Switzerland’s Informative Inventory Report 2021 (IIR)

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

Submission of March 2021
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 2021

Switzerland’s Informative Inventory Report 2021

Submission of March 2021
to the United Nations ECE Secretariat

Authors / Responsibilities

Federal Office for the Environment (FOEN)
Air Pollution Control and Chemicals Division
Industry and Combustion Section

Anouk Aimée Bass	Project leader, Energy
Rainer Kegel	Waste, Other
Daiana Leuenberger	Waste, Other
Beat Müller	Head of section
Sabine Schenker	IPPU, Agriculture

With contributions of Richard Ballaman and Harald Menzi, Air Quality Management Section

In collaboration with
Meteotest (Beat Rihm, Dominik Eggli, Pascal Graf) and
INFRAS (Felix Weber)

Table of contents

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
CHP	Combined Heat and Power production
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CRF	Common Reporting Format (UNFCCC)
CSS	Mix of special waste with saw dust; used as fuel in cement kilns
DDPS	Federal Department of Defense, Civil Protection and Sport
DETEC	Department of the Environment, Transport, Energy and Communications
DPF	Diesel Particle Filter
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
IcdP	Indeno(1,2,3-cd)pyrene (CLRTAP: POP)
FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2013 Agroscope)
FCA	Federal Customs Administration

FEDRO	Swiss Federal Roads Office
FOCA	Federal Office of Civil Aviation
FOEN	Federal Office for the Environment (former name SAEFL until 2005)
FSKB	Fachverband der Schweizerischen Kies- und Betonindustrie
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
INFRAS	Research and consulting company, Zurich (authors of IIR)
IPCC	Intergovernmental Panel on Climate Change
IIR	Informative Inventory Report (CLRTAP)
ICAO	International Civil Aviation Organization
I-Teq	International Toxic equivalent
kha	Kilo hectare
kt	Kilo tonne (1000 tonnes)
LPG	Liquefied Petroleum Gas (Propane/Butane)
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
MSW	Municipal Solid Waste
NCV	Net Calorific Value
NFR	Nomenclature For Reporting
NH_3	Ammonia
NIR	National Inventory Report
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
SGCI/SSCI	Schweiz. Gesellschaft für Chemische Industrie / Swiss Society of Chemical Industries
SO_x, SO_2	Sulphur Oxides (sum of SO_2 and SO_3), Sulphur dioxide
SGPV	Swiss association for cereal production
SGWA	Swiss Gas and Water Industry Association
SWISSMEM	Swiss Mechanical and Electrical Engineering Industries (Schweizer Maschinen-, Elektro- und Metallindustrie)
TAN	Total Ammonia Nitrogen
TEQ/WHO 1998-TEQ	Toxic Equivalent (unit of toxic equivalent factors for PCB’s, PCDDs, PCDFs for Humand and Wildlife. By WHO)
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
VTG	Verteidigung Luftwaffe (Swiss Air Force Administration)
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” (see chp. 9.2)
WM	Scenario “With Measures” (see chp. 9.2)
ZPK	Swiss association of pulp, paper and paperboard industry

Executive Summary

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 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 fourteenth 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 current 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 secors and source categories.

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 1990–2019 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: so-called landing and take-off (LTO) emissions of domestic and international flights are taken into account for the national total CLRTAP while emissions of international and domestic cruise flights are reported under memo items only.

Key categories, uncertainties and completeness

Key category analyses were conducted according to approaches 1 and 2. With approach 1, two level assessments were conducted for the years 2019 and 1990 and a trend assessment for 1990-2019. With approach 2, a level assessment for the year 2019 and a trend assessment for the period 1990-2019 were performed. The most relevant source categories stem from sectors 1 Energy, 2 IPPU and 3 Agriculture.

Uncertainties are evaluated on the Tier 1 level for the main pollutants (NO_x, NMVOC, SO_x, NH_3) as well as for PM2.5 and PM10. In addition, a Tier 2 approach was realised for agricultural NH_3 emissions in 2013. The uncertainty analysis has been carried out for level uncertainties 2019 and trend uncertainties 1990-2019. Level uncertainty estimations range from 7% to 75%, trend uncertainties from 1% to 14%. The level uncertainty estimations remained similar for all pollutants (change below 1 percentage point) as compared to the values of the previous submission 2020. Changes in trend uncertainties are lower than 1 percentage point for all pollutants compared to the previous submission as well.

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 2019). 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 recently that compares emissions of the previous and the last submission.

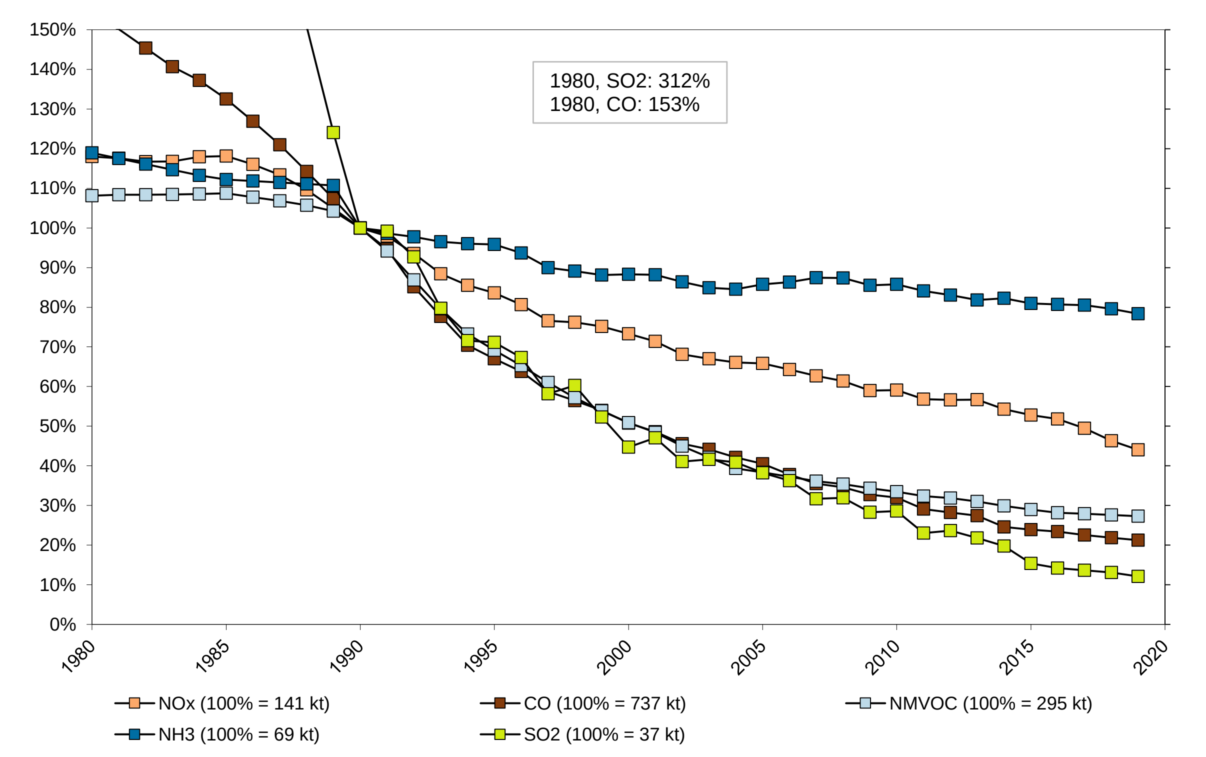
Emission trends

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 and NMVOC. Within sector 1 Energy, source category 1A3 Transport is the predominant source of all main pollutants except for SO_2 and PM2.5, where 1A2 Manufactuting industries and construction and 1A4 Other sectors, respectively, are the most important sources. Apart from NH_3, the emissions of all pollutants decreased continuously and significantly since 1990. NH_3 increased until 2000 and decreased too, since then.
- 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 PM2.5 and 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, and PM2.5. 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 occurred between 1980 and 2002, but since 2003 they remain more or less stable with some fluctuations. Emissions of NO_x on the other hand reveal a decreasing trend since 1990 (with a short period with increasing emissions between 2003 and 2008). NMVOC emissions mainly stem from 3B Manure management. Finally, the PM2.5 emissions show an increasing trend since 1996.
- 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 in memo items.
- 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 2019 (EMEP/EEA 2019), emissions from the combustion of waste-to-energy activities are therefore dealt within 1A Fuel combustion. The most important pollutants are NMVOC and NH_3. The waste sector is a relevant source of PCDD/PCDF and PCB emissions, mainly from 5C Incineration and open burning of waste. NMVOC emissions are mainly caused by 5B Biological treatment of solid waste, while NH_3 is emitted from composting activities and solid waste disposal. 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 a relevant source of heavy metals, PCDD/PCDF and PAHs as well as of PCB. Regarding the main pollutants however, emissions from sector 6 Other are minor when compared to sectors 1 to 5. Overall, emissions show more or less fluctuations without significant trends.

Emission trends 1980-2019



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 only show a slight reduction mainly due to the decrease of animal numbers and changes in agricultural production techniques. Emission trends for PM2.5 (not included in ES Figure 1.1, see Figure 2-3) reveal a significant decline between 1980 and 2019 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.

Projections for emissions until 2030

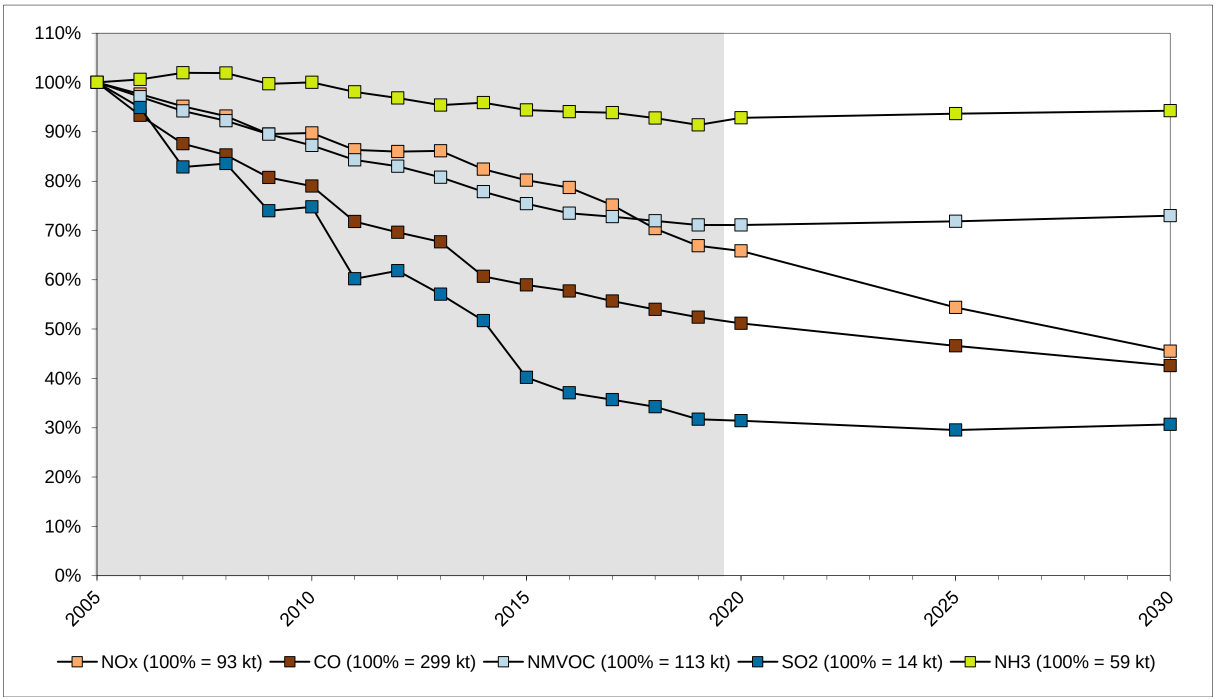
The latest full revision of the emission projections of air pollutants in Switzerland took place in the course of submission 2014. Since then, smaller changes of the projections per sector or source category have been conducted.

Two scenarios are reported: “With Measures (WM)” and “With Additional Measures (WAM)”. Both are based on the projected energy consumption of the Energy Perspectives 2050 (Prognos 2012a) and on further assumption for the activity data. Chp. 9 provides detailed assumptions for both scenarios, and the results for the WM scenario are depicted for all pollutants.

The data for the energy sector are mainly in accordance with the scenarios of the Energy Perspectives 2050 (Prognos 2012a) from 2020 onwards. For 1A3b Road transportation, more recent modelled data for the whole period is available (Prognos/INFRAS/TEP/Ecoplan 2021 and Swiss Confederation 2021).

For the sectors IPPU and Waste, the latest perspectives for Switzerland’s inhabitants are integrated (SFSO 2020p), and for the agricultural sector, independent scenarios were developed (Swiss Confederation 2017 and FOAG 2011).

ES Figure 1.2 shows the past emissions from 2005-2019 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 2005-2019 (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. For several main pollutants, a further decrease is forecast: Overall emissions of NO_x, and CO indicate a decline until 2030. A decline is also projected for SO_x emissions, however only until 2025; after that, emissions slightly start to increase again. NH_3 emissions are projected to remain stable until 2030, while NMVOC are expected to slightly increase (due to the increase of biogas production through anaerobic digestion at biogas facilities under 5B2). Forecasts for suspended primary particulate matter predict a declining trend in PM2.5 and BC emissions and a stagnation in the decline of PM10 and TSP emissions. Emissions of heavy metals are expected to stabilize (Pb) or increase (Cd, Hg) on a low level. Details regarding the projected trends of all pollutants are described in chp. 9.

Gothenburg Protocol

Under the CLRTAP, the Gothenburg Protocol requires that parties shall reduce and maintain the reduction in annual emission in accordance with national emission targets set for 2010 and 2020. 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 2019 are in compliance with the emission ceilings.

ES Table 1.1 Emission ceilings of the Gothenburg Protocol for 2010 and beyond compared to the reported emissions for 2010 and 2019 of the current submission (2021).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2021)	Compliance with emission ceilings 2010 in 2010	Emissions 2019 (Subm. 2021)	Compliance with emission ceilings 2010 in 2019
	kt	kt		kt	
SO_x	26	10	yes	4.4	yes
NO_x	79	83	no	62	yes
NMVOC	144	99	yes	81	yes
NH_3	63	59	yes	54	yes

The 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 2019. The emission reduction commitments 2020 have already been achieved for SO_x, NH_3 and PM2.5 in the year 2019 whereas for NMVOC the commitment still seems within reach for 2020. However, for NO_x, the emission reduction commitment will not be met in 2020.

ES Table 1.2 Reported emission reductions in 2019 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 2019
	%-reduction of 2005 level	
SO_x	21%	68%
NO_x	41%	33%
NMVOC	30%	29%
NH_3	8.0%	8.6%
PM2.5	26%	42%

Recalculations and improvements

For the year 2018, recalculations cause a higher emission level by at least 3% for NMVOC, BC, CO, PAH and HCB emissions. A decrease due to recalculations by at least 3% is observed for SO_x, PM2.5, PM10, Cd and PCDD/PCDF. A major recalculation stems from the revision of the country-specific emission factor model for wood energy, which was completely updated for the entire time period based on air pollution control and laboratory measurements and literature data yielding revised emission factors of all pollutants for all wood combustion installations. Amongst others, this recalculation affects several main pollutants such as NO_x, SO_x and PM2.5.

In 1990, recalculations cause an increase of more than 3% for BC emissions. A decrease by 3% or more is observed for Cd and PAH emissions.

Detailed information on recalculations is provided in chapter 8.1.

In the current submission, several improvements were conducted. Details are given in chp. 1.4.1. A number of further improvements are identified but could not yet be realised. They are documented in chp. 8.2. Switzerland prioritizes inventory improvements according to the key category analysis (KCA) and the uncertainty analysis where appropriate.

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.
- The 1998 Aarhus Protocol on Persistent Organic Pollutants.
- The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone and its amendement 2012 (national emission reduction commitments for 2020 for SO_2, NO_x, 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 2021, Switzerland provides for the fourteenth 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. However, 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) and IPCC Guidelines 2006 (IPCC 2006), 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 2021/(*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.

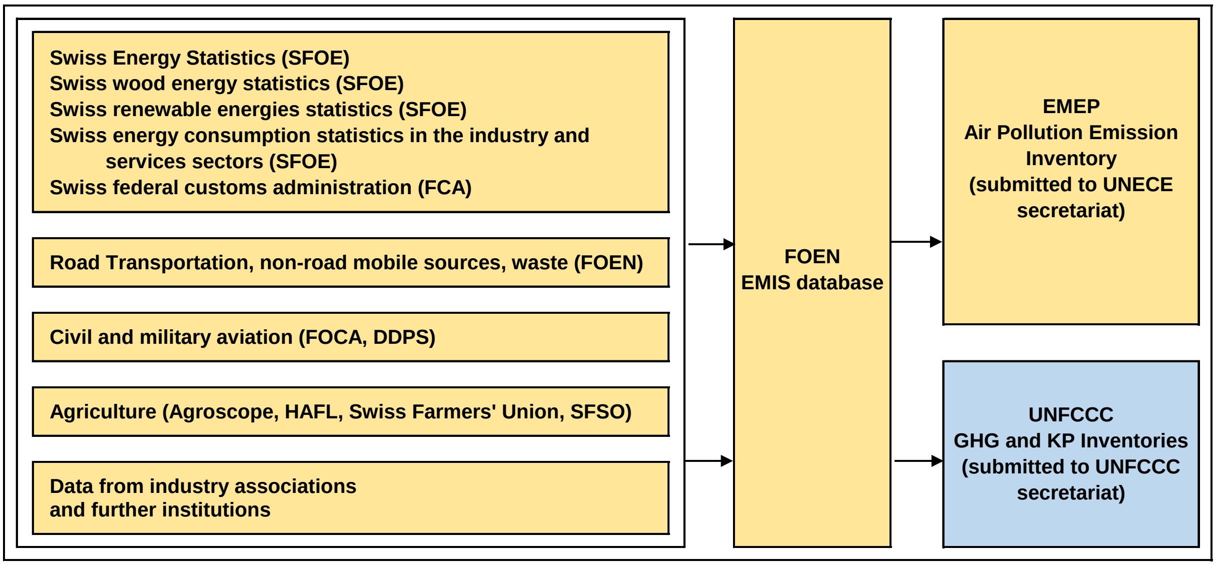


Figure 1-1: Data collection for EMIS database and CLRTAP air pollution emission inventory (GHG: Greenhouse Gas, KP: Kyoto Protocol).

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 Report (NIR, see FOEN 2021) 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 CEIP and documented on the EMEP Website (UNECE 2020). 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 current 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 2020 in chp. 8.2 (FOEN 2020b). 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:

- *General: Possibilities of adding an approach 2 uncertainty analysis in subsequent submissions are currently assessed.*
  Current state: In progress.
- *1A1a, 1A2gviii, 1A4: A revision of the country-specific emission factor model for wood energy is planned.*
  Current state: Done (see respective chapters for source categories under 1A Energy Stationary).
- *1B2ai Fugitive emissions from oil transport: Due to the fact that Switzerland uses the tier 1 NMVOC emission factor of 5.4 * 10-5 Gg per 1000 m3 oil transported by piplines as published in the IPCC Guidelines 2006 (table 4.2.4), there is an overestimation of NMVOC emissions from oil transportation. This emission factor refers to pipelines above ground as used in Noth America. As in Switzerland the pipelines for oil transportation are all under ground, there is no emission of NMVOC from this process.*
  Current state: Done (see recalculation in chp. 3.3.2.3).
- *3B: Since the data basis of the NMVOC emission factors proposed in the EMEP/EEA Guidebook 2016 (EMEP/EEA 2016) seems to be rather unclear (Bühler and Kupper 2018) a study was launched in 2018 in order to measure NMVOC emissions from dairy cattle with and without silage feeding in an experimental housing during summer, winter and transitional season.*
  Current state: In progress
- *3B, 3Da2a, 3Da3: A comparison of the country-specific tier 3 NH_3 emission factors with Tier 2 emission factors according to the EMEP/EEA Guidebook 2019 (EMEP/EEA 2019) is planned.*
  Current state: In progress
- *3B, 3Da2a, 3Da3: A new uncertainty analysis for NH_3 emissions from livestock husbandry and manure management will be conducted.*
  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 transport (see Figure 3-6 and description of system boundaries in chapter 3.1.6.1). When comparing numbers from the IIR with the NFR tables, please refer to the blue coloured line in the NFR table reporting the national compliance assessment. However, the KCA and the uncertainty analysis were carried out with emission numbers based on fuel sold.

The methods used for the NFR sectors are given in the following Table 1-1. The classification follows the EMEP/EEA Guidebook 2019 (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	T1	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 calculates emissions for various pollutants using emission factors and activity data according to the EMEP/EEA methodology. Pollutants in EMIS include NO_x, NMVOC, SO_x, NH_3, particulate matter (PM2.5, PM10, TSP and BC), CO, priority heavy metals (Pb, Cd, and Hg), POPs such as PCDD/PCDF, 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 production data and emission factors from the industry, industry associations and research institutions, as well as population, employment, waste and agriculture statistics: Input data for the EMIS database comprise 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				
13	Avernergy Suisse / Swiss Petroleum Association	Oil statistics						x	x				
	Data suppliers (sporadic updates)												
14	FOEN, Air Pollution Control	Non-road database		x	x	x	x						
15	SGWA	Gas distribution losses						x					
16	Empa	Various emission factors	x	x	x	x							
17	INFRAS	On-road emission model			x								
18	INFRAS	Non-road emission model		x	x	x	x						
19	KBP	Solvents							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, a key Category Analysis (KCA) is performed according to the methodology described in the Emission Inventory Guidebook 2019 (EMEP/EEA 2019). A key category is prioritised within the inventory system because its estimate has a significant influence on a national total. Depending on the scope of the inventory, the KCA can be performed on different levels: on the inventory total emission level, the emission trend or the emission level uncertainty.

Note that the key category analysis is performed based on the approach “fuels sold”, in the reporting tables characterized as “National total for the entire territory (based on fuel sold” (in contrast to “fuels used”; for differentiation of the two approaches see chapter 3.1.6.1).

Key category analyses were conducted according to approach 1 and 2. Approach 1 level assessments are available for the base year (1990) and the current year (2019). Approach 2 level assessments are reported for the first time and are available for the current year (2019). All level assessments were performed for all emission sources accounting for 80% of the total national emissions. Additionally, approach 1 and 2 trend assessments 1990–2019 were conducted. The following pollutants are included in these analyses: NO_x, NMVOC, SO_x, NH_3, PM2.5 and PM10.

1.5.1 KCA approach 1 results

1.5.1.1 Level key category analysis (approach 1)

The results of the approach 1 level KCA 2019 are summarized in Table 1-3, and of the level KCA 1990 in Table 1-4. The numbers show the percentage level contribution to pollutant totals and the tables are ranked per source category. The columns on the right of these two tables show the summation of percentage contributions, which provides a ranking of the source categories for all pollutants considered (main pollutants).

Table 1-3: List of Switzerland's approach 1 level key categories 2019 for the main pollutants, PM2.5 and PM10. The table shows their percentage contributions to pollutant totals and the cumulative total.

NFR Code	Key categories: % level contribution to pollutant totals 2019 (cumulative 80%)						Sum of KC % contrib.
	NO_x (as NO_2)	NMVOC	SO_x (as SO_2)	NH_3	PM2.5	PM10	
1A1a	3.4		4.8				8
1A2f	6.1		31.5				38
1A2gvii	3.4				6.4	16.5	26
1A2gviii			7.9				8
1A3ai(i)	3.6						4
1A3bi	36.4	5.9			3.3		46
1A3bii	8.8						9
1A3biii	8.1						8
1A3bv		2.5					2
1A3bvi					15.4	19.7	35
1A3c					3.7	10.5	14
1A4ai	3.9		6.4		4.9	2.3	18
1A4bi	7.8	3.3	15.9		23.2	10.7	61
1A4ci					3.4		3
1A4cii					2.9		3
1A5b						1.9	2
2A1						1.8	2
2A5a					3.6	3.1	7
2B5			15.7				16
2D3a		14.3					14
2D3b		3.5					3
2D3d		9.9					10
2D3g		4.4					4
2D3h		4.7					5
2D3i		2.6					3
2G		8.2			5.9	3.2	17
2H1					3.2		3
2H2		2.5			2.9	2.3	8
3B1a		10.2		20.2			30
3B1b		8.4		13.7			22
3B3				8.8			9
3Da1				4.6			5
3Da2a				37.2			37
3De						7.1	7
5C1a					4.0	2.0	6
cumula-tive 80%	*81.4*	*80.3*	*82.2*	*84.5*	*82.9*	*81.0*	

Table 1-4: List of Switzerland's approach 1 level key categories 1990 for the main pollutants, PM2.5 and PM10. The table contains their percentage contributions to pollutant totals and the cumulative total.

NFR Code	Key categories: % level contribution to pollutant totals 1990 (cumulative 80%)						Sum of KC % contrib.
	NO_x (as NO_2)	NMVOC	SO_x (as SO_2)	NH_3	PM2.5	PM10	
1A1a	4.4		9.8		4.7	4.1	23
1A2d			8.4				8
1A2f	7.3		9.6		2.7	3.3	23
1A2gvii	4.4				4.4	8.6	17
1A2gviii			9.0		3.2	2.2	14
1A3bi	34.1	20.8	5.1		3.9	2.5	66
1A3bii	4.3						4
1A3biii	19.4		4.4		8.9	5.8	39
1A3bv		5.3					5
1A3bvi					4.5	8.7	13
1A3c						3.9	4
1A4ai			9.3		3.0	2.1	14
1A4bi	8.0	2.9	25.1		30.9	21.4	88
1A4ci					3.3	2.1	5
1B2av		5.6					6
2C1					5.0	5.9	11
2D3a		3.0					3
2D3d		13.4					13
2D3e		3.7					4
2D3g		9.0					9
2D3h		6.7					7
2G		7.5			3.1	2.3	13
2I						3.4	3
3B1a		3.4		14.5			18
3B1b				8.1			8
3B3				9.9			10
3Da2a				49.0			49
3De						4.2	4
5C1a					2.8		3
cumula-tive 80%	*81.9*	*81.4*	*80.7*	*81.5*	*80.5*	*80.5*	

1.5.1.2 Trend key category analysis (approach 1)

The results of the approach 1 trend KCA 1990-2019 are summarized in Table 1-5. The numbers show the percentage contribution trend and the table is ranked per source category.

Table 1-5: List of Switzerland's approach 1 trend key categories 1990–2019 for the main pollutants, PM2.5 and PM10. The table contains their percentage contributions to pollutant totals and the cumulative total

NFR Code	Key categories: % contribution to trend 1990-2019 (cumulative 80%)						Sum of KC % contrib.
	NO_x (as NO_2)	NMVOC	SO_x (as SO_2)	NH_3	PM2.5	PM10	
1A1a	3.0		5.6		6.4	5.1	20
1A2d			9.4				9
1A2f	3.7		24.7		3.1	3.7	35
1A2gvii	2.9				3.2	10.6	17
1A2gviii	3.4						3
1A3ai(i)	8.5		3.8				12
1A3bi	7.0	20.2	4.1				31
1A3bii	13.6						14
1A3biii	34.5		4.6		12.0	7.0	58
1A3bv		3.8					4
1A3bvi					17.1	14.8	32
1A3c					4.2	8.8	13
1A3dii	2.8						3
1A4ai			3.3		3.1		6
1A4bi			10.4		12.1	14.3	37
1B2av		5.1					5
2A5a					3.9	2.3	6
2B5			16.4				16
2C1					7.7	7.8	15
2D3a		15.3					15
2D3b		2.5					3
2D3d		4.7					5
2D3g		6.3					6
2D3h		2.7					3
2G					4.3		4
2H1					2.7		3
2H2		2.5			2.8		5
2I						3.2	3
3B1a		9.2		16.1			25
3B1b		8.4		16.1			25
3Da1				4.6			5
3Da2a	3.0			33.7			37
3Da2b				4.8			5
3Da2c				4.6			5
3Da3				3.8			4
3De						3.9	4
cumula-tive 80%	*82.5*	*80.6*	*82.3*	*83.7*	*82.6*	*81.4*	

1.5.2 KCA approach 2 results

1.5.2.1 Level key category analysis (approach 2)

The results of the approach 2 level KCA 2019 are summarized in Table 1-6. The numbers show the percentage level contribution to pollutant totals and the tables are ranked per source category.

Table 1-6: List of Switzerland's approach 2 level key categories 2019 for the main pollutants, PM2.5 and PM10. The table contains their percentage contributions to pollutant totals and the cumulative total.

NFR Code	Key categories: % level contribution to pollutant totals 2019 (cumulative 80%)						Sum of KC % contrib.
	NO_x (as NO_2)	NMVOC	SO_x (as SO_2)	NH_3	PM2.5	PM10	
1A1a	2.5		6.4				9
1A2f	3.5		32.7				36
1A2gvii					2.9	7.3	10
1A2gviii			8.3				8
1A3ai(i)							0
1A3bi	47.9						48
1A3bii	9.5						9
1A3biii	5.0						5
1A3biv		2.6					3
1A3bvi					7.0	8.4	15
1A3c						4.5	5
1A4ai			3.6		3.4		7
1A4bi	3.6		9.3		16.0	7.0	36
2A1					4.9	3.1	8
2A5a					16.9	13.5	30
2B5			17.2				17
2B10a			4.8				5
2D3a		14.2					14
2D3d		2.5					2
2D3i		2.4					2
2G		8.3			5.5	2.8	17
2H1					5.7		6
2H2					13.0	10.3	23
2I					2.7	4.5	7
3B1a		25.7		22.3			48
3B1b		20.4		10.0			30
3B3		2.5		9.3		2.7	14
3B4gi				2.8		2.6	5
3B4gii		3.2				3.5	7
3Da1	4.0			6.5			11
3Da2a	4.2			24.7			29
3De						12.4	12
5C1a					2.1		2
6A				5.4			5
cumulative 80%	*80.1*	*81.7*	*82.2*	*81.0*	*80.2*	*82.6*	

1.5.2.2 Trend key category analysis (approach 2)

The results of the approach 2 trend KCA 1990-2019 are summarized in Table 1-7. The numbers show the percentage contribution trend and the table is ranked per source category.

Table 1-7: List of Switzerland's approach 2 trend key categories 1990–2019 for main pollutants, PM2.5 and PM10. The table contains their percentage contributions to pollutant totals and the cumulative total.

NFR Code	Key categories: % contribution to trend 1990-2019 (cumulative 80%)						Sum of KC % contrib.
	NO_x (as NO_2)	NMVOC	SO_x (as SO_2)	NH_3	PM2.5	PM10	
1A1a	2.5		7.7		4.2	3.4	18
1A2d			7.6				8
1A2f	2.5		27.1				30
1A2gvii						5.0	5
1A2gviii	2.2						2
1A3ai(i)	6.5						7
1A3bi	10.5	5.9					16
1A3bii	16.9						17
1A3biii	24.1		2.7		2.9		30
1A3bvi					7.8	6.7	15
1A3c						4.1	4
1A4bi			6.4		8.4	10.0	25
1B2aiv			3.0				3
2A1					3.4		3
2A5a					18.6	10.4	29
2B5			19.0				19
2B10a			4.5				4
2C1					8.8	9.1	18
2D3a		16.7					17
2D3g		3.6					4
2G					4.1		4
2H1					4.9		5
2H2				5.0	12.4	7.0	24
2I					5.2	14.7	20
3B1a		25.4		17.6			43
3B1b		22.6		11.6			34
3B3		2.3					2
3B4gii		4.3		3.3		4.0	12
3Da1	4.2			6.4			11
3Da2a	6.0			22.0			28
3Da2c				7.0			7
3Da3	5.6			4.0			10
3De						7.3	7
5C1biv			2.5				2
6A				5.1			5
cumulative 80%	*80.9*	*80.8*	*80.5*	*82.1*	*80.8*	*81.7*	

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 2019). 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 2021a) 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 current submission for the base year and the latest common year. In addition, the time-series consistency is incrementally checked by comparing the latest inventory year with the preceding year. Any exceptional deviations are investigated by the sectoral or the EMIS database experts. These checks are performed in 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_2)
- 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 Air Pollutant Emission Inventory 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 in-depth review of Switzerland’s emission inventory (UNECE 2020). 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 Tier 1 analysis of the main air pollutants and particulate matter

Based on the uncertainties for the activity data of the Swiss GHG Inventory (FOEN 2021) and on further information about emission factor uncertainty, an uncertainty analysis Tier 1 for main pollutants and particulate matter has been carried out for the current submission. Note that for NH_3 emissions of agriculture a Tier 2 uncertainty analysis was performed in 2013 (see next chapter).

Uncertainties are assessed in accordance with the EMEP/EEA Emission Inventory Guidebook 2019 (EMEP/EEA 2019: Part A, chapter 5) and with the IPCC Guidelines 2006 (IPCC 2006).

1.7.2 Data sources and data used

Activity data and emission factors are analysed on the same level of aggregation as used for the NFR tables (classification according to EMEP/EEA 2019).

Several sources for uncertainties are utilised and shown in the list below. Uncertainty values for activity data and emission factors were updated where appropriate.

- Uncertainty analysis of Switzerland's GHG Inventory: Uncertainties of activity data are used (FOEN 2021).
- Uncertainties for the emission factors and emissions of mobile sources from the study IFEU/INFRAS (2009), 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 EMEP/EEA (2019) (part A, chp. 5, table 2-2).
- Uncertainties for NH_3 emissions from sector 3 Agriculture had been thoroughly investigated in 2013 by a Tier 2 approach (Monte Carlo simulation) applied to the data of the Agrammon model from 2010. New uncertainty results per livestock category had been derived which turned out to be much smaller than previous estimates of uncertainties and which showed that the results for NH_3 emissions were more precise than reported before (INFRAS 2015b). A subsequent study reassessed these uncertainties by taking into account additional factors such as correlations and uncertainties due to extrapolation (INFRAS 2017b). The results show slightly higher uncertainties, but they generally confirm the results of the previous study (INFRAS 2015b). For the current submission, uncertainties provided by INFRAS (2017b) are used for the uncertainty analysis.
- Detailed references for the uncertainties are shown in Annex 5.

1.7.3 Results of Tier 1 uncertainty evaluation

Table 1-8 shows the results of the uncertainty evaluation. 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 emission trends of these pollutants 1990-2019 are also shown in the table to give a quantitative meaning to the trend uncertainties.

Table 1-8: Relative Tier 1 uncertainties for total emission levels 2019 and for emission trends 1990-2019 of the main pollutants, PM2.5 and PM10. The last column shows the emission trends 1990-2019. Legend for example NO_x: Trend uncertainty is 1%, emission trend is -58%: This means that the emission trend 1990-2019 lies in the interval -57% and -59% with a probability of 95%.

Pollutant	Level uncertainty 2019	Trend uncertainty 1990-2019	Emission trend 1990-2019
NO_x	15%	1%	-58%
NMVOC	75%	14%	-73%
SO_x	7%	1%	-88%
NH_3	13%	5%	-22%
PM2.5	33%	8%	-62%
PM10	32%	11%	-40%

Level uncertainty estimations range from 7% to 75%, trend uncertainties from 1% to 14%. The level uncertainty estimations remained similar for all pollutants (change below 1 percentage point) as compared to the values of the previous submission 2020. Changes in trend uncertainties are lower than 1 percentage point for all pollutants compared to the previous submission as well.

The detailed information on the uncertainties of activity data and the emission factors are shown 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.

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 2019 Guidebook, 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 ressources, 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 does 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 1980-2019

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 1980-2019 (see Table 2-1). Note that there is a methodological discrepancy 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	2005	2019	1980-2019	2005-2019
NO_x	kt	166	93	62	-63%	-33%
NMVOC	kt	319	113	81	-75%	-29%
SO_2	kt	115	14	4.4	-96%	-68%
NH_3	kt	82	59	54	-34%	-8.6%
PM2.5 total	kt	19	10	6.1	-68%	-42%
PM2.5 exhaust	kt	17	8.2	3.7	-78%	-55%
PM2.5 non-exhaust	kt	2.3	2.3	2.5	8.2%	8.4%
PM10 total	kt	29	18	14	-52%	-22%
PM10 exhaust	kt	20	9.0	4.1	-79%	-54%
PM10 non-exhaust	kt	9.4	9.0	9.9	5.7%	11%
TSP total	kt	53	32	28	-47%	-13%
TSP exhaust	kt	26	9.6	4.5	-83%	-53%
TSP non-exhaust	kt	27	22	23	-13%	4.5%
BC total	kt	4.9	3.5	1.2	-76%	-66%
BC exhaust	kt	4.9	3.4	1.1	-78%	-68%
BC non-exhaust	kt	0.026	0.078	0.094	264%	21%
CO	kt	1'124	299	157	-86%	-48%
Pb	t	1'326	21	15	-99%	-30%
Cd	t	5.4	0.70	0.69	-87%	-2.3%
Hg	t	7.6	0.81	0.68	-91%	-16%
PCDD/PCDF	g I-Teq	444	32	16	-96%	-50%
BaP	t	2.2	1.4	0.81	-64%	-43%
BbF	t	2.5	1.6	0.86	-66%	-47%
BkF	t	1.5	1.0	0.54	-65%	-48%
IcdP	t	1.1	0.82	0.48	-58%	-42%
PAH tot	t	7.4	4.9	2.7	-64%	-45%
HCB	kg	97	0.44	0.36	-100%	-20%
PCB	t	3.6	1.3	0.44	-88%	-65%

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 (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.

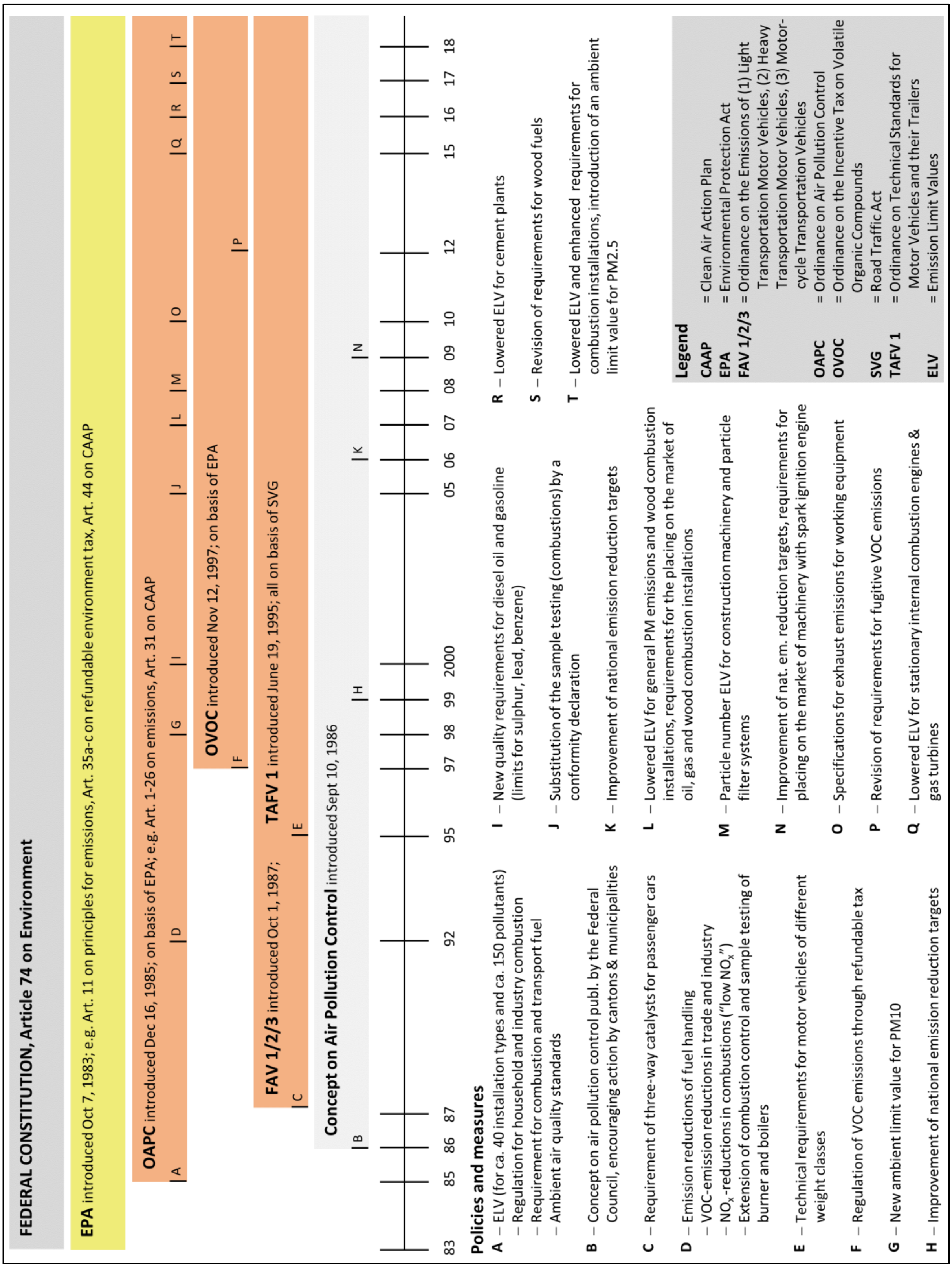


Figure 2-1: Overview of the OAPC Revisions in Switzerland. The Concept on Air Pollution Control is also referred to as the Air Pollution Control Strategy.

For further information on legislation on the abatement of air pollution, see: https://www.bafu.admin.ch/bafu/en/home/topics/air/law.html [03.02.2021].

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, the incentive tax on VOC and voluntary agreements with industry sectors. As a result, NO_x, NMVOC and CO emissions declined between 1980 and 2019.

Furthermore, due to legal restriction of sulphur content in liquid fuels and decrease in coal consumption, 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 3-8, whereas the time series of Switzerland's decreasing coal consumption is given in Table 3-3. 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 ammonia emissions (NH_3) in the past 40 years is not as pronounced as for the pollutants mentioned above. NH_3 emissions are influenced by changes in farm animal numbers, 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).

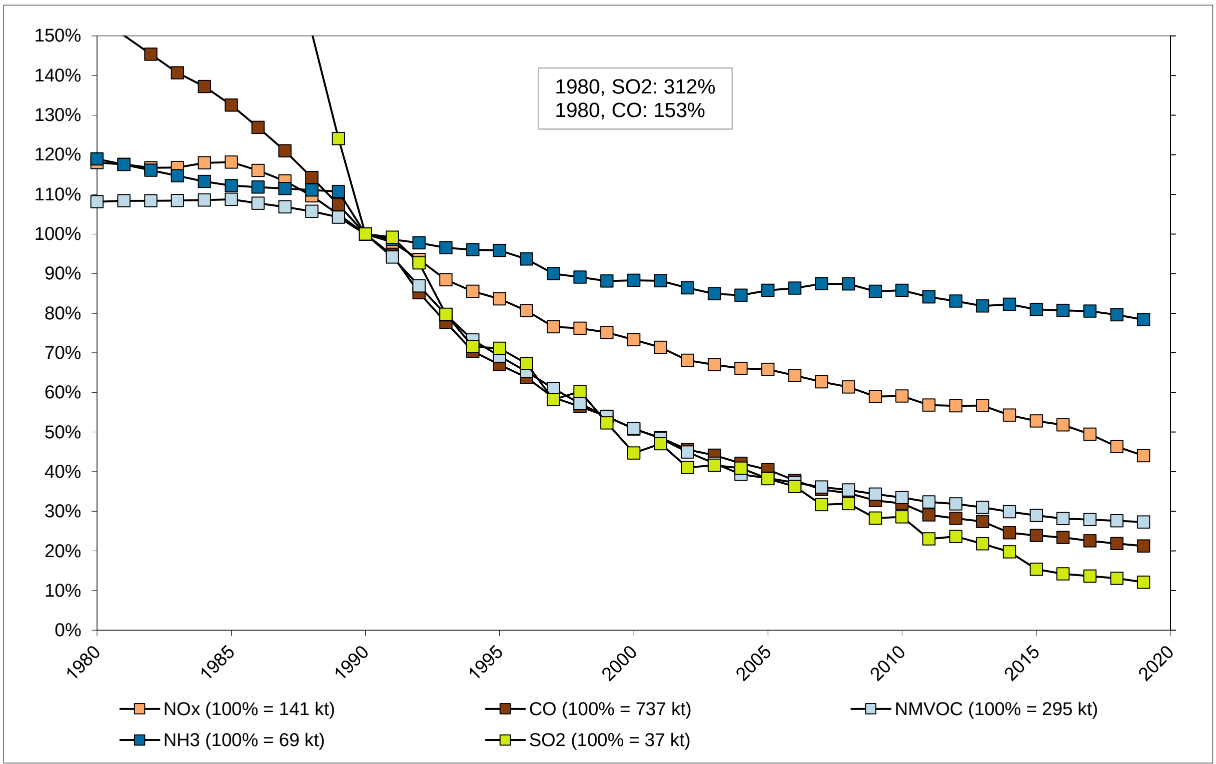


Figure 2-2: Relative trends for the total emissions of main air pollutants and CO in Switzerland 1980–2019 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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_2	NH_3	CO
	kt				
1980	166	319	115	82	1'124
1985	166	321	74	77	977
1990	141	295	37	69	737
1995	118	204	26	66	494
2000	103	150	16	61	374
2005	93	113	14	59	299
2010	83	99	10	59	236
2011	80	96	8.4	58	214
2012	80	94	8.7	57	208
2013	80	92	8.0	56	202
2014	76	88	7.2	56	181
2015	74	85	5.6	56	176
2016	73	83	5.2	55	172
2017	70	82	5.0	55	166
2018	65	82	4.8	55	161
2019	62	81	4.4	54	157
2005 to 2019 (%)	-33%	-29%	-68%	-8.6%	-48%

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 underlying 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).

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 an increase in the consumption of wood energy in the commercial sector (1A4ai) and in agriculture and forestry (1A4ci).

There are no condensables included in PM emissions except for few sources (i.e. 1A4bi Bonfire and 1A4bi Use of charcoal, see chp. 3.2.4.2). For details see table Table A - 21 in Annex 6.

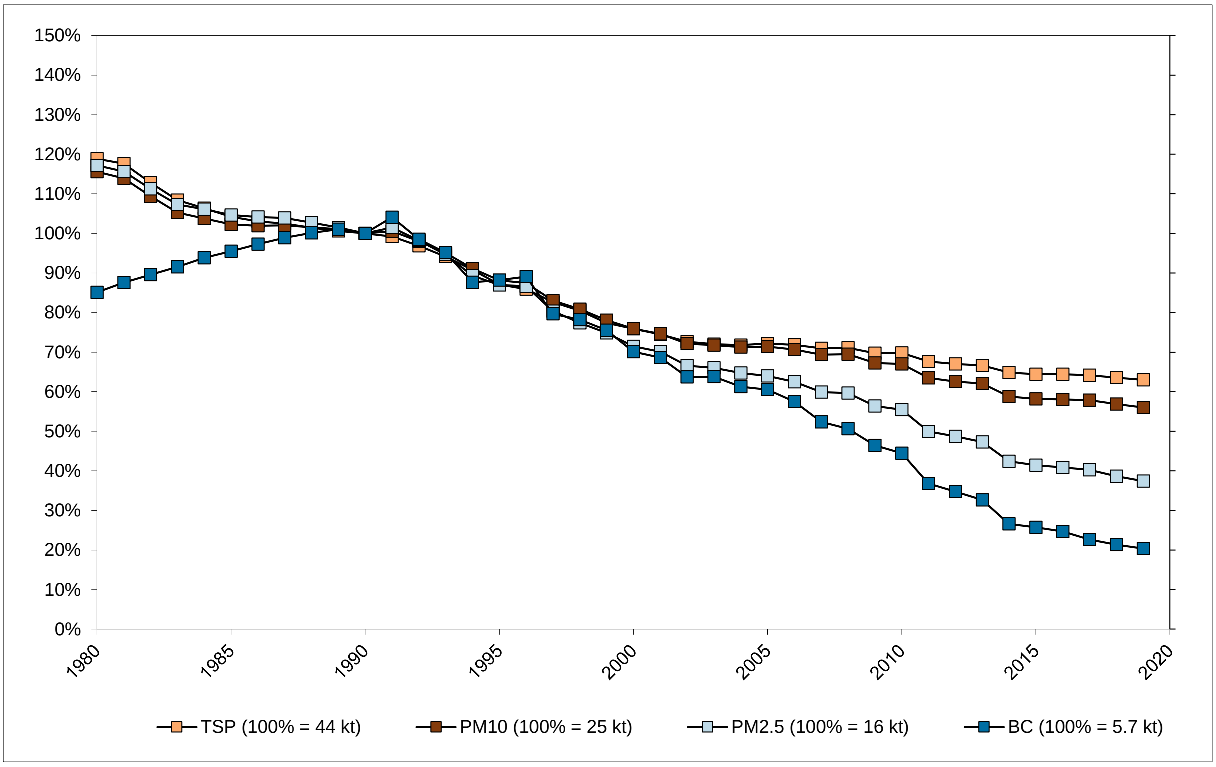


Figure 2-3: Total emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2019 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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	16	25	44	5.7
1995	14	22	39	5.1
2000	12	19	34	4.0
2005	10	18	32	3.5
2010	9.1	17	31	2.6
2011	8.2	16	30	2.1
2012	8.0	16	30	2.0
2013	7.8	16	30	1.9
2014	7.0	15	29	1.5
2015	6.8	15	29	1.5
2016	6.7	15	29	1.4
2017	6.6	15	28	1.3
2018	6.3	14	28	1.2
2019	6.1	14	28	1.2
2005 to 2019 (%)	-42%	-22%	-13%	-66%

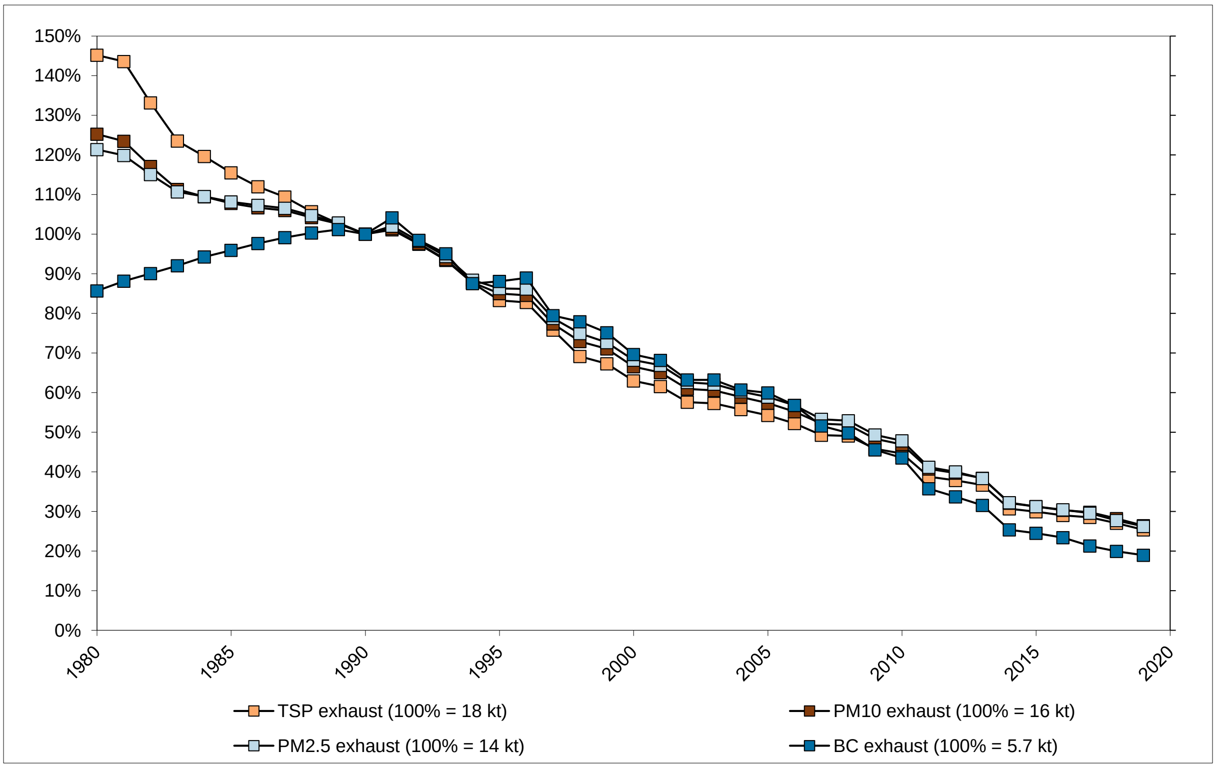


Figure 2-4: Exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2019 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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 exhaust**	**PM10 exhaust**	**TSP exhaust**	**BC exhaust**
	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	9.5	10	11	4.0
2005	8.2	9.0	9.6	3.4
2010	6.7	7.4	7.9	2.5
2011	5.8	6.4	6.8	2.0
2012	5.6	6.2	6.7	1.9
2013	5.4	6.0	6.5	1.8
2014	4.5	5.0	5.4	1.4
2015	4.4	4.9	5.3	1.4
2016	4.3	4.8	5.1	1.3
2017	4.1	4.7	5.0	1.2
2018	3.9	4.4	4.8	1.1
2019	3.7	4.1	4.5	1.1
2005 to 2019 (%)	-55%	-54%	-53%	-68%

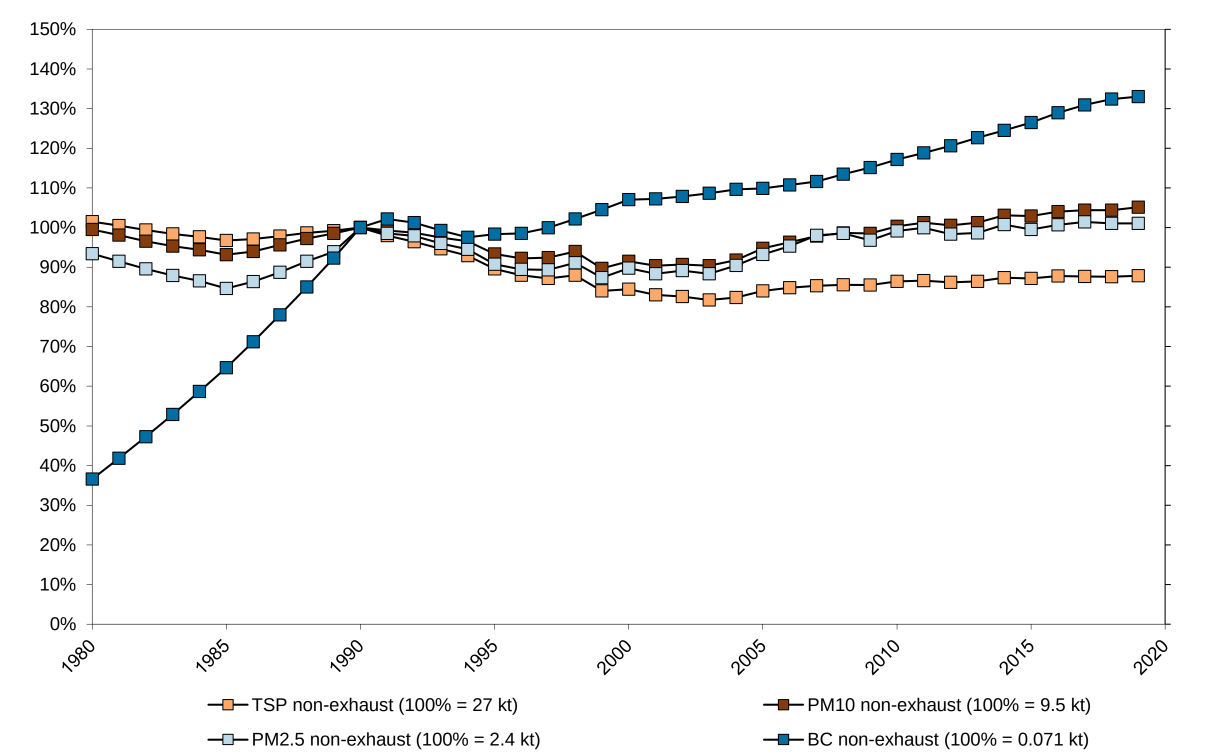


Figure 2-5: Non-exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2019 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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 non-exh.**	**PM10 non-exh.**	**TSP non-exh.**	**BC non-exh.**
	kt	kt	kt	kt
1980	2.3	9.4	27	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
2011	2.4	9.6	23	0.084
2012	2.4	9.5	23	0.085
2013	2.4	9.6	23	0.087
2014	2.5	9.7	23	0.088
2015	2.4	9.7	23	0.089
2016	2.5	9.8	23	0.091
2017	2.5	9.9	23	0.092
2018	2.5	9.9	23	0.093
2019	2.5	9.9	23	0.094
2005 to 2019 (%)	8.4%	11%	4.5%	21%

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. Pb and Hg emissions show a less pronounced continuation of the decreasing trend between 2003 and 2014 that stopped afterwards. Cd emissions slightly increase from 2014 onwards due to an increase of waste volumes incinerated (1A1) and and increase of mileage (1A3b, non-exhaust emissions).

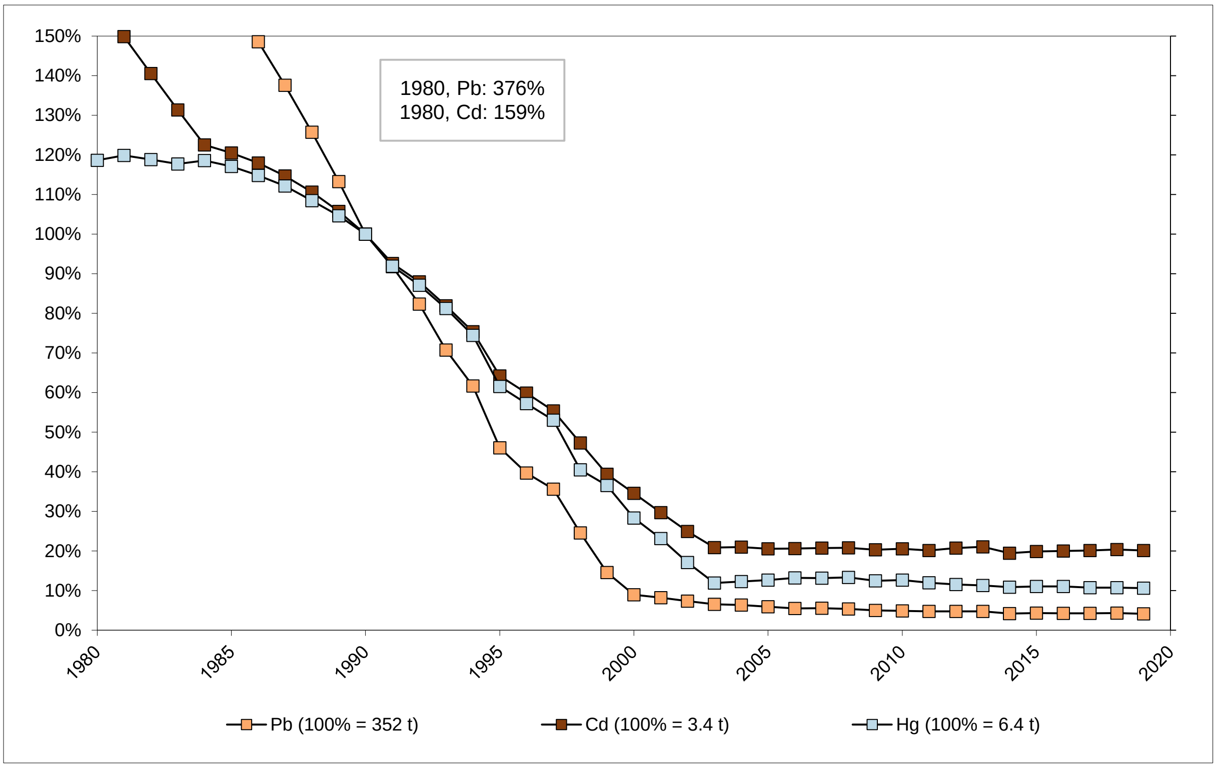


Figure 2-6: Emissions of priority heavy metals in Switzerland 1980–2019 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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	352	3.4	6.4
1995	162	2.2	3.9
2000	32	1.2	1.8
2005	21	0.70	0.81
2010	17	0.70	0.81
2011	17	0.69	0.76
2012	17	0.71	0.74
2013	17	0.72	0.72
2014	15	0.67	0.69
2015	15	0.68	0.71
2016	15	0.68	0.71
2017	15	0.69	0.69
2018	15	0.70	0.69
2019	15	0.69	0.68
2005 to 2019 (%)	-30%	-2.3%	-16%

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 result of an indirect effect of the equipment of waste incineration plants with DeNOx techniques. From 2003 onward, emissions continue to decrease on a low level.

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 half and increased by about a factor of six in manually operated furnaces and automatic combustion installations, respectively.

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 only plant for secondary aluminium production in Switzerland which ceased in 1993. Since then, total HCB emissions are slightly decreasing on a low level. 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 (on a low level) 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, accidential release by fire, small and large capacitors and waste incineration were important emission sources as well.

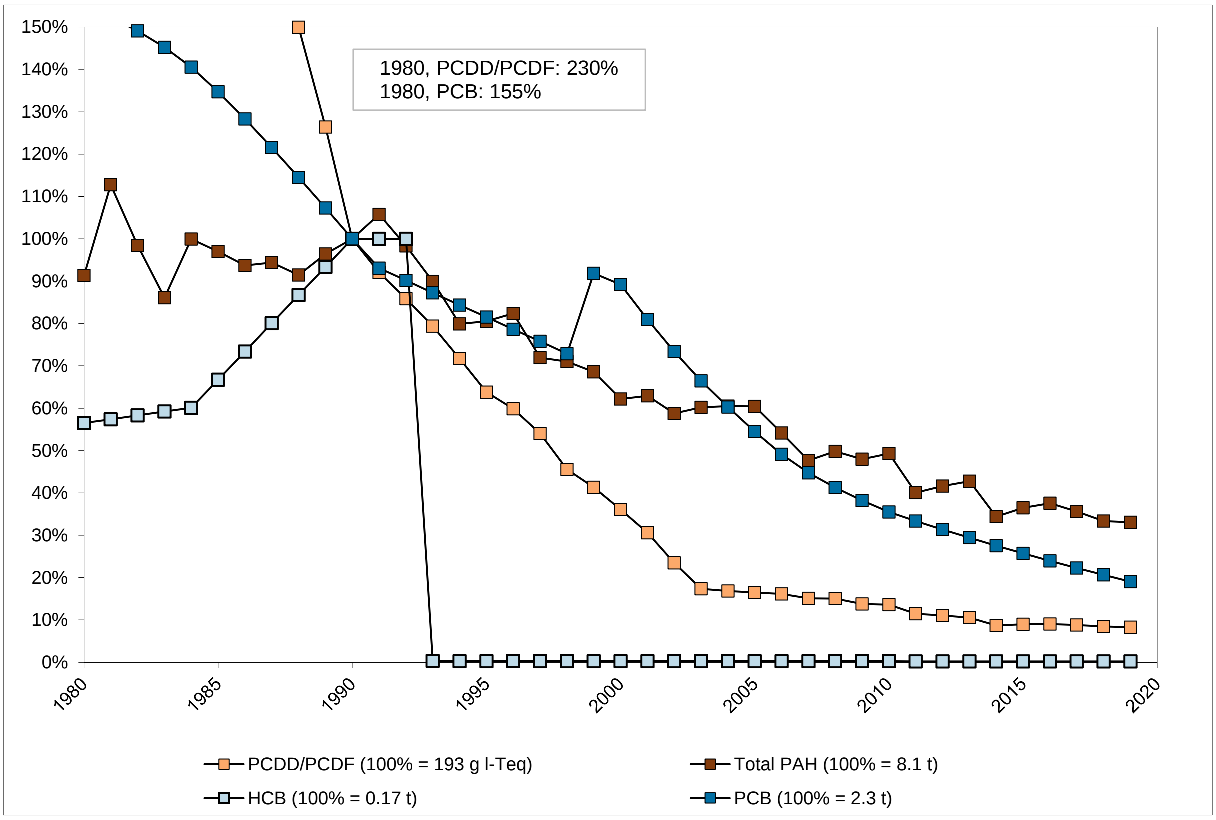


Figure 2-7: Emissions of POPs Annex III[1]: PAH – as the sum of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene – PCDD/PCDF (PCDD/F) HCB and PCB in Switzerland 1980–2019. Note that values for PCDD/PCDF before 1989 are not displayed here but illustrated in the table below. Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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

Table 2-7: Total emissions of POPs Annex III (see footnote 1, p. 44). 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	2.2	2.5	1.5	1.1	7.4	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	123	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	0.82	4.9	0.44	1.3
2010	26	1.2	1.3	0.77	0.70	4.0	0.44	0.83
2011	22	1.0	1.1	0.63	0.57	3.3	0.38	0.78
2012	21	1.0	1.1	0.66	0.59	3.4	0.40	0.73
2013	20	1.1	1.1	0.67	0.61	3.5	0.40	0.69
2014	17	0.85	0.90	0.55	0.49	2.8	0.34	0.64
2015	17	0.90	0.95	0.58	0.52	3.0	0.36	0.60
2016	17	0.93	0.98	0.60	0.54	3.1	0.37	0.56
2017	17	0.88	0.93	0.58	0.52	2.9	0.37	0.52
2018	16	0.82	0.87	0.54	0.48	2.7	0.35	0.48
2019	16	0.81	0.86	0.54	0.48	2.7	0.36	0.44
2005 to 2019 (%)	-50%	-43%	-47%	-48%	-42%	-45%	-20%	-65%

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 2019.

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 road transportation (1A3b) 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 of 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 past few years because of an increasing share of diesel-powered passenger cars and higher EF than expected (the "dieselgate" scandal[2], detected in the year 2015).

[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 [03.02.2021]

- The reductions in manufacturing industries (1A2) 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. In 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 2019). These two effects compensated for the additional heated area, and lead to a reduction of NO_x emissions under category 1A4 Other sectors.

Table 2-8: NO_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).

NO_x emissions	**1990**	**2005**	**2010**	**2019**	**1990-2010**	**2005-2019**	**2005-2019**	**share in 2019**
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	135	88	78	58	-56	-30	-34%	93%
1A Fuel combustion	135	88	78	58	-56	-30	-34%	93%
1A1 Energy industries	6.8	2.9	3.0	2.4	-3.8	-0.54	-18%	3.9%
1A2 Manufacturing industries	23	14	12	8.2	-11	-6.2	-43%	13%
1A3 Transport	83	54	49	37	-34	-16	-30%	60%
1A4 Other sectors	21	16	14	9.5	-7.0	-6.8	-42%	15%
1A5 Other (Military)	0.88	0.60	0.54	0.39	-0.34	-0.21	-35%	0.63%
1B Fugitive emissions from fuels	0.21	0.29	0.11	0.0017	-0.099	-0.29	-99%	0.0027%
2 IPPU	0.49	0.32	0.38	0.23	-0.11	-0.082	-26%	0.38%
3 Agriculture	5.0	3.9	4.0	3.7	-0.94	-0.23	-5.8%	5.9%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.30	0.16	0.15	0.15	-0.15	-0.016	-9.9%	0.24%
6 Other	0.084	0.092	0.099	0.10	0.015	0.0056	6.1%	0.16%
National total for compliance	141	93	83	62	-57	-31	-33%	100%
Gothenburg Protocol			**2010**			Gothenburg Protocol revised		**2005-2020**
Emission ceiling / reduction			79					-41%

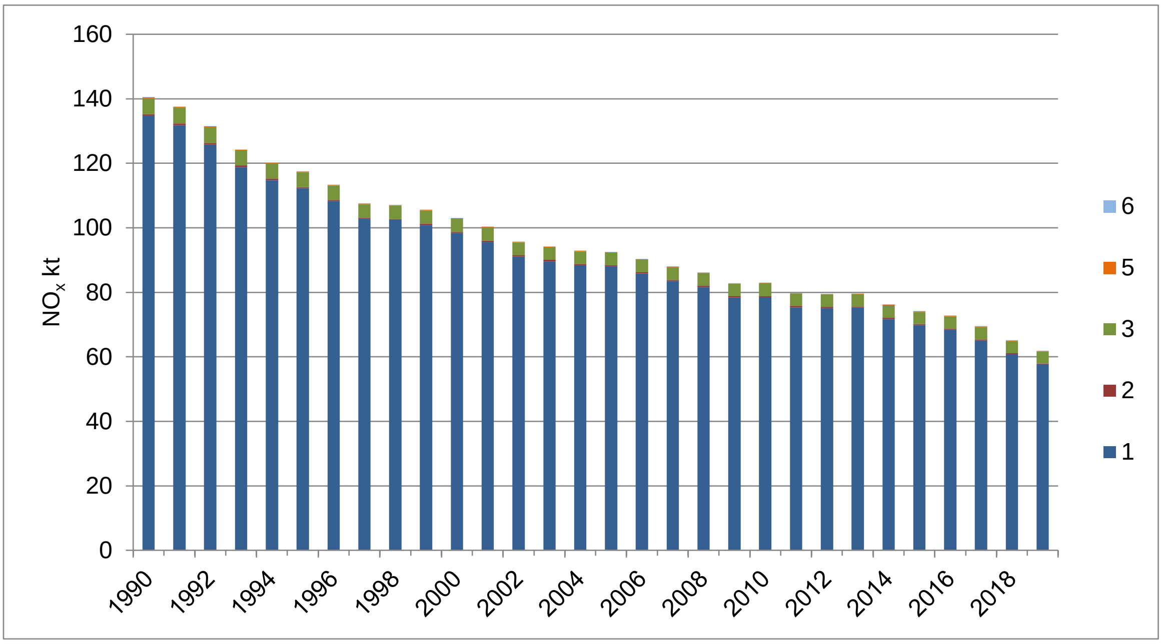


Figure 2-8: Trend of NOx emissions (kt) in Switzerland by sectors 1-6.

Emission trends 1980-2019: Trends of main pollutants per gas and sectors - Trends for NOx

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 1990-2019.

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 and non-industrial paint application (2001-2004) which is partly due to substitution of conventional paints by powder coatings. Despite an increase of emissions from 2D3a Domestic solvent use including fungicides from 2001-2019 due to changing emission factors and population growth, the trend of NMVOC emissions from sector 2 IPPU was still slightly decreasing from 2004-2019. This was a result of reduced emissions in categories 2D3d Coating applications, 2D3h Printing and 2G Other product manufacture and use, 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 2019, which leads to a decrease of NMVOC emissions. NMVOC emissions of source category 1A4 Other sectors declined in the same period as well due to to the technical improvements of wood combustion installations and a reduction in the number and energy consumption of emission intensive types of wood furnaces.

NMVOC emissions from agriculture show a slightly fluctuating and decreasing trend. They are mainly depending on the development of animal numbers.

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**	**2019**	**1990-2010**	**2005-2019**	**2005-2019**	**share in 2019**
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	124	41	29	17	-96	-24	-59%	21%
1A Fuel combustion	105	35	25	14	-80	-21	-59%	18%
1A1 Energy industries	0.30	0.22	0.20	0.16	-0.11	-0.062	-28%	0.20%
1A2 Manufacturing industries	2.4	2.0	1.6	0.96	-0.79	-1.1	-53%	1.2%
1A3 Transport	86	23	15	8.4	-71	-14	-63%	10%
1A4 Other sectors	16	10	8.3	4.9	-7.8	-5.6	-54%	6.0%
1A5 Other (Military)	0.16	0.11	0.090	0.062	-0.070	-0.047	-43%	0.077%
1B Fugitive emissions from fuels	20	5.4	3.4	2.3	-16	-3.0	-56%	2.9%
2 IPPU	150	53	50	44	-100	-9.0	-17%	54%
3 Agriculture	20	19	19	19	-0.81	-0.42	-2.2%	23%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.74	0.76	0.96	1.5	0.22	0.75	100%	1.9%
6 Other	0.19	0.19	0.20	0.22	0.016	0.032	17%	0.28%
National total for compliance	295	113	99	81	-196	-33	-29%	100%
Gothenburg Protocol			**2010**		Gothenburg Protocol revised			**2005-2020**
Emission ceiling / reduction			144					-30%

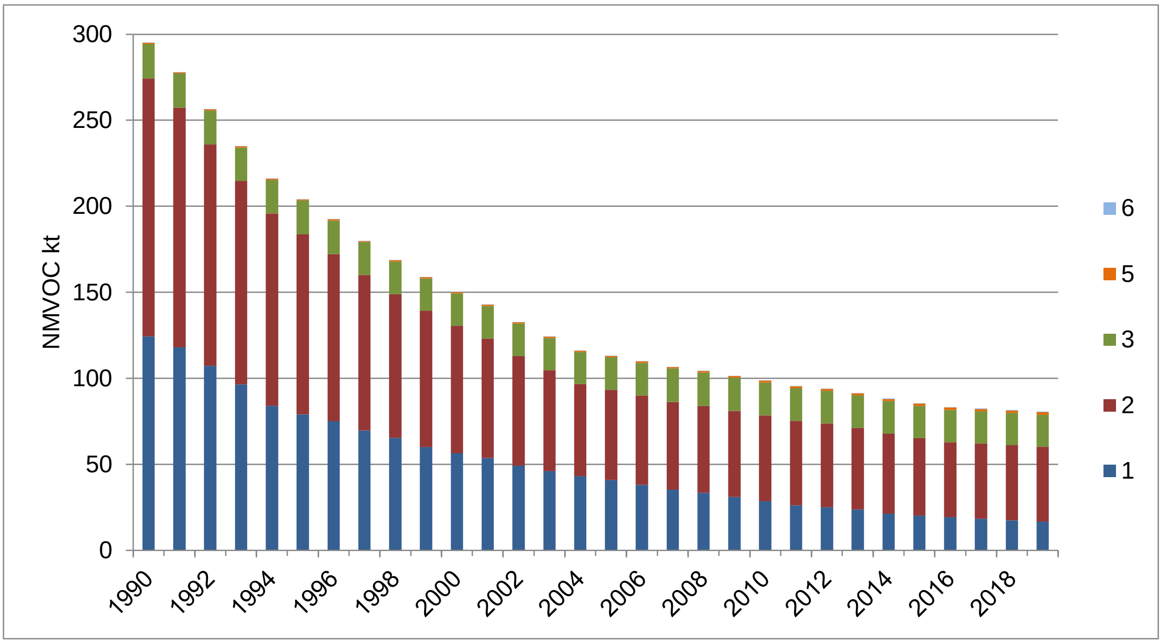


Figure 2-9: Trend of NMVOC emissions (kt) in Switzerland by sectors 1-6.

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 2019.

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

- First, a limitation of the sulphur content in fuels (stepwise lowering in 1993, 1999, 2000, 2005 and 2009; reduction by about a factor of 10 between 1990 and 2019, see Table 3-8) 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 and gasoline, see Table 3-8; stepwise lowering in 1993, 1999, 2000, 2005 and 2009 by the Ordinance on Air Pollution Control (Swiss Confederation 1985)).
- 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 2019).
- 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_2 emissions from 2C Metal production strongly declined 1990–2006, mainly following the decrease in aluminium production volume. SO_2 emissions of sector 2B Chemical industry show no clear trend in the period 1990–2019; in 2019, they have a share of approximately 20%.

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	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	35	13	9.6	3.5	-25	-9.3	-72%	80%
1A Fuel combustion	34	12	9.4	3.5	-25	-8.8	-71%	79%
1A1 Energy industries	4.2	1.7	1.7	0.27	-2.5	-1.4	-84%	6.0%
1A2 Manufacturing industries	13	4.1	3.0	1.9	-9.8	-2.2	-53%	43%
1A3 Transport	4.0	0.21	0.23	0.26	-3.7	0.045	21%	5.8%
1A4 Other sectors	13	6.3	4.5	1.1	-8.8	-5.3	-83%	24%
1A5 Other (Military)	0.077	0.037	0.037	0.030	-0.041	-0.0074	-20%	0.68%
1B Fugitive emissions from fuels	0.72	0.51	0.22	0.016	-0.50	-0.49	-97%	0.36%
2 IPPU	1.5	1.1	0.79	0.81	-0.67	-0.26	-24%	18%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.16	0.063	0.063	0.070	-0.10	0.0066	10%	1.6%
6 Other	0.010	0.011	0.010	0.011	-0.00015	0.00014	1.3%	0.25%
National total for compliance	37	14	10	4.4	-26	-9.6	-68%	100%
Gothenburg Protocol			**2010**			Gothenburg Protocol revised		**2005-2020**
Emission ceiling / reduction			26					-21%

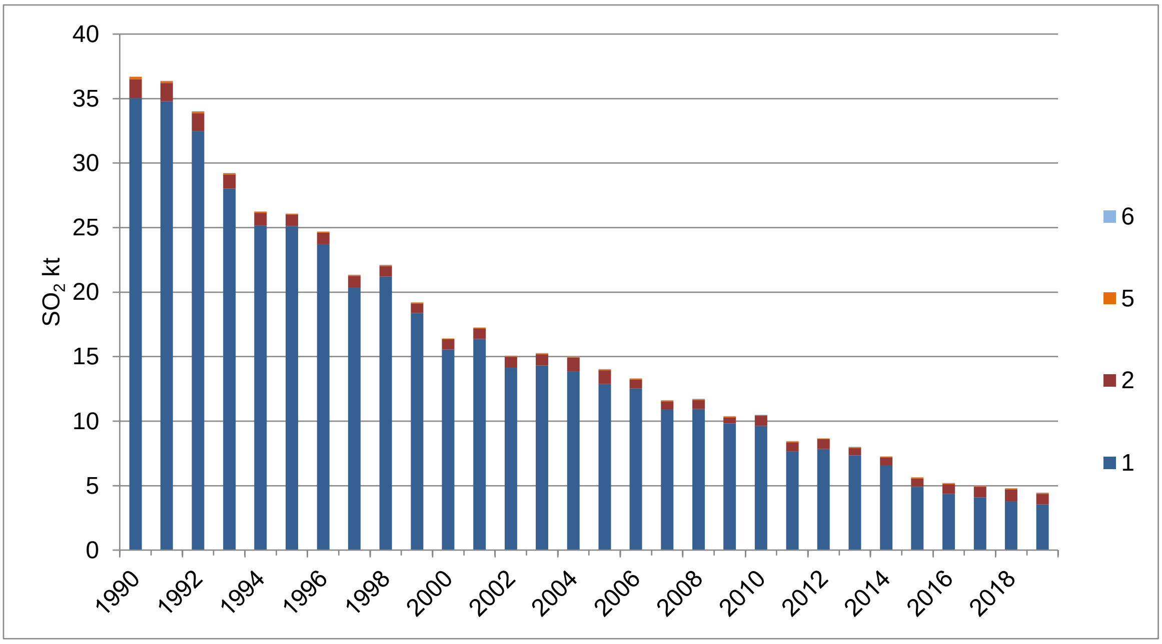


Figure 2-10: Trend of SO_2 emissions (kt) in Switzerland by sectors 1-6 (SO_x as SO_2).

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 2019.

The emission reduction (with fluctuations) can be mainly attributed to source category 3D Agricultural soils (especially 3Da2a Animal manure applied to soils). A decrease of the agricultural ammonia emissions already happened in the preceding decade 1980-1990 due to declining number of animals and use of mineral fertiliser. The decrease continued until 2004, followed by a slight increase until 2008 and another decrease since then. This manifold trend results from a combination of changes in animal numbers, introduction of new housing systems due to developments in animal welfare regulations, increase of animal productivity and changes in production techniques (Kupper et al. 2018).

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	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	1.7	3.9	2.8	1.4	1.1	-2.5	-65%	2.6%
1A Fuel combustion	1.7	3.9	2.8	1.4	1.1	-2.5	-65%	2.6%
1A1 Energy industries	0.0047	0.026	0.035	0.035	0.030	0.0091	35%	0.065%
1A2 Manufacturing industries	0.17	0.19	0.24	0.20	0.075	0.011	5.6%	0.38%
1A3 Transport	1.3	3.5	2.4	1.0	1.1	-2.5	-71%	1.9%
1A4 Other sectors	0.21	0.16	0.16	0.12	-0.047	-0.042	-26%	0.23%
1A5 Other (Military)	0.000037	0.000039	0.000042	0.000041	0.0000048	0.0000015	3.8%	0.000076%
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	0.37	0.35	0.20	0.13	-0.17	-0.23	-64%	0.23%
3 Agriculture	65	53	54	50	-11	-2.4	-4.6%	94%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.91	0.93	0.89	0.92	-0.023	-0.0141	-1.51%	1.7%
6 Other	0.84	0.89	0.92	1.0	0.079	0.11	12%	1.9%
National total for compliance	69	59	59	54	-9.8	-5.1	-8.6%	100%
Gothenburg Protocol			2010			Gothenburg Protocol revised		2005-2020
Emission ceiling / reduction			63					-8%

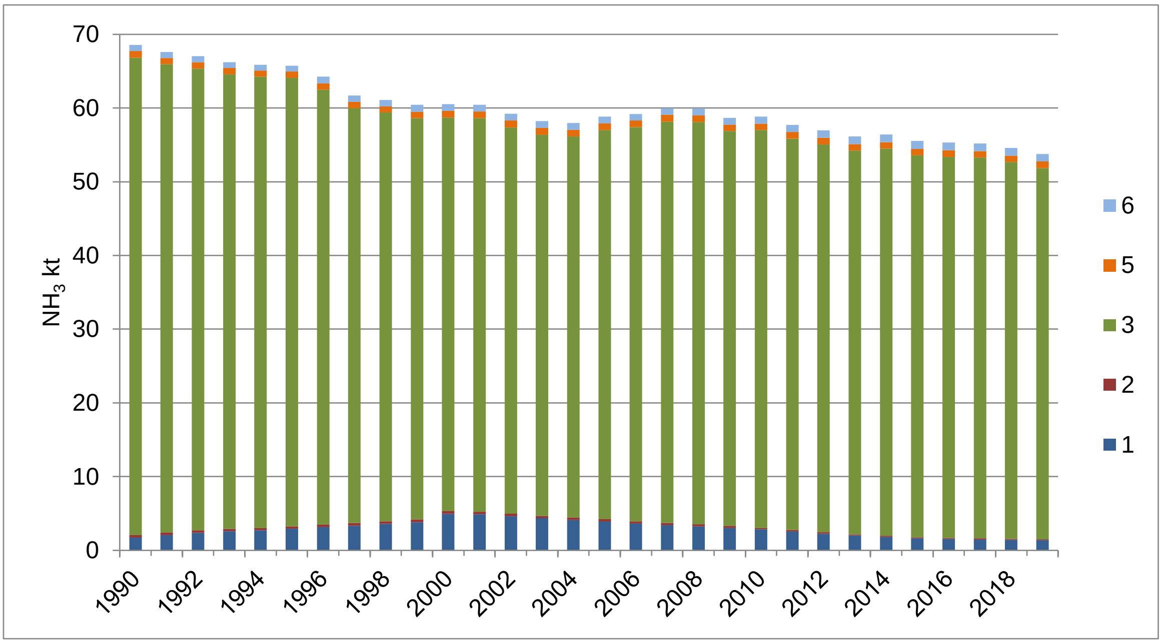


Figure 2-11: Trend of NH_3 emissions (kt) in Switzerland by sectors 1-6.

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. All particulate matter emissions – except from sector 3 Agriculture – 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 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 half and increased by about a factor of six 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.
- 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 show a decrease of about 40% in the period 1990-1999 and fluctuate only slightly since then. In 1990, the three source categories 2A Mineral products, 2C Metal production and 2H Other contributed the most to the particulate matter emissions. The 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. Afterwards, IPPU emissions (e.g. from cement production, gravel plants and use of fireworks and tobacco) 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 and less for PM2.5 (see chp. 2.4.4).

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

PM2.5 emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	13	8.5	7.1	4.5	-6.0	-4.0	-47%	73%
1A Fuel combustion	13	8.5	7.1	4.5	-6.0	-4.0	-47%	73%
1A1 Energy industries	0.82	0.18	0.19	0.060	-0.64	-0.12	-67%	0.97%
1A2 Manufacturing industries	1.9	1.5	1.1	0.62	-0.88	-0.87	-58%	10%
1A3 Transport	3.7	2.8	2.4	1.6	-1.4	-1.2	-42%	27%
1A4 Other sectors	6.5	4.0	3.5	2.1	-3.1	-1.8	-46%	35%
1A5 Other (Military)	0.087	0.057	0.050	0.045	-0.037	-0.012	-21%	0.73%
1B Fugitive emissions from fuels	0.00016	0.000070	0.000074	0.000047	-0.000086	-0.000023	-33%	0.00077%
2 IPPU	2.6	1.5	1.5	1.2	-1.1	-0.26	-18%	20%
3 Agriculture	0.12	0.13	0.14	0.14	0.015	0.013	10%	2.3%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.59	0.38	0.36	0.31	-0.22	-0.075	-20%	5.0%
6 Other	0.0042	0.0041	0.0048	0.0058	0.00063	0.0017	40%	0.095%
National total for compliance	16	10	9.1	6.1	-7.3	-4.4	-42%	100%
Gothenburg Protocol			**2010**		Gothenburg Protocol revised			**2005-2020**
Emission ceiling / reduction			79					-26%

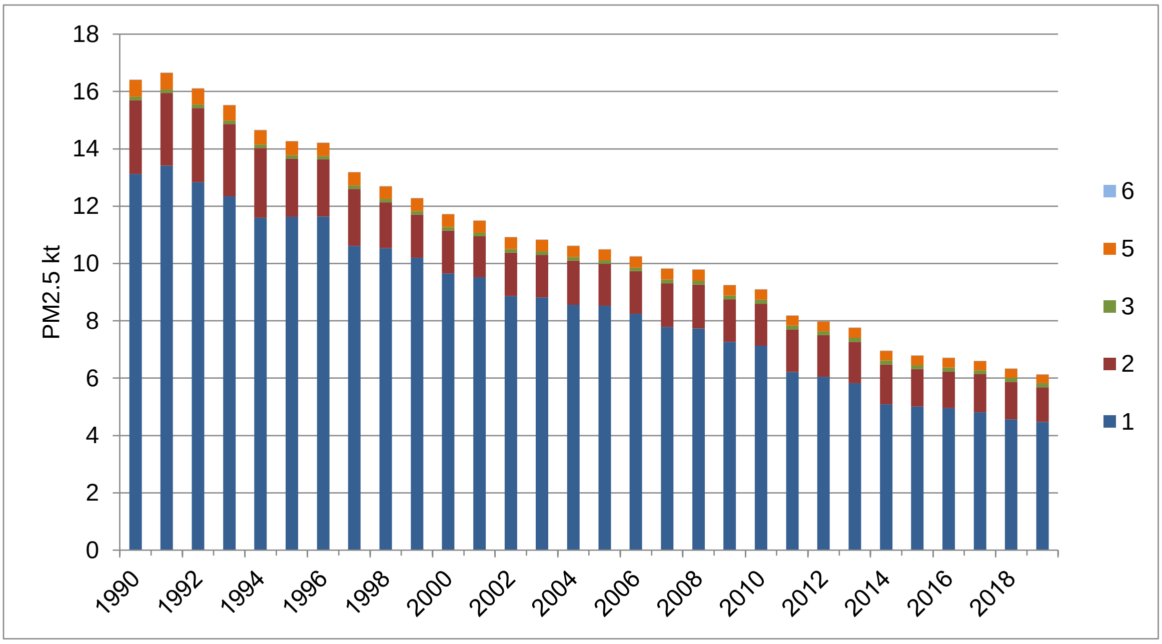


Figure 2-12: Trend of PM2.5 emissions (kt) in Switzerland by sectors 1-6.

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).

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

PM10 emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	18	13	12	10	-5.8	-3.5	-26%	70%
1A Fuel combustion	18	13	12	10	-5.8	-3.5	-26%	70%
1A1 Energy industries	1.1	0.18	0.19	0.061	-0.90	-0.12	-67%	0.43%
1A2 Manufacturing industries	3.8	3.4	3.0	2.6	-0.86	-0.77	-23%	18%
1A3 Transport	5.9	5.4	5.1	4.7	-0.82	-0.66	-12%	33%
1A4 Other sectors	7.0	4.2	3.7	2.3	-3.3	-2.0	-46%	16%
1A5 Other (Military)	0.29	0.27	0.27	0.26	-0.018	-0.0040	-1.5%	1.9%
1B Fugitive emissions from fuels	0.0016	0.00070	0.00074	0.00047	-0.00086	-0.00023	-33%	0.0033%
2 IPPU	4.5	2.3	2.3	1.9	-2.2	-0.35	-15%	14%
3 Agriculture	1.7	1.7	1.7	1.7	0.020	0.085	5.1%	12%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.66	0.42	0.41	0.34	-0.26	-0.080	-19%	2.4%
6 Other	0.20	0.20	0.18	0.19	-0.024	-0.011	-5.5%	1.3%
National total for compliance	25	18	17	14	-8.3	-3.9	-22%	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 micrometers 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 of PM10 and PM2.5.

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

TSP total emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	20	15	14	12	-6.2	-3.5	-23%	43%
1A Fuel combustion	20	15	14	12	-6.2	-3.5	-23%	43%
1A1 Energy industries	1.1	0.20	0.21	0.065	-0.90	-0.14	-68%	0.23%
1A2 Manufacturing industries	5.2	4.5	4.1	3.8	-1.1	-0.69	-16%	14%
1A3 Transport	6.2	5.8	5.5	5.2	-0.70	-0.57	-10%	19%
1A4 Other sectors	7.5	4.5	4.0	2.5	-3.5	-2.1	-46%	8.8%
1A5 Other (Military)	0.40	0.39	0.40	0.39	-0.0054	0.0010	0.26%	1.4%
1B Fugitive emissions from fuels	0.0040	0.0017	0.0019	0.0012	-0.0022	-0.00057	-33%	0.0042%
2 IPPU	10	3.3	3.4	2.9	-6.6	-0.45	-14%	10%
3 Agriculture	13	13	13	13	-0.31	-0.0062	-0.049%	45%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.81	0.52	0.49	0.42	-0.32	-0.099	-19%	1.5%
6 Other	0.25	0.25	0.23	0.24	-0.021	-0.0099	-4.0%	0.86%
National total for compliance	44	32	31	28	-13	-4.1	-13%	100%

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

TSP exhaust emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	14	8.0	6.3	3.2	-7.7	-4.7	-59%	73%
1A Fuel combustion	14	8.0	6.3	3.2	-7.7	-4.7	-59%	73%
1A1 Energy industries	1.1	0.20	0.21	0.065	-0.90	-0.14	-68%	1.5%
1A2 Manufacturing industries	2.6	1.4	0.91	0.35	-1.7	-1.1	-75%	7.8%
1A3 Transport	2.9	1.9	1.3	0.48	-1.6	-1.4	-75%	11%
1A4 Other sectors	7.3	4.4	3.9	2.3	-3.5	-2.1	-47%	53%
1A5 Other (Military)	0.057	0.020	0.012	0.0065	-0.044	-0.014	-68%	0.15%
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	2.5	0.85	0.81	0.59	-1.7	-0.26	-30%	13%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.81	0.51	0.49	0.41	-0.32	-0.099	-19%	9.2%
6 Other	0.24	0.23	0.21	0.22	-0.034	-0.016	-6.9%	4.8%
National total for compliance	18	9.6	7.9	4.5	-9.7	-5.1	-53%	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	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	6.4	7.4	7.9	8.6	1.5	1.2	16%	37%
1A Fuel combustion	6.4	7.4	7.9	8.6	1.5	1.2	16%	37%
1A1 Energy industries	NA	NA	NA	NA	–	–	–	–
1A2 Manufacturing industries	2.6	3.0	3.2	3.4	0.61	0.37	12%	15%
1A3 Transport	3.3	3.9	4.2	4.7	0.87	0.84	22%	20%
1A4 Other sectors	0.13	0.12	0.11	0.11	-0.021	-0.015	-13%	0.45%
1A5 Other (Military)	0.34	0.37	0.38	0.38	0.039	0.015	4.1%	1.6%
1B Fugitive emissions from fuels	0.0040	0.0017	0.0019	0.0012	-0.0022	-0.00057	-33%	0.0050%
2 IPPU	7.4	2.5	2.6	2.3	-4.8	-0.20	-7.9%	10%
3 Agriculture	13	13	13	13	-0.31	-0.0062	-0.049%	53%
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.0034	0.0036	0.0036	0.0036	0.00024	0	0%	0.015%
6 Other	0.0072	0.017	0.020	0.023	0.013	0.0062	36%	0.10%
National total for compliance	27	22	23	23	-3.6	1.0	4.5%	100%

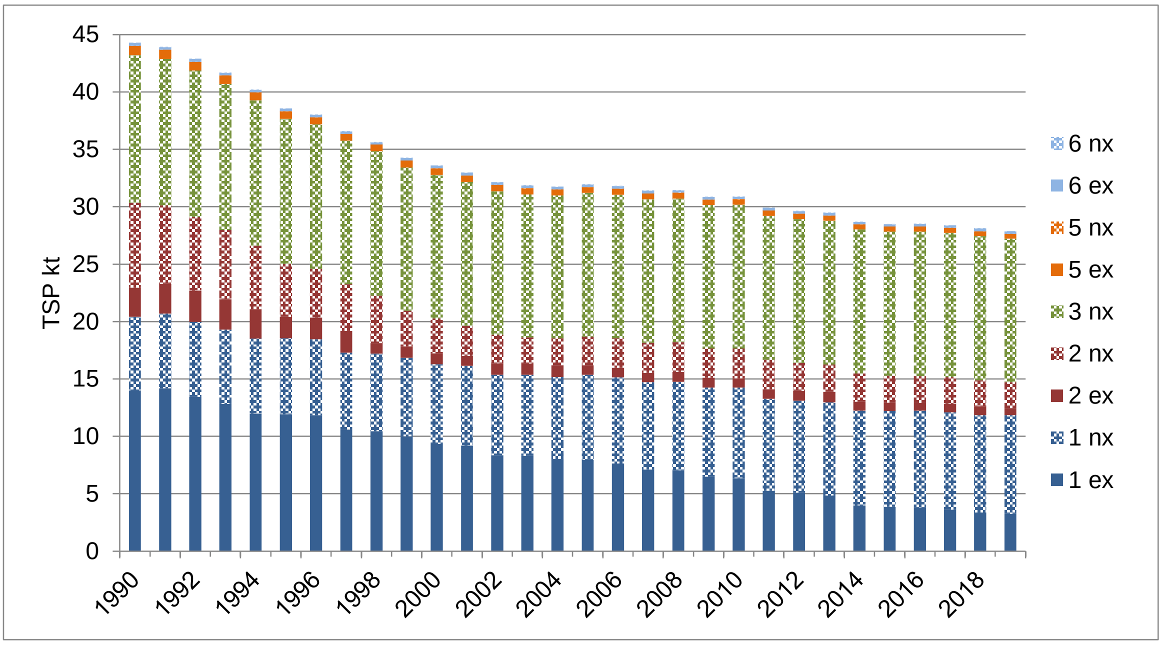


Figure 2-13: Trend of TSP emissions (kt) in Switzerland by sectors 1-6 splitted in exhaust (ex) and non-exhaust (nx) fraction. Non-exhaust emissions cross-hatched.

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 1990-2019.

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

BC emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	5.7	3.4	2.5	1.1	-3.2	-2.3	-67%	98%
1A Fuel combustion	5.7	3.4	2.5	1.1	-3.2	-2.3	-67%	98%
1A1 Energy industries	0.036	0.012	0.011	0.0035	-0.025	-0.0081	-70%	0.30%
1A2 Manufacturing industries	0.42	0.32	0.14	0.047	-0.28	-0.27	-85%	4.1%
1A3 Transport	1.4	1.2	0.92	0.35	-0.50	-0.90	-72%	30%
1A4 Other sectors	3.8	1.9	1.5	0.74	-2.4	-1.1	-60%	64%
1A5 Other (Military)	0.026	0.0099	0.0058	0.0031	-0.020	-0.0067	-68%	0.27%
1B Fugitive emissions from fuels	0.00010	0.000042	0.000045	0.000028	-0.000052	-0.000014	-33%	0.0024%
2 IPPU	0.0063	0.0026	0.0016	0.0013	-0.0047	-0.0013	-51%	0.11%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.041	0.027	0.026	0.022	-0.016	-0.0057	-21%	1.8%
6 Other	0.00014	0.00014	0.00012	0.00013	-0.000019	-0.0000088	-6.4%	0.011%
National total for compliance	5.7	3.5	2.6	1.2	-3.2	-2.3	-66%	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 1990-2019.

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).
- 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	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	726	292	231	152	-495	-140	-48%	97%
1A Fuel combustion	726	292	231	152	-495	-140	-48%	97%
1A1 Energy industries	1.3	1.0	1.0	0.68	-0.34	-0.28	-30%	0.43%
1A2 Manufacturing industries	27	21	20	16	-7.4	-4.9	-23%	10%
1A3 Transport	535	164	118	73	-417	-91	-55%	47%
1A4 Other sectors	161	105	91	61	-70	-44	-42%	39%
1A5 Other (Military)	1.2	0.92	0.87	0.74	-0.34	-0.18	-19%	0.47%
1B Fugitive emissions from fuels	0.047	0.063	0.027	0.00028	-0.020	-0.063	-100%	0.00018%
2 IPPU	7.3	4.3	2.9	2.8	-4.5	-1.5	-34%	1.8%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	2.8	1.9	1.7	1.5	-1.1	-0.44	-23%	0.95%
6 Other	0.80	0.76	0.69	0.71	-0.11	-0.056	-7.3%	0.45%
National total for compliance	737	299	236	157	-501	-142	-48%	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 until 2014. After that, emissions remain about constant.

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 and the installation of new filters in the electric arc furnaces of the remaining secondary steel production plants in 1995 and 1998/1999, respectively.
- 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 improving the technology installed already.

Between 2003 and 2014, 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 since gasoline has a much higher lead content than diesel oil.

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

Pb emissions	**1990**	**2005**	**2010**	**2019**	**1990-2010**	**2005-2019**	**2005-2019**	**share in 2019**
	t	t	t	t	t	t	%	%
1 Energy	274	9.9	8.1	5.8	-266	-4.0	-41%	40%
1A Fuel combustion	270	9.9	8.1	5.8	-262	-4.0	-41%	40%
1A1 Energy industries	30	1.9	1.8	1.5	-28	-0.48	-25%	10%
1A2 Manufacturing industries	6.3	2.7	1.8	0.88	-4.5	-1.8	-67%	6.0%
1A3 Transport	230	4.3	3.7	2.8	-227	-1.5	-34%	19%
1A4 Other sectors	3.8	0.95	0.90	0.65	-2.9	-0.31	-32%	4.4%
1A5 Other (Military)	0.032	0.00045	0.00043	0.00039	-0.032	-0.000060	-13%	0.0027%
1B Fugitive emissions from fuels	3.5	NA	NA	NA	–	–	–	–
2 IPPU	67	2.1	0.69	0.57	-66	-1.5	-73%	3.9%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	4.3	2.3	2.3	2.0	-2.0	-0.31	-13%	14%
6 Other	6.8	6.6	6.0	6.3	-0.76	-0.33	-5.1%	43%
National total for compliance	352	21	17	15	-335	-6.2	-30%	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 2014. After that, emissions slightly increase.

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

- By equipping municipal solid waste incineration plants with flue gas treatment or 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 the data basis, i.e. 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 and the installation of new filters in the electric arc furnaces of the remaining secondary steel production plants in 1995 and 1998/1999, respectively.

The slight increase since 2014 is due to an increase of waste volumes incinerated under source category 1A1 Energy industries and an increase of mileages in source category 1A3b Road transportation (mainly exhaust emissions).

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

Cd emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	t	t	t	t	t	t	%	%
1 Energy	2.6	0.43	0.44	0.42	-2.2	-0.0084	-2.0%	61%
1A Fuel combustion	2.6	0.43	0.44	0.42	-2.2	-0.0084	-2.0%	61%
1A1 Energy industries	1.8	0.18	0.20	0.21	-1.6	0.028	16%	30%
1A2 Manufacturing industries	0.74	0.10	0.090	0.068	-0.65	-0.035	-34%	10%
1A3 Transport	0.070	0.077	0.083	0.093	0.013	0.016	21%	14%
1A4 Other sectors	0.084	0.067	0.066	0.050	-0.018	-0.018	-26%	7.2%
1A5 Other (Military)	0.00048	0.00051	0.00054	0.00053	0.000058	0.000018	3.4%	0.077%
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	0.56	0.092	0.087	0.078	-0.47	-0.014	-16%	11%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.047	0.021	0.027	0.036	-0.020	0.015	71%	5.2%
6 Other	0.17	0.16	0.15	0.16	-0.019	-0.0084	-5.1%	23%
National total for compliance	3.4	0.70	0.70	0.69	-2.7	-0.016	-2.3%	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 continued a slightly decreasing trend until 2014. After that, emissions remain about constant.

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 improving the technology installed already.
- The closing down of two production sites 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 (1A1) and manufacturing industries of non-metallic minerals (1A2f, e.g. cement production). Since 2014, emissions remain about constant.

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

Hg emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	t	t	t	t	t	t	%	%
1 Energy	4.3	0.59	0.59	0.51	-3.7	-0.078	-13%	75%
1A Fuel combustion	4.3	0.59	0.59	0.51	-3.7	-0.078	-13%	75%
1A1 Energy industries	3.9	0.34	0.32	0.30	-3.6	-0.040	-12%	45%
1A2 Manufacturing industries	0.25	0.12	0.14	0.09	-0.11	-0.028	-23%	14%
1A3 Transport	0.034	0.037	0.037	0.035	0.0026	-0.0027	-7.3%	5.1%
1A4 Other sectors	0.089	0.085	0.091	0.078	0.0026	-0.0071	-8.3%	11%
1A5 Other (Military)	0.000027	0.000028	0.000030	0.000029	0.0000030	0.00000087	3.1%	0.0043%
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	1.5	0.067	0.066	0.048	-1.4	-0.019	-28%	7.1%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.52	0.077	0.081	0.050	-0.44	-0.027	-36%	7.3%
6 Other	0.080	0.076	0.069	0.071	-0.012	-0.0056	-7.3%	10%
National total for compliance	6.4	0.81	0.81	0.68	-5.6	-0.13	-16%	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 improving the technology installed already. 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 and installation of new filters in the electric arc furnaces of the remaining secondary steel production plants in 1995 and 1998/1999, respectively). 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 decreased by 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	2019	1990-2010	2005-2019	2005-2019	share in 2019
	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	%	%
1 Energy	161	23	19	10	-142	-13	-57%	61%
1A Fuel combustion	161	23	19	10	-142	-13	-57%	61%
1A1 Energy industries	130	5.2	3.4	1.9	-127	-3.3	-63%	12%
1A2 Manufacturing industries	8.4	2.7	2.1	0.92	-6.3	-1.8	-67%	5.7%
1A3 Transport	1.6	1.7	1.7	0.66	0.10	-1.1	-62%	4.1%
1A4 Other sectors	20	13	12	6.3	-8.5	-7.0	-53%	40%
1A5 Other (Military)	0.00036	0.00038	0.00040	0.00039	0.000040	0.000011	3.0%	0.0024%
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	17	2.1	1.2	0.76	-16	-1.4	-64%	4.7%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	13	4.3	4.0	3.1	-9.2	-1.2	-28%	19%
6 Other	2.5	2.5	2.3	2.3	-0.29	-0.13	-5.1%	15%
National total for compliance	193	32	26	16	-167	-16	-50%	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 2019, except for 1A3b Road transportation, where PAH emissions increased in parallel with the increase of traffic volumes.

The PAH emissions are dominated by wood energy combustion and their reduction has mainly been achieved in the dominant source category 1A4, mainly 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 half and increased by about a factor of six 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	2019	1990-2010	2005-2019	2005-2019	share in 2019
	t	t	t	t	t	t	%	%
1 Energy	6.7	4.1	3.7	2.4	-3.0	-1.7	-42%	88%
1A Fuel combustion	6.7	4.1	3.7	2.4	-3.0	-1.7	-42%	88%
1A1 Energy industries	0.0076	0.0085	0.011	0.0038	0.0030	-0.0047	-56%	0.14%
1A2 Manufacturing industries	0.23	0.18	0.15	0.10	-0.078	-0.077	-44%	3.7%
1A3 Transport	0.15	0.17	0.21	0.29	0.061	0.12	74%	11%
1A4 Other sectors	6.3	3.7	3.3	2.0	-3.0	-1.7	-47%	74%
1A5 Other (Military)	0.00071	0.00073	0.00076	0.00069	0.000051	-0.000037	-5.1%	0.026%
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	0.95	0.50	0.012	0.011	-0.94	-0.48	-98%	0.43%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.37	0.25	0.21	0.19	-0.16	-0.059	-24%	7.1%
6 Other	0.072	0.093	0.098	0.11	0.026	0.018	20%	4.2%
National total for compliance	8.1	4.9	4.0	2.7	-4.1	-2.2	-45%	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 started to slightly increase on a very low level.

The decrease of HCB emissions in 1993 occurred in category 1A2b Non-ferrous metals due to the shutdown of the secondary aluminium production plant. Since then, the trend of HCB emissions continues to decrease on a low level. Emissions continue to decrease 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.

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

HCB emissions	1990	2005	2010	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	173	0.44	0.44	0.36	-172	-0.086	-20%	100%
1A Fuel combustion	173	0.44	0.44	0.36	-172	-0.086	-20%	100%
1A1 Energy industries	0.11	0.15	0.17	0.19	0.060	0.035	23%	53%
1A2 Manufacturing industries	172	0.050	0.050	0.035	-172	-0.016	-31%	9.7%
1A3 Transport	NA, NE	NA, NE	NA, NE	NA, NE	–	–	–	–
1A4 Other sectors	0.38	0.24	0.21	0.13	-0.16	-0.11	-44%	37%
1A5 Other (Military)	NA	NA	NA	NA	–	–	–	–
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	0.44	0.36	-172	-0.086	-20%	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 2019 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.

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 occured in 1999 although they should have been treated as hazardous 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. Accidential release by fire is dominating the emissions from sector 6 Other which has decreased continuously since 1980.

PCB emissions from 1A1a Municipal 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 hazardous 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	2019	1990-2010	2005-2019	2005-2019	share in 2019
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	165	1.4	0.55	0.41	-164	-1.0	-71%	0.093%
1A Fuel combustion	165	1.4	0.55	0.41	-164	-1.0	-71%	0.093%
1A1 Energy industries	164	1.1	0.18	0.079	-164	-0.99	-93%	0.018%
1A2 Manufacturing industries	0.50	0.35	0.38	0.33	-0.12	-0.022	-6.3%	0.075%
1A3 Transport	0.00037	0.00037	0.00035	0.00014	-0.000020	-0.00023	-62%	0.000031%
1A4 Other sectors	0.0022	0.0015	0.0013	0.00076	-0.00095	-0.00072	-49%	0.00017%
1A5 Other (Military)	NE	NE	NE	NE	–	–	–	–
1B Fugitive emissions from fuels	NA	NA	NA	NA	–	–	–	–
2 IPPU	1'537	922	708	400	-829	-521	-57%	90%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	347	254	56	10	-291	-244	-96%	2.3%
6 Other	282	93	62	33	-220	-60	-65%	7.4%
National total for compliance	2'332	1'270	827	444	-1'505	-826	-65%	100%

2.8 Compliance with the Gothenburg Protocol

2.8.1 Emission ceilings 2010

Under the CLRTAP, the 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 2019 are in compliance with the emission ceilings.

Table 2-26: Emission ceilings of the Gothenburg Protocol for 2010 and beyond compared to the reported emissions for 2010 and 2019 of the current submission (2021).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2021)	Compliance with emission ceilings 2010 in 2010	Emissions 2019 (Subm. 2021)	Compliance with emission ceilings 2010 in 2019
	kt	kt		kt	
SO_x	26	10	yes	4.4	yes
NO_x	79	83	no	62	yes
NMVOC	144	99	yes	81	yes
NH_3	63	59	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 2019. The emission reduction commitments 2020 have already been achieved for SO_x, NH_3 and PM2.5 in the year 2019 whereas for NMVOC the commitment still seems within reach for 2020. However, for NO_x, the emission reduction commitment will not be met in 2020.

Table 2-27: Reported emission reductions in 2019 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 2019**
	%-reduction of 2005 level	
SO_x	21%	68%
NO_x	41%	33%
NMVOC	30%	29%
NH_3	8.0%	8.6%
PM2.5	26%	42%

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 and PM2.5 and SO_2 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. Various measures led to a total NOx reduction between 1990 and 2019. 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.

- The reductions in road transportation (1A3b) 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 of 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 past few years because of an increasing share of diesel-powered passenger cars and higher EF than expected (the “dieselgate” scandal[3], detected in the year 2015).
- The reductions in manufacturing industries (1A2) 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. In 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

[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 [03.02.2021]

consumption almost doubled from 1990 to 2019). 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.

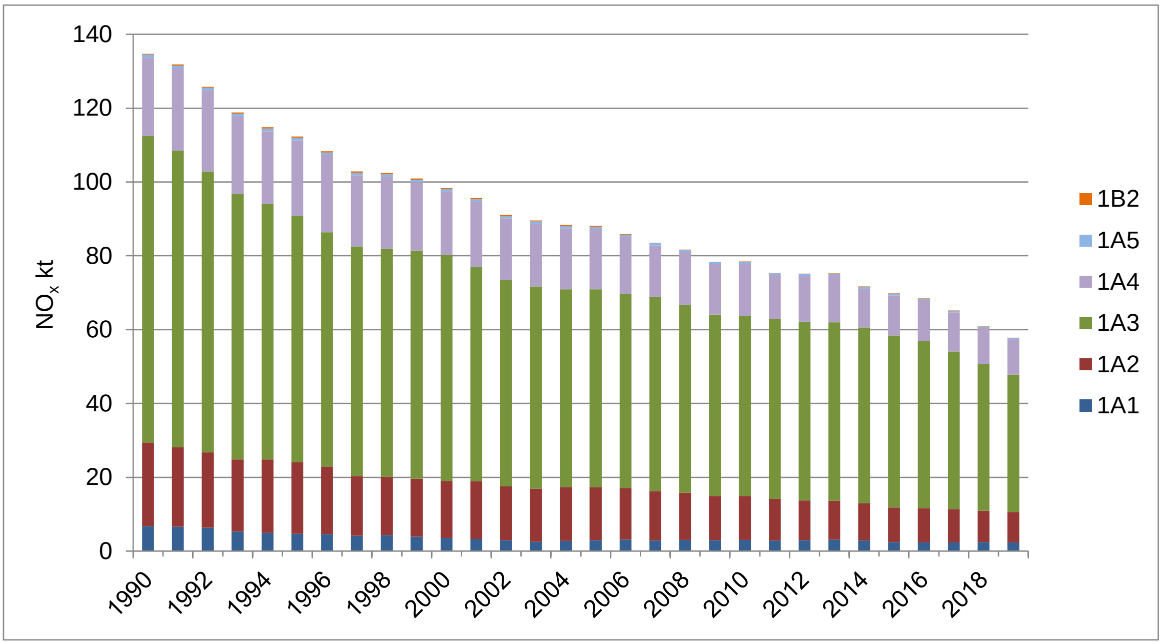


Figure 3-1: Switzerland's NO_x emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2019. The corresponding data table can be found in Annex A7.2.

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 2019. Furthermore, 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 2019, which leads to a decrease of NMVOC emissions.
- NMVOC emissions of source category 1A4 Other sectors declined in the same period as well due to to the technical improvements of wood combustion installations, and a reduction in the number and energy consumption of emission intensive types of wood furnaces.
- The decline of NMVOC emissions in 1B2 is due to technical improvement concerning fugitive emissions caused by distribution and storage of gasoline.

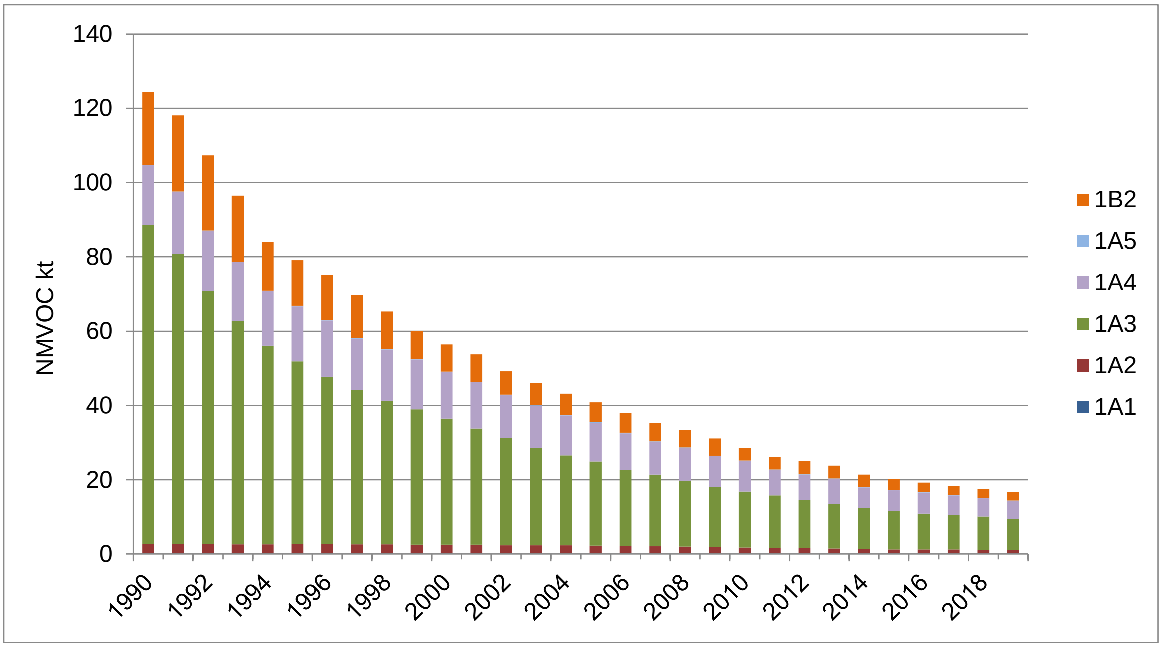


Figure 3-2: Switzerland's NMVOC emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2019. The corresponding data table can be found in Annex A7.2.

3.1.3 Overview and trend for SO_2

Figure 3-3 depicts the SO_2 emissions in energy related sectors since 1990. In 2019, the main contributions from the sector 1 Energy are SO_2 emissions from the source categories 1A2 Manufacturing industries and construction and 1A4 Other sectors. SO_2 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 show also some fluctuations from year to year. These fluctuations are mainly due to annual variations in the number of heating degree days, which causes fluctations in the SO_2 emissions from fossil fuel-based heating systems in sector 1A4 Other sectors.

- First, a limitation of the sulphur content in fuels (stepwise lowering in 1993, 1999, 2000, 2005 and 2009; reduction by about a factor of 10 between 1990 and 2019, see Table 3-8) 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 and gasoline, see Table 3-8; stepwise lowering in 1993, 1999, 2000, 2005 and 2009 by the Ordinance on Air Pollution Control (Swiss Confederation 1985)).
- 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 2019).
- 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 (e.g. no more consumption of residual fuel oil since 2011 and no more bituminous coal since 2000) and by closing of a refinery plant in 2015. The SO_2 emissions from 1B2 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 untis and flaring decrease over time and one refinery is closed in 2015.

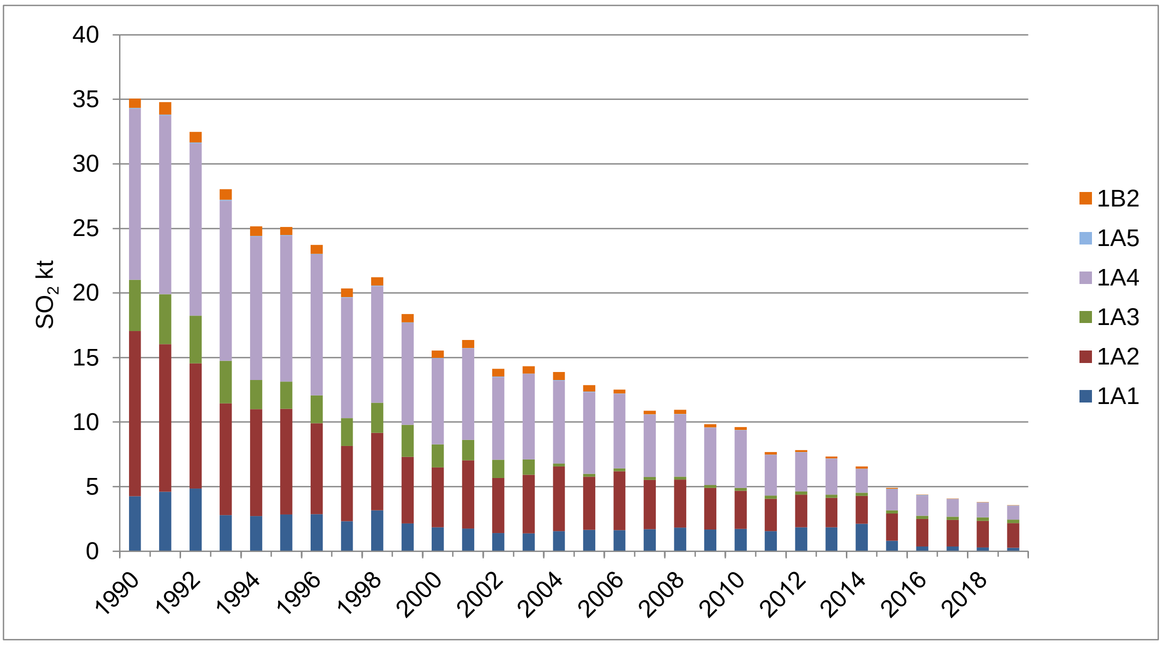


Figure 3-3: Switzerland's SO_2 emissions from the energy sector by source category 1A1-1A5 and 1B2 between 1990 and 2019. The detailed corresponding data table can be found in Annex A7.2.

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. Emissions from the other source categories are comparably small and there are no emissions from source category 1B. 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.

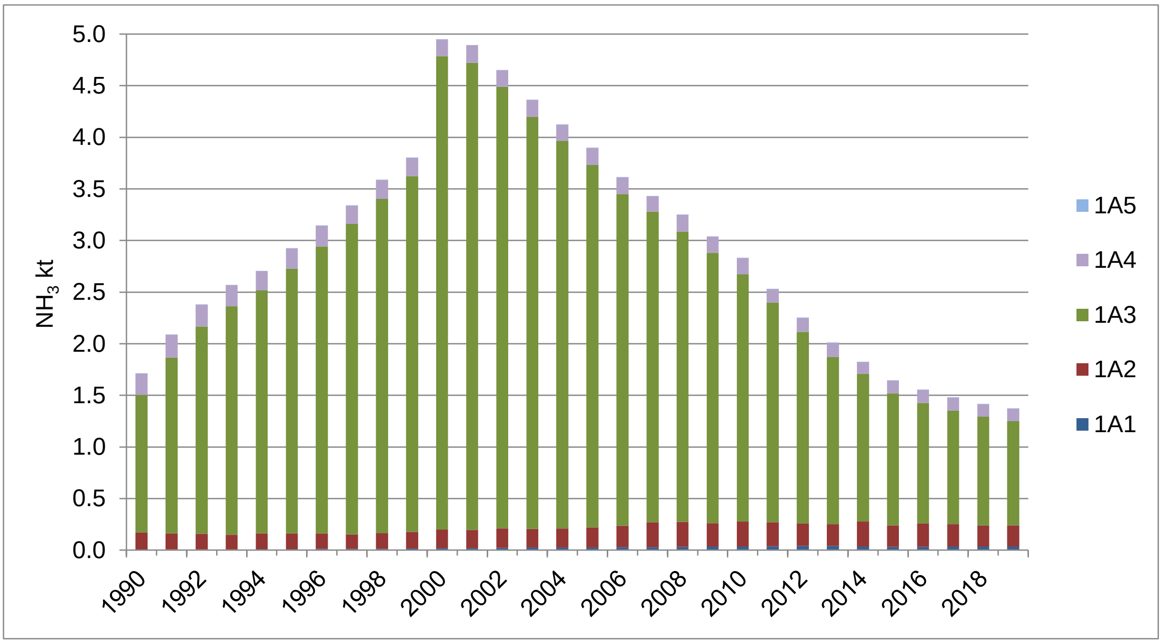


Figure 3-4: Switzerland's NH_3 emissions from the energy sec tor by source category 1A1-1A5 between 1990 and 2019. There are no emissions from 1B. The detailed corresponding data table can be found in Annex A7.2.

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 (1990–2019), 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 half and increased by about a factor of six 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.
- A further reduction of exhaust emissions under 1A3 Transport was caused by the abatement of exhaust emissions from road vehicles. Throughout the years, a continuous reduction of these emissions has been achieved with the stepwise adoption of the Euro standards. New diesel cars must be equipped with diesel particle filters.
- Under category 1A2 Manufacturing industries and construction, a reduction of exhaust emissions resulted from technological improvements in construction machineries (an installation of particle filters for new construction machineries with diesel engines is required by the Ordinance on Air Pollution Control (OAPC) since 2009) and from a fuel switch in stationary combustion (i.e. from coal, residual fuel oil and gas oil to natural gas).

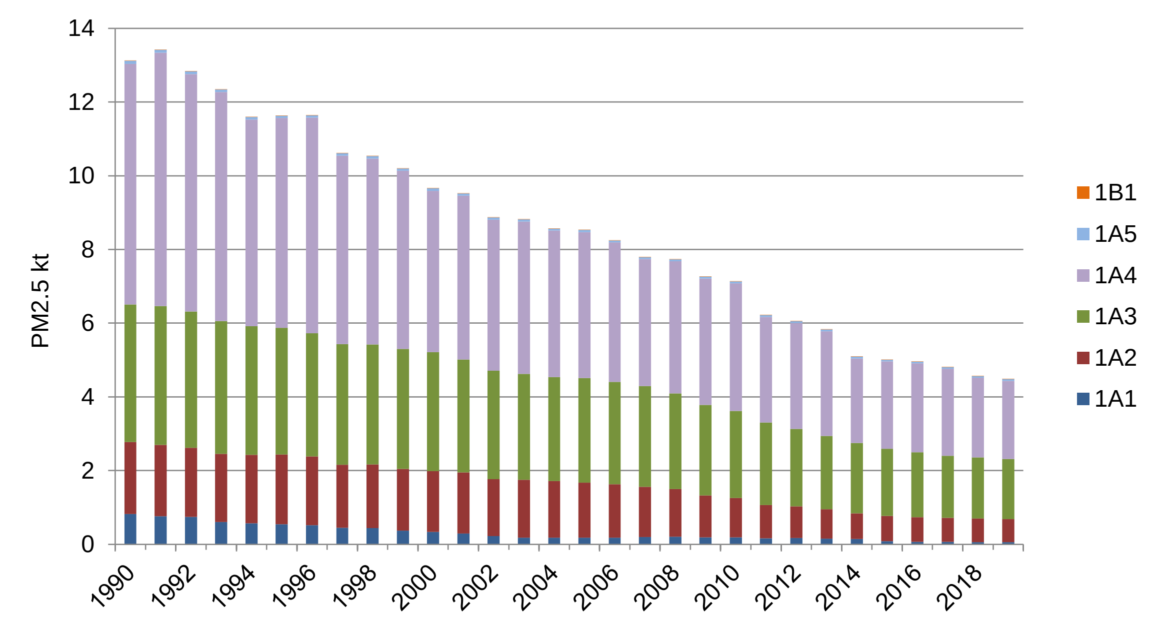


Figure 3-5: Switzerland's PM2.5 emissions from the energy sector by source categories 1A1-1A5 and 1B1 between 1990 and 2019. The corresponding data table can be found in Annex A7.2.

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 Figure 3-6, columns CLRTAP / NFR Template "national total" and UNFCCC/CRF-Tables "national total" compared to CLRTAP / NFR Template "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 neighbouring countries. Note that the fuel tourism and statistical difference from road transportation (1A3b) is reported differently for the GHG inventory and 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. 3.2.6.2.23.2.6.2.2). 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 2021, 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. 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 Figure 3-6).

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

Figure 3-6: Accounting rules for emissions from 1A3a Aviation and 1A3b Road transportation for CLRTAP and UNFCCC.

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 3-1 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 3-1: 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 3-2.

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 (2020)	46.0
Petroleum coke	SFOE (2020), Cemsuisse (2010a)	35.0 (1998), 31.8 (2010)
Other bituminous coal	SFOE (2020), Cemsuisse (2010a)	28.052 (1998), 25.5 (2010)
Lignite	SFOE (2020), Cemsuisse (2010a)	20.097 (1998), 23.6 (2010)
Natural gas	SGWA	*see caption*
Biofuel	**Data sources**	
Biodiesel	SFOE (2020)	38.0
Bioethanol	SFOE (2020)	26.5
Biogas	*assumed equal to natural gas*	*see caption*
Wood	SFOE (2020b)	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 2020). A first campaign was conducted by the Swiss Federal Laboratories for Materials Science and Technology (EMPA) in 1998 (EMPA 1999). Since previous 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 Swiss refineries) 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 2020), is assumed to be constant over the entire reporting period.

Liquefied petroleum gas (LPG)

The NCV of liquefied petroleum gas is the same as used by the Swiss Federal Office of Energy (SFOE 2020) and is – as in the Swiss overall energy statistics – constant over the entire reporting period. It is assumed that liquefied petroleum gas (LPG) consists of 50% propane and 50% butane.

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 2020). 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 3-2) and also the CO_2 emission factor 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 (2020). 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 (2020i). 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 3-2: 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 (2020). Spreadsheet to determine national averages: FOEN 2020i.

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

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 2020b).

Table 3-1 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 2020) 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 2020). 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 2020), 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 2020). 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 Swiss federal customs administration (FCA).
- Data provided by industry associations (GVS, SGWA, Cemsuisse, VSG, VSTB etc.).
- Swiss electricity statistics (SFOE 2020g).
- Swiss renewable energies statistics (SFOE 2020a).
- Swiss wood energy statistics (SFOE 2020b).
- Swiss statistics on combined heat and power generation (SFOE 2020c).

As can be seen in Figure 3-7, fossil fuels amount to slightly more than half of primary energy consumption. The main end-users of fossil fuels are the transport and the housing sector, as electricity generation is predominantly based on hydro- and nuclear power stations. The most recent energy balance is given in Annex 4.

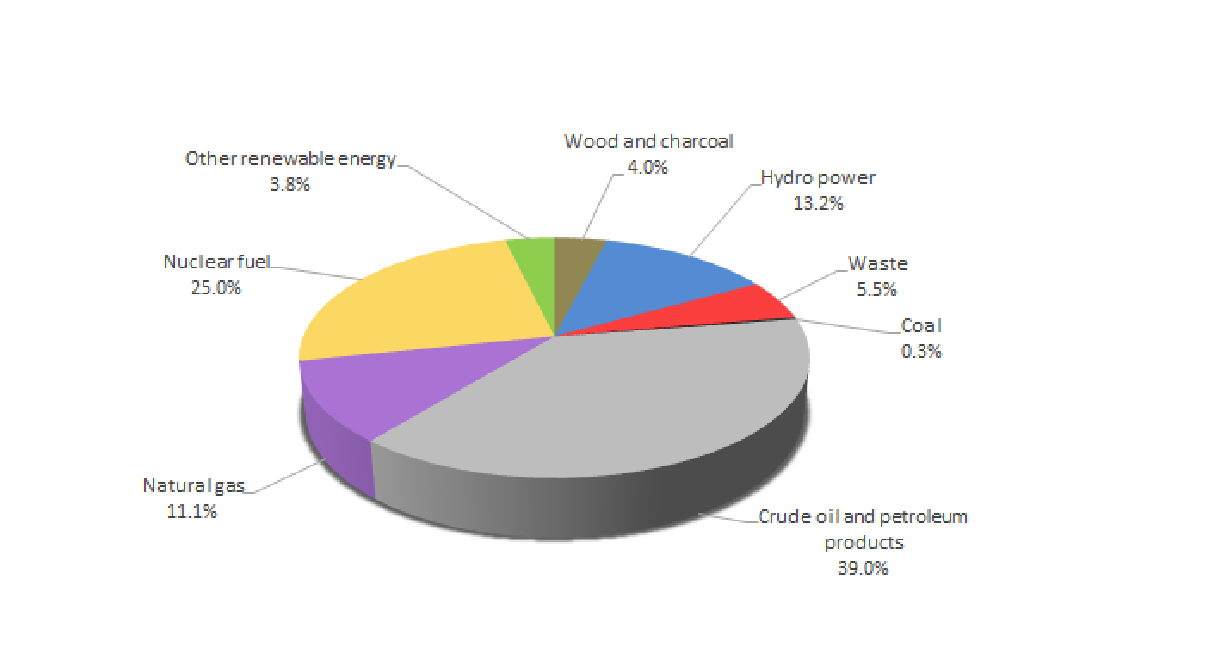


Figure 3-7: Switzerland's primary energy consumption in 2019 by fuel type (see corresponding data in SFOE 2020).

Table 3-3 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 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.

Table 3-3: 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 consumption from fuel tourism, all fuels sold for domestic and international aviation.

Year	Gasoline	Kerosene used for LTO	Kerosene used for cruise (memo item)	Diesel	Diesel Navigation (memo item)	Gas oil	Residual fuel oil	Refinery gas & LPG	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	155'785	8'059	40'008	46'745	813	218'510	23'342	8'890	1'400	14'901	67'861	19'161	46'715	611'367	652'188
1991	162'225	7'640	38'922	47'403	751	238'602	23'590	12'437	980	12'162	76'114	18'596	48'698	648'447	688'120
1992	168'100	7'803	41'297	45'940	766	236'809	24'170	11'492	315	8'758	79'984	19'009	47'628	650'007	692'070
1993	155'897	7'861	42'915	44'215	764	225'920	17'165	12'388	1'120	7'442	83'911	19'158	47'924	622'999	666'678
1994	156'087	7'911	44'198	46'921	827	207'141	17'860	13'455	1'470	7'632	82'737	19'155	45'897	606'266	651'291
1995	151'290	7'987	46'960	47'848	756	217'523	17'278	12'756	1'260	7'962	91'275	19'688	47'901	622'769	670'485
1996	155'209	8'017	48'736	44'925	672	226'289	15'097	13'939	1'015	5'456	98'876	20'584	51'428	640'836	690'243
1997	161'171	8'320	50'454	46'718	667	212'223	12'581	14'236	280	4'590	95'453	21'655	48'287	625'514	676'635
1998	162'477	8'540	52'728	48'664	545	222'407	15'882	15'259	455	3'960	98'301	23'802	49'812	649'560	702'832
1999	168'025	8'762	56'482	51'624	560	212'349	11'058	15'805	521	4'105	101'863	24'403	50'545	649'060	706'102
2000	168'165	9'074	58'987	55'151	526	196'137	7'923	13'649	551	6'120	101'282	26'536	50'170	634'758	694'271
2001	163'543	8'598	55'610	56'282	428	213'089	9'942	14'069	410	6'233	105'478	27'068	53'330	658'041	714'079
2002	160'375	8'128	51'278	58'370	351	196'655	6'446	15'584	679	5'565	103'548	27'876	52'913	636'139	687'769
2003	159'636	7'327	46'110	61'827	424	208'040	7'061	13'642	202	5'663	109'522	27'642	55'442	656'005	702'540
2004	156'812	6'886	43'555	66'466	427	203'370	7'561	16'429	1'819	5'420	113'047	28'845	56'322	662'977	706'959
2005	152'062	7'020	44'081	72'565	500	205'729	5'805	16'432	2'906	5'940	116'100	29'236	58'367	672'162	716'743
2006	147'436	7'291	46'280	78'600	462	195'926	6'419	18'578	3'324	6'467	112'887	31'233	61'399	669'561	716'303
2007	146'012	7'538	49'627	84'408	477	171'313	5'179	15'587	2'730	7'196	109'874	30'015	60'408	640'261	690'365
2008	142'801	7'773	53'378	92'683	459	178'833	4'606	16'288	3'616	6'562	117'083	30'854	64'269	665'368	719'205
2009	138'968	7'496	51'169	94'134	435	173'219	3'575	16'301	3'254	6'193	112'313	29'811	64'177	649'440	701'044
2010	134'043	7'699	53'921	97'775	472	182'295	2'987	15'463	3'498	6'208	125'494	31'185	68'668	675'315	729'707
2011	128'856	7'970	57'726	100'455	421	143'760	2'292	14'856	2'957	5'792	111'269	30'882	64'459	613'549	671'697
2012	124'301	8'258	59'048	106'618	379	154'448	2'780	12'247	3'148	5'269	122'051	31'145	70'205	640'470	699'897
2013	118'634	8'243	59'825	111'468	356	162'532	1'959	15'053	2'735	5'567	128'592	30'925	73'614	659'321	719'502
2014	113'877	8'282	60'259	114'373	311	122'694	1'581	14'473	3'148	5'704	111'346	31'320	68'285	595'082	655'653
2015	105'591	8'414	62'374	112'815	335	129'349	862	9'822	1'145	5'205	118'996	32'084	71'644	595'927	658'636
2016	102'297	8'577	65'584	114'036	342	132'325	378	9'136	890	4'795	125'030	33'583	77'622	608'669	674'595
2017	99'155	8'581	67'352	113'707	299	123'726	350	8'770	763	4'609	125'289	33'342	80'796	599'090	666'741
2018	97'588	8'756	71'494	115'227	256	111'225	87	8'890	781	4'285	118'611	34'510	80'454	580'414	652'164
2019	96'786	8'587	72'482	115'343	200	108'624	111	8'108	777	3'812	121'615	34'964	82'749	581'476	654'159

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 2020). 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 2020), the Swiss renewable energy statistics (SFOE 2020a), the Swiss wood energy statistics (SFOE 2020b), the energy consumption statistics in the industry and services sectors (SFOE 2020d), 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 3-8 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.

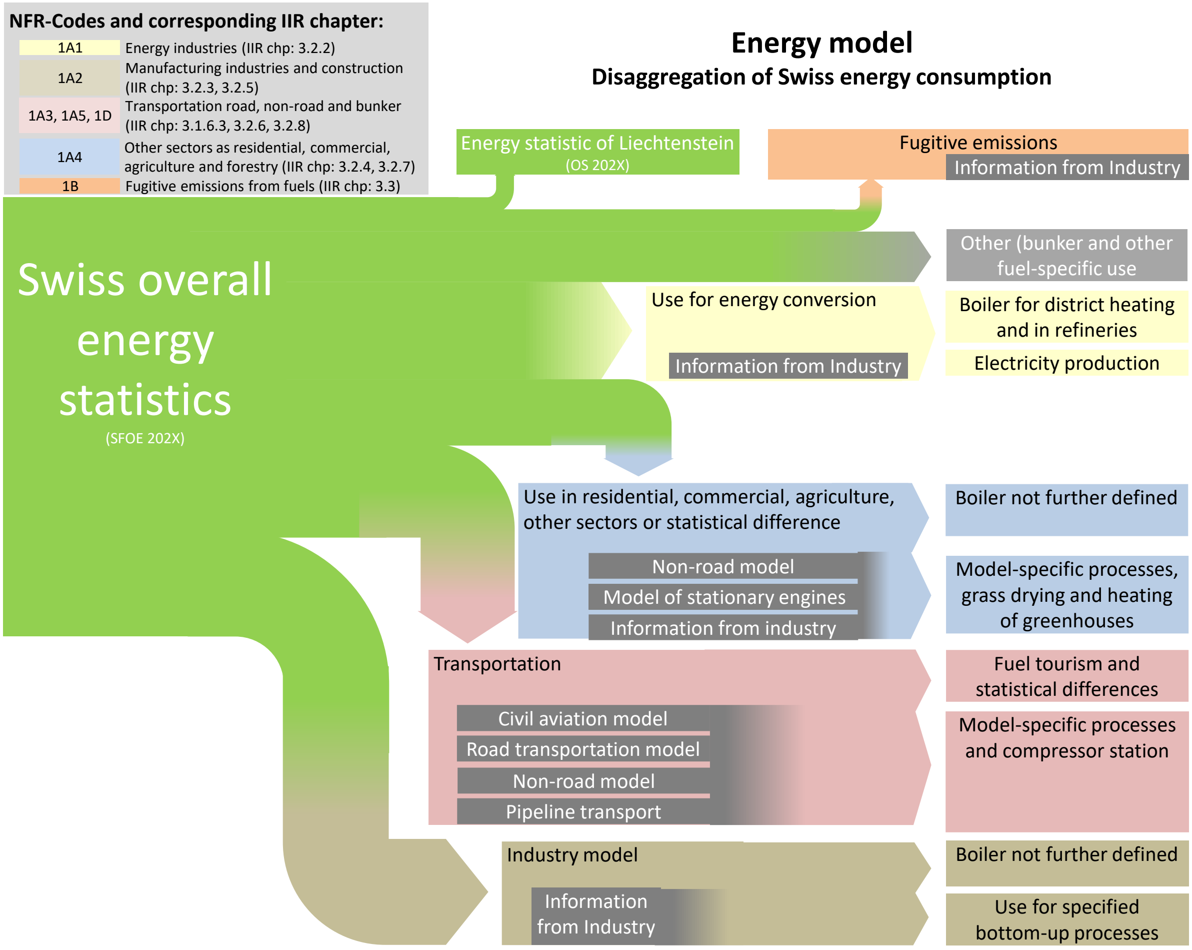


Figure 3-8 Overview of Switzerland's energy model. In the abbreviations SFOE 202X and OS 202X the "X" refers to the latest edition of the respective statistics.

Industry model (Details are given in chp. 3.2.3.2)

The industry model is a based on two pillars: (1) the energy consumption statistics in the industry and services sectors (SFOE 2020d), which is a comprehensive annual survey of fuel consumptions for all years since 1999 or 2002 (depending on the fuel type), and (2) a bottom-up industry model (Prognos 2013) which extends fuel consumptions back to 1990. The resulting industry model provides a consistent split of energy consumption by source category and fuel type for the full reporting period. Further disaggregation is then achieved by using plant-level industry data for specific processes, as far as available.

Civil aviation model (Details are given in chp. 3.2.6.2.1)

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 2020b), 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 2020) into the relevant source categories 1A1-1A5 (Figure 3-9). For each fuel type, the disaggregation process of the energy model as shown schematically in Figure 3-8, the interaction between the different sub-models and additional data sources are visualized separately in Figure 3-10 to Figure 3-19.

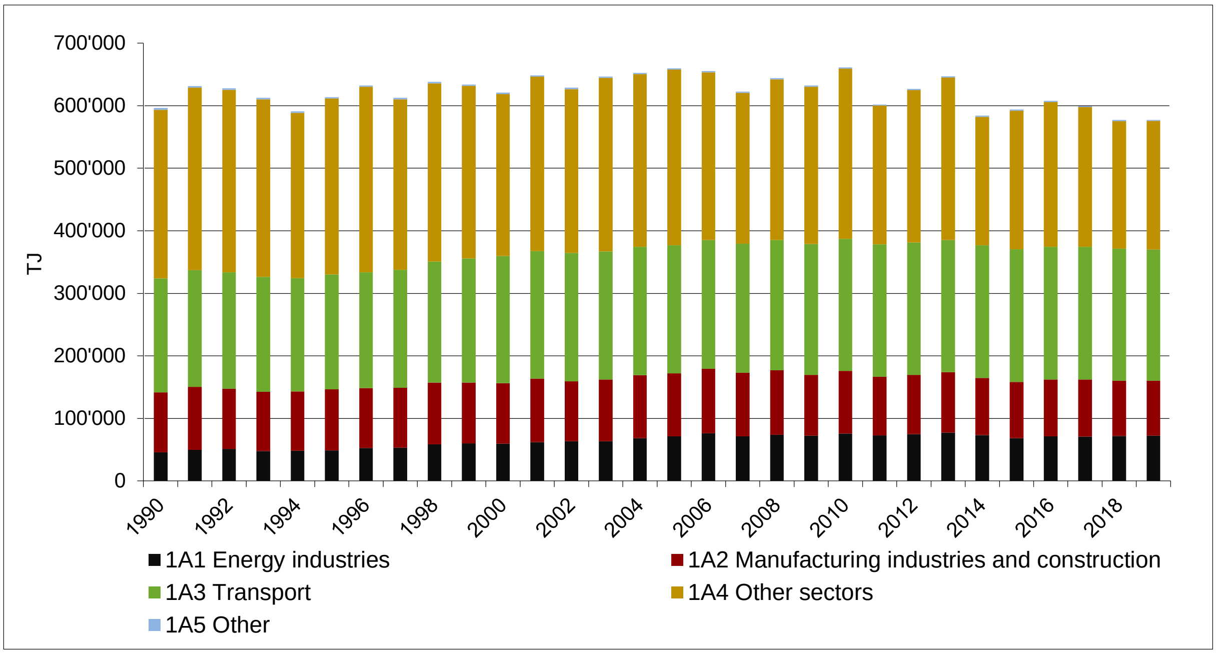


Figure 3-9: Switzerland's energy consumption by source categories 1A1-1A5 based on the Swiss energy model. Note that in the same period population increased by about 28%, industrial production by about 80% and the motor vehicle fleet by about 63% (SFOE 2020, table 43)

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 3-8).

- 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.

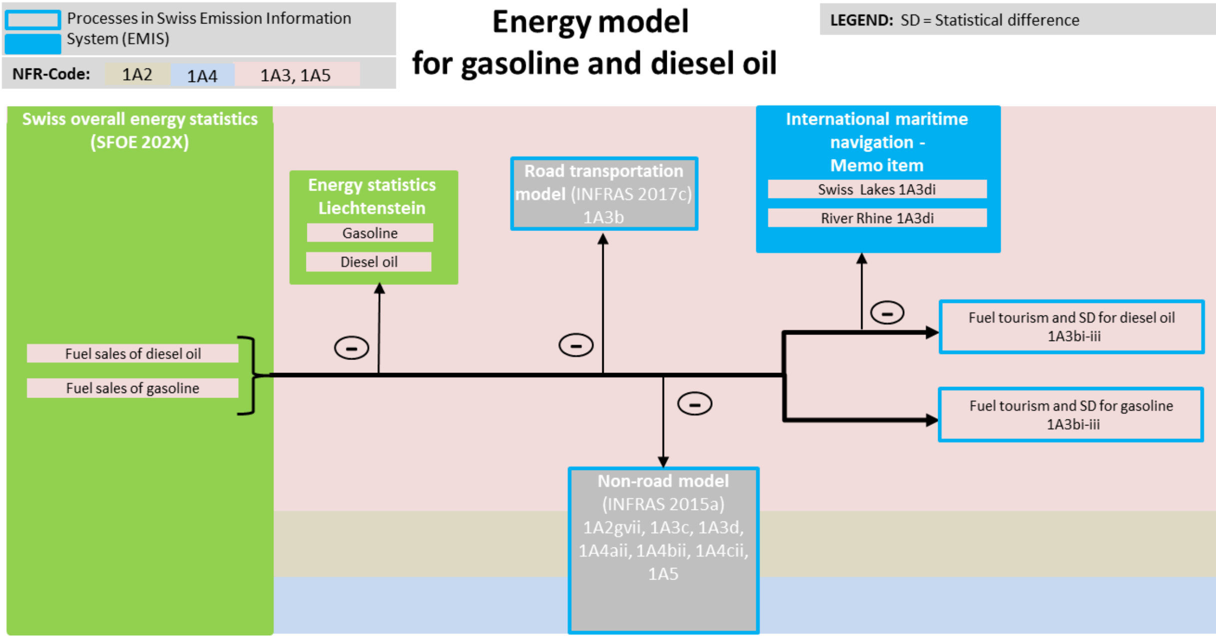


Figure 3-10: Schematic disaggregation of 1A Fuel consumption for gasoline and diesel oil. Marine bunker fuel consumption is based on the national customs statistics (see chapter 3.1.6.1 on memo items)

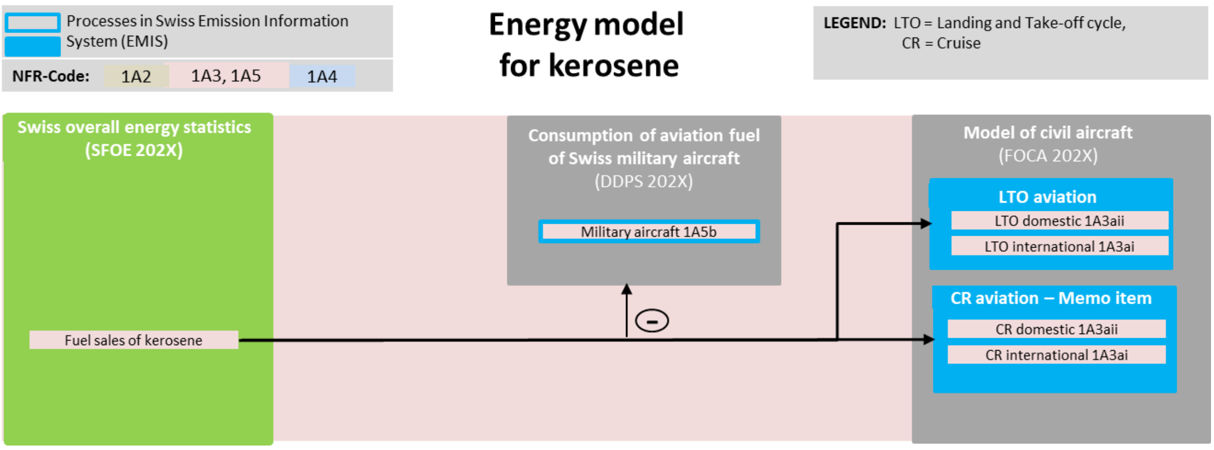


Figure 3-11: Schematic disaggregation of 1A Fuel consumption for kerosene. Fuel consumption for military aircraft is provided by the Federal Department of Defence, Civil Protection and Sport (DDPS). The differentiation between domestic and international aviation as well as between CR and LTO is provided by the civil aviation model (see chp. 3.2.6.2.1)

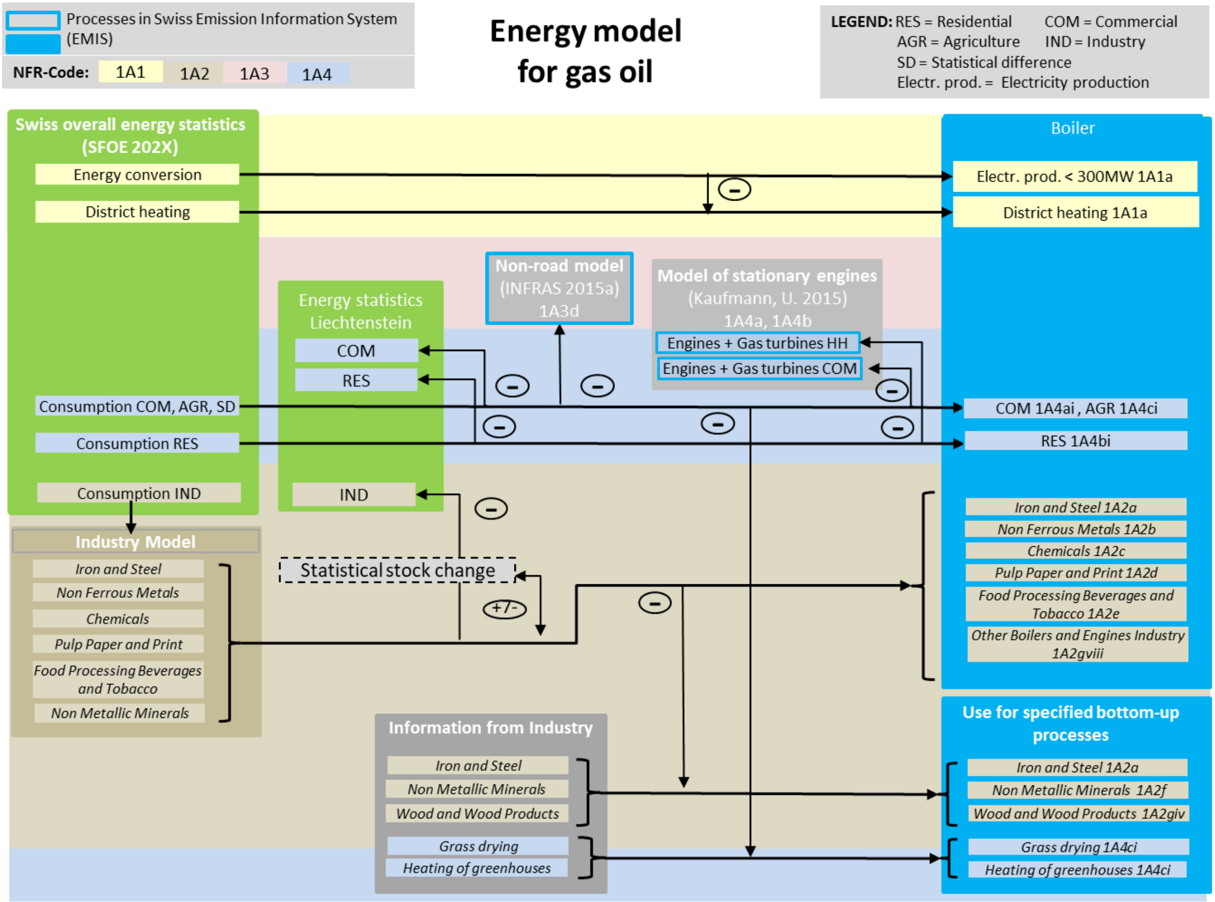


Figure 3-12: Schematic disaggregation of 1A Fuel consumption for gas oil. The Swiss overall energy statistics provide gas oil use for energy conversion and the amount thereof being used for district heating. Based on this information, gas oil use is split into 1A1ai Electricity generation and 1A1aiii Heat plants. According to the non-road model, a small amount of gas oil is consumed in source category 1A3d navigation (steam-powered vessels).

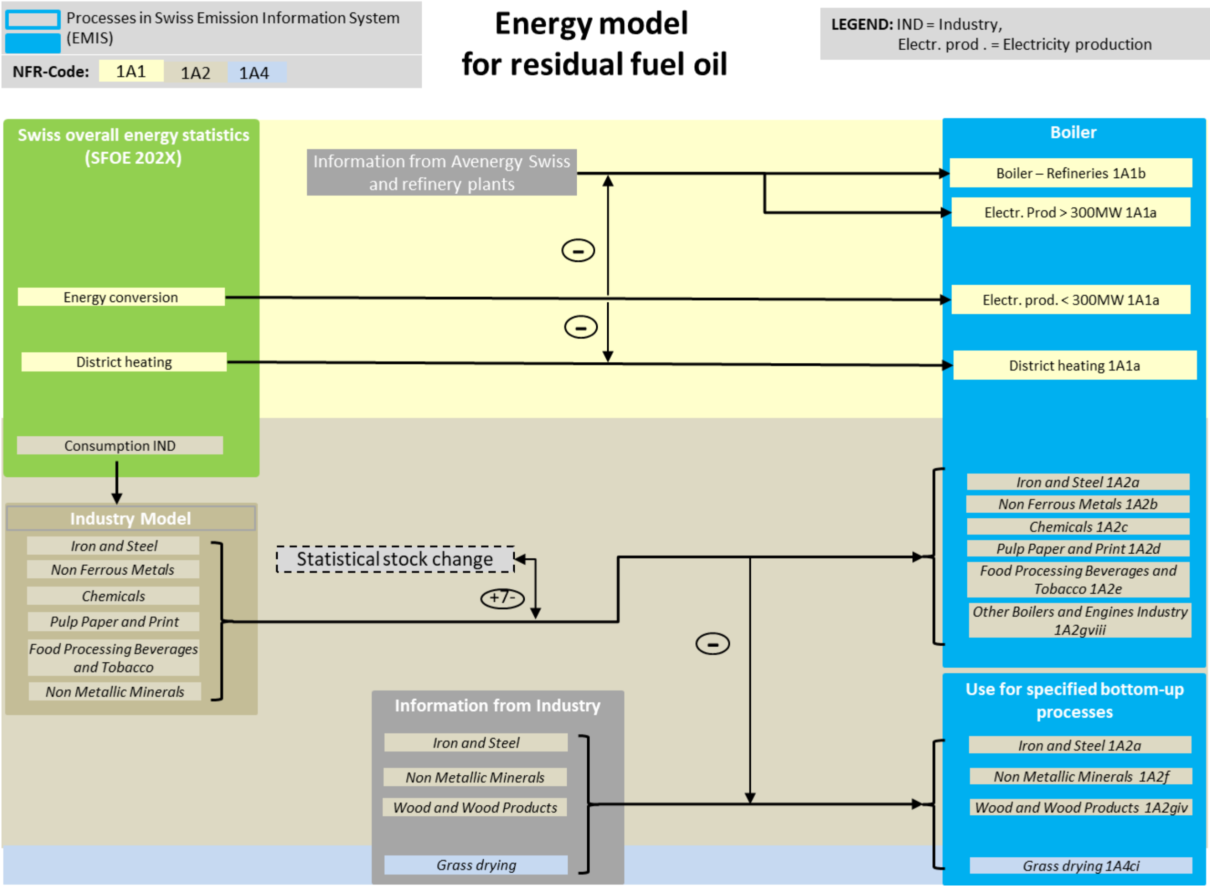


Figure 3-13: Schematic disaggregation of 1A Fuel consumption for residual fuel oil. The Swiss overall energy statistics report residual fuel oil use in energy conversion and the amount thereof consumed in electricity production (one single fossil fuel power station, operational from 1985 to 1994), district 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.

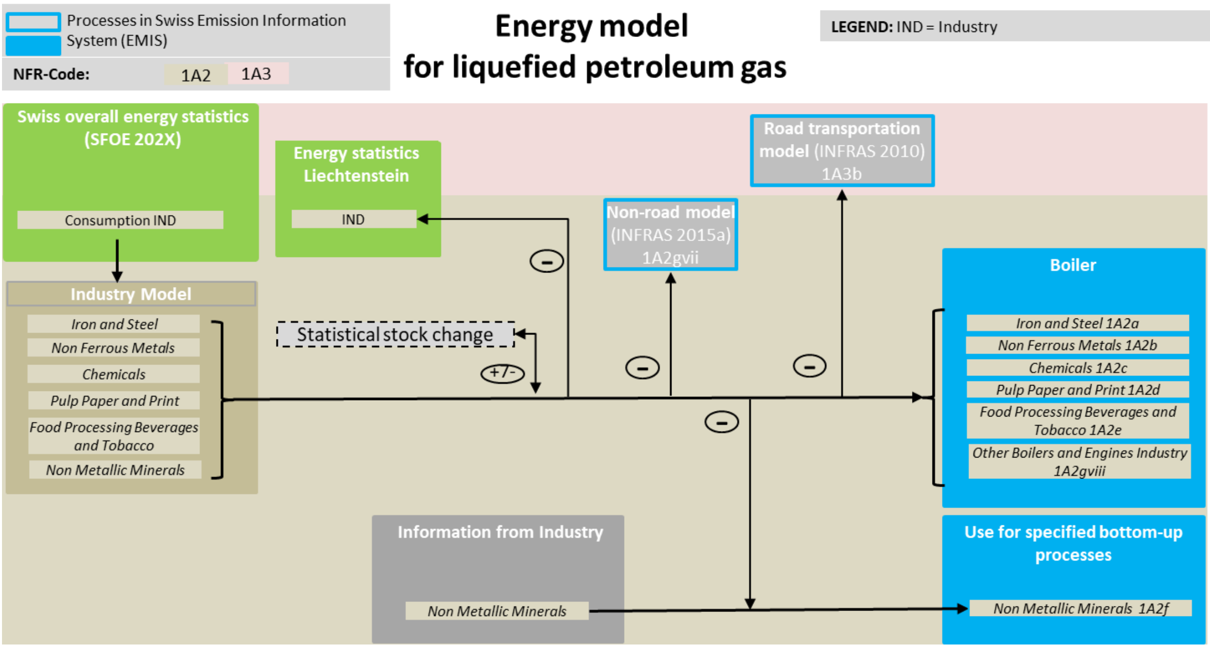


Figure 3-14: Schematic disaggregation of 1A Fuel consumption for liquefied petroleum gas.

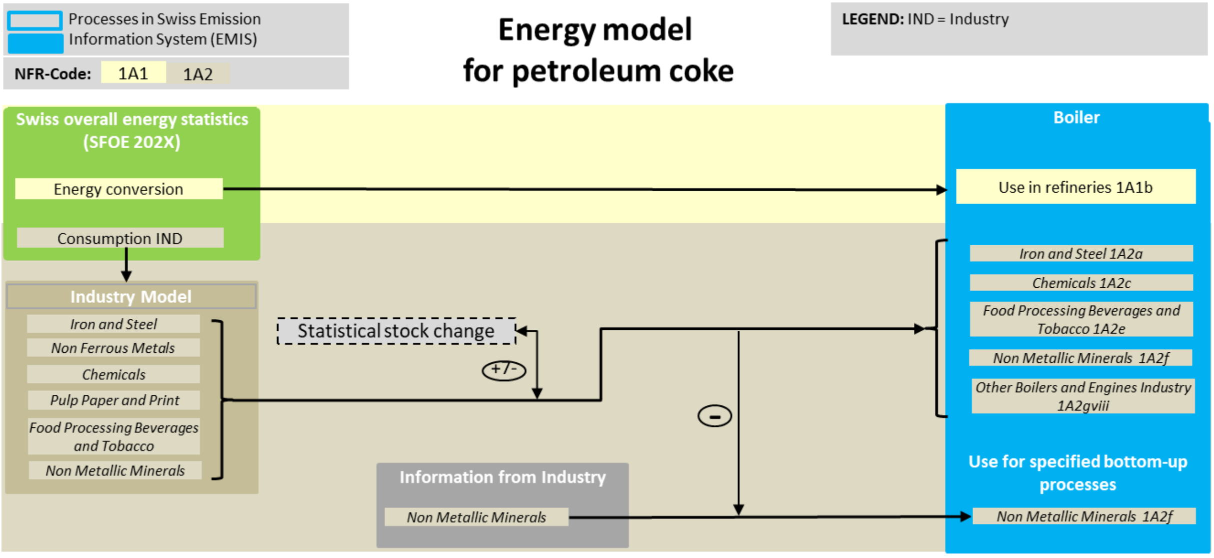


Figure 3-15: Schematic disaggregation of 1A Fuel consumption for petroleum coke.

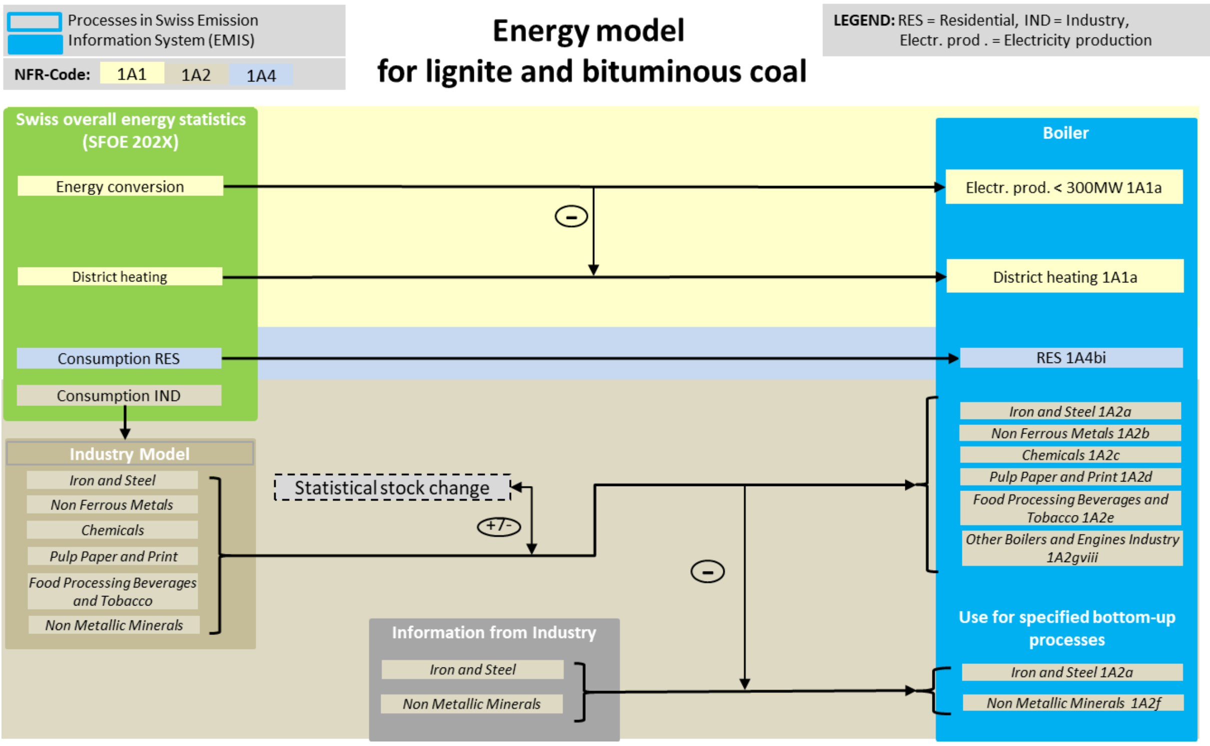


Figure 3-16: Schematic disaggregation of 1A Fuel consumption for lignite and bituminous coal. The Swiss overall energy statistics provide bituminous coal use for energy conversion and the amount thereof being used for district heating. Based on this information, use of bituminous coal in energy industries is split into 1A1ai Electricity generation and 1A1aiii Heat plants up to 1995. Coal consumption for Public electricity and heat production ceased thereafter.

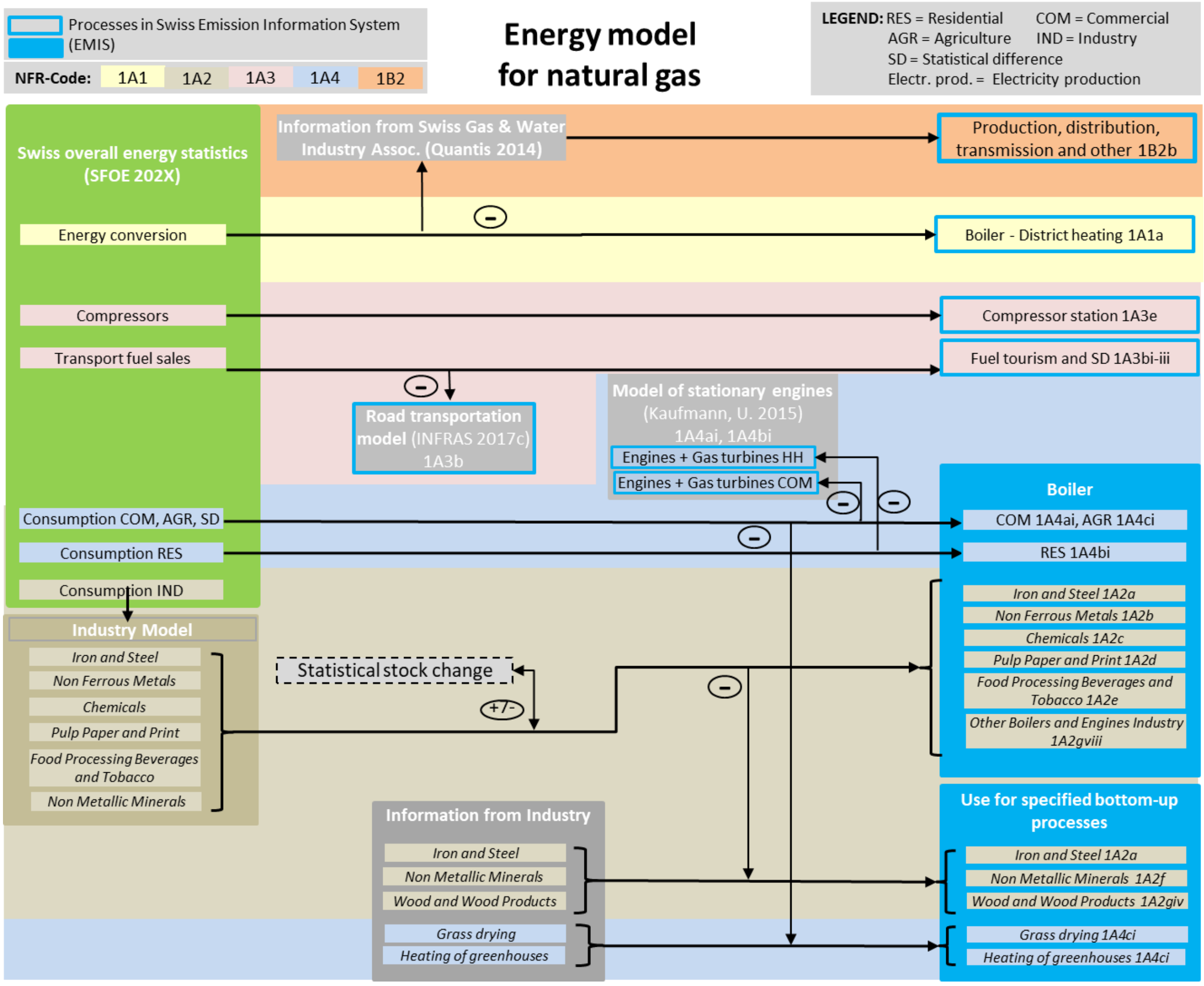


Figure 3-17: Schematic disaggregation of 1A Fuel consumption (and 1B Fugitive emissions from fuels) for natural gas. The Swiss overall energy statistics (SFOE 2020) provide gas use in the transformation sector (energy conversion and distribution losses). Distribution losses as estimated by the Swiss 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.

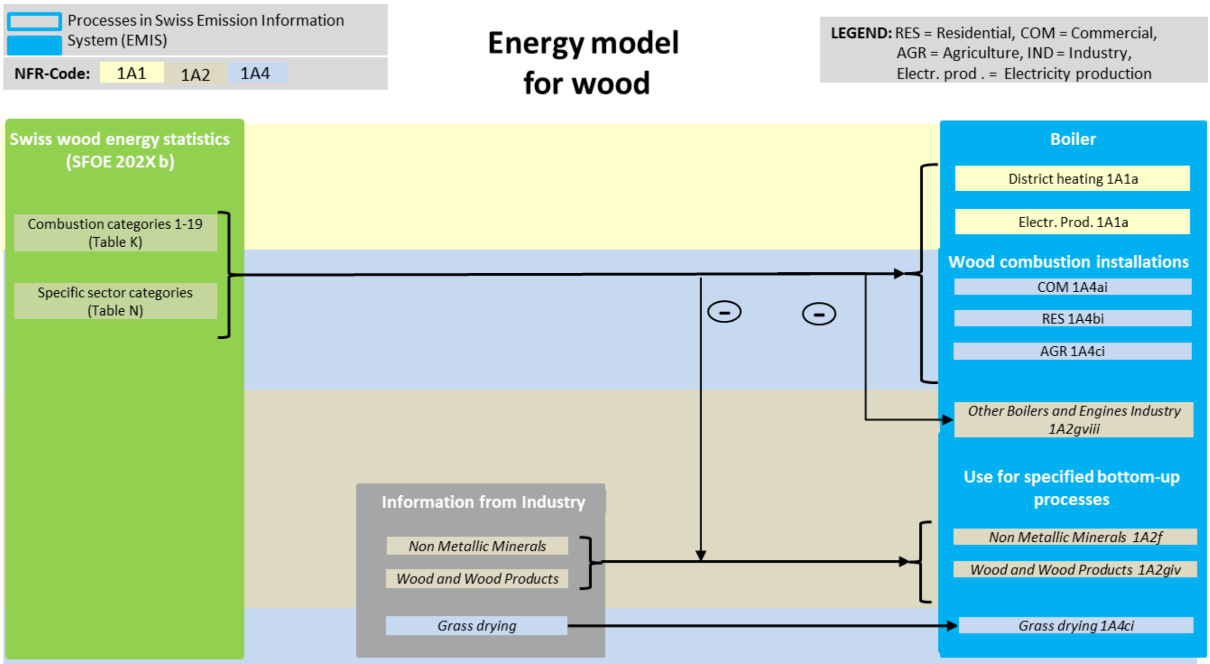


Figure 3-18: Schematic disaggregation of 1A Fuel consumption for wood. For a detailed description of the Energy model for wood combustion, see chapter 3.2.1.1.2.

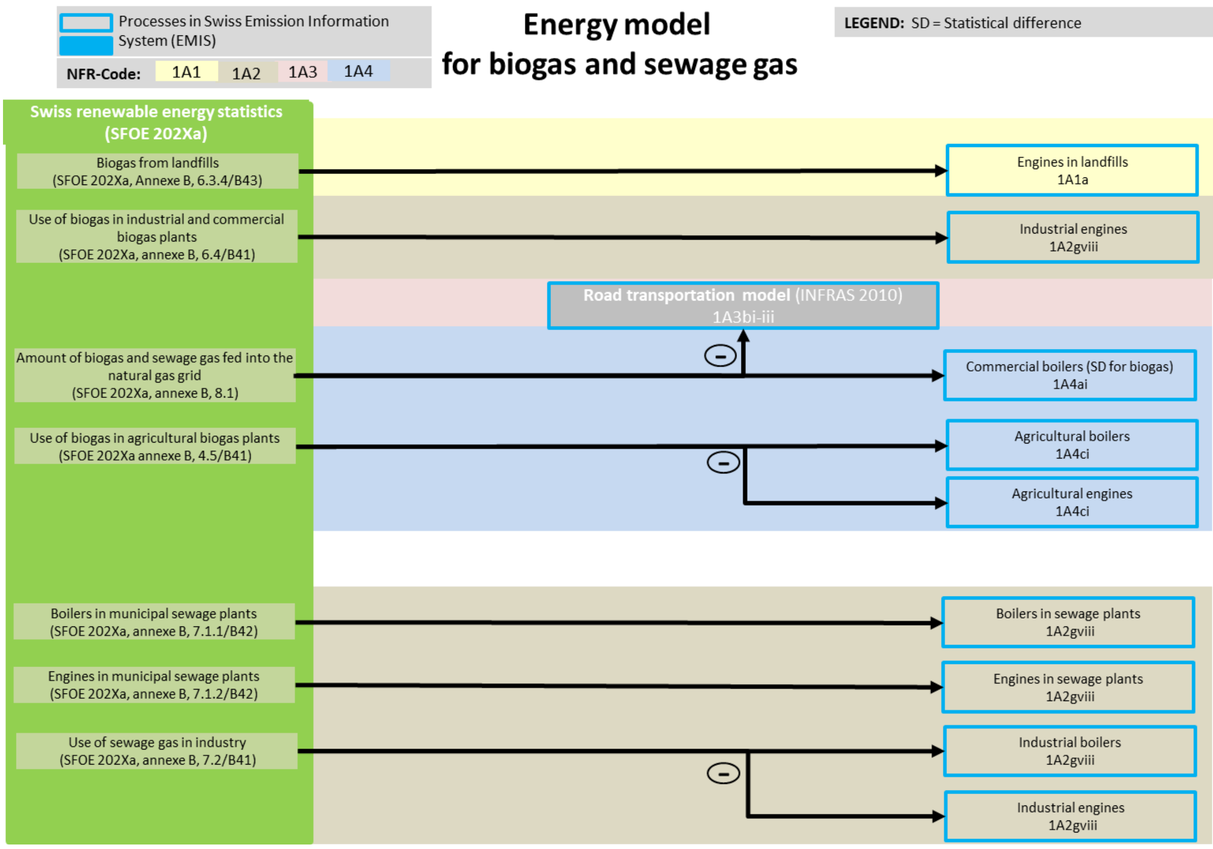


Figure 3-19: Schematic disaggregation of 1A Fuel consumption for biogas and sewage gas.

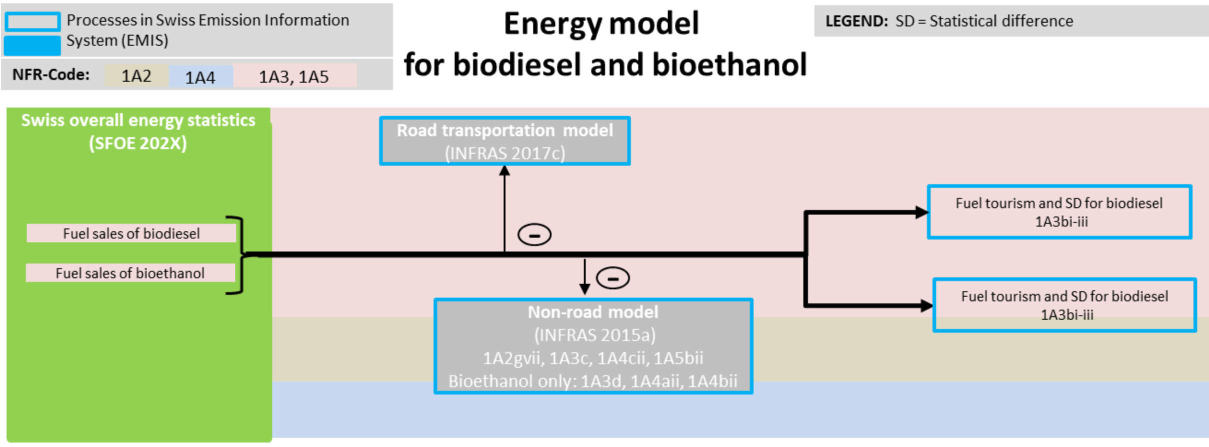


Figure 3-20: Schematic disaggregation of 1A Fuel consumption for biodiesel and bioethanol.

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 3-4), the air pollutant emissions are calculated by a Tier 3 method based on the corresponding decision trees given in EMEP/EEA Guidebook 2019 (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 3-4: Non-road categories (FOEN 2015j) and the corresponding NFR nomenclature (reporting tables).

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

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

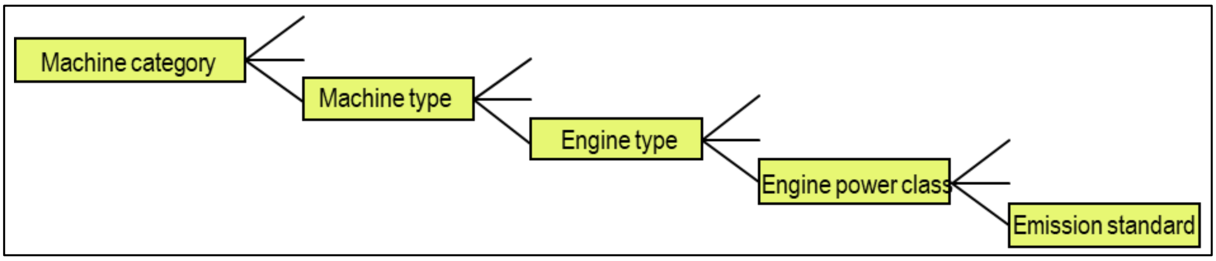


Figure 3-21: Each non-road vehicle is classified by its engine-power class, engine type, machine type, machine category, and emission standard.

The emission modelling is based on activity data and emission factors by means of the following equation, which is implemented at the most disaggregated level (Figure 3-21):

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

with

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

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

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

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

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

Note that the emissions are only calculated in steps of 5 years 1980, 1985…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_2 is country-specific, see Table 3-8. 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 are generally given in FOEN (2015j) and INFRAS (2015a). BC exhaust emission factors stem from Neosys (2013).
- 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).
- For SO_x the emission factors are based upon the sulphur content of fuels. These are country- and fuel-specific, see implied emission factors in Table 3-8 (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 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, PM2.5 (exhaust), CO can be visualised and downloaded (tables in CSV format) by a query from the public part of the 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 (MOFIS) run by the the Federal Roads Office (FEDRO 2013). In addition, several publications serve as further data source:

- SBV (2013) for construction machinery

---

[4] https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html [03.02.2021]

- 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 public part of the non-road database INFRAS (2015a), which is the data pool of FOEN (2015j). They can be queried by vehicle type, fuel type, power class and emission standard either at aggregated or disaggregated levels.

In Annex A2.1.2 (Table A - 5) the stock numbers and the operating hours of non-road vehicles are summarised for each non-road category.

3.2.1.1.2 Energy model for wood 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 EMEP/EEA (2019).

Methodology

The Swiss wood energy statistics (SFOE 2020b) provide both the annual wood consumption for specified categories of combustion installations (table K, categories 1-19) and the allocations of the combustion categories to the sectoral consumer categories (table N, household, agriculture/forestry, industry, services, electricity and district heating). This allows for assigning the annual wood consumption at the level of combustion installation categories (Table 3-5) to the source categories 1A1a Public Electricity and Heat Production, 1A2gviii Other, 1A4ai Commercial/Institutional, 1A4bi Residential and 1A4ci Agriculture/Forestry/Fishing.

Table 3-5: Categories of wood combustion installations based on SFOE 2020b.

Categories of wood combustion installations
Open fireplaces
Closed fireplaces, log wood stoves
Pellet stoves
Log wood hearths
Log wood boilers
Log wood dual chamber boilers
Automatic chip boilers < 50 kW
Automatic pellet boilers < 50 kW
Automatic chip boilers 50-300 kW w/o wood processing companies
Automatic pellet boilers 50-300 kW
Automatic chip boilers 50-300 kW within wood processing companies
Automatic chip boilers 300-500 kW w/o wood processing companies
Automatic pellet boilers 300-500 kW
Automatic chip boilers 300-500 kW within wood processing companies
Automatic chip boilers > 500 kW w/o wood processing companies
Automatic pellet boilers > 500 kW
Automatic chip boilers > 500 kW within wood processing companies
Combined chip heat and power plants
Plants for renewable waste from wood products

Emission factors

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 et al. (2021). 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, EFs in the Nordic countries) and the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA 2019) and takes into account both various technology standards of combustion installations and operating influences. For automatic chip boilers >50 kW, combined heat and power plants and plants for renewable waste from waste products, the emission factors of NO_x, NMVOC, 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.

Table 3-6: Emission factors 2019 of pollutants due to wood combustion from source categories 1A1-1A4 (“w/o wood comp.” 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	316	10	5	87	93	100	60	3'000
Closed fireplaces, log wood stoves	85	290	10	5	80	86	92	56	2'833
Pellet stoves	85	22	10	2	37	39	42	15	395
Log wood hearths	70	419	10	5	174	186	200	120	4'000
Log wood boilers	100	104	10	2	54	58	62	16	1'717
Log wood dual chamber boilers	70	409	10	5	174	186	200	120	4'000
Automatic chip boilers < 50 kW	120	47	10	2	80	86	92	16	917
Automatic pellet boilers < 50 kW	70	15	10	2	28	30	32	7.3	335
Automatic chip boilers 50-300 kW w/o wood proc. companies	130	26	3	2	54	58	62	3.0	458
Automatic pellet boilers 50-300 kW	75	8.2	3	2	28	30	32	1.2	175
Automatic chip boilers 50-300 kW within wood proc. companies	140	26	3	2	54	58	62	3.0	467
Automatic chip boilers 300-500 kW w/o wood proc. companies	130	26	3	2	54	58	62	3.0	458
Automatic pellet boilers 300-500 kW	75	8.2	3	2	28	30	32	1.2	175
Automatic chip boilers 300-500 kW within wood proc. companies	140	26	3	2	54	58	62	3.0	467
Automatic chip boilers > 500 kW w/o wood proc. companies	120	9.5	3	2	10	10	11	0.22	142
Automatic pellet boilers > 500 kW	75	3.4	3	2	4	5	5	0.1	50
Automatic chip boilers > 500 kW within wood proc. companies	120	9.5	3	2	20	22	23	0.48	152
Combined chip heat and power plants	40	1.2	1	2	0.30	0.32	0.32	0.003	10
Plants for renewable waste from wood products	130	2.2	20	4.9	1.3	1.4	1.5	0.03	60

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	500	50	50	30	30	0.005	60
Closed fireplaces, log wood stoves	20	1	2	500	50	50	30	30	0.005	60
Pellet stoves	20	1	2	50	10	10	4	4	0.005	10
Log wood hearths	20	1	2	500	50	50	30	30	0.005	60
Log wood boilers	20	1	2	252	30	30	15	15	0.005	20
Log wood dual chamber boilers	20	1	2	500	100	100	60	60	0.005	60
Automatic chip boilers < 50 kW	20	1	2	100	10	10	4	4	0.005	20
Automatic pellet boilers < 50 kW	20	1	2	50	10	10	4	4	0.005	10
Automatic chip boilers 50-300 kW w/o wood proc. companies	16	1	2	52	5	5	3	3	0.005	10
Automatic pellet boilers 50-300 kW	16	1	2	52	5	5	3	3	0.005	10
Automatic chip boilers 50-300 kW within wood proc. companies	16	1	2	100	5	5	3	3	0.005	10
Automatic chip boilers 300-500 kW w/o wood proc. companies	11	1	2	52	1	1	1	1	0.005	10
Automatic pellet boilers 300-500 kW	11	1	2	52	1	1	1	1	0.005	10
Automatic chip boilers 300-500 kW within wood proc. companies	11	1	2	100	1	1	1	1	0.005	10
Automatic chip boilers > 500 kW w/o wood proc. companies	11	1	2	50	1	1	1	1	0.001	10
Automatic pellet boilers > 500 kW	11	1	2	50	1	1	1	1	0.001	10
Automatic chip boilers > 500 kW within wood proc. companies	11	1	2	100	1	1	1	1	0.001	10
Combined chip heat and power plants	11	1	2	10	0.1	0.1	0.1	0.1	0.001	10
Plants for renewable waste from wood products	107	2.2	2	50	1	1	1	1	0.001	10

Activity data

In submission 2010, the categories of wood combustion installations have been revised entirely according to the Swiss Wood Energy statistics (SFOE 2009b, see there in chp. 3.1) and since then all activity data is based on those statistics, see Table 3-7 (SFOE 2020b).

As additional data source, specific bottom-up information from the industry are 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 2021/1A 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 3-18):

- 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 3-7: Wood energy consumption in 1A Fuel combustion.

1A Wood combustion	1990	1995	2000	2005
	g CH_4/GJ			
Open fireplaces	130	127	124	122
Closed fireplaces, log wood stoves	130	124	119	113
Pellet stoves	NO	NO	16	13
Log wood hearths	200	192	183	175
Log wood boilers	70	62	53	45
Log wood dual chamber boilers	200	192	183	175
Automatic chip boilers < 50 kW	60	52	43	35
Automatic pellet boilers < 50 kW	NO	NO	14	12
Automatic chip boilers 50-300 kW w/o wood proc. companies	30	27	24	22
Automatic pellet boilers 50-300 kW	NO	NO	7.8	6.7
Automatic chip boilers 50-300 kW within wood proc. companies	30	27	24	22
Automatic chip boilers 300-500 kW w/o wood proc. companies	30	27	24	22
Automatic pellet boilers 300-500 kW	NO	NO	NO	6.7
Automatic chip boilers 300-500 kW within wood proc. companies	30	27	24	22
Automatic chip boilers > 500 kW w/o wood proc. companies	10	8.9	7.8	6.7
Automatic pellet boilers > 500 kW	NO	NO	NO	3.0
Automatic chip boilers > 500 kW within wood proc. companies	12	11	10	9.5
Combined chip heat and power plants	NO	0.89	0.78	0.67
Plants for renewable waste from wood products	4.0	3.7	3.4	3.2

1A Wood combustion	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	g CH_4/GJ									
Open fireplaces	113	110	107	103	100	100	100	100	100	100
Closed fireplaces, log wood stoves	107	105	103	102	100	98	97	95	93	92
Pellet stoves	10	9.0	8.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0
Log wood hearths	157	150	143	137	130	130	130	130	130	130
Log wood boilers	37	35	33	32	30	30	30	30	30	30
Log wood dual chamber boilers	157	150	143	137	130	130	130	130	130	130
Automatic chip boilers < 50 kW	27	25	23	22	20	20	20	20	20	20
Automatic pellet boilers < 50 kW	10	10	10	10	10	9.3	8.7	8.0	7.3	6.7
Automatic chip boilers 50-300 kW w/o wood proc. companies	17	15	13	12	10	10	10	10	10	10
Automatic pellet boilers 50-300 kW	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0	3.0
Automatic chip boilers 50-300 kW within wood proc. companies	17	15	13	12	10	10	10	10	10	10
Automatic chip boilers 300-500 kW w/o wood proc. companies	17	15	13	12	10	10	10	10	10	10
Automatic pellet boilers 300-500 kW	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0	3.0
Automatic chip boilers 300-500 kW within wood proc. companies	17	15	13	12	10	10	10	10	10	10
Automatic chip boilers > 500 kW w/o wood proc. companies	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0	3.0
Automatic pellet boilers > 500 kW	2.3	2.0	1.7	1.3	1.0	1.0	1.0	1.0	1.0	1.0
Automatic chip boilers > 500 kW within wood proc. companies	7.0	6.0	5.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
Combined chip heat and power plants	0.47	0.40	0.33	0.27	0.20	0.20	0.20	0.20	0.20	0.20
Plants for renewable waste from wood products	2.3	2.0	1.7	1.3	1.0	1.0	1.0	1.0	1.0	1.0

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_2. Table 3-8 shows sulphur contents and SO_2 emission factors per fuel type. Explanations:

- For liquid and solid fuels, the SO_2 emission factors are determined by the sulphur content. The 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 Customs Administration (FCA) 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_2.

$$EF_{SO_2} = \frac{M_{SO\,2}}{M_S} * \frac{S}{NCV} = 2\frac{S}{NCV}$$

- Gas oil: starting from 1990 and for each fifth subsequent year up to and including 2015 the values for the SO_2 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, FCA 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_2/TJ) shown in Table 3-8 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_2/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 3-8: Sulphur contents and SO_2 emissions factors. For explanation see text.

Year	Maximum legal limit of sulphur content						
	Diesel oil	Gasoline	Gas oil (Euro)	Natural gas	Res. fuel oil	Res. fuel oil	Coal
	ppm	ppm	ppm	ppm	Class A, %	Class B, %	%
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
2010-2019	10	10	1000	190	1.0	2.8	1-3

Year	Effective sulphur content				
	Diesel oil	Gasoline	Gas oil (Euro)	Gas oil (Oeko)	Res. fuel oil
	ppm	ppm	ppm	ppm	%
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				

Year	SO_2 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			380			23.3
1996	17	9.4	*52*			*376*			23.3
1997	17	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	6.7	37			360			23.2
2001	12	5.7	*36*			*364*			23.2
2002	11	4.8	*35*			*368*			23.2
2003	9.3	3.8	*35*			*372*			23.2
2004	0.47	0.38	*34*	0.5	NE	*376*		350	23.2
2005	0.47	0.38	33			380			23.2
2006	0.47	0.38	*31*			*392*			23.1
2007	0.47	0.38	*30*			*404*			23.2
2008	0.47	0.38	*28*			*416*			23.2
2009	0.47	0.38	*27*			*428*			23.2
2010	0.47	0.38	25			440			23.2
2011	0.47	0.38	*22*			*480*			23.2
2012	0.47	0.38	*19*			*520*	500		23.2
2013	0.47	0.38	*17*			*560*			23.1
2014	0.47	0.38	*14*			*600*			23.1
2015	0.47	0.38	11			640			23.1
2016	0.47	0.38	*10*			*633*			23.1
2017	0.47	0.38	*9.2*			*626*			23.1
2018	0.47	0.38	*8.3*			*619*			23.2
2019	0.47	0.38	*7.4*			*612*			23.2

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 3-9: 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 3-10: Key categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 1A1 Energy Industries.

Code	Source category	Pollutant	Identification criteria
1A1a	Public electricity and heat production	NOx	L1, L2, T1, T2
1A1a	Public electricity and heat production	SO2	L1, L2, T1, 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, 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 (CHP) 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 Public electricity and heat production (1A1a) 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 waste incinerated. They are all country-specific and based on an extensive measurement campaign in municipal waste incineration and special waste incineration plants (TBF 2015) as well as on expert estimates. Both sources are also documented in the EMIS database (EMIS 2021/1A1a Kehrichtverbrennungsanlagen and EMIS 2021/1A1a 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 solid waste and special waste incineration are based on the mass flow and emission model of former use and disposal of PCBs in Sitzerland (Glüge et al. 2017), see Annex A2.2.

Until 2003 the same emission factors for special waste and municipal solid waste incineration plants have been applied. The emission factors were evaluated in the year 2015 (TBF 2015) and have been revised according to this study. For special waste incineration plants considerably higher emission factors are now estimated (in average factor 2 to 4, Cd about factor 10).

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 US-EPA (NO_x, NMVOC, SO_x, PM exhaust, PM10 exhaust, PM2.5 exhaust, CO) (EMIS 2021/1A1a 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 2021/1A 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_2 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_2 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_2 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 3-11: Emission factors for 1A1a Public electricity and heat production of energy industries in 2019.

1A1a Public electricity and heat production	NO_x	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ	kg/TJ
Gas oil	32	2	7.4	0.002	0.2	0.2	0.2	0.0078	6.1
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	9.2
Other fuels (MSW)	31	2.1	3.5	0.45	0.60	0.60	0.60	0.0054	7.5
Other fuels (special waste)	37	5.0	4.3	0.61	1.4	1.4	1.4	0.013	16
Biomass (wood, renewable waste)	53	0.48	3.7	2.4	0.44	0.47	0.48	0.0071	17
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	g/TJ	g/TJ	mg I-TEQ/TJ	g/TJ	g/TJ	g/TJ	g/TJ	mg/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	0.0005	0.00056	0.00084	0.00084	0.00084	NA	NA
Other fuels (MSW)	25	2.5	5.3	0.034	NE	NE	NE	NE	3.8	1.6
Other fuels (special waste)	29	16	7.3	0.043	NE	NE	NE	NE	NE	0.63
Biomass (wood, renewable waste)	24	1.2	2	0.016	0.23	0.23	0.23	0.23	1	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 waste and special waste incineration are based on annual waste statistics (FOEN 2020h) and provided in the table below.

Table 3-12: 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
Total Other fuels	kt	2'603	2'433	3'040	3'527
Municipal solid waste (MSW)	kt	2'470	2'270	2'801	3'297
Special waste	kt	133	163	239	230

1A1a Other fuels	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total Other fuels	kt	3'968	3'924	4'104	4'035	4'066	4'150	4'264	4'248	4'297	4'322
Municipal solid waste (MSW)	kt	3'717	3'676	3'841	3'773	3'817	3'889	4'010	4'011	4'042	4'059
Special waste	kt	252	247	263	262	249	261	254	236	255	262

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 2020; 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 2020a). 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 2020b) as described in chapter 3.2.1.1.2 Energy model for wood combustion.

Table 3-13: Activity data of 1A1a Public electricity/heat.

1A1a Public electricity and heat production	Unit	1990	1995	2000	2005
Total fuel consumption	TJ	40'379	39'179	49'913	56'976
Gas oil	TJ	980	554	790	1'300
Residual fuel oil	TJ	3'214	1'813	340	290
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	530	46	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	4'339	5'422	8'292	9'827
Other fuels (waste-to-energy)	TJ	30'768	30'264	39'371	44'508
Biomass (wood, renewable waste)	TJ	301	466	547	844
Biogas (co-generation from landfills)	TJ	247	614	573	207

1A1a Public electricity and heat production	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total fuel consumption	TJ	61'740	59'796	63'402	63'334	59'366	61'381	65'016	64'743	65'334	66'485
Gas oil	TJ	490	400	800	670	770	660	430	490	380	450
Residual fuel oil	TJ	40	10	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	9'926	7'512	8'213	8'449	5'082	7'080	8'956	7'927	8'141	8'454
Other fuels (waste-to-energy)	TJ	48'277	47'847	49'313	48'228	49'161	50'548	52'422	52'316	53'097	53'552
Biomass (wood, renewable waste)	TJ	2'958	3'982	5'032	5'949	4'321	3'071	3'195	4'003	3'711	4'021
Biogas (co-generation from landfills)	TJ	49	44	44	39	31	21	13	6.5	6.0	8.4

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 Guidebooks.

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 Guidebook (EMEP/EEA 2019, table 4-6).

Activity data (1A1b)

Activity data on fuel combustion for petroleum refining (1A1b) is provided by the Swiss overall energy statistics (SFOE 2020) 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 2020). Since 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. This is explained by the fact that in 1990 one of the two Swiss refineries operated at reduced capacity and in later years resumed full production, leading to higher fuel consumption. Between 2004 and 2015, one of the Swiss refineries is also using petroleum coke as a fuel and since 2015 natural gas is used additionally to residual fuel oil and refinery gas.

Net calorific values are provided by the annual monitoring reports of the refining industries for the years 2005-2011 and 2013-2017 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 2020).

Table 3-14: Activity data of 1A1b Petroleum Refining.

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

1A1b Petroleum refining	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total fuel consumption	TJ	14'176	13'169	11'242	13'834	14'173	7'232	6'355	6'298	6'627	5'911
Residual fuel oil	TJ	891	764	1'212	1'094	1'330	C	C	C	C	NO
Refinery gas	TJ	11'282	10'720	8'249	11'055	10'935	C	C	C	C	C
Petroleum coke	TJ	2'003	1'685	1'781	1'685	1'908	C	NO	NO	NO	NO
Natural gas	TJ	NO	NO	NO	NO	NO	NO	NO	C	C	C

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

Methodology (1A1c)

Based on the decision tree Fig. 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 2021/1A1c). The emission factor for BC (% PM2.5) is estimated based on Nussbaumer and Hälg (2015). Neither the 1996 IPCC Guidelines nor the EMEP/EEA Guidebook 2019 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 3-15: Emission factors of 1A1c charcoal production in 2019.

1A1c Charcoal	NO_x	NMVOC	SO2	NH3	PM2.5 exh.	PM10 exh.	TSP exh.	BC exh.	CO
	kg/TJ								
Charcoal production	10	1'700	NE	NE	3'700	3'900	4'800	555	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 2021/1A1c).

Table 3-16: Activity data of 1A1c charcoal production.

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

1A1c Charcoal	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Charcoal production	TJ	3.6	3.7	4.1	3.3	4.3	3.8	4.1	3.9	4.3	5.1

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

The following recalculations were implemented in submission 2021:

- 1A1a: Activity data (wood, wood waste) of all combustion installations in source category 1A1a have been revised for 1990-2018 due to recalculations in the Swiss wood energy statistics (SFOE 2020b).
- 1A1a: The country-specific emission factor model for wood energy was completely updated for the entire time period based on air pollution control and laboratory measurements and literature data yielding revised emission factors of all pollutants for all wood combustion installations. See chp. 3.2.1.1.2.
- 1A1a: A very small recalculation (0.001%) concerning use of natural gas in sector 1A1a for the year 2016 was made.
- 1A1a: Activity data for engines on landfills has slightly changed for the years 2000 to 2018 due to an adjustment in the rounding of the numbers taken from the statistics of renewable energies by SFOE to two significant digits.

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 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 3-17: 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 3-18: Key Categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 1A2 Manufacturing Industries and Construction.

Code	Source category	Pollutant	Identification criteria
1A2d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	SO2	T1, T2
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	NOx	L1, L2, T1, T2
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	SO2	L1, L2, T1, 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
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	T1, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	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 EMEP/EEA (2019), the emissions are calculated according to a Tier 2 approach based on country-specific emission factors.

Overview Industry Model

The industry model is one sub-model of the Swiss energy model (see chp. 3.1.6.3.2). The industry model disaggregates the stationary fuel consumption into the source categories and processes under 1A2 Manufacturing industries and construction. The following figure visualizes the disaggregation process.

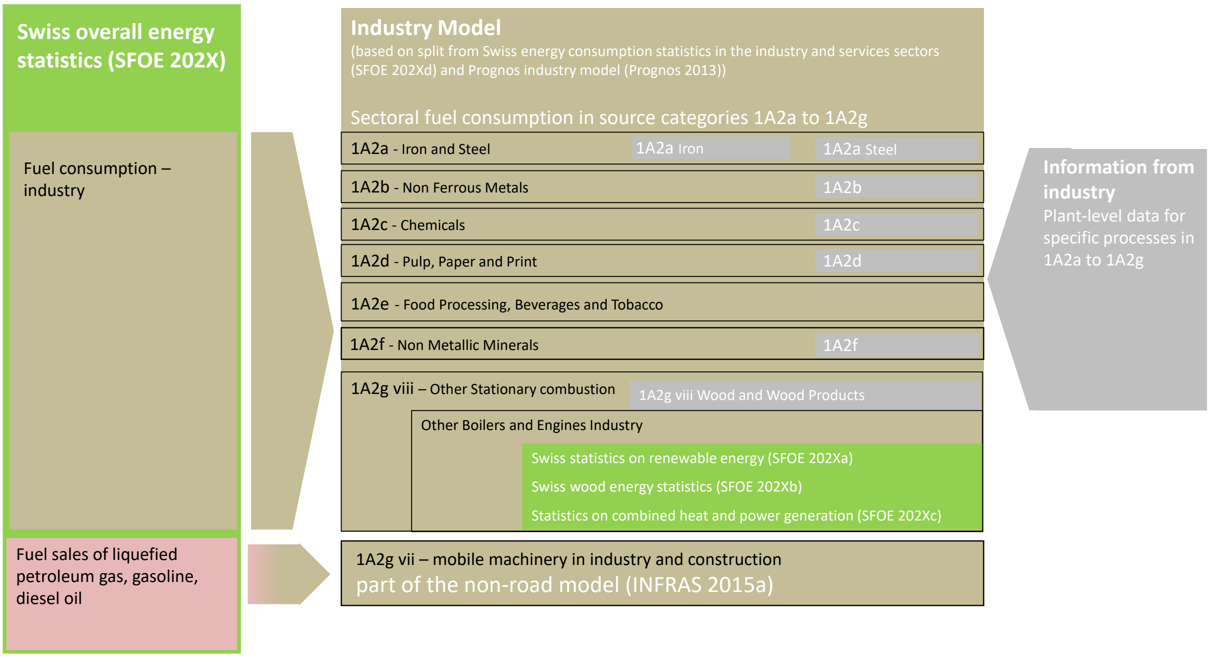


Figure 3-22: Schematic presentation of the data sources used for the industrial sectors 1A2a – 1A2g. The references SFOE 202X, SFOE 202Xa, 202Xb and 202Xc refer to the 2020 edition of the corresponding energy statistics. For each fuel type, the Swiss overall energy statistics provide the total consumption for industry. The total consumption is then distributed to the different source categories based on information from industry surveys (SFOE 2020d) and the Prognos industry model (Prognos 2013). The grey boxes on the right show the specific bottom-up industry information.

The total fuel consumption regarding each fuel type in the industry sector is provided by the Swiss overall energy statistics (SFOE 2020, see also description in chp. 3.1.6.3.2). The energy disaggregation into the source categories 1A2a to 1A2g is carried out for each fuel type individually based on the energy consumption statistics in the industry and services sectors (SFOE 2020d). These statistics are available since 1999 for gas oil and natural gas. For all other fossil fuels (i.e. residual fuel oil, liquefied petroleum gas, petroleum coke, other bituminous coal and lignite) data are available since 2002. In order to generate consistent time series since 1990, additional data from another industry model is applied (Prognos 2013) as described in the following paragraphs.

In addition, the share of fuel used for co-generation in turbines and engines within 1A2 is derived from a model of stationary engines developed by Eicher + Pauli (Kaufmann 2015) for the statistics on combined heat and power generation (SFOE 2020c).

Energy consumption statistics in the industry and services sectors

The energy consumption statistics in the industry and services sectors (SFOE 2020d) refer to representative surveys with about 12’000 workplaces in the industry and services sectors that are then grossed up or extrapolated to the entire industry branch. For certain sectors and fuel types (i.e. industrial waste, residual fuel oil, other bituminous coal and lignite) the surveys represent a census covering all fuel consumed. The surveys are available for all years since 1999 or 2002, depending on the fuel type.

In 2015, a change in the survey method of the energy consumption statistics in the industry and services sectors was implemented (SFOE 2015d). In brief, the business and enterprise register, which forms the basis for the samples of the surveys, was revised. While previously the business and enterprise register was based on direct surveys with work places, it is now based on annual investigations of registry data (e.g. from the old-age and 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

The energy consumption statistics in the industry and services sectors are complemented by a bottom-up industry model (Prognos 2013). The model is based on 164 individual industrial processes and further 64 processes related to infrastructure in industry. Fuel consumption of a specific process is calculated 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 overlap, systematic differences between the two time series can be detected. These two data sets have been combined in order to obtain consistent time series of the shares of each source category 1A2a-1A2g for each fuel type. For this purpose, the approach to “generate consistent time series from overlapping time series” is used according to the 2006 IPCC Guidelines (IPCC 2006, Volume 1, Chapter 5, consistent overlap). To illustrate the approach, an example for gas oil attributed to source category 1A2c is provided in Figure 3-23. A detailed description for all fuel types and source categories (1A2a-1A2g), including further assumptions, is provided in the underlying documentation of the EMIS database (EMIS 2021/1A2_Sektorgliederung Industrie).

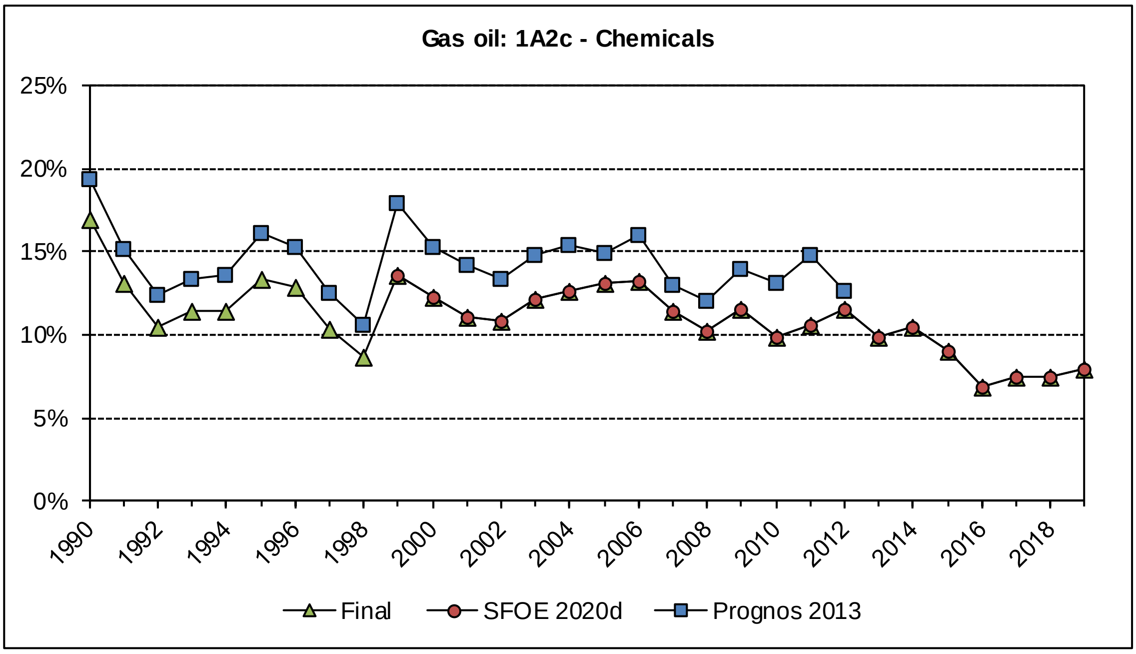


Figure 3-23: Illustrative example for combining time series with consistent overlap according to the 2006 IPCC Guidelines (IPCC 2006, Volume 1, chp. 5). The y-axis indicates the share of source category 1A2c of total gas oil consumption in the industry sector. The green line corresponds to the share finally used to calculate the fuel consumption in 1A2c and is based on the combination of the shares from the energy consumption statistics in the industry and services sectors (SFOE 2020d, red line from 1999 to 2019) and the bottom-up industry model (Prognos 2013, blue line from 1990 to 2012). Similar calculations are performed for each source category and fuel type.

Bottom-up industry data

Grey colored boxes in Figure 3-22 represent source categories, i.e. 1A2a-d, 1A2f and 1A2gviii for which bottom-up data from the industry are used in order to 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 – 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 as documented in the energy consumption statistics in the industry and services sectors (SFOE 2020d).

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

Fuel consumption of wood, wood waste, biogas and sewage gas in manufacturing industries is based on the Swiss wood energy statistics (SFOE 2020b) as well as on data from the Swiss renewable energy statistics (SFOE 2020a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2020c), 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_2 (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_2 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 Customs Administration (FCA), 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 (Tier 2 Residential plants, boilers burning liquid fuels, chp. 1A4). While the emission factors of PAHs are taken from table 3-9 (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 3-19: Emission factors for boilers of 1A2 Stationary combustion in manufacturing industries and construction in 2019.

1A2 Boiler	NO_x	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Boiler gas oil	31	2	7.4	0.002	0.2	0.2	0.2	0.0078	6.2
Boiler residual fuel oil	125	4	612	0.002	20	20	23	2	10
Boiler liquefied petroleum gas	19	2	0.5	0.001	0.1	0.1	0.1	0.0054	7.3
Boiler petroleum coke	125	4	612	0.002	20	20	23	2	10
Boiler other bituminous coal	200	10	500	0.003	45	45	50	2.88	100
Boiler lignite	202	10	500	0.003	45	45	50	2.88	100
Boiler natural gas	19	2	0.5	0.001	0.1	0.1	0.1	0.0054	7.3

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 3-20 shows the total fuel consumption in 1A2 and Table 3-21 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. Please note that 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 3-20: Fuel consumption of 1A2 Stationary combustion in manufacturing industries and construction.

1A2 Manufacturing industries and constr. (stationary sources)	**Unit**	**1990**	**1995**	**2000**	**2005**
Total fuel consumption	TJ	89'947	90'524	89'051	92'446
Gas oil	TJ	22'910	24'471	25'892	25'317
Residual fuel oil	TJ	18'870	13'678	5'675	4'613
Liquefied petroleum gas	TJ	4'354	4'458	5'627	4'309
Petroleum coke	TJ	1'400	1'260	551	1'093
Other bituminous coal	TJ	13'476	7'303	5'866	4'799
Lignite	TJ	265	153	124	742
Natural gas	TJ	19'450	28'500	31'850	34'760
Other fossil fuels	TJ	2'556	2'818	4'053	4'525
Biomass	TJ	6'667	7'883	9'413	12'288

1A2 Manufacturing industries and constr. (stationary sources)	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Total fuel consumption	TJ	91'326	85'089	86'243	87'810	82'341	80'887	81'977	82'345	79'512	79'081
Gas oil	TJ	21'137	17'314	17'575	18'007	12'444	12'725	12'812	11'489	10'871	10'071
Residual fuel oil	TJ	2'056	1'518	1'568	848	231	196	155	123	34	111
Liquefied petroleum gas	TJ	3'912	3'861	3'731	3'740	3'288	3'340	2'752	3'131	3'050	2'924
Petroleum coke	TJ	1'495	1'272	1'367	1'049	1'240	795	890	763	781	777
Other bituminous coal	TJ	4'348	3'868	3'794	3'910	2'403	1'946	1'517	1'634	1'665	1'450
Lignite	TJ	1'460	1'624	1'175	1'357	3'102	3'060	3'078	2'876	2'520	2'262
Natural gas	TJ	38'330	37'250	38'280	39'620	40'200	39'360	39'870	40'910	39'230	39'470
Other fossil fuels	TJ	5'183	5'307	4'883	5'186	5'270	5'252	5'926	5'912	6'513	6'679
Biomass	TJ	13'406	13'075	13'869	14'092	14'164	14'214	14'977	15'508	14'849	15'336

Table 3-21: Fuel consumption in boilers of 1A2 Stationary combustion in manufacturing industries and construction.

Source (Boilers)	Unit	1990	1995	2000	2005
1A2a Iron and steel	TJ	1'031	1'005	966	1'085
Gas oil	TJ	480	262	338	401
Residual fuel oil	TJ	26	131	20	39
Liquefied petroleum gas	TJ	408	193	286	217
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	118	419	322	429
Other fossil fuels	TJ	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO
1A2b Non-ferrous metals	TJ	2'242	1'958	1'549	971
Gas oil	TJ	451	336	225	119
Residual fuel oil	TJ	NO	NO	NO	NO
Liquefied petroleum gas	TJ	27	17	15	7.1
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	1'764	1'605	1'309	845
Other fossil fuels	TJ	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO
1A2c Chemicals	TJ	14'431	15'158	13'497	15'477
Gas oil	TJ	3'942	3'313	3'215	3'345
Residual fuel oil	TJ	1'434	693	252	36
Liquefied petroleum gas	TJ	15	13	12	10
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	9'039	11'138	10'017	12'086
Other fossil fuels	TJ	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO
1A2d Pulp, paper and print	TJ	9'675	12'343	9'883	9'326
Gas oil	TJ	1'188	1'751	1'403	1'456
Residual fuel oil	TJ	5'250	3'061	1'417	2'092
Liquefied petroleum gas	TJ	86	141	148	100
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	3'151	7'389	6'916	5'678
Other fossil fuels	TJ	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO
1A2e Food processing, beverages an	TJ	9'858	8'784	10'437	10'239
Gas oil	TJ	7'410	5'511	5'515	4'070
Residual fuel oil	TJ	1'160	466	137	NO
Liquefied petroleum gas	TJ	204	308	535	534
Petroleum coke	TJ	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO
Natural gas	TJ	1'085	2'500	4'250	5'635
Other fossil fuels	TJ	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO
1A2g viii Other	TJ	17'990	22'164	22'823	23'874
Gas oil	TJ	7'418	11'626	13'484	14'497
Residual fuel oil	TJ	5'237	3'605	47	4.9
Liquefied petroleum gas	TJ	3'091	3'288	4'164	3'116
Petroleum coke	TJ	765	914	15	383
Other bituminous coal	TJ	205	140	12	88
Lignite	TJ	NO	NO	NO	4.7
Natural gas	TJ	781	2'088	4'588	5'281
Other fossil fuels	TJ	NO	NO	NO	NO
Biomass (biogas, sewage gas, woo	TJ	493	504	513	499

Continuation of Table 3-21, fuel consumption in boilers of 1A2 Stationary combustion in manufacturing industries and construction.

Source (Boilers)	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1A2a Iron and steel	TJ	1'649	1'526	1'455	1'428	1'504	1'912	1'884	2'151	2'283	2'122
Gas oil	TJ	315	271	172	139	86	136	134	123	127	97
Residual fuel oil	TJ	51	1.5	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	219	226	438	438	388	393	327	368	358	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	1'065	1'027	845	851	1'031	1'383	1'423	1'660	1'799	1'683
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	1'214	1'174	1'745	1'592	1'914	1'790	1'681	1'638	1'744	1'948
Gas oil	TJ	108	73	152	127	88	77	74	77	53	58
Residual fuel oil	TJ	0.024	0.023	0.78	23	NO	44	NO	4	NO	NO
Liquefied petroleum gas	TJ	7.7	8.2	11	11	9.8	9.9	8.3	9.3	9.0	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	1'098	1'093	1'581	1'430	1'816	1'660	1'598	1'549	1'682	1'882
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	11'814	12'167	13'909	14'125	12'125	12'525	14'370	13'806	13'283	11'786
Gas oil	TJ	2'103	1'847	2'055	1'797	1'321	1'167	881	860	825	803
Residual fuel oil	TJ	66	0.16	0.16	1.2	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	7.5	7.1	10	10	8.9	9.0	7.5	8.4	8.2	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	9'637	10'312	11'845	12'317	10'795	11'349	13'482	12'937	12'450	10'975
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	6'773	6'051	5'374	5'474	4'643	3'655	2'982	2'851	2'073	2'151
Gas oil	TJ	852	561	623	711	297	383	410	288	293	346
Residual fuel oil	TJ	279	4.0	2.8	0.018	22	19	9.0	8.8	NO	NO
Liquefied petroleum gas	TJ	61	62	67	67	60	60	50	57	55	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	5'581	5'424	4'681	4'696	4'264	3'193	2'513	2'498	1'725	1'752
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 an	TJ	13'161	11'374	11'310	13'079	12'438	11'572	10'974	11'212	10'824	11'818
Gas oil	TJ	3'778	3'197	3'237	3'681	2'395	2'522	2'503	2'110	1'925	2'051
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	659	675	935	935	828	838	699	785	763	731
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	8'723	7'502	7'138	8'463	9'215	8'212	7'772	8'318	8'137	9'036
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	24'262	21'262	21'341	20'458	17'587	18'609	18'489	18'426	17'518	17'215
Gas oil	TJ	12'705	10'124	10'239	10'373	7'050	7'342	7'785	6'912	6'568	5'597
Residual fuel oil	TJ	29	1.7	0.26	2.1	0.33	2.8	7.9	4.3	2.2	2.4
Liquefied petroleum gas	TJ	2'855	2'756	2'162	2'165	1'949	1'977	1'615	1'860	1'812	1'737
Petroleum coke	TJ	318	154	405	181	108	104	155	113	168	169
Other bituminous coal	TJ	10.7	16	50	110	105	134	125	102	140	58
Lignite	TJ	111	131	95	75	189	204	197	182	153	141
Natural gas	TJ	7'703	7'511	7'824	7'012	7'632	8'316	8'075	8'736	8'211	9'048
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	529	569	567	540	553	529	529	517	463	462

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 3-19 and Table 3-21, 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_2 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 factor of BC (% PM2.5) is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019) (EMIS 2021/1A2a Stahl-Produktion Wärmeöfen).

Cupola furnaces in iron foundries

Emission factors of NO_x, NMVOC, SO_2, 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 emission inventory guidebook (EMEP/EEA 2019, chp.1A4, Table 3.23). Emission factors of PAH are based on data from literature, see USEPA (1998a) and EMIS 2021/1A2a Eisengiessereien Kupolöfen). The Hg emission factor is based on the default value for other bitumonius coal of Table 3.23 of the EMEP/EEA emission inventory guidebook (EMEP/EEA 2019).

Table 3-22: Emission factors of 1A2a Iron and Steel in 2019.

1A2a Iron and steel	NO_x	NMVOC	SO_2	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 2021/1A2a).

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 2020).

Table 3-23: 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
Iron foundries, cupola	kt iron	90	60	55	32
Steel plants, reheating furnaces	kt steel	1'108	716	1'022	1'082

1A2a Iron and steel	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Iron foundries, cupola	kt iron	13	15	11	11	11	9.2	8.6	8.8	8.6	6.0
Steel plants, reheating furnaces	kt steel	1'082	1'183	1'162	1'126	1'176	1'144	1'085	1'138	1'160	1'037

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 3-19 and Table 3-21, 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 2021/1A2b Buntmetallgiessereien übriger Betrieb). The emission factors are based on information of the Swiss foundry association (GVS).

Table 3-24: Emission factors of 1A2b Non-ferrous metals in 2019.

1A2b Non-ferrous metals	NO_x	NMVOC	SO_2	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 3-21).

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

Table 3-25: 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
Aluminium production	kt aluminium	34	NO	NO	NO
Foundries	kt non-ferrous metals	60	56	53	33

1A2b Non-ferrous metals	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Aluminium production	kt aluminium	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foundries	kt non-ferrous metals	20	12	7	6	9.5	8.9	9.0	8.0	6.8	6.4

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 3-19 and Table 3-21, 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. The ammonia and ethylene production by thermal cracking produces two by-products, the so-called heating gas and gasolio. In 2018 the cracker process and the subsequent integrated production chain were modified yielding synthesis gas as additional cracker 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 2B5 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 3-19. For synthesis gas (about 23% CO, 77% 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 3-19.

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 2021/1A2c 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 3-19 and Table 3-21, 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_2 emission factors are derived from air pollution control measurements. The emission factor of BC (% PM2.5) is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019) as documented in the EMIS database (EMIS 2021/1A2d).

Activity data (1A2d)

Activity data on annual cellulose production are provided by the industry as documented in the EMIS database (EMIS 2021/1A2d Zellulose-Produktion Feuerung). The only plant closed in 2008.

In 2019, natural gas is the most important fuel in this category (see Table 3-21). 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 different 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, the major part of revenues is provided by meat production, milk products and convenience food. Further productions comprise chocolate, sugar or baby food (Fial 2013). Fossil fuels are used for steam production and drying processes.

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-19 and Table 3-21, respectively.

In 2019, 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 3-21.

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 2021/1A2f). 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 2021/1A2f).

Table 3-26: Emission factors for Non-metallic minerals 1A2f in 2019.

1A2f Non-metallic minerals	NO_x	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	g/t								
Cement	930	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	1.1	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 3-27 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 2021/1A2f).

Table 3-27: Activity data for Non-metallic minerals 1A2f.

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

1A2f Non-metallic minerals	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cement	kt	3'642	3'587	3'368	3'415	3'502	3'195	3'296	3'279	3'239	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	36	41	39	33	32	31	32	36	40	47
Tableware glass	kt	C	C	C	C	C	C	C	C	C	C
Brick and tile	kt	879	800	792	785	765	726	660	622	581	554
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	5'250	5'300	4'770	4'770	5'260	4'850	4'710	5'260	5'180	5'210

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 (other bituminous coal and lignite), 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 industrial wastes, waste wood, animal residues or used tyres. The fuels consumed in this category are very diverse and depend on the fuel use within the specific plant (see detailed documentation below). Between 1990 and 2016 there has been a diversification in fuel consumption from mainly other bituminous coal and residual fuel oil to other fuels, biomass and natural gas.

Emission factors

Table 3-26 shows product-specific emission factors for cement production (EMIS 2021/1A2f 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 from years 2013 to 2017 led to a change in EF for the years 2009 to 2018. The value for PCB is based on the Tier 2 emission factor in the EMEP/EEA guidebook (EMEP/EEA 2019).

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 3-27). 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 3-28. The amount of fuels consumed in the Swiss cement production plants (in TJ) is also provided in the annual monitoring reports of the cement production plants as documented in the respective EMIS 2021/1A2f Zementwerke Feuerung.

Table 3-28: Fuel consumption of cement industry (fossil without waste, fossil waste derived and biomass waste derived).

Cement industry	**Unit**	**1990**	**1995**	**2000**	**2005**
Cement, total incl. waste	TJ	17'194	12'774	11'017	11'623
Cement fossil without waste	TJ	15'319	9'993	7'332	6'208
Gas oil	TJ	NO	NO	NO	72
Residual fuel oil	TJ	1'907	2'825	1'530	637
Petroleum coke	TJ	550	300	480	638
Other bituminous coal	TJ	12'235	6'547	5'176	4'120
Lignite	TJ	265	153	124	737
Gas	TJ	362	168	22	3.9
Cement, waste derived fuel	TJ	1'874	2'781	3'685	5'415
Used oil	TJ	1'170	1'485	1'520	1'411
Sewage sludge (dry)	TJ	9.4	128	333	494
Used wood	TJ	NO	322	NO	NO
Solvents	TJ	283	181	426	976
Used tires	TJ	330	415	421	645
Plastics	TJ	NO	55	572	841
Animal meal	TJ	NO	NO	198	856
CSS	TJ	23	135	158	133
Used charcoal	TJ	59	59	59	58
Other fossil waste fuels	TJ	NO	NO	NO	NO
Industrial waste	TJ	NO	NO	NO	NO
Agricultural waste	TJ	NO	NO	NO	NO
Other biomass	TJ	NO	NO	NO	NO

Cement industry	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Cement, total incl. waste	TJ	12'388	12'187	11'462	11'866	12'339	11'348	11'583	11'476	11'474	11'478
Cement fossil without waste	TJ	6'278	5'859	5'406	5'512	5'847	4'917	4'544	4'354	3'965	3'736
Gas oil	TJ	5.4	0.68	0.10	88	75	87	50	56	63	106
Residual fuel oil	TJ	112	101	297	86	58	45	90	59	NO	63
Petroleum coke	TJ	1'130	1'081	920	815	1'052	622	658	574	542	552
Other bituminous coal	TJ	3'662	3'167	3'097	3'203	1'713	1'267	826	938	938	831
Lignite	TJ	1'348	1'493	1'081	1'283	2'912	2'856	2'881	2'694	2'367	2'120
Gas	TJ	21.5	16	11	38	37	41	39	34	56	65
Cement, waste derived fuel	TJ	6'109	6'329	6'056	6'354	6'492	6'431	7'039	7'122	7'509	7'743
Used oil	TJ	1'253	1'170	839	876	923	1'142	1'567	1'311	1'336	1'466
Sewage sludge (dry)	TJ	477	483	527	418	428	420	479	499	519	512
Used wood	TJ	292	409	586	732	886	896	811	840	840	861
Solvents	TJ	1'189	1'264	1'294	1'414	1'273	1'292	1'534	1'398	1'380	1'623
Used tires	TJ	842	1'033	964	985	1'021	958	951	1'041	1'045	1'041
Plastics	TJ	1'252	1'163	1'092	1'299	1'360	1'177	1'171	1'398	1'722	1'627
Animal meal	TJ	624	614	572	479	457	412	409	470	522	475
CSS	TJ	123	96	100	96	103	80	98	78	73	58
Used charcoal	TJ	NO	NO	NO	NO	NO	NO	NO	66	61	48
Other fossil waste fuels	TJ	45	55	36	25	19	12	11	5.7	5.4	NO
Industrial waste	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Agricultural waste	TJ	7.3	18	28	NO	NO	NO	NO	9.2	NO	NO
Other biomass	TJ	5.7	24	17	32	21	42	7.9	5.6	5.4	31

Fuel consumption in cement plants has decreased since 1990. This is partly due to a decrease in production since 1990 and an increase in energy efficiency. In the same period, the fuel mix has changed significantly from mainly fossil fuels to the mix of fuels mentioned above. The fossil fuels used in 1990 were bituminous coal, residual fuel oil and petroleum coke.

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 2021/1A2f Hohlglas Produktion) and partly on information from industry. The SO_2

emission factor is based on air pollution control measurements from 2011. The emission factor of BC (% PM2.5) is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019).

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 3-27). 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. The large increase in natural gas share between 2012 and 2013 is due to the fact that the plant has switched its glass kiln completely to natural gas in autumn 2013.

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_2, NMVOC, CO are based on information from industry (EMIS 2021/1A2f 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 (LPG and residual fuel oil until 1995). The emission factor of BC (% PM2.5) is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019).

Activity data

For tableware glass production, activity data are provided by monitoring reports of the Swiss ETS (Table 3-27). 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 3-26 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 2021/1A2f Glaswolle Produktion) and partly on information from industry. The emission factor for SO_2 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 emission inventory guidebook (EMEP/EEA 2019).

Activity data

Activity data consist of annual production data provided by monitoring reports from the industry (Table 3-27). 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_2, 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 2021/1A2f). The emission factor of BC (% PM2.5) is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019) (EMIS 2021/1A2f 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. However, in 2013, the main kiln has been switched to natural gas. Since 1995, no other bituminous coal is used anymore as it was replaced by residual fuel oil.

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 3-26 shows emission factors for brick and tile production. Emission factors of NO_x, NMVOC, SO_2, PM2.5/PM10/TSP, CO, Pb, Cd und Hg are derived from air pollution control measurements as described in the EMIS database (EMIS 2021/1A2f Ziegeleien). The emission factor of BC (% PM2.5) is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019).

Activity data

Activity data consist of annual production data provided by the industry (Table 3-27). 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 2019 are mainly natural gas as well as small amounts of residual fuel oil, 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 grease are used since 2000. But wood consumption is no longer reported in the monitoring reports since 2013.

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_2 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_2 is assumed to be constant. The emission factor of BC (% PM2.5) is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019) (EMIS 2021/1A2f 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_2) for rock wool production are based on annual flux analysis from industry - except for the emission factor of BC (% PM2.5), which is taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019) (EMIS 2021/1A2f 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 3-26 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 mesurements show no clear trend in the emission factors, a constant country-specific, average emission factor is used from 2001 onwards. Emission factors of SO_2, Hg and PCCD/PCDF are based on data from the industry association (Schweizerische Mischgut-Industrie) (EMIS 2021/1A2f Mischgut Produktion).

Activity data

Activity data consist of annual production data provided by the industry association (Schweizerische Mischgut-Industrie) (Table 3-27).

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 is produced in two plants in Switzerland, where thermal energy is used for heating and drying processes.

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 3-19). For animal grease 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 3-6.

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 3-6.

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_2, 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, Table 3.26 and Table 3.30).

Table 3-29: Emission factors in 2019 for 1A2gviii

1A2gviii Other	NO_x	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Boiler industrial sewage gas	19	2	0.5	0.001	0.1	0.1	0.1	0.0054	7.3
Boiler municipal sewage gas	19	2	0.5	0.001	0.1	0.1	0.1	0.0054	7.3
Engines biogas	21	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 2019 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 3-21. Fuel consumption of wood, wood waste, biogas and sewage gas in this source category is based on the Swiss wood energy statistics (SFOE 2020b) as well as on data from the Swiss renewable energy statistics (SFOE 2020a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2020c) (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 2019 from fossil fuels to biomass (wood waste). Between 2001 and 2013, also animal grease 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 2021/1A2giv).

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

The following recalculations were implemented in submission 2021:

- 1A2a: In source category 1A2a Electric arc furnaces of steel production, a typing error in the consumption of other bituminous coal has been corrected for 2018.
- 1A2a to 1A2f and 1A2gviii: Small recalculations of use of gas oil and of natural gas in the year 2018 were made due to correction of an error in the industry model.
- 1A2b: Acitvity data of 1A2b Non-ferrous metal foundries have been revised for the years 1990-2008 and 2012-2018 based on industry data and estimates.
- 1A2f Container glass production: Typing errors in the emission factors of PM2.5, PM10 and BC have been corrected from 2012 onwards.
- 1A2f Non-metallic minerals: AD of sewage sludge used as alternative fuel in cement production has decreased by 18% in 2018 (correction of reporting error).
- 1A2f: The emission factors of NO_x, SO_x, PM2.5, PM10, TSP, BC and CO for source category 1A2f Lime prodution have been revised for 2014-2018 based on air pollution control measurements in 2017.
- 1A2f: EF of all air pollutants for cement production have changed due to a reassessment based on emission measurement reports from years 2013 to 2017. This leads to a change in EF for the years 2009 to 2018.
- 1A2f: EF for PCB emissions in cement production have been implemented for all years based on the Tier 2 EF in the Guidebook 2019.
- 1A2gviii: Activity data (wood, wood waste) of all combustion installations in source category 1A2gviii have been revised for 1990-2018 due to recalculations in the Swiss wood energy statistics (SFOE 2020b). The biggest changes were in the automatic boilers within wood processing industry.
- 1A2gviii: AD of sewage gas from industrial waste water treatment used in boilers and in engines has changed (by less than 1%) for the years 2013-2018. The data is taken from the national statistical report of renewable energies by SFOE and has been updated.
- 1A2gviii: The country-specific emission factor model for wood energy was completely updated for the entire time period based on air pollution control and laboratory measurements and literature data yielding revised emission factors of all pollutants for all wood combustion installations.
- 1A2gviii: Recalculation concerning stock changes leads to changes in activity data for boilers using residual fuel oil in the years 2014 and 2015.
- 1A2gviii: Recalculation concerning stock change leads to changed activity data for boilers using petroleum coke in the year 2018.
- 1A2gviii: Due to changed activity data in bottom-up process 1A2a Electric arc furnaces of steel production also the activity data of boilers in 1A2gviii using other bituminous coal changed for the year 2018.

- 1A2gviii: Due to small recaclulation concerning use of LPG in 1A3b Road transportation for the years 2011-2018, the activity data of boilers in 1A2gviii Other changes too, because this source category represents the statistical difference of over all reported amount of liquefied petroleum sold and the modelled use in the different source-categories.

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)

Table 3-30: Specification of source category 1A4 Other sectors (stationary).

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 3-31: Key Categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 1A4 Other Sectors (stationary).

Code	Source category	Pollutant	Identification criteria
1A4ai	Commercial/institutional: Stationary	NOx	L1
1A4ai	Commercial/institutional: Stationary	SO2	L1, L2, T1
1A4ai	Commercial/institutional: Stationary	PM2.5	L1, L2, T1
1A4ai	Commercial/institutional: Stationary	PM10	L1
1A4bi	Residential: Stationary	NOx	L1, L2
1A4bi	Residential: Stationary	NMVOC	L1
1A4bi	Residential: Stationary	SO2	L1, L2, T1, T2
1A4bi	Residential: Stationary	PM2.5	L1, L2, T1, T2
1A4bi	Residential: Stationary	PM10	L1, L2, T1, T2
1A4ci	Agriculture/Forestry/Fishing: Stationary	PM2.5	L1

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

Methodology (1A4 ai/bi/ci stationary)

For the calculation of the emissions from the use of gas oil and natural gas, the following sources are differentiated: (a) heat only boilers, (b) combined heat and power production in turbines and (c) combined heat and power production in engines. 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 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 3-32, Table 3-33 and Table 3-34 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 developement from 0 g/TJ to 510 g/TJ (gas turbines with catalysator) from 1990 to 2019 was taken from SAEFL 2000.
- 1A4ai and 1A4bi: The CO emission factor of gas turbines from 1990 to 2010 stem from SAEFL 2000. The developement from 50 kg/TJ to 10 kg/TJ was adjusted slightliy. From the year 2015 on forward the emisison factor of 4.8 kg/TJ from the EMEP Guidebook (EMEP/EEA 2019, table 3-17) 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_2 of gas 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 Customs Administration (FCA) (see chp. 3.2.1.2).
- The emission factor for SO_2 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_2 of coal is based on 1% sulphur content which holds for heat capacities below 1MW (see chp. 3.2.1.2).
- Emission factors for Pb, Cd, Hg and PAH for natural gas, biogas, and gas oil are taken from EMEP/EEA emission inventory guidebook (EMEP/EEA 2019) except for wood and biomass.
- Wood combustion in1A4ai/bi/ci: The country-specific emission factor model for wood energy was completely updated in submission 2021, see chp. 3.2.1.1.2.
- 1A4ai/bi gas oil boiler Pb/Cd/Hg: emission factors are taken from table 3-18 (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 Guidebook representing average of Tier 2 EFs for commercial/institutional liquid fuel combustion for all technologies. These PAH EF 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.
- 1A4bi Hg emission factors for other bituminous coal stem from table 3-23 (EMEP/EEA 2019) allocated to non-residential sources (automatic boilers) burning coal fuels and not

from table 3-15 (EMEP/EEA 2019) allocated to residential boilers burning solid fuels. This choice was made because table 3-15 proides 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_2, 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) as shown in Table 3-33. According to the 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 2021/1A4bi Lagerfeuer and EMIS 2021/1A4bi Holzkohle Verbrauch.

Table 3-32: Emission factors for 1A4ai for 2019. All fuels not listed are "NO".

Source/fuel	NO_x	NMVOC	SO_2	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	7.4	2.6	0.25	0.25	0.25	0.0099	6.2
Gas oil heat only boilers	32	6	7.4	1	0.2	0.2	0.2	0.0078	6.1
Gas oil engines	40	8	7.4	600	20	20	20	0.78	30
Natural gas (weighted average)	19	1.9	0.5	1.1	0.1	0.10	0.1	0.0052	12
NG heat only boilers	16	2	0.5	1	0.1	0.1	0.1	0.0054	9.2
NG turbines	19	0.1	0.5	510	0.1	0.1	0.1	0.0025	4.8
NG engines	59	1	0.5	NA	0.1	0.12	0.1	0.0025	55
Biomass (weighted average)	113	47	5.8	2'767	34	36	39	11	691
Biomass (wood)	113	47	5.8	2'768	34	36	39	11	691
Biomass (biogas)	16	2	0.5	1	0.1	0.1	0.1	0.0054	9.2

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)	0.0124	0.00102	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil heat only boilers	0.0120	0.001	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil engines	0.1500	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	1.4	0.90	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	0.0006	1.2	9.0	1.7	1.8	NA	NA
Biomass (weighted average)	22	1.1	2	0.13	10'336	10'336	6'316	6'316	3.0	0.019
Biomass (wood)	22	1.1	2	0.13	10'337	10'337	6'317	6'317	3.0	0.019
Biomass (biogas)	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA

Table 3-33: Emission factors for 1A4bi (including charcoal and bonfires) for 2019. All fuels not listed are "NO".

Source/fuel	NO_x	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ			g/TJ	kg/TJ				
1A4bi Other sectors (stationary): Residential									
Gas oil (weighted average)	34	6.0	7.4	1.2	0.21	0.21	0.21	0.0081	11
Gas oil heat only boilers	34	6.0	7.4	1.0	0.2	0.2	0.2	0.0078	11
Gas oil engines	40	8.0	7.4	600	20	20	20	0.78	30
Natural gas (weighted average)	15	4.0	0.5	0.99	0.1	0.10	0.1	0.0054	13
NG heat only boilers	15	4	0.5	1	0.1	0.1	0.1	0.0054	12
NG engines	31	1	0.5	NA	0.1	0.11	0.1	0.0025	55
Other bituminous coal	65	100	350	1'600	71	72	102	4.5	1'200
Biomass	94	112	8.1	4'976	74	78	84	28	1'493
Wood	95	99	8.0	3'162	54	58	63	27	1'427
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	21	1.4	2.0	0.25	26'818	26'562	14'608	15'350	4.4	0.030
Wood	20	1.1	2	0.24	24'344	24'344	13'889	13'889	4.3	0.029
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	5.6	0.06

Table 3-34: Emission factors for 1A4ci for 2019. All fuels not listed are "NO".

1A4ci Agriculture/forestry/fishing	NO_x	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ			g/TJ	kg/TJ				
Drying of grass	67	90	75	NA	258	258	258	12	516
Heating of greenhouses (weighted average)	23	2	2.8	1.3	0.13	0.13	0.13	0.0062	6.9
Gas oil	31.2	2	7.4	2	0.2	0.2	0.2	0.0078	6.2
Natural gas	18.6	2	0.5	1	0.1	0.1	0.1	0.0054	7.3
Other biomass combustion (weighted average)	49	10.5	2.6	669	13.9	14.9	16.0	2.6	256
Biogas heat only boilers	16.3	2	0.5	1	0.1	0.1	0.1	0.0054	9.2
Biogas engines	20.8	1	0.5	0	0.1	0.1	0.1	0.0025	55.4
Wood combustion	104	29	7	1'948	40	43	46	7.6	640

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	5.6	1.1	0.6	NE	NE	NE	NE	NE	NE	NE
Heating of greenhouses (weighted average)	0.005	0.001	0.11	0.00094	0.56	5.59	1.13	1.0614	0.22	0.00011
Gas oil	0.012	0.001	0.12	0.0018	NA	15	1.7	1.5	0.22	0.00011
Natural gas	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA
Other biomass combustion (weighted average)	7	0.3	0.7	0.032	3'105	3'110	1'531	1'531	3.3	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	9.00	1.70	1.8000	NA	NA
Wood combustion	20	1	1.75	0.09	9'038	9'038	4'453	4'453	3.3	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 2020).

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 3-13 and Figure 3-17.

Since submission 2015, data on fuel consumption for grass drying are available and used for emission calculations (see EMIS 2021/1A4ci Grastrocknung). The use of gas oil and natural gas for grass drying in 1A4ci is substracted from boilers in 1A4ai.

The fuel consumtion 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 2021/1A4ci Gewächshäuser).

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 2020).

The total wood demand for bonfires under 1A4bi is assumed to be constant over time. As a consequence, the total amount of energy remains stable. Per capita wood demand is decreasing since 1990 due to an increasing number of inhabitants (for further details see documentation in EMIS 2021/1A4bi Lagerfeuer).

Table 3-35: Activity data of 1A4ai Commercial/institutional. All fuels not listed are "NO".

1A4ai Other sectors (stationary): Commercial/institutional	**Unit**	**1990**	**1995**	**2000**	**2005**
Total fuel consumption	TJ	72'347	80'074	76'719	83'258
Gas oil	TJ	52'977	54'379	48'777	51'197
Gas oil heat only boilers	TJ	52'953	54'204	48'426	50'880
Gas oil engines	TJ	24	175	351	318
Natural gas	TJ	16'399	21'843	23'552	26'732
NG heat only boilers	TJ	16'123	20'672	21'815	24'699
NG turbines	TJ	85	78	NO	28
NG engines	TJ	192	1'093	1'737	2'004
Biomass (total)	TJ	2'971	3'852	4'390	5'329
Biomass (wood)	TJ	2'932	3'821	4'363	5'282
Biogas (heat only boilers)	TJ	39	32	27	46

1A4ai Other sectors (stationary): Commercial/institutional	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Total fuel consumption	TJ	78'890	64'857	71'291	76'597	60'404	66'314	69'538	66'991	60'382	60'803
Gas oil	TJ	46'525	37'088	39'750	42'727	32'993	35'153	36'440	34'222	30'879	30'273
Gas oil heat only boilers	TJ	46'406	36'983	39'656	42'640	32'910	35'071	36'358	34'140	30'797	30'191
Gas oil engines	TJ	119	105	94	86	82	82	82	82	82	82
Natural gas	TJ	25'307	21'857	24'733	26'341	20'237	23'102	24'326	23'967	21'166	21'766
NG heat only boilers	TJ	23'602	20'277	23'180	24'844	18'801	21'666	22'890	22'531	19'730	20'330
NG turbines	TJ	23	17	4.9	7.3	7.3	7.3	7.3	7.3	7.3	7.3
NG engines	TJ	1'681	1'564	1'548	1'490	1'429	1'429	1'429	1'429	1'429	1'429
Biomass (total)	TJ	7'058	5'912	6'809	7'530	7'174	8'059	8'771	8'802	8'337	8'764
Biomass (wood)	TJ	6'954	5'828	6'733	7'471	7'127	8'038	8'747	8'778	8'325	8'749
Biogas (heat only boilers)	TJ	104	83	76	59	47	21	24	24	13	14

Table 3-36: Activity data of 1A4bi Residential. All fuels not listed are "NO".

1A4bi Other sectors (stationary): Residential	**Unit**	**1990**	**1995**	**2000**	**2005**
Total fuel consumption	TJ	185'301	189'262	170'439	185'944
Gas oil	TJ	136'887	133'548	116'295	124'024
Gas oil heat only boilers	TJ	136'887	133'544	116'242	123'961
Gas oil engines	TJ	0.59	4.5	53	63
Natural gas	TJ	25'864	34'088	36'261	42'633
NG heat only boilers	TJ	25'804	33'830	35'822	42'103
NG turbines	TJ	NO	NO	NO	NO
NG engines	TJ	60	258	439	530
Other bituminous coal	TJ	630	460	130	400
Biomass (wood, charcoal, bonfires)	TJ	21'920	21'166	17'753	18'888
Wood	TJ	21'449	20'714	17'301	18'414
Use of charcoal	TJ	311	291	292	313
Bonfires	TJ	160	160	160	160

1A4bi Other sectors (stationary): Residential	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Total fuel consumption	TJ	181'622	145'765	160'897	172'086	134'704	144'436	150'498	144'319	132'480	133'267
Gas oil	TJ	111'731	86'989	94'103	99'373	75'136	79'406	81'340	76'113	67'901	66'642
Gas oil heat only boilers	TJ	111'695	86'955	94'072	99'344	75'109	79'379	81'312	76'085	67'874	66'615
Gas oil engines	TJ	36	34	32	29	27	27	27	27	27	27
Natural gas	TJ	48'229	40'910	47'043	50'957	42'357	46'096	48'825	48'335	45'915	47'574
NG heat only boilers	TJ	47'723	40'440	46'577	50'509	41'927	45'666	48'395	47'905	45'486	47'145
NG turbines	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NG engines	TJ	506	470	466	448	430	430	430	430	430	430
Other bituminous coal	TJ	400	300	300	300	200	200	200	100	100	100
Biomass (wood, charcoal, bonfires)	TJ	21'261	17'566	19'451	21'456	17'012	18'734	20'133	19'772	18'563	18'951
Wood	TJ	20'757	17'063	18'947	20'953	16'497	18'220	19'639	19'238	18'049	18'466
Use of charcoal	TJ	344	344	344	343	354	354	334	374	354	325
Bonfires	TJ	160	160	160	160	160	160	160	160	160	160

Table 3-37: 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
Total fuel consumption	TJ	6'378	6'100	5'794	5'511
Drying of grass	TJ	1'895	1'544	1'223	994
Gas oil	TJ	1'156	942	746	607
Residual fuel oil	TJ	NO	NO	NO	NO
Natural gas	TJ	739	602	477	388
Biomass	TJ	NO	NO	NO	NO
Heating of greenhouses	TJ	4'000	4'000	4'000	3'735
Gas oil	TJ	3'490	3'490	3'490	3'133
Natural gas	TJ	510	510	510	601
Other biomass combustion	TJ	483	556	571	782
Biogas heat only boilers	TJ	39	32	27	46
Biogas engines	TJ	16	15	35	82
Wood combustion	TJ	427	510	509	654

1A4ci Other sectors (stationary): Agriculture/forestry/fishing	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total fuel consumption	TJ	5'617	5'145	5'758	5'253	4'723	4'895	5'391	5'910	5'433	5'765
Drying of grass	TJ	739	891	685	458	524	431	492	610	545	684
Gas oil	TJ	451	543	418	106	104	89	86	118	116	124
Residual fuel oil	TJ	NO	NO	NO	17	20	22	18	25	13	NO
Natural gas	TJ	288	347	267	220	264	233	279	338	296	427
Biomass	TJ	NO	NO	NO	114	136	88	109	129	120	132
Heating of greenhouses	TJ	3'677	3'121	3'671	3'389	2'800	2'900	2'899	3'238	2'754	2'732
Gas oil	TJ	1'803	1'269	1'647	1'496	1'095	1'165	1'066	1'145	930	916
Natural gas	TJ	1'874	1'852	2'025	1'893	1'705	1'735	1'834	2'093	1'824	1'816
Other biomass combustion	TJ	1'202	1'133	1'402	1'406	1'399	1'565	2'000	2'061	2'134	2'349
Biogas heat only boilers	TJ	104	83	76	59	47	21	24	24	13	14
Biogas engines	TJ	394	472	599	754	880	1'020	1'168	1'248	1'390	1'597
Wood combustion	TJ	705	578	727	594	471	524	807	789	731	737

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 2021:

- 1A4: The country-specific emission factor model for wood energy was completely updated for the entire time period based on air pollution control and laboratory measurements and literature data yielding revised emission factors of all pollutants for all wood combustion installations.
- 1A4ai (and 1A4ci): Due to recalculations concerning use of gas oil and natural gas for greenhouses allocated to 1A4ci (see below) the activity data of gas oil and natural gas boilers changes in source-category 1A4ai, too. These recalculations are very small for the years 2002-2013, 2016 and bigger for 2014-2015 and 2017.
- 1A4ai/bi/ci: Activity data (wood, wood waste) of all combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2018 due to recalculations in the Swiss wood energy statistics (SFOE 2020b).
- 1A4bi: A typing error of the CO emission factor for 1A4bi Bonfires has been corrected for the entire time series.
- 1A4bi: Small recalculations concerning use of natural gas in housholds were made in the energy statistics for the years 2016-2018.
- 1A4ci: Activity data for the consumption of gas oil and natural gas used for heating of greenhouses have been increased (by less than 1%) for the years 2014 and 2015 due to a revision of the statistics for the total area of greenhouses. There are small differences due to rounding to the years 2002-2013 and 2016.
- 1A4ci Stationary combustion in other sectors: From 1990 to 2018, EF of biogas heat only boilers have been inadvertently applied to biogas engines for all pollutants. This mistake has now been corrected by applying EF of 1A2gviii engines biogas.

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 3-38: 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 3-39: Key Categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source categories 1A2 Mobile combustion in manufacturing industries and construction.

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

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

Methodology (1A2gvii)

Based on the decision tree Fig. 3.1 in chapter Non-road mobile sources and machinery of the EMEP/EEA Guidebook 2019 (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 3-40 to Table 3-43. Implied emission factors 2019 are shown in Table 3-44.

Table 3-40: 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 3-41: 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 3-42: 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 3-43: 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 3-44: Implied emission factors for 1A2gvii in 2019.

1A2gvii Non-road vehicles and other machinery	NO_x	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Gasoline	105	654	0.38	0.09	0.11	0.11	0.11	0.0056	19'678
Diesel oil	241	22	0.47	0.17	6.3	6.3	6.3	3.8	113
LPG	98	8.8	NA	0.22	0.47	0.47	0.47	0.024	24
Biodiesel	206	19	0.40	0.15	5.4	5.4	5.4	3.2	97
Bioethanol	51	240	0.24	0.058	0.080	0.080	0.080	0.0040	12'087

1A2gvii Non-road vehicles and other machinery	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/GJ	mg/GJ		ng I-TEQ/GJ	mg/GJ				ng/GJ	
Gasoline	0.031	2.26	0.20	2.71	1.01	1.01	0.10	0.30	NE	NE
Diesel oil	NA	2.17	0.11	1.52	0.67	1.11	0.83	0.19	NE	NE
LPG	NA	0.23	NA	NA	0.0043	NA	0.0043	0.0043	NE	NE
Biodiesel	NA	1.85	0.098	1.297	0.57	0.95	0.71	0.16	NE	NE
Bioethanol	0.015	1.45	0.126	1.743	0.66	0.66	0.064	0.19	NE	NE

Activity data (1A2gvii)

Table 3-45 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 2020a). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-45: Activity data for 1A2gvii.

1A2gvii Non-road vehicles and other machinery	Unit	1990	1995	2000	2005
Total fuel consumption	TJ	5'721	6'852	7'636	8'169
Gasoline	TJ	196	224	227	225
Diesel oil	TJ	5'359	6'380	7'106	7'626
Liquefied petroleum gas	TJ	165	248	294	290
Biodiesel	TJ	NO	NO	9.2	28
Bioethanol	TJ	NO	NO	NO	NO

1A2gvii Non-road vehicles and other machinery	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total fuel consumption	TJ	8'779	8'811	8'843	8'875	8'906	8'938	8'944	8'949	8'955	8'960
Gasoline	TJ	220	213	206	198	191	184	180	177	174	171
Diesel oil	TJ	8'254	8'283	8'312	8'341	8'370	8'399	8'380	8'361	8'342	8'323
Liquefied petroleum gas	TJ	269	260	252	243	235	226	215	203	192	180
Biodiesel	TJ	36	54	73	91	110	128	166	205	243	282
Bioethanol	TJ	0.0047	0.26	0.51	0.76	1.0	1.3	2.0	2.7	3.3	4.0

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

No recalculations were carried out in source category 1A2 (mobile sources).

3.2.6 Source category 1A3 - Transport

3.2.6.1 Source category description for 1A3 Transport

Table 3-46: Specification of source category 1A3 Transport.

1A3	Source category	Specification
1A3ai(i)	International aviation LTO (civil)	LTO: Landing/Take-off
1A3ai(ii)	International aviation CR (civil)	CR: Cruise Memo item - not to be included in national total
1A3aii(i)	Domestic aviation LTO (civil)	LTO: Landing/Take-off Large (jet, turboprop) & small (piston) aircrafts, helicopters
1A3aii(ii)	Domestic aviation CR (civil)	CR: Cruise Large (jet, turboprop) & small (piston) aircrafts, helicopters Memo item - not to be included in national total
1A3bi	Road transport: Passenger cars	Emissions from passenger cars
1A3bii	Road transport: Light duty vehicles	Emissions from light duty vehicles
1A3biii	Road transport: Heavy duty vehicles and buses	Emissions from heavy duty vehicles, coaches and buses
1A3biv	Road transport: Mopeds & motorcycles	Emissoins from 2-stroke and 4-stroke motorcycles
1A3bv	Road transport: Gasoline evaporation	NMVOC Emissions from gasoline evaporation
1A3bvi	Road transport: Automobile tyre and brake wear	Non-exhaust emissions from road transportation
1A3bvii	Road transport: Automobile road abrasion	Not reported separately but included 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 the cruise in civil aviation (see also Figure 3-6; 1A3ai(ii) International aviation CR and 1A3aii(ii) Domestic aviation CR) as well as emissions from international inland waterways are reported under “memo items” and not considered for the national total.

Table 3-47: Key categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source categories 1A3 Transport.

Code	Source category	Pollutant	Identification criteria
1A3ai(i)	International aviation LTO (civil)	NOx	L1, T1, T2
1A3ai(i)	International aviation LTO (civil)	SO2	T1
1A3bi	Road transport: Passenger cars	NOx	L1, L2, T1, T2
1A3bi	Road transport: Passenger cars	NMVOC	L1, T1, T2
1A3bi	Road transport: Passenger cars	SO2	T1
1A3bi	Road transport: Passenger cars	PM2.5	L1
1A3bii	Road transport: Light duty vehicles	NOx	L1, L2, T1, T2
1A3biii	Road transport: Heavy duty vehicles and buses	NOx	L1, L2, T1, T2
1A3biii	Road transport: Heavy duty vehicles and buses	SO2	T1, T2
1A3biii	Road transport: Heavy duty vehicles and buses	PM2.5	T1, T2
1A3biii	Road transport: Heavy duty vehicles and buses	PM10	T1
1A3biv	Road transport: Mopeds & motorcycles	NMVOC	L2
1A3bv	Road transport: Gasoline evaporation	NMVOC	L1, T1
1A3bvi	Road transport: Automobile tyre and brake wear	PM2.5	L1, L2, T1, T2
1A3bvi	Road transport: Automobile tyre and brake wear	PM10	L1, L2, T1, T2
1A3c	Railways	PM2.5	L1, T1
1A3c	Railways	PM10	L1, L2, T1, T2
1A3dii	National navigation (shipping)	NOx	T1

3.2.6.2 Methodological issues for 1A3 Transport

3.2.6.2.1 Civil aviation (1A3a)

Methodology (1A3a)

According to the decision tree Figure 3-1 in chapter 1A3a Aviation in 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, 2007-2019. The results of the emission modelling have been transmitted from FOCA to FOEN in an aggregated form (FOCA 2006, 2006a, 2007a, 2008-2020). Years in-between are interpolated. Further details of emission modelling are described in Switzerland's National Inventory Report (FOEN 2021).

Emission factors (1A3a)

The emission factors used are country-specific or taken from the ICAO engine emissions database from EMEP/CORINAIR databases (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 EF see Table 3-48.

- 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_2 is based on the suphur content of kerosene (see Table 3-8).
- PM10 and PM2.5 have been determined by the Federal Office of Civil Aviation (FOCA 2016a). 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(PM exhaust) = 2 x EF(BC), see also chapter 1.A.3.a, 1.A.5.b * Aviation of 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 3-48: Emission factors for 1A3a Civil aviation, year 2019. (LTO: Landing take-off cycle, CR: cruise.)

1A3a Civil aviation	**NO_x**	**NMVOC**	**SO_2**	**PM2.5**	**PM10**	**TSP**	**BC**
	kg/TJ						
Kerosene, domestic, LTO	217	105	21	6.4	6.4	6.4	6.1
Kerosene, domestic, CR	256	61	22	3.2	3.2	3.2	1.5
Kerosene, international, LTO	320	26	23	2.6	2.6	2.6	1.5
Kerosene, international, CR	362	8.0	23	0.28	0.28	0.28	0.22

1A3a Civil aviation	**CO**	**Pb**	**PCDD/ PCDF**	**HCB**	**PCB**
	kg/TJ		kg I-TEQ/TJ	kg/TJ	
Kerosene, domestic, LTO	2'850	2.1	NA	NA	NE
Kerosene, domestic, CR	589	1.0	NA	NA	NE
Kerosene, international, LTO	280	0.0050	NA	NA	NE
Kerosene, international, CR	40	0.0041	NA	NA	NE

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 3-49 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 is due to an increasing number of flights.

Table 3-49: 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.

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

1A3a/1D1 Civil aviation	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
	Fuel consumption in TJ									
Kerosene, domestic, LTO	464	509	504	494	525	387	421	384	346	321
Kerosene, domestic, CR	1'230	1'306	1'371	1'323	1'396	1'500	1'511	1'257	1'234	1'250
Kerosene, international, LTO (not part of national total)	5'643	6'041	6'226	6'208	6'142	6'459	6'529	6'728	6'953	6'963
Kerosene, international, CR (not part of national total)	52'691	56'420	57'677	58'501	58'864	60'874	64'073	66'096	70'261	71'233
Total Civil aviation	60'028	64'277	65'778	66'526	66'927	69'220	72'534	74'465	78'793	79'767
1990 = 100%	132%	142%	145%	147%	148%	153%	160%	164%	174%	176%

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 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 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 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 into the NFR reporting tables to source categories 1A3bi, 1A3bii and 1A3biii 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) and Matzer et al. (2019). 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 2019, 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, LPG, bioethanol, biodiesel, gas (CNG), 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, PM10 and Pb 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 and 2019 (INFRAS 2017c, INFRAS 2019, INFRAS 2019a). These emission factors are compiled in a database called “Handbook of Emission Factors for Road Transport” (INFRAS 2019). Version 4.1 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.
- Emission factors for Cd exhaust, PCDD/F, PAH and PCB are taken from the EMEP Guidebook (EMEP/EEA 2019).
- Emission factors for non-exhaust emissions of particulate matter (TSP, PM10, PM2.5, Cd) 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 2021/1A3b-Strassenverkehr.

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 CNG use. Table 3-50 shows a selection of implied emission factors (emissions devided by specific fuel consumption per source-category) for 2019.

Table 3-50: Implied emission factors for road transport, passenger cars in 2019.

1A3b Road Transportation Gasoline / Bioethanol	NO_X	NMVOC	SO_2	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	37	46	0.38	10	0.71	4.8	0.71	13	0.71	13	0.12	0.48
1A3bii: Light duty vehicles	127	127	0.38	11	3.2	5.3	3.2	11	3.2	11	0.58	0.53
1A3biii: Heavy duty vehicles	782	557	0.38	0.22	NE	5.9	NE	27	NE	27	NE	0.59
1A3biv: Motorcycles	100	341	0.38	1.2	14	3.2	14	5.7	14	5.7	2.8	0.38
1A3bv: Gasoline evaporation	NA	21	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 differnces	42	81	0.38	10	1.2	4.7	1.22	13	1.22	13	0.22	0.47

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	537	24	0.0047	0.40	0.20	0.0030	0.13	0.15	0.11	0.16	NE	607
1A3bii: Light duty vehicles	3'005	24	0.0047	0.66	0.20	0.0033	0.11	0.12	0.086	0.14	NE	665
1A3biii: Heavy duty vehicles	669	24	0.0047	0.77	NE	0.020	NE	NE	NE	NE	NE	NE
1A3biv: Motorcycles	3'109	24	0.0044	0.31	0.19	0.012	0.18	0.20	0.14	0.22	NE	4681
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 differnces	663	24	0.0047	0.41	0.20	0.0034	0.13	0.15	0.11	0.16	NE	752

1A3b Road Transportation Diesel / Biodiesel	NO_X	NMVOC	SO_2	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	298	4.2	0.48	1.3	2.1	4.5	2.1	12	2.1	12	1.4	0.45
1A3bii: Light duty vehicles	346	2.0	0.48	0.84	6.1	4.3	6.1	8.9	6.1	8.9	4.5	0.43
1A3biii: Heavy duty vehicles	179	4.3	0.48	1.01	2.9	4.6	2.9	21	2.9	21	1.6	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 differnces	252	3.7	0.45	1.1	2.7	4.2	2.7	13	2.7	13	1.7	0.42

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	NA	0.0012	0.39	0.12	0.0043	0.67	0.75	0.59	0.62	NE	868
1A3bii: Light duty vehicles	47	NA	0.0012	0.56	0.12	0.0046	0.49	0.55	0.43	0.45	NE	916
1A3biii: Heavy duty vehicles	65	NA	0.0012	0.60	0.21	0.0005	0.08	0.46	0.52	0.12	NE	92
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 differnces	48	NE	0.0011	0.44	0.14	0.0030	0.44	0.60	0.51	0.43	NE	607

1A3b Road Transportation Gas / Biogas	NO_X	NMVOC	SO_2	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	39	1.4	NA	9.5	2.1	5.1	2.1	14	2.1	14	0.32	0.51
1A3bii: Light duty vehicles	15	0.62	NA	7.5	2.5	5.1	2.5	10	2.5	10	0.37	0.51
1A3biii: Heavy duty vehicles	92	1.3	NA	4.3	1.3	3.2	1.3	20	1.3	20	0.19	0.32
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 differnces	57	1.3	NA	5.8	1.8	4.4	1.8	16	1.8	16	0.27	0.44

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	189	NA	NA	0.43	0.19	NA	0.14	0.16	0.11	0.17	NE	NE
1A3bii: Light duty vehicles	1218	NA	NA	0.65	0.19	NA	0.10	0.12	0.084	0.13	NE	NE
1A3biii: Heavy duty vehicles	40	NA	NA	0.39	NE	NA	0.0028	0.0045	0.0022	0.0017	NE	NE
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 differnces	227	NA	NA	0.44	0.12	NA	0.085	0.096	0.069	0.10	NE	NE

1A3b Road Transportation Liquified petroleum gas	NO_X	NMVOC	SO_2	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	36	3.6	NA	7.8	0.61	4.3	0.61	11	0.61	11	0.092	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 differnces	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

1A3b Road Transportation Liquified 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	466	NA	NA	0.36	0.19	NA	0.11	0.13	0.092	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 differnces	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

For fuel tourism and statistical differences of gasoline, bioethanol, diesel 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.

Table 3-50 continued

1A3b Road Transportation Hydrogen / electricity	NO_x	NMVOC	SO_2	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi: Passenger cars	NA	NA	NA	NA	NA	17	NA	44	NA	44	NA	1.7
1A3bii: Light duty vehicles	NA	NA	NA	NA	NA	12	NA	23	NA	23	NA	1.2
1A3biii: Heavy duty vehicles	NA	NA	NA	NA	NA	7.7	NA	47	NA	47	NA	0.8
1A3biv: Motorcycles	NA	NA	NA	NA	NA	124	NA	233	NA	233	NA	15
1A3bvii: Automobile road abrasion	NA	NA	NA	NA	NA	IE	NA	IE	NA	IE	NA	IE
1A3bi: Fuel tourism and statistical differnces	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

1A3b Road Transportation Hydrogen / electricity	CO	Pb	Cd ex	Cd nx	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ				mg I-TEQ/TJ	g/TJ				ng/TJ	
1A3bi: Passenger cars	NA	NA	NA	1.3	NA	NA	NA	NA	NA	NA	NA	NA
1A3bii: Light duty vehicles	NA	NA	NA	1.5	NA	NA	NA	NA	NA	NA	NA	NA
1A3biii: Heavy duty vehicles	NA	NA	NA	0.93	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 differnces	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Activity data (1A3b)

The activity data are derived from different data sources:

- Vehicle stock: The federal vehicle registration database MOFIS (run by the Federal Roads Office FEDRO) contains vehicle stock data including all parameters needed for the emission modelling (vehicle category, engine capacity, fuel type, total weight, vehicle age and exhaust technology). The data are not public, but the ordinary vehicle stock numbers are published by the Swiss Federal Statistical Office (SFSO 2020e). 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 (SFSO 2020e). 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 2020e, 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/2021 1A3bi-viii “Strassenverkehr”), Consumption of biofuels is provided by the statistics of renewable energies (SFOE 2020a).

The total mileage of each vehicle category is differentiated by “traffic situations” (characteristic patterns of driving behaviour) which serve as a key to select the appropriate emission factor and which are also available per traffic situation (see above). The relative shares of the traffic situations are derived from a national road traffic model (operated by the Federal Office of Spatial Development, see ARE 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 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 3-51 shows the mileage per vehicle category. Numbers hold for the version “fuel used” and represent the vehicle kilometres driven within the Swiss territory.

Table 3-51: Mileages in millions of vehicle kilometres. PC: passenger cars, LDV: light duty vehicles, HDV: heavy duty vehicles.

Veh. category	Unit	1990	1995	2000	2005
PC	million vehicle-km	42'649	41'324	45'613	48'040
LDV	million vehicle-km	2'600	2'746	2'957	3'228
HDV	million vehicle-km	1'992	2'107	2'273	2'120
Coaches	million vehicle-km	108	110	99	106
Urban Bus	million vehicle-km	174	192	200	229
2-Wheelers	million vehicle-km	2'025	1'563	1'700	1'785
Sum	million vehicle-km	49'548	48'043	52'841	55'507
(1990=100%)		100%	97%	107%	112%

Veh. category	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PC	million vehicle-km	52'066	52'696	53'721	54'695	55'641	56'620	57'737	58'735	59'344	59'208
LDV	million vehicle-km	3'502	3'635	3'776	3'874	3'998	4'129	4'269	4'392	4'529	4'682
HDV	million vehicle-km	2'226	2'258	2'229	2'243	2'236	2'235	2'235	2'242	2'238	2'310
Coaches	million vehicle-km	118	122	124	125	128	131	134	136	139	143
Urban Bus	million vehicle-km	244	250	254	262	267	272	281	280	291	292
2-Wheelers	million vehicle-km	1'852	1'877	1'899	1'904	1'920	1'937	1'976	2'008	2'046	2'041
Sum	million vehicle-km	60'009	60'838	62'003	63'102	64'188	65'324	66'631	67'793	68'588	68'676
(1990=100%)		121%	123%	125%	127%	130%	132%	134%	137%	138%	139%

Since 1990, the total mileage has been increasing by about 1 per cent per year on an average. 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 3-52 that depicts the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990–2019.

Table 3-52: Specific fuel consumption of road transport. Data are adopted from the territorial road transportation model. They include excess fuel consumption by cold starts.

Veh. cat.	Fuel	1990	1995	2000	2005
		MJ/veh-km			
PC	Gasoline	3.13	3.21	3.27	3.20
	Diesel	3.32	3.15	3.03	2.74
	LPG	NO	NO	NO	NO
	CNG	NO	NO	NO	NO
LDV	Gasoline	3.85	3.73	3.63	3.59
	Diesel	4.53	4.49	4.31	3.96
	CNG	NO	NO	NO	NO
HDV	Gasoline	NO	NO	NO	NO
	Diesel	11.3	11.7	11.7	12.2
	CNG	NO	NO	NO	10.5
Coach	Diesel	12.7	12.6	12.3	12.0
Urban Bus	Diesel	16.3	16.7	16.8	16.8
	CNG	NO	NO	NO	NO
2-Wheeler	Gasoline	1.49	1.66	1.48	1.58
Average		3.52	3.65	3.66	3.54
(1990=100%)		100%	104%	104%	101%

Veh. cat.	Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
		MJ/veh-km									
PC	Gasoline	3.06	3.01	2.94	2.87	2.80	2.72	2.65	2.57	2.49	2.44
	Diesel	2.71	2.70	2.69	2.67	2.65	2.61	2.57	2.52	2.48	2.48
	LPG	NO	2.99	2.96	2.94	2.92	2.86	2.84	2.82	NO	NO
	CNG	2.08	2.02	2.00	1.91	1.91	1.82	1.85	1.77	1.81	1.76
LDV	Gasoline	3.52	3.48	3.43	3.38	3.33	3.26	3.20	3.13	3.04	2.99
	Diesel	3.76	3.74	3.71	3.71	3.69	3.66	3.61	3.54	3.44	3.40
	CNG	2.40	2.70	2.69	2.55	2.55	2.44	2.48	2.38	2.41	2.35
HDV	Gasoline	NO	9.15	9.15	9.16	9.15	9.11	9.11	9.07	9.05	9.00
	Diesel	11.9	11.9	11.8	11.8	11.7	11.5	11.4	11.2	10.9	10.8
	CNG	13.2	13.0	13.0	12.5	12.7	12.2	12.6	12.2	10.9	10.7
Coach	Diesel	11.6	11.7	10.7	10.6	10.5	10.3	10.2	10.0	9.7	9.7
Urban Bus	Diesel	16.3	16.2	16.1	16.1	15.9	15.7	15.5	15.1	15.0	14.9
	CNG	17.0	16.6	16.7	16.0	16.0	15.4	15.9	15.3	16.0	15.7
2-Wheeler	Gasoline	1.52	1.54	1.55	1.53	1.58	1.62	1.58	1.58	1.60	1.60
Average		3.36	3.32	3.26	3.20	3.15	3.08	3.01	2.93	2.86	2.84
(1990=100%)		96%	94%	93%	91%	89%	87%	86%	83%	81%	81%

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 3-53. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific household surveys (ARE/SFSO 2005, 2012, 2017).

Table 3-53: Vehicle stock numbers (gasoline vehicles only – relevant for diurnal evaporation) and average number of starts per vehicle per day (gasoline, diesel oil, and CNG vehicles).

Veh. Category	1990	1995	2000	2005
	stock in 1000 veh. (gasoline/bioeth.)			
PC	2'838	3'048	3'303	3'265
LDV	167	164	148	112
2-Wheelers	764	688	712	746
	starts per veh. per day			
PC	2.61	2.53	2.46	2.40
LDV	1.97	1.97	1.96	1.96

Veh. Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	stock in 1000 veh. (gasoline/bioeth.)									
PC	2'957	2'925	2'879	2'833	2'784	2'736	2'685	2'681	2'744	2'741
LDV	77	73	69	64	61	58	56	54	51	50
2-Wheelers	766	775	780	793	802	805	816	836	849	859
	starts per veh. per day									
PC	2.34	2.34	2.33	2.33	2.32	2.33	2.32	2.31	2.30	2.28
LDV	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.94	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 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 3-54.

- Only diesel is being used as fuel, therefore all emission factors refer to diesel except for PM2.5 non-exhaust.
- PM2.5 non-exhaust emission factors distinguish between passenger and freight rail transport. It is based on a study from the Swiss Federal Railways Company in the year 2005 concerning PM10 emissions from railway traffic. Details to non-exhaust emission factors can be found in EMIS 2021/1A3c-Schienenverkehr.

Implied emission factors 2019 are shown in Table 3-55.

Table 3-54: 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 3-55: Implied emission factors in 2019 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_2	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	990	116	0.47	182	7.9	0.019	7.9	0.13	7.9	0.17	2.6	NA
Biodiesel	846	99	0.40	155	6.7	0.019	6.7	0.13	6.7	0.17	2.2	NA

1A3c Railways	CO	Pb	Cd	Hg	PCDD/	BaP	BbF	BkF	IcdP	HCB	PCB
Fuel	kg/TJ	g/TJ			mg I-TEQ/TJ	mg/TJ					
Diesel oil	533	NA	2.3	0.12	0.0016	848	1413	1051	195	NA	NE
Biodiesel	456	NA	1.9	0.10	0.0014	725	1208	899	167	NA	NE

Activity data (1A3c)

Table 3-56 shows the activity data of 1A3d taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-56: Activity data (diesel oil consumption) for railways. Data in TJ refer to exhaust emissions, whereas data in km refer to non-exhaust emissions.

1A3c Railways	Unit	1990	1995	2000	2005
Diesel	TJ	390	441	455	472
Biodiesel	TJ	NO	NO	0.59	1.7
Total Railways	TJ	390	441	456	474
1990=100%		100%	113%	117%	121%
tonne-kilometers	Mio. km	9'045	8'856	11'080	11'677
passenger-kilometers	Mio. km	12'978	12'978	12'978	16'210

1A3c Railways	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Diesel	TJ	492	471	451	431	410	390	388	387	385	383
Biodiesel	TJ	2.1	2.9	3.7	4.4	5.2	5.9	7.7	9.4	11	13
Total Railways	TJ	494	474	455	435	416	396	396	396	396	396
1990=100%		127%	122%	117%	112%	107%	102%	102%	102%	102%	102%
tonne-kilometers	Mio. km	11'074	11'526	11'061	11'812	12'313	12'431	12'447	11'665	11'776	11'673
passenger-kilometers	Mio. km	19'252	19'549	19'340	19'525	20'090	20'475	20'894	20'953	20'704	21'831

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 3-57 to Table 3-60 (FOEN 2015j). Implied emission factors 2019 are shown in Table 3-61.

Table 3-57: 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 3-58: 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 3-59: 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 3-60: 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 3-61: Implied emission factors in 2019 for 1A3d Navigation.

1A3d Navigation	NO_X	NMVOC	SO_2	NH_3	PM2.5	PM10	TSP	BC	CO
	kg/TJ								
Gasoline	543	404	0.38	0.09	0.17	0.17	0.17	0.009	8'446
Diesel oil	823	240	0.47	0.18	33.3	33.3	33.3	17.9	510
Gas oil	26.3	1.6	6.2	0.042	0.13	0.13	0.13	0.020	6.9
Biodiesel	704	205	0.40	0.16	28.4	28.4	28.4	15.3	436
Bioethanol	350	249	0.24	0.056	NA	NA	NA	NA	5'341

1A3d Navigation	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	mg/TJ					
Gasoline	24	2.2	0.19	0.0026	NA	NA	105	286	NA	NE
Diesel oil	NA	2.3	0.12	0.0016	799	1'331	990	198	NA	NE
Gas oil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NE
Biodiesel	NA	2.0	0.10	0.0014	683	1'138	847	169	NA	NE
Bioethanol	15	1.4	0.12	0.0017	693	693	68	185	NA	NE

Activity data (1A3d)

Table 3-62 shows the activity data of 1A3di taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-62: Activity Data for domestic navigation.

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

1A3d Domestic navigation	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoline	TJ	535	530	526	522	518	514	512	511	509	508
Diesel oil	TJ	868	870	872	874	876	878	873	867	862	857
Gas oil	TJ	159	157	156	154	153	151	150	149	148	147
Biodiesel	TJ	4	6	8	10	11	13	17	21	25	29
Bioethanol	TJ	0.0	0.8	1.6	2.3	3.1	3.9	6.3	8.6	11.0	13
Total Navigation	TJ	1'565	1'564	1'563	1'562	1'561	1'560	1'559	1'557	1'556	1'554
1990 = 100%		101%	101%	101%	101%	101%	101%	101%	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 2019 does not contain a decision tree to determine theTier 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/F and PAH), the emission factors stem from the EMEP/EEA Guidebook 2019.

Emission factors (1A3e)

The emission factors are used as for gas turbines (see Table 3-32) and are based on different sources. For the main pollutants (NO_x, NMVOC, SO_2, NH_3), the emission factors stem from the section “Gasturbinen; Erdgas” of SAEFL (2000). 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 2019.

Table 3-63: Emission factors of 1A3e for 2019.

1A3ei Pipeline transport	Pollutant	Fuel	Unit	Emisson factor
	NO_x	Gas	g/GJ	23.7
	NMVOC	Gas	g/GJ	0.1
	SO_2	Gas	g/GJ	0.5
	NH_3	Gas	g/GJ	0.6
	PM2.5 exh.	Gas	g/GJ	0.1
	PM10 exh.	Gas	g/GJ	0.1
	TSP exh.	Gas	g/GJ	0.1
	BC exh.	Gas	g/GJ	0.0025
	CO	Gas	g/GJ	4.8
	Hg	Gas	mg/GJ	0.1
	PCDD/ PCDF	Gas	ng I-TEQ/GJ	0.5
	BaP	Gas	ng/GJ	560
	BbF	Gas	ng/GJ	840
	BkF	Gas	ng/GJ	840
	IcdP	Gas	ng/GJ	840

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 2020; Table 17e).

Table 3-64: Activity data of 1A3e.

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

1A3ei Pipeline transport	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Natural gas	TJ	830	840	810	410	830	760	340	470	490	600
1990=100%		148%	150%	145%	73%	148%	136%	61%	84%	88%	107%

3.2.6.3 Category-specific recalculations for 1A3 Transport

- 1A3a: The ratio BC from PM2.5 was 48% according to the EMEP Guidebook default value for all flight processes (Cruise and LTO) for the years 1980-2014. As there are better estimates for all flight processes of the years 2015-2018 (FOCA 2016-2019) already in the database, the factors were adapted to those estimates also for the years 1980-2014.
- 1A3b: Cd exhaust, PCDD/F and PCB emission factors for road transportation were updated according to the latest version of the EMEP Guidebook 2019 (EMEP/EEA 2019, tables 3-77 to 3-79). In previous submissions, PCB was not estimated and Cd exhaust was assumed to be zero.
- 1A3b: There are some recalculations concering activity data in category 1A3b in the road transportation model, which lead to minor differences (mainly <2%) compared to the emissions of the previous submission:

- Update of activity data to the latest available dataset 1990-2019 (SFOE 2020e, ex-post analysis 2019). This concernes mainly the years 2016-2018 for all fuels and 2005 for biogas.
- Activity data of biogenic fuels are newly treated in the same way as fossil fuels and allocated to the individual vehicle categories. Also, the statistical difference of biodiesel and bioethanol is now allocated to "fuel tourism and statistical difference", similar as it is done for diesel and gasoline This leads to recalculations in all source-categories of 1A3bi-1A3biii for all years 1990-2018.

- 1A3c: Recalculation of the activity data (number of driven km on railways) that is used to calculate the non-exhaust emissions in 1A3c for the year 2011-2018. The activity data was updated to the recent available statistics.
- 1A3ei: Emissions of Pb, Cd, and PAHs were wrongly reported as "NA" in all NFR tables in previous submission, although there are emissions. This error was corrected.

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)

Table 3-65: 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 3-66: Key Categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source categories 1A4 –Non-road and machinery sources in residential, commercial, agriculture and forestry sectors.

Code	Source category	Pollutant	Identification criteria
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	PM2.5	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 Guidebook 2019 (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 3-40 to Table 3-42 (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 2019 for all pollutants are shown in Table 3-67.

Table 3-67: Implied emission factors 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry) in 2019.

Source/fuel	NO_x	NMVOC	SO_2	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							
1A4aii Other sectors (mobile): Commercial/institutional												
Gasoline	185	1'364	0.38	85	NA	IE	NA	IE	NA	IE	NA	IE
Bioethanol	85	474	0.24	61	NA	IE	NA	IE	NA	IE	NA	IE
1A4bii Other sectors (mobile): Residential												
Gasoline	156	910	0.38	91	NA	IE	NA	IE	NA	IE	NA	IE
Bioethanol	93	463	0.24	61	NA	NA	NA	NA	NA	NA	NA	NA
1A4cii Other sectors (mobile): Agriculture/forestry/fishing												
Gasoline	177	1'418	0.38	81	NA	21	NA	140	NA	210	NA	1.6
Diesel	398	46	0.47	160	34	IE	34	IE	34	IE	23	IE
Biodiesel	340	39	0.40	137	29	IE	29	IE	29	IE	NE	IE
Bioethanol	80	565	0.24	55	NA	IE	NA	IE	NA	IE	NA	IE

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	26'674	24	2.4	0.20	2'823	949	949	93	313	NE	NE
Bioethanol	15'696	15	1.5	0.13	1'824	615	615	60	202	NE	NE
1A4bii Other sectors (mobile): Residential											
Gasoline	25'319	24	2.4	0.20	2'825	954	954	93	313	NE	NE
Bioethanol	15'733	15	1.5	0.13	1'822	616	616	60	202	NE	NE
1A4cii Other sectors (mobile): Agriculture/forestry/fishing											
Gasoline	24'363	24	2.2	0.19	2'615	1'053	1'053	103	290	NE	NE
Diesel	231	NA	2.0	0.11	1'404	659	1'098	817	173	NE	NE
Biodiesel	198	NA	1.7	0.09	1'200	563	939	698	147	NE	NE
Bioethanol	14'915	15	1.4	0.12	1'642	706	706	69	182	NE	NE

The Expert Review Team noted during the Stage 3 review in 2016 that the IEF 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 IEF 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 3-68 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 the categories 1A4aii and 1A4bii only gasoline and bioethanol being used as fuel. In category 1A4cii mainly diesel oil is consumed and only small amounts of gasoline (e.g. chainsaws) and biodiesel.

Table 3-68: Activity Data for 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry).

Source/Fuel	Unit	1990	1995	2000	2005
1A4aii Other sectors (mobile):	TJ	191	245	295	295
Gasoline	TJ	191	245	295	295
Bioethanol	TJ	NO	NO	NO	NO
1A4bii Other sectors (mobile): Residential	TJ	142	155	165	166
Gasoline	TJ	142	155	165	166
Bioethanol	TJ	NO	NO	NO	NO
1A4cii Other sectors (mobile): Agriculture/forestry/fishing	TJ	1'160	5'674	5'889	5'642
Gasoline	TJ	NO	1'070	963	824
Diesel oil	TJ	4'269	4'604	4'920	4'802
Biodiesel	TJ	NO	NO	6.4	17
Bioethanol	TJ	NO	NO	NO	NO

Source/Fuel	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1A4aii Other sectors (mobile): Commercial/institutional	TJ	287	280	274	267	261	254	253	252	252	251
Gasoline	TJ	287	280	273	266	260	253	251	250	248	247
Bioethanol	TJ	0.0039	0.2415	0.48	0.72	0.95	1.19	1.9	2.6	3.3	4.0
1A4bii Other sectors (mobile): Residential	TJ	163	162	161	160	159	157	157	157	156	156
Gasoline	TJ	163	162	160	159	158	156	155	154	153	152
Bioethanol	TJ	0.0034	0.2148	0.43	0.64	0.85	1.06	1.7	2.3	2.9	3.6
1A4cii Other sectors (mobile): Agriculture/forestry/fishing	TJ	5'592	5'573	5'554	5'535	5'517	5'498	5'487	5'477	5'466	5'456
Gasoline	TJ	689	665	641	616	592	568	551	535	519	503
Diesel oil	TJ	4'882	4'876	4'870	4'864	4'859	4'853	4'835	4'817	4'800	4'782
Biodiesel	TJ	21	32	42	53	63	74	96	118	140	162
Bioethanol	TJ	0.0120	0.6598	1.31	2.0	2.6	3.3	4.8	6.4	8.0	9.6

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

No recalculations were carried out in source category 1A4 (mobile sources).

3.2.8 Source category 1A5b - Other, mobile (Military)

3.2.8.1 Source category description for 1A5b Other, mobile (Military)

Table 3-69: 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 3-70: Key categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source categories 1A5b Other mobile.

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 2019 (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_2 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 1990–2018. 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 infomrations from DDPS the same way as for NO_x, NMVOC, CO (see explanation above).
- TSP, PM10, PM2.5 non-exhaust: emission factors for TSP, PM10, PM2.5 non-exhaust are assumed to be equal. The implied emission factor (0.0016 g/GJ) from territorial processes (means all flights only in Swiss territory) in the year 1990 are taken for the whole time period.
- BC exhaust: the BC-factor is the same as for civil aviation with 48% from PM2.5 exhaust and constant over the period 1990-2019.

- Implied emission factors 2019 are shown in Table 3-71.

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 2019 are shown in Table 3-71.

Table 3-71: Emission factors for 1A5b Other (Military, mobile) in 2019.

1A5b Other: Military (mobile)	NO_x	NMVOC	SO_2	NH_3	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
Gasoline	133	735	0.38	0.091	NA	NA	NA	NA	NA	NA	NA	NA
Kerosene	232	33	23.0	NA	3.4	0.0016	3.4	0.0016	3.4	0.0016	1.6	NA
Diesel	339	29	0.47	0.16	8.1	NA	8.1	NA	8.1	NA	4.0	NA
Biodiesel	289	25	0.40	0.13	6.9	NA	6.9	NA	6.9	NA	NA	NA
Bioethanol	71	294	0.24	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
	kg/TJ	g/TJ			mg I-TEQ/TJ	mg/TJ					
Gasoline	24'426	24	2.3	0.20	0.0028	959	959	93	312	NE	NE
Kerosene	235	NA	NA	NA	NA	NA	NA	NA	NA	NE	NE
Diesel	150	NA	1.9	0.10	0.0014	621	1'035	770	167	NE	NE
Biodiesel	128	NA	1.7	0.088	0.0012	531	885	658	143	NE	NE
Bioethanol	15'494	15	1.5	0.13	0.0018	618	618	60	201	NE	NE

Activity data (1A5b)

The fuel consumption of 1A5bi Military aviation is copied from the logbooks of the military aircrafts, is summed up yearly by DDPS (2020) and provided to FOEN.

The fuel consumption of 1A5bii military non-road vehicles and machines is based on activity data provided by 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 3-72 shows activity data of both categories 1A5bi and 1A5bii.

Table 3-72: Activity data (fuel consumption) for 1A5b Other (Military, mobile).

1A5b	Unit	1990	1995	2000	2005
Military aviation					
Jet kerosene	Fuel cons. in TJ	2'733	1'955	1'794	1'624
Military non-road		239	248	252	257
Gasoline	Fuel cons. in TJ	19	19	19	19
Diesel oil	Fuel cons. in TJ	220	228	233	238
Biodiesel	Fuel cons. in TJ	NO	NO	0.30	0.86
Bioethanol	Fuel cons. in TJ	NO	NO	NO	NO

TJ

1A5b	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Military aviation											
Jet kerosene	Fuel cons. in TJ	1'592	1'420	1'527	1'542	1'615	1'567	1'627	1'469	1'457	1'303
Military non-road		275	275	275	275	275	275	274	273	272	271
Gasoline	Fuel cons. in TJ	18	18	18	17	17	17	17	16	16	16
Diesel oil	Fuel cons. in TJ	256	256	255	255	254	254	252	250	248	246
Biodiesel	Fuel cons. in TJ	1.1	1.7	2.2	2.8	3.3	3.9	5.0	6.1	7.2	8.3
Bioethanol	Fuel cons. in TJ	0.00038	0.023	0.046	0.069	0.092	0.11	0.18	0.25	0.31	0.38

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

No recalculations were carried out in source category 1A5b.

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

Table 3-73: Specification of source category 1B1a Coal mining and handling.

1B1	Source category	Specification
1B1a	Fugitive emission from solid fuels: Coal mining and handling	Only PM emissions from handling of coal.

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 PM emissions from coal handling occur.

Based on 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 EMEP/EEA (2019). 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 3-74: Emission factors in 1B1 Fugitive emissions from solid fuels in 2019.

1B1 Fugitive emissions attributed to solid fuels	Unit	PM2.5 non-exh.	PM10 non-exh.	TSP non-exh.	BC non-exh.
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 Swiss overall energy statistics (SFOE 2020).

Table 3-75: Activity data in 1B1 Fugitive emissions from solid fuels

1B1 Fugitive emissions from solid fuels	Unit	1990	1995	2000	2005
1B1a Coal handling, Other bituminous coal imported	t	534'938	286'007	210'347	232'974

1B1 Fugitive emissions from solid fuels	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1B1a Coal handling, Other bituminous coal imported	t	248'060	230'305	206'436	222'598	233'487	213'788	197'752	189'824	176'005	156'612

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. There is only crude oil transport by underground pipelines in Switzerland. Fugitive emissions in the oil industry result exclusively from the refineries and several fuel handling stations. At the beginning of 2015, one of the two refineries ceased operation.

Table 3-76: 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	Emissions from Claus-units and leakage in refineries
1B2av	Distribution of oil products	Fugitive emissions caused by distribution and storage of gasoline

Table 3-77: Key Categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 1B2 Oil and Natural Gas

Code	Source category	Pollutant	Identification criteria
1B2aiv	Fugitive emissions oil: Refining and storage	SO2	T2
1B2av	Distribution of oil products	NMVOC	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 EMEP/EEA (2019), emissions reported under 1B2ai are estimated using a Tier 3 approach where emission estimates 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 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_2 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 - gasoline distribution: Following the decision tree, Figure 3-1 in EMEP/EEA (2019), emissions reported under 1B2av are estimated using a Tier 2 approach where technology-specific activity data and emission factors are available. Basis for the method is a database of Swiss storage tanks and gasoline vapour recovery systems. For this database, a model is used in which data is calibrated with spot checks of the gas recovery systems of gas stations. Further information is provided in the EMIS database (EMIS 2021/1B2av Benzinumschlag Tanklager, EMIS 2021/1B2av Benzinumschlag Tankstellen).

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 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 2021/1B2aiv_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 2021/1B2aiv). 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 (PRTR 2020 database 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_2 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 distribution: The emission factors of NMVOC from 1B2av are country-specific and are provided by Weyer und Partner (Schweiz) AG until 2015 using a database of Swiss storage tanks and gasoline vapour recovery systems. After 2015, they are kept constant. Pb emissions were occurring between 1990-1999 only (in 2000, unleaded gasoline was introduced). Pb emission factors are based on the lead content of the different gasoline types.

Table 3-78: NMVOC and SO_2 emission factors in 1B2a – Oil, for 2019. All other emission factors including Pb (where emissions occurred from 1990 to 1999) since the year 2000 are not applicable for this source-category.

1B2a Fugitive emissions attributed to oil	Unit	NMVOC	SO_2
1B2ai Crude oil transport (per pipeline/refinery)	g/no.	10'000	NA
1B2aiv Refinery leackage	g/t	88	NA
1B2aiv Refinery claus units (per amount of crude oil imported)	g/t	NA	5
1B2av Gasoline distribution (per amount of gasoline sold)	g/GJ	15.6	NA

Activity data (1B2a)

As crude oil is transported per pipeline to the refineries in Switzerland, activity data for 1B2ai reflect the numer 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. Thiese data are provided by Avenergy Suisse (Avenergy 2020) in their annual statistics and also reported in the Swiss overall energy statistics (SFOE 2020).

The activity data for 1B2av concerning fugitive emissions from storage tanks and gasoline stations are the amount of gasoline sold based on the Swiss overall energy statistics (SFOE

2020), corrected for consumption of Liechtenstein, as documented in the EMIS database (EMIS 2021/1B2av Benzinumschlag Tanklager, EMIS 2021/1B2av Benzinumschlag Tankstellen).

Table 3-79: Activity data of 1B2a – Oil.

1B2a Fugitive emissions attributed to oil	Amount of	Unit	1990	1995	2000	2005
1B2ai Transport of crude oil by pipelines	Refineries	Number	2	2	2	2
1B2aiv Refining and storage	Crude oil	kt	3'127	4'657	4'649	4'877
1B2av Gasoline distribution	Gasoline sold	TJ	156'516	151'672	168'353	152'182

1B2a Fugitive emissions attributed to oil	Amount of	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2019 to 1990
1B2ai Transport of crude oil by pipelines	Refineries	Number	2	2	2	2	2	1	1	1	1	1	-50%
1B2aiv Refining and storage	Crude oil	kt	4'546	4'452	3'455	4'935	4'975	2'836	3'006	2'889	3'076	2'780	-11%
1B2av Gasoline distribution	Gasoline sold	TJ	134'129	128'941	124'386	118'717	113'956	105'664	102'367	99'223	97'654	96'850	-38%

3.3.2.3 Category-specific recalculations for 1B2a - Oil

- 1B2ai: Fugitive NMVOC emissions from crude oil transport in pipelines have been revised based on expert information from the oil industry (Canton of Neuchâtel 2019). In previous submissions, the default emission factor from 2006 IPCC Guidelines was used, but this factor refers to long above ground pipelines as used in North America. In contrast, crude oil pipelines in Switzerland are relatively short (max. 70 km) and underground. Negligible emissions occur at the pig trap only. Therefore, the activity data was changed to number of refineries (which is equal to the number of pipelines and pig traps) and the emission factors were reestimated. NMVOC emissions are calculated based on the estimation of 0.5 m^3 VOC per week and pipeline. Actually, those NMVOC emissions are negligible with 10-20 kg NMVOC per year.
- 1B2aiv: NMVOC emission factors in 1B2aiv are adapted for the year 2018 to reach the total NMVOC emissions as reported in the Swiss Pollutant Release and Transfer Register (PRTR). Data for the latest year is not available in the PRTR early enough for the data collection for the inventory. Therefore, the emissions are recalculated once the PRTR data is available.

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 3-80: 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 network Production of natural gas (only 1990-1994)

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 are 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 EMEP/EEA (2019) for 1B2ai and 1B2b (Fugitive emissions - Exploration production transport) emissions resulting from natural gas production under 1B2b Natural gas are estimated using a Tier 2 approach where technology specific activity data and specific emission factors are available.

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 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 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 2021/1B2b 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 2021/1B2b 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 3-81: Emission factors in 1B2b – Natural gas, for 2019.

1B2b Fugitive emissions attributed to naturtal gas	Unit	NMVOC
NG distribution losses, Transit	g/GJ	1'399
NG distribution losses, Distribution	g/GJ	1'399
NG distribution losses, Other	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 2020)

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 2021/1B2b 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 2021/1B2b 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 is considered. So far, two events have been reported by the transit pipeline operator, one in 2010 and one in 2011.

Table 3-82: Activity data of 1B2b – Natural gas.

1B2b Fugitive emissions attributed to naturtal gas	Fuel	Unit	1990	1995	2000	2005
Gas production	Natural gas	GJ	130'000	NO	NO	NO
Gas distribution losses, Transit	Natural gas	GJ	28'226	30'874	32'571	33'491
Gas distribution losses, Distribution	Natural gas	GJ	710'246	817'028	655'267	512'036
Gas distribution losses, Other	Natural gas	GJ	NO	NO	NO	NO

1B2b Fugitive emissions attributed to naturtal gas	Fuel	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2019 to 1990
Gas production	Natural gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-
Gas distribution losses, Transit	Natural gas	GJ	34'595	34'569	34'483	34'852	35'125	35'468	35'743	35'884	35'809	36'020	28%
Gas distribution losses, Distribution	Natural gas	GJ	449'418	441'857	435'545	399'993	389'310	388'251	390'185	383'203	377'827	380'054	-46%
Gas distribution losses, Other	Natural gas	GJ	35'444	28'114	NO	NO	NO	NO	NO	NO	NO	NO	-

3.3.3.3 Category-specific recalculations for 1B2b

- 1B2b: Recalculation of natural gas losses for the years 2017 and 2018 due to changes in the data of the length of pipelines.

3.3.4 Source category 1B2c - Fugitive emissions from venting and flaring

3.3.4.1 Source category description for 1B2c

In Switzerland, oil production is not occurring, and only one production site for natural gas production was operational from 1985–1994. Therefore, emissions from flaring result primarily from the torches, which were operational at the two refineries. Since 2015, there is only one refinery in operation. In addition, CO_2 emissions from H_2 production in one of the two refineries are also reported under 1B2c since 2005.

Table 3-83: 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 1990-1994)

Source category 1B2c – Venting and flaring is not a key category.

3.3.4.2 Methodological issues for 1B2c

Methodology (1B2c)

Following the decision tree, Figure 3-1 in 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 data from the refining industry as documented in the EMIS database (EMIS 2021/1B2c 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_2, CO) is assumed to be proportional to the CO_2 emission factor. Emission factors for 2019 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.

Table 3-84: Emission factors in 1B2c – Venting and flaring, for 2019.

1B2c Fugitive emissions attributed to venting and flaring	Unit	NO_x	NMVOC	SO_2	CO
1B2ci Flaring oil	g/t	C	C	C	C
1B2cii Flaring gas	g/t	NO	NO	NO	NO

Activity data (1B2c)

1B2c Fugitive emissions from venting and flaring

Before 2005, the amount of flared gas 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 refinery gas flared. Activity data since 2014 are considered confidential and are available to reviewers on request.

For gas production (only occurring from 1990-1994), the amount flared is estimated based on the amount of gas produced.

Table 3-85: Activity data of 1B2c – Venting and flaring.

1B2c Fugitive emissions attributed to venting and flaring	Fuel	Unit	1990	1995	2000	2005
1B2ci Flaring oil	Oil	kt	C	C	C	C
1B2cii Flaring gas	Gas	GJ	130'000	NO	NO	NO

1B2c Fugitive emissions attributed to venting and flaring	Fuel	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2019 to 1990
1B2ci Flaring oil	Oil	kt	C	C	C	C	C	C	C	C	C	C	C
1B2cii Flaring gas	Gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-

3.3.4.3 Category-specific recalculations for 1B2c

No recalculations were carried out in source category 1B2c.

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 2019 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 Pb, Cd, Hg, and PCDD/PCDF 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 slight decreasing trend afterwards. The trend until 2004 is mainly due to reductions in 2D Other solvent and 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 for more than half of the NMVOC emissions of source category 2D whereas all the other source categories account for the rest. In 2019, the largest shares in source category 2D come from 2D3a Domestic solvent use including fungicides and 2D3d Coating applications 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 and non-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 and non-industrial paint application and paint application in construction whereas in 2019, by emissions from paint application in construction on wood.

The NMVOC emissions from the most important single source category 2D3a Household cleaning agents increase between 1990 and 1998, then they drop until 2001. From 2002 until

2019, the emissions are again increasing. Factors contributing to this trend are changes in the NMVOC emission factor and population growth.

Within source category 2D, a significant reduction in emissions from 2D3g Chemical products and 2D3h Printing between 1990 and 2019 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 1990–2019. In addition, general technological improvements and post-combustion installations contribute to further emission reductions.

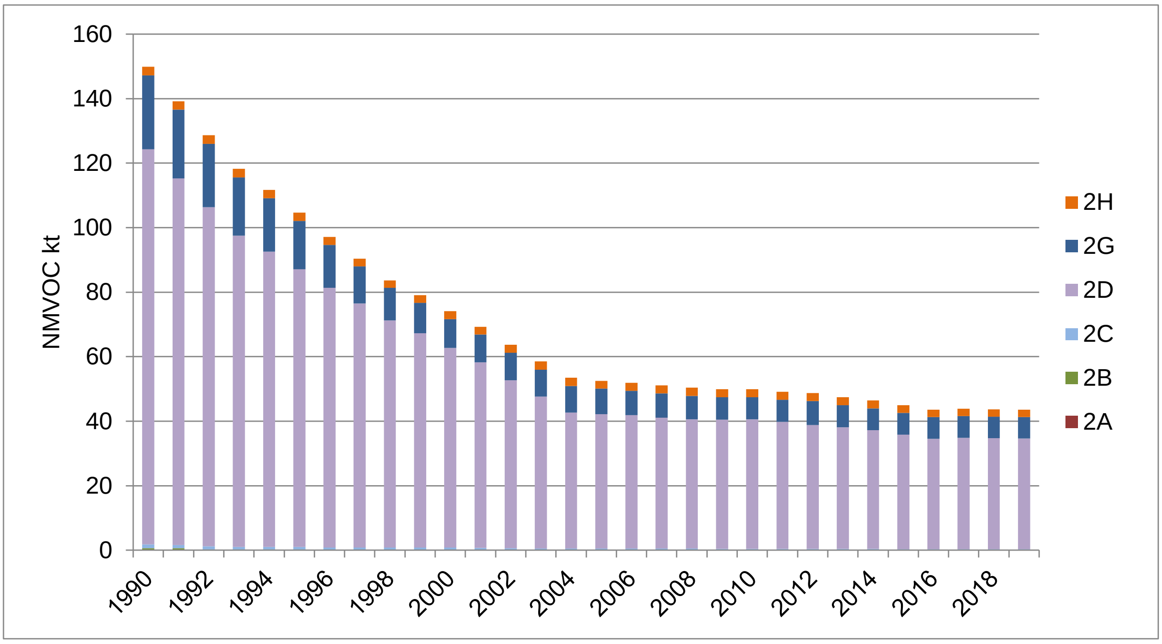


Figure 4-1: Switzerland’s NMVOC emissions from industrial processes and product use by source categories 2A-2D and 2G-2H between 1990 and 2019. The corresponding data table can be found in Annex A7.3.

4.1.2 Overview and trend for SO_2

According to Figure 4-2, total SO_2 emissions from 2 Industrial processes and product use show an intermittent decrease of almost 70% in the period 1990-2009. Since 2010, there is again an increase in SO_2 emissions. In 1990, source category 2C Metal production shows the largest contribution to the total SO_2 emissions and other significant contributions are due to 2B Chemical industry. In 2019, the largest shares of emissions are due to 2B Chemical industry. The emissions from 2A Mineral products are negligible over the entire time period and there are no emissions from 2D. The varying and even increasing SO_2 emissions from 2B Chemical industry stem mainly from the graphite and silicon carbide production, i.e. the sulphur content of the raw materials (petroleum coke and other bituminous coal) and reflect the production volume between 1990 and 2019. In 2019, it is the largest emission source within sector 2. The SO_2 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_2 emissions from 2G Other product use stems from the use of fireworks.

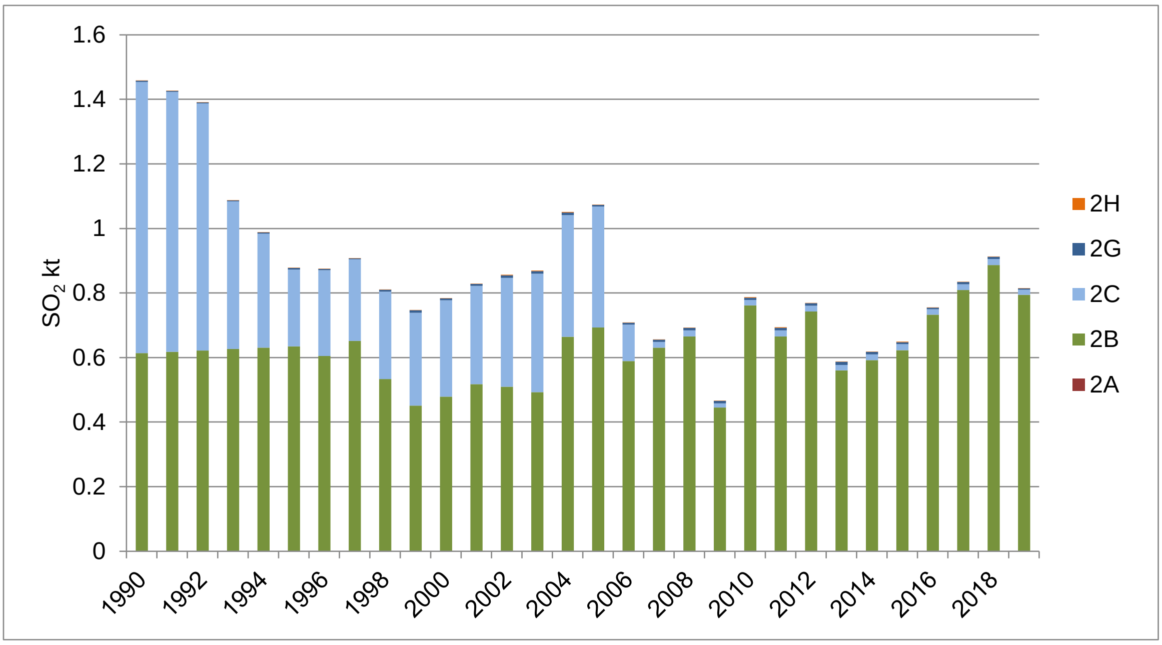


Figure 4-2: Switzerland's SO_2 emissions from industrial processes and product use by source categories 2A–2C and 2G-2H between 1990 and 2019. The corresponding data table can be found in Annex A7.3.

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. Since 2013 emissions are fluctuating with a slight decreasing trend. In 1990, the source categories 2A Mineral products, 2C Metal production, 2G Other product use and 2H Other contribute the most to the total PM2.5 emissions.

In 2019, the highest contribution to the total PM2.5 emissions is due to the source categories 2A, 2G and 2H. The other source categories are of minor importance in 2019. 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 is dominated by the emissions from the source category 2C1 Iron and steel production, show a strong decrease between 1990 and 2019 and are almost exclusively responsible for the total PM2.5 emission reduction in this source category. The reason for the initial emission reduction in 1995 is the closing down of two steel production sites in Switzerland, whereas the drastic drop in emission 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 slight decreasing trend since then. In 1990, 2G emissions were dominated by tobacco use. In 2019, 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. In this source category, the main contributions arise from 2H1 Chipboard and fibreboard production.

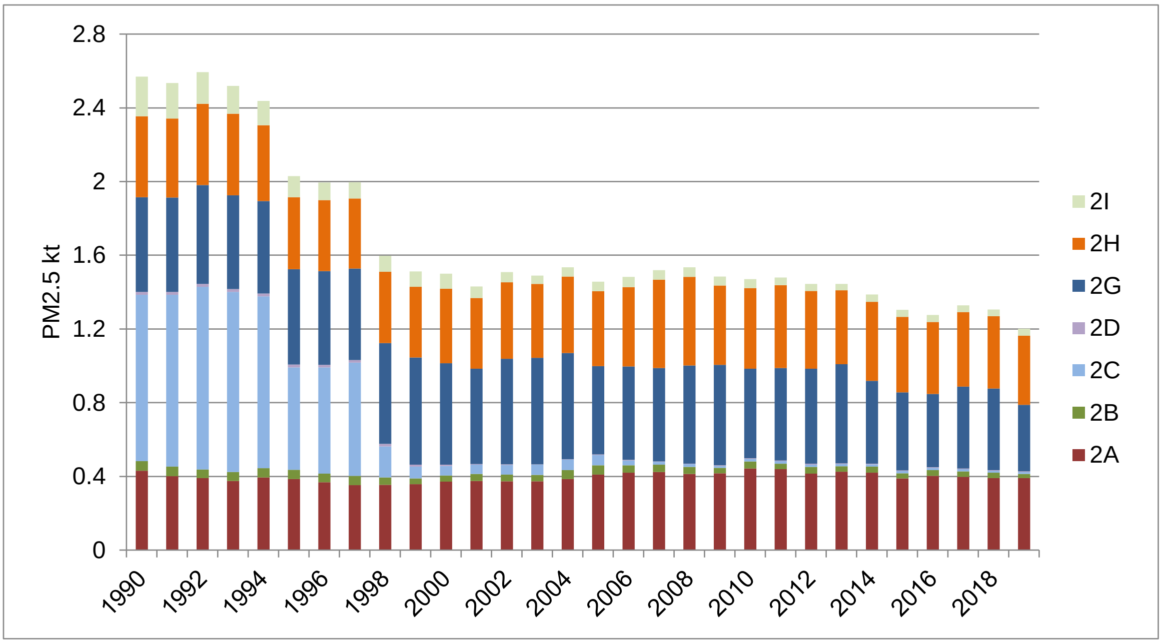


Figure 4-3: Switzerland's PM2.5 emissions from industrial processes and product use by source categories 2A-2D and 2G-2I between 1990 and 2019. The corresponding data table can be found in Annex A7.3.

4.2 Source category 2A – Mineral products

4.2.1 Source category description

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, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 2A Mineral products in Switzerland

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, L2, T1, T2
2A5a	Quarrying and mining of minerals other than coal	PM10	L1, L2, T1, 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 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 2021/2A1. 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 EMEP/EEA (2019).

Table 4-3: Emission factors for blasting operations of 2A1 Cement production in 2019.

2A1 Cement production	Unit	NOx	NMVOC	SO_2
Blasting operations	g/t clinker	3.3	8.6	0.14

2A1 Cement production	Unit	PM2.5 exh.	PM2.5 non-exh.	PM10 exh.	PM10 non-exh.	TSP exh.	TSP non-exh.	BC exh.	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 2021/2A1_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
Clinker	kt	4'808	3'706	3'214	3'442

2A1 Cement production	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Clinker	kt	3'642	3'587	3'368	3'415	3'502	3'195	3'296	3'279	3'239	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 EMEP/EEA (2019), emissions from blasting operations in the quarry are determined by a Tier 2 method using country-specific emission factors (EMIS 2021/2A2). 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_2, 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 emission inventory guidebook 2019 (EMEP/EEA 2019).

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 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 emission inventory guidebook 2019 (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. The emissions stem mainly from blasting operations and crushing of stones either in plaster production or gravel plants.

Based on 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 2021/2A5a). 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, emission factors are provided by SAEFL 2000.

Table 4-5: Emission factors of 2A5a Gravel plants and Plaster production in 2019.

2A5a Quarrying and mining of minerals other than coal	Unit	NOx	NMVOC	SO_2
Gravel plants	g/t gravel	NA	NA	NA
Plaster production	g/t rocks	5.6	14.4	0.24

2A5a Quarrying and mining of minerals other than coal	Unit	PM2.5 exh.	PM2.5 non-exh.	PM10 exh.	PM10 non-exh.	TSP exh.	TSP non-exh.	BC exh.	CO
Gravel plants	g/t gravel	NA	4	NA	8	NA	16	NA	NA
Plaster production	g/t rocks	0.9	150	1.44	300	1.44	450	NE	33

Activity data (2A5a)

Activity data for 2A5a 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.

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 most current 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
Gravel plants	kt gravel	33'798	36'791	39'785	44'960
Plaster production	kt rocks	319	304	288	327

2A5a Quarrying and mining of minerals other than coal	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gravel plants	kt gravel	50'540	51'940	49'780	53'940	53'090	50'610	52'750	51'480	49'880	49'973
Plaster production	kt rocks	335	293	271	213	166	140	148	146	152	149

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

Recalculations in 2A Mineral products

The following recalculations were implemented in submission 2021:

- 2A5a: The last year's extrapolated activity data of 2A5a Gravel plants for 2018 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, sulfuric acid; Production of PVC (ceased in 1996)

Table 4-8: Key categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 2B Chemical industry.

Code	Source category	Pollutant	Identification criteria
2B5	Carbide production	SO2	L1, L2, T1, T2
2B10a	Other Chemical industry	SO2	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 EMEP/EEA (2019), the emissions from 2B1 Ammonia production are calculated by a Tier 2 method using plant-specific emission factors documented in EMIS 2021/2B1.

Emission factors (2B1)

The NH_3 emission factor per tonne of ammonia produced is confidential but available to reviewers on request. From 1990 to 2001, a constant emission factor based on measurements is applied. In 2002, the scrubber was replaced. For 2011 and since 2013 the emission factor is determined based on measurements provided by the plant. For the years 2002 – 2010 and 2012 the average value of the years 2011 and 2013 – 2017 is applied.

Table 4-9: Emission factor for 2B1 Ammonia production in 2019.

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 1990-2019. 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 results 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 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 2021/2B2).

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 EF 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 one plant. This silicon carbide is used in abrasives, refractories, metallurgy and anti-skid flooring. The Swiss silicon carbide is produced in an electric furnace at temperatures above 2000ºC using the Acheson process. Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in EMEP/EEA (2019), the SO_2 and particulate matter emissions from 2B5 Silicon carbide production are calculated by a Tier 2 method using plant-specific emission factors (EMIS 2021/2B5). Included in the emissions of this source category are also the ones from the production of graphite at the same production site.

Emission factors (2B5)

The emission factors comprise the unsplit emissions from both production processes (silicon carbide and graphite). They are confidential but available to reviewers on request.

Table 4-10: Emission factor for 2B5 Carbide production in 2019.

2B5 Carbide production	Unit	SO_2	PM2.5 exh.	PM10 exh.	TSP exh.	BC exh.	CO
Silicon carbide	g/t carbide	C	C	C	C	NE	NE

Activity data (2B5)

Activity data on annual production of silicon carbide and graphite is provided by the production plant for the years 1990 and from 1995 onwards. 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 EMEP/EEA (2019), emissions from 2B10a Chemical industry are calculated by a Tier 2 method using plant-specific emission factors (EMIS 2021/2B10a).

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 2021/2B10 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 2019.

2B10a Chemical industry: Other	Unit	NO_x	NMVOC	SO_2	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 2021/2B10 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
Ammonium nitrate production	kt	C	C	C	C
Chlorine gas production	kt	C	C	C	C
Acetic acid production	kt	30	27	24	8
Ethylene production	kt	C	C	C	C
Sulfuric acid production	kt	C	C	C	C
Niacin production	kt	C	C	C	C
PVC production	kt	43	43	NO	NO

2B10a Chemical industry: Other	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ammonium nitrate production	kt	C	C	C	C	C	C	C	C	C	NO
Chlorine gas production	kt	C	C	C	C	C	C	C	C	C	C
Acetic acid production	kt	20	18	12	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 2021/2B10 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 2021/2B10 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 has been 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 2021/2B10 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 2021/2B10 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 2021/2B10 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 2021/2B10 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.

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 and 2018 as documented in EMIS 2021/2B10 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 2021/2B10 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_2 is emitted.

Emission factors

The emission factor for SO_2 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 2021/2B10 Schwefelsäure-Produktion. Between 1990 and 2008 the mean value is applied. The SO_2 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 2021/2B10 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 2021/2B10 PVC-Produktion).

Activity data

The annual amount of PVC produced is based on data from industry and expert estimates documented in EMIS 2021/2B10 PVC-Produktion (see Table 4-12).

4.3.3 Category-specific recalculations

Recalculations in 2B Chemical industry

There were no recalculations implemented in submission 2021.

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, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 2C Metal production

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 EMEP/EEA (2019), the emissions from 2C1 Iron and steel production are calculated by a Tier 2 method using country-specific emission factors (EMIS 2021/2C1).

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_2, 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 emission inventory guidebook (EMEP/EEA 2019).

Table 4-15: Emission factors 2C1 Iron and steel production in 2019. Unit of PCDD/PCDF is in I-TEQ.

2C1 Iron and steel production	Unit	NO_x	NMVOC	SO_2	NH_3	PM2.5 exh.	PM2.5 non-exh.	PM10 exh.	PM10 non-exh.	TSP exh.	TSP non-exh.	BC exh.	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	1.5
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 table shows that 2C1 Steel production decreased between 1994 and 1995 significantly due to the closing of two steel production sites in Switzerland. The remarkable reduction in activity data within the metal industry in 2009 seems to be due to the effects of the financial crisis, as a recovery of the production is indicated along with the recovery of the economy in the aftermath of 2009 until 2014.

Table 4-16: Activity data for 2C1 Iron and steel production.

2C1 Iron and steel production	Unit	1990	1995	2000	2005
Iron production,					
electric melting furnace	kt	80	70	65	35
other processes	kt	170	130	120	67
Steel production,					
electric arc furnace	kt	1'108	716	1'022	1'159
other processes	kt	1'108	716	NO	NO
rolling mill	kt	1'108	716	1'022	1'082

2C1 Iron and steel production	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Iron production,											
electric melting furnace	kt	40	46	34	34	33	28	26	27	26	18
other processes	kt	53	61	46	45	43	37	34	35	34	24
Steel production,											
electric arc furnace	kt	1'218	1'322	1'252	1'231	1'315	1'296	1'238	1'270	1'291	1'130
other processes	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
rolling mill	kt	1'082	1'183	1'162	1'126	1'176	1'144	1'085	1'138	1'160	1'037

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 of EMEP/EEA (2019), emissions from source category 2C3 are calculated by a Tier 2 method using country-specific emission factors (EMIS 2021/2C3).

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 2019.

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
	kt	87	21	36	45

2C3 Aluminium production	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	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 production of non-ferrous metals occur.

Based on the decision tree Fig. 3.1 in chapter 2C7a of EMEP/EEA (2019), emissions from source category 2C7a are calculated by a Tier 2 method (EMIS 2021/2C7a) 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 2019. Unit of PCDD/PCDF is in I-TEQ.

2C7a Copper production	Unit	NMVOC	PM2.5 exh.	PM10 exh.	TSP exh.	BC exh.	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
Foundries of non-ferrous metals	kt	60	56	53	33

2C7a Copper production	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Foundries of non-ferrous metals	kt	20	12	6.6	6.4	9.5	8.9	9.0	8.0	6.8	6.4

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 of EMEP/EEA (2019), emissions from source category 2C7c are calculated by a Tier 2 approach (EMIS 2021/2C7c) 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_2, 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_2, TSP, CO, Pb, Cd, Hg and PCDD/F 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 2019. Unit of PCDD/PCDF is in I-TEQ.

2C7c Other metal production	Unit	NO_x	NMVOC	SO_2	NH_3	PM2.5 exh.	PM2.5 nonexh.	PM10 exh.	PM10 nonexh.	TSP exh.	TSP nonexh.	BC exh.	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	0	C	NA	NA	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 2021/2C7c_Batterie-Recycling, EMIS 2021/2C7c_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
Galvanazing plants	kt	102	84	99	88
Battery recycling	kt	NO	C	C	C

2C7c Other metal production	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Galvanazing plants	kt	93	96	92	92	91	91	91	90	90	89
Battery recycling	kt	C	C	C	C	C	C	C	C	C	C

4.4.3 Category-specific recalculations

Recalculations in 2C Metal production

The following recalculations were implemented in submission 2021:

- 2C7a: Acitvity data of 2C7a Non-ferrous metal foundries have been revised for the years 1990-2008 and 2012-2018 based on industry data and estimates.
- 2C7c: Acitvity data of 2C7c Battery recycling have been revised for the years 1990-2002 based on industry data. The recycling plant started operation in 1992 only.

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	Use of spray cans in households; domestic use of cleaning agents, solvents, cosmetics, 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, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 2D Other solvent use

Code	Source category	Pollutant	Identification criteria
2D3a	Domestic solvent use	NMVOC	L1, L2, T1, T2
2D3b	Road paving with asphalt	NMVOC	L1, T1
2D3d	Coating applications	NMVOC	L1, L2, T1
2D3g	Chemical products	NMVOC	L1, T1, T2
2D3h	Printing	NMVOC	L1, T1
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 spray cans and pharmaceuticals. These products contain solvents, which evaporate during use or after the application. Among the numerous NMVOC emission sources, the use of household cleaning agents is the largest single source in source category 2D3.

Based on the decision tree Fig. 3.1 in chapter 2D3a in EMEP/EEA (2019), the emissions are calculated by a Tier 2 method (EMIS 2021/2D3a) 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 includes the use of cosmetics, toiletries, cleaning agents and care products. Its resulting emission factor bases thus on a multitude of products, their NMVOC contents, emission fractions and consumption numbers. About 80% of the NMVOC emissions stem from the use of cosmetics and toiletries whereas the rest arises from the use of cleaning agents and care products.

Available data sources consist of surveys of the use of household cleaning agents, cosmetics and toiletries in Switzerland (1990) and information from the Swiss association of cosmetics and detergents (SKW 2010) as well as surveys from Germany (1998, 2005). From 2001 until 2010 a constant EF is assumed for domestic use of cleaning agents. The value is based both on information from the Swiss association of cosmetics and detergents (SKW 2010) and from a German study on NMVOC emissions from solvent use and abatement possibilities by Theloke (2005). There were no significant improvements in the solvent compositions of the employed detergents.

In a study conducted in 2013/2014 in Switzerland more accurate data of household cleaning agents, cosmetics and toiletries was collected based on comprehensive surveys at retailers, producers, industry associations and experts as well as analysis of import statistics (Hubschmid 2014). As a result of this study, the emission factor of household cleaning agents was adjusted in 2013. The study indicates again an increase in the NMVOC emission factor in 2013.

Domestic use of spray cans

Emission factors of domestic use of spray cans are based on surveys in Switzerland (1990) and a Swiss study conducted in 2013/2014. This study provided more accurate data of aerosol contents of domestic spray cans based on comprehensive surveys at retailers, producers, industry associations and experts as well as analysis of import statistics (Hubschmid 2014). As a result of this study, the emission factor of spray cans was adjusted. It is assumed constant for the time period since 1998.

Domestic use of pharmaceutical products

Emission factors of domestic use of pharmaceutical products are available from surveys in Switzerland (1990) and Germany (1998) and from the Swiss business association for the chemical, pharmaceutical and biotech industry (scienceindustries) for 2011, as documented in the EMIS database. For years with no survey data, emission factors are interpolated.

Table 4-24: Emission factors of 2D3a Domestic solvent use including fungicides in 2019.

2D3a Domestic solvent use	Unit	NMVOC
Household cleaning agents	g/inhabitant	966
Domestic use of spray cans	g/inhabitant	360
Domestic use of pharmaceutical products	g/inhabitant	30

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 (SFSO 2020c).

Table 4-25: Activity data of 2D3a Domestic solvent use including fungicides.

2D3a Domestic solvent use	Unit	1990	1995	2000	2005
	inhabitants	6'712'000	7'041'000	7'184'000	7'437'000

2D3a Domestic solvent use	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	inhabitants	7'825'000	7'912'000	7'997'000	8'089'000	8'189'000	8'282'000	8'373'000	8'452'000	8'514'000	8'575'000

4.5.2.2 Road paving with asphalt (2D3b)

Methodology (2D3b)

Based on the decision tree Fig. 3.1 in chapter 2D3b in 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 2021/2D3b. 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 patrticulate matter are not estimated so far.

Table 4-26: Emission factors of 2D3b Road paving with asphalt in 2019.

2D3b Road paving with asphalt	Unit	NMVOC	PM2.5 exh.	PM10 exh.	TSP exh.	BC exh.
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 asphalt	Unit	1990	1995	2000	2005
Asphalt concrete	kt	5'500	4'800	5'170	4'780

2D3b Road paving with asphalt	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Asphalt concrete	kt	5'250	5'300	4'770	4'770	5'260	4'850	4'710	5'260	5'180	5'210

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 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 2021/2D3c. Emissions of PM2.5, PM10, TSP, BC and CO 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 are taken from the EMEP/EEA Guidebook (EMEP/EEA 2019).

Table 4-28: Emission factors of 2D3c Asphalt roofing in 2019.

2D3c Asphalt roofing	Unit	NMVOC	PM2.5 exh.	PM10 exh.	TSP exh.	BC exh.	CO
Asphalt roofing	kg/t sheeting	5.2	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.

Table 4-29: Activity data of 2D3c Asphalt roofing.

2D3c Asphalt roofing	Unit	1990	1995	2000	2005
Asphalt roofing	kt sheeting	54	56	58	51

2D3c Asphalt roofing	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Asphalt roofing	kt sheeting	68	74	74	73	73	73	72	72	72	71

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. Based on the decision tree Fig. 3.1 in chapter 2D3d in 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 2019, 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 2021/2D3d). 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 and non-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.

Table 4-30: Emission factors of 2D3d Coating applications in 2019.

2D3d Coating applications	Unit	NMVOC
Paint application, construction	kg/t paint	61
Paint application, households	kg/t paint	64
Paint application, industrial	kg/t paint	180
Paint application, wood	kg/t paint	317
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 2021/2D3d). 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 & non-industrial: Between 1990 and 2016, the activity of industrial and non-industrial paint application decreased significantly. There was a clear decrease between 2001 and 2004 due to structural changes in the industrial sectors and a widespread application of powder coatings from 2004 onwards. Since 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
Paint application, construction	kt	60	43	33	42
Paint application, households	kt	12	13	13	12
Paint application, industrial	kt	20	21	21	8.8
Paint application, wood	kt	8.7	8.7	8.5	9.2
Paint application, car repair	kt	2.7	2.2	2.0	1.9

2D3d Coating applications	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Paint application, construction	kt	54	53	52	50	49	49	47	46	46	45
Paint application, households	kt	11	11	11	11	10	10	10	10	10	10
Paint application, industrial	kt	8.3	8.2	8.0	7.9	7.8	7.6	7.5	7.5	7.5	7.5
Paint application, wood	kt	13.0	13	13	13	11	10.0	9.5	9.3	9.2	9.0
Paint application, car repair	kt	1.7	1.5	1.4	1.2	1.1	1.0	0.9	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. Based on the decision tree Fig. 3.1 in chapter 2D3e in

EMEP/EEA (2019), the NMVOC emissions from 2D3e Degreasing are calculated by a Tier 2 method (EMIS 2021/2D3e) 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 and 2012) and expert estimates as documented in the EMIS database.

Table 4-32: Emission factors of 2D3e Degreasing in 2019.

2D3e Degreasing	Unit	NMVOC
Cleaning of electronic components	kg/t solvent	500
Degreasing of metal	kg/t solvent	460
Other industrial cleaning	kg/t solvent	610

Activity data (2D3e)

Activity data correspond to the annual consumption of solvents for degreasing. Data are based on data from the association of Swiss mechanical and electric engineering industries (swissmem) in 2004, 2007 and 2012, VOC balances of the most important companies, import statistics and expert estimates, documented in the EMIS database (EMIS 2021/2D3e). A comparison between the surveys and the evaluations of VOC balances showed an underestimation of the survey data by about 6%. Thus, the emissions based on survey data from the industry association (swissmem) have been corrected by +10%. (EMIS 2021/2D3e).

By far, the highest activity data, i.e. consumption of solvents shows 2D3e Metal degreasing – which is the most important source of NMVOC emissions within source category 2D3e – for the entire time series.

Table 4-33: Activity data of 2D3e Degreasing.

2D3e Degreasing	Unit	1990	1995	2000	2005
Cleaning of electronic components	kt	0.90	0.56	0.35	0.64
Degreasing of metal	kt	16	10	5.9	2.6
Other industrial cleaning	kt	0.63	0.62	0.56	1.4

2D3e Degreasing	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cleaning of electronic components	kt	0.67	0.70	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Degreasing of metal	kt	2.1	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Other industrial cleaning	kt	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

4.5.2.6 Dry cleaning (2D3f)

Methodology (2D3f)

Based on the decision tree Fig. 3.1 in chapter 2D3f in EMEP/EEA (2019), the NMVOC emissions from 2D3f Dry cleaning are calculated by a Tier 2 method (EMIS 2021/2D3f) 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 2019.

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 SFSO (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
Solvent	kt	1.3	0.77	0.23	0.097

2D3f Dry cleaning	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Solvent	kt	0.081	0.076	0.074	0.072	0.072	0.071	0.071	0.070	0.070	0.069

4.5.2.7 Chemical products (2D3g)

Methodology (2D3g)

Based on the decision tree Fig. 3.1 in chapter 2D3g in 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 2021/2D3g).

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 2019.

2D3g Chemical products	Unit	NMVOC
Fine chemicals production	t/production index	3.5
Glue production	kg/t glue	0.80
Handling and storing of solvents	t/production index	1.6
Ink production	kg/t ink	5.0
Paint production	kg/t paint	3.0
Pharmaceutical production	kg/t pharmaceuticals	7.3
Polyester processing	kg/t polyester	50
Polystyrene processing	kg/t polystyrene	36
Polyurethane processing	kg/t polyurethane	3.1
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. 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
Fine chemicals production	prod. index	70	100	163	224
Glue production	kt	19	32	44	60
Handling and storing of solvents	prod. index	70	100	163	224
Ink production	kt	20	29	36	55
Paint production	kt	88	78	72	77
Pharmaceutical production	kt	16	21	20	28
Polyester processing	kt	11	7.0	6.5	6.9
Polystyrene processing	kt	20	19	19	24
Polyurethane processing	kt	17	35	45	54
Production of adhesive tape	kt	1.5	NO	NO	NO
PVC processing	kt	94	94	78	64
Rubber processing	tyres	120'000	119'375	103'667	67'000
Tanning of leather	employees	110	108	102	88

2D3g Chemical products	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fine chemicals production	prod. index	314	299	302	305	307	310	313	316	319	322
Glue production	kt	63	63	63	62	62	62	61	61	61	60
Handling and storing of solvents	prod. index	314	299	302	305	307	310	313	316	319	322
Ink production	kt	65	63	62	60	52	43	35	37	39	41
Paint production	kt	78	75	72	69	66	63	60	60	60	60
Pharmaceutical production	kt	30	30	30	30	31	31	31	31	31	31
Polyester processing	kt	3.4	3.5	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Polystyrene processing	kt	35	36	34	30	29	27	23	24	22	23
Polyurethane processing	kt	54	40	40	38	38	37	37	36	36	35
Production of adhesive tape	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PVC processing	kt	52	55	40	38	37	36	35	34	32	31
Rubber processing	tyres	77'500	80'000	80'000	81'000	82'000	83'000	84'000	85'000	86'000	87'000
Tanning of leather	employees	65	54	44	33	22	11	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 EMEP/EEA (2019), a Tier 2 method using country-specific emission factors is used for calculating the NMVOC emissions from the ink applications (EMIS 2021/2D3h).

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 2019.

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

Activity data (2D3h)

The activity data correspond to the consumption of printing ink. These data stem from industry associations (SOLV, viscom), surveys on the VOC balances, Swiss Federal Office of Statistics, emission control authorities and expert estimates, documented in the EMIS database.

Table 4-39: Activity data of 2D3h Printing.

2D3h Printing	Unit	1990	1995	2000	2005
Printing	kt	13	13	14	12
Package printing	kt	5.9	5.9	5.5	9.1

2D3h Printing	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Printing	kt	8.3	8.2	8.1	8.0	7.8	7.7	7.5	7.6	7.6	7.7
Package printing	kt	13	13	13	13	13	13	13	13	13	13

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 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 2021/2D3i). 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) and expert estimates, as documented in the EMIS database.

Table 4-40: Emission factors of 2D3i Other solvent use in 2019.

2D3i Other solvent use	Unit	NMVOC
Production of cosmetics	kg/employee	63
Production of paper and paperboard	g/t	35
Production of perfume and flavour	kg/employee	37
Production of textiles	kg/employee	8
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 the majority of production processes and services – such as production of perfume and flavour and production of textiles – the activity data correspond to the number of employees in the respective industrial sectors (SFSO 2020d). The quantity of NMVOC emission per employee originates from the bottom-up approach in these industrial sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are referred to the number of employees in order to calculate the Swiss total.

For production of paper and paperboard and fat, edible and non-edible oil extraction, the activity data are based on production volumes. Annual production volumes of paper and paperboard are provided by the Swiss association of pulp, paper and paperboard industry (ZPK). For the removal of paint and lacquer the activity data correspond to the 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
Fat, edible and non-edible oil extraction	kt	40	38	12	NO
Production of cosmetics	employees	2'200	2'200	2'267	2'100
Production of paper and paperboard	kt	1'510	1'560	1'780	1'750
Production of perfume and flavour	employees	2'200	2'325	2'567	3'200
Production of textiles	employees	25'200	26'763	24'300	17'067
Production of tobacoo	employees	3'300	2'988	2'733	2'700
Removal of paint and lacquer	t	700	600	502	405
Scientific laboratories	employees	10'194	18'604	23'217	23'000
Vehicles dewaxing	employees	200'000	166'250	72'667	NO

2D3i Other solvent use	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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	1'540	1'380	1'372	1'363	1'355	1'346	1'338	1'329	1'321	1'313
Production of perfume and flavour	employees	3'475	3'500	3'521	3'542	3'563	3'583	3'604	3'625	3'646	3'667
Production of textiles	employees	13'800	14'800	14'768	14'737	14'705	14'674	14'642	14'611	14'579	14'547
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	307	288	268	249	229	210	190	190	190	190
Scientific laboratories	employees	23'000	23'000	23'083	23'167	23'250	23'333	23'417	23'500	23'583	23'667
Vehicles dewaxing	employees	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

4.5.3 Category-specific recalculations

Recalculations in 2D– Other solvent use

The following recalculations were implemented in submission 2021:

- 2D3a: Since the survey methodology of the Swiss mean population has been revised (SFSO 2020c) for the years 1900 to 2010 the activity data (population) of all source categories in 2D3a Domestic solvent use including fungicides have changed for the respective years.
- 2D3d: Activity data of 2D3d Coating application, construction has been updated for 1990 based on information from industry association and expert judgment yielding revised data for 1990 to 1997.
- 2D3d Coating application, wood has been revised and includes now also the applications of glazes for wood preservation which have been reported so far under 2G Preservation of wood.
- 2D3g: Activity data of 2D3g Paint production have been revised based on information from industry association and revised activity data in coating applications for the years 1990-1997 and 2005-2015.

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, 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, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 2G Other product use

Code	Source category	Pollutant	Identification criteria
2G	Other product use	NMVOC	L1, L2
2G	Other product use	PM2.5	L1, L2, T1, 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 2019 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 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 2021/2G).

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.

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) and expert estimates, as documented in the EMIS database.

Table 4-44: Emission factors of 2G Other product use in 2019.

2G Other product use	Unit	NMVOC
Application of glues and adhesives	kg/t solvent	735
Commercial and industrial use of cleaning agents	g/employee	411
Cosmetic institutions	kg/employee	28
De-icing of airplanes	kg/t de-icing agent	54
Glass wool enduction	g/t glass wool	136
Hairdressers	kg/employee	14
Health care, other	kg/employee	8.4
Medical practices	kg/employee	7.6
Preservation of wood	kg/t preservative	30
Rock wool enduction	g/t rock wool	106
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	340
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 2021/2G) are displayed in Table 4-45. Emission factors of fireworks are documented in FOEN (2014d). Emission factors for use of tobacco are according to the EMEP/EEA Guidebook (EMEP/EEA 2019). 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 2019. Unit of PCDD/PCDF is in I-TEQ.

2G	Unit	NO_x	SO_x	NH_3	PM2.5 exh.	PM10 exh.	TSP exh.	BC exh.	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 refererenced 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) 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 2020), respectively.

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

2G Other product use	Unit	1990	1995	2000	2005
Application of glues and adhesives	kt solvent	4.0	3.0	2.0	1.5
Commercial and industrial use of cleaning agents	employees	3'950'000	3'867'500	3'954'667	4'133'667
Cosmetic institutions	employees	2'600	3'100	3'533	3'800
De-icing of airplanes	kt	1.2	2.4	1.8	2.5
De-icing of airport surfaces	kt	0.34	0.39	0.32	0.41
Fireworks	kt	0.84	1.0	1.5	1.4
Glass wool enduction	kt	24	24	31	37
Hairdressers	employees	20'553	22'826	23'530	22'200
Health care, other	employees	113'000	129'250	145'667	161'667
Medical practices	employees	27'625	42'047	50'833	55'357
Preservation of wood	kt	4.8	6.5	7.8	6.6
Rock wool enduction	kt	38	40	51	46
Underseal treatment and conservation of vehicles	kt	0.060	0.060	0.076	0.12
Use of antifreeze agents in vehicles	Mio vehicle km	47'523	46'479	51'142	53'723
Use of concrete additives	kt	24	25	29	36
Use of cooling lubricants	kt	5.0	5.2	5.8	4.5
Use of lubricants	kt	1.3	1.3	1.3	3.7
Use of pesticides	kt	2.4	2.4	2.3	2.3
Use of tobacco	Mio cigarette eq.	16'192.0	15'774.0	15'328.0	13'256.0

2G Other product use	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Application of glues and adhesives	kt solvent	1.1	1.0	1.9	1.0	1.0	0.98	0.97	0.96	0.95	0.95
Commercial and industrial use of cleaning agents	employees	4'404'000	4'333'333	4'262'667	4'192'000	4'236'000	4'280'000	4'324'000	4'368'000	4'412'000	4'456'000
Cosmetic institutions	employees	4'800	5'000	5'111	5'222	5'333	5'444	5'556	5'667	5'778	5'889
De-icing of airplanes	kt	3.3	2.6	3.8	3.1	2.3	2.3	2.3	2.3	2.4	2.4
De-icing of airport surfaces	kt	0.0180	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fireworks	kt	1.7	2.0	1.9	2.3	1.8	1.6	1.2	1.7	1.8	1.0
Glass wool enduction	kt	36	41	39	33	32	31	32	36	40	47
Hairdressers	employees	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000
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	1.0	1.2	0.9	0.9	0.6	0.6	0.7	0.7	0.5	0.6
Rock wool enduction	kt	56	57	57	54	53	47	52	52	57	51
Underseal treatment and conservation of vehicles	kt	0.16	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Use of antifreeze agents in vehicles	Mio vehicle km	57'039	58'007	58'976	59'944	60'913	61'881	62'260	62'638	63'017	63'395
Use of concrete additives	kt	41	44	38	38	37	37	36	36	35	35
Use of cooling lubricants	kt	3.9	4.4	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0
Use of lubricants	kt	0.35	0.49	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Use of pesticides	kt	2.1	2.3	2.2	2.3	2.2	2.2	2.2	2.0	2.1	2.1
Use of tobacco	Mio cigarette eq.	12'360	11'856	12'705	12'162	10'628	10'284	10'702	10'702	10'318	10'030

4.6.3 Category-specific recalculations

The following recalculations were implemented in submission 2021:

- 2G Preservation of wood has been revised completely and includes now all industrial wood preservation applications including creosote while applications of glazes for wood preservation are reported under 2D3d Coating application, wood.
- 2G Use of Tobacco: AD for the use of tobacco has changed from 1997 to 2010 due to a change in the population, which is used in the calculation of the AD for 1997-2015. The survey methodology of the Swiss mean population has been revised (SFSO 2020c) for the years 1900 to 2010. Since 2016 the total use of tobacco is modelled using a linear regression based on parameters deduced from the period of 1997 to 2015. Therefore, values since 2016 have also changed.

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, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 2H Other.

Code	Source category	Pollutant	Identification criteria
2H1	Pulp and paper industry	PM2.5	L1, L2, T1, T2
2H2	Food and beverages industry	NMVOC	L1, T1
2H2	Food and beverages industry	NH3	T2
2H2	Food and beverages industry	PM2.5	L1, L2, T1, 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 are produced in one and two plants, respectively. 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 EMEP/EEA (2019), the emissions are calculated by a Tier 2 method using country-specific emission factors (EMIS 2021/2H1).

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.

Table 4-49: Emission factors for 2H1 Pulp and paper industry in 2019. Unit of PCDD/PCDF is in I-TEQ.

2H1 Pulp and paper industry	Unit	NOx	NMVOC	SOx	PM2.5 non-exh.	PM10 non-exh.	TSP non-exh.	BC non-exh.	CO	PCDD/ PCDF
Fibreboard production	g/t fibreboard	NE	520	NE	430	440	500	NE	NE	NA
Chipboard production	g/t chipboard	NE	518	NE	418	434	501	NE	NE	0.0000005

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.

There are only two production sites for chipboard and fibreboard in Switzerland. Due to confidentiality, only the sum of the production volume of 2H1 Pulp and paper industry is provided. 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
Sum of chipboard, fibreboard and cellulose production	kt	604	593	641	693

2H1 Pulp and paper industry	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sum of chipboard, fibreboard and cellulose production	kt	602	564	533	510	516	519	503	507	502	460

4.7.2.2 Food and beverages industry (2H2)

Methodology (2H2)

Based on the decision tree Fig. 3.1 in chapter 2H2 in 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 2021/2H2).

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 2021/2H2 Brot Produktion).

Table 4-51: Emission factors for 2H2 Food and beverages industry in 2019. Unit of PCDD/PCDF is in I-TEQ.

2H2 Food and beverages industry	Unit	NMVOC	NH_3
Breweries	g/m^3 beer	250	NA
Spirits production	g/m^3 alcohol	10'000	NA
Bread production	g/t bread	4'500	NA
Meat smokehouses	g/t meat	1'300	NA
Roasting facilities	g/t coffee	30	NA
Milling companies	g/t flour	NA	NA
Wine production	g/m^3 wine	580	NA
Sugar production	g/t sugar	195	125

2H2 Food and beverages industry	Unit	PM2.5 exh.	PM2.5 non-exh.	PM10 exh.	PM10 non-exh.	TSP exh.	TSP non-exh.	BC exh.	CO	PCDD/ PCDF
Breweries	g/m^3 beer	NA	NA	NA	NE	NA	NA	NA	NA	NA
Spirits production	g/m^3 alcohol	NA	NA	NA	NE	NA	NA	NA	NA	NA
Bread production	g/t bread	NA	NA	NA	NE	NA	NA	NA	NA	NA
Meat smokehouses	g/t meat	350	NA	350	NE	350	NA	NE	250	0.000003
Roasting facilities	g/t coffee	NA	30	NA	60	NA	60	NA	NA	NA
Milling companies	g/t flour	NA	50	NA	100	NA	160	NA	NA	NA
Wine production	g/m^3 wine	NA	NA	NA	NE	NA	NA	NA	NA	NA
Sugar production	g/t sugar	NA	260	NA	520	NA	600	NA	NA	NA

Activity data (2H2)

Activity data on annual production have been provided by industry, 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 (SFSO 2020c) 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 2021/2H2 Brot Produktion).

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

2H2 Food and beverages industry	Unit	1990	1995	2000	2005
Breweries	m^3	436'814	401'555	366'956	342'085
Spirits production	m^3	4'158	3'271	2'179	2'266
Bread production	kt	336	352	359	372
Meat smokehouses	kt	66	64	60	62
Roasting facilities	kt	56	50	58	78
Milling companies	kt	1'644	1'519	1'603	1'425
Wine production	m^3	120'000	111'693	123'073	108'526
Sugar production	kt	147	129	219	197

2H2 Food and beverages industry	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Breweries	m^3	357'435	357'591	354'293	339'348	345'861	346'214	348'171	346'300	365'900	367'500
Spirits production	m^3	1'945	1'340	1'989	1'158	1'150	1'636	1'211	1'010	961	1'624
Bread production	kt	386	384	382	380	378	376	373	370	373	376
Meat smokehouses	kt	66	66	65	66	67	67	67	67	68	67
Roasting facilities	kt	102	110	110	120	119	125	127	131	141	148
Milling companies	kt	1'602	1'633	1'648	1'602	1'625	1'645	1'663	1'626	1'629	1'580
Wine production	m^3	108'319	102'522	98'621	108'564	99'556	99'859	90'174	88'116	90'404	95'742
Sugar production	kt	241	331	286	245	344	261	240	299	246	273

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 2019.

2H3 Other industrial processes	Unit	NO_x	NMVOC	SO_2	NH_3	PM2.5 exh.	PM10 exh.	TSP exh.	BC exh.	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 2020).

Table 4-54: Activity data of 2H3 Other industrial processes.

2H3 Other industrial processes	Unit	1990	1995	2000	2005
Blasting and shooting	kt explosive	2.6	1.3	1.9	0.79

2H3 Other industrial processes	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Blasting and shooting	kt explosive	2.4	2.9	2.3	2.2	2.1	2.1	0.67	0.73	0.81	0.67

4.7.3 Category-specific recalculations

The following recalculations were implemented in submission 2021:

- 2H2 Bread production: The activity data (population) for bread production has changed for the years 1990 to 2010. This is because the survey methodology of the Swiss mean population has been revised (SFSO 2020c) for the years 1900 to 2010.
- 2H2 Meat smoakhouses: AD of meat smokehouses has changed for the years 1980 to 2010 since the population, which is used in the calculation, has changed for the years 1980 to 2010. The survey methodology of the Swiss mean population has been revised (SFSO 2020c) for those years. In addition, the AD "per capita meat consumption" for 2017 and 2018 has changed due to a revised statistical source (SFSO 2020c).
- 2H2 Milling companies: AD for milling companies has changed for the years 2016 to 2018 because the "self-sufficiency rate" for those years have changed in the underlying statistical report by the Federal Office for Agriculture (FOAG).
- 2H2 Sugar production: The EF for NH_3 from sugar production in 2018 was 297 g/t sugar. In 2019, due to an error in data processing, the EF for NH_3 from sugar production was reported to be 125 g/t sugar. The correct EF for NH_3 from sugar production in 2019 is 297 g/t sugar and will be corrected accordingly for the next submission 2022.

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, level 2019 (L1, L2) and trend 1990-2019 (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.

Code	Source category	Pollutant	Identification criteria
2I	Wood processing	PM2.5	L2, T2
2I	Wood processing	PM10	L2, T1, 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 EMEP/EEA (2019), the calculation of emissions is based on a Tier 1 method based on country-specific emission factors (EMIS 2021/2I Holzbearbeitung).

Emission factors (2I)

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

Table 4-57: Emission factors for 2I Wood processing in 2019.

2I Wood processing	Unit	PM2.5 non-exh.	PM10 non-exh.	TSP non-exh.
Wood processing	g/t sawnwood	62	246	615

Activity data (2I)

Activity data of wood processing are the annual amount of sawnwood based on the yearbook forest and wood (FOEN 2020f).

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

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

2I Wood processing	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wood processing	kt sawnwood	774	670	606	564	634	626	622	578	597	598

4.8.2.2 Usage of PCBs (2K)

Methodology (2K)

Source category 2K includes PCB emissions from use of polychlorinated biphenyls (PCBs) in transformers, small and large capacitors, anti-corrosive paints and joint sealants in Switzerland between 1946 and 1986. In 1986, a total ban was placed on any form of PCB use. The use in so-called open systems, i.e. anti-corrosive paints and joint sealants, was allowed until 1972 only. For the time being, anti-corrosive paints and joint sealants are the predominant PCB emission sources. Emissions from demolition/renovation of steel constructions and buildings containing PCBs in anti-corrosive paints and joint sealants, respectively, are also reported in source category 2K.

A dynamic mass flow model was developed for the usage of PCBs in Switzerland for the time period 1930 to 2100 (Glüge et al. 2017). The model takes into account the entire life cycle, i.e. import, usage, export, treatment, disposal and accidental release of PCBs. A description of the model is given in see 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 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 demolition/renovation of steel constructions and buildings containing PCBs in anti-corrosive paints and joint sealants are expressed in units per tonnes of PCBs demolished or renovated.

Table 4-59: Emission factors for 2K Usage of PCBs in 2019.

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
Transformers	t PCB	1'257	840	501	265
Large capacitors	t PCB	356	235	139	73
Small capacitors	t PCB	361	213	108	47
Anti-corrosive paints	t PCB	209	196	178	156
Joint sealants	t PCB	209	196	178	156
Demolition and renovation	t PCB	2.4	4.0	6.2	8.5

2K Usage of PCBs	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Transformers	t PCB	123	104	87	73	60	50	41	33	27	22
Large capacitors	t PCB	33	28	24	20	16	13	11	9	7.3	5.8
Small capacitors	t PCB	17	14	11	9	6.7	5.2	4.0	3.1	2.4	1.8
Anti-corrosive paints	t PCB	128	123	117	110	104	98	92	86	80	73
Joint sealants	t PCB	129	123	117	110	104	98	92	86	80	73
Demolition and renovation	t PCB	10	11	11	11	11	11	11	11	11	11

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 jdatabase (EMIS 2021/2 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 2019.

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 2021/2 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
Freezers filling	t	178	201	224	246
Freezers storage	t	1'100	1'100	1'200	1'200

2L Ammonia from freezers	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Freezers filling	t	269	273	278	283	287	292	295	298	301	304
Freezers storage	t	1'200	1'279	1'357	1'436	1'515	1'593	1'616	1'638	1'661	1'683

4.8.3 Category-specific recalculations

The following recalculation was implemented in submission 2021:

- 2I Wood processing has been revised completely for the entire times series 1990-2018. On one hand the activity data has been changed from inhabitants to the more appropriate quantity of sawnwood. But also the emission factor has been changed for 2003.

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 1990-2019 (see Figure 5-1). The trend is more pronounced between 1990 and 2004, and since then continues on a lower level with some fluctuations. Main source is category 3D 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 e.g. the number of dairy cattle (the most important livestock category) decreased almost continuously by 29% between 1990 and 2019.

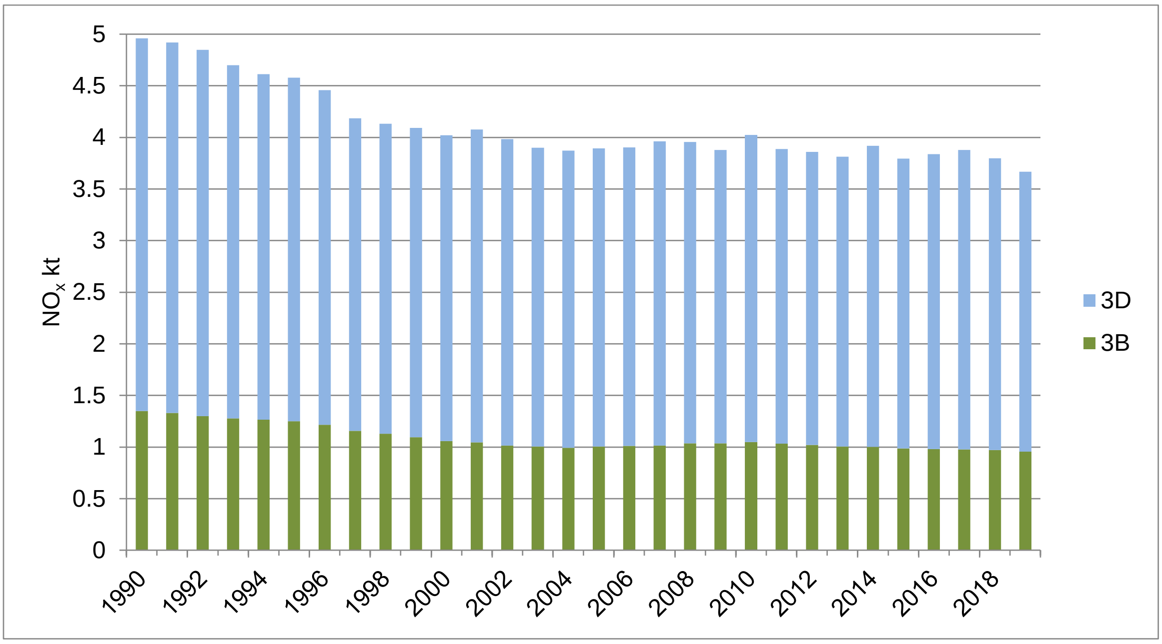


Figure 5-1: Switzerland's NO_x emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.1.

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 considerable contribution to the national total of the 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 and show a minor decreasing trend between 1990 and 2019 with some fluctuations in between. The main emission share stems from cattle husbandry with silage feeding as important emission source besides manure management.

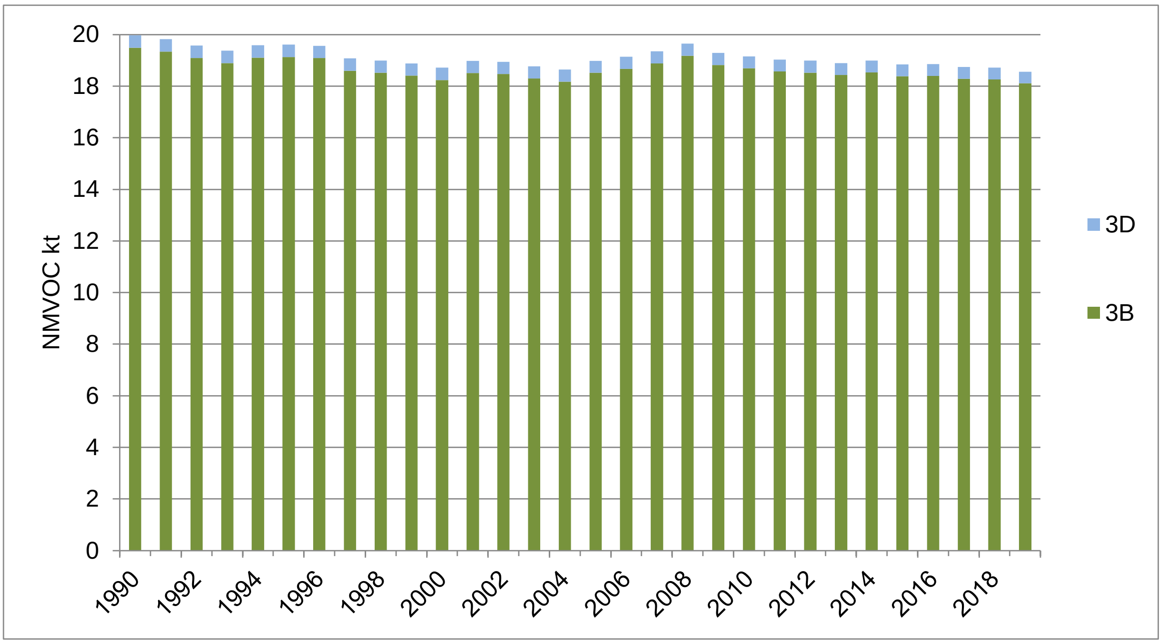


Figure 5-2: Switzerland's NMVOC emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.2.

5.1.3 Overview and trend for NH_3

Agriculture is the main 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 category 3B Manure management is subject to little variation throughout the period 1990-2019, category 3D Crop production and agricultural soils shows a fluctuating and decreasing trend. Both categories are about equally important in the year 2019. A decrease of the agricultural ammonia emissions already happened in the preceding decade 1980-1990 due to declining number of animals and use of mineral fertiliser. The decrease continued until 2003, followed by a slight increase until 2008 and another decrease since then. This manifold trend results from a combination of changes in animal numbers, introduction of new housing systems due to developments in animal welfare regulations, increase of animal productivity and changes in production techniques (Kupper et al. 2015, 2018).

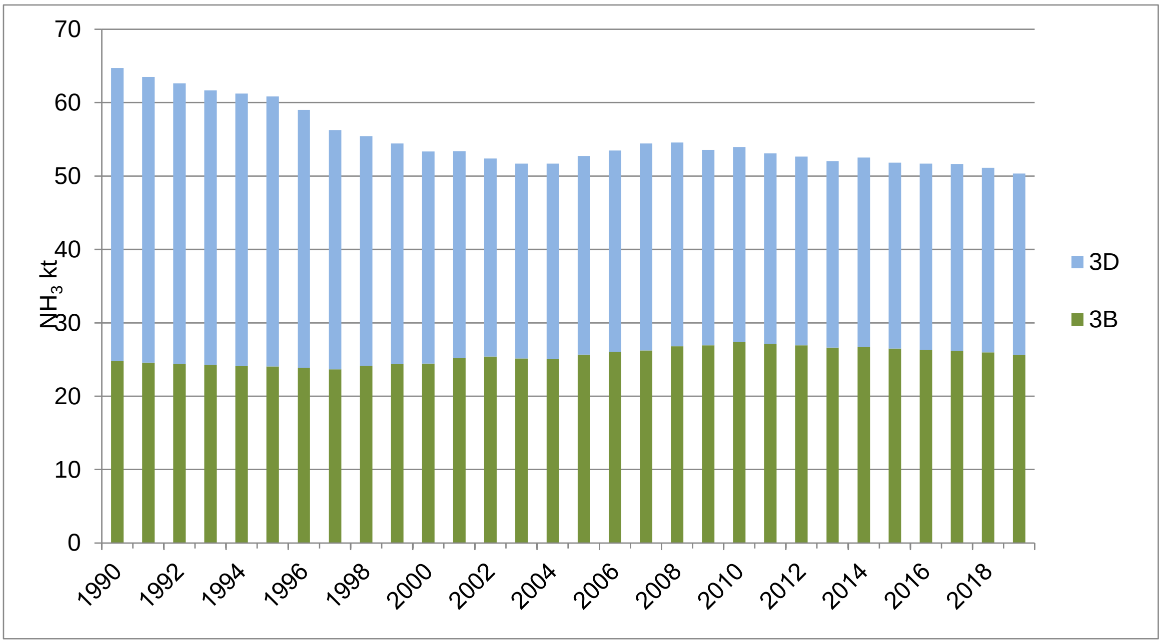


Figure 5-3: Switzerland's NH_3 emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.4.

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. This 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.

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 approach 1, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 3B Manure Management

Code	Source category	Pollutant	Identification criteria
3B1a	Manure management - Dairy cattle	NMVOC	L1, L2, T1, T2
3B1a	Manure management - Dairy cattle	NH3	L1, L2, T1, T2
3B1b	Manure management - Non-dairy cattle	NMVOC	L1, L2, T1, T2
3B1b	Manure management - Non-dairy cattle	NH3	L1, L2, T1, T2
3B3	Manure management - Swine	NMVOC	L2, T2
3B3	Manure management - Swine	NH3	L1, L2
3B3	Manure management - Swine	PM10	L2
3B4gi	Manure management - Layers	NH3	L2
3B4gi	Manure management - Layers	PM10	L2
3B4gii	Manure management - Broilers	NMVOC	L2, T2
3B4gii	Manure management - Broilers	NH3	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 2019 (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 the last revision of the model (Kupper et al. 2018) the model 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 (Agroscope 2017). To take into account the varying milk yield level of dairy cattle, a linear correction factor also given in Agroscope (2017) was applied. AGRAMMON considers important parameters on farm and manure management influencing the emissions of ammonia at the different levels of a farm. 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 and 2015. Each survey consisted of a representative stratified random sample covering approximately 2000 to 3000 farms (in total, there are about 50'000 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 four 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 2015 was established with the calculated emission factors (2002, 2007, 2010, 2015), with interpolated emission factors for the years 2003-2006, 2008-2009 and 2011-2014, and the known development of the number of animals in different livestock categories (activity data). Emission factors beyond 2015 are kept constant until new survey results are available (planned for submission 2022). The experience gained from the detailed surveys between 2002 and 2015 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 detailed reports accessible on the internet site of AGRAMMON (Kupper et al. 2018).

A comparison of the country-specificly calulated Tier 3 results for N flows and NH_3 emissions from animal husbandry factors with the results of the Tier 2 calculations with the TFEIP N flow tool was performed for 2015 (the last year with a representative survey on farm management. Annex A2.3 shows some preliminary results.

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 and Table 5-4 show that the share of the total N exretions from all agricultural livestock and cattle only, respectively, that went into the slurry flow remained almost constant around 60%. The share of N going to pasture, range and padock nearly doubled because of animal welfare incentives and the share going to digesters increased from 0.5% to 3.9% and the share going to deep litter and poultry manure rouse from 5.4% to 8.0% due to a strong growth of poultry production. The share going to solid manure decreased by nearly halve, mainly because of the shift in cattle housing systems and more grazing. Table 5-5 shows the share of N excretions going to the liquid manure flow (including digesters) for the different livestock categories.

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 2015 (in % of total N excretions). Data based on representative surveys on farm mangement technique in 2002, 2007, 2010 and 2015; for 1990 and 1995 based on expert assumptions (Kupper et al. 2018).

Distribution of N excretion (%)	**1990**	**1995**	**2002**	**2007**	**2010**	**2015**
Liquid / Slurry	62.4%	62.7%	58.1%	58.4%	57.0%	58.0%
Solid manure	22.9%	21.8%	16.6%	15.1%	15.6%	13.2%
Other (Deep litter, Poultry manure)	5.4%	5.2%	6.3%	7.1%	8.1%	8.0%
Digesters	0.5%	0.4%	0.5%	1.4%	2.1%	3.9%
Pasture, range and paddock	8.8%	9.7%	18.5%	18.0%	17.2%	16.9%

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 2015 (in % of total N excretions). Data based on representative surveys on farm mangement technique in 2002, 2007, 2010 and 2015; for 1990 and 1995 based on expert assumptions (Kupper et al., 2018).

Distribution of N excretion (%)	**1990**	**1995**	**2002**	**2007**	**2010**	**2015**
Liquid / Slurry	58.6%	60.1%	57.6%	60.2%	59.1%	61.9%
Solid manure	28.9%	26.5%	19.0%	16.8%	17.5%	14.1%
Other (Deep litter)	1.4%	1.3%	1.3%	1.3%	1.6%	1.4%
Digesters	0.4%	0.4%	0.5%	1.3%	1.8%	3.4%
Pasture, range and paddock	10.7%	11.7%	21.6%	20.5%	19.9%	19.2%

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 2015 (in % of total N excretions of the respective category). Data based on representative surveys on farm mangement technique in 2002, 2007, 2010 and 2015; for 1990 and 1995 based on expert assumptions (Kupper et al., 2018).

% N excretion going to liquid phase	1990	1995	2002	2007	2010	2015
Dairy cattle	64.2%	66.1%	65.8%	68.8%	68.9%	73.3%
Non-dairy cattle	41.6%	39.6%	40.3%	50.9%	49.8%	54.4%
Young Cattle	48.0%	48.8%	42.7%	46.8%	46.7%	50.6%
Sheep	0.0%	0%	0%	0%	0%	0%
Swine	100%	100%	100%	99%	100%	100%
Goats	0%	0%	0%	0%	0%	0%
Horses	0%	0%	0%	0%	0%	0%
Mules and asses	0%	0%	0%	0%	0%	0%
Poultry (layers, borilers, turkey)	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 (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 2019 (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 (perennial) study was launched in 2018 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. In the meantime, NMVOC emissions are reported in the inventory based on a Tier 1 approach using default Tier 1 emission factors (EMEP/EEA 2019). Preliminary results of the emission factors for dairy cattle with and without silage feeding for the Swiss plateau and mountain area, respectively are available. The emission factors for silage feeding in the plateau and the mountain area are somewhat higher and comparable to Tier 1 values (EMEP/EEA 2019), respectively, whereas the emission factors without silage feeding are both considerably lower. In Switzerland, as much as 44% of the dairy cattle are fed without silage because the unpastorised milk is used for making hard cheese. Thus, we consider that overall, the values of the Tier 1 emission factors yield reasonable NMVOC emissions until country-specific emission factors will be available (presumably for submission 2022).

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 (3B3 & 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 (AGRAMMON 2018, Kupper et al. 2015, Kupper et al. 2018). N excretions of livestock categories have been revised based on new national standard data on N excretion rates (Richner et al. 2017 in Agroscope 2017), considering animal category specific correction factors for various feeding strategies as well as for milk yield of dairy cows (Kupper et al. 2018).

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 account for 67% of the total N flow through manure storage. 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.

The NMVOC emission factors for all livestock categories are based on default Tier 1 emission factors (EMEP/EEA 2019, chp. 3B Manure management, Table 3.4), see Table 5-8. For dairy cattle, the emission factors are scaled with the Swiss dairy cattle weight (660 kg). Also the fractions of cattle getting silage feeding are taken into account.

The particulate matter emission factors (PM2.5, PM10, and TSP) are listed in Table 5-9. They have been revised completely 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 (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 EFs as for the corresponding agricultural animals are applied (see chp. 7.2.2).

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
3B1a	Dairy cattle	kg/animal	13	14	15	17
3B1b	Non-dairy cattle	kg/animal	13	14	14	16
3B1c	Young cattle	kg/animal	5.1	5.3	5.6	5.8
3B2	Sheep	kg/animal	1.4	1.3	1.4	1.2
3B3	Swine	kg/animal	3.5	3.6	3.9	3.8
3B4a	Buffalos	kg/animal	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	NO	NO	2.4	1.9
3B4c	Deer	kg/animal	3.6	3.9	3.8	3.3
3B4d	Goats	kg/animal	2.4	2.3	2.4	2.1
3B4e	Horses	kg/animal	9.8	9.6	8.8	8.5
3B4f	Mules and asses	kg/animal	3.6	3.5	3.2	3.0
3B4gi	Layers	kg/animal	0.31	0.30	0.23	0.21
3B4gii	Broilers	kg/animal	0.10	0.099	0.086	0.086
3B4giii	Turkey	kg/animal	0.36	0.36	0.32	0.32
3B4giv	Growers	kg/animal	0.17	0.15	0.16	0.12
3B4giv	Other poultry	kg/animal	0.15	0.14	0.15	0.16
3B4hi	Rabbits	kg/animal	0.23	0.23	0.23	0.23
3B4hii	Bisons	kg/animal	NO	4.8	5.6	5.6

NH3 emission factors		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3B1a	Dairy cattle	kg/animal	19	19	19	19	19	20	20	20	20	20
3B1b	Non-dairy cattle	kg/animal	16	16	16	16	16	16	16	16	16	16
3B1c	Young cattle	kg/animal	6.1	6.2	6.3	6.3	6.4	6.4	6.4	6.4	6.3	6.3
3B2	Sheep	kg/animal	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
3B3	Swine	kg/animal	3.6	3.6	3.5	3.4	3.3	3.3	3.3	3.3	3.3	3.3
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.9
3B4c	Deer	kg/animal	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.6	3.6
3B4d	Goats	kg/animal	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3
3B4e	Horses	kg/animal	7.9	8.0	8.1	8.3	8.4	8.6	8.6	8.6	8.6	8.6
3B4f	Mules and asses	kg/animal	2.8	2.9	3.0	3.0	3.1	3.2	3.2	3.2	3.2	3.2
3B4gi	Layers	kg/animal	0.22	0.21	0.21	0.20	0.19	0.18	0.18	0.18	0.18	0.18
3B4gii	Broilers	kg/animal	0.081	0.077	0.074	0.070	0.066	0.063	0.063	0.063	0.063	0.063
3B4giii	Turkey	kg/animal	0.28	0.29	0.30	0.30	0.31	0.32	0.32	0.32	0.32	0.32
3B4giv	Growers	kg/animal	0.083	0.081	0.079	0.077	0.075	0.073	0.073	0.073	0.073	0.073
3B4giv	Other poultry	kg/animal	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16
3B4hi	Rabbits	kg/animal	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
3B4hii	Bisons	kg/animal	6.1	6.3	6.1	6.1	6.0	6.0	6.0	6.0	7.8	7.6

Table 5-7: Time series of NO_x emission factors for livestock categories.

NOx emisson factors		Unit	1990	1995	2000	2005
3B1a	Dairy cattle	g/animal	879	848	765	740
3B1b	Non-dairy cattle	g/animal	681	698	566	545
3B1c	Young cattle	g/animal	325	324	290	279
3B2	Sheep	g/animal	171	174	179	168
3B3	Swine	g/animal	94	92	74	65
3B4a	Buffalos	g/animal	IE	IE	IE	IE
3B4b	Camels and llamas	g/animal	NO	NO	312	264
3B4c	Deer	g/animal	455	499	493	450
3B4d	Goats	g/animal	317	314	323	333
3B4e	Horses	g/animal	667	665	579	558
3B4f	Mules and asses	g/animal	245	245	214	200
3B4gi	Layers	g/animal	2.3	2.3	2.2	2.3
3B4gii	Broilers	g/animal	1.3	1.3	1.3	1.4
3B4giii	Turkey	g/animal	4.6	4.6	4.5	4.5
3B4giv	Growers	g/animal	1.1	1.1	1.1	1.0
3B4giv	Other poultry	g/animal	1.8	1.8	1.8	1.8
3B4hi	Rabbits	g/animal	16	16	16	16
3B4hii	Bisons	g/animal	NO	280	275	244

NOx emisson factors		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3B1a	Dairy cattle	g/animal	759	755	750	745	740	735	733	732	731	729
3B1b	Non-dairy cattle	g/animal	526	522	516	511	506	501	500	499	498	496
3B1c	Young cattle	g/animal	295	294	291	289	288	286	286	285	285	284
3B2	Sheep	g/animal	184	182	181	181	177	174	174	176	175	175
3B3	Swine	g/animal	64	63	62	62	62	62	62	62	61	61
3B4a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	g/animal	270	271	272	272	268	265	262	262	261	262
3B4c	Deer	g/animal	481	480	479	484	481	478	481	484	488	491
3B4d	Goats	g/animal	332	337	338	338	339	331	331	331	331	331
3B4e	Horses	g/animal	534	539	545	552	558	567	568	568	569	569
3B4f	Mules and asses	g/animal	208	208	207	206	205	204	204	204	204	204
3B4gi	Layers	g/animal	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4
3B4gii	Broilers	g/animal	1.5	1.4	1.4	1.3	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	1.0	1.0	0.99	0.98	0.98	0.98	0.98	0.98
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	239	245	235	234	230	229	229	226	296	289

Table 5-8: Time series of NMVOC emission factors for livestock categories.

NMVOC emission factors		Unit	1990	1995	2000	2005
3B1a	Dairy cattle	kg/animal	13	14	15	15
3B1b	Non-dairy cattle	kg/animal	8.6	8.6	8.6	8.6
3B1c	Young cattle	kg/animal	6.1	6.4	6.6	6.8
3B2	Sheep	kg/animal	0.17	0.17	0.17	0.17
3B3	Swine	kg/animal	0.57	0.57	0.55	0.55
3B4a	Buffalos	kg/animal	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	NO	NO	0.27	0.27
3B4c	Deer	kg/animal	0.045	0.045	0.045	0.045
3B4d	Goats	kg/animal	0.54	0.54	0.54	0.54
3B4e	Horses	kg/animal	4.3	4.3	4.3	4.3
3B4f	Mules and asses	kg/animal	1.5	1.5	1.5	1.5
3B4gi	Layers	kg/animal	0.17	0.17	0.17	0.17
3B4gii	Broilers	kg/animal	0.11	0.11	0.11	0.11
3B4giii	Turkey	kg/animal	0.49	0.49	0.49	0.49
3B4giv	Growers	kg/animal	0.17	0.17	0.17	0.17
3B4giv	Other poultry	kg/animal	0.49	0.49	0.49	0.49
3B4hi	Rabbits	kg/animal	0.059	0.059	0.059	0.059
3B4hii	Bisons	kg/animal	NO	3.6	3.6	3.6

NMVOC emission factors		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3B1a	Dairy cattle	kg/animal	15	15	15	15	15	15	15	15	15	15
3B1b	Non-dairy cattle	kg/animal	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
3B1c	Young cattle	kg/animal	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.7	6.8
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	0.55	0.55
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
3B4c	Deer	kg/animal	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
3B4d	Goats	kg/animal	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
3B4e	Horses	kg/animal	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
3B4f	Mules and asses	kg/animal	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3B4gi	Layers	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
3B4gii	Broilers	kg/animal	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
3B4giii	Turkey	kg/animal	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
3B4giv	Growers	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
3B4giv	Other poultry	kg/animal	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
3B4hi	Rabbits	kg/animal	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
3B4hii	Bisons	kg/animal	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6

Table 5-9: Emission factors of PM2.5, PM10 and TSP for livestock categories in year 2019 (based on measurements in Switzerland, literature data and the EMEP/EEA Guidebook 2019).

Emmission factors		Unit	PM2.5	PM10	TSP
3B1a	Dairy cattle	g/animal	44	178	612
3B1b	Non-dairy cattle	g/animal	23	93	321
3B1c	Young cattle	g/animal	23	92	317
3B2	Sheep	g/animal	2	50	140
3B3	Swine	g/animal	4	101	436
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 2020, SFSO 2020a) for the time period 1990 to 2019 is shown in Table 5-10. The figures represent harmonized livestock numbers coming from various sources since 1990. The methodology of the harmonization is documented in HAFL (2011). Because the official livestock census statistics are based on a key date (1st May until 2014, 1st January since 2015), the Federal Office of Statistics provided a dataset with average livestock numbers over the whole year, as suggested by EMEP/EEA (2019). Thus, for fattening pigs over 25kg 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 for the time series 1990-2017 (SFSO 2020b) and based on data of the Swiss animal tracing database from 2018 onwards (ATD 2020). Thus, the acitivity data of all equids are no longer based on one reporting per year but on a mean over the 365 days of the year.

Table 5-10: Time series of animal numbers in different livestock categories from (in thousand animals).

Activity data 3B		Unit	1990	1995	2000	2005
3B1a	Dairy cattle	1'000 animals	783	740	669	621
3B1b	Non-dairy cattle	1'000 animals	12	23	45	78
3B1c	Young cattle	1'000 animals	1'060	986	874	856
3B2	Sheep	1'000 animals	395	387	421	446
3B3	Swine	1'000 animals	1'965	1'739	1'670	1'744
3B4a	Buffalos	1'000 animals	IE	IE	IE	IE
3B4b	Camels and llamas	1'000 animals	NO	NO	1.0	3.1
3B4c	Deer	1'000 animals	0.17	1.4	2.8	3.8
3B4d	Goats	1'000 animals	68	53	62	74
3B4e	Horses	1'000 animals	28	41	50	55
3B4f	Mules and asses	1'000 animals	5.9	7.6	12	16
3B4gi	Layers	1'000 animals	3'083	2'118	2'150	2'189
3B4gii	Broilers	1'000 animals	3'392	3'637	3'985	5'711
3B4giii	Turkey	1'000 animals	95	170	173	132
3B4giv	Growers	1'000 animals	719	714	832	868
3B4giv	Other poultry	1'000 animals	22	17	21	11
3B4hi	Rabbits	1'000 animals	61	41	28	25
3B4hii	Bisons	1'000 animals	NO	0.10	0.26	0.37

Activity data 3B		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3B1a	Dairy cattle	1'000 animals	589	589	591	587	587	583	576	569	564	555
3B1b	Non-dairy cattle	1'000 animals	111	111	114	117	118	118	121	123	125	128
3B1c	Young cattle	1'000 animals	891	877	859	854	857	853	859	852	854	842
3B2	Sheep	1'000 animals	434	424	417	409	403	395	397	398	403	400
3B3	Swine	1'000 animals	1'750	1'726	1'678	1'615	1'631	1'605	1'553	1'544	1'498	1'448
3B4a	Buffalos	1'000 animals	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	1'000 animals	6.1	6.0	5.8	5.9	6.1	6.4	6.5	6.6	6.7	6.6
3B4c	Deer	1'000 animals	5.5	5.7	5.7	5.7	5.7	6.0	6.0	6.0	6.4	6.6
3B4d	Goats	1'000 animals	83	83	85	85	85	84	85	88	91	92
3B4e	Horses	1'000 animals	62	57	58	57	57	55	56	56	47	48
3B4f	Mules and asses	1'000 animals	20	19	20	20	20	20	20	21	32	32
3B4gi	Layers	1'000 animals	2'438	2'437	2'521	2'589	2'665	2'822	3'056	3'174	3'371	3'486
3B4gii	Broilers	1'000 animals	7'184	7'410	7'737	8'126	8'506	8'614	9'064	9'048	9'390	9'503
3B4giii	Turkey	1'000 animals	58	58	51	55	57	49	71	77	84	75
3B4giv	Growers	1'000 animals	926	970	1'076	1'055	1'196	1'033	959	1'084	1'078	1'242
3B4giv	Other poultry	1'000 animals	23	29	25	20	22	23	30	16	20	21
3B4hi	Rabbits	1'000 animals	35	34	28	28	27	25	25	22	22	21
3B4hii	Bisons	1'000 animals	0.51	0.51	0.52	0.50	0.53	0.56	0.56	0.57	0.54	0.46

5.2.3 Category-specific recalculations 3B Manure management

- 3B: NH_3 and NO_x emissions from manure management were recalculated for the years 1990-2018. The share of nitrogen that is managed in anaerobic digesters was revised due to an error correction in the calculation model. The impact on overall emissions is negligible.
- 3B1a: The Tier 1 NMVOC emission factors of the EMEP/EEA guidebook – 2019 are now scaled with the Swiss dairy cattle weight (660 kg) yielding revised emission factors for the entire time period.
- 3B4e, 3B4f: Animal population data (AD) of horses (3B4e), mules and asses (3B4f) in 2018 were revised. This was necessary because until 2017 the statistics of the Federal

Office for Statistics on animal numbers for equids (horses, mules, asses etc) was based the annual farm census and since 2018 on the Swiss Animal Tracing Database (ATD). This database provides animal keepers with unique ear tags to identify the cloven-hoofed animals (cattle, pig, sheep, goat, etc.) and the holder has to immediately report any displacement of the animal to another holder. Thus the statistics are no longer based on one reporting per year but on a mean over the 365 days of the year.

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 fertiliser (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 5-11: 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 to soils (dairy cattle, non-dairy cattle, sheep, swine, buffalos, goats, horses, mules/asses, laying hens, broilers, turkeys, 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)
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 5-12: Key Categories approach 1, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 3D Agricultural Soils (NFR codes as of EMEP/EEA 2019).

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, L2, T1, T2
3Da2a	Animal manure applied to soils	NOx	L2, T1, T2
3Da2a	Animal manure applied to soils	NH3	L1, L2, T1, T2
3Da2b	Sewage sludge applied to soils	NH3	T1
3Da2c	Other organic fertilisers applied to soils	NH3	T1, T2
3Da3	Urine and dung deposited by grazing animals	NOx	T2
3Da3	Urine and dung deposited by grazing animals	NH3	T1, T2
3De	Cultivated crops	PM10	L1, L2, T1, T2

5.3.2 Methodological issues of 3D Crop production and agricultural soils

Methodology (3D)

The emissions are calculated by Tier 3 (3Da2a, 3Da3 (NH_3)), Tier 2 (3Da1, 3De) and Tier 1 (3Da2b, 3Da2c, 3Da3 (NO_x)) methods based on the decision tree in Fig. 3.1 in chapter 3D Crop production and agricultural soils of the EMEP/EEA Guidebook 2019 (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 2019 (EMEP/EEA 2019) were used. In 3Da1 only the agricultural use of inorganic fertilisers and urea 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 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 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. Note that the emissions of NMVOC, PM2.5, PM10 and TSP from crop production and agricultural soils operations have been reallocated from source category 3Dc Farm-level agricultural operations to 3De Cultivated crops.

Emission factors (3Da)

For fertiliser default Tier 2 NH_3 emission factors from the EMEP/EEA Guidebook 2019 (EMEP/EEA 2019, 3D Crop production and agricultural soils, Table 3.2) were used for the whole time series. The climate zone for Switzerand is "cool". Based on official fertiliser trade statistics (Agricura 2019) 54% of fertilisers are used on soils with pH $\geq$7.0 and 46% on soils with pH >7.0. The soil pH was assessed based on the Swiss agricultural soil use capability map (Bodeneignungskarte; first published by Frei et al. 1980), which indicated that 54% of the soils on which inorganic fertiliser is applied are of normal pH (<7) and 46% of high pH

(>7). A detailed description of the methodology is given by Kupper et al. (2018; chapters 7.8 – 7.10).

NH_3-emission factors for 3Da2c are based on Kupper et al. (2018; chp. 7.11.2). The EFs used were 60% of TAN for liquid residues and 80% of TAN for solid residues.

Table 5-13 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 5-13: NH_3 and NO_x emission factors 2019 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	38
3Da2b	Sewage sludge	kg / tN	18	317
3Da2c	Organic compost	kg / tN	18	149

Emission factors for the application of animal manure are displayed in Table 5-14 and Table 5-15. They are based on the livestock category specific N flow calculations with AGRAMMON (see chapter 5.2.2).

Table 5-14: 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
3Da2a1a	Dairy cattle	kg/animal	25.6	25.5	22.4	22.3
3Da2a1b	Non-dairy cattle	kg/animal	14.7	14.1	11.0	11.6
3Da2a1c	Young cattle	kg/animal	6.76	6.76	5.41	5.19
3Da2a2	Sheep	kg/animal	0.17	0.20	0.20	0.24
3Da2a3	Swine	kg/animal	2.91	2.74	1.88	1.56
3Da2a4a	Buffalos	kg/animal	IE	IE	IE	IE
3Da2a4b	Camels and llamas	kg/animal	NO	NO	0.34	0.38
3Da2a4c	Deer	kg/animal	0.45	0.58	0.54	0.64
3Da2a4d	Goats	kg/animal	0.32	0.38	0.34	0.66
3Da2a4ei	Horses	kg/animal	1.41	1.67	1.20	1.24
3Da2a4fi	Mules and asses	kg/animal	0.52	0.61	0.42	0.44
3Da2a4gi	Layers	kg/animal	0.07	0.08	0.09	0.09
3Da2a4gii	Broilers	kg/animal	0.05	0.06	0.05	0.05
3Da2a4giii	Turkey	kg/animal	0.17	0.20	0.17	0.20
3Da2a4giv	Growers	kg/animal	0.03	0.04	0.03	0.03
3Da2a4giv	Other poultry	kg/animal	0.07	0.08	0.06	0.05
3Da2a4hi	Rabbits	kg/animal	0.09	0.09	0.08	0.08
3Da2a4hii	Bisons	kg/animal	NO	7.07	6.20	5.53

NH3 emission factors		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3Da2a1a	Dairy cattle	kg/animal	21.3	21.1	20.9	20.7	20.5	20.3	20.3	20.3	20.3	20.3
3Da2a1b	Non-dairy cattle	kg/animal	11.7	11.7	11.6	11.6	11.5	11.4	11.4	11.4	11.4	11.4
3Da2a1c	Young cattle	kg/animal	5.17	5.15	5.13	5.10	5.06	5.02	4.99	4.98	4.96	4.95
3Da2a2	Sheep	kg/animal	0.28	0.27	0.26	0.25	0.24	0.23	0.23	0.23	0.23	0.23
3Da2a3	Swine	kg/animal	1.46	1.44	1.42	1.42	1.41	1.41	1.41	1.41	1.40	1.40
3Da2a4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	kg/animal	0.40	0.40	0.39	0.38	0.37	0.35	0.35	0.35	0.35	0.35
3Da2a4c	Deer	kg/animal	0.72	0.70	0.68	0.68	0.66	0.64	0.64	0.64	0.65	0.65
3Da2a4d	Goats	kg/animal	0.44	0.46	0.48	0.50	0.52	0.53	0.53	0.53	0.53	0.53
3Da2a4ei	Horses	kg/animal	1.45	1.48	1.52	1.56	1.60	1.65	1.66	1.66	1.66	1.66
3Da2a4fi	Mules and asses	kg/animal	0.84	0.78	0.71	0.64	0.58	0.51	0.51	0.51	0.51	0.51
3Da2a4gi	Layers	kg/animal	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
3Da2a4gii	Broilers	kg/animal	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05
3Da2a4giii	Turkey	kg/animal	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
3Da2a4giv	Growers	kg/animal	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
3Da2a4giv	Other poultry	kg/animal	0.09	0.08	0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05
3Da2a4hi	Rabbits	kg/animal	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
3Da2a4hii	Bisons	kg/animal	5.20	5.28	5.01	4.94	4.80	4.72	4.72	4.65	6.10	5.96

Table 5-15: Time series of NO_x emission factors for the application of anial manure to soils (3Da2a).

NOx emission factors		Unit	1990	1995	2000	2005
3Da2a1a	Dairy cattle	g/animal	1430	1414	1315	1309
3Da2a1b	Non-dairy cattle	g/animal	903	888	751	765
3Da2a1c	Young cattle	g/animal	411	410	356	339
3Da2a2	Sheep	g/animal	67	69	71	68
3Da2a3	Swine	g/animal	202	194	142	117
3Da2a4a	Buffalos	g/animal	IE	IE	IE	IE
3Da2a4b	Camels and llamas	g/animal	NO	NO	124	106
3Da2a4c	Deer	g/animal	179	197	196	181
3Da2a4d	Goats	g/animal	126	126	129	138
3Da2a4ei	Horses	g/animal	561	563	484	465
3Da2a4fi	Mules and asses	g/animal	206	207	179	167
3Da2a4gi	Layers	g/animal	7.9	8.0	8.6	9.4
3Da2a4gii	Broilers	g/animal	5.5	5.5	5.7	6.2
3Da2a4giii	Turkey	g/animal	19	19	19	19
3Da2a4giv	Growers	g/animal	3.5	3.7	3.6	3.8
3Da2a4giv	Other poultry	g/animal	7.7	7.7	7.4	7.2
3Da2a4hi	Rabbits	g/animal	13	13	13	13
3Da2a4hii	Bisons	g/animal	NO	414	388	342

NOx emission factors		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3Da2a1a	Dairy cattle	g/animal	1333	1339	1345	1350	1356	1361	1362	1362	1362	1362
3Da2a1b	Non-dairy cattle	g/animal	777	780	782	784	786	788	788	788	788	788
3Da2a1c	Young cattle	g/animal	351	353	354	355	355	355	354	352	351	351
3Da2a2	Sheep	g/animal	74	73	73	73	71	70	70	71	70	70
3Da2a3	Swine	g/animal	116	116	115	116	115	116	117	116	116	116
3Da2a4a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	g/animal	109	109	109	109	108	107	106	106	105	105
3Da2a4c	Deer	g/animal	194	193	193	195	194	192	194	195	196	198
3Da2a4d	Goats	g/animal	135	137	137	138	138	135	135	135	135	135
3Da2a4ei	Horses	g/animal	449	453	457	462	467	474	475	475	476	476
3Da2a4fi	Mules and asses	g/animal	179	177	175	173	171	169	169	169	169	169
3Da2a4gi	Layers	g/animal	10	10	10	10	10	10	10	10	10	10
3Da2a4gii	Broilers	g/animal	6.7	6.4	6.2	5.9	5.6	5.4	5.4	5.4	5.4	5.4
3Da2a4giii	Turkey	g/animal	20	20	20	19	19	19	19	19	19	19
3Da2a4giv	Growers	g/animal	4.1	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
3Da2a4giv	Other poultry	g/animal	7.6	7.5	7.4	7.4	7.3	7.2	7.2	7.2	7.2	7.2
3Da2a4hi	Rabbits	g/animal	13	13	13	13	13	13	13	13	13	13
3Da2a4hii	Bisons	g/animal	340	349	335	334	328	327	327	322	423	413

The following tables 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).

Table 5-16: 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
3Da31a	Dairy cattle	g/animal	470	547	915	1079
3Da31b	Non-dairy cattle	g/animal	1'239	1'237	1'669	1'556
3Da31c	Young cattle	g/animal	288	290	444	461
3Da32	Sheep	g/animal	136	139	158	182
3Da33	Swine	g/animal	NO	NO	1.7	13
3Da34a	Buffalos	g/animal	IE	IE	IE	IE
3Da34b	Camels and llamas	g/animal	NO	NO	280	292
3Da34c	Deer	g/animal	373	408	443	499
3Da34d	Goats	g/animal	92	91	86	62
3Da34e	Horses	g/animal	181	181	508	590
3Da34f	Mules and asses	g/animal	67	67	179	234
3Da34gi	Layers	g/animal	NO	2.1	14	25
3Da34gii	Broilers	g/animal	NO	0.80	1.1	2.1
3Da34giii	Turkey	g/animal	NO	2.8	16	22
3Da34giv	Growers	g/animal	NO	1.0	0.53	1.52
3Da34giv	Other poultry	g/animal	NO	NO	6.3	8.8
3Da34hi	Rabbits	g/animal	NO	NO	NO	NO
3Da34hii	Bisons	g/animal	NO	529	791	800

NH3 emission factors		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3Da31a	Dairy cattle	g/animal	1'039	1'029	1'020	1'010	1'000	991	991	991	991	991
3Da31b	Non-dairy cattle	g/animal	1'529	1'519	1'510	1'501	1'492	1'483	1'483	1'483	1'483	1'483
3Da31c	Young cattle	g/animal	411	412	415	413	412	411	409	411	407	406
3Da32	Sheep	g/animal	173	176	181	185	187	189	189	191	190	191
3Da33	Swine	g/animal	2.1	1.8	1.4	1.1	0.7	0.36	0.36	0.36	0.35	0.35
3Da34a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	g/animal	263	269	275	280	282	283	281	280	279	280
3Da34c	Deer	g/animal	468	476	484	499	505	512	515	519	522	525
3Da34d	Goats	g/animal	68	72	74	77	79	80	80	80	80	80
3Da34e	Horses	g/animal	680	662	641	618	595	566	564	563	561	561
3Da34f	Mules and asses	g/animal	201	204	208	211	215	218	218	218	218	218
3Da34gi	Layers	g/animal	25	25	26	27	27	28	28	28	28	28
3Da34gii	Broilers	g/animal	0.6	0.57	0.54	0.51	0.48	0.45	0.45	0.45	0.45	0.45
3Da34giii	Turkey	g/animal	14	15	17	19	20	22	22	22	22	22
3Da34giv	Growers	g/animal	1.9	1.6	1.4	1.1	0.8	0.56	0.56	0.56	0.56	0.56
3Da34giv	Other poultry	g/animal	3.4	4.2	4.9	5.7	6.4	7.2	7.2	7.2	7.2	7.2
3Da34hi	Rabbits	g/animal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da34hii	Bisons	g/animal	709	732	707	709	701	703	702	693	909	887

Table 5-17: Time series of NO_x emission factors for N excretion during grazing (3Da3) for different livestock categories.

NOx emission factors		Unit	1990	1995	2000	2005
3Da31a	Dairy Cattle	g/animal	150	175	294	348
3Da31b	Non dairy Cattle	g/animal	404	403	544	507
3Da31c	Young Cattle	g/animal	94	95	145	150
3Da32	Sheep	g/animal	41	41	47	54
3Da33	Swine	g/animal	NO	NO	0.18	1.4
3Da34a	Buffalos	g/animal	IE	IE	IE	IE
3Da34b	Camels and llamas	g/animal	NO	NO	83	87
3Da34c	Deer	g/animal	111	121	132	148
3Da34d	Goats	g/animal	27	27	26	18
3Da34e	Horses	g/animal	54	54	151	176
3Da34f	Mules and Asses	g/animal	20	20	53	70
3Da34gi	Layers	g/animal	NO	0.076	0.49	0.90
3Da34gii	Broilers	g/animal	NO	0.028	0.040	0.074
3Da34giii	Turkey	g/animal	NO	0.099	0.58	0.78
3Da34giv	Growers	g/animal	NO	0.036	0.019	0.054
3Da34giv	Other poultry	g/animal	NO	NO	0.22	0.31
3Da34hi	Rabbits	g/animal	NO	NO	NO	NO
3Da34hii	Bisons	g/animal	NO	172	258	261

NOx emission factors		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3Da31a	Dairy Cattle	g/animal	337	334	331	328	325	322	322	322	322	322
3Da31b	Non dairy Cattle	g/animal	498	495	492	489	486	483	483	483	483	483
3Da31c	Young Cattle	g/animal	134	134	135	135	134	134	133	134	133	132
3Da32	Sheep	g/animal	52	52	54	55	56	56	56	57	57	57
3Da33	Swine	g/animal	0.23	0.19	0.15	0.11	0.08	0.038	0.038	0.038	0.038	0.038
3Da34a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	g/animal	78	80	82	83	84	84	84	83	83	83
3Da34c	Deer	g/animal	139	142	144	149	150	152	153	154	155	156
3Da34d	Goats	g/animal	20	21	22	23	24	24	24	24	24	24
3Da34e	Horses	g/animal	202	197	191	184	177	168	168	167	167	167
3Da34f	Mules and Asses	g/animal	60	61	62	63	64	65	65	65	65	65
3Da34gi	Layers	g/animal	0.88	0.90	0.93	0.95	0.97	1.00	1.00	1.00	1.00	1.00
3Da34gii	Broilers	g/animal	0.021	0.020	0.019	0.018	0.017	0.016	0.016	0.016	0.016	0.016
3Da34giii	Turkey	g/animal	0.48	0.54	0.60	0.66	0.72	0.78	0.78	0.78	0.78	0.78
3Da34giv	Growers	g/animal	0.067	0.058	0.048	0.039	0.029	0.020	0.020	0.020	0.020	0.020
3Da34giv	Other poultry	g/animal	0.12	0.15	0.17	0.20	0.23	0.25	0.25	0.25	0.25	0.25
3Da34hi	Rabbits	g/animal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da34hii	Bisons	g/animal	231	239	230	231	229	229	229	226	296	289

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 2019 taking into account country-specific values for the mean dry matter yield (Agroscope 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 (Agroscope 2017). The resulting NMVOC emission factors are constant for the entire time series and are given in Table 5-18.

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 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 (Agroscope 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 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 in 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 5-18.

Table 5-18: NMVOC and PM2.5 emission factors of 2019 for 3De Crop production and agricultural soils.

Emission factors		Unit	NMVOC	PM2.5	PM10	TSP
3De	Cropland	g/ha	376	40	753	7'530
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 2020, Agricura 2019, 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 5-19.

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 5-10. 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 2020a), 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 5-19: 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
3Da1	Urea containing fertiliser	tN	16'284	10'707	7'631	6'605
3Da1	Other synthetic N-fertiliser	tN	50'391	47'652	43'042	43'478
3Da2b	Sewage sludge	tN	4'815	4'942	3'356	1'054
3Da2c	Organic compost	tN	817	1'286	1'829	2'169
3De	Cropland	ha	313'247	308'284	290'954	283'802
3De	Grassland	ha	724'556	737'229	743'849	742'474
3De	Summering pastures	ha	538'676	499'774	496'667	487'956

Activity data of agricultural soils		Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3Da1	Urea containing fertiliser	tN	7'101	6'517	5'378	5'793	7'942	7'223	8'872	9'250	8'326	7'753
3Da1	Other synthetic N-fertiliser	tN	45'986	40'213	39'771	37'924	41'393	36'521	37'531	40'113	37'446	32'403
3Da2b	Sewage sludge	tN	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da2c	Organic compost	tN	3'281	3'676	4'345	4'670	4'751	4'955	5'497	5'609	5'710	6'045
3De	Cropland	ha	270'371	267'683	267'531	269'820	269'337	270'092	269'536	270'557	270'146	266'207
3De	Grassland	ha	741'837	744'727	743'594	739'588	740'097	737'463	736'455	732'125	729'073	729'073
3De	Summering pastures	ha	486'382	483'414	481'379	479'745	475'690	474'575	472'465	472'618	470'837	469'280

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 (SFSO 2020i). In addition, for NMVOC emissions also the emissions from summering pastures (SFSO 2020b) are included where no agricultural crop operations take place. The activity data of these agricultural areas are also given in Table 5-19.

5.3.3 Category-specific recalculations for 3D Crop production and agricultural soils

- 3Da2a, 3Da3: Animal population data for horses (3Da2a4e, 3Da34e), mules and asses (3Da2a4f, 3Da34f) were revised due to the new assessment methodology in the animal tracing database.
- 3Da1: NH_3 and NO_x emissions from inorganic nitrogen fertilisers were recalculated for the years 2008, 2009 and 2011-2018. Nitrogen inputs from urea-ammonia-nitrate fertilisers (AD) were revised. The impact on overall emissions is negligible.
- 3Da2c: NH_3 and NO_x emissions due to "N input from application of other organic fertilizers" were recalculated for the years 1996-2018. The amount of nitrogen input from co-substrates from agricultural biogas plants (AD) was recalculated due to a revision of the nitrogen content of these co-substrates. The impact on overall emissions is negligible.
- 3Da2c: NH_3 and NO_x emissions from other organic fertilisers applied to soils were recalculated for 2014-2018. Nitrogen Inputs from compost from industrial plants (AD) were revised (see recalculations in the waste sector). The impact on overall emissions is negligible.
- 3Da2c: NH_3 and NO_x emissions from other organic fertilisers applied to soils were recalculated for 1996-2018. Nitrogen Inputs from liquid and solid digestates from biogas plants were revised due to an error correction when interpolating data from gas losses. The impact on overall emissions is negligible.
- 3De: Acitivity data of summering pastures and cropland have been revised for 2016-2018 and 2018, respectively.

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 by most relevant pollutants are presented. Likewise, surfacing trends and changes are analysed and discussed for individual source categories in the period between 1990 and 2019. Among the main contributors to air pollution in the waste sector are NMVOC and to a lesser extent PM2.5, NH_3, NO_x.

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 IPCC Guidelines (IPCC 2006) and EMEP/EEA Guidebook 2019 (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 2019 can be observed.

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 stem from 5B Biological treatment of solid waste. The reason for this development is an increase of industrial and commercial composting activities and in particular the digesting of organic waste. Digestion has become economically more attractive due to cost covering feed-in tariffs for electricity and due to additional revenues as CO_2 compensation projects. The increase of treated quantities is also linked to population growth.

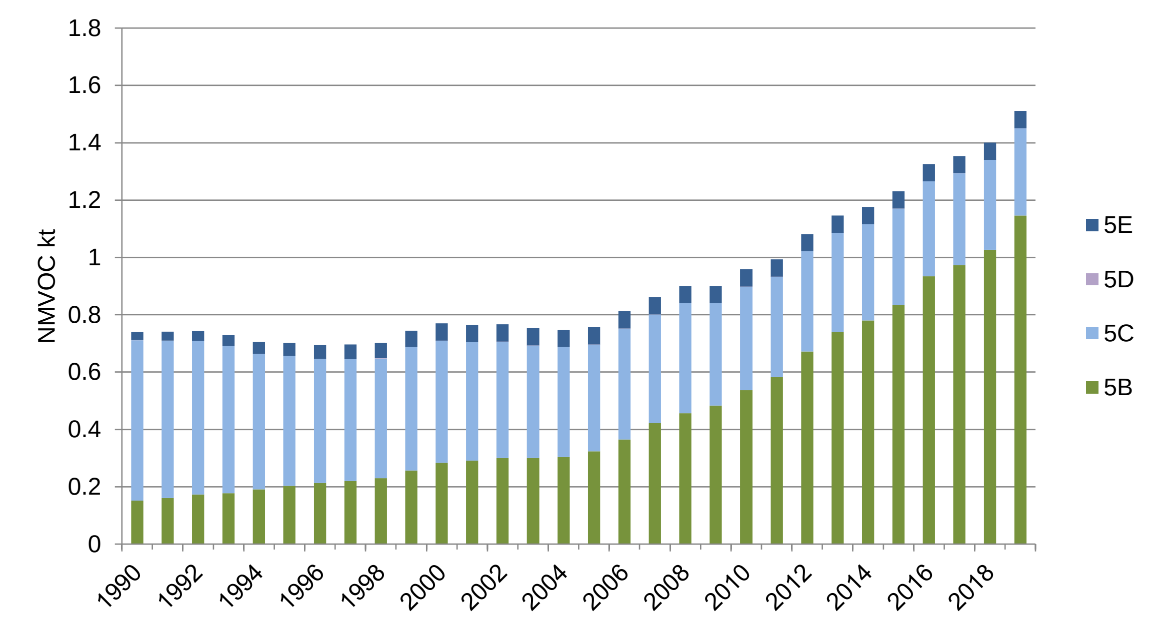


Figure 6-1: Switzerland's NMVOC emissions from the waste sector by source categories 5B-5E. The corresponding data table can be found in Annex A7.5.

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 contributes most to total PM2.5 emissions from the waste sector over the whole reporting period.

Between 1990 and 2019 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 because of the reduction of the emissions from sewage sludge incineration, refurbishment of crematoriums, the cessation of burning cable insulation in 1995 as well as clinical waste incineration in 2002 and a decreasing trend in the open burning of natural residues in agriculture and households.

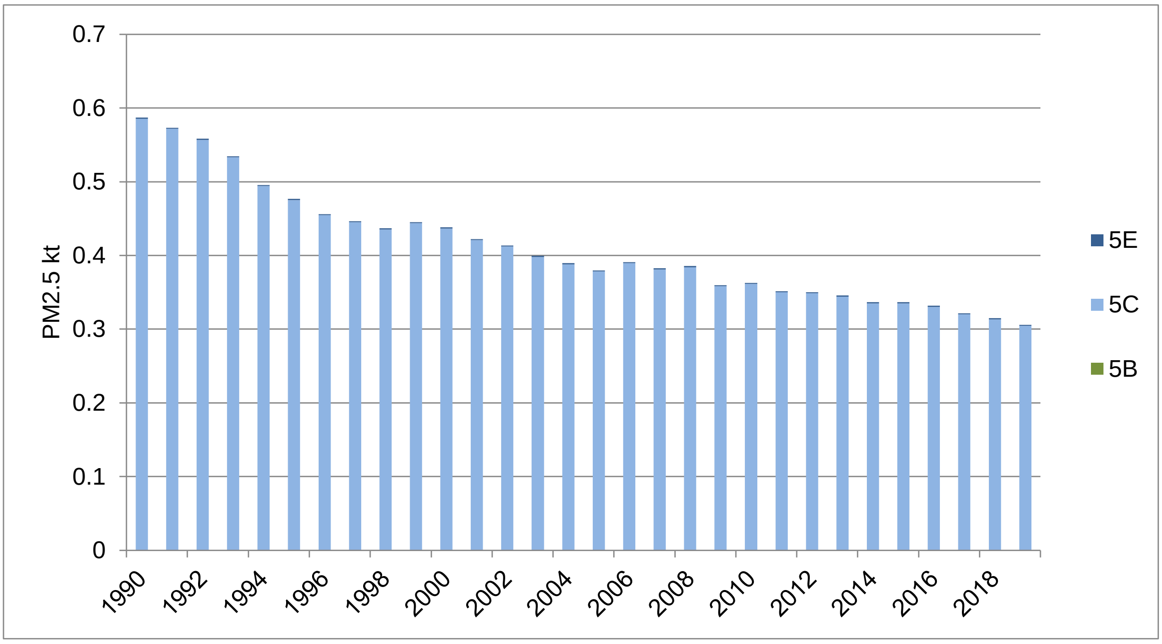


Figure 6-2: Switzerland's PM2.5 emissions from the waste sector by source categories 5B, 5C and 5E. Note that PM2.5 emissions from 5D are not occurring. The corresponding data table can be found in Annex A7.5.

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 comprises all emissions from handling of solid waste 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 2020a). The landfill gas is generally used in combined heat and power plants to produce electricity and heat (reported under 1A Fuel combustion). Some landfill gas is used to generate heat only. A very small portion of the landfill gas is flared (reported under 5A).

The methane emissions are calculated using a First Order Decay (FOD) model that is compliant with IPCC 2006 (see below). By reason of legal requirements and regulations it is assumed that open burning did not take place after 1990 anymore (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

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 (although the use of Tier 2 is not officially recommended for this source). 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 2021):

1. CH_4 emissions are modelled with the FOD model according to 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 2021/1A1a & 5A), see Table 6-2. 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 6-2: Emission factors 2019 for 5A Biological treatment of waste - Solid waste disposal on land.

5A1 Solid waste disposal on land	Unit	NOx	NH_3	PM2.5 exh.	PM10 exh.	TSP exh.	CO	PCB
Flaring	kg/t CH4 produced	1	NA	0.4	0.4	0.4	17	NA
Direct emission	kg/t CH4	NA	20	NE	NE	NE	NA	NA
Direct emission	g/t PCB	NA	NA	NA	NA	NA	NA	12

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 2021/1A1a & 5A. Table 6-3 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 6-3: Activity data for 5A Biological treatment of waste - Solid waste disposal on land (source EMIS 2021/1A1a & 5A).

5A1 Solid waste disposal on land	Unit	1990	1995	2000	2005
Total waste quantity	kt	860	628	350	16
Municipal solid waste (MSW)	kt	650	540	292	14
Construction waste (CW)	kt	150	60	54	1.4
Sewage sludge (SS)	kt (dry)	60	28	4.2	0.98
Open burned waste	kt	NO	NO	NO	NO

5A1 Solid waste disposal on land	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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 6-4). 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 6-4: 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
CH_4 flared	kt	1.8	5.3	5.6	3.4
PCB quantity available	kt	0.40	0.37	0.35	0.33

5A1 Solid waste disposal on land	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CH_4 flared	kt	2.4	2.1	1.8	1.6	1.4	1.4	1.4	1.4	1.4	1.4
PCB quantity available	kt	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	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 2021.

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 that use biogas from digestion are reported under 1A2gviii Other and 1A4a Commercial/Institutional.

Within 5B1 Composting two kinds of composting are distinguished, i.e. industrial composting and backyard composting. Industrial composting covers the emissions from centralized composting activities with a capacity of more than 100 tonnes of organic matter per year as well as the composting of organic material at the border of agricultural fields. Backyard composting in private households or communities is also common practice in Switzerland. Activity data and emission factors for industrial and backyard composting have been thoroughly reassessed in 2017, new data were gained and EMIS 2021/5B1 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 (CHP) or upgraded and used as fuel for cars or fed into the natural gas grid.

Table 6-5: 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

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)

For the emissions from composting a Tier 2 method is used (see decision tree in chapter 5B1 Biological treatment of waste – Composting of the EMEP/EEA Guidebook (EMEP/EEA 2019).

For the emissions from digestion a Tier 2 method is used (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 process steps are taken into account where emissions occur. 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 the CHP units
- P6: Emissions from flaring of biogas

P5 as energy-related emissions are reported in sector 1 Energy source category 1A2gviii Other.

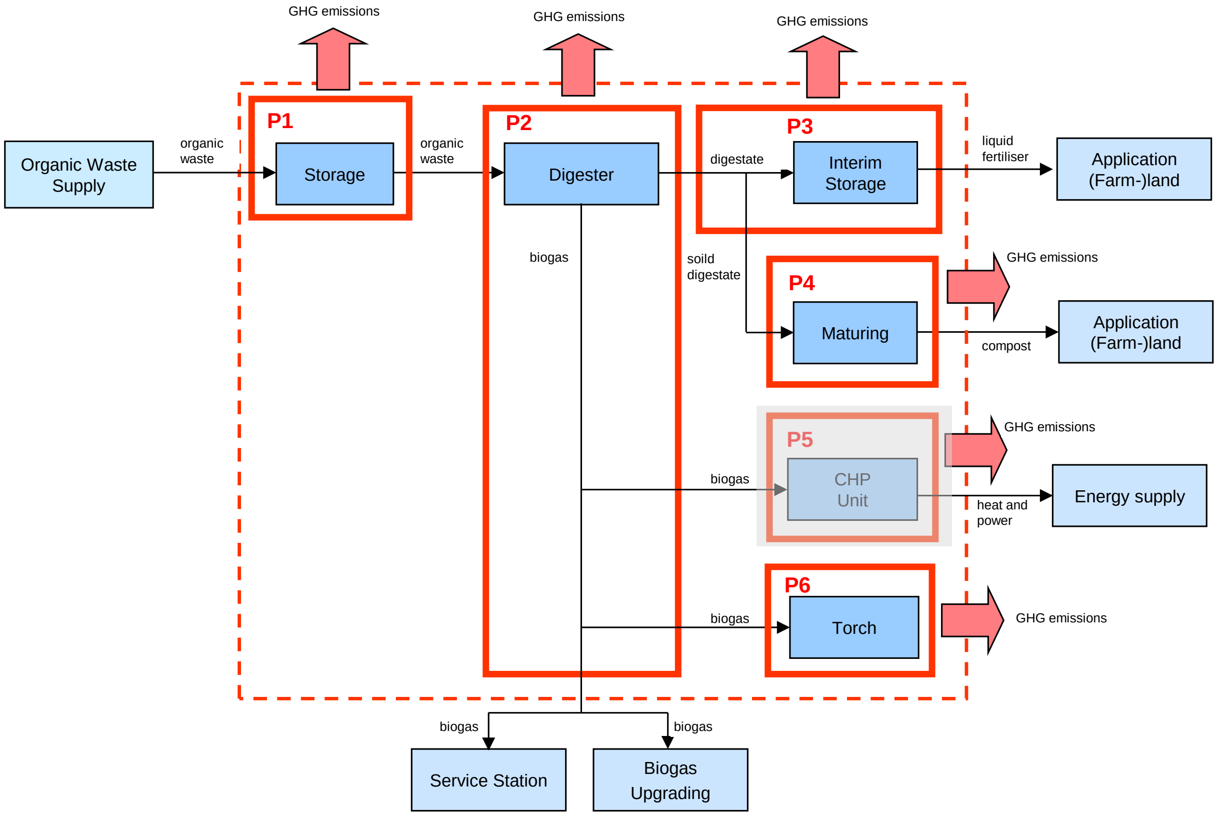


Figure 6-3: Schematic design of an industrial biogas plant.

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 the CHP units
- P6: Emissions from the utilisation of biogas in the gas boiler
- P7: Emissions from flaring of biogas

Emissions from P1 are reported in sector 3 Agriculture, and emissions from P5 and P6 are reported in sector 1 Energy source category 1A4ai Commercial/Institutional.

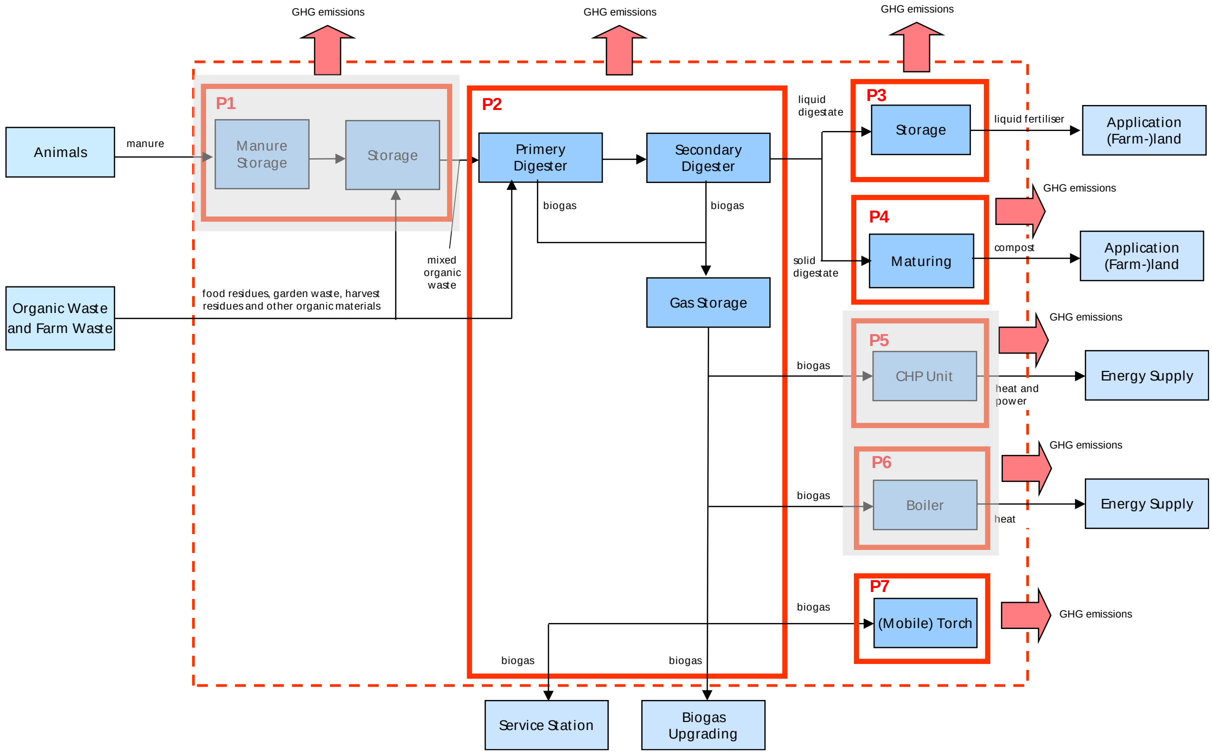


Figure 6-4: Schematic design of an agricultural biogas plant.

Emission factors (5B)

Emission factors for composting are country-specific based on measurements and expert estimates, documented in comment of the database (EMIS 2021/5B1 Kompostierung). For all years emission factors are considered to remain constant.

Emission factors for digestion are country-specific based on measurements according to Edelmann and Schleiss (1999), Cuhls (2010) and Butz (2003). Emission factors for digestion are documented in comments to the database (EMIS 2021/1A2g and 5B2 Vergärung IG and EMIS 2021/1A4a and 5B2 Vergärung LW). The following table presents the emission factors used in 5B.

Table 6-6: Emission factors of 5B Biological treatment of waste - Composting and anaerobic digestion at biogas facilities in 2019.

5B Composting and anaerobic digestion at biogas facilities	Unit	NOx	NMVOC	SO_2	NH_3	PM2.5 exh.	PM10 exh.	TSP exh.	CO
Composting (industrial)	g/t composted waste	NA	300	NA	500	NA	NA	NA	NA
Composting (backyard)	g/t composted waste	NA	300	NA	500	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, CH4)	g/t CH4	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, CH4)	g/t CH4	4066	82	616	NA	37	37	37	2054

Activity data (5B)

Activity data for 5B Biological treatment of waste are extracted from EMIS 2021/5B1 Kompostierung, EMIS 2021/1A1a and 5B2 Vergärung IG and EMIS 2021/1A1a and 5B2 Vergärung LW. Activity data for digestion are based on reliable statistical data from the statistics of renewable energies (SFOE 2020a). Activity data for industrial and backyard composting are based on a study from the year 2017 (Schleiss 2017). Activity data for composting are based on data from the years 1989, 1993, 2000 and 2013, supplied by plant operators. As of 2014, activity data for industrial composting are adopted from the annual statistical reports by the inspectorate system for the Composting and Fermentation Industry in Switzerland CVIS as recommended by Schleiss (2017). As of 2012, activity data for backyard composting are assumed to be constant as recommended by Schleiss (2017).

There is a continous increase of organic material composted until the year 2000 and afterwards a strong increase of organic material digested.

Table 6-7: Activity data of 5B Biological treatment of waste.

5B Composting and anaerobic digestion at biogas facilities	Unit	1990	1995	2000	2005
Composting (industrial)	kt wet	240	360	519	526
Composting (backyard)	kt wet	110	155	180	170
Digestion (ind., digestable waste / storage)	kt wet	NO	27	60	108
Digestion (ind., digested waste liquid / storage)	kt wet	NO	15	33	60
Digestion (ind., digested waste solid / rotting)	kt wet	NO	9.4	20	37
Digestion (ind., flaring, CH_4)	kt	NO	0.037	0.10	0.18
Digestion (agr., digested waste liquid / process water)	kt wet	113	94	125	181
Digestion (agr., digested waste solid / rotting)	kt wet	5.9	4.9	6.5	10
Digestion (agr., flaring, CH_4)	kt	NO	NO	NO	NO

5B Composting and anaerobic digestion at biogas facilities	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Composting (industrial)	kt wet	530	532	534	536	478	430	503	490	475	544
Composting (backyard)	kt wet	120	110	100	100	100	100	100	100	100	100
Digestion (ind., digestable waste / storage)	kt wet	289	372	508	561	590	650	695	712	729	770
Digestion (ind., digested waste liquid / storage)	kt wet	161	207	283	313	329	362	387	397	406	429
Digestion (ind., digested waste solid / rotting)	kt wet	99	127	174	192	201	222	237	243	249	263
Digestion (ind., flaring, CH_4)	kt	0.51	0.63	0.84	0.91	0.90	0.95	1.00	1.0	1.0	1.0
Digestion (agr., digested waste liquid / process water)	kt wet	569	612	711	829	940	1053	1201	1290	1416	1619
Digestion (agr., digested waste solid / rotting)	kt wet	30	32	37	44	50	55	63	68	75	85
Digestion (agr., flaring, CH_4)	kt	0.12	0.13	0.16	0.20	0.23	0.26	0.29	0.31	0.34	0.40

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

The following recalculation was implemented in submission 2021:

- 5B1 Composting industrial: Emissions of NH_3 and NMVOC have decreased for 2014-2018 due to a decrease in the AD "compost" by 2.3-4.2%. The amount of wood removed from total compost amounts before digestion/fermentation has erroneously not been referred to country scale and has thus been too low. This recalculation leads to decreasing emissions of 7-11 t NH_3 and 4-7 t NMVOC per annum for 2014-2018.
- 5B2 Anaerobic digestion at industrial biogas facilities: AD for the storage of organic waste, for fermentation and for the storage of solid and liquid digestate at industrial biogas plants have changed in 2018. An error in the interpolation of the factor accounting for the fractions of gas loss due to leakage from the fermenter, gas piping and

overproduction was corrected. This influences the AD of the four subprocesses named above. Emissions of NH_3 and NMVOC decreased (<1%).

- 5B2 Anaerobic digestion at agricultural biogas facilities: AD for losses / leakage and for the storage of solid and liquid digestate at agricultural biogas plants have changed in the years 2014 and 2016-2018. An error in the interpolation of the factor accounting for the fractions of gas loss due to leakage from the fermenter, gas piping and overproduction was corrected. This influences the AD of the three subprocesses named above. Emissions of NH_3 and NMVOC decreased (<1%).

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. 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 IPCC 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 6-8.

Table 6-8: Specification of source category 5C Waste incineration and open bruning 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 6-9 gives an overview of other waste incineration sources in Switzerland and the source category, where respective emissions are reported in the national inventory.

Table 6-9: 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 6-10: Key Categories, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 5C Waste incineration and open burning of waste (NFR code as of EMEP/EEA 2019).

Code	Source category	Pollutant	Identification criteria
5C1a	Municipal waste incineration	PM2.5	L1, L2
5C1a	Municipal waste incineration	PM10	L1
5C1biv	Sewage sludge incineration	SO2	T2

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 hazardous 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 hazardous 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 2021/5C1 Abfallverbrennung illegal, EMIS 2021/5C1 Kabelbrand, EMIS 2021/5C1 Spitalabfallverbrennung, EMIS 2021/5C1 Krematorien, EMIS 2021/5C1 Klärschlammverbrennung, EMIS 2021/5C2 Abfallverbrennung Land- und Forstwirtschaft).

The emission factor of dioxine for 5C1 Illegal waste incineration in particular is defined based on Wevers (2004) and Lemieux (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). INFRAS (2014) concluded, that Tier 2 default EF for incineration of natural residues in forestry would best account for EF for incineration of natural residues in agriculture and private gardens as well, except for NH_3 (EMEP 2002), Hg (Singer 2003) and IcdP (USEPA 1998a).

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 form 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 (see EMIS 2021/5C1 (5C1biv UNECE) Klärschlamm-verbrennung). From 1990 to 2002 and from 2002 to 2015, emission factors are interpolated linearly. From 2015 onwards the emission factors are assumed to be constant.

The following Table 6-11 depicts the emission factors used in 5C.

Table 6-11: Emission factors for 5C Waste incineration and open burning of waste in 2019. Unit of PCDD/PCDF is in I-TEQ.

5C Incineration and open burning of waste	Unit	NOx	NMVOC	SO2	NH3	PM2.5 exh.	PM10 exh.	TSP exh.	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	615	100	555	265	107	150	150	165
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	6.2	NA	NA	15	15	17	44

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	NE	NE	NE	NE
Illegal waste incineration	mg/t waste	100'000	200	100	0.16	0.34	0.20	0.27	0.10
Insulation material from cables	mg/t cable	80'000	1'900	200	0.017	NE	NE	NE	NE
Sewage sludge incineration	mg/t sludge	2'700	300	400	0.000	NE	NE	NE	NE
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	52	NA	120	0.001	NE	NE	NE	NE

Activity data (5C)

The clinical waste incineration quantities are based on rough expert estimates (EMIS 2021/5C1 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 lack of reliable data 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 get the illegal waste quantity the percentage quotation is multiplied by the total amount of municipal solid waste and waste from construction work (EMIS 2021/5C1 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 (SFSO 2020c). 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 MSWIP, 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 waste (see Table 6-12) is about to decrease since 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 2021/5C2 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 within the informative inventory report (Natural sources, natural and man induced forest fires).

Table 6-12: 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**
Total	kt	134	105	109	132
Clinical waste incineration	kt	15	8.8	2.5	NO
Illegal waste incineration	kt	32	26	25	22
Insulation material from cables	kt	7.5	NO	NO	NO
Open burning of PCB	kt	0.0011	0.00020	NO	NO
Sewage sludge incineration	kt dry	57	50	64	95
Open burning of natural residues in agriculture	kt	16	15	14	13
Open burning of natural residues in private households	kt	6.1	4.9	3.6	2.4
Cremation	Numb.	37'513	40'968	44'821	48'169

5C Incineration and open burning of waste	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Total	kt	124	116	108	126	124	129	130	132	128	129
Clinical waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Illegal waste incineration	kt	21	20	20	20	19	19	19	18	18	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	90	83	75	94	93	97	99	102	98	100
Open burning of natural residues in agriculture	kt	12	11	11	11	11	11	11	11	11	10
Open burning of natural residues in private households	kt	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1
Cremation	Numb.	52'813	52'530	50'567	53'205	55'616	59'664	54'634	57'694	54'842	57'746

Note that since 2002, all specific clinical waste incineration plants have ceased operation and all hospital waste is incinerated in municipal solid waste incineration plants (accounted for in 1A1 Energy industry). All burning of insulation material cables (industrial waste incineration in the table above) has ceased as well since 1995.

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

The following recalculations were implemented in submission 2021:

- 5C1 incineration of waste / sewage sludge: AD of the amount of sewage sludge incineration has changed from 2000 to 2018. As of 2000, new values for annual per capita produced sewage sludge are proposed (VBSA 2017) and multiplied with total population numbers. This leads to an overall decrease in AD by 15% to 20% and thus to decreasing emissions of NO_x, CO, NMVOC, NH_3, SO_2, PM10, PM2.5 and TSP. AD in the year 2018 decreased by additional 20% due to a correction of incorrectly reported amounts of incinerated sewage sludge.
- 5C1 incineration of waste / sewage sludge: Changes in all relevant air pollutant emission factors (Cd, CO, HCl, HF, Hg, NH_3, NMVOC, NO_x, Pb, PCDD/F, PM, PM10, PM2.5, SO_2, Zn) for incineration of sewage sludge from 2015 to 2018 are based on the evaluation of emission reports from three sewage sludge incineration plants in 2015 (VBSA 2017).
- 5C1bi Waste incineration and open burning of waste: EF of Hg and Cd exhaust have accidentaly been applied reversed from 1990 to 2018 for incineration of insulation materials from cables. They have now been assigned correctly.
- 5C2i, 5C2ii Waste incineration and open burning of waste: EF of Pb and Cd exhaust have been implemented for open burning of natural residues in agriculture and private households based on default Tier 2 EF in the EMEP/EEA Guidebook 2019.

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 (WWTP) treat wastewater from single cities or several cities and municipalities together. Wastewater in general is treated in three steps: 1. Mechanical treatment, 2. Biological treatment, and 3. Chemical treatment. The treated wastewater flows into a receiving system (lake, river or stream). Switzerland's wastewater management infrastructure is now practically complete (FOEN 2017c). The vast majority of WWTP apply an 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 comprises 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 WWTP) 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 WWTP.

Table 6-13: 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

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 MSW 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.

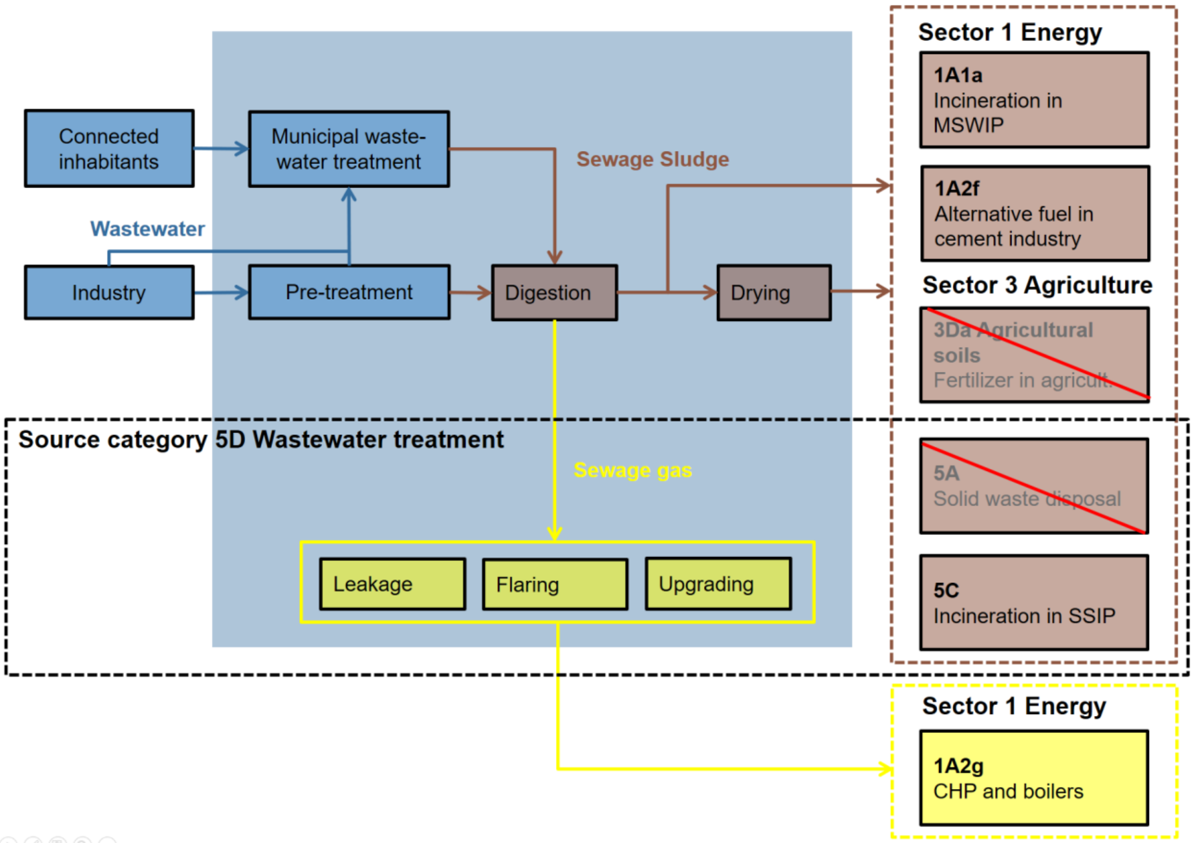


Figure 6-5: System boundaries of emissions related to wastewater handling. Abbreviations: CHP Combined Heat and Power Generation, MSWIP municipal solid waste incinearion plant, SSIP sewage sludge incineration plant.

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 the emission factors are calculated on the basis of the total emissions divided by the number of inhabitants (Swiss population, SFSO 2020c).

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 2021/5D1, EMIS 2021/5D2), see Table 6-14.

Table 6-14: Emission factors for 5D Wastewater handling in 2019.

5D Wastewater handling	Unit	NO_x	NMVOC	SO_x	NH_3	CO
5D1 Domestic wastewater handling	g/person	0.56	0.011	0.0028	15	0.28
5D2 Industrial wastewater handling	g/person	0.13	0.0026	0.00064	NA	0.063

Activity data (5D)

Activity data for 5D1 Domestic wastewater handling and 5D2 Industrial wastewater handling are the total number of inhabitants extracted from SFSO (2020c). The number of inhabitants connected to the system (ICS) is the product of the number of inhabitants and the service level. The fraction and number of persons connected to waste water systems is indicated below for informational reason.

Table 6-15: Activity data in 5D Wastewater handling: Population and fraction connected to waste water treatment plants.

5D Wastewater handling	Unit	1990	1995	2000	2005
Inhabitants	persons in 1000	6'712	7'041	7'184	7'437
Fraction connected to waste water treatment plants	%	90.0	93.7	95.4	96.8
Inhabitants connected	persons in 1000	6'041	6'597	6'854	7'199

5D Wastewater handling	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Inhabitants	persons in 1000	7'825	7'912	7'997	8'089	8'189	8'282	8'373	8'452	8'514	8'575
Fraction connected to waste water treatment plants	%	97.2	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3
Inhabitants connected	persons in 1000	7'606	7'698	7'781	7'871	7'968	8'058	8'147	8'224	8'284	8'343

6.5.3 Category-specific recalculations in 5D - Wastewater handling

The following recalculations were implemented in submission 2021:

- 5D1 Domestic wastewater treatment: Changes in the AD "population" (new mode of estimation by SFSO 2020c) lead to changes in EF of NO_x, CO, NMVOC, and SO_2 from 1990 to 2010 since figures for emissions are taken from the statistics of renewable energy.
- 5D1 Domestic wastewater treatment: Changes in the AD "population" (new mode of estimation by SFSO 2020c) leads to annually decreasing emissions of NH_3 from 1990 to 2010 (<1%, <1 kt). EFs remain constant.
- 5D1 Domestic wastewater treatment: A decrease in the amount of gas input into the natural gas grid (<1%) from communal wastewater treatment plants reported in the national statistical report of renewable energy leads to a decrease in EFs of NO_x, CO, NMVOC, SO_2 from 2014 to 2016.

- 5D1 Domestic wastewater treatment: The combined recalculations in this sector yield the following changes in the respective air pollutant emissions from 1990 to 2018: Decreasing emissions of NO_x, CO, NH_3, NMVOC and SO_2 of less than 1% (<1 t a^{-1}).
- 5D2 Industrial wastewater treatment: Changes in the AD "population" (new mode of estimation by SFSO) lead to changes in EF of NO_x, CO, NMVOC, and SO_2 from 1990 to 2010. Figures for emissions are taken from the statistics of renewable energy and, therefore, remain unchanged.
- 5D2 Industrial wastewater treatment: A decrease in the amount of energy used in boilers for heat generation in industrial wastewater treatment plants (<1%), reported in the national statistical report of renewable energy, leads to a decrease in the EF of NO_x, CO, NMVOC and SO_2 from 2013-2018.
- 5D2 Industrial wastewater treatment: The combined recalculations in this sector yield the following changes in the respective air pollutant emissions from 1990-2018: Annually decreasing emissions of NO_x, CO, NMVOC and SO_2 for 1990 - 2018 of < 1% (< 1 t).

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 waste incineration plants or in dedicated sewage sludge incineration plants. The remaining 20 - 30% is incinerated in cement production (2A1). 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 6-16: 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

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 of the EMEP/EEA Guidebook (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 2021/5E Shredder Anlagen). For all years, emission factors are considered to remain constant. The PCB emission factor expressed in units per tonnes of PCBs shreddered is based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 6-17: Emission factors for 5E Other waste, car shredding and shredder in 2019. Unit of PCDD/PCDF is in I-TEQ.

5E Other waste	Unit	NMVOC	PM2.5 non-exh.	PM10 non-exh.	TSP non-exh.	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	0.072

Activity data (5E)

The quantities of shreddered cars from 1990 are data provided by the Swiss shredder association. The data from 2003 and 2007 are taken from Swiss waste statstics. In between years are interpolated. From 2007 onwards the quantites are assumed to remain constant due to the lack of data (EMIS 2021/5E 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 occured in 1999 although they should have been treated as hazardous waste from 1998 onwards.

Table 6-18: Activity data for car shredding (source EMIS 2021/5E Shredder Anlagen)

5E Other waste	Unit	1990	1995	2000	2005
Car shredding	kt	280	300	300	300
Shredder	t PCB	3.0	3.3	10	3.5

5E Other waste	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Car shredding	kt	300	300	300	300	300	300	300	300	300	300
Shredder	t PCB	0.7	0.58	0.48	0.39	0.31	0.25	0.20	0.15	0.12	0.09

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

There were no recalculations implemented in submission 2021.

7 Other and natural emissions

7.1 Overview of emissions

In this introductory chapter, an overview of emissions separated by the most relevant pollutants is presented. Likewise, surfacing trends and changes are analysed and discussed for individual source categories in the period between 1990 and 2019. 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 depicts the trend of NH_3 emissions in sector 6 Other and natural emissions since 1990. Total emissions fluctuate and have slightly increased within the reporting period. Emissions from source category 6Ab Pets that includes also livestock outside agriculture contributes the largest share to total emissions. Emissions from the other two source categories 6Aa Humans and 6Ac Fertilisers remain considerably stable in total during past years, although 6Aa shows a very slight increase with population.

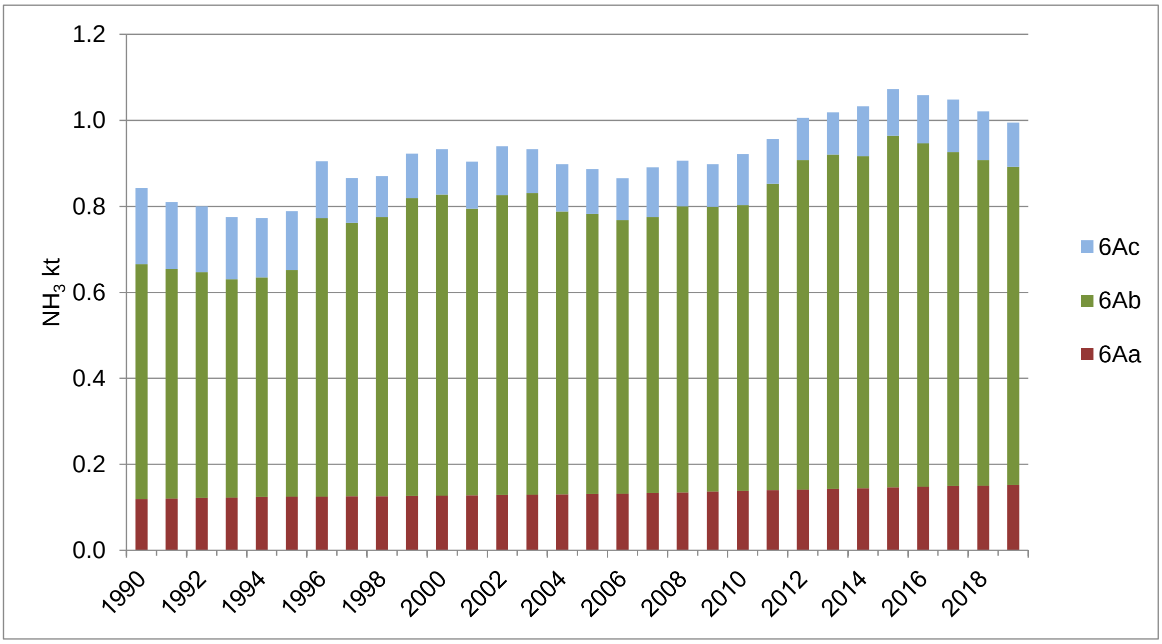


Figure 7-1: Switzerland's NH_3 emissions from sector 6 Other and natural emissions by source categories 6Aa, 6Ab and 6Ac. The corresponding data table can be found in Annex A7.6.

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 2019 are summarised in Figure 7-2. The overall emissions fluctuate 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 6Ad Fire damages estates and motor vehicles remained stable.

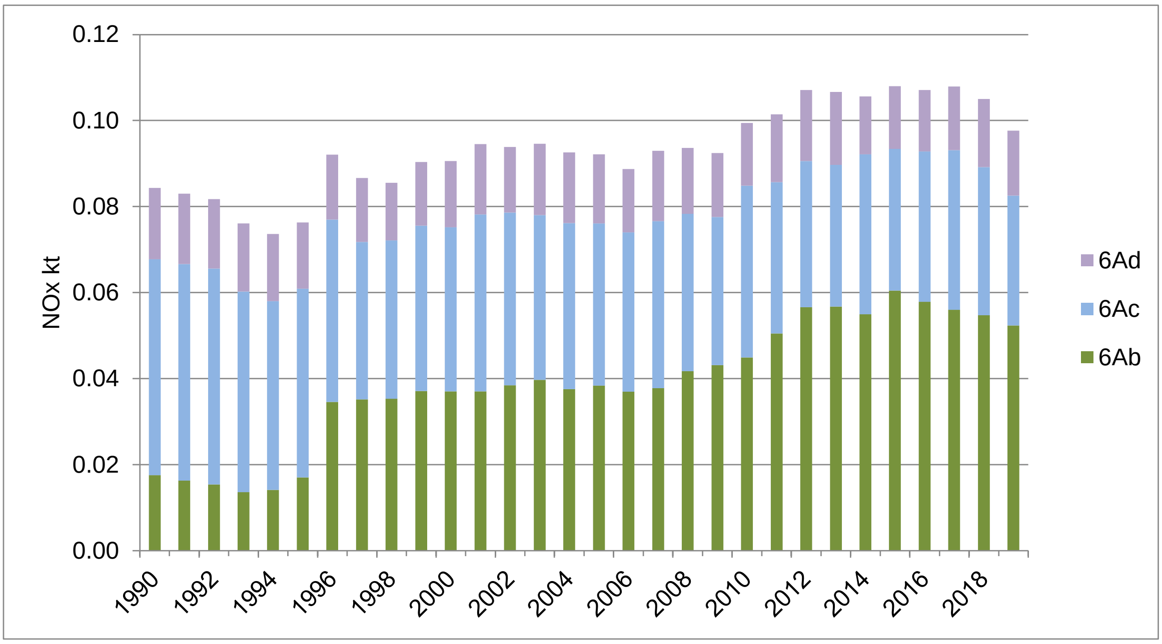


Figure 7-2: Switzerland's NO_x emissions from the sector 6 Other and natural emissions by source categories 6Ab-6Ad. The corresponding data table can be found in Annex A7.6.

7.1.3 Overview and trend for PM2.5

PM2.5 emissions in the sector 6 Other emissions stem predominantly from 6Ab Pets. Emissions from 6Ad Fire damages estates and motor vehicles are the other relevant source category. Total emission levels are low; however, they show an increasing trend from 2008 to 2012.

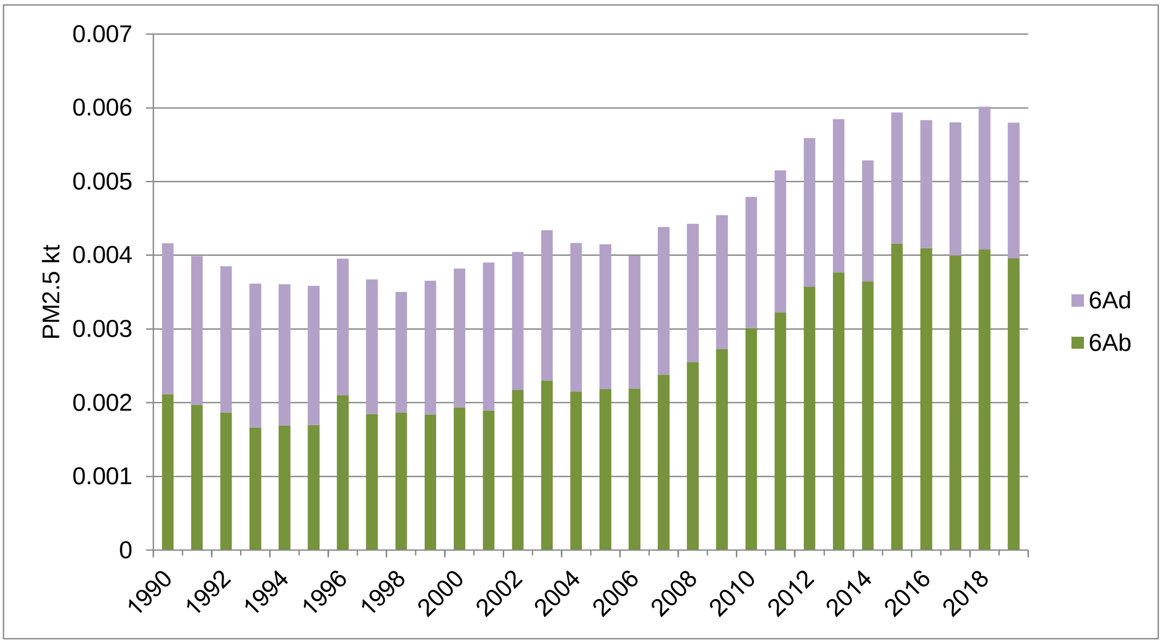


Figure 7-3: Switzerland's PM2.5 emissions from the sector 6 Other emissions. The corresponding data table can be found in Annex A7.6.

7.1.4 Overview and trend for NMVOC from Forests

NMVOC emissions in the sector 11C Other natural emissions stem predominantly from Norway spruce and fir stands. Total emissions in 1990 were 60.8 kt; they are increasing on average by 0.34% per year.

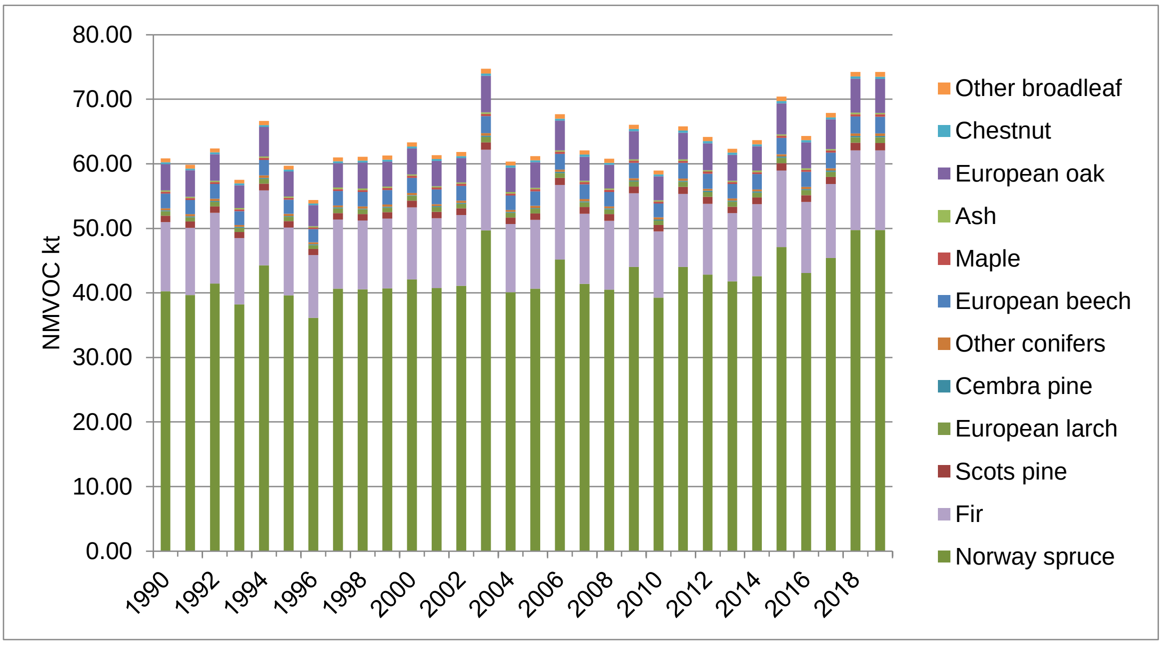


Figure 7-4: Switzerland's NMVOC emissions from the sector 11C Other natural emissions (forest stands).

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	Ammonia emissions from respiration and transpiration and diapers
6Ab	Pets and livestock outside agriculture	NOx, NMVOC, ammonia, 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	NOx and ammonia 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 approach 1, level 2019 (L1, L2) and trend 1990-2019 (T1, T2), for source category 6A Other emissions.

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)

Emissions from the use of mineral fertilisers are calculated by multiplying activity data of Table 7-6 by the emission factors of Table 7-3. The methodology is the same as for fertilisers used and reported 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 EMEP/EEA (2019) taking into account the specified list of fertilisers, climate zone and pH. This methodology is applied to source category 6Ac.

Emissions from fire damage estates and motor vehicles and emissions from accidential 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 1992 to 2001 show that the average damage sum per fire incident in buildings amounts to approx. CHF 20'000. It is assumed that this corresponds to 780 kg of flammable material per case. It is further assumed that in average 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 2021/6A).

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 2021/6A). During a car fire incident, a car burns down only partially. It is assumed that approx. 100 kg of material burns down during a car fire. With these assumptions, the total 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 accidential 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 5-13.

Ammonia emissions (6Aa-6Ac)

Emission factors for human ammonia emissions are extracted from Sutton et al (2000). Emission factors for pet ammonia emissions are retrieved from Reidy and Menzi (2005). The ammonia emission factor for livestock outside agriculture is derived from 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 in accordance with the unrounded values of the implied emission factors in source category 3B. For detailed information about these emission factors please refer to 3B – Manure management (see chp. 5.2.2).

Table 7-3: Emission factors for the year 2019 in sector 6 Other emissions (source EMIS 2021/6A).

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	496	1'045	3'637	38	92	222
Cats	g/animal	NA	NA	90	NA	NA	NA
Dogs	g/animal	NA	NA	407	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	61	NA	NA	NA

Fire damages (6Ad)

Fire damages estates: Emission factors for CO, NO_x and SO_2 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 2021/6A "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/F emission factor is the same as for illegal waste incineration. The emission factor for B(a)P is taken from USEPA 1998a (chp. 4.10.5 Open burning of municipal refuse).

Fire damage motor vehicles: Emission factors for CO, NO_x and SO_2 are country-specific based on measurements and expert estimates originally derived for wire burn off, documented in EMIS 2021/6A Brand- und Feuerschäden Motorfahrzeuge". The PCDD/F emission factors for fire damage of motor vehicles are determined by USEPA 1998a (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 EF for B(a)P of car scrap due to higher B(a)P EF values of car tires.

Table 7-4 presents the emission factors used. The emission factors for Pb, Cd, Hg, and B(a)P are identical for estates and motor vehicles.

Table 7-4: Emission factors for fires reported under 6Ad Fire damages estates and motor vehicles in 2019 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_2	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 accidential release of PCBs (6Ad)

The PCB emission factors from accidential 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 accidential release of PCB by fire and to soil, respectively, reported under 6Ad Other emissions in 2019 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	0.38

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
6Aa Human emissions					
Human respiration	person	6'712'000	7'041'000	7'184'000	7'437'000
Human transpiration	person	6'712'000	7'041'000	7'184'000	7'437'000
Children <1y	person	83'939	82'203	78'458	72'903
Children 1-3y	person	238'030	253'652	237'941	217'302
Aged inhabitants	person	9'000	9'752	10'504	11'029
6Ab Pets and livestock outside agriculture					
Livestock, outside agriculture	animals	16'326	18'649	88'285	89'276
Cats	animals	1'164'786	1'205'000	1'379'000	1'417'000
Dogs	animals	456'015	438'000	513'000	487'000
Zoo animals	t	140	140	140	140
6Ac Private application of synthetic fertilizer					
Fertilizer, outside agriculture	t	2'778	2'432	2'111	2'087

6 Other emissions	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
6Aa Human emissions											
Human respiration	person	7'825'000	7'912'000	7'997'000	8'089'000	8'189'000	8'282'000	8'373'000	8'452'000	8'514'000	8'575'000
Human transpiration	person	7'825'000	7'912'000	7'997'000	8'089'000	8'189'000	8'282'000	8'373'000	8'452'000	8'514'000	8'575'000
Children <1y	person	80'290	80'808	82'164	82'731	85'287	86'559	87'883	87'381	87'851	86'172
Children 1-3y	person	229'471	235'267	239'384	243'262	245'703	250'182	254'577	259'729	261'823	263'115
Aged inhabitants	person	17'357	17'393	17'972	18'389	18'679	19'278	19'244	19'793	20'337	20'630
6Ab Pets and livestock outside agriculture											
Livestock, outside agriculture	animals	95'332	102'848	113'853	111'397	108'866	120'094	113'379	109'783	110'898	105'536
Cats	animals	1'507'000	1'497'000	1'487'000	1'543'317	1'618'406	1'655'951	1'655'951	1'645'096	1'634'240	1'678'277
Dogs	animals	445'000	475'500	506'000	511'297	518'360	521'891	521'891	513'816	505'740	504'375
Zoo animals	t	140	140	140	140	140	140	140	140	140	140
6Ac Private application of synthetic fertilizer											
Fertilizer, outside agriculture	t	2'212	1'947	1'881	1'822	2'056	1'823	1'933	2'057	1'907	1'673

Fire damages and accidential release of PCBs (6Ad)

Activity data for source category fire damages and accidential release of PCBs (6Ad) are given in Table 7-7. For accidential 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 2021/6A).

6Ad Fire damages	Unit	1990	1995	2000	2005
Fire damage estates	kt	8.0	7.3	7.3	7.6
Fire damage motor vehicles	kt	0.48	0.52	0.58	0.64
6Ad Accidential release of PCB					
by fire	t	2.4	1.7	1.1	0.70
to soil	t	39	41	41	41

6Ad Fire damages	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fire damage estates	kt	6.8	7.4	7.8	8.0	6.3	6.8	6.6	6.9	7.4	7.1
Fire damage motor vehicles	kt	0.68	0.69	0.71	0.72	0.73	0.75	0.76	0.77	0.77	0.78
6Ad Accidential release of PCB											
by fire	t	0.43	0.39	0.35	0.32	0.29	0.26	0.24	0.22	0.20	0.18
to soil	t	41	41	41	41	41	40	40	40	40	40

7.2.3 Recalculations in 6 - Other emissions

The following recalculations were implemented in submission 2021:

- 6Aa Human emissions: Changes in the "number of people in retirement and nursing homes" for 2018 (update of statistics by SFSO) lead to a change in AD for human emissions.
- 6Aa Human emissions: AD of human respiration and human transpiration has changed for the years 1980 to 2010 due to a revised methodology for the Swiss population by SFSO (2020c).
- 6Ab: The activity data of livestock not covered by the agricultural census, so-called livestock outside agriculture, was recalculated for 1990-2018. Population data for the

respective horses was revised due to a better census approach of the SFSO. Thus, also the implied emission factors of NO_x, NMVOC, NH_3, PM2.5, PM10 and TSP have changed.

- 6Ab livestock outside agriculture: Activity data and emission factor of zoo animals have been overestimated by a factor of 1000 due to an error in the unit (new AD 140 t instead of old 140'000 t, EF 41'400 g/t instead of 41.4 g/t). This correction does not affect emissions. AD from 1980 to 1989 shows a slight increase due to a change in the slope of the interpolation function resulting from an improved estimate of AD for the year 1900.
- 6Ac: The activity data and NH_3 emission factor of other synthetic fertiliser have been revised.

7.3 Source category 11B - Forest fires

7.3.1 Source category description of 11B - Forest fires

Within 11B Forest fires following source categories are reported:

- Emissions from wildfires on forest land and grassland occurring naturally or caused accidentally by humans.
- 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.

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 2021/4VA1-11B-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) and USEPA as documented in EMIS 2021/5C2 Abfall-verbrennung Land- und Forstwirtschaft.

Table 7-8: Emission factors 2019 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_2	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 2020) as documented in the EMIS database (EMIS 2021/4VA1-11B-NFR_Waldbrände). For the years since 1990, the swissfire database is also used in the GHGI (FOEN 2020). 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 at 1 January 2009). Activity data are documented in EMIS 2021/5C2 Abfallverbrennung Land- und Forstwirtschaft.

Table 7-9: Activity data of 11B Forest fires, grassland fires and open burning of natural residues in forestry.

11B Forest fires	Unit	1990	1995	2000	2005
Forest fires	ha	1'067	363	47	41
Burning grassland	ha	637	82	22	20
Open burning of natural residues in forestry	kt	29	25	20	16

11B Forest fires	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Forest fires	ha	26	171	26	24	43	43	256	106	55	15
Burning grassland	ha	1.3	66	14	3.6	2.6	8.0	212	38	29	16
Open burning of natural residues in forestry	kt	12	11	11	11	11	11	11	11	11	10

7.3.3 Recalculations in 11B - Forest fires

The following recalculations were implemented in submission 2021:

- 11B Forest fires: The time series of wildfires on forest land and grassland were recalculated with updated activity data (since 2015) and emission factors (since 1980). To calculate the emission factors, updated values for available fuel (biomass) were used by incorporating data of the latest national forest inventory 2015-2019 and new litter data from the Yasso07-model (FOEN 2021).
- 11B Forest fires: EF of Pb and Cd exhaust have been implemented for open burning of natural residues in forestry based on default Tier 2 EF in the EMEP/EEA Guidebook 2019.

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.

7.4.2 Methodology of 11C – Other natural emissions

The biogenic NMVOC emissions from forests were calculated for the years 1900-2018 and 2050 on the basis of monthly maps for the parameters temperature, vegetation period and for 12 different tree species (Meteotest 2019a, EMIS 2021/11C Wald). This corresponds to the simplified method according to chapter 11C in 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 7-10). They represent annual implied emission factors derived from the monthly emission maps. The values after 2018 are interpolated between the modelled years 2018 and 2050.

Table 7-10: Implied emission factors 2019 of 11C NMVOC for different tree species.

11C Tree species	Unit	NMVOC
Norway spruce	g/ha	85'445
Fir	g/ha	88'502
Scots pine	g/ha	22'602
European larch	g/ha	10'777
Cembra pine	g/ha	14'526
Other conifers	g/ha	119'894
European beech	g/ha	11'275
Maple	g/ha	22'260
Ash	g/ha	8'260
European oak	g/ha	209'422
Chestnut	g/ha	12'884
Other broadleaf	g/ha	11'191

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 2021/11C Wald).

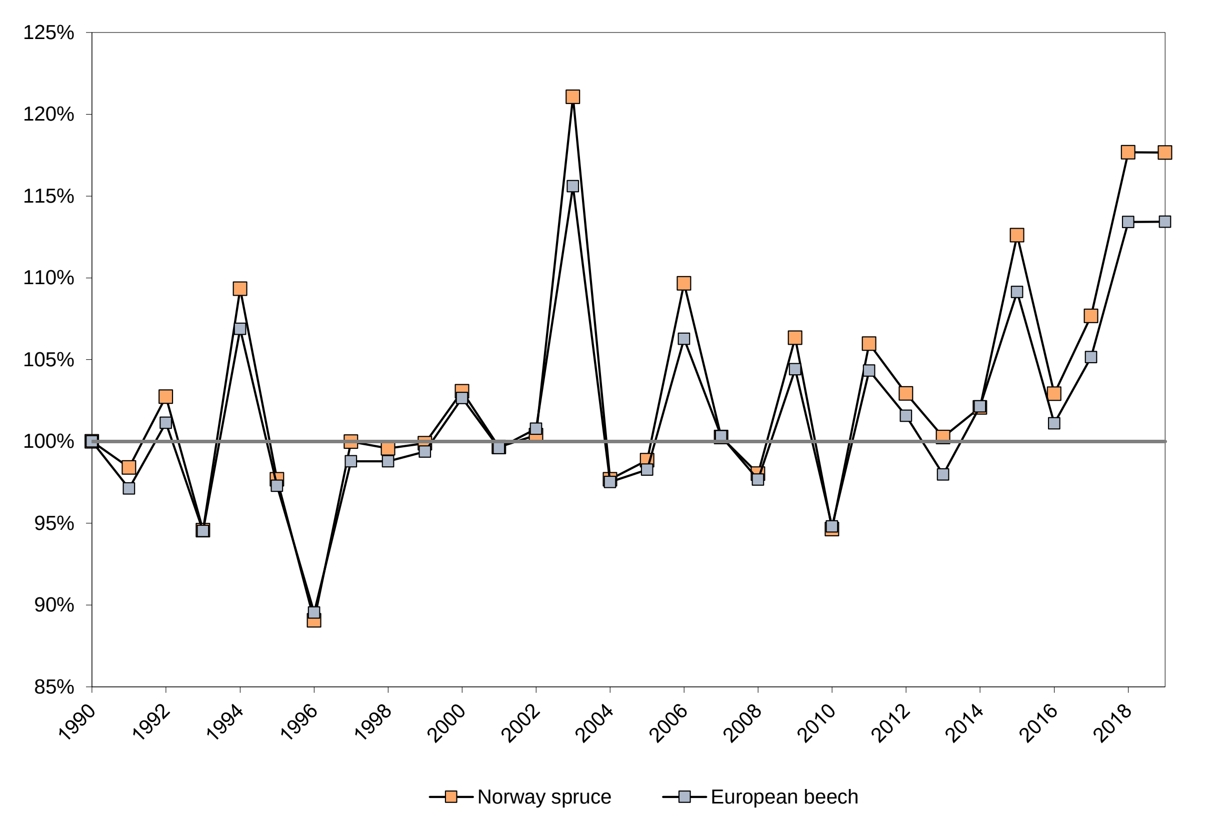


Figure 7-5: Relative trends oft the (implied) NMVOC emission factors for two selected tree species 1990-2019.

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 7-11.

Table 7-11: Activity data of 11C; forest areas covered by the twelve main tree species.

11C Tree species	Unit	1990	1995	2000	2005
Total	ha	1'211'651	1'220'183	1'229'051	1'237'835
Total coniferous	ha	829'570	835'789	842'127	848'438
Norway spruce	ha	554'168	558'151	562'292	566'457
Fir	ha	138'196	138'374	138'497	138'634
Scots pine	ha	49'503	49'823	50'136	50'400
European larch	ha	73'421	74'919	76'432	77'933
Cembra pine	ha	11'025	11'261	11'502	11'745
Other conifers	ha	3'257	3'261	3'268	3'269
Total non-coniferous	ha	382'081	384'394	386'924	389'397
European beech	ha	226'751	227'722	228'738	229'799
Maple	ha	15'325	15'461	15'614	15'729
Ash	ha	28'555	28'655	28'782	28'911
European oak	ha	24'911	24'919	24'978	25'023
Chestnut	ha	26'877	27'097	27'353	27'578
Other broadleaf	ha	59'662	60'540	61'459	62'357

11C Tree species	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total	ha	1'245'663	1'247'178	1'248'737	1'250'343	1'251'863	1'253'440	1'254'956	1'261'833	1'263'879	1'263'600
Total coniferous	ha	854'795	856'068	857'381	858'737	859'987	861'305	862'586	868'300	870'017	869'785
Norway spruce	ha	571'009	571'930	572'879	573'867	574'751	575'680	576'601	580'815	582'061	581'890
Fir	ha	138'905	138'963	139'010	139'066	139'130	139'193	139'248	139'502	139'591	139'580
Scots pine	ha	50'624	50'668	50'722	50'781	50'821	50'873	50'926	51'138	51'192	51'184
European larch	ha	79'036	79'244	79'457	79'672	79'894	80'118	80'333	81'179	81'457	81'422
Cembra pine	ha	11'943	11'983	12'030	12'067	12'106	12'154	12'190	12'368	12'416	12'409
Other conifers	ha	3'278	3'280	3'283	3'284	3'285	3'287	3'288	3'298	3'300	3'300
Total non-coniferous	ha	390'868	391'110	391'356	391'606	391'876	392'135	392'370	393'533	393'862	393'815
European beech	ha	230'564	230'699	230'842	230'981	231'153	231'310	231'446	232'112	232'299	232'272
Maple	ha	15'831	15'861	15'880	15'905	15'931	15'951	15'975	16'074	16'105	16'101
Ash	ha	28'978	28'989	29'000	29'010	29'016	29'033	29'038	29'125	29'142	29'139
European oak	ha	25'023	25'024	25'027	25'027	25'027	25'029	25'031	25'041	25'045	25'045
Chestnut	ha	27'660	27'665	27'671	27'679	27'685	27'690	27'694	27'722	27'733	27'732
Other broadleaf	ha	62'812	62'872	62'936	63'004	63'064	63'122	63'186	63'459	63'538	63'527

7.4.3 Recalculations in 11C - Other natural emissions

No recalculations were implemented in submission 2021.

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.

8.1.1 1 Energy

8.1.1.1 Category specific recalculations for 1A1 Energy industries (stationary)

- 1A1a: Activity data (wood, wood waste) of all combustion installations in source category 1A1a have been revised for 1990-2018 due to recalculations in the Swiss wood energy statistics (SFOE 2020b).
- 1A1a: The country-specific emission factor model for wood energy was completely updated for the entire time period based on air pollution control and laboratory measurements and literature data yielding revised emission factors of all pollutants for all wood combustion installations. See chp. 3.2.1.1.2.
- 1A1a: A very small recalculation (0.001%) concerning use of natural gas in sector 1A1a for the year 2016 was made.
- 1A1a: Activity data for engines on landfills has slightly changed for the years 2000 to 2018 due to an adjustment in the rounding of the numbers taken from the statistics of renewable energies by SFOE to two significant digits.

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

- 1A2a: In source category 1A2a Electric arc furnaces of steel production, a typing error in the consumption of other bituminous coal has been corrected for 2018.
- 1A2a to 1A2f and 1A2gviii: Small recalculations of use of gas oil and of natural gas in the year 2018 were made due to correction of an error in the industry model.
- 1A2b: Acitvity data of 1A2b Non-ferrous metal foundries have been revised for the years 1990-2008 and 2012-2018 based on industry data and estimates.
- 1A2f Container glass production: Typing errors in the emission factors of PM2.5, PM10 and BC have been corrected from 2012 onwards.
- 1A2f: AD of sewage sludge used as alternative fuel in cement production has decreased by 18% in 2018 (correction of reporting error).
- 1A2f: The emission factors of NO_x, SO_x, PM2.5, PM10, TSP, BC and CO for source category 1A2f Lime prodution have been revised for 2014-2018 based on air pollution control measurements in 2017.
- 1A2f: EF of all air pollutants for cement production have changed due to a reassessment based on emission measurement reports from years 2013 to 2017. This leads to a change in EF for the years 2009 to 2018.
- 1A2f: EF for PCB emissions in cement production have been implemented for all years based on the Tier 2 EF in the Guidebook 2019.
- 1A2gviii: Activity data (wood, wood waste) of all combustion installations in source category 1A2gviii have been revised for 1990-2018 due to recalculations in the Swiss

wood energy statistics (SFOE 2020b). The biggest changes were in the automatic boilers within wood processing industry.

- 1A2gviii: AD of sewage gas from industrial waste water treatment used in boilers and in engines has changed (by less than 1%) for the years 2013-2018. The data is taken from the national statistical report of renewable energies by SFOE and has been updated.
- 1A2gviii: The country-specific emission factor model for wood energy was completely updated for the entire time period based on air pollution control and laboratory measurements and literature data yielding revised emission factors of all pollutants for all wood combustion installations.
- 1A2gviii: Recalculation concerning stock changes leads to changes in activity data for boilers using residual fuel oil in the years 2014 and 2015.
- 1A2gviii: Recalculation concerning stock change leads to changed activity data for boilers using petroleum coke in the year 2018.
- 1A2gviii: Due to changed activity data in bottom-up process 1A2a Electric arc furnaces of steel production also the activity data of boilers in 1A2gviii using other bituminous coal changed for the year 2018.
- 1A2gviii: Due to small recaclulation concerning use of LPG in 1A3b Road transportation for the years 2011-2018, the activity data of boilers in 1A2gviii Other changes too, because this source category represents the statistical difference of over all reported amount of liquefied petroleum sold and the modelled use in the different source-categories.

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

- 1A4: The country-specific emission factor model for wood energy was completely updated for the entire time period based on air pollution control and laboratory measurements and literature data yielding revised emission factors of all pollutants for all wood combustion installations.
- 1A4ai (and 1A4ci): Due to recalculations concerning use of gas oil and natural gas for greenhouses allocated to 1A4ci (see below) the activity data of gas oil and natural gas boilers changes in source-category 1A4ai, too. These recalculations are very small for the years 2002-2013, 2016 and bigger for 2014-2015 and 2017.
- 1A4ai/bi/ci: Activity data (wood, wood waste) of all combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2018 due to recalculations in the Swiss wood energy statistics (SFOE 2020b).
- 1A4bi: A typing error of the CO emission factor for 1A4bi Bonfires has been corrected for the entire time series.
- 1A4bi: Small recalculations concerning use of natural gas in housholds were made in the energy statistics for the years 2016-2018.
- 1A4ci: Activity data for the consumption of gas oil and natural gas used for heating of greenhouses have been increased (by less than 1%) for the years 2014 and 2015 due to a revision of the statistics for the total area of greenhouses. There are small differences due to rounding to the years 2002-2013 and 2016.
- 1A4ci Stationary combustion in other sectors: From 1990 to 2018, EF of biogas heat only boilers have been inadvertently applied to biogas engines for all pollutants. This mistake has now been corrected by applying EF of 1A2gviii engines biogas.

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

No recalculations were carried out in source category 1A2 (mobile sources).

8.1.1.5 Category-specific recalculations for 1A3 Transport

- 1A3a: The ratio BC from PM2.5 was 48% according to the EMEP Guidebook default value for all flight processes (Cruise and LTO) for the years 1980-2014. As there are better estimates for all flight processes of the years 2015-2018 (FOCA 2016-2019) already in the database, the factors were adapted to those estimates also for the years 1980-2014.
- 1A3b: Cd exhaust, PCDD/F and PCB emission factors for road transportation were updated according to the latest version of the EMEP Guidebook 2019 (EMEP/EEA 2019, tables 3-77 to 3-79). In previous submissions, PCB was not estimated and Cd exhaust was assumed to be zero.
- 1A3b: There are some recalculations concering activity data in category 1A3b in the road transportation model, which lead to minor differences (mainly <2%) compared to the emissions of the previous submission:
  - Update of activity data to the latest available dataset 1990-2019 (SFOE 2020e, ex-post analysis 2019). This concernes mainly the years 2016-2018 for all fuels and 2005 for biogas.
  - Activity data of biogenic fuels are newly treated in the same way as fossil fuels and allocated to the individual vehicle categories. Also, the statistical difference of biodiesel and bioethanol is now allocated to "fuel tourism and statistical difference", similar as it is done for diesel and gasoline This leads to recalculations in all source-categories of 1A3bi-1A3biii for all years 1990-2018.
- 1A3c: Recalculation of the activity data (number of driven km on railways) that is used to calculate the non-exhaust emissions in 1A3c for the year 2011-2018. The activity data was updated to the recent available statistics.
- 1A3ei: Emissions of Pb, Cd, and PAHs were wrongly reported as "NA" in all NFR tables in previous submission, although there are emissions. This error was corrected.

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

No recalculations were carried out in source category 1A4 (mobile sources).

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

No recalculations were carried out in source category 1A5b.

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.
- 1B2ai: Fugitive NMVOC emissions from crude oil transport in pipelines have been revised based on expert information from the oil industry (Canton of Neuchâtel 2019). In previous submissions, the default emission factor from 2006 IPCC Guidelines was used, but this factor refers to long above ground pipelines as used in North America. In

contrast, crude oil pipelines in Switzerland are relatively short (max. 70 km) and underground. Negligible emissions occur at the pig trap only. Therefore, the activity data was changed to number of refineries (which is equal to the number of pipelines and pig traps) and the emission factors were reestimated. NMVOC emissions are calculated based on the estimation of 0.5 m^3 VOC per week and pipeline. Actually, those NMVOC emissions are negligible with 10-20 kg NMVOC per year.

- 1B2aiv: NMVOC emission factors in 1B2aiv are adapted for the year 2018 to reach the total NMVOC emissions as reported in the Swiss Pollutant Release and Transfer Register (PRTR). Data for the latest year is not available in the PRTR early enough for the data collection for the inventory. Therefore, the emissions are recalculated once the PRTR data is available.
- 1B2b: Recalculation of natural gas losses for the years 2017 and 2018 due to changes in the data of the length of pipelines.

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 2018 has been revised based on effective production data from the industry association.

8.1.2.2 Category-specific recalculations in 2B Chemical industry

There were no recalculations implemented in submission 2021.

8.1.2.3 Category-specific recalculations in 2C Metal production

- 2C7a: Acitvity data of 2C7a Non-ferrous metal foundries have been revised for the years 1990-2008 and 2012-2018 based on industry data and estimates.
- 2C7c: Acitvity data of 2C7c Battery recycling have been revised for the years 1990-2002 based on industry data. The recycling plant started operation in 1992 only.

8.1.2.4 Category-specific recalculations in 2D Other solvent use

- 2D3a: Since the survey methodology of the Swiss mean population has been revised (SFSO 2020c) for the years 1900 to 2010 the activity data (population) of all source categories in 2D3a Domestic solvent use including fungicides have changed for the respective years.
- 2D3d: Activity data of 2D3d Coating application, construction has been updated for 1990 based on information from industry association and expert judgment yielding revised data for 1990 to 1997.
- 2D3d Coating application, wood has been revised and includes now also the applications of glazes for wood preservation which have been reported so far under 2G Preservation of wood.
- 2D3g: Activity data of 2D3g Paint production have been revised based on information from industry association and revised activity data in coating applications for the years 1990-1997 and 2005-2015.

8.1.2.5 Category-specific recalculations in 2G Other product use

- 2G Preservation of wood has been revised completely and includes now all industrial wood preservation applications including creosote while applications of glazes for wood preservation are reported under 2D3d Coating application, wood.
- 2G Use of Tobacco: AD for the use of tobacco has changed from 1997 to 2010 due to a change in the population, which is used in the calculation of the AD for 1997-2015. The survey methodology of the Swiss mean population has been revised (SFSO 2020c) for the years 1900 to 2010. Since 2016 the total use of tobacco is modelled using a linear regression based on parameters deduced from the period of 1997 to 2015. Therefore, values since 2016 have also changed.

8.1.2.6 Category-specific recalculations in 2H Other industry production

- 2H2 Bread production: The activity data (population) for bread production has changed for the years 1990 to 2010. This is because the survey methodology of the Swiss mean population has been revised (SFSO 2020c) for the years 1900 to 2010.
- 2H2 Meat smoakhouses: AD of meat smokehouses has changed for the years 1980 to 2010 since the population, which is used in the calculation, has changed for the years 1980 to 2010. The survey methodology of the Swiss mean population has been revised (SFSO 2020c) for those years. In addition, the AD "per capita meat consumption" for 2017 and 2018 has changed due to a revised statistical source (SFSO 2020c).
- 2H2 Milling companies: AD for milling companies has changed for the years 2016 to 2018 because the "self-sufficiency rate" for those years have changed in the underlying statistical report by the Federal Office for Agriculture (FOAG).
- 2H2 Sugar production: The EF for NH_3 from sugar production in 2018 was 297 g/t sugar. In 2019, due to an error in data processing, the EF for NH_3 from sugar production was reported to be 125 g/t sugar. The correct EF for NH_3 from sugar production in 2019 is 297 g/t sugar and will be corrected accordingly for the next submission 2022.

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

- 2I Wood processing has been revised completely for the entire times series 1990-2018. On one hand the activity data has been changed from inhabitants to the more appropriate quantity of sawnwood. But also the emission factor has been changed for 2003.

8.1.3 3 Agriculture

8.1.3.1 Category-specific recalculations in 3B Manure management

- 3B: NH_3 and NO_x emissions from manure management were recalculated for the years 1990-2018. The share of nitrogen that is managed in anaerobic digesters was revised due to an error correction in the calculation model. The impact on overall emissions is negligible.
- 3B1a: The Tier 1 NMVOC emission factors of the EMEP/EEA guidebook – 2019 are now scaled with the Swiss dairy cattle weight (660 kg) yielding revised emission factors for the entire time period.

- 3B4e, 3B4f: Animal population data (AD) of horses (3B4e), mules and asses (3B4f) in 2018 were revised due to the new assessment methodology in the animal traffic database.

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

- 3Da2a, 3Da3: Animal population data for horses (3Da2a4e, 3Da34e), mules and asses (3Da2a4f, 3Da34f) were revised due to the new assessment methodology in the animal traffic database.
- 3Da1: NH_3 and NO_x emissions from inorganic nitrogen fertilisers were recalculated for the years 2008, 2009 and 2011-2018. Nitrogen inputs from urea-ammonia-nitrate fertilisers (AD) were revised. The impact on overall emissions is negligible.
- 3Da2c: NH_3 and NO_x emissions due to "N input from application of other organic fertilizers" were recalculated for the years 1996-2018. The amount of nitrogen input from co-substrates from agricultural biogas plants (AD) was recalculated due to a revision of the nitrogen content of these co-substrates. The impact on overall emissions is negligible.
- 3Da2c: NH_3 and NO_x emissions from other organic fertilisers applied to soils were recalculated for 2014-2018. Nitrogen Inputs from compost from industrial plants (AD) were revised (see recalculations in the waste sector). The impact on overall emissions is negligible.
- 3Da2c: NH_3 and NO_x emissions from other organic fertilisers applied to soils were recalculated for 1996-2018. Nitrogen Inputs from liquid and solid digestates from biogas plants were revised due to an error correction when interpolating data from gas losses. The impact on overall emissions is negligible.
- 3De: Acitivity data of summering pastures and cropland have been revised for 2016-2018 and 2018, respectively.

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 2021.

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

- 5B1 Composting industrial: Emissions of NH_3 and NMVOC have decreased for 2014-2018 due to a decrease in the AD "compost" by 2.3-4.2%. The amount of wood removed from total compost amounts before digestion/fermentation has erroneously not been referred to country scale and has thus been too low. This recalculation leads to decreasing emissions of 7-11 t NH_3 and 4-7 t NMVOC per annum for 2014-2018.
- 5B2 Anaerobic digestion at industrial biogas facilities: AD for the storage of organic waste, for fermentation and for the storage of solid and liquid digestate at industrial biogas plants have changed in 2018. An error in the interpolation of the factor accounting for the fractions of gas loss due to leakage from the fermenter, gas piping and overproduction was corrected. This influences the AD of the four subprocesses named above. Emissions of NH_3 and NMVOC decreased (<1%).

- 5B2 Anaerobic digestion at agricultural biogas facilities: AD for losses / leakage and for the storage of solid and liquid digestate at agricultural biogas plants have changed in the years 2014 and 2016-2018. An error in the interpolation of the factor accounting for the fractions of gas loss due to leakage from the fermenter, gas piping and overproduction was corrected. This influences the AD of the three subprocesses named above. Emissions of NH_3 and NMVOC decreased (<1%).

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

- 5C1 incineration of waste / sewage sludge: AD of the amount of sewage sludge incineration has changed from 2000 to 2018. As of 2000, new values for annual per capita produced sewage sludge are proposed (VBSA 2017) and multiplied with total population numbers. This leads to an overall decrease in AD by 15% to 20% and thus to decreasing emissions of NO_x, CO, NMVOC, NH_3, SO_2, PM10, PM2.5 and TSP. AD in the year 2018 decreased by additional 20% due to a correction of incorrectly reported amounts of incinerated sewage sludge.
- 5C1 incineration of waste / sewage sludge: Changes in all relevant air pollutant emission factors (Cd, CO, HCl, HF, Hg, NH_3, NMVOC, NO_x, Pb, PCDD/F, PM, PM10, PM2.5, SO_2, Zn) for incineration of sewage sludge from 2015 to 2018 are based on the evaluation of emission reports from three sewage sludge incineration plants in 2015 (VBSA 2017).
- 5C1bi Waste incineration and open burning of waste: EF of Hg and Cd exhaust have accidentaly been applied reversed from 1990 to 2018 for incineration of insulation materials from cables. They have now been assigned correctly.
- 5C2i, 5C2ii Waste incineration and open burning of waste: EF of Pb and Cd exhaust have been implemented for open burning of natural residues in agriculture and private households based on default Tier 2 EF in the EMEP/EEA Guidebook 2019.

8.1.4.4 Category-specific recalculations in 5D Wastewater handling

- 5D1 Domestic wastewater treatment: Changes in the AD "population" (new mode of estimation by SFSO 2020c) lead to changes in EF of NO_x, CO, NMVOC, and SO_2 from 1990 to 2010 since figures for emissions are taken from the statistics of renewable energy.
- 5D1 Domestic wastewater treatment: Changes in the AD "population" (new mode of estimation by SFSO 2020c) leads to annually decreasing emissions of NH_3 from 1990 to 2010 (<1%, <1 kt). EFs remain constant.
- 5D1 Domestic wastewater treatment: A decrease in the amount of gas input into the natural gas grid (<1%) from communal wastewater treatment plants reported in the national statistical report of renewable energy leads to a decrease in EFs of NO_x, CO, NMVOC, SO_2 from 2014 to 2016.
- 5D1 Domestic wastewater treatment: The combined recalculations in this sector yield the following changes in the respective air pollutant emissions from 1990 to 2018: Decreasing emissions of NO_x, CO, NH_3, NMVOC and SO_2 of less than 1% (<1 t a^{-1}).
- 5D2 Industrial wastewater treatment: Changes in the AD "population" (new mode of estimation by SFSO) lead to changes in EF of NO_x, CO, NMVOC, and SO_2 from 1990 to 2010. Figures for emissions are taken from the statistics of renewable energy and, therefore, remain unchanged.
- 5D2 Industrial wastewater treatment: A decrease in the amount of energy used in boilers for heat generation in industrial wastewater treatment plants (<1%), reported in the

national statistical report of renewable energy, leads to a decrease in the EF of NO_x, CO, NMVOC and SO_2 from 2013-2018.

- 5D2 Industrial wastewater treatment: The combined recalculations in this sector yield the following changes in the respective air pollutant emissions from 1990-2018: Annually decreasing emissions of NO_x, CO, NMVOC and SO_2 for 1990 - 2018 of < 1% (< 1 t).

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

There were no recalculations implemented in submission 2021.

8.1.5 6 Other

8.1.5.1 Recalculations in 6 Other emissions

- 6Aa Human emissions: Changes in the "number of people in retirement and nursing homes" for 2018 (update of statistics by SFSO) lead to a change in AD for human emissions.
- 6Aa Human emissions: AD of human respiration and human transpiration has changed for the years 1980 to 2010 due to a revised methodology for the Swiss population by SFSO (2020c).
- 6Ab: The activity data of livestock not covered by the agricultural census, so-called livestock outside agriculture, was recalculated for 1990-2018. Population data for the respective horses was revised due to a better census approach of the SFSO. Thus, also the implied emission factors of NO_x, NMVOC, NH_3, PM2.5, PM10 and TSP have changed.
- 6Ab Livestock outside agriculture: Activity data and emission factor of zoo animals have been overestimated by a factor of 1000 due to an error in the unit (new AD 140 t instead of old 140'000 t, EF 41'400 g/t instead of 41.4 g/t). This correction does not affect emissions. AD from 1980 to 1989 shows a slight increase due to a change in the slope of the interpolation function resulting from an improved estimate of AD for the year 1900.
- 6Ac: The activity data and NH_3 emission factor of other synthetic fertiliser have been revised.

8.1.5.2 Recalculations in 11B Forest fires

- 11B Forest fires: The time series of wildfires on forest land and grassland were recalculated with updated activity data (since 2015) and emission factors (since 1980). To calculate the emission factors, updated values for available fuel (biomass) were used by incorporating data of the latest national forest inventory 2015-2019 and new litter data from the Yasso07-model (FOEN 2021).
- 11B Forest fires: EF of Pb and Cd exhaust have been implemented for open burning of natural residues in forestry based on default Tier 2 EF in the EMEP/EEA Guidebook 2019.

8.1.5.3 Recalculations in 11C Other natural emissions

No recalculations were implemented in submission 2021.

8.1.6 Implications of recalculation for emission levels

Table 8-1 shows the effect of recalculations on the emission levels 2018 and 1990, based on the previous (2020) and latest (2021) NFR submission. In 2018, recalculations cause a higher emission level by at least 3% for NMVOC, BC, CO, PAH and HCB emissions. A decrease due to recalculations by at least 3% is observed for SO_x, PM2.5, PM10, Cd and PCDD/PCDF.

In 1990, recalculations cause an increase of more than 3% for BC emissions. A decrease by 3% or more is observed for Cd and PAH emissions.

Table 8-1: Recalculations: Implications for the emission levels 2018 and 1990. The values refer to the NFR submission 2020 (previous) and 2021 (latest). Differences are given in absolute and relative numbers for all pollutants.

Pollutant	Units	2018			
		previous subm. 2020	latest subm. 2021	difference (abs.)	difference (rel.) previous = 100%
NO_x	kt	66	65	-1.4	-2.1%
NMVOC	kt	80	82	2.4	3.0%
SO_x	kt	5.1	4.8	-0.32	-6.3%
NH_3	kt	55	55	-0.21	-0.39%
PM2.5	kt	6.8	6.4	-0.47	-6.9%
PM10	kt	15	14	-0.45	-3.1%
TSP	kt	29	28	-0.72	-2.5%
BC	kt	1.2	1.2	0.042	3.5%
CO	kt	157	165	7.8	5.0%
Pb	t	15	15	0.23	1.5%
Cd	t	1.2	0.70	-0.46	-40%
Hg	t	0.67	0.69	0.020	2.9%
PCDD/PCDF	g I-TEQ	20	16	-3.4	-17%
PAH (total)	t	2.6	2.7	0.086	3.3%
HCB	kg	0.34	0.35	0.017	5.1%
PCB	kg	480	481	481	0.069%

Pollutant	Units	1990			
		previous subm. 2020	latest subm. 2021	difference (abs.)	difference (rel.) previous = 100%
NO_x	kt	145	145	-0.060	-0.042%
NMVOC	kt	306	305	-0.93	-0.30%
SO_x	kt	37	37	0.031	0.086%
NH_3	kt	69	69	-0.062	-0.090%
PM2.5	kt	16	16	0.22	1.4%
PM10	kt	25	25	0.43	1.7%
TSP	kt	44	44	0.25	0.57%
BC	kt	5.1	5.7	0.58	11%
CO	kt	806	799	-7	-0.86%
Pb	t	379	380	2	0.42%
Cd	t	3.7	3.4	-0.26	-7.0%
Hg	t	6.4	6.4	0.018	0.28%
PCDD/PCDF	g I-TEQ	196	194	-2.6	-1.3%
PAH (total)	t	12	8.1	-3.9	-33%
HCB	kg	172	173	0.22	0.13%
PCB	kg	2'331	2'332	2'332	0.021%

The source categories with the most important recalculations implemented for main pollutants and PM2.5 in submission 2021 in terms of absolute emissions are listed in Table

8-2 and Table 8-3 for the years 2018 and 1990, respectively. The two most important recalculations for each year and each pollutant are the following:

NO_x

- For 2018 and 1990, the most important recalculation concerning NO_x is in category 1A3b road transportation. Activity data has been updated and biogenic fuels are newly treated in the same way as fossil fuels and allocated to the individual vehicle categories. Also, the statistical difference of biodiesel and bioethanol is now treated as "fuel tourism and statistical difference", similar as it is done for diesel and gasoline. This leads to recalculations in all source-categories of 1A3bi-1A3bii for all years 1990-2018.
- A mix of different recalculations leads to the change of NO_x emissions in source categories 1A1a (year 2018) and 1A2gviii (years 1990 and 2018). The change can be mainly attributed to the revised emissions factors of large automatic chip boilers, combined chip heat and power plants and plants for renewable waste from wood products. The country-specific emission factor model for wood energy was completely updated for all pollutants for the entire time period based on air pollution control and laboratory measurements and literature data.

NMVOC

- The main recalculations in 1990 and 2018 occur in category 2D3d Coating applications. Both coating aplications in contruction and on wood were updated based on information from industry association and expert judgement. Coating applications on wood includes now also glazes for wood preservation which have been reported so far under 2G Preservation of wood.
- Another important recalculation for the year 1990 (and less important for 2018) concerns category 2G Other product use. Preservation of wood has been revised completely for the entire time series and includes now all industrial wood preservation applications including creosote, while applications of glazes for wood preservation are reported under 2D3d Coating application, wood.
- In both years, 1990 and 2018, a recalculation in 3B1a Manure management – Dairy cattle is relevant for NMVOC emissions. The Tier 1 NMVOC emission factors for dairy cattle of the EMEP/EEA guidebook – 2019 are now scaled with the Swiss dairy cattle weight (660 kg) yielding revised emission factors for the entire time period.
- Another relevant recalculation for both years 1990 and 2018 concerns category 1A4bi Residential: Stationary. The complete revision of the country-specific emission factor model for wood energy yielded significantly higher NMVOC emission factors for all combustion installations. This has thus the highest impact on NMVOC emissions of small manually-operated installations in households.

SO_x

- The recalculations in SO_x emissions of source categories 1A1a, 1A2gviii, 1A4ai and 1A4bi in 1990 and 2018 are due to the complete revision of the country-specific emission factor model for wood energy. The revised SO_x emission factors are lower for all wood combustion installations except for for renewable waste from wood products, for which they are higher.
- For 1990, recalculations in source category 1A3b Road transportation lead to changes in SO_x emissions. Activity data has been updated and biogenic fuels are newly treated in the same way as fossil fuels and allocated to the individual vehicle categories. Also, the statistical difference of biodiesel and bioethanol is now treated as "fuel tourism and statistical difference", similar as it is done for diesel and gasoline.

NH_3

- The major recalculations for the year 2018 occur in the agriculture sector, in categories 3Da2c Other organic fertilisers applied to soils and 3B4e Manure management – Horses. For 3Da2c, NH_3 emissions from other organic fertilisers applied to soils were recalculated for 2014-2018. Nitrogen Inputs from compost from industrial plants (AD) were revised (see also recalculations in the waste sector). For 3B4e, NH_3 emissions from manure management of horses were recalculated for the year 2018. Animal population data (AD) was revised due to the new assessment methodology in the animal traffic database.
- Another relevant recalculation in 2018 concerns category 2H2 Food and beverages industry. This recalculation arose, however, to an error in data processing (see chapter 4.7.3) and is therefore not real. The error will be corrected in the next submission 2022.
- A recalculation that affects both years, 1990 and 2018, is in source category 6A Other. The activity data of livestock not covered by the agricultural census (6Ab lifestock outside), so-called livestock outside agriculture, was recalculated for 1990-2018. Population data for the respective horses was revised due to a better census approach of the SFSO.
- Another recalculation in 1A2f Stationary combustion in manufacturing industries and construction: Non-metallic minerals affects NH3 emissions in 2018. AD of sewage sludge used as alternative fuel in cement production has decreased by 18% (correction of reporting error).

PM2.5

- A mix of different recalculations leads to the change of PM2.5 emissions in source categories 1A1a, 1A2gviii, 1A4ai and 1A4bi. The change can be mainly attributed to the revised country-specific emission factor model for wood energy, which was completely updated for all pollutants for the entire time period based on air pollution control and laboratory measurements and literature data. The revised PM2.5 emission factors are mostly higher for 1990 and lower for 2018.
- Furthermore, a recalculation in source category 2I Wood processing affects PM2.5 emissions in the years 1990 and 2018. 2I Wood processing has been revised completely for the entire times series 1990-2018. On one hand the activity data has been changed from inhabitants to the more appropriate quantity of sawnwood. But also the emission factor has been changed for 2003.

Table 8-2: NFR categories with most important implications of recalculations on emission levels in 2018 in terms of absolute differences for the main pollutants and PM2.5. The values refer to the NFR submission 2020 and 2021. 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	-1.7	2D3d_Coating applications	1.2	1A2gviii_Stationary combustion in manufacturing industries and construction: Other	-0.23	3Da2c_Other organic fertilisers applied to soils (including compost)	-0.08	1A4ai_Commercial/Institutional: Stationary	-0.16
1A3bi_Road transport: Passenger cars	0.6	3B1a_Manure management - Dairy cattle	0.8	1A4ai_Commercial/Institutional: Stationary	-0.042	3B4e_Manure management - Horses	-0.07	1A2gviii_Stationary combustion in manufacturing industries and construction: Other	-0.14
1A2gviii_Stationary combustion in manufacturing industries and construction: Other	-0.23	1A4bi_Residential: Stationary	0.7	1A4bi_Residential: Stationary	-0.039	2H2_Food and beverages industry	-0.04	1A4bi_Residential: Stationary	-0.12
1A1a_Public electricity and heat production	-0.21	2G_Other product use	-0.21	1A1a_Public electricity and heat production	-0.027	6A_Other (included in national total for entire territory)	0.019	2I_Wood processing	-0.06
1A3bii_Road transport: Light duty vehicles	0.19	3De_Cultivated crops	0.0003	1A2f_Stationary combustion in manufacturing industries and construction: Non-metallic minerals	0.021	1A2f_Stationary combustion in manufacturing industries and construction: Non-metallic minerals	-0.016	1A1a_Public electricity and heat production	-0.03

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 2020 and 2021. 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	0.4	2D3d_Coating applications	-3.6	1A2gviii_Stationary combustion in manufacturing industries and construction: Other	0.03	6A_Other	-0.13	1A4bi_Residential: Stationary	0.15
1A3bi_Road transport: Passenger cars	-0.3	2G_Other product use	1.4	1A3biii_Road transport: Heavy duty vehicles and buses	0.02	1A4bi_Residential: Stationary	0.06	1A4ai_Commercial/Institutional: Stationary	0.06
1A2gviii_Stationary combustion in manufacturing industries and construction: Other	-0.2	3B1a_Manure management - Dairy cattle	1.0	1A3bi_Road transport: Passenger cars	-0.02	1A2gviii_Stationary combustion in manufacturing industries and construction: Other	0.01	1A2gviii_Stationary combustion in manufacturing industries and construction: Other	0.02
1A4bi_Residential: Stationary	0.08	1A4bi_Residential: Stationary	0.9	1A1a_Public electricity and heat production	0.02	1A4ai_Commercial/Institutional: Stationary	0.007	1A1a_Public electricity and heat production	0.02
1A3bii_Road transport: Light duty vehicles	-0.02	2D3g_Chemical products	-0.2	1A4bi_Residential: Stationary	-0.01	1A4ci_Agriculture/Forestry/Fishing: Stationary	0.002	2I_Wood processing	-0.02

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

The emission trends 1990–2018 are affected through the recalculations differently for the main pollutants and PM2.5. The most significant change caused by recalculations occurred for the trend of PM2.5 emissions, where the decreasing trend is 3% lower in the latest compared to the previous submission. For NMVOC emissions, the trend is slightly more decreasing (1% more decrease). On the contrary, for NO_x, SO_x and NH_3, he decreasing trend is slightly weaker (1% less decrease each).

Table 8-4: Recalculations: Implications for the emission trends between 1990 and 2018 for the main pollutants. The values refer to the NFR submission 2020 and 2021.

Pollutant	Trend 1990-2018 (1990 = 100%)	
	previous subm. 2020	latest subm. 2021
	%	%
NO_x	46	45
NMVOC	26	27
SO_x	14	13
NH_3	80	79
PM2.5	42	39

8.2 Planned improvements

The following improvements are planned for the submission 2021:

General no planned improvements

Energy (stationary)

- 1B2c: As recommended from the Expert Review Team (ERT) in the recent Stage 3 review 2020, Switzerland will revise the NO_x, CO, NMVOC and SO_x emissions from flaring in refineries and add the missing emission estimates for PM10, PM2.5, BC, Pb, Cd and Hg for this source category.

Energy (mobile) no planned improvements

IPPU

- 2D3 and 2G: A comprehensive update of all NMVOC emissions from solvent and product use is on-going.

Agriculture

- 3B: Since the data basis of the NMVOC emission factors proposed in the EMEP/EEA Guidebook 2016 (EMEP/EEA 2016) seems to be rather unclear (Bühler and Kupper 2018) a study was launched in 2018 in order to measure NMVOC emissions from dairy cattle with and without silage feeding in an experimental housing during summer, winter and transitional season.
- The NH_3 emission inventory for the submission 2022 will be prepared with the revised version 2021 of the AGRAMMON model and will be based on the new representative survey on farm and manure management performed at the end of 2019. Thus, it will be possible to intrapolate the emission NH_3 inventory beteween 2015 and 2019 and to extrapolate it after 2019 taking into account up-to-date data on farm and manure management.
- 3B, 3Da2a, 3Da3: A comparison of the country-specific Tier 3 NH_3 emission factors with Tier 2 emission factors according to the EMEP/EEA Guidebook 2019 (EMEP/EEA 2019) is under way (as suggested in the Stage 3 in-depth review of emission inventories submitted under the UNECE LRTAP Convention in summer 2020). This will also comprise a comparison of NH_3 emissions and N flows according to the Agrammon tool and the new TFEIP N-flow spreadsheet tool (www.eea.europa.eu). The report will also be shared with the TFEIP chair persons.
- 3B, 3Da2a, 3Da3: A new uncertainty analysis for NH_3 emissions from livestock husbandry and manure management will be available for the submission 2022.

Waste no planned improvements

Other and Natural no planned improvements

9 Emission projections 2020–2030

9.1 Comments on projections

Two scenarios are presented in this chapter, “With Measures (WM)” and “With Additional Measures (WAM)”. Both are based on the energy consumption of the Energy Perspectives 2050 (Prognos 2012a) and on further assumptions for the activity data. The emission projections of air pollutants in Switzerland have been fully revised in the course of submission 2014. The data for the energy sector are in accordance with the scenarios of the Energy Perspectives 2050 (Prognos 2012a) from 2030 onwards. For the sectors IPPU and Waste the latest perspectives for Switzerland’s inhabitants are integrated (SFSO 2020p), and for the agricultural sector, independent scenarios were developed (according to Swiss Confederation 2017 for WM and FOAG 2011 for WAM).

Note that all emission data for the projections refer to the “national total for compliance” assessment based on fuel used principle, which deviate from the “national total” for the entire territory based on fuel sold (for details see chapter 1.4.2 and 3.1.6.1. The submitted emission projections templates 2A and 2B therefore base on the fuel sold principle, which is not congruent with the Swiss “national total for compliance”.

In the IIR on hand the air pollutant emissions in chps. 9.3 to 9.6 are shown for the “With Measures (WM)” scenario only.

9.2 Assumptions for projections for two scenarios (WM and WAM)

9.2.1 Emission factors

Overall, the emission factors are determined independently from the WM and WAM scenario and thus are the same in both.

Emission factors for the sectors 1 Energy are mainly based on available emission measurements and assumptions about their future development. Where no such assumptions can be made, the emission factors are kept constant.

Emission factors for the sector 1 Energy are taken from the following reports:

- Fuel combustion / heating systems: Internal emission database EMIS (2021)
- Road transportation: EMEP/EEA (2019), INFRAS (2019)
- Domestic aviation: EMEP/EEA (2019), FOCA (2006, 2006a, 2007a, 2008-2020)
- Non-road vehicles: EMEP/EEA (2019), FOEN (2015j), INFRAS (2015a)

Emission factors for the sector 2 Industrial processes and product use are based on available emission measurements, industry data, EMEP/EEA Guidebook 2019 (EMEP/EEA 2019) and assumptions about their future development. Where no such assumption can be made, the emission factors are kept constant.

Emission factors for the sector 3 Agriculture are derived mainly from the AGRAMMON model (Kupper et al. 2018) and EMEP/EEA Guidebook 2019 (EMEP/EEA 2019) and are kept constant as in 2015 due to uncertain assumptions about the evolution of production parameters (Kupper et al. 2018).

Emission factors for sector 5 Waste and sector 6 Other are taken from various literature sources. Details about respective data sources are provided in sector chapters 9.3- 9.6.

9.2.2 Activity data

9.2.2.1 Two scenarios WM and WAM

The projections of emissions of air pollutants in Switzerland have been fully revised in the course of submission 2014. In order to provide consistent scenarios for shaping future energy and climate policies, the energy scenarios of Energy Perspectives 2050 (Prognos 2012a) are used as framework for the projections presented here. For the WM scenario, updated EF and AD are applied for 1A3b Road transport and for non-road vehicles and machines. Note that since one of the two petroleum refineries in Switzerland ceased operation in 2015, the corresponding projections were revised accordingly. Independent scenarios were developed for the agriculture sector.

For the projections of the CLRTAP Inventory requiring a scenario “With Measures (WM)” (ECE 2014a) the scenario “Politische Massnahmen (POM)” - “Political Measures” - from the Energy Perspectives 2050 (Prognos 2012a) is used. It is based on the effects of a package of measures which was in the political process of the Parliament. A second scenario “With Additional Measures” (WAM) is required by CLRTAP (ECE 2014a). For this purpose, the scenario “Neue Energiepolitik (NEP)” - “New Energy Policy” (NEP)” – from Prognos (2012a) is used. It accounts for the effects of additional measures compared to the “with measures (WM)” scenario.

The energy scenarios of Prognos (2012a) are all based on energy consumption data from 2010 onwards. That means that for the period 2011-2019, statistical and projected data exist. The statistical data available between 2010 and 2019 (Swiss overall energy statistics) are used to calculate the emissions as reported in the preceeding sectoral chapters. Data from 2020 to 2029 is linearly interpolated between statistical data 2019 and projected data 2030, and from 2030 onwards, the original projections of Prognos (2012a) are used. Note that since one of the two petroleum refineries in Switzerland ceased operation in 2015, the corresponding projections were revised accordingly (see chp. 3.2.2.2.2).

Table 9-1 provides an overview of the respective sectoral background scenarios used for WM and WAM scenarios. The underlying assumptions are discussed hereinafter.

Table 9-1: Overview of sectoral underlying detailed scenarios in the WM and WAM scenario.

Sector	Scenario	Sectoral scenario	Reference
1 Energy	WM	Energy scenario "political measures", electricity generation option C&E from Energy Perspectives with updates concerning number of refineries and projected developpement in road transportation.	Prognos (2012a) Prognos/INFRAS/TEP/Ecoplan (2021) and Swiss Confederation (2021) EPFL (2017)
	WAM	Energy scenario "new energy policy", electricity generation option E from Energy Perspectives with updated number of refineries.	Prognos (2012a) INFRAS (2017) EPFL (2017)
2 IPPU	WM = WAM	Scenario based on key parameters of the Energy Perspectives but updated with new national reference scenario for popoulation ("A-00-2020")	Prognos (2012a) SFSO (2020p)
3 Agriculture	WM	Agricultural policy 2018-2021	Swiss Confederation (2017)
	WAM	Climate strategy for agriculture	FOAG (2011)
5 Waste	WM	Scenario based on key parameters of the Energy Perspectives but updated with new national reference scenario for popoulation ("A-00-2020")	Prognos (2012a) SFSO (2020p)
	WAM	Energy scenario "new energy policy", electricity generation option E from Energy Perspectives (for 5 B 2 Anaerobic Digestion at Biogas Facilities)	Prognos (2012a)

9.2.2.2 WM scenario

A detailed description of the WM scenario can be found in Switzerland’s 7th National Communication under the UNFCCC - therein named as “With Existing Measures (WEM)” (FOEN 2017d). Table 9-2 lists the key factors underlying the WM scenario and their assumed development between 2010 and 2030. All effects of enforced and already implemented measures to improve energy efficiency and to reduce energy consumption are accounted for in this scenario. A relevant assumption used for the projections under the WM scenario is that population increases further by 12% between 2010 and 2030. This is one of the factors leading to increases in energy reference area and transport. GDP is also assumed to increase considerably over the coming decades. Finally, also oil and gas prices are expected to increase by 28% and 95% respectively until 2030.

Table 9-2: Trend of underlying key factors of the WM (WEM) scenario between 2010 and 2030 (SFSO 2020c and SFSO 2020p for population, Prognos 2012a, INFRAS 2017 for vehicle km)

Indicator	**2010**	**2015**	**2020**	**2025**	**2030**	**2010-2030**
Population (million)	7.83	8.28	8.65	9.02	9.39	20%
GDP (prices 2010, billion CHF)	547	584	618	646	671	23%
Oil price (prices 2010, CHF/barrel)	79.3	93.7	98.3	101	102	28%
Gas price (prices 2010, CHF/tonne)	321	518	561	598	627	95%
Heating degree days	3'585	3'335	3'244	3'157	3'064	-15%
Cooling degree days	153	169	186	203	219	43%
Energy reference area (million m^2)	709	754	799	836	863	22%
Passenger cars (million vehicle km)	52'066	56'620	59'633	61'749	63'691	22%

Please note that the population data for the WM (WEM) scenario do not match the official statistics which are generally used within the air pollutant (and greenhouse gas) inventory, since the Energy Perspectives 2050 (Prognos 2012a) are based on a specific population growth scenario defined by the Federal Statistical Office. These specific numbers are only used for the emission projections 2020-2030 and are similar to the official statistics. For further details, see Prognos (2012a).

For each sector, further specific methods and respective assumptions apply that are described below in more detail:

Sector 1 Energy

Energy consumption in the WEM scenario is based on the scenario “political measures”, option C&E (central fossil “C” and renewable “E” electricity generation to replace nuclear power generation) of the most recent energy scenarios (Prognos 2012a). The energy scenarios 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 (Prognos 2012a). Figure 9-1 depicts the total energy demand in recent years and as projected in the WEM scenario up to 2030 for each source category in the energy sector.

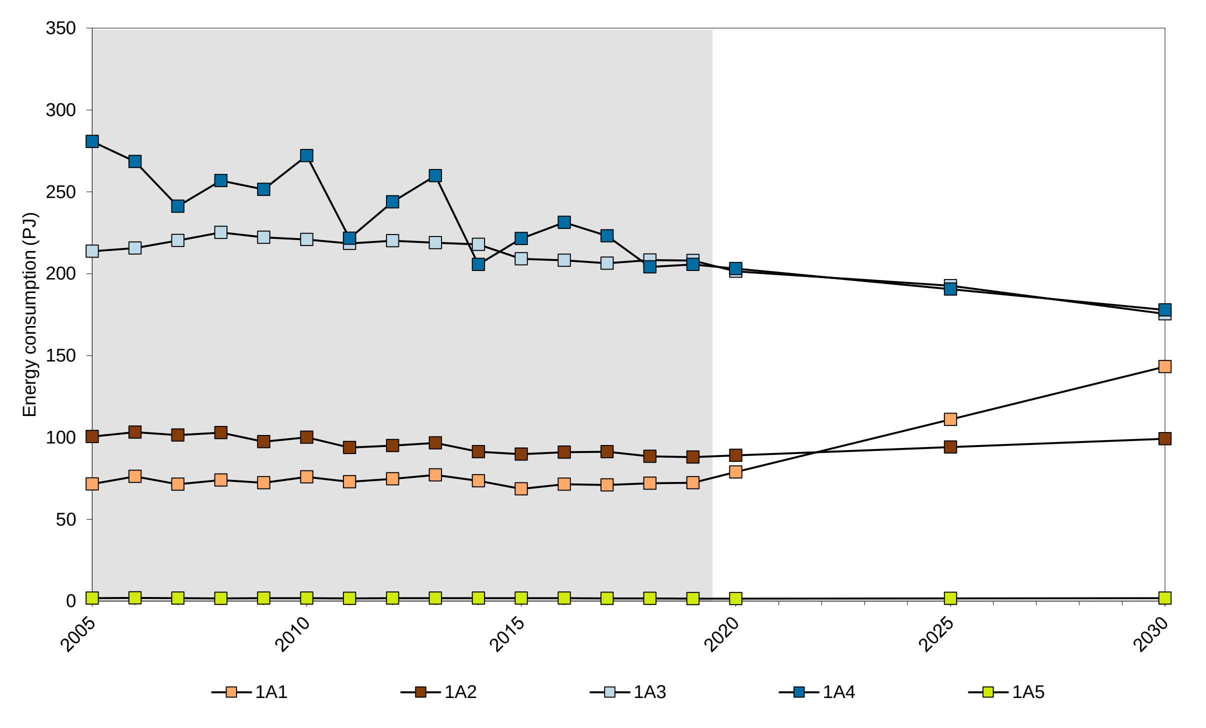


Figure 9-1: Energy demand in Switzerland as projected in the WM (WEM) scenario in source categories 1A1 – 1A5 of the sector 1 Energy.

Energy demand in 1A1 Energy industries is mainly caused by waste generation. It is assumed to remain at the current levels per capita. Due to population growth, the amount of waste is increasing leading to growing energy production in this source-category based on waste incineration. Another relevant assumption under source category 1A1 is that wood energy consumption will strongly increase (about 6-times higher wood energy consumption for electricity generation and about 3-times higher wood energy consumption with CHP in 2030 compared to 2010). This assumption was based on the effects of a package of measures which was part of the political process within the Parliament during the time the projections were established. Note that since one of the two petroleum refineries in Switzerland ceased operation in 2015, the corresponding projections were revised accordingly (see chp. 3.2.2.2.2).

Energy demand in 1A2 Manufacturing industries and construction is based on 164 industrial production processes and 64 building and facility management processes, 12 energy sources and 12 industry branches. Energy use is then projected based on activity data for the branches and specific energy use per process. The projected increase of energy demand also depends on the use of biogas and sewage gas in boilers and engines, which is reported under 1A2 Manufacturing industries and construction. Note that in the past years it became visible that the projected wood energy consumption in industry for 2030 is probably too low. Accordingly, the development between 2019 and 2030 shows a decrease (since the consumption 2019 is larger than the projected consumption 2030). However, under actual circumstances, a decrease of wood energy consumption between 2019 and 2030 – as it is estimated based on the projections made in 2012 – is not realistic.

For the transport sector, parameters such as tonne-kilometers, passenger-kilometers, vehicle-kilometers, 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 of heating, hot water, air conditioning, lighting, office appliances, engines and other uses, split for 9 different energy sources and 7 different 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.

The main measures and underlying assumptions in the energy scenario are:

- Building renovation program: continuation and intensification of the current program (Annual funds CHF 300 million in 2014, CHF 600 million from 2015)
- Building codes: continuously rising building standards, along with technological progress. Energy consumption for new buildings nearing zero by 2020
- CO_2 levy on fossil combustible fuels, such as gas oil and natural gas: e.g. gas oil 2016: 84 CHF/tonne.
- Overall substitution of gas oil by natural gas continues and gasoline will also partly be substituted by diesel oil.
- CO_2 emission standards for new vehicles: 2015: 130 g/km; 2020: 95 g/km; further reduction towards 35 g/km in 2050.
- Competitive call for tender for energy efficiency measures (in particular electricity) in industry, trades and services with an annual budget of CHF 100 million from 2015.
- Continuation of the program SwissEnergy (provision of incentives for energy saving measures) with moderately increasing funds.
- Feed-in remuneration at cost for electricity production from renewable energy sources.

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 goods 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 are represented in Prognos/INFRAS/TEP/Ecoplan (2021) and Swiss Confederation (2021).
- Non-road vehicles: 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). In addition, CNG in non-road has been replaced with LPG, 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 Energy Perspectives 2050 (Prognos 2012a). In particular, sectoral indices of production volumes of cement (2A1 Cement production, 2A2 Lime production and 2A5a Plaster production), food (all 2H2 source categories except 2H2 Bread production), metals (2C1 Iron and steel production and 2C7a Non-ferrous metal foundries) and so-called other (2H1 Chipboard and fibreboard production) have been used. For other processes, such as production of basic chemicals of source category 2B Chemical industry, the provided increasing 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 or production volume indices (Prognos 2012a). However, the Energy Perspectives 2050 provide no appropriate key parameters or measures for the majority of source categories and therefore, the estimates based on information from industry, industry associations or expert judgement are continuously applied.

The main measure is:

- All indices of production volume applied in sector 2 Industrial processes and product use will decrease by about 10% to 50% between 2010 and 2050, based on the assumptions for industrial production used in the energy perspectives 2050 (Prognos 2012a). For the indices of metal and food industry still a slight increase is projected until 2020. Afterwards they decline as well.

Sector 3 Agriculture

The basis of the WM (WEM) scenario is the continuation of the agricultural policy 2018–2021 (Swiss Confederation 2017). Möhring et al. (2018) elaborated respective projections of animal populations, milk yields, cropping areas and fertiliser use. In general, no major changes were implemented compared to the previous agricultural policy (2014–2017, Swiss Confederation 2013). Projections are based on data and information available by 2018 on the development of the macroeconomical variables (gross domestic product, population, crop yields) and the expected development of the domestic producer prices. 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 increases. Dairy cows are projected to exhibit a further increase in milk yield. Beyond 2027 (the time horizon of Möhring et al. 2018) 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 2017.
- 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 slightly increase. 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 by 8.1 per cent between 2017 and 2027 (Möhring et al., 2018). 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.

9.2.2.3 WAM scenario

Beside the WM (WEM) scenario an additional scenario called “with additional measures” (WAM) was developed in the energy scenarios by Prognos (2012a). A detailed description of the WAM scenario can be found in Switzerland’s 7th National Communication under the UNFCCC (FOEN 2017d). The scenario is a long-term target scenario that follows the strategic orientation in key policy areas (FOEN 2017d, FOAG 2011). However, the scenario is not based on concrete policies and measures but rather assumes that policies and measures are developed and implemented in due time in order to reach the strategic goals.

The following assumptions are made in the WAM scenario:

- Energy consumption for the WAM scenario is based on the scenario “New Energy Policy”, option E of the latest energy scenarios (Prognos 2012a). This scenario assumes that efforts are made to curb GHG emissions (1-1.5 t CO_2 per capita in 2050) and thus also air pollutant emissions are affected. Overall, the scenario relies on substantial energy efficiency gains in all sectors. When compared to the WM (WEM) scenario, differences in the WAM scenario mainly occur due to efficiency improvements. Figure 9-2 depicts the total energy demand in recent years and as projected in the WAM scenario up to 2030 for each source category in the energy sector.
- Transport requirements are projected to increase more moderately compared to the WM (WEM) scenario. The projections are based on Prognos/INFRAS/TEP/Ecoplan (2021) and Swiss Confederation (2021).
- Assumptions for emissions from sector 2 Industrial processes and product use are the same as in the WM (WEM) scenario.
- The WAM scenario in sector 3 Agriculture is consistent with the long-term target in this sector as stated in the Climate Strategy (FOAG 2011). Up to 2027, emissions follow the same course as in the WM (WEM) scenario. After 2027 consumption of commercial fertilisers is projected to decline by 15 per cent until 2050 due to further promotion of nitrogen use efficiency. Additionally, livestock populations are projected to decrease until overall agricultural greenhouse gas emissions reach the minimum reduction target set in the climate strategy for agriculture in 2050 (FOAG, 2011), i.e. one third of the level of 1990. Otherwise, the same projections are used as in the WM (WEM) scenario for the years after 2027.
- Finally, the projections in the waste sector for the WAM scenario are the same as for the WM (WEM) scenario. No specific additional policies and measures are currently under consideration.

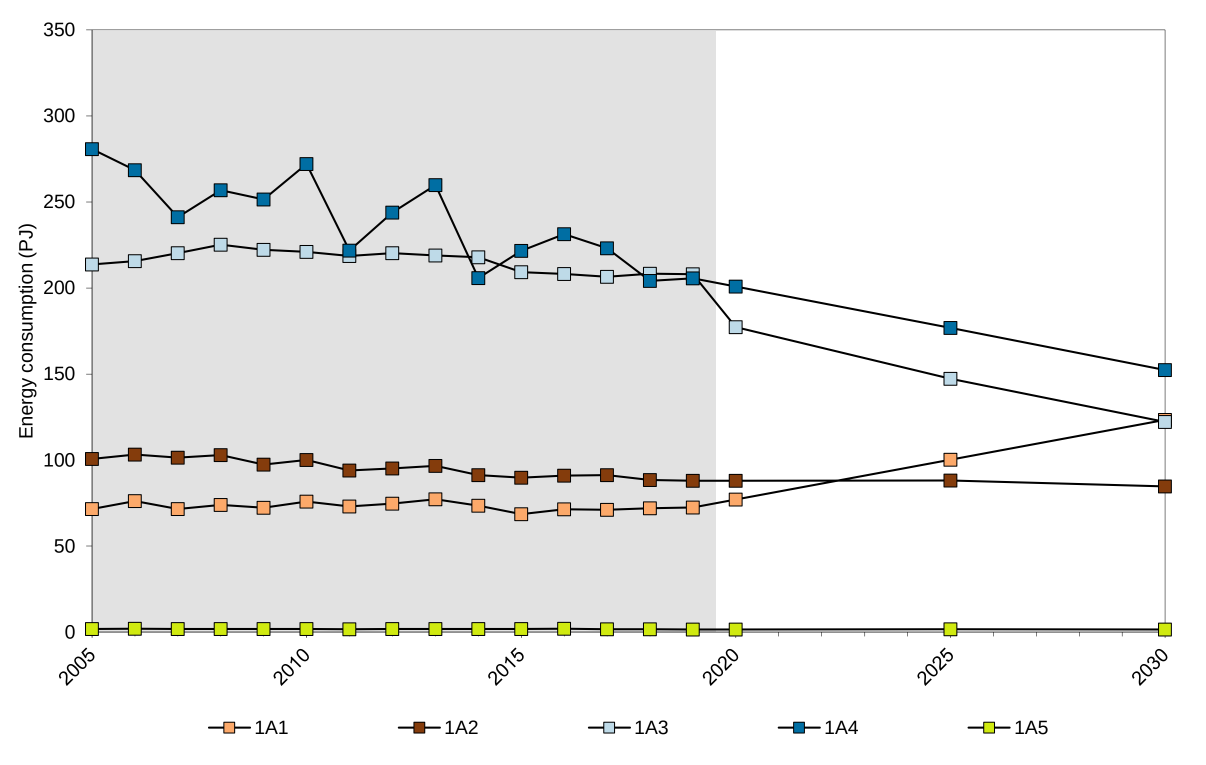


Figure 9-2: Energy demand in Switzerland as projected in the WAM scenario in source categories 1A1 – 1A5 of sector 1 Energy.

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 decline between 2005 and 2030 (Figure 9-3). NH_3 emissions are projected to be only slightly below 2005 levels in 2030. The following developments are expected for the time period 2020-2030:

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 and in-use compliance under real driving conditions are relevant drivers. For 1A2 Manufacturing industry and construction and 1A4 Other sectors, reduced emissions from domestic and commercial heating, higher shares of solar heating and heat pumps and increased use of eco-grade gas oil are expected.

NMVOC emissions are projected to slightly increase compared to the current levels. The main driver for the overall increase is sector 5 Waste. This increase is based on the assumption that the production of biogas will strongly increase, in particular anaerobic digestion at biogas facilities under 5B2. Furthermore, population growth and, to some extent, the stagnation of the effects of the VOC incentive tax (Swiss Confederation 1997) will lead to an increase of NMVOC emissions in sector 2 IPPU. In the energy sector, however, NMVOC emissions are projected to continue their decrease.

The SO_x emissions are projected to decrease until 2025 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 2023 onwards. The slight increase in SO_x emissions between 2025 and 2030 is due to a large projected wood energy consumption as well as a projected reintroduction of residual fuel oil for electricity production (which currently seems to be rather unrealistic).

NH_3 emissions are projected to remain more or less on constant, but slightly higher level than in 2019 (mainly depending on animal numbers, which are projected to decrease only slightly up to 2027 and remain constant afterwards).

Concerning CO emissions, a continuous decreasing trend is projected mainly because of improved emission abatement technology for road vehicles, better insulation of buildings and a higher share of solar heating and heat pumps.

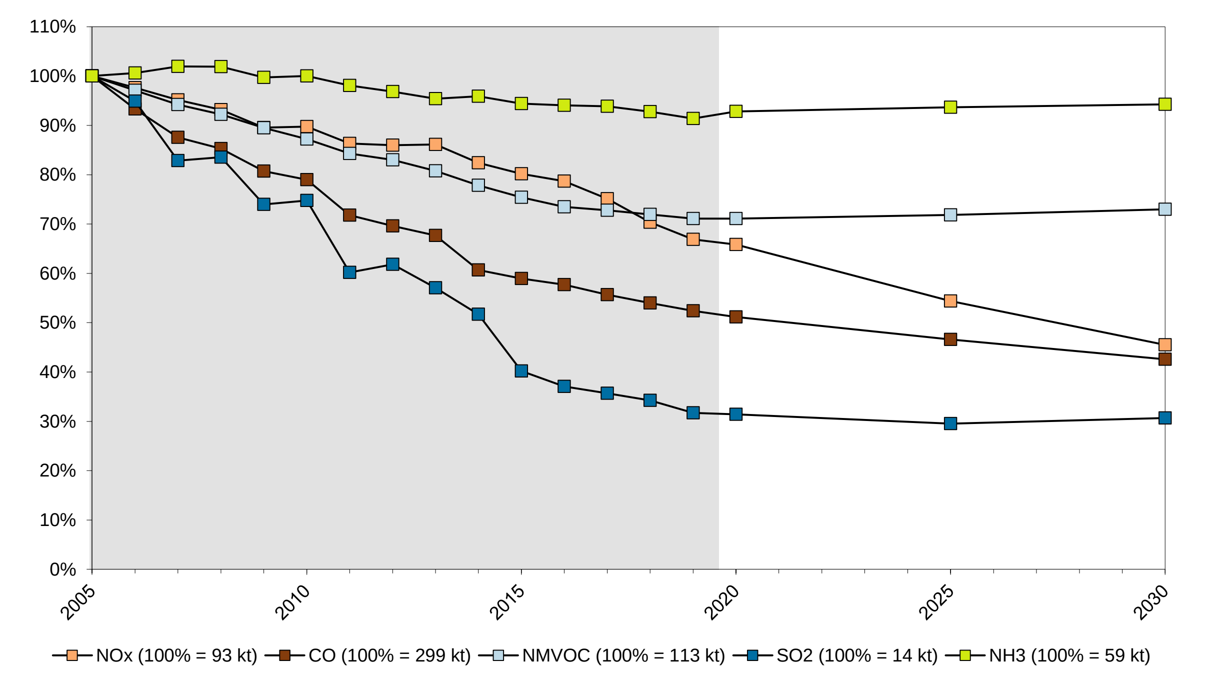


Figure 9-3: Relative trends for the total emissions of main air pollutants and CO in Switzerland as projected in the WM (WEM) scenario. 100% corresponds to the 2005 levels (base year of the Gothenburg Protocol).

Table 9-3: Main air pollutants and CO: Total emissions of the WM (WEM) projections until 2030 in kt.

Year	NO_x	NMVOC	SO_2	NH_3	CO
	kt	kt	kt	kt	kt
2005	93	113	14	59	299
2010	83	99	10	59	236
2011	80	96	8.4	58	214
2012	80	94	8.7	57	208
2013	80	92	8.0	56	202
2014	76	88	7.2	56	181
2015	74	85	5.6	56	176
2016	73	83	5.2	55	172
2017	70	82	5.0	55	166
2018	65	82	4.8	55	161
2019	62	81	4.4	54	157
2020	61	81	4.4	55	153
2025	50	81	4.1	55	139
2030	42	83	4.3	55	127
2019 to 2030 (%)	-32%	3%	-3%	3%	-19%

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 Table 9-4). The most significant reductions happen in source category 1A Fuel combustion – especially in 1A3b with the largest absolute contribution and the strongest relative decrease – but also in source categories 1A2 and 1A4.

Reductions under 1A are expected to be achieved by improved emission abatement technology and by improved in-use compliance under real driving conditions for road vehicles (source category 1A3b, triggered by the Euro 6/VI standards and a reduction of fuel consumption (see Figure 9-1)) as well as by measures related to domestic and commercial heating such as better insulation of buildings, higher share of solar heating and heat pumps or increased use of eco-grade gas oil (with low sulphur and nitrogen content; source category 1A4. In source category 1A2, reductions of production volumes (e.g. cement industry and other non-metallic minerals) also contribute to the overall projected emission reduction until 2030. The emission increase of 1A1 is caused by growing amount of waste incinerated and a large projected wood energy consumption for electricity production. 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. Similarly, in sector 3 Agriculture, emissions are expected to be lower in 2030 than in 2005, but to slightly increase compared to current levels. In sector 5 Waste, a continuous increase in emissions is expected until 2030 compared to 2005 (mainly due to population growth). However, this trend has a minimal impact on total emissions in absolute terms. In sector 6 Other, emissions are on a very low level and are expected to slighty increase until 2030 compared to 2005.

Table 9-4: WM (WEM) projections: Relative trends of NO_x emissions per sector (2005 represents 100%).

NO_x emissions	2005	2019	2020	2025	2030
	kt	%	%		
1 Energy	88	66%	64%	52%	43%
1A Fuel combustion	88	66%	65%	52%	43%
1A1 Energy industries	2.9	82%	92%	144%	194%
1A2 Manufacturing industries and constr.	14	57%	55%	51%	49%
1A3 Transport	54	70%	68%	49%	33%
1A4 Other sectors	16	58%	56%	49%	44%
1A5 Other (Military)	0.60	65%	64%	65%	67%
1B Fugitive emissions from fuels	0.29	0.6%	0.6%	0.5%	0.5%
2 IPPU	0.32	74%	75%	79%	82%
3 Agriculture	3.9	94%	97%	97%	97%
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.16	90%	91%	96%	102%
6 Other	0.092	106%	109%	109%	108%
National total	93	67%	66%	54%	45%

9.3.2 Projections for NMVOC

The bulk of NMVOC emission reductions has been achieved until 2016, and a minor increase of emissions is expected from 2019 up to 2030 (see Table 9-3 and Table 9-5). The most important source for NMVOC emissions is sector 2 IPPU. However, the main driver for the overall increase is sector 5 Waste.

The increase in the waste sector is based on the assumption that the production of biogas will strongly increase, in particular anaerobic digestion at biogas facilities under 5B2. Another driver for the increase is sector 2 IPPU, where a slight increase of emissions is projected due to population growth and, to some extent, due to stagnating effects of the VOC incentive tax in 2000 (Swiss Confederation 1997). NMVOC emission reductions are projected to happen in 1A Fuel combustion. A substantial reduction will take place in 1A3b caused by improved emission abatement technology for road vehicles and a reduction of fuel consumption (see Figure 9-1). In sector 3 Agriculture, emissions are expected to remain about constant (mainly due to the development of population numbers of cattle). In sector 6 Other, emissions have increased between 2005 and 2015, but have stabilized afterwards and are expected to remain relatively constant at the current (very low) level until 2030.

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

NMVOC emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	kt	%		%	
1 Energy	41	41%	40%	34%	30%
1A Fuel combustion	35	41%	39%	34%	29%
1A1 Energy industries	0.22	72%	75%	90%	105%
1A2 Manufacturing industries and constr.	2.0	47%	45%	43%	42%
1A3 Transport	23	37%	35%	28%	23%
1A4 Other sectors	10.5	46%	46%	42%	39%
1A5 Other (Military)	0.11	57%	57%	58%	60%
1B Fugitive emissions from fuels	5.4	44%	42%	38%	33%
2 IPPU	53	83%	83%	85%	86%
3 Agriculture	19	98%	99%	99%	99%
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.76	200%	255%	532%	808%
6 Other	0.19	117%	114%	113%	114%
National total	113	71%	71%	72%	73%

9.3.3 Projections for SO_x

The decreasing trend of SO_x emissions is expected to continue until 2025, thereafter is a slight increase between 2025 and 2030 (see Table 9-6). 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 2023 onwards and a reduced use of gas oil because of better insulation of buildings, a higher share of solar heating and heat pumps as well as a fuel switch to natural gas (revised CO_2 law, Swiss Confederation 2011). The slight increase in SO_x emissions between 2025 and 2030 is due to a large projected wood energy consumption as well as a projected reintroduction of residual fuel oil for electricity production (which seems to be rather unrealistic). Only marginal emission reductions or stable levels are projected for all other source categories.

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

SO_x emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	kt	%		%	
1 Energy	13	28%	27%	26%	27%
1A Fuel combustion	12	29%	28%	27%	28%
1A1 Energy industries	1.7	16%	21%	44%	65%
1A2 Manufacturing industries and constr.	4.1	47%	46%	43%	41%
1A3 Transport	0.21	121%	120%	116%	111%
1A4 Other sectors	6.3	17%	15%	7.7%	6.9%
1A5 Other (Military)	0.037	80%	82%	88%	95%
1B Fugitive emissions from fuels	0.51	3.2%	3.1%	2.8%	2.5%
2 IPPU	1.1	76%	74%	70%	67%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.063	110%	111%	112%	114%
6 Other	0.011	101%	101%	101%	101%
National total	14	32%	31%	30%	31%

9.3.4 Projections for NH_3

Emission projections for NH_3 are highly dependend on sector 3 Agriculture. Overall, NH_3 emissions are expected to be more or less constant between 2019 and 2030, but on a slightly higher level in 2030 than in 2019.

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 (Peter at al. 2010, Zimmermann et al. 2011). Projections are calculated with unchanged emission factors (except for dairy cattle, see chapter 9.2) resulting for different livestock categories on the basis of the detailed farm survey carried out in 2015 (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, 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. Agricultural NH_3 emissions between 2019 and 2030 are expected to remain about constant 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 decreasing trends for sectors 1 Energy (due to new low emission vehicles and machinery) and 2 Industrial processes and product use. An increase compared to 2005 level 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 relatively constant at the current level until 2030.

Table 9-7: WM (WEM) projections: Relative trends of NH_3 emissions per sector (2005 represents 100%).

NH_3 emissions	2005	2019	2020	2025	2030
	kt	%	%		
1 Energy	3.9	35%	34%	32%	32%
1A Fuel combustion	3.9	35%	34%	32%	32%
1A1 Energy industries	0.026	135%	166%	320%	473%
1A2 Manufacturing industries and constr.	0.19	106%	107%	101%	94%
1A3 Transport	3.5	29%	27%	24%	24%
1A4 Other sectors	0.16	74%	74%	72%	68%
1A5 Other (Military)	0.000039	104%	103%	103%	103%
1B Fugitive emissions from fuels	NA	NA	NA	NA	NA
2 IPPU	0.35	36%	33%	32%	31%
3 Agriculture	53	95%	97%	97%	97%
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.93	98%	108%	154%	203%
6 Other	0.89	112%	112%	112%	113%
National total	59	91%	93%	94%	94%

9.3.5 Projections for CO

For the next years, a continuous decreasing trend for total CO emissions is projected (see Figure 9-4 and Table 9-8).

Similar to NO_x emissions, this reduction should be achieved by improved emission abatement technology for road vehicles (triggered by the Euro 6/VI standards and a reduction of fuel consumption (see Figure 9-1)) and for domestic and commercial heating such as better insulation of buildings, higher share of solar heating and heat pumps. Accordingly, the bulk of emission reductions occur in 1A Fuel combustion, particularly in 1A3 Transport as well as in in source category 1A4 Other sectors (see chp. 2). An increase in emissions can be observed in 1A1 Energy industries (due to the large projected wood energy consumption for electricity production).

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

CO emissions	2005	2019	2020	2025	2030
	kt	%	%		
1 Energy	292	52%	51%	46%	42%
1A Fuel combustion	292	52%	51%	46%	42%
1A1 Energy industries	1.0	70%	90%	181%	262%
1A2 Manufacturing industries and constr.	21	77%	75%	71%	68%
1A3 Transport	164	45%	42%	35%	29%
1A4 Other sectors	105	58%	58%	56%	55%
1A5 Other (Military)	0.92	81%	81%	83%	85%
1B Fugitive emissions from fuels	0.063	0.4%	0.4%	0.4%	0.3%
2 IPPU	4.3	66%	66%	68%	71%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	1.9	77%	76%	70%	64%
6 Other	0.76	93%	93%	93%	93%
National total	299	52%	51%	47%	43%

9.4 Suspended particulate matter

Projected trends for suspended particulate matter PM2.5, PM10, TSP and BC show an overall decline since 2005 and up to 2030 (see Figure 9-4 and Table 9-9).

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 re-suspension 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 9-5 and Table 9-13), 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.

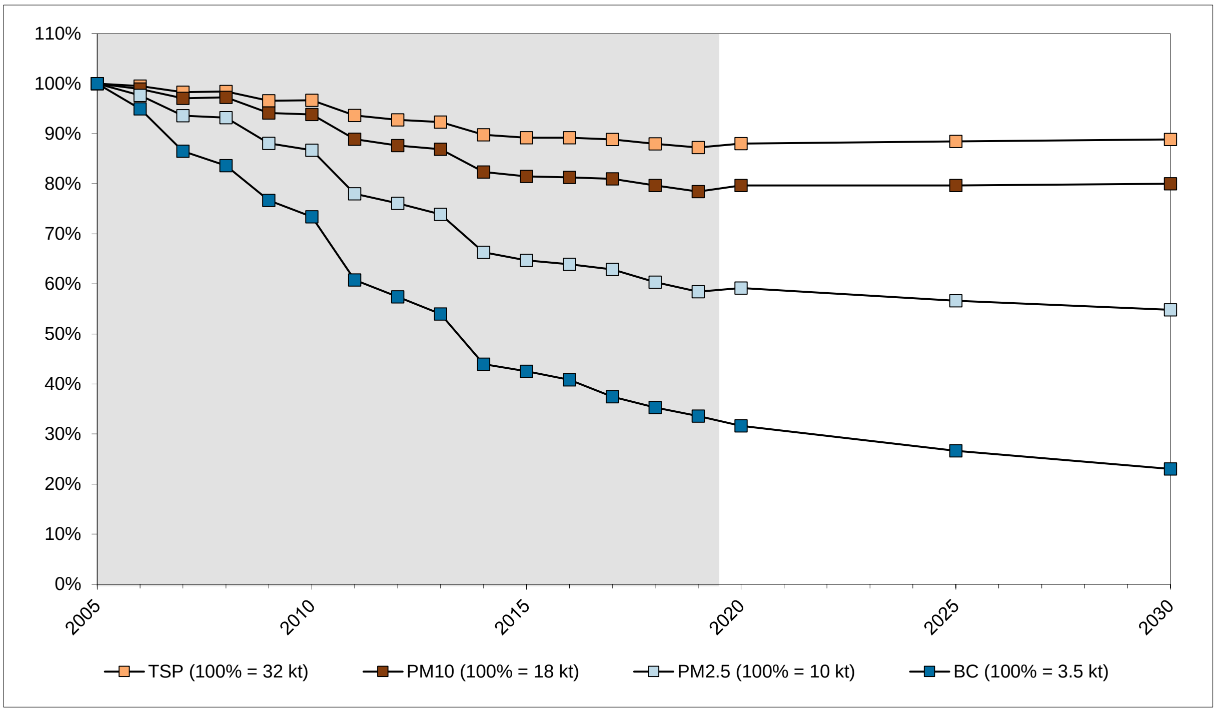


Figure 9-4: Projection of total emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland of the WM (WEM) scenario (in percentage of 2005). The figure shows the sum of exhaust and non-exhaust particles.

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

Year	PM2.5	PM10	TSP	BC
	kt	kt	kt	kt
2005	10	18	32	3.5
2010	9.1	17	31	2.6
2011	8.2	16	30	2.1
2012	8.0	16	30	2.0
2013	7.8	16	30	1.9
2014	7.0	15	29	1.5
2015	6.8	15	29	1.5
2016	6.7	15	29	1.4
2017	6.6	15	28	1.3
2018	6.3	14	28	1.2
2019	6.1	14	28	1.2
2020	6.2	14	28	1.1
2025	5.9	14	28	0.93
2030	5.8	14	28	0.80
2019 to 2030 (%)	-6%	2%	2%	-31%

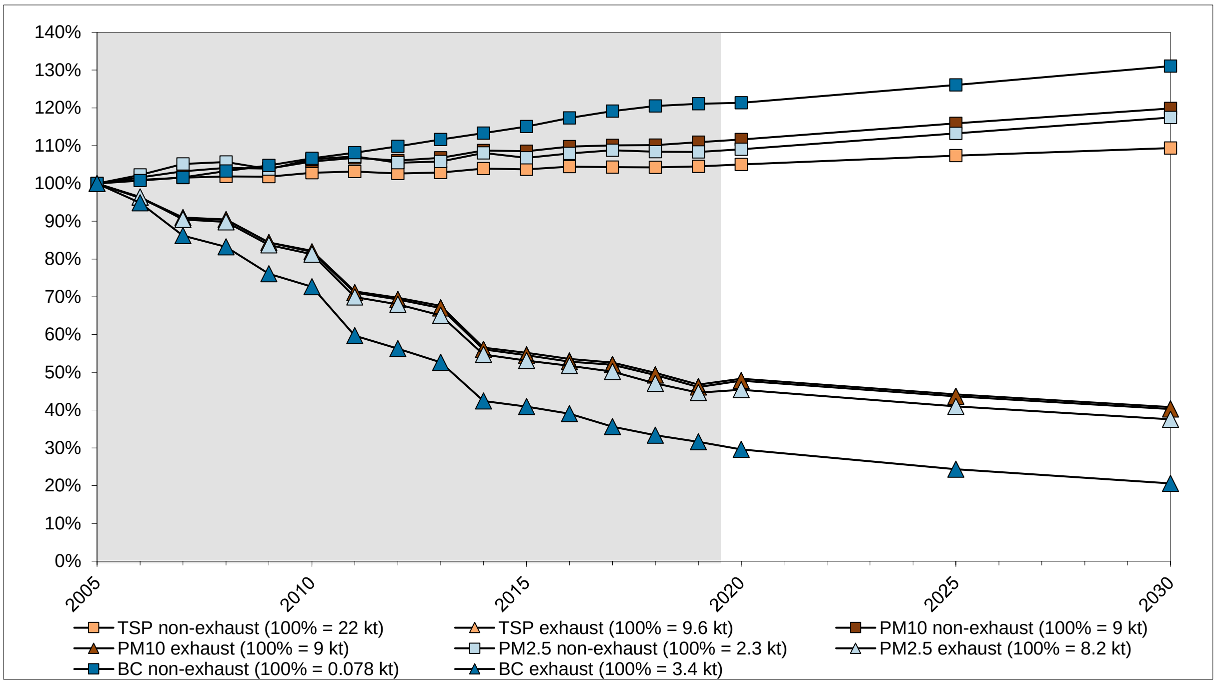


Figure 9-5: Projection of exhaust and non-exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland of the WM (WEM) scenario (in percentage of 2005).

Table 9-10: Projected exhaust emissions of the WEM scenario concerning particulate matter until 2030 in kt.

Year	PM2.5 exhaust	PM10 exhaust	TSP exhaust	BC exhaust
	kt	kt	kt	kt
2005	8.2	9.0	9.6	3.4
2010	6.7	7.4	7.9	2.5
2011	5.8	6.4	6.8	2.0
2012	5.6	6.2	6.7	1.9
2013	5.4	6.0	6.5	1.8
2014	4.5	5.0	5.4	1.4
2015	4.4	4.9	5.3	1.4
2016	4.3	4.8	5.1	1.3
2017	4.1	4.7	5.0	1.2
2018	3.9	4.4	4.8	1.1
2019	3.7	4.1	4.5	1.1
2020	3.7	4.3	4.6	1.01
2025	3.4	3.9	4.2	0.83
2030	3.1	3.6	3.9	0.70
2019 to 2030 (%)	-16%	-13%	-13%	-35%

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

Year	PM2.5 non-exh.	PM10 non-exh.	TSP non-exh.	BC non-exh.
	kt	kt	kt	kt
2005	2.3	9.0	22	0.078
2010	2.4	9.5	23	0.083
2011	2.4	9.6	23	0.084
2012	2.4	9.5	23	0.085
2013	2.4	9.6	23	0.087
2014	2.5	9.7	23	0.088
2015	2.4	9.7	23	0.089
2016	2.5	9.8	23	0.091
2017	2.5	9.9	23	0.092
2018	2.5	10	23	0.093
2019	2.5	10	23	0.094
2020	2.5	10	24	0.094
2025	2.6	10	24	0.098
2030	2.7	11	24	0.10
2019 to 2030 (%)	8%	8%	5%	8%

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 9-4 and Table 9-12).

The largest future reductions are expected to occur in 1A Fuel combustion, particularly in 1A3 Transport and in small combustion intallations in source category 1A4. There are three main arguments that can back these expectations: 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, and wood-fired installations must comply with stricter air pollution control requirements from 2007 onwards. 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 slightly increase, emissions from 6 Other to slightly decrease (both on a higher level than in 2005). In sector 5 Waste, a reduction occurs between the current year and 2030.

Table 9-12: WM (WEM) projections: Relative trends of PM2.5 emissions per sector (2005 represents 100%).

PM2.5 emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	kt	%		%	
1 Energy	8.5	53%	52%	49%	47%
1A Fuel combustion	8.5	53%	52%	49%	47%
1A1 Energy industries	0.18	33%	35%	46%	57%
1A2 Manufacturing industries and constr.	1.5	42%	41%	39%	38%
1A3 Transport	2.8	58%	56%	54%	53%
1A4 Other sectors	4.0	54%	54%	49%	45%
1A5 Other (Military)	0.057	79%	79%	79%	80%
1B Fugitive emissions from fuels	0.000070	67%	68%	74%	80%
2 IPPU	1.5	82%	90%	92%	94%
3 Agriculture	0.13	110%	112%	114%	114%
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.38	80%	79%	70%	61%
6 Other	0.0041	140%	127%	126%	127%
National total	10	58%	59%	57%	55%

9.4.2 Projections for PM10

PM10 emissions are expected to slightly increase until 2030 (see Figure 9-4 and Table 9-13).

An increase of emissions is expected in non-exhaust particulate emissions (mainly larger particles, i.e. PM10 and TSP). 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, PM10 are expected to increase as compared to the projected decrease in PM2.5 emissions.

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 9-13: WM (WEM) projections: Relative trends of PM10 emissions per sector (2005 represents 100%).

PM10 emissions	2005	2019	2020	2025	2030
	kt	%		%	
1 Energy	13.4	74%	74%	74%	74%
1A Fuel combustion	13.4	74%	74%	74%	74%
1A1 Energy industries	0.18	33%	35%	46%	57%
1A2 Manufacturing industries and constr.	3.4	77%	77%	78%	78%
1A3 Transport	5.4	88%	87%	90%	93%
1A4 Other sectors	4.2	54%	55%	50%	45%
1A5 Other (Military)	0.27	99%	98%	98%	99%
1B Fugitive emissions from fuels	0.00070	67%	68%	74%	80%
2 IPPU	2.3	85%	94%	95%	97%
3 Agriculture	1.7	105%	106%	108%	109%
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.42	81%	79%	71%	62%
6 Other	0.20	94%	94%	94%	94%
National total	18	78%	80%	80%	80%

9.4.3 Projections for TSP

TSP emissions show a similar projected development as PM10 emissions (see Figure 9-4 and Table 9-14, Table 9-15, Table 9-16).

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.

Reductions are expected to occur in 1A4 and to a smaller extent in 1A3 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 (since exhaust TSP emissions from the energy sector are generally decreasing). Considering non-exhaust TSP emissions only, agriculture is and remains even the predominating emission source.

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

TSP total emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	kt	%		%	
1 Energy	15.4	77%	77%	78%	78%
1A Fuel combustion	15.4	77%	77%	78%	78%
1A1 Energy industries	0.20	32%	34%	45%	56%
1A2 Manufacturing industries and constr.	4.5	84%	85%	86%	87%
1A3 Transport	5.8	90%	90%	93%	97%
1A4 Other sectors	4.5	54%	54%	50%	45%
1A5 Other (Military)	0.39	100%	100%	100%	100%
1B Fugitive emissions from fuels	0.0017	67%	68%	74%	80%
2 IPPU	3.3	86%	93%	94%	95%
3 Agriculture	13	100%	100%	101%	101%
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.52	81%	79%	70%	61%
6 Other	0.25	96%	96%	95%	95%
National total	32	87%	88%	88%	89%

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

TSP exhaust emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	kt	%		%	
1 Energy	8.0	41%	40%	36%	32%
1A Fuel combustion	8.0	41%	40%	36%	32%
1A1 Energy industries	0.20	32%	34%	45%	56%
1A2 Manufacturing industries and constr.	1.4	25%	24%	21%	18%
1A3 Transport	1.9	25%	22%	16%	13%
1A4 Other sectors	4.4	53%	54%	49%	44%
1A5 Other (Military)	0.020	32%	32%	32%	33%
1B Fugitive emissions from fuels	NA	–	–	–	–
2 IPPU	0.85	70%	93%	93%	92%
3 Agriculture	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.51	81%	79%	70%	61%
6 Other	0.23	93%	93%	93%	93%
National total	9.6	47%	48%	44%	41%

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

TSP non-exhaust emissions	2005	2019	2020	2025	2030
	kt	%		%	
1 Energy	7.4	116%	117%	122%	128%
1A Fuel combustion	7.4	116%	117%	122%	128%
1A1 Energy industries	NA	–	–	–	–
1A2 Manufacturing industries and constr.	3.0	112%	113%	116%	119%
1A3 Transport	3.9	122%	123%	130%	138%
1A4 Other sectors	0.12	87%	87%	84%	82%
1A5 Other (Military)	0.37	104%	104%	104%	104%
1B Fugitive emissions from fuels	0.0017	67%	68%	74%	80%
2 IPPU	2.5	92%	92%	94%	96%
3 Agriculture	13	100%	100%	101%	101%
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.0036	100%	100%	100%	100%
6 Other	0.017	136%	129%	127%	127%
National total	22	105%	105%	107%	109%

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 9-4 and Table 9-17). 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 9-17: WM (WEM) projections: Relative trends of BC emissions per sector (2005 represents 100%).

BC emissions	2005	2019	2020	2025	2030
	kt	%		%	
1 Energy	3.4	33%	31%	26%	23%
1A Fuel combustion	3.4	33%	31%	26%	23%
1A1 Energy industries	0.0116	30%	32%	42%	52%
1A2 Manufacturing industries and constr.	0.32	15%	14%	8%	5%
1A3 Transport	1.2	28%	23%	17%	14%
1A4 Other sectors	1.9	40%	40%	36%	32%
1A5 Other (Military)	0.010	32%	32%	32%	33%
1B Fugitive emissions from fuels	0.000042	67%	68%	74%	80%
2 IPPU	0.0026	49%	49%	49%	49%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.027	79%	77%	69%	60%
6 Other	0.00014	94%	94%	94%	94%
National total	3.5	34%	32%	27%	23%

9.5 Priority heavy metals

Projected emission trends for priority heavy metals Pb, Cd and Hg are shown in Figure 9-6 and Table 9-18. While Pb emissions are projected to remain about constant between 2019 and 2030, Cd and Hg are considered to increase. The increase of Cd emissions started in 2014 already, for Hg, the increase is predicted to start from 2020 on. For Cd, this increase is related to a huge predicted increase of wood energy consumption mainly for electricity production (source category 1A1a Public electricity and heat production). For Hg, the increase is also partly related to the increase of wood energy consumption, and additionally to an expected increase in the amount of waste incinerated (1A1 Energy industries).

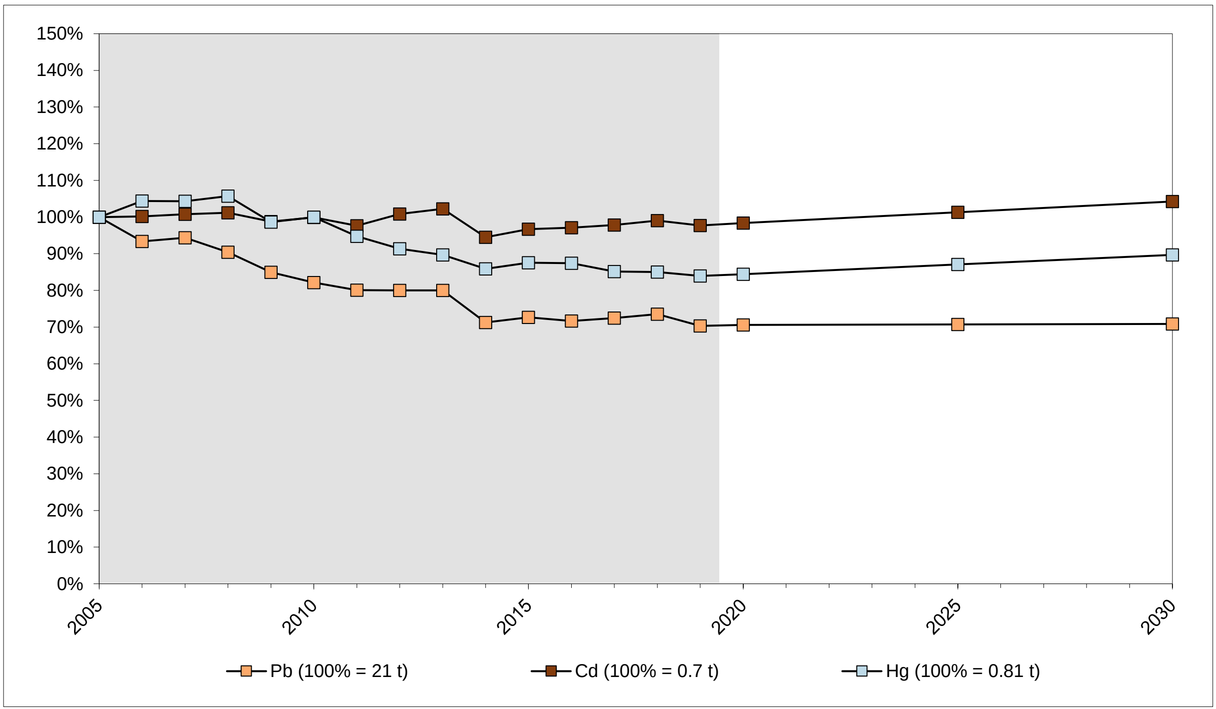


Figure 9-6: Projected emissions of priority heavy metals in Switzerland until 2030 of the WM (WEM) scenario (in percentage of 2005 level).

Table 9-18: WM (WEM) projected total emissions of priority heavy metal in tonnes.

Year	Pb	Cd	Hg
	t	t	t
2005	21	0.70	0.81
2010	17	0.70	0.81
2011	17	0.69	0.76
2012	17	0.71	0.74
2013	17	0.72	0.72
2014	15	0.67	0.69
2015	15	0.68	0.71
2016	15	0.68	0.71
2017	15	0.69	0.69
2018	15	0.70	0.69
2019	15	0.69	0.68
2020	15	0.69	0.68
2025	15	0.71	0.70
2030	15	0.73	0.72
2019 to 2030 (%)	1%	7%	7%

9.5.1 Projections for lead (Pb)

The annual national total of lead emissions will presumably remain more or less on constant until 2030 compared to current levels (see Table 9-19 and Figure 9-6).

In the energy sector emissions are expected to slightly increase from 2018 to 2030. This increase is mainly because of increasing emissions from source category 1A1 due to growing amount of waste incinerated and large projected wood energy consumption for electricity production. On contrary, Pb emissions from 1A3 Transport are projected to continue their decreasing trend due to the assumption that in the future, the share of diesel will continue to increase compared to gasoline.

Also for sector 5 Waste, the decreasing trend is projected to continue, mainly based on the assumption that the amount of illegally burned waste (under 5C1a) is reduced in the future. The emissions from sector 2 Industrial processes and product use are projected to remain about constant. The projection for the major source 6A4 Fire damage estates and motor vehicles assumes that emission factor and activity data remain constant until 2030.

Table 9-19: WM (WEM) projections: Relative trends of Pb emissions per sector (2005 represents 100%).

Pb emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	t	%	%		
1 Energy	9.9	59%	59%	61%	64%
1A Fuel combustion	9.9	59%	59%	61%	64%
1A1 Energy industries	1.9	75%	81%	108%	135%
1A2 Manufacturing industries and constr.	2.7	33%	32%	33%	35%
1A3 Transport	4.3	66%	64%	59%	55%
1A4 Other sectors	0.95	68%	64%	53%	42%
1A5 Other (Military)	0.00045	87%	86%	85%	84%
1B Fugitive emissions from fuels	NO	NO	NO	NO	NO
2 IPPU	2.1	27%	33%	33%	34%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	2.3	87%	85%	75%	65%
6 Other	6.6	95%	95%	95%	95%
National total	21	70%	71%	71%	71%

9.5.2 Projections for cadmium (Cd)

Cadmium emissions are expected to increase until 2030 (see Table 9-20 and Figure 9-6). Responsible for the increase in cadmium emissions is the predicted increase of wood energy consumption until 2030 mainly for electricity production in source category 1A1a Public electricity and heat production.

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

Cd emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	t	%		%	
1 Energy	0.43	98%	98%	103%	108%
1A Fuel combustion	0.43	98%	98%	103%	108%
1A1 Energy industries	0.18	116%	118%	129%	140%
1A2 Manufacturing industries and constr.	0.10	66%	65%	64%	63%
1A3 Transport	0.077	121%	121%	125%	130%
1A4 Other sectors	0.067	74%	72%	70%	67%
1A5 Other (Military)	0.00051	103%	103%	103%	102%
1B Fugitive emissions from fuels	NA	NA	NA	NA	NA
2 IPPU	0.092	84%	88%	88%	88%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.021	171%	171%	171%	170%
6 Other	0.16	95%	95%	95%	95%
National total	0.70	98%	98%	101%	104%

9.5.3 Projections for mercury (Hg)

Overall, the annual national total of mercury emissions is expected to increase until 2030 (see Table 9-21 and Figure 9-6). Emissions from sector 1 Energy are expected to increase, mainly due to source category 1A1, the main source for Hg emissions. The increase is due to the increasing wood energy consumption and due to an expected increase in the amount of waste incinerated. Sectors 5 Waste and 6 Other are on low levels. While Hg emissions from the waste sector decrease, emissions from the sector other (fire damages) are expected to increase. Emissions from sector 2 Industrial processes and product use are expected to slightly decrease until 2030.

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

Hg emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	t	%		%	
1 Energy	0.59	87%	88%	91%	95%
1A Fuel combustion	0.59	87%	88%	91%	95%
1A1 Energy industries	0.34	88%	90%	99%	109%
1A2 Manufacturing industries and constr.	0.12	77%	77%	74%	72%
1A3 Transport	0.037	93%	91%	85%	77%
1A4 Other sectors	0.085	92%	91%	87%	83%
1A5 Other (Military)	0.000028	103%	103%	102%	102%
1B Fugitive emissions from fuels	NA	NA	NA	NA	NA
2 IPPU	0.067	72%	72%	72%	71%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.077	64%	63%	62%	61%
6 Other	0.076	93%	93%	93%	93%
National total	0.81	84%	84%	87%	90%

9.6 Persistent organic pollutants (POPs)

Figure 9-7 shows projected emission trends for persistent organic pollutants (POP). More detailed figures on projections are given in Table 9-22. PCB emissions are projected to continuously decrease until 2030. In the same timeframe, PCDD/PCDF emissions are expected to slightly decrease, PAH and HCB emissions to slightly increase.

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 slight decrease in emissions is the projected decline in illegally incinerated waste in sector 5 Waste.

For HCB, the slight increase mainly occurs due to the predicted increase of wood energy consumption and an increase of energy generation from waste incineration plants in source category 1A1a Electricity and heat production.

The main source of PAH emissions will be small wood combustion installations of source category 1A4 Other sectors. Total emissions are estimated to slightly increase, since a decrease under 1A4 Other sectors is expected to be compensated by an increase under 1A3 Transport.

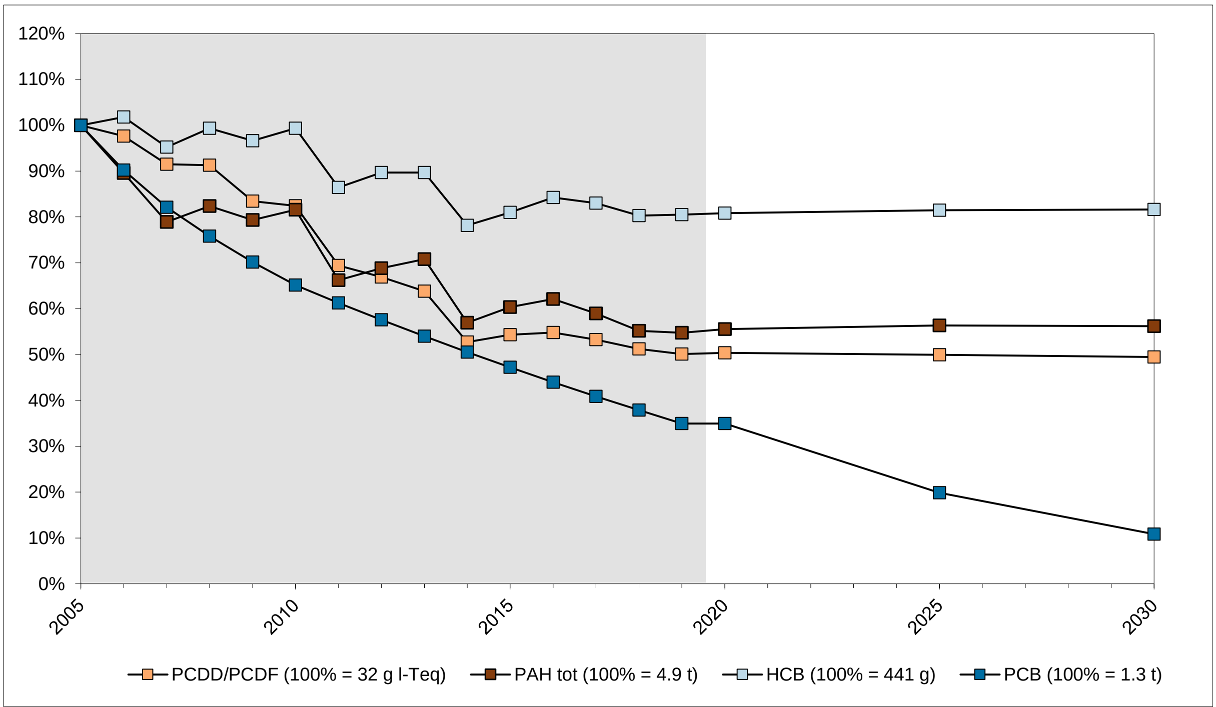


Figure 9-7: Emissions of POPs: PCDD/PCDF, PAH as the sum of benzo(a)pyrene), benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, and HCB in Switzerland in the WM (WEM) scenario (in percent of 2005).

Table 9-22: 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	0.8	4.9	0.44	1.3
2010	26	1.2	1.3	0.77	0.7	4.0	0.44	0.83
2011	22	1.0	1.1	0.63	0.57	3.3	0.38	0.78
2012	21	1.0	1.1	0.66	0.59	3.4	0.40	0.73
2013	20	1.1	1.1	0.67	0.61	3.5	0.40	0.69
2014	17	0.85	0.90	0.55	0.49	2.8	0.34	0.64
2015	17	0.90	0.95	0.58	0.52	3.0	0.36	0.60
2016	17	0.93	0.98	0.60	0.54	3.1	0.37	0.56
2017	17	0.88	0.93	0.58	0.52	2.9	0.37	0.52
2018	16	0.82	0.87	0.54	0.48	2.7	0.35	0.48
2019	16	0.81	0.86	0.54	0.48	2.7	0.36	0.44
2020	16	0.82	0.87	0.55	0.49	2.7	0.36	0.41
2025	16	0.84	0.89	0.55	0.49	2.8	0.36	0.25
2030	16	0.84	0.89	0.54	0.48	2.8	0.36	0.14
2019 to 2030 (%)	-1%	4%	4%	1%	0%	3%	1%	-69%

9.6.1 Projections for PCDD/PCDF

PCDD/PCDF emissions are expected to continue a decreasing trend until 2030 (see Table 9-23 and Figure 9-7).

Only a minimal decrease in emissions is expected between 2019 and 2030. The major part of the emissions reduction is expected to happen in sector 5 Waste (mainly due to a reduction of illegally incinerated waste under 5C1a). In contrast, an increase is projected under 1A4 Other sectors (mainly due to an increase of wood combustion in 1A4bi) and 1A1 Energy industries (mainly from wood energy consumption for electricity production and waste incineration plants).

Table 9-23: WM (WEM) projections: Relative trends of PCDD/PCDF emissions per sector (2005 represents 100%).

PCDD/PCDF emissions	2005	2019	2020	2025	2030
	g I-Teq	%		%	
1 Energy	23	43%	43%	44%	44%
1A Fuel combustion	23	43%	43%	44%	44%
1A1 Energy industries	5.2	37%	38%	44%	49%
1A2 Manufacturing industries and constr.	2.7	33%	34%	34%	33%
1A3 Transport	1.73	38%	37%	24%	18%
1A4 Other sectors	13	47%	48%	48%	48%
1A5 Other (Military)	0.0004	103%	103%	102%	102%
1B Fugitive emissions from fuels	NA	NA	NA	NA	NA
2 IPPU	2.1	36%	37%	43%	49%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	4.3	72%	70%	61%	52%
6 Other	2.5	95%	95%	95%	95%
National total	32	50%	50%	50%	49%

9.6.2 Projections for polycyclic aromatic hydrocarbons (PAH)

Overall, the annual national total of PAH emissions is expected to slightly increase until 2030 (see Table 9-24 and Figure 9-7. The main relevant source of PAH emissions remaining in the future are small wood combustion installations of source category 1A4.

A significant increase of PAH emissions is expected under 1A3 Transport. It is assumed that 1A3 will be a relevant source of PAH emissions in 2030. The reason for this emission increase is the rising share of diesel oil use under 1A3b. In 1A4, a reduction of emissions is projected (e.g. wood furnaces).

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

PAHs emissions	**2005**	**2019**	**2020**	**2025**	**2030**
	t	%	%		
1 Energy	4.1	58%	59%	60%	60%
1A Fuel combustion	4.1	58%	59%	60%	60%
1A1 Energy industries	0.01	44%	93%	299%	457%
1A2 Manufacturing industries and constr.	0.18	56%	60%	78%	96%
1A3 Transport	0.17	174%	180%	187%	187%
1A4 Other sectors	3.7	53%	54%	53%	52%
1A5 Other (Military)	0.00073	95%	94%	92%	91%
1B Fugitive emissions from fuels	NA	NA	NA	NA	NA
2 IPPU	0.50	2.3%	2.3%	2.3%	2.3%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	0.25	76%	75%	75%	75%
6 Other	0.093	120%	120%	120%	120%
National total	4.9	55%	56%	56%	56%

9.6.3 Projections for hexachlorobenzene (HCB)

HCB emissions on national level are projected to slightly increase from 2019 until 2030 (see Table 9-25 and Figure 9-7).

HCB emissions will increase in source category 1A1a Electricity and heat production due to the predicted increase of wood energy consumption and an increase of energy generation from waste incineration plants. However, in source categories 1A4 (technical improvement of wood furnaces, similar to particulate matter emissions) and 1A2gviii (due to the low projection of wood energy consumption of industry, which turns out to currently already being higher than projected; accordingly, this decrease is probably not accurate), HCB emissions are projected to decrease.

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

HCB emissions	2005	2019	2020	2025	2030
	kg	%		%	
1 Energy	0.44	80%	81%	81%	82%
1A Fuel combustion	0.44	80%	81%	81%	82%
1A1 Energy industries	0.15	123%	125%	135%	144%
1A2 Manufacturing industries and constr.	0.050	69%	68%	63%	58%
1A3 Transport	NA, NE	NA, NE	NA, NE	NA, NE	NA, NE
1A4 Other sectors	0.24	56%	55%	51%	47%
1A5 Other (Military)	NE	NE	NE	NE	NE
1B Fugitive emissions from fuels	NA	NA	NA	NA	NA
2 IPPU	NA	NA	NA	NA	NA
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	NA	NA	NA	NA	NA
6 Other	NA	NA	NA	NA	NA
National total	0.44	80%	81%	81%	82%

9.6.4 Projections for polychlorinated biphenyl (PCBs)

PCB emissions are expected to decrease considerably until 2030 (see Table 9-26 and Figure 9-7). 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 accidential releases of PCB by fire and from soil due to former PCB spillages (6Ad) contribute to future PCB emissions. In 2020 both sources 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 9-26: WM (WEM) projections: Relative trends of PCB emissions per sector (2005 represents 100%).

PCB emissions	2005	2019	2020	2025	2030
	t	%		%	
1 Energy	1.4	28.9%	28.2%	24.7%	21.4%
1A Fuel combustion	1.4	28.9%	28.2%	24.7%	21.4%
1A1 Energy industries	1.1	7.4%	6.9%	4.9%	3.1%
1A2 Manufacturing industries and constr.	0.35	94%	92%	84%	76%
1A3 Transport	0.00037	38%	35%	23%	17%
1A4 Other sectors	0.0015	51%	52%	52%	52%
1A5 Other (Military)	NE	NE	NE	NE	NE
1B Fugitive emissions from fuels	NA	NA	NA	NA	NA
2 IPPU	922	43%	40%	24%	13%
3 Agriculture	NA	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR	NR
5 Waste	254	4.0%	3.3%	1.5%	0.9%
6 Other	93	35%	33%	24%	18%
National total	1270	35%	32%	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.

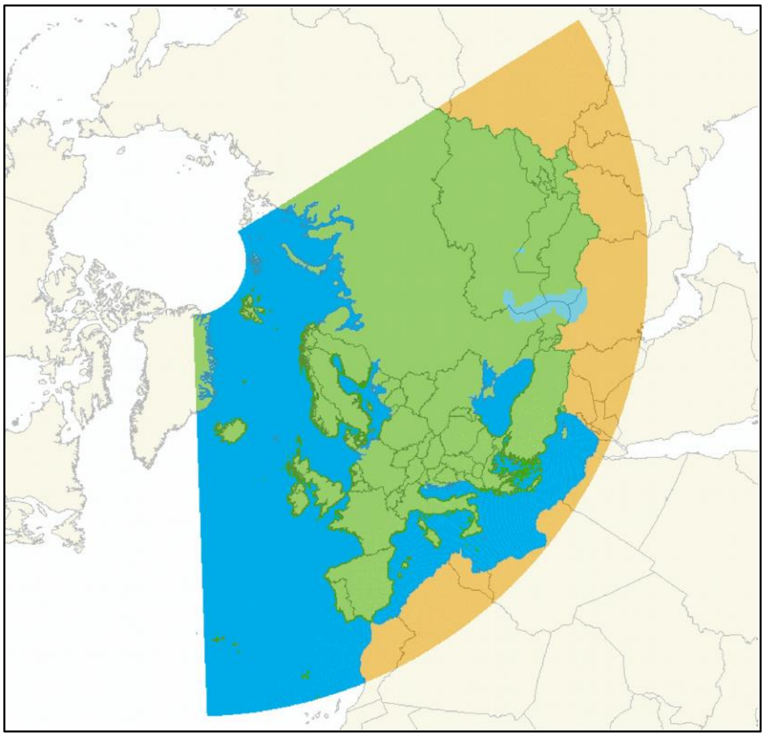


Figure 10-1: EMEP domain in the latitude-longitude projection (30°N-82°N, 30°W-90°E) (EMEP 2012a, https://www.emep.int/grid/lonlatgrid.pdf).

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.

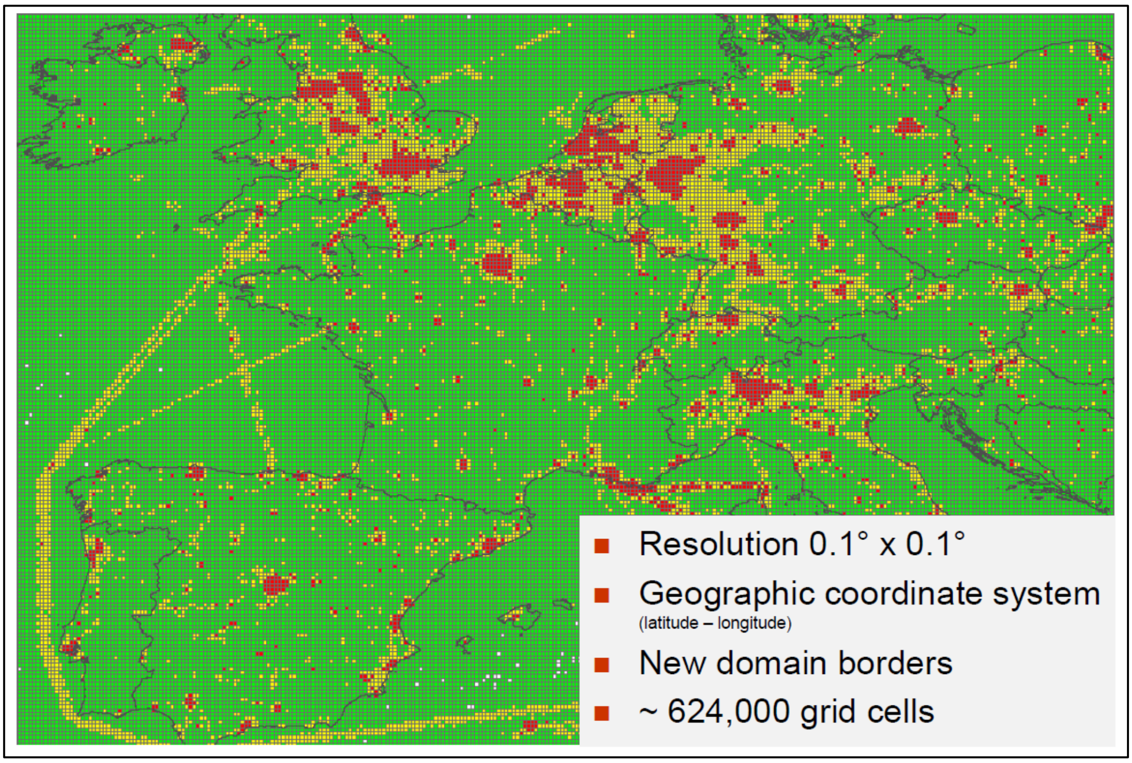


Figure 10-2: Resolution of the EMEP grid for Europe (EMEP 2012b).

In Switzerland's air pollution inventory of current submission 2021, the EMEP grid on local scale (0.1° x 0.1°) is applied for the fifth time (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, 2014 and 2015).

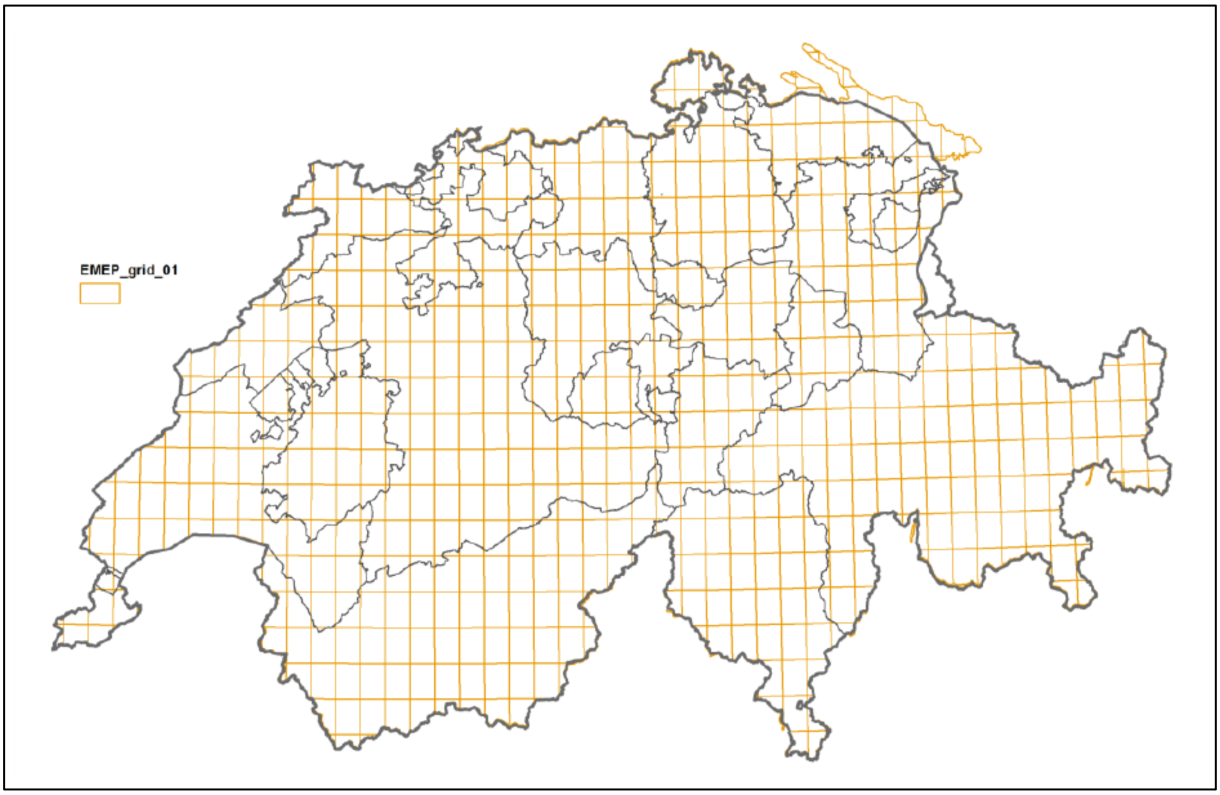


Figure 10-3: EMEP grid in Switzerland with 0.1° x 0.1° spatial resolution (from Meteotest 2013, downloaded from EMEP).

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 2019 for all main air pollutants including PM2.5.

Table 10-1: GNFR categories and their part (%) of total emissions in 2019 (national total) for the main air pollutants including PM2.5.

GNFR aggregated sectors	NO_x	NMVOC	SO_x	NH_3	PM2.5
A_PublicPower	3.38%	0.18%	4.84%	0.06%	0.64%
B_Industry	10.82%	7.87%	62.48%	0.47%	17.65%
C_OtherStatComb	12.02%	4.24%	23.78%	0.22%	31.58%
D_Fugitive	0.00%	2.88%	0.36%	0.00%	0.00%
E_Solvents	0.03%	46.58%	0.09%	0.15%	5.87%
F_RoadTransport	53.81%	10.19%	1.97%	2.01%	22.30%
G_Shipping	1.65%	0.52%	0.03%	0.00%	0.48%
H_Aviation	3.74%	0.26%	3.78%	0.00%	0.33%
I_Offroad	8.16%	2.26%	0.84%	0.01%	13.77%
J_Waste	0.24%	1.86%	1.57%	1.70%	4.98%
K_AgriLivestock	1.56%	22.31%	0.00%	47.63%	1.58%
L_AgriOther	4.42%	0.56%	0.00%	45.90%	0.73%
M_Other	0.16%	0.28%	0.25%	1.85%	0.09%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

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. This work has been done by Meteotest under mandate of the FOEN. Numerous GNFR categories overlap with various source categories thus 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.

For the current submission, Switzerland calculated gridded emissions for the entire time series 1980-2019. For the allocation process of the emissions various data sources were applied for the time intervals 1980-1989, 1990-1999, 2000-2010 and >2010. 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, 2000-2010 and >2010 (Meteotest 2015).

Data source	Available years	Applied data source for gridded emission time series			
		1980-1989	1990-1999	2000-2010	> 2010
Population data	1990, 2000, 2010	1990	1990	2000	2010
Census of enterprises sector 1	1996, 2000, 2005, 2008	1996	1996	2005	2008
Census of enterprises sector 2+3	1995, 1998, 2001, 2005, 2008	1995	1995	2005	2008
Land use statistics	1979/85, 1992/97, 2004/09	1979/85	1992/97	2004/09	2004/09
NO_x emission maps	1990, 2000, 2005, 2010	2005	2005	2005	2005
PM10 emission maps	2005, 2010	2005	2005	2005	2005
NH_3 emission maps	1990, 2000, 2007, 2010	1990	2000	2007	2010

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).

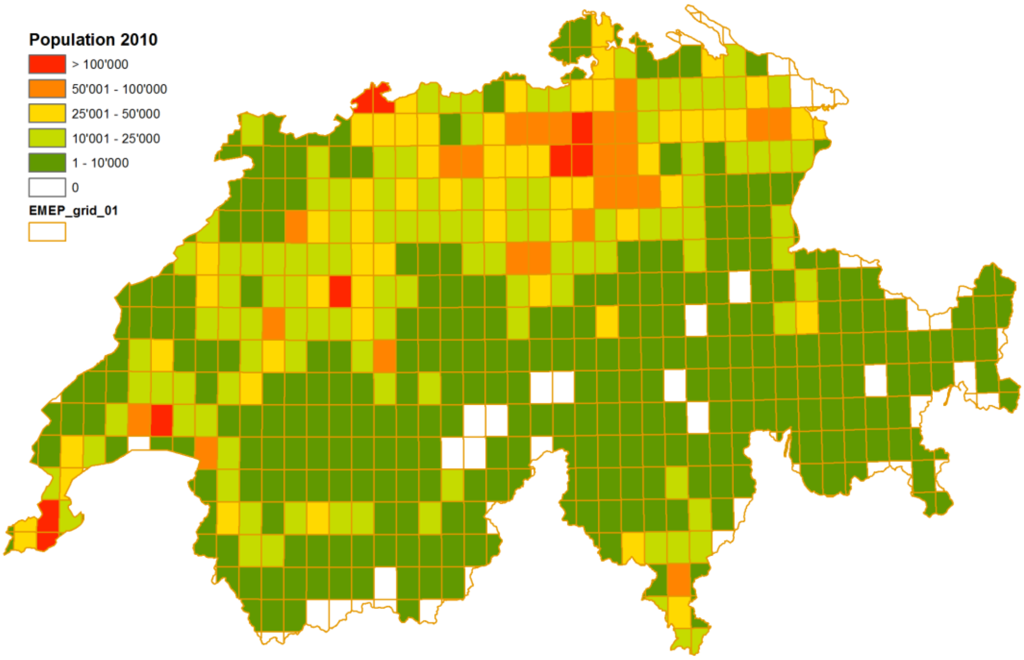


Figure 10-4: Population number per EMEP grid cell in Switzerland in 2010 (SFSO 2011a, Meteotest).

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 by the Federal Statistical Office and the most recent publication is based on data from 2008 (SFSO 2009). 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 (SFSO 2007) 74 categories are available. They are aggregated to 9 main land use categories to apply them to the EMEP grid (Meteotest 2014, 2015). 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 modeling 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 2011a)
- NO_x: Emissions of navigation (FOEN 2011a)
- NO_x: Emissions of construction machinery (FOEN 2011a)
- NO_x: Emissions of industrial vehicles (FOEN 2011a)
- PM10: Emissions of rail traffic (FOEN 2013d)
- NH_3: Emissions of manure management - farming of animals without pasture (Kupper et al. 2013)

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, 2015).

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 2010 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 (2015).

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 2014, 2015).

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 2019

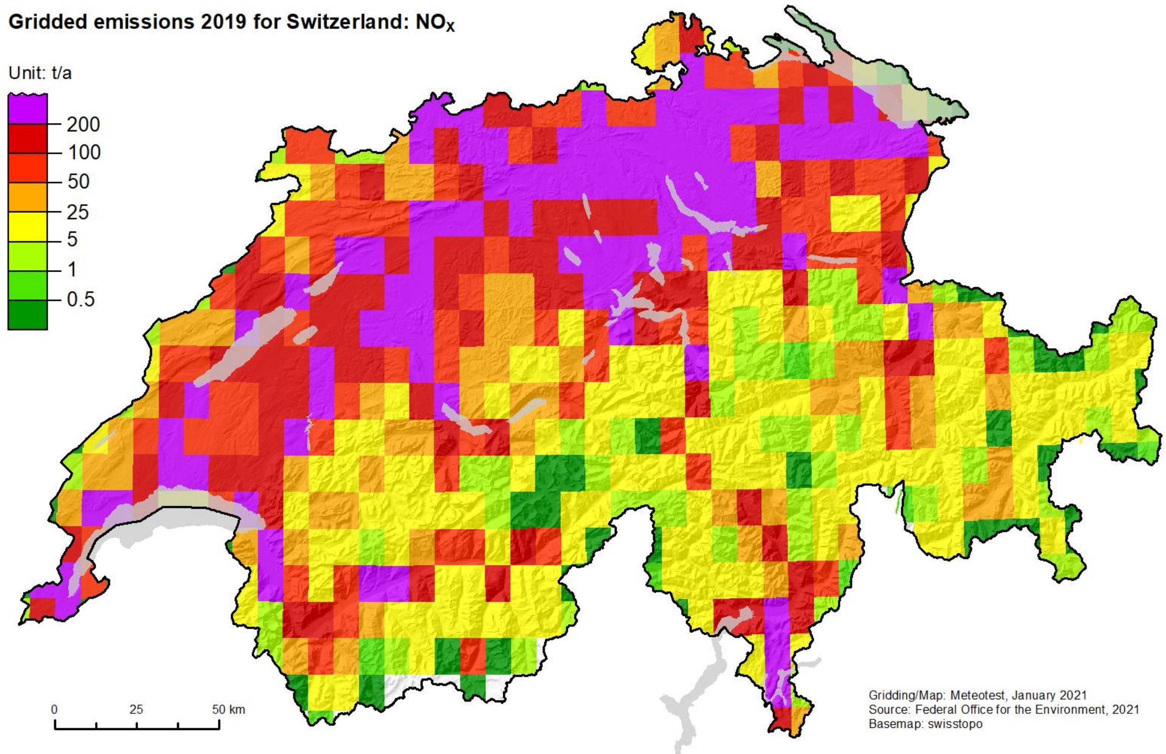


Figure 10-5: Spatial distribution of the NO_x emissions in Switzerland.

10.3.2 Spatial distribution of Switzerland's NMVOC emissions 2019

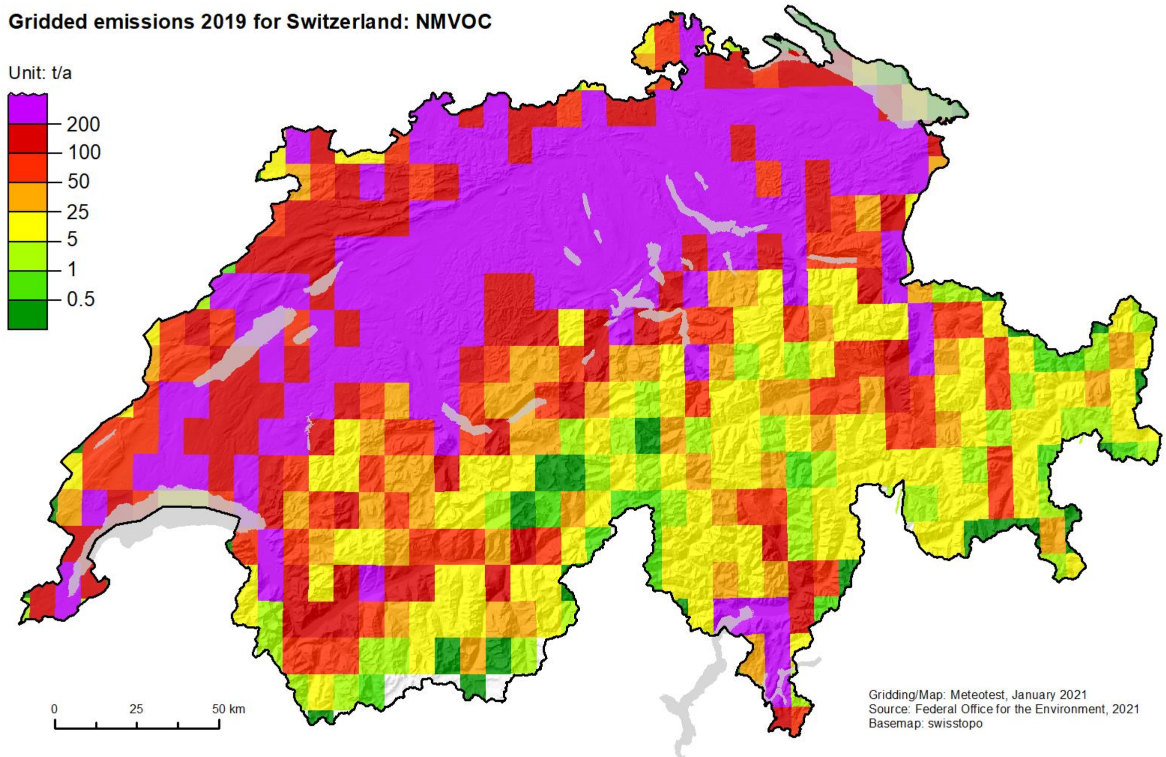


Figure 10-6: Spatial distribution of the NMVOC emissions in Switzerland.

10.3.3 Spatial distribution of Switzerland's SO_x emissions 2019

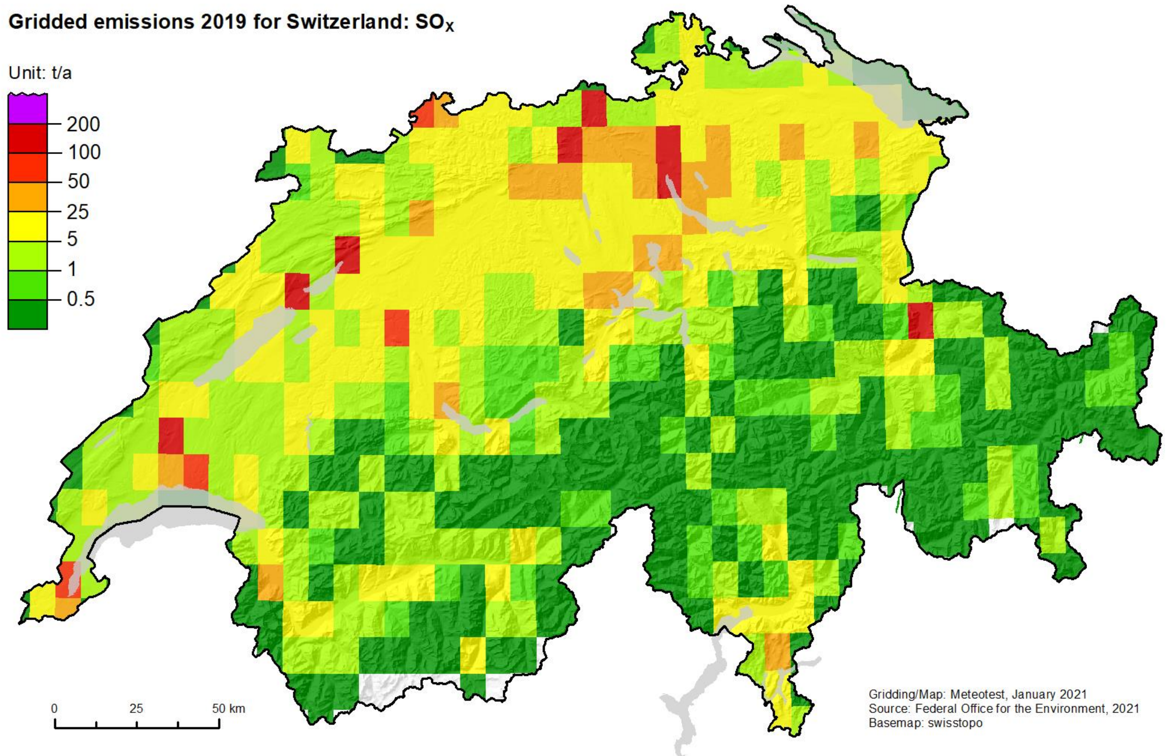


Figure 10-7: Spatial distribution of the SO_x emissions in Switzerland.

10.3.4 Spatial distribution of Switzerland's NH_3 emissions 2019

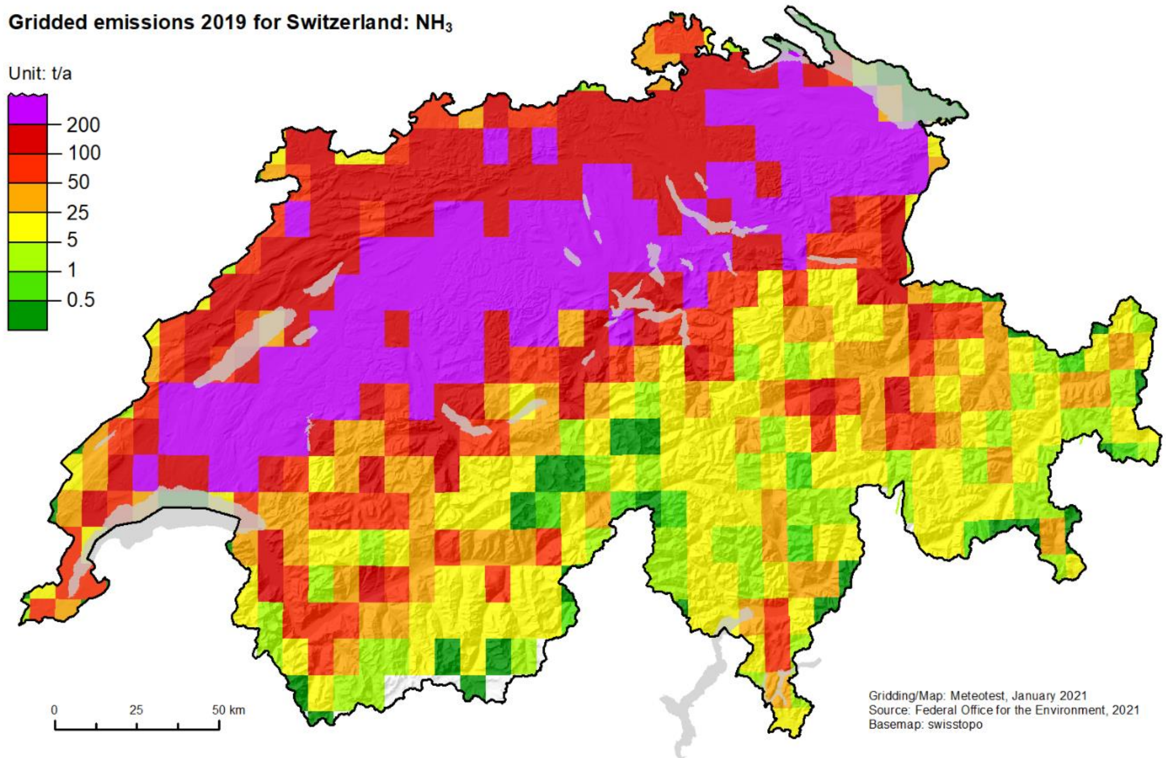


Figure 10-8: Spatial distribution of the NH_3 emissions in Switzerland.

10.3.5 Spatial distribution of Switzerland's PM2.5 emissions 2019

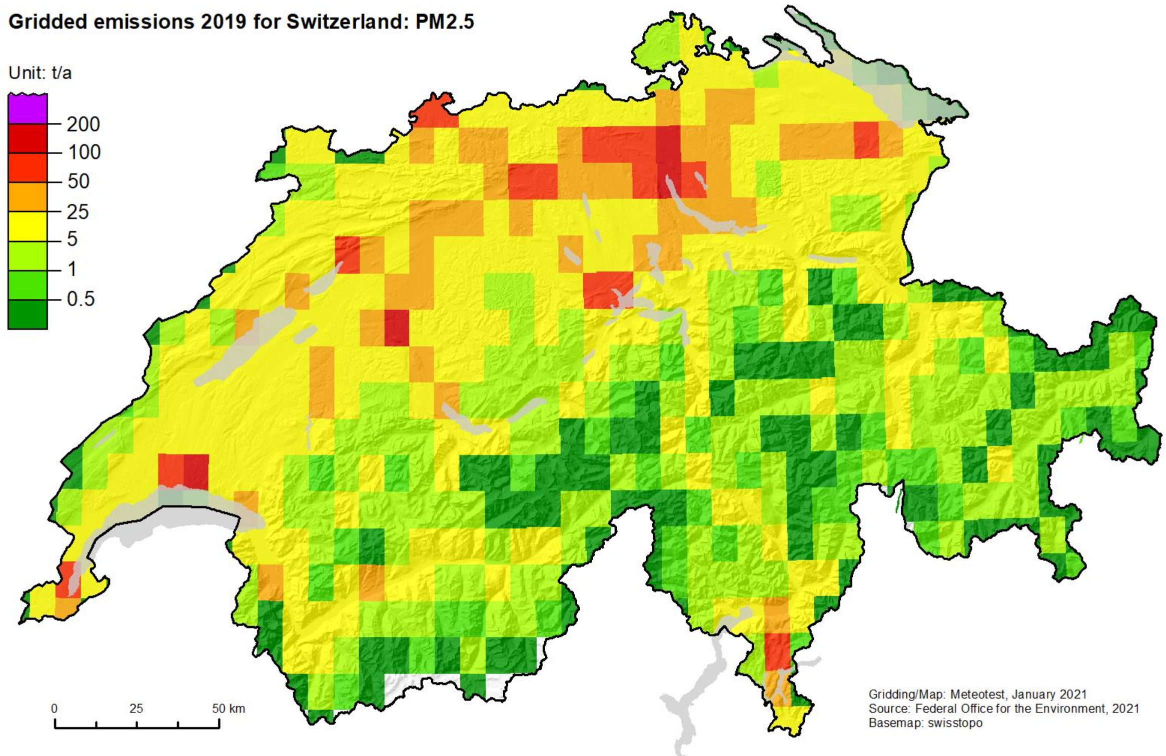


Figure 10-9: Spatial distribution of the PM2.5 emissions in Switzerland.

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 2007-2019 are reported based on the most recent data of the Swiss Pollution Release and Transfer Register (PRTR 2021). 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 2019, the list of Switzerland's LPS includes 31 facilities, in particular of the industrial and waste sectors. As in previous years, most significant LPS are cement production plants and installations for incineration of municipal waste, 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.

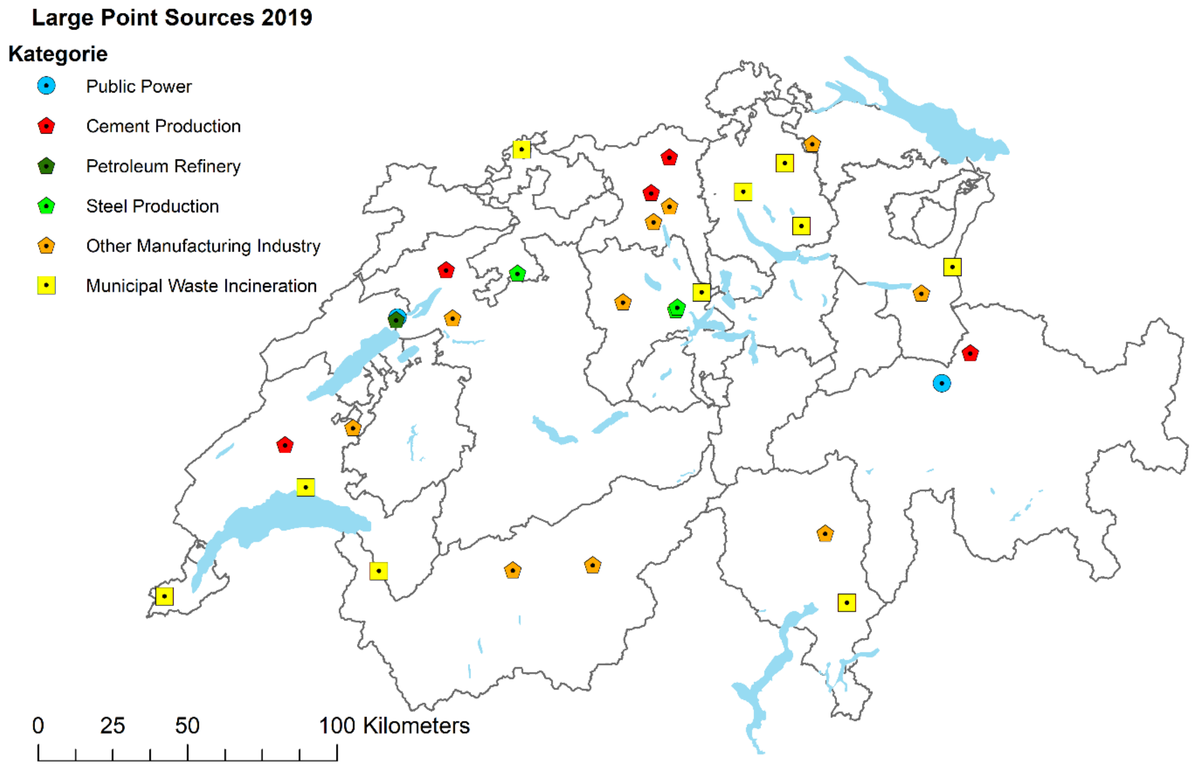


Figure 10-10: Spatial distribution of Switzerland's LPS in 2019.

11 Adjustments

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

12 References and assignments to EMIS categories

12.1 References

AGRAMMON 2018: The Swiss agricultural ammonia emission calculation model, developed by the Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences in cooperation with Bonjour Engineering GmbH and Oetiker + Partner AG on behalf of the Federal Office for the Environment FOEN. Internet version 5.0 in German, French and English:
https://agrammon.ch/en/downloads/ [27.01.2021];
Technical description for download (updated periodically):
https://agrammon.ch/en/dokumentation-zum-modell/technical-description/ [27.01.2021]

Agricura 2019: Geschäftsbericht 2018/2019. Agricura, Bern [confidential/internal].

Agroscope 2017: Grundlagen für die Düngung landwirtschaftlicher Kulturen in der Schweiz (GRUD). Agroscope, Richner, W. and Sinaj, S. (Eds.) June 2017.
https://www.agroscope.admin.ch/agroscope/en/home/topics/plant-production/field-crops/Pflanzenernaehrung/grud.html [27.01.2021], [available in German, French and Italian]

ARE 2002: Fahrleistungen der Schweizer Fahrzeuge. Ergebnisse der periodischen Erhebung Fahrleistungen (PEFA) 2000. Bundesamt für Raumentwicklung (ARE), Bern.
http://www.news-service.admin.ch/NSBSubscriber/message/attachments/1588.pdf [01.02.2021]

ARE 2016: Perspektiven des Schweizerischen Personen- und Güterverkehrs bis 2040 - Technischer Bericht.
https://www.are.admin.ch/are/de/home/medien-und-publikationen/publikationen/verkehr/verkehrsperspektiven-2040-technischer-bericht.html [01.02.2021]

ARE/SFSO 2005: Mobilität in der Schweiz. Ergebnisse des Mikrozensus 2005 zum Verkehrsverhalten. Federal Office for Spatial Development, Bern and Swiss Federal Statistical Office, Neuchâtel. 2005.

ARE/SFSO 2012: Mobilität in der Schweiz. Ergebnisse des Mikrozensus Mobilität und Verkehr 2010. Federal Office for Spatial Development, Bern and Swiss Federal Statistical Office, Neuchâtel. 2012.

ARE/SFSO 2017: Verkehrsverhalten der Bevölkerung – Ergebnisse des Mikrozensus Mobilität und Verkehr 2015. Federal Office for Spatial Development, Bern and Swiss Federal Statistical Office, Neuchâtel. 2017.
https://www.are.admin.ch/dam/are/de/dokumente/verkehr/dokumente/mikrozensus/verkehrsverhalten-der-bevolkerung-ergebnisse-des-mikrozensus-mobilitat-und-verkehr-2015.pdf.download.pdf/Mikrozensus_Verkehrsverhalten%20der%20Bev%C3%B6lkerung%202015_de.pdf [01.02.2021]

ATD 2020: Animal Tracing Database. Identitas AG on behalf of the Federal Office for Agriculture (FOAG). Bern, Schweiz. [30.9.2020]

Avenergy 2020: Jahresbericht 2020. Avenergy Suisse. Zürich.
https://avenergy.ch/de/publikationen/jahresbericht [12.06.2020]

Bühler, M. and Kupper, T. 2018: Agricultural emissions of NMVOC and PM. Literature review and selection of emission factors, HAFL Zollikofen, Bern.
https://www.aramis.admin.ch/Default.aspx?DocumentID=49766&Load=true [27.01.2021]

Butz 2003: Neuere rechtliche Vorgaben im Bereich Deponiegasanlagen – TA-Luft, EEG, Deponieverordnung. Trierer Berichte zur Abfallwirtschaft Band 14.

Canton of Neuchâtel 2019: Émissions de la raffinerie. Information concerning fugitive emissions of oil at the refinery in Cressier. E-Mail communication from F. Gretillat, Canton of Neuchâtel, to A. Bass, FOEN (15.10.2019).

Cemsuisse 2010a: Bestimmung der Emissionsfaktoren an Mischproben, Interner Bericht von Wessling im Auftrag von Cemsuisse, 2010.

Citepa 2012: Inventaire des emissions de polluants atmospheriques en France au titre de la Convention sur la Pollution Atmospherique Transfrontaliere a longue Distance et de la Directive Europeenne relative aux plafonds d'emissions nationaux (NEC). Ministère de l'Ecologie, du Développement Durable, des Transport et du Logement. CITEPA, Mars 2012.

Consaba 2016: Erhebung Verwertung Deponiegas über Fackelanlagen in der Schweiz 1990 bis 2014. Bern, Schlussbericht, 23.09.2016 [confidential/internal].

Cuhls 2010: Emissionen aus Biogasanlagen und technische Massnahmen zu ihrer Minderung. TK Verlag – Fachverlag für Kreislaufwirtschaft. Band 4 (2010). September 2010.

Danish Informative Inventory Report 2018: Nielsen, O-K., Plejdrup, M.S., Winther, M., Mikkelsen, M.H., Nielsen, M., Gyldenkærne, S., Fauser, P., Albrektsen, R., Hjelgaard, K.H., Bruun, H.G. & Thomsen, M. Aarhus University, DCE – Danish Centre for Environment and Energy, Scientific Report No. 267. March 2018. https://www.ceip.at/status-of-reporting-and-review-results/2018-submissions [28.01.2021]

DDPS 2014a: List of military non-road machinery (stocks, engine-power, annual operating hours). E-Mail C. Stucki (Federal Department of Defence, Civil Protection and Sport) to B. Notter (INFRAS) 27.05.2014 [confidential/internal].

DDPS 2020: Consumption of aviation fuel and jet kerosene of Swiss military aircraft 1990-2019. Désirée Föry (Federal Department of Defence, Civil Protection and Sport) to Anouk Aimée Bass (FOEN, Bern), 21.07.2020 [confidential/internal].

Düring, I., Schmidt, W. 2016: Ermittlung von Emissionsfaktoren von Kraftfahrzeugen unter Berücksichtigung zukünftiger Antriebskonzepte und der Vorkette von Kraftstoffen - Arbeitspaket 2: Emissionsfaktoren aus Abrieb und Wiederaufwirbelung. Ingenieurbüro Lohmeyer GmbH & Co. KG, Radebeul.

EC 2004: Directive 2004/42/DDPSCE of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC. Official Journal of the European Union. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004L0042&qid=1455622565462&from=EN [29.01.2021]

ECE 2014: Guidelines for Reporting Emissions and Projections data under the Convention on Long-range Transboundary Air Pollution. ECE/EB.AIR/125. 13 March 2014. https://www.ceip.at/reporting-instructions [25.01.2021]

ECE 2014a: Annexes for the revised 2014 reporting guideline: Annex II Recommended Structure for Informative Inventory Report for Report, Annex V Gridding NFR sectors, Annex VI LPS data https://www.ceip.at/reporting-instructions/annexes-to-the-2014-reporting-guidelines [25.01.2021]

Edelmann, W., Schleiss, K. 1999: Ökologischer, energetischer und ökonomischer Vergleich von Vergärung, Kompostierung und Verbrennung fester biogener Abfallstoffe. Zweite Auflage Februar 2001. On behalf of the Swiss Federal Office of Energy, Bern and the Swiss Agency for the Environment, Forests and Landscape, Bern. http://www.bafu.admin.ch/ghginv-ref [28.01.2021]

EMEP 2012a: Considerations of Changing the EMEP Grid. 36th Session of the EMEP Steering Body, 17 to 19 September 2012, Geneva, Switzerland. http://www.unece.org/index.php?id=30313 [05.02.2021]

EMEP 2012b: The new EMEP grid – An overview of the upcoming changes. https://www.ceip.at/fileadmin/inhalte/ceip/6_grid_lps/ceip_new_emep_grid.pdf [05.02.2021]

EMEP/EEA 2016: EMEP/EEA air pollutant emission inventory guidebook - 2016 https://www.eea.europa.eu/publications/emep-eea-guidebook-2016 [09.02.2021]

EMEP/EEA 2019: EMEP/EEA air pollutant emission inventory guidebook 2019. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019 [02.02.2021]

EMIS 2021/(NFR-Code): Comments to EMIS database. Internal documents. Federal Office for the Environment, Bern. To find the EMIS comment that belongs to the specified NFR Code, see Table 12-1 on page 318 [available in German only]. If not further specified in the reference and more than one comment appear under the same NFR Code, all comments are relevant.

EMPA 1999: Written communication from Dr. H.W. Jäckl (EMPA, Dübendorf) to Andreas Liechti (FOEN, Bern), 09.03.1999. www.bafu.admin.ch/ghginv-ref [31.01.2021]

EMPA 2004: PM10-Emissionen bei Anlagen der Holzbearbeitung, Bericht zur Hauptstudie, März 2004. Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf.

EV 2014: Jahresbericht 2014. Erdöl-Vereinigung [Rapports annuel 2013. L'Union Pétrolière]. Zürich. https://www.avenergy.ch/images/pdf/ev_jahresbericht_2014.pdf in German [29.01.2021]

FCA 2015a: Bunkers of diesel oil 1990-2014. Written communication Wolfgang Kobler, Federal Customs Administration (FCA) to Anouk Bass (FOEN), 21.09.2016.

FCA 2015c: Import- und Exportstatistik Swiss-Impex. Tarifnummer 87 Automobile etc. (tarif no. 87 motorised vehicles) https://www.swiss-impex.admin.ch [03.02.2021]

FEDPOL 2020: Bundesamt für Polizei fedpol, Statistik Pyrotechnikumsatz in der Schweiz. https://www.fedpol.admin.ch/fedpol/de/home/sicherheit/sprengstoff_pyrotechnik/pyrotechnische-gegenstaende/statistik.html [29.01.2021]

FEDRO 2013: Extract 2AA of MOFIS database (reference date 30.09.2013) of the Federal Roads Office (FEDRO) containing vehicle stock numbers. E-mail from A. Lehmann (FEDRO) to P. Wüthrich, INFRAS on 14.11.2013

Fial 2013: Die Schweizer Nahrungsmittel-Industrie im Jahr 2012. http://www.fial.ch/wp-content/uploads/2017/03/fial_Statistik-2012_de.pdf [08.02.2021]

FOAG 2011: Klimastrategie Landwirtschaft: Klimaschutz und Anpassung an den Klimawandel für eine nachhaltige Schweizer Land- und Ernährungswirtschaft. Federal Office for Agriculture, Bern. https://www.blw.admin.ch/blw/de/home/nachhaltige-produktion/umwelt/klima.html [05.02.2021], [in German]

FOCA 1991: Crossair confidential data 1991. Federal Office of Civil Aviation, Bern.

FOCA 1991a: L'aviation civile Suisse en 1990. Federal Office of Civil Aviation, Bern. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2004: Unternehmensstatistik der Schweizerischen Helikopterunternehmungen. Federal Office of Civil Aviation, Bern. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2006: GHG emissions of Swiss civil aircraft in 1990 and 2004: data, proceeding and description of the calculations. Written communication from Theo Rindlisbacher and Paul Stulz (FOCA, Bern) to Andreas Liechti (FOEN, Bern), 20./22.02.2006.

FOCA 2006a: GHG emissions of Swiss civil aircraft in 1990, 1995, 2000, 2002, 2004 and 2005: data, proceeding and description of the calculations. Written communication from Theo Rindlisbacher (FOCA, Bern) to Paul Filliger (FOEN, Bern), 17.11.2006. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2007a: Aircraft Piston Engine Emissions. Summary Report. Federal Office of Civil Aviation. Report Ref. 0 / 3/33/33-05-003 ECERT. Bern. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2008: GHG emissions of Swiss civil aircraft in 2007. Written communication from Theo Rindlisbacher (FOCA, Bern) to Beat Müller (FOEN, Bern), 01.12.2008. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2009: GHG emissions of Swiss civil aircraft in 2008. Written communication from Theo Rindlisbacher (FOCA, Bern) to Beat Müller (FOEN, Bern), 16.2.2010. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2010: GHG emissions of Swiss civil aircraft in 2009. Written communication from Theo Rindlisbacher (FOCA, Bern) to Sophie Hoehn (FOEN, Bern), 18.11.2010. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2011: GHG emissions of Swiss civil aircraft in 2010. Written communication from Theo Rindlisbacher (FOCA, Bern) to Sophie Hoehn (FOEN, Bern), 09.11.2011. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2012: GHG emissions of Swiss civil aircraft in 2011. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk Bass (FOEN, Bern), 07.09.2012. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2013: GHG emissions of Swiss civil aircraft in 2012. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk Bass (FOEN, Bern), 07.11.2013. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/references.html [01.02.2021]

FOCA 2014: GHG emissions of Swiss civil aircraft in 2013 and corrections for the year 2011. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 30.10.2014 [confidential/internal].

FOCA 2015: GHG emissions of Swiss civil aircraft in 2014. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 29.10.2015 [confidential/internal].

FOCA 2016: GHG emissions of Swiss civil aircraft in 2015. Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 6.12.2016 [confidential/internal].

FOCA 2016a: Abschätzung von PM Emissionen aus dem Luftverkehr mittel genereischer Faktoren. Aktennotiz. Bundesamt für Zivilluftfahrt BAZL. 26. Sept. 2016. Uster.

FOCA 2017: GHG emissions of Swiss civil aircraft in 2016. "BAFU EMIS Inputtabelle BAZL 2016.xlsx". Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 24.11.2017 [confidential/internal].

FOCA 2018: GHG emissions of Swiss civil aircraft in 2017. "BAFU EMIS Inputtabelle BAZL 2017.xlsx". Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 12.07.2018 [confidential/internal].

FOCA 2019: GHG emissions of Swiss civil aircraft in 2018. "BAFU EMIS Inputtabelle BAZL 2018.xlsx". Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 25.06.2019 [confidential/internal].

FOCA 2020: GHG emissions of Swiss civil aircraft in 2019. "BAFU EMIS Inputtabelle BAZL 2019.xlsx". Written communication from Theo Rindlisbacher (FOCA, Bern) to Anouk-Aimée Bass (FOEN, Bern), 24.8.2020 [confidential/internal].

FOEN 2006: Prozess EMIS (Emissions-Informationssytem Schweiz). Beschrieb des Prozesses (= Handbuch zur EMIS-Datenbank (Entwurf)). Internes Dokument. [Manual to EMIS database]. Federal Office for the Environment. 23. Mai 2006. Bern.

FOEN 2008: Switzerland's Informative Inventory Report 2008 (IIR). Submission under the UNECE Convention on Long-range Transboundary Air Pollution. Submission of March 2008 to the United Nations ECE Secretariat.

FOEN 2011a: NO_2 ambient concentrations in Switzerland. Modelling results for 2005, 2010, 2015. Federal Office for the Environment, Bern. Environmental studies no. 1123. INFRAS/Meteotest, Zürich, Bern.

FOEN 2013d: PM10 and PM2.5 ambient concentrations in Switzerland. Modelling results for 2005, 2010, 2020. Federal Office for the Environment, Bern. Environmental studies no. 1301. INFRAS/Meteotest, Zürich, Bern.

FOEN 2014d: Von Arx U.: Feuerwerkskörper. Umweltauswirkungen und Sicherheitsaspekte. Bundesamt für Umwelt, Bern. Umwelt-Wissen Nr.1423.

FOEN 2015j: Non-road energy consumption and pollutant emissions. Study for the period from 1980 to 2050 (Original in German: Energieverbrauch und Schadstoffemissionen des Nonroad-Sektors. Studie für die Jahre 1980-2050. Schlussbericht). INFRAS. Ed. by the Federal Office for the Environment. https://www.bafu.admin.ch/bafu/en/home/topics/air/publications-studies/publications/non-road-energy-consumption-and-pollutant-emissions.html [29.01.2021]

FOEN 2017c: Adressliste der Schweizer Kläranlagen mit Angaben zur Ausbaugrösse. Federal Office for the Environment, Bern, 29.08.2017. https://www.bafu.admin.ch/dam/bafu/de/dokumente/wasser/fachinfo-daten/ARA_Liste_August2017_Version_Internet_.xlsx.download.xlsx/ARA_Liste_August2017_Version_Internet_.xlsx [28.01.2021]

FOEN 2017d: Switzerland's 7th National Communication and Third Biennial Report under the UNFCCC. Fourth National Communication under the Kyoto Protocol to the UNFCCC. Federal Office for the Environment, Bern. https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/climate-reporting/national-communications-and-biennial-reports.html [06.02.2021]

FOEN 2020: Switzerland's Greenhouse Gas Inventory 1990–2018, National Inventory Report 2020 and CRF tables 1990–2018. Submission of April 2020 to the United Nations Framework Convention on Climate Change. Federal Office for the Environment, Bern. http://www.climatereporting.ch [25.01.2021]

FOEN 2020b: Switzerland's Informative Inventory Report 2020 (IIR). Submission under the UNECE Convention on Long-range Transboundary Air Pollution. Submission of March 2020 to the United Nations ECE Secretariat. https://www.ceip.at/status-of-reporting-and-review-results/2020-submissions [25.01.2021]

FOEN 2020f: Jahrbuch Wald und Holz 2019. Umwelt-Zustand Nr. 1914 [Annuaire La forêt et le bois 2019. Etat de l'environnement no 1914]. Federal Office for the Environment, Bern. https://www.bafu.admin.ch/uz-1914-d [German] https://www.bafu.admin.ch/uz-1914-f [French] [29.01.2021]

FOEN 2020h: Waste Statistics for 2019. Federal Office for the Environment, Bern. https://www.bafu.admin.ch/bafu/en/home/topics/waste/state/data.html [29.01.2021] selected data.

FOEN 2020i: CO_2-Emissionsfaktor Erdgas, Zeitreihe für das Treibhausgasinventar der Schweiz, internal documentation, Federal Office for the Environment, Bern.

FOEN 2021: Switzerland's Greenhouse Gas Inventory 1990–2019, National Inventory Report 2021 and CRF tables 1990–2019. Submission of April 2021 to the United Nations Framework Convention on Climate Change. Federal Office for the Environment, Bern. http://www.climatereporting.ch [forthcoming]

FOEN 2021a: Qualitätsmanagement Treibhausgasinventar – Handbuch. Bundesamt für Umwelt (BAFU), Bern [German for: Quality management system Greenhouse Gas Inventory – Manual. Federal Office for the Environment (FOEN), Bern [confidential/internal].

Frei E., Vökt U., Flückiger R., Brunner H. and Schai F. 1980: Bodeneignungskarte der Schweiz, Massstab 1:200000. Grundlagen für die Raumplanung, Bundesämter für Raumplanung, Landwirtschaft und Forstwesen, EDMZ Bern.

Glüge J., Steinlin C. and Bogdal C. 2017: Emission inventory for polychlorinated biphenyls (PCBs) in Switzerland, Report, ETH Zurich [draft]
PCB emission model (Microsoft Excel/VBA) can be downloaded from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0183768#sec039 [28.01.2021]

Graf 1990: Schmoll AG Basel Kabelzerlegungsanlage, Konzept Rauchgasreinigung.

HAFL 2011: Bestimmung Tiere der Rindviehkategorien ab 2009 für die Berechnung des Ammoniakinventars. Hochschule für Agrar-, Forst- und Lebensmittelwissenschaften. Zollikofen. 2011.

HTAP 2010: Task Force on Hemispheric Transport of Air Pollution – Advice on Future O3 Boundary Conditions for Europe. Assessment Report, October 2012. http://www.htap.org/publications/assessment_reports.htm [05.02.2021]

Hubschmid S., 2014: VOC-Emissionen aus lösungsmittelhaltigen Haushaltsprodukten, Master-Arbeit Silvia Hubschmid, FHNW 2014

IFEU 2010: Aktualisierung des Modells TREMOD - Mobile Machinery (TRE-MOD-MM). Endbericht im Auftrag des Umweltbundesamtes. UBA Texte 28/2010. Institut für Energie- und Umweltforschung (IFEU), Heidelberg. https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3944.pdf [08.02.2021]

IFEU/INFRAS 2009: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland, Endbericht. IFEU und INFRAS im Auftrag des Umweltbundesamts Dessau/Deutschland, FKZ 360 16 023. Heidelberg/Zürich/Bern. 31. Oktober 2009.

INFRAS 2007: PM10-Emissionen des Verkehrs, Teil Schienenverkehr. INFRAS commissioned by FOEN. Internal report. 10.01.2007

INFRAS 2011a: Bunker fuels Bodensee/Genfersee, Datenverfügbarkeit und Berechnung der Bunker Fuels. Internal document. Federal Office for the Environment. September 2011.

INFRAS 2015a: Online database of emission factors, activity data and emissions of non-road vehicles (corresponding report is FOEN 2015j) https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html [29.01.2021]

INFRAS 2015b: Ammoniakemissionen aus der Landwirtschaft. Unsicherheitsanalyse. Schlussbericht. Zürich, 26. Juni 2015 (Uncertainties of agricultural ammonia emissions). INFRAS mandated by the Federal Office for the Environment FOEN. Internal report, 26th June 2015 Zürich.

INFRAS 2017: Pilotstudie zum Treibstoffverbrauch und den Treibhausgasemissionen im Verkehr 1990-2050 - Szenarien für den Strassenverkehr. Schlussbericht. Bundesamt für Umwelt BAFU. Mandated by the Swiss Federal Office for the Environment. Internal Report of FOEN (in German). Bern.
http://goo.gl/dgVNT2 [03.02.2021]

INFRAS 2017b: Ammoniakemissionen aus der Landwirtschaft. Unsicherheitsanalyse Teil II. Schlussbericht. (Uncertainties of agricultural ammonia emissions – part II; Report in German only). INFRAS mandated by the Federal Office for the Environment FOEN. Internal report, January 2017 Zürich.

INFRAS 2017c: Luftschadstoffemissionen des Strassenverkehrs der Schweiz. Schlussbericht, Bern, 24. November 2017.
https://www.bafu.admin.ch/dam/bafu/de/dokumente/luft/externe-studien-berichte/Bericht_Luftschadstoffemissionen_des_Strassenverkehrs_der_Schweiz_1990_2050.pdf.download.pdf/Bericht_Luftschadstoffemissionen_des_Strassenverkehrs_der_Schweiz_1990_2050.pdf [01.02.2021], [in German]

INFRAS 2019: The Handbook Emission Factors for Road Transport (HBEFA), version 4.1 (MS Access runtime application). INFRAS in cooperation with further editors: FOEN/Switzerland; Umweltbundesamt Dessau/Germany; Umweltbundesamt Wien/Austria; Swedish Road Administration, ADEME/France; SFT/Norway. Bern. 12.09.2019.
http://www.hbefa.net/e/index.html [01.02.2021]

INFRAS 2019a: HBEFA 4.1 – Development Report. Notter, B., Keller, M., Althaus, H.-J., Cox, B., Knörr, W., Heidt, C., Biemann, K., Räder, D., Jamet, M. Commissioned by FOEN/Switzerland; Umweltbundesamt Dessau/Germany; Umweltbundesamt Wien/Austria; Swedish Road Administration, ADEME/France; SFT/Norway. Bern, Heidelberg. 21.08.2019.

Integer 2013: Emissions Control in Non-Road Mobile Machinery (NRMM) Markets: 2013 Edition. Integer Research Limited, London.

IPCC 1996: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change.
https://www.ipcc.ch/report/revised-1996-ipcc-guidelines-for-national-greenhouse-gas-inventories [09.02.2021]

IPCC 2006: IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change.
http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html [25.01.2021]

Jardin Suisse 2012: Zahlen zum Schweizerischen Gartenbau. Unternehmerverband Gärtner Schweiz. Internal document FOEN.

Kaufmann 2015: Energieverbrauch stationäre Motoren und Gasturbinen ab 1990. Excel data file for internal use on behalf of the Federal Office for the Environment, Bern. Eicher + Pauli, Liestal, 13.10.2015.

Külling, D.R., Stadelmann, F.X., 2002: Nährstoffe und Schwermetalle im Klärschlamm 1975 – 1999. AGRARForschung 9 (5): 200-205, 2002.

Kupper, T., Bonjour, C., Achermann, B., Zaucker, F., Rihm, B., Menzi, H., 2013: Ammoniakemissionen in der Schweiz 1990-2010 und Prognose bis 2020. Berner Fachhochschule. Hochschule für Agrar-, Forst- und Lebensmittelwissenschaften. http://agrammon.ch [04.03.2021]

Kupper, T., Bonjour, C., Menzi, H., 2015: Evolution of farm and manure management and their influence on ammonia emissions from agriculture in Switzerland between 1990 and 2010. Atmospheric Environment 103, 215-221

Kupper, T., Bonjour, C., Menzi, H., Zaucker, F., Bretscher, D., 2018: Ammoniakemissionen der schweizerischen Landwirtschaft 1990-2015 und Prognose bis 2030. Hochschule für Agrar-, Forst- und Lebensmittelwissenschaften. Zollikofen, Schweiz. https://agrammon.ch/de/downloads/ [27.01.2021]

Kurz, D., Alveteg, M., Sverdrup, H., 1998: Acidification of Swiss forest soils. Development of a regional dynamic assessment. Bern: Swiss Agency for the environment, Forests and Landscape (SAEFL), Environmental Documentation 89. 115 p.

KWF 2012: P. Harbauer: Forstmaschinenstatistik zeigt deutliche Stabilisierung des Marktes. 17. KWF-Tagung. https://kwf2018.kwf-online.de/index.php/aktuelles/presse/159-kwf-forstmaschinenstatistik-zeigt-deutliche-stabilisierung-des-marktes [03.02.2021]

Lemieux, P., et al. 2003: Variables affecting emissions of PCDD/Fs from uncontrolled combustion of household waste in barrels. Air & Waste Management Association. 53: 523–531. USA.

Leupro 2012: Entwicklung und Prognose der Emissionsfaktoren Feuerungen für den Zeitraum 1990 – 2035. Leupro im Auftrag des Bundesamtes für Umwelt (BAFU), 2012.

LUBW 1995: Stoffbericht Hexachlorbenzol (HCB). Texte und Bericht zur Altlastenbearbeitung 18/95. Landesanstalt für Umweltschutz, Baden-Württemberg, Karlsruhe. Germany. https://pudi.lubw.de/detailseite/-/publication/27419-Stoffbericht_Hexachlorbenzol_%28HCB%29.pdf [08.02.2021]

Matzer, C., Weller, K., Dippold, M., Lipp, S., Röck, M., Rexeis, M., Hausberger, S., 2019: Update of emission factors for HBEFA 4.1. Final report. Technische Universität (TU) Graz, Austria. 12.04.2019.

Mejía-Centeno 2007: Effect of low-sulfur fuels upon NH_3 and N_2O emission during operation of commercial three-way catalytic converters. Topics in Catalysis. Volume 42-43, Numbers 1-4.

Meteotest 2013: Rasterung der Emissionsdaten der Schweiz auf 0.1°-Gitter – Methodik (Vorstudie). Meteotest im Auftrag des Bundesamtes für Umwelt (BAFU), 2013.

Meteotest 2014: Rasterung der Emissionsdaten Schweiz auf 0.1°-Gitter. Anpassungen an neue UNECE-Guidelines und Überprüfung neuer Datengrundlagen. Bericht vom 27.10.2014. Im Auftrag des Bundesamts für Umwelt.

Meteotest 2015: Datengrundlagen/Verteilschlüssel für GNFR-Tool im MESAP: Anpassungen für die Submission 2015. Aktennotiz zu den GNFR-Anpassungen. Meteotest im Auftrag des Bundesamtes für Umwelt (BAFU), 2015.

Meteotest 2019a: NMVOC-Emissionen der Waldflächen in der Schweiz; Zeitreihe 1990–2016, langfristige Entwicklung, Sensitivitätsanalyse für zwei Extremtage. Meteotest AG, Bern, commissioned by the Federal Office for the Environment (FOEN).

Möhring, A., Mack, G., Zimmermann, A., Mann, S., Ferjani, A. 2018: Evaluation Versorgungssicherheitsbeiträge: Schlussbericht. Agroscope Science Nr. 66, Agroscope. Ettenhausen, Switzerland.

Neosys 2013: EMIS Comments Black Carbon factors. Im Auftrag des Bundesamts für Umwelt (BAFU) 2013.

Nielsen et al. 2013. Nielsen, O.-K., Plejdrup, M.S., Winther, M., Nielsen, M., Fauser, P., Mikkelsen, M.H., Albrektsen, R., Hjelgaard, K., Hoffmann, L., Thomsen, M., Bruun, H.G.; Danish emission inventory for hexachlorobenzene and polychlorinated biphenyls. Aarhus University, DCE – Danish Centre for Environment and Energy, 65 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 103 http://dce2.au.dk/pub/SR103.pdf [29.01.2021]

Nussbaumer, T., Hälg, L. 2015: Emissionsfaktoren von Holzfeuerungen – Aktualisierung und Ergänzung 2014. Verenum im Auftrag des Bundesamtes für Umwelt (BAFU) 2015, inkl. Excelfile.

Off-Highway Research 2005: The Market for Construction Equipment and Agricultural Tractors in Switzerland. Internal document INFRAS Bern. September 2005 [confidential/hardcopy].

Off-Highway Research 2008: The Market for Construction Equipment and Agricultural Tractors in Switzerland. Internal document FOEN. November 2008 [confidential/internal]

Off-Highway Research 2012: The Market for Construction Equipment and Agricultural Tractors in Switzerland. Internal document FOEN. April 2012 [confidential/internal].

OS 2020: Liechtenstein's energy statistics 2019. Office of statistics Liechtenstein. https://www.llv.li/files/as/energiestatistik-2019.pdf [03.02.2021]

Passant et al. 1993: Emissions of volatile organic compounds (VOCs) from the food and drink industries of the European Community, Atmospheric Environment Vol. 27A, No. 16, 1993.

Peter, S., Lehmann, B., Valsangiacomo, A. 2010: "Stickstoff 2020" – Möglichkeiten und Einschränkungen zur Vermeidung landwirtschaftlicher Stickstoffemissionen in der Schweiz. Zürich, Switzerland: ETH Zürich, Gruppe Agrar-, Lebensmittel- und Umweltökonomie (AFEE), Institut für Umweltentscheidungen (IED).

Prognos 2012a: Die Energieperspektiven für die Schweiz bis 2050 – Energienachfrage und Elektrizitätsangebot in der Schweiz 2000–2050. Prognos AG im Auftrag des Bundesamtes für Energie, Basel. https://www.bfe.admin.ch/bfe/de/home/politik/energiestrategie-2050/dokumentation/energieperspektiven-2050.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvNjczNw==.html [05.02.2021]

Prognos 2013: CO_2-Emissionen 1990-2012 von Industrie- und Dienstleistungen, Endbericht / Kurzdokumentation zuhanden Bundesamt für Umwelt, Bern. Prognos, Basel. http://www.bafu.admin.ch/ghginv-ref [29.01.2021]

Prognos/INFRAS/TEP/Ecoplan 2021: Energy perspectives of Switzerland up to 2060. Update 2020. Federal Office for Energy (SFOE). Forthcoming. https://www.bfe.admin.ch/bfe/de/home/politik/energieperspektiven-2050-plus.html [04.03.3021]

PRTR 2020: Swiss Pollutant Release and Transfer Register (Swiss PRTR) in year 2020. https://www.bafu.admin.ch/bafu/en/home/topics/chemicals/state/swissprtr-pollutant-register.html [03.02.2021]

PRTR 2021: Swiss Pollutant Release and Transfer Register (Swiss PRTR) in year 2021. https://www.bafu.admin.ch/bafu/en/home/topics/chemicals/state/swissprtr-pollutant-register.html [09.02.2021]

Quantis 2014: Methanemissionen der Schweizer Gaswirtschaft. Zeitreihe 1990 bis 2012. Schlussbericht. Quantis im Auftrag des Schweizerischen Vereins des Gas- und Wasserfaches SVGW und des Bundesamts für Umwelt BAFU. http://www.bafu.admin.ch/ghginv-ref [03.02.2021]

Raffinerie de Cressier 1992: Project CRISTAL – Influence sur l'environnement (incl. annexes), Raffinerie de Cressier (rapports préparé en collaboration avec Badger BV, Pays-Bas), Cressier [confidential/internal].

Reidy, B. and Menzi H. 2005: Ammoniakemissionen in der Schweiz: Neues Emissionsinventar 1990 bis 2000 mit Hochrechnungen bis 2003. Technischer Schlussbericht, HAFL Zollikofen, Bern.

Rentz, O., Karl, U., Haase, M., Koch, M. 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs). Umweltbundesamt (UBA) 2008. Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs) | Umweltbundesamt [03.02.2021]

Richner, W., Flisch, R., Schlegel, P., Zähner, M, Menzi, H.2017: Eigenschaften und Anwendung von Düngern. In chapter 4: Grundlagen für die Düngung landwirtschaftlicher Kulturen in der Schweiz (GRUD 2017) (Ed. Richner, W., Sinaj, S). Agrarforschung Schweiz, 8 (6), Spezialpublikation, 217 S.

SAEFL 1996a: Luftschadstoff-Emissionen aus natürlichen Quellen der Schweiz. [Emissions polluantes dues aux sources naturelles en Suisse]. Schriftenreihe Umwelt Nr. 257. [Cahier de l'environnement No 257]. Swiss Agency for the Environment, Forests and Landscape, Bern. http://www.climatereporting.ch

SAEFL 2000: Handbuch Emissionsfaktoren für stationäre Quellen. Bundesamt für Umwelt, Wald und Landschaft (BUWAL). Reihe Vollzug Umwelt. Bern.

SBB 2005: PM10-Emissionen des Schienenverkehrs. Schlussbericht Teil SBB, Umwelt-Center der Schweiz. Bundesbahnen. FOEN-internal document. 25. August 2005.

SBV 2013: Betriebsinterne Verrechnungsansätze und Inventar-Grunddaten (BIV) 2013. Schweizerischer Baumeisterverband. Verlag SBV [confidential/internal].

SBV 2020: Statistiques et évaluations concernant l'agriculture et l'alimentation, 2019. [Statistische Erhebungen und Schätzungen über Landwirtschaft und Ernährung, 2019]. Swiss Farmers Union, Brugg. [available in German and French, partly online, partly hardcopy] https://www.sbv-usp.ch/fr/service/agristat-statistique-de-lagriculture-suisse/statistiques-et-evaluations-see/ [27.01.2021]

Schleiss, C. 2017: Erhebung Schweizer Daten zu Mengen in der Kompostierung, Schlussbericht, Grenchen, 17.11.2017.

Schrade, S. 2009: Ammoniak- und PM10-Emissionen im Laufstall für Milchvieh mit freier Lüftung und Laufhof anhand einer Tracer-Ratio-Methode, Christian-Albrechts-Universität, Kiel, Germany, 2009. [in German]

Schwager, S. 2005: Personal communication from Stefan Schwager (FOEN, Bern) to Andreas Liechti (FOEN, Bern), 23.12.2005. http://www.bafu.admin.ch/ghginv-ref [29.01.2021]

SEPA 2010: Sweden's Informative Inventory Report 2010, Submitted under the Convention on Long-Range Transboundary Air Pollution. Swedish Environmental, Protection Agency.

SFOE 1991: Schweizerische Gesamtenergiestatistik 1990. Statistique globale suisse de l'énergie 1990. Swiss Federal Office of Energy, Bern.

SFOE 2009b: Schweizerische Holzenergiestatistik. Erhebung für das Jahr 2008. Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/en/home/versorgung/statistik-und-geodaten/energiestatistiken/teilstatistiken.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvNDU3OQ==.html [03.02.2020]

SFOE 2014c: Thermische Stromproduction inklusive Wärmekraftkopplung (WKK) in der Schweiz. Ausgabe 2013. Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/de/home/news-und-medien/publikationen.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvNzU4OA==.html [08.02.2021]

SFOE 2015d: Energieverbrauch in der Industrie und im Dienstleistungssektor. Resultate 2014 (German/French). Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/sector-statistics.html#kw-87276 [01.02.2021]

SFOE 2020: Schweizerische Gesamtenergiestatistik 2019. Statistique globale suisse de l'énergie 2019. Swiss Federal Office of Energy, Bern. In German and French https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/overall-energy-statistics.html [28.01.2021]

SFOE 2020a: Schweizerische Statistik der erneuerbaren Energien (Swiss renewable energy statistics). Ausgabe 2019. Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/sector-statistics.html [28.01.2021]

SFOE 2020b: Schweizerische Holzenergiestatistik. Erhebung für das Jahr 2019. Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/de/home/news-und-medien/publikationen.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTAxNzE=.html https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/teilstatistiken.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvOTgxMQ==.html [31.01.2020]

SFOE 2020c: Thermische Stromproduktion inklusive Wärmekraftkopplung (WKK) in der Schweiz (Ausgabe 2019). Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/sector-statistics.html [29.01.2021]

SFOE 2020d: Energieverbrauch in der Industrie und im Dienstleistungssektor. Resultate 2019 (German/French). Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/sector-statistics.html [29.01.2021]

SFOE 2020e: Analyse des schweizerischen Energieverbrauchs 2000 - 2019 nach Verwendungszwecken. Prognos, im Auftrag des Bundesamts für Energie. 2020. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/analysis-of-energy-consumption-by-specific-use.html [01.02.2021] und Ex-Post-Analyse Energieverbrauch nach Verwendungszwecken 2000 – 2019 (xlsx, 303 KB), Tabellen. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/analysis-of-energy-consumption-by-specific-use.html [01.02.2021]

SFOE 2020g: Schweizerische Elektrizitätsstatistik (Swiss electricity statistics). Ausgabe 2019. Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/elektrizitaetsstatistik.html/ [24.02.2021]

SFOE/FOEN 2014: Messung von Heizwerten und CO_2-Emissionsfaktoren von Erdölprodukten 2013. Statistische Analyse der Messresultate, Bern.

SFSO 2007: Federal Statistical Office – Land Use statistics (GEOSTAT) according to 1992 nomeclature.

SFSO 2009: Federal Statistical Office – Census of enterprises (GEOSTST).

SFSO 2011a: Swiss Federal Statistical Office – Statistics of population and households (STATPOP) 2010.

SFSO 2013a: Landwirtschaftliche Betriebszählung – Zusatzerhebung. Swiss Federal Statistical Office (SFSO), Neuchâtel. Internal/confidential.

SFSO 2020a: STAT-TAB: Die interaktive Statistikdatenbank; Datenwürfel für Thema 07.2 – Landwirtschaft. Swiss Federal Statistical Office, Neuchâtel. https://www.pxweb.bfs.admin.ch/pxweb/de/ [28.01.2021]

SFSO 2020b: Background data of the Gross Nutrient Balance of the Swiss Federal Statistical Office. Swiss Federal Statistical Office, Neuchâtel. [confidential/internal, queries from database].

SFSO 2020c: Die Bevölkerung der Schweiz 2019 (Switzerland's population 2019). Swiss Federal Statistical Office. Neuchâtel. https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung/stand-entwicklung/bevoelkerung.assetdetail.14941612.html [28.01.2021]

SFSO 2020d: Die Beschäftigungsstatistik der Schweiz 2019 (Switzerland's job statistics 2019). Swiss Federal Statistical Office, Neuchâtel. https://www.bfs.admin.ch/bfs/en/home/statistics/industry-services/businesses-employment/jobs-statistics.html [28.01.2021]

SFSO 2020e: Distribution of road vehicles by vehicle group. Swiss Federal Statistical Office 2019 https://www.bfs.admin.ch/bfs/en/home/statistics/mobility-transport/transport-infrastructure-vehicles/vehicles/road-vehicles-stock-level-motorisation.html [01.02.2021]

SFSO 2020i: Farm structure census 2019 (Landwirtschaftliche Strukturerhebung). Swiss Federal Office. Neuchâtel. https://www.bfs.admin.ch/bfs/en/home/statistics/agriculture-forestry/farming.html [28.01.2021]

SFSO 2020p: Szenarien zur Bevölkerungsentwicklung der Schweiz 2020-2050. Referenzszenario A-00-2020. https://www.pxweb.bfs.admin.ch/pxweb/de/px-x-0104000000_102/-/px-x-0104000000_102.px/ [04.03.3031]

SFSO/BUWAL 2004: Wald und Holz in der Schweiz Jahrbuch 2004. Bundesamt für Statistik (SFSO) und Bundesamt für Umwelt, Wald und Landschaft (BUWAL). Bern.

SGWA 2020: Erdgaseigenschaften. Calculations and written communication R. Huber (Swiss Gas and Water Industry Association) to A. Schilt (FOEN). 28.04.2020 [confidential/internal]

SKW 2010: Annual reports of the Swiss Cosmetic and Detergent Association. Zurich.

Stehfest, E., Bouwman, L. 2006: N_2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. Nutrient Cycling in Agroecosystems 74 (3): 207-228. http://link.springer.com/article/10.1007%2Fs10705-006-9000-7 [28.01.2021]

Sutton, M. A., U. Dragosits, Y. S. Tang, and D. Fowler. 2000: "Ammonia Emissions from Non-Agricultural Sources in the UK." Atmospheric Environment 34(6): 855-869

Swiss Confederation 1983: Loi fédérale du 7 octobre 1983 sur la protection de l'environnement (Loi sur la protection de l'environnement, LPE). As at 1 August 2008. http://www.admin.ch/ch/f/rs/c814_01.html [official text in German, French and Italian] [03.02.2021]

Swiss Confederation 1985: Ordonnance du 16 décembre 1985 sur la protection de l'air (OPair). [Swiss Federal Ordinance on Air Pollution Control, OAPC]. As at 1 January 2009: Annex.
http://www.admin.ch/ch/f/rs/c814_318_142_1.html [official text in German, French and Italian]
https://www.admin.ch/opc/en/classified-compilation/19850321/index.html [English; as at 1 April 2017] [01.02.2021]

Swiss Confederation 1995: Ordinance of 19 June 1995 on the Technical Standards for Motor Vehicles and Their Trailors (TAFV1). As at 1 July 2008.
http://www.admin.ch/ch/d/sr/c741_412.html [official text in German/French/Italian] [03.02.2021]

Swiss Confederation 1997: Ordonnance du 12 novembre 1997 sur la taxe d'incitation sur les composés organiques volatils (OCOV). As at 1 January 2009.
http://www.admin.ch/ch/f/rs/c814_018.html [official text in German/French/Italian] [02.02.2021]

Swiss Confederation 1999: Federal Constitution of the Swiss Confederation of 18 April 1999 (Status as of 12 February 2017).
in French: https://www.admin.ch/opc/fr/classified-compilation/19995395/index.html
in English: https://www.admin.ch/opc/en/classified-compilation/19995395/index.html
(English is not an official language of the Swiss Confederation. This translation is provided for information purposes only and has no legal force.) [03.02.2021]

Swiss Confederation 2004: Botschaft zur Ratifikation des Protokolls vom 30. November 1999 zum Übereinkommen von 1979 über weiträumige grenzüberschreitende Luftverunreinigung, betreffend die Verringerung von Versauerung, Eutrophierung und bodennahem Ozon.
http://www.admin.ch/ch/d/ff/2004/3013.pdf [in German] [25.01.2021]

Swiss Confederation 2009: Bericht zum Konzept betreffend Lufthygienischen Massnahmen des Bundes (LRK) vom 11. September 2009.
http://www.admin.ch/ch/d/ff/2009/6585.pdf [in German] [03.02.2021]

Swiss Confederation 2011: Bundesgesetz über die Reduktion der CO_2-Emissionen (CO_2-Gesetz). Status as of 01.01.2018. http://www.admin.ch/ch/d/sr/c641_71.html [official text in German, French and Italian]; Federal Act on the Reduction of CO2 Emissions [English translation for information purposes only]: https://www.admin.ch/opc/en/classified-compilation/20091310/index.html [29.01.2021]

Swiss Confederation 2012: Verordnung über die Reduktion der CO_2-Emissionen (CO_2-Verordnung). As of 12.2.2013.
http://www.admin.ch/ch/d/sr/c641_711.html [29.01.2021]

Swiss Confederation 2013: Verordnungspaket zur Agrarpolitik 2014-2017. Schweizerischer Bundesrat.Bern.
https://www.blw.admin.ch/blw/de/home/politik/agrarpolitik/fruehere-reformetappen/ap-14-17/verordnungspaket-ap-14-17.html [06.02.2021]

Swiss Confederation 2017: Verordnungspaket zur Agrarpolitik 2018-2021. Schweizerischer Bundesrat.Bern.
https://www.blw.admin.ch/blw/de/home/politik/agrarpolitik/agrarpakete-aktuell/verordnungspaket-2017.html [05.02.2021]

Swiss Confederation 2018: Botschaft zur Genehmigung des Beschlusses 2012/2 vom 4. Mai 2012 zur Änderung des Protokolls von 1999 zum Übereinkommen über weiträumige grenzüberschreitende Luftverunreinigung, betreffend die Verringerung von Versauerung, Eutrophierung und bodennahem Ozon.
https://www.admin.ch/opc/de/federal-gazette/2018/5671.pdf [in German], [08.02.2021]

Swiss Confederation 2021: Switzerland’s Long-Term Climate Strategy. Swiss Confederation. https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/fachinfo-daten/langfristige-klimastrategie-der-schweiz.pdf.download.pdf/Switzerland's%20Long-Term%20Climate%20Strategy.pdf [24.02.2021].

Swiss Safety Center 2019: Quality management system according to ISO 9001:2015. Certificate. Scope: National Inventory System and Reporting under the UNFCCC and the Kyoto Protocol. Registration Number: 13-299-113. Initial certification: 25.11.2013. Recertification: 24.09.2019. Valid until: 24.11.2022. http://www.climatereporting.ch

TBF 2015: Neubearbeitung des Projektes "LEA - Emissionsfaktoren aus der Abfallverbrennung". Schlussbericht. Zürich, 22. September 2015.

Theloke, J., Obermeier, A., Friedrich, R. 2000: Ermittlung der Lösemittelemissionen 1994 in Deutschland und Methoden zur Fortschreibung. Institut für Energiewirtschaft und Rationelle Energieanwendung (IER) der Universität Stuttgart.Forschungsbericht 295 42 628. Im Auftrag des Umweltbundesamtes. https://www.umweltbundesamt.de/publikationen/ermittlung-loesemittelemissionen-1994-in [29.01.2021]

Theloke, J. 2005: NMVOC-Emissionen aus der Lösemittelanwendung und Möglichkeiten zu ihrer Minderung. Fortschritt-Berichte VDI Reihe 15 Nr. 252. Düsseldorf: VDI-Verlag. http://dx.doi.org/10.18419/opus-1660 [29.01.2021]

UK NAEI 2019: UK NAEI - National Atmospheric Emissions Inventory http://naei.beis.gov.uk/ [29.01.2021]

UNECE 2010: Report for the Stage 3 in-depth review of emission inventories submitted under the UNECE LRTAP Convention and EU National Emissions Ceilings, CEIP/S3.RR/2010/SWITZERLAND, 24.11.2010

UNECE 2016: Report for the Stage 3 in-depth review of emission inventories submitted under the UNECE LRTAP Convention and EU National Emissions Ceilings, CEIP/S3.RR/2016/SWITZERLAND, 26.09.2016

UNECE 2020: Stage 1 review report and Stage 2 review data from the Annual Synthesis & Assessment CLRTAP Inventory review https://www.ceip.at/status-of-reporting-and-review-results/2020-submissions [25.01.2021]

UNECE 2020a: Report for the Stage 3 in-depth review of emission inventories submitted under the UNECE LRTAP Convention and EU National Emissions Ceilings, CEIP/S3.RR/2020/SWITZERLAND, 03.11.2020

UNFCCC 2014a: Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention. Decision 24/CP.19 (FCCC/CP/2013/10/Add.3) http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf [26.01.2021]

USEPA 1995: Compilation of air pollutant emission factors (AP-42). https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors [28.01.2021]

USEPA 1998a: Locating and Estimating Air Emissions from Sources of Polycyclic Organic Matter. EPA 454/R-98-014. https://www.epa.gov/air-emissions-factors-and-quantification/locating-and-estimating-le-documents [26.02.2021]

USEPA 2010: Exhaust and Crankcase Emission Factors for Nonroad Engine Modelling - Compression Ignition. EPA-420-R-10-018 / NR-009d. Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency. July 2010. https://nepis.epa.gov/Exe/ZyPDF.cgi/P10005BI.PDF?Dockey=P10005BI.PDF [08.02.2021]

van Bruggen, C., Bannink, A., Groenestein, C.M., de Haan, B.J., Huijsmans, J.F.M., Luesink, H.H., van der Sluis, S.M., Velthof, G.L. 2014: Emissions into the atmosphere from agricultural activities in 2012. Calculations for ammonia, nitric oxide, nitrous oxide, methane and fine particulate matter using the NEMA model. Wageningen. WOt technical report 3 (in Dutch). Wageningen, NL: The Statutory Research Task Unit for Nature and the Environment (WOT Natuur & Milieu).

VBSA 2017: Klärschlammentsorgung in der Schweiz - Erhebung der Daten 2016. B. Freidl, VBSA, im Auftrag des Bundesamtes für Umwelt.

Wevers 2004: M. Wevers et al., Effect of backyard burning on dioxin deposition and air concetrations. Chemosphere 54, pp. 1351-1356.

WSL 2020: Database extract «swissfire» 1900-2019 by B. Pezzatti, 4. Mai 2020. Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf. www.wsl.ch/swissfire [02.02.2021]

Zimmermann, A., Möhring, A., Mack, G., Mann, S., Ferjani, A., Gennai, M.-P. 2011: Die Auswirkungen eines weiterentwickelten Direktzahlungssystems. Modellberechnungen mit SILAS und SWISSland. ART Bericht Nr. 744.

Zotter et al. 2021: Emissionsfaktoren von Holzfeuerungen – Aktualisierung und Ergänzung 2020. Verenum, im Auftrag des Bundesamtes für Umwelt 2021, inkl. Excelfile. In preparation

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. Green cell: new comments for the submission at hand.

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**	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	Gasproduktion und 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	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**
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*	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]	Kläranlagen 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
Cursive: 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 gives an overview over the level (2019) and trend (1990-2019) assessments with approach 1 and approach 2. Note that the key category analysis is performed based on the approach “fuels sold”, in the reporting tables characterized as “National total for the entire territory based on fuel sold” (in contrast to “fuels used”; for differentiation of the two approaches see chapter 3.1.6.1).

Table A - 1: Summary of Switzerland's key category analysis. Legend: L = Level (2019), T = Trend (1990-2019), 1 = approach 1 and 2 = approach 2.

KeyCategories		**NO_x (as NO_2)**	**NMVOC**	**SO_x (as SO_2)**	**NH_3**	**PM2.5**	**PM10**
NFR	Longname						
1A1a	Public electricity and heat production	L1, L2, T1, T2		L1, L2, T1, 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, L2, T1, T2		L1, L2, T1, T2		T1	T1
1A2gvii	Mobile combustion in manufacturing industries and construction	L1, T1				L1, L2, T1	L1, L2, T1, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	T1, T2		L1, L2			
1A3ai(i)	International aviation LTO (civil)	L1, T1, T2		T1			
1A3bi	Road transport: Passenger cars	L1, L2, T1, T2	L1, T1, T2	T1		L1	
1A3bii	Road transport: Light duty vehicles	L1, L2, T1, T2					
1A3biii	Road transport: Heavy duty vehicles and buses	L1, L2, T1, T2		T1, T2		T1, T2	T1
1A3biv	Road transport: Mopeds & motorcycles		L2				
1A3bv	Road transport: Gasoline evaporation		L1, T1				
1A3bvi	Road transport: Automobile tyre and brake wear					L1, L2, T1, T2	L1, L2, T1, T2
1A3c	Railways					L1, T1	L1, L2, T1, T2
1A3dii	National navigation (shipping)	T1					
1A4ai	Commercial/institutional: Stationary	L1		L1, L2, T1		L1, L2, T1	L1
1A4bi	Residential: Stationary	L1, L2	L1	L1, L2, T1, T2		L1, L2, T1, T2	L1, L2, T1, T2
1A4ci	Agriculture/Forestry/Fishing: Stationary					L1	
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery					L1	
1A5b	Other mobile (including military, land based and recreational boats)						L1
1B2aiv	Fugitive emissions oil: Refining and storage			T2			
1B2av	Distribution of oil products		T1				
2A1	Cement production					L2, T2	L1, L2
2A5a	Quarrying and mining of minerals other than coal					L1, L2, T1, T2	L1, L2, T1, T2
2B5	Carbide production			L2, T2			
2B10a	Other Chemical industry			L1, L2, T1, T2			
2C1	Iron and steel production					T1, T2	T1, T2
2D3a	Domestic solvent use		L1, L2, T1, T2				
2D3b	Road paving with asphalt		L1, T1				
2D3d	Coating applications		L1, L2, T1				
2D3g	Chemical products		L1, T1, T2				
2D3h	Printing		L1, T1				
2D3i	Other solvent use		L1, L2				
2G	Other product use		L1, L2			L1, L2, T1, T2	L1, L2
2H1	Pulp and paper industry					L1, L2, T1, T2	
2H2	Food and beverages industry		L1, T1		T2	L1, L2, T1, T2	L1, L2, T2
2I	Wood processing					L2, T2	L2, T1, T2
3B1a	Manure management - Dairy cattle		L1, L2, T1, T2		L1, L2, T1, T2		
3B1b	Manure management - Non-dairy cattle		L1, L2, T1, T2		L1, L2, T1, T2		
3B3	Manure management - Swine		L2, T2		L1, L2		L2
3B4gi	Manure management - Layers				L2		L2
3B4gii	Manure management - Broilers		L2, T2		T2		L2, T2
3Da1	Inorganic N-fertilizers (includes also urea application)	L2, T2			L1, L2, T1, T2		
3Da2a	Animal manure applied to soils	L2, T1, T2			L1, L2, T1, T2		
3Da2b	Sewage sludge applied to soils				T1		
3Da2c	Other organic fertilisers applied to soils				T1, T2		
3Da3	Urine and dung deposited by grazing animals	T2			T1, T2		
3De	Cultivated crops						L1, L2, T1, T2
5C1a	Municipal waste incineration					L1, L2	L1
5C1biv	Sewage sludge incineration			T2			
6A	Other sources				L2, T2		

A1.2 Detailed results of approach 1 assessment

The following tables depict the detailed results for the approach 1 level and trend assessments.

Table A - 2: List of Switzerland's approach 1 level key categories 2019 for the main pollutants, PM2.5 and PM10 ranked per pollutant and level contribution (Lx,t).

APPROACH 1 LEVEL ASSESSMENT FOR 2019						
NFR Code	**Source category**	**Pollutant**	**Ex,t (kt)**	**|Ex,t| (kt)**	**Lx,t**	**Cumula-tive Total**
1A3bi	Road transport: Passenger cars	NOx	22346	22346	36.4%	36.4%
1A3bii	Road transport: Light duty vehicles	NOx	5370	5370	8.8%	45.2%
1A3biii	Road transport: Heavy duty vehicles and	NOx	4975	4975	8.1%	53.3%
1A4bi	Residential: Stationary	NOx	4757	4757	7.8%	61.1%
1A2f	Stationary combustion in manufacturing	NOx	3718	3718	6.1%	67.1%
1A4ai	Commercial/institutional: Stationary	NOx	2387	2387	3.9%	71.0%
1A3ai(i)	International aviation LTO (civil)	NOx	2227	2227	3.6%	74.6%
1A2gvii	Mobile combustion in manufacturing	NOx	2097	2097	3.4%	78.1%
1A1a	Public electricity and heat production	NOx	2072	2072	3.4%	81.4%
3Da2a	Animal manure applied to soils	NH3	20028	20028	37.2%	37.2%
3B1a	Manure management - Dairy cattle	NH3	10869	10869	20.2%	57.4%
3B1b	Manure management - Non-dairy cattle	NH3	7375	7375	13.7%	71.1%
3B3	Manure management - Swine	NH3	4745	4745	8.8%	79.9%
3Da1	Inorganic N-fertilizers (includes also urea	NH3	2461	2461	4.6%	84.5%
2D3a	Domestic solvent use	NMVOC	11625	11625	14.3%	14.3%
3B1a	Manure management - Dairy cattle	NMVOC	8288	8288	10.2%	24.5%
2D3d	Coating applications	NMVOC	8049	8049	9.9%	34.5%
3B1b	Manure management - Non-dairy cattle	NMVOC	6800	6800	8.4%	42.8%
2G	Other product use	NMVOC	6653	6653	8.2%	51.0%
1A3bi	Road transport: Passenger cars	NMVOC	4763	4763	5.9%	56.9%
2D3h	Printing	NMVOC	3827	3827	4.7%	61.6%
2D3g	Chemical products	NMVOC	3534	3534	4.4%	66.0%
2D3b	Road paving with asphalt	NMVOC	2813	2813	3.5%	69.4%
1A4bi	Residential: Stationary	NMVOC	2716	2716	3.3%	72.8%
2D3i	Other solvent use	NMVOC	2100	2100	2.6%	75.4%
1A3bv	Road transport: Gasoline evaporation	NMVOC	2026	2026	2.5%	77.9%
2H2	Food and beverages industry	NMVOC	1999	1999	2.5%	80.3%
1A3bvi	Road transport: Automobile tyre and	PM10	2780	2780	19.7%	19.7%
1A2gvii	Mobile combustion in manufacturing	PM10	2335	2335	16.5%	36.2%
1A4bi	Residential: Stationary	PM10	1513	1513	10.7%	46.9%
1A3c	Railways	PM10	1483	1483	10.5%	57.4%
3De	Cultivated crops	PM10	1002	1002	7.1%	64.5%
2G	Other product use	PM10	452	452	3.2%	67.6%
2A5a	Quarrying and mining of minerals other	PM10	445	445	3.1%	70.8%
2H2	Food and beverages industry	PM10	332	332	2.3%	73.1%
1A4ai	Commercial/institutional: Stationary	PM10	325	325	2.3%	75.4%
5C1a	Municipal waste incineration	PM10	277	277	2.0%	77.4%
1A5b	Other mobile (including military, land	PM10	262	262	1.9%	79.2%
2A1	Cement production	PM10	251	251	1.8%	81.0%
1A4bi	Residential: Stationary	PM2.5	1429	1429	23.2%	23.2%
1A3bvi	Road transport: Automobile tyre and	PM2.5	945	945	15.4%	38.6%
1A2gvii	Mobile combustion in manufacturing	PM2.5	396	396	6.4%	45.0%
2G	Other product use	PM2.5	361	361	5.9%	50.9%
1A4ai	Commercial/institutional: Stationary	PM2.5	304	304	4.9%	55.8%
5C1a	Municipal waste incineration	PM2.5	249	249	4.0%	59.9%
1A3c	Railways	PM2.5	228	228	3.7%	63.6%
2A5a	Quarrying and mining of minerals other	PM2.5	222	222	3.6%	67.2%
1A4ci	Agriculture/Forestry/Fishing: Stationary	PM2.5	211	211	3.4%	70.6%
1A3bi	Road transport: Passenger cars	PM2.5	204	204	3.3%	73.9%
2H1	Pulp and paper industry	PM2.5	194	194	3.2%	77.1%
1A4cii	Agriculture/Forestry/Fishing: Off-road	PM2.5	179	179	2.9%	80.0%
2H2	Food and beverages industry	PM2.5	178	178	2.9%	82.9%
1A2f	Stationary combustion in manufacturing	SO2	1398	1398	31.5%	31.5%
1A4bi	Residential: Stationary	SO2	705	705	15.9%	47.3%
2B5	Carbide production	SO2	696	696	15.7%	63.0%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	350	350	7.9%	70.9%
1A4ai	Commercial/institutional: Stationary	SO2	286	286	6.4%	77.3%
1A1a	Public electricity and heat production	SO2	215	215	4.8%	82.2%

Table A - 3: List of Switzerland's approach 1 level key categories in the base year 1990 for the main pollutants, PM2.5 and PM10 ranked per pollutant and level contribution (Lx,0).

APPROACH 1 LEVEL ASSESSMENT FOR BASE YEAR						
NFR Code	**Source category**	**Pollutant**	**Ex,0 (kt)**	**|Ex,0| (kt)**	**Lx,0**	**Cumula-tive Total**
1A3bi	Road transport: Passenger cars	NOx	49357	49357	34.1%	34.1%
1A3biii	Road transport: Heavy duty vehicles and buses	NOx	28043	28043	19.4%	53.5%
1A4bi	Residential: Stationary	NOx	11629	11629	8.0%	61.6%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	NOx	10535	10535	7.3%	68.9%
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	6334	6334	4.4%	73.3%
1A1a	Public electricity and heat production	NOx	6294	6294	4.4%	77.6%
1A3bii	Road transport: Light duty vehicles	NOx	6197	6197	4.3%	81.9%
3Da2a	Animal manure applied to soils	NH3	33704	33704	49.0%	49.0%
3B1a	Manure management - Dairy cattle	NH3	10000	10000	14.5%	63.6%
3B3	Manure management - Swine	NH3	6804	6804	9.9%	73.5%
3B1b	Manure management - Non-dairy cattle	NH3	5538	5538	8.1%	81.5%
1A3bi	Road transport: Passenger cars	NMVOC	63465	63465	20.8%	20.8%
2D3d	Coating applications	NMVOC	40731	40731	13.4%	34.2%
2D3g	Chemical products	NMVOC	27504	27504	9.0%	43.2%
2G	Other product use	NMVOC	22927	22927	7.5%	50.7%
2D3h	Printing	NMVOC	20354	20354	6.7%	57.4%
1B2av	Distribution of oil products	NMVOC	17189	17189	5.6%	63.0%
1A3bv	Road transport: Gasoline evaporation	NMVOC	16246	16246	5.3%	68.4%
2D3e	Degreasing	NMVOC	11218	11218	3.7%	72.0%
3B1a	Manure management - Dairy cattle	NMVOC	10494	10494	3.4%	75.5%
2D3a	Domestic solvent use	NMVOC	9195	9195	3.0%	78.5%
1A4bi	Residential: Stationary	NMVOC	8849	8849	2.9%	81.4%
1A4bi	Residential: Stationary	PM10	5393	5393	21.4%	21.4%
1A3bvi	Road transport: Automobile tyre and brake wear	PM10	2182	2182	8.7%	30.0%
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2173	2173	8.6%	38.7%
2C1	Iron and steel production	PM10	1485	1485	5.9%	44.5%
1A3biii	Road transport: Heavy duty vehicles and buses	PM10	1465	1465	5.8%	50.3%
3De	Cultivated crops	PM10	1054	1054	4.2%	54.5%
1A1a	Public electricity and heat production	PM10	1034	1034	4.1%	58.6%
1A3c	Railways	PM10	983	983	3.9%	62.5%
2I	Wood processing	PM10	864	864	3.4%	65.9%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	PM10	833	833	3.3%	69.2%
1A3bi	Road transport: Passenger cars	PM10	637	637	2.5%	71.8%
2G	Other product use	PM10	588	588	2.3%	74.1%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM10	557	557	2.2%	76.3%
1A4ci	Agriculture/Forestry/Fishing: Stationary	PM10	542	542	2.1%	78.5%
1A4ai	Commercial/institutional: Stationary	PM10	521	521	2.1%	80.5%
1A4bi	Residential: Stationary	PM2.5	5068	5068	30.9%	30.9%
1A3biii	Road transport: Heavy duty vehicles and buses	PM2.5	1465	1465	8.9%	39.8%
2C1	Iron and steel production	PM2.5	818	818	5.0%	44.8%
1A1a	Public electricity and heat production	PM2.5	772	772	4.7%	49.5%
1A3bvi	Road transport: Automobile tyre and brake wear	PM2.5	745	745	4.5%	54.1%
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	729	729	4.4%	58.5%
1A3bi	Road transport: Passenger cars	PM2.5	637	637	3.9%	62.4%
1A4ci	Agriculture/Forestry/Fishing: Stationary	PM2.5	536	536	3.3%	65.7%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM2.5	530	530	3.2%	68.9%
2G	Other product use	PM2.5	513	513	3.1%	72.0%
1A4ai	Commercial/institutional: Stationary	PM2.5	489	489	3.0%	75.0%
5C1a	Municipal waste incineration	PM2.5	465	465	2.8%	77.8%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	PM2.5	438	438	2.7%	80.5%
1A4bi	Residential: Stationary	SO2	9208	9208	25.1%	25.1%
1A1a	Public electricity and heat production	SO2	3587	3587	9.8%	34.9%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	SO2	3530	3530	9.6%	44.5%
1A4ai	Commercial/institutional: Stationary	SO2	3426	3426	9.3%	53.8%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	3314	3314	9.0%	62.8%
1A2d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	SO2	3091	3091	8.4%	71.3%
1A3bi	Road transport: Passenger cars	SO2	1857	1857	5.1%	76.3%
1A3biii	Road transport: Heavy duty vehicles and buses	SO2	1613	1613	4.4%	80.7%

Table A - 4: List of Switzerland's approach 1 trend key categories 1990-2019 for the main pollutants, PM2.5 and PM10 ranked per pollutant and contribution to trend.

APPROACH 1 TREND ASSESSMENT FOR 2019							
NFR Code	**Source category**	**Pollutant**	**Ex,0 (kt)**	**Ex,t (kt)**	**Trend Assess-ment**	**Contri-bution to Trend**	**Cumula-tive Total**
1A3biii	Road transport: Heavy duty vehicles and buses	NOx	28043	4975	0.048%	34.5%	34.5%
1A3bii	Road transport: Light duty vehicles	NOx	6197	5370	0.019%	13.6%	48.1%
1A3ai(i)	International aviation LTO (civil)	NOx	1214	2227	0.012%	8.5%	56.6%
1A3bi	Road transport: Passenger cars	NOx	49357	22346	0.010%	7.0%	63.6%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	NOx	10535	3718	0.005%	3.7%	67.4%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	2337	1670	0.005%	3.4%	70.7%
3Da2a	Animal manure applied to soils	NOx	2063	1485	0.004%	3.0%	73.8%
1A1a	Public electricity and heat production	NOx	6294	2072	0.004%	3.0%	76.8%
1A2gvii	Mobile combustion in manufacturing industries and construction	NOx	6334	2097	0.004%	2.9%	79.7%
1A3dii	National navigation (shipping)	NOx	1055	1010	0.004%	2.8%	82.5%
3Da2a	Animal manure applied to soils	NH3	33704	20028	0.092%	33.7%	33.7%
3B1a	Manure management - Dairy cattle	NH3	10000	10869	0.044%	16.1%	49.8%
3B1b	Manure management - Non-dairy cattle	NH3	5538	7375	0.044%	16.1%	65.8%
3Da2b	Sewage sludge applied to soils	NH3	1169	0	0.013%	4.8%	70.7%
3Da2c	Other organic fertilisers applied to soils	NH3	34	901	0.013%	4.6%	75.3%
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4258	2461	0.013%	4.6%	79.9%
3Da3	Urine and dung deposited by grazing animals	NH3	754	1310	0.010%	3.8%	83.7%
1A3bi	Road transport: Passenger cars	NMVOC	63465	4763	0.040%	20.2%	20.2%
2D3a	Domestic solvent use	NMVOC	9195	11625	0.030%	15.3%	35.5%
3B1a	Manure management - Dairy cattle	NMVOC	10494	8288	0.018%	9.2%	44.7%
3B1b	Manure management - Non-dairy cattle	NMVOC	6579	6800	0.017%	8.4%	53.1%
2D3g	Chemical products	NMVOC	27504	3534	0.012%	6.3%	59.4%
1B2av	Distribution of oil products	NMVOC	17189	1514	0.010%	5.1%	64.5%
2D3d	Coating applications	NMVOC	40731	8049	0.009%	4.7%	69.2%
1A3bv	Road transport: Gasoline evaporation	NMVOC	16246	2026	0.008%	3.8%	73.0%
2D3h	Printing	NMVOC	20354	3827	0.005%	2.7%	75.6%
2D3b	Road paving with asphalt	NMVOC	4895	2813	0.005%	2.5%	78.2%
2H2	Food and beverages industry	NMVOC	1956	1999	0.005%	2.5%	80.6%
1A3bvi	Road transport: Automobile tyre and brake wear	PM10	2182	2780	0.062%	14.8%	14.8%
1A4bi	Residential: Stationary	PM10	5393	1513	0.060%	14.3%	29.1%
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2173	2335	0.044%	10.6%	39.7%
1A3c	Railways	PM10	983	1483	0.037%	8.8%	48.5%
2C1	Iron and steel production	PM10	1485	12	0.033%	7.8%	56.3%
1A3biii	Road transport: Heavy duty vehicles and buses	PM10	1465	83	0.029%	7.0%	63.3%
1A1a	Public electricity and heat production	PM10	1034	40	0.021%	5.1%	68.4%
3De	Cultivated crops	PM10	1054	1002	0.016%	3.9%	72.3%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	PM10	833	77	0.015%	3.7%	76.0%
2I	Wood processing	PM10	864	147	0.013%	3.2%	79.2%
2A5a	Quarrying and mining of minerals other than coal	PM10	367	445	0.009%	2.3%	81.4%
1A3bvi	Road transport: Automobile tyre and brake wear	PM2.5	745	945	0.041%	17.1%	17.1%
1A4bi	Residential: Stationary	PM2.5	5068	1429	0.029%	12.1%	29.2%
1A3biii	Road transport: Heavy duty vehicles and buses	PM2.5	1465	83	0.028%	12.0%	41.2%
2C1	Iron and steel production	PM2.5	818	8	0.018%	7.7%	48.9%
1A1a	Public electricity and heat production	PM2.5	772	39	0.015%	6.4%	55.3%
2G	Other product use	PM2.5	513	361	0.010%	4.3%	59.7%
1A3c	Railways	PM2.5	174	228	0.010%	4.2%	63.9%
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	222	0.009%	3.9%	67.8%
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	729	396	0.007%	3.2%	71.0%
1A4ai	Commercial/institutional: Stationary	PM2.5	489	304	0.007%	3.1%	74.0%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	PM2.5	438	45	0.007%	3.1%	77.1%
2H2	Food and beverages industry	PM2.5	188	178	0.007%	2.8%	79.9%
2H1	Pulp and paper industry	PM2.5	236	194	0.006%	2.7%	82.6%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	SO2	3530	1398	0.026%	24.7%	24.7%
2B5	Carbide production	SO2	445	696	0.018%	16.4%	41.1%
1A4bi	Residential: Stationary	SO2	9208	705	0.011%	10.4%	51.5%
1A2d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	SO2	3091	3	0.010%	9.4%	60.9%
1A1a	Public electricity and heat production	SO2	3587	215	0.006%	5.6%	66.5%
1A3biii	Road transport: Heavy duty vehicles and buses	SO2	1613	14	0.005%	4.6%	71.1%
1A3bi	Road transport: Passenger cars	SO2	1857	65	0.004%	4.1%	75.2%
1A3ai(i)	International aviation LTO (civil)	SO2	100	161	0.004%	3.8%	79.0%
1A4ai	Commercial/institutional: Stationary	SO2	3426	286	0.004%	3.3%	82.3%

A1.3 Detailed results of appoach 2 assessment

The following tables depict detailed results for the approach 2 level and trend assessments. Note that for approach 2 only the level assessment for the current year (2019) is available.

Table A - 5: List of Switzerland's approach 2 level key categories 2019 for the main pollutants, PM2.5 and PM10 ranked per pollutant and level contribution (Lx,t).

APPROACH 2 LEVEL ASSESSMENT FOR 2019						
NFR Code	**Source category**	**Pollutant**	**Ex,t (kt)**	**|Ex,t| (kt)**	**Lx,t**	**Cumula-tive Total**
1A3bi	Road transport: Passenger cars	NOx	22346	22346	47.9%	47.9%
1A3bii	Road transport: Light duty vehicles	NOx	5370	5370	9.5%	57.3%
1A3biii	Road transport: Heavy duty vehicles and buses	NOx	4975	4975	5.0%	62.3%
3Da2a	Animal manure applied to soils	NOx	1485	1485	4.2%	66.5%
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	726	726	4.0%	70.5%
1A4bi	Residential: Stationary	NOx	4757	4757	3.6%	74.1%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	NOx	3718	3718	3.5%	77.6%
1A1a	Public electricity and heat production	NOx	2072	2072	2.5%	80.1%
3Da2a	Animal manure applied to soils	NH3	20028	20028	24.7%	24.7%
3B1a	Manure management - Dairy cattle	NH3	10869	10869	22.3%	47.0%
3B1b	Manure management - Non-dairy cattle	NH3	7375	7375	10.0%	57.0%
3B3	Manure management - Swine	NH3	4745	4745	9.3%	66.3%
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	2461	2461	6.5%	72.8%
6A	Other sources	NH3	995	995	5.4%	78.2%
3B4gi	Manure management - Layers	NH3	643	643	2.8%	81.0%
3B1a	Manure management - Dairy cattle	NMVOC	8288	8288	25.7%	25.7%
3B1b	Manure management - Non-dairy cattle	NMVOC	6800	6800	20.4%	46.1%
2D3a	Domestic solvent use	NMVOC	11625	11625	14.2%	60.3%
2G	Other product use	NMVOC	6653	6653	8.3%	68.5%
3B4gii	Manure management - Broilers	NMVOC	1026	1026	3.2%	71.8%
1A3biv	Road transport: Mopeds & motorcycles	NMVOC	1076	1076	2.6%	74.4%
2D3d	Coating applications	NMVOC	8049	8049	2.5%	76.8%
3B3	Manure management - Swine	NMVOC	793	793	2.5%	79.3%
2D3i	Other solvent use	NMVOC	2100	2100	2.4%	81.7%
2A5a	Quarrying and mining of minerals other than coal	PM10	445	445	13.5%	13.5%
3De	Cultivated crops	PM10	1002	1002	12.4%	26.0%
2H2	Food and beverages industry	PM10	332	332	10.3%	36.2%
1A3bvi	Road transport: Automobile tyre and brake wear	PM10	2780	2780	8.4%	44.6%
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2335	2335	7.3%	51.9%
1A4bi	Residential: Stationary	PM10	1513	1513	7.0%	59.0%
1A3c	Railways	PM10	1483	1483	4.5%	63.5%
2I	Wood processing	PM10	147	147	4.5%	67.9%
3B4gii	Manure management - Broilers	PM10	190	190	3.5%	71.4%
2A1	Cement production	PM10	251	251	3.1%	74.5%
2G	Other product use	PM10	452	452	2.8%	77.3%
3B3	Manure management - Swine	PM10	146	146	2.7%	80.0%
3B4gi	Manure management - Layers	PM10	139	139	2.6%	82.6%
2A5a	Quarrying and mining of minerals other than coal	PM2.5	222	222	16.9%	16.9%
1A4bi	Residential: Stationary	PM2.5	1429	1429	16.0%	32.9%
2H2	Food and beverages industry	PM2.5	178	178	13.0%	45.9%
1A3bvi	Road transport: Automobile tyre and brake wear	PM2.5	945	945	7.0%	52.9%
2H1	Pulp and paper industry	PM2.5	194	194	5.7%	58.6%
2G	Other product use	PM2.5	361	361	5.5%	64.2%
2A1	Cement production	PM2.5	161	161	4.9%	69.0%
1A4ai	Commercial/institutional: Stationary	PM2.5	304	304	3.4%	72.4%
1A2gvii	Mobile combustion in manufacturing industries and construction	PM2.5	396	396	2.9%	75.4%
2I	Wood processing	PM2.5	37	37	2.7%	78.1%
5C1a	Municipal waste incineration	PM2.5	249	249	2.1%	80.2%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	SO2	1398	1398	32.7%	32.7%
2B5	Carbide production	SO2	696	696	17.2%	49.9%
1A4bi	Residential: Stationary	SO2	705	705	9.3%	59.2%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	350	350	8.3%	67.5%
1A1a	Public electricity and heat production	SO2	215	215	6.4%	73.9%
2B10a	Other Chemical industry	SO2	97	97	4.8%	78.6%
1A4ai	Commercial/institutional: Stationary	SO2	286	286	3.6%	82.2%

Table A - 6: List of Switzerland's approach 2 trend key categories 1990-2019 for the main pollutants, PM2.5 and PM10 ranked per pollutant and contribution to trend.

APPROACH 2 TREND ASSESSMENT WITH UNCERTAINTIES FOR 2019							
NFR Code	**Source category**	**Pollutant**	**Ex,0 (kt)**	**Ex,t (kt)**	**Trend Assess-ment**	**Contri-bution to Trend**	**Cumula-tive Total**
1A3biii	Road transport: Heavy duty vehicles and buses	NOx	28043	4975	0.009%	24.1%	24.1%
1A3bii	Road transport: Light duty vehicles	NOx	6197	5370	0.006%	16.9%	41.0%
1A3bi	Road transport: Passenger cars	NOx	49356	22346	0.004%	10.5%	51.5%
1A3ai(i)	International aviation LTO (civil)	NOx	1214	2227	0.002%	6.5%	58.0%
3Da2a	Animal manure applied to soils	NOx	2063	1485	0.002%	6.0%	63.9%
3Da3	Urine and dung deposited by grazing animals	NOx	241	392	0.002%	5.6%	69.5%
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1205	726	0.001%	4.2%	73.7%
1A1a	Public electricity and heat production	NOx	6294	2072	0.001%	2.5%	76.2%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	NOx	10535	3718	0.001%	2.5%	78.7%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	2337	1670	0.001%	2.2%	80.9%
3Da2a	Animal manure applied to soils	NH3	33705	20028	0.022%	22.0%	22.0%
3B1a	Manure management - Dairy cattle	NH3	10000	10870	0.017%	17.6%	39.6%
3B1b	Manure management - Non-dairy cattle	NH3	5538	7375	0.012%	11.6%	51.1%
3Da2c	Other organic fertilisers applied to soils	NH3	34	901	0.007%	7.0%	58.1%
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4258	2461	0.006%	6.4%	64.6%
6A	Other sources	NH3	843	995	0.005%	5.1%	69.7%
2H2	Food and beverages industry	NH3	132	34	0.005%	5.0%	74.7%
3Da3	Urine and dung deposited by grazing animals	NH3	754	1310	0.004%	4.0%	78.8%
3B4gii	Manure management - Broilers	NH3	353	597	0.003%	3.3%	82.1%
3B1a	Manure management - Dairy cattle	NMVOC	10490	8288	0.091%	25.4%	25.4%
3B1b	Manure management - Non-dairy cattle	NMVOC	6578	6801	0.081%	22.6%	48.0%
2D3a	Domestic solvent use	NMVOC	9196	11624	0.060%	16.7%	64.7%
1A3bi	Road transport: Passenger cars	NMVOC	63469	4763	0.021%	5.9%	70.6%
3B4gii	Manure management - Broilers	NMVOC	366	1026	0.016%	4.3%	74.9%
2D3g	Chemical products	NMVOC	27506	3535	0.013%	3.6%	78.5%
3B3	Manure management - Swine	NMVOC	1126	793	0.008%	2.3%	80.8%
2I	Wood processing	PM10	864	147	0.067%	14.7%	14.7%
2A5a	Quarrying and mining of minerals other than coal	PM10	367	445	0.048%	10.4%	25.1%
1A4bi	Residential: Stationary	PM10	5393	1513	0.046%	10.0%	35.1%
2C1	Iron and steel production	PM10	1485	12	0.041%	9.1%	44.2%
3De	Cultivated crops	PM10	1054	1003	0.033%	7.3%	51.5%
2H2	Food and beverages industry	PM10	310	332	0.032%	7.0%	58.5%
1A3bvi	Road transport: Automobile tyre and brake wear	PM10	2182	2780	0.031%	6.7%	65.2%
1A2gvii	Mobile combustion in manufacturing industries and construction	PM10	2173	2335	0.023%	5.0%	70.2%
1A3c	Railways	PM10	983	1483	0.019%	4.1%	74.3%
3B4gii	Manure management - Broilers	PM10	68	190	0.018%	4.0%	78.3%
1A1a	Public electricity and heat production	PM10	1034	40	0.016%	3.4%	81.7%
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	222	0.049%	18.6%	18.6%
2H2	Food and beverages industry	PM2.5	188	178	0.033%	12.4%	31.0%
2C1	Iron and steel production	PM2.5	818	8	0.023%	8.8%	39.8%
1A4bi	Residential: Stationary	PM2.5	5068	1429	0.022%	8.4%	48.2%
1A3bvi	Road transport: Automobile tyre and brake wear	PM2.5	745	945	0.020%	7.8%	56.0%
2I	Wood processing	PM2.5	216	37	0.014%	5.2%	61.2%
2H1	Pulp and paper industry	PM2.5	236	194	0.013%	4.9%	66.2%
1A1a	Public electricity and heat production	PM2.5	772	39	0.011%	4.2%	70.4%
2G	Other product use	PM2.5	513	361	0.011%	4.1%	74.5%
2A1	Cement production	PM2.5	240	161	0.009%	3.4%	77.9%
1A3biii	Road transport: Heavy duty vehicles and buses	PM2.5	1465	83	0.008%	2.9%	80.8%
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	SO2	3530	1398	0.005%	27.1%	27.1%
2B5	Carbide production	SO2	445	696	0.004%	19.0%	46.0%
1A1a	Public electricity and heat production	SO2	3587	215	0.001%	7.7%	53.7%
1A2d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	SO2	3091	3	0.001%	7.6%	61.4%
1A4bi	Residential: Stationary	SO2	9208	705	0.001%	6.4%	67.8%
2B10a	Other Chemical industry	SO2	168	97	0.001%	4.5%	72.3%
1B2aiv	Fugitive emissions oil: Refining and storage	SO2	419	14	0.001%	3.0%	75.3%
1A3biii	Road transport: Heavy duty vehicles and buses	SO2	1613	14	0.000%	2.7%	78.0%
5C1biv	Sewage sludge incineration	SO2	74	56	0.000%	2.5%	80.5%

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 - 8), machine type, engine type (diesel, gasoline/2-/4-stroke, LPG, 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 - 7: 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 [03.02.2021]

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 - 8: 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	19.0	21.4	23.8	25.6	26.9
Industrial machinery	17.8	29.0	48.4	47.5	47.1	47.0
Agricultural machinery	39.9	38.8	37.7	33.0	30.6	29.0
Forestry machinery	2.4	2.8	2.6	2.3	2.0	1.9
Garden-care / hobby appliances	14.6	25.7	39.3	149.7	190.8	201.3
Navigation machinery	3.7	3.9	3.5	3.4	3.4	3.4
Railway machinery	0.5	0.8	0.8	0.5	0.5	0.5
Military machinery	0.8	0.9	0.9	0.9	0.9	0.9
Total	**95**	**121**	**155**	**261**	**301**	**311**

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.

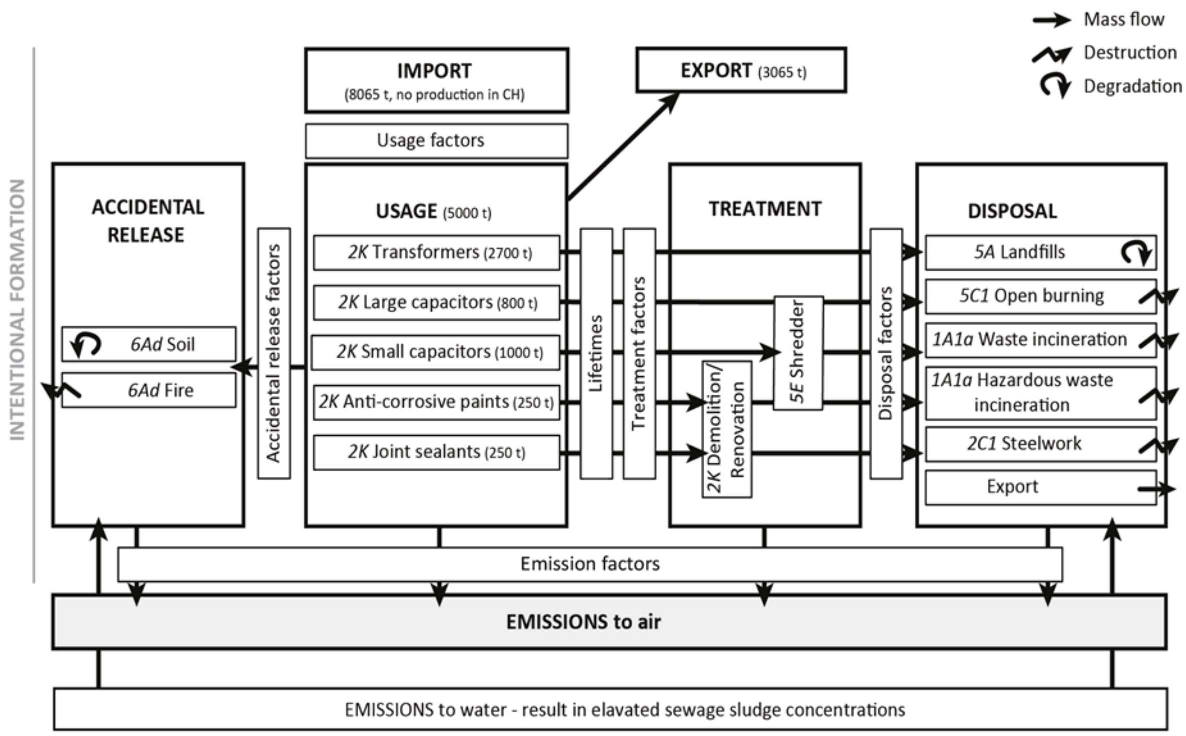


Figure A - 1: Model setup for the dynamic mass flow and emissions of PCBs taking into account the import, usage, export, treatment, disposal and accidential release. Emissions to air occur from usage, treatment, disposal, and accidental release.

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 chps. 3.2.2 - 3.2.4.

Import and usage

PCBs have not been produced in Switzerland. Therefore, the chemicals enter the system solely through import (Figure A - 1, top part). The imported amounts are then distributed to the usage categories according to usage factors (Figure A - 1, middle part). The imported amounts, as well as the usage factors, vary over time. In this study, five usage categories that were identified to be important for Switzerland are included: transformers, large capacitors (> 1 kg), small capacitors (< 1 kg), anti-corrosive paints on steel and joint sealants. Other uses, such as PCBs in hydraulic oils (used in mining), plastics, or insecticides are considered as being of minor importance in Switzerland and are thus, not included in the model. For the time being, anti-corrosive paints and joint sealants are the predominant PCB emission sources (see Figure A - 2). The emissions from the five usage categories are reported in source category 2K Consumption of POPs and heavy metals.

Export

The exported amounts to other countries could have been estimated only roughly. PCBs were mainly exported in disposed PCB-containing transformers and capacitors and electronic waste, but also in old installations, such as for example hydraulic turbines with PCB-containing paints.

Disposal

When a PCB-containing product reaches its end of life it is disposed of. In the model, six disposal categories that have been relevant in Switzerland are included: landfills (5A), open burning (5C1), municipal waste incineration (1A1a), hazardous 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 hazardous waste from 1998 onwards (see Figure A - 2). 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 waste water.

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 - 2 shows the resulting PCB emissions from all stages of the life cycle of PCB applications, i.e. usage, treatment, disposal and accidental release. Anti-corrosive paints and joint sealants are the predominant PCB emission sources for most of the time. Between 1975 and 1985 and around 2000, open burning and the above-mentioned shredding of small capacitors, respectively, were the dominant PCB sources. Only after 2040, emissions from soil due to former 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.

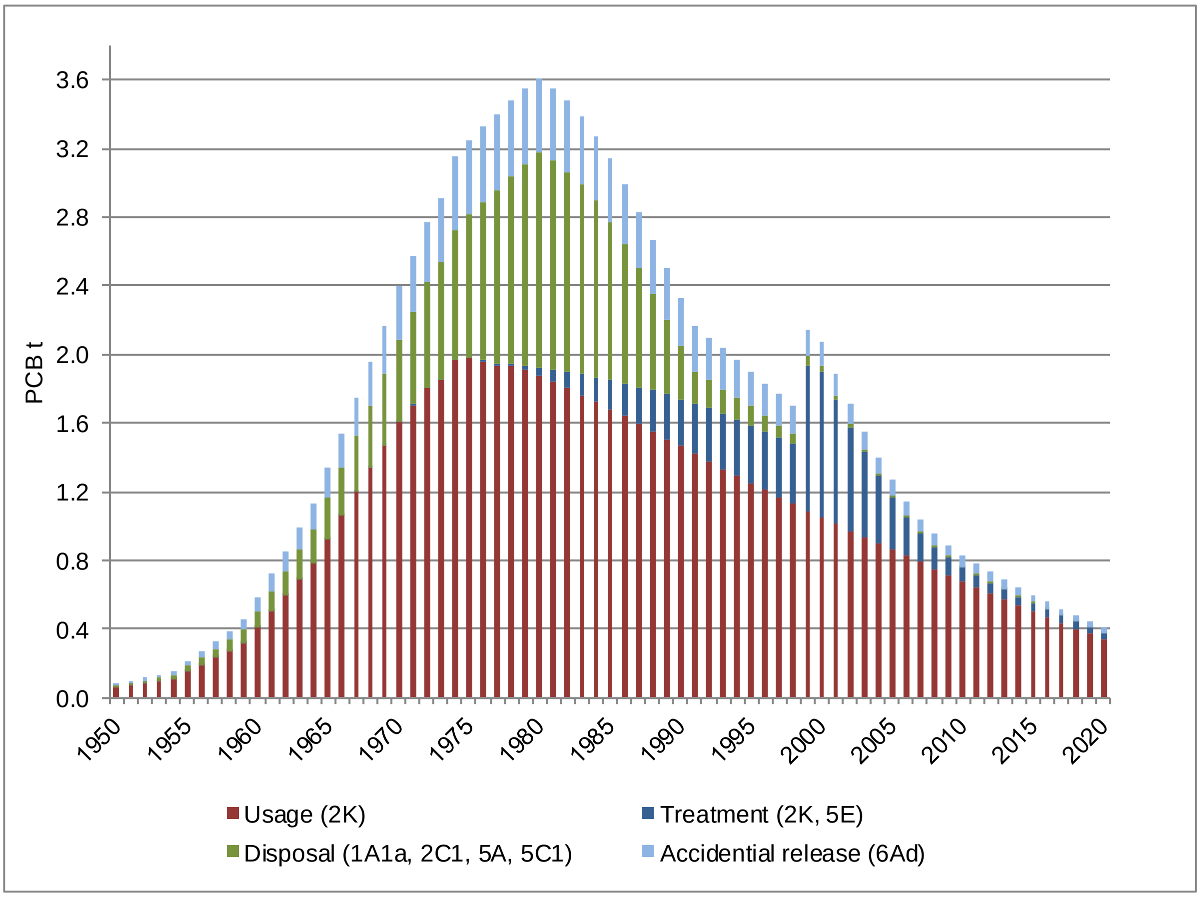


Figure A - 2: PCB emissions from usage (2K Transformers, large and small condensators, anti-corrosive paints and joint sealants), treatment (2K Demoition and renovation, 5E Shredder), disposal (1A1a Municipal and hazardous waste incineration, 2C1 Secondary steel production, 5A Landfills, 5C1 Open burning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

A2.3 Comparison of the country-specificly calulated Tier 3 results for N flows and NH_3 emissions from animal husbandry with the results of the Tier 2 calculations with 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 EFs as well as a comparison of the national EFs and the Guidebook EFs with a rationale of the discrepancies." Because it is not only the EFs that have a strong influence on the emission inventory calculations but also other assumptions like N excretions, length of housing period or percentage of TAN in the manure, it was decided to not only compare the EFs 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, the last year with data from a representative survey on farm and manure management. The detailed report on this project will be available in early summer in 2021. Here we can give some preliminary results of the ongoing study. The focus is on cattle which contribute 79% of N excretions and NH_3 emissions. The other livestock categories need more checking. These preliminary findings can be summarised as follows:

- Total N excretions of cattle compare quite well between the two models. According to the Swiss Agrammon model they are 106% of the values according to the N flow model for dairy cattle, 108% for non-dairy cattle and 110% for non-dairy cattle (calves). For dairy cattle this difference is well explicable, because the average weight of a cow is assumed with 600 kg in the N flow tool and 660 kg in the Swiss norms (Agroscope 2017) and Agrammon.
- The share of N excretions in the housing area and during grazing is considerably different between the two models. For example the share of N excreted during grazing for dairy cattle is 16% according to the Swiss reporting and 38% according to the N flow tool. This can mainly be explained by the assumptions about the housing and grazing period. The N flow model assumes a "housed period" of 180 days for all cattle sub-categories. It is then assumed that during the whole year 25% of the N excretions are in the yard area and the remaining 75% in the housing area during the housing period and outside on the pastures during the grazing period. Taking into account the assumed length of the housing and grazing period in the Swiss reporting the distribution of the total N excretions over the whole year is 37% in the housing area, 38% in the yard area and 25% during grazing on the pastures. In Switzerland, most cattle are also in the housing area part of the day during the summer period (approx. May to October). For example, in 2015 (survey) dairy cows on average spent 8.2 hours per day outside for grazing during 174 days per year. For the rest of the summer day the animals in tied stalls (45%) are fully in the house. A part of the animals in loose housing systems has free access to the yard while they are in the house but would spend most the time in the house itself. The considerably lower N excretion during grazing in Agrammon compared to the N flow tool therefore has two reasons: 1) The number of days with grazing is lower in Switzerland than assumed in the N flow tool and 2) The animals spend only part of the "grazing day" outside in the grazing area. These two points lead to a considerable underestimation of the N excretion and emissions in the housing area.
- For dairy cattle the N flow tool assumes that 80% of the TAN excreted leaving the housing area (excretion minus emissions housing) goes to slurry and 20% to solid manure. In Switzerland the ratio is 86% to slurry and 14% to solid manure, when taking into account the differentiation between housing systems with only slurry (57.3% of the animals), with liquid and solid manure (41.7%) and housing systems with solid manure only (0.9%). These different housing and manure collection systems also have an influence on the proportion of TAN (% of total N) in the resulting manure.

- For dairy cattle total emissions agree quite well between the two models; the values from the Swiss reporting are 105% those from the N flow tool. This implies that the underestimation of N excretions and thus of the N flow through the manure management chain was largly compensated by the higher weight of the animals as compared to the N flow tool, the ratio between liquid and solid manure and the Tier 3 inputs considered in the Swiss reporting, e.g. for feeding, covered slurry stores, slurry spreading technique etc.
- For non-dairy cattle the difference is larger (non-dairy cattle Swiss reporting 118% of N flow tool; non-dairy cattle (calves) Swiss reporting 158% of N flow tool).

A direct comparison of N flows or emission factors is impeded in different places by the differences between the models in the allocation of N flows. For example, a) the N flow tool differentiates between EFs for liquid and solid manure in the housing area while Agrammon has only one EF for housing because a clear allocation of excreta and soiled surfaces to liquid and solid manure is not possible, b) for slurry storage the EFs 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 because the urine which contains soluble N which is potentially emitted is primarily collected in the liquid manure, while the feces containing primarily organic N primarily go to 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 detailed report on the comparison between the Swiss tier 3 reporting and the tier 2 N flow tool will show the comparison for all animal categories and discussion of the holistic discussion of the results and conclusions.

Annex 3 Further elaboration of completeness use of IE and (potential) sources of air pollutant emissions excluded

Table A - 9: Explanation of the NE notation key in NFR table 2 Add Info from current submission.

NFR code	Substance(s)	Reason for not estimation
all	As, Cr, Cu, Ni, Se, Zn	Lack of data
1A (Offroad)	HCB, PCBs	Lack of data
1A (mobile)	HCB, PCBs	Lack of data (for the years 1980-1989)
1A3b	HCB	no EF available
1A1c	SO_x, NH_3, Pb, Cd, Hg, POPs	Lack of data
2A5a	BC	no EF available
2B5	BC, CO	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_2, 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 - 10: Explanation of the IE Notation key in NFR table 2 Add Info from current submission.

NFR code	Substance(s)	Included in NFR code
1A3bvii	TSP, PM_{10}, $PM_{2.5}$, Cd	1A3bvi
1A4ciii	All	1A3dii
1B1a	Activity Data "Solid Fuels"	1B1a - Activity Data "Other activity"
2A3	NO_x, SO_2, $PM_{2.5}$, 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	3B1a (from 1990 onwards)
3B4f	NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, TSP	3B4e (for the years 1980-1989)
3B4gii	$PM_{2.5}$, PM_{10}, TSP	3B4gi (for the years 1980-1989)
3B4giv	$PM_{2.5}$, PM_{10}, TSP	3B4gi (for the years 1980-1989)
3Da2a	NH_3	3B1-3B4 (for the years 1980-1989)
3Da2c	NO_x, NH_3	3Da1 (for the years 1980-1989)
3Da3	NO_x, NH_3	3B1-3B4 (for the years 1980-1989)
3Db	NMVOC, NH_3	3Da1 (for the years 1980-1989)
5D2	NO_x, NMVOC, SO_x, NH_3, CO	5D1 (for the years 1980-1989)

Table A - 11: List of sub-sources accounted for in reporting codes "other" in NFR table 2 Add Info from current 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, 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
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, 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_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO, Pb	Blasting and shooting
2L	NH_3	Use of NH3 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
5E	NMVOC, $PM_{2.5}$, PM_{10}, TSP, CO, Pb, Cd, PCDD/F, PCBs	Car shredding
5C1bvi	-	NO
5D3	-	NO
6A	NOx, NMVOC, SOx, NH3, PM2.5, PM10, 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	-	NO

Table A - 12: Basis for estimating emissions from mobile sources as listed in NFR table 2 Add Info from current 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 2019 and 1990 in TJ as published by the Swiss Federal Office of Energy (SFOE 2020, SFOE 1991) in German and French.

Fig. 5 Detailliertes Energieflussdiagramm der Schweiz 2019 (in TJ)
Flux énergétique détaillé de la Suisse en 2019 (en TJ)

BFE, Schweizerische Gesamtenergiestatistik 2019 (Fig. 5)
OFEN, Statistique globale suisse de l'énergie 2019 (fig. 5)

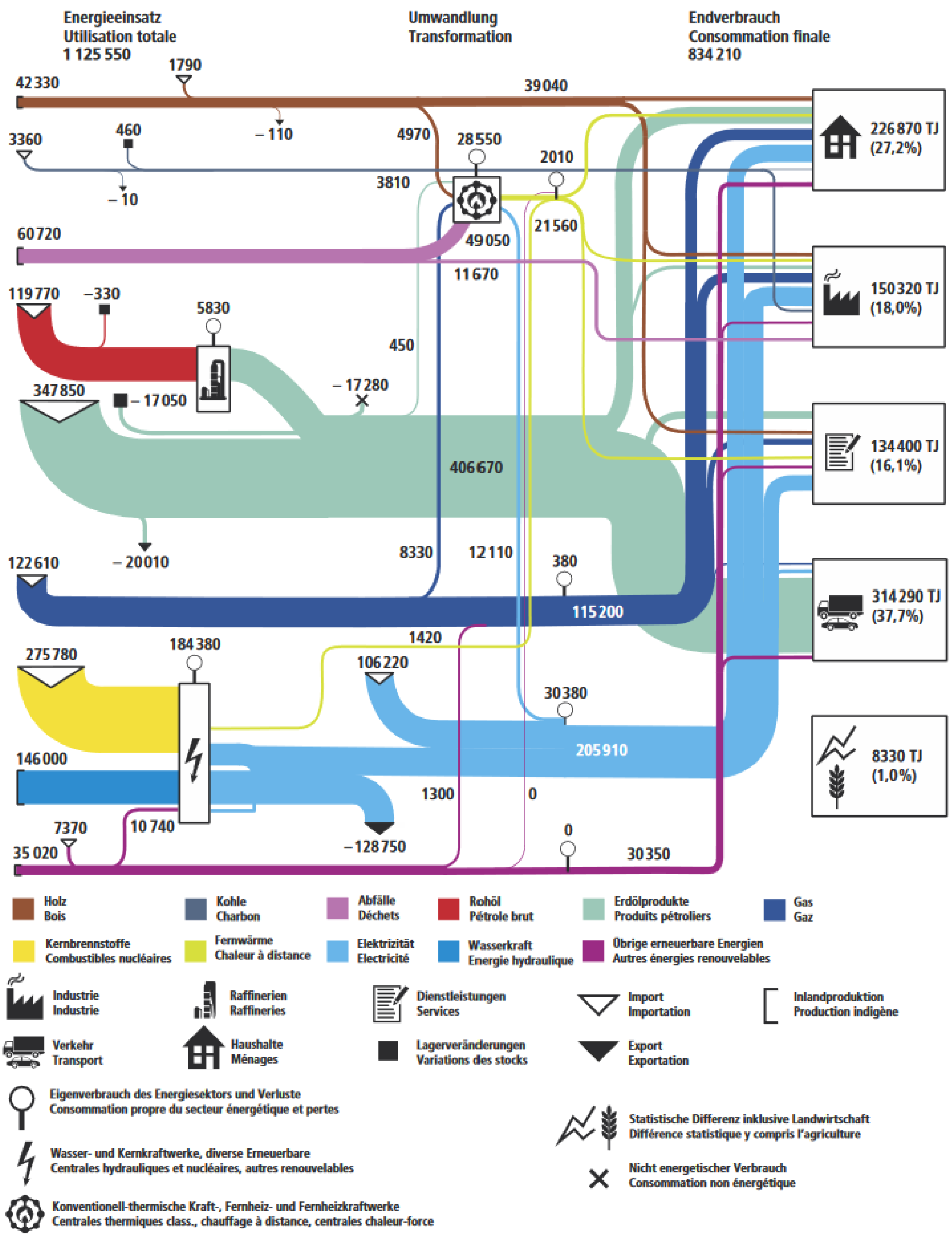


Figure A - 2: Energy flow in Switzerland 2019 (SFOE 2020, figure 5). Depicted values are in TJ.

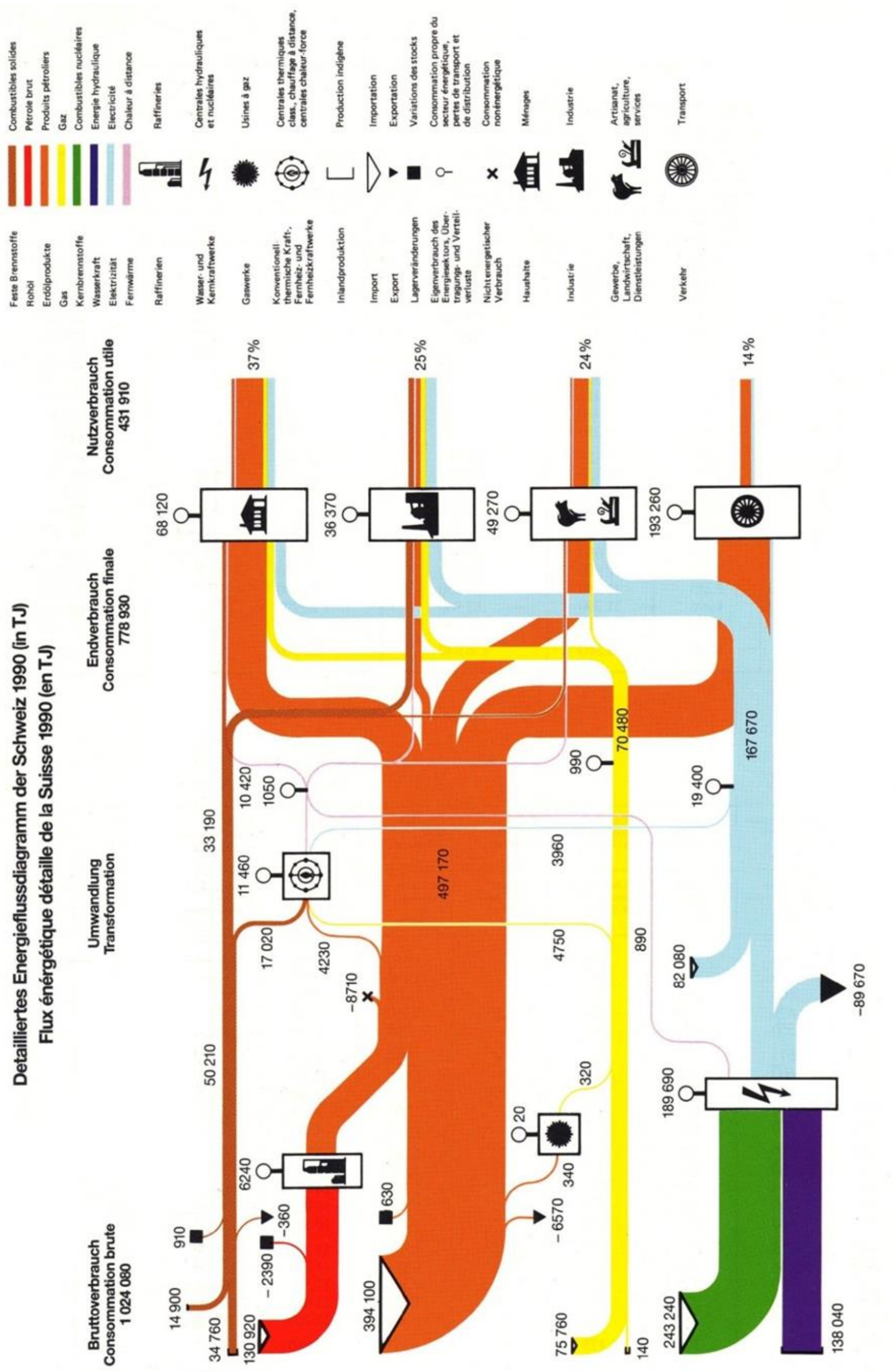


Figure A - 3: Energy flow in Switzerland 1990 (SFOE 1991). Depicted values are in TJ.

Table A - 13: Energy balance for Switzerland 2019 (table 4, Swiss overall energy statistics, SFOE 2020) in TJ.[7].

Tab. 4 Energiebilanz der Schweiz für das Jahr 2019 (in TJ)
Bilan énergétique de la Suisse pour 2019 (en TJ)

		Holzenergie	Kohle	Müll und Industrie-abfälle	Rohöl	Erdöl-produkte	Gas	Wasserkraft	Kernbrenn-stoffe	Übrige erneuerbare Energien	Elektrizität	Fernwärme	Total	
		Energie du bois	Charbon	Ord. mén. et déchets ind.	Pétrole brut	Produits pétroliers	Gaz	Energie hydraulique	Combustibles nucléaires	Autres énergies renouvelables	Electricité	Chaleur à distance		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
Inlandproduktion	(a)	42 330	–	60 720	–	–	–	146 000	–	35 020	–	–	284 070	Production indigène
+ Import	(b)	1 790	3 360	–	119 770	347 850	122 610	–	275 780	7 370	106 220	–	984 750	+ Importation
+ Export	(c)	−110	−10	–	–	−20 010	–	–	–	–	−128 750	–	−148 880	+ Exportation
+ Lagerveränderung¹	(d)	–	460	–	−330	−17 050	–	–	–	–	–	–	−16 920	+ Variation de stock¹
= Bruttoverbrauch	(e)	44 010	3 810	60 720	119 440	310 790	122 610	146 000	275 780	42 390	−22 530	0	1 103 020	= Consommation brute
+ Energieumwandlung:														+ Transformation d'énergie:
· Wasserkraftwerke	(f)	–	–	–	–	–	–	−146 000	–	–	146 000	–	0	· Centrales hydrauliques
· Kernkraftwerke	(g)	–	–	–	–	–	–	–	−275 780	–	91 010	1 420	−183 350	· Centrales nucléaires
· konventionell-thermische Kraft-, Fernheiz- und Fernheizkraftwerke	(h)	−3 310	–	−49 050	–	−450	−8 330	–	–	–	10 980	22 150	−28 010	· Centrales thermiques class., chauffage à distance, centrales chaleur-force
· Gaswerke	(i)	–	–	–	–	–	–	–	–	–	–	–	0	· Usines à gaz
· Raffinerien	(j)	–	–	–	−119 440	119 440	–	–	–	–	–	–	0	· Raffineries
· Diverse Erneuerbare	(k)	−1 660	–	–	–	–	1 300	–	–	−12 040	10 830	–	−1 570	· Renouvelables div.
+ Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherungen	(l)	–	–	–	–	−5 830	−380	–	–	–	−30 380	−2 010	−38 600	+ Consommation propre du secteur énergétique, pertes de réseau, pompage d'accumulation
+ Nichtenergetischer Verbrauch	(m)	–	–	–	–	−17 280	–	–	–	–	–	–	−17 280	+ Consommation non énergétique
= Endverbrauch	(n)	39 040	3 810	11 670	0	406 670	115 200	0	0	30 350	205 910	21 560	834 210	= Consommation finale
Haushalte	(o)	18 340	100	–	–	66 740	47 730	–	–	16 650	68 730	8 580	226 870	Ménages
Industrie	(p)	11 330	3 710	11 670	–	12 770	39 470	–	–	1 810	62 170	7 390	150 320	Industrie
Dienstleistungen	(q)	8 540	0	–	–	30 210	25 810	–	–	3 590	60 660	5 590	134 400	Services
Verkehr	(r)	–	–	–	–	294 360	1 180	–	–	7 800	10 950	0	314 290	Transport
Statistische Differenz inkl. Landwirtschaft	(s)	830	0	–	–	2 590	1 010	–	–	500	3 400	0	8 330	Différence statistique, y compris l'agriculture

¹ + Lagerabnahme
− Lagerzunahme

¹ + diminution de stock
− augmentation de stock

BFE, Schweizerische Gesamtenergiestatistik 2019 (Tab. 4)
OFEN, Statistique globale suisse de l'énergie 2019 (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 to be considered part of the IIR submission concerning uncertainties

The following tables provide information about the level and trend uncertainty analysis of all relevant air pollutant emissions in 1990 and 2019.

Table A - 14: Uncertainty analysis of NO_x emissions 1990 and 2019.

A	B	C	D	E	F	G	H	I	J	K	L	M
NFR	Pollutant	Emissions 1990	Emissions 2019	AD uncertainty 2019	EF uncertainty 2019	Combined uncertainty 2019	Combined uncertainty as % of national total 2019	Type A sensitivity	Type B sensitivity	Uncertainty in trend introduced by emission factor uncertainty	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		t	t	%	%	%	%	%	%	%	%	%
1A1a	NOx	6'294.04	2'072.05	10%	19%	21%	0.005%	0.414%	1.43%	0.08%	0.20%	0.000%
1A1b	NOx	494.17	317.67	1%	20%	20%	0.000%	0.075%	0.22%	0.01%	0.00%	0.000%
1A1c	NOx	0.01	0.05	5%	20%	21%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A2a	NOx	278.40	118.74	2%	27%	27%	0.000%	0.000%	0.08%	0.00%	0.00%	0.000%
1A2b	NOx	126.80	36.92	2%	20%	20%	0.000%	0.012%	0.03%	0.00%	0.00%	0.000%
1A2c	NOx	1'046.46	272.78	2%	10%	10%	0.000%	0.118%	0.19%	0.01%	0.01%	0.000%
1A2d	NOx	1'260.62	44.27	2%	10%	10%	0.000%	0.339%	0.03%	0.03%	0.00%	0.000%
1A2e	NOx	743.24	245.17	2%	10%	10%	0.000%	0.049%	0.17%	0.00%	0.00%	0.000%
1A2f	NOx	10'534.54	3'718.03	2%	17%	17%	0.011%	0.520%	2.57%	0.09%	0.07%	0.000%
1A2gvii	NOx	6'333.94	2'096.55	1%	13%	13%	0.002%	0.409%	1.45%	0.05%	0.03%	0.000%
1A2gviii	NOx	2'336.88	1'670.40	2%	17%	17%	0.002%	0.470%	1.16%	0.08%	0.03%	0.000%
1A3ai(i)	NOx	1'214.30	2'226.67	1%	20%	20%	0.005%	1.184%	1.54%	0.24%	0.03%	0.001%
1A3aii(i)	NOx	153.76	69.55	1%	20%	20%	0.000%	0.003%	0.05%	0.00%	0.00%	0.000%
1A3bi	NOx	49'356.81	22'346.36	1%	38%	38%	1.941%	0.967%	15.46%	0.37%	0.28%	0.002%
1A3bii	NOx	6'196.89	5'369.66	1%	32%	32%	0.080%	1.895%	3.71%	0.61%	0.07%	0.004%
1A3biii	NOx	28'043.44	4'975.39	1%	18%	18%	0.021%	4.781%	3.44%	0.86%	0.06%	0.007%
1A3biv	NOx	308.61	315.89	1%	36%	36%	0.000%	0.128%	0.22%	0.05%	0.00%	0.000%
1A3c	NOx	595.50	390.30	1%	13%	13%	0.000%	0.095%	0.27%	0.01%	0.00%	0.000%
1A3dii	NOx	1'054.73	1'010.25	1%	13%	13%	0.000%	0.389%	0.70%	0.05%	0.01%	0.000%
1A3ei	NOx	145.60	14.21	2%	50%	50%	0.000%	0.033%	0.01%	0.02%	0.00%	0.000%
1A4ai	NOx	4'694.75	2'387.34	2%	16%	16%	0.004%	0.273%	1.65%	0.04%	0.04%	0.000%
1A4aii	NOx	16.28	45.91	1%	13%	13%	0.000%	0.027%	0.03%	0.00%	0.00%	0.000%
1A4bi	NOx	11'629.05	4'757.40	4%	13%	14%	0.011%	0.123%	3.29%	0.02%	0.17%	0.000%
1A4bii	NOx	18.76	24.05	1%	30%	30%	0.000%	0.011%	0.02%	0.00%	0.00%	0.000%
1A4ci	NOx	382.34	229.05	21%	30%	37%	0.000%	0.046%	0.16%	0.01%	0.05%	0.000%
1A4cii	NOx	4'357.53	2'045.91	1%	13%	13%	0.002%	0.136%	1.42%	0.02%	0.03%	0.000%
1A5b	NOx	882.99	389.60	1%	13%	13%	0.000%	0.010%	0.27%	0.00%	0.00%	0.000%
1B2c	NOx	212.64	1.67	22%	30%	37%	0.000%	0.061%	0.00%	0.02%	0.00%	0.000%
2A1	NOx	15.87	10.65	2%	200%	200%	0.000%	0.003%	0.01%	0.01%	0.00%	0.000%
2A2	NOx	0.27	0.23	2%	500%	500%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2A5a	NOx	1.79	0.84	5%	500%	500%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2B2	NOx	82.78	0.00	0%	0%	0%	0.000%	0.024%	0.00%	0.00%	0.00%	0.000%
2C1	NOx	245.46	158.51	2%	50%	50%	0.000%	0.038%	0.11%	0.02%	0.00%	0.000%
2C3	NOx	17.41	0.00	0%	0%	0%	0.000%	0.005%	0.00%	0.00%	0.00%	0.000%
2C7c	NOx	0.00	1.65	5%	100%	100%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
2G	NOx	29.36	18.32	25%	100%	103%	0.000%	0.004%	0.01%	0.00%	0.00%	0.000%
2H3	NOx	91.00	23.49	3%	200%	200%	0.000%	0.010%	0.02%	0.02%	0.00%	0.000%
3B1a	NOx	688.00	404.07	6%	50%	50%	0.001%	0.078%	0.28%	0.04%	0.03%	0.000%
3B1b	NOx	352.66	302.66	6%	50%	50%	0.001%	0.106%	0.21%	0.05%	0.02%	0.000%
3B2	NOx	67.60	70.14	6%	50%	50%	0.000%	0.029%	0.05%	0.01%	0.00%	0.000%
3B3	NOx	185.28	88.81	6%	50%	50%	0.000%	0.007%	0.06%	0.00%	0.01%	0.000%
3B4d	NOx	21.62	30.30	6%	50%	50%	0.000%	0.015%	0.02%	0.01%	0.00%	0.000%
3B4e	NOx	18.78	27.09	6%	50%	50%	0.000%	0.013%	0.02%	0.01%	0.00%	0.000%
3B4f	NOx	1.44	6.55	6%	50%	50%	0.000%	0.004%	0.00%	0.00%	0.00%	0.000%
3B4gi	NOx	7.19	8.53	6%	50%	50%	0.000%	0.004%	0.01%	0.00%	0.00%	0.000%
3B4gii	NOx	4.46	11.21	6%	50%	50%	0.000%	0.006%	0.01%	0.00%	0.00%	0.000%
3B4giii	NOx	0.44	0.33	6%	50%	50%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
3B4giv	NOx	0.84	1.26	6%	50%	50%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
3B4h	NOx	1.04	5.43	6%	50%	50%	0.000%	0.003%	0.00%	0.00%	0.00%	0.000%
3Da1	NOx	1'204.92	725.69	5%	100%	100%	0.014%	0.148%	0.50%	0.15%	0.04%	0.000%
3Da2a	NOx	2'062.86	1'484.61	6%	50%	50%	0.015%	0.421%	1.03%	0.21%	0.09%	0.001%
3Da2b	NOx	87.01	0.00	0%	0%	0%	0.000%	0.026%	0.00%	0.00%	0.00%	0.000%
3Da2c	NOx	14.76	109.24	20%	100%	102%	0.000%	0.071%	0.08%	0.07%	0.02%	0.000%
3Da3	NOx	241.26	392.10	6%	100%	100%	0.004%	0.200%	0.27%	0.20%	0.02%	0.000%
5A	NOx	1.83	1.36	10%	50%	51%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5B2	NOx	0.00	5.85	20%	100%	102%	0.000%	0.004%	0.00%	0.00%	0.00%	0.000%
5C1a	NOx	80.75	43.25	50%	40%	64%	0.000%	0.006%	0.03%	0.00%	0.02%	0.000%
5C1bi	NOx	9.75	0.00	0%	0%	0%	0.000%	0.003%	0.00%	0.00%	0.00%	0.000%
5C1biii	NOx	22.50	0.00	0%	0%	0%	0.000%	0.007%	0.00%	0.00%	0.00%	0.000%
5C1biv	NOx	114.00	61.74	20%	50%	54%	0.000%	0.009%	0.04%	0.00%	0.01%	0.000%
5C1bv	NOx	11.25	12.13	5%	30%	30%	0.000%	0.005%	0.01%	0.00%	0.00%	0.000%
5C2	NOx	31.10	16.00	48%	133%	141%	0.000%	0.002%	0.01%	0.00%	0.01%	0.000%
5D1	NOx	25.35	4.80	1%	10%	10%	0.000%	0.004%	0.00%	0.00%	0.00%	0.000%
5D2	NOx	0.25	1.09	10%	10%	14%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
6A	NOx	84.35	97.69	30%	50%	58%	0.000%	0.043%	0.07%	0.02%	0.03%	0.000%
Total		**144'547**	**61'338**	**Level uncertainty:**			**15%**	**Trend uncertainty:**				**1.3%**

Table A - 15: Uncertainty analysis of NMVOC emissions 1990 and 2019.

A	B	C	D	E	F	G	H	I	J	K	L	M
NFR	Pollutant	Emissions 1990	Emissions 2019	AD uncertainty 2019	EF uncertainty 2019	Combined uncertainty 2019	Combined uncertainty as % of national total 2019	Type A sensitivity	Type B sensitivity	Uncertainty in trend introduced by emission factor uncertainty	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		t	t	%	%	%	%	%	%	%	%	%
1A1a	NMVOC	292.47	147.18	10%	32%	34%	0.000%	0.023%	0.05%	0.01%	0.01%	0.000%
1A1b	NMVOC	6.95	3.85	1%	20%	20%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
1A1c	NMVOC	2.13	8.62	5%	20%	21%	0.000%	0.003%	0.00%	0.00%	0.00%	0.000%
1A2a	NMVOC	8.93	7.39	2%	18%	18%	0.000%	0.002%	0.00%	0.00%	0.00%	0.000%
1A2b	NMVOC	53.59	6.60	2%	19%	19%	0.000%	0.003%	0.00%	0.00%	0.00%	0.000%
1A2c	NMVOC	34.06	25.55	2%	10%	10%	0.000%	0.005%	0.01%	0.00%	0.00%	0.000%
1A2d	NMVOC	29.85	4.30	2%	10%	10%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
1A2e	NMVOC	22.04	23.64	2%	10%	10%	0.000%	0.006%	0.01%	0.00%	0.00%	0.000%
1A2f	NMVOC	596.56	468.82	2%	30%	30%	0.000%	0.102%	0.15%	0.03%	0.00%	0.000%
1A2gvii	NMVOC	1'331.50	303.75	1%	34%	34%	0.000%	0.017%	0.10%	0.01%	0.00%	0.000%
1A2gviii	NMVOC	278.19	117.07	2%	30%	30%	0.000%	0.014%	0.04%	0.00%	0.00%	0.000%
1A3ai(i)	NMVOC	247.46	178.67	1%	50%	50%	0.000%	0.037%	0.06%	0.02%	0.00%	0.000%
1A3aii(i)	NMVOC	58.81	33.75	1%	50%	50%	0.000%	0.006%	0.01%	0.00%	0.00%	0.000%
1A3bi	NMVOC	63'464.72	4'763.15	1%	52%	52%	0.094%	3.971%	1.56%	2.07%	0.03%	0.043%
1A3bii	NMVOC	4'919.59	192.73	1%	46%	46%	0.000%	0.366%	0.06%	0.17%	0.00%	0.000%
1A3biii	NMVOC	3'185.66	212.84	1%	22%	22%	0.000%	0.208%	0.07%	0.05%	0.00%	0.000%
1A3biv	NMVOC	5'733.49	1'076.48	1%	400%	400%	0.281%	0.148%	0.35%	0.59%	0.01%	0.003%
1A3c	NMVOC	83.76	45.73	1%	34%	34%	0.000%	0.008%	0.02%	0.00%	0.00%	0.000%
1A3dii	NMVOC	1'640.55	419.97	1%	34%	34%	0.000%	0.005%	0.14%	0.00%	0.00%	0.000%
1A3ei	NMVOC	0.06	0.06	2%	50%	50%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4ai	NMVOC	1'130.94	634.98	2%	56%	56%	0.002%	0.110%	0.21%	0.06%	0.00%	0.000%
1A4aii	NMVOC	1'091.65	338.27	1%	75%	75%	0.001%	0.016%	0.11%	0.01%	0.00%	0.000%
1A4bi	NMVOC	8'849.15	2'715.53	4%	68%	68%	0.052%	0.118%	0.89%	0.08%	0.05%	0.000%
1A4bii	NMVOC	398.23	140.16	1%	75%	75%	0.000%	0.011%	0.05%	0.01%	0.00%	0.000%
1A4ci	NMVOC	220.64	92.96	21%	75%	78%	0.000%	0.011%	0.03%	0.01%	0.01%	0.000%
1A4cii	NMVOC	4'369.08	943.93	1%	75%	75%	0.008%	0.072%	0.31%	0.05%	0.01%	0.000%
1A5b	NMVOC	160.25	62.32	1%	34%	34%	0.000%	0.006%	0.02%	0.00%	0.00%	0.000%
1B2c	NMVOC	10.95	0.08	22%	51%	56%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
2A1	NMVOC	41.25	27.69	2%	200%	200%	0.000%	0.005%	0.01%	0.01%	0.00%	0.000%
2A2	NMVOC	0.69	0.61	2%	500%	500%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2A5a	NMVOC	4.59	2.15	5%	500%	500%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2B2	NMVOC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2C1	NMVOC	1'053.60	216.95	2%	100%	100%	0.001%	0.021%	0.07%	0.02%	0.00%	0.000%
2C3	NMVOC	56.57	0.00	0%	0%	0%	0.000%	0.005%	0.00%	0.00%	0.00%	0.000%
2C7c	NMVOC	0.00	0.53	5%	100%	100%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2G	NMVOC	22'927.29	6'652.68	25%	200%	202%	2.73%	0.180%	2.18%	0.36%	0.77%	0.007%
2H3	NMVOC	156.00	40.26	3%	200%	200%	0.000%	0.000%	0.01%	0.00%	0.00%	0.000%
3B1a	NMVOC	10'494.40	8'287.73	6%	500%	500%	26.07%	1.801%	2.72%	9.01%	0.25%	0.812%
3B1b	NMVOC	6'579.19	6'800.15	6%	500%	500%	17.55%	1.656%	2.23%	8.28%	0.20%	0.686%
3B2	NMVOC	66.79	67.55	6%	500%	500%	0.002%	0.016%	0.02%	0.08%	0.00%	0.000%
3B3	NMVOC	1'126.15	793.21	6%	500%	500%	0.239%	0.162%	0.26%	0.81%	0.02%	0.007%
3B4d	NMVOC	37.02	49.65	6%	500%	500%	0.001%	0.013%	0.02%	0.07%	0.00%	0.000%
3B4e	NMVOC	120.39	203.59	6%	500%	500%	0.016%	0.056%	0.07%	0.28%	0.01%	0.001%
3B4f	NMVOC	8.64	47.26	6%	500%	500%	0.001%	0.015%	0.02%	0.07%	0.00%	0.000%
3B4gi	NMVOC	508.70	575.13	6%	500%	500%	0.126%	0.144%	0.19%	0.72%	0.02%	0.005%
3B4gii	NMVOC	366.34	1'026.31	6%	500%	500%	0.400%	0.305%	0.34%	1.52%	0.03%	0.023%
3B4giii	NMVOC	46.28	36.73	6%	500%	500%	0.001%	0.008%	0.01%	0.04%	0.00%	0.000%
3B4giv	NMVOC	129.27	215.07	6%	500%	500%	0.018%	0.059%	0.07%	0.30%	0.01%	0.001%
3B4h	NMVOC	3.60	4.98	6%	500%	500%	0.000%	0.001%	0.00%	0.01%	0.00%	0.000%
3Da1	NMVOC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2a	NMVOC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2b	NMVOC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2c	NMVOC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da3	NMVOC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B2	NMVOC	46.44	953.18	20%	30%	36%	0.002%	0.309%	0.31%	0.09%	0.09%	0.000%
5C1a	NMVOC	516.80	276.80	50%	50%	71%	0.001%	0.046%	0.09%	0.02%	0.06%	0.000%
5C1bi	NMVOC	3.75	0.00	0%	0%	0%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5C1biii	NMVOC	4.50	0.00	0%	0%	0%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5C1biv	NMVOC	0.46	10.04	20%	20%	28%	0.000%	0.003%	0.00%	0.00%	0.00%	0.000%
5C1bv	NMVOC	1.20	0.36	5%	30%	30%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5C2	NMVOC	33.13	17.05	48%	133%	141%	0.000%	0.003%	0.01%	0.00%	0.00%	0.000%
5D1	NMVOC	0.51	0.10	1%	27%	27%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5D2	NMVOC	0.01	0.02	10%	20%	22%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
6A	NMVOC	186.62	224.64	30%	50%	58%	0.000%	0.057%	0.07%	0.03%	0.03%	0.000%
Total		**304'874**	**81'158**	**Level uncertainty:**			**75%**	**Trend uncertainty:**				**14%**

Table A - 16: Uncertainty analysis of SO_x emissions 1990 and 2019.

A	B	C	D	E	F	G	H	I	J	K	L	M
NFR	Pollutant	Emissions 1990	Emissions 2019	AD uncertainty 2019	EF uncertainty 2019	Combined uncertainty 2019	Combined uncertainty as % of national total 2019	Type A sensitivity	Type B sensitivity	Uncertainty in trend introduced by emission factor uncertainty	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		t	t	%	%	%	%	%	%	%	%	%
1A1a	SO2	3'587.18	215.23	10%	22%	24%	0.014%	0.596%	0.59%	0.13%	0.08%	0.000%
1A1b	SO2	660.41	50.30	1%	20%	20%	0.001%	0.081%	0.14%	0.02%	0.00%	0.000%
1A1c	SO2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1A2a	SO2	357.86	11.44	2%	15%	15%	0.000%	0.087%	0.03%	0.01%	0.00%	0.000%
1A2b	SO2	63.56	1.40	2%	10%	10%	0.000%	0.017%	0.00%	0.00%	0.00%	0.000%
1A2c	SO2	1'102.74	131.33	2%	11%	11%	0.001%	0.006%	0.36%	0.00%	0.01%	0.000%
1A2d	SO2	3'091.28	3.46	2%	14%	14%	0.000%	1.009%	0.01%	0.14%	0.00%	0.000%
1A2e	SO2	985.20	20.06	2%	12%	12%	0.000%	0.270%	0.05%	0.03%	0.00%	0.000%
1A2f	SO2	3'530.25	1'398.07	2%	19%	19%	0.361%	2.642%	3.81%	0.50%	0.11%	0.003%
1A2gvii	SO2	352.45	4.07	1%	10%	10%	0.000%	0.105%	0.01%	0.01%	0.00%	0.000%
1A2gviii	SO2	3'314.27	350.21	2%	19%	19%	0.023%	0.139%	0.95%	0.03%	0.03%	0.000%
1A3ai(i)	SO2	99.68	161.45	1%	10%	10%	0.001%	0.407%	0.44%	0.04%	0.01%	0.000%
1A3aii(i)	SO2	24.94	6.60	1%	10%	10%	0.000%	0.010%	0.02%	0.00%	0.00%	0.000%
1A3bi	SO2	1'856.85	65.04	1%	10%	10%	0.000%	0.435%	0.18%	0.04%	0.00%	0.000%
1A3bii	SO2	285.63	7.67	1%	10%	10%	0.000%	0.073%	0.02%	0.01%	0.00%	0.000%
1A3biii	SO2	1'612.76	13.69	1%	10%	10%	0.000%	0.494%	0.04%	0.05%	0.00%	0.000%
1A3biv	SO2	28.33	1.19	1%	10%	10%	0.000%	0.006%	0.00%	0.00%	0.00%	0.000%
1A3c	SO2	25.50	0.18	1%	10%	10%	0.000%	0.008%	0.00%	0.00%	0.00%	0.000%
1A3dii	SO2	63.17	1.52	1%	10%	10%	0.000%	0.017%	0.00%	0.00%	0.00%	0.000%
1A3ei	SO2	0.28	0.30	2%	10%	10%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
1A4ai	SO2	3'425.50	286.04	2%	10%	10%	0.004%	0.350%	0.78%	0.04%	0.02%	0.000%
1A4aii	SO2	1.79	0.09	1%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4bi	SO2	9'207.85	705.16	4%	10%	11%	0.029%	1.113%	1.92%	0.11%	0.10%	0.000%
1A4bii	SO2	1.34	0.06	1%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4ci	SO2	306.40	65.34	21%	18%	28%	0.002%	0.077%	0.18%	0.01%	0.05%	0.000%
1A4cii	SO2	290.19	2.49	1%	10%	10%	0.000%	0.089%	0.01%	0.01%	0.00%	0.000%
1A5b	SO2	77.42	30.09	1%	10%	10%	0.000%	0.056%	0.08%	0.01%	0.00%	0.000%
1B2c	SO2	300.19	2.22	22%	31%	38%	0.000%	0.093%	0.01%	0.03%	0.00%	0.000%
2A1	SO2	0.69	0.46	2%	200%	200%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
2A2	SO2	0.01	0.01	2%	500%	500%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2A5a	SO2	0.08	0.04	5%	500%	500%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2B2	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2C1	SO2	144.04	15.83	2%	100%	100%	0.001%	0.004%	0.04%	0.00%	0.00%	0.000%
2C3	SO2	696.30	0.00	0%	0%	0%	0.000%	0.230%	0.00%	0.00%	0.00%	0.000%
2C7c	SO2	0.00	0.02	5%	100%	100%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
2G	SO2	3.44	4.12	25%	100%	103%	0.000%	0.010%	0.01%	0.01%	0.00%	0.000%
2H3	SO2	1.30	0.34	3%	200%	200%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
3B1a	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B1b	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B2	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B3	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4d	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4e	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4f	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4gi	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4gii	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4giii	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4giv	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3B4h	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da1	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2a	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2b	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2c	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da3	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B2	SO2	0.00	0.89	20%	100%	102%	0.000%	0.002%	0.00%	0.00%	0.00%	0.000%
5C1a	SO2	24.23	12.98	50%	40%	64%	0.000%	0.027%	0.04%	0.01%	0.02%	0.000%
5C1bi	SO2	45.00	0.00	0%	0%	0%	0.000%	0.015%	0.00%	0.00%	0.00%	0.000%
5C1biii	SO2	19.50	0.00	0%	0%	0%	0.000%	0.006%	0.00%	0.00%	0.00%	0.000%
5C1biv	SO2	74.10	55.72	20%	30%	36%	0.002%	0.127%	0.15%	0.04%	0.04%	0.000%
5C1bv	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C2	SO2	0.68	0.35	48%	117%	126%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
5D1	SO2	0.13	0.02	1%	37%	37%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5D2	SO2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6A	SO2	10.40	10.95	30%	50%	58%	0.000%	0.026%	0.03%	0.01%	0.01%	0.000%
Total		**36'705**	**4'444**	**Level uncertainty:**			**7.4%**	**Trend uncertainty:**				**0.70%**

Table A - 17: Uncertainty analysis of NH_3 emissions 1990 and 2019.

A	B	C	D	E	F	G	H	I	J	K	L	M
NFR	Pollutant	Emissions 1990	Emissions 2019	AD uncertainty 2019	EF uncertainty 2019	Combined uncertainty 2019	Combined uncertainty as % of national total 2019	Type A sensitivity	Type B sensitivity	Uncertainty in trend introduced by emission factor uncertainty	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		t	t	%	%	%	%	%	%	%	%	%
1A1a	NH3	4.64	34.79	10%	20%	22%	0.000%	0.045%	0.05%	0.01%	0.01%	0.000%
1A1b	NH3	0.01	0.01	1%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A1c	NH3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1A2a	NH3	0.00	0.00	2%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A2b	NH3	0.11	0.00	2%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A2c	NH3	0.02	0.01	2%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A2d	NH3	0.02	0.00	2%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A2e	NH3	0.02	0.01	2%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A2f	NH3	147.02	170.15	2%	9%	9%	0.000%	0.080%	0.25%	0.01%	0.01%	0.000%
1A2gvii	NH3	1.00	1.54	1%	50%	50%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
1A2gviii	NH3	16.97	33.20	2%	9%	9%	0.000%	0.029%	0.05%	0.00%	0.00%	0.000%
1A3ai(i)	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3aii(i)	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi	NH3	1'483.06	1'019.92	1%	50%	50%	0.009%	0.205%	1.48%	0.10%	0.03%	0.000%
1A3bii	NH3	8.57	26.77	1%	50%	50%	0.000%	0.029%	0.04%	0.01%	0.00%	0.000%
1A3biii	NH3	4.13	29.48	1%	50%	50%	0.000%	0.038%	0.04%	0.02%	0.00%	0.000%
1A3biv	NH3	3.26	3.76	1%	50%	50%	0.000%	0.002%	0.01%	0.00%	0.00%	0.000%
1A3c	NH3	0.07	0.07	1%	50%	50%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A3dii	NH3	0.20	0.21	1%	50%	50%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A3ei	NH3	0.00	0.36	2%	50%	50%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
1A4ai	NH3	19.04	24.32	2%	10%	10%	0.000%	0.014%	0.04%	0.00%	0.00%	0.000%
1A4aii	NH3	0.01	0.02	1%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4bi	NH3	184.13	94.58	4%	10%	11%	0.000%	0.072%	0.14%	0.01%	0.01%	0.000%
1A4bii	NH3	0.01	0.01	1%	10%	10%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4ci	NH3	2.88	1.65	21%	10%	23%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
1A4cii	NH3	0.76	0.83	1%	50%	50%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A5b	NH3	0.04	0.04	1%	50%	50%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1B2c	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2A1	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2A2	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2A5a	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2B2	NH3	0.73	0.00	0%	0%	0%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
2C1	NH3	11.90	1.68	2%	200%	200%	0.000%	0.011%	0.00%	0.02%	0.00%	0.000%
2C3	NH3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C7c	NH3	9.19	8.08	5%	500%	500%	0.000%	0.001%	0.01%	0.01%	0.00%	0.000%
2G	NH3	203.15	78.34	25%	40%	47%	0.000%	0.117%	0.11%	0.05%	0.04%	0.000%
2H3	NH3	1.04	0.27	3%	200%	200%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
3B1a	NH3	10'000.45	10'869.50	6%	38%	39%	0.614%	4.417%	15.81%	1.69%	1.44%	0.049%
3B1b	NH3	5'537.52	7'374.59	6%	25%	26%	0.124%	4.419%	10.73%	1.10%	0.98%	0.022%
3B2	NH3	533.57	517.47	6%	54%	54%	0.003%	0.145%	0.75%	0.08%	0.07%	0.000%
3B3	NH3	6'803.83	4'745.27	6%	36%	37%	0.104%	0.845%	6.90%	0.30%	0.63%	0.005%
3B4d	NH3	165.15	210.28	6%	57%	58%	0.001%	0.118%	0.31%	0.07%	0.03%	0.000%
3B4e	NH3	277.33	408.87	6%	34%	35%	0.001%	0.279%	0.59%	0.10%	0.05%	0.000%
3B4f	NH3	21.26	101.83	6%	47%	48%	0.000%	0.124%	0.15%	0.06%	0.01%	0.000%
3B4gi	NH3	947.42	643.15	6%	83%	83%	0.010%	0.143%	0.94%	0.12%	0.09%	0.000%
3B4gii	NH3	353.20	597.34	6%	69%	69%	0.006%	0.467%	0.87%	0.32%	0.08%	0.001%
3B4giii	NH3	34.49	24.01	6%	78%	78%	0.000%	0.004%	0.03%	0.00%	0.00%	0.000%
3B4giv	NH3	122.23	93.38	6%	55%	56%	0.000%	0.003%	0.14%	0.00%	0.01%	0.000%
3B4h	NH3	14.58	44.63	6%	50%	50%	0.000%	0.048%	0.06%	0.02%	0.01%	0.000%
3Da1	NH3	4'258.37	2'461.37	5%	50%	50%	0.053%	1.268%	3.58%	0.63%	0.25%	0.005%
3Da2a	NH3	33'704.35	20'027.59	6%	22%	23%	0.743%	9.205%	29.14%	2.05%	2.65%	0.112%
3Da2b	NH3	1'169.36	0.00	0%	0%	0%	0.000%	1.332%	0.00%	0.00%	0.00%	0.000%
3Da2c	NH3	34.00	900.80	20%	50%	54%	0.008%	1.272%	1.31%	0.64%	0.37%	0.005%
3Da3	NH3	753.90	1'309.60	6%	38%	38%	0.009%	1.047%	1.91%	0.39%	0.17%	0.002%
5A	NH3	615.79	228.23	10%	50%	51%	0.000%	0.369%	0.33%	0.18%	0.05%	0.000%
5B2	NH3	9.63	204.33	20%	75%	78%	0.001%	0.286%	0.30%	0.21%	0.08%	0.001%
5C1a	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C1bi	NH3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5C1biii	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C1biv	NH3	5.70	26.60	20%	50%	54%	0.000%	0.032%	0.04%	0.02%	0.01%	0.000%
5C1bv	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C2	NH3	18.03	9.28	48%	25%	54%	0.000%	0.007%	0.01%	0.00%	0.01%	0.000%
5D1	NH3	90.61	125.15	1%	50%	50%	0.000%	0.079%	0.18%	0.04%	0.00%	0.000%
5D2	NH3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6A	NH3	843.00	994.56	30%	100%	104%	0.037%	0.487%	1.45%	0.49%	0.61%	0.006%
Total		**68'733**	**53'808**	**Level uncertainty:**			**13%**	**Trend uncertainty:**				**4.6%**

Table A - 18: Uncertainty analysis of PM2.5 emissions 1990 and 2019.

A	B	C	D	E	F	G	H	I	J	K	L	M
NFR	Pollutant	Emissions 1990	Emissions 2019	AD uncertainty 2019	EF uncertainty 2019	Combined uncertainty 2019	Combined uncertainty as % of national total 2019	Type A sensitivity	Type B sensitivity	Uncertainty in trend introduced by emission factor uncertainty	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		t	t	%	%	%	%	%	%	%	%	%
1A1a	PM2.5	771.59	39.46	10%	71%	72%	0.002%	1.524%	0.24%	1.08%	0.03%	0.012%
1A1b	PM2.5	47.66	1.34	1%	20%	20%	0.000%	0.101%	0.01%	0.02%	0.00%	0.000%
1A1c	PM2.5	4.64	18.76	5%	20%	21%	0.000%	0.104%	0.11%	0.02%	0.01%	0.000%
1A2a	PM2.5	14.80	2.76	2%	28%	28%	0.000%	0.017%	0.02%	0.00%	0.00%	0.000%
1A2b	PM2.5	20.38	1.23	2%	30%	30%	0.000%	0.039%	0.01%	0.01%	0.00%	0.000%
1A2c	PM2.5	40.75	5.15	2%	10%	10%	0.000%	0.062%	0.03%	0.01%	0.00%	0.000%
1A2d	PM2.5	149.61	0.25	2%	33%	33%	0.000%	0.341%	0.00%	0.11%	0.00%	0.000%
1A2e	PM2.5	25.68	1.39	2%	10%	10%	0.000%	0.050%	0.01%	0.01%	0.00%	0.000%
1A2f	PM2.5	437.58	45.13	2%	65%	65%	0.002%	0.726%	0.28%	0.47%	0.01%	0.002%
1A2gvii	PM2.5	728.86	396.47	1%	50%	50%	0.104%	0.749%	2.42%	0.37%	0.04%	0.001%
1A2gviii	PM2.5	530.19	170.93	2%	65%	65%	0.033%	0.171%	1.04%	0.11%	0.03%	0.000%
1A3ai(i)	PM2.5	92.40	18.12	1%	30%	30%	0.000%	0.101%	0.11%	0.03%	0.00%	0.000%
1A3aii(i)	PM2.5	22.68	2.05	1%	30%	30%	0.000%	0.039%	0.01%	0.01%	0.00%	0.000%
1A3bi	PM2.5	637.17	203.71	1%	57%	57%	0.036%	0.216%	1.24%	0.12%	0.02%	0.000%
1A3bii	PM2.5	327.15	96.36	1%	48%	48%	0.006%	0.161%	0.59%	0.08%	0.01%	0.000%
1A3biii	PM2.5	1'464.61	83.03	1%	27%	27%	0.001%	2.843%	0.51%	0.77%	0.01%	0.006%
1A3biv	PM2.5	208.81	44.35	1%	54%	54%	0.002%	0.207%	0.27%	0.11%	0.00%	0.000%
1A3c	PM2.5	174.35	228.16	1%	50%	50%	0.034%	0.992%	1.39%	0.50%	0.03%	0.002%
1A3dii	PM2.5	59.09	29.44	1%	50%	50%	0.001%	0.044%	0.18%	0.02%	0.00%	0.000%
1A3ei	PM2.5	0.11	0.06	2%	27%	27%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4ai	PM2.5	489.05	303.95	2%	78%	78%	0.148%	0.734%	1.85%	0.57%	0.04%	0.003%
1A4aii	PM2.5	0.00	0.00	0%	0%	0%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4bi	PM2.5	5'068.28	1'429.38	4%	76%	76%	3.121%	2.875%	8.71%	2.18%	0.46%	0.050%
1A4bii	PM2.5	0.00	0.00	0%	0%	0%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4ci	PM2.5	536.38	210.91	21%	39%	44%	0.023%	0.058%	1.29%	0.02%	0.39%	0.001%
1A4cii	PM2.5	435.10	178.63	1%	80%	80%	0.054%	0.093%	1.09%	0.07%	0.02%	0.000%
1A5b	PM2.5	86.95	44.76	1%	50%	50%	0.001%	0.074%	0.27%	0.04%	0.00%	0.000%
1B2c	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2A1	PM2.5	240.48	161.41	2%	200%	200%	0.275%	0.434%	0.98%	0.87%	0.03%	0.008%
2A2	PM2.5	7.21	6.35	2%	500%	500%	0.003%	0.022%	0.04%	0.11%	0.00%	0.000%
2A5a	PM2.5	183.33	222.41	5%	500%	500%	3.263%	0.936%	1.36%	4.68%	0.10%	0.219%
2B2	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2C1	PM2.5	817.90	8.11	2%	125%	125%	0.000%	1.821%	0.05%	2.28%	0.00%	0.052%
2C3	PM2.5	78.33	0.00	0%	0%	0%	0.000%	0.179%	0.00%	0.00%	0.00%	0.000%
2C7c	PM2.5	1.53	1.40	5%	500%	500%	0.000%	0.005%	0.01%	0.03%	0.00%	0.000%
2G	PM2.5	512.78	361.17	25%	100%	103%	0.366%	1.028%	2.20%	1.03%	0.78%	0.017%
2H3	PM2.5	15.60	4.03	3%	200%	200%	0.000%	0.011%	0.02%	0.02%	0.00%	0.000%
3B1a	PM2.5	20.61	24.14	6%	300%	300%	0.014%	0.100%	0.15%	0.30%	0.01%	0.001%
3B1b	PM2.5	18.26	21.91	6%	300%	300%	0.011%	0.092%	0.13%	0.28%	0.01%	0.001%
3B2	PM2.5	0.79	0.80	6%	300%	300%	0.000%	0.003%	0.00%	0.01%	0.00%	0.000%
3B3	PM2.5	9.57	6.51	6%	300%	300%	0.001%	0.018%	0.04%	0.05%	0.00%	0.000%
3B4d	PM2.5	0.14	0.18	6%	300%	300%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
3B4e	PM2.5	3.94	6.67	6%	300%	300%	0.001%	0.032%	0.04%	0.09%	0.00%	0.000%
3B4f	PM2.5	0.59	3.21	6%	300%	300%	0.000%	0.018%	0.02%	0.05%	0.00%	0.000%
3B4gi	PM2.5	9.25	10.46	6%	300%	300%	0.003%	0.043%	0.06%	0.13%	0.01%	0.000%
3B4gii	PM2.5	6.78	19.01	6%	300%	300%	0.009%	0.100%	0.12%	0.30%	0.01%	0.001%
3B4giii	PM2.5	1.89	1.50	6%	300%	300%	0.000%	0.005%	0.01%	0.01%	0.00%	0.000%
3B4giv	PM2.5	1.98	3.00	6%	300%	300%	0.000%	0.014%	0.02%	0.04%	0.00%	0.000%
3B4h	PM2.5	0.24	0.11	6%	300%	300%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
3Da1	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2a	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2b	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2c	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da3	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B2	PM2.5	0.00	0.05	20%	100%	102%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5C1a	PM2.5	465.12	249.12	50%	30%	58%	0.056%	0.454%	1.52%	0.14%	1.07%	0.012%
5C1bi	PM2.5	0.47	0.00	0%	0%	0%	0.000%	0.001%	0.00%	0.00%	0.00%	0.000%
5C1biii	PM2.5	16.50	0.00	0%	0%	0%	0.000%	0.038%	0.00%	0.00%	0.00%	0.000%
5C1biv	PM2.5	14.25	10.74	20%	34%	39%	0.000%	0.033%	0.07%	0.01%	0.02%	0.000%
5C1bv	PM2.5	4.39	0.87	5%	33%	33%	0.000%	0.005%	0.01%	0.00%	0.00%	0.000%
5C2	PM2.5	84.75	43.60	48%	133%	141%	0.010%	0.072%	0.27%	0.10%	0.18%	0.000%
5D1	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5D2	PM2.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6A	PM2.5	4.16	5.80	30%	40%	50%	0.000%	0.026%	0.04%	0.01%	0.02%	0.000%
Total		**16'402**	**6'156**	**Level uncertainty:**			**33%**	**Trend uncertainty:**				**7.6%**

Table A - 19: Uncertainty analysis of PM10 emissions 1990 and 2019.

A	B	C	D	E	F	G	H	I	J	K	L	M
NFR	Pollutant	Emissions 1990	Emissions 2019	AD uncertainty 2019	EF uncertainty 2019	Combined uncertainty 2019	Combined uncertainty as % of national total 2019	Type A sensitivity	Type B sensitivity	Uncertainty in trend introduced by emission factor uncertainty	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		t	t	%	%	%	%	%	%	%	%	%
1A1a	PM10	1'009.91	73.12	10%	71%	72%	0.001%	2.135%	0.29%	1.52%	0.04%	0.023%
1A1b	PM10	47.66	2.99	1%	20%	20%	0.000%	0.103%	0.01%	0.02%	0.00%	0.000%
1A1c	PM10	4.89	16.58	5%	20%	21%	0.000%	0.055%	0.07%	0.01%	0.00%	0.000%
1A2a	PM10	20.52	3.62	2%	28%	28%	0.000%	0.035%	0.01%	0.01%	0.00%	0.000%
1A2b	PM10	28.47	1.16	2%	30%	30%	0.000%	0.064%	0.00%	0.02%	0.00%	0.000%
1A2c	PM10	40.75	5.96	2%	10%	10%	0.000%	0.074%	0.02%	0.01%	0.00%	0.000%
1A2d	PM10	166.57	0.23	2%	33%	33%	0.000%	0.400%	0.00%	0.13%	0.00%	0.000%
1A2e	PM10	25.68	1.29	2%	10%	10%	0.000%	0.057%	0.01%	0.01%	0.00%	0.000%
1A2f	PM10	832.63	83.96	2%	65%	65%	0.001%	1.665%	0.34%	1.08%	0.01%	0.012%
1A2gvii	PM10	2'173.23	2'326.63	1%	50%	50%	0.618%	4.148%	9.38%	2.07%	0.17%	0.043%
1A2gviii	PM10	513.91	335.45	2%	65%	65%	0.022%	0.116%	1.35%	0.08%	0.04%	0.000%
1A3ai(i)	PM10	102.66	19.72	1%	30%	30%	0.000%	0.168%	0.08%	0.05%	0.00%	0.000%
1A3aii(i)	PM10	25.20	2.30	1%	30%	30%	0.000%	0.051%	0.01%	0.02%	0.00%	0.000%
1A3bi	PM10	637.25	205.80	1%	57%	57%	0.006%	0.704%	0.83%	0.40%	0.02%	0.002%
1A3bii	PM10	327.15	95.41	1%	48%	48%	0.001%	0.403%	0.38%	0.19%	0.01%	0.000%
1A3biii	PM10	1'494.78	104.49	1%	27%	27%	0.000%	3.175%	0.42%	0.86%	0.01%	0.007%
1A3biv	PM10	208.81	40.03	1%	54%	54%	0.000%	0.341%	0.16%	0.18%	0.00%	0.000%
1A3c	PM10	969.78	1'259.49	1%	50%	50%	0.181%	2.744%	5.08%	1.37%	0.09%	0.019%
1A3dii	PM10	59.09	31.81	1%	50%	50%	0.000%	0.014%	0.13%	0.01%	0.00%	0.000%
1A3ei	PM10	0.11	0.05	2%	27%	27%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4ai	PM10	433.80	481.79	2%	78%	78%	0.065%	0.899%	1.94%	0.70%	0.04%	0.005%
1A4aii	PM10	0.00	0.00	0%	0%	0%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4bi	PM10	5'018.14	1'639.84	4%	76%	76%	0.711%	5.454%	6.61%	4.15%	0.35%	0.173%
1A4bii	PM10	0.00	0.00	0%	0%	0%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
1A4ci	PM10	530.94	192.71	21%	39%	44%	0.003%	0.501%	0.78%	0.20%	0.23%	0.001%
1A4cii	PM10	511.19	255.21	1%	80%	80%	0.019%	0.201%	1.03%	0.16%	0.02%	0.000%
1A5b	PM10	286.52	262.52	1%	50%	50%	0.008%	0.369%	1.06%	0.18%	0.02%	0.000%
1B2c	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2A1	PM10	374.35	252.16	2%	200%	200%	0.116%	0.116%	1.02%	0.23%	0.03%	0.001%
2A2	PM10	14.41	12.64	2%	500%	500%	0.002%	0.016%	0.05%	0.08%	0.00%	0.000%
2A5a	PM10	366.54	453.78	5%	500%	500%	2.351%	0.948%	1.83%	4.74%	0.13%	0.225%
2B2	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2C1	PM10	1'485.46	15.07	2%	125%	125%	0.000%	3.513%	0.06%	4.39%	0.00%	0.193%
2C3	PM10	113.15	0.00	0%	0%	0%	0.000%	0.272%	0.00%	0.00%	0.00%	0.000%
2C7c	PM10	3.25	2.77	5%	500%	500%	0.000%	0.003%	0.01%	0.02%	0.00%	0.000%
2G	PM10	588.38	607.01	25%	100%	103%	0.179%	1.032%	2.45%	1.03%	0.87%	0.018%
2H3	PM10	15.60	4.85	3%	200%	200%	0.000%	0.018%	0.02%	0.04%	0.00%	0.000%
3B1a	PM10	84.47	100.65	6%	300%	300%	0.042%	0.203%	0.41%	0.61%	0.04%	0.004%
3B1b	PM10	74.85	90.57	6%	300%	300%	0.034%	0.185%	0.37%	0.56%	0.03%	0.003%
3B2	PM10	19.76	20.15	6%	300%	300%	0.002%	0.034%	0.08%	0.10%	0.01%	0.000%
3B3	PM10	213.16	150.97	6%	300%	300%	0.094%	0.096%	0.61%	0.29%	0.06%	0.001%
3B4d	PM10	3.42	4.55	6%	300%	300%	0.000%	0.010%	0.02%	0.03%	0.00%	0.000%
3B4e	PM10	6.20	12.17	6%	300%	300%	0.001%	0.034%	0.05%	0.10%	0.00%	0.000%
3B4f	PM10	0.94	4.29	6%	300%	300%	0.000%	0.015%	0.02%	0.05%	0.00%	0.000%
3B4gi	PM10	123.32	134.85	6%	300%	300%	0.075%	0.247%	0.54%	0.74%	0.05%	0.006%
3B4gii	PM10	67.84	187.81	6%	300%	300%	0.145%	0.594%	0.76%	1.78%	0.07%	0.032%
3B4giii	PM10	10.41	9.28	6%	300%	300%	0.000%	0.012%	0.04%	0.04%	0.00%	0.000%
3B4giv	PM10	18.52	25.33	6%	300%	300%	0.003%	0.058%	0.10%	0.17%	0.01%	0.000%
3B4h	PM10	0.50	0.86	6%	300%	300%	0.000%	0.002%	0.00%	0.01%	0.00%	0.000%
3Da1	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2a	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2b	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da2c	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3Da3	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5A	PM10	0.73	0.55	10%	30%	32%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5B2	PM10	0.00	0.05	20%	100%	102%	0.000%	0.000%	0.00%	0.00%	0.00%	0.000%
5C1a	PM10	516.80	286.40	50%	50%	71%	0.019%	0.089%	1.16%	0.04%	0.82%	0.007%
5C1bi	PM10	3.08	0.00	0%	0%	0%	0.000%	0.007%	0.00%	0.00%	0.00%	0.000%
5C1biii	PM10	24.00	0.00	0%	0%	0%	0.000%	0.058%	0.00%	0.00%	0.00%	0.000%
5C1biv	PM10	19.95	5.06	20%	35%	40%	0.000%	0.028%	0.02%	0.01%	0.01%	0.000%
5C1bv	PM10	4.39	0.88	5%	33%	33%	0.000%	0.007%	0.00%	0.00%	0.00%	0.000%
5C2	PM10	93.09	48.42	48%	133%	141%	0.002%	0.029%	0.20%	0.04%	0.13%	0.000%
5D1	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5D2	PM10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6A	PM10	206.32	195.80	30%	40%	50%	0.004%	0.293%	0.79%	0.12%	0.34%	0.001%
Total		**24'796**	**14'799**	**Level uncertainty:**			**32%**	**Trend uncertainty:**				**11%**

Table A - 20: Uncertainty analysis: Overview and data sources (legend see next page).

NFR	Relative uncertainties (95%)													
Code	Activity data		EF NOx		EF NMVOC		EF SOx		EF NH3		EF PM2.5		EF PM10	
	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source	Value	Source
1A1a	10.0%	GHGI	19%	EMIS	32%	EMIS	22%	EMIS	20%	EMIS	71%	EMIS	71%	EMIS
1A1b	1.3%	GHGI	20%	EMIS	20%	EMIS	20%	EMIS	10%	EMIS	20%	EMIS	20%	EMIS
1A1c	5.0%	EMIS	20%	EMEP/EEA 2019	20%	EMEP/EEA 2019	NE		NE		20%	EMEP/EEA 2019	20%	EMEP/EEA 2019
1A2a	2.0%	GHGI	27%	EMIS	18%	EMIS	15%	EMIS	10%	EMIS	28%	EMIS	28%	EMIS
1A2b	2.0%	GHGI	20%	EMIS	19%	EMIS	10%	EMIS	10%	EMIS	30%	EMIS	30%	EMIS
1A2c	2.0%	GHGI	10%	EMIS	10%	EMIS	11%	EMIS	10%	EMIS	10%	EMIS	10%	EMIS
1A2d	2.0%	GHGI	10%	EMIS	10%	EMIS	14%	EMIS	10%	EMIS	33%	EMIS	33%	EMIS
1A2e	2.0%	GHGI	10%	EMIS	10%	EMIS	12%	EMIS	10%	EMIS	10%	EMIS	10%	EMIS
1A2f	2.0%	GHGI	17%	EMIS	30%	EMIS	19%	EMIS	9%	EMIS	65%	EMIS	65%	EMIS
1A2gvii	1.3%	GHGI	13%	UBA	34%	UBA	10%	EMEP/EEA 2019	50%	France	50%	UBA/INFRAS	50%	UBA/INFRAS
1A2gviii	2.05%	GHGI	17%	EMIS	30%	EMIS	19%	EMIS	9%	EMIS	65%	EMIS	65%	EMIS
1A3ai(i)	1.3%	GHGI	20%	EMEP/EEA 2019	50%	EMEP/EEA 2019	10%	EMEP/EEA 2019	NA		30%	UBA/INFRAS	30%	UBA/INFRAS
1A3aii(i)	1.3%	GHGI	20%	EMEP/EEA 2019	50%	EMEP/EEA 2019	10%	EMEP/EEA 2019	NA		30%	UBA/INFRAS	30%	UBA/INFRAS
1A3bi	1.3%	GHGI	38%	UBA	52%	UBA	10%	EMEP/EEA 2019	50%	France	57%	UBA/INFRAS	57%	UBA/INFRAS
1A3bii	1.3%	GHGI	32%	UBA	46%	UBA	10%	EMEP/EEA 2019	50%	France	48%	UBA/INFRAS	48%	UBA/INFRAS
1A3biii	1.3%	GHGI	18%	UBA	22%	UBA	10%	EMEP/EEA 2019	50%	France	27%	UBA/INFRAS	27%	UBA/INFRAS
1A3biv	1.3%	GHGI	36%	UBA	400%	UBA	10%	EMEP/EEA 2019	50%	France	54%	UBA/INFRAS	54%	UBA/INFRAS
1A3bv	1.3%	GHGI	NA		40%	UBA	NA		NA		NA		NA	
1A3bvi	1.3%	GHGI	NA		NA		NA		NA		50%	UBA/INFRAS	50%	UBA/INFRAS
1A3c	1.3%	GHGI	13%	UBA	34%	UBA	10%	EMEP/EEA 2019	50%	France	50%	UBA/INFRAS	50%	UBA/INFRAS
1A3dii	1.3%	GHGI	13%	UBA	34%	UBA	10%	EMEP/EEA 2019	50%	France	50%	UBA/INFRAS	50%	UBA/INFRAS
1A3ei	2.0%	GHGI	50%	EMEP/EEA 2019	50%	EMEP/EEA 2019	10%	EMEP/EEA 2019	50%	France	27%	UBA/INFRAS	27%	UBA/INFRAS
1A4ai	1.6%	GHGI	16%	EMIS	56%	EMIS	10%	EMIS	10%	EMIS	78%	EMIS	78%	EMIS
1A4aii	1.3%	GHGI	13%	UBA	75%	Sweden	10%	EMEP/EEA 2019	10%	EMIS	NA		50%	UBA/INFRAS
1A4bi	3.7%	GHGI	13%	EMIS	68%	EMIS	10%	EMIS	10%	EMIS	76%	EMIS	76%	EMIS
1A4bii	1.3%	GHGI	30%	EMIS	75%	Sweden	10%	EMEP/EEA 2019	10%	EMIS	NA		50%	UBA/INFRAS
1A4ci	21.2%	GHGI	30%	EMIS	75%	EMIS	18%	EMIS	10%	EMIS	39%	EMIS	39%	EMIS
1A4cii	1.3%	GHGI	13%	UBA	75%	Sweden	10%	EMEP/EEA 2019	50%	France	80%	EMIS	80%	EMIS
1A5b	1.3%	GHGI	13%	UBA	34%	UBA	10%	EMEP/EEA 2019	50%	France	50%	UBA/INFRAS	50%	UBA/INFRAS
1B1a	30.0%	EMEP/EEA 2019	NA		NA		NA		NA		40%	EMIS	40%	EMIS
1B2ai	30.0%		NA		50%	EMEP/EEA 2019	NA		NA		NA		NA	
1B2aiv	30.0%	EMEP/EEA 2019	NA		47%	EMIS	47%	EMIS	NA		NA		NA	
1B2av	1.3%	EMEP/EEA 2019	NA		26%	EMIS	NA		NA		NA		NA	
1B2b	22.0%	EMIS	NA		50%	EMEP/EEA 2019	NA		NA		NA		NA	
1B2c	22.0%	EMIS	30%	EMIS	51%	EMIS	31%	EMIS	NA		NA		NA	
2A1	2.0%	GHGI	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	NA		200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
2A2	2.0%	GHGI	500%	EMEP/EEA 2019	500%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		500%	EMEP/EEA 2019	500%	EMEP/EEA 2019
2A5a	5.0%	EMIS	500%	EMEP/EEA 2019	500%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		500%	EMEP/EEA 2019	500%	EMEP/EEA 2019
2B1	2.0%	GHGI	NA		IE		NA		10%	EMEP/EEA 2019	NA		NA	
2B2	2.0%	GHGI	10%	EMEP/EEA 2019	NA		NA		10%	EMEP/EEA 2019	NA		NA	
2B5	2.0%	GHGI	NA		NA		20%	EMEP/EEA 2019	NA		200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
2B10a	2.0%	GHGI	60%	P/EEA 2019 (B "hoch")	40%	EMEP/EEA 2019	40%	EMEP/EEA 2019	40%	EMEP/EEA 2019	40%	EMEP/EEA 2019	40%	EMEP/EEA 2019
2C1	2.0%	GHGI	50%	EMEP/EEA 2019	100%	EMEP/EEA 2019	100%	EMEP/EEA 2019	200%	EMEP/EEA 2019	125%	EMEP/EEA 2019	125%	EMEP/EEA 2019
2C3	5.0%	GHGI	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	NO		200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
2C7a	5.0%	EMIS	NA		200%	EMEP/EEA 2019	NA		NA		200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
2C7c	5.0%	EMIS	100%	EMEP/EEA 2019	100%	EMEP/EEA 2019	100%	EMEP/EEA 2019	500%	EMEP/EEA 2019	500%	EMEP/EEA 2019	500%	EMEP/EEA 2019
2D3a	1.0%	EMIS	NA		200%	EMEP/EEA 2019	NA		NA		NA		NA	
2D3b	5.0%	EMIS	NA		100%	EMEP/EEA 2019	NA		NA		IE		IE	
2D3c	20.0%	EMIS	NA		100%	EMEP/EEA 2019	NA		NA		200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
2D3d	30.0%	EMIS	NA		40%	EMEP/EEA 2019	NA		NA		NA		NA	
2D3e	40.0%	EMIS	NA		100%	EMEP/EEA 2019	NA		NA		NA		NA	
2D3f	20.0%	EMIS	NA		100%	EMEP/EEA 2019	NA		NA		NA		NA	
2D3g	30.0%	EMIS	NA		100%	EMEP/EEA 2019	NA		NA		NA		NA	
2D3h	20.0%	EMIS	NA		40%	EMEP/EEA 2019	NA		NA		NA		NA	
2D3i	30.0%	EMEP/EEA 2019 (E)	NA		180%	EMEP/EEA 2019	NA		NA		500%	EMEP/EEA 2019	500%	EMEP/EEA 2019
2G	25.0%	EMIS	100%	EMEP/EEA 2019	200%	EMEP/EEA 2019	100%	EMEP/EEA 2019	40%	EMEP/EEA 2019	100%	EMEP/EEA 2019	100%	EMEP/EEA 2019
2H1	30.0%	EMEP/EEA 2019 (E)	NA		200%	EMEP/EEA 2019	NA		NA		200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
2H2	10.0%	EMEP/EEA 2019 (E)	NA		100%	EMEP/EEA 2019	NA		500%	EMEP/EEA 2019	500%	EMEP/EEA 2019	500%	EMEP/EEA 2019
2H3	3.0%	EMIS	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
2I	10.0%	EMEP/EEA 2019	NA		NA		NA		NA		500%	EMEP/EEA 2019	500%	EMEP/EEA 2019
2L	25.0%	EMIS	NA		NA		NA		100%	EMEP/EEA 2019	NA		NA	
3B1a	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		38%	Infras 2017b	300%	EMIS	300%	EMIS
3B1b	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		25%	Infras 2017b	300%	EMIS	300%	EMIS
3B2	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		54%	Infras 2017b	300%	EMIS	300%	EMIS
3B3	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		36%	Infras 2017b	300%	EMIS	300%	EMIS
3B4d	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		57%	Infras 2017b	300%	EMIS	300%	EMIS
3B4e	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		34%	Infras 2017b	300%	EMIS	300%	EMIS
3B4f	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		47%	Infras 2017b	300%	EMIS	300%	EMIS
3B4gi	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		83%	Infras 2017b	300%	EMIS	300%	EMIS
3B4gii	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		69%	Infras 2017b	300%		300%	
3B4giii	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		78%	Infras 2017b	300%		300%	
3B4giv	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		55%	Infras 2017b	300%		300%	
3B4h	6.4%	GHGI	50%	EMEP/EEA 2019	500%	EMEP/EEA 2019	NA		50%	Infras 2017b	300%		300%	
3Da1	5.0%	GHGI	100%	EMEP/EEA 2019	NA		NA		50%	Kupper 2012	NA		NA	
3Da2a	6.4%	GHGI	50%	EMEP/EEA 2019	NA		NA		22%	Infras 2017b	NA		NA	
3Da2b	6.4%	GHGI	100%	EMEP/EEA 2019	NA		NA		50%	Kupper 2012	NA		NA	
3Da2c	20.0%	Schleiss 2017	100%	EMEP/EEA 2019	NA		NA		50%	Kupper 2012	NA		NA	
3Da3	6.4%	GHGI	100%	EMEP/EEA 2019	NA		NA		38%	Infras 2017b	NA		NA	
3De	5.0%	GHGI (LULUCF)	NA		200%	EMEP/EEA 2019	NA		NA		200%	EMEP/EEA 2019	200%	EMEP/EEA 2019
5A	10.0%	GHGI	50%	EMIS	NA	EMIS	NA	EMIS	50%	EMIS	NA	EMIS	30%	EMIS
5B1	20.0%	Schleiss 2017	NA		100%	EMIS	NA		100%	EMIS	NA		NA	
5B2	20.0%	EMIS	100%	EMEP/EEA 2019	30%	EMIS	100%	EMIS	75%	INFRAS 2014	100%	EMIS	100%	EMIS
5C1a	50.0%	EMIS	40%	EMIS	50%	EMIS	40%	EMIS	NA		30%	EMIS	50%	EMIS
5C1bi	30.0%	EMIS	30%	EMIS	30%	EMIS	30%	EMIS	NO		30%	EMIS	30%	EMIS
5C1biii	30.0%	EMIS	30%	EMIS	30%	EMIS	30%	EMIS	nA		30%	EMIS	30%	EMIS
5C1biv	20.0%	EMIS	50%	EMIS	20%	EMIS	30%	EMIS	50%	EMIS	34%	EMIS	35%	EMIS
5C1bv	5.0%	EMIS	30%	EMIS	30%	EMIS	NA		NA		33%	EMIS	33%	EMIS
5C2	48.0%	EMIS	133%	EMIS	133%	EMIS	117%	EMIS	25%	EMIS	133%	EMIS	133%	EMIS
5D1	1.3%	EMIS	10%	EMIS	27%	EMIS	37%	EMIS	50%	EMIS	NA		NA	
5D2	10.0%	EMIS	10%	EMIS	20%	EMIS	20%	EMIS	NA		NA		NA	
5E	20.0%	EMIS	NA		24%	EMIS	NA		NA		30%	EMIS	30%	EMIS
6A	30.0%	GHGI	50%	EMIS	50%	EMIS	50%	EMIS	100%	EMEP/EEA 2019	40%	EMIS	40%	EMIS

Legend:

EMEP/EEA 2019: Default values of EMEP/EEA 2019 (activity data and emission factors). The uncertainties are based on the rating definitions (A, B, C, D) contained in Table 2-2 or on the indicative error ranges in activity data for uncertainty analysis in Table 2-1.

GHGI: Uncertainty analysis of Switzerland's greenhouse gas inventory (FOEN 2021); mainly activity data.

EMIS: Uncertainties that are implemented in the EMIS database (activity data and emission factors).

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 (2009), in which uncertainties are evaluated for road and non-road vehicles via Monte Carlo simulation (emission factors).

UBA/INFRAS: PM10 emission factor uncertainties derived from raw data of IFEU/INFRAS (2009).

Kupper 2012: see References (chp. 12.1).

INFRAS 2017b: see References (chp. 12.1).

Schleiss 2017: see References (chp. 12.1).

Annex 6 Summary information on condensables in PM

Table A - 21: Inclusion/exclusion of the condensable component from PM10 and PM2.5 emission factors.

NFR codes	Source/sector name	PM emissions: the condensable		EF 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 (petrol engines with/without catalytic converter, diesel engines with/without particulate filter, etc.).
1A4bi	Charcoal use, Bonfire	X		The EF of particulate matter of these two source categories are based on default Tier-2 EF of the EMEP/EEA Guidebook 2019 (chp. 1A4, Table 3-39). These EF values correspond to total particles which include both filterable and condensable PM.
2	IPPU		X	
3	Agriculture	NA	NA	
5	Waste		X	
6	Other		X	

Annex 7 Emission time series of main air pollutants, PM2.5 and BC for 1980–2019 and 2020–2050

A7.1 Emission time series by pollutant and aggregated sectors

A7.1.1 NO_x emission time series

Table A - 22: NO_x emissions by sectors 1-6. The last column indicates the relative trend.

NOx	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	157.7	157.1	155.9	156.1	157.8	158.1	155.3	151.8	146.9	140.7
2	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.1	0.9	0.7
3	6.3	6.2	6.1	6.1	6.0	5.9	5.9	5.8	5.7	5.7
5	0.8	0.8	0.8	0.9	0.9	0.8	0.7	0.6	0.5	0.4
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum	165.9	165.3	164.1	164.2	165.8	166.0	163.1	159.3	154.1	147.5

NOx	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	134.7	131.9	125.8	118.8	114.8	112.3	108.4	102.9	102.4	100.9
2	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3
3	5.0	4.9	4.8	4.7	4.6	4.6	4.5	4.2	4.1	4.1
5	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sum	140.6	137.6	131.5	124.3	120.2	117.5	113.4	107.7	107.1	105.6

NOx	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	98.4	95.7	91.1	89.6	88.3	88.1	85.9	83.5	81.7	78.4
2	0.3	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.3
3	4.0	4.1	4.0	3.9	3.9	3.9	3.9	4.0	4.0	3.9
5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sum	103.0	100.4	95.7	94.2	92.9	92.6	90.4	88.1	86.2	82.9

NOx	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1	78.4	75.4	75.1	75.3	71.7	69.8	68.4	65.1	60.8	57.8	-34
2	0.4	0.4	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.2	-26
3	4.0	3.9	3.9	3.8	3.9	3.8	3.8	3.9	3.8	3.7	-6
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-10
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	6
Sum	83.1	79.9	79.6	79.7	76.3	74.2	72.8	69.5	65.1	61.9	-33

Table A - 23: NO_x emissions by sectors 1-6 (projection).

NOx	2020	2025	2030	2035	2040	2045	2050
	kt						
1	56.7	46.0	37.8	30.4	26.7	24.6	23.2
2	0.2	0.2	0.3	0.3	0.3	0.2	0.2
3	3.8	3.8	3.8	3.8	3.8	3.8	3.8
5	0.1	0.2	0.2	0.2	0.2	0.2	0.2
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sum	60.9	50.3	42.1	34.7	31.0	28.9	27.4

A7.1.2 NMVOC emission time series

Table A - 24: NMVOC emissions by sectors 1-6. The last column indicates the relative trend.

NMVOC total	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	152.8	152.5	151.4	150.8	150.1	148.6	144.7	140.1	135.2	129.7
2	140.5	141.9	143.4	144.9	146.4	148.8	150.4	152.5	154.7	156.3
3	23.3	22.9	22.6	22.3	22.0	21.7	21.5	21.2	21.0	20.7
5	2.6	2.4	2.2	2.1	1.9	1.6	1.5	1.3	1.1	0.9
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sum	319.3	320.0	319.9	320.2	320.4	320.9	318.1	315.3	312.1	307.8

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	124.4	118.1	107.3	96.5	84.0	79.1	75.1	69.7	65.3	60.0
2	149.9	139.2	128.7	118.2	111.8	104.7	97.1	90.4	83.7	79.1
3	20.0	19.8	19.6	19.4	19.6	19.6	19.6	19.1	19.0	18.9
5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sum	295.2	278.1	256.5	235.0	216.2	204.2	192.6	180.1	168.8	159.0

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	56.4	53.7	49.2	46.1	43.1	40.8	38.0	35.2	33.4	31.1
2	74.1	69.3	63.7	58.5	53.5	52.5	51.9	51.1	50.4	50.0
3	18.7	19.0	18.9	18.8	18.6	19.0	19.1	19.4	19.6	19.3
5	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.9	0.9	0.9
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sum	150.2	143.0	132.8	124.3	116.2	113.3	110.0	106.7	104.5	101.4

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1	28.6	26.1	25.0	23.8	21.4	20.2	19.2	18.3	17.5	16.7	-59
2	50.0	49.2	48.8	47.4	46.4	45.0	43.6	43.8	43.7	43.5	-17
3	19.2	19.0	19.0	18.9	19.0	18.8	18.9	18.7	18.7	18.6	-2
5	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	100
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	17
Sum	98.8	95.5	94.0	91.5	88.2	85.5	83.2	82.4	81.5	80.6	-29

Table A - 25: NMVOC emissions by sectors 1-6 (projection).

NMVOC total	2020	2025	2030	2035	2040	2045	2050
	kt						
1	16.2	13.9	12.2	10.8	9.9	9.0	8.3
2	43.5	44.4	45.4	45.8	46.1	46.4	46.7
3	18.7	18.8	18.8	18.8	18.8	18.8	18.8
5	1.9	4.0	6.1	6.9	7.2	7.4	7.3
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sum	80.6	81.4	82.7	82.5	82.2	81.8	81.3

A7.1.3 SO_x emission time series

Table A - 26: SO_x emissions by sectors 1-6. The last column indicates the relative trend.

SO2	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	111.5	98.5	87.3	80.9	77.9	71.2	65.6	60.6	53.3	43.7
2	2.8	2.8	2.7	2.6	2.5	2.3	2.2	2.0	1.8	1.6
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sum	114.6	101.5	90.2	83.8	80.6	73.8	68.0	62.8	55.3	45.5

SO2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	35.0	34.8	32.5	28.0	25.2	25.1	23.7	20.3	21.2	18.4
2	1.5	1.4	1.4	1.1	1.0	0.9	0.9	0.9	0.8	0.7
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sum	36.7	36.4	34.0	29.2	26.2	26.1	24.7	21.3	22.1	19.2

SO2	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	15.6	16.4	14.1	14.3	13.9	12.9	12.5	10.9	10.9	9.8
2	0.8	0.8	0.9	0.9	1.1	1.1	0.7	0.7	0.7	0.5
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sum	16.4	17.3	15.1	15.3	15.0	14.0	13.3	11.6	11.7	10.4

SO2	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1	9.6	7.7	7.8	7.3	6.6	4.9	4.4	4.1	3.8	3.5	-72
2	0.8	0.7	0.8	0.6	0.6	0.6	0.8	0.8	0.9	0.8	-24
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1
Sum	10.5	8.4	8.7	8.0	7.2	5.6	5.2	5.0	4.8	4.4	-68

Table A - 27: SO_x emissions by sectors 1-6 (projection).

SO2	2020	2025	2030	2035	2040	2045	2050
	kt						
1	3.5	3.3	3.5	2.8	2.6	2.4	2.3
2	0.8	0.8	0.7	0.7	0.7	0.7	0.7
3	NA	NA	NA	NA	NA	NA	NA
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sum	4.4	4.1	4.3	3.6	3.4	3.2	3.1

A7.1.4 NH_3 emission time series

Table A - 28: NH_3 emissions by sectors 1-6. The last column indicates the relative trend.

NH3	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	0.3	0.3	0.3	0.4	0.4	0.4	0.6	0.9	1.1	1.4
2	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
3	77.8	77.0	76.1	75.2	74.4	73.8	73.4	73.1	72.8	72.4
5	2.3	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.4	1.2
6	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Sum	81.5	80.6	79.6	78.6	77.7	76.9	76.7	76.4	76.2	75.9

NH3	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	1.7	2.1	2.4	2.6	2.7	2.9	3.1	3.3	3.6	3.8
2	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4
3	64.7	63.5	62.6	61.7	61.2	60.8	59.0	56.3	55.4	54.4
5	0.9	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9	0.9
6	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9
Sum	68.6	67.6	67.0	66.2	65.8	65.7	64.2	61.7	61.1	60.4

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	4.9	4.9	4.6	4.4	4.1	3.9	3.6	3.4	3.2	3.0
2	0.4	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3
3	53.4	53.4	52.4	51.7	51.7	52.8	53.5	54.4	54.6	53.6
5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sum	60.5	60.4	59.2	58.2	58.0	58.8	59.2	60.0	59.9	58.7

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1	2.8	2.5	2.3	2.0	1.8	1.6	1.6	1.5	1.4	1.4	-65
2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	-64
3	54.0	53.1	52.6	52.0	52.5	51.8	51.7	51.6	51.1	50.3	-5
5	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9	-2
6	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.0	1.0	1.0	12
Sum	58.8	57.7	57.0	56.1	56.4	55.5	55.3	55.2	54.6	53.7	-9

Table A - 29: NH_3 emissions by sectors 1-6 (projection).

NH3	2020	2025	2030	2035	2040	2045	2050
	kt						
1	1.3	1.3	1.2	1.2	1.1	1.0	0.9
2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	51.1	51.3	51.2	51.2	51.2	51.2	51.2
5	1.0	1.4	1.9	2.1	2.1	2.1	2.1
6	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sum	54.6	55.1	55.4	55.5	55.5	55.5	55.3

A7.1.5 PM2.5 emission time series

Table A - 30: PM2.5 emissions by sectors 1-6. The last column indicates the relative trend.

PM2.5	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	12.2	12.5	12.4	12.4	12.8	12.9	13.1	13.2	13.2	13.2
2	4.5	4.0	3.6	3.2	2.8	2.6	2.6	2.6	2.5	2.5
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	2.4	2.3	2.1	1.9	1.7	1.5	1.3	1.1	0.9	0.8
6	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Sum	19.2	19.0	18.3	17.6	17.4	17.2	17.1	17.0	16.9	16.7

PM2.5	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	13.1	13.4	12.8	12.3	11.6	11.6	11.6	10.6	10.5	10.2
2	2.6	2.5	2.6	2.5	2.4	2.0	2.0	2.0	1.6	1.5
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4
6	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Sum	16.4	16.7	16.1	15.5	14.7	14.3	14.2	13.2	12.7	12.3

PM2.5	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	9.7	9.5	8.9	8.8	8.6	8.5	8.2	7.8	7.7	7.3
2	1.5	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
6	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005
Sum	11.7	11.5	10.9	10.8	10.6	10.5	10.3	9.8	9.8	9.2

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1	7.1	6.2	6.1	5.8	5.1	5.0	5.0	4.8	4.6	4.5	-47
2	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.2	-18
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10
5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-20
6	0.005	0.005	0.006	0.006	0.005	0.006	0.006	0.006	0.006	0.006	40
Sum	9.1	8.2	8.0	7.8	7.0	6.8	6.7	6.6	6.3	6.1	-42

Table A - 31: PM2.5 emissions by sectors 1-6 (projection).

PM2.5	2020	2025	2030	2035	2040	2045	2050
	kt						
1	4.5	4.2	4.0	3.7	3.6	3.5	3.4
2	1.3	1.3	1.4	1.3	1.3	1.3	1.2
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.3	0.3	0.2	0.2	0.2	0.2	0.2
6	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Sum	6.2	5.9	5.8	5.4	5.2	5.1	4.9

A7.1.6 BC emission time series

Table A - 32: BC emissions by sectors 1-6. The last column indicates the relative trend.

BC	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	4.71	4.86	4.99	5.12	5.26	5.38	5.49	5.60	5.68	5.75
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.17	0.16	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.05
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	4.89	5.03	5.15	5.26	5.39	5.49	5.59	5.68	5.75	5.81

BC	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	5.70	5.93	5.61	5.42	5.00	5.03	5.08	4.54	4.46	4.30
2	0.01	0.01	0.01	0.01	0.01	0.004	0.004	0.004	0.003	0.003
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	5.75	5.98	5.66	5.47	5.04	5.07	5.12	4.58	4.49	4.34

BC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	3.99	3.91	3.63	3.63	3.49	3.45	3.27	2.98	2.88	2.64
2	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	4.03	3.94	3.66	3.67	3.52	3.48	3.30	3.01	2.91	2.67

BC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1	2.53	2.09	1.97	1.85	1.50	1.45	1.39	1.28	1.20	1.15	-67
2	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	-51
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-21
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	-6
Sum	2.55	2.11	2.00	1.88	1.53	1.48	1.42	1.30	1.23	1.17	-66

Table A - 33: BC emissions by sectors 1-6 (projection).

BC	2020	2025	2030	2035	2040	2045	2050
	kt						
1	1.08	0.91	0.78	0.62	0.57	0.52	0.48
2	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3	NA	NA	NA	NA	NA	NA	NA
5	0.02	0.02	0.02	0.02	0.01	0.01	0.01
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	1.10	0.93	0.80	0.63	0.58	0.54	0.50

A7.2 1 Energy

A7.2.1 1 Energy: NO_x

Table A - 34: NO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2. The last column indicates the relative trend.

NOx	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1A1	4.4	4.5	4.5	4.6	4.6	5.0	5.4	5.8	6.2	6.3
1A2	24	23	22	21	21	20	22	23	23	23
1A3	110	110	110	111	111	111	106	101	96	90
1A4	18	18	18	19	20	21	21	21	21	21
1A5	0.69	0.71	0.73	0.75	0.77	0.79	0.81	0.83	0.85	0.87
1B2	0.31	0.30	0.29	0.29	0.28	0.28	0.27	0.27	0.27	0.24
Sum	158	157	156	156	158	158	155	152	147	141

NOx	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1A1	6.8	6.6	6.4	5.3	5.0	4.7	4.6	4.2	4.4	3.9
1A2	23	21	20	19	20	19	18	16	16	16
1A3	83	80	76	72	69	67	63	62	62	62
1A4	21	22	22	21	20	20	21	19	19	19
1A5	0.88	0.83	0.80	0.78	0.76	0.71	0.68	0.71	0.70	0.66
1B2	0.21	0.32	0.29	0.32	0.33	0.32	0.36	0.34	0.34	0.35
Sum	135	132	126	119	115	112	108	103	102	101

NOx	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1A1	3.5	3.3	3.0	2.6	2.8	2.9	3.1	2.9	3.1	3.0
1A2	15	16	15	14	15	14	14	13	13	12
1A3	61	58	56	55	54	54	53	53	51	49
1A4	17	18	17	17	16	16	15	14	14	14
1A5	0.67	0.66	0.67	0.62	0.58	0.60	0.61	0.57	0.55	0.54
1B2	0.32	0.34	0.33	0.32	0.35	0.29	0.13	0.13	0.16	0.12
Sum	98	96	91	90	88	88	86	84	82	78

NOx	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1A1	3.0	2.9	3.0	3.1	2.9	2.4	2.4	2.4	2.4	2.4	-18
1A2	12	11	11	11	10	9.4	9.3	9.0	8.5	8.2	-43
1A3	49	49	48	48	48	47	45	43	40	37	-30
1A4	14	12	12	13	11	11	11	11	9.6	9.5	-42
1A5	0.54	0.49	0.51	0.50	0.51	0.49	0.49	0.45	0.43	0.39	-35
1B2	0.11	0.093	0.083	0.074	0.090	0.051	0.0030	0.0023	0.0025	0.0017	-99
Sum	78	75	75	75	72	70	68	65	61	58	-34

Table A - 35: NO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2 (projection).

NOx	2020	2025	2030	2035	2040	2045	2050
	kt						
1A1	2.7	4.2	5.7	5.5	5.3	5.2	5.0
1A2	7.9	7.3	7.1	6.5	6.2	5.9	5.6
1A3	36	26	18	12	9.4	8.4	7.8
1A4	9.2	8.0	7.1	6.1	5.4	4.8	4.4
1A5	0.39	0.39	0.40	0.39	0.38	0.37	0.37
1B2	0.0030	0.0023	0.0025	0.0017	0.0016	0.0015	0.0013
Sum	57	46	38	30	27	25	23

A7.2.2 1 Energy: NMVOC

Table A - 36: NMVOC emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2. The last column indicates the relative trend.

NMVOC total	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1A1	0.60	0.61	0.62	0.62	0.63	0.60	0.57	0.52	0.47	0.38
1A2	2.3	2.3	2.3	2.2	2.2	2.2	2.3	2.3	2.3	2.3
1A3	123	122	121	120	118	116	111	105	99	93
1A4	13	14	14	14	15	15	15	16	16	16
1A5	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16
1B2	13	14	14	14	14	14	15	16	17	18
Sum	153	153	151	151	150	149	145	140	135	130

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1A1	0.30	0.29	0.28	0.25	0.24	0.24	0.24	0.23	0.24	0.23
1A2	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3
1A3	86	78	68	60	53	49	45	42	39	36
1A4	16	17	16	16	15	15	15	14	14	13
1A5	0.16	0.15	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.13
1B2	20	21	20	18	13	12	12	12	10	7.6
Sum	124	118	107	96	84	79	75	70	65	60

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1A1	0.23	0.23	0.22	0.21	0.22	0.22	0.23	0.21	0.21	0.20
1A2	2.3	2.3	2.1	2.1	2.1	2.0	2.0	1.8	1.7	1.6
1A3	34	31	29	26	24	23	20	19	18	16
1A4	13	12	12	11	11	10	9.9	8.9	8.9	8.3
1A5	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.095	0.092
1B2	7.3	7.3	6.3	6.0	5.7	5.4	5.4	4.9	4.7	4.6
Sum	56	54	49	46	43	41	38	35	33	31

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1A1	0.20	0.18	0.18	0.17	0.15	0.15	0.16	0.15	0.16	0.16	-28
1A2	1.6	1.4	1.3	1.3	1.2	1.1	1.1	1.0	0.99	0.96	-53
1A3	15	14	13	12	11	10	10	9.2	8.9	8.4	-63
1A4	8.3	6.9	6.9	6.9	5.6	5.6	5.6	5.4	5.0	4.9	-54
1A5	0.090	0.082	0.082	0.080	0.079	0.075	0.076	0.070	0.068	0.062	-43
1B2	3.4	3.4	3.5	3.4	3.4	3.0	2.6	2.4	2.4	2.3	-56
Sum	29	26	25	24	21	20	19	18	17	17	-59

Table A - 37: NMVOC emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2 (projection).

NMVOC total	2020	2025	2030	2035	2040	2045	2050
	kt						
1A1	0.17	0.20	0.23	0.23	0.22	0.22	0.21
1A2	0.93	0.88	0.86	0.82	0.79	0.76	0.74
1A3	7.9	6.3	5.2	4.6	4.1	3.7	3.3
1A4	4.8	4.4	4.1	3.5	3.2	2.9	2.7
1A5	0.062	0.063	0.066	0.064	0.063	0.062	0.062
1B2	2.6	2.4	2.4	2.3	2.3	2.0	1.8
Sum	16	14	12	11	10	9.0	8.3

A7.2.3 1 Energy: SO_x

Table A - 38: SO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2. The last column indicates the relative trend.

SO2	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1A1	7.4	7.3	7.2	7.2	7.2	6.9	6.6	6.2	5.8	4.8
1A2	49	40	34	30	27	22	22	23	22	18
1A3	6.8	6.5	6.2	5.9	5.5	5.1	4.8	4.5	4.1	3.8
1A4	47	43	39	37	38	36	31	26	21	16
1A5	0.075	0.074	0.074	0.074	0.074	0.074	0.074	0.075	0.076	0.077
1B2	1.1	1.0	1.0	1.0	0.94	0.93	0.93	0.93	0.92	0.82
Sum	112	99	87	81	78	71	66	61	53	44

SO2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1A1	4.2	4.6	4.9	2.8	2.7	2.8	2.9	2.3	3.2	2.2
1A2	13	11	9.7	8.6	8.3	8.2	7.0	5.8	6.0	5.1
1A3	4.0	3.9	3.7	3.3	2.3	2.1	2.2	2.2	2.3	2.5
1A4	13	14	13	12	11	11	11	9.3	9.0	7.9
1A5	0.077	0.070	0.065	0.060	0.056	0.049	0.045	0.048	0.048	0.043
1B2	0.72	0.98	0.83	0.82	0.75	0.62	0.70	0.65	0.65	0.65
Sum	35	35	32	28	25	25	24	20	21	18

SO2	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1A1	1.8	1.7	1.4	1.4	1.6	1.7	1.6	1.7	1.8	1.7
1A2	4.7	5.3	4.3	4.5	5.0	4.1	4.6	3.8	3.7	3.2
1A3	1.8	1.6	1.4	1.2	0.22	0.21	0.22	0.22	0.23	0.22
1A4	6.7	7.1	6.4	6.6	6.4	6.3	5.8	4.8	4.8	4.4
1A5	0.044	0.043	0.044	0.039	0.035	0.037	0.039	0.036	0.035	0.035
1B2	0.58	0.61	0.60	0.56	0.62	0.51	0.30	0.27	0.32	0.24
Sum	16	16	14	14	14	13	13	11	11	10

SO2	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1A1	1.7	1.5	1.9	1.8	2.1	0.81	0.37	0.37	0.29	0.27	-84
1A2	3.0	2.5	2.5	2.3	2.2	2.1	2.1	2.0	2.1	1.9	-53
1A3	0.23	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.26	0.26	21
1A4	4.5	3.2	3.0	2.8	1.8	1.6	1.6	1.4	1.1	1.1	-83
1A5	0.037	0.033	0.035	0.036	0.037	0.036	0.038	0.034	0.034	0.030	-20
1B2	0.22	0.19	0.16	0.14	0.16	0.085	0.020	0.018	0.019	0.016	-97
Sum	9.6	7.7	7.8	7.3	6.6	4.9	4.4	4.1	3.8	3.5	-72

Table A - 39: SO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2 (projection).

SO2	2020	2025	2030	2035	2040	2045	2050
	kt						
1A1	0.35	0.74	1.1	0.70	0.68	0.67	0.65
1A2	1.9	1.8	1.7	1.5	1.3	1.2	1.1
1A3	0.25	0.25	0.23	0.23	0.22	0.22	0.21
1A4	1.0	0.49	0.44	0.39	0.34	0.30	0.27
1A5	0.031	0.033	0.036	0.035	0.034	0.034	0.034
1B2	0.020	0.018	0.019	0.016	0.016	0.014	0.013
Sum	3.5	3.3	3.5	2.8	2.6	2.4	2.3

A7.2.4 1 Energy: NH_3

Table A - 40: NH_3 emissions from sector 1 Energy by source categories 1A1-1A5. The last column indicates the relative trend.

NH3	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1A1	0.0048	0.0048	0.0048	0.0047	0.0046	0.0047	0.0047	0.0048	0.0048	0.0047
1A2	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.15	0.16
1A3	0.076	0.078	0.080	0.082	0.083	0.085	0.31	0.54	0.79	1.1
1A4	0.13	0.14	0.15	0.15	0.16	0.17	0.18	0.19	0.19	0.20
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
Sum	0.33	0.34	0.35	0.36	0.37	0.38	0.62	0.87	1.1	1.4

NH3	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1A1	0.0047	0.0054	0.0067	0.0078	0.0089	0.010	0.012	0.012	0.014	0.016
1A2	0.17	0.16	0.15	0.14	0.15	0.15	0.15	0.14	0.15	0.16
1A3	1.3	1.7	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4
1A4	0.21	0.22	0.21	0.21	0.19	0.19	0.20	0.18	0.18	0.18
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
Sum	1.7	2.1	2.4	2.6	2.7	2.9	3.1	3.3	3.6	3.8

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1A1	0.018	0.020	0.023	0.024	0.025	0.026	0.028	0.029	0.033	0.034
1A2	0.18	0.18	0.19	0.18	0.18	0.19	0.21	0.24	0.24	0.23
1A3	4.6	4.5	4.3	4.0	3.8	3.5	3.2	3.0	2.8	2.6
1A4	0.16	0.17	0.16	0.16	0.16	0.16	0.16	0.15	0.16	0.16
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
Sum	4.9	4.9	4.6	4.4	4.1	3.9	3.6	3.4	3.2	3.0

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1A1	0.035	0.037	0.040	0.042	0.033	0.031	0.032	0.034	0.034	0.035	35
1A2	0.24	0.23	0.22	0.21	0.24	0.21	0.22	0.22	0.21	0.20	5.6
1A3	2.4	2.1	1.9	1.6	1.4	1.3	1.2	1.1	1.1	1.0	-71
1A4	0.16	0.13	0.14	0.14	0.11	0.12	0.13	0.13	0.12	0.12	-26
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	3.8
Sum	2.8	2.5	2.3	2.0	1.8	1.6	1.6	1.5	1.4	1.4	-65

Table A - 41: NH_3 emissions from sector 1 Energy by source categories 1A1-1A5 (projection).

NH3	2020	2025	2030	2035	2040	2045	2050
	kt						
1A1	0.043	0.082	0.12	0.12	0.12	0.11	0.11
1A2	0.21	0.20	0.18	0.16	0.15	0.14	0.12
1A3	0.96	0.86	0.83	0.80	0.74	0.67	0.58
1A4	0.12	0.12	0.11	0.10	0.10	0.091	0.086
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
Sum	1.3	1.3	1.2	1.2	1.1	1.0	0.90

A7.2.5 1 Energy: PM2.5

Table A - 42: PM2.5 emissions from sector 1 Energy by source categories 1A1-1A5 and 1B1. The last column indicates the relative trend.

PM2.5	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1A1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	0.93	0.86
1A2	2.5	2.4	2.2	2.1	2.1	2.0	2.1	2.2	2.1	2.1
1A3	3.9	3.9	3.9	4.0	4.0	4.0	3.9	3.9	3.9	3.8
1A4	4.6	5.1	5.1	5.2	5.6	5.8	5.9	6.1	6.2	6.4
1A5	0.10	0.10	0.10	0.10	0.095	0.094	0.093	0.092	0.091	0.089
1B1	0.00016	0.00017	0.00019	0.00020	0.00022	0.00023	0.00018	0.00013	0.00008	0.00003
Sum	12	13	12	12	13	13	13	13	13	13

PM2.5	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1A1	0.82	0.76	0.74	0.60	0.57	0.55	0.52	0.45	0.44	0.37
1A2	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.7	1.7	1.7
1A3	3.7	3.8	3.7	3.6	3.5	3.4	3.3	3.3	3.3	3.3
1A4	6.5	6.9	6.4	6.2	5.6	5.7	5.8	5.1	5.0	4.8
1A5	0.087	0.080	0.076	0.072	0.068	0.063	0.062	0.063	0.063	0.062
1B1	0.00016	0.00014	0.00009	0.00008	0.00008	0.00009	0.00006	0.00005	0.00004	0.00004
Sum	13	13	13	12	12	12	12	11	11	10

PM2.5	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1A1	0.34	0.29	0.22	0.18	0.18	0.18	0.18	0.20	0.20	0.19
1A2	1.6	1.7	1.5	1.6	1.5	1.5	1.5	1.4	1.3	1.1
1A3	3.2	3.1	2.9	2.9	2.8	2.8	2.8	2.7	2.6	2.5
1A4	4.4	4.4	4.1	4.1	4.0	4.0	3.8	3.4	3.6	3.4
1A5	0.062	0.061	0.061	0.059	0.057	0.057	0.056	0.054	0.053	0.051
1B1	0.00006	0.00007	0.00006	0.00006	0.00006	0.00007	0.00008	0.00009	0.00008	0.00007
Sum	9.7	9.5	8.9	8.8	8.6	8.5	8.2	7.8	7.7	7.3

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1A1	0.19	0.16	0.17	0.15	0.14	0.08	0.063	0.062	0.058	0.060	-67
1A2	1.1	0.90	0.86	0.80	0.69	0.69	0.68	0.66	0.64	0.62	-58
1A3	2.4	2.2	2.1	2.0	1.9	1.8	1.8	1.7	1.7	1.6	-42
1A4	3.5	2.9	2.9	2.8	2.3	2.4	2.4	2.4	2.2	2.1	-46
1A5	0.050	0.049	0.048	0.048	0.047	0.046	0.046	0.046	0.045	0.045	-21
1B1	0.00007	0.00007	0.00006	0.00007	0.00007	0.00006	0.00006	0.00006	0.00005	0.00005	-33
Sum	7.1	6.2	6.1	5.8	5.1	5.0	5.0	4.8	4.6	4.5	-47

Table A - 43: PM2.5 emissions from sector 1 Energy by source categories 1A1-1A5 and 1B1 (projection).

PM2.5	2020	2025	2030	2035	2040	2045	2050
	kt						
1A1	0.063	0.083	0.10	0.090	0.089	0.088	0.086
1A2	0.61	0.58	0.57	0.54	0.54	0.54	0.54
1A3	1.6	1.5	1.5	1.5	1.5	1.5	1.5
1A4	2.1	2.0	1.8	1.5	1.4	1.3	1.2
1A5	0.045	0.045	0.045	0.044	0.044	0.044	0.043
1B1	0.00006	0.00006	0.00005	0.00005	0.00005	0.00005	0.00006
Sum	4.5	4.2	4.0	3.7	3.6	3.5	3.4

A7.2.6 1 Energy: BC

Table A - 44: BC emissions from sector 1 Energy by source categories 1A1-1A5 and 1B1. The last column indicates the relative trend.

BC	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1A1	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.042	0.041	0.039
1A2	0.43	0.43	0.43	0.42	0.43	0.43	0.43	0.44	0.43	0.41
1A3	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.5	1.5	1.5
1A4	2.5	2.7	2.8	3.0	3.1	3.3	3.4	3.6	3.7	3.8
1A5	0.030	0.030	0.030	0.030	0.030	0.029	0.029	0.028	0.027	0.027
1B1	0.00009	0.00010	0.00011	0.00012	0.00013	0.00014	0.00011	0.00008	0.00005	0.00002
Sum	4.7	4.9	5.0	5.1	5.3	5.4	5.5	5.6	5.7	5.7

BC	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1A1	0.036	0.035	0.035	0.024	0.023	0.022	0.023	0.018	0.020	0.014
1A2	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.43	0.42	0.42
1A3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3
1A4	3.8	4.0	3.7	3.5	3.1	3.2	3.2	2.8	2.7	2.5
1A5	0.026	0.022	0.020	0.018	0.016	0.014	0.013	0.014	0.013	0.013
1B1	0.00010	0.00008	0.00006	0.00005	0.00005	0.00005	0.00004	0.00003	0.00002	0.00003
Sum	5.7	5.9	5.6	5.4	5.0	5.0	5.1	4.5	4.5	4.3

BC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1A1	0.013	0.013	0.011	0.011	0.011	0.012	0.011	0.013	0.013	0.012
1A2	0.41	0.39	0.37	0.36	0.34	0.32	0.28	0.24	0.21	0.17
1A3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.0
1A4	2.2	2.2	2.0	2.0	1.9	1.9	1.7	1.5	1.5	1.4
1A5	0.013	0.012	0.012	0.011	0.010	0.010	0.0093	0.0083	0.0073	0.0065
1B1	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00005	0.00005	0.00005	0.00004
Sum	4.0	3.9	3.6	3.6	3.5	3.4	3.3	3.0	2.9	2.6

BC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
1A1	0.011	0.0098	0.010	0.0086	0.0082	0.0045	0.0034	0.0033	0.0031	0.0035	-70
1A2	0.14	0.12	0.10	0.09	0.071	0.064	0.060	0.055	0.051	0.047	-85
1A3	0.92	0.83	0.71	0.62	0.56	0.49	0.42	0.37	0.38	0.35	-72
1A4	1.5	1.1	1.1	1.1	0.86	0.90	0.91	0.85	0.77	0.74	-60
1A5	0.0058	0.0050	0.0048	0.0044	0.0042	0.0038	0.0038	0.0035	0.0034	0.0031	-68
1B1	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00003	0.00003	0.00003	-33
Sum	2.5	2.1	2.0	1.9	1.5	1.5	1.4	1.3	1.2	1.1	-67

Table A - 45: BC emissions from sector 1 Energy by source categories 1A1-1A5 and 1B1 (projection).

BC	2020	2025	2030	2035	2040	2045	2050
	kt						
1A1	0.0037	0.0048	0.0060	0.0046	0.0044	0.0043	0.0041
1A2	0.044	0.025	0.017	0.014	0.014	0.013	0.013
1A3	0.29	0.21	0.17	0.15	0.15	0.15	0.14
1A4	0.74	0.67	0.59	0.44	0.40	0.36	0.32
1A5	0.0031	0.0032	0.0032	0.0031	0.0028	0.0028	0.0028
1B1	0.00004	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
Sum	1.1	0.91	0.78	0.62	0.57	0.52	0.48

A7.3 2 Industrial processes and product use

A7.3.1 2 Industrial processes and product use: NO_x

Table A - 46: NO_x emissions from sector 2 Industrial processes and product use by source categories 2A-2C, 2G and 2H. The last column indicates the relative trend.

NOx	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
2A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
2B	0.75	0.75	0.74	0.73	0.73	0.77	0.82	0.67	0.50	0.30
2C	0.24	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.26
2G	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2H	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Sum	1.13	1.12	1.11	1.11	1.10	1.15	1.20	1.05	0.89	0.70

NOx	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
2A	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2B	0.09	0.08	0.07	0.07	0.08	0.08	0.08	0.07	0.08	0.08
2C	0.26	0.27	0.29	0.29	0.28	0.15	0.14	0.14	0.13	0.14
2G	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2H	0.09	0.08	0.07	0.06	0.06	0.05	0.02	0.03	0.04	0.06
Sum	0.49	0.48	0.49	0.47	0.46	0.32	0.28	0.28	0.29	0.31

NOx	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
2A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2B	0.09	0.09	0.09	0.08	0.09	0.08	0.09	0.08	0.09	0.08
2C	0.15	0.16	0.17	0.17	0.18	0.17	0.18	0.18	0.19	0.13
2G	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02
2H	0.07	0.07	0.12	0.14	0.13	0.03	0.05	0.04	0.05	0.07
Sum	0.35	0.36	0.42	0.44	0.44	0.32	0.35	0.34	0.37	0.32

NOx	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
2A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-13
2B	0.08	0.08	0.08	0.06	0.06	0.04	0.06	0.07	0.03	0.02	-74
2C	0.17	0.19	0.18	0.17	0.19	0.18	0.18	0.18	0.18	0.16	-8
2G	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-24
2H	0.08	0.10	0.08	0.08	0.07	0.07	0.02	0.03	0.03	0.02	-15
Sum	0.38	0.40	0.37	0.34	0.36	0.33	0.29	0.30	0.27	0.23	-26

Table A - 47: NO_x emissions from sector 2 Industrial processes and product use by source categories 2A-2C, 2G and 2H (projection).

NOx	2020	2025	2030	2035	2040	2045	2050
	kt						
2A	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2B	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2C	0.16	0.16	0.16	0.15	0.14	0.13	0.12
2G	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2H	0.03	0.04	0.06	0.07	0.07	0.07	0.07
Sum	0.24	0.25	0.26	0.26	0.25	0.24	0.23

A7.3.2 2 Industrial processes and product use: NMVOC

Table A - 48: NMVOC emissions from sector 2 Industrial processes and product use by source categories 2A-2D, 2G and 2H. The last column indicates the relative trend.

NMVOC total	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
2A	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2B	0.96	0.94	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85
2C	0.99	0.84	0.69	0.56	0.43	0.40	0.36	0.32	0.28	0.24
2D	135.89	137.51	139.14	140.76	142.38	144.85	146.43	148.14	150.19	151.77
2G	0.19	0.20	0.21	0.23	0.24	0.25	0.26	0.73	0.88	0.92
2H	2.43	2.42	2.41	2.43	2.38	2.39	2.41	2.43	2.43	2.45
Sum	140.48	141.95	143.42	144.93	146.37	148.82	150.38	152.54	154.68	156.28

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
2A	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2B	0.61	0.60	0.21	0.20	0.19	0.18	0.13	0.08	0.03	0.03
2C	1.11	0.94	0.92	0.75	0.76	0.76	0.67	0.68	0.72	0.72
2D	122.56	113.68	105.20	96.50	91.60	86.09	80.49	75.66	70.47	66.45
2G	22.93	21.31	19.66	18.06	16.53	15.01	13.32	11.57	10.07	9.51
2H	2.67	2.66	2.68	2.70	2.63	2.59	2.45	2.40	2.33	2.38
Sum	149.92	139.23	128.72	118.25	111.75	104.66	97.08	90.43	83.66	79.12

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
2A	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03
2B	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02
2C	0.71	0.64	0.53	0.49	0.47	0.45	0.44	0.45	0.48	0.31
2D	61.89	57.52	52.09	47.07	42.10	41.63	41.33	40.61	40.08	40.09
2G	9.00	8.67	8.53	8.39	8.32	8.00	7.62	7.45	7.22	6.99
2H	2.41	2.41	2.49	2.51	2.53	2.38	2.45	2.50	2.54	2.51
Sum	74.07	69.29	63.70	58.52	53.47	52.53	51.89	51.07	50.38	49.95

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
2A	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	-13
2B	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.02	-44
2C	0.35	0.39	0.32	0.31	0.31	0.29	0.27	0.28	0.28	0.22	-52
2D	40.21	39.35	38.38	37.75	36.82	35.48	34.26	34.51	34.37	34.33	-18
2G	6.77	6.80	7.52	6.86	6.77	6.75	6.74	6.70	6.68	6.65	-17
2H	2.55	2.55	2.47	2.43	2.43	2.41	2.28	2.28	2.29	2.28	-4
Sum	49.95	49.15	48.75	47.42	46.40	44.98	43.59	43.81	43.66	43.52	-17

Table A - 49: NMVOC emissions from sector 2 Industrial processes and product use by source categories 2A-2D, 2G and 2H (projection).

NMVOC total	2020	2025	2030	2035	2040	2045	2050
	kt						
2A	0.03	0.03	0.03	0.02	0.02	0.02	0.02
2B	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2C	0.23	0.28	0.33	0.31	0.29	0.27	0.26
2D	34.25	34.86	35.47	35.82	36.14	36.38	36.65
2G	6.65	6.68	6.72	6.74	6.75	6.75	6.76
2H	2.32	2.56	2.79	2.87	2.91	2.94	2.97
Sum	43.49	44.42	45.35	45.79	46.13	46.39	46.66

A7.3.3 2 Industrial processes and product use: SO_x

Table A - 50: SO_x emissions from sector 2 Industrial processes and product use by source categories 2A-2C and 2G-2H. The last column indicates the relative trend.

SO2	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
2A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2B	1.43	1.43	1.43	1.42	1.42	1.29	1.16	1.03	0.89	0.75
2C	1.41	1.33	1.25	1.17	1.08	1.05	1.01	0.96	0.92	0.87
2G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	2.85	2.76	2.68	2.60	2.51	2.34	2.17	2.00	1.82	1.63

SO2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
2A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2B	0.61	0.62	0.62	0.63	0.63	0.63	0.60	0.65	0.53	0.45
2C	0.84	0.81	0.76	0.46	0.35	0.24	0.27	0.25	0.27	0.29
2G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	1.46	1.43	1.39	1.09	0.99	0.88	0.88	0.91	0.81	0.75

SO2	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
2A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2B	0.48	0.52	0.51	0.49	0.66	0.69	0.59	0.63	0.67	0.44
2C	0.30	0.31	0.34	0.37	0.38	0.37	0.11	0.02	0.02	0.01
2G	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.78	0.83	0.86	0.87	1.05	1.07	0.71	0.66	0.69	0.47

SO2	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
2A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-13
2B	0.76	0.66	0.74	0.56	0.59	0.62	0.73	0.81	0.89	0.79	15
2C	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-96
2G	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	-26
2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-15
Sum	0.79	0.69	0.77	0.59	0.62	0.65	0.76	0.83	0.91	0.81	-24

Table A - 51: SO_x emissions from sector 2 Industrial processes and product use by source categories 2A-2C and 2G-2H (projection).

SO2	2020	2025	2030	2035	2040	2045	2050
	kt						
2A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2B	0.77	0.73	0.69	0.69	0.69	0.69	0.69
2C	0.02	0.02	0.02	0.01	0.01	0.01	0.01
2G	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.79	0.76	0.72	0.72	0.72	0.72	0.71

A7.3.4 2 Industrial processes and product use: NH_3

Table A - 52: NH_3 emissions from sector 2 Industrial processes and product use by source categories 2B, 2C, 2G, 2H and 2L. The last column indicates the relative trend.

NH3	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
2B	0.34	0.31	0.27	0.24	0.21	0.17	0.14	0.10	0.07	0.04
2C	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2G	0.15	0.16	0.16	0.16	0.16	0.16	0.17	0.18	0.19	0.20
2H	0.05	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.12	0.13
2L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.58	0.55	0.53	0.51	0.49	0.46	0.44	0.42	0.40	0.38

NH3	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
2B	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
2C	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02
2G	0.20	0.20	0.20	0.19	0.21	0.20	0.18	0.21	0.22	0.24
2H	0.13	0.11	0.11	0.11	0.09	0.10	0.13	0.13	0.12	0.11
2L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.37	0.33	0.33	0.32	0.32	0.32	0.33	0.35	0.36	0.38

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
2B	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
2C	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2G	0.24	0.20	0.17	0.20	0.21	0.24	0.19	0.15	0.14	0.13
2H	0.13	0.10	0.12	0.10	0.10	0.09	0.09	0.12	0.11	0.12
2L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.39	0.32	0.31	0.31	0.33	0.35	0.30	0.29	0.27	0.26

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
2B	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	-100
2C	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-23
2G	0.09	0.08	0.09	0.07	0.07	0.06	0.06	0.07	0.08	0.08	-67
2H	0.09	0.11	0.09	0.07	0.09	0.06	0.05	0.05	0.04	0.03	-63
2L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39
Sum	0.20	0.21	0.19	0.15	0.17	0.14	0.13	0.14	0.13	0.12	-65

Table A - 53: NH_3 emissions from sector 2 Industrial processes and product use by source categories 2B, 2C, 2G, 2H and 2L (projection).

NH3	2020	2025	2030	2035	2040	2045	2050
	kt						
2B	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2C	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2G	0.07	0.07	0.06	0.06	0.06	0.06	0.05
2H	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2L	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.11	0.11	0.11	0.10	0.10	0.09	0.09

A7.3.5 2 Industrial processes and product use: PM2.5

Table A - 54: PM2.5 emissions from sector 2 Industrial processes and product use by source categories 2A-2D and 2G-2I. The last column indicates the relative trend.

PM2.5	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
2A	0.33	0.34	0.34	0.34	0.35	0.35	0.37	0.39	0.40	0.42
2B	0.12	0.12	0.12	0.12	0.12	0.11	0.10	0.09	0.08	0.06
2C	2.47	2.10	1.74	1.38	1.02	1.00	0.98	0.96	0.94	0.92
2D	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
2G	0.47	0.48	0.49	0.50	0.50	0.50	0.50	0.50	0.51	0.51
2H	0.83	0.76	0.69	0.63	0.56	0.47	0.44	0.42	0.40	0.38
2I	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Sum	4.24	3.82	3.40	2.99	2.57	2.44	2.40	2.36	2.34	2.31

PM2.5	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
2A	0.43	0.40	0.39	0.38	0.39	0.39	0.37	0.35	0.36	0.36
2B	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.03
2C	0.90	0.93	0.99	0.98	0.93	0.56	0.58	0.61	0.17	0.06
2D	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
2G	0.51	0.51	0.54	0.51	0.50	0.52	0.51	0.50	0.55	0.58
2H	0.44	0.43	0.44	0.44	0.41	0.39	0.38	0.38	0.39	0.38
2I	0.22	0.19	0.17	0.15	0.13	0.11	0.10	0.09	0.09	0.08
Sum	2.57	2.54	2.59	2.52	2.44	2.03	2.00	2.00	1.60	1.51

PM2.5	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
2A	0.37	0.38	0.37	0.37	0.39	0.41	0.42	0.42	0.41	0.42
2B	0.03	0.04	0.04	0.03	0.05	0.05	0.04	0.04	0.04	0.03
2C	0.05	0.05	0.05	0.06	0.06	0.06	0.03	0.02	0.02	0.01
2D	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2G	0.55	0.52	0.57	0.58	0.58	0.48	0.51	0.51	0.53	0.55
2H	0.40	0.38	0.41	0.40	0.41	0.41	0.43	0.48	0.48	0.43
2I	0.08	0.06	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.05
Sum	1.50	1.43	1.51	1.49	1.53	1.46	1.48	1.52	1.53	1.48

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
2A	0.44	0.44	0.42	0.43	0.42	0.39	0.40	0.40	0.39	0.39	-5
2B	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	-56
2C	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-82
2D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45
2G	0.49	0.50	0.52	0.54	0.45	0.42	0.40	0.44	0.44	0.36	-25
2H	0.44	0.45	0.42	0.40	0.43	0.41	0.39	0.41	0.39	0.38	-7
2I	0.05	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	-30
Sum	1.47	1.48	1.44	1.44	1.39	1.30	1.28	1.33	1.31	1.20	-18

Table A - 55: PM2.5 emissions from sector 2 Industrial processes and product use by source categories 2A-2D and 2G-2I (projection).

PM2.5	2020	2025	2030	2035	2040	2045	2050
	kt						
2A	0.39	0.39	0.38	0.36	0.35	0.33	0.32
2B	0.04	0.03	0.03	0.03	0.03	0.03	0.03
2C	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2D	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2G	0.45	0.45	0.45	0.45	0.45	0.45	0.45
2H	0.38	0.41	0.45	0.44	0.42	0.41	0.40
2I	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sum	1.31	1.34	1.37	1.33	1.30	1.28	1.25

A7.3.6 2 Industrial processes and product use: BC

Table A - 56: BC emissions from sector 2 Industrial processes and product use by source categories 2A, 2C, 2D and 2G. The last column indicates the relative trend.

BC	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	t									
2A	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07
2C	9.22	7.94	6.67	5.40	4.12	4.15	4.17	4.19	4.20	4.23
2D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2G	1.91	1.95	1.98	2.02	2.00	1.96	1.96	1.97	1.96	1.98
Sum	11.19	9.95	8.72	7.48	6.19	6.16	6.19	6.22	6.24	6.28

BC	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	t									
2A	0.08	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05
2C	4.24	4.24	4.30	3.56	3.21	2.01	2.18	2.30	0.75	0.79
2D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2G	1.97	1.98	2.09	1.97	1.92	1.92	1.88	1.91	1.94	1.87
Sum	6.29	6.29	6.45	5.59	5.19	3.98	4.12	4.26	2.73	2.71

BC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	t									
2A	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.05
2C	0.76	0.78	0.86	0.94	0.96	0.96	0.28	0.03	0.03	0.02
2D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2G	1.86	1.82	1.83	1.84	1.79	1.61	1.66	1.57	1.60	1.65
Sum	2.68	2.65	2.74	2.82	2.80	2.62	2.00	1.66	1.69	1.73

BC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	t										%
2A	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	-7
2C	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	-97
2D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45
2G	1.50	1.44	1.54	1.48	1.29	1.25	1.30	1.30	1.25	1.22	-24
Sum	1.59	1.53	1.63	1.56	1.38	1.33	1.38	1.38	1.33	1.30	-51

Table A - 57: BC emissions from sector 2 Industrial processes and product use by source categories 2A, 2C, 2D and 2G (projection).

BC	2020	2025	2030	2035	2040	2045	2050
	t						
2A	0.05	0.05	0.04	0.04	0.03	0.03	0.03
2C	0.03	0.03	0.03	0.02	0.02	0.02	0.02
2D	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2G	1.22	1.22	1.22	1.22	1.22	1.22	1.22
Sum	1.29	1.29	1.29	1.28	1.27	1.27	1.26

A7.4 3 Agriculture

A7.4.1 3 Agriculture: NO_x

Table A - 58: NO_x emissions from Sector 3 Agriculture by source categories 3B and 3D. The last column indicates the relative trend.

NOx	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
3B	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.1	3.1	3.0
3D	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.6
Sum	6.3	6.2	6.1	6.1	6.0	5.9	5.9	5.8	5.7	5.7

NOx	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
3B	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1
3D	3.6	3.6	3.5	3.4	3.3	3.3	3.2	3.0	3.0	3.0
Sum	5.0	4.9	4.8	4.7	4.6	4.6	4.5	4.2	4.1	4.1

NOx	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
3B	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3D	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.8
Sum	4.0	4.1	4.0	3.9	3.9	3.9	3.9	4.0	4.0	3.9

NOx	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
3B	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-4.8
3D	3.0	2.9	2.8	2.8	2.9	2.8	2.9	2.9	2.8	2.7	-6.1
Sum	4.0	3.9	3.9	3.8	3.9	3.8	3.8	3.9	3.8	3.7	-5.8

Table A - 59: NO_x emissions from Sector 3 Agriculture by source categories 3B and 3D (projection).

NOx	2020	2025	2030	2035	2040	2045	2050
	kt						
3B	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3D	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Sum	3.8	3.8	3.8	3.8	3.8	3.8	3.8

A7.4.2 3 Agriculture: NMVOC

Table A - 60: NMVOC emissions from Sector 3 Agriculture by source category 3B and 3D. The last column indicates the relative trend.

NMVOC total	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
3B	21.2	20.9	20.5	20.2	19.9	19.6	19.3	19.1	18.8	18.5
3D	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.2	2.2
Sum	23.3	22.9	22.6	22.3	22.0	21.7	21.5	21.2	21.0	20.7

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
3B	19.5	19.3	19.1	18.9	19.1	19.1	19.1	18.6	18.5	18.4
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sum	20.0	19.8	19.6	19.4	19.6	19.6	19.6	19.1	19.0	18.9

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
3B	18.2	18.5	18.5	18.3	18.2	18.5	18.7	18.9	19.2	18.8
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sum	18.7	19.0	18.9	18.8	18.6	19.0	19.1	19.4	19.6	19.3

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
3B	18.7	18.6	18.5	18.4	18.5	18.4	18.4	18.3	18.3	18.1	-2.2
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-3.1
Sum	19.2	19.0	19.0	18.9	19.0	18.8	18.9	18.7	18.7	18.6	-2.2

Table A - 61: NMVOC emissions from Sector 3 Agriculture by source category 3B and 3D (projection).

NMVOC total	2020	2025	2030	2035	2040	2045	2050
	kt						
3B	18.3	18.4	18.4	18.4	18.4	18.4	18.4
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sum	18.7	18.8	18.8	18.8	18.8	18.8	18.8

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 - 62: NH_3 emissions from Sector 3 Agriculture by source categories 3B and 3D. The last column indicates the relative trend.

NH3	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
3B	68.7	67.6	66.6	65.5	64.5	63.7	62.9	62.1	61.2	60.4
3D	9.2	9.3	9.5	9.7	9.9	10.1	10.6	11.1	11.5	12.0
Sum	77.8	77.0	76.1	75.2	74.4	73.8	73.4	73.1	72.8	72.4

NH3	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
3B	24.8	24.6	24.4	24.3	24.1	24.1	23.9	23.7	24.2	24.4
3D	39.9	38.9	38.2	37.4	37.1	36.8	35.1	32.6	31.3	30.1
Sum	64.7	63.5	62.6	61.7	61.2	60.8	59.0	56.3	55.4	54.4

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
3B	24.4	25.2	25.4	25.2	25.1	25.7	26.1	26.2	26.8	26.9
3D	28.9	28.2	27.0	26.5	26.6	27.1	27.4	28.2	27.8	26.6
Sum	53.4	53.4	52.4	51.7	51.7	52.8	53.5	54.4	54.6	53.6

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
3B	27.4	27.1	26.9	26.6	26.7	26.5	26.3	26.2	26.0	25.6	-0.2
3D	26.6	26.0	25.7	25.4	25.8	25.3	25.4	25.5	25.2	24.7	-8.8
Sum	54.0	53.1	52.6	52.0	52.5	51.8	51.7	51.6	51.1	50.3	-4.6

Table A - 63: NH_3 emissions from Sector 3 Agriculture by source categories 3B and 3D (projection).

NH3	2020	2025	2030	2035	2040	2045	2050
	kt						
3B	26.0	26.1	26.1	26.1	26.1	26.1	26.1
3D	25.2	25.2	25.1	25.1	25.1	25.1	25.1
Sum	51.1	51.3	51.2	51.2	51.2	51.2	51.2

A7.4.5 3 Agriculture: PM2.5

Table A - 64: PM2.5 emissions from Sector 3 Agriculture by source category 3B and 3D. The last column indicates the relative trend.

PM2.5	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
3B	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
3D	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sum	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

PM2.5	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
3B	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08
3D	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sum	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

PM2.5	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
3B	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09
3D	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sum	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
3B	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	18.0
3D	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	-3.5
Sum	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	10.2

Table A - 65: PM2.5 emissions from Sector 3 Agriculture by source category 3B and 3D (projection).

PM2.5	2020	2025	2030	2035	2040	2045	2050
	kt						
3B	0.10	0.10	0.10	0.10	0.10	0.10	0.10
3D	0.05	0.04	0.04	0.04	0.04	0.04	0.04
Sum	0.14	0.15	0.15	0.15	0.15	0.15	0.15

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 indicates the relative trend.

NOx	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
5A	0.24	0.22	0.19	0.17	0.14	0.11	0.09	0.06	0.04	0.02
5B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C	0.23	0.24	0.24	0.24	0.24	0.25	0.25	0.26	0.26	0.26
5D	0.29	0.34	0.41	0.47	0.54	0.48	0.40	0.32	0.23	0.13
Sum	0.76	0.80	0.84	0.88	0.92	0.83	0.74	0.64	0.53	0.42

NOx	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
5A	0.002	0.006	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.006
5B	NA	NA	0.0000	0.0000	0.0001	0.0001	0.0002	0.0003	0.0003	0.0004
5C	0.27	0.25	0.23	0.22	0.20	0.19	0.19	0.18	0.18	0.17
5D	0.026	0.025	0.024	0.023	0.021	0.020	0.019	0.017	0.016	0.015
Sum	0.30	0.28	0.26	0.24	0.22	0.22	0.21	0.21	0.20	0.19

NOx	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
5A	0.006	0.005	0.005	0.004	0.004	0.003	0.003	0.003	0.003	0.002
5B	0.0004	0.0005	0.0006	0.0006	0.0006	0.0007	0.0010	0.0012	0.0013	0.0017
5C	0.16	0.15	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.14
5D	0.013	0.012	0.010	0.009	0.007	0.005	0.004	0.004	0.005	0.005
Sum	0.18	0.17	0.16	0.17	0.17	0.16	0.16	0.16	0.15	0.15

NOx	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
5A	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	-60
5B	0.003	0.003	0.004	0.004	0.005	0.005	0.005	0.005	0.006	0.006	686
5C	0.14	0.13	0.13	0.14	0.13	0.14	0.14	0.14	0.13	0.13	-13
5D	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	10
Sum	0.15	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	-10

Table A - 67: NO_x emissions from sector 5 Waste by source categories 5A-5D (projection).

NOx	2020	2025	2030	2035	2040	2045	2050
	kt						
5A	0.0014	0.0012	0.0008	0.0005	0.0003	0.0001	NA
5B	0.008	0.021	0.034	0.039	0.041	0.042	0.042
5C	0.13	0.13	0.12	0.12	0.12	0.12	0.12
5D	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sum	0.15	0.16	0.16	0.17	0.17	0.17	0.17

A7.5.2 5 Waste: NMVOC

Table A - 68: NMVOC emissions from sector 5 Waste by source categories 5A-5E. The last column indicates the relative trend.

NMVOC total	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
5A	1.55	1.39	1.23	1.06	0.87	0.68	0.55	0.41	0.27	0.14
5B	0.04	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.13	0.14
5C	0.99	0.96	0.93	0.89	0.86	0.83	0.78	0.72	0.67	0.61
5D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5E	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Sum	2.60	2.43	2.25	2.06	1.85	1.64	1.46	1.28	1.10	0.92

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.26
5C	0.56	0.55	0.54	0.51	0.47	0.45	0.43	0.43	0.42	0.43
5D	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003
5E	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.06
Sum	0.74	0.74	0.74	0.73	0.71	0.70	0.69	0.70	0.70	0.75

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.28	0.29	0.30	0.30	0.30	0.32	0.36	0.42	0.46	0.48
5C	0.43	0.41	0.41	0.39	0.38	0.37	0.39	0.38	0.38	0.36
5D	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
5E	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Sum	0.77	0.76	0.77	0.75	0.75	0.76	0.81	0.86	0.90	0.90

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.54	0.58	0.67	0.74	0.78	0.83	0.93	0.97	1.03	1.15	254
5C	0.36	0.35	0.35	0.35	0.34	0.34	0.33	0.32	0.31	0.30	-18
5D	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	10
5E	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0
Sum	0.96	0.99	1.08	1.15	1.18	1.23	1.33	1.35	1.40	1.51	100

Table A - 69: NMVOC emissions from sector 5 Waste by source categories 5A-5E (projection).

NMVOC total	2020	2025	2030	2035	2040	2045	2050
	kt						
5A	NA	NA	NA	NA	NA	NA	NA
5B	1.57	3.70	5.84	6.66	6.97	7.14	7.14
5C	0.30	0.26	0.22	0.20	0.18	0.16	0.14
5D	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
5E	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Sum	1.93	4.02	6.12	6.92	7.21	7.36	7.34

A7.5.3 5 Waste: SO_x

Table A - 70: SO_x emissions from sector 5 Waste by source categories 5A-5D. The last column indicates the relative trend.

SO2	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
5A	0.07	0.07	0.06	0.05	0.04	0.03	0.03	0.02	0.01	0.01
5B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C	0.15	0.15	0.16	0.17	0.18	0.18	0.18	0.17	0.17	0.17
5D	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	0.22	0.22	0.22	0.22	0.22	0.21	0.20	0.19	0.18	0.17

SO2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	NA	NA	0.00001	0.00001	0.00001	0.00002	0.00003	0.00004	0.00005	0.0001
5C	0.16	0.14	0.13	0.11	0.09	0.08	0.08	0.08	0.07	0.07
5D	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	0.16	0.14	0.13	0.11	0.089	0.080	0.079	0.076	0.073	0.068

SO2	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003
5C	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
5D	0.00007	0.00006	0.00005	0.00004	0.00004	0.00003	0.00002	0.00002	0.00002	0.00002
Sum	0.062	0.058	0.054	0.059	0.064	0.063	0.064	0.063	0.064	0.063

SO2	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.0004	0.0005	0.0006	0.0007	0.0007	0.0007	0.0008	0.0008	0.0009	0.0009	686
5C	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	9
5D	0.00002	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	10
Sum	0.063	0.060	0.057	0.067	0.066	0.070	0.071	0.072	0.069	0.070	10

Table A - 71: SO_x emissions from sector 5 Waste by source categories 5A-5D (projection).

SO2	2020	2025	2030	2035	2040	2045	2050
	kt						
5A	NA	NA	NA	NA	NA	NA	NA
5B	0.001	0.003	0.005	0.006	0.006	0.006	0.006
5C	0.07	0.07	0.07	0.07	0.07	0.07	0.07
5D	0.00003	0.00003	0.00003	0.00003	0.00003	0.00004	0.00004
Sum	0.070	0.071	0.072	0.074	0.075	0.075	0.076

A7.5.4 5 Waste: NH_3

Table A - 72: NH_3 emissions from sector 5 Waste by source categories 5A-5D. The last column indicates the relative trend.

NH3	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
5A	0.58	0.58	0.59	0.59	0.60	0.63	0.65	0.66	0.68	0.69
5B	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17
5C	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5D	1.67	1.58	1.48	1.35	1.21	1.07	0.91	0.73	0.53	0.32
Sum	2.35	2.27	2.17	2.07	1.95	1.85	1.71	1.56	1.39	1.21

NH3	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
5A	0.62	0.54	0.54	0.51	0.46	0.46	0.45	0.44	0.43	0.42
5B	0.18	0.20	0.22	0.23	0.25	0.27	0.29	0.30	0.31	0.34
5C	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5D	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Sum	0.91	0.86	0.88	0.85	0.83	0.85	0.86	0.86	0.86	0.88

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
5A	0.42	0.43	0.44	0.42	0.43	0.42	0.42	0.40	0.38	0.37
5B	0.37	0.37	0.38	0.38	0.37	0.37	0.38	0.39	0.39	0.39
5C	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
5D	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Sum	0.91	0.93	0.95	0.92	0.93	0.93	0.93	0.93	0.91	0.90

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
5A	0.35	0.34	0.32	0.31	0.29	0.28	0.27	0.26	0.24	0.23	-46
5B	0.40	0.40	0.42	0.44	0.42	0.41	0.46	0.47	0.47	0.53	41
5C	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	42
5D	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	16
Sum	0.89	0.88	0.89	0.89	0.87	0.85	0.89	0.88	0.87	0.92	-1.5

Table A - 73: NH_3 emissions from sector 5 Waste by source categories 5A-5D (projection).

NH3	2020	2025	2030	2035	2040	2045	2050
	kt						
5A	0.22	0.17	0.14	0.11	0.09	0.08	0.07
5B	0.62	1.10	1.57	1.76	1.83	1.88	1.88
5C	0.04	0.04	0.04	0.04	0.04	0.04	0.04
5D	0.13	0.13	0.14	0.14	0.15	0.15	0.15
Sum	1.00	1.43	1.88	2.05	2.11	2.14	2.14

A7.5.5 5 Waste: PM2.5

Table A - 74: PM2.5 emissions from sector 5 Waste by source categories 5A-5C and 5E. The last column indicates the relative trend.

PM2.5	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
5A	1.4	1.3	1.1	1.0	0.8	0.6	0.5	0.4	0.2	0.1
5B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.6
5E	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sum	2.44	2.27	2.08	1.89	1.69	1.48	1.30	1.12	0.94	0.77

PM2.5	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
5A	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
5B	NA	NA	0.000000	0.000000	0.000001	0.000001	0.000002	0.000002	0.000003	0.000004
5C	0.59	0.57	0.56	0.53	0.49	0.48	0.45	0.45	0.44	0.44
5E	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002
Sum	0.59	0.58	0.56	0.54	0.50	0.48	0.46	0.45	0.44	0.45

PM2.5	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
5A	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
5B	0.000004	0.000005	0.000006	0.000005	0.000006	0.000007	0.000009	0.000011	0.000012	0.000015
5C	0.44	0.42	0.41	0.40	0.39	0.38	0.39	0.38	0.38	0.36
5E	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Sum	0.44	0.42	0.42	0.40	0.39	0.38	0.39	0.38	0.39	0.36

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
5A	0.0010	0.0009	0.0007	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	NA
5B	0.000023	0.000028	0.000037	0.000040	0.000041	0.000044	0.000047	0.000049	0.000051	0.000053	686
5C	0.36	0.35	0.35	0.34	0.33	0.33	0.33	0.32	0.31	0.30	-20
5E	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0
Sum	0.36	0.35	0.35	0.35	0.34	0.34	0.33	0.32	0.32	0.31	-20

Table A - 75: PM2.5 emissions from sector 5 Waste by source categories 5A-5C and 5E (projection).

PM2.5	2020	2025	2030	2035	2040	2045	2050
	kt						
5A	0.00054	0.00047	0.00034	0.00020	0.00011	0.00004	NA
5B	0.0001	0.0002	0.0003	0.0004	0.0004	0.0004	0.0004
5C	0.30	0.26	0.23	0.21	0.19	0.17	0.16
5E	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Sum	0.3	0.3	0.2	0.2	0.2	0.2	0.2

A7.5.6 5 Waste: BC

Table A - 76: BC emissions from sector 5 Waste by source categories 5A-5C. The last column indicates the relative trend.

BC	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
5A	0.10	0.09	0.08	0.07	0.06	0.04	0.03	0.03	0.02	0.01
5B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5C	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
Sum	0.17	0.16	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.05

BC	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	NA	NA	0.00000001	0.00000001	0.00000002	0.00000003	0.00000005	0.00000006	0.00000007	0.00000010
5C	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Sum	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03

BC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000002	0.0000002	0.0000003	0.0000003	0.0000004
5C	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Sum	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

BC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	686
5C	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-21
Sum	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-21

Table A - 77: BC emissions from sector 5 Waste by source categories 5A-5C (projection).

BC	2020	2025	2030	2035	2040	2045	2050
	kt						
5A	NA	NA	NA	NA	NA	NA	NA
5B	0.000002	0.000005	0.00001	0.00001	0.00001	0.00001	0.00001
5C	0.021	0.019	0.016	0.015	0.014	0.012	0.011
Sum	0.021	0.019	0.016	0.015	0.014	0.012	0.011

A7.6 6 Other

A7.6.1 6 Other: NO_x

Table A - 78: NO_x emissions from sector 6 Other by source categories 6Ab-6Ad. The last column indicates the relative trend.

NOx	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
6Ab	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6Ac	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6Ad	0.016	0.016	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Sum	0.016	0.016	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017

NOx	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
6Ab	0.018	0.016	0.015	0.014	0.014	0.017	0.035	0.035	0.035	0.037
6Ac	0.050	0.050	0.050	0.047	0.044	0.044	0.042	0.037	0.037	0.039
6Ad	0.017	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.013	0.015
Sum	0.084	0.083	0.082	0.076	0.074	0.076	0.092	0.087	0.086	0.090

NOx	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
6Ab	0.037	0.037	0.038	0.040	0.038	0.038	0.037	0.038	0.042	0.043
6Ac	0.038	0.041	0.040	0.038	0.039	0.038	0.037	0.039	0.037	0.034
6Ad	0.015	0.016	0.015	0.017	0.016	0.016	0.015	0.016	0.015	0.015
Sum	0.091	0.095	0.094	0.095	0.093	0.092	0.089	0.093	0.094	0.092

NOx	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
6Ab	0.045	0.050	0.057	0.057	0.055	0.060	0.058	0.056	0.055	0.052	36
6Ac	0.040	0.035	0.034	0.033	0.037	0.033	0.035	0.037	0.034	0.030	-20
6Ad	0.015	0.016	0.017	0.017	0.013	0.015	0.014	0.015	0.016	0.015	-6
Sum	0.099	0.101	0.107	0.107	0.106	0.108	0.107	0.108	0.105	0.098	6

Table A - 79: NO_x emissions from sector 6 Other by source categories 6Ab-6Ad (projection).

NOx	2020	2025	2030	2035	2040	2045	2050
	kt						
6Ab	0.052	0.051	0.051	0.051	0.051	0.051	0.051
6Ac	0.034	0.034	0.034	0.034	0.034	0.034	0.034
6Ad	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Sum	0.101	0.100	0.100	0.100	0.100	0.100	0.100

A7.6.2 6 Other: NMVOC

Table A - 80: NMVOC emissions from sector 6 Other by source category 6Ab and 6Ad. The last column indicates the relative trend.

NMVOC total	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
6Ab	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6Ad	0.1287	0.1287	0.1288	0.1288	0.1288	0.1288	0.1288	0.1289	0.1289	0.1289
Sum	0.1287	0.1287	0.1288	0.1288	0.1288	0.1288	0.1288	0.1289	0.1289	0.1289

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
6Ab	0.0577	0.0536	0.0505	0.0446	0.0463	0.0496	0.0667	0.0599	0.0607	0.0606
6Ad	0.1290	0.1269	0.1248	0.1227	0.1206	0.1185	0.1164	0.1145	0.1025	0.1137
Sum	0.1866	0.1804	0.1753	0.1672	0.1669	0.1681	0.1831	0.1744	0.1631	0.1743

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
6Ab	0.0631	0.0619	0.0693	0.0724	0.0684	0.0697	0.0691	0.0736	0.0801	0.0837
6Ad	0.1180	0.1260	0.1170	0.1279	0.1264	0.1230	0.1125	0.1254	0.1170	0.1136
Sum	0.1811	0.1880	0.1862	0.2003	0.1948	0.1928	0.1815	0.1990	0.1971	0.1973

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
6Ab	0.0913	0.0991	0.1096	0.1145	0.1103	0.1252	0.1225	0.1190	0.1145	0.1103	58
6Ad	0.1109	0.1202	0.1261	0.1299	0.1018	0.1106	0.1078	0.1121	0.1205	0.1144	-7
Sum	0.2022	0.2194	0.2357	0.2444	0.2120	0.2357	0.2304	0.2311	0.2350	0.2246	17

Table A - 81: NMVOC emissions from sector 7 Other by source category 6Ab and 6Ad (projection).

NMVOC total	2020	2025	2030	2035	2040	2045	2050
	kt						
6Ab	0.1055	0.1042	0.1050	0.1050	0.1050	0.1050	0.1050
6Ad	0.1144	0.1144	0.1144	0.1144	0.1144	0.1144	0.1144
Sum	0.2199	0.2185	0.2194	0.2194	0.2194	0.2194	0.2194

A7.6.3 6 Other: SO_x

Table A - 82: SO_x emissions from sector 6 Other by source category 6Ad. The last column indicates the relative trend.

SO2	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
6Ad	0.0097	0.0098	0.0099	0.0100	0.0100	0.0101	0.0101	0.0102	0.0102	0.0103
Sum	0.0097	0.0098	0.0099	0.0100	0.0100	0.0101	0.0101	0.0102	0.0102	0.0103

SO2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
6Ad	0.0104	0.0103	0.0102	0.0101	0.0100	0.0099	0.0099	0.0098	0.0091	0.0099
Sum	0.0104	0.0103	0.0102	0.0101	0.0100	0.0099	0.0099	0.0098	0.0091	0.0099

SO2	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
6Ad	0.0102	0.0108	0.0103	0.0110	0.0110	0.0108	0.0102	0.0111	0.0105	0.0104
Sum	0.0102	0.0108	0.0103	0.0110	0.0110	0.0108	0.0102	0.0111	0.0105	0.0104

SO2	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
6Ad	0.0102	0.0109	0.0113	0.0116	0.0099	0.0106	0.0104	0.0108	0.0113	0.0110	1
Sum	0.0102	0.0109	0.0113	0.0116	0.0099	0.0106	0.0104	0.0108	0.0113	0.0110	1

Table A - 83: SO_x emissions from sector 6 Other by source category 6Ad (projection).

SO2	2020	2025	2030	2035	2040	2045	2050
	kt						
6Ad	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110
Sum	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110

A7.6.4 6 Other: NH_3

Table A - 84: NH_3 emissions from sector 6 Other by source categories 6Aa-6Ac. The last column indicates the relative trend.

NH3	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
6Aa	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12
6Ab	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.35
6Ac	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.46	0.46	0.46

NH3	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
6Aa	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13
6Ab	0.55	0.53	0.52	0.51	0.51	0.53	0.65	0.64	0.65	0.69
6Ac	0.18	0.16	0.15	0.14	0.14	0.14	0.13	0.10	0.10	0.10
Sum	0.84	0.81	0.80	0.78	0.77	0.79	0.90	0.87	0.87	0.92

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
6Aa	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14
6Ab	0.70	0.67	0.70	0.70	0.66	0.65	0.64	0.64	0.67	0.66
6Ac	0.11	0.11	0.11	0.10	0.11	0.10	0.10	0.11	0.11	0.10
Sum	0.93	0.90	0.94	0.93	0.90	0.89	0.87	0.89	0.91	0.90

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
6Aa	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	16
6Ab	0.66	0.71	0.77	0.78	0.77	0.82	0.80	0.78	0.76	0.74	14
6Ac	0.12	0.10	0.10	0.10	0.12	0.11	0.11	0.12	0.11	0.10	-2
Sum	0.92	0.96	1.01	1.02	1.03	1.07	1.06	1.05	1.02	0.99	12

Table A - 85: NH_3 emissions from sector 6 Other by source categories 6Aa-6Ac (projection).

NH3	2020	2025	2030	2035	2040	2045	2050
	kt						
6Aa	0.15	0.16	0.17	0.17	0.18	0.18	0.18
6Ab	0.73	0.72	0.72	0.72	0.72	0.72	0.72
6Ac	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Sum	0.99	0.99	1.00	1.01	1.01	1.02	1.02

A7.6.5 6 Other: PM2.5

Table A - 86: PM2.5 emissions from sector 6 Other by source categories 6Ab and 6Ad. The last column indicates the relative trend.

PM2.5	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
6Ab	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6Ad	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Sum	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

PM2.5	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
6Ab	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
6Ad	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Sum	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004

PM2.5	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
6Ab	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003
6Ad	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Sum	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	05-19
	kt										%
6Ab	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	81
6Ad	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	-6
Sum	0.005	0.005	0.006	0.006	0.005	0.006	0.006	0.006	0.006	0.006	40

Table A - 87: PM2.5 emissions from sector 6 Other by source categories 6Ab and 6Ad (projection).

PM2.5	2020	2025	2030	2035	2040	2045	2050
	kt						
6Ab	0.003	0.003	0.003	0.003	0.003	0.003	0.003
6Ad	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Sum	0.005	0.005	0.005	0.005	0.005	0.005	0.005