwards and are expected to remain about constant at the current level.

Table 9-8 WM projections: Relative trends of NH_3 emissions per sector (2005 represents 100 %).

NH_3 emissions	**2005**	**2021**	**2025**	**2030**
	kt	%	%	
1 Energy	3.9	32%	32%	31%
1A Fuel combustion	3.9	32%	32%	31%
1A1 Energy industries	0.026	138%	156%	177%
1A2 Manufacturing industries and constr.	0.19	125%	119%	114%
1A3 Transport	3.5	24%	24%	24%
1A4 Other sectors	0.16	67%	63%	59%
1A5 Other (Military)	0.000039	103%	103%	103%
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	0.35	42%	41%	36%
3 Agriculture	54	94%	92%	92%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.93	97%	105%	117%
6 Other	0.88	114%	114%	114%
National total	60	90%	89%	88%

9.3.5 Projections for CO

Up to 2030, a continuous decreasing trend for total CO emissions is projected (see Figure 9-3 and Table 9-9).

Similar to NO_x emissions, this reduction is expected to be achieved by improved emission abatement technology for road vehicles (triggered by the Euro 6/VI standards and a reduction of fuel consumption due to the increase in electromobility (see Figure 9-1)). For domestic and commercial heating, continuous 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) are expected. Accordingly, the bulk of emission reductions occur in 1A Fuel combustion, particularly in 1A3 Transport and 1A4 Other sectors (see chp. 2). An increase in emissions can be observed in 1A1 Energy industries due to population growth and thereby an increase of waste incineration.

Table 9-9 WM projections: Relative trends of CO emissions per sector (2005 represents 100 %).

CO emissions	2005	2021	2025	2030
	kt	%	%	
1 Energy	295	47%	44%	38%
1A Fuel combustion	295	47%	44%	38%
1A1 Energy industries	0.96	61%	64%	66%
1A2 Manufacturing industries and constr.	21	76%	75%	74%
1A3 Transport	167	38%	36%	30%
1A4 Other sectors	106	56%	51%	45%
1A5 Other (Military)	0.92	80%	79%	79%
1B Fugitive emissions from fuels	0.063	0.4%	0.4%	0.4%
2 IPPU	8.1	70%	70%	84%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	1.9	75%	69%	62%
6 Other	0.91	87%	87%	87%
National total	306	48%	45%	40%

9.4 Suspended particulate matter

Projected trends for suspended particulate matter PM2.5, PM10, TSP and BC show an overall decline between 2005 and 2030 (see Figure 9-3 and Table 9-10).

The decline can be explained by two main measures: The tightening of emission standards for diesel engine vehicles that will prescribe lower limit values, and the tightening of emission limit values for particle emissions of (wood) combustion installations.

A considerable amount of particle emissions stems from road traffic abrasion and resuspension processes (non-exhaust emissions). They are not subject to reduction and are expected to increase with increasing activity (vehicle kilometres). Therefore, the expected decline of exhaust emissions is partially compensated by the expected increase of non-exhaust emissions. Since non-exhaust emissions are more relevant for larger fractions (see Figure 9-4 and Table 9-14), the overall expected decline of TSP and PM10 emissions is less pronounced than for the smaller fractions – and, from 2019 on, turns into a slight increase. In 2020/2021, due to the COVID-19 pandemic and thereby lower traffic volumes, non-exhaust PM emissions dropped (see Figure 9-4). Therefore, the overall trend for PM10 and TSP (exhaust and non-exhaust) is increasing between 2021 and 2025, afterwards, emissions remain about constant until 2030.

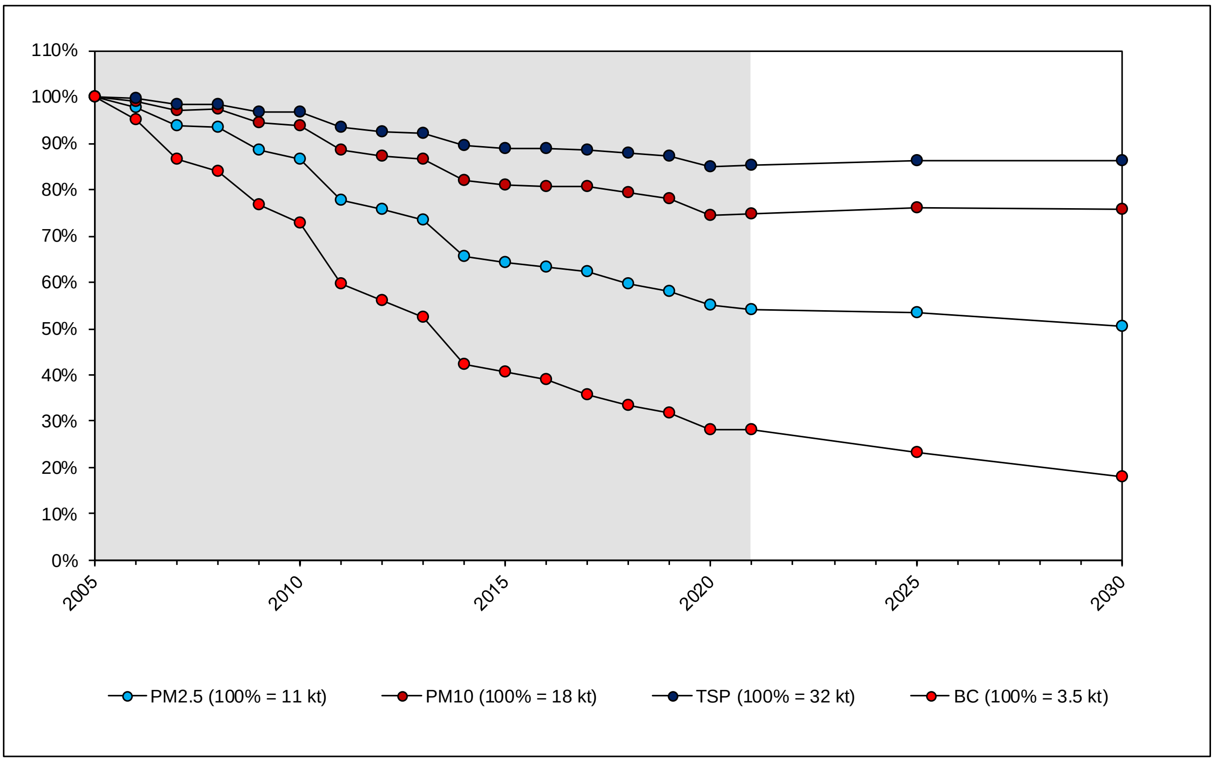

Figure 9-3 Projection of total emissions of suspended particulate matter PM2.5, PM10, TSP and BC in Switzerland of the WM (WEM) scenario (in percentage of 2005). The figure shows the sum of exhaust and non-exhaust particles.

Table 9-10 Projected total emissions of the WM scenario concerning particulate matter until 2030 in kt.

Year	PM2.5	PM10	TSP	BC
	kt	kt	kt	kt
2005	11	18	32	3.5
2010	9.2	17	31	2.6
2012	8.1	16	30	2.0
2013	7.8	16	30	1.9
2014	7.0	15	29	1.5
2015	6.8	15	29	1.4
2016	6.8	15	29	1.4
2017	6.6	15	28	1.3
2018	6.4	14	28	1.2
2019	6.2	14	28	1.1
2020	5.9	14	27	1.0
2021	5.7	14	27	1.0
2025	5.7	14	28	0.83
2030	5.4	14	28	0.64
2030 vs. 2021 (%)	-6%	1%	1%	-36%

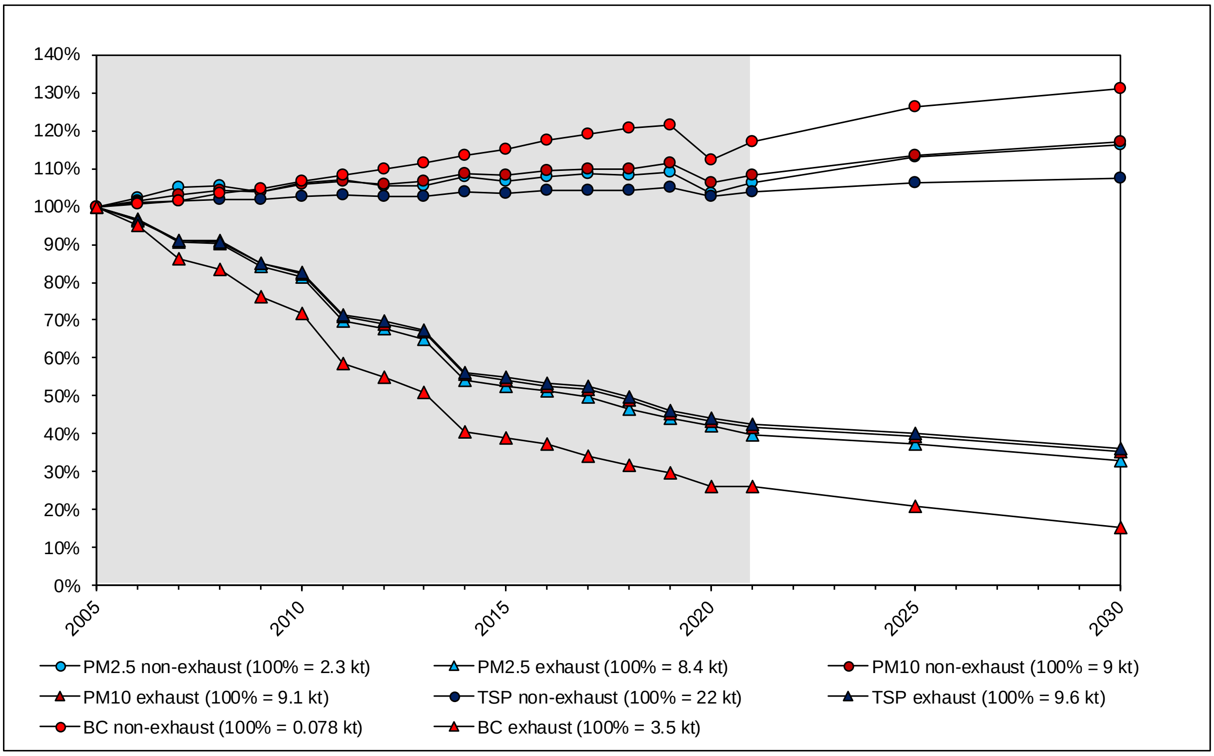

Figure 9-4 Projection of exhaust and non-exhaust emissions of suspended particulate matter PM2.5, PM10, TSP and BC in Switzerland of the WM scenario (in percentage of 2005).

Table 9-11 Projected exhaust emissions of the WM scenario concerning particulate matter until 2030 in kt.

Year	PM2.5 ex	PM10 ex	TSP ex	BC ex
	kt	kt	kt	kt
2005	8.4	9.1	9.6	3.5
2010	6.8	7.5	7.9	2.5
2012	5.7	6.3	6.7	1.9
2013	5.4	6.1	6.5	1.8
2014	4.5	5.1	5.4	1.4
2015	4.4	5.0	5.3	1.4
2016	4.3	4.8	5.1	1.3
2017	4.2	4.7	5.0	1.2
2018	3.9	4.5	4.8	1.1
2019	3.7	4.2	4.4	1.0
2020	3.5	4.0	4.3	0.91
2021	3.3	3.8	4.1	0.91
2025	3.1	3.6	3.9	0.73
2030	2.7	3.2	3.5	0.53
2030 vs. 2021 (%)	-17%	-15%	-15%	-41%

Table 9-12 Projected non-exhaust emissions of the WM scenario concerning particulate matter until 2030 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
2012	2.4	9.5	23	0.085
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	9.9	23	0.092
2018	2.5	9.9	23	0.093
2019	2.5	10	24	0.094
2020	2.4	9.6	23	0.087
2021	2.4	9.8	23	0.091
2025	2.6	10	24	0.098
2030	2.7	11	24	0.102
2030 vs. 2021 (%)	9%	8%	4%	12%

9.4.1 Projections for PM2.5

The overall decreasing trend of emissions from PM2.5 emissions is expected to continue until 2030 (see Figure 9-3 and Table 9-13).

The largest future reductions are expected to occur in 1A Fuel combustion, particularly in small combustion installations in source category 1A4, due to continuous technological improvements of wood combustion installations and a further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves), because they must comply with stricter air pollution control requirements from 2007 onwards as well as a continuous decrease in wood energy consumption in manually operated furnaces. Since emissions in source category 1A3b Road transportation have dropped in 2020/2021 due to COVID-19, a potential reduction of total PM2.5 emission in this category is not visible anymore between 2021 and 2030. However, there are some reductions that will happen compared to the year 2019 (without “COVID-19 effect”): The Euro 6/VI standard, a reduction of fuel consumption (see Figure 9-1) and a limit value for particle number emissions for non-road vehicles (under the EU stage V emission standard starting in January 2019) will diminish future 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.

The other sectors are of minor importance compared to the energy sector. In sector 2 IPPU, the emission reduction stopped in 2016 and is projected to turn into a slightly increasing trend until 2030 mainly due to an increase in food production (however, emissions in 2030 are still projected to be lower than in 2005). Emissions from sectors 3 Agriculture are expected to remain on current levels, emissions from 6 Other to slightly increase (the emissions of both sectors being on a higher level than in 2005). In sector 5 Waste, a reduction occurs between the current year and 2030.

Table 9-13 WM projections: Relative trends of PM2.5 emissions per sector (2005 represents 100 %).

PM2.5 emissions	**2005**	**2021**	**2025**	**2030**
	kt	%	%	
1 Energy	8.7	47%	46%	42%
1A Fuel combustion	8.7	47%	46%	42%
1A1 Energy industries	0.18	34%	36%	39%
1A2 Manufacturing industries and constr.	1.5	42%	40%	38%
1A3 Transport	2.8	49%	53%	52%
1A4 Other sectors	4.1	47%	43%	36%
1A5 Other (Military)	0.057	79%	78%	78%
1B Fugitive emissions from fuels	0.00066	7%	7%	8%
2 IPPU	1.5	86%	91%	94%
3 Agriculture	0.13	113%	112%	112%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.38	76%	68%	57%
6 Other	0.0045	128%	130%	130%
National total	11	54%	53%	51%

9.4.2 Projections for PM10

PM10 emissions are expected to slightly increase until 2025 and afterwards remain about constant until 2030 (see Figure 9-3 and Table 9-14).

An increase of emissions is expected in non-exhaust particulate emissions (mainly larger particles, i.e. PM10 and TSP). Because of the drop of emissions in 2020/2021 due to COVID-19, this increase appears even larger. A growth of activity data from mobile sources 1A3 and 1A2gvii is projected for the future (i.e. increasing annual mileage and machine hours). Therefore, overall PM10 are expected to increase.

However, future reductions of PM10 exhaust emissions are expected to occur in 1A Fuel combustion, particularly in 1A4 and 1A3. The measures for the projected reductions of exhaust PM10 emissions are the same as for PM2.5, i.e. tightening of emission standards for diesel engine vehicles that will prescribe lower limit values, EU stage V emission standard for non-road vehicles (starting from January 2019) and tightening of emission limit values for particle emissions of (wood) combustion installations as well.

Table 9-14 WM projections: Relative trends of PM10 emissions per sector (2005 represents 100 %).

PM10 emissions	2005	2021	2025	2030
	kt	%	%	
1 Energy	14	68%	70%	69%
1A Fuel combustion	14	68%	70%	69%
1A1 Energy industries	0.19	34%	36%	39%
1A2 Manufacturing industries and constr.	3.4	78%	78%	78%
1A3 Transport	5.4	79%	85%	89%
1A4 Other sectors	4.3	48%	43%	37%
1A5 Other (Military)	0.27	98%	98%	98%
1B Fugitive emissions from fuels	0.0013	36%	37%	38%
2 IPPU	2.3	87%	93%	96%
3 Agriculture	1.7	107%	107%	107%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.42	76%	68%	58%
6 Other	0.23	88%	88%	88%
National total	18	75%	76%	76%

9.4.3 Projections for TSP

TSP emissions show a similar projected development as PM10 emissions (see Figure 9-3 and Table 9-15, Table 9-16, Table 9-17).

In comparison with PM10, the differences between projected exhaust and non-exhaust emissions is much more pronounced for TSP. The tables below show clearly that the projected reductions (due to the reasons mentioned above) are mainly related to exhaust emissions. In contrast, non-exhaust emissions are assumed to increase until 2030. A growth of activity data from mobile sources under 1A3 and 1A2gvii is expected, which will strongly influence non-exhaust emissions from large particles. Because of the drop of emissions in 2020/2021 due to COVID-19, this increase appears even larger.

Reductions are expected to occur in 1A4 and to a smaller extent in 1A3 (exhaust emissions) through tightened emission standards for diesel engine vehicles, the EU stage V emission standards and tightened emission limit values for particle emissions from (wood) combustion installations.

Besides the energy sector, sector 3 Agriculture contributes considerably to total TSP emissions. They are dominated by non-exhaust TSP emissions from source category 3De Cultivated crops that are assumed to remain about constant until 2030. Thus, the relative share of agriculture sector on total TSP emissions is increasing over time (since exhaust TSP emissions from the energy sector are generally decreasing). Considering both non-exhaust and total TSP emissions, agriculture even is and remains the predominating emission source.

Table 9-15 WM projections: Relative trends of total TSP emissions per sector (2005 represents 100 %).

TSP total emissions	**2005**	**2021**	**2025**	**2030**
	kt	%	%	
1 Energy	15	72%	73%	73%
1A Fuel combustion	15	72%	73%	73%
1A1 Energy industries	0.20	33%	35%	38%
1A2 Manufacturing industries and constr.	4.5	85%	86%	87%
1A3 Transport	5.8	81%	87%	92%
1A4 Other sectors	4.6	48%	43%	37%
1A5 Other (Military)	0.39	100%	100%	100%
1B Fugitive emissions from fuels	0.0023	49%	50%	52%
2 IPPU	3.4	90%	94%	95%
3 Agriculture	13	101%	101%	101%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.52	76%	68%	57%
6 Other	0.29	90%	90%	90%
National total	32	85%	86%	86%

Table 9-16 WM projections: Relative trends of TSP exhaust emissions per sector (2005 represents 100 %).

TSP exhaust emissions	**2005**	**2021**	**2025**	**2030**
	kt	%	%	
1 Energy	8.0	35%	32%	27%
1A Fuel combustion	8.0	35%	32%	27%
1A1 Energy industries	0.20	33%	35%	38%
1A2 Manufacturing industries and constr.	1.4	25%	22%	19%
1A3 Transport	1.9	16%	17%	13%
1A4 Other sectors	4.5	47%	42%	36%
1A5 Other (Military)	0.020	31%	30%	29%
1B Fugitive emissions from fuels	0.00059	0%	0%	0%
2 IPPU	0.84	76%	82%	90%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.51	76%	68%	57%
6 Other	0.28	87%	87%	87%
National total	9.6	42%	40%	36%

Table 9-17 WM projections: Relative trends of TSP non-exhaust emissions per sector (2005 represents 100 %).

TSP non-exhaust emissions	**2005**	**2021**	**2025**	**2030**
	kt	%	%	
1 Energy	7.4	112%	118%	123%
1A Fuel combustion	7.4	112%	118%	123%
1A1 Energy industries	NA	NA	NA	NA
1A2 Manufacturing industries and constr.	3.0	114%	116%	119%
1A3 Transport	3.9	112%	122%	130%
1A4 Other sectors	0.12	86%	84%	82%
1A5 Other (Military)	0.37	104%	104%	104%
1B Fugitive emissions from fuels	0.0017	66%	67%	69%
2 IPPU	2.6	94%	98%	97%
3 Agriculture	13	101%	101%	101%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.0036	100%	100%	100%
6 Other	0.017	130%	131%	130%
National total	22	104%	106%	108%

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 measure mainly focus on combustion particles which largely consists of BC (see Figure 9-3 and Table 9-18).

The largest future reductions are expected to occur in 1A Fuel combustion, and particularly in 1A3 Transport and in small combustion in source category 1A4. There are the same arguments that can back these expectations as for PM2.5: The Euro 6/VI standard, a reduction of fuel consumption (see Figure 9-1) and the EU stage V emission standard for non-road vehicles will diminish future emissions, and wood-fired installations must comply with stricter air pollution control requirements from 2007 onwards.

Table 9-18 WM projections: Relative trends of BC emissions per sector (2005 represents 100 %).

BC emissions	**2005**	**2021**	**2025**	**2030**
	kt	%	%	
1 Energy	3.5	28%	23%	18%
1A Fuel combustion	3.5	28%	23%	18%
1A1 Energy industries	0.016	47%	48%	50%
1A2 Manufacturing industries and constr.	0.32	13%	8%	5%
1A3 Transport	1.2	18%	16%	13%
1A4 Other sectors	1.9	37%	30%	22%
1A5 Other (Military)	0.0099	31%	30%	29%
1B Fugitive emissions from fuels	0.00018	15%	16%	16%
2 IPPU	0.0026	50%	50%	50%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.027	77%	69%	59%
6 Other	0.00016	88%	88%	88%
National total	3.5	28%	23%	18%

9.5 Priority heavy metals

Projected emissions for priority heavy metals Pb, Cd and Hg are shown in Figure 9-5 and Table 9-19.

While Pb emissions are projected to decrease between 2021 and 2030, Cd emissions are expected to increase and Hg emissions to remain about constant. For Pb, the reduction is mainly due to an assumed reduction of illegal waste incineration. For Cd, the increase is related to an increase in the amount of waste, wood and wood waste incinerated in 1A1 Energy industries and to increased traffic volumes, which leads to an increase in Cd non-exhaust emissions. For Hg, a slight increase is projected in the most important source category 1A1 Energy industries (waste, wood and wood waste), which is compensated by slight decreases in other sectors.

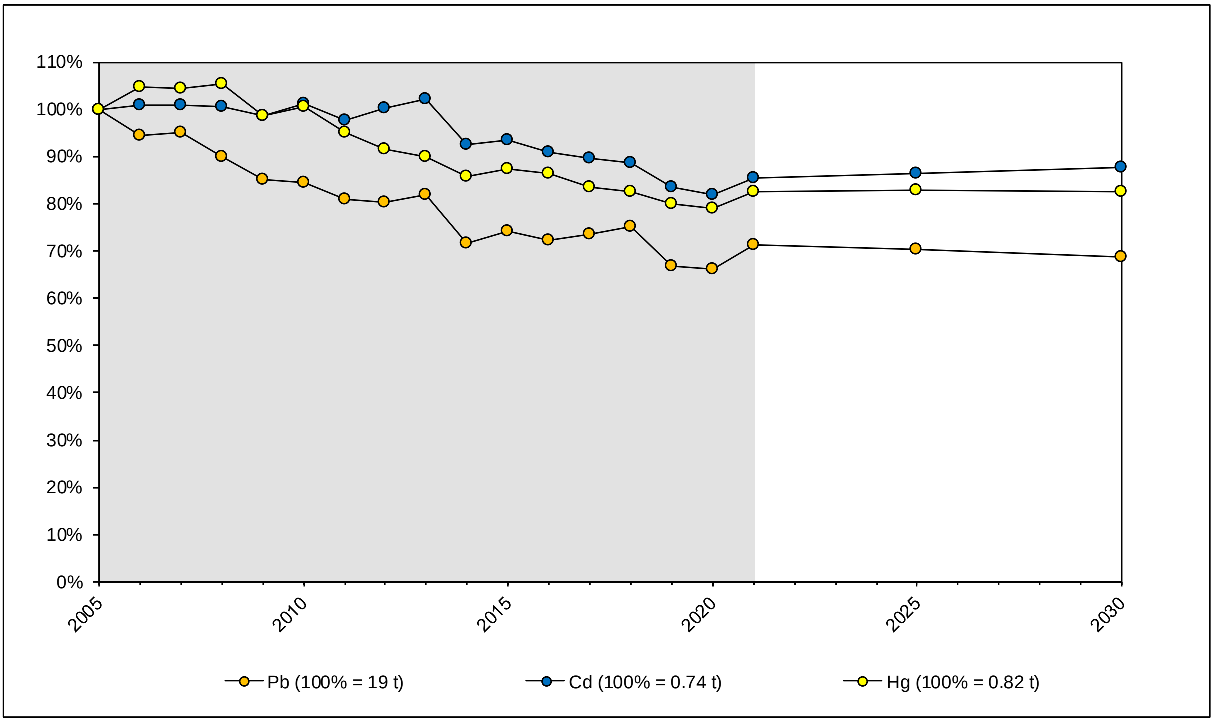

Figure 9-5 Projected emissions of priority heavy metals in Switzerland until 2030 of the WM scenario (in percentage of 2005 level).

Table 9-19 WM projected total emissions of priority heavy metal in tonnes.

Year	Pb	Cd	Hg
	t	t	t
2005	19	0.74	0.82
2010	16	0.74	0.83
2012	15	0.74	0.75
2013	16	0.75	0.74
2014	14	0.68	0.71
2015	14	0.69	0.72
2016	14	0.67	0.71
2017	14	0.66	0.69
2018	14	0.65	0.68
2019	13	0.62	0.66
2020	13	0.60	0.65
2021	14	0.63	0.68
2025	13	0.64	0.68
2030	13	0.65	0.68
2030 vs. 2021 (%)	-4%	3%	0%

9.5.1 Projections for lead (Pb)

The annual national total of lead emissions will presumably slightly decrease until 2030 compared to current levels (see Table 9-20 and Figure 9-5).

The projected reduction of Pb emissions is mainly due to an assumed reduction of illegal waste incineration (in source category 5C1a).

In the energy sector, emissions are expected to slightly decrease from 2021 to 2030, mainly due to expected reductions in source category 1A4 Other sectors. In contrary, Pb emissions from source category 1A1 Energy industries are expected to increase due to growing amounts of waste, wood and wood waste incinerated.

The emissions from sector 2 Industrial processes and product use are projected to slightly increase. The projection for the major source 6Ad Fire damage estates and motor vehicles assumes that emission factor and activity data remain constant until 2030.

Table 9-20 WM projections: Relative trends of Pb emissions per sector (2005 represents 100 %).

Pb emissions	2005	2021	2025	2030
	t	%	%	
1 Energy	6.7	63%	63%	62%
1A Fuel combustion	6.7	63%	63%	62%
1A1 Energy industries	1.9	86%	89%	93%
1A2 Manufacturing industries and constr.	2.7	38%	38%	36%
1A3 Transport	1.2	78%	78%	77%
1A4 Other sectors	0.94	73%	64%	52%
1A5 Other (Military)	0.00023	105%	105%	104%
1B Fugitive emissions from fuels	0.0011	0.5%	0.5%	0.5%
2 IPPU	2.1	29%	30%	32%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	2.3	74%	64%	53%
6 Other	7.8	89%	89%	89%
National total	19	71%	70%	69%

9.5.2 Projections for cadmium (Cd)

Cadmium emissions are expected to increase until 2030 (see Table 9-21 and Figure 9-5). Responsible for this development of cadmium emissions is an expected increase of emissions in source category 1A1 Energy industries from waste incineration due to population growth and increased consumption of wood and wood waste as well as an increase of traffic volumes 1A3b Road transportation.

Table 9-21 WM projections: Relative trends of Cd emissions per sector (2005 represents 100 %).

Cd emissions	2005	2021	2025	2030
	t	%	%	
1 Energy	0.43	85%	88%	89%
1A Fuel combustion	0.43	86%	88%	90%
1A1 Energy industries	0.18	86%	89%	93%
1A2 Manufacturing industries and constr.	0.10	70%	68%	67%
1A3 Transport	0.077	117%	126%	130%
1A4 Other sectors	0.068	74%	72%	69%
1A5 Other (Military)	0.00051	103%	103%	102%
1B Fugitive emissions from fuels	0.0015	0.001%	0.001%	0.001%
2 IPPU	0.092	86%	87%	87%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.021	42%	41%	39%
6 Other	0.19	89%	89%	89%
National total	0.74	85%	87%	88%

9.5.3 Projections for mercury (Hg)

Overall, the annual national total of mercury emissions is expected to remain about constant until 2030 compared to 2021 (see Table 9-22 and Figure 9-5).

Emissions from sector 1 Energy are expected to slightly increase. The increase occurs in source category 1A1 Energy industries, the main source for Hg emissions, as a result of an expected increase in the amounts of waste, wood and wood waste incinerated. This increase is partially compensated by a decrease of Hg emissions in source category 1A2 Manufacturing industries and construction.

The slight increase of Hg emissions 2021-2030 in the energy sector is compensated by a slight decrease in other sectors. Emissions from sectors 5 Waste and 6 Other are on low levels and trends are projected to level off. Emissions from sector 2 Industrial processes and product use, which are very low compared to other sectors, are expected to be on a lower level in 2030 compared to 2005.

Table 9-22 WM projections: Relative trends of Hg emissions per sector (2005 represents 100 %).

Hg emissions	2005	2021	2025	2030
	t	%	%	
1 Energy	0.59	88%	89%	89%
1A Fuel combustion	0.59	88%	89%	89%
1A1 Energy industries	0.34	87%	90%	94%
1A2 Manufacturing industries and constr.	0.12	82%	80%	79%
1A3 Transport	0.037	86%	85%	77%
1A4 Other sectors	0.085	103%	96%	87%
1A5 Other (Military)	0.000028	103%	102%	102%
1B Fugitive emissions from fuels	0.00025	0.0001%	0.0001%	0.0001%
2 IPPU	0.067	81%	81%	80%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.077	36%	36%	36%
6 Other	0.091	87%	87%	87%
National total	0.82	83%	83%	83%

9.6 Persistent organic pollutants (POPs)

Figure 9-6 shows projected emission trends for persistent organic pollutants (POP). More detailed figures on projections are given in Table 9-23. The emissions of all POPs are expected to decrease. The decrease of PCB emissions is higher than for the other pollutants.

The reduction of PCB emissions is mainly expected to happen in source category 2K Usage of PCBs due to ongoing renovation or replacement of both PCB containing anti-corrosive paints on steel constructions and joint sealants in windows frames.

For PCDD/PCDF, the main reason for the expected decrease in emissions is in sector 1A4 Other sectors (1A4a Commercial and 1A4b Residential) due to technical improvements in wood furnaces and a continued decrease in wood energy consumption in manually operated furnaces as well as the projected decline in illegally incinerated waste in sector 5 Waste.

For HCB, the decrease is expected mainly in source category 1A4 Other sectors due to continuous technical improvements of wood combustion installations and a decrease in wood energy consumption.

The main source of PAH emissions will be small wood combustion installations of source category 1A4 Other sectors. Total emissions are estimated to decrease due to technical improvements in wood furnaces and a continued decrease in wood energy consumption in manually operated furnaces.

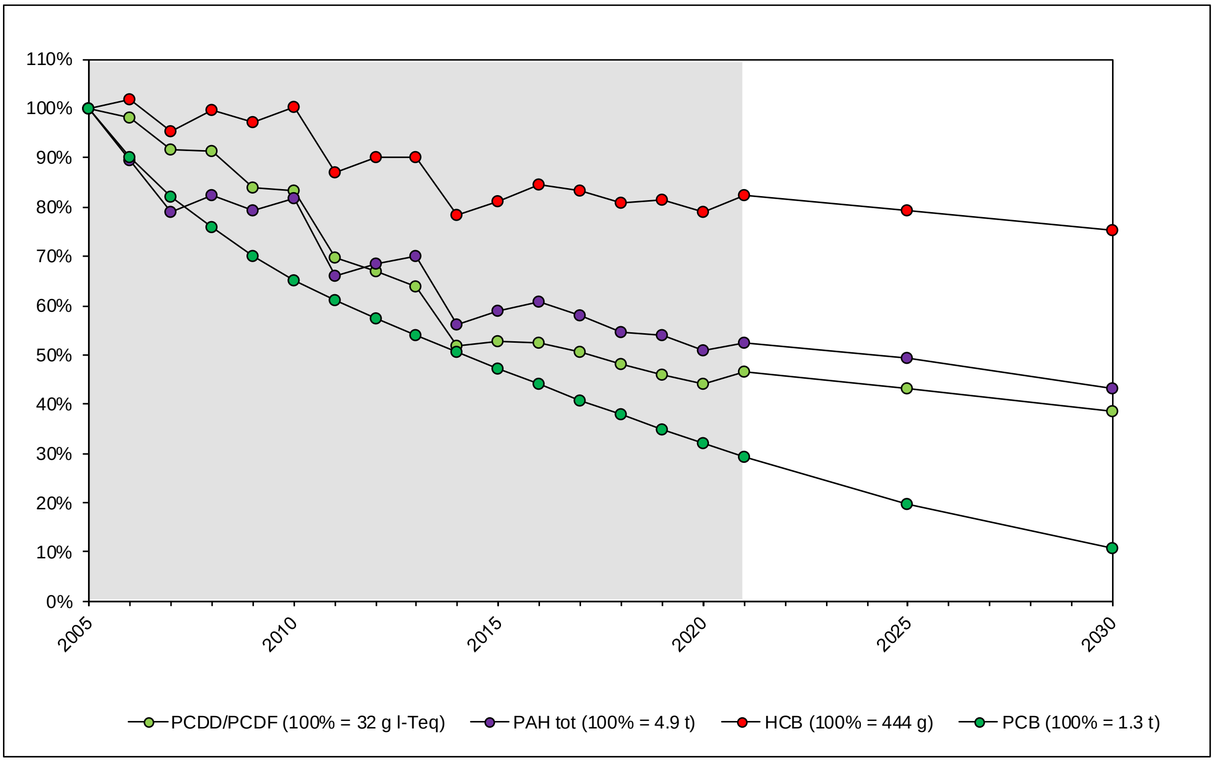

Figure 9-6 Emissions of POPs: PCDD/PCDF, PAH as the sum of benzo(a)pyrene), benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, and HCB in Switzerland in the WM scenario (in percent of 2005).

Table 9-23 Projected total emissions of POPs. Please take note of different units.

Year	PCDD/ PCDF	BaP	BbF	BkF	IcdP	PAH tot	HCB	PCB
	g I-Teq	t	t	t	t	t	kg	t
2005	32	1.4	1.6	1.0	0.83	4.9	0.44	1.3
2010	27	1.3	1.3	0.77	0.70	4.0	0.45	0.83
2012	22	1.0	1.1	0.65	0.59	3.4	0.40	0.73
2013	21	1.1	1.1	0.67	0.60	3.4	0.40	0.69
2014	17	0.8	0.9	0.55	0.48	2.8	0.35	0.64
2015	17	0.89	0.93	0.57	0.51	2.9	0.36	0.60
2016	17	0.91	0.96	0.59	0.53	3.0	0.38	0.56
2017	16	0.86	0.91	0.57	0.51	2.9	0.37	0.52
2018	16	0.81	0.86	0.54	0.48	2.7	0.36	0.48
2019	15	0.80	0.85	0.53	0.47	2.7	0.36	0.44
2020	14	0.76	0.80	0.50	0.45	2.5	0.35	0.41
2021	15	0.78	0.83	0.52	0.46	2.6	0.37	0.37
2025	14	0.73	0.78	0.50	0.42	2.4	0.35	0.25
2030	13	0.64	0.69	0.44	0.37	2.1	0.34	0.14
2030 vs. 2021 (%)	-17%	-18%	-16%	-17%	-19%	-17%	-9%	-63%

9.6.1 Projections for PCDD/PCDF

PCDD/PCDF emissions are expected to continue a decreasing trend until 2030 (see Table 9-24 and Figure 9-6).

The major part of the emissions reduction is expected to happen in source category 1A4 Other sectors (1A4a Commercial and 1A4b Residential) due to continuous technical improvements in wood combustion installations, a continued 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). Furthermore, emission reductions are expected in sector 5 Waste (mainly due to a reduction of illegally incinerated waste under 5C1a).

Table 9-24 WM projections: Relative trends of PCDD/PCDF emissions per sector (2005 represents 100 %).

PCDD/PCDF emissions	2005	2021	2025	2030
	g I-Teq	%	%	
1 Energy	23	38%	34%	30%
1A Fuel combustion	23	38%	34%	30%
1A1 Energy industries	5.2	18%	19%	20%
1A2 Manufacturing industries and constr.	2.8	38%	36%	33%
1A3 Transport	1.7	27%	24%	18%
1A4 Other sectors	13	47%	41%	35%
1A5 Other (Military)	0.00038	103%	102%	102%
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	2.1	39%	40%	40%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	4.3	69%	61%	51%
6 Other	2.9	89%	89%	89%
National total	32	47%	43%	39%

9.6.2 Projections for polycyclic aromatic hydrocarbons (PAH)

Overall, the annual national total of PAH emissions is expected to decrease until 2030 (see Table 9-25 and Figure 9-6. The main relevant source of PAH emissions now and remaining in future are small wood combustion installations of source category 1A4.

The projected decrease of PAH emissions in 1A4 is due to continuous technical improvements in wood combustion installations, 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). In contrast, a significant emission increase is expected under 1A3 Transport. It is assumed that 1A3 will be a relevant source of PAH emissions in 2030. The reason for this increase is the rising share of diesel oil use under 1A3b.

Table 9-25 WM projections: Relative trends of PAHs emissions per sector (2005 represents 100 %).

PAHs emissions	2005	2021	2025	2030
	t	%	%	
1 Energy	4.1	56%	52%	44%
1A Fuel combustion	4.1	56%	52%	44%
1A1 Energy industries	0.0085	71%	83%	94%
1A2 Manufacturing industries and constr.	0.18	61%	90%	85%
1A3 Transport	0.17	163%	187%	187%
1A4 Other sectors	3.7	50%	44%	36%
1A5 Other (Military)	0.00073	93%	92%	91%
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	0.50	2.6%	2.5%	2.5%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.25	75%	75%	75%
6 Other	0.095	122%	122%	122%
National total	4.9	52%	49%	43%

9.6.3 Projections for hexachlorobenzene (HCB)

HCB emissions on national level are projected to decrease from 2021 until 2030 (see Table 9-26 and Figure 9-6).

The major part of the reduction is expected in the currently most relevant source category for HCB emissions, 1A4 Other sectors, due to continuous technical improvements of wood combustion installations and a decrease in wood energy consumption. In contrast, HCB emissions will increase in source category 1A1a Electricity and heat production due to an increase of energy generation from waste incineration plants.

Table 9-26 WM projections: Relative trends of HCB emissions per sector (2005 represents 100 %).

HCB emissions	2005	2021	2025	2030
	kg	%	%	
1 Energy	0.44	83%	79%	75%
1A Fuel combustion	0.44	83%	79%	75%
1A1 Energy industries	0.15	123%	127%	131%
1A2 Manufacturing industries and constr.	0.051	74%	72%	67%
1A3 Transport	NE	NE	NE	NE
1A4 Other sectors	0.24	59%	51%	42%
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	0.44	83%	79%	75%

9.6.4 Projections for polychlorinated biphenyl (PCBs)

PCB emissions are expected to decrease considerably until 2030 (see Table 9-27 and Figure 9-6). 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. To a lesser extent, also accidental releases of PCB by fire and from soil due to former PCB spillages (6Ad) contribute to future PCB emissions. In 2021, both sources of 6Ad are about the same size whereas in 2030, emissions from soil will be relevant only. Additionally, a very small emission contribution is projected from source categories 5E Shredding of electronic waste and 5A Landfills.

Table 9-27 WM projections: Relative trends of PCB emissions per sector (2005 represents 100 %).

PCB emissions	**2005**	**2021**	**2025**	**2030**
	kg	%	%	
1 Energy	1.4	28%	27%	25%
1A Fuel combustion	1.4	28%	27%	25%
1A1 Energy industries	1.1	6.5%	4.9%	3.1%
1A2 Manufacturing industries and constr.	0.35	94%	93%	93%
1A3 Transport	0.00037	26%	23%	17%
1A4 Other sectors	0.0015	53%	48%	42%
1A5 Other (Military)	NE	NE	NE	NE
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	922	37%	24%	13%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	254	2.8%	1.5%	0.9%
6 Other	93	31%	24%	18%
National total	1270	29%	20%	11%

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 2014). 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.

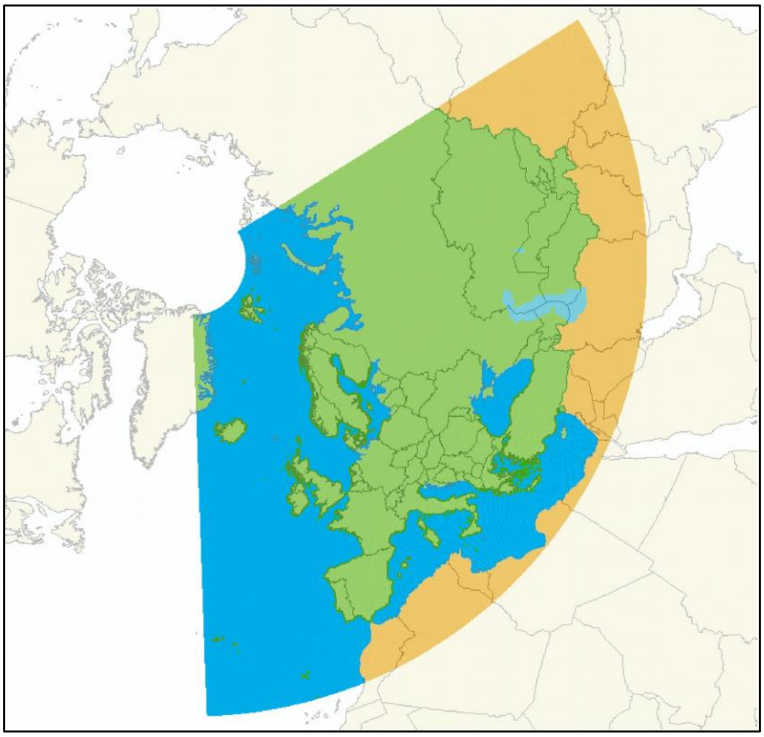

Figure 10-1 EMEP domain in the latitude-longitude projection (30°N-82°N, 30°W-90°E) (EMEP 2012a, https://www.emep.int/grid/lonlatgrid.pdf).

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.

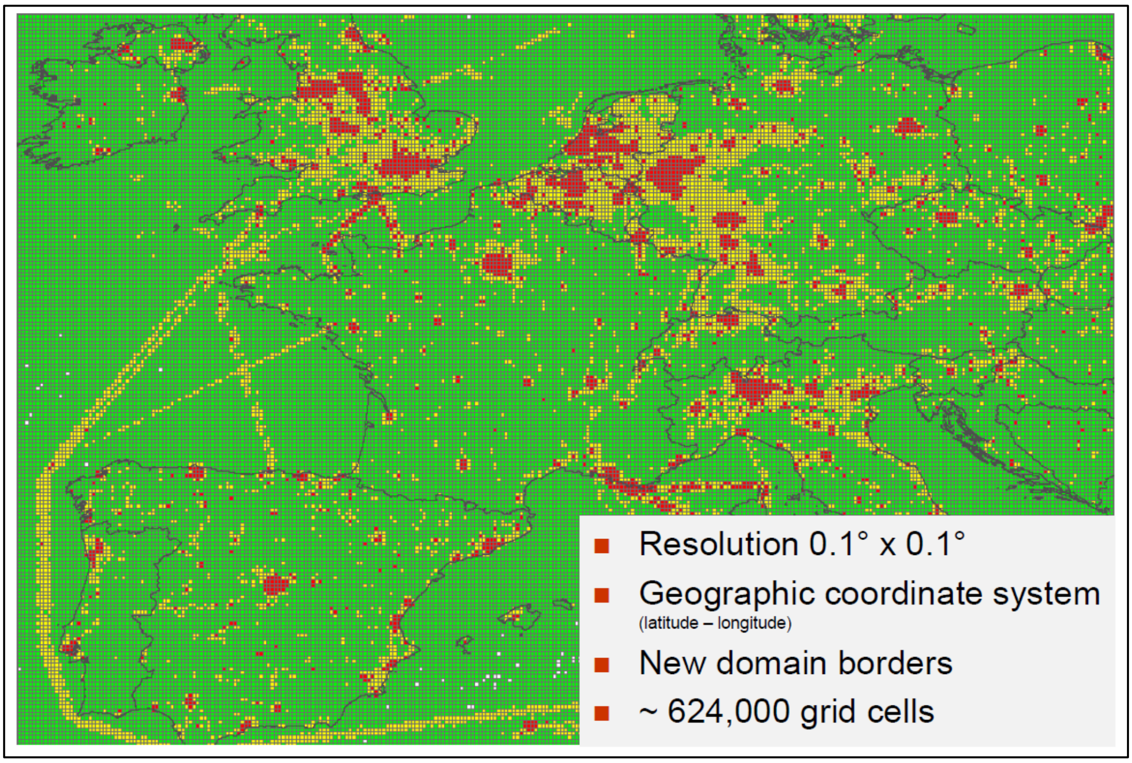

Figure 10-2 Resolution of the EMEP grid for Europe (EMEP 2012b).

In Switzerland's air pollution inventory of the latest submission 2023, 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).

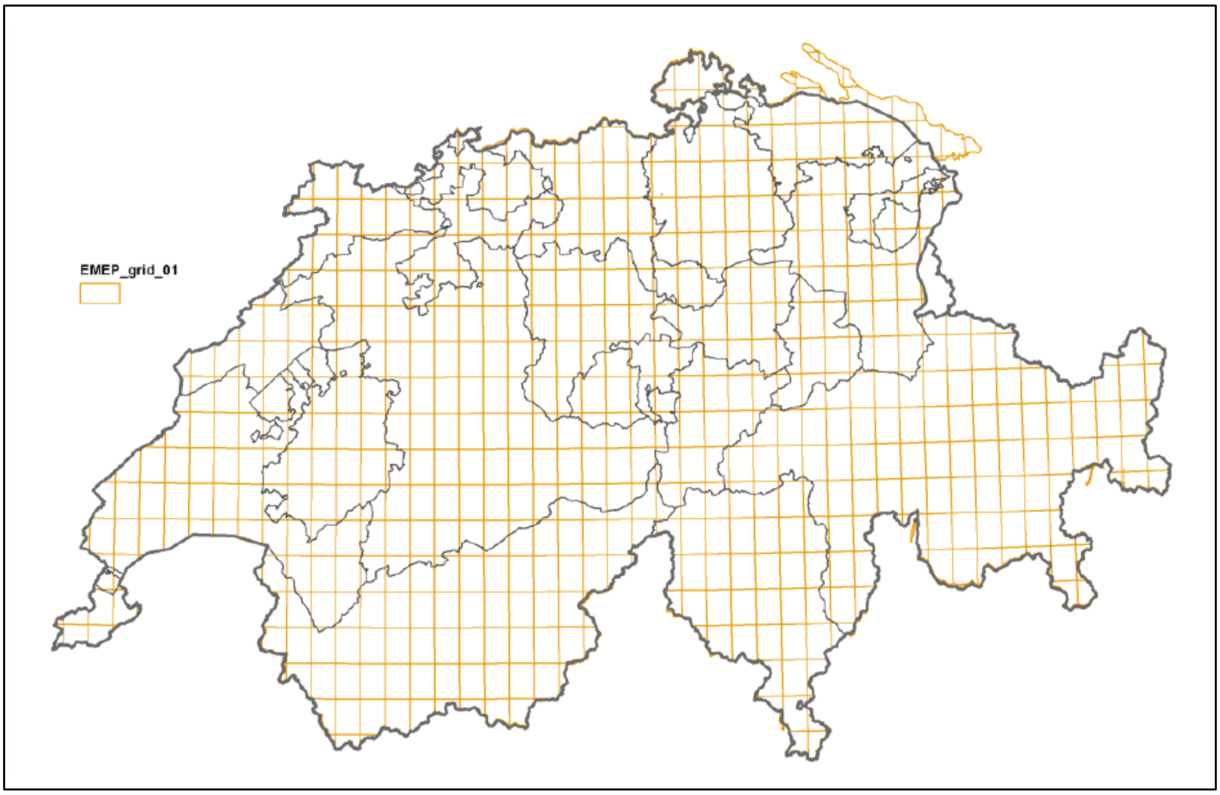

Figure 10-3 EMEP grid in Switzerland with 0.1° x 0.1° spatial resolution (from Meteotest 2013, downloaded from EMEP).

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 2014a). Table 10-1 shows the relative shares of the GNFR categories of Switzerland's total emissions (national total) in 2021 for all main air pollutants including PM2.5 and CO.

Table 10-1 GNFR categories and their part (%) of total emissions in 2021 (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	4.2%	0.22%	6.6%	0.066%	0.76%	0.35%
B_Industry	12%	8.4%	64%	0.57%	20%	11%
C_OtherStatComb	15%	4.7%	24%	0.20%	31%	24%
D_Fugitive	0.0027%	3.7%	0.36%	NA	0.00084%	0.00015%
E_Solvents	0.036%	42%	0.11%	0.15%	6.4%	0.38%
F_RoadTransport	48%	10%	1.5%	1.7%	20%	40%
G_Shipping	1.9%	0.54%	0.029%	0.00039%	0.44%	3.3%
H_Aviation	1.8%	0.14%	1.8%	NA	0.15%	1.1%
I_Offroad	8.4%	2.3%	0.92%	0.0048%	14%	19%
J_Waste	0.24%	2.4%	0.78%	1.7%	5.0%	0.95%
K_AgriLivestock	1.7%	25%	NA	47%	1.7%	NA
L_AgriOther	5.5%	0.61%	NA	47%	0.78%	NA
M_Other	0.19%	0.31%	0.32%	1.8%	0.10%	0.52%
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 2023, Switzerland calculated gridded emissions for the entire time series 1980-2021. 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).

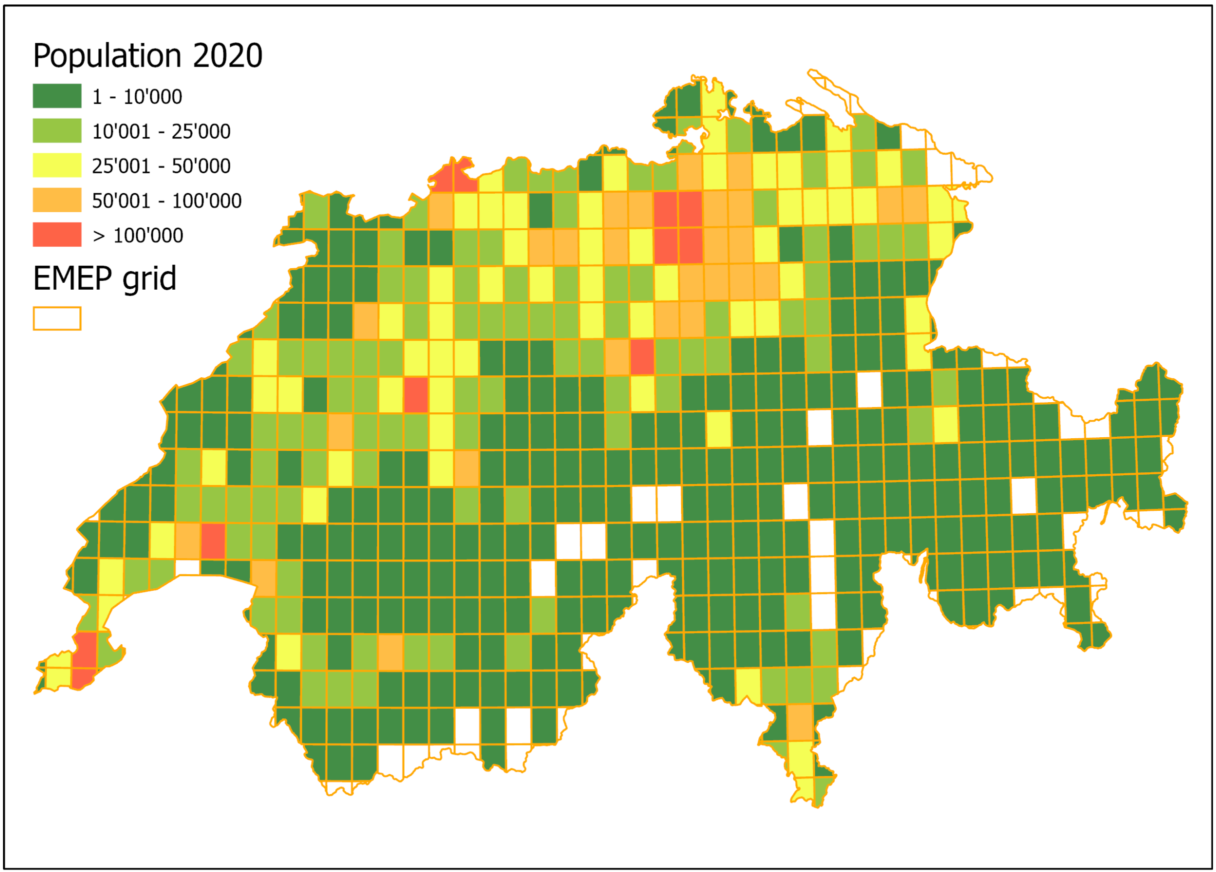

Figure 10-4 Population number per EMEP grid cell in Switzerland in 2020.

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

As additional data for allocation purposes specific emission models are used. 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 2021 are described under 10.4 and illustrated in Figure 10-10.

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 2021

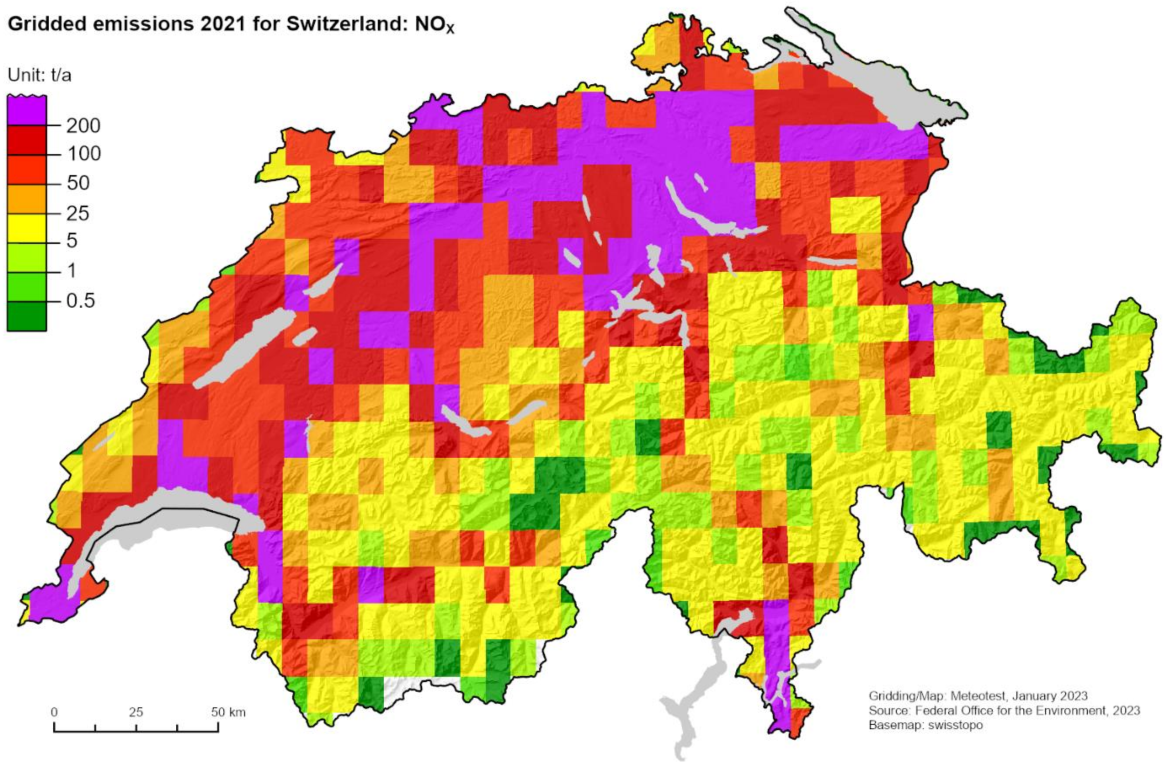

Figure 10-5 Spatial distribution of the NO_x emissions in Switzerland.

10.3.2 Spatial distribution of Switzerland's NMVOC emissions 2021

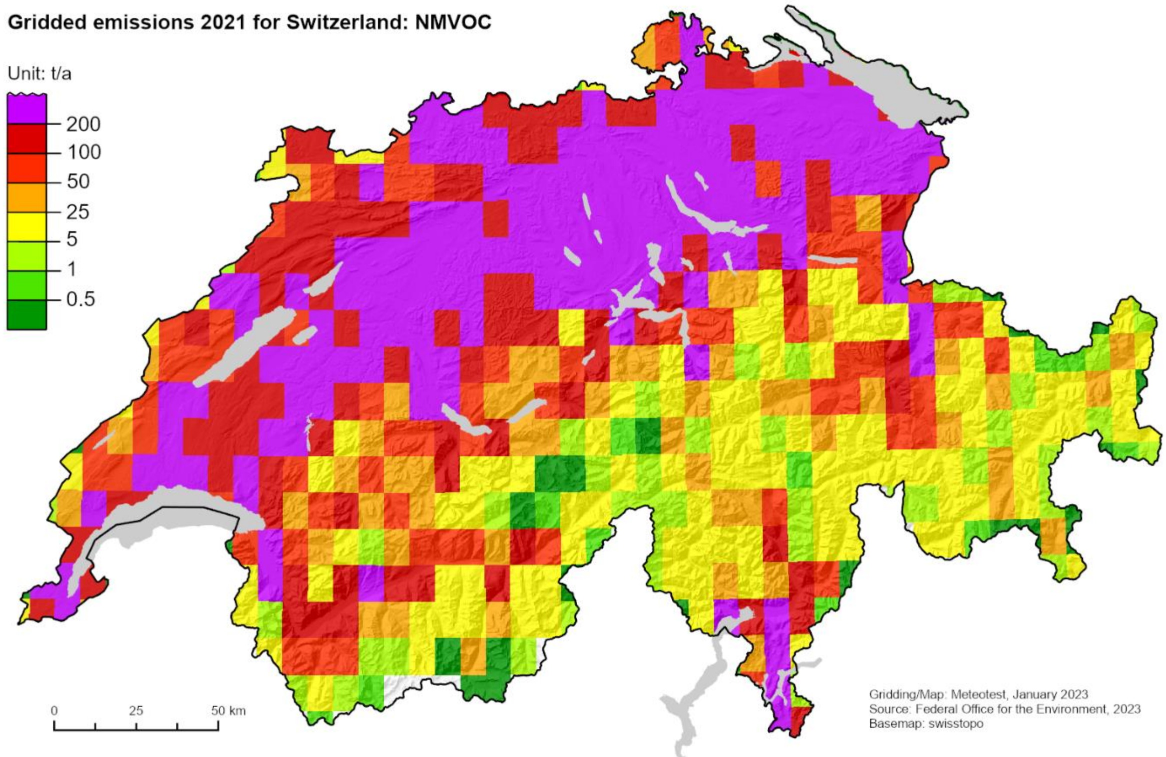

Figure 10-6 Spatial distribution of the NMVOC emissions in Switzerland.

10.3.3 Spatial distribution of Switzerland's SO_x emissions 2021

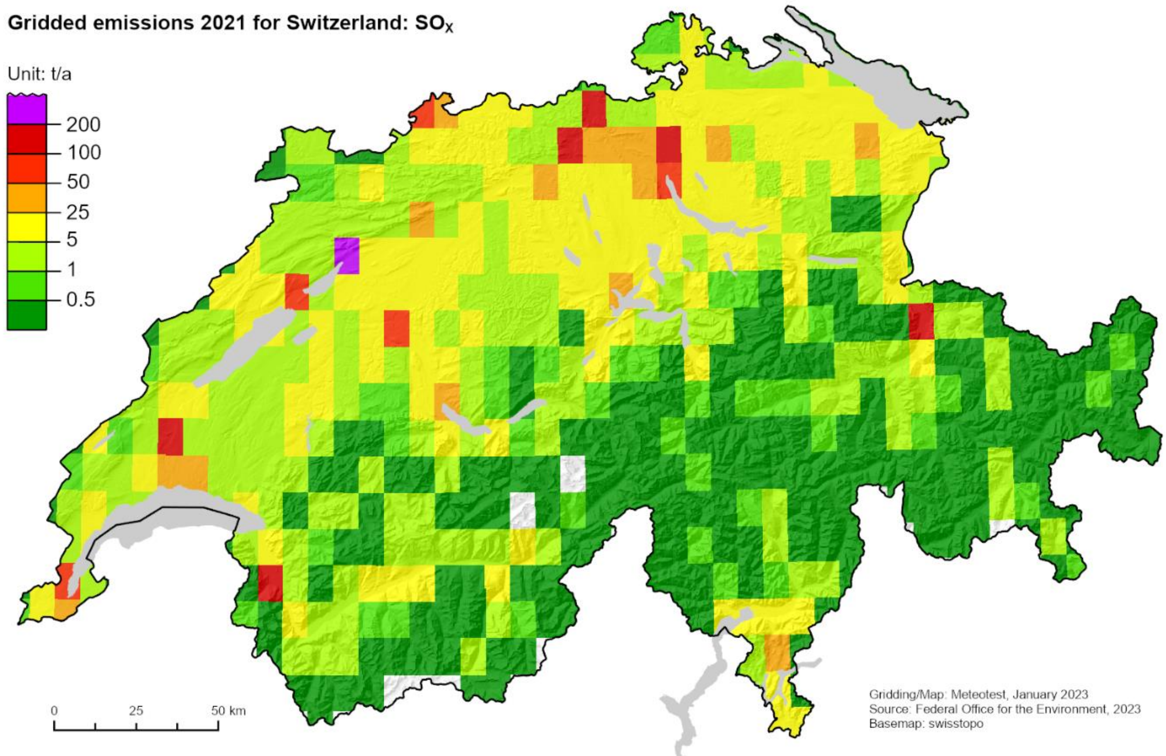

Figure 10-7 Spatial distribution of the SO_x emissions in Switzerland.

10.3.4 Spatial distribution of Switzerland's NH_3 emissions 2021

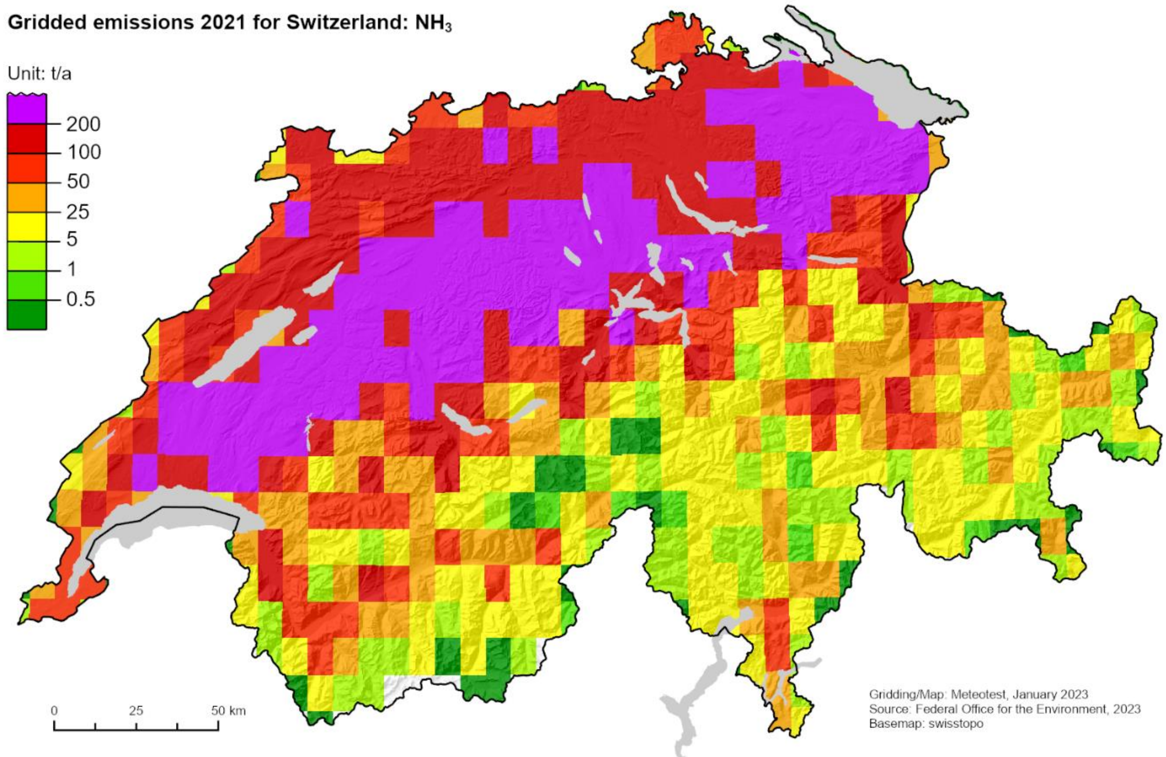

Figure 10-8 Spatial distribution of the NH_3 emissions in Switzerland.

10.3.5 Spatial distribution of Switzerland's PM2.5 emissions 2021

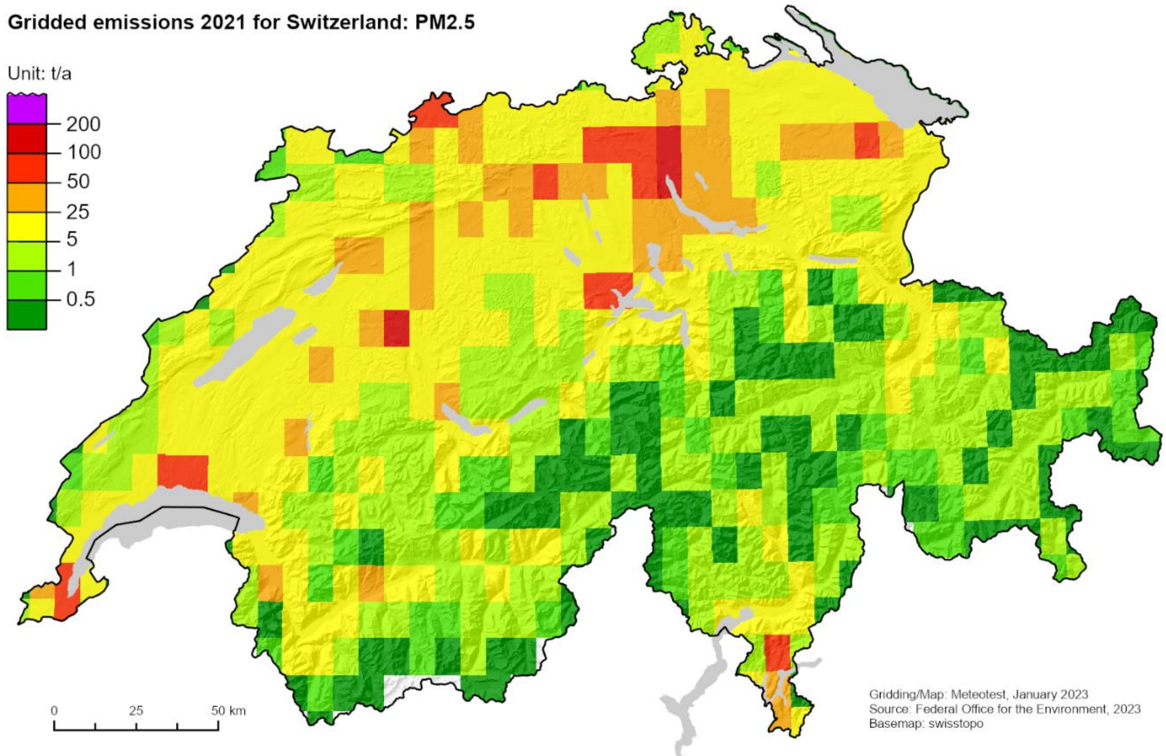

Figure 10-9 Spatial distribution of the PM2.5 emissions in Switzerland.

10.4 Large point sources (LPS)

Large Point Sources (LPS) are reported according to the definitions of the ECE Guidelines (ECE 2014). 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 2014).

Facility designations, locations and emissions of Switzerland's LPS of the years 2007-2020 are reported based on the most recent data of the Swiss Pollution Release and Transfer Register (PRTR 2022). 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 2021, the list of Switzerland's LPS includes 30 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 10-10).

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.

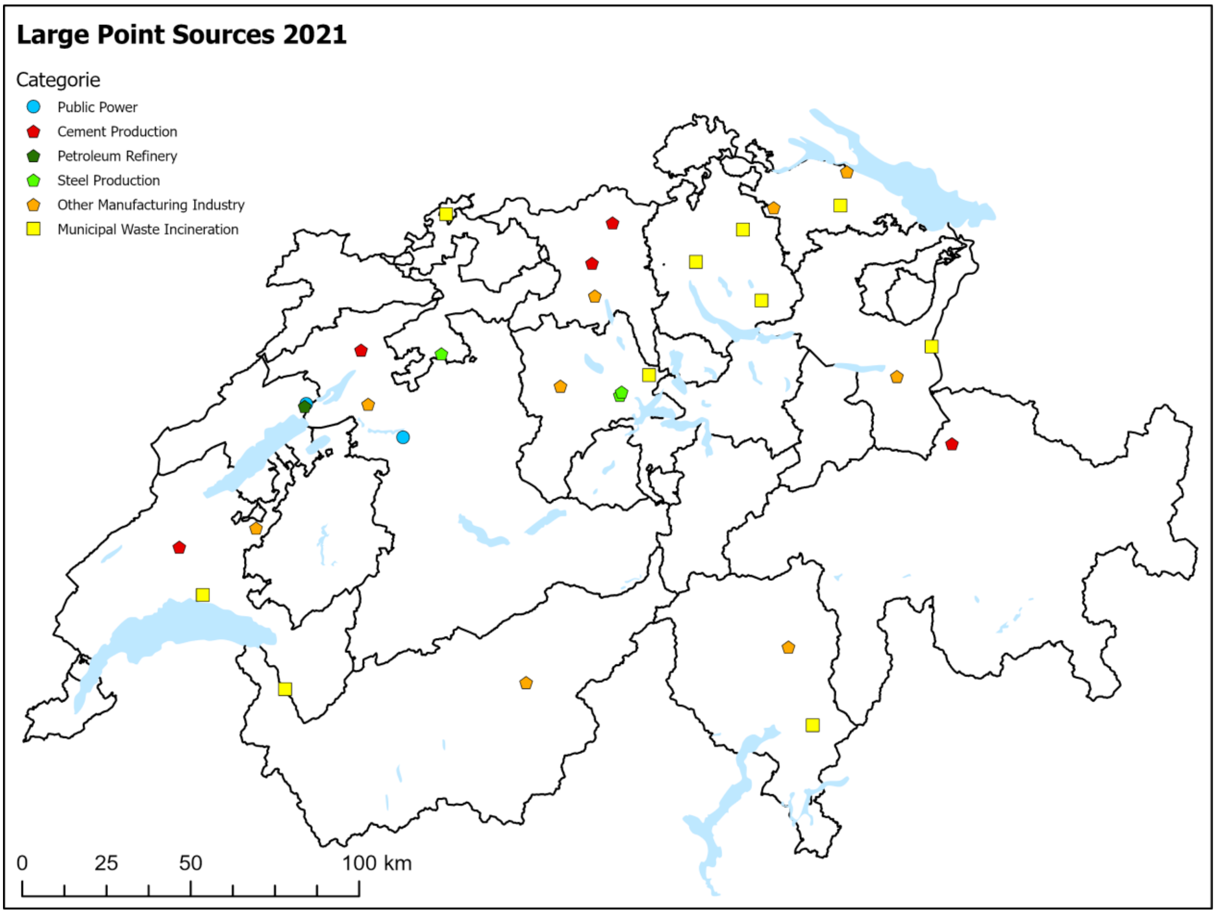

Figure 10-10 Spatial distribution of Switzerland's LPS in 2021.

11 Adjustments

There are no adjustments in Switzerland's air pollutant emission inventory.

12 References and assignments to EMIS categories

12.1 References

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12.2 Assignment of EMIS categories to NFR code

Table 12-1 Assignements 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]	Gummi-Verarbeitung**
1 A	Holzfeuerungen	2 D 3 a [2 D 3 g]	Klebband-Produktion
1 A 2	Sektorgliederung Industrie	2 D 3 a [2 D 3 g]	Klebstoff-Produktion**
1 A 1 a	Kehrichtverbrennungsanlagen	2 D 3 a [2 D 3 g]	Lösungsmittel-Umschlag und -Lager
1 A 1 a	Sondermüllverbrennungsanlagen	2 D 3 a [2 D 3 g]	Pharmazeutische Produktion**
1 A 1 a & 5 A	Kehrichtdeponien	2 D 3 a [2 D 3 g]	Polyester-Verarbeitung
1 A 1 b	Heizkessel Raffinerien* (ab 2016)	2 D 3 a [2 D 3 g]	Polystyrol-Verarbeitung**
1 A 1 c	Holzkohle Produktion	2 D 3 a [2 D 3 g]	Polyurethan-Verarbeitung
1 A 2 a & 2 C 1	Eisengiessereien Kupolöfen	2 D 3 a [2 D 3 g]	PVC-Verarbeitung
1 A 2 a	Stahl-Produktion Wärmeöfen**	2 D 3 a [2 D 3 g]	Gerben von Ledermaterialien
1 A 2 b	Buntmetallgiessereien übriger Betrieb**	2 D 3 b	Strassenbelagsarbeiten**
1 A 2 b & 2 C 3	Aluminium Produktion	2 D 3 c	Dachpappe**
1 A 2 c & 2 B 8 b [2 B 10 a]	Ethen-Produktion*	2 D 3 d	Urea (AdBlue) Einsatz Strassenverkehr
1 A 2 d & 2 A 4 d	Zellulose-Produktion Feuerung*	2 G 3 a	Lachgasanwendung Spitäler**
1 A 2 f	Kalkproduktion, Feuerung*	2 G 3 b	Lachgasanwendung Haushalt**
1 A 2 f	Mischgut Produktion	2 G 4 [2 D 3 a]	Pharma-Produkte im Haushalt
1 A 2 f	Zementwerke Feuerung	2 G 4 [2 D 3 a]	Reinigungs- und Lösemittel; Haushalte
1 A 2 f & 2 A 3	Glas übrige Produktion*	2 G 4 [2 D 3 a]	Spraydosen Haushalte**
1 A 2 f & 2 A 3	Glaswolle Produktion Rohprodukt*	2 G 4 [2 D 3 h]	Verpackungsdruckereien**
1 A 2 f & 2 A 3	Hohlglas Produktion*	2 G 4 [2 D 3 h]	Druckereien uebrige**
1 A 2 f & 2 A 4 a	Feinkeramik Produktion*	2 G 4 [2 D 3 i]	Entfernung von Farben und Lacken**
1 A 2 f & 2 A 4 a	Ziegeleien**	2 G 4 [2 D 3 i]	Entwachsung von Fahrzeugen
1 A 2 f & 2 A 4 d	Steinwolle Produktion*	2 G 4 [2 D 3 i]	Kosmetika-Produktion**
1 A 2 g iv	Faserplatten Produktion* (ab 2020)	2 G 4 [2 D 3 i]	Lösungsmittel-Emissionen IG nicht zugeordnet
1A2gvii, 1A3c, 1A3e, 1A4aii/bii/cii, 1A5b (without military aviation)	Non-Road	2 G 4 [2 D 3 i]	Öl- und Fettgewinnung
1 A 2 g viii & 5 B 2	Vergärung IG (industriell-gewerblich)	2 G 4 [2 D 3 i]	Papier- und Karton-Produktion**
1 A 3 a & 1 A 5	Flugverkehr	2 G 4 [2 D 3 i]	Parfum- und Aromen-Produktion**
1 A 3 b i-viii	Strassenverkehr	2 G 4 [2 D 3 i]	Tabakwaren Produktion**
1 A 3 c	Schienenverkehr	2 G 4 [2 D 3 i]	Textilien-Produktion**
1 A 3 e	Gastransport Kompressorstation	2 G 4 [2 D 3 i]	Wissenschaftliche Laboratorien
1 A 4 b i	Holzkohle-Verbrauch	2 G 4 [2 G]	Korrosionsschutz im Freien
1 A 4 b i	Lagerfeuer	2 G 4 [2 G]	Betonzusatzmittel-Anwendung
1 A 4 c i	Gewächshäuser**	2 G 4 [2 G]	Coiffeursalons
1 A 4 c i	Grastrocknung**	2 G 4 [2 G]	Fahrzeug-Unterbodenschutz**
1 A 4 c i & 5 B 2	Vergärung LW (landwirtschaftlich)	2 G 4 [2 G]	Feuerwerke
1 B 2 a iii	Raffinerie, Pipelinetransport	2 G 4 [2 G]	Flaechenenteisung Flughaefen
1 B 2 a iv	Raffinerie, Leckverluste*	2 G 4 [2 G]	Flugzeug-Enteisung
1 B 2 a iv	H2-Produktion*	2 G 4 [2 G]	Frostschutzmittel Automobil
1 B 2 a iv	Raffinerie, Clausanlage*	2 G 4 [2 G]	Gas-Anwendung
1 B 2 a v	Benzinumschlag Tanklager	2 G 4 [2 G]	Gesundheitswesen, übrige**
1 B 2 a v	Benzinumschlag Tankstellen	2 G 4 [2 G]	Glaswolle Imprägnierung*
1 B 2 b ii & 1 B 2 c ii 2	Gasproduktion & Gasproduktion, Flaring	2 G 4 [2 G]	Holzschutzmittel-Anwendung
1 B 2 b iv-vi	Netzverluste Erdgas	2 G 4 [2 G]	Klebstoff-Anwendung**
1 B 2 c ii 1	Raffinerie, Abfackelung	2 G 4 [2 G]	Kosmetik-Institute
2 A 1	Zementwerke Rohmaterial	2 G 4 [2 G]	Kühlschmiermittel-Verwendung
2 A 1	Zementwerke übriger Betrieb	2 G 4 [2 G]	Medizinische Praxen**
2 A 2	Kalkproduktion, Rohmaterial*	2 G 4 [2 G]	Pflanzenschutzmittel-Verwendung
2 A 2	Kalkproduktion, übriger Betrieb*	2 G 4 [2 G]	Reinigung Gebäude IGD**
2 A 4 d	Kehrichtverbrennungsanlagen Karbonat**	2 G 4 [2 G]	Schmierstoff-Verwendung
2 A 4 d	Karbonatanwendung weitere	2 G 4 [2 G]	Spraydosen IndustrieGewerbe
2 A 5 a	Gips-Produktion übriger Betrieb*	2 G 4 [2 G]	Tabakwaren Konsum
2 A 5 a	Kieswerke	2 G 4 [2 G]	Steinwolle-Imprägnierung*
2 B 1	Ammoniak-Produktion*	2 H 1	Faserplatten Produktion* (ab 2020)
2 B 10 [2 B 10 a]	Ammoniumnitrat-Produktion*	2 H 1	Zellulose Produktion übriger Betrieb*
2 B 10 [2 B 10 a]	Chlorgas-Produktion*	2 H 1	Spanplatten Produktion*
2 B 10 [2 B 10 a]	Essigsäure-Produktion* (ab 2013)	2 H 2	Bierbrauereien
2 B 10 [2 B 10 a]	*Formaldehyd-Produktion*	2 H 2	Branntwein Produktion
2 B 10 [2 B 10 a]	PVC-Produktion	2 H 2	Brot Produktion
2 B 10 [2 B 10 a]	*Salzsäure-Produktion**	2 H 2	Fleischräuchereien
2 B 10 [2 B 10 a]	Schwefelsäure-Produktion*	2 H 2	Kaffeeröstereien
2 B 10	Kalksteingrube*	2 H 2	Müllereien
2 B 10	Niacin-Produktion*	2 H 2	Wein Produktion
2 B 2	Salpetersäure Produktion*	2 H 2	Zucker Produktion
2 B 5	Graphit und Siliziumkarbid Produktion*	2 H 3	Sprengen und Schiessen
2 C - 2 G	Synthetische Gase	2 I	Holzbearbeitung
2 C 1	Eisengiessereien Elektroschmelzöfen	2K, 1A1a, 2C1, 5A, 5C1, 5E & 6Ad	Emissions due to former PCB usage
2 C 1	Eisengiessereien übriger Betrieb	2 L	NH3 aus Kühlanlagen
2 C 1 & 1 A 2 a	Stahl-Produktion Elektroschmelzöfen**	3	Landwirtschaft
2 C 1	Stahl-Produktion übriger Betrieb**	3 B	Tierhaltung
2 C 1	Stahl-Produktion Walzwerke**	3 C	Reisanbau
2 C 7 a	Buntmetallgiessereien Elektroöfen**	3 D e	Landwirtschaftsflächen
2 C 7 c	Verzinkereien	4 V A 1 [11 B]	Waldbrände
2 C 7 c	Batterie-Recycling*	5 B 1	Kompostierung
2 D 1	Schmiermittel-Anwendung	5 B 2	Biogasaufbereitung (Methanverlust)
2 D 1	Schmiermittel-Verbrauch B2T	5 C 1 [5 C 1 a]	Abfallverbrennung illegal
2 D 2	Paraffinwachs-Anwendung	5 C 1 [5 C 1 b i]	Kabelabbrand
2 D 3 a [2 D 3 d]	Farben-Anwendung Bau	5 C 1 [5 C 1 b iii]	Spitalabfallverbrennung
2 D 3 a [2 D 3 d]	Farben-Anwendung andere	5 C 1 [5 C 1 b iv]	Klärschlammverbrennung
2 D 3 a [2 D 3 d]	Farben-Anwendung Haushalte**	5 C 1 [5 C 1 b v]	Krematorien
2 D 3 a [2 D 3 d]	Farben-Anwendung Holz	5 C 2 / 4 V A 1 (Forstwirtschaft)	Abfallverbrennung Land- und Forstwirtschaft und Private
2 D 3 a [2 D 3 d]	Farben-Anwendung Autoreparatur**	5 D 1 [5 D]	Kläranlagen kommunal (Luftschadstoffe)
2 D 3 a [2 D 3 e]	Elektronik-Reinigung**	5 D 2 [5 D]	Kläranlagen industriell (Luftschadstoffe)
2 D 3 a [2 D 3 e]	Metallreinigung**	5 D 1 / 5 D 2 [5 D]	Abwasserbehandlung GHG
2 D 3 a [2 D 3 e]	Reinigung Industrie übrige**	5 E	Shredder Anlagen
2 D 3 a [2 D 3 f]	Chemische Reinigung**	6 A d	Brand- und Feuerschäden Immobilien
2 D 3 a [2 D 3 g]	Druckfarben Produktion**	6 A d	Brand- und Feuerschäden Motorfahrzeuge
2 D 3 a [2 D 3 g]	Farben-Produktion**	[11 C]	NMVOC Emissionen Wald
2 D 3 a [2 D 3 g]	Feinchemikalien-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 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 2021) and trend (1990-2021) 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 (2021); T: trend assessment (1990-2021); 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, T1, L2, T2		T1, T2	T1, T2
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, T1, L2, T2		L1, T1, L2, T2		T1	T1, T2
1A2gvii	Mobile Combustion in manufacturing industries and construction	T1				L1, T1, L2	L1, T1, L2, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: other	L1, T1, T2		L1, T1, L2, T2		L1, L2	
1A3ai(i)	Civil aviation (domestic, landing/take-off (LTO))	T1, T2					
1A3bi	Road transportation: passenger cars	L1, T1, L2, T2	L1, T1, L2, T2	T1			T1
1A3bii	Road transportation: light-duty vehicles	L1, T1, L2, T2	T1				
1A3biii	Road transportation: heavy-duty vehicles and buses	L1, T1, L2, T2		T1, T2		T1, T2	T1
1A3biv	Road transportation: mopeds and motorcycles		L2, T2				
1A3bv	Road transportation: gasoline evaporation		L1, T1, T2				
1A3bvi	Road transportation: automobile tyre and brake wear					L1, T1, L2, T2	L1, T1, L2, T2
1A3c	Railways					L1, T1	L1, T1, L2, T2
1A3dii	National navigation (shipping)	T1					
1A4ai	Commercial/institutional: stationary	L1, T1, L2, T2		L1, T1, L2		L1, T1, L2, T2	L1
1A4bi	Residential: stationary plants	L1, T1, L2	L1, L2	L1, T1, L2, T2		L1, T1, L2, T2	L1, T1, L2, 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
1B2aiv	Fugitive emissions oil: refining / storage			T2			
1B2av	Distribution of oil products		L1, T1				
1B2c	Venting and flaring (oil, gas, combined oil and gas)	T2					
2A1	Cement production					L2, T2	L1, L2
2A5a	Quarrying and mining of minerals other than coal					L1, T1, L2, T2	L1, T1, L2, T2
2B5	Carbide production			L1, T1, L2, T2			
2B10a	Chemical industry: other			L2, T2			
2C1	Iron and steel production					T1, T2	T1, T2
2D3a	Domestic solvent use including fungicides		L1, T1, L2, T2				
2D3b	Road paving with asphalt		L1, T1, L2, T2				
2D3d	Coating applications		L1, T1, L2, T2				
2D3e	Degreasing		T1, T2				
2D3g	Chemical products		L1, T1, L2, T2				
2D3h	Printing		L1, T1, L2				
2D3i	Other solvent use		L1, L2				
2G	Other product use		L1, L2, T2			L1, T1, L2, T2	L1, L2
2H1	Pulp and paper industry					L1, T1, L2, T2	L2
2H2	Food and beverages industry		L1, T1, L2, T2			L1, L2, T2	L1, L2, T2
2I	Wood processing					L2, T2	T1, L2, T2
3B1a	Manure management - Dairy cattle		L1, T1, L2, T2		L1, T1, L2, T2		
3B1b	Manure management - Non-dairy cattle		L1, T1, L2, T2		L1, T1, L2, 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			L1, T1, L2, T2		
3Da2a	Animal manure applied to soils	T1, L2, T2			L1, T1, L2, 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	T2			T1, L2, T2		
3De	Cultivated crops						L1, T1, L2, T2
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 (2021); T: trend assessment (1990-2021); 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	PCBs
1A1a	Public electricity and heat production	T1			L1	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						T1				
1A3aii(i)	Civil aviation (domestic, cruise)				L1						
1A3bi	Road transportation: passenger cars		L1	L1, T1	T1				L1, T1		
1A3bii	Road transportation: light-duty vehicles			T1							
1A3biii	Road transportation: heavy-duty vehicles and buses	T1	T1								
1A3biv	Road transportation: mopeds and motorcycles			L1							
1A3bvi	Road transportation: automobile tyre and brake wear	L1, T1	L1, T1			L1, T1					
1A3c	Railways	L1, T1									
1A3dii	National navigation (shipping)			L1							
1A4ai	Commercial/institutional: stationary		L1, T1	L1, T1				L1, T1	L1, T1	L1	
1A4aii	Commercial/institutional: mobile			L1, T1							
1A4bi	Residential: stationary plants	L1, T1	L1, T1	L1, T1			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									
2B10a	Chemical industry: other						T1				
2C1	Iron and steel production	T1			T1	T1	L1, T1				
2C3	Aluminium production								T1		
2G	Other product use					L1, T1					
2I	Wood processing	L1, 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	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 2021 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 2021, 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 2021					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, t (t)	Lx, t (%)	Cumu-lative Total (%)
1A3bi	Road transportation: passenger cars	NOx	16'717	32.0	32.0
1A4bi	Residential: stationary plants	NOx	4'873	9.3	41.3
1A3bii	Road transportation: light-duty vehicles	NOx	4'366	8.4	49.7
1A3biii	Road transportation: heavy-duty vehicles and buses	NOx	4'284	8.2	57.9
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	3'253	6.2	64.1
1A4ai	Commercial/institutional: stationary	NOx	2'766	5.3	69.4
1A1a	Public electricity and heat production	NOx	2'137	4.1	73.5
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	1'922	3.7	77.2
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	1'798	3.4	80.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	1'722	3.3	84.0
3Da2a	Animal manure applied to soils	NOx	1'461	2.8	86.8
2D3d	Coating applications	NMVOC	8'280	11.2	11.2
3B1b	Manure management - Non-dairy cattle	NMVOC	8'279	11.2	22.4
3B1a	Manure management - Dairy cattle	NMVOC	7'127	9.6	32.0
2D3a	Domestic solvent use including fungicides	NMVOC	6'372	8.6	40.6
2G	Other product use	NMVOC	6'289	8.5	49.1
1A3bi	Road transportation: passenger cars	NMVOC	3'782	5.1	54.2
2D3h	Printing	NMVOC	3'667	5.0	59.2
2D3g	Chemical products	NMVOC	3'143	4.2	63.4
1A4bi	Residential: stationary plants	NMVOC	2'693	3.6	67.0
2D3b	Road paving with asphalt	NMVOC	2'678	3.6	70.7
1B2av	Distribution of oil products	NMVOC	2'038	2.8	73.4
2H2	Food and beverages industry	NMVOC	1'997	2.7	76.1
1A3bv	Road transportation: gasoline evaporation	NMVOC	1'952	2.6	78.7
2D3i	Other solvent use	NMVOC	1'930	2.6	81.3
2D3e	Degreasing	NMVOC	1'566	2.1	83.5
3B4gii	Manure management - Broilers	NMVOC	1'131	1.5	85.0
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NMVOC	1'083	1.5	86.5
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	1'436	38.0	38.0
1A4bi	Residential: stationary plants	SOx	589	15.6	53.6
2B5	Carbide production	SOx	383	10.1	63.8
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	256	6.8	70.6
1A4ai	Commercial/institutional: stationary	SOx	252	6.7	77.2
1A1a	Public electricity and heat production	SOx	247	6.6	83.8
1A2c	Stationary combustion in manufacturing industries and construction: chemicals	SOx	141	3.7	87.5
3Da2a	Animal manure applied to soils	NH3	20'400	38.0	38.0
3B1a	Manure management - Dairy cattle	NH3	10'396	19.3	57.3
3B1b	Manure management - Non-dairy cattle	NH3	7'050	13.1	70.4
3B3	Manure management - Swine	NH3	4'961	9.2	79.6
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	2'652	4.9	84.6
3Da3	Urine and dung deposited by grazing animals	NH3	1'412	2.6	87.2
1A4bi	Residential: stationary plants	PM2.5	1'215	21.1	21.1
1A3bvi	Road transportation: automobile tyre and brake wear	PM2.5	892	15.5	36.6
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	390	6.8	43.4
2G	Other product use	PM2.5	370	6.4	49.9
1A4ai	Commercial/institutional: stationary	PM2.5	354	6.2	56.0
5C1a	Municipal waste incineration	PM2.5	240	4.2	60.2
2A5a	Quarrying and mining of minerals other than coal	PM2.5	230	4.0	64.2
2H1	Pulp and paper industry	PM2.5	207	3.6	67.8
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	199	3.5	71.3
1A3c	Railways	PM2.5	198	3.4	74.7
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	190	3.3	78.1
2H2	Food and beverages industry	PM2.5	164	2.8	80.9
2A1	Cement production	PM2.5	161	2.8	83.7
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	151	2.6	86.3
1A3bvi	Road transportation: automobile tyre and brake wear	PM10	2'627	19.4	19.4
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2'351	17.3	36.7
1A3c	Railways	PM10	1'287	9.5	46.2
1A4bi	Residential: stationary plants	PM10	1'281	9.5	55.7
3De	Cultivated crops	PM10	1'001	7.4	63.1
2G	Other product use	PM10	464	3.4	66.5
2A5a	Quarrying and mining of minerals other than coal	PM10	460	3.4	69.9
1A4ai	Commercial/institutional: stationary	PM10	377	2.8	72.7
2H2	Food and beverages industry	PM10	304	2.2	74.9
5C1a	Municipal waste incineration	PM10	267	2.0	76.9
1A5b	Other, mobile (including military, land-based and recreational boats)	PM10	261	1.9	78.8
2A1	Cement production	PM10	251	1.9	80.7
2H1	Pulp and paper industry	PM10	214	1.6	82.2
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM10	210	1.5	83.8
3B4gii	Manure management - Broilers	PM10	209	1.5	85.3

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	Road transportation: passenger cars	NOx	43'772	31.1	31.1
1A3biii	Road transportation: heavy-duty vehicles and buses	NOx	29'689	21.1	52.2
1A4bi	Residential: stationary plants	NOx	11'630	8.3	60.5
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	10'535	7.5	68.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	6'334	4.5	72.5
1A1a	Public electricity and heat production	NOx	6'294	4.5	77.0
1A3bii	Road transportation: light-duty vehicles	NOx	6'197	4.4	81.4
1A4ai	Commercial/institutional: stationary	NOx	4'696	3.3	84.7
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	4'358	3.1	87.8
1A3bi	Road transportation: passenger cars	NMVOC	55'938	19.1	19.1
2D3d	Coating applications	NMVOC	40'731	13.9	33.1
2D3g	Chemical products	NMVOC	27'504	9.4	42.5
2G	Other product use	NMVOC	22'432	7.7	50.1
2D3h	Printing	NMVOC	20'354	7.0	57.1
1A3bv	Road transportation: gasoline evaporation	NMVOC	16'981	5.8	62.9
1B2av	Distribution of oil products	NMVOC	14'400	4.9	67.8
2D3e	Degreasing	NMVOC	11'731	4.0	71.8
1A4bi	Residential: stationary plants	NMVOC	10'042	3.4	75.3
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	3.0	78.3
3B1a	Manure management - Dairy cattle	NMVOC	7'075	2.4	80.7
1A3biv	Road transportation: mopeds and motorcycles	NMVOC	5'733	2.0	82.7
2D3i	Other solvent use	NMVOC	5'470	1.9	84.5
3B1b	Manure management - Non-dairy cattle	NMVOC	5'368	1.8	86.4
1A4bi	Residential: stationary plants	SOx	9'208	25.0	25.0
1A1a	Public electricity and heat production	SOx	3'587	9.7	34.7
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	9.6	44.3
1A4ai	Commercial/institutional: stationary	SOx	3'426	9.3	53.6
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	3'314	9.0	62.6
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SOx	3'091	8.4	71.0
1A3biii	Road transportation: heavy-duty vehicles and buses	SOx	1'743	4.7	75.7
1A3bi	Road transportation: passenger cars	SOx	1'705	4.6	80.3
1A2c	Stationary combustion in manufacturing industries and construction: chemicals	SOx	1'103	3.0	83.3
1A2e	Stationary combustion in manufacturing industries and construction: food processing, beverages and tobacco	SOx	985	2.7	86.0
3Da2a	Animal manure applied to soils	NH3	34'567	50.4	50.4
3B1a	Manure management - Dairy cattle	NH3	9'337	13.6	64.1
3B3	Manure management - Swine	NH3	6'965	10.2	74.2
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	88.0
1A4bi	Residential: stationary plants	PM2.5	5'227	31.4	31.4
1A3biii	Road transportation: heavy-duty vehicles and buses	PM2.5	1'587	9.5	41.0
2C1	Iron and steel production	PM2.5	818	4.9	45.9
1A1a	Public electricity and heat production	PM2.5	772	4.6	50.6
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	4.4	54.9
1A3bvi	Road transportation: automobile tyre and brake wear	PM2.5	689	4.1	59.1
1A3bi	Road transportation: passenger cars	PM2.5	578	3.5	62.6
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	544	3.3	65.8
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	539	3.2	69.1
2G	Other product use	PM2.5	513	3.1	72.2
1A4ai	Commercial/institutional: stationary	PM2.5	506	3.0	75.2
5C1a	Municipal waste incineration	PM2.5	465	2.8	78.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM2.5	438	2.6	80.7
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	435	2.6	83.3
1A3bii	Road transportation: light-duty vehicles	PM2.5	327	2.0	85.2
1A4bi	Residential: stationary plants	PM10	5'500	21.7	21.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2'173	8.6	30.3
1A3bvi	Road transportation: automobile tyre and brake wear	PM10	2'050	8.1	38.4
1A3biii	Road transportation: heavy-duty vehicles and buses	PM10	1'587	6.3	44.7
2C1	Iron and steel production	PM10	1'485	5.9	50.6
3De	Cultivated crops	PM10	1'054	4.2	54.7
1A1a	Public electricity and heat production	PM10	1'034	4.1	58.8
1A3c	Railways	PM10	983	3.9	62.7
2I	Wood processing	PM10	864	3.4	66.1
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	3.3	69.4
2G	Other product use	PM10	588	2.3	71.7
1A3bi	Road transportation: passenger cars	PM10	578	2.3	74.0
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM10	567	2.2	76.2
1A4ci	Agriculture/forestry/fishing: stationary	PM10	544	2.1	78.4
1A4ai	Commercial/institutional: stationary	PM10	533	2.1	80.5
5C1a	Municipal waste incineration	PM10	517	2.0	82.5
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM10	511	2.0	84.6
2A1	Cement production	PM10	374	1.5	86.0

Table A - 5 Switzerland's key categories according to approach 1 trend assessment for 1990-2021, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in orange have increased emissions in 2021 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 1 TREND ASSESSMENT 1990 - 2021								
A	B	C	D	E		F	G	H
NFR code	Source category	Pollutant	Ex, 0 (t)	Ex, t (t)	Category trend (%)	Trend Assess-ment	Contri-bution to trend (%)	Cumu-lative Total (%)
1A3biii	Road transportation: heavy-duty vehicles and buses	NOx	29'689	4'284	-86	0.048	37.2	37.2
1A3bii	Road transportation: light-duty vehicles	NOx	6'197	4'366	-30	0.015	11.4	48.5
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	2'338	1'922	-18	0.007	5.8	54.4
1A4ai	Commercial/institutional: stationary	NOx	4'696	2'766	-41	0.007	5.6	60.0
3Da2a	Animal manure applied to soils	NOx	2'075	1'461	-30	0.005	3.8	63.8
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	10'535	3'253	-69	0.005	3.6	67.4
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	6'334	1'722	-73	0.004	3.5	70.9
1A3dii	National navigation (shipping)	NOx	1'055	956	-9	0.004	3.1	74.0
1A4bi	Residential: stationary plants	NOx	11'630	4'873	-58	0.004	3.1	77.1
1A3bi	Road transportation: passenger cars	NOx	43'772	16'717	-62	0.003	2.5	79.6
1A3ai(i)	Civil aviation (domestic, landing/take-off (LTO))	NOx	1'214	904	-26	0.003	2.5	82.1
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	NOx	1'261	46	-96	0.003	2.3	84.4
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1'205	820	-32	0.003	2.1	86.5
1A3bi	Road transportation: passenger cars	NMVOC	55'938	3'782	-93	0.035	19.4	19.4
3B1b	Manure management - Non-dairy cattle	NMVOC	5'368	8'279	54	0.024	13.0	32.4
3B1a	Manure management - Dairy cattle	NMVOC	7'075	7'127	1	0.018	10.0	42.4
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	6'372	-28	0.014	7.7	50.1
2D3g	Chemical products	NMVOC	27'504	3'143	-89	0.013	7.2	57.3
1A3bv	Road transportation: gasoline evaporation	NMVOC	16'981	1'952	-89	0.008	4.4	61.7
2D3d	Coating applications	NMVOC	40'731	8'280	-80	0.007	3.8	65.5
1B2av	Distribution of oil products	NMVOC	14'400	2'038	-86	0.005	3.0	68.5
2H2	Food and beverages industry	NMVOC	1'956	1'997	2	0.005	2.8	71.3
2D3h	Printing	NMVOC	20'354	3'667	-82	0.005	2.8	74.1
2D3b	Road paving with asphalt	NMVOC	4'895	2'678	-45	0.005	2.7	76.8
2D3e	Degreasing	NMVOC	11'731	1'566	-87	0.005	2.6	79.4
1A3bii	Road transportation: light-duty vehicles	NMVOC	4'920	168	-97	0.004	2.0	81.4
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NMVOC	46	1'083	2'232	0.004	2.0	83.5
3B4gii	Manure management - Broilers	NMVOC	366	1'131	209	0.004	1.9	85.4
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	1'436	-59	0.029	33.1	33.1
1A4bi	Residential: stationary plants	SOx	9'208	589	-94	0.010	10.9	44.0
2B5	Carbide production	SOx	625	383	-39	0.009	9.8	53.9
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SOx	3'091	2	-100	0.009	9.7	63.5
1A3biii	Road transportation: heavy-duty vehicles and buses	SOx	1'743	10	-99	0.005	5.2	68.7
1A3bi	Road transportation: passenger cars	SOx	1'705	39	-98	0.004	4.2	72.9
1A1a	Public electricity and heat production	SOx	3'587	247	-93	0.003	3.7	76.6
1A4ai	Commercial/institutional: stationary	SOx	3'426	252	-93	0.003	3.0	79.6
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	3'314	256	-92	0.002	2.6	82.2
1A2e	Stationary combustion in manufacturing industries and construction: food processing, beverages and tobacco	SOx	985	18	-98	0.002	2.6	84.8
2C3	Aluminium production	SOx	696	0	-100	0.002	2.2	87.0
3Da2a	Animal manure applied to soils	NH3	34'567	20'400	-41	0.098	34.7	34.7
3B1a	Manure management - Dairy cattle	NH3	9'337	10'396	11	0.045	15.9	50.5
3B1b	Manure management - Non-dairy cattle	NH3	5'191	7'050	36	0.043	15.4	65.9
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	34	979	2'779	0.014	4.9	70.9
3Da2b	Sewage sludge applied to soils	NH3	1'169	0	-100	0.013	4.7	75.6
3Da3	Urine and dung deposited by grazing animals	NH3	761	1'412	86	0.012	4.2	79.8
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4'258	2'652	-38	0.010	3.6	83.4
3B3	Manure management - Swine	NH3	6'965	4'961	-29	0.007	2.6	86.0
1A3bvi	Road transportation: automobile tyre and brake wear	PM2.5	689	892	29	0.039	16.0	16.0
1A4bi	Residential: stationary plants	PM2.5	5'227	1'215	-77	0.036	14.5	30.5
1A3biii	Road transportation: heavy-duty vehicles and buses	PM2.5	1'587	51	-97	0.030	12.2	42.7
2C1	Iron and steel production	PM2.5	818	9	-99	0.016	6.7	49.4
1A1a	Public electricity and heat production	PM2.5	772	44	-94	0.013	5.5	54.8
2G	Other product use	PM2.5	513	370	-28	0.012	4.7	59.5
1A4ai	Commercial/institutional: stationary	PM2.5	506	354	-30	0.011	4.4	63.9
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	230	26	0.010	4.1	68.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	390	-47	0.008	3.4	71.4
1A3c	Railways	PM2.5	174	198	14	0.008	3.4	74.8
2H1	Pulp and paper industry	PM2.5	236	207	-12	0.008	3.1	77.8
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM2.5	438	47	-89	0.006	2.6	80.4
2H2	Food and beverages industry	PM2.5	188	164	-13	0.006	2.4	82.8
5C1a	Municipal waste incineration	PM2.5	465	240	-48	0.005	1.9	84.7
1A3bi	Road transportation: passenger cars	PM2.5	578	121	-79	0.005	1.9	86.7
1A4bi	Residential: stationary plants	PM10	5'500	1'281	-77	0.066	15.5	15.5
1A3bvi	Road transportation: automobile tyre and brake wear	PM10	2'050	2'627	28	0.060	14.2	29.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2'173	2'351	8	0.047	11.1	40.8
1A3biii	Road transportation: heavy-duty vehicles and buses	PM10	1'587	51	-97	0.032	7.4	48.2
2C1	Iron and steel production	PM10	1'485	13	-99	0.031	7.3	55.5
1A3c	Railways	PM10	983	1'287	31	0.030	7.1	62.6
1A1a	Public electricity and heat production	PM10	1'034	44	-96	0.020	4.7	67.3
3De	Cultivated crops	PM10	1'054	1'001	-5	0.017	4.1	71.4
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	79	-90	0.014	3.4	74.8
2I	Wood processing	PM10	864	195	-77	0.011	2.5	77.3
2A5a	Quarrying and mining of minerals other than coal	PM10	367	460	26	0.010	2.5	79.7
1A3bi	Road transportation: passenger cars	PM10	578	121	-79	0.007	1.8	81.5
3B4gii	Manure management - Broilers	PM10	68	209	209	0.007	1.6	83.1
2G	Other product use	PM10	588	464	-21	0.006	1.4	84.5
2H2	Food and beverages industry	PM10	310	304	-2	0.005	1.3	85.8

Table A - 6 Switzerland's key categories according to approach 1 level assessment for the year 2021, 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 2021					
A	B	C	D	E	F
NFR code	Source category	Pollutant (unit)	Ex, t	Lx, t (%)	Cumu-lative Total (%)
3De	Cultivated crops	TSP (t)	10'009	36.5	36.5
1A2gvii	Mobile Combustion in manufacturing industries and construction	TSP (t)	3'505	12.8	49.3
1A3bvi	Road transportation: automobile tyre and brake wear	TSP (t)	2'627	9.6	58.9
1A3c	Railways	TSP (t)	1'711	6.2	65.1
1A4bi	Residential: stationary plants	TSP (t)	1'343	4.9	70.0
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	908	3.3	73.3
3B4gi	Manure management - Laying hens	TSP (t)	735	2.7	76.0
3B3	Manure management - Swine	TSP (t)	645	2.4	78.3
2I	Wood processing	TSP (t)	488	1.8	80.1
2G	Other product use	TSP (t)	464	1.7	81.8
2H2	Food and beverages industry	TSP (t)	419	1.5	83.3
3B4gii	Manure management - Broilers	TSP (t)	419	1.5	84.9
1A4ai	Commercial/institutional: stationary	TSP (t)	392	1.4	86.3
1A4bi	Residential: stationary plants	BC (t)	506	50.6	50.6
1A4ai	Commercial/institutional: stationary	BC (t)	94	9.4	60.0
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	94	9.3	69.4
1A3bvi	Road transportation: automobile tyre and brake wear	BC (t)	89	8.9	78.3
1A3bi	Road transportation: passenger cars	BC (t)	47	4.7	83.0
1A3bii	Road transportation: light-duty vehicles	BC (t)	38	3.8	86.7
1A3bi	Road transportation: passenger cars	CO (t)	44'575	30.2	30.2
1A4bi	Residential: stationary plants	CO (t)	28'148	19.1	49.3
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	12'831	8.7	58.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	CO (t)	9'137	6.2	64.2
1A4ai	Commercial/institutional: stationary	CO (t)	6'942	4.7	68.9
1A4aii	Commercial/institutional: mobile	CO (t)	6'585	4.5	73.3
1A3biv	Road transportation: mopeds and motorcycles	CO (t)	6'068	4.1	77.4
1A3dii	National navigation (shipping)	CO (t)	4'955	3.4	80.8
1A2gvii	Mobile Combustion in manufacturing industries and construction	CO (t)	4'197	2.8	83.7
1A4bii	Residential: household and gardening (mobile)	CO (t)	3'902	2.6	86.3
6A	Other sources	Pb (kg)	6'959	51.3	51.3
5C1a	Municipal waste incineration	Pb (kg)	1'670	12.3	63.7
1A1a	Public electricity and heat production	Pb (kg)	1'660	12.2	75.9
1A3aii(i)	Civil aviation (domestic, cruise)	Pb (kg)	761	5.6	81.5
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Pb (kg)	668	4.9	86.5
6A	Other sources	Cd (kg)	174	27.7	27.7
1A1a	Public electricity and heat production	Cd (kg)	154	24.5	52.2
1A3bvi	Road transportation: automobile tyre and brake wear	Cd (kg)	86	13.6	65.8
2G	Other product use	Cd (kg)	73	11.7	77.5
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Cd (kg)	29	4.6	82.0
1A4bi	Residential: stationary plants	Cd (kg)	23	3.7	85.8
1A1a	Public electricity and heat production	Hg (kg)	298	43.9	43.9
6A	Other sources	Hg (kg)	79	11.6	55.5
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Hg (kg)	64	9.4	64.9
1A4bi	Residential: stationary plants	Hg (kg)	55	8.0	73.0
2C1	Iron and steel production	Hg (kg)	52	7.6	80.6
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Hg (kg)	31	4.6	85.2
1A4bi	Residential: stationary plants	PCDD/PCDF (mg I-	4'795	31.7	31.7
5C1a	Municipal waste incineration	PCDD/PCDF (mg I-	2'672	17.7	49.4
6A	Other sources	PCDD/PCDF (mg I-	2'610	17.3	66.7
1A4ai	Commercial/institutional: stationary	PCDD/PCDF (mg I-	1'347	8.9	75.6
1A1a	Public electricity and heat production	PCDD/PCDF (mg I-	959	6.3	81.9
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PCDD/PCDF (mg I-	801	5.3	87.2
1A4bi	Residential: stationary plants	PAHs total (kg)	1'534	59.5	59.5
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	306	11.9	71.3
1A3bi	Road transportation: passenger cars	PAHs total (kg)	194	7.5	78.8
5C2	Open burning of waste	PAHs total (kg)	189	7.3	86.1
1A1a	Public electricity and heat production	HCB (g)	187	51.0	51.0
1A4bi	Residential: stationary plants	HCB (g)	98	26.7	77.7
1A4ai	Commercial/institutional: stationary	HCB (g)	40	10.8	88.5
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCBs (g)	336'069	89.8	89.8

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 (%)
3De	Cultivated crops	TSP (t)	10'540	23.8	23.8
1A4bi	Residential: stationary plants	TSP (t)	5'819	13.1	36.9
2I	Wood processing	TSP (t)	4'322	9.8	46.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	TSP (t)	3'023	6.8	53.5
2C1	Iron and steel production	TSP (t)	2'686	6.1	59.6
1A3bvi	Road transportation: automobile tyre and brake wear	TSP (t)	2'050	4.6	64.2
1A3biii	Road transportation: heavy-duty vehicles and buses	TSP (t)	1'587	3.6	67.8
1A3c	Railways	TSP (t)	1'298	2.9	70.7
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	TSP (t)	1'227	2.8	73.5
1A1a	Public electricity and heat production	TSP (t)	1'048	2.4	75.9
3B3	Manure management - Swine	TSP (t)	915	2.1	77.9
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	685	1.5	79.5
5C1a	Municipal waste incineration	TSP (t)	646	1.5	80.9
1A2gviii	Stationary combustion in manufacturing industries and construction: other	TSP (t)	609	1.4	82.3
2G	Other product use	TSP (t)	588	1.3	83.6
3B4gi	Manure management - Laying hens	TSP (t)	586	1.3	84.9
1A3bi	Road transportation: passenger cars	TSP (t)	578	1.3	86.2
1A4bi	Residential: stationary plants	BC (t)	3'220	56.2	56.2
1A3biii	Road transportation: heavy-duty vehicles and buses	BC (t)	794	13.9	70.1
1A4ai	Commercial/institutional: stationary	BC (t)	300	5.2	75.3
1A2gvii	Mobile Combustion in manufacturing industries and construction	BC (t)	256	4.5	79.7
1A3bi	Road transportation: passenger cars	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	Road transportation: passenger cars	CO (t)	425'322	56.3	56.3
1A4bi	Residential: stationary plants	CO (t)	111'867	14.8	71.1
1A3bii	Road transportation: light-duty vehicles	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	Road transportation: mopeds and motorcycles	CO (t)	24'680	3.3	87.7
1A3bi	Road transportation: passenger cars	Pb (kg)	211'229	59.8	59.8
2C1	Iron and steel production	Pb (kg)	59'858	16.9	76.7
1A1a	Public electricity and heat production	Pb (kg)	29'818	8.4	85.2
1A1a	Public electricity and heat production	Cd (kg)	1'754	51.2	51.2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Cd (kg)	665	19.4	70.6
2C1	Iron and steel production	Cd (kg)	443	12.9	83.6
6A	Other sources	Cd (kg)	174	5.1	88.6
1A1a	Public electricity and heat production	Hg (kg)	3'915	61.3	61.3
2C1	Iron and steel production	Hg (kg)	1'108	17.3	78.6
2B10a	Chemical industry: other	Hg (kg)	384	6.0	84.7
5C1biii	Clinical waste incineration	Hg (kg)	240	3.8	88.4
1A1a	Public electricity and heat production	PCDD/PCDF (mg I-	130'484	67.5	67.5
1A4bi	Residential: stationary plants	PCDD/PCDF (mg I-	17'673	9.1	76.6
2C1	Iron and steel production	PCDD/PCDF (mg I-	12'419	6.4	83.0
5C1biii	Clinical waste incineration	PCDD/PCDF (mg I-	6'900	3.6	86.6
1A4bi	Residential: stationary plants	PAHs total (kg)	5'698	70.1	70.1
2C3	Aluminium production	PAHs total (kg)	940	11.6	81.7
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	516	6.4	88.0
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)	PCBs (g)	1'525'788	65.4	65.4
6A	Other sources	PCBs (g)	281'955	12.1	77.5
5E	Other waste	PCBs (g)	215'511	9.2	86.8

Table A - 8 Switzerland's key categories according to approach 1 trend assessment for 1990-2021, 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 2021 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 1 TREND ASSESSMENT 1990 - 2021								
A	B	C	D	E		F	G	H
NFR code	Source category	Pollutant (unit)	Ex, 0	Ex, t	Category trend (%)	Trend Assess-ment	Contri-bution to trend (%)	Cumu-lative Total (%)
3De	Cultivated crops	TSP (t)	10'540	10'009	-5	0.079	17.9	17.9
1A4bi	Residential: stationary plants	TSP (t)	5'819	1'343	-77	0.051	11.6	29.5
2I	Wood processing	TSP (t)	4'322	488	-89	0.049	11.2	40.7
2C1	Iron and steel production	TSP (t)	2'686	15	-99	0.037	8.5	49.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	TSP (t)	3'023	3'505	16	0.037	8.4	57.6
1A3bvi	Road transportation: automobile tyre and brake wear	TSP (t)	2'050	2'627	28	0.031	7.0	64.5
1A3biii	Road transportation: heavy-duty vehicles and buses	TSP (t)	1'587	51	-97	0.021	4.8	69.3
1A3c	Railways	TSP (t)	1'298	1'711	32	0.020	4.7	74.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	TSP (t)	1'227	90	-93	0.015	3.4	77.4
1A1a	Public electricity and heat production	TSP (t)	1'048	44	-96	0.014	3.1	80.5
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	685	908	33	0.011	2.5	83.0
3B4gi	Manure management - Laying hens	TSP (t)	586	735	25	0.008	1.9	84.9
3B4gii	Manure management - Broilers	TSP (t)	136	419	209	0.008	1.7	86.6
1A3biii	Road transportation: heavy-duty vehicles and buses	BC (t)	794	21	-97	0.021	26.5	26.5
1A3bvi	Road transportation: automobile tyre and brake wear	BC (t)	69	89	29	0.013	17.3	43.8
1A4bi	Residential: stationary plants	BC (t)	3'220	506	-84	0.010	12.6	56.4
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	232	94	-60	0.009	11.9	68.3
1A4ai	Commercial/institutional: stationary	BC (t)	300	94	-69	0.007	9.4	77.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	BC (t)	256	25	-90	0.003	4.4	82.1
5C1a	Municipal waste incineration	BC (t)	33	17	-48	0.002	2.5	84.6
1A3bii	Road transportation: light-duty vehicles	BC (t)	161	38	-77	0.002	2.1	86.8
1A3bi	Road transportation: passenger cars	CO (t)	425'322	44'575	-90	0.051	38.6	38.6
1A3bii	Road transportation: light-duty vehicles	CO (t)	72'490	3'756	-95	0.014	10.4	49.1
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	28'368	12'831	-55	0.010	7.3	56.4
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	CO (t)	13'126	9'137	-30	0.009	6.6	63.0
1A4bi	Residential: stationary plants	CO (t)	111'867	28'148	-75	0.008	6.3	69.3
1A4aii	Commercial/institutional: mobile	CO (t)	4'117	6'585	60	0.008	5.8	75.1
1A4ai	Commercial/institutional: stationary	CO (t)	11'159	6'942	-38	0.006	4.8	79.9
1A4bii	Residential: household and gardening (mobile)	CO (t)	3'271	3'902	19	0.004	3.3	83.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	CO (t)	7'253	4'197	-42	0.004	2.8	86.0
1A3bi	Road transportation: passenger cars	Pb (kg)	211'229	100	-100	0.023	36.4	36.4
6A	Other sources	Pb (kg)	6'941	6'959	0	0.019	30.5	66.9
2C1	Iron and steel production	Pb (kg)	59'858	264	-100	0.006	9.3	76.2
5C1a	Municipal waste incineration	Pb (kg)	3'230	1'670	-48	0.004	7.0	83.2
1A3aii(i)	Civil aviation (domestic, cruise)	Pb (kg)	2'027	761	-62	0.002	3.1	86.3
1A1a	Public electricity and heat production	Cd (kg)	1'754	154	-91	0.049	24.2	24.2
6A	Other sources	Cd (kg)	174	174	0	0.041	20.5	44.7
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Cd (kg)	665	29	-96	0.027	13.5	58.1
2C1	Iron and steel production	Cd (kg)	443	5	-99	0.022	11.0	69.1
1A3bvi	Road transportation: automobile tyre and brake wear	Cd (kg)	65	86	32	0.021	10.6	79.7
2G	Other product use	Cd (kg)	102	73	-28	0.016	7.9	87.6
1A1a	Public electricity and heat production	Hg (kg)	3'915	298	-92	0.019	23.2	23.2
6A	Other sources	Hg (kg)	82	79	-4	0.011	13.8	37.0
2C1	Iron and steel production	Hg (kg)	1'108	52	-95	0.010	13.0	50.0
1A4bi	Residential: stationary plants	Hg (kg)	72	55	-24	0.007	9.2	59.2
2B10a	Chemical industry: other	Hg (kg)	384	0	-100	0.006	8.0	67.2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	Hg (kg)	226	64	-72	0.006	7.9	75.0
1A2gviii	Stationary combustion in manufacturing industries and construction: other	Hg (kg)	13	31	133	0.005	5.8	80.8
1A4ai	Commercial/institutional: stationary	Hg (kg)	14	30	116	0.004	5.6	86.4
1A1a	Public electricity and heat production	PCDD/PCDF (mg I-	130'484	959	-99	0.048	41.4	41.4
1A4bi	Residential: stationary plants	PCDD/PCDF (mg I-	17'673	4'795	-73	0.018	15.3	56.7
6A	Other sources	PCDD/PCDF (mg I-	2'603	2'610	0	0.012	10.8	67.5
5C1a	Municipal waste incineration	PCDD/PCDF (mg I-	5'168	2'672	-48	0.012	10.2	77.7
1A4ai	Commercial/institutional: stationary	PCDD/PCDF (mg I-	2'112	1'347	-36	0.006	5.3	83.0
2C1	Iron and steel production	PCDD/PCDF (mg I-	12'419	172	-99	0.004	3.6	86.6
2C3	Aluminium production	PAHs total (kg)	940	0	-100	0.037	25.6	25.6
1A4bi	Residential: stationary plants	PAHs total (kg)	5'698	1'534	-73	0.034	23.6	49.2
1A3bi	Road transportation: passenger cars	PAHs total (kg)	103	194	88	0.020	13.8	63.0
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	516	306	-41	0.017	12.2	75.1
6A	Other sources	PAHs total (kg)	72	115	59	0.011	7.9	83.0
5C2	Open burning of waste	PAHs total (kg)	371	189	-49	0.009	6.1	89.1
1A2b	Stationary combustion in manufacturing industries and construction: non-ferrous metals	HCB (g)	172'000	0	-100	0.002	50.0	50.0
1A1a	Public electricity and heat production	HCB (g)	114	187	64	0.001	25.6	75.6
1A4bi	Residential: stationary plants	HCB (g)	322	98	-70	0.001	13.3	88.9
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCBs (g)	1'525'788	336'069	-78	0.039	49.8	49.8
5E	Other waste	PCBs (g)	215'511	3'802	-98	0.013	16.8	66.6
1A1a	Public electricity and heat production	PCBs (g)	164'493	70	-100	0.011	14.4	81.0
5C1bii	Hazardous waste incineration	PCBs (g)	111'813	0	-100	0.008	9.8	90.8

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 2021 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 2021, 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 2021					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, t (t)	Lx, t (%)	Cumu-lative Total (%)
1A3bi	Road transportation: passenger cars	NOx	16'717	42.4	42.4
1A3bii	Road transportation: light-duty vehicles	NOx	4'366	9.3	51.7
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	820	5.4	57.1
1A3biii	Road transportation: heavy-duty vehicles and buses	NOx	4'284	5.1	62.2
3Da2a	Animal manure applied to soils	NOx	1'461	4.9	67.1
1A4bi	Residential: stationary plants	NOx	4'873	4.4	71.5
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	3'253	3.7	75.2
1A1a	Public electricity and heat production	NOx	2'137	3.0	78.2
1A4ai	Commercial/institutional: stationary	NOx	2'766	2.9	81.2
3Da3	Urine and dung deposited by grazing animals	NOx	417	2.8	83.9
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	1'922	2.2	86.1
2G	Other product use	NMVOC	6'289	16.3	16.3
2D3a	Domestic solvent use including fungicides	NMVOC	6'372	9.9	26.2
3B1b	Manure management - Non-dairy cattle	NMVOC	8'279	9.8	36.0
3B1a	Manure management - Dairy cattle	NMVOC	7'127	7.2	43.3
2D3d	Coating applications	NMVOC	8'280	6.2	49.5
2D3g	Chemical products	NMVOC	3'143	5.1	54.6
2D3i	Other solvent use	NMVOC	1'930	4.7	59.2
2D3b	Road paving with asphalt	NMVOC	2'678	4.2	63.4
1A3bi	Road transportation: passenger cars	NMVOC	3'782	3.3	66.7
1A3biv	Road transportation: mopeds and motorcycles	NMVOC	789	3.3	70.0
2H2	Food and beverages industry	NMVOC	1'997	3.1	73.1
1A4bi	Residential: stationary plants	NMVOC	2'693	3.1	76.2
3B4gii	Manure management - Broilers	NMVOC	1'131	2.9	79.1
2D3h	Printing	NMVOC	3'667	2.8	81.9
3B3	Manure management - Swine	NMVOC	803	2.1	83.9
2D3e	Degreasing	NMVOC	1'566	1.7	85.6
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	1'436	39.6	39.6
2B5	Carbide production	SOx	383	11.1	50.7
1A4bi	Residential: stationary plants	SOx	589	9.1	59.8
1A1a	Public electricity and heat production	SOx	247	8.6	68.4
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	256	7.1	75.5
1A4ai	Commercial/institutional: stationary	SOx	252	3.7	79.1
2B10a	Chemical industry: other	SOx	59	3.4	82.6
1A1b	Petroleum refining	SOx	85	2.5	85.0
3Da2a	Animal manure applied to soils	NH3	20'400	23.9	23.9
3B1a	Manure management - Dairy cattle	NH3	10'396	16.5	40.4
3B3	Manure management - Swine	NH3	4'961	10.7	51.1
3B1b	Manure management - Non-dairy cattle	NH3	7'050	10.4	61.6
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	2'652	7.1	68.7
6A	Other sources	NH3	995	5.6	74.3
3Da3	Urine and dung deposited by grazing animals	NH3	1'412	4.7	79.0
3B4gii	Manure management - Broilers	NH3	672	3.1	82.1
3B4gi	Manure management - Laying hens	NH3	678	3.0	85.1
1A4bi	Residential: stationary plants	PM2.5	1'215	17.6	17.6
2A5a	Quarrying and mining of minerals other than coal	PM2.5	230	12.1	29.8
2H2	Food and beverages industry	PM2.5	164	8.7	38.5
1A3bvi	Road transportation: automobile tyre and brake wear	PM2.5	892	8.5	47.0
2G	Other product use	PM2.5	370	6.7	53.7
2H1	Pulp and paper industry	PM2.5	207	6.1	59.8
1A4ai	Commercial/institutional: stationary	PM2.5	354	5.3	65.1
2A1	Cement production	PM2.5	161	4.7	69.8
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	390	3.7	73.5
5C1a	Municipal waste incineration	PM2.5	240	2.7	76.2
2I	Wood processing	PM2.5	49	2.6	78.8
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	190	2.4	81.1
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	151	2.3	83.4
1A3c	Railways	PM2.5	198	1.9	85.3
3De	Cultivated crops	PM10	1'001	12.1	12.1
1A3bvi	Road transportation: automobile tyre and brake wear	PM10	2'627	10.4	22.5
2A5a	Quarrying and mining of minerals other than coal	PM10	460	10.1	32.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2'351	9.3	42.0
1A4bi	Residential: stationary plants	PM10	1'281	7.7	49.7
2H2	Food and beverages industry	PM10	304	6.7	56.4
1A3c	Railways	PM10	1'287	5.1	61.5
2I	Wood processing	PM10	195	4.3	65.8
2G	Other product use	PM10	464	3.5	69.3
3B4gii	Manure management - Broilers	PM10	209	3.4	72.7
2A1	Cement production	PM10	251	3.0	75.7
2H1	Pulp and paper industry	PM10	214	2.6	78.3
3B4gi	Manure management - Laying hens	PM10	155	2.5	80.8
3B3	Manure management - Swine	PM10	149	2.4	83.2
1A4ai	Commercial/institutional: stationary	PM10	377	2.3	85.6

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	Road transportation: passenger cars	NOx	43'772	45.2	45.2
1A3biii	Road transportation: heavy-duty vehicles and buses	NOx	29'689	14.5	59.7
1A3bii	Road transportation: light-duty vehicles	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	11'630	4.3	74.2
1A1a	Public electricity and heat production	NOx	6'294	3.7	77.9
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1'205	3.3	81.1
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	Road transportation: passenger cars	NMVOC	55'938	14.0	30.6
2D3g	Chemical products	NMVOC	27'504	12.7	43.2
2D3d	Coating applications	NMVOC	40'731	8.7	51.9
1A3biv	Road transportation: mopeds and motorcycles	NMVOC	5'733	6.8	58.7
2D3h	Printing	NMVOC	20'354	4.4	63.1
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	3.9	67.0
2D3i	Other solvent use	NMVOC	5'470	3.8	70.8
2D3e	Degreasing	NMVOC	11'731	3.6	74.4
1A4bi	Residential: stationary plants	NMVOC	10'042	3.3	77.7
1A3bv	Road transportation: gasoline evaporation	NMVOC	16'981	3.3	80.9
2D3b	Road paving with asphalt	NMVOC	4'895	2.2	83.1
3B1a	Manure management - Dairy cattle	NMVOC	7'075	2.0	85.1
2C3	Aluminium production	SOx	696	15.8	15.8
1A4bi	Residential: stationary plants	SOx	9'208	14.5	30.3
1A1a	Public electricity and heat production	SOx	3'587	12.9	43.2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	10.0	53.1
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	3'314	9.4	62.5
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SOx	3'091	6.5	69.0
1A4ai	Commercial/institutional: stationary	SOx	3'426	5.1	74.1
1B2aiv	Fugitive emissions oil: refining / storage	SOx	419	3.4	77.5
1A3biii	Road transportation: heavy-duty vehicles and buses	SOx	1'743	2.6	80.1
1A3bi	Road transportation: passenger cars	SOx	1'705	2.5	82.7
2C1	Iron and steel production	SOx	144	2.0	84.7
1A1b	Petroleum refining	SOx	660	2.0	86.6
3Da2a	Animal manure applied to soils	NH3	34'567	33.9	33.9
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	Road transportation: passenger cars	NH3	1'325	3.0	85.3
1A4bi	Residential: stationary plants	PM2.5	5'227	30.9	30.9
2C1	Iron and steel production	PM2.5	818	7.0	37.9
2I	Wood processing	PM2.5	216	4.7	42.6
1A1a	Public electricity and heat production	PM2.5	772	4.3	46.9
2H2	Food and beverages industry	PM2.5	188	4.1	51.0
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	3.9	54.9
2G	Other product use	PM2.5	513	3.8	58.7
1A3biii	Road transportation: heavy-duty vehicles and buses	PM2.5	1'587	3.3	62.1
1A4ai	Commercial/institutional: stationary	PM2.5	506	3.1	65.1
2A1	Cement production	PM2.5	240	2.9	68.0
2H1	Pulp and paper industry	PM2.5	236	2.8	70.8
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	2.8	73.7
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM2.5	544	2.8	76.4
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	435	2.7	79.1
1A3bvi	Road transportation: automobile tyre and brake wear	PM2.5	689	2.7	81.8
1A3bi	Road transportation: passenger cars	PM2.5	578	2.6	84.4
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM2.5	438	2.2	86.6
1A4bi	Residential: stationary plants	PM10	5'500	18.8	18.8
2I	Wood processing	PM10	864	10.8	29.6
2C1	Iron and steel production	PM10	1'485	7.4	37.0
3De	Cultivated crops	PM10	1'054	7.3	44.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2'173	4.9	49.1
1A3bvi	Road transportation: automobile tyre and brake wear	PM10	2'050	4.6	53.7
2A5a	Quarrying and mining of minerals other than coal	PM10	367	4.6	58.3
2H2	Food and beverages industry	PM10	310	3.9	62.2
1A1a	Public electricity and heat production	PM10	1'034	3.3	65.5
2A1	Cement production	PM10	374	2.6	68.1
2G	Other product use	PM10	588	2.5	70.6
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	2.4	73.0
1A3c	Railways	PM10	983	2.2	75.2
3B3	Manure management - Swine	PM10	213	2.0	77.2
1A3biii	Road transportation: heavy-duty vehicles and buses	PM10	1'587	1.9	79.1
1A4ai	Commercial/institutional: stationary	PM10	533	1.9	81.0
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM10	511	1.8	82.8
2H1	Pulp and paper industry	PM10	244	1.7	84.5
1A2gviii	Stationary combustion in manufacturing industries and construction: other	PM10	567	1.7	86.2

Table A - 11 Switzerland's key categories according to approach 2 trend assessment for 1990-2021, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in orange have increased emissions in 2021 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, TREND ASSESSMENT 1990 - 2021								
A	B	C	D	E		F	G	H
NFR code	Source category	Pollutant	Ex, 0 (t)	Ex, t (t)	Category trend (%)	Trend Assess-ment	Contri-bution to trend (%)	Cumu-lative Total (%)
1A3biii	Road transportation: heavy-duty vehicles and buses	NOx	29'689	4'284	-86	0.048	25.4	25.4
1A3bii	Road transportation: light-duty vehicles	NOx	6'197	4'366	-30	0.015	13.9	39.4
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1'205	820	-32	0.003	7.8	47.2
3Da2a	Animal manure applied to soils	NOx	2'075	1'461	-30	0.005	7.3	54.5
3Da3	Urine and dung deposited by grazing animals	NOx	243	417	71	0.002	6.9	61.4
1A2gviii	Stationary combustion in manufacturing industries and construction: other	NOx	2'338	1'922	-18	0.007	3.8	65.1
1A3bi	Road transportation: passenger cars	NOx	43'772	16'717	-62	0.003	3.7	68.8
1A4ai	Commercial/institutional: stationary	NOx	4'696	2'766	-41	0.007	3.4	72.3
1B2c	Venting and flaring (oil, gas, combined oil and gas)	NOx	213	1	-99	0.001	2.5	74.8
3Da2c	Other organic fertilisers applied to soils (including compost)	NOx	15	117	692	0.001	2.4	77.2
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	NOx	10'535	3'253	-69	0.005	2.4	79.5
1A3ai(i)	Civil aviation (domestic, landing/take-off (LTO))	NOx	1'214	904	-26	0.003	1.9	81.4
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	6'334	1'722	-73	0.004	1.7	83.2
1A4bi	Residential: stationary plants	NOx	11'630	4'873	-58	0.004	1.6	84.7
1A3dii	National navigation (shipping)	NOx	1'055	956	-9	0.004	1.5	86.3
1A3bi	Road transportation: passenger cars	NMVOC	55'938	3'782	-93	0.035	14.1	14.1
3B1b	Manure management - Non-dairy cattle	NMVOC	5'368	8'279	54	0.024	12.7	26.8
2D3a	Domestic solvent use including fungicides	NMVOC	8'867	6'372	-28	0.014	9.9	36.7
2D3g	Chemical products	NMVOC	27'504	3'143	-89	0.013	9.5	46.2
3B1a	Manure management - Dairy cattle	NMVOC	7'075	7'127	1	0.018	8.4	54.6
1A3biv	Road transportation: mopeds and motorcycles	NMVOC	5'733	789	-86	0.002	4.3	58.8
3B4gii	Manure management - Broilers	NMVOC	366	1'131	209	0.004	4.1	63.0
2H2	Food and beverages industry	NMVOC	1'956	1'997	2	0.005	3.6	66.6
2D3b	Road paving with asphalt	NMVOC	4'895	2'678	-45	0.005	3.5	70.0
2G	Other product use	NMVOC	22'432	6'289	-72	0.002	2.4	72.5
1A3bv	Road transportation: gasoline evaporation	NMVOC	16'981	1'952	-89	0.008	2.4	74.9
2D3d	Coating applications	NMVOC	40'731	8'280	-80	0.007	2.4	77.3
2D3e	Degreasing	NMVOC	11'731	1'566	-87	0.005	2.3	79.6
3B3	Manure management - Swine	NMVOC	1'126	803	-29	0.002	2.1	81.7
2D3i	Other solvent use	NMVOC	5'470	1'930	-65	0.002	2.0	83.7
3B4gi	Manure management - Laying hens	NMVOC	509	638	25	0.002	2.0	85.7
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	SOx	3'530	1'436	-59	0.029	37.1	37.1
2B5	Carbide production	SOx	625	383	-39	0.009	11.6	48.7
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SOx	3'091	2	-100	0.009	8.0	56.7
1A4bi	Residential: stationary plants	SOx	9'208	589	-94	0.010	6.8	63.5
1A1a	Public electricity and heat production	SOx	3'587	247	-93	0.003	5.2	68.8
1B2aiv	Fugitive emissions oil: refining / storage	SOx	419	12	-97	0.001	3.1	71.9
1A3biii	Road transportation: heavy-duty vehicles and buses	SOx	1'743	10	-99	0.005	3.1	75.0
2B10a	Chemical industry: other	SOx	168	59	-65	0.001	3.0	78.0
1A2gviii	Stationary combustion in manufacturing industries and construction: other	SOx	3'314	256	-92	0.002	2.9	80.9
1A3bi	Road transportation: passenger cars	SOx	1'705	39	-98	0.004	2.5	83.4
1B2c	Venting and flaring (oil, gas, combined oil and gas)	SOx	300	2	-99	0.001	2.0	85.4
3Da2a	Animal manure applied to soils	NH3	34'567	20'400	-41	0.098	21.8	21.8
3B1a	Manure management - Dairy cattle	NH3	9'337	10'396	11	0.045	13.5	35.2
3B1b	Manure management - Non-dairy cattle	NH3	5'191	7'050	36	0.043	12.2	47.5
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	34	979	2'779	0.014	7.6	55.0
3Da3	Urine and dung deposited by grazing animals	NH3	761	1'412	86	0.012	7.5	62.6
3B4gii	Manure management - Broilers	NH3	305	672	121	0.006	5.5	68.1
6A	Other sources	NH3	846	995	18	0.005	5.2	73.3
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4'258	2'652	-38	0.010	5.1	78.4
3B3	Manure management - Swine	NH3	6'965	4'961	-29	0.007	3.0	81.4
5B1	Biological treatment of waste - Composting	NH3	175	324	85	0.003	2.8	84.2
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NH3	10	231	2'303	0.003	2.6	86.8
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	230	26	0.010	13.3	13.3
1A4bi	Residential: stationary plants	PM2.5	5'227	1'215	-77	0.036	13.0	26.2
1A3bvi	Road transportation: automobile tyre and brake wear	PM2.5	689	892	29	0.039	9.4	35.6
2C1	Iron and steel production	PM2.5	818	9	-99	0.016	8.7	44.3
2H2	Food and beverages industry	PM2.5	188	164	-13	0.006	7.9	52.2
2H1	Pulp and paper industry	PM2.5	236	207	-12	0.008	5.6	57.8
2G	Other product use	PM2.5	513	370	-28	0.012	5.3	63.0
1A1a	Public electricity and heat production	PM2.5	772	44	-94	0.013	4.6	67.7
1A4ai	Commercial/institutional: stationary	PM2.5	506	354	-30	0.011	4.0	71.7
1A3biii	Road transportation: heavy-duty vehicles and buses	PM2.5	1'587	51	-97	0.030	3.9	75.6
2A1	Cement production	PM2.5	240	161	-33	0.005	3.4	79.0
2I	Wood processing	PM2.5	216	49	-77	0.002	2.0	81.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	390	-47	0.008	2.0	83.0
1A3c	Railways	PM2.5	174	198	14	0.008	2.0	85.0
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM2.5	438	47	-89	0.006	2.0	87.0
1A4bi	Residential: stationary plants	PM10	5'500	1'281	-77	0.066	13.8	13.8
2C1	Iron and steel production	PM10	1'485	13	-99	0.031	9.4	23.3
1A3bvi	Road transportation: automobile tyre and brake wear	PM10	2'050	2'627	28	0.060	8.4	31.7
2I	Wood processing	PM10	864	195	-77	0.011	8.2	39.8
2A5a	Quarrying and mining of minerals other than coal	PM10	367	460	26	0.010	8.0	47.8
3De	Cultivated crops	PM10	1'054	1'001	-5	0.017	7.3	55.1
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2'173	2'351	8	0.047	6.5	61.6
1A3c	Railways	PM10	983	1'287	31	0.030	4.2	65.8
2H2	Food and beverages industry	PM10	310	304	-2	0.005	4.2	70.0
1A1a	Public electricity and heat production	PM10	1'034	44	-96	0.020	4.0	74.0
3B4gii	Manure management - Broilers	PM10	68	209	209	0.007	3.9	77.9
1A2f	Stationary combustion in manufacturing industries and construction: non-metallic minerals	PM10	833	79	-90	0.014	2.6	80.5
1A3biii	Road transportation: heavy-duty vehicles and buses	PM10	1'587	51	-97	0.032	2.4	82.8
3B4gi	Manure management - Laying hens	PM10	123	155	25	0.004	2.0	84.8
2G	Other product use	PM10	588	464	-21	0.006	1.6	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 [06.02.2023]

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	15.7	19	21.4	23.8	25.6	26.9
Industrial machinery	17.8	29	48.4	47.5	47.1	47
Agricultural machinery	39.9	38.8	37.7	33	30.6	29
Forestry machinery	2.4	2.8	2.6	2.3	2	1.9
Garden-care / hobby appliances	14.6	25.7	39.3	149.7	190.8	201.3
Navigation machinery	3.7	3.9	3.5	3.4	3.4	3.4
Railway machinery	0.5	0.8	0.8	0.5	0.5	0.5
Military machinery	0.8	0.9	0.9	0.9	0.9	0.9
Total	**95.4**	**120.9**	**154.6**	**261.1**	**300.9**	**310.9**

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.

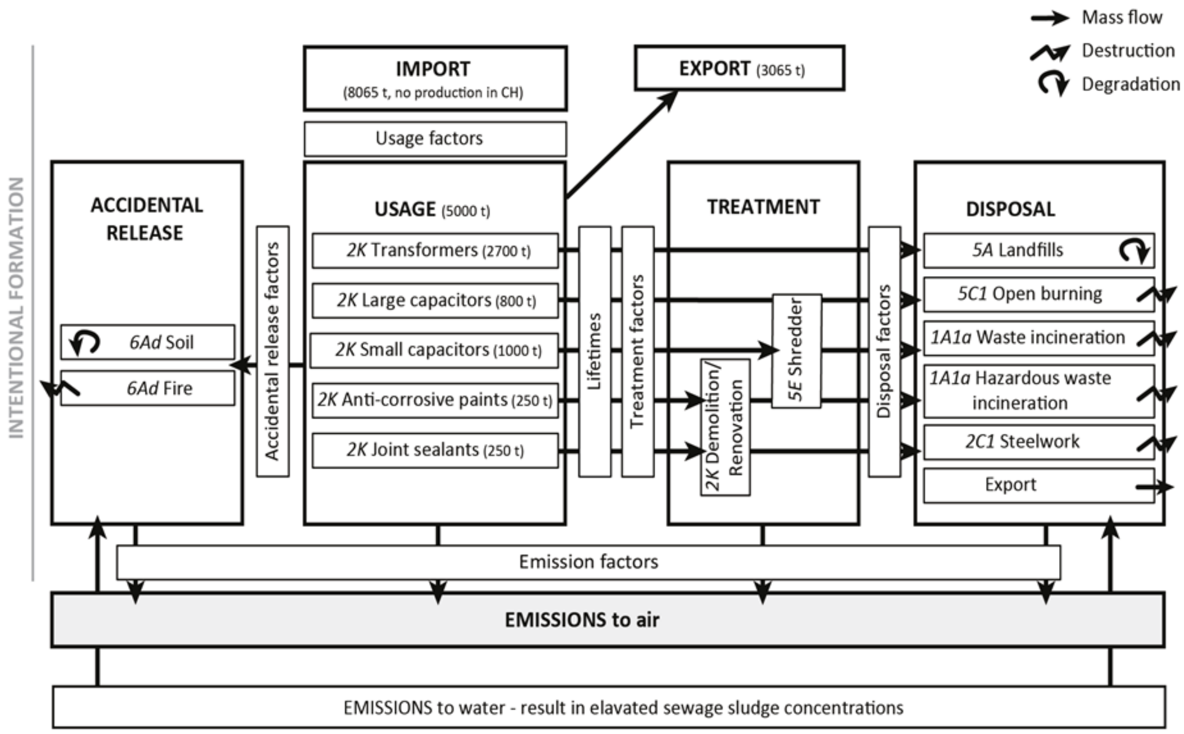

Figure A - 1 Model setup for the dynamic mass flow and emissions of PCBs taking into account the import, usage, export, treatment, disposal and accidential release. Emissions to air occur from usage, treatment, disposal, and accidental release. (Waste and hazardous waste incineration correspond to municipal 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 - 3). 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 occured in 1999 although they should have been treated as special waste from 1998 onwards (see Figure 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.

Accidential 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 - 3 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 accidential releases to soil become the most important emission source. Mainly in the seventies and eighties, accidential release by fire, small and large capacitors and waste incineration were important emission sources as well.

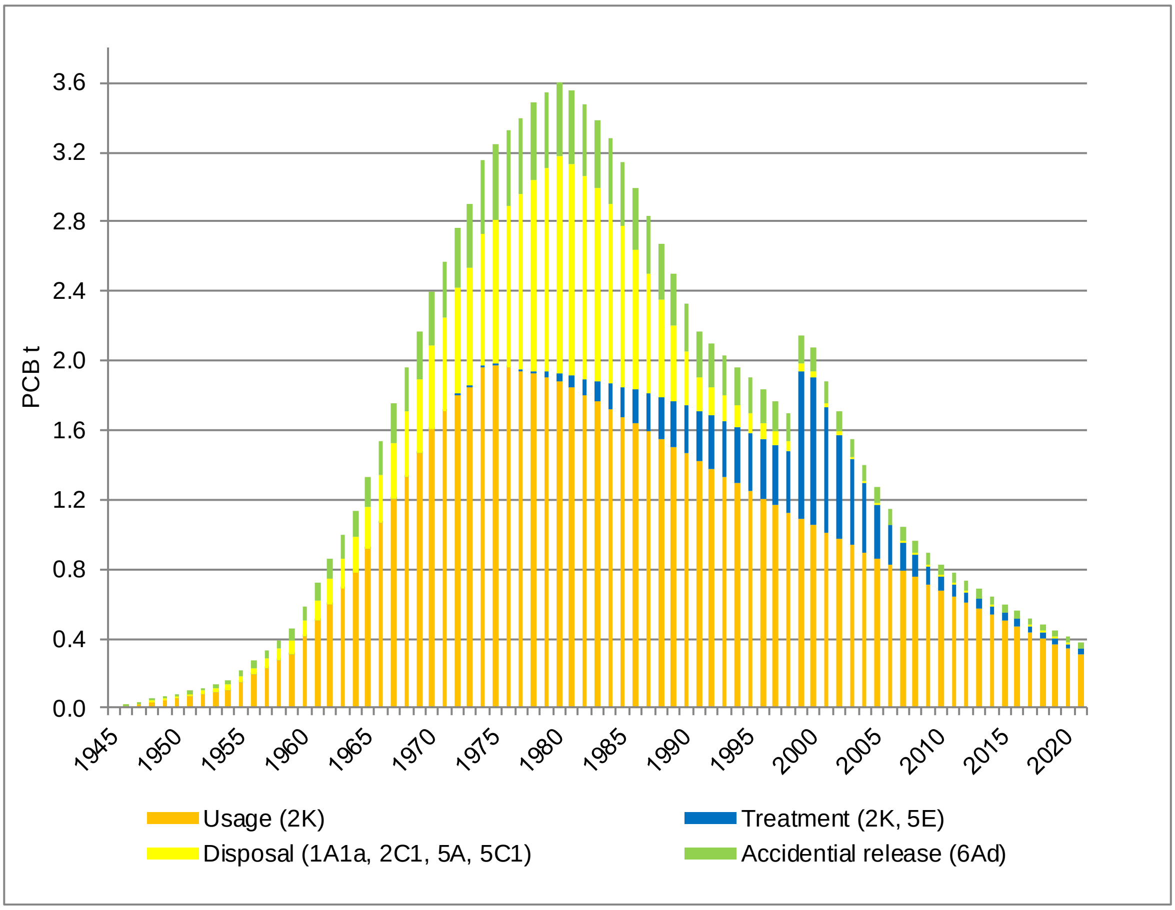

Figure A - 2 PCB emissions from usage (2K Transformers, large and small condensators, anti-corrosive paints and joint sealants), treatment (2K Demoition and renovation, 5E Shredder), disposal (1A1a Municipal solid waste and special waste incineration, 2C1 Secondary steel production, 5A Landfills, 5C1 Open burning (until 1999)) and accidental release (6Ad Accidential 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 summarized 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 summarized 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 Fertilizer 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 NH3 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 NH3 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.

Distribution of NH_3 emissions to the stages of the manure management chain

- The distribution of NH3 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 Further elaboration of completeness use of IE and (potential) sources of air pollutant emissions excluded

Table A - 17 Explanation of the NE notation key in NFR table 2 Add Info 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 NFR table 2 Add Info 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 NFR table 2 Add Info 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 as listed in NFR table 2 Add Info 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 2021 and 1990 in TJ as published by the Swiss Federal Office of Energy (SFOE 2022, SFOE 1991) in German and French.

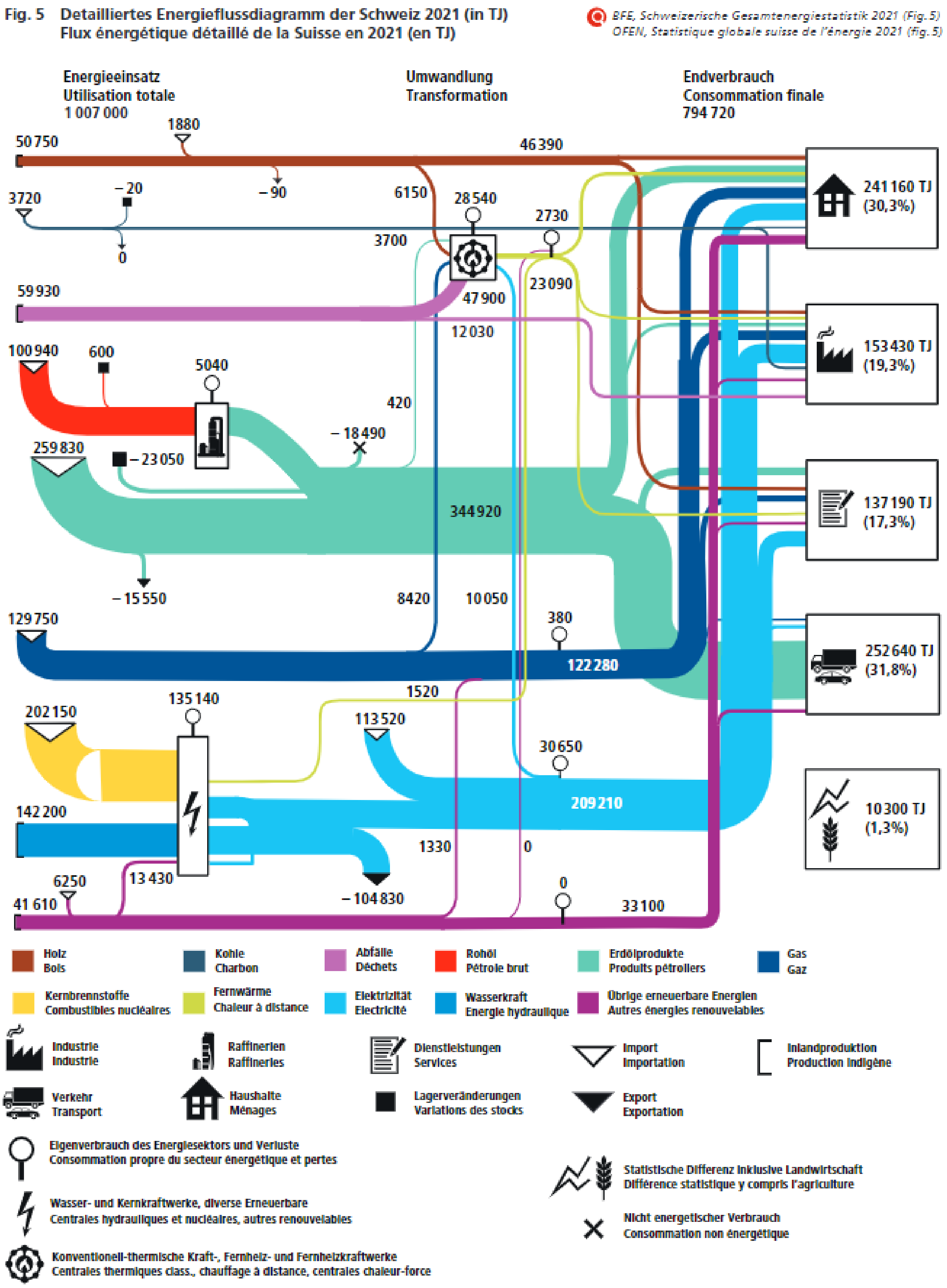

Figure A - 3 Energy flow in Switzerland 2020 (SFOE 2022, figure 5). Depicted values are in TJ.

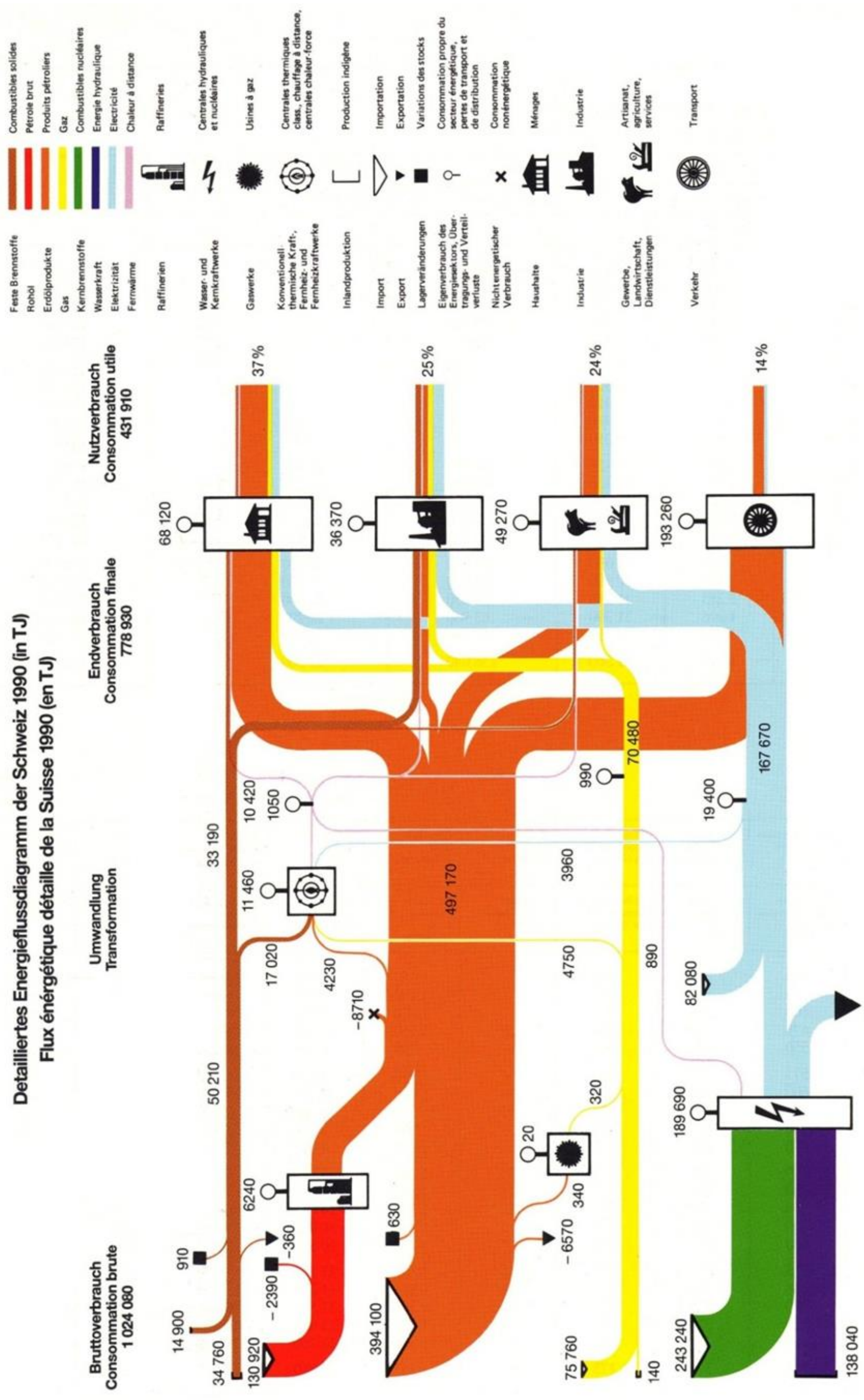

Figure A - 4 Energy flow in Switzerland 1990 (SFOE 1991). Depicted values are in TJ.

Table A - 21 Energy balance for Switzerland 2021 (table 4, Swiss overall energy statistics, SFOE 2022) in TJ.[7].

Tab. 4 Energiebilanz der Schweiz für das Jahr 2021 (in TJ)
Bilan énergétique de la Suisse pour 2021 (en TJ)

		Holzenergie Energie du bois	Kohle Charbon	Müll und Industrie-abfälle Ord. mén. et déchets ind.	Rohöl Pétrole brut	Erdöl-produkte Produits pétroliers	Gas Gaz	Wasserkraft Energie hydraulique	Kernbrenn-stoffe Combustibles nucléaires	Übrige erneuerbare Energien Autres énergies renouvelables	Elektrizität Electricité	Fernwärme Chaleur à distance	Total	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
Inlandproduktion	(a)	50 750	–	59 930	–	–	–	142 200	–	41 610	–	–	294 490	Production indigène
+Import	(b)	1 880	3 720	–	100 940	259 830	129 750	–	202 150	6 250	113 520	–	818 040	+Importation
+Export	(c)	–90	–	–	–	–15 550	–	–	–	–	–104 830	–	–120 470	+Exportation
+Lagerveränderung[1]	(d)	–	–20	–	600	23 050	–	–	–	–	–	–	23 630	+Variation de stock[1]
=Bruttoverbrauch	(e)	52 540	3 700	59 930	101 540	267 330	129 750	142 200	202 150	47 860	8 690	–	1 015 690	=Consommation brute
+Energieumwandlung:														+Transformation d'énergie:
· Wasserkraftwerke	(f)	–	–	–	–	–	–	–142 200	–	–	142 200	–	0	· Centrales hydrauliques
· Kernkraftwerke	(g)	–	–	–	–	–	–	–	–202 150	–	66 710	1 520	–133 920	· Centrales nucléaires
· konventionell-thermische Kraft-, Fernheiz- und Fernheizkraftwerke	(h)	–3 630	–	–47 900	–	–420	–8 420	–	–	–	8 310	24 300	–27 760	· Centrales thermiques class., chauffage à distance, centrales chaleur-force
· Gaswerke	(i)	–	–	–	–	–	0	–	–	–	–	–	0	· Usines à gaz
· Raffinerien	(j)	–	–	–	–101 540	101 540	–	–	–	–	–	–	0	· Raffineries
· Diverse Erneuerbare	(k)	–2 520	–	–	–	–	1 330	–	–	–14 760	13 950	–	–2 000	· Renouvelables div.
+Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherpumpen	(l)	–	–	–	–	–5 040	–380	–	–	–	–30 650	–2 730	–38 800	+Consommation propre du secteur énergétique, pertes de réseau, pompage d'accumulation
+Nichtenergetischer Verbrauch	(m)	–	–	–	–	–18 490	–	–	–	–	–	–	–18 490	+Consommation non énergétique
=Endverbrauch	(n)	46 390	3 700	12 030	–	344 920	122 280	–	–	33 100	209 210	23 090	794 720	=Consommation finale
Haushalte	(o)	19 760	100	–	–	66 130	53 240	–	–	19 850	72 480	9 600	241 160	Ménages
Industrie	(p)	13 900	3 600	12 030	–	11 840	39 620	–	–	2 080	62 500	7 860	153 430	Industrie
Dienstleistungen	(q)	11 610	–	–	–	31 070	26 280	–	–	4 050	58 550	5 630	137 190	Services
Verkehr	(r)	0	–	–	–	233 210	660	–	–	6 570	12 200	–	252 640	Transport
Statistische Differenz inkl. Landwirtschaft	(s)	1 120	–	–	–	2 670	2 480	–	–	550	3 480	–	10 300	Différence statistique, y compris l'agriculture

[1] +Lagerabnahme
–Lagerzunahme

[1] +diminution de stock
–augmentation de stock

BFE, Schweizerische Gesamtenergiestatistik 2021 (Tab. 4)
OFEN, Statistique globale suisse de l'énergie 2021 (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 2021. 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 2023); 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).

Table A - 22 Input uncertainties for NO_x for the year 2021, 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 2021				Emission factor uncertainty year 2021			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	NOx	normal	10	no	GHGI	normal	19	yes	EMIS
1A1b	NOx	normal	1	no	GHGI	normal	20	yes	EMIS
1A1c	NOx	normal	5	no	EMIS	normal	20	yes	EMEP/EEA 2019
1A2a	NOx	normal	2	no	GHGI	normal	27	yes	EMIS
1A2b	NOx	normal	2	no	GHGI	normal	20	yes	EMIS
1A2c	NOx	normal	2	no	GHGI	normal	10	yes	EMIS
1A2d	NOx	normal	2	no	GHGI	normal	10	yes	EMIS
1A2e	NOx	normal	2	no	GHGI	normal	10	yes	EMIS
1A2f	NOx	normal	2	no	GHGI	normal	17	yes	EMIS
1A2gvii	NOx	normal	1	no	GHGI	normal	13	yes	UBA
1A2gviii	NOx	normal	2	no	GHGI	normal	17	yes	EMIS
1A3ai(i)	NOx	normal	1	no	GHGI	normal	20	yes	EMEP/EEA 2019
1A3aii(i)	NOx	normal	1	no	GHGI	normal	20	yes	EMEP/EEA 2019
1A3bi	NOx	normal	1	no	GHGI	normal	38	yes	UBA
1A3bii	NOx	normal	1	no	GHGI	normal	32	yes	UBA
1A3biii	NOx	normal	1	no	GHGI	normal	18	yes	UBA
1A3biv	NOx	normal	1	no	GHGI	normal	36	yes	UBA
1A3c	NOx	normal	1	no	GHGI	normal	13	yes	UBA
1A3dii	NOx	normal	1	no	GHGI	normal	13	yes	UBA
1A3ei	NOx	normal	2	no	GHGI	normal	50	yes	EMEP/EEA 2019
1A4ai	NOx	normal	2	no	GHGI	normal	16	yes	EMIS
1A4aii	NOx	normal	1	no	GHGI	normal	13	yes	UBA
1A4bi	NOx	normal	4	no	GHGI	normal	13	yes	EMIS
1A4bii	NOx	normal	1	no	GHGI	normal	30	yes	EMIS
1A4ci	NOx	normal	21	no	GHGI	normal	30	yes	EMIS
1A4cii	NOx	normal	1	no	GHGI	normal	13	yes	UBA
1A5b	NOx	normal	1	no	GHGI	normal	13	yes	UBA
1B2c	NOx	normal	22	no	EMIS	gamma	200	yes	EMIS
2A1	NOx	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2A2	NOx	normal	2	no	GHGI	gamma	500	yes	EMEP/EEA 2019
2A5a	NOx	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2B2	NOx	normal	2	no	GHGI	normal	10	yes	EMEP/EEA 2019
2B10a	NOx	normal	2	no	GHGI	normal	60	yes	EMEP/EEA 2019
2C1	NOx	normal	2	no	GHGI	normal	50	yes	EMEP/EEA 2019
2C3	NOx	normal	5	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7c	NOx	normal	5	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2G	NOx	normal	25	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2H3	NOx	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
3B1a	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B1b	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B2	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B3	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4d	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4e	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4f	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4gi	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4gii	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4giii	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4giv	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3B4h	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3Da1	NOx	normal	5	no	GHGI	normal	100	yes	EMEP/EEA 2019
3Da2a	NOx	normal	6	no	GHGI	normal	50	yes	EMEP/EEA 2019
3Da2b	NOx	normal	6	no	GHGI	normal	100	yes	EMEP/EEA 2019
3Da2c	NOx	normal	20	no	Schleiss 2017	normal	100	yes	EMEP/EEA 2019
3Da3	NOx	normal	6	no	GHGI	normal	100	yes	EMEP/EEA 2019
5A	NOx	normal	10	no	GHGI	normal	50	yes	EMIS
5B2	NOx	normal	20	no	EMIS	normal	100	yes	EMEP/EEA 2019
5C1a	NOx	normal	50	no	EMIS	normal	40	yes	EMIS
5C1bi	NOx	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biii	NOx	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biv	NOx	normal	20	no	EMIS	normal	50	yes	EMIS
5C1bv	NOx	normal	5	no	EMIS	normal	30	yes	EMIS
5C2	NOx	normal	48	no	EMIS	gamma	156	yes	EMIS
5D1	NOx	normal	1	no	EMIS	normal	10	yes	EMIS
5D2	NOx	normal	10	no	EMIS	normal	10	yes	EMIS
6A	NOx	normal	30	no	EMIS	normal	50	yes	EMIS

Table A - 23 Input uncertainties for NMVOC for the year 2021, 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 2021				Emission factor uncertainty year 2021			
		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	NMVOC	normal	1	no	GHGI	normal	52	yes	UBA
1A3bii	NMVOC	normal	1	no	GHGI	normal	46	yes	UBA
1A3biii	NMVOC	normal	1	no	GHGI	normal	22	yes	UBA
1A3biv	NMVOC	normal	1	no	GHGI	gamma	400	yes	UBA
1A3bv	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	None	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	normal	26	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	gamma	100	yes	EMEP/EEA 2019
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 (E)	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 (E)	gamma	200	yes	EMEP/EEA 2019
2H2	NMVOC	normal	10	no	EMEP/EEA 2019 (E)	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	Agroscope/EMPA 2022, EMEP/EEA 2019
3B1b	NMVOC	normal	6	no	GHGI	normal	70	yes	Agroscope/EMPA 2022, EMEP/EEA 2019
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 2021, 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 2021				Emission factor uncertainty year 2021			
		Distribu-tion type	2*std. dev. %	Corr.	Ref.	Distribu-tion type	2*std. dev. %	Corr.	Ref.
1A1a	SOx	normal	10	no	GHGI	normal	22	yes	EMIS
1A1b	SOx	normal	1	no	GHGI	normal	20	yes	EMIS
1A2a	SOx	normal	2	no	GHGI	normal	15	yes	EMIS
1A2b	SOx	normal	2	no	GHGI	normal	10	yes	EMIS
1A2c	SOx	normal	2	no	GHGI	normal	11	yes	EMIS
1A2d	SOx	normal	2	no	GHGI	normal	14	yes	EMIS
1A2e	SOx	normal	2	no	GHGI	normal	12	yes	EMIS
1A2f	SOx	normal	2	no	GHGI	normal	19	yes	EMIS
1A2gvii	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A2gviii	SOx	normal	2	no	GHGI	normal	19	yes	EMIS
1A3ai(i)	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3aii(i)	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3bi	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3bii	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3biii	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3biv	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3c	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3dii	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A3ei	SOx	normal	2	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A4ai	SOx	normal	2	no	GHGI	normal	10	yes	EMIS
1A4aii	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A4bi	SOx	normal	4	no	GHGI	normal	10	yes	EMIS
1A4bii	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A4ci	SOx	normal	21	no	GHGI	normal	18	yes	EMIS
1A4cii	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1A5b	SOx	normal	1	no	GHGI	normal	10	yes	EMEP/EEA 2019
1B2aiv	SOx	normal	30	no	EMEP/EEA 2019	normal	47	yes	EMIS
1B2c	SOx	normal	22	no	EMIS	normal	31	yes	EMIS
2A1	SOx	normal	2	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2A2	SOx	normal	2	no	GHGI	gamma	500	yes	EMEP/EEA 2019
2A5a	SOx	normal	5	no	EMIS	gamma	500	yes	EMEP/EEA 2019
2B5	SOx	normal	2	no	GHGI	normal	20	yes	EMEP/EEA 2019
2B10a	SOx	normal	2	no	GHGI	normal	40	yes	EMEP/EEA 2019
2C1	SOx	normal	2	no	GHGI	gamma	100	yes	EMEP/EEA 2019
2C3	SOx	normal	5	no	GHGI	gamma	200	yes	EMEP/EEA 2019
2C7c	SOx	normal	5	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2G	SOx	normal	25	no	EMIS	gamma	100	yes	EMEP/EEA 2019
2H3	SOx	normal	3	no	EMIS	gamma	200	yes	EMEP/EEA 2019
5B2	SOx	normal	20	no	EMIS	normal	100	yes	EMIS
5C1a	SOx	normal	50	no	EMIS	normal	40	yes	EMIS
5C1bi	SOx	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biii	SOx	normal	30	no	EMIS	normal	30	yes	EMIS
5C1biv	SOx	normal	20	no	EMIS	normal	30	yes	EMIS
5C2	SOx	normal	48	no	EMIS	gamma	133	yes	EMIS
5D1	SOx	normal	1	no	EMIS	normal	37	yes	EMIS
5D2	SOx	normal	10	no	EMIS	normal	20	yes	EMIS
6A	SOx	normal	30	no	EMIS	normal	50	yes	EMIS

Table A - 25 Input uncertainties for NH_3 for the year 2021, 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 2021				Emission factor uncertainty year 2021			
		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	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3bii	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3biii	NH3	normal	1	no	GHGI	normal	50	yes	France
1A3biv	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 (E)	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 2021, 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 2021				Emission factor uncertainty year 2021			
		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	PM2.5	normal	1	no	GHGI	normal	57	yes	UBA/INFRAS
1A3bii	PM2.5	normal	1	no	GHGI	normal	48	yes	UBA/INFRAS
1A3biii	PM2.5	normal	1	no	GHGI	normal	27	yes	UBA/INFRAS
1A3biv	PM2.5	normal	1	no	GHGI	normal	54	yes	UBA/INFRAS
1A3bvi	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 (E)	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 (E)	gamma	200	yes	EMEP/EEA 2019
2H2	PM2.5	normal	10	no	EMEP/EEA 2019 (E)	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 2021, 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 2021				Emission factor uncertainty year 2021			
		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	PM10	normal	1	no	GHGI	normal	57	yes	UBA/INFRAS
1A3bii	PM10	normal	1	no	GHGI	normal	48	yes	UBA/INFRAS
1A3biii	PM10	normal	1	no	GHGI	normal	27	yes	UBA/INFRAS
1A3biv	PM10	normal	1	no	GHGI	normal	54	yes	UBA/INFRAS
1A3bvi	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 (E)	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 (E)	gamma	200	yes	EMEP/EEA 2019
2H2	PM10	normal	10	no	EMEP/EEA 2019 (E)	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 2021 and for the trend 1990-2021. 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 code	Pollutant	Emissions 1990	Emissions 2021	Emission combined uncertainty 2021		Category contribution to inventory variance 2021		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	6'294.03	2'136.65	21	21	0.772	0.772	0.001	0.015	0.215	0.215	0.027	0.027	0.047	0.047
1A1b	NOx	494.17	283.12	20	20	0.012	0.012	0.001	0.002	0.004	0.004	0.014	0.014	0.000	0.000
1A1c	NOx	0.01	0.04	21	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2a	NOx	278.40	119.93	27	27	0.004	0.004	0.000	0.001	0.002	0.002	0.003	0.003	0.000	0.000
1A2b	NOx	126.80	38.12	20	20	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
1A2c	NOx	1'046.46	256.20	10	10	0.003	0.003	0.001	0.002	0.005	0.005	0.009	0.009	0.000	0.000
1A2d	NOx	1'260.62	46.20	10	10	0.000	0.000	0.003	0.000	0.001	0.001	0.030	0.030	0.001	0.001
1A2e	NOx	743.24	251.51	10	10	0.002	0.002	0.000	0.002	0.005	0.005	0.002	0.002	0.000	0.000
1A2f	NOx	10'534.54	3'253.01	17	17	1.137	1.137	0.005	0.023	0.065	0.065	0.080	0.080	0.011	0.011
1A2gvii	NOx	6'333.94	1'722.02	13	13	0.186	0.186	0.004	0.012	0.022	0.022	0.058	0.058	0.004	0.004
1A2gviii	NOx	2'337.67	1'921.86	17	17	0.397	0.397	0.007	0.014	0.040	0.040	0.127	0.127	0.018	0.018
1A3ai(i)	NOx	1'214.30	904.10	20	20	0.120	0.120	0.003	0.006	0.012	0.012	0.064	0.064	0.004	0.004
1A3aii(i)	NOx	153.76	38.06	20	20	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A3bi	NOx	43'771.53	16'717.00	38	38	149.906	149.906	0.003	0.119	0.217	0.217	0.125	0.125	0.063	0.063
1A3bii	NOx	6'196.89	4'366.40	32	32	7.262	7.262	0.015	0.031	0.057	0.057	0.473	0.473	0.227	0.227
1A3biii	NOx	29'689.49	4'284.26	18	18	2.193	2.193	0.048	0.030	0.056	0.056	0.861	0.861	0.745	0.745
1A3biv	NOx	308.61	230.96	36	36	0.025	0.025	0.001	0.002	0.003	0.003	0.030	0.030	0.001	0.001
1A3c	NOx	595.50	369.20	13	13	0.009	0.009	0.001	0.003	0.005	0.005	0.014	0.014	0.000	0.000
1A3dii	NOx	1'054.73	955.90	13	13	0.057	0.057	0.004	0.007	0.012	0.012	0.052	0.052	0.003	0.003
1A3ei	NOx	145.60	2.28	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.018	0.000	0.000
1A4ai	NOx	4'695.63	2'766.44	16	16	0.726	0.726	0.007	0.020	0.044	0.044	0.116	0.116	0.015	0.015
1A4aii	NOx	16.28	43.71	13	13	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.003	0.000	0.000
1A4bi	NOx	11'629.84	4'873.11	14	14	1.592	1.592	0.004	0.035	0.182	0.182	0.051	0.051	0.036	0.036
1A4bii	NOx	18.76	22.29	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A4ci	NOx	382.42	259.50	37	37	0.033	0.033	0.001	0.002	0.055	0.055	0.025	0.025	0.004	0.004
1A4cii	NOx	4'357.53	1'798.04	13	13	0.202	0.202	0.001	0.013	0.023	0.023	0.017	0.017	0.001	0.001
1A5b	NOx	882.99	376.06	13	13	0.009	0.009	0.000	0.003	0.005	0.005	0.004	0.004	0.000	0.000
1B2c	NOx	212.79	1.40	100	270	0.000	0.000	0.001	0.000	0.000	0.000	0.054	0.054	0.003	0.003
2A1	NOx	15.87	10.65	97	269	0.000	0.003	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
2A2	NOx	0.27	0.26	100	727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2A5a	NOx	1.79	0.48	100	727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B2	NOx	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	8.93	13.18	60	60	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
2C1	NOx	245.46	181.33	50	50	0.030	0.030	0.001	0.001	0.004	0.004	0.032	0.032	0.001	0.001
2C3	NOx	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	NA	1.61	73	119	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2G	NOx	29.36	18.67	77	122	0.001	0.002	0.000	0.000	0.005	0.005	0.004	0.004	0.000	0.000
2H3	NOx	91.00	21.25	98	269	0.002	0.012	0.000	0.000	0.001	0.001	0.009	0.009	0.000	0.000
3B1a	NOx	672.34	383.89	50	50	0.137	0.137	0.001	0.003	0.025	0.025	0.048	0.048	0.003	0.003
3B1b	NOx	344.32	273.46	50	50	0.070	0.070	0.001	0.002	0.018	0.018	0.052	0.052	0.003	0.003
3B2	NOx	67.60	63.21	50	50	0.004	0.004	0.000	0.000	0.004	0.004	0.014	0.014	0.000	0.000
3B3	NOx	185.29	88.16	50	50	0.007	0.007	0.000	0.001	0.006	0.006	0.007	0.007	0.000	0.000
3B4d	NOx	21.62	22.53	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.000
3B4e	NOx	17.58	26.04	50	50	0.001	0.001	0.000	0.000	0.002	0.002	0.007	0.007	0.000	0.000
3B4f	NOx	1.35	6.97	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
3B4gi	NOx	7.19	9.44	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
3B4gii	NOx	4.46	12.32	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000
3B4giii	NOx	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	0.84	1.18	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3B4h	NOx	1.03	4.90	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
3Da1	NOx	1'204.90	819.90	100	100	2.472	2.472	0.003	0.006	0.041	0.041	0.265	0.265	0.072	0.072
3Da2a	NOx	2'075.01	1'461.30	50	50	1.991	1.991	0.005	0.010	0.095	0.095	0.246	0.246	0.069	0.069
3Da2b	NOx	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	14.76	116.97	102	102	0.052	0.052	0.001	0.001	0.024	0.024	0.079	0.079	0.007	0.007
3Da3	NOx	243.41	417.17	100	100	0.641	0.641	0.002	0.003	0.027	0.027	0.232	0.232	0.055	0.055
5A	NOx	1.83	1.31	51	51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5B2	NOx	NA	6.01	102	102	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000
5C1a	NOx	80.75	41.75	64	64	0.003	0.003	0.000	0.000	0.021	0.021	0.003	0.003	0.000	0.000
5C1bi	NOx	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	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	114.00	38.56	54	54	0.002	0.002	0.000	0.000	0.008	0.008	0.001	0.001	0.000	0.000
5C1bv	NOx	11.25	13.46	30	30	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
5C2	NOx	31.10	15.83	103	206	0.001	0.004	0.000	0.000	0.008	0.008	0.003	0.003	0.000	0.000
5D1	NOx	25.35	4.80	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5D2	NOx	0.25	1.12	14	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6A	NOx	84.34	98.56	58	58	0.012	0.012	0.000	0.001	0.030	0.030	0.024	0.024	0.001	0.001
Total						170.1	170.1							1.4	1.4
Total		140'600	52'214	Emissions 2021 uncertainty (%):		13.0	13.0			Trend uncertainty (%):				1.2	1.2

Table A - 29 Uncertainty analysis of NMVOC emissions, approach 1, for 2021 and for the trend 1990-2021. 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 code	Pollutant	Emissions 1990	Emissions 2021	Emission combined uncertainty 2021		Category contribution to inventory variance 2021		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	NMVOC	292.47	165.68	34	34	0.006	0.006	0.000	0.001	0.008	0.008	0.010	0.010	0.000	0.000
1A1b	NMVOC	6.95	3.12	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	6.21	21	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2a	NMVOC	8.93	7.18	18	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2b	NMVOC	53.59	7.19	19	19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2c	NMVOC	34.06	23.82	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A2d	NMVOC	29.85	4.67	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2e	NMVOC	22.04	24.13	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	452.05	30	30	0.034	0.034	0.001	0.002	0.004	0.004	0.031	0.031	0.001	0.001
1A2gvii	NMVOC	1'331.50	272.32	34	34	0.016	0.016	0.000	0.001	0.002	0.002	0.008	0.008	0.000	0.000
1A2gviii	NMVOC	292.93	121.26	30	30	0.002	0.002	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.000
1A3ai(i)	NMVOC	247.46	70.22	50	50	0.002	0.002	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3aii(i)	NMVOC	58.81	32.05	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A3bi	NMVOC	55'937.77	3'781.50	52	52	7.118	7.118	0.035	0.013	0.024	0.024	1.850	1.850	3.423	3.423
1A3bii	NMVOC	4'919.59	168.04	46	46	0.011	0.011	0.004	0.001	0.001	0.001	0.168	0.168	0.028	0.028
1A3biii	NMVOC	3'413.85	100.88	22	22	0.001	0.001	0.003	0.000	0.001	0.001	0.057	0.057	0.003	0.003
1A3biv	NMVOC	5'733.49	788.72	100	587	1.135	39.055	0.002	0.003	0.005	0.005	0.227	0.227	0.051	0.051
1A3bv	NMVOC	16'980.67	1'952.08	40	40	1.113	1.113	0.008	0.007	0.012	0.012	0.321	0.321	0.103	0.103
1A3c	NMVOC	83.76	43.31	34	34	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
1A3dii	NMVOC	1'640.55	404.58	34	34	0.035	0.035	0.000	0.001	0.003	0.003	0.001	0.001	0.000	0.000
1A3ei	NMVOC	0.06	0.01	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	NMVOC	1'225.16	700.02	56	56	0.281	0.281	0.001	0.002	0.005	0.005	0.075	0.075	0.006	0.006
1A4aii	NMVOC	1'091.65	322.60	75	75	0.107	0.107	0.000	0.001	0.002	0.002	0.012	0.012	0.000	0.000
1A4bi	NMVOC	10'041.86	2'692.68	68	68	6.134	6.134	0.001	0.009	0.048	0.048	0.035	0.035	0.004	0.004
1A4bii	NMVOC	398.23	130.01	75	75	0.017	0.017	0.000	0.000	0.001	0.001	0.007	0.007	0.000	0.000
1A4ci	NMVOC	229.53	87.50	78	78	0.008	0.008	0.000	0.000	0.009	0.009	0.008	0.008	0.000	0.000
1A4cii	NMVOC	4'369.08	855.62	75	75	0.751	0.751	0.001	0.003	0.005	0.005	0.064	0.064	0.004	0.004
1A5b	NMVOC	160.25	60.74	34	34	0.001	0.001	0.000	0.000	0.000	0.000	0.002	0.002	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	175.43	56	56	0.017	0.017	0.001	0.001	0.025	0.025	0.027	0.027	0.001	0.001
1B2av	NMVOC	14'399.98	2'038.09	26	26	0.513	0.513	0.005	0.007	0.013	0.013	0.143	0.143	0.021	0.021
1B2b	NMVOC	1'056.51	574.16	55	55	0.179	0.179	0.001	0.002	0.061	0.061	0.052	0.052	0.006	0.006
1B2c	NMVOC	13.64	0.09	76	121	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2A1	NMVOC	41.25	27.69	97	269	0.001	0.010	0.000	0.000	0.000	0.000	0.006	0.006	0.000	0.000
2A2	NMVOC	0.69	0.67	100	727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2A5a	NMVOC	4.59	1.24	100	727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B10a	NMVOC	608.61	15.74	40	40	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.019	0.000	0.000
2C1	NMVOC	1'053.60	221.39	73	119	0.047	0.127	0.000	0.001	0.002	0.002	0.011	0.011	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	0.38	98	269	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7c	NMVOC	NA	0.52	73	119	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	6'372.06	73	119	39.212	105.215	0.014	0.022	0.031	0.031	1.026	1.026	1.055	1.055
2D3b	NMVOC	4'895.00	2'678.40	73	119	6.959	18.621	0.005	0.009	0.065	0.065	0.358	0.358	0.132	0.132
2D3c	NMVOC	2'430.00	380.50	75	121	0.150	0.386	0.001	0.001	0.037	0.037	0.058	0.058	0.005	0.005
2D3d	NMVOC	40'731.00	8'280.20	45	45	25.014	25.014	0.007	0.028	0.801	0.801	0.278	0.278	0.718	0.718
2D3e	NMVOC	11'731.23	1'566.25	64	64	1.835	1.835	0.005	0.005	0.303	0.303	0.240	0.240	0.149	0.149
2D3f	NMVOC	910.00	61.40	45	45	0.001	0.001	0.001	0.000	0.006	0.006	0.023	0.023	0.001	0.001
2D3g	NMVOC	27'503.97	3'143.23	79	123	11.162	27.222	0.013	0.011	0.456	0.456	0.949	0.949	1.109	1.109
2D3h	NMVOC	20'353.80	3'666.72	45	45	4.905	4.905	0.005	0.013	0.355	0.355	0.203	0.203	0.167	0.167
2D3i	NMVOC	5'470.21	1'930.44	100	239	6.799	38.933	0.002	0.007	0.280	0.280	0.178	0.178	0.110	0.110
2G	NMVOC	22'431.61	6'288.96	101	270	73.050	526.144	0.002	0.022	0.760	0.760	0.203	0.203	0.619	0.619
2H1	NMVOC	554.99	248.76	102	271	0.117	0.826	0.000	0.001	0.036	0.036	0.036	0.036	0.003	0.003
2H2	NMVOC	1'955.66	1'997.22	73	120	3.924	10.408	0.005	0.007	0.097	0.097	0.374	0.374	0.149	0.149
2H3	NMVOC	156.00	36.42	98	269	0.002	0.017	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
3B1a	NMVOC	7'074.65	7'127.45	60	60	33.745	33.745	0.018	0.024	0.222	0.222	1.095	1.095	1.247	1.247
3B1b	NMVOC	5'367.84	8'278.76	70	70	61.781	61.781	0.024	0.028	0.258	0.258	1.656	1.656	2.809	2.809
3B2	NMVOC	66.79	67.32	98	269	0.008	0.060	0.000	0.000	0.002	0.002	0.017	0.017	0.000	0.000
3B3	NMVOC	1'126.15	802.76	98	269	1.122	8.504	0.002	0.003	0.025	0.025	0.173	0.173	0.030	0.030
3B4d	NMVOC	37.02	49.25	98	269	0.004	0.032	0.000	0.000	0.002	0.002	0.013	0.013	0.000	0.000
3B4e	NMVOC	120.39	201.44	98	269	0.071	0.536	0.001	0.001	0.006	0.006	0.057	0.057	0.003	0.003
3B4f	NMVOC	8.64	48.47	98	269	0.004	0.031	0.000	0.000	0.002	0.002	0.015	0.015	0.000	0.000
3B4gi	NMVOC	508.70	638.05	98	269	0.709	5.372	0.002	0.002	0.020	0.020	0.170	0.170	0.029	0.029
3B4gii	NMVOC	366.34	1'130.72	98	269	2.225	16.872	0.004	0.004	0.035	0.035	0.346	0.346	0.121	0.121
3B4giii	NMVOC	46.28	40.46	98	269	0.003	0.022	0.000	0.000	0.001	0.001	0.010	0.010	0.000	0.000
3B4giv	NMVOC	129.27	206.60	98	269	0.074	0.563	0.001	0.001	0.006	0.006	0.058	0.058	0.003	0.003
3B4h	NMVOC	3.60	4.62	98	269	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
3De	NMVOC	481.38	453.93	98	269	0.358	2.718	0.001	0.002	0.011	0.011	0.111	0.111	0.012	0.012
5A	NMVOC	405.68	136.25	51	51	0.009	0.009	0.000	0.000	0.007	0.007	0.006	0.006	0.000	0.000
5B1	NMVOC	104.96	194.13	102	102	0.071	0.071	0.001	0.001	0.019	0.019	0.057	0.057	0.004	0.004
5B2	NMVOC	46.44	1'082.92	36	36	0.278	0.278	0.004	0.004	0.105	0.105	0.110	0.110	0.023	0.023
5C1a	NMVOC	516.80	267.20	71	71	0.065	0.065	0.000	0.001	0.065	0.065	0.023	0.023	0.005	0.005
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	18.22	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	0.38	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	103	206	0.001	0.002	0.000	0.000	0.004	0.004	0.003	0.003	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	0.02	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	189.75	229.95	58	58	0.033	0.033	0.001	0.001	0.033	0.033	0.031	0.031	0.002	0.002
Total						291.2	945.8							12.2	12.2
Total		292'448	74'040	Emissions 2021 uncertainty (%):		17.1	30.8			Trend uncertainty (%):				3.5	3.5

Table A - 30 Uncertainty analysis of SO_x emissions, approach 1, for 2021 and for the trend 1990-2021. 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 code	Pollutant	Emissions 1990	Emissions 2021	Emission combined uncertainty 2021		Category contribution to inventory variance 2021		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	3'587.18	247.35	24	24	2.507	2.507	0.003	0.007	0.095	0.095	0.072	0.072	0.014	0.014
1A1b	SOx	660.41	85.48	20	20	0.206	0.206	0.000	0.002	0.004	0.004	0.010	0.010	0.000	0.000
1A2a	SOx	357.86	10.24	15	15	0.002	0.002	0.001	0.000	0.001	0.001	0.011	0.011	0.000	0.000
1A2b	SOx	63.56	1.37	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A2c	SOx	1'102.74	140.55	11	11	0.173	0.173	0.001	0.004	0.011	0.011	0.008	0.008	0.000	0.000
1A2d	SOx	3'091.28	2.41	14	14	0.000	0.000	0.009	0.000	0.000	0.000	0.119	0.119	0.014	0.014
1A2e	SOx	985.20	17.77	12	12	0.003	0.003	0.002	0.000	0.001	0.001	0.027	0.027	0.001	0.001
1A2f	SOx	3'530.25	1'436.32	19	19	52.835	52.835	0.029	0.039	0.110	0.110	0.553	0.553	0.318	0.318
1A2gvii	SOx	352.47	2.86	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.009	0.009	0.000	0.000
1A2gviii	SOx	3'314.27	255.67	19	19	1.675	1.675	0.002	0.007	0.020	0.020	0.043	0.043	0.002	0.002
1A3ai(i)	SOx	99.68	63.10	10	10	0.028	0.028	0.001	0.002	0.003	0.003	0.014	0.014	0.000	0.000
1A3aii(i)	SOx	24.94	3.29	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A3bi	SOx	1'704.67	39.39	10	10	0.011	0.011	0.004	0.001	0.002	0.002	0.037	0.037	0.001	0.001
1A3bii	SOx	285.80	5.30	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.007	0.007	0.000	0.000
1A3biii	SOx	1'743.11	10.21	10	10	0.001	0.001	0.005	0.000	0.001	0.001	0.046	0.046	0.002	0.002
1A3biv	SOx	28.33	0.82	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3c	SOx	25.50	0.13	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3dii	SOx	63.22	1.10	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3ei	SOx	0.28	0.06	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	SOx	3'425.52	251.86	10	10	0.456	0.456	0.003	0.007	0.015	0.015	0.027	0.027	0.001	0.001
1A4aii	SOx	1.79	0.06	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4bi	SOx	9'207.87	588.61	11	11	2.767	2.767	0.010	0.016	0.084	0.084	0.096	0.096	0.016	0.016
1A4bii	SOx	1.34	0.04	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ci	SOx	306.40	59.34	28	28	0.191	0.191	0.001	0.002	0.048	0.048	0.014	0.014	0.003	0.003
1A4cii	SOx	289.62	1.73	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.008	0.008	0.000	0.000
1A5b	SOx	77.42	30.02	10	10	0.006	0.006	0.001	0.001	0.001	0.001	0.006	0.006	0.000	0.000
1B2aiv	SOx	419.02	11.70	56	56	0.030	0.030	0.001	0.000	0.013	0.013	0.040	0.040	0.002	0.002
1B2c	SOx	300.19	1.87	38	38	0.000	0.000	0.001	0.000	0.002	0.002	0.024	0.024	0.001	0.001
2A1	SOx	0.69	0.46	97	269	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2A2	SOx	0.01	0.01	100	727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2A5a	SOx	0.08	0.02	100	727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B5	SOx	625.20	383.01	20	20	4.158	4.158	0.009	0.010	0.029	0.029	0.173	0.173	0.031	0.031
2B10a	SOx	168.00	59.00	40	40	0.392	0.392	0.001	0.002	0.005	0.005	0.045	0.045	0.002	0.002
2C1	SOx	144.04	18.11	73	119	0.122	0.327	0.000	0.000	0.001	0.001	0.007	0.007	0.000	0.000
2C3	SOx	696.30	NO	NO	NO	NO	NO	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7c	SOx	NA	0.02	73	119	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2G	SOx	3.44	4.29	77	122	0.008	0.019	0.000	0.000	0.004	0.004	0.008	0.008	0.000	0.000
2H3	SOx	1.30	0.30	98	269	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5B2	SOx	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	24.23	12.53	64	64	0.045	0.045	0.000	0.000	0.024	0.024	0.011	0.011	0.001	0.001
5C1bi	SOx	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	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	74.10	15.62	36	36	0.022	0.022	0.000	0.000	0.012	0.012	0.007	0.007	0.000	0.000
5C2	SOx	0.68	0.34	98	173	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
5D1	SOx	0.13	0.02	37	37	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5D2	SOx	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	10.60	11.90	58	58	0.034	0.034	0.000	0.000	0.014	0.014	0.015	0.015	0.000	0.000
Total						65.7	65.9							0.4	0.4
Total		36'863	3'775	Emissions 2021 uncertainty (%):		8.1	8.1			Trend uncertainty (%):				0.6	0.6

Table A - 31 Uncertainty analysis of NH_3 emissions, approach 1, for 2021 and for the trend 1990-2021. 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 code	Pollutant	Emissions 1990	Emissions 2021	Emission combined uncertainty 2021		Category contribution to inventory variance 2021		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	4.64	35.55	22	22	0.000	0.000	0.000	0.001	0.007	0.007	0.009	0.009	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	199.32	9	9	0.001	0.001	0.001	0.003	0.008	0.008	0.011	0.011	0.000	0.000
1A2gvii	NH3	1.00	1.54	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	43.15	9	9	0.000	0.000	0.000	0.001	0.002	0.002	0.004	0.004	0.000	0.000
1A3bi	NH3	1'324.97	778.45	50	50	0.525	0.525	0.004	0.011	0.021	0.021	0.190	0.190	0.037	0.037
1A3bii	NH3	8.57	28.65	50	50	0.001	0.001	0.000	0.000	0.001	0.001	0.016	0.016	0.000	0.000
1A3biii	NH3	4.55	34.20	50	50	0.001	0.001	0.000	0.000	0.001	0.001	0.022	0.022	0.001	0.001
1A3biv	NH3	3.26	3.85	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
1A3ei	NH3	NA	0.07	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	NH3	19.07	31.16	10	10	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	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	184.16	75.95	11	11	0.000	0.000	0.001	0.001	0.006	0.006	0.010	0.010	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	2.32	23	23	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	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	1.51	97	269	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.011	0.000	0.000
2C7c	NH3	9.19	8.19	100	727	0.000	0.012	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
2G	NH3	203.15	81.08	47	47	0.005	0.005	0.001	0.001	0.042	0.042	0.046	0.046	0.004	0.004
2H2	NH3	132.33	52.17	100	727	0.010	0.499	0.001	0.001	0.011	0.011	0.075	0.075	0.006	0.006
2H3	NH3	1.04	0.24	98	269	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2L	NH3	2.38	3.77	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	10'396.08	30	30	33.019	33.019	0.045	0.152	1.382	1.382	1.299	1.299	3.596	3.596
3B1b	NH3	5'190.92	7'049.89	28	28	13.257	13.257	0.043	0.103	0.937	0.937	1.173	1.173	2.253	2.253
3B2	NH3	509.75	471.54	87	87	0.586	0.586	0.001	0.007	0.063	0.063	0.091	0.091	0.012	0.012
3B3	NH3	6'965.04	4'961.02	41	41	13.986	13.986	0.007	0.072	0.659	0.659	0.293	0.293	0.520	0.520
3B4d	NH3	158.13	159.06	65	65	0.037	0.037	0.001	0.002	0.021	0.021	0.033	0.033	0.002	0.002
3B4e	NH3	256.31	386.54	52	52	0.142	0.142	0.003	0.006	0.051	0.051	0.141	0.141	0.022	0.022
3B4f	NH3	19.65	99.98	68	68	0.016	0.016	0.001	0.001	0.013	0.013	0.084	0.084	0.007	0.007
3B4gi	NH3	978.79	678.27	82	82	1.077	1.077	0.001	0.010	0.090	0.090	0.107	0.107	0.020	0.020
3B4gii	NH3	304.87	672.32	86	86	1.164	1.164	0.006	0.010	0.089	0.089	0.544	0.544	0.304	0.304
3B4giii	NH3	29.77	21.71	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	86.64	85	85	0.019	0.019	0.000	0.001	0.012	0.012	0.014	0.014	0.000	0.000
3B4h	NH3	14.55	42.98	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	2'652.07	50	50	6.148	6.148	0.010	0.039	0.274	0.274	0.502	0.502	0.326	0.326
3Da2a	NH3	34'567.08	20'400.40	22	22	69.514	69.514	0.097	0.298	2.712	2.712	2.046	2.046	11.540	11.540
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	978.97	54	54	0.962	0.962	0.014	0.014	0.404	0.404	0.695	0.695	0.646	0.646
3Da3	NH3	760.92	1'411.60	62	62	2.680	2.680	0.012	0.021	0.188	0.188	0.737	0.737	0.579	0.579
5A	NH3	615.79	206.73	51	51	0.038	0.038	0.004	0.003	0.043	0.043	0.202	0.202	0.042	0.042
5B1	NH3	175.00	323.66	102	102	0.377	0.377	0.003	0.005	0.134	0.134	0.272	0.272	0.092	0.092
5B2	NH3	9.63	231.43	78	78	0.112	0.112	0.003	0.003	0.096	0.096	0.245	0.245	0.069	0.069
5C1biv	NH3	5.70	1.83	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	126.16	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	994.86	104	104	3.735	3.735	0.005	0.015	0.616	0.616	0.484	0.484	0.614	0.614
Total						147.4	147.9							20.7	20.7
Total		68'526	53'745	Emissions 2021 uncertainty (%):		12.1	12.2			Trend uncertainty (%):				4.5	4.5

Table A - 32 Uncertainty analysis of PM2.5 emissions, approach 1, for 2021 and for the trend 1990-2021. 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 code	Pollutant	Emissions 1990	Emissions 2021	Emission combined uncertainty 2021		Category contribution to inventory variance 2021		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	772.49	43.88	72	72	0.300	0.300	0.013	0.003	0.037	0.037	0.953	0.953	0.910	0.910
1A1b	PM2.5	47.66	4.26	20	20	0.000	0.000	0.001	0.000	0.000	0.000	0.015	0.015	0.000	0.000
1A1c	PM2.5	4.64	13.52	21	21	0.002	0.002	0.001	0.001	0.006	0.006	0.014	0.014	0.000	0.000
1A2a	PM2.5	14.80	2.84	28	28	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
1A2b	PM2.5	20.38	1.41	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.010	0.000	0.000
1A2c	PM2.5	40.75	5.57	10	10	0.000	0.000	0.001	0.000	0.001	0.001	0.005	0.005	0.000	0.000
1A2d	PM2.5	149.61	0.26	33	33	0.000	0.000	0.003	0.000	0.000	0.000	0.102	0.102	0.010	0.010
1A2e	PM2.5	25.68	1.44	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
1A2f	PM2.5	437.58	46.89	65	65	0.281	0.281	0.006	0.003	0.008	0.008	0.408	0.408	0.167	0.167
1A2gvii	PM2.5	728.86	389.91	50	50	11.515	11.515	0.008	0.023	0.043	0.043	0.415	0.415	0.174	0.174
1A2gviii	PM2.5	544.40	190.33	65	65	4.639	4.639	0.000	0.011	0.033	0.033	0.008	0.008	0.001	0.001
1A3ai(i)	PM2.5	92.39	6.88	30	30	0.001	0.001	0.002	0.000	0.001	0.001	0.045	0.045	0.002	0.002
1A3aii(i)	PM2.5	22.67	1.73	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.011	0.000	0.000
1A3bi	PM2.5	577.66	121.33	57	57	1.466	1.466	0.005	0.007	0.013	0.013	0.270	0.270	0.073	0.073
1A3bii	PM2.5	327.15	61.28	48	48	0.265	0.265	0.003	0.004	0.007	0.007	0.151	0.151	0.023	0.023
1A3biii	PM2.5	1'587.21	51.17	27	27	0.058	0.058	0.030	0.003	0.006	0.006	0.808	0.808	0.652	0.652
1A3biv	PM2.5	208.81	40.78	54	54	0.147	0.147	0.002	0.002	0.004	0.004	0.102	0.102	0.010	0.010
1A3bvi	PM2.5	689.15	891.53	50	50	60.201	60.201	0.039	0.054	0.098	0.098	1.964	1.964	3.868	3.868
1A3c	PM2.5	174.35	198.01	50	50	2.970	2.970	0.008	0.012	0.022	0.022	0.414	0.414	0.172	0.172
1A3dii	PM2.5	59.09	25.36	50	50	0.049	0.049	0.000	0.002	0.003	0.003	0.015	0.015	0.000	0.000
1A3ei	PM2.5	0.11	0.01	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	506.01	354.43	78	78	23.149	23.149	0.011	0.021	0.047	0.047	0.842	0.842	0.711	0.711
1A4bi	PM2.5	5'226.81	1'214.74	76	76	258.662	258.662	0.036	0.073	0.384	0.384	2.701	2.701	7.442	7.442
1A4ci	PM2.5	539.23	199.14	44	44	2.367	2.367	0.001	0.012	0.359	0.359	0.030	0.030	0.130	0.130
1A4cii	PM2.5	435.10	150.70	80	80	4.401	4.401	0.000	0.009	0.017	0.017	0.001	0.001	0.000	0.000
1A5b	PM2.5	86.95	44.54	50	50	0.150	0.150	0.001	0.003	0.005	0.005	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	329	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2A1	PM2.5	240.48	161.41	97	269	7.497	57.035	0.005	0.010	0.027	0.027	0.459	0.459	0.211	0.211
2A2	PM2.5	7.21	7.04	100	727	0.015	0.793	0.000	0.000	0.001	0.001	0.027	0.027	0.001	0.001
2A5a	PM2.5	183.33	230.23	100	727	16.088	848.968	0.010	0.014	0.098	0.098	1.004	1.004	1.017	1.017
2B5	PM2.5	61.20	38.23	97	269	0.421	3.199	0.001	0.002	0.007	0.007	0.100	0.100	0.010	0.010
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	8.95	83	155	0.017	0.058	0.016	0.001	0.002	0.002	1.365	1.365	1.862	1.862
2C3	PM2.5	78.33	NO	NO	NO	NO	NO	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7a	PM2.5	5.66	0.71	98	269	0.000	0.001	0.000	0.000	0.000	0.000	0.007	0.007	0.000	0.000
2C7c	PM2.5	1.53	1.41	100	727	0.001	0.032	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.000
2D3c	PM2.5	4.00	3.79	99	270	0.004	0.032	0.000	0.000	0.006	0.006	0.014	0.014	0.000	0.000
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	370.22	77	122	24.559	61.540	0.012	0.022	0.788	0.788	0.844	0.844	1.333	1.333
2H1	PM2.5	235.77	206.90	102	271	13.479	94.873	0.008	0.012	0.528	0.528	0.735	0.735	0.819	0.819
2H2	PM2.5	187.99	163.56	100	727	8.180	428.527	0.006	0.010	0.139	0.139	0.593	0.593	0.371	0.371
2H3	PM2.5	15.60	3.64	98	269	0.004	0.029	0.000	0.000	0.001	0.001	0.010	0.010	0.000	0.000
2I	PM2.5	216.08	49.12	100	727	0.738	38.650	0.002	0.003	0.042	0.042	0.154	0.154	0.025	0.025
3B1a	PM2.5	20.61	23.62	100	430	0.169	3.125	0.001	0.001	0.013	0.013	0.099	0.099	0.010	0.010
3B1b	PM2.5	18.26	21.54	100	430	0.141	2.599	0.001	0.001	0.012	0.012	0.092	0.092	0.009	0.009
3B2	PM2.5	0.79	0.80	100	430	0.000	0.004	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000
3B3	PM2.5	9.57	6.64	100	430	0.013	0.247	0.000	0.000	0.004	0.004	0.020	0.020	0.000	0.000
3B4d	PM2.5	0.14	0.18	100	430	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
3B4e	PM2.5	3.94	6.60	100	430	0.013	0.244	0.000	0.000	0.004	0.004	0.031	0.031	0.001	0.001
3B4f	PM2.5	0.59	3.30	100	430	0.003	0.061	0.000	0.000	0.002	0.002	0.019	0.019	0.000	0.000
3B4gi	PM2.5	9.25	11.60	100	430	0.041	0.754	0.001	0.001	0.006	0.006	0.051	0.051	0.003	0.003
3B4gii	PM2.5	6.78	20.94	100	430	0.133	2.456	0.001	0.001	0.011	0.011	0.112	0.112	0.013	0.013
3B4giii	PM2.5	1.89	1.65	100	430	0.001	0.015	0.000	0.000	0.001	0.001	0.006	0.006	0.000	0.000
3B4giv	PM2.5	1.98	2.99	100	430	0.003	0.050	0.000	0.000	0.002	0.002	0.014	0.014	0.000	0.000
3B4h	PM2.5	0.24	0.10	100	430	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3De	PM2.5	47.50	44.92	98	269	0.582	4.418	0.002	0.003	0.019	0.019	0.167	0.167	0.028	0.028
5A	PM2.5	0.73	0.53	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	240.48	58	58	5.953	5.953	0.005	0.014	1.023	1.023	0.144	0.144	1.067	1.067
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	2.70	39	39	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005	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	0.001	0.001	0.000	0.000
5C2	PM2.5	84.75	43.12	103	206	0.600	2.393	0.001	0.003	0.176	0.176	0.076	0.076	0.037	0.037
5E	PM2.5	1.40	1.50	36	36	0.000	0.000	0.000	0.000	0.003	0.003	0.002	0.002	0.000	0.000
6A	PM2.5	4.21	5.77	50	50	0.003	0.003	0.000	0.000	0.015	0.015	0.010	0.010	0.000	0.000
Total						449.3	1'926.7							21.2	21.2
Total		16'621	5'747	Emissions 2021 uncertainty (%):		21.2	43.9			Trend uncertainty (%):				4.6	4.6

Table A - 33 Uncertainty analysis of PM10 emissions, approach 1, for 2021 and for the trend 1990-2021. 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 code	Pollutant	Emissions 1990	Emissions 2021	Emission combined uncertainty 2021		Category contribution to inventory variance 2021		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	1'034.29	43.88	72	72	0.054	0.054	0.020	0.002	0.025	0.025	1.430	1.430	2.046	2.046
1A1b	PM10	47.66	4.26	20	20	0.000	0.000	0.001	0.000	0.000	0.000	0.017	0.017	0.000	0.000
1A1c	PM10	4.89	14.25	21	21	0.000	0.000	0.000	0.001	0.004	0.004	0.009	0.009	0.000	0.000
1A2a	PM10	20.52	3.11	28	28	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.009	0.000	0.000
1A2b	PM10	29.24	1.49	30	30	0.000	0.000	0.001	0.000	0.000	0.000	0.017	0.017	0.000	0.000
1A2c	PM10	40.75	5.57	10	10	0.000	0.000	0.001	0.000	0.001	0.001	0.006	0.006	0.000	0.000
1A2d	PM10	166.57	0.26	33	33	0.000	0.000	0.004	0.000	0.000	0.000	0.116	0.116	0.013	0.013
1A2e	PM10	25.68	1.44	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.000	0.000
1A2f	PM10	832.63	79.16	65	65	0.144	0.144	0.014	0.003	0.009	0.009	0.942	0.942	0.887	0.887
1A2gvii	PM10	2'173.23	2'351.23	50	50	75.268	75.268	0.047	0.093	0.169	0.169	2.344	2.344	5.521	5.521
1A2gviii	PM10	567.41	200.41	65	65	0.925	0.925	0.004	0.008	0.023	0.023	0.266	0.266	0.071	0.071
1A3ai(i)	PM10	102.65	6.88	30	30	0.000	0.000	0.002	0.000	0.000	0.000	0.057	0.057	0.003	0.003
1A3aii(i)	PM10	25.19	1.73	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.014	0.000	0.000
1A3bi	PM10	577.66	121.33	57	57	0.263	0.263	0.007	0.005	0.009	0.009	0.426	0.426	0.181	0.181
1A3bii	PM10	327.15	61.28	48	48	0.048	0.048	0.005	0.002	0.004	0.004	0.217	0.217	0.047	0.047
1A3biii	PM10	1'587.21	51.17	27	27	0.010	0.010	0.032	0.002	0.004	0.004	0.852	0.852	0.725	0.725
1A3biv	PM10	208.81	40.78	54	54	0.026	0.026	0.003	0.002	0.003	0.003	0.152	0.152	0.023	0.023
1A3bvi	PM10	2'049.68	2'627.18	50	50	93.973	93.973	0.060	0.104	0.189	0.189	3.019	3.019	9.150	9.150
1A3c	PM10	982.81	1'287.46	50	50	22.568	22.568	0.030	0.051	0.093	0.093	1.503	1.503	2.267	2.267
1A3dii	PM10	59.09	25.36	50	50	0.009	0.009	0.000	0.001	0.002	0.002	0.012	0.012	0.000	0.000
1A3ei	PM10	0.11	0.01	27	27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	PM10	533.10	376.67	78	78	4.700	4.700	0.004	0.015	0.033	0.033	0.281	0.281	0.080	0.080
1A4bi	PM10	5'499.64	1'281.38	76	76	51.739	51.739	0.066	0.051	0.266	0.266	4.985	4.985	24.925	24.925
1A4ci	PM10	543.87	201.64	44	44	0.436	0.436	0.004	0.008	0.239	0.239	0.138	0.138	0.076	0.076
1A4cii	PM10	511.19	209.57	80	80	1.530	1.530	0.003	0.008	0.015	0.015	0.203	0.203	0.041	0.041
1A5b	PM10	286.52	261.18	50	50	0.929	0.929	0.004	0.010	0.019	0.019	0.213	0.213	0.046	0.046
1B1a	PM10	1.60	0.46	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
1B2c	PM10	0.44	0.00	102	329	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
2A1	PM10	374.35	251.27	97	269	3.266	24.845	0.002	0.010	0.028	0.028	0.196	0.196	0.039	0.039
2A2	PM10	14.41	14.06	100	727	0.011	0.569	0.000	0.001	0.002	0.002	0.025	0.025	0.001	0.001
2A5a	PM10	366.54	460.42	100	727	11.566	610.355	0.010	0.018	0.129	0.129	1.043	1.043	1.105	1.105
2B5	PM10	73.80	46.16	97	269	0.110	0.839	0.000	0.002	0.005	0.005	0.026	0.026	0.001	0.001
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	13.31	83	155	0.007	0.023	0.031	0.001	0.001	0.001	2.560	2.560	6.551	6.551
2C3	PM10	113.15	NO	NO	NO	NO	NO	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2C7a	PM10	5.96	0.75	98	269	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.009	0.000	0.000
2C7c	PM10	3.06	2.79	100	727	0.000	0.022	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.000
2D3c	PM10	19.98	18.96	99	270	0.019	0.142	0.000	0.001	0.021	0.021	0.032	0.032	0.001	0.001
2D3i	PM10	24.00	NA	NA	NA	NA	NA	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2G	PM10	588.38	464.45	77	122	6.948	17.410	0.006	0.018	0.649	0.649	0.429	0.429	0.605	0.605
2H1	PM10	243.80	213.73	102	271	2.586	18.199	0.003	0.008	0.358	0.358	0.320	0.320	0.231	0.231
2H2	PM10	310.39	303.52	100	727	5.064	265.290	0.005	0.012	0.170	0.170	0.542	0.542	0.323	0.323
2H3	PM10	15.60	3.64	98	269	0.001	0.005	0.000	0.000	0.001	0.001	0.018	0.018	0.000	0.000
2I	PM10	864.32	195.15	100	727	2.093	109.665	0.011	0.008	0.109	0.109	1.057	1.057	1.130	1.130
3B1a	PM10	84.47	96.79	100	430	0.512	9.434	0.002	0.004	0.035	0.035	0.204	0.204	0.043	0.043
3B1b	PM10	74.85	88.27	100	430	0.425	7.847	0.002	0.003	0.032	0.032	0.190	0.190	0.037	0.037
3B2	PM10	19.76	19.92	100	430	0.022	0.399	0.000	0.001	0.007	0.007	0.037	0.037	0.001	0.001
3B3	PM10	213.16	148.87	100	430	1.210	22.317	0.001	0.006	0.054	0.054	0.137	0.137	0.022	0.022
3B4d	PM10	3.42	4.54	100	430	0.001	0.021	0.000	0.000	0.002	0.002	0.011	0.011	0.000	0.000
3B4e	PM10	6.20	10.37	100	430	0.006	0.108	0.000	0.000	0.004	0.004	0.028	0.028	0.001	0.001
3B4f	PM10	0.94	5.28	100	430	0.002	0.028	0.000	0.000	0.002	0.002	0.019	0.019	0.000	0.000
3B4gi	PM10	123.32	154.68	100	430	1.306	24.094	0.004	0.006	0.056	0.056	0.350	0.350	0.126	0.126
3B4gii	PM10	67.84	209.39	100	430	2.394	44.153	0.007	0.008	0.075	0.075	0.683	0.683	0.473	0.473
3B4giii	PM10	10.41	9.10	100	430	0.005	0.083	0.000	0.000	0.003	0.003	0.014	0.014	0.000	0.000
3B4giv	PM10	18.52	28.37	100	430	0.044	0.810	0.001	0.001	0.010	0.010	0.073	0.073	0.005	0.005
3B4h	PM10	0.50	0.82	100	430	0.000	0.001	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
3De	PM10	1'053.99	1'000.91	98	269	51.934	394.344	0.017	0.040	0.280	0.280	1.680	1.680	2.901	2.901
5A	PM10	0.73	0.53	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	267.20	71	71	1.943	1.943	0.000	0.011	0.746	0.746	0.019	0.019	0.558	0.558
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	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1biv	PM10	19.95	3.86	40	40	0.000	0.000	0.000	0.000	0.004	0.004	0.009	0.009	0.000	0.000
5C1bv	PM10	4.39	0.88	33	33	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
5C2	PM10	93.09	47.37	103	206	0.130	0.519	0.000	0.002	0.127	0.127	0.009	0.009	0.016	0.016
5E	PM10	2.80	3.00	36	36	0.000	0.000	0.000	0.000	0.003	0.003	0.002	0.002	0.000	0.000
6A	PM10	208.71	207.57	50	50	0.586	0.586	0.004	0.008	0.348	0.348	0.151	0.151	0.144	0.144
Total						344.8	1'806.7							60.4	60.4
Total		25'311	13'555	Emissions 2021 uncertainty (%):		18.6	42.5			Trend uncertainty (%):				7.8	7.8

A5.3 Uncertainty estimations: results from approach 2

Numeric results of the uncertainty estimations using Monte Carlo simulations are summarized 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 1'000'000 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 2021 and for the trend 1990-2021. Monte Carlo simulations were run 1’000’000 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 2021	Activity data uncertainty 2021		Emission factor uncertainty 2021		Emission combined uncertainty 2021		Emission contri-bution to variance 2021	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	NOx	6'294.03	2'136.65	10	10	19	19	21	21	0.005	-2.967	0.809	0.770
1A1b	NOx	494.17	283.12	1	1	20	20	20	20	0.000	-0.151	0.036	0.035
1A1c	NOx	0.01	0.04	5	5	20	20	20	20	0.000	0.000	0.000	0.000
1A2a	NOx	278.40	119.93	2	2	26	27	26	27	0.000	-0.113	0.034	0.033
1A2b	NOx	126.80	38.12	2	2	20	19	20	20	0.000	-0.063	0.015	0.015
1A2c	NOx	1'046.46	256.20	2	2	10	10	10	10	0.000	-0.564	0.093	0.090
1A2d	NOx	1'260.62	46.20	2	2	10	10	10	10	0.000	-0.867	0.141	0.138
1A2e	NOx	743.24	251.51	2	2	10	10	10	10	0.000	-0.351	0.058	0.056
1A2f	NOx	10'534.54	3'253.01	2	2	17	17	17	17	0.007	-5.197	1.059	1.032
1A2gvii	NOx	6'333.94	1'722.02	1	1	13	13	13	13	0.001	-3.293	0.592	0.570
1A2gviii	NOx	2'337.67	1'921.86	2	2	17	16	17	17	0.002	-0.297	0.077	0.074
1A3ai(i)	NOx	1'214.30	904.10	1	1	20	20	20	20	0.001	-0.221	0.054	0.052
1A3aii(i)	NOx	153.76	38.06	1	1	20	20	20	20	0.000	-0.083	0.020	0.019
1A3bi	NOx	43'771.53	16'717.00	1	1	37	38	38	37	0.881	-19.102	4.981	5.217
1A3bii	NOx	6'196.89	4'366.40	1	1	31	32	31	32	0.043	-1.306	0.435	0.433
1A3biii	NOx	29'689.49	4'284.26	1	1	18	18	18	18	0.013	-18.113	3.398	3.304
1A3biv	NOx	308.61	230.96	1	1	35	35	36	35	0.000	-0.055	0.021	0.021
1A3c	NOx	595.50	369.20	1	1	13	13	13	13	0.000	-0.162	0.030	0.029
1A3dii	NOx	1'054.73	955.90	1	1	13	13	13	13	0.000	-0.071	0.018	0.018
1A3ei	NOx	145.60	2.28	2	2	49	49	49	49	0.000	-0.102	0.052	0.051
1A4ai	NOx	4'695.63	2'766.44	2	2	16	16	16	16	0.004	-1.377	0.283	0.274
1A4aii	NOx	16.28	43.71	1	1	13	13	13	13	0.000	0.020	0.003	0.004
1A4bi	NOx	11'629.84	4'873.11	4	4	13	13	13	13	0.009	-4.824	0.904	0.870
1A4bii	NOx	18.76	22.29	1	1	29	29	29	29	0.000	0.003	0.001	0.001
1A4ci	NOx	382.42	259.50	21	21	30	29	35	37	0.000	-0.088	0.077	0.073
1A4cii	NOx	4'357.53	1'798.04	1	1	13	13	13	13	0.001	-1.828	0.334	0.317
1A5b	NOx	882.99	376.06	1	1	13	13	13	13	0.000	-0.362	0.067	0.064
1B2c	NOx	212.79	1.40	22	21	100	200	100	202	0.000	-0.151	0.304	0.151
2A1	NOx	15.87	10.65	2	2	100	199	100	199	0.000	-0.004	0.007	0.004
2A2	NOx	0.27	0.26	2	2	100	445	100	445	0.000	0.000	0.000	0.000
2A5a	NOx	1.79	0.48	5	5	100	441	100	441	0.000	-0.001	0.004	0.001
2B2	NOx	82.78	NO	NO	NO	NO	NO	NO	NO	NO	-0.059	0.010	0.009
2B10a	NOx	8.93	13.18	2	2	59	59	58	59	0.000	0.003	0.002	0.002
2C1	NOx	245.46	181.33	2	2	49	49	50	48	0.000	-0.046	0.024	0.023
2C3	NOx	17.41	NO	NO	NO	NO	NO	NO	NO	NO	-0.012	0.025	0.012
2C7c	NOx	NA	1.61	5	5	82	99	82	99	0.000	0.001	0.001	0.001
2G	NOx	29.36	18.67	24	24	82	99	84	102	0.000	-0.008	0.011	0.008
2H3	NOx	91.00	21.25	3	3	100	200	100	200	0.000	-0.050	0.100	0.050
3B1a	NOx	672.34	383.89	6	6	49	49	49	50	0.001	-0.206	0.112	0.108
3B1b	NOx	344.32	273.46	6	6	49	49	50	49	0.000	-0.051	0.033	0.031
3B2	NOx	67.60	63.21	6	6	49	49	49	49	0.000	-0.003	0.005	0.004
3B3	NOx	185.29	88.16	6	6	49	49	50	49	0.000	-0.069	0.037	0.035
3B4d	NOx	21.62	22.53	6	6	49	49	50	49	0.000	0.001	0.001	0.002
3B4e	NOx	17.58	26.04	6	6	49	49	49	50	0.000	0.006	0.003	0.003
3B4f	NOx	1.35	6.97	6	6	50	48	49	50	0.000	0.004	0.002	0.002
3B4gi	NOx	7.19	9.44	6	6	49	49	49	50	0.000	0.002	0.001	0.001
3B4gii	NOx	4.46	12.32	6	6	49	49	49	50	0.000	0.006	0.003	0.003
3B4giii	NOx	0.44	0.37	6	6	49	49	49	50	0.000	0.000	0.000	0.000
3B4giv	NOx	0.84	1.18	6	6	49	49	49	49	0.000	0.000	0.000	0.000
3B4h	NOx	1.03	4.90	6	6	49	49	50	49	0.000	0.003	0.001	0.001
3Da1	NOx	1'204.90	819.90	5	5	98	98	99	98	0.015	-0.274	0.280	0.274
3Da2a	NOx	2'075.01	1'461.30	6	6	49	49	50	49	0.012	-0.438	0.255	0.240
3Da2b	NOx	87.01	NO	NO	NO	NO	NO	NO	NO	NO	-0.062	0.063	0.061
3Da2c	NOx	14.76	116.97	20	20	98	98	99	103	0.000	0.073	0.074	0.076
3Da3	NOx	243.41	417.17	6	6	99	97	98	98	0.004	0.124	0.124	0.127
5A	NOx	1.83	1.31	10	10	49	49	50	50	0.000	0.000	0.000	0.000
5B2	NOx	NA	6.01	20	20	99	98	100	102	0.000	0.004	0.004	0.004
5C1a	NOx	80.75	41.75	49	49	39	39	60	65	0.000	-0.028	0.036	0.033
5C1bi	NOx	9.75	NO	NO	NO	NO	NO	NO	NO	NO	-0.007	0.003	0.003
5C1biii	NOx	22.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.016	0.007	0.007
5C1biv	NOx	114.00	38.56	19	20	49	49	53	53	0.000	-0.054	0.033	0.031
5C1bv	NOx	11.25	13.46	5	5	29	30	30	30	0.000	0.002	0.001	0.001
5C2	NOx	31.10	15.83	47	47	99	153	100	164	0.000	-0.011	0.025	0.014
5D1	NOx	25.35	4.80	1	1	10	10	10	10	0.000	-0.015	0.002	0.002
5D2	NOx	0.25	1.12	10	10	10	10	14	14	0.000	0.001	0.000	0.000
6A	NOx	84.34	98.56	30	29	49	49	56	59	0.000	0.010	0.028	0.030
Total, Monte Carlo simulations		140'605	52'215					12.7	12.9	1.0	-62.9	1.2	1.2
Total, inventory		140'600	52'214								-62.9		

Table A - 35 Uncertainty analysis of NMVOC emissions, approach 2, for 2021 and for the trend 1990-2021. Monte Carlo simulations were run 1'000'000 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 2021	Activity data uncertainty 2021		Emission factor uncertainty 2021		Emission combined uncertainty 2021		Emission contribution to variance 2021	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	NMVOC	292.47	165.68	10	10	31	31	32	33	0.000	-0.044	0.021	0.020
1A1b	NMVOC	6.95	3.12	1	1	19	20	20	20	0.000	-0.001	0.000	0.000
1A1c	NMVOC	2.13	6.21	5	5	20	20	20	20	0.000	0.001	0.000	0.000
1A2a	NMVOC	8.93	7.18	2	2	18	18	18	18	0.000	-0.001	0.000	0.000
1A2b	NMVOC	53.59	7.19	2	2	19	19	19	19	0.000	-0.016	0.005	0.005
1A2c	NMVOC	34.06	23.82	2	2	10	10	10	10	0.000	-0.004	0.001	0.001
1A2d	NMVOC	29.85	4.67	2	2	10	10	10	10	0.000	-0.009	0.002	0.002
1A2e	NMVOC	22.04	24.13	2	2	10	10	10	10	0.000	0.001	0.000	0.000
1A2f	NMVOC	596.56	452.05	2	2	29	30	30	29	0.000	-0.050	0.020	0.019
1A2gvii	NMVOC	1'331.50	272.32	1	1	33	33	33	33	0.000	-0.367	0.152	0.145
1A2gviii	NMVOC	292.93	121.26	2	2	30	29	30	29	0.000	-0.060	0.023	0.022
1A3ai(i)	NMVOC	247.46	70.22	1	1	49	49	49	49	0.000	-0.061	0.034	0.033
1A3aii(i)	NMVOC	58.81	32.05	1	1	49	49	49	49	0.000	-0.009	0.005	0.005
1A3bi	NMVOC	55'937.77	3'781.50	1	1	51	51	51	51	0.011	-17.851	8.397	8.316
1A3bii	NMVOC	4'919.59	168.04	1	1	45	45	45	45	0.000	-1.647	0.839	0.805
1A3biii	NMVOC	3'413.85	100.88	1	1	21	22	21	22	0.000	-1.149	0.369	0.355
1A3biv	NMVOC	5'733.49	788.72	1	1	100	384	100	384	0.029	-1.598	6.122	1.598
1A3bv	NMVOC	16'980.67	1'952.08	1	1	39	39	40	39	0.002	-5.201	2.313	2.221
1A3c	NMVOC	83.76	43.31	1	1	33	33	33	33	0.000	-0.014	0.006	0.006
1A3dii	NMVOC	1'640.55	404.58	1	1	33	33	33	33	0.000	-0.429	0.177	0.170
1A3ei	NMVOC	0.06	0.01	2	2	49	49	49	49	0.000	0.000	0.000	0.000
1A4ai	NMVOC	1'225.16	700.02	2	2	55	55	55	55	0.000	-0.182	0.111	0.106
1A4aii	NMVOC	1'091.65	322.60	1	1	74	73	74	73	0.000	-0.267	0.209	0.204
1A4bi	NMVOC	10'041.86	2'692.68	4	4	67	66	67	66	0.010	-2.540	1.779	1.736
1A4bii	NMVOC	398.23	130.01	1	1	73	74	74	73	0.000	-0.093	0.073	0.071
1A4ci	NMVOC	229.53	87.50	21	21	74	73	76	77	0.000	-0.049	0.044	0.040
1A4cii	NMVOC	4'369.08	855.62	1	1	73	74	73	74	0.001	-1.217	0.940	0.927
1A5b	NMVOC	160.25	60.74	1	1	33	34	33	33	0.000	-0.035	0.014	0.014
1B2ai	NMVOC	0.02	0.01	29	29	48	49	56	59	0.000	0.000	0.000	0.000
1B2aiv	NMVOC	1'344.61	175.43	30	29	46	46	53	56	0.000	-0.406	0.258	0.238
1B2av	NMVOC	14'399.98	2'038.09	1	1	26	25	25	26	0.001	-4.285	1.467	1.403
1B2b	NMVOC	1'056.51	574.16	22	22	49	49	53	54	0.000	-0.167	0.133	0.119
1B2c	NMVOC	13.64	0.09	22	21	82	99	83	102	0.000	-0.005	0.005	0.004
2A1	NMVOC	41.25	27.69	2	2	100	200	100	200	0.000	-0.005	0.010	0.005
2A2	NMVOC	0.69	0.67	2	2	100	444	100	444	0.000	0.000	0.000	0.000
2A5a	NMVOC	4.59	1.24	5	5	100	445	100	444	0.000	-0.001	0.005	0.001
2B10a	NMVOC	608.61	15.74	2	2	39	39	39	39	0.000	-0.206	0.096	0.092
2C1	NMVOC	1'053.60	221.39	2	2	82	99	82	99	0.000	-0.289	0.292	0.241
2C3	NMVOC	56.57	NO	NO	NO	NO	NO	NO	NO	NO	-0.020	0.040	0.020
2C7a	NMVOC	2.98	0.38	5	5	100	200	100	200	0.000	-0.001	0.002	0.001
2C7c	NMVOC	NA	0.52	5	5	82	99	82	99	0.000	0.000	0.000	0.000
2D3a	NMVOC	8'866.55	6'372.06	1	1	82	98	82	98	0.120	-0.858	0.847	0.706
2D3b	NMVOC	4'895.00	2'678.40	5	5	82	99	82	99	0.021	-0.766	0.776	0.633
2D3c	NMVOC	2'430.00	380.50	20	20	82	99	82	102	0.000	-0.710	0.742	0.595
2D3d	NMVOC	40'731.00	8'280.20	20	20	39	39	43	45	0.041	-11.175	5.313	4.998
2D3e	NMVOC	11'731.23	1'566.25	39	39	49	49	60	65	0.003	-3.509	2.478	2.282
2D3f	NMVOC	910.00	61.40	20	20	39	39	43	45	0.000	-0.294	0.151	0.143
2D3g	NMVOC	27'503.97	3'143.23	29	30	82	99	84	105	0.032	-8.227	7.978	6.653
2D3h	NMVOC	20'353.80	3'666.72	19	20	39	39	43	45	0.008	-5.769	2.869	2.734
2D3i	NMVOC	5'470.21	1'930.44	30	29	100	179	100	182	0.037	-1.207	2.249	1.207
2G	NMVOC	22'431.61	6'288.96	24	25	100	200	100	202	0.481	-5.200	9.547	5.200
2H1	NMVOC	554.99	248.76	30	29	100	199	100	203	0.001	-0.106	0.229	0.106
2H2	NMVOC	1'955.66	1'997.22	10	10	82	99	83	99	0.012	0.014	0.110	0.118
2H3	NMVOC	156.00	36.42	3	3	100	199	100	200	0.000	-0.042	0.084	0.042
3B1a	NMVOC	7'074.65	7'127.45	6	6	59	59	59	59	0.055	0.019	0.238	0.241
3B1b	NMVOC	5'367.84	8'278.76	6	6	69	69	69	69	0.100	1.007	0.736	0.781
3B2	NMVOC	66.79	67.32	6	6	100	200	100	200	0.000	0.000	0.003	0.003
3B3	NMVOC	1'126.15	802.76	6	6	100	199	100	200	0.008	-0.112	0.227	0.112
3B4d	NMVOC	37.02	49.25	6	6	100	200	100	200	0.000	0.004	0.004	0.009
3B4e	NMVOC	120.39	201.44	6	6	100	200	100	200	0.000	0.028	0.028	0.057
3B4f	NMVOC	8.64	48.47	6	6	100	200	100	200	0.000	0.014	0.014	0.028
3B4gi	NMVOC	508.70	638.05	6	6	100	200	100	200	0.005	0.045	0.045	0.093
3B4gii	NMVOC	366.34	1'130.72	6	6	100	200	100	200	0.015	0.265	0.265	0.534
3B4giii	NMVOC	46.28	40.46	6	6	100	200	100	200	0.000	-0.002	0.005	0.002
3B4giv	NMVOC	129.27	206.60	6	6	100	199	100	199	0.001	0.027	0.027	0.054
3B4h	NMVOC	3.60	4.62	6	6	100	200	100	200	0.000	0.000	0.000	0.001
3De	NMVOC	481.38	453.93	5	5	100	200	100	200	0.002	-0.009	0.027	0.013
5A	NMVOC	405.68	136.25	10	10	49	49	49	51	0.000	-0.093	0.054	0.051
5B1	NMVOC	104.96	194.13	20	20	98	98	100	102	0.000	0.031	0.033	0.038
5B2	NMVOC	46.44	1'082.92	20	20	29	29	35	36	0.000	0.359	0.147	0.158
5C1a	NMVOC	516.80	267.20	49	49	49	49	66	72	0.000	-0.087	0.119	0.105
5C1bi	NMVOC	3.75	NO	NO	NO	NO	NO	NO	NO	NO	-0.001	0.001	0.001
5C1biii	NMVOC	4.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.002	0.001	0.001
5C1biv	NMVOC	0.46	18.22	20	20	20	19	27	28	0.000	0.006	0.002	0.002
5C1bv	NMVOC	1.20	0.38	5	5	29	30	30	30	0.000	0.000	0.000	0.000
5C2	NMVOC	33.13	16.86	47	47	100	153	100	164	0.000	-0.006	0.013	0.007
5D1	NMVOC	0.51	0.10	1	1	26	27	26	27	0.000	0.000	0.000	0.000
5D2	NMVOC	0.01	0.02	10	10	19	20	22	22	0.000	0.000	0.000	0.000
5E	NMVOC	28.00	60.00	19	20	23	23	30	30	0.000	0.011	0.006	0.006
6A	NMVOC	189.75	229.95	30	29	49	49	56	59	0.000	0.014	0.032	0.035
Total, Monte Carlo simulations		292'406	74'026					22.4	25.4	1.0	-74.6	4.0	4.1
Total, inventory		292'448	74'040								-74.7		

Table A - 36 Uncertainty analysis of SO_x emissions, approach 2, for 2021 and for the trend 1990-2021. Monte Carlo simulations were run 1'000'000 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 2021	Activity data uncertainty 2021		Emission factor uncertainty 2021		Emission combined uncertainty 2021		Emission contri-bution to variance 2021	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	SOx	3'587.18	247.35	10	10	22	21	24	24	0.038	-9.055	2.054	2.008
1A1b	SOx	660.41	85.48	1	1	20	19	20	20	0.003	-1.561	0.314	0.316
1A2a	SOx	357.86	10.24	2	2	15	15	15	15	0.000	-0.944	0.150	0.149
1A2b	SOx	63.56	1.37	2	2	10	10	10	10	0.000	-0.169	0.020	0.020
1A2c	SOx	1'102.74	140.55	2	2	11	11	11	11	0.003	-2.612	0.317	0.320
1A2d	SOx	3'091.28	2.41	2	2	14	14	14	14	0.000	-8.383	1.165	1.174
1A2e	SOx	985.20	17.77	2	2	12	12	12	12	0.000	-2.627	0.346	0.339
1A2f	SOx	3'530.25	1'436.32	2	2	19	19	19	19	0.803	-5.680	1.025	1.027
1A2gvii	SOx	352.47	2.86	1	1	10	10	10	10	0.000	-0.949	0.110	0.108
1A2gviii	SOx	3'314.27	255.67	2	2	19	19	19	19	0.025	-8.298	1.498	1.487
1A3ai(i)	SOx	99.68	63.10	1	1	10	10	10	10	0.000	-0.099	0.012	0.012
1A3aii(i)	SOx	24.94	3.29	1	1	10	10	10	10	0.000	-0.059	0.007	0.007
1A3bi	SOx	1'704.67	39.39	1	1	10	10	10	10	0.000	-4.521	0.509	0.499
1A3bii	SOx	285.80	5.30	1	1	10	10	10	10	0.000	-0.762	0.088	0.087
1A3biii	SOx	1'743.11	10.21	1	1	10	10	10	10	0.000	-4.704	0.529	0.518
1A3biv	SOx	28.33	0.82	1	1	10	10	10	10	0.000	-0.075	0.009	0.009
1A3c	SOx	25.50	0.13	1	1	10	10	10	10	0.000	-0.069	0.008	0.008
1A3dii	SOx	63.22	1.10	1	1	10	10	10	10	0.000	-0.169	0.019	0.019
1A3ei	SOx	0.28	0.06	2	2	10	10	10	10	0.000	-0.001	0.000	0.000
1A4ai	SOx	3'425.52	251.86	2	2	10	10	10	10	0.007	-8.614	0.937	0.916
1A4aii	SOx	1.79	0.06	1	1	10	10	10	10	0.000	-0.005	0.001	0.001
1A4bi	SOx	9'207.87	588.61	4	4	10	10	10	11	0.042	-23.385	2.208	2.259
1A4bii	SOx	1.34	0.04	1	1	10	10	10	10	0.000	-0.004	0.000	0.000
1A4ci	SOx	306.40	59.34	21	21	18	18	27	27	0.003	-0.671	0.217	0.211
1A4cii	SOx	289.62	1.73	1	1	10	10	10	10	0.000	-0.782	0.090	0.090
1A5b	SOx	77.42	30.02	1	1	10	10	10	10	0.000	-0.129	0.015	0.015
1B2aiv	SOx	419.02	11.70	29	29	46	46	53	56	0.000	-1.105	0.620	0.588
1B2c	SOx	300.19	1.87	22	22	30	30	36	38	0.000	-0.810	0.309	0.297
2A1	SOx	0.69	0.46	2	2	100	200	100	200	0.000	-0.001	0.001	0.001
2A2	SOx	0.01	0.01	2	2	100	443	100	443	0.000	0.000	0.000	0.000
2A5a	SOx	0.08	0.02	5	5	100	444	100	444	0.000	0.000	0.001	0.000
2B5	SOx	625.20	383.01	2	2	20	20	20	20	0.063	-0.658	0.139	0.137
2B10a	SOx	168.00	59.00	2	2	39	39	39	39	0.006	-0.296	0.118	0.117
2C1	SOx	144.04	18.11	2	2	82	98	83	98	0.003	-0.341	0.336	0.281
2C3	SOx	696.30	NO	NO	NO	NO	NO	NO	NO	NO	-1.859	3.610	1.859
2C7c	SOx	NA	0.02	5	5	82	99	82	99	0.000	0.000	0.000	0.000
2G	SOx	3.44	4.29	25	24	82	99	84	102	0.000	0.002	0.004	0.005
2H3	SOx	1.30	0.30	3	3	100	200	100	200	0.000	-0.003	0.005	0.003
5B2	SOx	NA	0.91	20	20	97	99	100	101	0.000	0.002	0.002	0.003
5C1a	SOx	24.23	12.53	49	49	39	39	61	64	0.001	-0.032	0.040	0.038
5C1bi	SOx	45.00	NO	NO	NO	NO	NO	NO	NO	NO	-0.122	0.052	0.050
5C1biii	SOx	19.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.053	0.023	0.021
5C1biv	SOx	74.10	15.62	20	20	30	29	34	36	0.000	-0.159	0.063	0.061
5C2	SOx	0.68	0.34	47	47	96	130	97	142	0.000	-0.001	0.002	0.001
5D1	SOx	0.13	0.02	1	1	36	37	36	37	0.000	0.000	0.000	0.000
5D2	SOx	0.00	0.01	10	10	20	20	22	22	0.000	0.000	0.000	0.000
6A	SOx	10.60	11.90	29	30	49	49	56	58	0.001	0.004	0.013	0.014
Total, Monte Carlo simulations		36'864	3'775					8.0	7.9	1.0	-89.8	0.7	0.7
Total, inventory		36'863	3'775								-89.8		

Table A - 37 Uncertainty analysis of NH_3 emissions, approach 2, for 2021 and for the trend 1990-2021. Monte Carlo simulations were run 1'000'000 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 2021	Activity data uncertainty 2021		Emission factor uncertainty 2021		Emission combined uncertainty 2021		Emission contri-bution to variance 2021	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	NH3	4.64	35.55	10	10	19	20	22	22	0.000	0.045	0.012	0.012
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	199.32	2	2	9	9	9	9	0.000	0.077	0.014	0.014
1A2gvii	NH3	1.00	1.54	1	1	49	49	49	49	0.000	0.001	0.000	0.000
1A2gviii	NH3	17.00	43.15	2	2	9	9	9	9	0.000	0.038	0.006	0.006
1A3bi	NH3	1'324.97	778.45	1	1	49	49	49	49	0.004	-0.800	0.404	0.398
1A3bii	NH3	8.57	28.65	1	1	49	49	49	49	0.000	0.029	0.015	0.015
1A3biii	NH3	4.55	34.20	1	1	49	49	49	49	0.000	0.043	0.022	0.022
1A3biv	NH3	3.26	3.85	1	1	49	49	49	49	0.000	0.001	0.000	0.000
1A3c	NH3	0.07	0.07	1	1	49	49	49	49	0.000	0.000	0.000	0.000
1A3dii	NH3	0.20	0.21	1	1	49	50	49	49	0.000	0.000	0.000	0.000
1A3ei	NH3	NA	0.07	2	2	49	49	49	49	0.000	0.000	0.000	0.000
1A4ai	NH3	19.07	31.16	2	2	10	10	10	10	0.000	0.018	0.003	0.003
1A4aii	NH3	0.01	0.02	1	1	10	10	10	10	0.000	0.000	0.000	0.000
1A4bi	NH3	184.16	75.95	4	4	10	10	10	10	0.000	-0.159	0.029	0.027
1A4bii	NH3	0.01	0.01	1	1	10	10	10	10	0.000	0.000	0.000	0.000
1A4ci	NH3	2.88	2.32	21	21	10	10	23	23	0.000	-0.001	0.001	0.001
1A4cii	NH3	0.76	0.83	1	1	49	49	49	49	0.000	0.000	0.000	0.000
1A5b	NH3	0.04	0.04	1	1	49	49	49	49	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	NO	-0.001	0.000	0.000
2B10a	NH3	7.73	NA	NA	NA	NA	NA	NA	NA	NA	-0.011	0.005	0.005
2C1	NH3	11.90	1.51	2	2	100	199	100	199	0.000	-0.015	0.030	0.015
2C7c	NH3	9.19	8.19	5	5	100	442	100	442	0.000	-0.001	0.006	0.001
2G	NH3	203.15	81.08	24	25	39	39	46	47	0.000	-0.179	0.110	0.104
2H2	NH3	132.33	52.17	10	10	100	442	100	442	0.002	-0.116	0.514	0.116
2H3	NH3	1.04	0.24	3	3	100	200	100	200	0.000	-0.001	0.002	0.001
2L	NH3	2.38	3.77	24	25	97	99	100	104	0.000	0.002	0.002	0.003
3B1a	NH3	9'337.10	10'396.08	6	6	29	28	29	29	0.223	1.551	1.349	1.407
3B1b	NH3	5'190.92	7'049.89	6	6	27	26	27	27	0.090	2.720	1.070	1.146
3B2	NH3	509.75	471.54	6	6	86	84	85	86	0.004	-0.056	0.092	0.072
3B3	NH3	6'965.04	4'961.02	6	6	39	39	40	40	0.095	-2.925	1.378	1.307
3B4d	NH3	158.13	159.06	6	6	64	63	64	64	0.000	0.001	0.023	0.023
3B4e	NH3	256.31	386.54	6	6	51	51	51	52	0.001	0.191	0.106	0.113
3B4f	NH3	19.65	99.98	6	6	67	67	67	67	0.000	0.118	0.080	0.082
3B4gi	NH3	978.79	678.27	6	6	80	80	80	81	0.007	-0.440	0.378	0.369
3B4gii	NH3	304.87	672.32	6	6	84	85	85	84	0.008	0.538	0.464	0.470
3B4giii	NH3	29.77	21.71	6	6	91	91	91	92	0.000	-0.012	0.012	0.011
3B4giv	NH3	124.46	86.64	6	6	83	83	84	83	0.000	-0.055	0.051	0.048
3B4h	NH3	14.55	42.98	6	6	49	49	49	49	0.000	0.042	0.021	0.022
3Da1	NH3	4'258.33	2'652.07	5	5	49	49	50	49	0.042	-2.345	1.192	1.171
3Da2a	NH3	34'567.08	20'400.40	6	6	21	21	21	22	0.471	-20.624	4.097	4.082
3Da2b	NH3	1'169.36	NO	NO	NO	NO	NO	NO	NO	NO	-1.712	0.868	0.860
3Da2c	NH3	34.00	978.97	20	20	49	49	52	54	0.007	1.385	0.738	0.780
3Da3	NH3	760.92	1'411.60	6	6	61	61	62	61	0.018	0.953	0.603	0.618
5A	NH3	615.79	206.73	10	10	49	49	50	50	0.000	-0.599	0.323	0.311
5B1	NH3	175.00	323.66	20	20	98	98	99	103	0.003	0.218	0.230	0.257
5B2	NH3	9.63	231.43	20	19	73	74	77	76	0.001	0.325	0.248	0.259
5C1biv	NH3	5.70	1.83	20	19	49	49	52	54	0.000	-0.006	0.003	0.003
5C2	NH3	18.03	9.18	47	47	25	24	52	54	0.000	-0.013	0.015	0.014
5D1	NH3	89.98	126.16	1	1	49	49	49	49	0.000	0.053	0.027	0.027
6A	NH3	845.54	994.86	29	30	97	99	101	106	0.026	0.219	0.622	0.751
Total, Monte Carlo simulations		68'520	53'740					11.8	12.0	1.0	-21.5	4.7	4.8
Total, inventory		68'526	53'745								-21.6		

Table A - 38 Uncertainty analysis of PM2.5 emissions, approach 2, for 2021 and for the trend 1990-2021. Monte Carlo simulations were run 1’000’000 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 2021	Activity data uncertainty 2021		Emission factor uncertainty 2021		Emission combined uncertainty 2021		Emission contri-bution to variance 2021	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	PM2.5	772.49	43.88	10	10	70	69	70	71	0.000	-4.446	3.373	3.214
1A1b	PM2.5	47.66	4.26	1	1	20	20	20	20	0.000	-0.267	0.096	0.087
1A1c	PM2.5	4.64	13.52	5	5	20	20	20	20	0.000	0.055	0.018	0.020
1A2a	PM2.5	14.80	2.84	2	2	27	28	28	27	0.000	-0.073	0.030	0.028
1A2b	PM2.5	20.38	1.41	2	2	29	29	30	29	0.000	-0.117	0.049	0.046
1A2c	PM2.5	40.75	5.57	2	2	10	10	10	10	0.000	-0.216	0.068	0.061
1A2d	PM2.5	149.61	0.26	2	2	32	32	32	32	0.000	-0.917	0.407	0.379
1A2e	PM2.5	25.68	1.44	2	2	10	10	10	10	0.000	-0.149	0.047	0.042
1A2f	PM2.5	437.58	46.89	2	2	63	64	64	63	0.000	-2.393	1.706	1.602
1A2gvii	PM2.5	728.86	389.91	1	1	48	49	49	49	0.010	-2.076	1.182	1.111
1A2gviii	PM2.5	544.40	190.33	2	2	63	64	64	63	0.004	-2.165	1.515	1.465
1A3ai(i)	PM2.5	92.39	6.88	1	1	29	29	29	30	0.000	-0.525	0.223	0.205
1A3aii(i)	PM2.5	22.67	1.73	1	1	29	29	30	29	0.000	-0.129	0.055	0.050
1A3bi	PM2.5	577.66	121.33	1	1	57	56	56	57	0.001	-2.793	1.783	1.677
1A3bii	PM2.5	327.15	61.28	1	1	48	47	48	47	0.000	-1.631	0.920	0.867
1A3biii	PM2.5	1'587.21	51.17	1	1	26	27	27	26	0.000	-9.418	3.622	3.338
1A3biv	PM2.5	208.81	40.78	1	1	53	53	53	53	0.000	-1.032	0.636	0.603
1A3bvi	PM2.5	689.15	891.53	1	1	49	49	49	49	0.053	1.240	0.675	0.706
1A3c	PM2.5	174.35	198.01	1	1	49	49	49	49	0.003	0.145	0.082	0.087
1A3dii	PM2.5	59.09	25.36	1	1	49	49	49	49	0.000	-0.207	0.122	0.114
1A3ei	PM2.5	0.11	0.01	2	2	26	27	27	27	0.000	-0.001	0.000	0.000
1A4ai	PM2.5	506.01	354.43	2	2	77	76	77	76	0.020	-0.927	0.761	0.737
1A4bi	PM2.5	5'226.81	1'214.74	4	4	74	75	74	75	0.226	-23.477	12.552	13.943
1A4ci	PM2.5	539.23	199.14	20	21	38	38	43	45	0.002	-2.084	1.247	1.146
1A4cii	PM2.5	435.10	150.70	1	1	78	79	79	78	0.004	-1.739	1.469	1.415
1A5b	PM2.5	86.95	44.54	1	1	49	49	49	49	0.000	-0.260	0.154	0.141
1B1a	PM2.5	0.16	0.05	29	29	39	39	47	50	0.000	-0.001	0.000	0.000
1B2c	PM2.5	0.44	0.00	21	22	100	238	100	239	0.000	-0.003	0.007	0.003
2A1	PM2.5	240.48	161.41	2	2	100	199	100	199	0.028	-0.479	0.951	0.479
2A2	PM2.5	7.21	7.04	2	2	100	442	100	442	0.000	-0.001	0.005	0.001
2A5a	PM2.5	183.33	230.23	5	5	100	442	100	441	0.353	0.270	0.270	1.209
2B5	PM2.5	61.20	38.23	2	2	100	200	100	200	0.002	-0.141	0.284	0.141
2B10a	PM2.5	7.86	NA	NA	NA	NA	NA	NA	NA	NA	-0.048	0.024	0.023
2C1	PM2.5	817.90	8.95	2	2	93	122	93	122	0.000	-4.868	5.757	4.524
2C3	PM2.5	78.33	NO	NO	NO	NO	NO	NO	NO	NO	-0.479	0.963	0.479
2C7a	PM2.5	5.66	0.71	5	5	100	199	100	200	0.000	-0.030	0.062	0.030
2C7c	PM2.5	1.53	1.41	5	5	100	443	100	443	0.000	-0.001	0.003	0.001
2D3c	PM2.5	4.00	3.79	20	20	100	199	100	201	0.000	-0.001	0.011	0.009
2D3i	PM2.5	12.00	NA	NA	NA	NA	NA	NA	NA	NA	-0.073	0.324	0.073
2G	PM2.5	512.78	370.22	25	24	82	99	84	102	0.039	-0.867	1.496	1.049
2H1	PM2.5	235.77	206.90	29	29	100	200	100	204	0.047	-0.173	1.004	0.736
2H2	PM2.5	187.99	163.56	10	10	100	444	100	444	0.177	-0.140	0.684	0.170
2H3	PM2.5	15.60	3.64	3	3	100	200	100	200	0.000	-0.073	0.149	0.073
2I	PM2.5	216.08	49.12	10	10	100	443	100	442	0.016	-0.952	4.286	0.952
3B1a	PM2.5	20.61	23.62	6	6	100	301	100	301	0.001	0.018	0.019	0.058
3B1b	PM2.5	18.26	21.54	6	6	100	300	100	300	0.001	0.020	0.020	0.062
3B2	PM2.5	0.79	0.80	6	6	100	301	100	301	0.000	0.000	0.001	0.001
3B3	PM2.5	9.57	6.64	6	6	100	300	100	300	0.000	-0.018	0.054	0.018
3B4d	PM2.5	0.14	0.18	6	6	100	301	100	301	0.000	0.000	0.000	0.001
3B4e	PM2.5	3.94	6.60	6	6	100	300	100	301	0.000	0.016	0.016	0.049
3B4f	PM2.5	0.59	3.30	6	6	100	300	100	300	0.000	0.017	0.017	0.050
3B4gi	PM2.5	9.25	11.60	6	6	100	301	100	301	0.000	0.014	0.014	0.044
3B4gii	PM2.5	6.78	20.94	6	6	100	300	100	300	0.001	0.087	0.087	0.262
3B4giii	PM2.5	1.89	1.65	6	6	100	300	100	300	0.000	-0.001	0.005	0.001
3B4giv	PM2.5	1.98	2.99	6	6	100	301	100	301	0.000	0.006	0.006	0.019
3B4h	PM2.5	0.24	0.10	6	6	100	301	100	301	0.000	-0.001	0.003	0.001
3De	PM2.5	47.50	44.92	5	5	100	200	100	200	0.002	-0.016	0.046	0.023
5A	PM2.5	0.73	0.53	10	10	30	29	31	31	0.000	-0.001	0.001	0.001
5B2	PM2.5	NA	0.05	19	20	99	97	100	102	0.000	0.000	0.000	0.000
5C1a	PM2.5	465.12	240.48	49	49	29	29	56	59	0.005	-1.372	1.760	1.632
5C1bi	PM2.5	0.47	NO	NO	NO	NO	NO	NO	NO	NO	-0.003	0.002	0.001
5C1biii	PM2.5	16.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.101	0.053	0.048
5C1biv	PM2.5	14.25	2.70	20	20	33	33	38	39	0.000	-0.071	0.037	0.034
5C1bv	PM2.5	4.39	0.88	5	5	32	32	33	33	0.000	-0.022	0.010	0.009
5C2	PM2.5	84.75	43.12	47	47	100	153	100	164	0.001	-0.255	0.577	0.323
5E	PM2.5	1.40	1.50	19	20	29	29	35	36	0.000	0.001	0.003	0.003
6A	PM2.5	4.21	5.77	29	29	39	39	48	50	0.000	0.010	0.013	0.015
Total, Monte Carlo simulations		16'622	5'748					30.1	32.8	1.0	-65.3	6.4	7.5
Total, inventory		16'621	5'747								-65.4		

Table A - 39 Uncertainty analysis of PM10 emissions, approach 2, for 2021 and for the trend 1990-2021. Monte Carlo simulations were run 1’000’000 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 2021	Activity data uncertainty 2021		Emission factor uncertainty 2021		Emission combined uncertainty 2021		Emission contri-bution to variance 2021	Contri-bution to trend	Contribution to uncertainty of trend	
		t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%
1A1a	PM10	1'034.29	43.88	10	10	70	69	70	70	0.000	-3.971	2.967	2.878
1A1b	PM10	47.66	4.26	1	1	20	20	20	19	0.000	-0.175	0.061	0.057
1A1c	PM10	4.89	14.25	5	5	20	20	20	20	0.000	0.038	0.013	0.014
1A2a	PM10	20.52	3.11	2	2	28	27	28	27	0.000	-0.070	0.028	0.026
1A2b	PM10	29.24	1.49	2	2	29	29	29	30	0.000	-0.112	0.046	0.044
1A2c	PM10	40.75	5.57	2	2	10	10	10	10	0.000	-0.142	0.043	0.041
1A2d	PM10	166.57	0.26	2	2	32	32	32	32	0.000	-0.670	0.292	0.275
1A2e	PM10	25.68	1.44	2	2	10	10	10	10	0.000	-0.098	0.030	0.028
1A2f	PM10	832.63	79.16	2	2	64	64	64	64	0.000	-3.026	2.124	1.995
1A2gvii	PM10	2'173.23	2'351.23	1	1	49	49	49	50	0.073	0.714	0.395	0.424
1A2gviii	PM10	567.41	200.41	2	2	64	63	64	63	0.001	-1.477	1.030	0.996
1A3ai(i)	PM10	102.65	6.88	1	1	29	30	29	30	0.000	-0.386	0.160	0.150
1A3aii(i)	PM10	25.19	1.73	1	1	29	29	29	30	0.000	-0.095	0.039	0.037
1A3bi	PM10	577.66	121.33	1	1	56	56	57	56	0.000	-1.836	1.149	1.116
1A3bii	PM10	327.15	61.28	1	1	47	47	47	47	0.000	-1.071	0.589	0.576
1A3biii	PM10	1'587.21	51.17	1	1	26	26	27	26	0.000	-6.184	2.350	2.236
1A3biv	PM10	208.81	40.78	1	1	52	53	52	53	0.000	-0.677	0.413	0.391
1A3bvi	PM10	2'049.68	2'627.18	1	1	48	50	49	49	0.091	2.316	1.200	1.275
1A3c	PM10	982.81	1'287.46	1	1	49	49	49	49	0.022	1.225	0.658	0.691
1A3dii	PM10	59.09	25.36	1	1	49	49	49	49	0.000	-0.136	0.078	0.075
1A3ei	PM10	0.11	0.01	2	2	27	27	27	27	0.000	0.000	0.000	0.000
1A4ai	PM10	533.10	376.67	2	2	77	76	77	76	0.005	-0.628	0.517	0.499
1A4bi	PM10	5'499.64	1'281.38	4	4	74	74	75	74	0.050	-16.454	10.405	10.775
1A4ci	PM10	543.87	201.64	21	21	39	38	43	44	0.000	-1.377	0.825	0.759
1A4cii	PM10	511.19	209.57	1	1	79	78	79	78	0.001	-1.213	1.009	0.993
1A5b	PM10	286.52	261.18	1	1	48	49	49	49	0.001	-0.102	0.062	0.058
1B1a	PM10	1.60	0.46	30	29	40	39	48	50	0.000	-0.005	0.003	0.003
1B2c	PM10	0.44	0.00	22	22	100	238	100	240	0.000	-0.002	0.004	0.002
2A1	PM10	374.35	251.27	2	2	100	199	100	200	0.013	-0.488	0.967	0.488
2A2	PM10	14.41	14.06	2	2	100	441	100	442	0.000	-0.001	0.007	0.002
2A5a	PM10	366.54	460.42	5	5	100	443	100	443	0.282	0.348	0.348	1.568
2B5	PM10	73.80	46.16	2	2	100	200	100	200	0.000	-0.111	0.224	0.111
2B10a	PM10	17.07	NA	NA	NA	NA	NA	NA	NA	NA	-0.069	0.034	0.032
2C1	PM10	1'485.46	13.31	2	2	93	123	93	123	0.000	-5.803	6.786	5.362
2C3	PM10	113.15	NO	NO	NO	NO	NO	NO	NO	NO	-0.455	0.914	0.455
2C7a	PM10	5.96	0.75	5	5	100	200	100	200	0.000	-0.021	0.043	0.021
2C7c	PM10	3.06	2.79	5	5	100	443	100	442	0.000	-0.001	0.005	0.001
2D3c	PM10	19.98	18.96	20	20	100	200	100	201	0.000	-0.004	0.037	0.030
2D3i	PM10	24.00	NA	NA	NA	NA	NA	NA	NA	NA	-0.096	0.425	0.096
2G	PM10	588.38	464.45	24	25	83	98	83	103	0.012	-0.495	1.059	0.815
2H1	PM10	243.80	213.73	29	30	100	199	100	203	0.010	-0.119	0.681	0.505
2H2	PM10	310.39	303.52	10	10	100	443	100	442	0.121	-0.025	0.400	0.298
2H3	PM10	15.60	3.64	3	3	100	200	100	200	0.000	-0.048	0.098	0.048
2I	PM10	864.32	195.15	10	10	100	446	100	445	0.051	-2.270	10.375	2.270
3B1a	PM10	84.47	96.79	6	6	100	300	100	300	0.004	0.049	0.049	0.155
3B1b	PM10	74.85	88.27	6	6	100	301	100	301	0.004	0.054	0.054	0.166
3B2	PM10	19.76	19.92	6	6	100	301	100	301	0.000	0.001	0.012	0.014
3B3	PM10	213.16	148.87	6	6	100	301	100	300	0.011	-0.255	0.768	0.255
3B4d	PM10	3.42	4.54	6	6	100	301	100	301	0.000	0.005	0.005	0.014
3B4e	PM10	6.20	10.37	6	6	100	301	100	301	0.000	0.017	0.017	0.051
3B4f	PM10	0.94	5.28	6	6	100	301	100	301	0.000	0.017	0.017	0.053
3B4gi	PM10	123.32	154.68	6	6	100	300	100	301	0.011	0.125	0.125	0.379
3B4gii	PM10	67.84	209.39	6	6	100	301	100	301	0.021	0.568	0.568	1.709
3B4giii	PM10	10.41	9.10	6	6	100	300	100	300	0.000	-0.005	0.017	0.005
3B4giv	PM10	18.52	28.37	6	6	100	300	100	300	0.000	0.040	0.040	0.120
3B4h	PM10	0.50	0.82	6	6	100	301	100	301	0.000	0.001	0.001	0.004
3De	PM10	1'053.99	1'000.91	5	5	100	200	100	200	0.212	-0.205	0.613	0.325
5A	PM10	0.73	0.53	10	10	29	29	31	31	0.000	-0.001	0.001	0.000
5B2	PM10	NA	0.05	20	20	97	99	100	102	0.000	0.000	0.000	0.000
5C1a	PM10	516.80	267.20	49	49	49	49	66	71	0.002	-1.002	1.382	1.214
5C1bi	PM10	3.08	NO	NO	NO	NO	NO	NO	NO	NO	-0.012	0.006	0.006
5C1biii	PM10	24.00	NO	NO	NO	NO	NO	NO	NO	NO	-0.097	0.050	0.046
5C1biv	PM10	19.95	3.86	20	20	34	34	39	40	0.000	-0.065	0.034	0.031
5C1bv	PM10	4.39	0.88	5	5	32	33	33	32	0.000	-0.014	0.006	0.006
5C2	PM10	93.09	47.37	47	47	99	153	100	164	0.000	-0.184	0.419	0.230
5E	PM10	2.80	3.00	20	20	29	29	35	36	0.000	0.001	0.003	0.003
6A	PM10	208.71	207.57	30	29	39	39	48	50	0.001	-0.005	0.369	0.364
Total, Monte Carlo simulations		25'317	13'557					28.0	32.3	1.0	-46.2	10.9	11.4
Total, inventory		25'311	13'555								-46.4		

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.

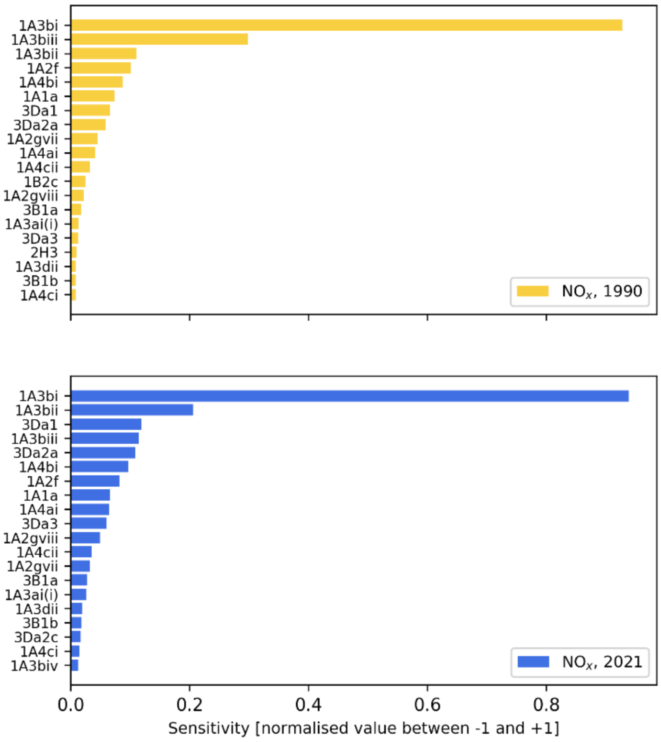

Figure A - 5 Results of the sensitivity analysis between emissions from each category and inventory emissions for NO_x, for the base year 1990 and the reporting year 2021. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

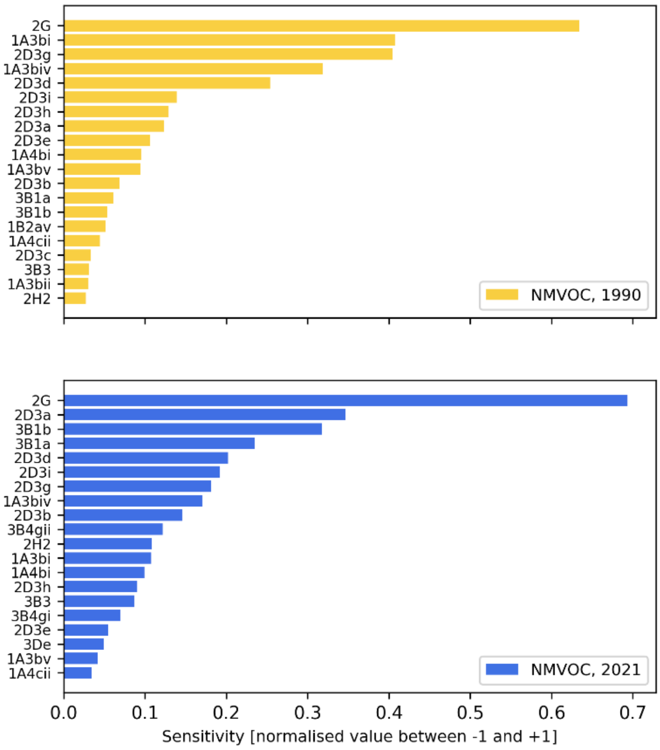

Figure A - 6 Results of the sensitivity analysis between emissions from each category and inventory emissions for NMVOC, for the base year 1990 and the reporting year 2021. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

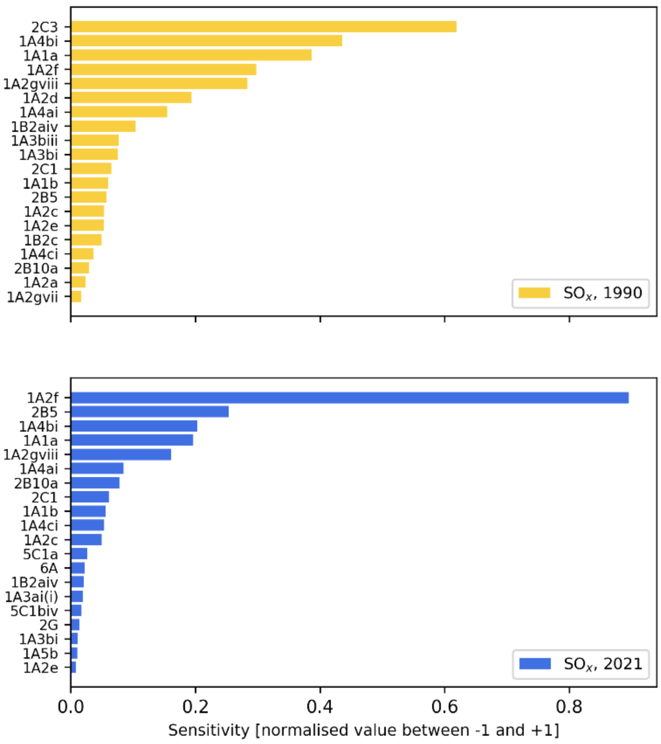

Figure A - 7 Results of the sensitivity analysis between emissions from each category and inventory emissions for SO_x (expressed as SO_2 equivalents), for the base year 1990 and the reporting year 2021. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

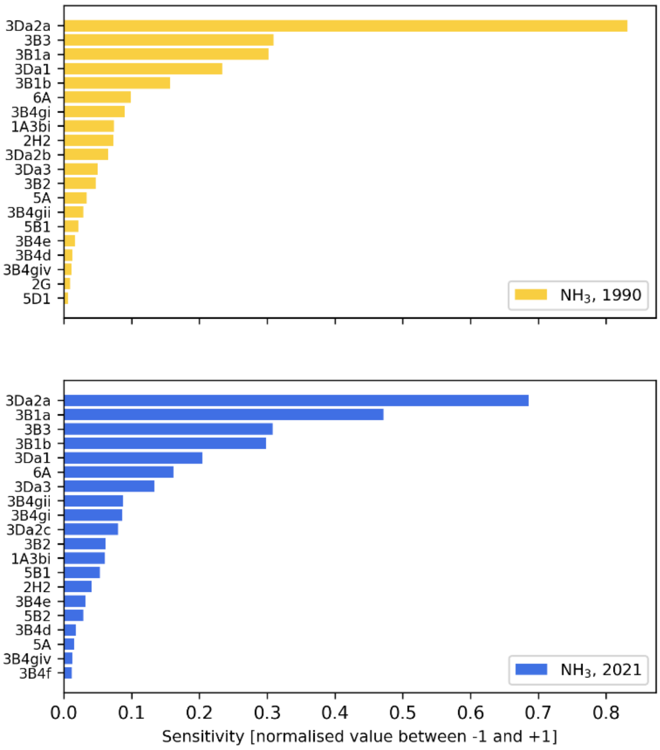

Figure A - 8 Results of the sensitivity analysis between emissions from each category and inventory emissions for NH_3, for the base year 1990 and the reporting year 2021. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

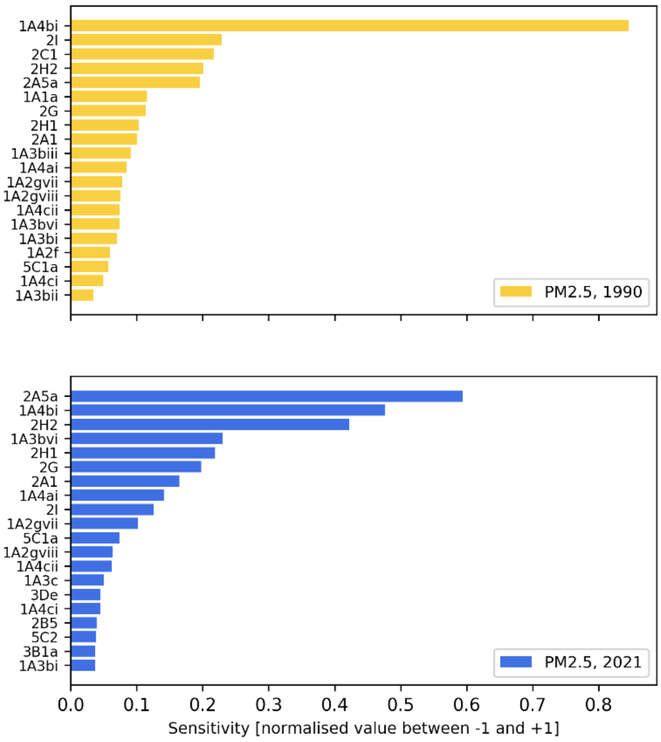

Figure A - 9 Results of the sensitivity analysis between emissions from each category and inventory emissions for PM2.5, for the base year 1990 and the reporting year 2021. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

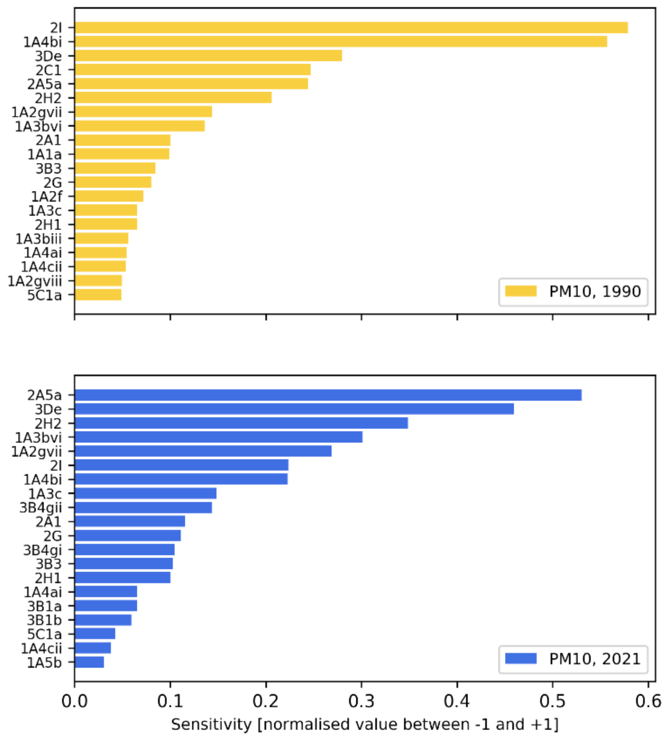

Figure A - 10 Results of the sensitivity analysis between emissions from each category and inventory emissions for PM10, for the base year 1990 and the reporting year 2021. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key 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.

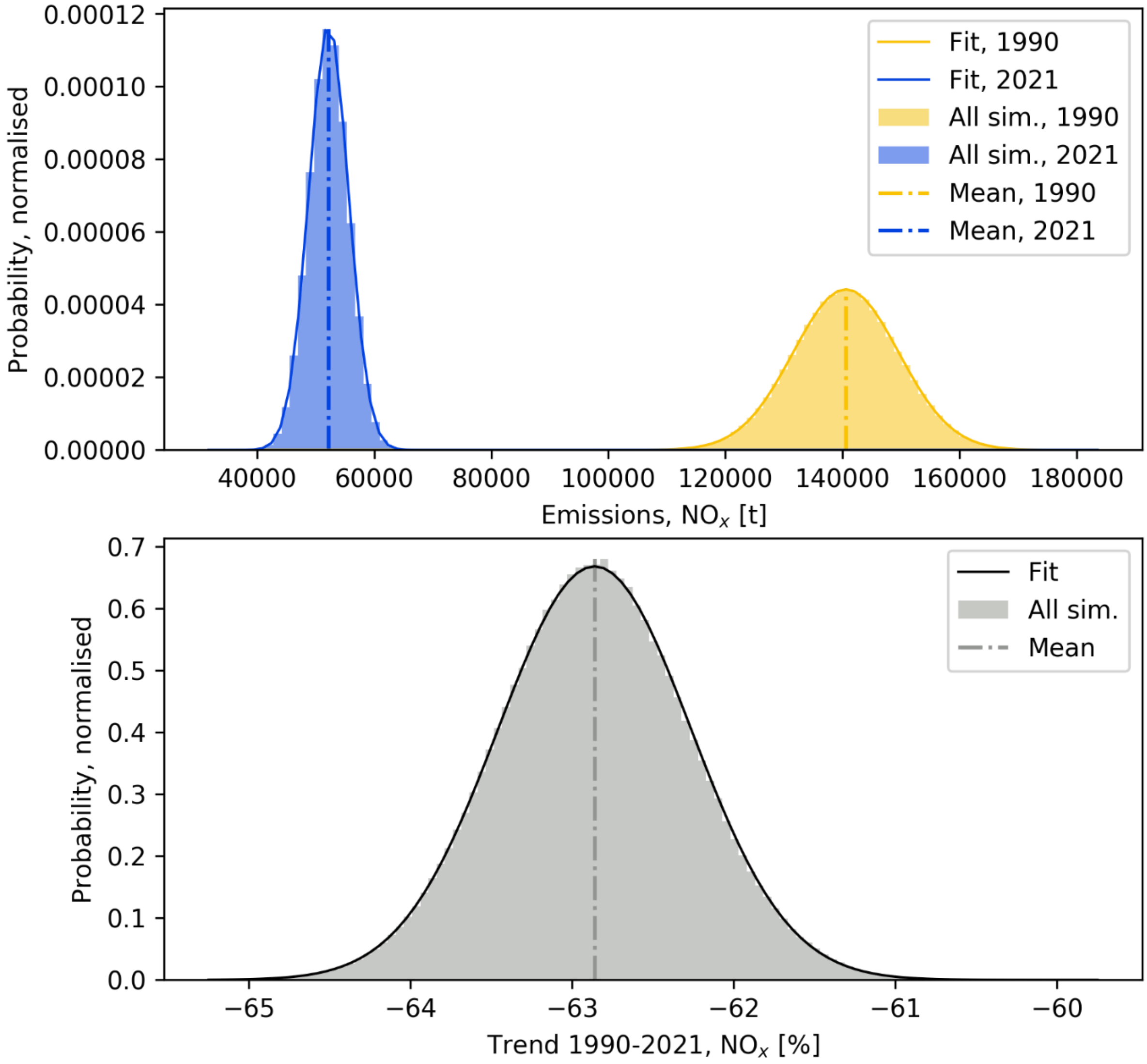

Figure A - 11 Monte Carlo simulations: Distributions obtained for the inventory mean emission for NO_x, for the base year 1990 (top panel, yellow), the reporting year 2021 (top panel, blue) and the trend 1990-2021 (bottom panel, grey). All sim.: all simulations (1'000'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

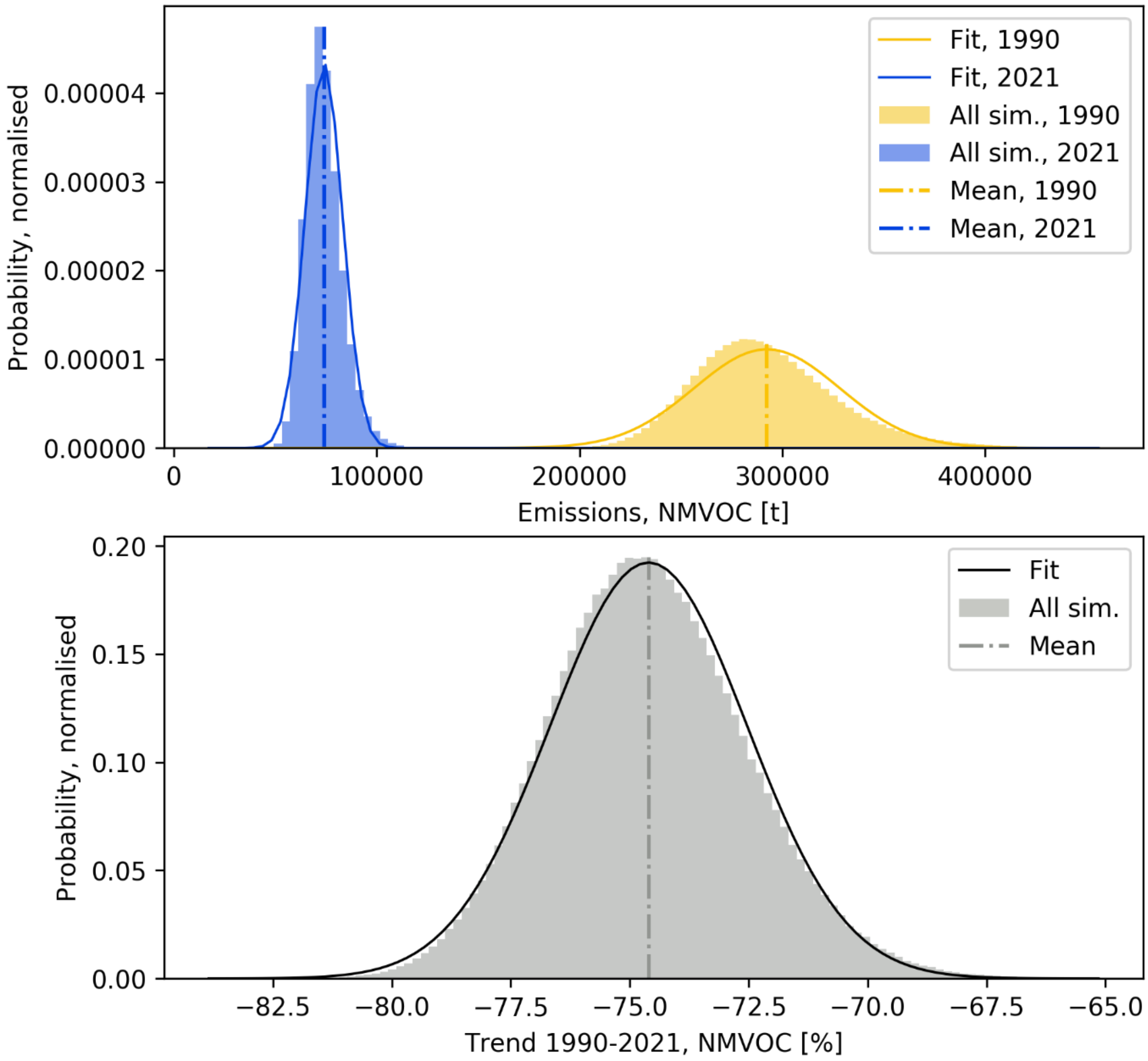

Figure A - 12 Monte Carlo simulations: Distributions obtained for the inventory mean emission for NMVOC, for the base year 1990 (top panel, yellow), the reporting year 2021 (top panel, blue) and the trend 1990-2021 (bottom panel, grey). All sim: all simulations (1'000'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

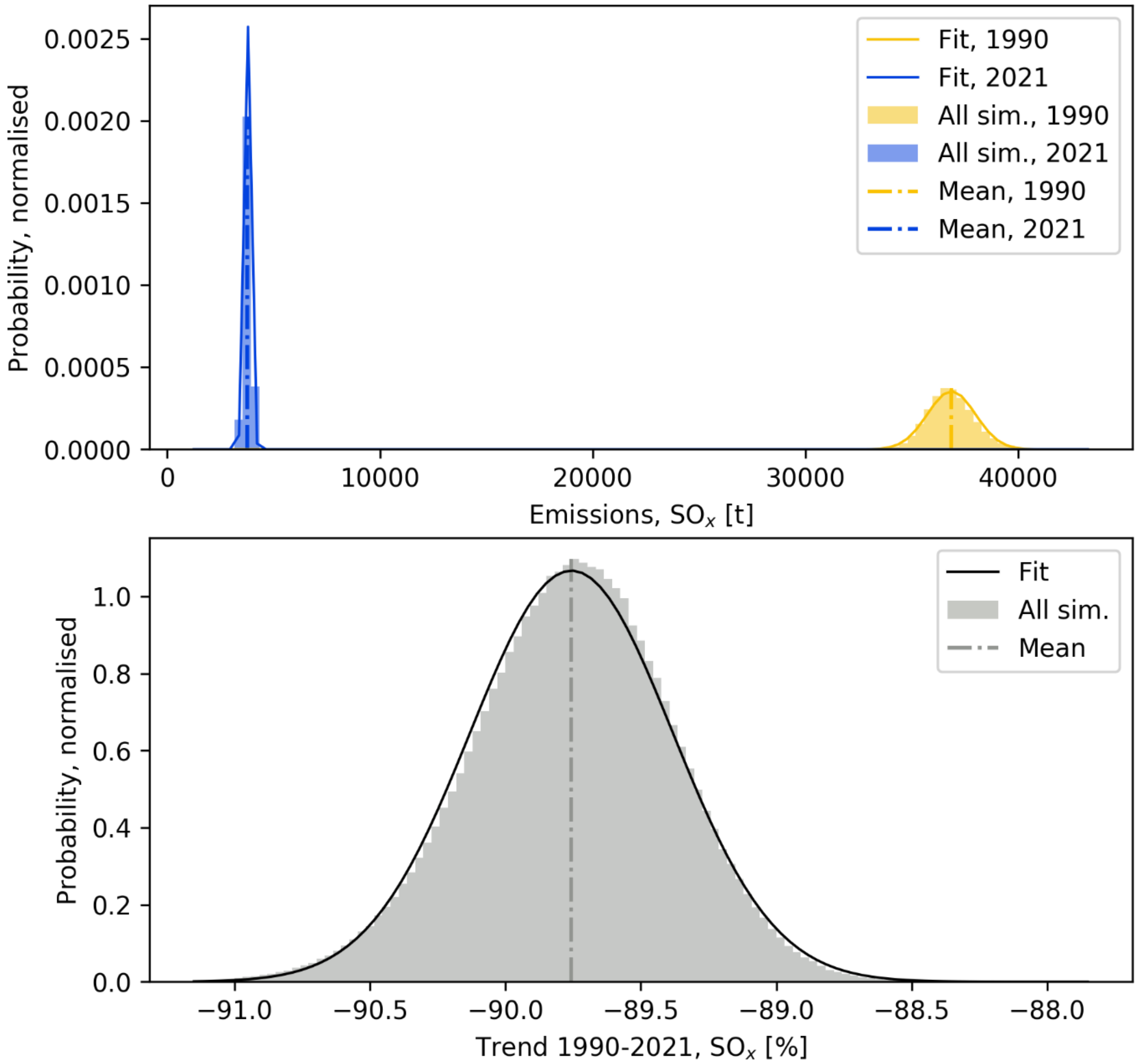

Figure A - 13 Monte Carlo simulations: Distributions obtained for the inventory mean emission for SO_x, for the base year 1990 (top panel, yellow), the reporting year 2021 (top panel, blue) and the trend 1990-2021 (bottom panel, grey). All sim: all simulations (1'000'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

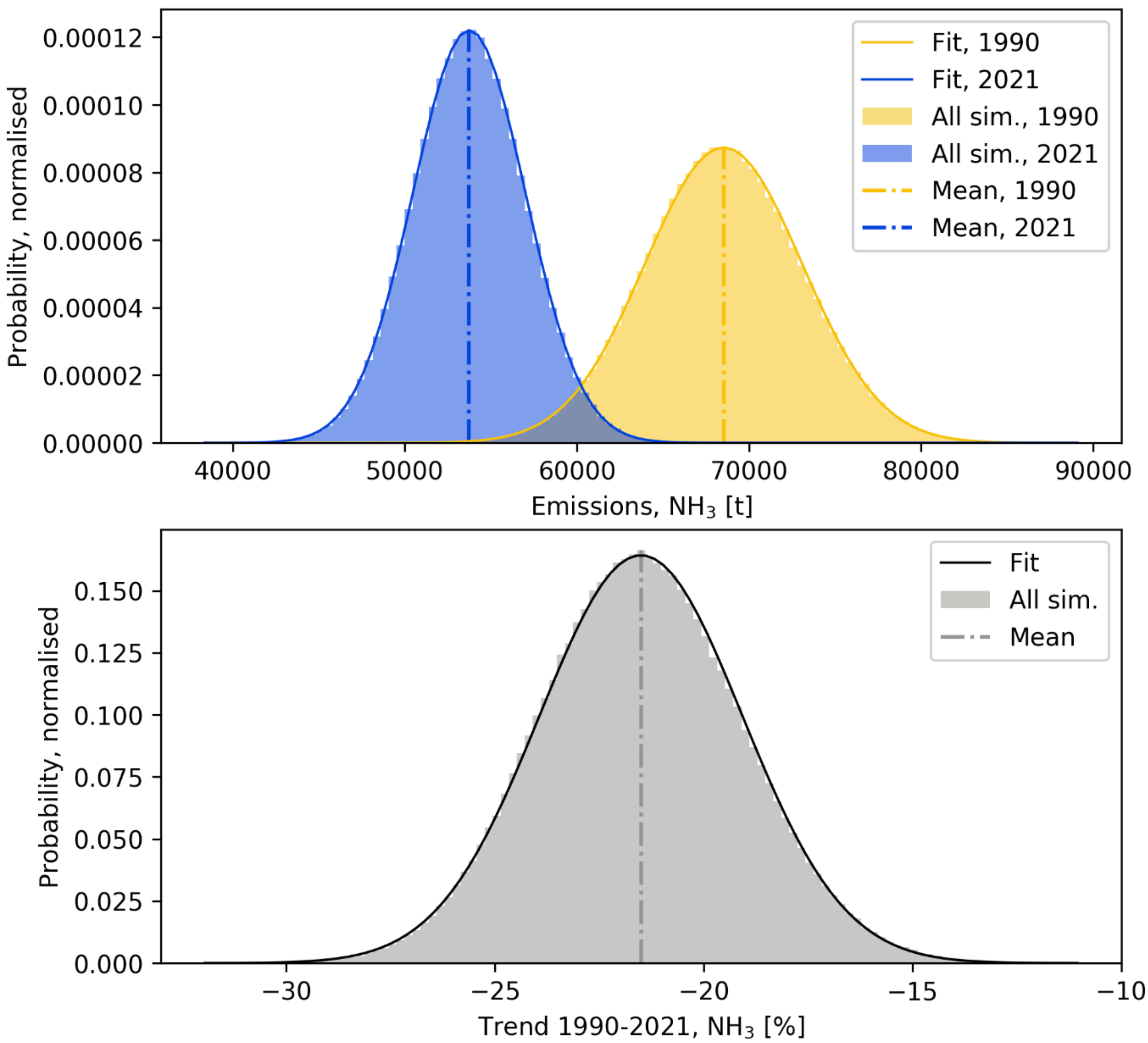

Figure A - 14 Monte Carlo simulations: Distributions obtained for the inventory mean emission for NH_3, for the base year 1990 (top panel, yellow), the reporting year 2021 (top panel, blue) and the trend 1990-2021 (bottom panel, grey). All sim: all simulations (1'000'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

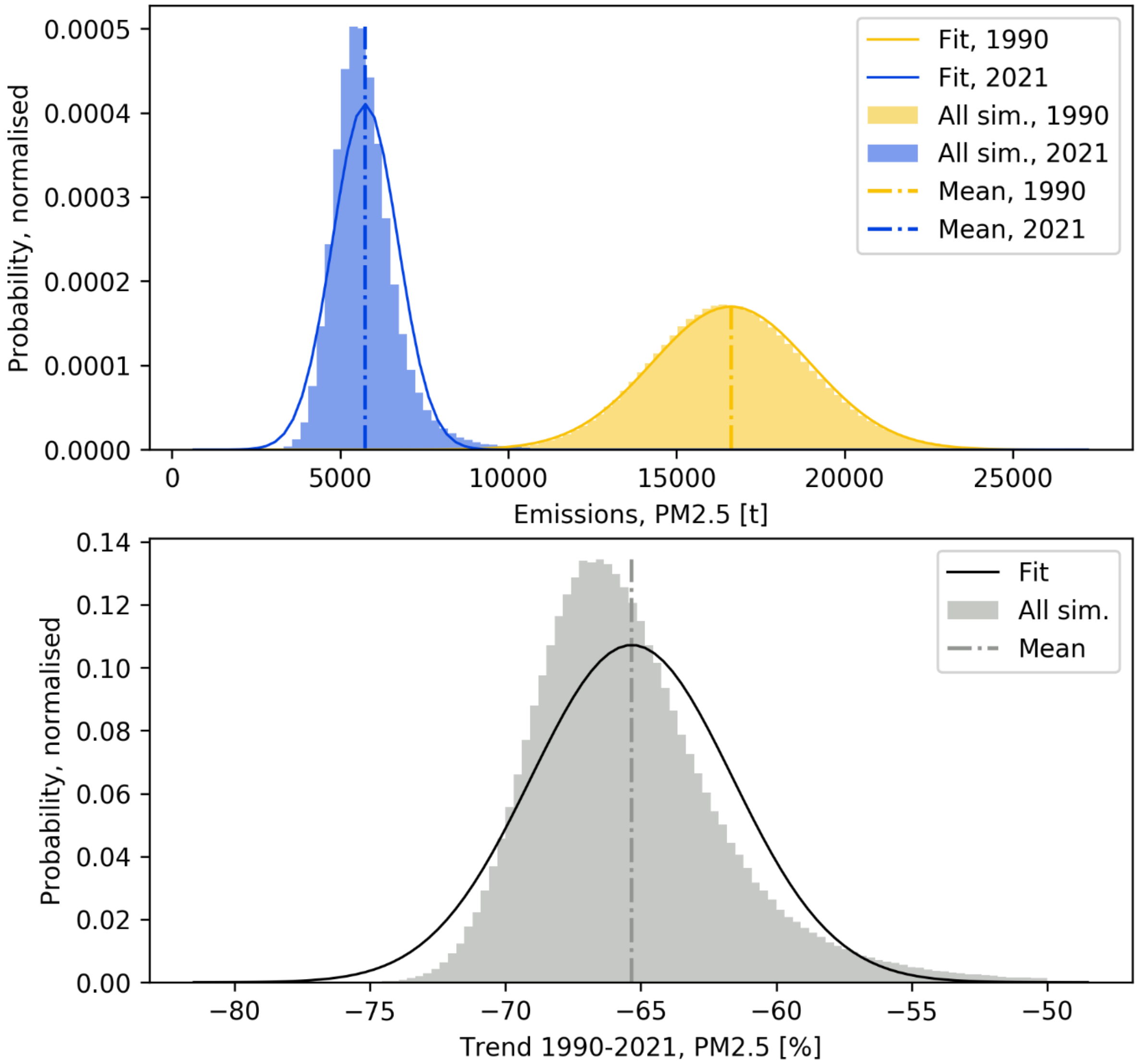

Figure A - 15 Monte Carlo simulations: Distributions obtained for the inventory mean emission for PM2.5, for the base year 1990 (top panel, yellow), the reporting year 2021 (top panel, blue) and the trend 1990-2021 (bottom panel, grey). All sim: all simulations (1'000'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

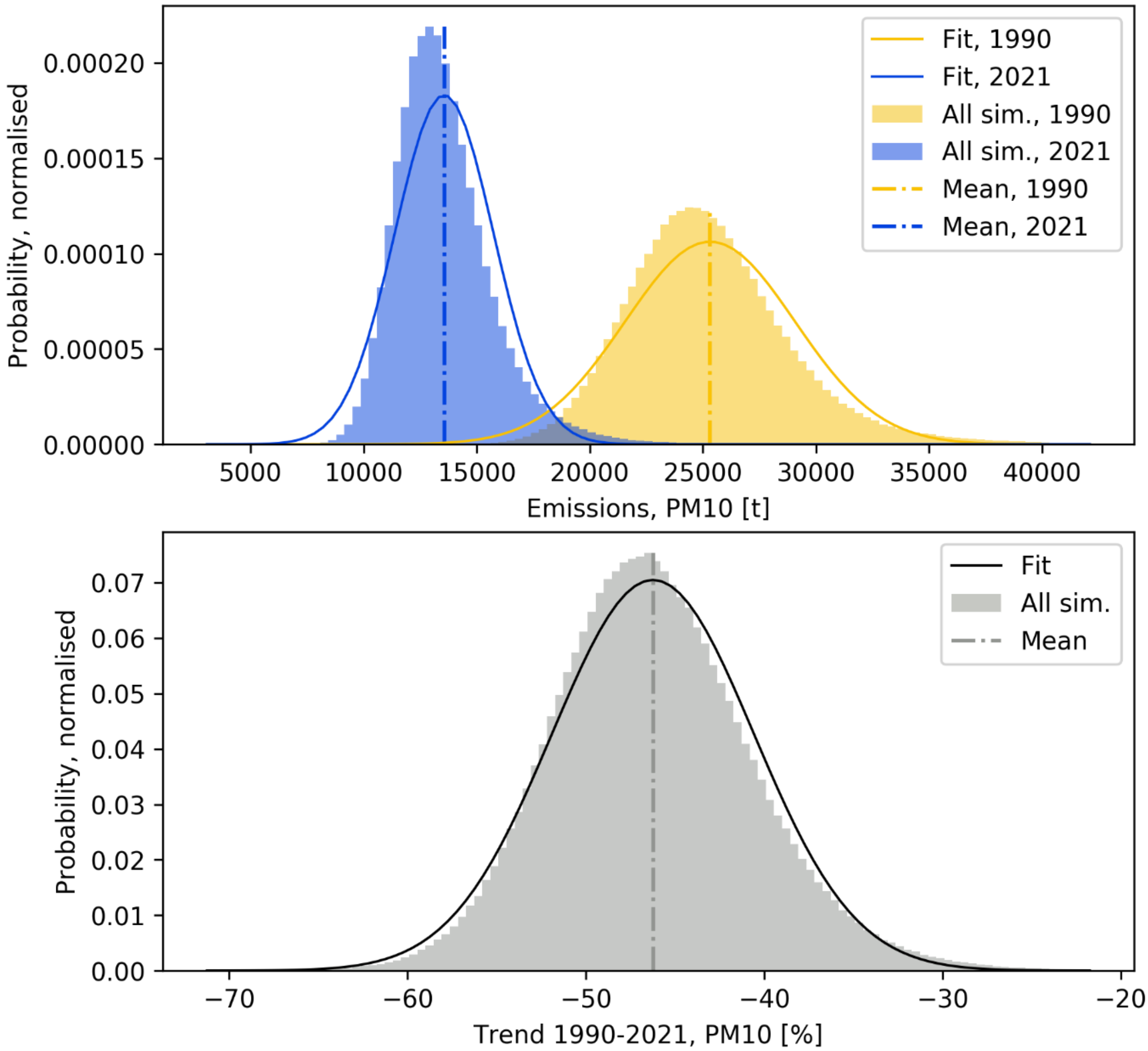

Figure A - 16 Monte Carlo simulations: Distributions obtained for the inventory mean emission for PM10, for the base year 1990 (top panel, yellow), the reporting year 2021 (top panel, blue) and the trend 1990-2021 (bottom panel, grey). All sim: all simulations (1’000’000 values for each distribution). 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.
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	

A6.1 Emissions of PM condensable from wood energy combustion

The emissions from wood combustion in 1A Fuel combustion activities are calculated by a Tier 2 method using country-specific emission factors (chp. 3.2.1.1.2). For submission 2021 of the inventory, the emission factor model was completely revised for the entire time series (including projections) by Zotter and Nussbaumer (2022). It is based on a large number of air pollution control measurements, laboratory and field measurements, literature data (e.g. be-Real, emission factors in the Nordic countries) and the EMEP/EEA guidebook (EMEP/EEA 2019) and takes into account various technology standards of combustion installations and operating influences. For automatic installations >50 kW (chip boilers, combined heat and power plants, plants for renewable waste from wood products), the emission factors of NO_x, NMVOC, TSP and CO were derived based on emission factors of the different operating phases and their effective combustion heat output, taking into account typical shares of the respective phases. Emission factor values were 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. So far, Switzerland's air pollutant emission inventory includes only PM exhaust emissions from wood energy combustion.

Besides the emission factors for PM exhaust, those for PM condensable were also derived. The condensable PM fractions were estimated based on literature data of the TSP/PMexhaust ratios (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 A - 41. For information, the time series of the emission factors and the resulting emissions of PM2.5 condensable for the different installation types are given in Table A - 42 and Table A - 43, respectively.

Table A - 41 TSP/PMexhaust ratios 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">TSP/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>

Table A - 42 Emission factors of PM2.5 condensable for wood combustion installations in 1A Fuel combustion.

1A Wood combustion	1990	1995	2000	2005	2010
	g PM2.5 condensable/GJ				
Open fireplaces	360	298	235	173	120
Closed fireplaces, log wood stoves	360	293	225	158	108
Pellet stoves	NO	NO	120	90	63
Log wood hearths	540	440	340	240	180
Log wood boilers	360	285	210	135	81
Log wood dual chamber boilers	540	440	340	240	180
Automatic chip boilers < 50 kW	360	298	235	173	120
Automatic pellet boilers < 50 kW	NO	NO	23	12	4.7
Automatic chip boilers 50-300 kW w/o wood proc. companies	68	52	35	19	8.0
Automatic pellet boilers 50-300 kW	NO	NO	23	12	4.7
Automatic chip boilers 50-300 kW within wood proc. companies	68	52	35	19	8.0
Automatic chip boilers 300-500 kW w/o wood proc. companies	68	52	35	19	8.0
Automatic pellet boilers 300-500 kW	NO	NO	NO	12	4.7
Automatic chip boilers 300-500 kW within wood proc. companies	68	52	35	19	8.0
Automatic chip boilers > 500 kW w/o wood proc. companies	57	43	29	15	4.5
Automatic pellet boilers > 500 kW	NO	NO	NO	12	3.5
Automatic chip boilers > 500 kW within wood proc. companies	57	43	29	15	6.0
Combined chip heat and power plants	NO	17	11	4.6	0.61
Plants for renewable waste from wood products	45	34	23	12	3.4

1A Wood combustion	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	g PM2.5 condensable/GJ									
Open fireplaces	105	98	90	90	90	90	90	90	90	89
Closed fireplaces, log wood stoves	99	95	90	89	87	86	84	83	81	77
Pellet stoves	54	50	45	44	42	41	39	38	36	34
Log wood hearths	180	180	180	180	180	180	180	180	180	177
Log wood boilers	72	68	63	62	60	59	57	56	54	52
Log wood dual chamber boilers	180	180	180	180	180	180	180	180	180	174
Automatic chip boilers < 50 kW	105	98	90	89	87	86	84	83	81	78
Automatic pellet boilers < 50 kW	4.3	4.2	4.0	3.8	3.7	3.5	3.3	3.2	3.0	2.9
Automatic pellet boilers 50-300 kW	4.3	4.2	4.0	3.8	3.7	3.5	3.3	3.2	3.0	2.9
Automatic chip boilers 50-300 kW within wood proc. companies	7.0	6.5	6.0	5.8	5.7	5.5	5.3	5.2	5.0	4.8
Automatic chip boilers 300-500 kW w/o wood proc. companies	7.0	6.5	6.0	5.8	5.7	5.5	5.3	5.2	5.0	4.8
Automatic pellet boilers 300-500 kW	4.3	4.2	4.0	3.8	3.7	3.5	3.3	3.2	3.0	2.9
Automatic chip boilers 300-500 kW within wood proc. companies	7.0	6.5	6.0	5.8	5.7	5.5	5.3	5.2	5.0	4.8
Automatic chip boilers > 500 kW w/o wood proc. companies	2.9	2.2	1.4	1.3	1.2	1.2	1.1	0.98	0.90	0.87
Automatic pellet boilers > 500 kW	2.0	1.3	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.49
Automatic chip boilers > 500 kW within wood proc. companies	5.0	4.5	4.0	3.8	3.7	3.5	3.3	3.2	3.0	2.9
Combined chip heat and power plants	0.33	0.18	0.040	0.038	0.037	0.035	0.033	0.032	0.030	0.030
Plants for renewable waste from wood products	1.8	1.0	0.20	0.19	0.18	0.17	0.15	0.14	0.13	0.13

Table A - 43 Emissions of PM2.5 condensable from wood energy consumption in 1A Fuel combustion.

1A Wood combustion, emissions of PM2.5 condensable	1990	1995	2000	2005	2010
			t		
Total	10'635	8'099	4'932	3'285	2'050
Open fireplaces	81	80	46	31	15
Closed fireplaces, log wood stoves	2'618	2'096	1'460	1'108	920
Pellet stoves	NO	NO	0.84	4.3	9.5
Log wood hearths	4'601	3'087	1'611	965	423
Log wood boilers	1'911	1'586	1'072	723	398
Log wood dual chamber boilers	1'061	782	332	115	49
Automatic chip boilers < 50 kW	86	129	129	130	121
Automatic pellet boilers < 50 kW	NO	NO	1.3	9.4	9.8
Automatic chip boilers 50-300 kW w/o wood proc. companies	31	44	41	35	22
Automatic pellet boilers 50-300 kW	NO	NO	0.068	1.3	2.8
Automatic chip boilers 50-300 kW within wood proc. companies	61	61	43	26	12
Automatic chip boilers 300-500 kW w/o wood proc. companies	16	27	25	19	12
Automatic pellet boilers 300-500 kW	NO	NO	NO	0.20	0.91
Automatic chip boilers 300-500 kW within wood proc. companies	28	29	21	12	5.4
Automatic chip boilers > 500 kW w/o wood proc. companies	18	46	49	34	20
Automatic pellet boilers > 500 kW	NO	NO	NO	0.11	0.65
Automatic chip boilers > 500 kW within wood proc. companies	79	94	70	43	18
Combined chip heat and power plants	NO	0.051	2.0	0.58	1.7
Plants for renewable waste from wood products	44	36	31	28	10

1A Wood combustion, emissions of PM2.5 condensable	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
					t					
Total	1'565	1'573	1'136	1'199	1'224	1'140	1'021	998	890	960
Open fireplaces	8.8	8.2	5.6	5.8	6.1	6.0	5.6	5.6	5.2	5.2
Closed fireplaces, log wood stoves	771	813	614	659	684	645	582	573	516	564
Pellet stoves	8.8	9.4	7.2	7.9	8.4	7.9	7.3	7.0	6.3	6.8
Log wood hearths	282	262	176	181	179	162	143	137	122	132
Log wood boilers	275	263	178	183	182	167	148	144	125	130
Log wood dual chamber boilers	34	33	23	21	20	16	12	10	7.6	6.6
Automatic chip boilers < 50 kW	91	92	67	70	69	63	56	53	45	45
Automatic pellet boilers < 50 kW	9.3	10	8.4	9.1	9.6	9.2	8.5	8.5	7.5	8.5
Automatic chip boilers 50-300 kW w/o wood proc. companies	19	21	16	18	19	18	17	17	16	18
Automatic pellet boilers 50-300 kW	3.2	3.8	3.4	4.1	4.7	5.0	4.9	5.1	4.8	5.8
Automatic chip boilers 50-300 kW within wood proc. companies	10	10	7.7	8.2	8.4	8.2	7.6	7.3	6.8	7.4
Automatic chip boilers 300-500 kW w/o wood proc. companies	11	11	8.6	9.5	10	10	9.2	9.3	8.6	9.6
Automatic pellet boilers 300-500 kW	1.1	1.1	0.96	1.1	1.2	1.2	1.2	1.2	1.1	1.3
Automatic chip boilers 300-500 kW within wood proc. companies	4.4	4.4	3.4	3.5	3.6	3.4	3.3	3.2	3.0	3.1
Automatic chip boilers > 500 kW w/o wood proc. companies	15	13	6.9	7.6	8.1	7.7	6.9	6.8	6.2	7.1
Automatic pellet boilers > 500 kW	0.52	0.37	0.14	0.16	0.18	0.18	0.17	0.19	0.18	0.20
Automatic chip boilers > 500 kW within wood proc. companies	14	13	10	10	10	9.2	8.3	8.1	7.3	7.9
Combined chip heat and power plants	1.6	0.99	0.21	0.15	0.14	0.17	0.16	0.19	0.18	0.20
Plants for renewable waste from wood products	5.4	3.5	0.69	0.63	0.78	0.81	0.68	0.64	0.64	0.86

Annex 7 Emission time series of main air pollutants, PM2.5 and BC for 1980–2021 and 2025–2050

A7.1 Emission time series by pollutant and aggregated sectors

A7.1.1 NO_x emission time series

Table A - 44 NO_x emissions by sector. The last column in the third part of the table indicates the relative trend.

NOx	1980	1985	1990	1995	2000	2005	2010
	kt						
1	158	158	135	112	99	89	78
2	1.1	1.1	0.5	0.3	0.3	0.3	0.4
3	4.7	4.8	4.9	4.6	4.0	3.8	4.0
5	0.8	0.8	0.3	0.2	0.2	0.2	0.1
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sum	165	165	141	117	104	93	83

NOx	2012	2013	2014	2015	2016	2017	2018
	kt						
1	75	75	72	70	69	65	61
2	0.4	0.3	0.4	0.3	0.3	0.3	0.3
3	3.8	3.8	3.9	3.7	3.8	3.8	3.7
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sum	79	79	76	74	73	69	65

NOx	2019	2020	2021	2005-2021
	kt			
1	58	49	48	-46%
2	0.2	0.2	0.2	-22%
3	3.6	3.6	3.7	-4%
5	0.1	0.1	0.1	-24%
6	0.1	0.1	0.1	6%
Sum	62	53	52	-44%

NOx	2025	2030	2035	2040	2045	2050
	kt					
1	45	35	28	24	23	21
2	0.2	0.3	0.3	0.3	0.3	0.3
3	3.6	3.6	3.6	3.6	3.6	3.6
5	0.1	0.1	0.1	0.1	0.1	0.1
6	0.1	0.1	0.1	0.1	0.1	0.1
Sum	49	39	32	28	27	25

A7.1.2 NMVOC emission time series

Table A - 45 NMVOC emissions by sector. The last column in the third part of the table indicates the relative trend.

NMVOC total	1980	1985	1990	1995	2000	2005	2010
	kt						
1	153	150	126	83	63	44	31
2	140	149	150	106	75	52	48
3	14	15	15	15	15	17	19
5	3.0	2.1	1.1	1.0	1.0	1.0	1.2
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sum	311	316	292	205	154	114	99

NMVOC total	2012	2013	2014	2015	2016	2017	2018
	kt						
1	27	25	23	21	20	19	19
2	45	43	42	40	38	38	37
3	19	19	19	19	19	19	19
5	1.3	1.3	1.4	1.4	1.5	1.5	1.6
6	0.3	0.3	0.2	0.3	0.2	0.2	0.2
Sum	92	89	85	82	79	78	77

NMVOC total	2019	2020	2021	2005-2021
	kt			
1	18	16	16	-63%
2	37	37	37	-29%
3	19	19	19	12%
5	1.7	1.7	1.8	71%
6	0.2	0.2	0.2	6%
Sum	76	74	74	-35%

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
1	14	12	11	9.7	8.9	8.2
2	37	38	38	38	38	38
3	19	19	19	19	19	19
5	2.2	2.8	3.3	3.6	3.7	3.9
6	0.2	0.2	0.2	0.2	0.2	0.2
Sum	73	71	71	70	70	69

A7.1.3 SO_x emission time series

Table A - 46 SO_x emissions by sector. The last column in the third part of the table indicates the relative trend.

SOx	1980	1985	1990	1995	2000	2005	2010
	kt						
1	112	71	35	25	16	13	9.6
2	3.3	2.8	1.6	1.0	0.8	1.0	0.8
3	NA	NA	NA	NA	NA	NA	NA
5	0.2	0.2	0.2	0.1	0.1	0.1	0.1
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sum	115	74	37	26	16	14	10

SOx	2012	2013	2014	2015	2016	2017	2018
	kt						
1	7.8	7.3	6.5	4.9	4.4	4.1	3.8
2	0.8	0.6	0.6	0.6	0.8	0.8	0.9
3	NA	NA	NA	NA	NA	NA	NA
5	0.1	0.1	0.1	0.1	0.1	0.04	0.03
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sum	8.6	8.0	7.2	5.6	5.2	5.0	4.8

SOx	2019	2020	2021	2005-2021
	kt			
1	3.5	3.2	3.3	-75%
2	0.8	0.5	0.5	-55%
3	NA	NA	NA	NA
5	0.03	0.03	0.03	-54%
6	0.01	0.01	0.01	-3%
Sum	4.4	3.8	3.8	-73%

SOx	2025	2030	2035	2040	2045	2050
	kt					
1	3.0	2.9	2.8	2.7	2.6	2.5
2	0.6	0.7	0.7	0.7	0.7	0.7
3	NA	NA	NA	NA	NA	NA
5	0.03	0.03	0.03	0.03	0.03	0.03
6	0.01	0.01	0.01	0.01	0.01	0.01
Sum	3.6	3.6	3.6	3.5	3.4	3.3

A7.1.4 NH_3 emission time series

Table A - 47 NH_3 emissions by sector. The last column in the third part of the table indicates the relative trend.

NH3	1980	1985	1990	1995	2000	2005	2010
	kt						
1	0.3	0.4	1.7	2.9	5.0	3.9	2.8
2	0.6	0.5	0.4	0.3	0.4	0.4	0.2
3	61	62	65	61	54	54	53
5	2.3	1.8	0.9	0.8	0.9	0.9	0.9
6	0.8	0.8	0.8	0.8	0.9	0.9	0.9
Sum	65	66	69	65	62	60	58

NH3	2012	2013	2014	2015	2016	2017	2018
	kt						
1	2.1	1.9	1.7	1.5	1.5	1.4	1.3
2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3	52	51	52	52	51	51	51
5	0.9	0.9	0.9	0.8	0.9	0.9	0.8
6	1.0	1.0	1.0	1.1	1.0	1.0	1.0
Sum	56	55	56	55	55	55	54

NH3	2019	2020	2021	2005-2021
	kt			
1	1.3	1.2	1.2	-68%
2	0.2	0.2	0.1	-58%
3	50	50	50	-6%
5	0.9	0.9	0.9	-3%
6	1.0	1.0	1.0	14%
Sum	54	53	54	-10%

NH3	2025	2030	2035	2040	2045	2050
	kt					
1	1.2	1.2	1.1	1.1	1.0	0.9
2	0.1	0.1	0.1	0.1	0.1	0.1
3	50	49	49	49	49	49
5	1.0	1.1	1.2	1.2	1.3	1.3
6	1.0	1.0	1.0	1.0	1.0	1.0
Sum	53	53	53	53	53	53

A7.1.5 PM2.5 emission time series

Table A - 48 PM2.5 emissions by sector. The last column in the third part of the table indicates the relative trend.

PM2.5 total	1980	1985	1990	1995	2000	2005	2010
	kt						
1	12	13	13	12	9.8	8.7	7.2
2	4.5	2.7	2.6	2.0	1.5	1.5	1.5
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	2.4	1.5	0.6	0.5	0.4	0.4	0.4
6	0.004	0.004	0.004	0.004	0.004	0.005	0.005
Sum	19	17	17	14	12	11	9.2

PM2.5 total	2012	2013	2014	2015	2016	2017	2018
	kt						
1	6.1	5.9	5.1	5.0	5.0	4.9	4.6
2	1.5	1.5	1.4	1.3	1.3	1.3	1.3
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.4	0.3	0.3	0.3	0.3	0.3	0.3
6	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Sum	8.1	7.8	7.0	6.8	6.8	6.6	6.4

PM2.5 total	2019	2020	2021	2005-2021
	kt			
1	4.5	4.2	4.1	-53%
2	1.2	1.2	1.2	-14%
3	0.1	0.1	0.1	13%
5	0.3	0.3	0.3	-24%
6	0.005	0.005	0.006	28%
Sum	6.2	5.9	5.7	-46%

PM2.5 total	2025	2030	2035	2040	2045	2050
	kt					
1	4.0	3.7	3.4	3.4	3.3	3.3
2	1.3	1.4	1.4	1.4	1.4	1.4
3	0.1	0.1	0.1	0.1	0.1	0.1
5	0.3	0.2	0.2	0.2	0.2	0.1
6	0.006	0.006	0.006	0.006	0.006	0.006
Sum	5.7	5.4	5.2	5.1	5.1	5.0

A7.1.6 BC emission time series

Table A - 49 BC emissions by sector. The last column in the third part of the table indicates the relative trend.

BC total	1980	1985	1990	1995	2000	2005	2010
	kt						
1	4.7	5.4	5.7	5.1	4.1	3.5	2.6
2	0.011	0.006	0.006	0.004	0.003	0.003	0.002
3	NA	NA	NA	NA	NA	NA	NA
5	0.171	0.104	0.041	0.034	0.031	0.027	0.026
6	0.00014	0.00014	0.00015	0.00015	0.00016	0.00016	0.00016
Sum	4.9	5.5	5.7	5.1	4.1	3.5	2.6

BC total	2012	2013	2014	2015	2016	2017	2018
	kt						
1	2.0	1.8	1.5	1.4	1.4	1.2	1.2
2	0.0016	0.0016	0.0014	0.0013	0.0014	0.0014	0.0013
3	NA	NA	NA	NA	NA	NA	NA
5	0.025	0.024	0.024	0.024	0.023	0.023	0.022
6	0.00016	0.00017	0.00013	0.00015	0.00014	0.00015	0.00016
Sum	2.0	1.9	1.5	1.4	1.4	1.3	1.2

BC total	2019	2020	2021	2005-2021
	kt			
1	1.1	1.0	1.0	-72%
2	0.0013	0.0013	0.0013	-50%
3	NA	NA	NA	NA
5	0.022	0.021	0.021	-23%
6	0.00013	0.00013	0.00014	-12%
Sum	1.1	1.0	1.0	-72%

BC total	2025	2030	2035	2040	2045	2050
	kt					
1	0.8	0.6	0.5	0.5	0.4	0.4
2	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
3	NA	NA	NA	NA	NA	NA
5	0.019	0.016	0.015	0.013	0.012	0.011
6	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014
Sum	0.8	0.6	0.5	0.5	0.4	0.4

A7.2 1 Energy

A7.2.1 1 Energy: NO_x

Table A - 50 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	1980	1985	1990	1995	2000	2005	2010
	kt						
1A1	4.4	5.0	6.8	4.7	3.5	2.9	3.0
1A2	24	20	23	19	15	14	12
1A3	110	111	83	67	62	55	48
1A4	18	21	21	20	17	16	14
1A5	0.69	0.79	0.88	0.71	0.67	0.60	0.54
1B2	0.31	0.28	0.21	0.32	0.32	0.29	0.11
Sum	158	158	135	112	99	89	78

NOx	2012	2013	2014	2015	2016	2017	2018
	kt						
1A1	3.0	3.1	2.9	2.4	2.4	2.4	2.4
1A2	11	11	10	9.4	9.2	8.8	8.2
1A3	48	48	48	47	45	43	40
1A4	12	13	11	11	11	11	10
1A5	0.51	0.50	0.51	0.49	0.49	0.45	0.43
1B2	0.062	0.074	0.090	0.051	0.003	0.0023	0.0025
Sum	75	75	72	70	69	65	61

NOx	2019	2020	2021	2005-2021
	kt			
1A1	2.4	2.4	2.4	-17%
1A2	7.9	7.3	7.6	-47%
1A3	37	30	28	-49%
1A4	10	9.0	10	-40%
1A5	0.39	0.40	0.38	-37%
1B2	0.0017	0.0017	0.0014	-100%
Sum	58	49	48	-46%

NOx	2025	2030	2035	2040	2045	2050
	kt					
1A1	2.6	2.7	2.7	2.8	2.9	2.9
1A2	7.2	6.2	5.7	5.6	5.5	5.5
1A3	26	18	13	10.0	8.9	8.2
1A4	8.5	7.1	6.2	5.6	5.0	4.4
1A5	0.36	0.35	0.34	0.33	0.33	0.33
1B2	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017
Sum	45	35	28	24	23	21

A7.2.2 1 Energy: NMVOC

Table A - 51 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	1980	1985	1990	1995	2000	2005	2010
	kt						
1A1	0.60	0.60	0.30	0.24	0.23	0.22	0.20
1A2	2.3	2.3	2.4	2.4	2.3	2.1	1.6
1A3	123	116	89	50	37	23	15
1A4	14	16	17	16	13	11	8.8
1A5	0.13	0.15	0.16	0.14	0.13	0.11	0.090
1B2	13	14	17	14	9.9	7.4	5.1
Sum	153	150	126	83	63	44	31

NMVOC total	2012	2013	2014	2015	2016	2017	2018
	kt						
1A1	0.18	0.17	0.16	0.16	0.17	0.17	0.18
1A2	1.4	1.3	1.2	1.1	1.1	1.0	1.0
1A3	13	12	11	10	9.6	9.2	8.9
1A4	7.3	7.2	5.8	5.8	5.9	5.6	5.2
1A5	0.082	0.080	0.079	0.075	0.076	0.070	0.068
1B2	4.9	4.7	4.5	4.0	3.5	3.3	3.3
Sum	27	25	23	21	20	19	19

NMVOC total	2019	2020	2021	2005-2021
	kt			
1A1	0.19	0.18	0.18	-21%
1A2	0.96	0.91	0.91	-56%
1A3	8.4	7.3	7.3	-68%
1A4	5.1	4.7	4.8	-57%
1A5	0.062	0.063	0.061	-44%
1B2	3.2	2.8	2.8	-62%
Sum	18	16	16	-63%

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.18	0.18	0.19	0.20	0.20	0.21
1A2	0.91	0.87	0.85	0.83	0.82	0.81
1A3	6.4	5.3	4.7	4.2	3.8	3.4
1A4	4.1	3.4	2.9	2.7	2.5	2.4
1A5	0.059	0.058	0.057	0.056	0.056	0.056
1B2	2.5	2.0	1.8	1.7	1.5	1.4
Sum	14	12	11	9.7	8.9	8.2

A7.2.3 1 Energy: SO_x

Table A - 52 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	1980	1985	1990	1995	2000	2005	2010
	kt						
1A1	7.4	7.0	4.2	2.8	1.8	1.7	1.7
1A2	50	22	13	8.2	4.7	4.1	2.9
1A3	6.8	5.1	4.0	2.1	1.8	0.21	0.22
1A4	47	36	13	11	6.7	6.3	4.5
1A5	0.075	0.074	0.077	0.049	0.044	0.037	0.037
1B2	1.1	0.93	0.72	0.62	0.58	0.51	0.22
Sum	112	71	35	25	16	13	10

SOx	2012	2013	2014	2015	2016	2017	2018
	kt						
1A1	1.9	1.8	2.1	0.8	0.39	0.39	0.32
1A2	2.5	2.3	2.2	2.1	2.1	2.0	2.1
1A3	0.23	0.22	0.22	0.22	0.22	0.23	0.23
1A4	3.0	2.8	1.8	1.6	1.6	1.4	1.1
1A5	0.035	0.036	0.037	0.036	0.038	0.034	0.034
1B2	0.12	0.14	0.16	0.09	0.020	0.018	0.019
Sum	7.8	7.3	6.5	4.9	4.4	4.1	3.8

SOx	2019	2020	2021	2005-2021
	kt			
1A1	0.29	0.29	0.33	-80%
1A2	1.9	1.9	1.9	-55%
1A3	0.23	0.11	0.12	-41%
1A4	1.06	0.90	0.90	-86%
1A5	0.030	0.031	0.030	-20%
1B2	0.016	0.017	0.014	-97%
Sum	3.5	3.2	3.3	-75%

SOx	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.37	0.43	0.43	0.44	0.44	0.44
1A2	1.8	1.8	1.7	1.6	1.6	1.6
1A3	0.24	0.26	0.25	0.24	0.23	0.22
1A4	0.51	0.43	0.38	0.35	0.31	0.28
1A5	0.030	0.030	0.030	0.030	0.030	0.030
1B2	0.014	0.014	0.015	0.015	0.016	0.016
Sum	3.0	2.9	2.8	2.7	2.6	2.5

A7.2.4 1 Energy: NH_3

Table A - 53 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	1980	1985	1990	1995	2000	2005	2010
	kt						
1A1	0.0048	0.0047	0.0046	0.010	0.018	0.026	0.035
1A2	0.11	0.13	0.17	0.15	0.18	0.19	0.24
1A3	0.076	0.085	1.3	2.6	4.6	3.5	2.3
1A4	0.13	0.17	0.21	0.19	0.16	0.16	0.16
1A5	0.000036	0.000036	0.000037	0.000038	0.000039	0.000039	0.000042
1B	NA	NA	NA	NA	NA	NA	NA
Sum	0.33	0.38	1.7	2.9	5.0	3.9	2.8

NH3	2012	2013	2014	2015	2016	2017	2018
	kt						
1A1	0.040	0.042	0.033	0.031	0.031	0.033	0.032
1A2	0.22	0.21	0.24	0.21	0.23	0.22	0.21
1A3	1.7	1.5	1.3	1.2	1.1	1.0	1.0
1A4	0.14	0.14	0.12	0.12	0.13	0.13	0.12
1A5	0.000041	0.000041	0.000041	0.000041	0.000041	0.000041	0.000041
1B	NA	NA	NA	NA	NA	NA	NA
Sum	2.1	1.9	1.7	1.5	1.5	1.4	1.3

NH3	2019	2020	2021	2005-2021
	kt			
1A1	0.033	0.033	0.036	38%
1A2	0.21	0.20	0.24	25%
1A3	0.9	0.81	0.85	-76%
1A4	0.12	0.13	0.11	-33%
1A5	0.000041	0.000041	0.000041	3%
1B	NA	NA	NA	NA
Sum	1.3	1.2	1.2	-68%

NH3	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.040	0.046	0.046	0.046	0.046	0.046
1A2	0.23	0.22	0.21	0.21	0.20	0.20
1A3	0.86	0.83	0.80	0.74	0.67	0.58
1A4	0.10	0.10	0.09	0.088	0.085	0.083
1A5	0.000041	0.000040	0.000040	0.000039	0.000039	0.000039
1B	NA	NA	NA	NA	NA	NA
Sum	1.2	1.2	1.1	1.1	1.00	0.91

A7.2.5 1 Energy: PM2.5

Table A - 54 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	1980	1985	1990	1995	2000	2005	2010
	kt						
1A1	1.1	1.0	0.82	0.55	0.34	0.18	0.19
1A2	2.5	2.1	2.0	1.9	1.7	1.5	1.1
1A3	3.9	4.0	3.7	3.4	3.3	2.8	2.3
1A4	4.8	5.9	6.7	5.9	4.5	4.1	3.6
1A5	0.096	0.094	0.087	0.063	0.062	0.057	0.050
1B1	0.00016	0.00023	0.00016	0.000086	0.000063	0.000070	0.000074
1B2	0.00064	0.00059	0.00044	0.00065	0.00065	0.00059	0.00024
Sum	12	13	13	12	9.8	8.7	7.2

PM2.5	2012	2013	2014	2015	2016	2017	2018
	kt						
1A1	0.2	0.2	0.15	0.09	0.07	0.07	0.06
1A2	0.9	0.8	0.7	0.7	0.7	0.7	0.7
1A3	2.0	1.9	1.8	1.8	1.7	1.6	1.6
1A4	3.0	2.9	2.4	2.4	2.5	2.4	2.2
1A5	0.048	0.048	0.047	0.046	0.046	0.046	0.045
1B1	0.00006	0.00007	0.00007	0.000064	0.000059	0.000057	0.000053
1B2	0.00013	0.00015	0.00018	0.00010	0.0000058	0.0000048	0.0000049
Sum	6	6	5.1	5.0	5.0	4.9	4.6

PM2.5	2019	2020	2021	2005-2021
	kt			
1A1	0.065	0.060	0.062	-66%
1A2	0.64	0.62	0.64	-58%
1A3	1.6	1.4	1.4	-51%
1A4	2.2	2.1	1.9	-53%
1A5	0.045	0.045	0.045	-21%
1B1	0.000047	0.000045	0.000046	-34%
1B2	0.0000031	0.0000036	0.0000027	-100%
Sum	4.5	4.2	4.1	-53%

PM2.5	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.066	0.071	0.072	0.073	0.074	0.075
1A2	0.61	0.58	0.54	0.55	0.55	0.55
1A3	1.5	1.5	1.5	1.5	1.5	1.5
1A4	1.7	1.5	1.3	1.2	1.2	1.1
1A5	0.044	0.044	0.044	0.043	0.043	0.043
1B1	0.000047	0.000048	0.000046	0.000044	0.000042	0.000040
1B2	0.0000028	0.0000028	0.0000029	0.0000030	0.0000031	0.0000032
Sum	4.0	3.7	3.4	3.4	3.3	3.3

A7.2.6 1 Energy: BC

Table A - 55 BC 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.

BC	1980	1985	1990	1995	2000	2005	2010
	kt						
1A1	0.044	0.044	0.038	0.024	0.016	0.016	0.016
1A2	0.43	0.43	0.42	0.45	0.41	0.32	0.14
1A3	1.7	1.6	1.4	1.4	1.3	1.2	0.88
1A4	2.5	3.3	3.8	3.2	2.3	1.9	1.5
1A5	0.030	0.029	0.026	0.014	0.013	0.0099	0.0058
1B1	0.000094	0.000141	0.000096	0.000051	0.000038	0.000042	0.000045
1B2	0.00015	0.00014	0.00011	0.00016	0.00016	0.00014	0.000057
Sum	4.7	5.4	5.7	5.1	4.1	3.5	2.6

BC	2012	2013	2014	2015	2016	2017	2018
	kt						
1A1	0.015	0.013	0.013	0.009	0.008	0.008	0.008
1A2	0.10	0.09	0.07	0.07	0.06	0.06	0.05
1A3	0.68	0.59	0.53	0.45	0.39	0.33	0.33
1A4	1.2	1.1	0.86	0.89	0.90	0.85	0.77
1A5	0.0048	0.0044	0.0042	0.0038	0.0038	0.0035	0.0034
1B1	0.000037	0.000040	0.000042	0.000038	0.000036	0.000034	0.000032
1B2	0.000031	0.000037	0.000044	0.000025	0.0000014	0.0000011	0.0000012
Sum	2.0	1.8	1.5	1.4	1.4	1.2	1.2

BC	2019	2020	2021	2005-2021
	kt			
1A1	0.0098	0.0077	0.0073	-53%
1A2	0.048	0.044	0.040	-87%
1A3	0.29	0.24	0.22	-82%
1A4	0.75	0.69	0.71	-63%
1A5	0.0031	0.0032	0.0031	-69%
1B1	0.000028	0.000027	0.000027	-34%
1B2	0.00000076	0.00000086	0.00000065	-100%
Sum	1.1	1.0	0.98	-72%

BC	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.0076	0.0079	0.0080	0.0082	0.0083	0.0084
1A2	0.025	0.016	0.013	0.013	0.013	0.013
1A3	0.20	0.17	0.15	0.15	0.14	0.14
1A4	0.57	0.42	0.32	0.28	0.25	0.23
1A5	0.0029	0.0028	0.0027	0.0025	0.0025	0.0025
1B1	0.000028	0.000029	0.000027	0.000026	0.000025	0.000024
1B2	0.00000066	0.00000068	0.00000070	0.00000072	0.00000074	0.00000076
Sum	0.81	0.62	0.49	0.45	0.42	0.39

A7.3 2 Industrial processes and product use

A7.3.1 2 Industrial processes and product use: NO_x

Table A - 56 NO_x emissions from sector 2 Industrial processes and product use by source categories 2A-2C, 2G and 2H. The last column in the third part of the table indicates the relative trend.

NOx	1980	1985	1990	1995	2000	2005	2010
	kt						
2A	0.014	0.014	0.018	0.014	0.013	0.013	0.014
2B	0.75	0.77	0.092	0.083	0.086	0.077	0.084
2C	0.24	0.24	0.26	0.15	0.15	0.17	0.17
2G	0.028	0.029	0.029	0.029	0.028	0.024	0.023
2H	0.091	0.090	0.091	0.046	0.065	0.028	0.084
Sum	1.1	1.1	0.49	0.32	0.35	0.32	0.38

NOx	2012	2013	2014	2015	2016	2017	2018
	kt						
2A	0.013	0.013	0.013	0.012	0.012	0.012	0.012
2B	0.075	0.055	0.065	0.042	0.059	0.065	0.031
2C	0.18	0.17	0.19	0.18	0.18	0.18	0.18
2G	0.023	0.022	0.020	0.019	0.020	0.020	0.019
2H	0.079	0.078	0.075	0.074	0.023	0.025	0.028
Sum	0.37	0.34	0.36	0.33	0.29	0.30	0.27

NOx	2019	2020	2021	2005-2021
	kt			
2A	0.012	0.011	0.011	-16%
2B	0.020	0.018	0.013	-83%
2C	0.16	0.16	0.18	5%
2G	0.018	0.019	0.019	-23%
2H	0.023	0.022	0.021	-23%
Sum	0.23	0.23	0.25	-22%

NOx	2025	2030	2035	2040	2045	2050
	kt					
2A	0.012	0.012	0.012	0.012	0.012	0.012
2B	0.00068	0.00066	0.00066	0.00066	0.00066	0.00066
2C	0.18	0.18	0.18	0.18	0.18	0.18
2G	0.019	0.019	0.019	0.019	0.019	0.019
2H	0.035	0.053	0.070	0.070	0.070	0.070
Sum	0.25	0.26	0.28	0.28	0.28	0.28

A7.3.2 2 Industrial processes and product use: NMVOC

Table A - 57 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	1980	1985	1990	1995	2000	2005	2010
	kt						
2A	0.037	0.037	0.047	0.037	0.032	0.035	0.037
2B	0.96	0.89	0.61	0.18	0.025	0.028	0.037
2C	0.99	0.40	1.11	0.76	0.71	0.45	0.35
2D	136	145	123	88	63	41	38
2G	0.19	0.25	22	14	8.2	7.6	6.9
2H	2.4	2.4	2.7	2.6	2.4	2.4	2.5
Sum	140	149	150	106	75	52	48

NMVOC total	2012	2013	2014	2015	2016	2017	2018
	kt						
2A	0.033	0.033	0.033	0.030	0.031	0.031	0.031
2B	0.027	0.025	0.023	0.020	0.016	0.013	0.015
2C	0.32	0.31	0.31	0.29	0.27	0.28	0.28
2D	35	34	32	30	29	29	28
2G	6.8	6.8	6.7	6.6	6.5	6.4	6.3
2H	2.5	2.4	2.4	2.4	2.3	2.3	2.3
Sum	45	43	42	40	38	38	37

NMVOC total	2019	2020	2021	2005-2021
	kt			
2A	0.030	0.029	0.030	-15%
2B	0.016	0.015	0.016	-44%
2C	0.22	0.20	0.22	-51%
2D	28	28	28	-32%
2G	6.3	6.3	6.3	-17%
2H	2.3	2.2	2.3	-4%
Sum	37	37	37	-29%

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
2A	0.031	0.031	0.031	0.031	0.031	0.031
2B	0.017	0.020	0.022	0.022	0.022	0.022
2C	0.22	0.22	0.22	0.22	0.22	0.22
2D	28	28	28	28	28	28
2G	6.3	6.4	6.5	6.5	6.5	6.5
2H	2.6	2.7	2.8	2.9	3.0	3.0
Sum	37	38	38	38	38	38

A7.3.3 2 Industrial processes and product use: SO_x

Table A - 58 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	1980	1985	1990	1995	2000	2005	2010
	kt						
2A	0.00062	0.00061	0.00078	0.00061	0.00054	0.00058	0.00061
2B	1.9	1.7	0.79	0.71	0.47	0.65	0.77
2C	1.4	1.0	0.84	0.24	0.30	0.37	0.017
2G	0.0021	0.0027	0.0034	0.0042	0.0062	0.0056	0.0069
2H	0.00130	0.00128	0.00130	0.00066	0.00093	0.00040	0.00120
Sum	3.3	2.8	1.6	0.95	0.78	1.0	0.80

SOx	2012	2013	2014	2015	2016	2017	2018
	kt						
2A	0.00056	0.00055	0.00055	0.00050	0.00052	0.00051	0.00051
2B	0.74	0.56	0.59	0.62	0.73	0.81	0.89
2C	0.018	0.017	0.018	0.018	0.017	0.018	0.018
2G	0.0079	0.0095	0.0074	0.0066	0.0050	0.0071	0.0075
2H	0.0011	0.0011	0.0011	0.0011	0.00033	0.00036	0.00040
Sum	0.77	0.59	0.62	0.65	0.76	0.83	0.91

SOx	2019	2020	2021	2005-2021
	kt			
2A	0.00051	0.00049	0.00049	-15%
2B	0.79	0.50	0.44	-32%
2C	0.016	0.016	0.018	-95%
2G	0.0041	0.0043	0.0043	-23%
2H	0.00034	0.00032	0.00030	-23%
Sum	0.81	0.52	0.47	-55%

SOx	2025	2030	2035	2040	2045	2050
	kt					
2A	0.00052	0.00052	0.00052	0.00052	0.00052	0.00051
2B	0.53	0.64	0.70	0.70	0.70	0.70
2C	0.018	0.018	0.018	0.018	0.018	0.018
2G	0.0054	0.0068	0.0082	0.0082	0.0082	0.0082
2H	0.00050	0.00075	0.0010	0.0010	0.0010	0.0010
Sum	0.55	0.67	0.73	0.73	0.73	0.73

A7.3.4 2 Industrial processes and product use: NH_3

Table A - 59 NH_3 emissions from sector 2 Industrial processes and product use by source categories 2B-2C, 2G-2H and 2L. The last column in the third part of the table indicates the relative trend.

NH3	1980	1985	1990	1995	2000	2005	2010
	kt						
2B	0.34	0.17	0.0085	0.0057	0.0058	0.0042	0.0050
2C	0.027	0.023	0.021	0.017	0.017	0.013	0.012
2G	0.15	0.16	0.20	0.20	0.24	0.24	0.094
2H	0.055	0.10	0.13	0.097	0.13	0.094	0.095
2L	0.0018	0.0020	0.0024	0.0024	0.0026	0.0026	0.0027
Sum	0.58	0.46	0.37	0.32	0.39	0.35	0.21

NH3	2012	2013	2014	2015	2016	2017	2018
	kt						
2B	0.0044	0.0035	0.0037	0.0050	0.0057	0.0054	0.0018
2C	0.012	0.011	0.011	0.011	0.011	0.011	0.011
2G	0.086	0.071	0.067	0.060	0.064	0.067	0.077
2H	0.11	0.088	0.12	0.088	0.077	0.093	0.074
2L	0.0030	0.0032	0.0033	0.0035	0.0035	0.0036	0.0036
Sum	0.21	0.17	0.20	0.16	0.16	0.18	0.16

NH3	2019	2020	2021	2005-2021
	kt			
2B	0.0000047	0.00000069	0.00000054	-100%
2C	0.010	0.010	0.010	-23%
2G	0.079	0.075	0.081	-66%
2H	0.078	0.062	0.052	-44%
2L	0.0037	0.0037	0.0038	42%
Sum	0.17	0.15	0.14	-59%

NH3	2025	2030	2035	2040	2045	2050
	kt					
2B	0.0000012	0.0000020	0.0000028	0.0000028	0.0000028	0.0000028
2C	0.010	0.010	0.010	0.010	0.010	0.010
2G	0.069	0.067	0.066	0.064	0.063	0.062
2H	0.061	0.046	0.030	0.030	0.030	0.030
2L	0.0040	0.0042	0.0044	0.0044	0.0044	0.0044
Sum	0.14	0.12	0.10	0.10	0.10	0.10

A7.3.5 2 Industrial processes and product use: PM2.5

Table A - 60 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	1980	1985	1990	1995	2000	2005	2010
	kt						
2A	0.33	0.35	0.43	0.39	0.37	0.41	0.44
2B	0.16	0.15	0.069	0.058	0.033	0.040	0.039
2C	2.5	1.0	0.90	0.56	0.051	0.055	0.014
2D	0.021	0.012	0.016	0.015	0.0069	0.0024	0.0033
2G	0.47	0.50	0.51	0.52	0.55	0.48	0.49
2H	0.83	0.47	0.44	0.39	0.40	0.41	0.44
2I	0.23	0.20	0.22	0.12	0.090	0.063	0.057
Sum	4.5	2.7	2.6	2.0	1.5	1.5	1.5

PM2.5	2012	2013	2014	2015	2016	2017	2018
	kt						
2A	0.42	0.43	0.42	0.39	0.40	0.40	0.39
2B	0.037	0.031	0.033	0.029	0.031	0.029	0.029
2C	0.012	0.012	0.013	0.012	0.012	0.012	0.012
2D	0.0037	0.0037	0.0037	0.0037	0.0037	0.0038	0.0038
2G	0.52	0.54	0.45	0.42	0.40	0.44	0.44
2H	0.42	0.40	0.43	0.41	0.39	0.41	0.39
2I	0.045	0.042	0.047	0.046	0.046	0.043	0.044
Sum	1.5	1.5	1.4	1.3	1.3	1.3	1.3

PM2.5	2019	2020	2021	2005-2021
	kt			
2A	0.41	0.40	0.40	-3%
2B	0.023	0.030	0.038	-3%
2C	0.010	0.010	0.011	-80%
2D	0.0038	0.0038	0.0038	57%
2G	0.36	0.38	0.37	-23%
2H	0.38	0.35	0.37	-8%
2I	0.044	0.046	0.049	-22%
Sum	1.2	1.2	1.2	-14%

PM2.5	2025	2030	2035	2040	2045	2050
	kt					
2A	0.41	0.40	0.40	0.40	0.40	0.40
2B	0.039	0.038	0.033	0.033	0.033	0.033
2C	0.011	0.011	0.011	0.011	0.011	0.011
2D	0.0038	0.0039	0.0041	0.0042	0.0043	0.0044
2G	0.39	0.42	0.45	0.45	0.45	0.45
2H	0.43	0.44	0.46	0.47	0.47	0.48
2I	0.047	0.045	0.045	0.045	0.045	0.045
Sum	1.3	1.4	1.4	1.4	1.4	1.4

A7.3.6 2 Industrial processes and product use: BC

Table A - 61 BC emissions from sector 2 Industrial processes and product use by source categories 2A, 2C-2D and 2G. The last column in the third part of the table indicates the relative trend.

BC	1980	1985	1990	1995	2000	2005	2010
	t						
2A	0.060	0.059	0.076	0.059	0.051	0.055	0.058
2C	9.2	4.1	4.2	2.0	0.76	0.96	0.029
2D	0.0021	0.0012	0.00040	0.00036	0.00033	0.00024	0.00033
2G	1.9	2.0	2.0	1.9	1.9	1.6	1.5
Sum	11	6.2	6.3	4.0	2.7	2.6	1.6

BC	2012	2013	2014	2015	2016	2017	2018
	t						
2A	0.053	0.054	0.055	0.050	0.052	0.052	0.051
2C	0.029	0.028	0.030	0.030	0.028	0.029	0.029
2D	0.00037	0.00037	0.00037	0.00037	0.00037	0.00038	0.00038
2G	1.5	1.5	1.3	1.2	1.3	1.3	1.3
Sum	1.6	1.6	1.4	1.3	1.4	1.4	1.3

BC	2019	2020	2021	2005-2021
	t			
2A	0.051	0.049	0.051	-6%
2C	0.025	0.025	0.029	-97%
2D	0.00038	0.00038	0.00038	57%
2G	1.2	1.3	1.2	-23%
Sum	1.3	1.3	1.3	-50%

BC	2025	2030	2035	2040	2045	2050
	t					
2A	0.052	0.052	0.052	0.052	0.052	0.052
2C	0.029	0.028	0.029	0.029	0.029	0.029
2D	0.00038	0.00039	0.00041	0.00042	0.00043	0.00044
2G	1.2	1.2	1.2	1.2	1.2	1.2
Sum	1.3	1.3	1.3	1.3	1.3	1.3

A7.4 3 Agriculture

A7.4.1 3 Agriculture: NO_x

Table A - 62 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	1980	1985	1990	1995	2000	2005	2010
	kt						
3B	1.3	1.3	1.3	1.2	1.0	0.97	0.99
3D	3.4	3.5	3.6	3.3	3.0	2.9	3.0
Sum	4.7	4.8	4.9	4.6	4.0	3.8	4.0

NOx	2012	2013	2014	2015	2016	2017	2018
	kt						
3B	0.96	0.95	0.95	0.93	0.93	0.92	0.91
3D	2.8	2.8	2.9	2.8	2.9	2.9	2.8
Sum	3.8	3.8	3.9	3.7	3.8	3.8	3.7

NOx	2019	2020	2021	2005-2021
	kt			
3B	0.90	0.89	0.89	-8%
3D	2.7	2.7	2.8	-2%
Sum	3.6	3.6	3.7	-4%

NOx	2025	2030	2035	2040	2045	2050
	kt					
3B	0.88	0.88	0.88	0.88	0.88	0.88
3D	2.7	2.7	2.7	2.7	2.7	2.7
Sum	3.6	3.6	3.6	3.6	3.6	3.6

A7.4.2 3 Agriculture: NMVOC

Table A - 63 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	1980	1985	1990	1995	2000	2005	2010
	kt						
3B	13	14	15	15	15	17	18
3D	0.54	0.50	0.48	0.48	0.47	0.47	0.46
Sum	14	15	15	15	15	17	19

NMVOC total	2012	2013	2014	2015	2016	2017	2018
	kt						
3B	18	18	19	19	19	19	19
3D	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Sum	19	19	19	19	19	19	19

NMVOC total	2019	2020	2021	2005-2021
	kt			
3B	19	19	19	13%
3D	0.46	0.45	0.45	-3%
Sum	19	19	19	12%

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
3B	18	18	18	18	18	18
3D	0.45	0.45	0.45	0.45	0.45	0.45
Sum	19	19	19	19	19	19

A7.4.3 3 Agriculture: SO_x

There are no SO_x emissions from sector 3 Agriculture.

A7.4.4 3 Agriculture: NH_3

Table A - 64 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	1980	1985	1990	1995	2000	2005	2010
	kt						
3B	23	23	24	23	25	26	26
3D	38	39	41	37	30	28	27
Sum	61	62	65	61	54	54	53

NH3	2012	2013	2014	2015	2016	2017	2018
	kt						
3B	25	25	26	26	26	25	25
3D	26	26	26	26	26	26	26
Sum	52	51	52	52	51	51	51

NH3	2019	2020	2021	2005-2021
	kt			
3B	25	25	25	-4%
3D	25	25	25	-8%
Sum	50	50	50	-6%

NH3	2025	2030	2035	2040	2045	2050
	kt					
3B	25	25	25	25	25	25
3D	25	25	25	25	25	25
Sum	50	49	49	49	49	49

A7.4.5 3 Agriculture: PM2.5

Table A - 65 PM2.5 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.

PM2.5	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**
	kt						
3B	0.067	0.069	0.074	0.074	0.076	0.082	0.089
3D	0.052	0.049	0.048	0.048	0.047	0.047	0.046
Sum	0.12	0.12	0.12	0.12	0.12	0.13	0.13

PM2.5	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
	kt						
3B	0.090	0.091	0.093	0.094	0.096	0.095	0.097
3D	0.046	0.046	0.046	0.046	0.045	0.045	0.045
Sum	0.14	0.14	0.14	0.14	0.14	0.14	0.14

PM2.5	**2019**	**2020**	**2021**	**2005-2021**
	kt			
3B	0.097	0.099	0.100	22%
3D	0.045	0.045	0.045	-4%
Sum	0.14	0.14	0.14	13%

PM2.5	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	kt					
3B	0.099	0.099	0.099	0.099	0.099	0.099
3D	0.045	0.045	0.045	0.045	0.045	0.045
Sum	0.14	0.14	0.14	0.14	0.14	0.14

A7.4.6 3 Agriculture: BC

There are no BC emissions from sector 3 Agriculture.

A7.5 5 Waste

A7.5.1 5 Waste: NO_x

Table A - 66 NO_x emissions from sector 5 Waste by source categories 5A-5D. The last column in the third part of the table indicates the relative trend.

NOx	1980	1985	1990	1995	2000	2005	2010
	kt						
5A	0.24	0.11	0.00183	0.00527	0.00559	0.00338	0.00243
5B	NA	NA	NA	0.00015	0.00043	0.00074	0.00254
5C	0.234	0.250	0.269	0.192	0.161	0.153	0.139
5D	0.29	0.48	0.026	0.020	0.013	0.0054	0.0050
Sum	0.76	0.83	0.30	0.22	0.18	0.16	0.15

NOx	2012	2013	2014	2015	2016	2017	2018
	kt						
5A	0.00179	0.00158	0.00136	0.00137	0.00137	0.00137	0.00136
5B	0.00408	0.00450	0.00457	0.00488	0.00525	0.00547	0.00566
5C	0.126	0.137	0.134	0.137	0.130	0.122	0.112
5D	0.0053	0.0053	0.0057	0.0057	0.0059	0.0060	0.0058
Sum	0.14	0.15	0.15	0.15	0.14	0.14	0.12

NOx	2019	2020	2021	2005-2021
	kt			%
5A	0.00136	0.00135	0.00131	-61%
5B	0.00585	0.00596	0.00601	708%
5C	0.112	0.112	0.110	-28%
5D	0.0059	0.0059	0.0059	10%
Sum	0.12	0.12	0.12	-24%

NOx	2025	2030	2035	2040	2045	2050
	kt					
5A	0.00117	0.00085	0.00051	0.00027	0.00011	NA
5B	0.00892	0.01255	0.01527	0.01701	0.01794	0.01883
5C	0.107	0.103	0.102	0.100	0.098	0.096
5D	0.0061	0.0064	0.0066	0.0068	0.0070	0.0072
Sum	0.12	0.12	0.12	0.12	0.12	0.12

A7.5.2 5 Waste: NMVOC

Table A - 67 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	1980	1985	1990	1995	2000	2005	2010
	kt						
5A	1.930	1.096	0.406	0.305	0.277	0.279	0.231
5B	0.04	0.09	0.15	0.20	0.28	0.32	0.54
5C	0.99	0.83	0.56	0.45	0.43	0.37	0.36
5D	0.00220	0.00328	0.00052	0.00041	0.00027	0.00011	0.00010
5E	0.022	0.029	0.028	0.045	0.060	0.060	0.060
Sum	2.99	2.05	1.15	1.01	1.05	1.04	1.19

NMVOC total	2012	2013	2014	2015	2016	2017	2018
	kt						
5A	0.211	0.202	0.194	0.185	0.177	0.169	0.160
5B	0.67	0.74	0.78	0.83	0.93	0.97	1.03
5C	0.35	0.35	0.34	0.34	0.33	0.33	0.32
5D	0.00011	0.00011	0.00012	0.00011	0.00012	0.00012	0.00012
5E	0.060	0.060	0.060	0.060	0.060	0.060	0.060
Sum	1.29	1.35	1.37	1.42	1.51	1.53	1.57

NMVOC total	2019	2020	2021	2005-2021
	kt			%
5A	0.150	0.143	0.136	-51%
5B	1.15	1.21	1.28	295%
5C	0.31	0.31	0.30	-19%
5D	0.00012	0.00012	0.00012	10%
5E	0.060	0.060	0.060	0%
Sum	1.67	1.72	1.78	71%

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
5A	0.112	0.090	0.074	0.061	0.051	0.043
5B	1.80	2.46	2.95	3.27	3.44	3.61
5C	0.27	0.23	0.21	0.19	0.17	0.15
5D	0.00012	0.00013	0.00013	0.00014	0.00014	0.00014
5E	0.060	0.060	0.060	0.060	0.060	0.060
Sum	2.24	2.83	3.29	3.58	3.72	3.86

A7.5.3 5 Waste: SO_x

Table A - 68 SO_x emissions from sector 5 Waste by source categories 5A-5D. The last column in the third part of the table indicates the relative trend.

SOx	1980	1985	1990	1995	2000	2005	2010
	kt						
5A	0.072	0.032	NA	NA	NA	NA	NA
5B	NA	NA	NA	0.000023	0.000065	0.000113	0.000385
5C	0.148	0.177	0.164	0.080	0.062	0.063	0.063
5D	0.000042	0.000079	0.000129	0.000102	0.000066	0.000027	0.000025
Sum	0.221	0.209	0.164	0.080	0.062	0.063	0.063

SOx	2012	2013	2014	2015	2016	2017	2018
	kt						
5A	NA	NA	NA	NA	NA	NA	NA
5B	0.000618	0.000682	0.000693	0.000740	0.000796	0.000829	0.000858
5C	0.056	0.066	0.066	0.069	0.057	0.044	0.030
5D	0.000027	0.000027	0.000029	0.000029	0.000030	0.000030	0.000029
Sum	0.057	0.067	0.066	0.070	0.058	0.045	0.031

SOx	2019	2020	2021	2005-2021
	kt			%
5A	NA	NA	NA	NA
5B	0.000886	0.000903	0.000910	708%
5C	0.030	0.029	0.028	-55%
5D	0.000030	0.000030	0.000030	10%
Sum	0.031	0.030	0.029	-54%

SOx	2025	2030	2035	2040	2045	2050
	kt					
5A	NA	NA	NA	NA	NA	NA
5B	0.001351	0.001902	0.002314	0.002578	0.002718	0.002854
5C	0.028	0.027	0.027	0.026	0.026	0.025
5D	0.000031	0.000032	0.000033	0.000034	0.000035	0.000036
Sum	0.029	0.029	0.029	0.029	0.029	0.028

A7.5.4 5 Waste: NH_3

Table A - 69 NH_3 emissions from sector 5 Waste by source categories 5A-5D. The last column in the third part of the table indicates the relative trend.

NH3	1980	1985	1990	1995	2000	2005	2010
	kt						
5A	0.582	0.632	0.616	0.462	0.420	0.424	0.351
5B	0.070	0.124	0.185	0.268	0.365	0.373	0.398
5C	0.020	0.022	0.024	0.021	0.021	0.025	0.028
5D	1.674	1.068	0.090	0.098	0.102	0.107	0.113
Sum	2.347	1.846	0.914	0.849	0.908	0.929	0.891

NH3	2012	2013	2014	2015	2016	2017	2018
	kt						
5A	0.320	0.307	0.295	0.281	0.268	0.256	0.242
5B	0.421	0.437	0.420	0.411	0.463	0.466	0.471
5C	0.027	0.032	0.033	0.035	0.028	0.020	0.011
5D	0.116	0.117	0.119	0.120	0.121	0.122	0.123
Sum	0.884	0.893	0.867	0.847	0.881	0.864	0.848

NH3	2019	2020	2021	2005-2021
	kt			%
5A	0.228	0.218	0.207	-51%
5B	0.526	0.530	0.555	49%
5C	0.011	0.011	0.011	-56%
5D	0.124	0.125	0.126	18%
Sum	0.890	0.884	0.899	-3.2%

NH3	2025	2030	2035	2040	2045	2050
	kt					
5A	0.169	0.136	0.112	0.093	0.078	0.065
5B	0.666	0.805	0.919	0.994	1.036	1.076
5C	0.011	0.011	0.011	0.011	0.011	0.012
5D	0.131	0.136	0.141	0.145	0.149	0.152
Sum	0.977	1.089	1.184	1.244	1.274	1.305

A7.5.5 5 Waste: PM2.5

Table A - 70 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	1980	1985	1990	1995	2000	2005	2010
	kt						
5A	1.39	0.61	0.00073	0.00211	0.00224	0.00135	0.00097
5B	NA	NA	NA	0.0000013	0.0000038	0.0000067	0.000023
5C	1.05	0.86	0.59	0.48	0.44	0.38	0.36
5E	0.0011	0.0015	0.0014	0.0015	0.0015	0.0015	0.0015
Sum	2.44	1.48	0.59	0.48	0.44	0.38	0.36

PM2.5 total	2012	2013	2014	2015	2016	2017	2018
	kt						
5A	0.00072	0.00063	0.00054	0.00055	0.00055	0.00055	0.00055
5B	0.000037	0.000040	0.000041	0.000044	0.000047	0.000049	0.000051
5C	0.35	0.34	0.33	0.33	0.33	0.31	0.31
5E	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Sum	0.35	0.35	0.34	0.34	0.33	0.32	0.31

PM2.5 total	2019	2020	2021	2005-2021
	kt			%
5A	0.00054	0.00054	0.00053	-61%
5B	0.000053	0.000054	0.000054	708%
5C	0.30	0.29	0.29	-24%
5E	0.0015	0.0015	0.0015	0%
Sum	0.30	0.29	0.29	-24%

PM2.5 total	2025	2030	2035	2040	2045	2050
	kt					
5A	0.00047	0.00034	0.00020	0.00011	0.00004	NA
5B	0.000080	0.000113	0.000137	0.000153	0.000161	0.000169
5C	0.26	0.22	0.20	0.18	0.16	0.14
5E	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Sum	0.26	0.22	0.20	0.18	0.16	0.15

A7.5.6 5 Waste: BC

Table A - 71 BC emissions from sector 5 Waste by source categories 5A-5C. The last column in the third part of the table indicates the relative trend.

BC total	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**
	kt						
5A	0.097	0.043	NA	NA	NA	NA	NA
5B	NA	NA	NA	0.00000003	0.00000010	0.00000017	0.00000057
5C	0.074	0.061	0.041	0.034	0.031	0.027	0.026
Sum	0.171	0.104	0.041	0.034	0.031	0.027	0.026

BC total	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
	kt						
5A	NA	NA	NA	NA	NA	NA	NA
5B	0.00000092	0.0000010	0.0000010	0.0000011	0.0000012	0.0000012	0.0000013
5C	0.025	0.024	0.024	0.024	0.023	0.023	0.022
Sum	0.025	0.024	0.024	0.024	0.023	0.023	0.022

BC total	**2019**	**2020**	**2021**	**2005-2021**
	kt			%
5A	NA	NA	NA	NA
5B	0.0000013	0.0000013	0.0000014	708%
5C	0.022	0.021	0.021	-23%
Sum	0.022	0.021	0.021	-23%

BC total	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	kt					
5A	NA	NA	NA	NA	NA	NA
5B	0.0000020	0.0000028	0.0000034	0.0000038	0.0000040	0.0000042
5C	0.019	0.016	0.015	0.013	0.012	0.011
Sum	0.019	0.016	0.015	0.013	0.012	0.011

A7.6 6 Other

A7.6.1 6 Other: NO_x

Table A - 72 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	1980	1985	1990	1995	2000	2005	2010
	kt						
6Ab	0.017	0.017	0.017	0.017	0.035	0.036	0.044
6Ac	0.044	0.048	0.050	0.044	0.038	0.038	0.040
6Ad	0.016	0.017	0.017	0.017	0.018	0.019	0.018
Sum	0.078	0.082	0.084	0.078	0.092	0.093	0.102

NOx	2012	2013	2014	2015	2016	2017	2018
	kt						
6Ab	0.055	0.055	0.053	0.058	0.056	0.054	0.049
6Ac	0.034	0.033	0.037	0.033	0.035	0.037	0.034
6Ad	0.019	0.020	0.016	0.017	0.016	0.017	0.018
Sum	0.108	0.108	0.106	0.108	0.107	0.108	0.102

NOx	2019	2020	2021	2005-2021
	kt			
6Ab	0.047	0.047	0.048	31%
6Ac	0.030	0.031	0.034	-9.4%
6Ad	0.015	0.015	0.017	-12%
Sum	0.093	0.093	0.099	5.9%

NOx	2025	2030	2035	2040	2045	2050
	kt					
6Ab	0.048	0.048	0.048	0.048	0.048	0.048
6Ac	0.031	0.030	0.030	0.030	0.030	0.030
6Ad	0.017	0.017	0.017	0.017	0.017	0.017
Sum	0.096	0.095	0.095	0.095	0.095	0.095

A7.6.2 6 Other: NMVOC

Table A - 73 NMVOC emissions from sector 6 Other by source category 6Ab and 6Ad. The last column in the third part of the table indicates the relative trend.

NMVOC total	1980	1985	1990	1995	2000	2005	2010
	kt						
6Ab	0.064	0.063	0.058	0.050	0.063	0.070	0.091
6Ad	0.129	0.129	0.132	0.133	0.140	0.147	0.142
Sum	0.193	0.192	0.190	0.183	0.203	0.217	0.233

NMVOC total	2012	2013	2014	2015	2016	2017	2018
	kt						
6Ab	0.110	0.114	0.110	0.125	0.123	0.119	0.101
6Ad	0.146	0.154	0.120	0.131	0.124	0.130	0.141
Sum	0.256	0.268	0.230	0.256	0.247	0.249	0.242

NMVOC total	2019	2020	2021	2005-2021
	kt			
6Ab	0.100	0.101	0.102	46%
6Ad	0.114	0.113	0.128	-13%
Sum	0.215	0.214	0.230	6.2%

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
6Ab	0.104	0.104	0.104	0.104	0.104	0.104
6Ad	0.128	0.128	0.128	0.128	0.128	0.128
Sum	0.232	0.232	0.232	0.232	0.232	0.232

A7.6.3 6 Other: SO_x

Table A - 74 SO_x emissions from sector 6 Other by source category 6Ad. The last column in the third part of the table indicates the relative trend.

SOx	1980	1985	1990	1995	2000	2005	2010
	kt						
6Ad	0.0097	0.0101	0.0106	0.0109	0.0116	0.0123	0.0122
Sum	0.0097	0.0101	0.0106	0.0109	0.0116	0.0123	0.0122

SOx	2012	2013	2014	2015	2016	2017	2018
	kt						
6Ad	0.0126	0.0131	0.0111	0.0118	0.0115	0.0119	0.0125
Sum	0.0126	0.0131	0.0111	0.0118	0.0115	0.0119	0.0125

SOx	2019	2020	2021	2005-2021
	kt			
6Ad	0.0110	0.0109	0.0119	-3.3%
Sum	0.0110	0.0109	0.0119	-3.3%

SOx	2025	2030	2035	2040	2045	2050
	kt					
6Ad	0.0119	0.0119	0.0119	0.0119	0.0119	0.0119
Sum	0.0119	0.0119	0.0119	0.0119	0.0119	0.0119

A7.6.4 6 Other: NH_3

Table A - 75 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	1980	1985	1990	1995	2000	2005	2010
	kt						
6Aa	0.11	0.11	0.12	0.12	0.13	0.13	0.14
6Ab	0.51	0.51	0.55	0.53	0.69	0.64	0.66
6Ac	0.14	0.16	0.18	0.14	0.11	0.10	0.12
Sum	0.76	0.78	0.85	0.79	0.92	0.88	0.92

NH3	2012	2013	2014	2015	2016	2017	2018
	kt						
6Aa	0.14	0.14	0.14	0.15	0.15	0.15	0.15
6Ab	0.76	0.76	0.76	0.80	0.78	0.76	0.71
6Ac	0.10	0.10	0.12	0.11	0.11	0.12	0.11
Sum	0.99	1.01	1.02	1.05	1.04	1.03	0.97

NH3	2019	2020	2021	2005-2021
	kt			
6Aa	0.15	0.15	0.15	17%
6Ab	0.70	0.70	0.73	14%
6Ac	0.10	0.10	0.11	5.8%
Sum	0.95	0.96	0.99	14%

NH3	2025	2030	2035	2040	2045	2050
	kt					
6Aa	0.16	0.17	0.17	0.18	0.18	0.18
6Ab	0.74	0.73	0.73	0.73	0.73	0.73
6Ac	0.10	0.10	0.10	0.10	0.10	0.10
Sum	0.99	1.00	1.00	1.01	1.01	1.02

A7.6.5 6 Other: PM2.5

Table A - 76 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	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**
	kt						
6Ab	0.0023	0.0023	0.0021	0.0017	0.0019	0.0022	0.0030
6Ad	0.0020	0.0020	0.0021	0.0021	0.0022	0.0023	0.0023
Sum	0.0043	0.0043	0.0042	0.0038	0.0042	0.0045	0.0053

PM2.5	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
	kt						
6Ab	0.0036	0.0038	0.0036	0.0042	0.0041	0.0040	0.0036
6Ad	0.0023	0.0024	0.0019	0.0021	0.0020	0.0021	0.0022
Sum	0.0059	0.0062	0.0056	0.0063	0.0061	0.0061	0.0059

PM2.5	**2019**	**2020**	**2021**	**2005-2021**
	kt			
6Ab	0.0036	0.0037	0.0037	70%
6Ad	0.0018	0.0018	0.0021	-12%
Sum	0.0055	0.0055	0.0058	28%

PM2.5	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	kt					
6Ab	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
6Ad	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
Sum	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059

A7.6.6 6 Other: BC

Table A - 77 BC emissions from sector 6 Other by source categories 6Ad. The last column in the third part of the table indicates the relative trend.

BC	1980	1985	1990	1995	2000	2005	2010
	kt						
6Ad	0.00014	0.00014	0.00015	0.00015	0.00016	0.00016	0.00016
Sum	0.00014	0.00014	0.00015	0.00015	0.00016	0.00016	0.00016

BC	2012	2013	2014	2015	2016	2017	2018
	kt						
6Ad	0.00016	0.00017	0.00013	0.00015	0.00014	0.00015	0.00016
Sum	0.00016	0.00017	0.00013	0.00015	0.00014	0.00015	0.00016

BC	2019	2020	2021	2005-2021
	kt			
6Ad	0.00013	0.00013	0.00014	-12%
Sum	0.00013	0.00013	0.00014	-12%

BC	2025	2030	2035	2040	2045	2050
	kt					
6Ad	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014
Sum	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014