

Switzerland's Informative Inventory Report 2022 (IIR)

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

Submission of March 2022
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 2022

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Table of contents

Table of contents	5
Glossary	8
Executive Summary	12
1 Introduction	19
1.1 National inventory background	19
1.2 Institutional arrangements	19
1.3 Inventory preparation process	19
1.4 Methods and data sources	21
1.5 Key categories	24
1.6 QA/QC and verification methods	36
1.7 General uncertainty evaluation	37
1.8 General assessment of completeness.....	42
2 Emission trends 1980-2020	43
2.1 Comments on trends	43
2.2 Overall trends of total emissions.....	46
2.3 Trends of main pollutants per gas and sectors	55
2.4 Trends of particulate matter per pollutant	60
2.5 Trends of other gases	65
2.6 Trends of priority heavy metals per pollutant	66
2.7 Trends of POPs.....	68
2.8 Compliance with the Gothenburg Protocol.....	71
3 Energy	73
3.1 Overview of emissions.....	73
3.2 Source category 1A - Fuel combustion activities	94
3.3 Source category 1B - Fugitive emissions from fuels	166
4 Industrial processes and product use	175
4.1 Overview of emissions.....	175
4.2 Source category 2A – Mineral products.....	178
4.3 Source category 2B – Chemical industry	182
4.4 Source category 2C – Metal production.....	188
4.5 Source category 2D3 – Other solvent use	192
4.6 Source category 2G – Other product use	204
4.7 Source categories 2H – Other	207
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.....	210

5	Agriculture	214
5.1	Overview of emissions.....	214
5.2	Source category 3B – Manure management	216
5.3	Source category 3D – Crop production and agricultural soils	225
5.4	Source category 3F – Field burning of agricultural residuals	232
6	Waste	233
6.1	Overview of emissions.....	233
6.2	Source category 5A – Biological treatment of waste - Solid waste disposal on land	235
6.3	Source category 5B - Biological treatment of waste - Composting and anaerobic digestion at biogas facilities.....	237
6.4	Source category 5C – Waste incineration and open burning of waste	242
6.5	Source category 5D – Wastewater handling.....	245
6.6	Source category 5E – Other waste, shredding	248
7	Other and natural emissions	250
7.1	Overview of emissions.....	250
7.2	Source category 6 - Other emissions.....	254
7.3	Source category 11B - Forest fires	259
7.4	Category 11C – Other natural emissions	261
8	Recalculations and improvements	264
8.1	Explanations and justifications for recalculation.....	264
8.2	Planned improvements.....	279
9	Emission projections 2021–2030	280
9.1	Comments on projections.....	280
9.2	Assumptions for projections for the WM scenario	280
9.3	Main pollutants and CO for the WM scenario	285
9.4	Suspended particulate matter.....	292
9.5	Priority heavy metals	300
9.6	Persistent organic pollutants (POPs).....	303
10	Reporting of gridded emissions and LPS	308
10.1	EMEP grid.....	308
10.2	Gridding of emissions.....	310
10.3	EMEP grid results (visualizations)	315
10.4	Large point sources (LPS).....	318
11	Adjustments	319
12	References and assignments to EMIS categories	320
12.1	References.....	320
12.2	Assignment of EMIS categories to NFR code.....	337

Annexes	338
Annex 1 Key category analysis (KCA)	338
Annex 2 Other detailed methodological descriptions for individual source categories	352
Annex 3 Further elaboration of completeness use of IE and (potential) sources of air pollutant emissions excluded	364
Annex 4 National energy balance	366
Annex 5 Additional information concerning uncertainties	369
Annex 6 Summary information on condensables in PM	399
Annex 7 Emission time series of main air pollutants, PM_{2.5} and BC for 1980–2019 and 2020–2050	402

Glossary

AD	Activity data
Avenergy	Avenergy Suisse (Swiss Petroleum Association, formerly Erdöl-Vereinigung (EV))
BaP	Benzo(a)pyrene (CLRTAP: POP)
BbF	Benzo(b)fluoranthene (CLRTAP: POP)
BC	Black Carbon
BkF	Benzo(k)fluoranthene (CLRTAP: POP)
Carbura	Swiss organisation for the compulsory stockpiling of oil products
CEIP	EMEP Centre on Emission Inventories and Projections
Cd	Cadmium (CLRTAP: priority heavy metal)
Cemsuisse	Association of the Swiss cement industry
CLRTAP	UNECE Convention on Long-Range Transboundary Air Pollution
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 (PM _{2.5} ex, PM ₁₀ ex, TSP ex, BC ex or Cd ex)) exhaust fraction of this pollutant emissions
FAL	Swiss Federal Research Station for Agroecology and Agriculture (since 2013 Agroscope)
FCA	Federal Customs Administration, since 03.01.2022: Federal Office for Customs and Border Security (FOCBS)
FEDRO	Swiss Federal Roads Office
FOCA	Federal Office of Civil Aviation

FOEN	Federal Office for the Environment (former name SAEFL until 2005)
FOCBS	Federal Office for Customs and Border Security, formerly Federal Customs Administration (FCA)
FSKB	Fachverband der Schweizerischen Kies- und Betonindustrie
Gas oil	Light fuel oil
GHG	Greenhouse Gas
GVS	Giesserei Verband der Schweiz / Swiss Foundry Association
ha	Hectare
HAFL	School of Agricultural, Forest and Food Sciences at Bern University of Applied Sciences
HCB	Hexachlorobenzene
Hg	Mercury (CLRTAP: priority heavy metal)
HM	Heavy Metals
IcdP	Indeno(1,2,3-cd)pyrene (CLRTAP: POP)
IIR	Informative Inventory Report (CLRTAP)
INFRAS	Research and consulting company, Zurich/Berne
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ICAO	International Civil Aviation Organization
I-Teq	International Toxic Equivalent (unit of toxic equivalent factors for PCB's, PCDDs, PCDFs for Human and Wildlife by WHO)
IVZ	Swiss information system traffic admission (Informationssystem Verkehrszulassung IVZ) run by FEDRO, formerly MOFIS
kt	Kilo tonne (1000 tonnes)
L1, L2	Key category according to level assessment with approach 1, approach 2
LTO	Landing and Takeoff-Cycle (Aviation)
LUBW	Baden-Württemberg State Institute for Environmental Protection (Landesanstalt für Umweltschutz Baden-Württemberg), Germany
LULUCF	Land Use, Land-Use Change and Forestry
MOFIS	Swiss federal vehicle registration database run by FEDRO (since 2022: IVZ)
MSW	Municipal Solid Waste
NCV	Net Calorific Value
NFR	Nomenclature For Reporting
NH ₃	Ammonia
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 (PM _{2.5} ex, PM ₁₀ 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, PM _{2.5} , PM ₁₀	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, 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)
T1, T2	Key category according to trend assessment with approach 1, approach 2
TAN	Total Ammonia Nitrogen
TFEIP	Task Force on Emission Inventory and Projections
TSP	Total Suspended Particulate matter
UNFCCC	United Nations Framework Convention on Climate Change
VKTS	Swiss supervising association of textile cleaning
VOC	Volatile Organic Compounds
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"
WHO	World Health Organization
WM	Scenario "With Measures"
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 1999 Gothenburg Protocol is a multi-pollutant protocol designed to reduce acidification, eutrophication and ground-level ozone by setting national emissions ceilings for sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia, which were to be met by 2010 and maintained afterwards. A revision of the Protocol including emission reduction commitments for 2020 and beyond expressed as a percentage reduction from the 2005 emission level was adopted in 2012 and entered into force on 7 October 2019. It includes newly also PM_{2.5} 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 fifteenth IIR of Switzerland.

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

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 (**E**Missions**I**nformation**s**system **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 1990–2020 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. For both approaches, level assessments were conducted for the years 2020 and 1990 and a trend assessment for 1990-2020. The most relevant source categories stem from sectors 1 Energy, 2 IPPU and 3 Agriculture.

For the main pollutants (NO_x , NMVOC, SO_x , NH_3) as well as for PM_{2.5} and PM₁₀, the uncertainty of the inventory, resulting from uncertainties from each category, is evaluated according to two methods: uncertainty propagation (approach 1) and Monte Carlo simulations (approach 2). In addition, a Tier 2 approach uncertainty estimation was conducted for agricultural NH_3 emissions in 2021.

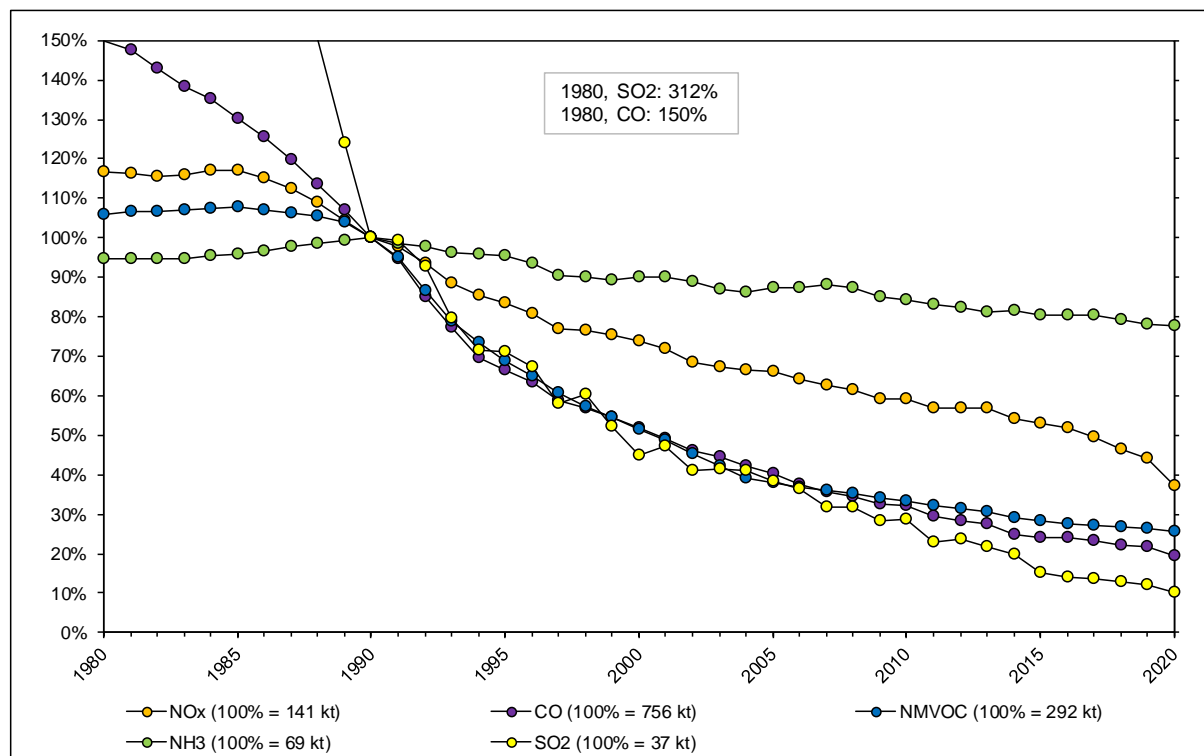
The uncertainty analysis has been carried out for level emissions for the years 1990 and 2020 and for the trend 1990-2020. Level uncertainty estimations from approach 2 for the reporting year range from 8 % to 34 %, trend uncertainties from 0.7 % to 11 %. Results from approach 1 are similar. The level uncertainty estimations remain similar for all pollutants (change below 1 percentage point) as compared to the values of the previous submission for the year 2019, except for NMVOC and NH_3 , for which the inventory uncertainty decreased (see discussion in chp. 1.7.3).

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

Quality assurance and quality control (QA/QC)

A QA/QC system for the GHG inventory is in place that also covers most of the preparation process of the CLRTAP Inventory. The National GHG Inventory, which is also derived from the Swiss Emission Information System (EMIS), complies with the ISO 9001:2015 standard (Swiss Safety Center 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 that compares emissions of the previous and the last submission.

Emission trends 1980-2020



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. The drop of emissions in 2020, especially visible for NO_x and CO, is due to reduced traffic volumes during the COVID-19 pandemic. 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, NH₃ emissions only show a slight reduction mainly due to the decrease of animal numbers and changes in agricultural production techniques.

Emission trends for PM_{2.5} (not included in ES Figure 1.1, see Figure 2-3) reveal a significant decline between 1980 and 2020 mainly as a result of the abatement of exhaust emissions from road vehicles and also to a minor extent from non-road machinery and from improved residential heating equipment.

Characteristics of the sectors

- **1 Energy:** the energy sector encompasses stationary and mobile fuel combustion activities and fugitive emissions from handling of fuels, such as losses in the gas network or refining and storage of gasoline and coal. Compared to the other sectors, fuel combustion activities are the main emission source of all air pollutants reported in the IIR except for NH₃, NMVOC, TSP and PCB. Within sector 1 Energy, source category 1A3 Transport is the predominant source of all main pollutants except for SO_x and PM_{2.5}, where 1A2 Manufacturing industries and construction and 1A4 Other sectors, respectively, are the most important sources. The emissions of all pollutants from the sector decreased compared to 1990.
- **2 Industrial processes and product use:** this sector comprises process emissions from the mineral, chemical and metal industry. Included are also other production industries such as pulp and paper industry and food and beverages industry as well as other solvent and product use, e.g. emissions from paint applications and domestic solvent use. Emissions from industrial processes and product use are the main emission source of NMVOC and an important source of particulate matter (mainly PM_{2.5}, but also PM₁₀ and TSP) as well as SO_x emissions. NMVOC emissions originate mainly from source category 2D3 Other solvent use. 2A1 Cement production, 2A5a Quarrying and mining other than coal, 2G Other product use (i.e. use of fireworks) and 2H1 Pulp and paper industry are responsible for considerable amounts of PM_{2.5} 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 NH₃ emissions, also contributing to a relevant share of NMVOC, NO_x, PM₁₀ and TSP emissions. Within the sector, the NH₃ emissions are attributed to the source categories 3B Manure management and 3D Agricultural soils. Most NH₃ emission reduction in agriculture occurred between 1980 and 2004 (-13 %), followed by an increase until 2007 and then showed a slight but rather constant decrease again. Between 1990 and 2020 the reduction of agricultural and total NH₃ was -23 %. Emissions of NO_x reveal a decreasing trend since 1990 with slight fluctuations. NMVOC emissions mainly stem from 3B Manure management. Finally, the PM₁₀ emissions show an increasing trend since 1997.
- **4 Land Use, Land-Use Change and Forestry (LULUCF):** The emissions of this sector are not accounted for in the commitments of the Gothenburg Protocol. Only forest fires (under 11B) and other natural emissions (under 11C) are reported under memo items in the official emission reporting templates and are described in chapter 7 Other and natural emissions.
- **5 Waste:** This sector encompasses solid waste disposal on land, biological treatment of solid waste, waste incineration and open burning of waste, wastewater handling and other waste. Overall, emissions of the main pollutants are minor when compared to the other sectors. The heat generated in waste incineration plants has to be recovered in Switzerland, and in accordance with the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from the combustion of waste-to-energy activities are therefore dealt within 1A Fuel combustion. Relevant pollutants within sector 5 Waste are NMVOC and NH₃. NMVOC emissions are mainly caused by 5B Biological treatment of solid waste, while NH₃ is emitted mainly by composting activities and solid waste disposal. Regarding total emissions, sector 5 Waste is also a relevant source of heavy metals (Pb, Hg), PCDD/PCDF and PAH emissions, mainly from 5C Incineration and open burning of

waste. Emissions in sector 5 Waste have declined since 1990, with the exception of NMVOC (increase), and NH₃, which is about the same as in 1990.

- 6 Other: In this sector, mainly emissions from human and pet ammonia, private application of synthetic fertiliser as well as fire damages in estates and in motor vehicles are reported. This sector is an important source of heavy metals (Pb, Cd, Hg), PCDD/PCDF and PCB as well as of PAH mainly due to 6Ad fire damage. Regarding the main pollutants however, emissions from sector 6 Other are minor when compared to sectors 1 to 5. Overall, emissions are fluctuating without any significant trends.

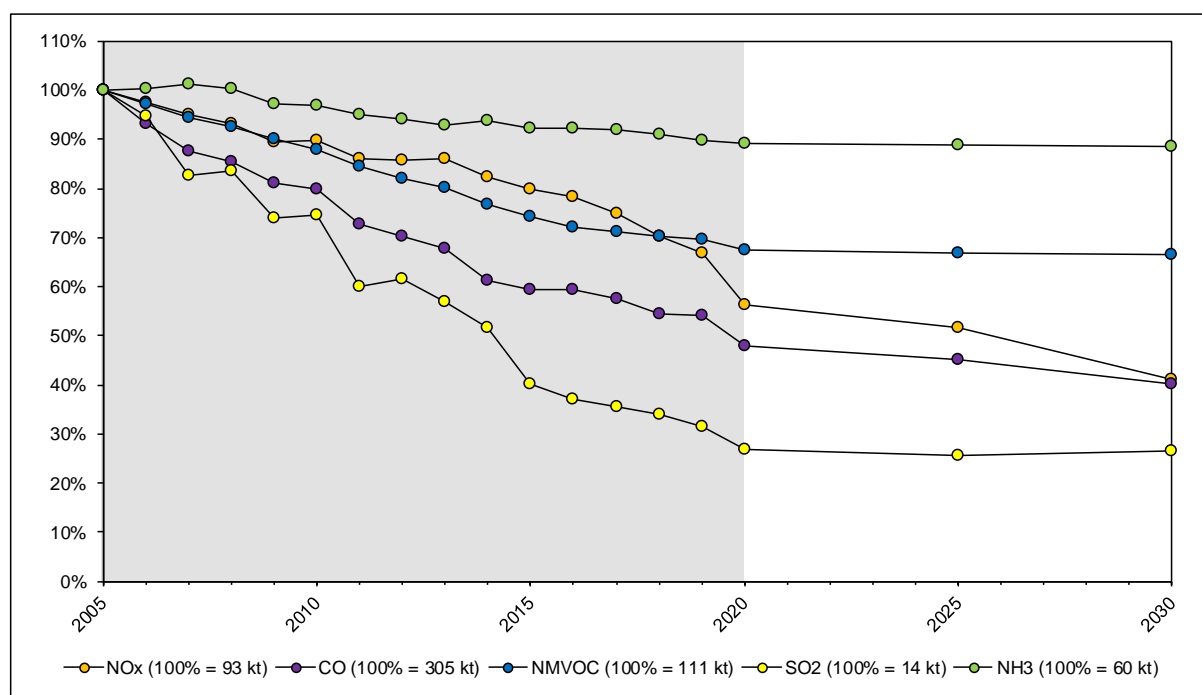
Projections for emissions until 2030

The emission projections of air pollutants in Switzerland have been fully revised in the course of the latest submission 2022 and a new “With Measures” (WM) scenario was elaborated.

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

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

ES Figure 1.2 shows the past emissions from 2005-2020 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 2005-2020 (grey area) and the projected emissions until 2030 for main pollutants and CO in the WM scenario. 100 % corresponds to 2005 levels (base year of the revised Gothenburg Protocol).

Total emissions of the main air pollutants are expected to develop differently from the reporting year onwards until 2030. Overall projections of the emissions of main pollutants

NO_x, NMVOC, SO_x and CO indicate a decline between 2005 and 2030. NH₃ emissions are projected to be slightly below 2005 levels in 2030. For NO_x, CO and SO_x, the drop in 2020 due to reduced traffic volumes in the COVID-19 pandemic led to a less pronounced decrease between 2020 and 2030 compared to earlier submissions. Forecasts for suspended primary particulate matter predict a declining trend in PM_{2.5} and BC emissions but a slight increase of PM₁₀ and TSP emissions due to the drop of emissions in 2020 caused by reduced traffic volumes during the COVID-19 pandemic and an increase of non-exhaust emissions due to the overall increasing trend of traffic. Concerning heavy metals, emissions of Pb are expected to slightly decrease and emissions of Cd and Hg to slightly increase.

Gothenburg Protocol

Under the CLRTAP, the 1999 Gothenburg Protocol requires that parties shall reduce and maintain the reduction in annual emission in accordance with national emission targets set for 2010. The following table shows the emission ceilings, the reported emissions for 2010 and the respective compliance. Accordingly, Switzerland is in compliance with the Gothenburg Protocol emission ceilings for all pollutants except for NO_x in 2010. All emissions 2020 are in compliance with the emission ceilings 2010.

ES Table 1.1 Emission ceilings of the Gothenburg Protocol for 2010 and beyond compared to the reported emissions for 2010 and 2020 of the latest submission (2022).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2022)	Compliance with emission ceilings 2010 in 2010	Emissions 2020 (Subm. 2022)	Compliance with emission ceilings 2010 in 2020
	kt	kt		kt	
SO _x (as SO ₂)	26	10	yes	3.8	yes
NO _x (as NO ₂)	79	83	no	53	yes
NMVOC	144	98	yes	75	yes
NH ₃	63	58	yes	53	yes

The 2012 revised Gothenburg Protocol included emission reduction commitments for 2020 and beyond expressed as a percentage reduction from the 2005 emission level. On 22 October 2019, the amended protocol including the new reduction commitments for 2020, including newly PM_{2.5}, has entered into force for Switzerland. ES Table 1.2 shows the emission reduction commitments for 2020 and the corresponding level of the emissions 2020. The emission reduction commitments 2020 are achieved for all pollutants.

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

Pollutant	Emission reduction commitments 2020	Reduction achieved in 2020	Compliance with emission ceilings 2020 in 2020
	<i>%-reduction of 2005 level</i>		
SO _x (as SO ₂)	21%	73%	yes
NO _x (as NO ₂)	41%	44%	yes
NMVOC	30%	32%	yes
NH ₃	8%	11%	yes
PM _{2.5}	26%	45%	yes

Recalculations and improvements

In 2019, recalculations cause a higher emission level by at least 3 % for CO emissions. A decrease due to recalculations by at least 3 % is observed for NMVOC, Pb, Cd, Hg and

PCDD/PCDF. For all other pollutants, the difference in emissions 2019 due to recalculations does not exceed 1.6 %.

In 1990, recalculations do not cause an increase or decrease of more than 3 % for any pollutant. The largest differences occur for CO and PM_{2.5} emissions (+2.3 % and +1.1 %, respectively), whereas the changes for all other pollutants does not exceed 1.0 %.

In the latest submission 2022, several improvements were conducted and a number of further planned improvements are identified. The following improvements, which were announced in the previous submission, were conducted in submission 2022 had a relevant impact on the inventory:

- 1B2c: Revision of NO_x, CO, NMVOC and SO_x emissions from flaring in refineries, introduction of missing emission estimates for PM₁₀, PM_{2.5}, BC, Pb, Cd and Hg.
- 3 Agriculture: Revision of the NH₃ emission inventory with the revised version of the AGRAMMON model.
- 5A1 Managed waste disposal sites: An emission factor for direct emissions of NMVOC has been introduced based on the EMEP/EEA guidebook (EMEP/EEA 2019).

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 and its amendment 2012.
- The 1998 Aarhus Protocol on Persistent Organic Pollutants and its both amendments adopted in 2009.
- The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone and its amendment 2012 (national emission reduction commitments for 2020 for SO₂, NO_x, NH₃, NMVOC and newly for PM_{2.5}).

According to the obligations of the CLRTAP, Switzerland is annually submitting its emission inventory (CLRTAP Inventory). For the present submission in March 2022, Switzerland provides for the fifteenth 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 2022/(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.

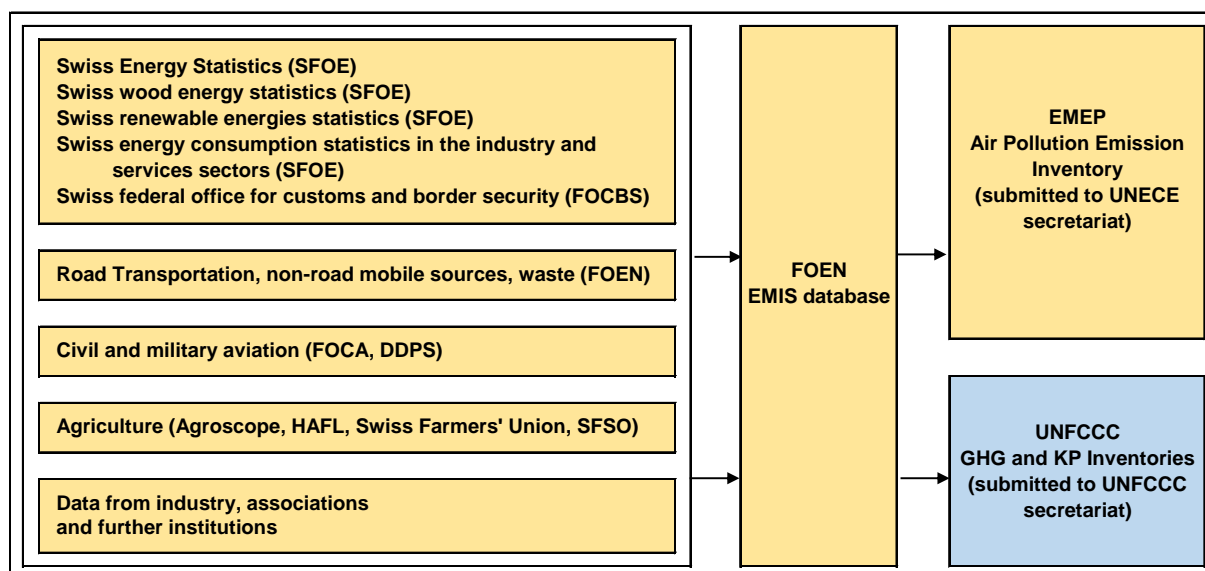


Figure 1-1: Data collection for EMIS database and CLRTAP air pollution emission inventory (GHG: Greenhouse Gas, KP: Kyoto Protocol).

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 2022) 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 2021). Additionally, three in-depth Stage 3 reviews took place in 2010, 2016 and 2020, documented in UNECE (2010, 2016, 2020a). The recommendations of the latest Stage 1, 2 and 3 reviews were implemented in the latest emission inventory and in the IIR as far as possible.

Archiving of the database and related internal documentation is carried out by the inventory compiler, while any other material is archived on the internal data management system by the QA/QC officer. Publicly available material will be published after submission on the website owned by the FOEN (www.climatereporting.ch).

1.4 Methods and data sources

1.4.1 Improvements conducted for this submission

The following issues were mentioned as planned improvements in the IIR of submission 2021 in chp. 8.2 (FOEN 2021b). 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: Done.
- *1A1a Public electricity and heat production: In consequence of reduced emission limit values in the Ordinance on Air Pollution Control (OAPC) for some air pollutants (e.g. Hg), emission factors for all relevant air pollutants of incinerated municipal solid waste have been reevaluated based on air pollution control measurements from 2015-2020 on all municipal solid waste incineration plants and special waste incineration plants (TBF 2021).*
Current state: Done
- *1B2c Venting and flaring: As recommended from the Expert Review Team (ERT) in the recent Stage 3 review 2020, Switzerland revised the NO_x, CO, NMVOC and SO_x emissions from flaring in refineries and added the missing emission estimates for PM₁₀, PM_{2.5}, BC, Pb, Cd and Hg for this source category. See recalculations in chapter 3.3.4.3.*
Current state: Done.
- *2D3 Other solvent use and 2G Other product use: A comprehensive update of all NMVOC emissions from solvent and product use is on-going.*
Current state: In progress
- *3 Agriculture: The NH₃ emission inventory for the submission 2022 were prepared with the revised version 2021 of the AGRAMMON model and was based on the new representative survey on farm and manure management performed at the end of 2019. Thus, it was possible to interpolate the emission NH₃ inventory between 2015 and 2019 and to extrapolate it after 2019 taking into account up-to-date data on farm and manure management. See recalculations for 3B and 3D in chapters 5.2.3 and 5.3.3).*
Current state: Done.
- *3B Manure management: Since the data basis of the NMVOC emission factors proposed in the EMEP/EEA guidebook (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 results of this study, i.e. new NMVOC emission factors for all cattle categories were incorporated in the inventory (see chp. 5.2.2 and chp. 5.2.3 for description of emission factors and recalculations, respectively.*
Current state: Done.
- *3B Manure management, 3Da2a Animal manure applied to soils, 3Da3 Urine and dung deposited by grazing animals: A comparison of the country-specific Tier 3 NH₃ emission factors with Tier 2 emission factors according to the EMEP/EEA guidebook (EMEP/EEA 2019) was performed, see Annex A2.3.*
Current state: Done.
- *3B Manure management, 3Da2a Animal manure applied to soils, 3Da3 Urine and dung deposited by grazing animals: A new uncertainty analysis for NH₃ emissions from livestock husbandry and manure management was conducted.*
Current state: Done.

- *5A1 Managed waste disposal sites: In consequence of the ERT recommendations in the recent Stage 3 review 2020, an emission factor for direct emissions of NMVOC has been introduced based on EMEP/EEA guidebook 2019 recommendations (5A Chap. 3.2.2) for the latest submission. A fraction of 1.3 % of all VOC emissions (1.317 % of CH₄ emissions) occur as NMVOC. Furthermore, an emission factor for emissions of NMVOC from flaring has been introduced for the latest submission based on a study on emissions from landfill gas installations (Butz 2003) suggesting NMVOC emissions equalling to 82.14779134 g/ t CH₄ flared ± 10 %. The emission factor for direct emissions of PM_{2.5} from managed waste disposal sites, as recommended by the ERT, has been introduced already submission 2021.*
Current state: Done.

1.4.2 General description

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

- UNECE: Guidelines for Estimating and Reporting Emission Data under the Convention on Long Range Transboundary Air Pollution, Edition 2014 (ECE 2014).
- EMEP/EEA air pollutant emission inventory guidebook — version 2019 (EMEP/EEA 2019), including:
 - Chp. 2. Key category analysis and methodological choice
 - Chp. 5. Uncertainties

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

“For Parties for which emission ceilings are derived from national energy projections based on the amount of fuels sold, compliance checking will be based on fuels sold in the geographic area of the Party. Other Parties within the EMEP region (i.e., Austria, Belgium, Ireland, Lithuania, Luxembourg, the Netherlands, Switzerland and the United Kingdom of Great Britain and Northern Ireland) may choose to use the national emission total calculated on the basis of fuels used in the geographic area of the Party as a basis for compliance with their respective emission ceilings.” (ECE 2014)

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

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

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

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

1.4.3 Swiss emission inventory system

Emission data is extracted from the Swiss emission information system (EMIS), which is operated by FOEN (see FOEN 2006). EMIS was established at SAEFL (former name of FOEN) in the late 1980s. Its initial purpose was to record and monitor emissions of air pollutants. Since then, it has been extended to cover greenhouse gases, too. Its structure corresponds to the EMEP/EEA system for classifying emission-generating activities. EMEP/EEA uses the Nomenclature for Reporting ("NFR code", ECE 2014).

EMIS maintains a database where emissions for various pollutants and greenhouse gases are calculated using emission factors and activity data according to the EMEP/EEA methodology, respectively IPCC guidelines. Pollutants included are NO_x, NMVOC, SO_x, NH₃, particulate matter (PM2.5, PM10, TSP and BC), CO, priority heavy metals (Pb, Cd and Hg), POPs (PCDD/PCDF and PAHs), HCB and PCB, as well as the greenhouse gases CO₂ (fossil/geogenic origin and CO₂ from biomass), CH₄, N₂O and F-gases. The input data originates from a variety of sources such as various emission measurements, production data and emission factors from the industry, industry associations and research institutions and from Swiss statistics concerning population size, employment, waste and agriculture.

Amongst others, these are the SFOE Swiss overall energy statistics, the SFOE Swiss wood energy statistics, FOEN statistics and models for emissions from road transportation, statistics and models of non-road activities, waste statistics and agricultural models and statistics (see Figure 1-1).

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

1.4.4 Data suppliers

Table 1-2: Primary and secondary data suppliers: 1–13 provide annual updates, 14–19 provide sporadic updates.

No.	Institution	Subject	Data supplied for inventory category											
			1A1	1A2	1A3	1A4	1A5	1B	2	3	5	6	11	
Data suppliers (annual updates)														
1	FOEN, Air Pollution Control	EMIS database	x	x		x	x	x	x	x	x	x	x	x
2	FOEN, Climate	Swiss ETS monitoring reports	x	x		x		x	x					
3	FOEN, Waste and Raw Materials	Waste statistics	x	x								x		
4	SFOE	Swiss overall energy statistics	x	x	x	x		x				x		
5	SFOE	Swiss wood energy statistics	x	x		x								
6	SFOE	Swiss renewable energy statistics	x	x	x	x						x		
7	SFOE	Energy consumption statistics in the industry and services sectors		x										
8	FOCA	Civil aviation			x									
9	DDPS	Military machinery and aviation					x							
10	SFSO	Transport, Solvents, Agriculture, Waste, Other			x				x	x		x	x	
11	HAFL	Agriculture									x			
12	Industry and Industry Associations	Ind. processes and solvents	x					x	x					
13	Avernergy Suisse / Swiss Petroleum Association	Oil statistics						x	x					
Data suppliers (sporadic updates)														
14	FOEN, Air Pollution Control	Non-road database		x	x	x	x							
15	SGWA	Gas distribution losses						x						
16	Empa	Various emission factors	x	x	x	x								
17	INFRAS	On-road emission model			x									
18	INFRAS	Non-road emission model		x	x	x	x							
19	ecolot	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 and/or to the associated uncertainties, a Key Category Analysis (KCA) is performed according to the methodology described in the EMEP/EEA guidebook (EMEP/EEA 2019). The KCA can be performed based on two approaches: in approach 1, categories are set out in decreasing order of contribution to the inventory emissions or trend. In approach 2, this ranking is weighted by the uncertainty assigned to each category. Approach 1 therefore highlights categories which mostly contribute to emissions or to emission changes, while approach 2 identifies categories mostly contributing to the inventory uncertainty. A key category is prioritised within the inventory system because its estimate has a significant influence on the national total.

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

For the pollutants for which uncertainty estimates are available (NO_x, NMVOC, SO_x, NH₃, PM2.5 and PM10), key category analyses were conducted according to approach 1 and 2, for the base year, the reporting year and the trend. For the first time for this reporting year, a KCA according to approach 1 was also conducted for TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, HCB and PCBs. All level and trend assessments were performed for all emission sources accounting for 80 % of the total national emissions (or total national trend).

1.5.1 Summary of KCA results, approaches 1 and 2

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

- For NO_x, category 1A3b Road transportation (including 1A3bi Passenger cars, 1A3bii Light duty-vehicles and 1A3biii Heavy-duty vehicles and buses) represents more than half of the inventory emissions. Each of these categories has a pronounced decreasing trend between 1990 and 2020 (see also chp. 2.3.1 and Annex A1.2).
- For NMVOCs, category 2D3a Domestic solvent use is the major contributor with 12 % of the inventory emissions, directly followed by 3B1b Manure management non-dairy cattle (11 %). The trend 1990-2020 for 2D3a is slightly negative and positive for 3B1b.
- For SO_x, category 1A2f Non-metallic minerals represents 36 % of emissions. Its trend for 1990-2020 is decreasing.
- Almost all NH₃ emissions originate from Sector 3 Agriculture, particularly from 3Da2a Animal manure applied to soils and 3B Manure management. The trend 1990-2020 for 3Da2a is negative.
- For PM2.5 the main source is category 1A4bi Residential: stationary plants, 24 % of emissions, followed by 1A3bvi Road transportation: automobile tyre and brake wear (14 %) and 1A2gvii Mobile Combustion in manufacturing industries and construction (7 %). The trend 1990-2020 for category 1A3bvi is positive whereas it is negative for 1A4bi and 1A2gvii.
- The main source of PM10 emissions is category 1A3bvi Road transportation: automobile tyre and brake wear, representing 18 % of emissions, followed by categories 1A2gvii Mobile Combustion in manufacturing industries and construction (17 %) and 1A4bi Residential: stationary plants (11 %). As for PM2.5, the trend 1990-2020 for category 1A3bvi is positive.

A few categories, which were not key for the year 2019 (for any of the approaches, level or trend) became key categories for the year 2020 according to at least one criterion:

- 1A2gviii Stationary combustion in manufacturing industries and construction: Other is newly key according to approach 1 level assessment in 2020, for PM2.5, albeit with a minor contribution.
- 1A4cii Agriculture/forestry/fishing: off-road vehicles and other machinery is newly key according to approach 1 level assessment in 2020, for NO_x. Within this source category, agricultural tractors contribute the most to the NO_x emissions. It is likely that source category 1A4cii has become key because of more pronounced emission decreases in other categories.

- 1B2c Venting and flaring (oil, gas, combined oil and gas) is newly key according to approach 2 trend assessment in 2020, for NO_x, albeit with a small contribution. This process has a steep decreasing trend between 1990 and 2020. This category probably became key for this submission because the contribution from category 1A3ai(i) International aviation (LTO) for the same assessment was much reduced (see also the next paragraph).
- 2D3e Degreasing is newly key according to approach 1 and 2, trend assessment, for NMVOC. This process has a pronounced decreasing trend since 1990, which was further enhanced in 2020 due to reduced emissions compared to 2019.
- 3Da2c Other organic fertilisers applied to soils (including compost) is newly key for NO_x according to approach 2, trend assessment, and constitutes the smallest contribution to this approach. This category has a positive trend since 1990.

The following categories were key for the year 2019, for at least one of the criteria, but are not key anymore for the year 2020:

- 1A3ai(i) International aviation (LTO) is not key anymore for NO_x. In 2019 it was key according to approach 1, level and trend assessment, and approach 2, trend assessment. However, the emissions for this category have significantly decreased in 2020 compared to 2019. This category is also not key anymore for SO_x. The decrease in NO_x and SO_x emissions may be interpreted as a consequence of the lockdown and subsequent measures associated with the COVID-19 pandemic that affected Switzerland from March 2020 onwards.
- 1A3bi Road transportation: Passenger cars is not key anymore for PM_{2.5}. In 2019, this category was key according to approach 1, level assessment, albeit with a minor contribution. In 2020, PM_{2.5} emissions from 1A3bi decreased sharply compared to 2019.
- 2H2 Food and beverages industry is not key anymore for NH₃. It was key in 2019 according to approach 2, trend assessment. Due to an emission factor for projections, erroneously inserted for 2020 instead of 2035 in the previous submission 2021, the slope of the generally decreasing trend was too steep. By correcting this error (see recalculations for 2H2 sugar production, chp. 4.7.3), emissions have doubled in 2020 compared to 2019. This yields a decreasing trend by comparison to 1990, which is less steep in submission 2022 than the trend for 1990-2019 in submission 2021. This may explain why this category is not key anymore for trend, approach 2.
- 3B3 Manure management – Swine is not key anymore for NMVOC. This category was key in 2019 according to approach 2, level and trend assessment, albeit with minor contributions. The assigned uncertainty for the emission factor of this category was reassessed and is now 200 % for the year 2020, whereas in the previous submission it was 500 % for the year 2019 (see chp. 5.2.3).
- 3B4gi Manure management - Laying hens is not key anymore for NH₃. In 2019, it was the smallest contributor to approach 2, level.
- 5C1biv Sewage sludge incineration is not key anymore for SO_x. SO_x emissions from this source category have sharply decreased for the year 2020 compared to the value reported for the year 2019 in the previous submission. Indeed, emission factors for all pollutants for this process have been reassessed and resulted in lower emissions from 2016 onwards (TBF 2019) (see details in chp. 6.4.3).

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

1.5.2 KCA approach 1 results

1.5.2.1 Level key category analysis (approach 1)

The results of the key category analysis according to approach 1, level, are summarized in Table 1-3 for the year 1990 and in Table 1-4 for the year 2020 for NO_x, NMVOC, SO_x, NH₃, PM2.5 and PM10. See Table 1-5 and Table 1-6 for TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, HCB and PCBs.

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

NFR code	Key categories approach 1: % level contribution to totals 1990						% sum of category
	NO _x	NMVOC	SO ₂	NH ₃	PM2.5	PM10	
1A1a	4.5		9.8		4.7	4.1	23
1A2d			8.4				8
1A2f	7.5		9.6		2.6	3.3	23
1A2gvii	4.5				4.4	8.6	17
1A2gviii			9.0		3.3	2.2	15
1A3bi	31.1	19.1	4.6		3.5	2.3	61
1A3bii	4.4						4
1A3biii	21.2		4.8		9.5	6.3	42
1A3bv		5.8					6
1A3bvi					4.2	8.1	12
1A3c						3.9	4
1A4ai			9.3		3.0	2.1	14
1A4bi	8.3	3.0	25.1		31.5	21.8	90
1A4ci					3.2	2.2	5
1B2av		5.0					5
2C1					4.9	5.9	11
2D3a		3.1					3
2D3d		13.9					14
2D3e		3.8					4
2D3g		9.4					9
2D3h		7.0					7
2G		8.1			3.1	2.3	14
2I						3.4	3
3B1a		2.4		13.6			16
3B1b				7.6			8
3B3				10.2			10
3Da2a				50.4			50
3De						4.2	4
5C1a					2.8		3
Fraction of total, %	81.4	80.8	80.7	81.8	80.7	80.6	

Table 1-4: List of Switzerland's approach 1 level key categories 2020, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR code	Key categories approach 1: % level contribution to totals 2020						% sum of category
	NOx	NMVOc	SO2	NH3	PM2.5	PM10	
1A1a	4.0		6.4				10
1A2f	6.0		36.3				42
1A2gvii	3.5				6.7	17.5	28
1A2gviii			8.1		3.0		11
1A3bi	33.9	5.0					39
1A3bii	9.2						9
1A3biii	8.2						8
1A3bv		2.5					3
1A3bvi					13.9	17.9	32
1A3c					3.3	9.4	13
1A4ai	4.6		6.4		5.3	2.5	19
1A4bi	8.3	3.3	15.5		24.1	11.0	62
1A4ci					3.9		4
1A4cii	3.6						4
1A5b						1.9	2
2A1						1.8	2
2A5a					4.0	3.5	7
2B5			11.2				11
2D3a		11.9					12
2D3b		3.5					4
2D3d		10.7					11
2D3g		4.2					4
2D3h		5.0					5
2D3i		2.7					3
2G		9.1			6.4	3.5	19
2H1					3.1		3
2H2		2.6			2.8	2.3	8
3B1a		9.5		19.5			29
3B1b		11.0		13.2			24
3B3				9.1			9
3Da2a				38.2			38
3De						7.5	7
5C1a					4.2	2.0	6
Fraction of total, %	81.2	81.1	83.8	80.0	80.8	80.8	

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

NFR code	Key categories approach 1: % level contribution to totals 1990										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/ PCDF	PAHs total	HCB	PCBs	
1A2gvii	7.3	4.5									12
1A3bi			57.5	66.4							124
1A3bii			9.8								10
1A3biii	3.8	14.0									18
1A3bvi	4.9				6.7						12
1A3c	3.1										3
1A4ai		5.3							11.8		17
1A4bi	14.0	56.8	15.1				31.3	70.3	79.3		267
2A5a	1.6										2
2B10a						17.2					17
2C1	6.5			18.8	45.6	49.7	22.0				143
2C3								11.6			12
2G					10.5		3.9				14
2I	10.4										10
2K										70.4	70
3B3	2.2										2
3De	25.3										25
5C1a	1.6						9.2				11
5C1biii						10.8	12.2				23
5C1biv						9.5					9
6A					17.4		4.5			13.0	35
Fraction of total, %	80.7	80.6	82.5	85.2	80.2	87.1	83.1	81.9	91.2	83.4	

Table 1-6: List of Switzerland's approach 1 level key categories 2020, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR code	Key categories approach 1: % level contribution to totals 2020										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCBs	
1A2gvii	12.9										13
1A2gviii						10.2					10
1A3aii(i)				6.0							6
1A3bi		6.2	31.0	14.9		7.7		7.5			67
1A3biv			4.7								5
1A3bvi	8.9	8.1			19.8						37
1A3c	6.2										6
1A3dii			3.6								4
1A4ai		8.4	4.5			9.2	9.1	10.9	23.2		65
1A4aii			4.9								5
1A4bi	5.7	47.6	19.7		6.4	17.5	35.6	61.0	59.9		253
1A4cii		10.0	9.6								20
2A5a	3.4										3
2B5			4.2								4
2C1						16.4					16
2G	1.7				18.7						20
2K										90.0	90
3B3	2.3										2
3B4gi	2.7										3
3De	37.0										37
5C1a				14.5			21.1				36
5C2								7.6			8
6A				48.2	35.5	22.8	16.4				123
Fraction of total, %	80.8	80.3	82.1	83.7	80.3	83.9	82.1	87.0	83.1	90.0	

1.5.2.2 Trend key category analysis (approach 1)

The results of the KCA according to approach 1, trend, for 1990-2020 are summarized in Table 1-7 and Table 1-8.

Table 1-7: List of Switzerland's approach 1 key categories for the trend 1990-2020, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR code	Key categories approach 1: % contribution to trend 1990 - 2020						% sum of category
	NOx	NMVOC	SO2	NH3	PM2.5	PM10	
1A1a			4.0		6.0	5.0	15
1A2d			9.8				10
1A2f	4.2		31.4		3.0	3.7	42
1A2gvii	3.0				3.5	11.8	18
1A2gviii	4.3						4
1A3bi	8.0	18.2	3.8				30
1A3bii	13.5						14
1A3biii	36.8		5.2		12.9	7.7	63
1A3bv		4.2					4
1A3bvi					15.0	13.0	28
1A3c					3.5	7.3	11
1A3dii	3.2						3
1A4ai	3.4		3.4		3.5		10
1A4bi			11.3		11.4	14.3	37
1B2av		5.0					5
2A5a					4.4	2.7	7
2B5			11.7				12
2C1					7.4	7.7	15
2D3a		11.4					11
2D3b		2.4					2
2D3d		4.2					4
2D3e		2.7					3
2D3g		6.7					7
2D3h		2.6					3
2G					5.1		5
2H1					2.6		3
2H2		2.6			2.6		5
2I						2.7	3
3B1a		9.2		16.4			26
3B1b		11.8		15.6			27
3Da1				4.3			4
3Da2a	3.7			34.0			38
3Da2b				4.7			5
3Da2c				4.8			5
3Da3				4.2			4
3De						4.4	4
Fraction of total, %	80.1	81.0	80.6	84.1	80.8	80.2	

Table 1-8: List of Switzerland's approach 1 key categories for the trend 1990-2020, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR code	Key categories approach 1: % contribution to trend 1990 - 2020										% sum of category
	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCBs	
1A2gvii	8.8										9
1A2gviii						7.5			18.7		26
1A3bi			39.4	34.2				14.7			88
1A3bii		6.0	9.8								16
1A3biii	5.6	22.4									28
1A3bvi	6.2	14.5			13.4						34
1A3c	4.8										5
1A4ai		6.6	4.4				6.7	10.6	29.3		58
1A4aii			6.4								6
1A4bi	13.0	19.5	6.7			11.1	5.3	21.8	50.0		127
1A4cii		12.6	8.6								21
2B10a						13.4					13
2B5			5.4								5
2C1	10.1			11.2	45.5	26.0	26.0				119
2C3								27.2			27
2G					8.4						8
2I	13.7										14
2K										50.0	50
3De	18.4										18
5C1a				9.0			14.9				24
5C1biii						8.4	15.3				24
5E										22.3	22
6A				30.7	18.4	15.0	14.8	8.5		14.0	101
Fraction of total, %	80.7	81.7	80.7	85.1	85.7	81.4	83.0	82.8	98.0	86.3	

1.5.3 KCA approach 2 results

1.5.3.1 Level key category analysis (approach 2)

The results of the KCA according to approach 2, level assessment, are summarized in Table 1-9 for the year 1990 and in Table 1-10 for the year 2020.

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

NFR code	Key categories approach 2: % level contribution to totals 1990						% sum of category
	NOx	NMVOC	SO2	NH3	PM2.5	PM10	
1A1a	3.7		12.9		4.3	3.3	24
1A2d			6.5				7
1A2f	4.9		10.1			2.4	17
1A2gvii					2.8	4.9	8
1A2gviii			9.4		2.8		12
1A3bi	45.3	13.9					59
1A3bii	5.4						5
1A3biii	14.5		2.6		3.3	1.9	22
1A3biv		6.7					7
1A3bv		3.2					3
1A3bvi					2.7	4.6	7
1A3c						2.2	2
1A4ai			5.1		3.1	1.9	10
1A4bi	4.3	2.9	14.6		31.0	18.8	72
1A4cii					2.7		3
1B2aiv			3.5				3
2A1					2.9	2.6	5
2A5a					4.0	4.6	9
2C1					7.0	7.4	14
2C3			15.9				16
2D3a		4.0					4
2D3d		8.7					9
2D3e		3.4					3
2D3g		12.6					13
2D3h		4.3					4
2D3i		3.8					4
2G		17.4			3.8	2.5	24
2H1					2.8		3
2H2					4.1	3.9	8
2I					4.7	10.7	15
3B1a				12.4			12
3B1b				6.4			6
3B3				12.6		2.0	15
3B4gi				3.6			4
3Da1	3.3			9.5			13
3Da2a				33.9			34
3De						7.3	7
6A				4.0			4
Fraction of total, %	81.2	81.0	80.6	82.3	82.0	81.1	

Table 1-10: List of Switzerland's approach 2 level key categories 2020, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR code	Key categories approach 2: % level contribution to totals 2020						% sum of category
	NOx	NMVOC	SO2	NH3	PM2.5	PM10	
1A1a	2.9		8.3				11
1A2f	3.5		37.7				41
1A2gvii					3.7	9.4	13
1A2gviii			8.4				8
1A3bi	44.3	3.2					48
1A3bii	10.1						10
1A3biii	5.1						5
1A3biv		2.8					3
1A3bvi					7.7	9.6	17
1A3c						5.0	5
1A4ai			3.5		4.6		8
1A4bi	3.8	2.8	8.9		20.3	9.0	45
1A4cii					2.5		2
2A1					4.5	3.0	7
2A5a					12.2	10.4	23
2B10a			4.5				4
2B5			12.2				12
2D3a		13.4					13
2D3b		4.0					4
2D3d		5.9					6
2D3g		4.9					5
2D3h		2.7					3
2D3i		4.7					5
2G		17.0			6.7	3.6	27
2H1					5.3		5
2H2		3.0			8.6	6.8	18
2I					2.4	4.0	6
3B1a		7.0		16.7			24
3B1b		9.4		10.5			20
3B3				10.7		2.4	13
3B4gi						2.5	3
3B4gii				3.0		3.3	6
3Da1	4.8			6.7			12
3Da2a	4.8			24.1			29
3Da3	2.7			4.7			7
3De						12.2	12
5C1a					2.7		3
6A				5.4			5
Fraction of total, %	82.0	80.8	83.5	82.0	81.3	81.1	

1.5.3.2 Trend key category analysis (approach 2)

The results of the KCA according to approach 2, trend assessment, for 1990-2020 are summarized in Table 1-11.

Table 1-11: List of Switzerland's approach 2 key categories for the trend 1990-2020, for the main pollutants, PM2.5 and PM10. Contributions are given in percentage of the total assessment per pollutant and depicted using a colour scale, a darker colour indicating a larger contribution. The bottom line reports the cumulative total over all key source categories per pollutant, which amounts to more than 80 % according to the KCA procedure. The column to the right reports the sum of contributions from all pollutants per category.

NFR code	Key categories approach 2: % contribution to trend 1990 - 2020						% sum of category
	NOx	NM VOC	SO ₂	NH ₃	PM _{2.5}	PM ₁₀	
1A1a			5.6		5.0	4.1	15
1A2d			8.1				8
1A2f	2.7		35.0		2.2	2.8	43
1A2gvii						6.8	7
1A2gviii	2.7						3
1A3bi	11.2	13.2	2.2				27
1A3bii	15.9						16
1A3biii	24.3		3.1		4.1		31
1A3biv		4.5					5
1A3bv		2.4					2
1A3bvi					8.8	7.5	16
1A3c						4.2	4
1A4ai					3.2		3
1A4bi			7.0		10.1	12.5	30
1B2aiv			2.9				3
1B2c	2.4						2
2A1					3.3		3
2A5a					14.3	8.7	23
2B10a			4.4				4
2B5			13.7				14
2C1					9.5	9.8	19
2D3a		14.6					15
2D3b		3.1					3
2D3d		2.6					3
2D3e		2.4					2
2D3g		9.0					9
2G		2.7			5.6		8
2H1					4.7		5
2H2		3.3			8.4	4.5	16
2I					2.6	8.7	11
3B1a		7.7		14.0			22
3B1b		11.6		12.4			24
3B3				3.3			3
3B4gii		3.6		5.3		3.9	13
3Da1	5.8			6.2			12
3Da2a	6.8			21.4			28
3Da2c	2.2			7.5			10
3Da3	6.4			7.6			14
3De						7.7	8
6A				4.7			5
Fraction of total, %	80.5	80.5	82.2	82.4	81.9	81.2	

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 2022a) contains all relevant information regarding the QMS. It is updated annually and made available to everyone contributing to the GHG inventory.

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

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

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

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

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

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

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

- Crosschecks with the greenhouse gas inventory concerning activity data and precursors (NO_x, CO, NMVOC and SO₂)
- Selective checks of emission factors of the inventory. For example, for submission 2020 a general comparison of emission factors with the newly published EMEP/EEA guidebook (EMEP/EEA 2019) has been conducted.
- Every year specific projects are implemented to improve the inventory in particular sections.

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

- The air pollutant inventory is intertwined with the GHG inventory, so any verification checks regarding precursor emissions or activity data in the GHG inventory are also applied to the air pollutant inventory.
- Switzerland systematically compares the emission factors with other European countries, especially if new emission factors are introduced to the inventory or if the accuracy of an emission factor or of a data source is questioned in an internal or external review process.
- Switzerland carries out sector-specific verification processes for individual source categories or processes.
- Switzerland regularly compares the emissions from the air pollutant inventory with the results of the national ambient concentration modelling "PolluMap" (NO₂, PM_{2.5} 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 2020a). Switzerland prioritizes inventory improvements based on the findings from the stage 3 reviews and according to the key category analysis (KCA) and the uncertainty analysis, where appropriate.

1.7 General uncertainty evaluation

1.7.1 Data sources and data used

The uncertainty analysis is conducted using activity data and emission factors at the same level of aggregation as used for the NFR reporting tables (classification according to EMEP/EEA 2019).

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

- Uncertainties of activity data are taken from the uncertainty analysis of Switzerland's GHG Inventory (FOEN 2022).
- Uncertainties for the emission factors and emissions of mobile sources are 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 the EMEP/EEA guidebook (EMEP/EEA 2019, part A, chp. 5, Table 2-2).

- To estimate the uncertainties associated with NH₃ emissions from sector 3 Agriculture, a model essentially based on the nitrogen-flow model AGRAMMON was previously developed by INFRAS (2015, 2017). Since then, the AGRAMMON model has been revised and in addition, a new survey on production techniques in Swiss agriculture has been performed in 2019. Based on these updates, INFRAS made a new uncertainty analysis for the year 2019 (INFRAS 2021). The new uncertainty estimate for ammonia emissions from Swiss agriculture is 12.6 %, which is slightly lower than the 13.6 % estimated in the previous study. Numeric values can be found in Annex A5.1.
- Detailed numeric values and references for the uncertainties are reported in Annex 5.

1.7.2 Methodology

The uncertainty aggregation for the main pollutants and particulate matter is carried out for the latest submission according to approach 1 (uncertainty propagation) and approach 2 (Monte Carlo simulations).

Input uncertainty values for activity data and emission factors at the same aggregation level as required for the key category analysis are used for the computation. For the main pollutants, PM_{2.5} and PM₁₀, a total of 127 categories were considered.

Uncertainties are assessed in accordance with the EMEP/EEA guidebook (EMEP/EEA 2019: Part A, chapter 5) and with the IPCC Guidelines 2006 (IPCC 2006). The Monte Carlo simulations follow the recommendations by JCGM (2008, Supplement 1).

The following assumptions were applied to both approaches:

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

The following factors are not accounted for:

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

For both approaches, all uncertainty results represent a 95 % confidence interval. For a symmetrical distribution, this interval is centred on the mean. For non-symmetrical distributions obtained by Monte Carlo simulations, the reported uncertainties represent the narrowest 95 % interval, in agreement with JCGM (2008, S1). Uncertainties are given for the lower range (from the lower edge to the mean) and the upper range (from the mean to the upper edge), expressed as a percentage of the mean.

1.7.2.1 Aggregation of uncertainties using approach 1: uncertainty propagation

The uncertainty propagation is computed using the open source software Python (version 3.6.1, <https://www.python.org/>), in which the equations given in the guidelines are programmed. Results of approach 1 for the reporting year and for the trend for each considered pollutant are summarised in Table 1-12.

1.7.2.2 Aggregation of uncertainties using approach 2: Monte Carlo simulations

The Monte Carlo simulations were performed for the base year 1990, the reporting year 2020 and the trend at the aggregation level required for the KCA. All input variables can be found in Annex 5. Results for each pollutant are summarized in Table 1-12.

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

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

Modelling framework

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

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

For each input quantity, 200'000 random values were generated resulting in equal numbers of values for the base year, the reporting year and the trend.

The average offset between the obtained mean for each process and the input mean is 0.07 % for NO_x, 0.13 % for NMVOC, 0.09 % for SO_x, 0.11 % for NH₃, 0.18 % for PM_{2.5} and 0.27 % for PM₁₀. This reflects the uncertainty introduced by the Monte Carlo method itself. This computational uncertainty remains small compared to the uncertainty introduced by activity data and emission factors.

Correlation

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

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

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

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

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

Sensitivity analysis

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

The sensitivity of a total value (total base year emission, total reporting year emission) to the variability of input quantities is computed as the correlation coefficient between total and input values, using in Python the function `corrcoef` from the `numpy` package. Each sensitivity value is computed on 200'000 pairs of points.

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

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

Source code availability

The Python source code is available on request. For the next submission, we plan to make the code available on a public repository.

1.7.3 Results of approach 1 and 2 uncertainty evaluation

Table 1-12 shows the results of the uncertainty evaluation using approaches 1 and 2 for the base year, the reporting year and the trend. Due to the availability of uncertainty data, the analysis was restricted to the main pollutants (NO_x , NMVOC, SO_x , NH_3) as well as PM2.5 and PM10. The total emissions in the base year and the reporting year as well as the emission trends 1990-2020 of these pollutants are also shown in Table 1-12. Since emission factors are generally the major sources of uncertainty (compared to activity data) and since they are considered correlated across years this may result in smaller uncertainties for the trends than for the emission levels.

Table 1-12: For each pollutant, emission levels for 1990 and 2020, trend and associated relative uncertainties obtained from the uncertainty propagation (approach 1) and from Monte Carlo simulations (approach 2), for the main pollutants, PM_{2.5} and PM₁₀. Note that the trend and its associated uncertainties are expressed in the same unit, in percent. As an example, for a trend of -10 % with uncertainties of 2 %, the trend is comprised between -12 % and -8 %.

Pollutant	Base year (1990)			Reporting year (2020)			Trend (1990-2020)		
	Emissions, t	U(-) %	U(+) %	Emissions, t	U(-) %	U(+) %	Trend, %	U(-) %	U(+) %
Monte Carlo simulations (approach 2)									
NO _x	140811	12	13	52522	13	13	-63	1.3	1.3
NM _{VOC}	292434	23	25	75192	25	27	-74	4	5
SO ₂	36694	6	6	3789	8	8	-90	0.7	0.7
NH ₃	68520	13	13	53317	12	12	-22	5	5
PM _{2.5}	16602	28	28	5862	30	34	-65	6	7
PM ₁₀	25283	27	29	13421	28	32	-47	10	11
Uncertainty propagation (approach 1)									
NO _x	140811	13	13	52522	14	14	-63	1.3	1.3
NM _{VOC}	292434	18	25	75192	18	27	-74	4	4
SO ₂	36694	5	6	3789	8	8	-90	0.7	0.7
NH ₃	68520	13	13	53317	12	12	-22	5	5
PM _{2.5}	16602	26	28	5862	22	34	-65	4	7
PM ₁₀	25283	20	30	13421	19	32	-47	7	12

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

Uncertainty estimations can be summarized as follow:

- For the base year, the estimations range from 5 % to 30 % for approach 1 and from 6 % to 29 % for approach 2.
- For the reporting year, the estimations range from 8 % to 34 % for both approaches.
- For the trend, the estimations range from 0.7 % to 12 % for approach 1 and from 0.7 % to 11 % for approach 2.

The level and trend uncertainty estimations for the latest submission remained similar for all pollutants as the values of the previous submission 2021, except for the following cases:

- For NM_{VOC}s, new uncertainty estimations for several processes of sectors 2 and 3 yielded a reduced uncertainty for the inventory total: for the year 2020, the total uncertainty is approximately 25 % for level emissions and 5 % for the trend, compared to 75 % and 14 % for the year 2019, respectively. See chp. 5.2.3 for more details.
- For NH₃, a 1 % reduction in the reporting year emission uncertainty may be attributed to a reduced uncertainty assigned to the two processes contributing most to the uncertainty: 3Da2a Animal manure applied to soils (-6 %) and 3B1a Manure management - Dairy cattle (-32 %).

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

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

The Monte Carlo simulations provide data to conduct a sensitivity analysis between emissions from each category and the inventory (total) emission for NO_x, NMVOC, NH₃, SO₂, PM_{2.5} and PM₁₀. This analysis quantifies the influence of a change in the emission of a given category on the inventory total. The results of the sensitivity analysis for the base year and the reporting year are shown in Annex A5.3.2. The processes ranked in descending order of importance according to the sensitivity analysis follow almost the same order as the processes ranked according to approach 2 of the key category analysis. Both methods highlight categories with large uncertainties, expressed in absolute values. The sensitivity analysis therefore confirms the results obtained by approach 2 of the KCA.

1.8 General assessment of completeness

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

1.8.1 Sources not estimated (NE)

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

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

1.8.2 Sources included elsewhere (IE)

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

1.8.3 Other notation keys

Not occurring (NO)

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

Not applicable (NA)

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

2 Emission trends 1980-2020

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 1980-2020 (see Table 2-1). Note that there is a methodological difference between data before 1990 and data from 1990 onward due to lower data availability before 1990. This can lead to interpolation-based edges in the time series.

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

Pollutant	Unit	1980	2005	2020	1980-2020	2005-2020
NO _x	kt	164	93	53	-68%	-44%
NMVOC	kt	310	111	75	-76%	-32%
SO ₂	kt	115	14	3.8	-97%	-73%
NH ₃	kt	65	60	53	-18%	-11%
PM2.5 total	kt	19	11	5.9	-70%	-45%
PM2.5 exhaust	kt	17	8.4	3.5	-79%	-58%
PM2.5 non-exhaust	kt	2.3	2.3	2.3	1.6%	1.5%
PM10 total	kt	29	18	13	-54%	-26%
PM10 exhaust	kt	20	9.1	4.0	-80%	-56%
PM10 non-exhaust	kt	9.5	9.0	9.4	-0.3%	4.9%
TSP total	kt	53	32	27	-49%	-15%
TSP exhaust	kt	26	9.6	4.3	-83%	-56%
TSP non-exhaust	kt	28	23	23	-17%	2.2%
BC total	kt	4.9	3.5	1.0	-79%	-71%
BC exhaust	kt	4.9	3.5	0.9	-81%	-73%
BC non-exhaust	kt	0.026	0.078	0.083	222%	7.2%
CO	kt	1'134	305	146	-87%	-52%
Pb	t	1'326	21	14	-99%	-35%
Cd	t	5.4	0.71	0.59	-89%	-17%
Hg	t	7.6	0.81	0.64	-92%	-21%
PCDD/PCDF	g I-Teq	444	32	14	-97%	-56%
BaP	t	2.2	1.4	0.76	-66%	-47%
BbF	t	2.5	1.6	0.80	-68%	-50%
BkF	t	1.5	1.0	0.50	-68%	-52%
IcdP	t	1.1	0.82	0.44	-61%	-46%
PAH tot	t	7.4	4.9	2.5	-66%	-49%
HCB	kg	97	0.44	0.35	-100%	-21%
PCB	t	3.6	1.3	0.41	-89%	-68%

2.1.2 Legal basis for the implementation of reduction measures

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

The air pollution control policy is based on:

- Federal Constitution of the Swiss Confederation: Article 74 “Protection of the environment” (Swiss Confederation 1999)
- Federal Act on the Protection of the Environment (EPA) (Swiss Confederation 1983).
- Ordinance on Air Pollution Control (OAPC) (Swiss Confederation 1985, see Figure 2-1 for an overview of the revisions).
- Federal Council’s “Concept on Air Pollution Control”: On behalf of the Swiss Parliament, the Federal Council has adopted a strategy containing national emission reduction targets, actions and measures at the national level, which will allow for reaching the air quality standards and an improved air quality in general. The strategy is regularly updated, the last version dates from 2009 and is still currently applicable (Swiss Confederation 2009).
- Ordinance on the Technical Standards for Motor Vehicles and their Trailers (Swiss Confederation 1995).
- Ordinance on the incentive tax on volatile organic compounds (VOC) since 2000 (Swiss Confederation 1997).
- Federal Act on the reduction of CO₂ 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.

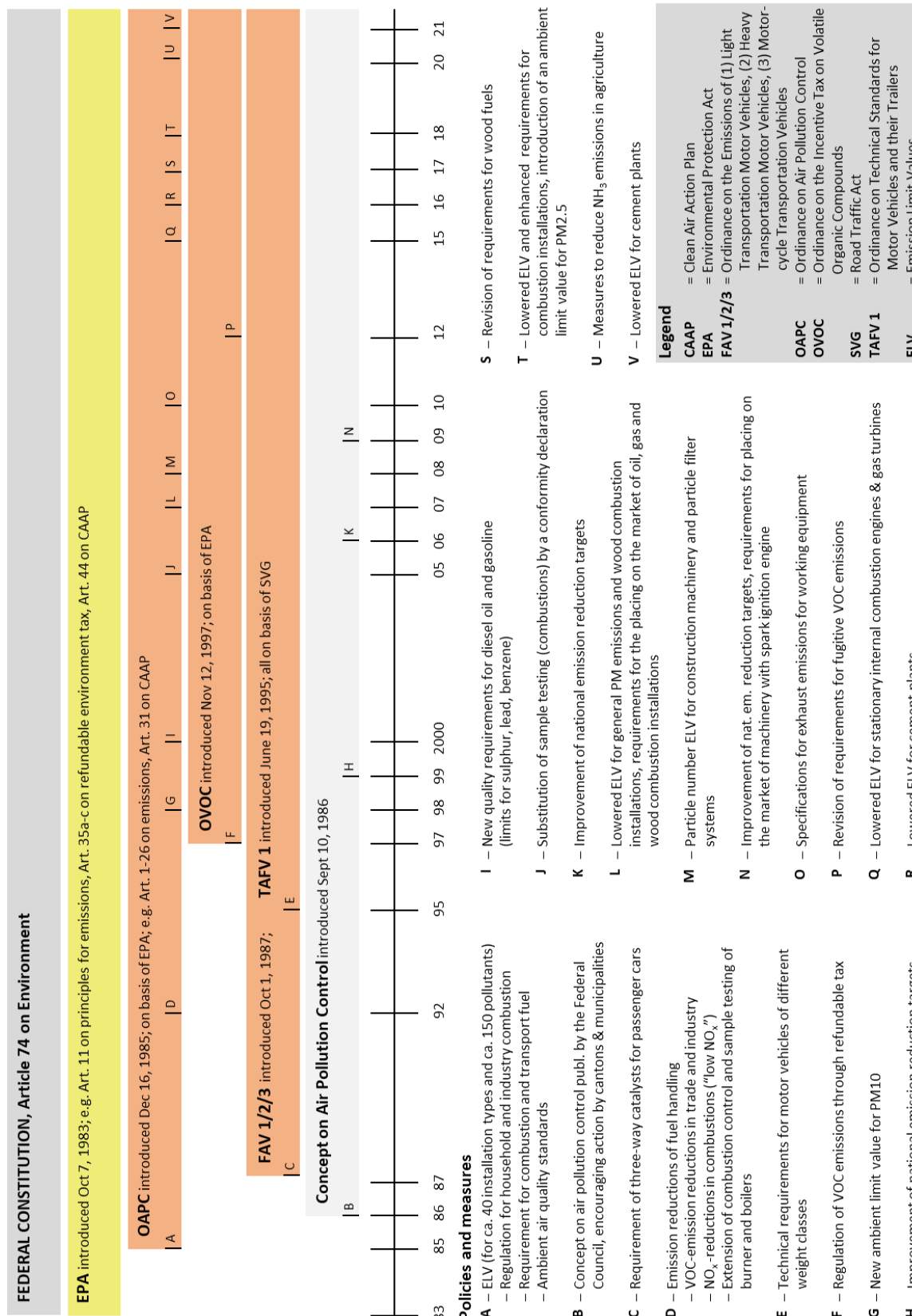


Figure 2-1: Overview of the OAPC Revisions in Switzerland. The Concept on Air Pollution Control is also referred to as the Air Pollution Control Strategy.

For further information on legislation on the abatement of air pollution, see: <https://www.bafu.admin.ch/bafu/en/home/topics/air/law.html> [05.02.2022].

2.2 Overall trends of total emissions

2.2.1 Main air pollutants and CO

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

Overall, the most effective reduction measures were the abatement of exhaust emissions from road vehicles and stationary installations and the incentive taxes on VOC (since 2000) and on fossil combustible fuels (since 2008). The latter measure was (jointly) responsible for the significant shift in the fuel mix of standard fossil fuels in industry from solid and liquid fuels to natural gas and the almost complete disappearance of residual fuel oil. As a result, NO_x, NMVOC and CO emissions clearly declined between 1980 and 2020.

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 3-9, whereas the time series of Switzerland's decreasing coal consumption is given in Table 3-4. Both trends resulted in a considerable reduction of the SO_x emissions. Annual fluctuations of SO_x emissions occur mainly due to annual variations of heating degree days, which affects the consumption of gas oil.

The reduction of NH₃ emissions in the past 40 years is not as pronounced as for the pollutants mentioned above. NH₃ emissions are influenced by changes in the number of livestock and thus N excretions, in housing systems due to developments in animal welfare regulations as well as in agricultural production techniques including a decline in the use of mineral fertiliser (see Figure 2-2). Between 1990 and 2020, the amount of N excreted by livestock decreased by 17 % (Kupper et al. 2022), which had a corresponding effect on NO_x and NH₃ emissions from agriculture (see chapters 5.1.1 and 5.1.3).

In the year 2020, the drop of NO_x and CO emissions is mainly due to the COVID-19 pandemic. This pandemic resulted in strongly reduced traffic volumes in Switzerland. Therefore, a reduction of overall emissions between 2019 and 2020 is visible for pollutants which are emitted by a large share from the transport sector (in particular 1A3b Road transportation).

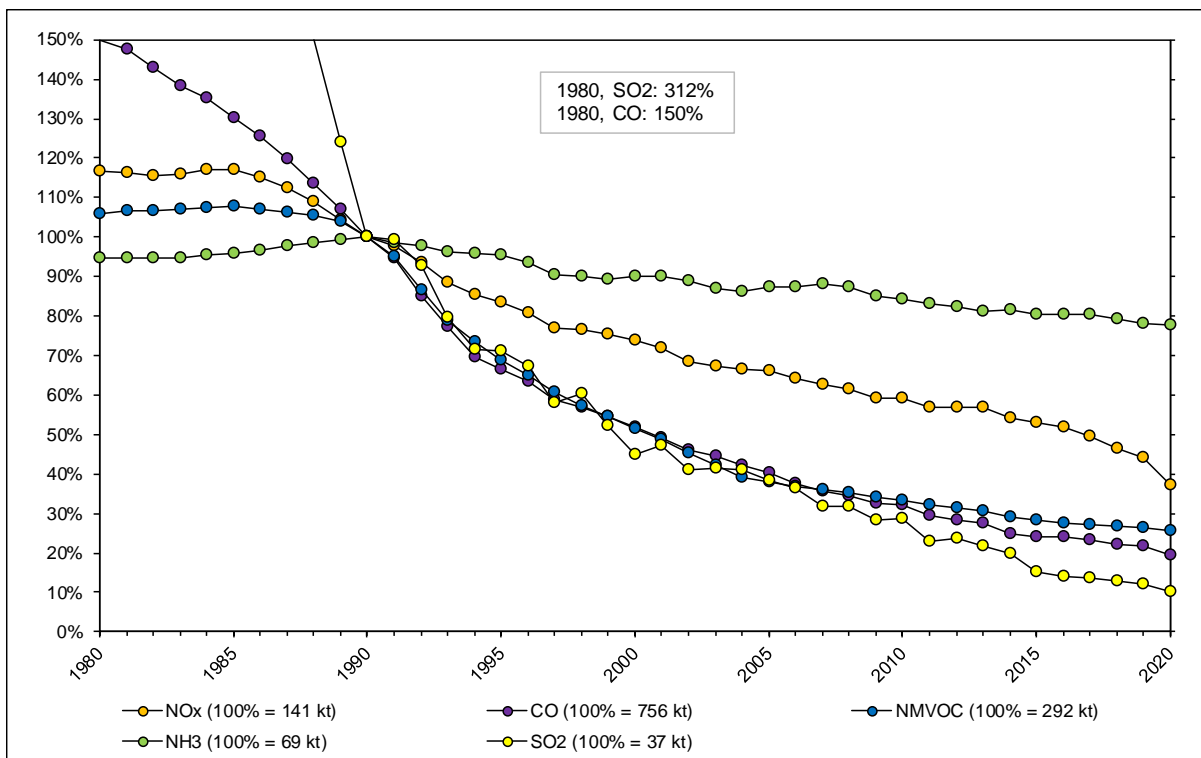


Figure 2-2: Relative trends for the total emissions of main air pollutants and CO in Switzerland 1980–2020 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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	164	310	115	65	1'134
1985	165	315	74	66	986
1990	141	292	37	69	756
1995	118	201	26	65	503
2000	104	150	16	62	392
2005	93	111	14	60	305
2010	83	98	10	58	244
2011	80	94	8.4	57	222
2012	80	91	8.6	56	215
2013	80	89	8.0	56	208
2014	76	86	7.3	56	187
2015	74	83	5.6	55	181
2016	73	80	5.2	55	182
2017	70	79	5.0	55	176
2018	65	78	4.8	54	166
2019	62	77	4.4	54	165
2020	53	75	3.8	53	146
2020 vs. 2005 (%)	-44%	-32%	-73%	-11%	-52%

2.2.2 Suspended particulate matter

Emissions for suspended particulate matter (PM_{2.5}, 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 (PM_{2.5}, 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 (PM_{2.5}) and soot (see also Figure 2-1).

In contrast to exhaust particulate matter emissions, non-exhaust emissions show an increasing trend since 2005 (see Figure 2-5, Table 2-5). This increase is mainly due to growing activity data (annual mileage and machine hours) of mobile sources, and in absolute terms it is more distinctive for TSP and PM₁₀ than for PM_{2.5} (see chp. 2.4.4). Since annual mileage dropped in 2020 due to the COVID-19 pandemic, non-exhaust particulate matter emissions have decreased between 2019 and 2020 as well (see Figure 2-5).

Note that in the years 1980 to 1990, BC exhaust emissions increased due to a large increase in the consumption of wood energy mainly in households (1A4bi), and to a lower extent also 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 - 37 in Annex 6.

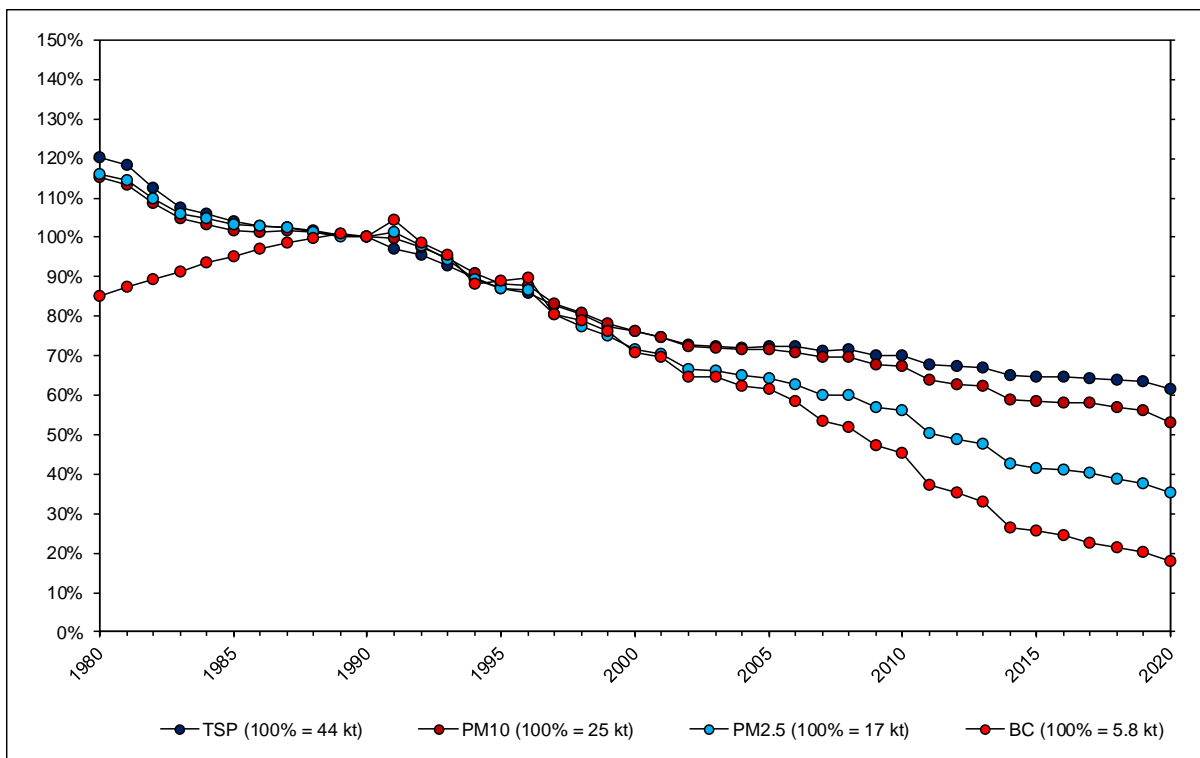


Figure 2-3: Total emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2020 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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

Year	PM2.5	PM10	TSP	BC
	kt	kt	kt	kt
1980	19	29	53	4.9
1985	17	26	46	5.5
1990	17	25	44	5.8
1995	14	22	39	5.1
2000	12	19	34	4.1
2005	11	18	32	3.5
2010	9.3	17	31	2.6
2011	8.3	16	30	2.1
2012	8.1	16	30	2.0
2013	7.9	16	30	1.9
2014	7.1	15	29	1.5
2015	6.9	15	29	1.5
2016	6.8	15	29	1.4
2017	6.7	15	28	1.3
2018	6.4	14	28	1.2
2019	6.2	14	28	1.2
2020	5.9	13	27	1.0
2020 vs. 2005 (%)	-45%	-26%	-15%	-71%

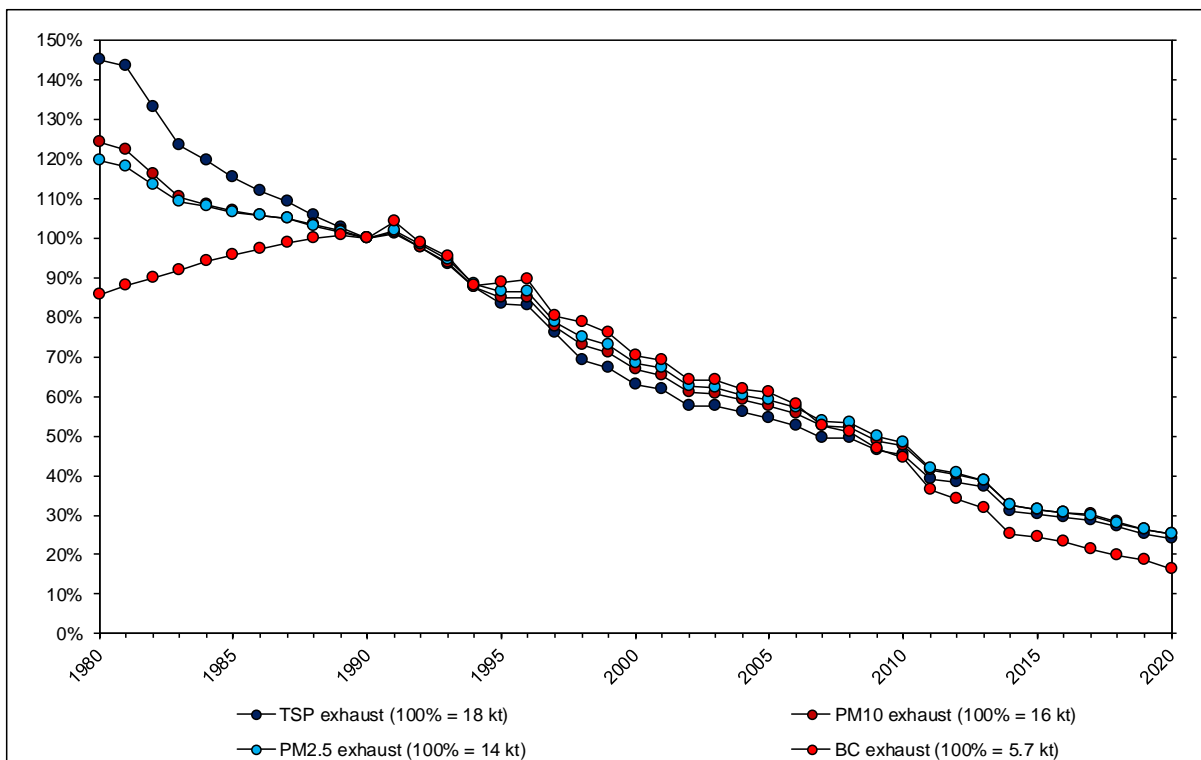


Figure 2-4: Exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2020 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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

Year	PM2.5 ex	PM10 ex	TSP ex	BC ex
	kt	kt	kt	kt
1980	17	20	26	4.9
1985	15	17	20	5.4
1990	14	16	18	5.7
1995	12	13	15	5.0
2000	9.7	11	11	4.0
2005	8.4	9.1	9.6	3.5
2010	6.9	7.5	7.9	2.5
2011	5.9	6.5	6.9	2.1
2012	5.7	6.4	6.7	1.9
2013	5.5	6.1	6.5	1.8
2014	4.6	5.1	5.4	1.4
2015	4.5	5.0	5.3	1.4
2016	4.3	4.8	5.1	1.3
2017	4.2	4.8	5.1	1.2
2018	4.0	4.5	4.8	1.1
2019	3.7	4.2	4.5	1.1
2020	3.5	4.0	4.3	0.94
2020 vs. 2005 (%)	-58%	-56%	-56%	-73%

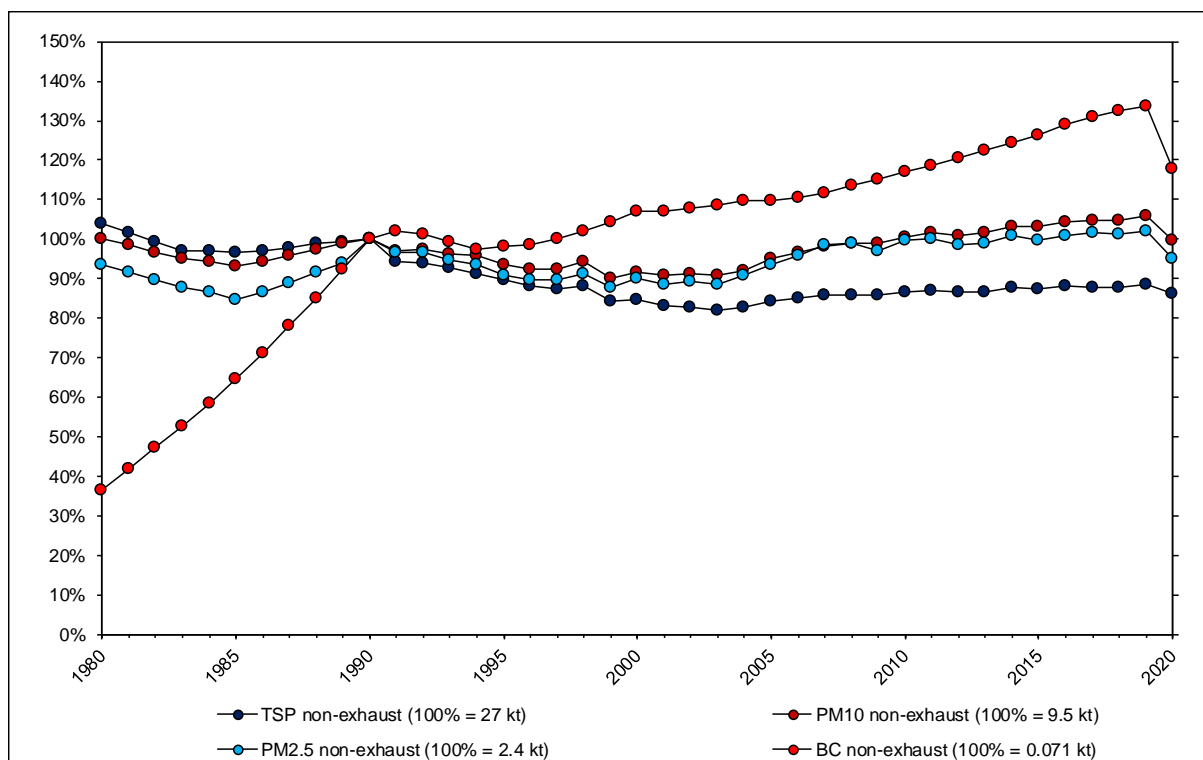


Figure 2-5: Non-exhaust emissions of suspended particulate matter TSP, PM10, PM2.5 and BC in Switzerland 1980–2020 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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

Year	PM2.5 nx	PM10 nx	TSP nx	BC nx
	kt	kt	kt	kt
1980	2.3	9.5	28	0.026
1985	2.1	8.8	26	0.046
1990	2.4	9.5	27	0.071
1995	2.2	8.8	24	0.069
2000	2.2	8.7	23	0.076
2005	2.3	9.0	23	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	9.8	23	0.088
2015	2.4	9.8	23	0.089
2016	2.5	9.9	23	0.091
2017	2.5	9.9	23	0.092
2018	2.5	9.9	23	0.093
2019	2.5	10.0	24	0.094
2020	2.3	9.4	23	0.083
2020 vs. 2005 (%)	1.5%	4.9%	2.2%	7.2%

2.2.3 Priority heavy metals

Between 1980 and 2003, emissions of priority heavy metals (Pb, Cd and Hg) show a pronounced decline (see Figure 2-6 and Table 2-6). The continuous decrease of the lead

content in gasoline and the final ban on leaded gasoline in 2000 resulted in an important decrease of Pb emissions. The decrease of Cd and Hg emissions is mainly due to the strict emission limit values for waste incineration plants. Since 2003, the decrease of heavy metals emissions is less pronounced.

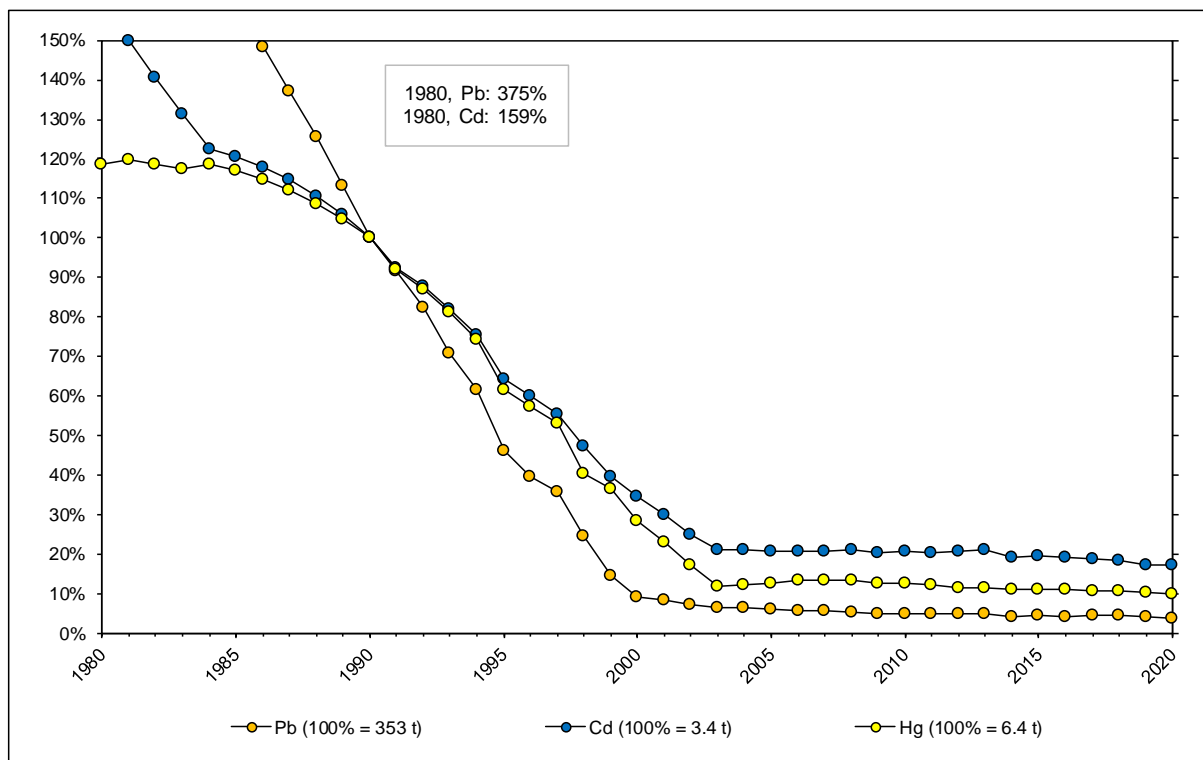


Figure 2-6: Emissions of priority heavy metals in Switzerland 1980–2020 (in percentage of 1990). Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

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

Year	Pb	Cd	Hg
	t	t	t
1980	1'326	5.4	7.6
1985	560	4.1	7.5
1990	353	3.4	6.4
1995	162	2.2	3.9
2000	32	1.2	1.8
2005	21	0.71	0.81
2010	17	0.71	0.81
2011	17	0.69	0.77
2012	17	0.71	0.74
2013	17	0.72	0.73
2014	15	0.66	0.70
2015	15	0.66	0.71
2016	15	0.65	0.70
2017	15	0.64	0.68
2018	15	0.63	0.67
2019	14	0.59	0.65
2020	14	0.59	0.64
2020 vs. 2005 (%)	-35%	-17%	-21%

2.2.4 Persistent organic pollutants (POPs)

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

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

Emissions of (total) PAH increased slightly in the period 1980-1989, but since then strongly decreased due to reduction measures for waste incineration plants and technological improvements of wood combustion installations in 1A Fuel combustion. In addition, the wood energy consumption decreased by more than half and increased by almost a factor of seven 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 single plant for secondary aluminium production in Switzerland which ceased in 1993. Since then, total HCB emissions remain on a generally low level with a slight further decrease. The remaining sources of HCB emissions are waste incineration plants in source category 1A1 Energy industries, all wood combustion installations and with a smaller share the use of coal (other bituminous coal and lignite) in 1A Fuel combustion. The annual fluctuations in HCB emissions are due to the wood consumption in 1A4bi Residential: Stationary which is strongly influenced by climate variabilities, in particular by the winter mean temperatures.

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

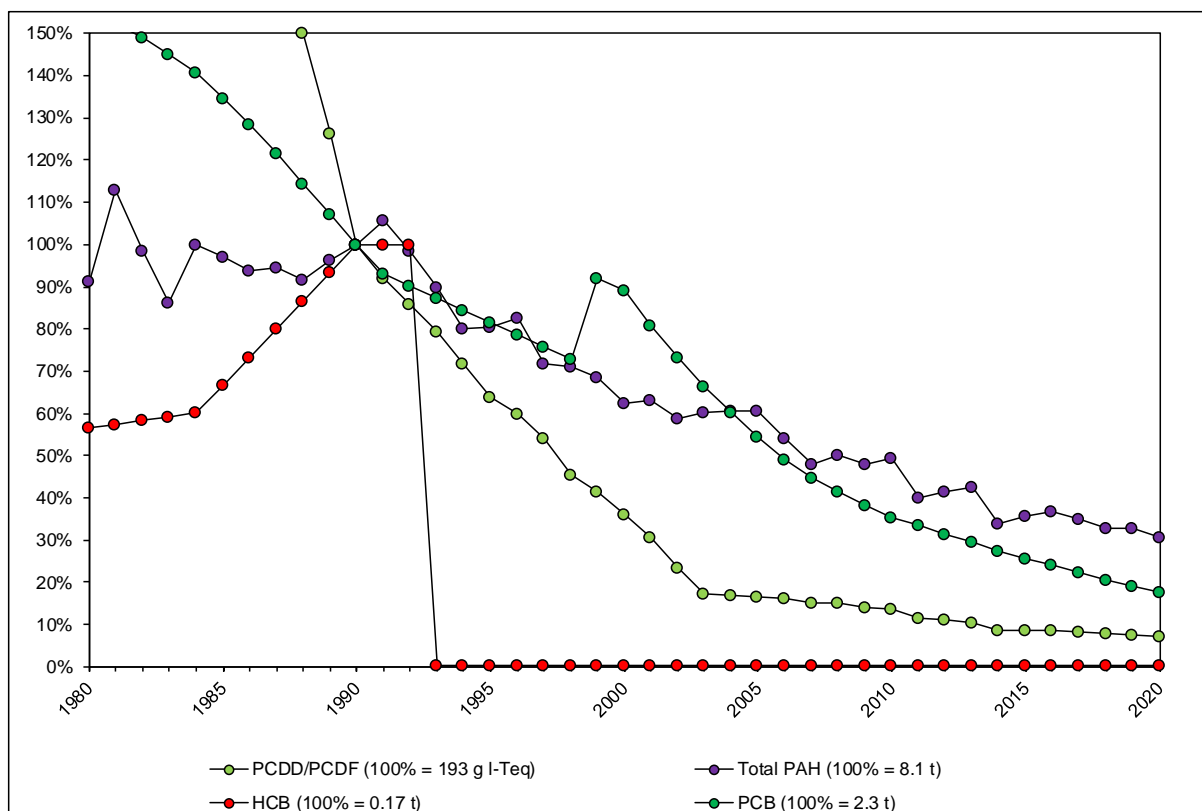


Figure 2-7: Emissions of POPs Annex III¹: PAH – as the sum of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene – PCDD/PCDF, HCB and PCB in Switzerland 1980–2020. Note that values for PCDD/PCDF before 1988 are not displayed here but illustrated in the table below. Potential discrepancies between the values before 1990 and those afterwards result from higher data availability after 1990.

Table 2-7: Total emissions of POPs Annex III (see footnote 1, p. 54). 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	27	1.3	1.3	0.77	0.70	4.0	0.45	0.83
2011	22	1.0	1.1	0.63	0.57	3.3	0.39	0.78
2012	21	1.0	1.1	0.65	0.59	3.4	0.40	0.73
2013	20	1.1	1.1	0.67	0.60	3.4	0.40	0.69
2014	17	0.84	0.89	0.54	0.48	2.8	0.35	0.64
2015	17	0.89	0.93	0.57	0.51	2.9	0.36	0.60
2016	17	0.91	0.96	0.59	0.53	3.0	0.38	0.56
2017	16	0.86	0.91	0.57	0.51	2.8	0.37	0.52
2018	15	0.81	0.86	0.54	0.48	2.7	0.36	0.48
2019	15	0.80	0.85	0.53	0.47	2.7	0.36	0.44
2020	14	0.76	0.80	0.50	0.44	2.5	0.35	0.41
2020 vs. 2005 (%)	-56%	-47%	-50%	-52%	-46%	-49%	-21%	-68%

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

2.3 Trends of main pollutants per gas and sectors

2.3.1 Trends for NO_x

Switzerland's emissions of NO_x (sum of NO and NO₂, expressed as NO₂ 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 2020.

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

- The reductions in 1A3b Road transportation were triggered by the implementation of new strict emission standards for road vehicles. The first step happened in the late 80's, when Switzerland improved the standards by setting a lower emission 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 years before 2015 because of an increasing share of diesel-powered passenger cars and higher emission factors than expected (the "dieselgate" scandal², detected in the year 2015). In 2020, the COVID-19 pandemic led to a strong reduction of NO_x emissions from road transportation due to reduced traffic volumes.
- The reductions in 1A2 Manufacturing industries and construction were a result of three main factors: First, there has been a fuel switch from residual fuel oil, coal and gas oil towards natural gas and a reduction in total fuel use since 2008 caused by the introduction of the incentive tax on fossil combustible fuels. Second, a reduction has been reached due to an on-going sectoral agreement (from 1998) targeting NO_x emissions of the cement industry. Third, manufacturing plants reduced NO_x emissions through technical improvements (e.g. DeNO_x technology, selective non-catalytic reduction technology SNCR).
- In the past, the number of buildings and apartments increased, as well as the average floor space per person and workplace. Both phenomena resulted in an increase of the total heated area. On the 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 2020). These two effects compensated for the additional heated area, and lead to a reduction of NO_x emissions under category 1A4 Other sectors.
- NO_x emissions from Agriculture decrease quite strongly, especially between 1990 and 2005. This was mainly due to a reduction and thus N excretions of livestock (-17 % between 1990 and 2020) and a strong decrease of N fertilizer use (-38 % N applied between 1990 and 2020) due to nutrient balance restrictions.

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 [05.02.2022]

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

NO _x emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	135	89	79	48	-56	-40	-45%	92%
1A Fuel combustion	135	88	79	48	-56	-40	-45%	92%
1A1 Energy industries	6.8	2.9	3.0	2.4	-3.8	-0.53	-18%	4.6%
1A2 Manufacturing industries	23	14	12	7.3	-11	-7.1	-49%	14%
1A3 Transport	83	54	49	29	-34	-25	-46%	56%
1A4 Other sectors	21	16	14	8.9	-6.9	-7.4	-45%	17%
1A5 Other (Military)	0.88	0.60	0.54	0.40	-0.34	-0.21	-34%	0.75%
1B Fugitive emissions from fuels	0.21	0.29	0.11	0.0017	-0.099	-0.29	-99%	0.0033%
2 IPPU	0.49	0.32	0.38	0.23	-0.11	-0.086	-27%	0.44%
3 Agriculture	4.9	3.8	4.0	3.6	-0.97	-0.22	-5.7%	6.9%
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.30	0.16	0.15	0.12	-0.15	-0.037	-23.1%	0.24%
6 Other	0.084	0.090	0.098	0.091	0.014	0.0013	1.5%	0.17%
National total for compliance	141	93	83	53	-57	-40	-44%	100%
Gothenburg Protocol	2010				Gothenburg Protocol revised 2005-2020			
Emission ceiling / reduction	79				-41%			

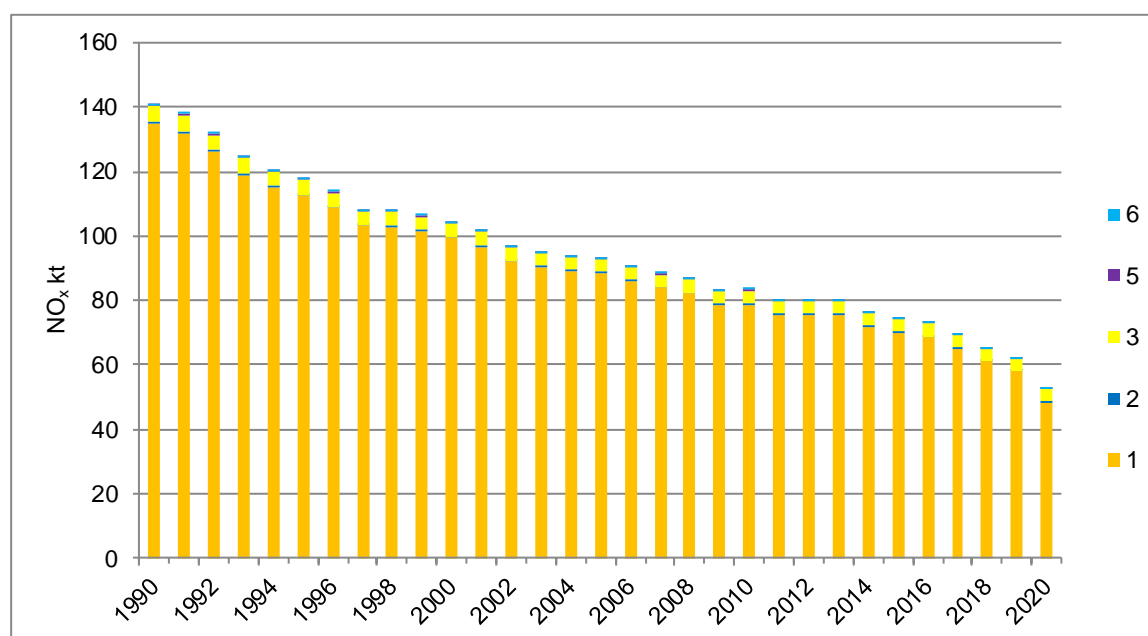


Figure 2-8: Trend of NO_x emissions (kt) in Switzerland by sector.

2.3.2 Trends for NMVOC

Switzerland’s emissions of NMVOC mainly stem from the sectors 2 IPPU, 3 Agriculture and 1 Energy. The trend of NMVOC emissions per sector is given in Table 2-9 and Figure 2-9. The NMVOC emissions have decreased in the time span 1990-2020.

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 population growth and the associated increase in product use (e.g. cosmetics, toiletries, cleaning agents and care products), the general trend of NMVOC emissions from sector 2 IPPU was still slightly decreasing from 2004-2020. This was mainly a result of reduced emissions caused by the ordinance on the VOC incentive tax (enactment of the tax in 2000 and revision in 2012).

- In sector 1 Energy, the emission reduction was mainly influenced from category 1A3b Road transportation, in particular resulting from the higher Euro standards for passenger cars (Euro 1 in 1993, Euro 2 in 1995, Euro 3 in 2000, Euro 4 in 2005, Euro 5 in 2009 and Euro 6 in 2014). Furthermore, the share of diesel oil in fuels used under 1A3b has increased compared to gasoline between 1990 and 2020, which leads to a decrease of NMVOC emissions. In 2020, the COVID-19 pandemic led to a reduction of NMVOC emissions from road transportation due to reduced traffic volumes.
- NMVOC emissions of source category 1A4 Other sectors declined in the same period as well due 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 significant increase between 2000 and 2008 and have remained at about constant level since 2014. They depend on the number of livestock, in particular the number of cattle receiving silage feeding. Thus, the emission increase is mainly due to the increase in non-dairy cattle which predominately are fed by silage.

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

NMVOC emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	125	40	29	15	-96	-26	-64%	19%
1A Fuel combustion	108	36	26	13	-82	-23	-64%	17%
1A1 Energy industries	0.30	0.22	0.20	0.18	-0.11	-0.043	-19%	0.24%
1A2 Manufacturing industries	2.4	2.1	1.6	0.91	-0.78	-1.1	-56%	1.2%
1A3 Transport	89	23	16	7.3	-73	-16	-68%	10%
1A4 Other sectors	16	10	8.3	4.5	-7.8	-6.0	-57%	6.0%
1A5 Other (Military)	0.16	0.11	0.090	0.063	-0.070	-0.046	-42%	0.084%
1B Fugitive emissions from fuels	17	4.5	2.7	1.7	-14	-2.8	-63%	2.2%
2 IPPU	151	53	49	40	-101	-13	-25%	53%
3 Agriculture	15	17	19	19	3.3	2.0	12%	25%
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	1.1	1.0	1.2	1.7	0.044	0.68	66%	2.3%
6 Other	0.19	0.19	0.20	0.20	0.016	0.010	5.0%	0.27%
National total for compliance	292	111	98	75	-195	-36	-32%	100%
Gothenburg Protocol			2010			Gothenburg Protocol revised		2005-2020
Emission ceiling / reduction			144					-30%

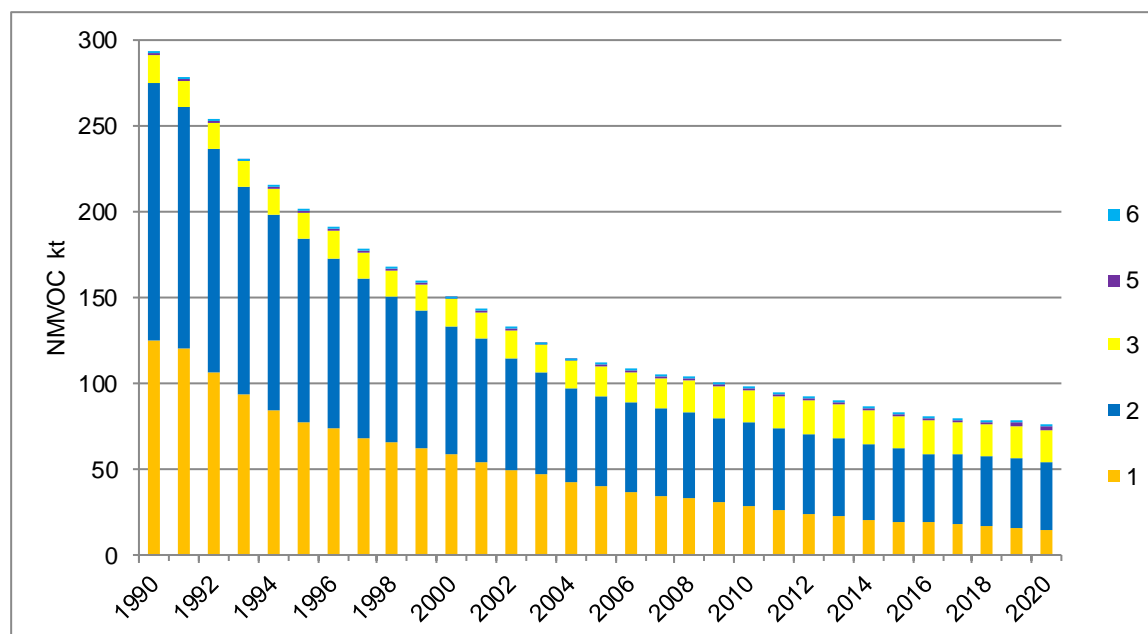


Figure 2-9: Trend of NMVOC emissions (kt) in Switzerland by sector.

2.3.3 Trends for SO_x

Switzerland's emissions of SO_x (sum of SO₂ and SO₃, expressed as SO₂ 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 2020.

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

- First, the Ordinance on Air Pollution Control (Swiss Confederation 1985) introduced a limitation of the sulphur content in fuels, with further stepwise lowering in 1993, 1999, 2000, 2005 and 2009 (Table 3-9). These stringent measures resulted in a significant decrease of the sulphur oxide emissions from fuel combustible under 1A3 Transport and 1A4 Other sectors (gas oil, diesel oil and gasoline, see Table 3-9).
- Second, a substantial substitution of gas oil with natural gas and eco-grade gas oil (with low sulphur and nitrogen content, from 2006 onwards) under 1A4 Other sectors resulted in further reductions of sulphur emissions (natural gas consumption almost doubled from 1990 to 2020).
- Third, a similar substitution of residual fuel oil, coal and gas oil by natural gas has reduced sulphur emissions as well in 1A2 Manufacturing industries (i.e. coal and residual fuel oil from 1990, gas oil from about 2005 onwards).

In addition, SO_x emissions from 2C Metal production strongly declined between 1990 and 2007, mainly following the decrease in aluminium production volume, which was ceased in 2006. SO_x emissions of sector 2B Chemical industry show no clear trend in the period 1990–2020. They stem predominately from the sulphur content of the raw materials of the graphite and silicon carbide production (petroleum coke and other bituminous coal) and reflect thus, the production volumes.

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

SO _x emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	35	13	9.6	3.2	-25	-9.6	-75%	85%
1A Fuel combustion	34	12	9.4	3.2	-25	-9.2	-74%	85%
1A1 Energy industries	4.2	1.7	1.7	0.29	-2.5	-1.4	-83%	7.6%
1A2 Manufacturing industries	13	4.1	3.0	1.9	-9.8	-2.3	-55%	49%
1A3 Transport	4.0	0.21	0.23	0.13	-3.8	-0.077	-36%	3.6%
1A4 Other sectors	13	6.3	4.5	0.90	-8.8	-5.4	-86%	24%
1A5 Other (Military)	0.077	0.037	0.037	0.032	-0.041	-0.0060	-16%	0.83%
1B Fugitive emissions from fuels	0.72	0.51	0.22	0.017	-0.50	-0.50	-97%	0.44%
2 IPPU	1.5	1.1	0.79	0.52	-0.67	-0.55	-51%	14%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.16	0.063	0.063	0.030	-0.10	-0.034	-53%	0.79%
6 Other	0.010	0.011	0.010	0.010	-0.00015	-0.00059	-5.5%	0.27%
National total for compliance	37	14	10	3.8	-26	-10	-73%	100%
Gothenburg Protocol			2010			Gothenburg Protocol revised	2005-2020	
Emission ceiling / reduction			26				-21%	

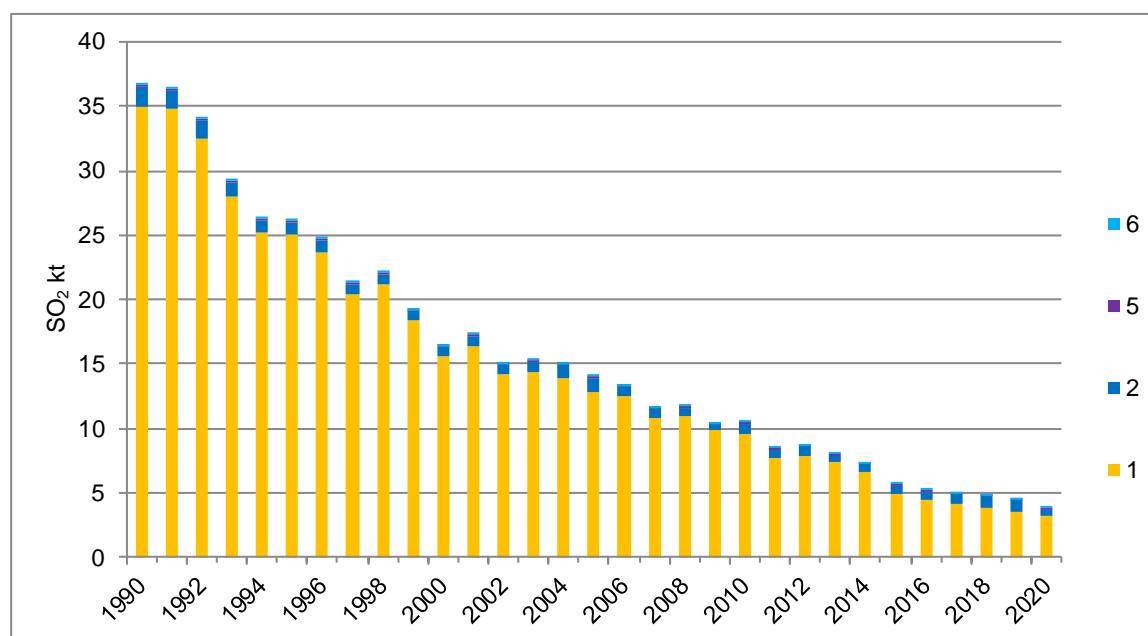


Figure 2-10: Trend of SO_x emissions (kt) in Switzerland by sector (SO_x as sum of SO₂ and SO₃, expressed as SO₂ equivalents).

2.3.4 Trends for NH₃

Switzerland’s emissions of NH₃ mainly stem from sector 3 Agriculture. The trend of NH₃ emissions per sector is given in Table 2-11 and Figure 2-11. NH₃ emissions show a decreasing trend between 1990 and 2020.

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 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 non-monotonic trend results from a combination of changes in animal numbers, introduction of new housing systems and more grazing due to developments in animal welfare regulations, increase of animal productivity and changes in production techniques and a considerable decrease of N fertilizer use due to nutrient balance restrictions (Kupper et al. 2018). As mentioned for NO_x

emissions in chapter 2.3.1, N excretions of livestock decreased by 17 % and the amount of N applied in mineral fertilizer by -38 % N applied between 1990 and 2020).

Table 2-11: NH₃ 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	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	1.7	3.9	2.8	1.2	1.1	-2.7	-69%	2.3%
1A Fuel combustion	1.7	3.9	2.8	1.2	1.1	-2.7	-69%	2.3%
1A1 Energy industries	0.0047	0.026	0.035	0.033	0.030	0.0077	30%	0.063%
1A2 Manufacturing industries	0.17	0.19	0.24	0.20	0.076	0.0055	2.8%	0.38%
1A3 Transport	1.3	3.5	2.4	0.9	1.1	-2.7	-76%	1.6%
1A4 Other sectors	0.21	0.16	0.16	0.12	-0.043	-0.040	-24%	0.23%
1A5 Other (Military)	0.000037	0.000039	0.000042	0.000041	0.0000048	0.0000013	3.4%	0.000076%
1B Fugitive emissions from fuels	NA	NA	NA	NA	-	-	-	-
2 IPPU	0.37	0.35	0.21	0.15	-0.16	-0.20	-57%	0.28%
3 Agriculture	65	54	53	50	-12	-3.6	-6.7%	94%
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.91	0.93	0.89	0.88	-0.023	-0.045	-4.8%	1.7%
6 Other	0.85	0.88	0.92	1.0	0.073	0.080	9.1%	1.8%
National total for compliance	69	60	58	53	-11	-6.4	-11%	100%
Gothenburg Protocol					Gothenburg Protocol revised			
Emission ceiling / reduction	2010 63				2005-2020 -8.0%			

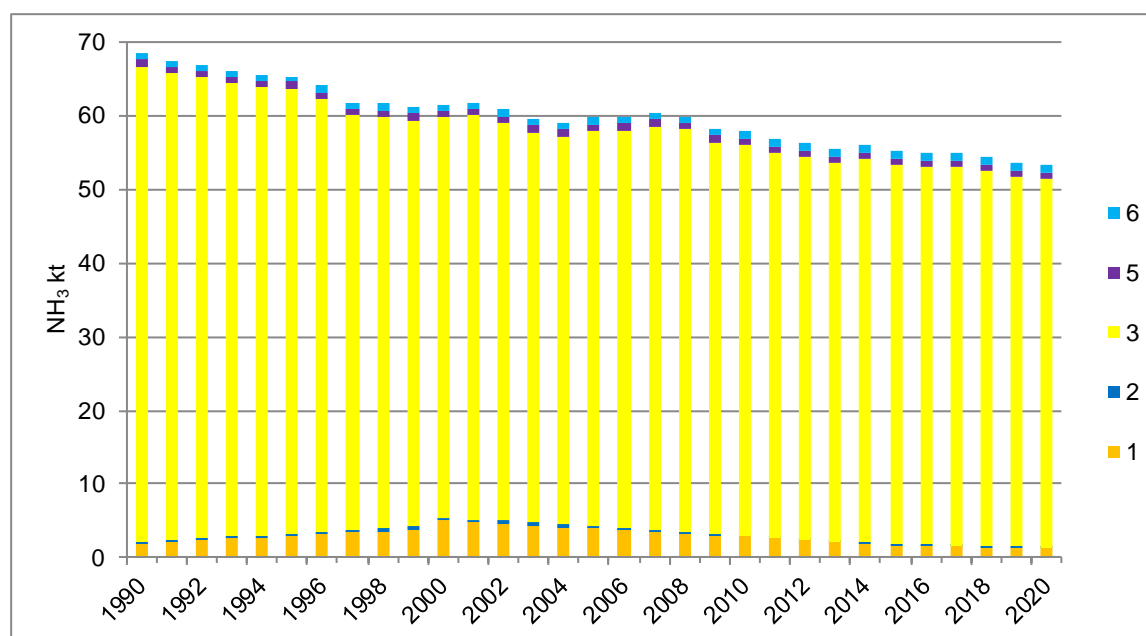


Figure 2-11: Trend of NH₃ emissions (kt) in Switzerland by sector.

2.4 Trends of particulate matter per pollutant

2.4.1 Features commonly holding for all particulate matter fractions PM_{2.5}, PM₁₀, TSP and BC

Switzerland's emissions of particulate matter (PM_{2.5}, 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 PM_{2.5}, in Table 2-13 for PM₁₀, in Table 2-14 to Table 2-16 for TSP and in Table 2-17 for BC. All total particulate matter emissions – except from sector 3 Agriculture – show decreasing trends from 1990 on.

The observed reduction of emissions in PM_{2.5}, PM₁₀, TSP and BC were achieved in sectors 1 Energy and 2 IPPU. In the energy sector, the decline can be mainly attributed to a reduction of exhaust particulate matter emissions. The following measures contributed to the reduction of particulate matter emissions:

- A reduction of exhaust emissions under 1A4 Other sectors was due to technological improvements of wood combustion installations and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, the wood energy consumption decreased by more than half and increased by almost a factor of seven in manually operated furnaces and automatic combustion installations (mainly in 1A1, 1A2), respectively. Furthermore, the revision of the Ordinance of Air Pollution (Swiss Confederation 1985) in 2007 introduced more stringent emission limits (2007, 2008 and 2012) for mainly automatic wood combustion installations.
- A further reduction of exhaust emissions under 1A3 Transport was caused by the abatement of exhaust emissions from road vehicles. Throughout the years, a continuous reduction of these emissions has been achieved with the stepwise adoption of the Euro standards. New diesel cars must be equipped with diesel particle filters.
- Particulate matter emissions from sector 2 Industrial processes and product use 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 PM_{2.5}

Switzerland's emissions of PM_{2.5} per sector are given in Table 2-12. In addition to the main trends mentioned in chp. 2.4.1, there is an underlying increasing trend of non-exhaust particulate emissions mainly driven by non-exhaust emissions from passenger cars (1A3bi) and non-road vehicles and machines in manufacturing industry and construction (1A2gvii). This increase in absolute values is more distinctive for TSP and PM₁₀ than for PM_{2.5} (see chp. 2.4.4). In 2020, despite this underlying increasing trend, the COVID-19 pandemic led to a reduction of non-exhaust PM_{2.5} emissions from road transportation due to reduced traffic volumes.

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

PM2.5 emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	13	8.7	7.3	4.2	-6.0	-4.5	-52%	72%
1A Fuel combustion	13	8.7	7.3	4.2	-6.0	-4.5	-52%	72%
1A1 Energy industries	0.82	0.18	0.19	0.060	-0.64	-0.12	-67%	1.0%
1A2 Manufacturing industries	2.0	1.5	1.1	0.62	-0.86	-0.90	-59%	11%
1A3 Transport	3.7	2.8	2.4	1.4	-1.4	-1.5	-52%	23%
1A4 Other sectors	6.7	4.1	3.6	2.1	-3.1	-2.0	-48%	36%
1A5 Other (Military)	0.087	0.057	0.050	0.045	-0.037	-0.012	-21%	0.76%
1B Fugitive emissions from fuels	0.00060	0.000663	0.000310	0.000049	-0.000293	-0.000614	-93%	0.00084%
2 IPPU	2.6	1.5	1.5	1.2	-1.1	-0.26	-18%	21%
3 Agriculture	0.12	0.13	0.14	0.14	0.015	0.015	12%	2.5%
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.59	0.38	0.36	0.29	-0.22	-0.087	-23%	5.0%
6 Other	0.0042	0.0041	0.0048	0.0053	0.00063	0.0012	28%	0.091%
National total for compliance	17	11	9.3	5.9	-7.3	-4.8	-45%	100%
Gothenburg Protocol			2010			Gothenburg Protocol revised		2005-2020
Emission ceiling / reduction			79					-26%

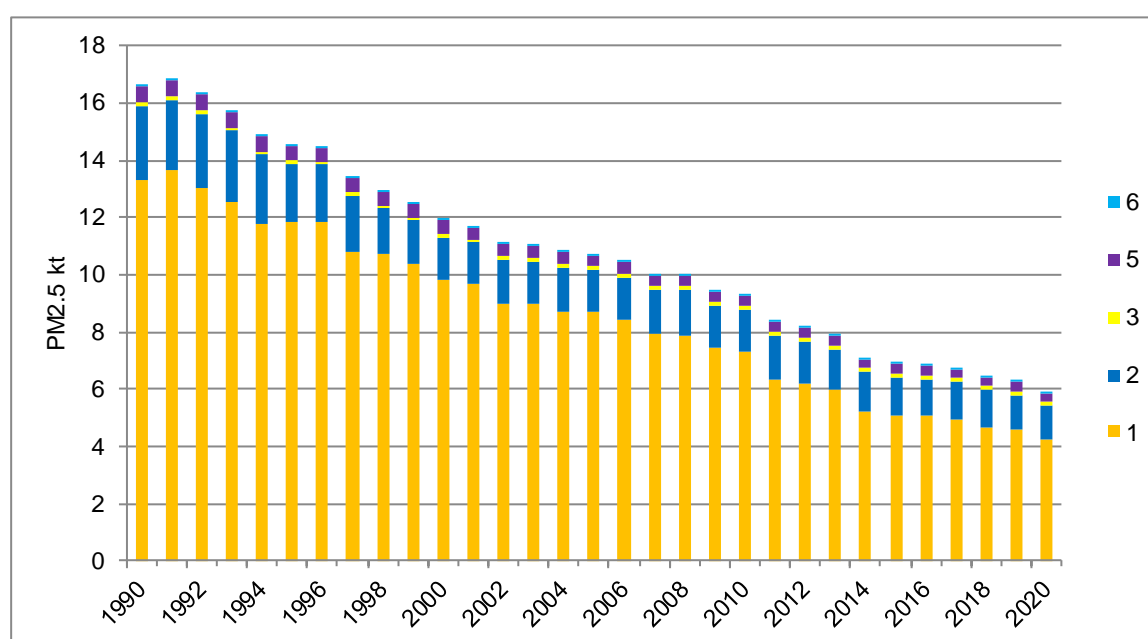


Figure 2-12: Trend of PM2.5 emissions (kt) in Switzerland by sector.

2.4.3 Trends for PM10

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

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

PM10 emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	18	14	12	9.2	-5.8	-4.3	-32%	69%
1A Fuel combustion	18	14	12	9.2	-5.8	-4.3	-32%	69%
1A1 Energy industries	1.1	0.19	0.19	0.061	-0.89	-0.12	-67%	0.45%
1A2 Manufacturing industries	3.9	3.4	3.0	2.6	-0.84	-0.79	-23%	19%
1A3 Transport	5.9	5.4	5.1	4.0	-0.82	-1.3	-25%	30%
1A4 Other sectors	7.1	4.3	3.8	2.3	-3.2	-2.1	-48%	17%
1A5 Other (Military)	0.29	0.27	0.27	0.26	-0.018	-0.0041	-1.6%	1.9%
1B Fugitive emissions from fuels	0.0020	0.00129	0.00098	0.00046	-0.00107	-0.00083	-65%	0.0034%
2 IPPU	4.5	2.3	2.3	1.9	-2.2	-0.35	-15%	14%
3 Agriculture	1.7	1.7	1.7	1.8	0.020	0.11	6.7%	13%
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.66	0.42	0.41	0.33	-0.26	-0.097	-23%	2.4%
6 Other	0.20	0.20	0.18	0.17	-0.024	-0.031	-16%	1.2%
National total for compliance	25	18	17	13	-8.2	-4.7	-26%	100%

2.4.4 Trends for TSP

Switzerland's emissions of TSP per sector are given in Table 2-14. In addition to the main (mostly) decreasing trends mentioned in chp. 2.4.1, there is an underlying increasing trend in TSP due to non-exhaust particulate emissions from growing activity data (annual mileage and machine hours) of mobile sources 1A3 and 1A2gvii which affects larger particle emissions (TSP and PM10) more than PM2.5 (see Table 2-16 and Figure 2-13). This is due to a larger share of non-exhaust emissions with a particle diameter of 10 micrometres and larger. Therefore, the overall decreasing trend in TSP emissions is less pronounced as compared to the decrease in PM2.5 emissions. An additional factor to be considered when comparing the decreasing trend of TSP with PM10 and PM2.5 is the contribution of sector 3 Agriculture to non-exhaust TSP emissions. Its dominant emission sources are soil cultivation and crop harvesting reported in 3De Cultivated crops. These emissions remained on a rather constant level since 1990 and account for a high share of TSP emissions. In comparison, non-exhaust PM10 and PM2.5 emissions from the agriculture sector contribute less. Accordingly, the (relative) decreasing trend of TSP is less pronounced than of PM10 and PM2.5. In 2020, despite this underlying increasing trend, the COVID-19 pandemic led to a reduction of non-exhaust PM emissions from road transportation due to reduced traffic volumes.

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

TSP total emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	20	15	14	11	-6.1	-4.3	-28%	41%
1A Fuel combustion	20	15	14	11	-6.1	-4.3	-28%	41%
1A1 Energy industries	1.1	0.20	0.21	0.064	-0.90	-0.14	-68%	0.24%
1A2 Manufacturing industries	5.2	4.5	4.1	3.8	-1.0	-0.70	-16%	14%
1A3 Transport	6.2	5.8	5.5	4.4	-0.70	-1.32	-23%	16%
1A4 Other sectors	7.5	4.6	4.1	2.4	-3.4	-2.2	-48%	8.8%
1A5 Other (Military)	0.40	0.39	0.40	0.39	-0.0054	0.00073	0.19%	1.4%
1B Fugitive emissions from fuels	0.0045	0.0023	0.0021	0.0011	-0.0024	-0.00120	-51%	0.0042%
2 IPPU	9.9	3.4	3.5	3.0	-6.5	-0.44	-13%	11%
3 Agriculture	13	13	13	13	-0.31	0.092	0.74%	46%
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.81	0.52	0.49	0.40	-0.32	-0.12	-23%	1.5%
6 Other	0.25	0.25	0.23	0.21	-0.021	-0.034	-14%	0.79%
National total for compliance	44	32	31	27	-13	-4.8	-15%	100%

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

TSP exhaust emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	14	8.0	6.4	3.0	-7.6	-5.0	-62%	72%
1A Fuel combustion	14	8.0	6.4	3.0	-7.6	-5.0	-62%	72%
1A1 Energy industries	1.1	0.20	0.21	0.064	-0.90	-0.14	-68%	1.5%
1A2 Manufacturing industries	2.6	1.4	0.93	0.34	-1.7	-1.1	-76%	7.9%
1A3 Transport	2.9	1.9	1.3	0.36	-1.6	-1.5	-81%	8.4%
1A4 Other sectors	7.3	4.5	3.9	2.3	-3.4	-2.2	-49%	54%
1A5 Other (Military)	0.057	0.020	0.012	0.0066	-0.044	-0.014	-68%	0.15%
1B Fugitive emissions from fuels	0.00044	NA	NA	NA	-	-	-	-
2 IPPU	2.5	0.85	0.81	0.62	-1.7	-0.23	-27%	15%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.81	0.51	0.49	0.40	-0.32	-0.12	-23%	9.3%
6 Other	0.24	0.23	0.21	0.19	-0.034	-0.039	-17%	4.5%
National total for compliance	18	9.6	7.9	4.3	-9.7	-5.3	-56%	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	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	6.4	7.4	7.9	8.0	1.5	0.61	8%	35%
1A Fuel combustion	6.4	7.4	7.9	8.0	1.5	0.61	8%	35%
1A1 Energy industries	NA	NA	NA	NA	-	-	-	-
1A2 Manufacturing industries	2.6	3.0	3.2	3.4	0.61	0.40	13%	15%
1A3 Transport	3.3	3.9	4.2	4.1	0.87	0.21	6%	18%
1A4 Other sectors	0.13	0.12	0.11	0.10	-0.021	-0.016	-13%	0.45%
1A5 Other (Military)	0.34	0.37	0.38	0.38	0.039	0.015	4.0%	1.7%
1B Fugitive emissions from fuels	0.0040	0.0017	0.0019	0.0011	-0.0022	-0.00061	-35%	0.0049%
2 IPPU	7.4	2.6	2.7	2.4	-4.7	-0.21	-8.2%	10%
3 Agriculture	13	13	13	13	-0.31	0.092	0.74%	55%
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.0034	0.0036	0.0036	0.0036	0.00024	0.0000	0.0%	0.016%
6 Other	0.0072	0.017	0.020	0.022	0.013	0.0050	29%	0.096%
National total for compliance	27	23	23	23	-3.5	0.49	2.2%	100%

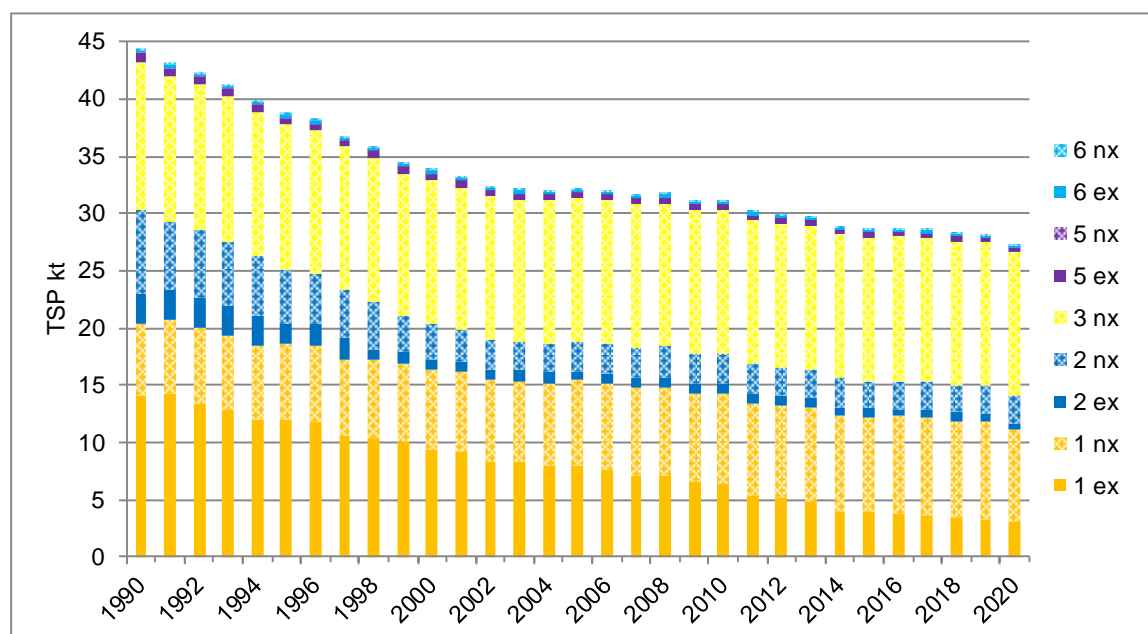


Figure 2-13: Trend of TSP emissions (kt) in Switzerland for sectors 1-6 splitted in exhaust (ex) and non-exhaust (nx) fraction. Non-exhaust emissions cross-hatched.

2.4.5 Trends for BC

Switzerland's emissions of BC mainly stem from sector 1 Energy, especially from stationary combustion in category 1A4bi Residential. The trend of BC emissions per sector is given in Table 2-17. BC emissions have decreased throughout the time period 1990-2020.

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

BC emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	5.7	3.5	2.6	1.0	-3.1	-2.5	-72%	98%
1A Fuel combustion	5.7	3.5	2.6	1.0	-3.1	-2.5	-72%	98%
1A1 Energy industries	0.036	0.012	0.011	0.0029	-0.025	-0.0087	-75%	0.28%
1A2 Manufacturing industries	0.42	0.32	0.14	0.044	-0.28	-0.27	-86%	4.3%
1A3 Transport	1.4	1.2	0.92	0.26	-0.50	-0.99	-79%	26%
1A4 Other sectors	3.8	1.9	1.5	0.69	-2.3	-1.2	-64%	67%
1A5 Other (Military)	0.026	0.0099	0.0058	0.0032	-0.020	-0.0067	-68%	0.31%
1B Fugitive emissions from fuels	0.00020	0.000184	0.000101	0.000028	-0.00010	-0.000156	-85%	0.0028%
2 IPPU	0.0063	0.0026	0.0016	0.0013	-0.0047	-0.0013	-49%	0.13%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.041	0.027	0.026	0.021	-0.016	-0.0061	-22%	2.1%
6 Other	0.00014	0.00014	0.00012	0.00012	-0.000019	-0.000022	-16%	0.011%
National total for compliance	5.8	3.5	2.6	1.0	-3.1	-2.5	-71%	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 1990-2020.

The relevant reductions were achieved in sector 1 Energy:

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

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

CO emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kt	kt	kt	kt	kt	kt	%	%
1 Energy	741	295	235	136	-506	-159	-54%	93%
1A Fuel combustion	741	295	235	136	-506	-159	-54%	93%
1A1 Energy industries	1.3	1.0	1.0	0.57	-0.34	-0.39	-41%	0.39%
1A2 Manufacturing industries	27	21	20	16	-7.2	-5.4	-26%	11%
1A3 Transport	550	166	122	61	-429	-105	-63%	42%
1A4 Other sectors	161	106	91	58	-70	-48	-45%	39%
1A5 Other (Military)	1.2	0.92	0.87	0.75	-0.34	-0.17	-18%	0.52%
1B Fugitive emissions from fuels	0.066	0.089	0.035	0.00054	-0.031	-0.088	-99%	0.00037%
2 IPPU	11	8.1	7.2	8.4	-3.9	0.24	3.0%	5.7%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	2.8	1.9	1.7	1.5	-1.1	-0.47	-24%	0.99%
6 Other	0.80	0.76	0.69	0.63	-0.11	-0.13	-18%	0.43%
National total for compliance	756	305	244	146	-512	-159	-52%	100%

2.6 Trends of priority heavy metals per pollutant

2.6.1 Lead (Pb)

Switzerland's emissions of Pb mainly stem from the sectors 1 Energy and 6 Other (from 2000 onwards). The trend of Pb emissions per sector is given in Table 2-19. Pb emissions have strongly declined between 1990 and 2000 and from then on continued a slightly decreasing trend.

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

- A pronounced decrease of Pb emissions in the energy sector (in particular 1A3b Road transportation) was achieved due to a stepwise reduction of lead content in gasoline, and finally due to the introduction of unleaded gasoline in the OAPC revision of the year 2000 (see Figure 2-1).
- Further measures that resulted in a significant decrease of the emissions under 2C1 Iron and steel production were the closing down of two production sites 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 by improving the already installed technology.

Since 2000, the emissions further decrease on a lower level. The main reductions in this time period were achieved in the sectors 2 IPPU (i.e. ban of Pb in fireworks (2G) in 2003) and 1 Energy, specifically source category 1A2f Non-metallic minerals (dominated by the emission reduction in container glass production due to reduced lead contamination of the glass cullet and installation of electrofilters in 2011) as well as 1A3b Road transportation due to a higher share of diesel oil in comparison to gasoline 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	2020	1990-2010	2005-2020	2005-2020	share in 2020
	t	t	t	t	t	t	%	%
1 Energy	275	9.9	8.2	5.7	-267	-4.2	-42%	42%
1A Fuel combustion	271	9.9	8.2	5.7	-263	-4.2	-42%	42%
1A1 Energy industries	30	1.9	1.8	1.7	-28	-0.28	-14%	12%
1A2 Manufacturing industries	6.3	2.7	1.8	0.86	-4.5	-1.8	-68%	6.3%
1A3 Transport	231	4.3	3.7	2.6	-228	-1.7	-40%	19%
1A4 Other sectors	3.8	0.96	0.92	0.62	-2.8	-0.35	-36%	4.5%
1A5 Other (Military)	0.032	0.00045	0.00043	0.00039	-0.032	-0.000062	-14%	0.0028%
1B Fugitive emissions from fuels	3.5	0.0011	0.00043	0.000065	–	–	–	–
2 IPPU	67	2.1	0.69	0.57	-66	-1.5	-73%	4.2%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	4.3	2.3	2.3	1.7	-2.0	-0.58	-25%	13%
6 Other	6.8	6.6	6.0	5.6	-0.76	-0.95	-14%	41%
National total for compliance	353	21	17	14	-336	-7.2	-35%	100%

2.6.2 Cadmium (Cd)

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

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

- By equipping municipal solid waste incineration plants with flue gas treatment or by improving the already installed technologies, a significant reduction has been achieved in the period 1990–2003 under category 1A1a. In contrast, since 2003, emissions from 1A1a and 1A3b increased due to the increase of municipal solid waste incineration and of mileage (exhaust emissions from vehicles), respectively.
- A significant reduction occurred also in source category 1A2 Manufacturing industries dominated by an emission decrease in the production of mixed goods (1A2f). (Please note that Cd emission measurements are extremely limited and thus these emissions are associated with a high uncertainty.)
- Further measures, resulting in a significant decrease of emissions under 2C1 Iron and steel production, were the closing down of two production sites 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 decrease since 2013 is mainly due to continuous technical improvement in municipal solid waste incineration plants (source category 1A1a), but also in sewage sludge incineration plants (source category 5C1).

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

Cd emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	t	t	t	t	t	t	%	%
1 Energy	2.6	0.43	0.44	0.36	-2.2	-0.072	-17%	61%
1A Fuel combustion	2.6	0.43	0.44	0.36	-2.2	-0.071	-17%	61%
1A1 Energy industries	1.8	0.18	0.20	0.16	-1.6	-0.022	-12%	27%
1A2 Manufacturing industries	0.74	0.10	0.091	0.066	-0.65	-0.037	-36%	11%
1A3 Transport	0.069	0.077	0.083	0.083	0.013	0.0058	7.6%	14%
1A4 Other sectors	0.084	0.068	0.068	0.050	-0.017	-0.018	-27%	8.5%
1A5 Other (Military)	0.00048	0.00051	0.00054	0.00053	0.000058	0.000016	3.1%	0.090%
1B Fugitive emissions from fuels	0.001	0.0015	0.00058	0.000088	-0.001	-0.0015	-99%	0.0015%
2 IPPU	0.56	0.092	0.087	0.080	-0.47	-0.012	-13%	14%
3 Agriculture	NA	NA	NA	NA	–	–	–	–
4 LULUCF	NR	NR	NR	NR	–	–	–	–
5 Waste	0.047	0.021	0.027	0.0089	-0.020	-0.012	-58%	1.5%
6 Other	0.17	0.16	0.15	0.14	-0.019	-0.024	-14%	24%
National total for compliance	3.4	0.71	0.71	0.59	-2.7	-0.12	-17%	100%

2.6.3 Mercury (Hg)

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

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

- A significant reduction under category 1A1 has been achieved in the period 1990–2003 by equipping municipal solid waste incineration plants with flue gas treatment or by improving the already installed technology.
- The closing down of two production sites and the installation of new filters in the two remaining secondary steel production plants in 1998/1999 were the leading measures in reducing emissions under 2C1.

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

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

Hg emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	t	t	t	t	t	t	%	%
1 Energy	4.3	0.59	0.59	0.50	-3.7	-0.086	-15%	78%
1A Fuel combustion	4.3	0.59	0.59	0.50	-3.7	-0.086	-15%	78%
1A1 Energy industries	3.9	0.34	0.32	0.30	-3.6	-0.042	-12%	47%
1A2 Manufacturing industries	0.25	0.12	0.14	0.094	-0.11	-0.028	-23%	15%
1A3 Transport	0.034	0.037	0.037	0.030	0.0028	-0.0072	-19%	4.7%
1A4 Other sectors	0.089	0.085	0.093	0.077	0.0046	-0.0089	-10%	12%
1A5 Other (Military)	0.000027	0.000028	0.000030	0.000029	0.0000030	0.00000076	2.7%	0.0046%
1B Fugitive emissions from fuels	0.000	0.00025	0.00010	0.0000015	0.000	-0.00025	-99%	0.00023%
2 IPPU	1.5	0.067	0.066	0.048	-1.4	-0.019	-29%	7.4%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.52	0.077	0.081	0.029	-0.44	-0.048	-63%	4.5%
6 Other	0.080	0.076	0.069	0.063	-0.012	-0.013	-18%	10%
National total for compliance	6.4	0.81	0.81	0.64	-5.6	-0.17	-21%	100%

2.7 Trends of POPs

2.7.1 PCDD/PCDF

Switzerland's emissions of PCDD/PCDF mainly stem from sector 1 energy. The trend of PCDD/PCDF emissions per sector is given in Table 2-22. PCDD/PCDF emissions were significantly reduced between 1990 and 2003. From then on, the decrease continues on a lower level.

The significant decrease between 1990 and 2003 was mainly achieved in category 1A1a by retrofitting municipal solid waste incineration plants with flue gas treatment or by improving the already installed technology. Further reductions between 1990 and 2003 were achieved in source categories 5C1 Waste incineration (i.e. a continuous reduction of clinical waste incinerated at the hospital sites themselves which ceased in 2002 completely) and 2C1 Iron and steel production (i.e. closing down of two production sites 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 more than half).

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

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

PCDD/PCDF emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	g I-Teq	%	%
1 Energy	161	23	19	8.3	-142	-15	-64%	59%
1A Fuel combustion	161	23	19	8.3	-142	-15	-64%	59%
1A1 Energy industries	130	5.2	3.4	0.95	-127	-4.3	-82%	6.8%
1A2 Manufacturing industries	8.4	2.8	2.1	0.93	-6.3	-1.8	-67%	6.6%
1A3 Transport	1.6	1.7	1.7	0.52	0.10	-1.2	-70%	3.7%
1A4 Other sectors	20	13	12	5.9	-8.3	-7.6	-56%	42%
1A5 Other (Military)	0.00036	0.00038	0.00040	0.00039	0.000040	0.000010	2.6%	0.0028%
1B Fugitive emissions from fuels	0.00001	NA	NA	NA	-	-	-	-
2 IPPU	17	2.1	1.2	0.70	-16	-1.4	-67%	5.0%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	13	4.3	4.0	3.0	-9.2	-1.3	-30%	21%
6 Other	2.5	2.5	2.3	2.1	-0.29	-0.36	-14%	15%
National total for compliance	193	32	27	14	-167	-18	-56%	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 2020, except for 1A3b Road transportation, where PAH emissions increased in parallel with the increase of traffic volumes (except for 2020, where traffic volumes shrank due to the COVID-19 pandemic).

The PAH emissions are dominated by wood energy combustion and their reduction has mainly been achieved in the dominant source category 1A4, through technological improvements of wood furnaces and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, the wood energy consumption decreased by more than half and increased by almost a factor of seven 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	2020	1990-2010	2005-2020	2005-2020	share in 2020
	t	t	t	t	t	t	%	%
1 Energy	6.7	4.1	3.7	2.2	-3.0	-1.9	-46%	88%
1A Fuel combustion	6.7	4.1	3.7	2.2	-3.0	-1.9	-46%	88%
1A1 Energy industries	0.0076	0.0085	0.011	0.0044	0.0030	-0.0041	-48%	0.18%
1A2 Manufacturing industries	0.23	0.18	0.16	0.099	-0.075	-0.079	-45%	3.9%
1A3 Transport	0.15	0.17	0.21	0.26	0.061	0.092	55%	10%
1A4 Other sectors	6.3	3.7	3.3	1.8	-3.0	-1.9	-51%	73%
1A5 Other (Military)	0.00071	0.00073	0.00076	0.00069	0.000051	-0.000046	-6.3%	0.027%
1B Fugitive emissions from fuels	0.0000015	0.0000020	0.0000081	0.00000012	-0.00000070	-0.0000020	-99%	0.0000049%
2 IPPU	0.95	0.50	0.012	0.011	-0.94	-0.48	-98%	0.46%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	0.37	0.25	0.21	0.19	-0.16	-0.061	-25%	7.5%
6 Other	0.072	0.093	0.098	0.11	0.026	0.019	20%	4.5%
National total for compliance	8.1	4.9	4.0	2.5	-4.1	-2.4	-49%	100%

2.7.3 HCB

Switzerland's emissions of HCB exclusively stem from sector 1 Energy. The trend of HCB emissions per sector is shown in Table 2-24. HCB emissions have significantly dropped in 1993 and then slightly decreased until 2020.

The decrease of HCB emissions in 1993 occurred in category 1A2b Non-ferrous metals due to the shutdown of the single secondary aluminium production plant. Since then, the trend of HCB emissions continues to slightly decrease. 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	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	173	0.44	0.45	0.35	-172	-0.094	-21%	100%
1A Fuel combustion	173	0.44	0.45	0.35	-172	-0.094	-21%	100%
1A1 Energy industries	0.11	0.15	0.17	0.19	0.060	0.036	24%	54%
1A2 Manufacturing industries	172	0.051	0.051	0.035	-172	-0.016	-32%	10.0%
1A3 Transport	NE	NE	NE	NE	–	–	–	–
1A4 Other sectors	0.38	0.24	0.22	0.13	-0.16	-0.11	-47%	36%
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	0.45	0.35	-172	-0.094	-21%	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 2020 with the exception of a sudden sharp increase in 1999.

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

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

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

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

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

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

PCB emissions	1990	2005	2010	2020	1990-2010	2005-2020	2005-2020	share in 2020
	kg	kg	kg	kg	kg	kg	%	%
1 Energy	165	1.4	0.55	0.40	-164	-1.0	-72%	0.10%
1A Fuel combustion	165	1.4	0.55	0.40	-164	-1.0	-72%	0.10%
1A1 Energy industries	164	1.1	0.18	0.074	-164	-1.0	-93%	0.018%
1A2 Manufacturing industries	0.50	0.35	0.38	0.32	-0.12	-0.032	-9.1%	0.079%
1A3 Transport	0.00037	0.00037	0.00035	0.00011	-0.000019	-0.00026	-71%	0.00003%
1A4 Other sectors	0.0022	0.0015	0.0013	0.00071	-0.00093	-0.00077	-52%	0.00017%
1A5 Other (Military)	NE	NE	NE	NE	-	-	-	-
1B Fugitive emissions from fuels	NA	NA	NA	NA	-	-	-	-
2 IPPU	1'537	922	708	369	-829	-553	-60%	90%
3 Agriculture	NA	NA	NA	NA	-	-	-	-
4 LULUCF	NR	NR	NR	NR	-	-	-	-
5 Waste	347	254	56	8.4	-291	-246	-97%	2.1%
6 Other	282	93	62	31	-220	-62	-67%	7.6%
National total for compliance	2'332	1'270	827	408	-1'505	-862	-68%	100%

2.8 Compliance with the Gothenburg Protocol

2.8.1 Emission ceilings 2010

Under the CLRTAP, the 1999 Gothenburg Protocol requires that parties shall reduce and maintain the reduction in annual emissions in accordance with emission ceilings set for 2010 and beyond. Table 2-26 shows the emission ceilings, the reported emissions for 2010 and the respective compliance. Accordingly, Switzerland is in compliance with the Gothenburg Protocol emission ceilings for all pollutants except for NO_x in 2010. All emissions 2020 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 2020 of the latest submission (2022).

Pollutants	National emission ceilings for 2010	Emissions 2010 (Subm. 2022)	Compliance with emission ceilings 2010 in 2010	Emissions 2020 (Subm. 2022)	Compliance with emission ceilings 2010 in 2020
	kt	kt		kt	
SO _x (as SO ₂)	26	10	yes	3.8	yes
NO _x (as NO ₂)	79	83	no	53	yes
NM VOC	144	98	yes	75	yes
NH ₃	63	58	yes	53	yes

2.8.2 Emission reduction commitments 2020

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

The revised protocol specifies emission reduction commitments in terms of percentage reductions from the reference year 2005 to 2020. It has also been extended to cover one additional air pollutant, namely particulate matter (PM_{2.5}), and thereby also black carbon as a component of PM_{2.5}. 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 2020. The emission reduction commitments 2020 are achieved for all the pollutants (SO_x, NO_x, NM VOC, NH₃ and PM_{2.5}).

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

Pollutant	Emission reduction commitments 2020	Reduction achieved in 2020	Compliance with emission ceilings 2020 in 2020
	<i>%-reduction of 2005 level</i>		
SO _x (as SO ₂)	21%	73%	yes
NO _x (as NO ₂)	41%	44%	yes
NMVOG	30%	32%	yes
NH ₃	8%	11%	yes
PM2.5	26%	45%	yes

3 Energy

3.1 Overview of emissions

In this introductory chapter, an overview of emissions separated by most relevant pollutants in sector 1 Energy is presented. In the sector 1 Energy the substances NO_x, NMVOC and PM_{2.5} and SO₂ 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 NO_x reduction between 1990 and 2020. 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 1A3b Road transportation were triggered by the implementation of new strict emission standards for road vehicles. The first step happened in the late 80's when Switzerland reduced the standards to a level that required the equipment of three-way catalysts 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 years before 2015 because of an increasing share of diesel-powered passenger cars and higher emission factor than expected (the "dieselgate" scandal³, detected in the year 2015). In 2020, the COVID-19 pandemic led to a strong reduction of NO_x emissions from road transportation due to reduced traffic volumes.
- The reductions in 1A2 Manufacturing industries and construction were a result of three main factors: First, there has been a fuel switch from residual fuel oil, coal and gas oil towards natural gas and a reduction in total fuel use since 2008. Second, a reduction has been reached due to an on-going sectoral agreement (from 1998) targeting NO_x emissions of the cement industry. Third, manufacturing plants reduced NO_x emissions through technical improvements (e.g. DeNO_x technology, selective non-catalytic reduction technology SNCR).
- In the past, the number of buildings and apartments increased, as well as the average floor space per person and workplace. Both phenomena resulted in an increase of the total heated area. On contrary, higher standards were specified for insulation and for combustion equipment efficiency for both new and renovated buildings including low-NO_x

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 [05.02.2022]

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 2020). 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.

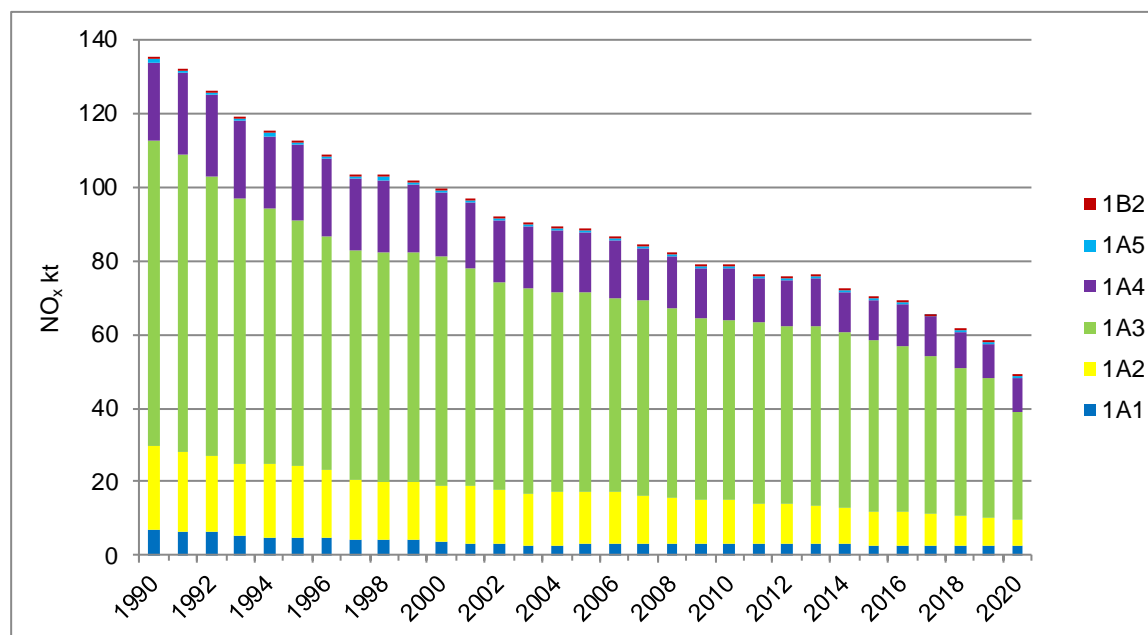


Figure 3-1: Switzerland's NO_x emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2020. The corresponding data table can be found in Annex A7.2.

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 2020. 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 2020, which leads to a decrease of NMVOC emissions. In 2020, the COVID-19 pandemic led to a reduction of NMVOC emissions from road transportation due to reduced traffic volumes.
- NMVOC emissions of source category 1A4 Other sectors declined in the same period as well due 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 to reduce fugitive emissions caused by distribution and storage of gasoline.

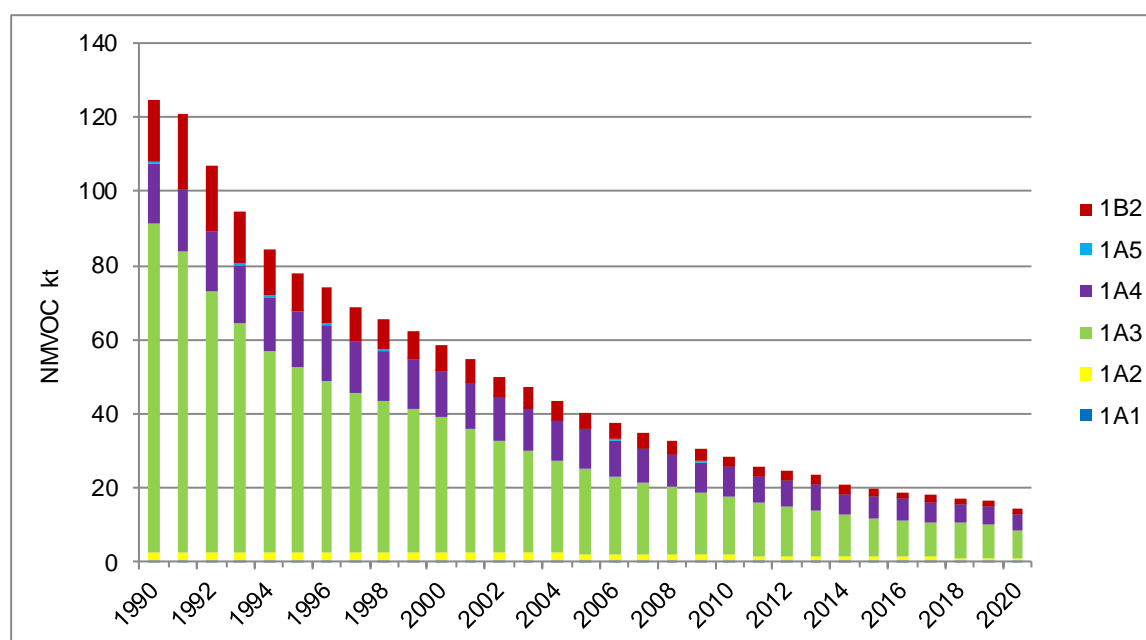


Figure 3-2: Switzerland's NMVOC emissions from the energy sector by source categories 1A1-1A5 and 1B2 between 1990 and 2020. The corresponding data table can be found in Annex A7.2.

3.1.3 Overview and trend for SO₂

Figure 3-3 depicts the SO₂ emissions in energy related sectors since 1990. In 2020, the main contributions from the sector 1 Energy are SO₂ emissions from the source categories 1A2 Manufacturing industries and construction and 1A4 Other sectors. SO₂ 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 fluctuations in the SO₂ 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 led to a massive reduction between 1990 and 2020, see Table 3-9) by the Ordinance on Air Pollution Control (Swiss Confederation 1985) resulted in a significant decrease of the sulphur oxide emissions from fuel combustion under 1A3 Transport and 1A4 Other sectors (gas oil, diesel oil and gasoline, see Table 3-9)..
- Second, a substantial substitution of gas oil with natural gas and eco-grade gas oil (with low sulphur and nitrogen content, from 2006 onwards) under 1A4 Other sectors resulted in further reductions of sulphur emissions (natural gas consumption almost doubled from 1990 to 2020).
- Third, a similar substitution of residual fuel oil, coal and gas oil by natural gas has reduced sulphur emissions as well in 1A2 Manufacturing industries (i.e. coal and residual fuel oil from 1990, gas oil from about 2005 onwards).

Additionally, emissions of 1A1 are decreasing caused by substitution of emission intensive fuels (e.g. no more consumption of residual fuel oil since 2011 and no more bituminous coal since 2000) and by closing of a refinery plant in 2015. The SO₂ 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 units and flaring decrease over time.

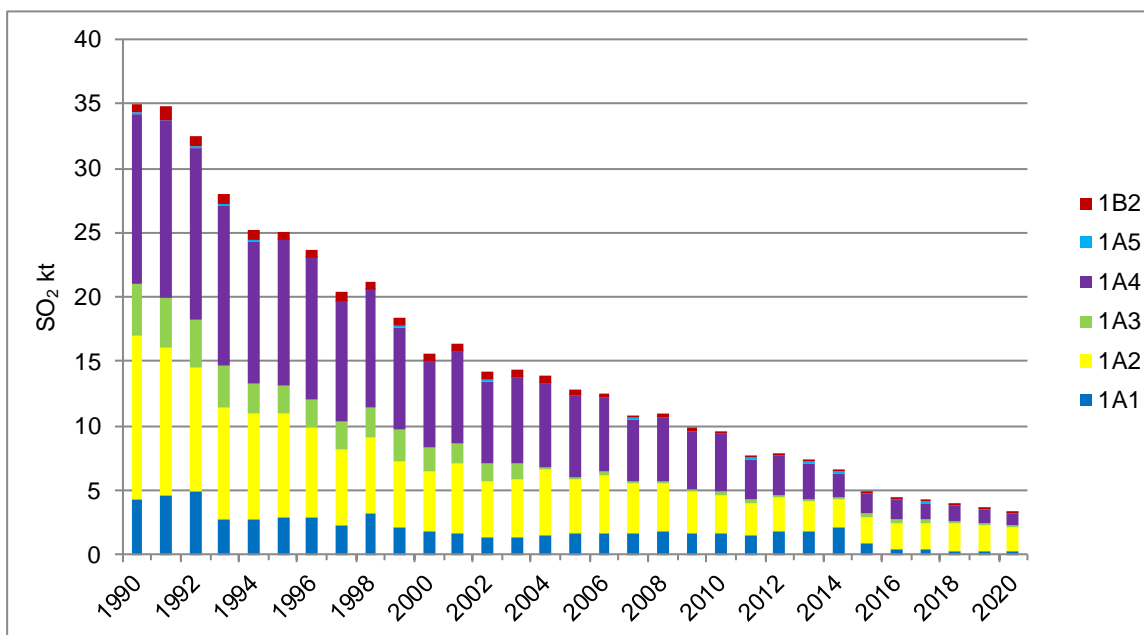


Figure 3-3: Switzerland's SO₂ emissions from the energy sector by source category 1A1-1A5 and 1B2 between 1990 and 2020. The detailed corresponding data table can be found in Annex A7.2.

3.1.4 Overview and trend for NH₃

Figure 3-4 depicts the NH₃ 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 NH₃. 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 NH₃ 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 NH₃ emissions due to technological improvements in three-way catalytic converters.

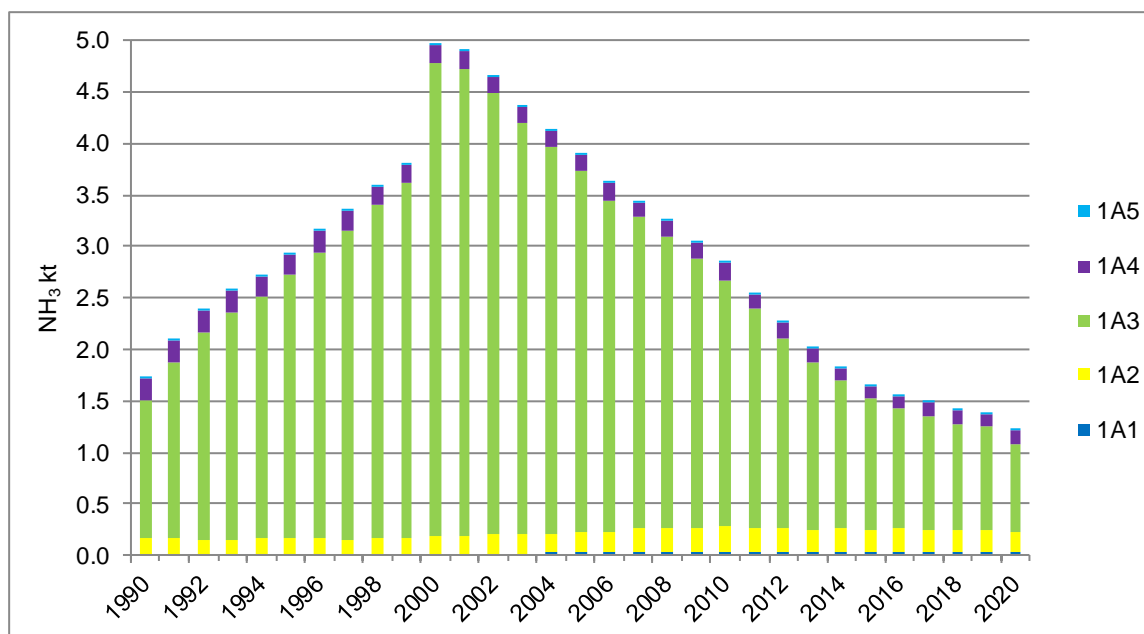


Figure 3-4: Switzerland's NH₃ emissions from the energy sector by source category 1A1-1A5 between 1990 and 2020. There are no emissions from 1B. The detailed corresponding data table can be found in Annex A7.2.

3.1.5 Overview and trend for PM_{2.5}

Figure 3-5 depicts the PM_{2.5} emissions in energy related sectors since 1990. The main contributor is source category 1A4 Other sectors, followed by 1A3 Transport and 1A2 Manufacturing industries and construction. Within source category 1A4 Other sectors, mainly wood combustion in small and mid-sized wood furnaces contribute to PM_{2.5} emissions. Overall emissions declined since 1990. The following effects mainly attributed to the reduction of particulate matter emissions:

- A reduction of exhaust emissions under 1A4 Other sectors was due to technological improvements of wood combustion installations and a reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In addition, the wood energy consumption decreased by more than half and increased by almost a factor of seven 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).

Note that 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). In 2020, despite this underlying increasing trend, the COVID-19 pandemic led to a reduction of non-exhaust PM2.5 emissions from road transportation due to reduced traffic volumes.

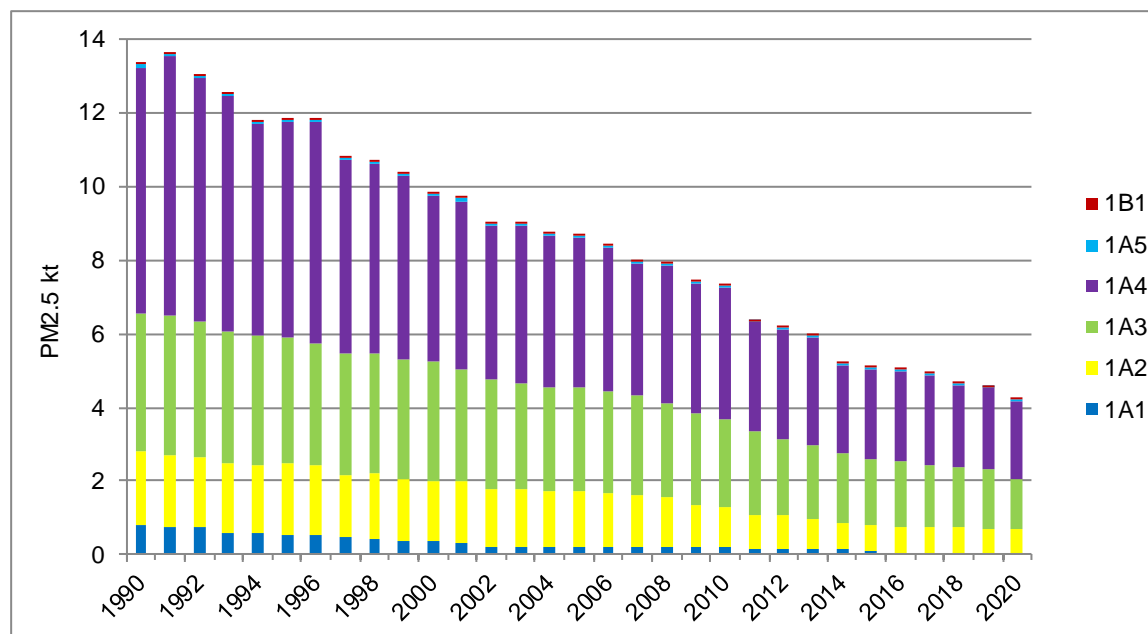


Figure 3-5: Switzerland’s PM2.5 emissions from the energy sector by source categories 1A1-1A5 and 1B1 between 1990 and 2020. The corresponding data table can be found in Annex A7.2.

3.1.6 General method and disaggregation of energy consumption

3.1.6.1 System boundaries: Differences between CLRTAP and UNFCCC reporting

Switzerland uses the same data base for the Swiss greenhouse gas inventory as for the Swiss air pollution inventory and reports its greenhouse gas emissions according to the requirements of the UNFCCC as well as air pollutants according to the requirements of the CLRTAP. The nomenclature for both reportings is (almost) the same (NFR), but there are differences concerning the system boundaries. Under the UNFCCC, the national total for assessing compliance is based on fuel sold within the national territory, whereas under the CLRTAP, the national total for assessing compliance is based on fuel used within the territory. One difference occurs for 1A3b Road transportation as can be seen from Table 3-1, columns CLRTAP / NFR tables “national total” and UNFCCC / CRF-tables “national total” compared to CLRTAP / NFR tables “national total for compliance”. The CLRTAP / NFR tables “national total for compliance” does not contain the amount of fuel sold in Switzerland but consumed abroad, which is called “fuel tourism and statistical difference”, and which is accounted for in Switzerland’s GHG inventory, but not in the reporting under the CLRTAP. The difference between the two approaches amounts to several percent, with considerable variation from year to year due to fluctuating fuel price differences between Switzerland and its neighboring countries. Note that the fuel tourism and statistical difference from 1A3b Road transportation is reported differently 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. 3.2.6.2.2). 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 2022, 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 Table 3-1).

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

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

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

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

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

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

3.1.6.2 Net calorific values (NCV)

Table 3-2 summarizes the net calorific values (NCV) which are used in order to convert from energy amounts in tonnes into energy quantities in gigajoules (GJ). More detailed explanations including information about the origin of the NCVs of the different fuels are given below.

Table 3-2: Net calorific values (NCVs) of various fuels. Where values for two years are indicated, the NCV is interpolated between these two years and constant NCVs are used before the first and after the second year (corresponding to the two indicated values). For the NCV of wood, a range covering all facility categories and years is provided. For the NCVs of natural gas and biogas see Table 3-3.

Fuel	Data sources	NCV [GJ/t]
Gasoline	EMPA (1999), SFOE/FOEN (2014)	42.5 (1998), 42.6 (2013)
Jet kerosene	EMPA (1999), SFOE/FOEN (2014)	43.0 (1998), 43.2 (2013)
Diesel oil	EMPA (1999), SFOE/FOEN (2014)	42.8 (1998), 43.0 (2013)
Gas oil	EMPA (1999), SFOE/FOEN (2014)	42.6 (1998), 42.9 (2013)
Residual fuel oil	EMPA (1999)	41.2
Liquefied petroleum gas	SFOE (2021)	46.0
Petroleum coke	SFOE (2021), Cemsuisse (2010a)	35.0 (1998), 31.8 (2010)
Other bituminous coal	SFOE (2021), Cemsuisse (2010a)	28.052 (1998), 25.5 (2010)
Lignite	SFOE (2021), Cemsuisse (2010a)	20.097 (1998), 23.6 (2010)
Natural gas	SGWA	see caption
Biofuel	Data sources	
Biodiesel	SFOE (2021)	38.0
Bioethanol	SFOE (2021)	26.5
Biogas	assumed equal to natural gas	see caption
Wood	SFOE (2021b)	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 2021). 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 2021), is assumed to be constant over the entire reporting period.

Liquefied petroleum gas

The NCV of liquefied petroleum gas is the same as used by the Swiss Federal Office of Energy (SFOE 2021) and is – as in the Swiss overall energy statistics – constant over the entire reporting period. It is assumed that liquefied petroleum gas 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 2021). For these fuels, the Swiss overall energy statistics contains NCVs for the years 1998 and 2010. Values in between are interpolated, before the first and after the last year of available data values are held constant. The NCVs for 2010 are based on measured samples taken from Switzerland's cement plants as they are the largest consumers of these fuels in Switzerland. Samples from the individual plants were taken from January to September 2010 and analysed for NCVs by an independent analytical laboratory (Cemsuisse 2010a). For each fuel, the measurements from the individual plants were weighted according to the relative consumption of each plant.

Natural gas, biogas

The NCV of natural gas (see Table 3-3) and also the CO₂ 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 (2021). 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 (2021i). The NCV of biogas is assumed to be equal to the NCV of natural gas since the raw biogas is treated to become the same quality level including its energetic properties as natural gas.

Table 3-3: Net calorific values of natural gas and biogas for selected years. Years in-between are linearly interpolated. Data source: annual reports of the Swiss Gas and Water Industry Association SGWA, the latest report is SGWA (2021). Spreadsheet to determine national averages: FOEN 2021i.

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

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 2021b).

Table 3-2 illustrates the range of the NCV for all wood fuel types.

Bioethanol and biodiesel

The NCVs of bioethanol and biodiesel are the same as used by the Swiss Federal Office of Energy (SFOE 2021) 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 2021). 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 2021), 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 2021). 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 Avenegy Suisse (formerly Swiss petroleum association, EV) for data on import, export, sales, stocks of oil products and for processing of crude oil in refineries.
- Annual import data for natural gas from the Swiss gas industry association (VSG).
- Annual import data for petroleum products and coal from the Federal Office for Customs and Border Security (FOCBS, formerly FCA).
- Data provided by industry associations (GVS, SGWA, Cemsuisse, VSG, VSTB etc.).
- Swiss electricity statistics (SFOE 2021g).
- Swiss renewable energies statistics (SFOE 2021a).
- Swiss wood energy statistics (SFOE 2021b).
- Swiss statistics on combined heat and power generation (SFOE 2021c).

As can be seen in Figure 3-6, 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.

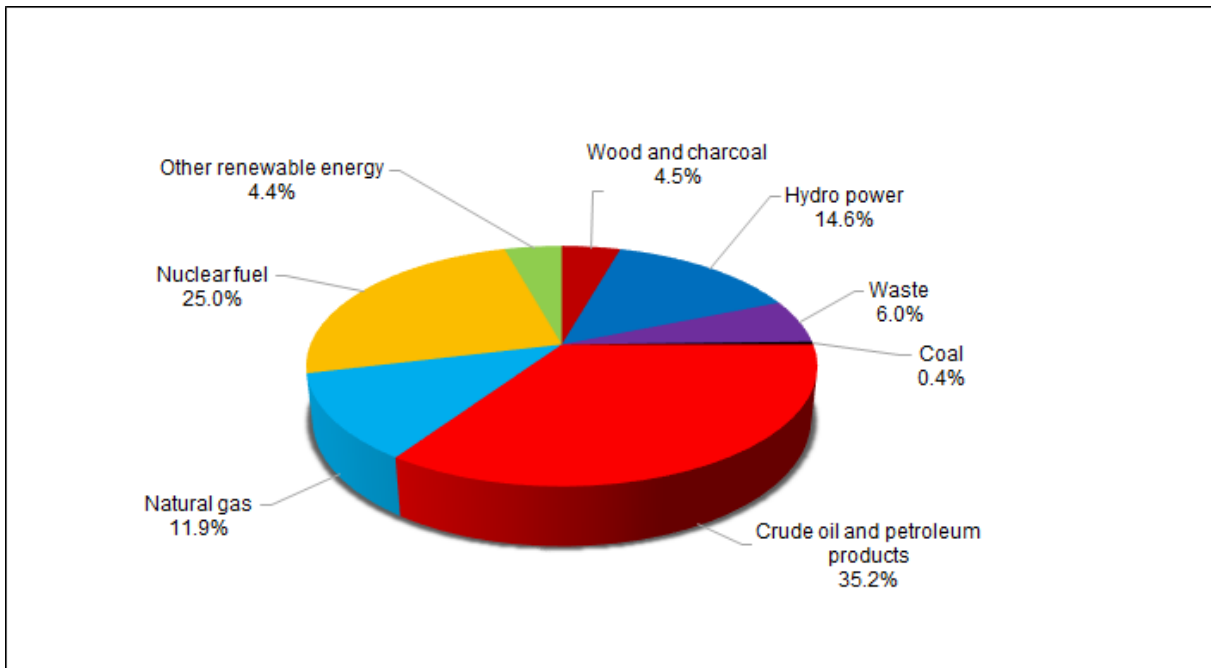


Figure 3-6: Switzerland's primary energy consumption in 2020 by fuel type (see corresponding data in SFOE 2021).

Table 3-4 shows primary energy consumption excluding nuclear fuel and hydro power. On the one hand, the combined effect of decreasing consumption of gasoline and increasing consumption of kerosene and diesel oil led to an increasing trend until about 2010 and a stabilization thereafter in the transport sector. On the other hand, consumption in the residential and industry sector (mainly gas oil) substantially decreased. Overall, liquid fossil fuel consumption changed only little between 1990 and about 2010 but started to decrease thereafter. Natural gas consumption increased since 1990, compensating to some extent the decreasing use of gas oil.

Table 3-4: Switzerland's energy consumption by fuel type. Only those fuels are shown that are implemented in the EMIS database (no hydro or nuclear power). The numbers are based on the fuels sold principle; thus, they include gasoline, diesel and biofuels consumption from fuel tourism, as well as all kerosene sold for domestic and international aviation. Natural gas and gasoline losses due to fugitive emissions (reported in sector 1B) are not included.

Year	Gasoline	Kerosene used for LTO	Kerosene used for cruise (memo item)	Diesel	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	155'892	8'059	40'008	46'736	821	218'510	23'342	8'890	1'400	14'901	67'861	19'161	46'738	611'488	652'318
1991	162'228	7'640	38'922	47'417	737	238'602	23'590	12'437	980	12'162	76'114	18'596	48'731	648'498	688'157
1992	168'218	7'803	41'297	45'926	780	236'809	24'170	11'492	315	8'758	79'984	19'009	47'693	650'176	692'253
1993	156'063	7'861	42'915	44'197	781	225'920	17'165	12'388	1'120	7'442	83'911	19'158	47'997	623'221	666'917
1994	156'096	7'911	44'198	46'924	824	207'141	17'860	13'455	1'470	7'632	82'737	19'155	45'973	606'353	651'376
1995	151'383	7'987	46'960	47'865	739	217'523	17'278	12'756	1'260	7'962	91'275	19'688	48'038	623'014	670'714
1996	155'303	8'017	48'736	44'946	651	226'289	15'097	13'939	1'015	5'456	98'876	20'584	51'538	641'060	690'447
1997	161'284	8'320	50'454	46'770	614	212'223	12'581	14'236	280	4'590	95'453	21'655	48'401	625'793	676'862
1998	162'548	8'540	52'728	48'681	528	222'407	15'882	15'259	455	3'960	98'301	23'802	49'947	649'782	703'038
1999	168'026	8'762	56'482	51'626	558	212'349	11'058	15'805	521	4'105	101'863	24'403	50'711	649'230	706'270
2000	168'191	9'074	58'987	55'146	531	196'137	7'923	13'649	551	6'120	101'282	26'536	50'361	634'970	694'488
2001	163'588	8'598	55'610	56'134	576	213'089	9'942	14'069	410	6'233	105'478	27'068	53'563	658'172	714'357
2002	160'401	8'128	51'278	58'346	375	196'655	6'446	15'584	679	5'565	103'548	27'876	53'151	638'379	688'033
2003	159'639	7'327	46'110	61'765	486	208'040	7'061	13'642	202	5'663	109'522	27'642	55'735	656'239	702'835
2004	156'844	6'886	43'555	66'447	446	203'370	7'561	16'429	1'819	5'420	113'047	28'845	56'630	663'298	707'299
2005	152'099	7'020	44'081	72'486	579	205'729	5'805	16'432	2'906	5'940	116'100	29'236	58'746	672'499	717'159
2006	147'474	7'291	46'280	78'606	457	195'926	6'419	18'578	3'324	6'467	112'887	31'233	61'870	670'075	716'812
2007	146'053	7'538	49'627	84'420	465	171'313	5'179	15'587	2'730	7'196	109'874	30'015	60'922	640'827	690'919
2008	142'840	7'773	53'378	92'627	516	178'833	4'606	16'288	3'616	6'562	117'083	30'854	65'027	666'108	720'002
2009	139'006	7'496	51'169	94'143	425	173'219	3'575	16'301	3'254	6'193	112'313	29'811	65'152	650'463	702'058
2010	134'072	7'699	53'921	97'733	514	182'295	2'987	15'463	3'498	6'208	125'494	31'185	69'966	676'600	731'035
2011	128'885	7'970	57'726	100'449	428	143'760	2'292	14'856	2'957	5'792	111'269	30'882	65'593	614'705	672'859
2012	124'332	8'258	59'048	106'568	428	154'448	2'780	12'247	3'148	5'269	122'051	31'145	71'547	641'794	701'269
2013	118'664	8'243	59'825	111'482	342	162'532	1'959	15'053	2'735	5'567	128'592	30'925	75'161	660'911	721'078
2014	113'907	8'282	60'259	114'385	299	122'694	1'581	14'473	3'148	5'704	111'346	31'320	69'546	596'386	656'944
2015	105'618	8'414	62'374	112'808	342	129'349	862	9'822	1'145	5'205	118'996	32'084	72'963	597'266	659'981
2016	102'322	8'577	65'584	114'079	299	132'325	378	9'136	890	4'795	125'030	33'583	79'164	610'280	676'163
2017	99'178	8'581	67'352	113'750	256	123'726	350	8'770	763	4'609	125'289	33'342	82'405	600'764	668'372
2018	97'608	8'756	71'494	115'283	200	111'225	87	8'890	781	4'285	118'611	34'510	82'191	582'227	653'922
2019	96'807	8'587	72'482	115'347	197	108'625	111	8'108	777	3'812	121'618	34'964	84'621	583'376	656'055
2020	85'731	3'885	26'730	109'312	189	97'246	41	7'627	700	3'664	118'458	34'723	83'138	544'524	571'443

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 2021). 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 2021), the Swiss renewable energy statistics (SFOE 2021a), the Swiss wood energy statistics (SFOE 2021b), the energy consumption statistics in the industry and services sectors (SFOE 2021d), as well as additional information from the industry.

The Swiss overall energy statistics are not only the main data input into the energy model, but also serve as calibration and quality control instrument: The total energy consumption given by the Swiss overall energy statistics has to be equal to the sum of the disaggregated activity data of all source categories within the energy sector (including memo items/bunker). Differences are explicitly taken into account as “statistical differences” (see chp. 3.2.6.2.2 Road transportation).

As shown in Figure 3-7 the energy model consists of several sub-models, such as the industry model, the civil aviation model, the road transportation model, the non-road transportation model, and the energy model for wood combustion. A brief overview of each of these models is given below. However, depending on the scope of these sub-models, they are either described in the corresponding source category chapter or in an overarching chapter preceding the detailed description of the individual source categories. In chapter 3.1.6.3.3, the resulting sectoral disaggregation is shown separately for each fuel type.

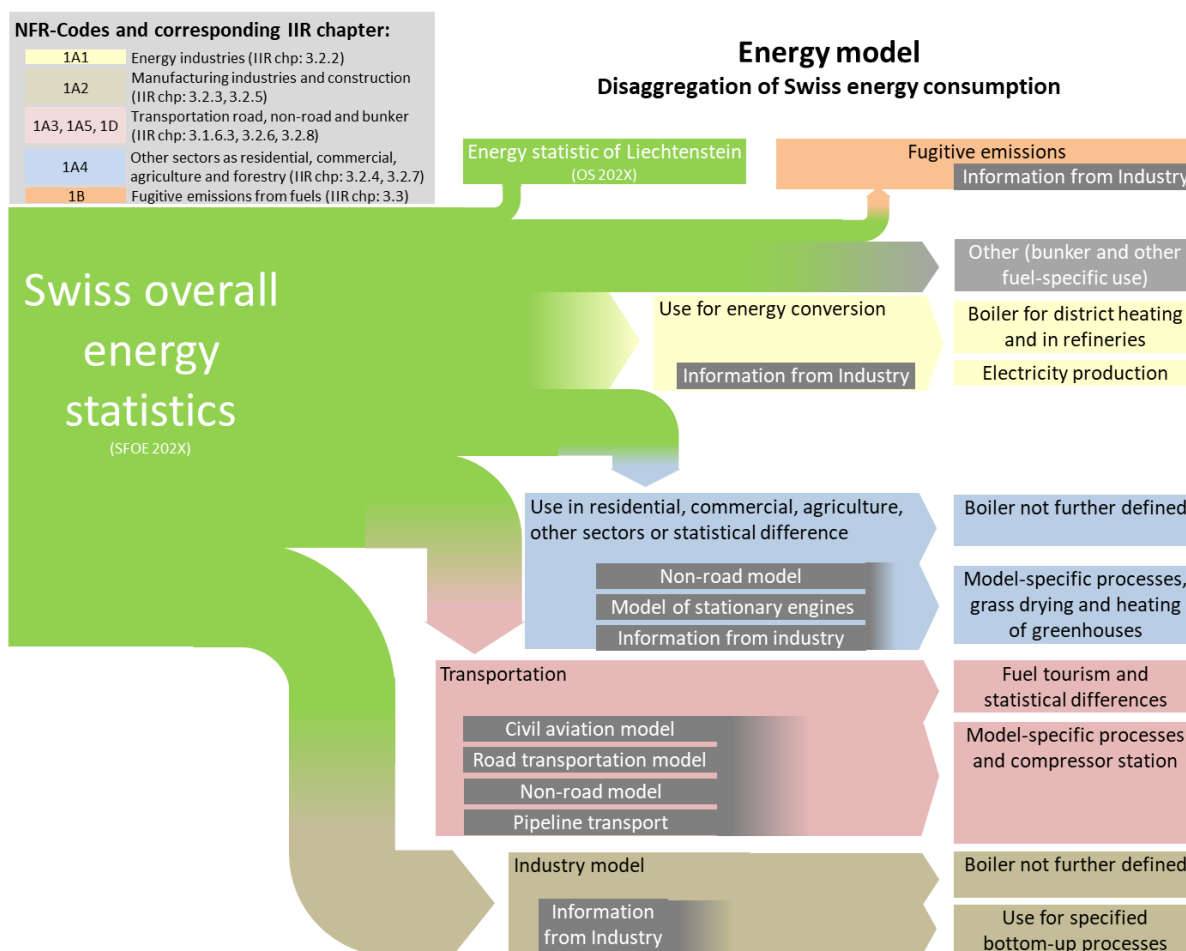


Figure 3-7 Overview of Switzerland’s energy model. In the abbreviations SFOE 202X and OS 202X the “X” refers to the latest edition of the respective statistics.

Industry model (Details are given in chp. 3.2.3.2)

The industry model is based on two pillars: (1) the energy consumption statistics in the industry and services sectors (SFOE 2021d), 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 2021b), 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 2021) into the relevant source categories 1A1-1A5 (Figure 3-8). For each fuel type, the disaggregation process of the energy model as shown schematically in Figure 3-7, the interaction between the different sub-models and additional data sources are visualized separately in Figure 3-9 to Figure 3-18.

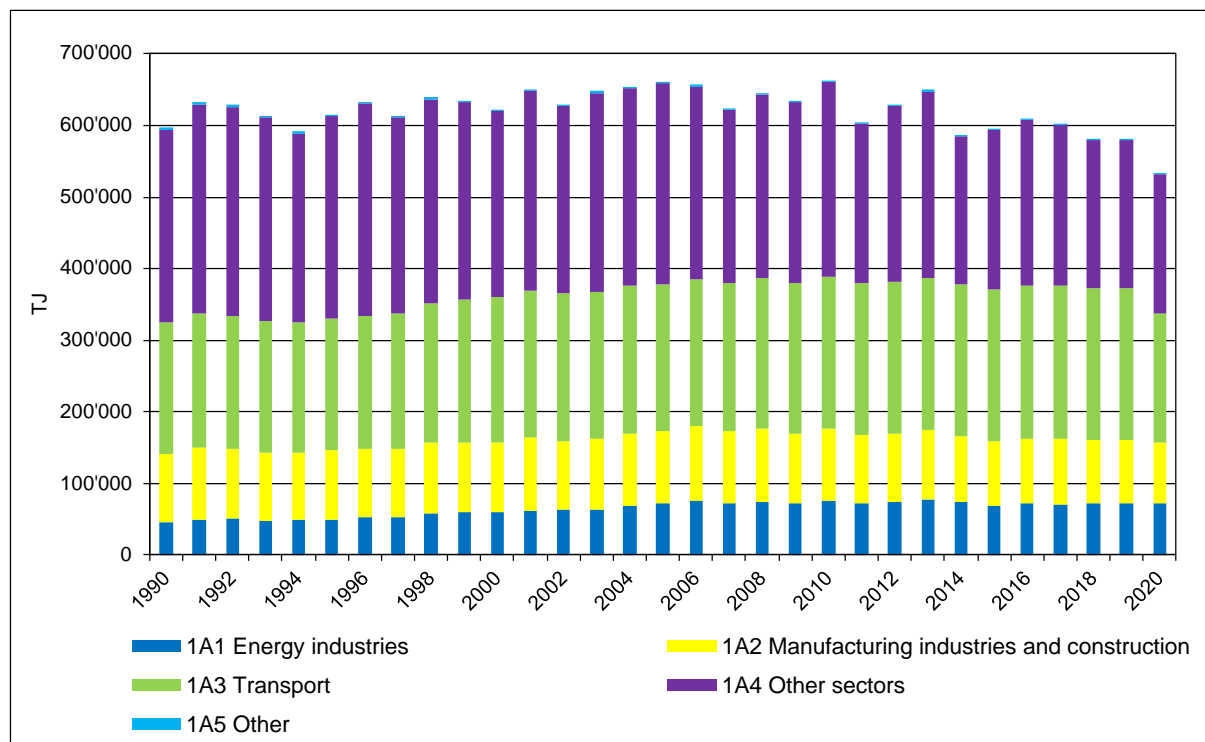


Figure 3-8: Switzerland’s energy consumption by source categories 1A1-1A5 based on the Swiss energy model. Note that in the same period population increased by about one third, industrial production by about three quarters and the motor vehicle fleet by about two third (SFOE 2021, table 43)

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 CO₂ levy, total energy consumption of all greenhouses within Switzerland is extrapolated. The respective fuel consumption for grass drying and greenhouses is

subtracted from the total fuel consumption of commercial, agriculture and statistical differences (see Figure 3-7).

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

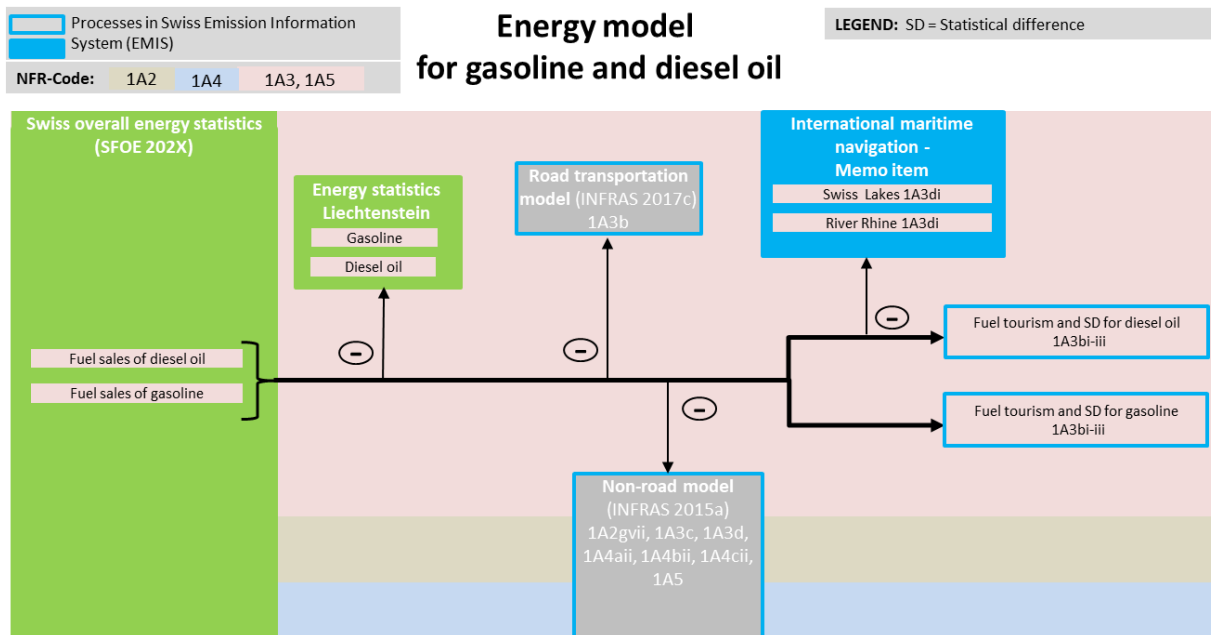


Figure 3-9: Schematic disaggregation of 1A Fuel consumption for gasoline and diesel oil. Marine bunker fuel consumption is based on the national customs statistics (see chapter 3.1.6.1 on memo items)

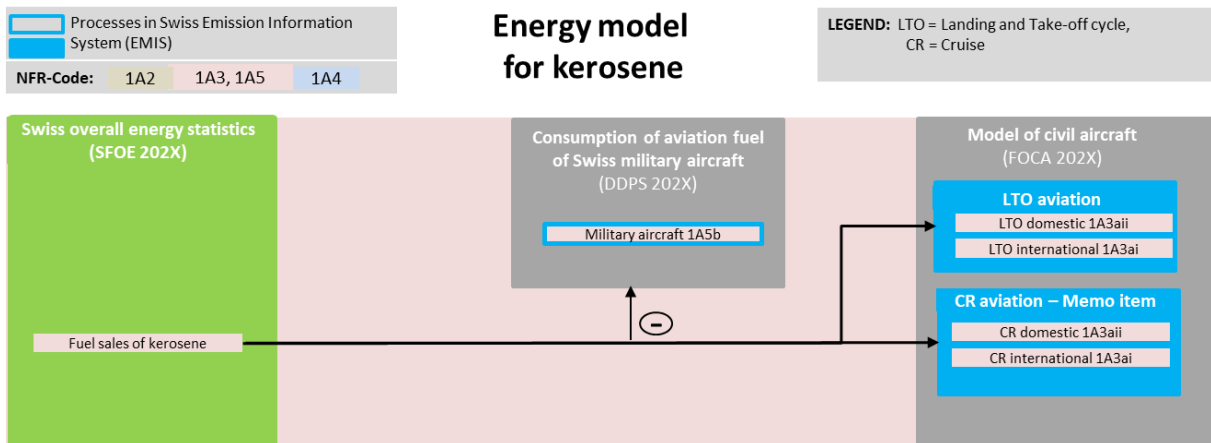


Figure 3-10: Schematic disaggregation of 1A Fuel consumption for kerosene. Fuel consumption for military aircraft is provided by the Federal Department of Defence, Civil Protection and Sport (DDPS). The differentiation between domestic and international aviation as well as between CR and LTO is provided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

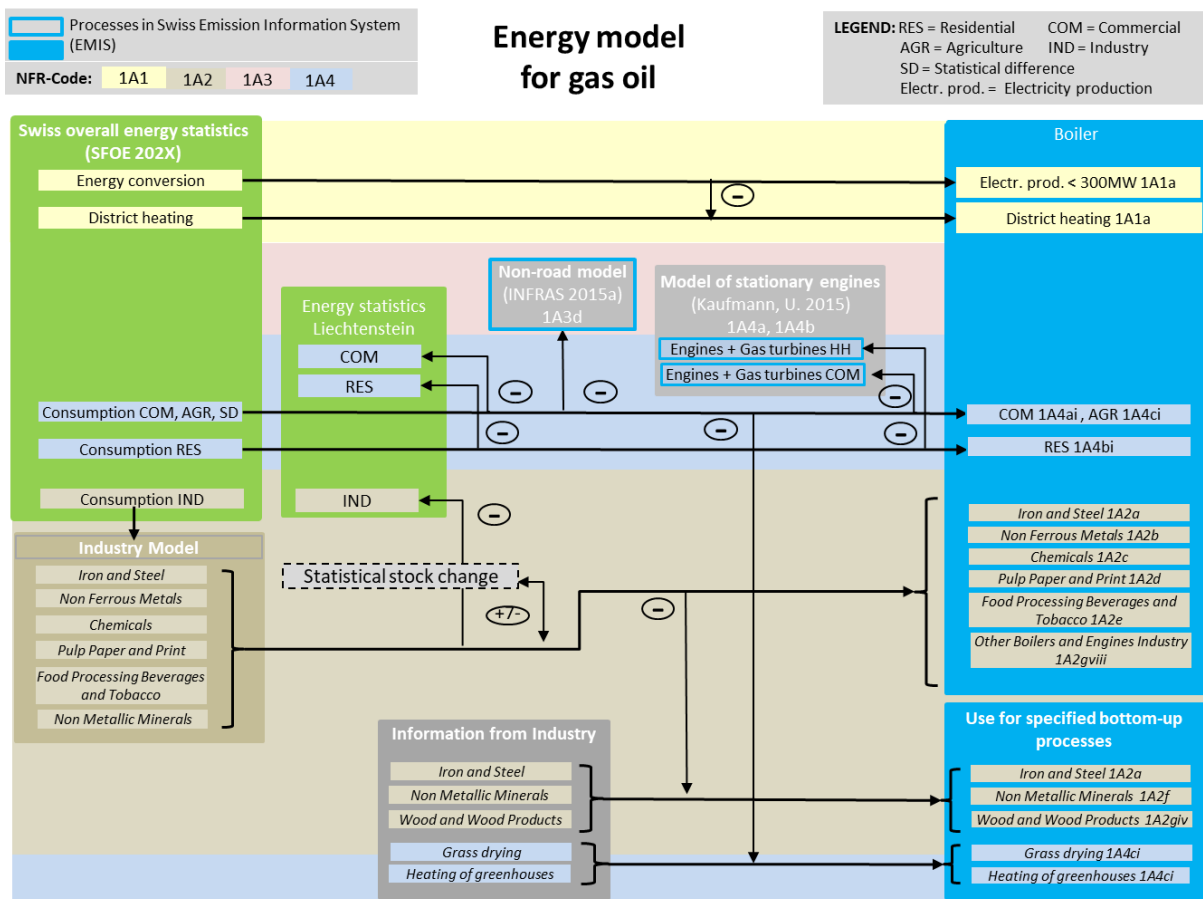


Figure 3-11: Schematic disaggregation of 1A Fuel consumption for gas oil. The Swiss overall energy statistics provide gas oil use for energy conversion and the amount thereof being used for district heating. Based on this information, gas oil use is split into 1A1ai Electricity generation and 1A1aiii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

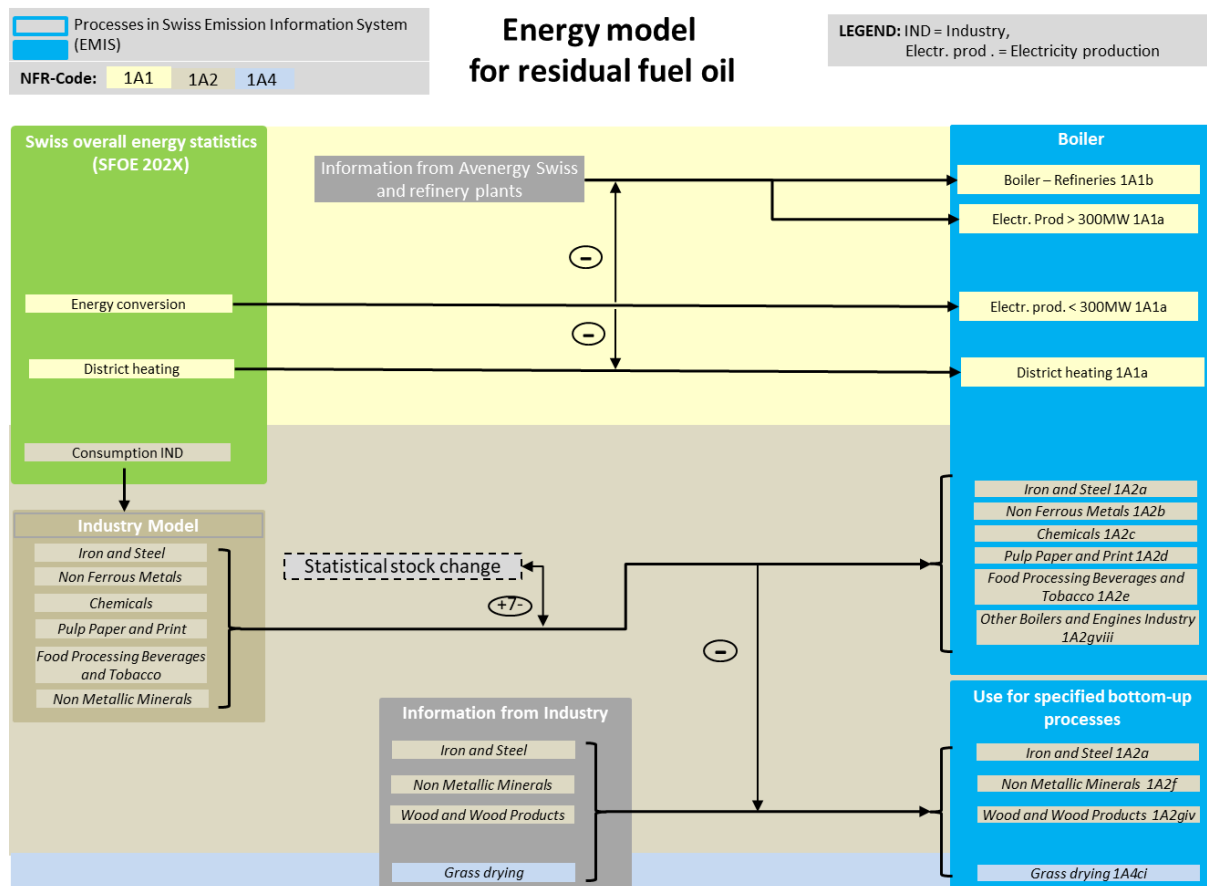


Figure 3-12: Schematic disaggregation of 1A Fuel consumption for residual fuel oil. The Swiss overall energy statistics report residual fuel oil use in energy conversion and the amount thereof consumed in electricity production (one single fossil fuel power station, operational from 1985 to 1994), district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

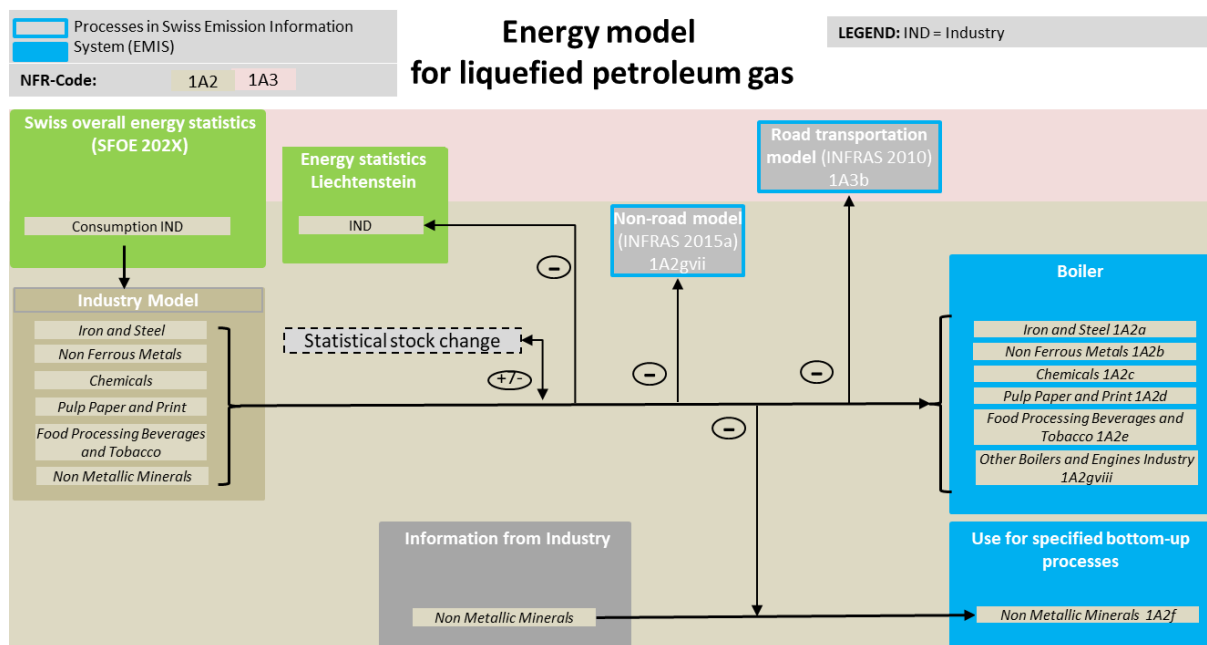


Figure 3-13: Schematic disaggregation of 1A Fuel consumption for liquefied petroleum gas.

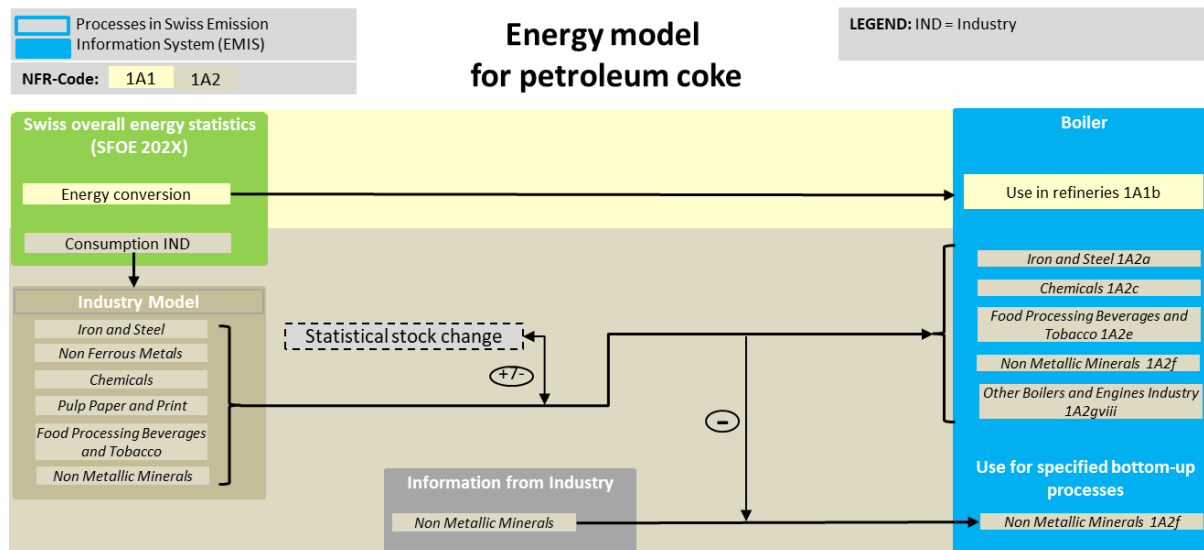


Figure 3-14: Schematic disaggregation of 1A Fuel consumption for petroleum coke.

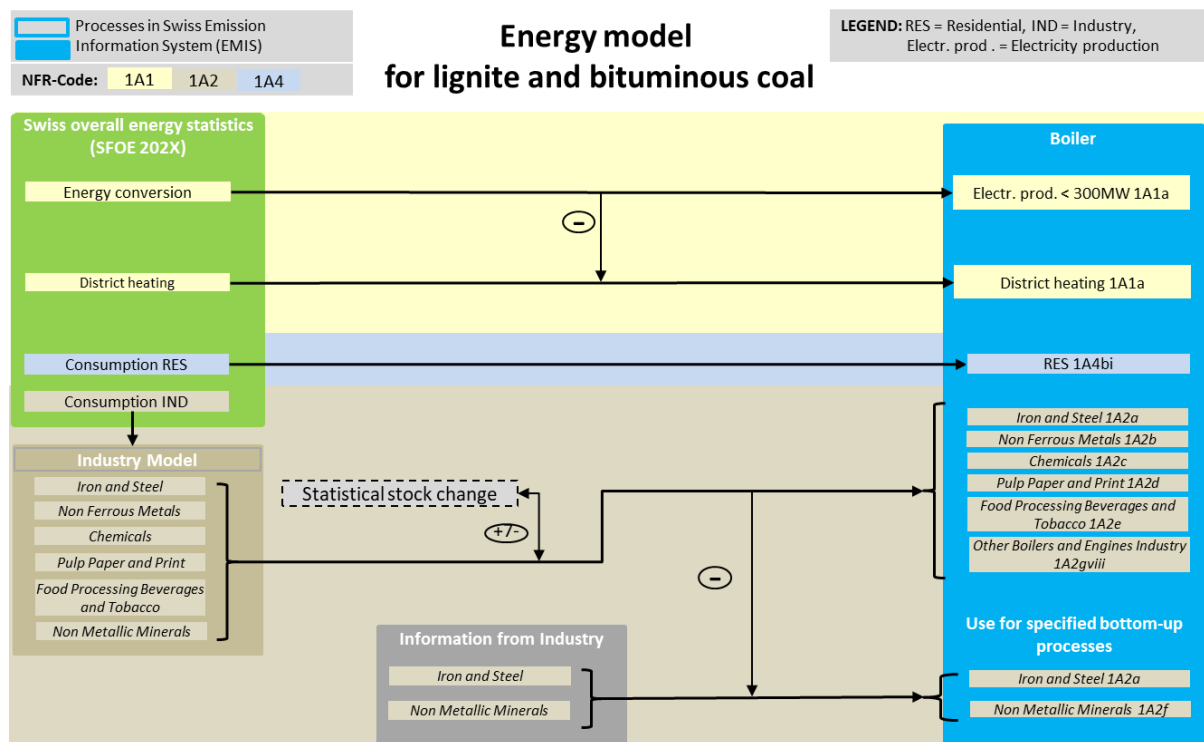


Figure 3-15: Schematic disaggregation of 1A Fuel consumption for lignite and bituminous coal. The Swiss overall energy statistics provide bituminous coal use for energy conversion and the amount thereof being used for district heating. Based on this information, use of bituminous coal in energy industries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

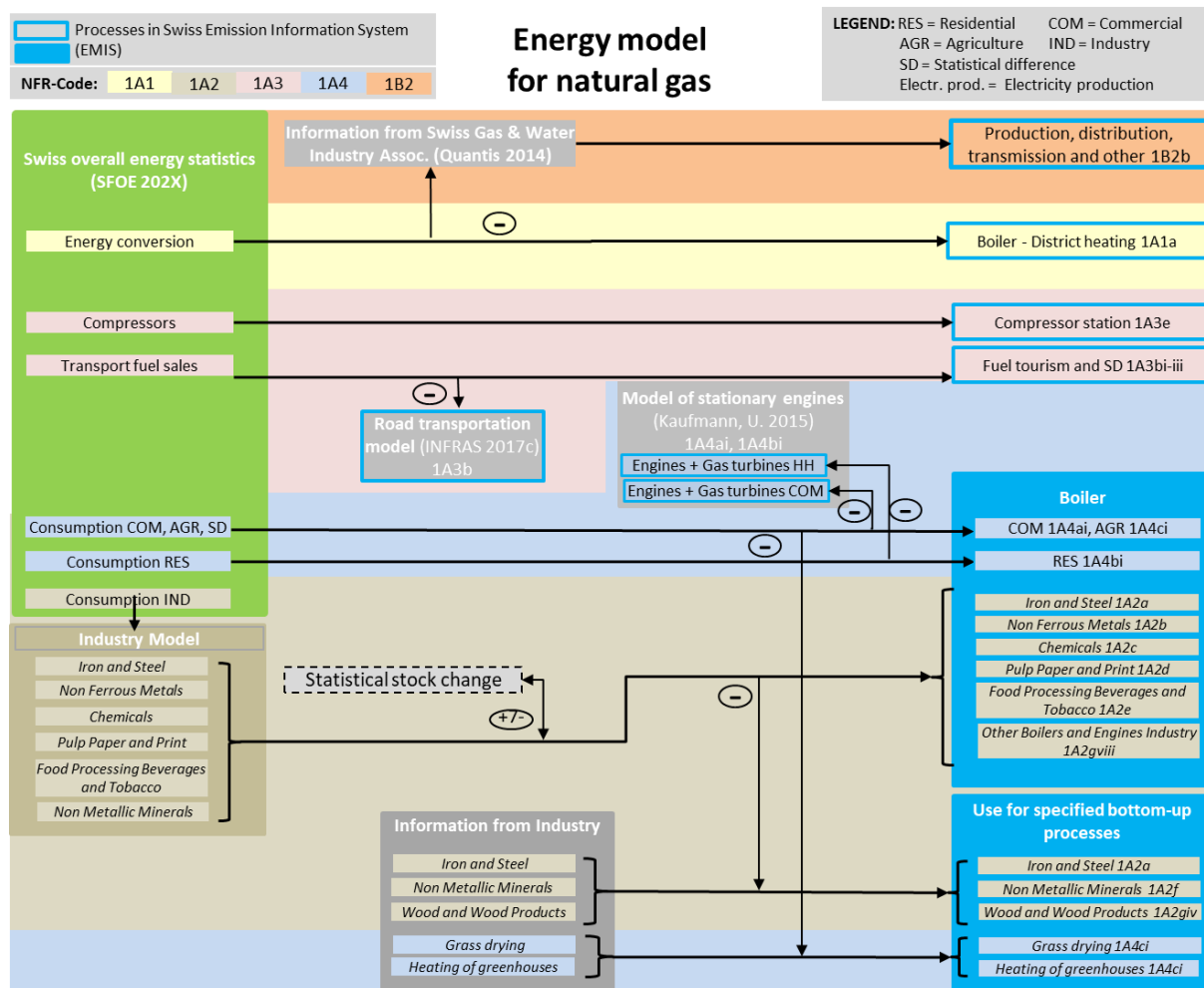


Figure 3-16: Schematic disaggregation of 1A Fuel consumption (and 1B Fugitive emissions from fuels) for natural gas. The Swiss overall energy statistics (SFOE 2021) provide gas use in the transformation sector (energy conversion and distribution losses). Distribution losses as estimated by the Swiss Gas and Water Industry Association SGWA are subtracted and reported under source category 1B2 Fugitive emissions from fuels. The remaining fuel consumption for natural gas is reported under 1A1a Public electricity and heat production.

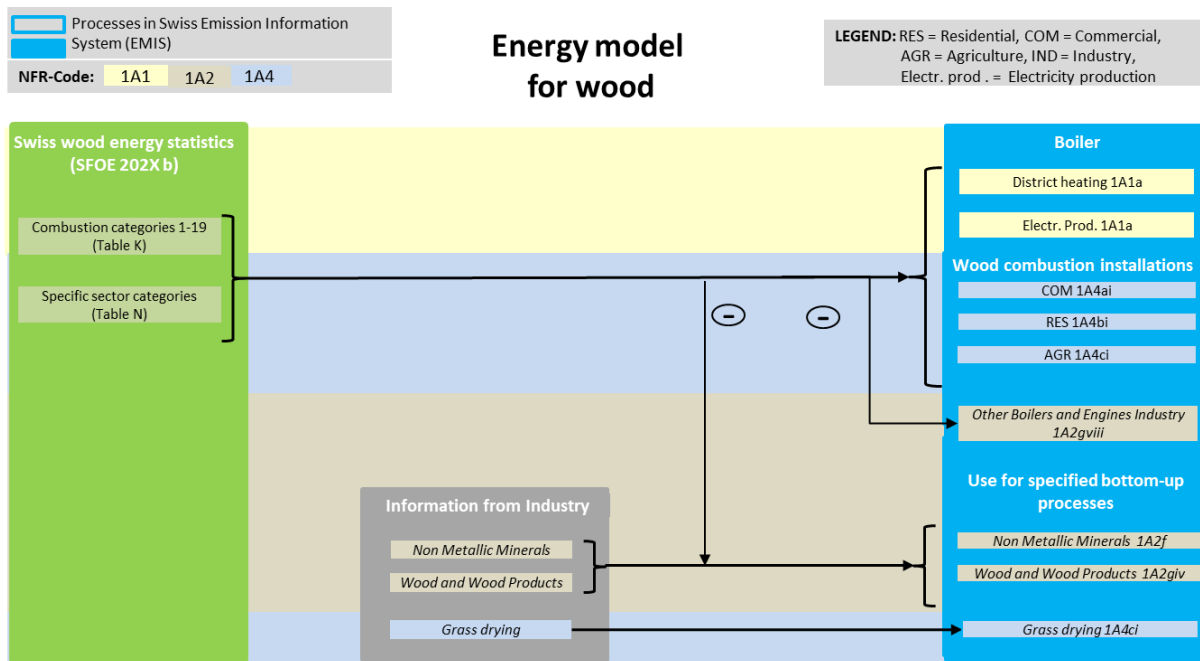


Figure 3-17: Schematic disaggregation of 1A Fuel consumption for wood. For a detailed description of the Energy model for wood combustion, see chapter 3.2.1.1.2.

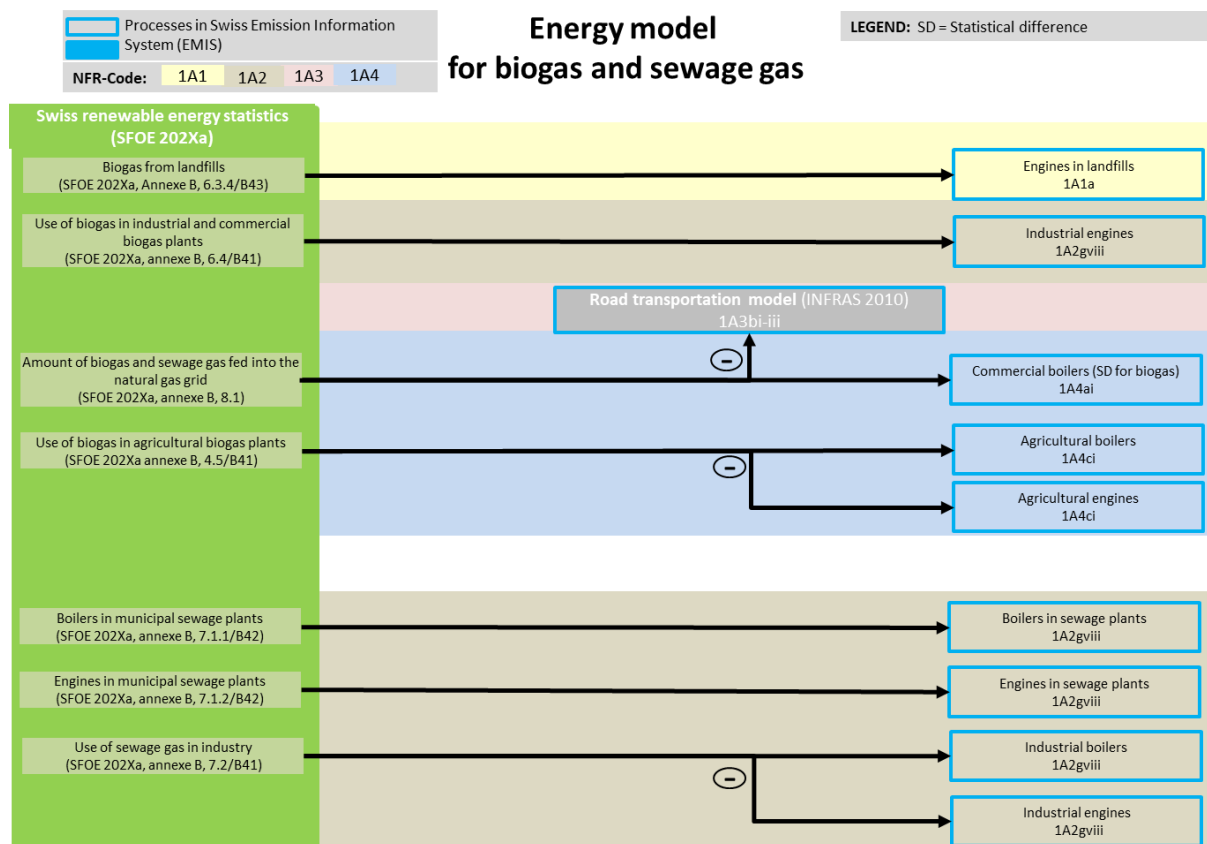


Figure 3-18: Schematic disaggregation of 1A Fuel consumption for biogas and sewage gas.

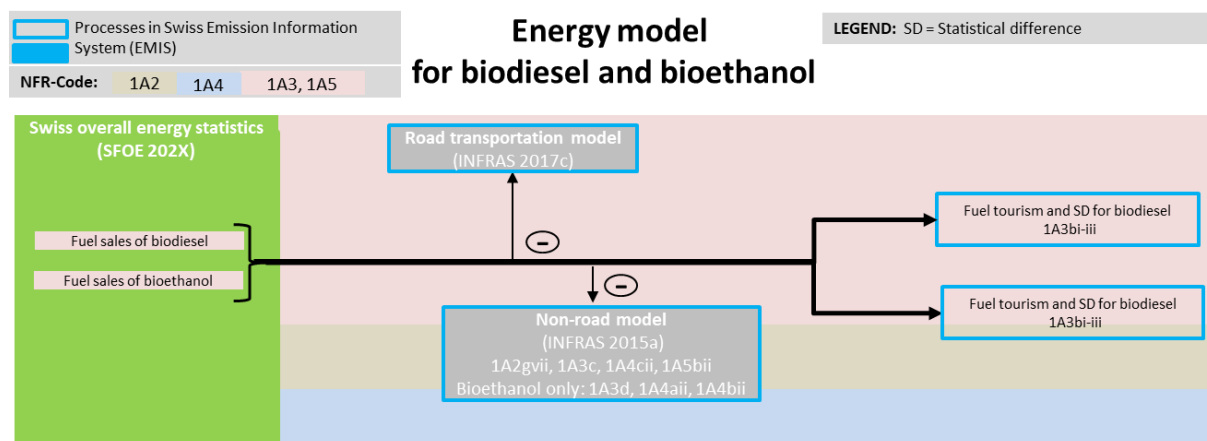


Figure 3-19: Schematic disaggregation of 1A Fuel consumption for biodiesel and bioethanol.

3.2 Source category 1A - Fuel combustion activities

3.2.1 Country-specific issues of 1A Fuel combustion

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

3.2.1.1 Models overlapping more than one source category

3.2.1.1.1 Non-road transportation model (excl. aviation)

Choice of method

For all source categories, for which the non-road transportation model is applied (Table 3-5), the air pollutant emissions are calculated by a Tier 3 method based on the corresponding decision trees given in EMEP/EEA guidebook (EMEP/EEA 2019). The detailed references to the related chapters of the Guidebook are shown in the chps. 3.2.5.2, 3.2.6.2, 3.2.7.2, and 3.2.8.2.

Methodology

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

Table 3-5: Non-road categories (FOEN 2015j) and the corresponding NFR nomenclature (reporting tables).

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

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

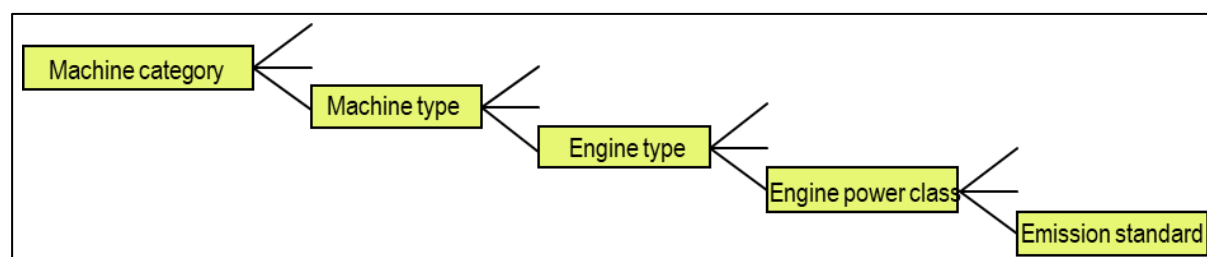


Figure 3-20: Each non-road vehicle is classified by its engine-power class, engine type, machine type, machine category, and emission standard.

The emission modelling is based on activity data and emission factors by means of the following equation, which is implemented at the most disaggregated level (Figure 3-20):

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

with

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

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

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

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

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

Note that the emissions are only calculated in steps of 5 years 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. SO₂ is country-specific, see Table 3-9. For other air pollutants, the main data sources are USEPA (2010), IFEU (2010), EMEP/EEA (2019) and Integer (2013). In general, the following sources are used for the emission factors (if not stated differently in the respective chapters 3.2.5.2, 3.2.6.2, 3.2.7.2 or 3.2.8.2):

- Emission factors for NO_x, VOC/CH₄, CO and exhaust particulate matter (PM) are generally given in FOEN (2015j) and INFRAS (2015a). BC exhaust emission factors stem from Neosys (2013).
- Non-exhaust particulate matter (PM) and non-exhaust BC emission factors are based on Carbotech (2000), with some modifications by BUWAL (2001). It should be noted that "PM" in BUWAL (2001) corresponds to total PM, including particles larger than 10 µm. For all non-road mobile machinery sources except rail abrasion, PM10 amounts to 67 % of total PM according to in BUWAL (2001). For rail abrasion, PM10 amounts to 90 % to 100 % of total PM according to in BUWAL (2001). The corresponding factors have been applied in PM10 emission calculation.
- NMVOC is not modelled bottom-up; the NMVOC emissions are calculated as the difference of VOC and CH₄ 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 3-9 (column diesel oil, gasoline, natural gas) and in specific tables in the non-road chapters.
- Emission factors for NH₃, priority heavy metals and POPs are generally taken from the EMEP/EEA guidebook (EMEP/EEA 2019). Pb emission factors are estimated based on the Pb content of fuels (according to EMEP/EEA 2019). PCDD/PCDF emissions are taken from Rentz et al. (2008).

Note that all emission factors (in kg/hr) of NO_x, NMVOC, 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.

⁴ <https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html> [04.02.2022]

Activity data

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

- SBV (2013) for construction machinery
- SFSO (2013a) for agricultural machinery
- Jardin Suisse (2012) for garden care /hobby and professional appliances
- KWF (2012) for forestry machinery
- The national statistics on imports/exports of non-road vehicles was assessed by FCA (2015c)
- Off-Highway Research (2005, 2008, 2012) provided information on the number of non-road vehicles.
- Federal Department of Defence, Civil Protection and Sport: List of military machinery with vehicle stock, engine-power classes and operating hours (DDPS 2014a).

From these data sources, all necessary information like size distributions, modelling of the fleets, annual operating hours (age-dependent), load factors, year of placing on the market, and age distribution was derived. Details are documented in FOEN (2015j). All activity data (vehicle stocks, operating hours, consumption factors) can be downloaded by query from the 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 - 9) the stock numbers and the operating hours of non-road vehicles are summarised for each non-road category.

3.2.1.1.2 *Model for wood energy combustion*

Choice of method

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

Methodology

The Swiss wood energy statistics (SFOE 2021b) 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 3-6) to the source categories 1A1a Public Electricity and Heat Production, 1A2gviii Other, 1A4ai Commercial/Institutional, 1A4bi Residential and 1A4ci Agriculture/Forestry/Fishing.

Table 3-6: Categories of wood combustion installations based on SFOE 2021b.

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. (2022). Emission factor values are modelled for the years 1990, 2008, 2014, 2020 and 2035, i.e. 2008 and 2014 being the update years of the previous models. Years in between are linearly interpolated.

The model is based on a large number of air pollution control measurements, laboratory and field measurements, literature data (e.g. beReal, emission factors in the Nordic countries) and the EMEP/EEA guidebook (EMEP/EEA 2019) and takes into account both various technology standards of combustion installations and operating influences. For automatic chip boilers >50 kW, combined heat and power plants and plants for renewable waste from wood 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. For all wood combustion installations, the shares of PM_{2.5} in TSP and PM₁₀ in TSP are assumed to be 90 % and 95 %, respectively.

Table 3-7: Emission factors 2020 of pollutants due to wood combustion from source categories 1A1-1A4 (“w/o wood proc. companies.” stands for “without wood processing companies”).

1A Wood combustion	NO _x	NM VOC	SO _x	NH ₃	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Open fireplaces	80	230	10	5	90	95	100	60	3'000
Closed fireplaces, log wood stoves	85	220	10	5	81	86	90	57	2'800
Pellet stoves	85	14	10	2	36	38	40	14	390
Log wood hearths	70	310	10	5	180	190	200	130	4'000
Log wood boilers	100	70	10	2	54	57	60	16	1'700
Log wood dual chamber boilers	70	310	10	5	180	190	200	130	4'000
Automatic chip boilers < 50 kW	120	40	10	2	81	86	90	16	900
Automatic pellet boilers < 50 kW	70	14	10	2	27	29	30	7	330
Automatic chip boilers 50-300 kW w/o wood proc. companies	130	20	3	2	54	57	60	3	450
Automatic pellet boilers 50-300 kW	75	7	3	2	27	29	30	1	170
Automatic chip boilers 50-300 kW within wood proc. companies	140	20	3	2	54	57	60	3	460
Automatic chip boilers 300-500 kW w/o wood proc. companies	130	20	3	2	54	57	60	3	450
Automatic pellet boilers 300-500 kW	75	7	3	2	27	29	30	1	170
Automatic chip boilers 300-500 kW within wood proc. companies	140	20	3	2	54	57	60	3	460
Automatic chip boilers > 500 kW w/o wood proc. companies	120	7	3	2	9	10	10	0.2	140
Automatic pellet boilers > 500 kW	75	2	3	2	5	5	5	0.1	50
Automatic chip boilers > 500 kW within wood proc. companies	120	7	3	2	18	19	20	0.5	150
Combined chip heat and power plants	40	0.3	1	2	0.3	0.3	0.3	0.003	10
Plants for renewable waste from wood products	130	1	20	5	1.3	1.3	1.4	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	250	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	15	1	2	50	5	5	3	3	0.005	10
Automatic pellet boilers 50-300 kW	15	1	2	50	5	5	3	3	0.005	10
Automatic chip boilers 50-300 kW within wood proc. companies	15	1	2	100	5	5	3	3	0.005	10
Automatic chip boilers 300-500 kW w/o wood proc. companies	10	1	2	50	1	1	1	1	0.005	10
Automatic pellet boilers 300-500 kW	10	1	2	50	1	1	1	1	0.005	10
Automatic chip boilers 300-500 kW within wood proc. companies	10	1	2	100	1	1	1	1	0.005	10
Automatic chip boilers > 500 kW w/o wood proc. companies	10	1	2	50	1	1	1	1	0.001	10
Automatic pellet boilers > 500 kW	10	1	2	50	1	1	1	1	0.001	10
Automatic chip boilers > 500 kW within wood proc. companies	10	1	2	100	1	1	1	1	0.001	10
Combined chip heat and power plants	10	1	2	10	0.1	0.1	0.1	0.1	0.001	10
Plants for renewable waste from wood products	100	2	2	50	1	1	1	1	0.001	10

Activity data

Categories of wood combustion installations and their respective wood energy consumption (see Table 3-8) are based on the Swiss wood energy statistics (SFOE 2021b, table K) as well as the disaggregation into the individual source categories 1A1a Public electricity and heat production, 1A2gviii Manufacturing industries: Other, 1A4ai Commercial/Institutional, 1A4bi Residential and 1A4ci Agriculture/Forestry/Fishing (SFOE 2021b, table M).

As additional data source, specific bottom-up information from the industry is used in order to allocate wood combustion emissions directly. Thus, activity data of wood combustion of 1A2f, 1A2gviii and 1A4ci are allocated on the basis of industry information. The information on the specific processes is documented in the respective EMIS database (EMIS 2022/1A Holzfeuerungen). Note that this specific industry data is subtracted from the activity data of the respective combustion installation category in order to avoid double counting within source category 1A2 and 1A4 (see Figure 3-17):

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

Table 3-8: Wood energy consumption in 1A Fuel combustion.

1A Wood combustion	1990	1995	2000	2005	2010
	TJ				
Total	28'219	29'700	27'425	31'395	40'084
Open fireplaces	226	270	195	181	124
Closed fireplaces, log wood stoves	7'272	7'167	6'486	7'036	8'520
Pellet stoves	NO	NO	6.6	48	151
Log wood hearths	8'520	7'018	4'737	4'020	2'348
Log wood boilers	5'306	5'564	5'105	5'357	4'909
Log wood dual chamber boilers	1'964	1'777	977	480	273
Automatic chip boilers < 50 kW	239	433	550	753	1'008
Automatic pellet boilers < 50 kW	NO	NO	56	804	2'106
Automatic chip boilers 50-300 kW w/o wood proc. companies	461	854	1'158	1'859	2'723
Automatic pellet boilers 50-300 kW	NO	NO	3.5	113	596
Automatic chip boilers 300-500 kW within wood proc. companies	897	1'188	1'217	1'366	1'533
Automatic chip boilers 300-500 kW w/o wood proc. companies	237	521	713	998	1'496
Automatic pellet boilers 300-500 kW	NO	NO	NO	19	195
Automatic chip boilers 300-500 kW within wood proc. companies	411	568	585	628	669
Automatic chip boilers > 500 kW w/o wood proc. companies	314	1'084	1'706	2'359	4'427
Automatic pellet boilers > 500 kW	NO	NO	NO	9.5	186
Automatic chip boilers > 500 kW within wood proc. companies	1'393	2'193	2'398	2'801	2'993
Combined chip heat and power plants	NO	3.5	186	127	2'756
Plants for renewable waste from wood products	979	1'060	1'345	2'438	3'071

1A Wood combustion	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	TJ									
Total	35'301	40'015	44'168	37'303	38'869	42'518	43'479	41'069	43'156	41'931
Open fireplaces	87	84	84	62	64	68	67	62	62	58
Closed fireplaces, log wood stoves	6'960	7'787	8'604	6'825	7'446	7'862	7'540	6'926	6'943	6'376
Pellet stoves	135	163	190	159	181	199	196	186	187	175
Log wood hearths	1'621	1'566	1'454	978	1'006	993	900	792	764	675
Log wood boilers	3'682	3'822	3'900	2'819	2'970	3'033	2'852	2'597	2'597	2'320
Log wood dual chamber boilers	194	190	182	125	119	112	88	67	57	42
Automatic chip boilers < 50 kW	799	867	946	739	786	798	742	667	644	559
Automatic pellet boilers < 50 kW	1'809	2'151	2'511	2'099	2'376	2'610	2'619	2'538	2'676	2'489
Automatic chip boilers 50-300 kW w/o wood proc. companies	2'344	2'762	3'164	2'628	3'009	3'324	3'347	3'222	3'336	3'169
Automatic pellet boilers 50-300 kW	578	733	905	843	1'068	1'284	1'425	1'459	1'565	1'550
Automatic chip boilers 50-300 kW within wood proc. companies	1'314	1'428	1'539	1'281	1'400	1'487	1'484	1'421	1'418	1'362
Automatic chip boilers 300-500 kW w/o wood proc. companies	1'318	1'548	1'744	1'427	1'632	1'804	1'809	1'726	1'788	1'706
Automatic pellet boilers 300-500 kW	194	246	269	239	277	332	347	343	355	341
Automatic chip boilers 300-500 kW within wood proc. companies	593	632	679	565	597	629	620	613	613	594
Automatic chip boilers > 500 kW w/o wood proc. companies	4'098	4'977	5'832	4'955	5'801	6'538	6'708	6'456	6'838	6'702
Automatic pellet boilers > 500 kW	223	258	297	281	317	364	362	346	366	346
Automatic chip boilers > 500 kW within wood proc. companies	2'577	2'786	2'979	2'502	2'660	2'741	2'632	2'490	2'515	2'417
Combined chip heat and power plants	3'900	5'010	5'421	5'325	3'792	3'935	4'856	4'696	5'920	6'144
Plants for renewable waste from wood products	2'877	3'005	3'467	3'450	3'367	4'405	4'886	4'464	4'513	4'905

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 SO₂. Table 3-9 shows sulphur contents and SO₂ emission factors per fuel type. Explanations:

- For liquid and solid fuels, the SO₂ emission factors are determined by the sulphur content. The upper table depicts the maximum values as defined in the Federal Ordinance on Air Pollution Control OAPC (Swiss Confederation 1985).
- The middle table contains the effective sulphur contents. They are based on measurements: Summary and annual reports of Avenergy, reports by the Federal Office for Customs and Border Security (FOCBS) since 2000, as well as their measurement project 'Schwerpunktaktion Brenn und Treibstoffe'. For diesel oil and gasoline, the measurement project 'Tankstellensurvey', arranged by the FOEN, is a central data source.
- The lower table shows the emission factors in kg/TJ. They are calculated from the effective sulphur content S, the net calorific value NCV and the quotient of the molar masses of S and SO₂.

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

- Gas oil: starting from 1990 and for each fifth subsequent year up to and including 2015 the values for the SO₂ emission factors are based on five-year averages (eg. the value for 1995 is based on an average of the years 1993-1997). 1990 is the exception: for this year, the value is based on an average of the three years 1990-1992. The values for all other years are linear interpolations between the two nearest five-year averages as described above. Furthermore, 2006 saw the introduction to the market of low-sulphur eco-grade gas oil with a maximum legal sulphur limit of 50 ppm. From this year onwards, FOCBS measurements include both standard Euro- and eco-grade gas oil. For each year, the two grades are weighted by the respective total annual fuel consumption. Additionally, as of 2018, heating gas is also classified as gas oil.
- Coal: The legal limit of sulphur content depends on the size of the heat capacity of the combustion system. The value of 1 % sulphur content (350 kg SO₂/TJ) shown in Table 3-9 holds for heat capacity below 1 MW (see OAPC Annex 3, §513 (Swiss Confederation 1985)). For larger capacities, the value is 3 % (OAPC Annex 5, §2, Swiss Confederation 1985). For industrial combustion plants, the limit for the exhaust emissions actually sets the corresponding maximum sulphur content to 1.4 % (500 kg SO₂/TJ).
- Residual fuel oil: OAPC Annex 5, §11, lit.2 sets 2.8 % for the legal limit (denoted as class B in the upper table). Simultaneously, OAPC dispenses from emission control measurements if residual fuel oil of class A is used with sulphur content of maximum 1 % (see OAPC Annex 3, §421, lit.2, Swiss Confederation 1985), which holds for most combustion plants. The emission factors are based on five-year averages in the case of 1995, 2000 and 2015. 1990 is based on an average of the years 1990-1992 because no non-interpolated data is available for 1988 and 1989. Similarly, because the emission factors of the years 2006-2008 are not available, the average of 2005 is based on the years 2003-2005 and that of 2010 on 2009-2012. The values for all other years are linear interpolations between the two nearest five-year averages as described above.
- Natural gas: OAPC Annex 5, §42 sets 190 ppm as the legal limit for natural gas.

Table 3-9: Sulphur contents and SO₂ emissions factors. For explanation see text.

Year	Maximum legal limit of sulphur content						
	Diesel oil ppm	Gasoline ppm	Gas oil (Euro) ppm	Natural gas ppm	Res. fuel oil Class A, %	Res. fuel oil Class B, %	Coal %
1990	1400	200	2000	190	1.0	2.8	1-3
1991	1300	200	2000	190	1.0	2.8	1-3
1992	1200	200	2000	190	1.0	2.8	1-3
1993	1000	200	2000	190	1.0	2.8	1-3
1994	500	200	2000	190	1.0	2.8	1-3
2000	350	150	2000	190	1.0	2.8	1-3
2005	50	50	2000	190	1.0	2.8	1-3
2008	50	50	1000	190	1.0	2.8	1-3
2009	10	50	1000	190	1.0	2.8	1-3
2010-2020	10	10	1000	190	1.0	2.8	1-3

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

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	16	9.4	48			372			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			376			23.2
2005	0.47	0.38	33	0.5	NE	380		350	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
2020	0.47	0.38	6.5			605			23.1

* blue cells = interpolation

3.2.2 Source category 1A1 - Energy industries (stationary)

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

The most important source category in Energy industries is 1A1a Public electricity and heat production, followed by 1A1b Petroleum refining. Activities in source category 1A1c Manufacture of solid fuels and other energy industries are virtually not occurring in Switzerland apart from a very small charcoal production activity in traditional and historic trade.

Table 3-10: Specification of source category 1A1 Energy industries.

1A1	Source category	Specification
1A1a	Public electricity and heat production	Main sources are waste incineration plants with heat and power generation (Other fuels) and public district heating systems, including a small fraction of combined heat and power. The only fossil fuelled public electricity generation unit "Vouvry" (300 MW _e ; no public heat production) ceased operation in 1999.
1A1b	Petroleum refining	Combustion activities supporting the refining of petroleum products, excluding evaporative emissions.
1A1c	Manufacture of solid fuels and other energy industries	Emissions from charcoal production.

Table 3-11: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1A1, Energy Industries.

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

3.2.2.2 Methodological issues for 1A1 Energy industries (stationary)

3.2.2.2.1 Public electricity and heat production (1A1a)

Methodology (1A1a)

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

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

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

Emission factors (1A1a)

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

Emission factors are expressed in pollutant per energy content of municipal solid waste incinerated. They are all country-specific and based on extensive and repeated emission control measurements according to the Ordinance on Air Pollution Control on municipal solid waste incineration and special waste incineration plants (TBF 2005, TBF 2015, TBF 2021) as well as on expert estimates. The sources are documented in the EMIS database (EMIS 2022/1A1a Kehrichtverbrennungsanlagen and EMIS 2022/1A1a Sonderabfallverbrennungsanlagen). Emission factors are taking into account flue gas cleaning standards in incineration plants. In addition, the burn-out efficiency in modern municipal solid and special waste incineration plants is very high. The PCB emission factors from municipal solid waste and special waste incineration are based on the mass flow and emission model of former use and disposal of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

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

Biogas for combined heat and power generation:

Emission factors for combined heat and power generation with landfill gas are considered to be the same as for natural gas engines in commercial and institutional buildings or stem from the Clearinghouse for Inventories and Emissions Factors (CHIEF) by US-EPA (NO_x, NMVOC, SO_x, PM exhaust, PM₁₀ exhaust, PM_{2.5} exhaust, CO) (EMIS 2022/1A1a 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 2022/1A 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 PM_{2.5}/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 SO₂ 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 SO₂ 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 SO₂ emissions since 1985.

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

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

- Natural gas; PCDD/PCDF: chp. 1A4, Tier 2 Table 3.28

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

Table 3-12: Emission factors for 1A1a Public electricity and heat production of energy industries in 2020.

1A1a Public electricity and heat production	NO _x	NM VOC	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	6.5	0.002	0.2	0.2	0.2	0.0078	6.0
Residual fuel oil	NO	NO	NO	NO	NO	NO	NO	NO	NO
Petroleum coke	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	17	2	0.5	0.001	0.1	0.1	0.1	0.0054	9
Other fuels (MSW)	32	2.3	4.4	0.39	0.69	0.69	0.69	0.0062	6.0
Other fuels (special waste)	38	7.6	1.2	0.82	1.7	1.7	1.7	0.015	12
Biomass (wood, renewable waste)	55	0.41	4.1	2.5	0.46	0.46	0.48	0.0074	18
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	lcdP	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	0.00050	0.00056	0.0008	0.00084	0.00084	NA	NA
Other fuels (MSW)	25	2.5	5.8	0.017	NE	NE	NE	NE	3.8	1.5
Other fuels (special waste)	70	6	2.1	0.013	NE	NE	NE	NE	NE	0.63
Biomass (wood, renewable waste)	25	1.2	2	0.016	0.25	0.25	0.25	0.25	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 municipal solid waste and special waste incineration are based on annual waste statistics (FOEN 2021h) and provided in the table below.

Table 3-13: Activity data for 1A1a Other fuels: municipal solid waste and special waste incineration plants (with heat and/or power generation).

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

1A1a Other fuels	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Other fuels	kt	3'924	4'104	4'035	4'066	4'150	4'264	4'248	4'297	4'322	4'312
Municipal solid waste (MSW)	kt	3'676	3'841	3'773	3'817	3'889	4'010	4'011	4'042	4'059	4'072
Special waste	kt	247	263	262	249	261	254	236	255	262	241

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 2021; 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 2021a). 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 2021b) as described in chapter 3.2.1.1.2 Energy model for wood combustion.

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

1A1a Public electricity and heat production	Unit	1990	1995	2000	2005	2010					
Total fuel consumption	TJ	40'379	39'179	49'913	56'976	61'740					
Gas oil	TJ	980	554	790	1'300	490					
Residual fuel oil	TJ	3'214	1'813	340	290	40					
Petroleum coke	TJ	NO	NO	NO	NO	NO					
Other bituminous coal	TJ	530	46	NO	NO	NO					
Lignite	TJ	NO	NO	NO	NO	NO					
Natural gas	TJ	4'339	5'422	8'292	9'827	9'926					
Other fuels (waste-to-energy)	TJ	30'768	30'264	39'371	44'508	48'277					
Biomass (wood, renewable waste)	TJ	301	466	547	844	2'958					
Biogas (co-generation from landfills)	TJ	247	614	573	207	49					
1A1a Public electricity and heat production	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total fuel consumption	TJ	59'796	63'402	63'334	59'366	61'381	65'016	64'743	65'334	66'495	65'476
Gas oil	TJ	400	800	670	770	660	430	490	380	450	340
Residual fuel oil	TJ	10	NO	NO	NO	NO	NO	NO	NO	NO	NO
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	7'512	8'213	8'449	5'082	7'080	8'956	7'927	8'141	8'464	7'541
Other fuels (waste-to-energy)	TJ	47'847	49'313	48'228	49'161	50'548	52'422	52'316	53'097	53'552	53'248
Biomass (wood, renewable waste)	TJ	3'982	5'032	5'949	4'321	3'071	3'195	4'003	3'711	4'021	4'343
Biogas (co-generation from landfills)	TJ	44	44	39	31	21	13	6.5	6.0	8.4	4.0

3.2.2.2 Petroleum refining (1A1b)

In Switzerland, there were originally two petroleum refining plants. One of the two Swiss refineries operated at reduced capacity in 1990 and resumed full production in later years. In 2012, one of the refineries was closed over six months due to insolvency and the search for a new buyer (EV 2014). Since one of the refineries ceased operation in 2015, the data are considered confidential. Data are available to reviewers on request. In addition, operation was interrupted several times in 2014.

Methodology (1A1b)

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

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

Emission factors (1A1b)

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

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

Activity data (1A1b)

Activity data on fuel combustion for 1A1b Petroleum refining is provided by the Swiss overall energy statistics (SFOE 2021) 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 2021). As one of the refineries ceased operation in 2015, the data are considered confidential since 2014. Data are available to reviewers on request.

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

Net calorific values are provided by the annual monitoring reports of the refining industries for the years 2005-2011 and 2013-2020 that are required under the Swiss Federal Act and Ordinance on the Reduction of CO₂ 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 2021).

Table 3-15: Activity data of 1A1b Petroleum Refining.

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

1A1b Petroleum refining	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total fuel consumption	TJ	13'169	11'242	13'834	14'173	7'232	6'355	6'298	6'627	5'911	5'987
Residual fuel oil	TJ	764	1'212	1'094	1'330	C	C	C	C	NO	NO
Refinery gas	TJ	10'720	8'249	11'055	10'935	C	C	C	C	C	C
Petroleum coke	TJ	1'685	1'781	1'685	1'908	C	NO	NO	NO	NO	NO
Natural gas	TJ	NO	NO	NO	NO	NO	NO	C	C	C	C

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

Methodology (1A1c)

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

Emission factors (1A1c)

Emission factors for NO_x, NMVOC, CO are based on the revised 1996 IPCC Guidelines (IPCC 1996) and for PM₁₀ exhaust and TSP exhaust based on USEPA (1995, Chapter 10.7 Charcoal). PM_{2.5} exhaust is supposed to be 95 % from PM₁₀ exhaust (EMIS 2022/1A1c). The emission factor for BC (% PM_{2.5}) is estimated based on Nussbaumer and Hälgl (2015). Neither the 1996 IPCC Guidelines nor the EMEP/EEA guidebook (EMEP/EEA 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 3-16: Emission factors of 1A1c charcoal production in 2020.

1A1c Charcoal	NO _x	NM VOC	SO ₂	NH ₃	PM _{2.5} ex	PM ₁₀ ex	TSP ex	BC ex	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 2022/1A1c).

Table 3-17: Activity data of 1A1c charcoal production.

1A1c Charcoal	Unit	1990	1995	2000	2005	2010					
Charcoal production	TJ	1.3	1.4	2.2	3.4	3.6					
1A1c Charcoal	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Charcoal production	TJ	3.7	4.1	3.3	4.3	3.8	4.1	3.9	4.3	5.1	3.9

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

The following recalculations were implemented in submission 2022:

- 1A1: The shares of PM_{2.5} and PM₁₀ in TSP for all wood combustion installations were changed from 87 % to 90 % and from 93 % to 95 %, respectively, based on a revaluation of measurement and literature data yielding revised emission factors of PM_{2.5} and PM₁₀ for the entire time series.
- 1A1: Since the share of PM_{2.5} in TSP was changed for all wood combustion installations also the BC emission factors were revised for the entire time series.
- 1A1a: Activity data of plants for renewable waste from wood products have been revised for 2019 due to a small recalculation in the Swiss wood energy statistics (SFOE 2021b).
- 1A1a: There is a small recalculation of natural gas consumption in the year 2019.
- 1A1a: There are recalculations of gas oil use for the years 2011-2012.
- 1A1a: Activity data of incinerated municipal solid waste, construction waste and other & special waste have changed for 2019 due to updates in the underlying statistics by the FOEN. Municipal solid waste has decreased by 9'820 t (-0.34 %), construction waste and other & special waste have increased by 8'665 t (+1.7 %) and 1'155 t (+0.56 %), respectively.
- 1A1a: Emission factors for all relevant air pollutants of incinerated municipal solid waste have changed from 2014 to 2019 in the framework of a study evaluating reports of emission measurements carried out in the period 2015-2020 on all municipal solid waste incineration plants in Switzerland.
- 1A1a: Emission factors for all relevant air pollutants of incinerated special waste have changed from 2014 to 2019 in the framework of a study evaluating reports of emission measurements carried out in the period 2015-2020 on all special waste incineration plants in Switzerland.
- 1A1a: small reallocation of gas oil use from 1A1aiii to 1A1ai (but no difference in total gas oil use in 1A1a).
- 1A1c: Activity data of charcoal production has changed for 2019 due to updated production of one of the charcoal production plants for the year 2019.

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 3-18: Specification of source category 1A2 Stationary combustion in manufacturing industries and construction (stationary without 1A2gvii) in Switzerland.

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

Table 3-19: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1A2 Combustion in manufacturing industries and construction (stationary only).

NFR code	Source category	Pollutant	Identification criteria
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SOx	T1, T2
1A2f	Stationary combustion in manufacturing industries and construction: Other	NOx	L1, T1, L2, T2
1A2f	Stationary combustion in manufacturing industries and construction: Other	SOx	L1, T1, L2, T2
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM2.5	T1, T2
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM10	T1, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	T1, T2
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SOx	L1, L2
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM2.5	L1

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

3.2.3.2.1 Methodology (1A2) and industry model

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

Overview Industry Model

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.

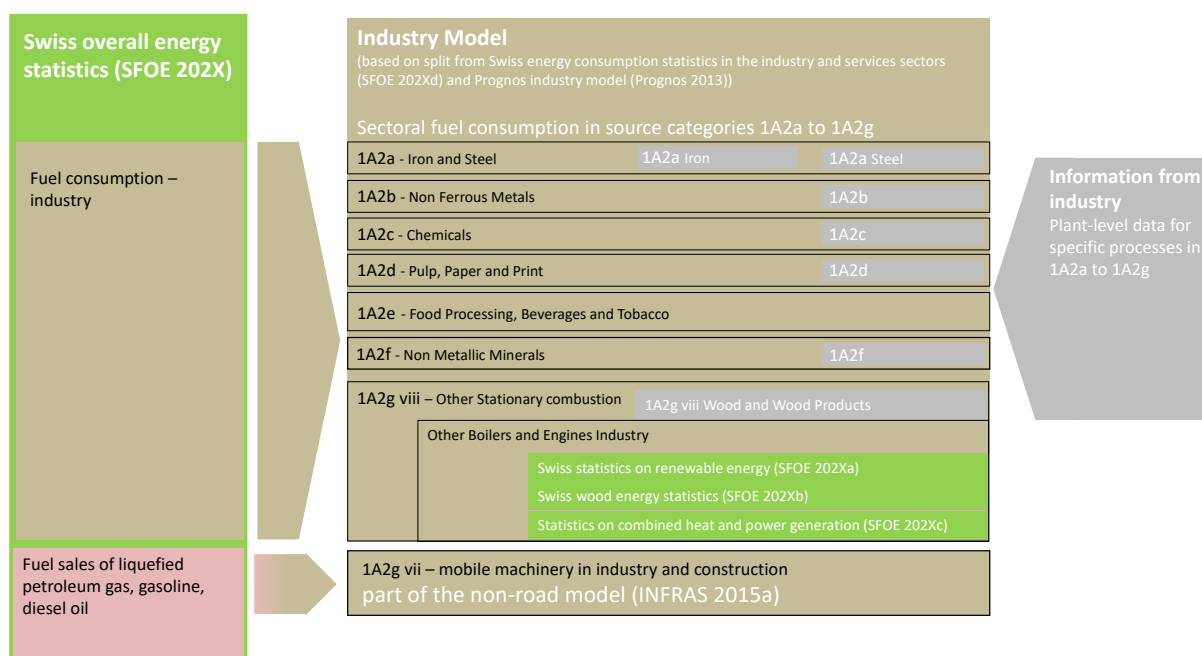


Figure 3-21: Schematic presentation of the data sources used for the industrial sectors 1A2a – 1A2g. The references SFOE 202X, SFOE 202Xa, 202Xb and 202Xc refer to the 2020 edition of the corresponding energy statistics. For each fuel type, the Swiss overall energy statistics provide the total consumption for industry. The total consumption is then distributed to the different source categories based on information from industry surveys (SFOE 2021d) 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 2021, 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 2021d). 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 2021c).

Energy consumption statistics in the industry and services sectors

The energy consumption statistics in the industry and services sectors (SFOE 2021d) 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 3-22. A detailed description for all fuel types and source categories (1A2a-1A2g), including further assumptions, is provided in the underlying documentation of the EMIS database (EMIS 2022/1A2_Sektorgliederung Industrie).

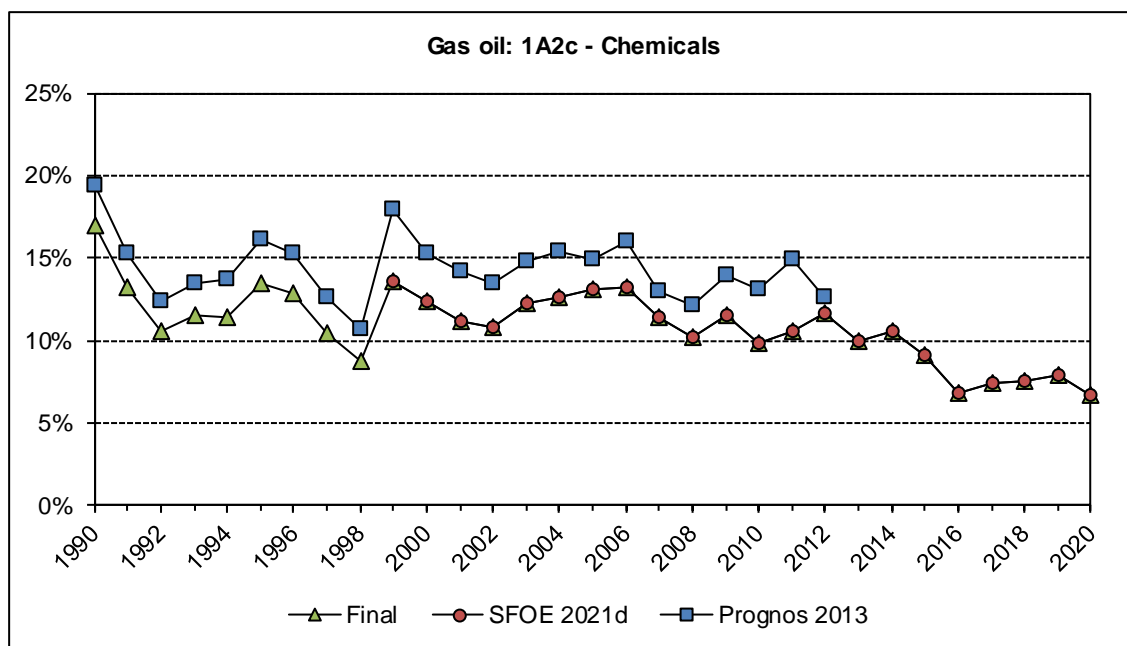


Figure 3-22: Illustrative example for combining time series with consistent overlap according to the 2006 IPCC Guidelines (IPCC 2006, Volume 1, chp. 5). The y-axis indicates the share of source category 1A2c of total gas oil consumption in the industry sector. The green line corresponds to the share 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 2021d, red line from 1999 to 2020) 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 3-21 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 CO₂ 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 2021d).

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 2021b) as well as on data from the Swiss renewable energy statistics (SFOE 2021a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2021c), 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, SO₂ (except for gas oil and residual fuel oil), NH₃, 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 SO₂ 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 Technology (EMPA, up to 2000) and Federal Office for Customs and Border Security (FOCBS), see also description in chp. 3.2.1.2.

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

Table 3-20: Emission factors for boilers of 1A2 Stationary combustion in manufacturing industries and construction in 2020.

1A2 Boiler	NO _x	NMVOC	SO ₂	NH ₃	PM2.5	PM10	TSP	BC	CO
	g/GJ								
Boiler gas oil	31	2	6.5	0.002	0.2	0.2	0.2	0.0078	6.0
Boiler residual fuel oil	125	4	605	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	7.0
Boiler petroleum coke	125	4	605	0.002	20	20	23	2	10
Boiler other bituminous coal	200	10	500	0.003	45	45	50	2.88	100
Boiler lignite	200	10	500	0.003	45	45	50	2.88	100
Boiler natural gas	19	2	0.5	0.001	0.1	0.1	0.1	0.0054	7.0

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

Activity data (1A2)

Table 3-21 shows the total fuel consumption in 1A2 and Table 3-22 shows fuel consumption in boilers of each source category 1A2a-1A2gviii as described above in the Industry model

Energy: Source category 1A - Fuel combustion activities - Source category 1A2 - Stationary combustion in manufacturing industries and construction

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

1A2 Manufacturing industries and constr. (stationary sources)	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	89'956	90'576	89'115	92'575	91'604
Gas oil	TJ	22'910	24'471	25'892	25'317	21'137
Residual fuel oil	TJ	18'870	13'678	5'675	4'613	2'056
Liquefied petroleum gas	TJ	4'354	4'458	5'627	4'309	3'912
Petroleum coke	TJ	1'400	1'260	551	1'093	1'495
Other bituminous coal	TJ	13'476	7'303	5'866	4'799	4'348
Lignite	TJ	265	153	124	742	1'460
Natural gas	TJ	19'450	28'500	31'850	34'760	38'330
Other fossil fuels	TJ	2'556	2'818	4'053	4'525	5'183
Biomass	TJ	6'676	7'935	9'477	12'418	13'684

1A2 Manufacturing industries and constr. (stationary sources)	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total fuel consumption	TJ	85'354	86'540	88'144	82'646	81'202	82'305	82'676	79'870	79'452	76'532
Gas oil	TJ	17'314	17'575	18'007	12'444	12'725	12'812	11'489	10'871	10'071	8'854
Residual fuel oil	TJ	1'518	1'568	848	231	196	155	123	34	111	41
Liquefied petroleum gas	TJ	3'861	3'731	3'740	3'288	3'340	2'752	3'131	3'051	2'925	2'798
Petroleum coke	TJ	1'272	1'367	1'049	1'240	795	890	763	781	777	700
Other bituminous coal	TJ	3'868	3'794	3'910	2'403	1'946	1'517	1'634	1'665	1'450	1'153
Lignite	TJ	1'624	1'175	1'357	3'102	3'060	3'078	2'876	2'520	2'262	2'410
Natural gas	TJ	37'250	38'280	39'620	40'200	39'360	39'870	40'910	39'230	39'470	38'090
Other fossil fuels	TJ	5'307	4'883	5'186	5'270	5'252	5'926	5'912	6'513	6'679	6'805
Biomass	TJ	13'340	14'166	14'427	14'468	14'530	15'305	15'839	15'205	15'707	15'680

Table 3-22: Fuel consumption in boilers of 1A2 Stationary combustion in manufacturing industries and construction.

Source (Boilers)	Unit	1990	1995	2000	2005	2010
1A2a Iron and steel	TJ	1'031	1'005	966	1'085	1'649
Gas oil	TJ	480	262	338	401	315
Residual fuel oil	TJ	26	131	20	39	51
Liquefied petroleum gas	TJ	408	193	286	217	219
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	118	419	322	429	1'065
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2b Non-ferrous metals	TJ	2'242	1'958	1'549	971	1'214
Gas oil	TJ	451	336	225	119	108
Residual fuel oil	TJ	NO	NO	NO	NO	0.024
Liquefied petroleum gas	TJ	27	17	15	7.1	7.7
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	1'764	1'605	1'309	845	1'098
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2c Chemicals	TJ	14'431	15'158	13'497	15'477	11'814
Gas oil	TJ	3'942	3'313	3'215	3'345	2'103
Residual fuel oil	TJ	1'434	693	252	36	66
Liquefied petroleum gas	TJ	15	13	12	10	7.5
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	9'039	11'138	10'017	12'086	9'637
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2d Pulp, paper and print	TJ	9'675	12'343	9'883	9'326	6'773
Gas oil	TJ	1'188	1'751	1'403	1'456	852
Residual fuel oil	TJ	5'250	3'061	1'417	2'092	279
Liquefied petroleum gas	TJ	86	141	148	100	61
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	3'151	7'389	6'916	5'678	5'581
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2e Food processing, bevera	TJ	9'858	8'784	10'437	10'239	13'161
Gas oil	TJ	7'410	5'511	5'515	4'070	3'778
Residual fuel oil	TJ	1'160	466	137	NO	NO
Liquefied petroleum gas	TJ	204	308	535	534	659
Petroleum coke	TJ	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO
Natural gas	TJ	1'085	2'500	4'250	5'635	8'723
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO
1A2g viii Other	TJ	17'990	22'164	22'823	23'874	24'262
Gas oil	TJ	7'418	11'626	13'484	14'497	12'705
Residual fuel oil	TJ	5'237	3'605	47	4.9	29
Liquefied petroleum gas	TJ	3'091	3'288	4'164	3'116	2'855
Petroleum coke	TJ	765	914	15	383	318
Other bituminous coal	TJ	205	140	12	88	11
Lignite	TJ	NO	NO	NO	4.7	111
Natural gas	TJ	781	2'088	4'588	5'281	7'703
Other fossil fuels	TJ	NO	NO	NO	NO	NO
Biomass (biogas, sewage ga	TJ	493	504	513	499	529

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

Source (Boilers)	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1A2a Iron and steel	TJ	1'526	1'455	1'428	1'504	1'912	1'884	2'151	2'283	2'135	2'113
Gas oil	TJ	271	172	139	86	136	134	123	127	97	81
Residual fuel oil	TJ	1.5	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	226	438	438	388	393	327	368	358	342	327
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	1'027	845	851	1'031	1'383	1'423	1'660	1'799	1'696	1'705
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	1'174	1'745	1'592	1'914	1'790	1'681	1'638	1'744	1'961	1'802
Gas oil	TJ	73	152	127	88	77	74	77	53	60	48
Residual fuel oil	TJ	0.023	0.78	23	NO	44	NO	3.7	NO	NO	NO
Liquefied petroleum gas	TJ	8.2	11	11	9.8	9.9	8.3	9.3	9.0	8.6	8.3
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	1'093	1'581	1'430	1'816	1'660	1'598	1'549	1'682	1'892	1'746
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	12'167	13'909	14'125	12'125	12'525	14'370	13'806	13'283	11'809	10'875
Gas oil	TJ	1'847	2'055	1'797	1'321	1'167	881	860	825	799	600
Residual fuel oil	TJ	0.16	0.16	1.2	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	7.1	10	10	8.9	9.0	7.5	8.4	8.2	7.9	7.5
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	10'312	11'845	12'317	10'795	11'349	13'482	12'937	12'450	11'001	10'268
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	6'051	5'374	5'474	4'643	3'655	2'982	2'851	2'073	2'151	2'057
Gas oil	TJ	561	623	711	297	383	410	288	293	345	282
Residual fuel oil	TJ	4.0	2.8	0.018	22	19	9.0	8.8	NO	NO	NO
Liquefied petroleum gas	TJ	62	67	67	60	60	50	57	55	53	50
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	5'424	4'681	4'696	4'264	3'193	2'513	2'498	1'725	1'753	1'724
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, bevera	TJ	11'374	11'310	13'079	12'438	11'572	10'974	11'212	10'824	11'831	11'858
Gas oil	TJ	3'197	3'237	3'681	2'395	2'522	2'503	2'110	1'925	2'119	2'007
Residual fuel oil	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Liquefied petroleum gas	TJ	675	935	935	828	838	699	785	763	731	699
Petroleum coke	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lignite	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	TJ	7'502	7'138	8'463	9'215	8'212	7'772	8'318	8'137	8'981	9'153
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2g viii Other	TJ	21'262	21'341	20'458	17'587	18'609	18'489	18'427	17'521	17'155	15'894
Gas oil	TJ	10'124	10'239	10'373	7'050	7'342	7'785	6'912	6'568	5'534	4'839
Residual fuel oil	TJ	1.7	0.26	2.1	0.33	2.8	7.9	4.3	2.2	2.4	4.1
Liquefied petroleum gas	TJ	2'756	2'162	2'165	1'949	1'977	1'615	1'860	1'813	1'738	1'667
Petroleum coke	TJ	154	405	181	108	104	155	113	168	169	65
Other bituminous coal	TJ	16	50	110	105	134	125	102	140	58	101
Lignite	TJ	131	95	75	189	204	197	182	153	141	144
Natural gas	TJ	7'511	7'824	7'012	7'632	8'316	8'075	8'736	8'211	9'051	8'615
Other fossil fuels	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	TJ	569	567	540	553	530	530	518	464	462	458

3.2.3.2.2 Iron and steel (1A2a)

Methodology (1A2a)

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-20 and Table 3-22, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as

outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2a.

Reheating furnaces in steel production

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

Electric arc furnaces in steel production:

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

Cupola furnaces in iron foundries

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

Emission factors (1A2a)

Reheating furnaces in steel production

For NO_x, PM_{2.5}/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, SO₂ and Hg country-specific emission factors are used. Emission factors for Pb and Cd are available for selected years. Since 1995, emission factors are assumed to be constant. The emission factors of BC (% PM_{2.5}) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil and table 3.16 for natural gas), see EMIS 2022/1A2a Stahl-Produktion Wärmeöfen.

Cupola furnaces in iron foundries

Emission factors of NO_x, NMVOC, SO₂, PM_{2.5}/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 (% PM_{2.5}) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp.1A4, Table 3.23). Emission factors of PAH are based on data from literature, see USEPA (1998) and EMIS 2022/1A2a Eisengiessereien Kupolöfen). The Hg emission factor is based on the default value for other bitumoniou coal of Table 3.23 (chp. 1A4) of EMEP/EEA (2019).

Table 3-23: Emission factors of 1A2a Iron and Steel in 2020.

1A2a Iron and steel	NO _x	NM VOC	SO ₂	NH ₃	PM _{2.5}	PM ₁₀	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 2022/1A2a).

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 2021).

Table 3-24: Activity data from production of iron and steel that is used to calculate bottom-up emissions from sources of 1A2a.

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

1A2a Iron and steel	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron foundries, cupola	kt iron	15	11	11	11	9.2	8.6	8.8	8.6	6.0	5.1
Steel plants, reheating furnaces	kt steel	1'183	1'162	1'126	1'176	1'144	1'085	1'138	1'160	1'037	1'031

3.2.3.2.3 Non-ferrous metals (1A2b)

Methodology (1A2b)

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-20 and Table 3-22, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2b.

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

Secondary aluminium production plants:

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

Non-ferrous metals smelters and furnaces

Regarding non-ferrous metal industry in Switzerland, only casting and no production of non-ferrous metals occur. There is one large company and several small foundries, which are organized within the Swiss foundry association (GVS).

Emission factors (1A2b)

Emissions from non-ferrous metals smelters and furnaces are derived from the emission factors per tonne of metal as shown in the following table as documented in the EMIS database (EMIS 2022/1A2b Buntmetallgiessereien übriger Betrieb). The emission factors are based on information of the Swiss foundry association (GVS).

Table 3-25: Emission factors of 1A2b Non-ferrous metals in 2020.

1A2b Non-ferrous metals	NO _x	NM VOC	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 3-22).

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

Table 3-26: Activity data from production of Non-ferrous metals that are used to calculate bottom-up emissions from sources of 1A2b.

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

1A2b Non-ferrous metals	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Aluminium production	kt aluminium	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foundries	kt non-ferrous metals	12	6.6	6.4	9.5	8.9	9.0	8.0	6.8	6.4	5.1

3.2.3.2.4 Chemicals (1A2c)

Methodology (1A2c)

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

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-20 and Table 3-22, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2c.

Steam production from cracker by-products

There is one large company producing ammonia and ethylene by thermal cracking of liquefied petroleum gas and light virgin naphtha. In addition, thermal cracking also produces so-called heating gas and gasolio as by-products. In 2018 the cracking process and the subsequent integrated production chain were modified yielding synthesis gas as additional by-product. These cracker by-products are used thermally for steam production within the same plant and are accounted for within source category 1A2c as other fossil fuels. Process emissions from ammonia and ethylene production are reported in source category 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 3-20. For synthesis gas (about 23 % vol. CO, 77 % vol. H₂) emissions of NO_x and NH₃ are assumed only. Thus, for NO_x and NH₃, the same emission factors as of boilers, natural gas are applied, see Table 3-20.

Activity data (1A2c)

Activity data on gasolio, heating gas and synthesis gas (from 2018 onwards) are provided by the industry. Since 2013, they are based on monitoring reports of the Swiss ETS as documented in the EMIS database (EMIS 2022/1A2c ethylene production). The activity data are confidential but available to reviewers on request.

3.2.3.2.5 Pulp, paper and print (1A2d)

Methodology (1A2d)

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

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-20 and Table 3-22, respectively. In the following chapters, only those source categories are described, that are directly based on bottom-up industry data as outlined above in chapter 3.2.3.2.1. In addition, the chapter on activity data provides an overview on the fuel consumption within 1A2d.

Emission factors (1A2d)

For the cellulose production plant, NO_x and SO₂ emission factors were derived from air pollution control measurements. The emission factor of BC (% PM_{2.5}) was taken according to the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E) as documented in the EMIS database (EMIS 2022/1A2d Zellulose-Produktion Feuerung).

Activity data (1A2d)

Activity data on annual cellulose production are provided by the industry as documented in the EMIS database (EMIS 2022/1A2d Zellulose-Produktion Feuerung). The only plant closed in 2008.

In 2020, natural gas is the most important fuel in this category (see Table 3-22). Biomass used in paper production is reported in source category 1A2gviii, because no comprehensive data exist to distribute biomass consumption to the specific industries within 1A2.

The overall fuel consumption within the Swiss pulp and paper industry has decreased significantly due to the closure of the cellulose production plant in 2008 and the closure of 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, a major part of revenues is provided by meat production, milk products and convenience food. Further productions comprise chocolate, sugar or baby food (Fial 2013). Fossil fuels are used for steam production and drying processes.

Emission factors and activity data of fuel consumption in boilers of this source category are documented in Table 3-20 and Table 3-22, respectively.

In 2020, the fuels used in this category were mainly natural gas as well as gas oil and small amounts of liquefied petroleum gas. All fuel is consumed in boilers. Activity data are provided in Table 3-22.

3.2.3.2.7 Non-metallic minerals (1A2f)

Source category 1A2f Non-metallic minerals includes several large fuel consumers from mineral industry as for example cement, lime or brick and tile, glass and rock wool production (EMIS 2022/1A2f). 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 2022/1A2f).

Table 3-27: Emission factors for Non-metallic minerals 1A2f in 2020.

1A2f Non-metallic minerals	NO _x	NM VOC	SO ₂	NH ₃	PM2.5	PM10	TSP	BC	CO
	g/t								
Cement	790	67	280	45	3	4	5	0.25	2'600
Lime	C	C	C	NE	C	C	C	C	C
Container glass	C	NA	C	NE	C	C	C	C	C
Glass wool	5'000	14	3.4	NE	342	611	630	18	80
Tableware glass	C	C	C	NE	C	C	C	C	C
Brick and tile	530	140	80	NE	19	29	32	1.0	560
Fine ceramics	C	C	C	NE	C	C	C	C	C
Rock wool	C	IE	C	C	C	C	C	C	C
Mixed goods	10	32	17	NE	1	2.9	3	0.044	85

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

Activity data (1A2f)

Table 3-28 provides an overview of activity data in source category 1A2f. Data sources are described for each process in the following chapters and are documented in the EMIS database (EMIS 2022/1A2f).

Table 3-28: Activity data for Non-metallic minerals 1A2f.

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

1A2f Non-metallic minerals	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cement	kt	3'587	3'368	3'415	3'502	3'195	3'296	3'279	3'239	3'227	3'129
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	41	39	33	32	31	32	36	40	47	40
Tableware glass	kt	C	C	C	C	C	C	C	C	C	C
Brick and tile	kt	800	792	785	765	726	660	622	581	554	531
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	5'300	4'770	4'770	5'260	4'850	4'710	5'260	5'180	5'210	4'910

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).

Emission factors

Table 3-27 shows product-specific emission factors for cement production (EMIS 2022/1A2f Zementwerke Feuerung). Since 2008, emission factors are based on various air pollution control measurements under the Ordinance on Air Pollution Control (Swiss Confederation 1985). A reassessment of emission measurement reports of the years 2013 and 2018 led to changes in emission factors for the years 2009-2012 and from 2013 onwards. Regarding NO_x, an industry agreement defines an emission reduction path for the years 2016-2021. Emission data for monitoring compliance with the agreement were evaluated and the emission factor for NO_x was computed accordingly. The value for PCB is based on the Tier 2 emission factor in the EMEP/EEA guidebook (EMEP/EEA 2019, chp.1A2, Table 3.24).

Activity data

Activity data of annual clinker production of each cement production plant in Switzerland are provided by the association of the Swiss cement industry (see Table 3-28). Since 2008, activity data are available from monitoring reports of the Swiss ETS.

For information purposes, annual fuel consumption of the cement production plants in Switzerland are shown in Table 3-29. The 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 2022/1A2f Zementwerke Feuerung.

Table 3-29: Fuel consumption of cement industry (fossil without waste, fossil waste derived, and biomass waste derived).

Cement industry	Unit	1990	1995	2000	2005	2010
Cement, total incl. waste	TJ	17'194	12'774	11'017	11'623	12'388
Cement fossil without waste	TJ	15'319	9'993	7'332	6'208	6'278
Gas oil	TJ	NO	NO	NO	72	5.4
Residual fuel oil	TJ	1'907	2'825	1'530	637	112
Petroleum coke	TJ	550	300	480	638	1'130
Other bituminous coal	TJ	12'235	6'547	5'176	4'120	3'662
Lignite	TJ	265	153	124	737	1'348
Gas	TJ	362	168	22	3.9	21
Cement, waste derived fuel	TJ	1'874	2'781	3'685	5'415	6'109
Used oil	TJ	1'170	1'485	1'520	1'411	1'253
Sewage sludge (dry)	TJ	9.4	128	333	494	477
Used wood	TJ	NO	322	NO	NO	292
Solvents	TJ	283	181	426	976	1'189
Used tires	TJ	330	415	421	645	842
Plastics	TJ	NO	55	572	841	1'252
Animal meal	TJ	NO	NO	198	856	624
CSS	TJ	23	135	158	133	123
Used charcoal	TJ	59	59	59	58	NO
Other fossil waste fuels	TJ	NO	NO	NO	NO	45
Industrial waste	TJ	NO	NO	NO	NO	NO
Agricultural waste	TJ	NO	NO	NO	NO	7.3
Other biomass	TJ	NO	NO	NO	NO	5.7

Cement industry	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cement, total incl. waste	TJ	12'187	11'462	11'866	12'339	11'348	11'583	11'476	11'474	11'478	11'213
Cement fossil without waste	TJ	5'859	5'406	5'512	5'847	4'917	4'544	4'354	3'965	3'736	3'465
Gas oil	TJ	0.68	0.10	88	75	87	50	56	63	106	54
Residual fuel oil	TJ	101	297	86	58	45	90	59	NO	63	NO
Petroleum coke	TJ	1'081	920	815	1'052	622	658	574	542	552	591
Other bituminous coal	TJ	3'167	3'097	3'203	1'713	1'267	826	938	938	831	528
Lignite	TJ	1'493	1'081	1'283	2'912	2'856	2'881	2'694	2'367	2'120	2'266
Gas	TJ	16	11	38	37	41	39	34	56	65	26
Cement, waste derived fuel	TJ	6'329	6'056	6'354	6'492	6'431	7'039	7'122	7'509	7'743	7'748
Used oil	TJ	1'170	839	876	923	1'142	1'567	1'311	1'336	1'466	1'460
Sewage sludge (dry)	TJ	483	527	418	428	420	479	499	519	512	553
Used wood	TJ	409	586	732	886	896	811	840	840	861	867
Solvents	TJ	1'264	1'294	1'414	1'273	1'292	1'534	1'398	1'380	1'623	1'288
Used tires	TJ	1'033	964	985	1'021	958	951	1'041	1'045	1'041	1'018
Plastics	TJ	1'163	1'092	1'299	1'360	1'177	1'171	1'398	1'722	1'627	2'034
Animal meal	TJ	614	572	479	457	412	409	470	522	475	441
CSS	TJ	96	100	96	103	80	98	78	73	58	0
Used charcoal	TJ	NO	NO	NO	NO	NO	NO	66	61	48	52
Other fossil waste fuels	TJ	55	36	25	19	12	11	5.7	5.4	NO	NO
Industrial waste	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Agricultural waste	TJ	18	28	NO	NO	NO	NO	9.2	NO	NO	NO
Other biomass	TJ	24	17	32	21	42	7.9	5.6	5.4	31	36

In 2020, the Swiss cement industry used about two-thirds of waste derived fuels (fossil and biogenic) and one-third of standard fossil fuels. Today, fossil fuels used in cement industry are mainly lignite, plastics, waste tyres, waste oil and solvents and residues from distillation whereas petroleum coke and other bituminous coke are less important. Biogenic wastes contain mainly wood waste, sewage sludge and animal residues (animal meal). The main fossil fuel used in 1990 was other bituminous coal, but residual fuel oil and waste oil were also of importance.

Fuel consumption in cement plants has decreased between 1990 and 2020. This is partly due to a decrease in production since 1990 and an increase in energy efficiency. In the same period, the fuel mix has changed significantly from mainly standard fossil fuels to the above-mentioned mix of fuels.

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

Container glass (1A2f)

Methodology

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

Emission factors

For container glass production, emission factors of NO_x and PM_{2.5}/PM₁₀/TSP are based on various air pollution control measurements under the Ordinance on Air Pollution Control (EMIS 2022/1A2f Hohlglas Produktion) and partly on information from industry. The SO₂ emission factor is based on air pollution control measurements from 2011. The emission factor of BC (% PM_{2.5}) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil and table 3.16 for natural gas).

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

Activity data

Activity data consist of annual production data provided by the industry (Table 3-28). Since 2008, activity data are available from monitoring reports of the Swiss ETS.

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

Tableware glass (1A2f)

Methodology

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

Emission factors

For tableware glass production, emission factors of NO_x and PM_{2.5}/PM₁₀/TSP are based on various air pollution control measurements under the Ordinance on Air Pollution Control whereas those of SO₂, NMVOC, CO are based on information from industry (EMIS 2022/1A2f Glas übrige Produktion). Emission factors of Pb and Cd are assumed proportional to the emissions of TSP. The emission factor of Hg is calculated proportional to the composition of fuels consumed in the production process (liquefied petroleum gas and residual fuel oil until 1995). The emission factors of BC (% PM_{2.5}) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil and table 3.16 for liquefied petroleum gas gas).

Activity data

For tableware glass production, activity data are provided by monitoring reports of the Swiss ETS (Table 3-28). Activity data of tableware glass are considered confidential and are available to reviewers on request.

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

Glass wool (1A2f)

Methodology

In Switzerland, glass wool is produced in two plants.

Emission factors

Table 3-27 shows product-specific emission factors for glass wool production. For glass wool, emission factors of NO_x and PM_{2.5}/PM₁₀/TSP are based on various air pollution control measurements under the Ordinance on Air Pollution Control (EMIS 2022/1A2f Glaswolle Produktion) and partly on information from industry. The emission factor for SO₂ 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 (% PM_{2.5}) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.16).

Activity data

Activity data consist of annual production data provided by monitoring reports from the industry (Table 3-28). Currently, fuel consumption for glass wool production includes only natural gas. Production of glass wool has increased since 1990, but the natural gas consumption decreased. This can be explained by an increase in energy efficiency in the production process.

Lime (1A2f)

Methodology

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

Emission factors

For lime production, emission factors of NO_x, SO₂, PM_{2.5}/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 2022/1A2f). The emission factor of BC (% PM_{2.5}) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil, table 3.23 for other bituminous coal and table 3.16 for natural gas), see EMIS 2022/1A2f Kalkproduktion Feuerung.

Activity data

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

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

Brick and Tile (1A2f)

Methodology

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

Emission factors

Table 3-27 shows emission factors for brick and tile production. Emission factors of NO_x, NMVOC, SO₂, PM_{2.5}/PM₁₀/TSP, CO, Pb, Cd und Hg are derived from air pollution control measurements as described in the EMIS database (EMIS 2022/1A2f Ziegeleien). The emission factors of BC (% PM_{2.5}) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil, table Liquid fuels (rounded mean value), Appendix E for residual fuel oil, paper pulp and animal fat and table 3.16 for liquefied petroleum gas and natural gas).

Activity data

Activity data consist of annual production data provided by the industry (Table 3-28). Since 2013, for one large plant activity data are available from monitoring reports of the Swiss ETS.

Fuels used in the brick and tile production in 2020 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, SO₂ 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 PM_{2.5}/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 SO₂ is assumed to be constant. The emission factors of BC (% PM_{2.5}) are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil and table 3.16 for natural gas), see EMIS 2022/1A2f 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, NH₃, SO₂) for rock wool production are based on annual flux analysis from industry – except for the emission factors of BC (% PM_{2.5}), which are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, table 3.18 for gas oil, table 3.23 for other bituminous coal and table 3.16 for liquefied petroleum gas and natural gas), see EMIS 2022/1A2f Steinwolle Produktion.

Activity data

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

Currently, other bituminous coal and natural gas are used in the production process. Until 2004 also gas oil and liquefied petroleum gas were used. In 2005, these fuels were substituted by natural gas. Since 1990, there was a decrease in the specific energy consumption of rock wool production.

Mixed Goods (1A2f)

Methodology

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

Emission factors

Table 3-27 shows product-specific emission factors for production of mixed goods. Emission factors of NO_x, NMVOC, CO, PM_{2.5}/PM₁₀/TSP, Pb and Cd are based on air pollution control measurements from the time period between 2001 and 2015. This includes about 150 measurements from 55 out of 110 Swiss producers. As these measurements show no clear trend in the emission factors, a constant country-specific, average emission factor is used

from 2001 onwards. Emission factors of SO₂, Hg and PCCD/PCDF are based on data from the industry association (Schweizerische Mischgut-Industrie) (EMIS 2022/1A2f Mischgut Produktion).

Activity data

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

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

3.2.3.2.8 Other (1A2gviii)

Methodology (1A2gviii)

Source category 1A2gviii Other covers fossil fuel combustion in boilers of manufacturing industries and construction mainly within non-metallic mineral industries as well as combustion of wood, wood waste, biogas and sewage gas in all manufacturing industries. For more detailed descriptions on methodologies of biogas and sewage gas, see source categories 5B Biological treatment of waste (chp. 6.3) and 5D Wastewater handling (chp. 6.5), respectively.

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

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

Emission factors (1A2gviii)

Emission factors of fossil fuel consumption in 1A2gviii in boilers and in fibreboard production are determined top-down (see Table 3-20). For animal 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 3-7.

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

Emission factors of biogas and sewage gas are assumed to be the same as for natural gas. For boilers the emission factors are thus the same as documented above in chapter 3.2.3.2: Emission factors 1A2. For engines the emission factors of NO_x, NMVOC, SO₂, NH₃, PM_{2.5}, PM₁₀, TSP and CO are documented in the Handbook on emission factors for stationary sources (SAEFL 2000) whereas those of BC (% PM_{2.5}), Pb, Cd, Hg, PCDD/PCDF and PAH are taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4, Table 3.26 and Table 3.30).

Table 3-30: Emission factors in 2020 for 1A2gviii

1A2gviii Other	NO _x	NM VOC	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	7.0
Boiler municipal sewage gas	19	2	0.5	0.001	0.1	0.1	0.1	0.0054	7.0
Engines biogas	20	1	0.5	NE	0.1	0.1	0.1	0.0025	55
Engines sewage gas	15	1	0.5	NE	0.1	0.1	0.1	0.0025	45

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

Activity data (1A2gviii)

In 2015, fuel consumption of 1A2gviii Other comprises mainly biomass, gas oil and natural gas. Overall, there has been a shift in fuel consumption between 1990 and 2020 from liquid and solid fuels to liquid fuels, biomass and natural gas. Activity data of fossil fuels is derived from the industry model and given in Table 3-22. Fuel consumption of wood, wood waste, biogas and sewage gas in this source category is based on the Swiss wood energy statistics (SFOE 2021b) as well as on data from the Swiss renewable energy statistics (SFOE 2021a) and the Statistics on combined heat and power generation in Switzerland (SFOE 2021c) (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 2020 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 2022/1A2giv).

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

The following recalculations were implemented in submission 2022:

- 1A2: There was a recalculation of gas oil use in boilers in manufacturing industries and construction for the year 2019.
- 1A2: There was a small recalculation of natural gas consumption in the year 2019.
- 1A2f: The emission factor for NO_x for cement production has changed for the years 2016-2019. The Swiss cement industry has entered into an industry agreement to reduce its NO_x emissions from 2016 to 2021 according to a defined reduction path. Emission data for monitoring compliance with the agreement were evaluated and the emission factor for NO_x was adjusted accordingly.
- 1A2gviii: A typing error in the HCB emission factor (2014) of some wood combustion installations was corrected yielding revised values for the years 2009-2019.
- 1A2gviii: The shares of PM2.5 and PM10 in TSP for all wood combustion installations were changed from 87 % to 90 % and from 93 % to 95 %, respectively, based on a revaluation of measurement and literature data yielding revised emission factors of PM2.5 and PM10 for the entire time series.
- 1A2gviii: Since the share of PM2.5 in TSP was changed for all wood combustion installations also the BC emission factors were revised for the entire time series.
- 1A2gviii: Activity data (wood, wood waste) of combustion installations in source category 1A2gviii have been revised for 1990-2019 due to recalculations in the Swiss wood energy

statistics (SFOE 2021b). The biggest changes were in automatic boilers >50 kW after 2005.

- 1A2gviii: Activity data of sewage gas from industrial wastewater treatment used in boilers and in engines has changed (by less than 1 %) for the years 2015-2018. The data is taken from the national statistical report of renewable energies by SFOE and has been updated.
- 1A2gviii: Due to small recalculations of consumption of liquefied petroleum gas in the road transportation sector 2011-2019, the use of liquefied petroleum gas in 1A2gviii Other boilers has changed a little, too.

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

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

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

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

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

Table 3-32: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1A4 Stationary combustion in other sectors.

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

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

Methodology (1A4 ai/bi/ci stationary)

For the calculation of the emissions from the use of gas oil and natural gas, the following sources are differentiated: (a) heat only boilers, (b) combined heat and power production in turbines and (c) combined heat and power production in engines. Beside the main energy sources, also charcoal use and bonfires are considered in source category 1A4bi. Emissions from 1A4ci originate from fuel combustion for the heating of greenhouses and grass drying, as well as from wood combustion for heating in agriculture and forestry.

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

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

Table 3-33, Table 3-34 and Table 3-35 present the emission factors applied for source categories 1A4ai, 1A4bi and 1A4ci, respectively. Please note the following additional information:

- For boilers, the emission factors of NO_x and CO for natural gas, biogas and gas oil are based on a study by Leupro (2012). Within this study, measurements from the control of combustion installations in eight Swiss cantons were analysed. Emission factors are thus country specific.
- The emission factors for PM₁₀, PM_{2.5} 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 NH₃ with a development from 0 g/TJ to 500 g/TJ (gas turbines with catalysator) from 1990 to 2020 was taken from SAEFL 2000.
- 1A4ai and 1A4bi: The CO emission factor of gas turbines from 1990 to 2010 stem from SAEFL 2000. The development from 50 kg/TJ to 10 kg/TJ was adjusted slightly. From the year 2015 on forward the emission factor of 4.8 kg/TJ from the EMEP guidebook (EMEP/EEA 2019, chp. 1A4, table 3-28) is taken. This corresponds to measurements in the years 2013-2017 from the only Swiss compressor station.
- Emission factors for NMVOC for combustion boilers, turbines and engines in the residential, commercial institutional and agricultural sectors are documented in SAEFL (2000).
- Emission factors for SO₂ of gas oil are based on five-year averages of the annual sulphur analysis by the Swiss Federal Laboratories for Materials Science and Technology (EMPA, up to 2000) and Federal Office for Customs and Border Security (FOCBS) (see chp. 3.2.1.2).
- The emission factor for SO₂ of natural gas and biogas is based on the legal limit of 190 ppm (see chp. 3.2.1.2).
- The emission factor for SO₂ of coal is based on 1 % sulphur content which holds for heat capacities below 1 MW (see chp. 3.2.1.2).

- Emission factors for Pb, Cd, Hg and PAH for natural gas and biogas are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1.A.4 Small combustion) as follows. 1A4ai: natural gas turbines table 3-28, natural gas boilers/biogas table 3-27, natural gas engines table 3-30. 1A4bi: natural gas boilers table 3-16, natural gas engines table 3-30. 1A4ci: natural gas/biogas boilers table 3-28, biogas engines table 3-30.
- 1A4ai/bi gas oil engines: Emission factors are from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1.A.4 Small combustion, table 3-31).
- 1A4ai/bi/ci gas oil boiler Pb/Cd/Hg: emission factors are taken from table 3-18 in the EMEP/EEA guidebook (EMEP/EEA 2019), but PAHs are from table 3-31 and 3-9 (Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using liquid fuels), respectively, as stated in the EMEP/EEA guidebook representing average of Tier 2 emission factors for commercial/institutional liquid fuel combustion for all technologies. These PAH emission factor values have been taken since the proposed values in table 3-21 are based on a relatively old reference from 1995 and are rather high compared to other PAH values within the guidebook.
- Wood combustion in 1A4ai/bi/ci: The country-specific emission factor model for wood energy is described in chp. 3.2.1.1.2.
- 1A4bi Hg emission factors for other bituminous coal stem from table 3-23 in the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 1A4) allocated to non-residential sources (automatic boilers) burning coal fuels and not from table 3-15 in the EMEP/EEA guidebook (EMEP/EEA 2019) allocated to residential boilers burning solid fuels. This choice was made because table 3-15 provides for Hg with 6 g/TJ a lower value than table 3-23 with 16 g/TJ for advanced technology.
- 1A4ci Emission factors for grass drying are based on air pollution control measurements (NO_x since 2002, NMVOC since 1990, TSP and CO since 2000).
- HCB emission factors of boilers, stationary engines, turbines and CCGT-plants (combined cycle gas turbines) using gaseous and liquid fuels are based on the approach of the Danish Emission Inventory for hexachlorobenzene and polychlorinated biphenyls (Nielsen et al. 2013).
- Emission factors of PCB for stationary combustion (1A4ai, 1A4bi and 1A4ci) 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, SO₂, PM_{2.5}/PM₁₀, TSP, CO, NH₃, Pb, Cd, Hg, PCDD/PCDF, PAH and HCB are taken from EMEP/EEA guidebook, Tier 2 level of source category open fireplaces burning biomass (EMEP/EEA 2019, chp.1A4, Table 3-39) as shown in Table 3-34. According to the EMEP/EEA guidebook (EMEP/EEA 2019, chp.1A4, Table 3-39), the values for particulate matter correspond to total particles including both filterable and condensable particulate matter. More details are described in EMIS 2022/1A4bi Lagerfeuer and EMIS 2022/1A4bi Holzkohle Verbrauch.

Table 3-33: Emission factors for 1A4ai for 2020. All fuels not listed are "NO".

Source/fuel	NO _x	NM VOC	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	6.5	2.8	0.26	0.26	0.26	0.010	6.1
Gas oil heat only boilers	32	6	6.5	1	0.2	0.2	0.2	0.0078	6
Gas oil engines	40	8	6.5	600	20	20	20	0.78	30
Natural gas (weighted average)	18	1.9	0.5	1.1	0.1	0.1	0.1	0.0052	12
NG heat only boilers	16	2	0.5	1	0.1	0.1	0.1	0.0054	9
NG turbines	19	0.1	0.5	500	0.1	0.1	0.1	0.0025	4.8
NG engines	50	1	0.5	NA	0.1	0.1	0.1	0.0025	55
Biomass (weighted average)	113	38	5.4	2'635	31	33	34	8.5	573
Biomass (wood)	113	38	5.4	2'635	31	33	34	8.5	573
Biomass (biogas)	16	2	0.5	1	0.1	0.1	0.1	0.0054	9

Source/fuel	Pb	Cd	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	mg/TJ					
1A4ai Other sectors (stationary): Commercial/institutional										
Gas oil (weighted average)	0.012	0.0010	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil heat only boilers	0.012	0.001	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil engines	0.15	0.01	0.11	0.0010	1.9	15	1.7	1.5	0.22	0.00011
Natural gas (weighted average)	0.0015	0.00025	0.1	0.00050	0.60	1.4	0.90	0.91	NA	NA
NG heat only boilers	0.0015	0.00025	0.1	0.0005	0.6	0.84	0.84	0.84	NA	NA
NG turbines	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA
NG engines	0.0015	0.00025	0.1	0.00057	1.2	9	1.7	1.8	NA	NA
Biomass (weighted average)	20	1.1	2	0.11	8'408	8'408	5'184	5'184	2.9	0.017
Biomass (wood)	20	1.1	2	0.11	8'409	8'409	5'185	5'185	2.9	0.017
Biomass (biogas)	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84	NA	NA

Table 3-34: Emission factors for 1A4bi (including charcoal and bonfires) for 2020. All fuels not listed are "NO".

Source/fuel	NO _x	NM VOC	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)	33	6.0	6.5	1.3	0.21	0.21	0.21	0.0082	11
Gas oil heat only boilers	33	6.0	6.5	1	0.2	0.2	0.2	0.0078	11
Gas oil engines	40	8.0	6.5	600	20	20	20	0.78	30
Natural gas (weighted average)	15	4.0	0.5	0.99	0.1	0.1	0.1	0.0054	12
NG heat only boilers	15	4	0.5	1	0.1	0.1	0.1	0.0054	12
NG engines	30	1	0.5	NA	0.1	0.1	0.1	0.0025	55
Other bituminous coal	65	100	350	1'600	70	70	100	4.5	1'000
Biomass	94	110	8.0	5'382	78	82	86	27	1'444
Wood	96	94	7.9	3'119	54	57	60	26	1'360
Use of charcoal	50	600	11	74'000	820	840	880	57	4'000
Bonfires	50	600	11	74'000	820	840	880	57	4'000

Source/fuel	Pb	Cd	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	g/TJ			mg I-TEQ/TJ	mg/TJ					
1A4bi Other sectors (stationary): Residential										
Gas oil (weighted average)	0.012	0.0010	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil heat only boilers	0.012	0.001	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Gas oil engines	0.15	0.01	0.11	0.0010	1.9	15	1.7	1.5	0.22	0.00011
Natural gas (weighted average)	0.0015	0.00025	0.1	0.0015	0.57	0.91	0.85	0.85	NA	NA
NG heat only boilers	0.0015	0.00025	0.1	0.0015	0.56	0.84	0.84	0.84	NA	NA
NG engines	0.0015	0.00025	0.1	0.00057	1.2	9	1.7	1.8	NA	NA
Other bituminous coal	200	3	16	0.5	270'000	250'000	100'000	90'000	0.62	0.066
Biomass	20	1.4	2.0	0.25	26'427	26'108	14'217	15'143	4.3	0.029
Wood	20	1.0	2	0.23	23'309	23'309	13'301	13'301	4.3	0.028
Use of charcoal	27	13	0.56	0.8	121'000	111'000	42'000	71'000	5	0.06
Bonfires	27	13	0.56	0.8	121'000	111'000	42'000	71'000	5.7	0.06

Table 3-35: Emission factors for 1A4ci for 2020. All fuels not listed are "NO".

1A4ci Agriculture/forestry/fishing	NO _x	NM VOC	SO ₂	NH ₃	PM2.5	PM10	TSP	BC	CO
	kg/TJ			g/TJ	kg/TJ				
Drying of grass	69	93	77	NA	265	265	265	13	531
Heating of greenhouses (weighted average)	22	2	2.4	1.3	0.13	0.13	0.13	0.0061	6.7
Gas oil	31.0	2	6.5	2	0.2	0.2	0.2	0.0078	6.0
Natural gas	18.5	2	0.5	1	0.1	0.1	0.1	0.0054	7.0
Other biomass combustion (weighted average)	50	8.9	2.4	1'932	14	14	15	2.1	225
Biogas heat only boilers	16	2	0.5	1	0.1	0.1	0.1	0.0054	9.0
Biogas engines	20	1	0.5	NA	0.1	0.1	0.1	0.0025	55
Wood combustion	102	23	5.8	1'961	37	40	41	5.9	527

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	5.8	1.2	0.6	NE	NE	NE	NE	NE	NE	NE
Heating of greenhouses (weighted average)	0.005	0.00048	0.11	0.00090	0.56	5.2	1.11	1.0449	0.22	0.00011
Gas oil	0.012	0.001	0.12	0.0018	1.9	15	1.7	1.5	0.22	0.00011
Natural gas	0.0015	0.00025	0.10	0.0005	0.56	0.84	0.84	0.84	NA	NA
Other biomass combustion (weighted average)	6.7	0.3	0.7	0.029	2'709	2'714	1'357	1'357	3.3	0.01
Biogas heat only boilers	0.0015	0.00025	0.1	0.0005	0.56	0.84	0.84	0.84000	NA	NA
Biogas engines	0.0015	0.00025	0.1	0.0006	1.20	9.0	1.7	1.80000	NA	NA
Wood combustion	19	0.95	1.78	0.08	7'500	7'500	3'756	3'756	3.3	0.01

Energy: Source category 1A - Fuel combustion activities - Source category 1A4 - Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

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 2021).

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

Since submission 2015, data on fuel consumption for grass drying are available and used for emission calculations (see EMIS 2022/1A4ci Grastrocknung). The use of gas oil and natural gas for grass drying in 1A4ci is subtracted from boilers in 1A4ai.

The fuel consumption for the heating of greenhouses is extrapolated from the information provided by the Energy Agency of the Swiss Private Sector (EnAW) as documented in the EMIS database (EMIS 2022/1A4ci 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 2021).

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 2022/1A4bi Lagerfeuer).

Table 3-36: Activity data of 1A4ai Commercial/institutional. All fuels not listed are "NO".

1A4ai Other sectors (stationary): Commercial/institutional	Unit	1990	1995	2000	2005	2010					
Total fuel consumption	TJ	72'354	80'124	76'796	83'381	79'434					
Gas oil	TJ	52'977	54'379	48'777	51'197	46'525					
Gas oil heat only boilers	TJ	52'953	54'204	48'426	50'880	46'406					
Gas oil engines	TJ	24	175	351	318	119					
Natural gas	TJ	16'399	21'843	23'552	26'732	25'307					
NG heat only boilers	TJ	16'123	20'672	21'815	24'699	23'602					
NG turbines	TJ	85	78	NO	28	23					
NG engines	TJ	192	1'093	1'737	2'004	1'681					
Biomass (total)	TJ	2'978	3'902	4'467	5'452	7'602					
Biomass (wood)	TJ	2'939	3'871	4'439	5'406	7'498					
Biogas (heat only boilers)	TJ	39	32	27	46	104					

1A4ai Other sectors (stationary): Commercial/institutional	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total fuel consumption	TJ	65'350	71'905	77'291	60'970	66'946	70'275	67'737	61'160	61'617	58'597
Gas oil	TJ	37'088	39'750	42'727	32'993	35'153	36'440	34'222	30'879	30'273	27'596
Gas oil heat only boilers	TJ	36'983	39'656	42'640	32'910	35'071	36'358	34'140	30'797	30'191	27'514
Gas oil engines	TJ	105	94	86	82	82	82	82	82	82	82
Natural gas	TJ	21'857	24'733	26'341	20'237	23'102	24'326	23'967	21'166	21'759	21'042
NG heat only boilers	TJ	20'277	23'180	24'844	18'801	21'666	22'890	22'531	19'730	20'323	19'606
NG turbines	TJ	17	4.9	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
NG engines	TJ	1'564	1'548	1'490	1'429	1'429	1'429	1'429	1'429	1'429	1'429
Biomass (total)	TJ	6'405	7'422	8'223	7'740	8'690	9'509	9'548	9'115	9'585	9'959
Biomass (wood)	TJ	6'322	7'347	8'165	7'693	8'669	9'484	9'524	9'102	9'570	9'944
Biogas (heat only boilers)	TJ	83	76	59	47	21	24	24	13	14	15

Table 3-37: Activity data of 1A4bi Residential. All fuels not listed are "NO".

1A4bi Other sectors (stationary): Residential	Unit	1990	1995	2000	2005	2010					
Total fuel consumption	TJ	185'308	189'294	170'485	186'058	182'065					
Gas oil	TJ	136'887	133'548	116'295	124'024	111'731					
Gas oil heat only boilers	TJ	136'887	133'544	116'242	123'961	111'695					
Gas oil engines	TJ	0.59	4.5	53	63	36					
Natural gas	TJ	25'864	34'088	36'261	42'633	48'229					
NG heat only boilers	TJ	25'804	33'830	35'822	42'103	47'723					
NG turbines	TJ	NO	NO	NO	NO	NO					
NG engines	TJ	60	258	439	530	506					
Other bituminous coal	TJ	630	460	130	400	400					
Biomass (wood, charcoal, bonfires)	TJ	21'926	21'198	17'799	19'001	21'705					
Wood	TJ	21'455	20'746	17'347	18'528	21'201					
Use of charcoal	TJ	311	291	292	313	344					
Bonfires	TJ	160	160	160	160	160					

1A4bi Other sectors (stationary): Residential	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total fuel consumption	TJ	146'111	161'283	172'563	135'061	144'771	150'929	144'805	133'038	133'898	124'335
Gas oil	TJ	86'989	94'103	99'373	75'136	79'406	81'340	76'113	67'901	66'642	59'375
Gas oil heat only boilers	TJ	86'955	94'072	99'344	75'109	79'379	81'312	76'085	67'874	66'615	59'348
Gas oil engines	TJ	34	32	29	27	27	27	27	27	27	27
Natural gas	TJ	40'910	47'043	50'957	42'357	46'096	48'825	48'335	45'915	47'575	47'195
NG heat only boilers	TJ	40'440	46'577	50'509	41'927	45'666	48'395	47'905	45'486	47'145	46'765
NG turbines	TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NG engines	TJ	470	466	448	430	430	430	430	430	430	430
Other bituminous coal	TJ	300	300	300	200	200	200	100	100	100	100
Biomass (wood, charcoal, bonfires)	TJ	17'912	19'837	21'932	17'368	19'069	20'564	20'258	19'122	19'582	17'665
Wood	TJ	17'408	19'333	21'429	16'854	18'555	20'070	19'724	18'608	19'097	17'102
Use of charcoal	TJ	344	344	343	354	354	334	374	354	325	404
Bonfires	TJ	160	160	160	160	160	160	160	160	160	160

Table 3-38: Activity data of 1A4ci Agriculture / forestry / fishing. All fuels not listed are "NO".

1A4ci Other sectors (stationary): Agriculture/forestry/fishing	Unit	1990	1995	2000	2005	2010					
Total fuel consumption	TJ	6'378	6'103	5'798	5'524	5'650					
Drying of grass	TJ	1'895	1'544	1'223	994	739					
Gas oil	TJ	1'156	942	746	607	451					
Residual fuel oil	TJ	NO	NO	NO	NO	NO					
Natural gas	TJ	739	602	477	388	288					
Biomass	TJ	NO	NO	NO	NO	NO					
Heating of greenhouses	TJ	4'000	4'000	4'000	3'735	3'677					
Gas oil	TJ	3'490	3'490	3'490	3'133	1'803					
Natural gas	TJ	510	510	510	601	1'874					
Other biomass combustion	TJ	483	559	575	795	1'235					
Biogas heat only boilers	TJ	39	32	27	46	104					
Biogas engines	TJ	16	15	35	82	394					
Wood combustion	TJ	428	513	513	667	738					

1A4ci Other sectors (stationary): Agriculture/forestry/fishing	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total fuel consumption	TJ	5'174	5'803	5'295	4'758	4'932	5'437	5'956	5'481	5'816	5'913
Drying of grass	TJ	891	685	458	524	431	492	610	545	684	721
Gas oil	TJ	543	418	106	104	89	86	118	116	124	148
Residual fuel oil	TJ	NO	NO	17	20	22	18	25	13	NO	NO
Natural gas	TJ	347	267	220	264	233	279	338	296	427	435
Biomass	TJ	NO	NO	114	136	88	109	129	120	132	138
Heating of greenhouses	TJ	3'121	3'671	3'389	2'800	2'900	2'899	3'238	2'754	2'732	2'537
Gas oil	TJ	1'269	1'647	1'496	1'095	1'165	1'066	1'145	930	916	788
Natural gas	TJ	1'852	2'025	1'893	1'705	1'735	1'834	2'093	1'824	1'816	1'749
Other biomass combustion	TJ	1'162	1'447	1'448	1'434	1'602	2'045	2'107	2'182	2'400	2'655
Biogas heat only boilers	TJ	83	76	59	47	21	24	24	13	14	15
Biogas engines	TJ	472	599	754	880	1'020	1'168	1'248	1'390	1'597	1'747
Wood combustion	TJ	608	772	636	506	561	853	835	780	788	893

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 2022:

Energy: Source category 1A - Fuel combustion activities - Source category 1A4 - Stationary combustion in other sectors (commercial, residential, agriculture and forestry)

- 1A4: Activity data (wood, wood waste) of combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2019 due to recalculations in the Swiss wood energy statistics (SFOE 2021b). The biggest changes were in automatic boilers >50 kW after 2005.
- 1A4: The shares of PM2.5 and PM10 in TSP for all wood combustion installations were changed from 87 % to 90 % and from 93 % to 95 %, respectively, based on a revaluation of measurement and literature data yielding revised emission factors of PM2.5 and PM10 for the entire time series.
- 1A4: Since the share of PM2.5 in TSP was changed for all wood combustion installations also the BC emission factors were revised for the entire time series.
- 1A4: A typing error in the HCB emission factor (2014) of some wood combustion installations was corrected yielding revised values for the years 2009-2019 in 1A4ai, 1A4bi and 1A4ci.
- 1A4a: Due to recalculations of activity data in 1A2 Manufacturing and construction for gas oil and natural gas the activity data of boilers in 1A4a Commercial changed too.
- 1A4b: Due to recalculations of activity data in 1A2 Manufacturing and construction for gas oil and natural gas the activity data of boilers in 1A4b residential changed too.
- 1A4ci: Due to a mistake in the database, emissions of BaP für gas oil in greenhouses were not reported so far.

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

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

Table 3-39: Specification of source category 1A2 Mobile combustion in manufacturing industries and construction.

1A2	Source category	Specification
1A2gvii	Mobile combustion in manufacturing industries and construction	Industry sector: forklifts and snow groomers etc. Construction machines: excavators, loaders, dump trucks, mobile compressors etc.

Table 3-40: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1A2 Combustion in manufacturing industries and construction (mobile only).

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

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

Methodology (1A2gvii)

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

Emission factors (1A2gvii)

The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard-specific emission factors are shown in Table 3-41 to Table 3-44. Implied emission factors 2019 are shown in Table 3-45.

Table 3-41: Emission factors for diesel-powered machinery (1A2gvii) per emission standard.

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

Table 3-42: Emission factors for gasoline-powered machinery (4-stroke engines) (1A2gvii) per emission standard.
cc: cubic centimetres

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

Table 3-43: Emission factors for gasoline-powered machinery (2-stroke engines) (1A2gvii) per emission standard.
cc: cubic centimetres

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

Table 3-44: Emission factors for gas-operated machinery (1A2gvii).

Pollutant	Without catalyst	With oxidation catalysts	50% with 3-way catalysts	100% with 3-way catalysts
	g/kWh			
CO	10	0.2	0.2	0.2
HC	8	0.5	0.5	0.5
NO _x	10	10	6	2
PM	0.02	0.01	0.01	0.01
Fuel consumption	450	450	455	460
Assumptions regarding introduction of emission stages				
All capacities		1980	1994	2000

Table 3-45: Implied emission factors for 1A2gvii in 2020.

1A2gvii Non-road vehicles and other machinery	NO _x	NMVOOC	SO _x	NH _x	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
	g/GJ				g/h		g/GJ	g/h	g/GJ	g/h	g/GJ	g/h
Gasoline	105	632	0.38	0.09	0.12	2.4	0.12	16	0.12	24	0.0058	0.0030
Diesel oil	208	20	0.47	0.17	5.6	2.4	5.6	16	5.6	24	3.4	0.0030
LPG	96	8.8	NA	0.22	0.47	2.4	0.47	16	0.47	24	0.024	0.0030
Biodiesel	177	17	0.40	0.15	4.8	2.4	4.8	16	4.8	24	2.9	0.0030
Bioethanol	50	231	0.24	0.058	0.084	2.4	0.084	16	0.084	24	0.0042	0.0030

1A2gvii Non-road vehicles and other machinery	CO	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCb	PCB
	g/GJ	mg/GJ				ng I-TEQ/GJ	mg/GJ			ng/GJ	
Gasoline	19733	0.031	2.3	0.20	2.7	1.0	1.0	0.10	0.30	NE	NE
Diesel oil	102	NA	2.2	0.11	1.5	0.66	1.1	0.82	0.19	NE	NE
LPG	24	NA	0.2	NA	NA	0.0043	NA	0.0043	0.0043	NE	NE
Biodiesel	87	NA	1.9	0.10	1.3	0.56	0.94	0.70	0.16	NE	NE
Bioethanol	12065	0.015	1.5	0.13	1.8	0.65	0.65	0.064	0.19	NE	NE

Activity data (1A2gvii)

Table 3-46 shows the activity data of 1A2gvii taken from FOEN (2015j). Diesel oil is the main fuel type consumed in this category. Data on biofuels are provided by the statistics of renewable energies (SFOE 2021a). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-46: Activity data for 1A2gvii.

1A2gvii Non-road vehicles and other machinery	Unit	1990	1995	2000	2005	2010
Total fuel consumption	TJ	5'721	6'852	7'636	8'169	8'779
Gasoline	TJ	196	224	227	225	220
Diesel oil	TJ	5'359	6'380	7'106	7'626	8'254
Liquefied petroleum gas	TJ	165	248	294	290	269
Biodiesel	TJ	NO	NO	9.2	28	36
Bioethanol	TJ	NO	NO	NO	NO	0.0047

1A2gvii Non-road vehicles and other machinery	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total fuel consumption	TJ	8'811	8'843	8'875	8'906	8'938	8'944	8'949	8'955	8'960	8'966
Gasoline	TJ	213	206	198	191	184	180	177	174	171	168
Diesel oil	TJ	8'283	8'312	8'341	8'370	8'399	8'380	8'361	8'342	8'323	8'304
Liquefied petroleum gas	TJ	260	252	243	235	226	215	203	192	180	168
Biodiesel	TJ	54	73	91	110	128	166	205	243	282	320
Bioethanol	TJ	0.26	0.51	0.76	1.0	1.3	2.0	2.7	3.3	4.0	4.7

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

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

Table 3-47: Specification of source category 1A3 Transport.

1A3	Source category	Specification
1A3ai(i)	International aviation LTO (civil)	LTO: Landing/Take-off emissions from international flights
1A3ai(ii)	International aviation CR (civil)	CR: Cruise emissions of international flights Memo item - not to be included in national total
1A3aii(i)	Domestic aviation LTO (civil)	LTO: Landing/Take-off emissions from domestic flights Large (jet, turboprop) & small (piston) aircrafts, helicopters
1A3aii(ii)	Domestic aviation CR (civil)	CR: Cruise emissions from domestic flights Large (jet, turboprop) & small (piston) aircrafts, helicopters Memo item - not to be included in national total
1A3bi	Road 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	Emissions from 2-stroke and 4-stroke motorcycles
1A3bv	Road transport: Gasoline evaporation	NMVO 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 non-exhaust emissions reported in 1A3bvi
1A3c	Railways	Diesel locomotives, abrasion by merchandise and person traffic
1A3di(ii)	International maritime navigation	Shipping leaving Switzerland on the river Rhine and on Lake Geneva and Lake Constance Memo item - not to be included in national total
1A3dii	National navigation (shipping)	Passenger ships, motor and sailing boats on the Swiss lakes and the river Rhine
1A3ei	Pipeline transport	Emissions from the one compressor station in Ruswil (canton Lucerne)

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

Table 3-48: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1A3, Transport.

NFR code	Source category	Pollutant	Identification criteria
1A3bi	Road transport: passenger cars	NOx	L1, T1, L2, T2
1A3bi	Road transport: passenger cars	NMVOC	L1, T1, L2, T2
1A3bi	Road transport: passenger cars	SOx	T1, T2
1A3bii	Road transport: light-duty vehicles	NOx	L1, T1, L2, T2
1A3biii	Road transport: heavy-duty vehicles and buses	NOx	L1, T1, L2, T2
1A3biii	Road transport: heavy-duty vehicles and buses	SOx	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 and motorcycles	NMVOC	L2, T2
1A3bv	Road transport: gasoline evaporation	NMVOC	L1, T1, T2
1A3bvi	Road transport: automobile tyre and brake wear	PM2.5	L1, T1, L2, T2
1A3bvi	Road transport: automobile tyre and brake wear	PM10	L1, T1, L2, T2
1A3c	Railways	PM2.5	L1, T1
1A3c	Railways	PM10	L1, T1, L2, T2
1A3dii	National navigation (shipping)	NOx	T1

3.2.6.2 Methodological issues for 1A3 Transport

3.2.6.2.1 Civil aviation (1A3a)

Methodology (1A3a)

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

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

A complete emission modelling (LTO and cruise emissions for domestic and international flights) has been carried out by FOCA for 1990, 1995, 2000, 2002, 2004, 2005, 2007-2020. The results of the emission modelling have been transmitted from FOCA to FOEN in an aggregated form (FOCA 2006, 2006a, 2007a, 2008-2021). Years in-between are interpolated. Further details of emission modelling are described in Switzerland's National Inventory Report (FOEN 2022).

Emission factors (1A3a)

The emission factors used are country-specific or taken from the ICAO engine emissions database from the EMEP/EEA guidebook (EMEP/EEA 2019), Swedish Defence Research Agency (FOI) and Swiss FOCA measurements. Emission factors are case sensitive and for that reason separated into emission factors concerning the LTO cycle and cruise phase. Values of emission factors (EF) see Table 3-49.

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

- NMVOC is calculated as fraction of VOC. For LTO $EF_{NMVOC} = 0.47 * EF_{VOC}$, whereas for cruise $EF_{NMVOC} = EF_{VOC}$ i.e, there is no emission of CH₄ for the cruise phase.
- SO₂ is based on the sulphur content of kerosene (see Table 3-9).
- PM10 and PM2.5 have been determined by the Federal Office of Civil Aviation (FOCA 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 $EF_{PM2.5\ exhaust} = 2 * EF_{BC}$, see also chapter 1.A.3.a, 1.A.5.b * Aviation of the EMEP/EEA guidebook (EMEP/EEA 2019), notes to table 3.11 on p.28.
- For non-exhaust emissions as tyre, break and airstrip abrasion, the findings the FOCA provide the weighted non-exhaust emission factor of 0.1 g per LTO-cycle, which is based on 0.08 g per landing of a short-distant flight and 0.27 g per landing of a long-distant flight.
- EF(Pb) is based on the content of the aviation fuels.

LTO

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

Cruise

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

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

Table 3-49: Emission factors for 1A3a Civil aviation, year 2020. (LTO: Landing take-off cycle, CR: cruise.)

1A3a Civil aviation	NO _x	NMVOC	SO ₂	NH ₃	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSM ex	TSP nx	BC ex	BC nx
	kg/TJ											
Kerosene, domestic, LTO	204	169	18	NA	9.2	0.028	9.2	0.028	9.2	0.028	9.0	NA
Kerosene, domestic, CR	266	81	21	NA	3.9	NA	3.9	NA	3.9	NA	1.9	NA
Kerosene, international, LTO	331	26	23	NA	2.6	0.018	2.6	0.018	2.6	0.018	1.4	NA
Kerosene, international, CR	395	5.8	23	NA	0.28	NA	0.28	NA	0.28	NA	0.23	NA

1A3a Civil aviation	CO	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ		kg I-TEQ/TJ		kg/TJ						
Kerosene, domestic, LTO	5261	4.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Kerosene, domestic, CR	865	1.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
Kerosene, international, LTO	279	0.0087	NA	NA	NA	NA	NA	NA	NA	NA	NA
Kerosene, international, CR	38	0.0070	NA	NA	NA	NA	NA	NA	NA	NA	NA

Activity data (1A3a)

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

Scheduled and charter aviation

The statistical basis has been extended after 1996. Therefore, the modelling details are not exactly the same for the years 1990/1995 as for the subsequent years. The source for the 1990 and 1995 modelling are the movement statistics, which record for every movement information on airline, number of seats, Swiss airport, arrival/departure, origin/destination, number of passengers, distance. From 1996 onwards, every movement in the FOCA statistics also contains the individual aircraft tail number (aircraft registration). This is the key variable to connect airport data and aircraft data. All annual aircraft movements recorded are split into domestic and international flights.

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

Airports and most of the airfields report individual aircraft data (aircraft registration). FOCA is therefore able to compute also the inventory for small aircraft with a Tier 3 approach. However, for 1990 and 1995, the emissions for non-scheduled, non-charter and general aviation (helicopters etc.) could not be calculated with a Tier 3 approach. Its fuel consumption is estimated to be 10 % of the domestic fuel consumption. Data were taken from two studies by FOCA (FOCA 1991, FOCA 1991a). Since 2000, all movements from airfields are registered, which allows a more detailed modelling of the emissions.

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

Table 3-50 summarises the activity data for civil aviation. Note that the cruise emissions are included in international bunkers and reported as memo items (1A3ai(ii) and 1A3aii(ii)). The increase in energy consumption from 1990 to 2019 is due to an increasing number of flights. In 2020, the COVID-19 pandemic led to a strong reduction of energy consumption due to significantly reduced number of flights.

Table 3-50: Kerosene consumption of domestic and international aviation in TJ. Note that domestic and international LTO emissions are reported and included in the national total for the entire territory (based on fuel sold), whereas domestic and international cruise emissions are reported under memo items only.

1A3a/1D1 Civil aviation	1990	1995	2000	2005	2010
Fuel consumption in TJ					
Kerosene, domestic, LTO	1'050	935	773	518	464
Kerosene, domestic, CR	2'401	2'139	1'768	1'184	1'230
Kerosene, international, LTO (not part of national total)	4'277	5'097	6'507	4'878	5'643
Kerosene, international, CR (not part of national total)	37'608	44'821	57'219	42'896	52'691
Total Civil aviation	45'334	52'993	66'267	49'477	60'028
1990 = 100%	100%	117%	146%	109%	132%

1A3a/1D1 Civil aviation	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fuel consumption in TJ										
Kerosene, domestic, LTO	509	504	494	525	387	421	384	346	321	170
Kerosene, domestic, CR	1'306	1'371	1'323	1'396	1'500	1'511	1'257	1'234	1'250	910
Kerosene, international, LTO (not part of national total)	6'041	6'226	6'208	6'142	6'459	6'529	6'728	6'953	6'963	2'350
Kerosene, international, CR (not part of national total)	56'420	57'677	58'501	58'864	60'874	64'073	66'096	70'261	71'233	25'820
Total Civil aviation	64'277	65'778	66'526	66'927	69'220	72'534	74'465	78'793	79'767	29'250
1990 = 100%	142%	145%	147%	148%	153%	160%	164%	174%	176%	65%

3.2.6.2.2 Road transportation (1A3b)

Methodology (1A3b)

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

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

The emission computation is based on emission factors and activity data. For general methods see INFRAS (2017c), updated emission factors see INFRAS (2019a) 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 2020, statistical data was used for calculating activity data from 1A3b Road transportation (ex-post). Emissions are calculated as follows:

$$\begin{aligned} \text{Hot emissions:} & E_{hot} = VKT \cdot EF_{hot} \\ \text{Cold start excess emissions:} & E_{start} = N_{start} \cdot EF_{start} \\ \text{Evaporation soak and diurnal NMVOC emissions:} & E_{evap,i} = N_{evap,i} \cdot EF_{evap,i} \\ \text{Evaporation running NMVOC losses:} & E_{evap-RL} = VKT \cdot EF_{Evap-RL} \end{aligned}$$

with

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

Emission factors (1A3b)

Emission factors in 1A3b originate from the following sources:

- Emission factors for exhaust pollutants NO_x , NMVOC, NH_3 , CO, PM_{2.5}, 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, Zn exhaust, Hg, PCDD/PCDF (except for natural gas engines, see below), PAH and PCB are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chapter 1.A.3.b.i-iv Road transport 2019).
- Emission factor for PCDD/PCDF emissions from natural gas engines is taken from Rentz et al. (2008).

- Emission factors for BC and Cd stem from the Handbook of Emission Factors for Road Transport as well as non-exhaust emissions of particulate matter (TSP, PM10, PM2.5), which are based on Düring and Schmidt (2016); their integration into the Handbook of Emission Factors for Road Transport is described in INFRAS (2019a). Details to non-exhaust emission factors can be found in EMIS 2022/1A3b-Strassenverkehr.
- Note that there is still no HCB emission factor available in the EMEP/EEA guidebook (EMEP/EEA 2019). Therefore, these emissions are still NE for the years 1990-2020.

For biofuels, the respective air pollutant emission factors of 1A3b for fossil fuels are used as follows: for biodiesel and vegetable/waste oil the ones from diesel oil, for bioethanol the ones from gasoline and for biogas the ones from (compressed) natural gas use. Table 3-51 shows a selection of implied emission factors (emissions divided by specific fuel consumption per source category) for 2020.

Table 3-51: Implied emission factors for road transportation, passenger cars in 2020.

1A3b Road Transportation Gasoline / Bioethanol	NO _x	NM VOC	SO ₂	NH ₃	PM _{2.5} ex	PM _{2.5} nx	PM ₁₀ ex	PM ₁₀ nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	35	49	0.38	10	0.67	4.8	0.67	13	0.67	13	0.11	0.48
1A3bii Light duty vehicles	109	128	0.38	10	3.0	5.3	3.0	11	3.0	11	0.53	0.53
1A3biii Heavy duty vehicles	767	545	0.38	0.21	0.0018	6.0	0.0018	27	0.0018	27	0.00028	0.60
1A3biv Motorcycles	84	254	0.38	1.2	9.3	3.1	9.3	5.6	9.3	5.6	1.9	0.37
1A3bv Gasoline evaporation	NA	25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	IE	NA	IE	NA	IE	NA	IE
1A3bi Fuel tourism and statistical differences	38	82	0.38	9	1.0	4.8	1.02	13	1.02	13	0.18	0.48
1A3b Road Transportation Gasoline / Bioethanol	CO	Pb	Cd ex	Cd nx	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ											
1A3bi Passenger cars	543	24	0.0043	0.41	0.20	0.0030	0.13	0.15	0.11	0.16	NE	599
1A3bii Light duty vehicles	2794	24	0.0036	0.66	0.19	0.0031	0.11	0.12	0.085	0.13	NE	628
1A3biii Heavy duty vehicles	658	24	0.0044	0.77	NE	NE	NE	NE	NE	NE	NE	NE
1A3biv Motorcycles	2304	24	0.0045	0.30	0.20	0.010	0.18	0.20	0.15	0.22	NE	3237
1A3bv Gasoline evaporation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	644	24	0.0047	0.41	0.20	0.0033	0.13	0.15	0.11	0.16	NE	696
1A3b Road Transportation Diesel / Biodiesel	NO _x	NM VOC	SO ₂	NH ₃	PM _{2.5} ex	PM _{2.5} nx	PM ₁₀ ex	PM ₁₀ nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	271	4.1	0.47	1.5	1.6	4.5	1.6	12	1.6	12	1.0	0.45
1A3bii Light duty vehicles	314	2.0	0.47	1.02	5.4	4.4	5.4	9.0	5.4	9.0	3.8	0.44
1A3biii Heavy duty vehicles	158	3.7	0.47	1.05	2.5	4.6	2.5	21	2.5	21	1.3	0.46
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	IE	NA	IE	NA	IE	NA	IE
1A3bi Fuel tourism and statistical differences	272	4.1	0.52	1.4	2.7	5.0	2.7	16	2.7	16	1.6	0.50
1A3b Road Transportation Diesel / Biodiesel	CO	Pb	Cd ex	Cd nx	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ											
1A3bi Passenger cars	47	NA	0.0012	0.38	0.12	0.0035	0.67	0.75	0.59	0.62	NE	696
1A3bii Light duty vehicles	50	NA	0.0012	0.56	0.12	0.0038	0.49	0.55	0.43	0.46	NE	771
1A3biii Heavy duty vehicles	57	NA	0.0009	0.60	0.21	0.0004	0.08	0.47	0.52	0.12	NE	74
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	55	NA	0.0013	0.52	0.16	0.0030	0.53	0.71	0.60	0.51	NE	592
1A3b Road Transportation Gas / Biogas	NO _x	NM VOC	SO ₂	NH ₃	PM _{2.5} ex	PM _{2.5} nx	PM ₁₀ ex	PM ₁₀ nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	33	1.3	NA	9.3	1.9	5.2	1.9	14	1.9	14	0.29	0.52
1A3bii Light duty vehicles	15	0.62	NA	7.3	2.5	5.1	2.5	10	2.5	10	0.37	0.51
1A3biii Heavy duty vehicles	80	1.1	NA	NE	1.4	3.2	1.4	20	1.4	20	0.20	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 differences	47	1.2	NA	6.0	1.8	4.5	1.8	16	1.8	16	0.27	0.45
1A3b Road Transportation Gas / Biogas	CO	Pb	Cd ex	Cd nx	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ											
1A3bi Passenger cars	174	NA	NA	0.44	0.19	0.0026	0.14	0.16	0.11	0.17	NE	NA
1A3bii Light duty vehicles	1270	NA	NA	0.65	0.19	0.0020	0.10	0.12	0.085	0.13	NE	NA
1A3biii Heavy duty vehicles	37	NA	NA	0.39	NE	0.0010	0.0028	0.0044	0.0022	0.0017	NE	NA
1A3biv Motorcycles	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	262	NA	NA	0.45	0.13	0.0020	0.091	0.103	0.074	0.11	NE	NA
1A3b Road Transportation Liquefied petroleum gas	NO _x	NM VOC	SO ₂	NH ₃	PM _{2.5} ex	PM _{2.5} nx	PM ₁₀ ex	PM ₁₀ nx	TSP ex	TSP nx	BC ex	BC nx
	kg/TJ											
1A3bi Passenger cars	42	3.5	NA	7.7	0.59	4.3	0.59	11	0.59	11	0.089	0.43
1A3bii Light duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biii Heavy duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biv Motorcycles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3b Road Transportation Liquefied petroleum gas	CO	Pb	Cd ex	Cd nx	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ											
1A3bi Passenger cars	526	NA	NA	0.36	0.19	NA	0.11	0.13	0.093	0.14	NA	NA
1A3bii Light duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biii Heavy duty vehicles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3biv Motorcycles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bvii Automobile road abrasion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A3bi Fuel tourism and statistical differences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 3-51 continued

1A3b Road Transportation Hydrogen / electricity	NO _x	NM VOC	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 differences	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

1A3b Road Transportation Hydrogen / electricity	CO	Pb	Cd ex	Cd nx	Hg	PCDD/ PCDF	BaP	BbF	BkF	lcdP	HCb	PCB
	g/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 differences	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

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

Activity data (1A3b)

The activity data are derived from different data sources:

- Vehicle stock: The federal vehicle registration database IVZ (run by the Federal Roads Office FEDRO) contains vehicle stock data including all parameters needed for the emission modelling (vehicle category, engine capacity, fuel type, total weight, vehicle age and exhaust technology). The data are not public, but the ordinary vehicle stock numbers are published by the Swiss Federal Statistical Office (SFSO 2021e). 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 2021e). 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 2021e, 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 2022/1A3bi-viii “Strassenverkehr”), Consumption of biofuels is provided by the statistics of renewable energies (SFOE 2021a).

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 3-52 shows the mileage per vehicle category. Numbers hold for the version “fuel used” and represent the vehicle kilometres driven within the Swiss territory.

Table 3-52: Mileages in millions of vehicle kilometres. PC: passenger cars, LDV: light duty vehicles, HDV: heavy duty vehicles.

Veh. category	1990	1995	2000	2005	2010
	million vehicle-km				
PC	42'649	41'324	45'613	48'040	52'066
LDV	2'600	2'746	2'957	3'228	3'502
HDV	1'992	2'107	2'273	2'120	2'226
Coaches	108	110	99	106	118
Urban Bus	174	192	200	229	244
2-Wheelers	2'025	1'563	1'700	1'785	1'852
Sum	49'548	48'043	52'841	55'507	60'009
(1990=100%)	100%	97%	107%	112%	121%

Veh. category	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	million vehicle-km									
PC	52'696	53'721	54'695	55'641	56'620	57'737	58'735	59'344	59'833	52'055
LDV	3'635	3'776	3'874	3'998	4'129	4'269	4'392	4'530	4'668	4'668
HDV	2'258	2'229	2'243	2'236	2'235	2'235	2'242	2'238	2'226	1'937
Coaches	122	124	125	128	131	134	136	139	142	142
Urban Bus	250	254	262	267	272	281	280	291	300	255
2-Wheelers	1'877	1'899	1'904	1'920	1'937	1'976	2'008	2'046	2'068	1'799
Sum	60'838	62'003	63'102	64'188	65'324	66'631	67'793	68'588	69'237	60'856
(1990=100%)	123%	125%	127%	130%	132%	134%	137%	138%	140%	123%

Since 1990, the total mileage has been increasing by about 1 per cent per year on an average. This trend was halted in 2020, as total mileages decreased compared to the years before due to the restrictions related to the COVID-19 pandemic. The overwhelming part of vehicle kilometres was driven by passenger cars. In the whole reporting period on-road fuel consumption increased less strongly, indicating improved fuel efficiency. This effect is also reflected in Table 3-53 that depicts the specific fuel consumption per vehicle-km. For most vehicle categories, the specific consumption has decreased in the period 1990–2020.

Table 3-53: Specific fuel consumption of road transportation. Data are adopted from the territorial road transportation model. They include excess fuel consumption by cold starts.

Veh. Category	Fuel	1990	1995	2000	2005	2010
		MJ / veh-km				
PC	Gasoline	3.15	3.23	3.29	3.21	3.08
	Diesel oil	3.34	3.16	3.05	2.75	2.72
	LPG	NO	NO	NO	NO	NO
	CNG	NO	NO	NO	NO	2.08
LDV	Gasoline	3.85	3.75	3.65	3.62	3.55
	Diesel oil	4.54	4.51	4.33	3.98	3.78
	CNG	NO	NO	NO	NO	2.40
HDV	Gasoline	NO	NO	NO	NO	NO
	Diesel oil	11.3	11.7	11.7	12.3	11.9
	CNG	NO	NO	NO	10.5	13.2
Coach	Diesel oil	12.7	12.6	12.3	12.0	11.6
Urban Bus	Gasoline	NO	NO	NO	NO	NO
	Diesel oil	16.3	16.7	16.8	16.8	16.3
	CNG	NO	NO	NO	NO	17.0
2-Wheeler	Gasoline	1.49	1.66	1.48	1.59	1.53
Average (1990=100%)		3.53 100%	3.67 104%	3.69 104%	3.55 101%	3.38 96%

Veh. Category	Fuel	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
		MJ / veh-km									
PC	Gasoline	3.02	2.96	2.90	2.83	2.75	2.67	2.60	2.52	2.47	2.41
	Diesel oil	2.71	2.70	2.68	2.66	2.62	2.58	2.53	2.49	2.49	2.49
	LPG	2.99	2.96	2.94	2.92	2.86	2.84	2.82	2.83	2.81	2.80
	CNG	2.02	2.00	1.91	1.91	1.82	1.85	1.77	1.81	1.76	1.66
LDV	Gasoline	3.52	3.47	3.42	3.37	3.31	3.25	3.18	3.09	3.05	3.00
	Diesel oil	3.75	3.73	3.72	3.71	3.68	3.63	3.55	3.46	3.42	3.39
	CNG	2.70	2.69	2.55	2.55	2.44	2.48	2.38	2.41	2.35	2.23
HDV	Gasoline	9.15	9.15	9.16	9.15	9.11	9.11	9.07	9.05	9.00	8.97
	Diesel oil	11.9	11.8	11.7	11.6	11.5	11.4	11.1	10.9	10.9	10.8
	CNG	13.0	13.0	12.5	12.7	12.2	12.6	12.2	10.9	10.7	9.33
Coach	Diesel oil	11.7	10.7	10.6	10.5	10.3	10.2	10.0	9.70	9.67	9.46
Urban Bus	Gasoline	NO	NO	NO	NO	NO	NO	NO	9.41	9.39	9.38
	Diesel oil	16.2	16.1	16.1	15.9	15.7	15.5	15.1	14.9	14.9	14.9
	CNG	16.6	16.7	16.0	16.0	15.4	15.9	15.4	16.0	15.7	15.0
2-Wheeler	Gasoline	1.55	1.56	1.54	1.58	1.63	1.59	1.59	1.62	1.63	1.62
Average (1990=100%)		3.34 94%	3.27 93%	3.22 91%	3.16 90%	3.09 88%	3.03 86%	2.95 84%	2.89 82%	2.85 81%	2.83 80%

For modelling evaporative emissions, the stock, mileage, and numbers of stops of gasoline passenger cars and gasoline light duty vehicles are used. For modelling cold start emissions, numbers of starts of passenger cars and light duty vehicles are used as activity data. The corresponding numbers are summarised in Table 3-54. Vehicle stock figures correspond to registration data. The starts per vehicle are based on specific household surveys (ARE/SFSO 2005, 2012, 2017).

Table 3-54: Vehicle stock numbers (gasoline vehicles only – relevant for diurnal evaporation) and average number of starts per vehicle per day (gasoline, diesel oil, and (compressed) natural gas vehicles).

Veh. Category	1990	1995	2000	2005	2010
	stock in 1000 veh. (gasoline/bioeth.)				
PC	2'839	3'049	3'305	3'263	2'955
LDV	167	164	148	112	77
2-Wheelers	764	688	712	746	765
starts per veh. per day					
PC	2.94	2.68	2.91	2.52	2.56
LDV	1.97	1.97	1.96	1.96	1.96

Veh. Category	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	stock in 1000 veh. (gasoline/bioeth.)									
PC	2'924	2'878	2'833	2'784	2'737	2'687	2'685	2'702	2'701	2'727
LDV	73	69	64	61	58	56	54	51	52	54
2-Wheelers	775	779	792	801	812	820	834	855	866	863
starts per veh. per day										
PC	2.54	2.53	2.54	2.55	2.55	2.56	2.58	2.59	2.59	2.24
LDV	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.94	2.05	1.97

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 brake blocks and wheels, measurements on a test bench, ambient PM10 concentration measurements combined with receptor model. The emissions were quantified as a sum of brake, wheel, track and contact wire abrasion and were split into passenger and freight train origins. For projection purposes, the PM10 emissions were divided into emission factors per person-kilometre (passenger rail-transport) and tonne-kilometre (freight rail transport) and corresponding activity data. The share of PM2.5 was estimated to 15 % of the PM10 emissions.

Emission factors (1A3c)

The emission factors are country-specific. The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard specific emission factors are shown in Table 3-55.

- Only diesel oil and biodiesel are used as fuels, therefore all emission factors refer to the use of diesel oil and biodiesel for traffic on railways except for non-exhaust emissions.
- Non-exhaust particulate matter emission factors (PM2.5 and PM10) distinguish between passenger and freight transport, i.e. they are based on passenger and tonne kilometres. Emission factors are based on a study from the Swiss Federal Railways Company (SBB 2005). Details concerning non-exhaust emission factors can be found in EMIS 2022/1A3c-Schiennenverkehr.

Implied emission factors 2020 are shown in Table 3-56.

Table 3-55: Illustration of emission and consumption factors for rail vehicles with diesel engines per emission standard (Pre-EU etc.) and engine power.

engine power	Pre-EU	UIC I	UIC II	EU IIIA	EU IIIB	EU V
g/kWh						
Carbon monoxide (CO)						
<560 kW	4.0	3.0	2.5	2.5	2.5	2.5
>560 kW	4.0	3.0	3.0	3.0	3.0	3.0
Hydrocarbons (HC)						
<560 kW	1.60	0.80	0.60	0.40	0.17	0.17
>560 kW	1.60	0.80	0.80	0.50	0.40	0.36
Nitrogen oxides (NO_x)						
<560 kW	13	12	6	3.2	1.8	1.8
>560 kW	16	12	9.5	5.4	3.2	3.2
Particulate matter (PM)						
<560 kW	0.600	0.500	0.250	0.180	0.025	0.025
>560 kW	0.600	0.500	0.250	0.180	0.025	0.025
Fuel consumption						
<560 kW	223	223	223	223	223	223
>560 kW	223	223	223	223	223	223
Assumptions regarding the introduction of EU emission stages						
<560 kW		2000	2003	2006	2012	2020
>560 kW		2000	2003	2009	2012	2020

Table 3-56: Implied emission factors in 2020 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	NM VOC	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											
Diesel oil	986	116	0.47	182	7.5	0.017	7.5	0.11	7.5	0.15	2.4	NA
Biodiesel	843	99	0.40	155	6.4	0.017	6.4	0.11	6.4	0.15	2.1	NA

1A3c Railways	CO	Pb	Cd ex	Cd nx	Hg	PCDD/	BaP	BbF	BkF	IcdP	HCB	PCB	
Fuel	kg/TJ	g/TJ	g/TJ	g/km	g/TJ	mg I-TEQ/TJ	mg/TJ						
Diesel oil	534	NA	2.3	NE	0.12	0.0016	844	1407	1047	195	NA	NA	
Biodiesel	456	NA	1.9	NE	0.10	0.0014	722	1203	895	167	NA	NA	

Activity data (1A3c)

Table 3-57 shows the activity data of 1A3d taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a).

Table 3-57: Activity data for 1A3c Railways is either diesel oil and biodiesel consumption or number of driven km for freight transport as well as number of driven km for passenger transport. Data in TJ refer to exhaust emissions, whereas data in km refer to non-exhaust emissions.

1A3c Railways	Unit	1990	1995	2000	2005	2010
Diesel oil	TJ	390	441	455	472	492
Biodiesel	TJ	NO	NO	0.59	1.7	2.1
Total Railways	TJ	390	441	456	474	494
1990=100%		100%	113%	117%	121%	127%
tonne-kilometers	Mio. km	9'045	8'856	11'080	11'677	11'074
passenger-kilometers	Mio. km	12'978	12'978	12'978	16'210	19'252

1A3c Railways	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Diesel oil	TJ	471	451	431	410	390	388	387	385	383	382
Biodiesel	TJ	2.9	3.7	4.4	5.2	5.9	7.7	9.4	11	13	15
Total Railways	TJ	474	455	435	416	396	396	396	396	396	396
1990=100%		122%	117%	112%	107%	102%	102%	102%	102%	102%	102%
tonne-kilometers	Mio. km	11'526	11'061	11'812	12'313	12'431	12'447	11'665	11'776	11'673	11'500
passenger-kilometers	Mio. km	19'549	19'340	19'525	20'090	20'475	20'894	20'953	20'704	21'831	17'400

3.2.6.2.4 Domestic navigation (1A3d)

Methodology (1A3d)

Based on the decision tree Fig. 3.1 in the chapter 1A3d Navigation-shipping in the EMEP/EEA guidebook (EMEP/EEA 2019), the air pollutant emissions are calculated by a Tier 3 method. Emissions are calculated in line with the non-road transportation model described in chp. 3.2.1.1.1.

There are passenger ships, dredgers, fishing boats, motor and sailing boats on the lakes and rivers of Switzerland.

On the river Rhine and on Lake Geneva and Lake Constance, some of the boats cross the border and go abroad (France, Germany). Fuels bought in Switzerland will therefore become bunker fuel. Accordingly, the amount of bunker diesel oil is reported as a memo item "International maritime navigation". The emissions are calculated with a Tier 1 approach with implied emission factors from domestic navigation. Only diesel oil is concerned from navigating on the river Rhine (FCA 2015a) and of navigating two border lakes (Lake Constance, Lake Geneva) for which bunker fuel consumption was reported in INFRAS (2011a) after having performed surveys among the shipping companies involved.

Emission factors (1A3d)

The emission factors are country-specific. The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard-specific emission factors are shown in Table 3-58 to Table 3-61 (FOEN 2015j).

Implied emission factors 2020 are shown in Table 3-62.

Table 3-58: Emission factors for diesel-powered ships per emission standard.

engine power	Pre-SAV	SAV	EU I	EU II	EU IIIA	EU V
g/kWh						
Carbon monoxide (CO)						
<18 kW	6.7	6.7	6.7	6.7	6.7	6.7
18–37 kW	6.7	6.7	6.7	6.7	6.7	6.7
37–75 kW	5.9	5.9	5.9	4.5	4.5	4.5
75–130 kW	5.0	5.0	4.5	4.5	4.5	4.5
130–300 kW	5.0	5.0	4.5	4.5	4.5	3.15
300–560 kW	5.0	5.0	4.5	4.5	4.5	3.15
>560 kW	5.0	5.0	4.5	4.5	4.5	3.15
Hydrocarbons (HC)						
<18 kW	10	7.2	5.0	3.0	2.0	2.0
18–37 kW	10	7.2	5.0	3.0	2.0	2.0
37–75 kW	10	5.4	1.2	1.2	1.1	0.42
75–130 kW	10	4.1	1.2	0.9	0.8	0.49
130–300 kW	5.0	3.6	1.2	0.9	0.8	0.80
300–560 kW	5.0	3.2	1.2	0.9	0.8	0.17
>560 kW	5.0	2.8	1.2	0.9	0.8	0.17
Nitrogen oxides (NO_x)						
<18 kW	10.3	10.3	10.3	10.3	10.3	10.3
18–37 kW	10.3	10.3	10.3	10.3	10.3	10.3
37–75 kW	12.4	12.4	8.3	6.3	5.7	4.23
75–130 kW	12.5	12.5	8.3	6.3	5.7	4.86
130–300 kW	12.5	12.5	8.3	6.3	5.7	2.10
300–1000 kW	12.5	12.5	8.3	6.3	5.7	1.20
>1000 kW	12.5	12.5	8.3	6.3	5.7	0.40
Particulate matter (PM)						
<18 kW	1.50	1.20	1.00	0.80	0.70	0.70
18–37 kW	1.20	0.90	0.74	0.60	0.54	0.54
37–75 kW	1.10	0.58	0.77	0.36	0.36	0.30
75–130 kW	0.60	0.47	0.63	0.27	0.27	0.14
130–300 kW	0.60	0.47	0.49	0.18	0.18	0.11
300–1000 kW	0.60	0.47	0.49	0.18	0.18	0.02
>1000 kW	0.60	0.47	0.49	0.18	0.18	0.01
Fuel consumption						
<18 kW	248	248	248	248	248	248
18–37 kW	248	248	248	248	248	248
37–75 kW	248	248	248	248	248	248
75–130 kW	223	223	223	223	223	223
>130 kW	223	223	223	223	223	223
Assumptions regarding introduction of emission stages						
All capacities	(<1995)	1995	2003	2008	2009	2019

Table 3-59: Emission factors for diesel-powered boats per emission standard.

engine power	Pre-SAV	SAV	EU I	EU II
	g/kWh			
Carbon monoxide (CO)				
<4.4 kW	6.7	6.7	4.5	4.5
4.4–7.4 kW	6.7	6.7	4.5	4.5
7.4–37 kW	6.7	6.7	4.5	4.5
37–74 kW	5.9	5.9	4.5	4.5
74–100 kW	5.0	5.0	4.5	4.5
>100 kW	5.0	3.6 (6%)	3.6	3.6
Hydrocarbons (HC)				
<4.4 kW	10	10	2.4	2.40
4.4–7.4 kW	10	10	2.1	2.10
7.4–37 kW	10	2.0 (23%)	1.7	1.70
37–74 kW	10	1.4 (23%)	1.4	0.42
74–100 kW	10	1.2 (23%)	1.2	0.52
>100 kW	5	1.2 (30%)	1.2	0.52
Nitrogen oxides (NO_x)				
<4.4 kW	13	11	8.8	8.80
4.4–7.4 kW	13	11 (71%)	8.8	8.80
7.4–37 kW	13	11 (71%)	8.8	8.80
37–74 kW	13	11 (71%)	8.8	4.23
74–100 kW	13	11 (71%)	8.8	5.22
>100 kW	13	11 (73%)	8.8	5.22
Particulate matter (PM)				
<4.4 kW	1.5	1.2	0.9	0.9
4.4–7.4 kW	1.5	1.2	0.9	0.9
7.4–37 kW	1.2	1.1	0.9	0.9
37–74 kW	1.1	1.0	0.9	0.3
74–100 kW	0.9	0.9	0.9	0.15
>100 kW	0.9	0.9	0.9	0.15
Fuel consumption				
<4.4 kW	400	400	400	400
4.4–7.4 kW	400	400	400	400
7.4–37 kW	400	380	380	380
37–74 kW	380	350	350	350
74–100 kW	400	330	330	330
>100 kW	300	300	300	300
Assumptions regarding the introduction of emission stages				
All pow. classes	(<1995)	1995	2007	2015

Table 3-60: Emission factors for gasoline-powered boats per emission standard.

engine power	2-stroke gasoline engines			4-stroke gasoline engines		
	g/kWh					
	Pre-SAV	SAV	SAV/EU	Pre-SAV	SAV	EU
Carbon monoxide (CO)						
<4.4 kW	645	315	315	350	315	315
4.4–7.4 kW	645	200 (79%)	225	350	200 (79%)	225
7.4–37 kW	645	100 (79%)	162	350	100 (79%)	162
37–74 kW	645	65 (79%)	144	350	65 (79%)	144
74–100 kW	645	55 (79%)	141	350	55 (79%)	141
>100 kW	645	45 (73%)	139	350	45 (73%)	139
Hydrocarbons (HC)						
<4.4 kW	260	22	25	25	22	25
4.4–7.4 kW	260	12 (66%)	13	20	12 (66%)	13
7.4–37 kW	260	6.0 (66%)	8	20	6.0 (66%)	8
37–74 kW	260	4.0 (66%)	6	20	4.0 (66%)	6
74–100 kW	260	3.3 (66%)	5	20	3.3 (66%)	5
>100 kW	260	2.1 (52%)	5	20	2.1 (52%)	5
Nitrogen oxides (NO_x)						
<4.4 kW	15	13	13	3.5	13	13
4.4–7.4 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
7.4–37 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
37–74 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
74–100 kW	15	9.3 (62%)	9.3	3.5	9.3 (62%)	9.3
>100 kW	15	9.6 (64%)	9.6	3.5	9.6 (64%)	9.6
Fuel consumption						
<4.4 kW	700	400	400	400	400	400
4.4–7.4 kW	700	400	400	400	400	400
7.4–37 kW	650	380	380	380	380	380
37–74 kW	650	380	380	380	380	380
74–100 kW	650	380	380	380	380	380
>100 kW	650	380	380	380	380	380
Assumptions regarding the introduction of emission stages						
All capacities	(<1995)	1995	2007	(<1995)	1995	2007
Source of consumption factors: SAEFL, 1996a						

Table 3-61: Emission factors for steam-powered vessels per emission standard.

Pollutant	Steam 1	Steam 2	Steam 3	Steam 4	Steam 5	Steam 6	Steam 7
	g/kWh						
CO	0.30	0.30	0.30	0.09	0.09	0.09	0.09
HC	0.449	0.449	0.449	0.330	0.330	0.330	0.330
NO _x	2.336	2.336	2.336	1.770	1.558	1.257	1.027
PM2.5	0.033	0.024	0.015	0.009	0.006	0.006	0.006
Fuel cons.	1406	1115	1115	1115	1115	1115	1115
Assumptions regarding the date of introduction of improvements of steamships							
All classes	<1950	1950	1980	1990	1995	2000	2005

Table 3-62: Implied emission factors in 2020 for 1A3d Navigation.

1A3d Navigation	NO _x	NM VOC	SO ₂	NH ₃	PM2.5	PM10	TSP	BC	CO
	kg/TJ								
Gasoline	544	414	0.38	0.09	0.08	0.08	0.08	0.004	8'700
Diesel oil	796	226	0.47	0.18	30.7	30.7	30.7	16.6	504
Gas oil	26.3	1.6	4.7	0.042	0.13	0.13	0.13	0.020	6.9
Biodiesel	680	193	0.40	0.16	26.3	26.3	26.3	14.2	431
Bioethanol	350	255	0.24	0.056	NA	NA	NA	NA	5'507

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	1'077	1'077	105	287	NA	NE
Diesel oil	NA	2.3	0.12	0.0016	792	1'320	982	198	NA	NE
Gas oil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NE
Biodiesel	NA	2.0	0.10	0.0014	677	1'128	839	169	NA	NE
Bioethanol	15	1.4	0.12	0.0017	695	695	68	185	NA	NE

Activity data (1A3d)

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

Table 3-63: Activity Data for domestic navigation.

1A3d Domestic navigation	Unit	1990	1995	2000	2005	2010
Gasoline	TJ	701	654	616	565	535
Diesel oil	TJ	738	724	792	800	868
Gas oil	TJ	110	139	147	150	159
Biodiesel	TJ	NO	NO	1.0	2.9	3.8
Bioethanol	TJ	NO	NO	NO	NO	0.013
Total Navigation	TJ	1'550	1'517	1'556	1'518	1'565
1990 = 100%		100%	98%	100%	98%	101%

1A3d Domestic navigation	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	TJ	530	526	522	518	514	512	511	509	508	506
Diesel oil	TJ	870	872	874	876	878	873	867	862	857	851
Gas oil	TJ	157	156	154	153	151	150	149	148	147	146
Biodiesel	TJ	5.7	7.6	9.5	11	13	17	21	25	29	33
Bioethanol	TJ	0.79	1.6	2.3	3.1	3.9	6.3	8.6	11	13	16
Total Navigation	TJ	1'564	1'563	1'562	1'561	1'560	1'559	1'557	1'556	1'554	1'552
1990 = 100%		101%	101%	101%	101%	101%	101%	100%	100%	100%	100%

3.2.6.2.5 Other transportation – pipeline transport (1A3e)

This source category contains only emissions from 1A3ei Pipeline transport of natural gas due to one compressor station of the main gas pipeline.

Methodology (1A3e)

For source 1A3ei Pipeline transport, the emissions of main pollutants, particulate matter, CO, Hg, PCDD/PCDF and PAH from a compressor station located in Ruswil are considered.

The emissions are calculated with a Tier 2 method (note that the EMEP/EEA guidebook (EMEP/EEA 2019) does not contain a decision tree to determine the Tier level specifically). For the main pollutants, TSP, PM2.5 and PM10, country-specific emission factors were used. For all other pollutants (BC, CO, Hg, PCDD/PCDF and PAH), the emission factors stem from the EMEP/EEA guidebook (EMEP/EEA 2019).

Emission factors (1A3e)

The emission factors are used as for gas turbines (see Table 3-33) and are based on different sources.

- For NO_x, the emission factor stems from the Factsheet Emission Factors Furnaces (FOEN 2015k).
- For the other main pollutants (NMVOC, SO₂, NH₃), the emission factors stem from the section “Gasturbinen; Erdgas” of SAEFL (2000). For NMVOC, it is assumed that NMVOC amount to 5 % of total VOC (i.e. CH₄ amounts to 95 % of total VOC).
- For PM_{2.5}, PM₁₀ and TSP, emission factors stem from Leupro 2012.
- For all the other pollutants, the emission factors are taken from the EMEP/EEA Guidebook (EMEP/EEA 2019, Table 3.28). The BC exhaust emission factor corresponds to 2.5 % of the PM_{2.5} emission factor.

Table 3-64: Emission factors of 1A3e for 2020.

1A3ei Pipeline transport	NO _x	NMVOC	SO ₂	NH ₃	PM _{2.5} ex	PM ₁₀ ex	TSP ex	BC ex	CO
	g/GJ								
Gas	19	0.1	0.5	0.6	0.1	0.1	0.1	0.0025	4.8

1A3ei Pipeline transport	Pb	Cd ex	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	mg/GJ			ng I-TEQ/TJ						
Gas	0.0015	0.00025	0.10	0.5	560	840	840	840	NA	NA

Activity data (1A3e)

The data on fuel consumption for the operation of the compressor station in Ruswil is based on the Swiss overall energy statistics (SFOE 2021; Table 17e).

Table 3-65: Activity data of 1A3e.

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

1A3ei Pipeline transport	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Natural gas	TJ	840	810	410	830	760	340	470	490	600	540
1990=100%		150%	145%	73%	148%	136%	61%	84%	88%	107%	96%

3.2.6.3 Category-specific recalculations for 1A3 Transport

- 1A/1A3b: Due to recalculations in sector 1B2a of fugitive NMVOC emissions from gasoline storage tanks the total amount of gasoline used in sector 1A Fuel combustion activities changes a little for the years 1990-2019. This recalculation leads to changes for all pollutants for the years 1990-2019.
- 1A3b: There was no PCDD/PCDF emission factor set for natural gas engines in the road transportation model so far. A comparison with the German IIR 2021 (where an emission factor from Rentz et al. (2008) is used) and the emission factors in the EMEP/EEA guidebook (EMEP/EEA 2019) for small combustion was done and the emission factors from Rentz et al. (2008) were introduced in the Swiss Road transportation model for gas driven engines. This leads to a recalculation of the PCDD/PCDF emissions for the years 1990-2019.
- 1A3b: A comparison of the Zn exhaust emission factors so far used in HBEFA and the ones in the EMEP/EEA guidebook (EMEP/EEA 2019) led to a switch to the ones used in the EMEP/EEA guidebook. Also, because there was no reference available for the ones used in HBEFA so far. Due to this recalculation the Zn exhaust emissions for the years 1990-2019 from gasoline engines have reduced by 93 % and the ones from diesel oil by 97 % compared to the emissions in the previous submission.

- 1A3b: Due to a mistake, the cold start emissions were underestimated so far. The newly calculated energy consumption for cold start processes leads to 20 % higher emissions for Pb, Cd exhaust and SO₂ for the years 1990-2019.
- 1A3b: Based on newest available statistics some changes in the activity data have been done. This recalculation leads to changes for all pollutants for the years 1990-2019.
- 1A3b: Small recalculations for all pollutants for the years 1990-2019 due to newly defined roundings of activity data and emission factors.
- 1A3e: Emission factor for NO_x was higher in 2020 than for 2015. This was corrected and it is now constant from 2015 on (19g/GJ).
- 1A3: Small recalculation of diesel oil use in 1D2 International navigation (memo item) for all the years 1990-2019 leads to small recalculation in total diesel sold and therefore in activity data of diesel in tank tourism and statistical difference of 1A3b Road transportation looking at the fuel used approach in the reporting templates.

3.2.7 Source category 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

3.2.7.1 Source category description for 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

The source category 1A4 Non-road and machinery in other sectors comprises all emissions from the combustion of fuels in mobile non-road sources in commerce and institutions, households, agriculture and forestry. This includes use of conventional fossil fuels as well as biofuels. Note that information regarding stationary combustion of source categories 1A4 Stationary combustion in manufacturing industries and construction are provided in chp. 3.2.4.

Table 3-66: Specification of source category 1A4 – Non-road and machinery sources in residential, commercial, agriculture and forestry sectors.

1A4	Source category	Specification
1A4a	Commercial/Institutional: Mobile	Emissions from mobile machinery and motorised equipment used for professional gardening
1A4b	Residential: Household and gardening (mobile)	Emissions from mobile machinery and motorised equipment used for hobby gardening
1A4c	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	Emissions from non-road vehicles and machinery in agriculture and forestry

Table 3-67: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1A4 Non-road and machinery in other sectors (mobile).

NFR code	Source category	Pollutant	Identification criteria
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	L1
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	L2

3.2.7.2 Methodological issues for 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

Methodology (1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry))

Based on the decision tree Fig. 3.1 in chapter 1A4 of the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of mobile combustion in 1A4 Other sectors are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.1.1.1.

Emission factors (1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry))

The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Power class and emission standard-specific emission factors are shown in Table 3-41 to Table 3-43 (see chp. 3.2.5.2).

To avoid double counting there are no non-exhaust emissions of PM2.5, PM10 and TSP from resuspension caused by non-road vehicles and machinery in agriculture since they are included in the particle emissions from source categories 3Dc Soils operation of cropland and 3Dc Soils operation of grassland, see chp. 5.3.2.

Implied emission factors 2020 for all pollutants are shown in Table 3-68.

Table 3-68: Implied emission factors 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry) in 2020.

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	g/h	kg/TJ	g/h	kg/TJ	g/h	kg/TJ	g/h
1A4aii Other sectors (mobile): Commercial/institutional												
Gasoline	185	1'339	0.38	85	NA	NE	NA	NE	NA	NE	NA	NE
Bioethanol	84	467	0.24	61	NA	NE	NA	NE	NA	NE	NA	NE
1A4bii Other sectors (mobile): Residential												
Gasoline	155	881	0.38	92	NA	NE	NA	NE	NA	NE	NA	NE
Bioethanol	92	455	0.24	61	NA	NE	NA	NE	NA	NE	NA	NE
1A4cii Other sectors (mobile): Agriculture/forestry/fishing												
Gasoline	178	1'387	0.38	81	NA	0.10	NA	0.70	NA	1.05	NA	0.0082
Diesel oil	367	42	0.47	160	31	0.10	31	0.70	31	1.05	21	0.0082
Biodiesel	314	36	0.40	137	26	0.10	26	0.70	26	1.05	18	0.0082
Bioethanol	79	550	0.24	55	NA	0.10	NA	0.70	NA	1.05	NA	0.0082

Source/fuel	CO	Pb	Cd	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	HCB	PCB
	kg/TJ	g/TJ			ng I-TEQ/TJ	mg/TJ					
1A4aii Other sectors (mobile): Commercial/institutional											
Gasoline	26'760	24	2.4	0.21	2'837	946	946	92	314	NE	NE
Bioethanol	15'764	15	1.5	0.13	1'835	612	612	60	203	NE	NE
1A4bii Other sectors (mobile): Residential											
Gasoline	25'422	24	2.4	0.21	2'837	952	952	93	314	NE	NE
Bioethanol	15'789	15	1.5	0.13	1'830	614	614	60	203	NE	NE
1A4cii Other sectors (mobile): Agriculture/forestry/fishing											
Gasoline	24'532	24	2.2	0.19	2'637	1'048	1'048	102	292	NE	NE
Diesel oil	212	NA	2.0	0.11	1'404	652	1'087	809	172	NE	NE
Biodiesel	181	NA	1.7	0.09	1'200	558	929	691	147	NE	NE
Bioethanol	14'989	15	1.4	0.12	1'654	702	702	68	183	NE	NE

The Expert Review Team noted during the Stage 3 review in 2016 that the implied emission factors for NMVOC, CO and particulate matter from the non-road sector are much higher compared to other developed countries. Switzerland explained that only garden care and hobby mobile machinery are included in source categories 1A4a and 1A4b and they

Energy: Source category 1A - Fuel combustion activities - Source category 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry)

consume gasoline and bioethanol only, and indeed consist mainly of 2-stroke gasoline engines, which explains that the relatively high implied emission factor is justified. (The ERT encouraged the Party to include the explanation of this issue in the IIR.)

Activity data (1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry))

Table 3-69 shows the activity data of 1A4 – Non-road and machinery in other sectors (commercial, residential, agriculture and forestry) taken from FOEN (2015j). Detailed activity data can be downloaded from the online database INFRAS (2015a). In 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 3-69: Activity Data for 1A4 - Non-road and machinery in other sectors (commercial, residential, agriculture and forestry).

Source/Fuel	Unit	1990	1995	2000	2005	2010					
1A4aii Other sectors (mobile):											
Commercial/institutional											
Gasoline	TJ	191	245	295	295	287					
Bioethanol	TJ	NO	NO	NO	NO	0.0039					
1A4bii Other sectors (mobile):											
Residential											
Gasoline	TJ	142	155	165	166	163					
Bioethanol	TJ	NO	NO	NO	NO	0.0034					
1A4cii Other sectors (mobile):											
Agriculture/forestry/fishing											
Gasoline	TJ	5'429	5'674	5'889	5'642	5'592					
Diesel oil	TJ	1'160	1'070	963	824	689					
Biodiesel	TJ	4'269	4'604	4'920	4'802	4'882					
Bioethanol	TJ	NO	NO	6.4	17	21					
Bioethanol	TJ	NO	NO	NO	NO	0.012					
Source/Fuel	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1A4aii Other sectors (mobile):											
Commercial/institutional											
Gasoline	TJ	280	274	267	261	254	253	252	252	251	250
Bioethanol	TJ	0.24	0.48	0.72	0.95	1.2	1.9	2.6	3.3	4.0	4.7
1A4bii Other sectors (mobile):											
Residential											
Gasoline	TJ	162	161	160	159	157	157	157	156	156	155
Bioethanol	TJ	0.21	0.43	0.64	0.85	1.1	1.7	2.3	2.9	3.6	4.2
1A4cii Other sectors (mobile):											
Agriculture/forestry/fishing											
Gasoline	TJ	5'573	5'554	5'535	5'517	5'498	5'487	5'477	5'466	5'456	5'445
Diesel oil	TJ	665	641	616	592	568	551	535	519	503	486
Biodiesel	TJ	4'876	4'870	4'864	4'859	4'853	4'835	4'817	4'800	4'782	4'764
Bioethanol	TJ	32	42	53	63	74	96	118	140	162	184
Bioethanol	TJ	0.66	1.3	2.0	2.6	3.3	4.8	6.4	8.0	9.6	11

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)

The source category 1A5b Other includes emissions from fuel combustion in military aircraft and military non-road activities.

Table 3-70: Specification of source category 1A5 Other, mobile (Military)

1A5	Source category	Specification
1A5b	Other mobile (including military, land based and recreational boats)	Emissions from military aircrafts and machines like power generators, tanks, bulldozers, boats etc.

Table 3-71: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1A5 Other, mobile.

NFR code	Source category	Pollutant	Identification criteria
1A5b	Other, mobile (including military, land-based and recreational boats)	PM10	L1

3.2.8.2 Methodological issues for 1A5b Other, mobile (Military)

1A5bi military aviation

To calculate the emissions from military aviation, a Tier 2 method is used.

1A5bii military non-road vehicles and machines

Based on the decision tree Fig. 3.1 in chapter 1A4 Non-road mobile sources and machinery of the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of military non-road vehicles and machines are calculated by a Tier 3 method with the non-road transportation model described in chp. 3.2.1.1.1.

Emission factors (1A5b)

Emission factors 1A5bi military aviation

- NO_x, NMVOC, CO: average emission factors for military aircraft are calculated by the Federal Office of Civil Aviation (FOCA) based on information from the Federal Department of Defence, Civil Protection and Sport (DDPS) concerning fuel consumption per aircraft type in the year 2017-2018 (DDPS 2020). These emission factors stay constant for the whole time series from 1990 onwards.
- SO_x: the SO₂ 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 1990–2020. CCD means climb/cruise/descent.
- TSP, PM10, PM2.5 exhaust: emission factors for TSP, PM10, and PM2.5 exhaust are assumed to be equal. The implied emission factor from territorial processes (means all flights only in Swiss territory) are taken for the years 1990 (15.5 g/GJ), 1995 (7.8 g/GJ), 2000 (4.5 g/GJ) and linearly interpolated in between. From 2015 onwards an average emission factor (3.4 g/GJ) could be calculated by FOCA based on information from DDPS the same way as for NO_x, NMVOC, CO (see explanation above).

- TSP, PM10, PM2.5 non-exhaust: emission factors for TSP, PM10, PM2.5 non-exhaust are assumed to be equal. The implied emission factor (0.0016 g/GJ) from territorial processes (means all flights only in Swiss territory) in the year 1990 are taken for the whole time period (FOCA 2016a).
- BC exhaust: the BC-factor of 48 % from PM2.5 exhaust is the same as for civil aviation and constant over the period 1990-2020.
- Implied emission factors 2020 are shown in Table 3-72.

Emission factors of military non-road vehicles and machines

The general sources for the emission factors of the non-road model are described in chp. 3.2.1.1.1. Implied emission factors 2020 are shown in Table 3-72.

Table 3-72: Emission factors for 1A5b Other (Military, mobile) in 2020.

1A5b Other: Military (mobile)	NO _x	NM VOC	SO ₂	NH ₃	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	BC nx
Military aviation	kg/TJ											
Jet kerosene	232	33	23.0	NA	3.4	0.0016	3.4	0.0016	3.4	0.0016	1.6	NA
Military non-road	g/h											
Gasoline	133	714	0.38	0.092	NA	NA	NA	NA	NA	NA	NA	NA
Diesel oil	307	27	0.47	0.16	7.7	10	7.7	67	7.7	101	3.8	NA
Biodiesel	262	23	0.40	0.13	6.6	10	6.6	67	6.6	101	3	NA
Bioethanol	70	291	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
Military aviation	mg I-TEQ/TJ										
Jet kerosene	235	NA	NA	NA	NA	NA	NA	NA	NA	NE	NE
Military non-road	mg I-TEQ/TJ										
Gasoline	24'543	24	2.4	0.21	0.0028	956	956	93	314	NE	NE
Diesel oil	139	NA	1.9	0.10	0.0014	616	1'026	764	167	NE	NE
Biodiesel	119	NA	1.7	0.088	0.0012	526	877	653	143	NE	NE
Bioethanol	15'556	15	1.5	0.13	0.0018	617	617	60	202	NE	NE

Activity data (1A5b)

The fuel consumption of 1A5bi Military aviation is copied from the logbooks of the military aircrafts and summed up yearly by DDPS and provided to FOEN (DDPS 2021).

The fuel consumption of 1A5bii military non-road vehicles and machines is based on activity data provided by DDPS (DDPS 2014a) and calculated bottom-up by the non-road transportation model (chp. 3.2.1.1.1). Detailed activity data can be downloaded from the online database INFRAS (2015a).

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

Table 3-73: Activity data (fuel consumption) for 1A5b Other (Military, mobile).

1A5b Other: Military (mobile)	Unit	1990	1995	2000	2005	2010
Military aviation						
Jet kerosene	TJ	2'733	1'955	1'794	1'624	1'592
Military non-road		239	248	252	257	275
Gasoline	TJ	19	19	19	19	18
Diesel oil	TJ	220	228	233	238	256
Biodiesel	TJ	NO	NO	0.30	0.86	1.1
Bioethanol	TJ	NO	NO	NO	NO	0.00038

1A5b Other: Military (mobile)	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Military aviation											
Jet kerosene	TJ	1'420	1'527	1'542	1'615	1'567	1'627	1'469	1'457	1'303	1'365
Military non-road		275	275	275	275	275	274	273	272	271	270
Gasoline	TJ	18	18	17	17	17	17	16	16	16	16
Diesel oil	TJ	256	255	255	254	254	252	250	248	246	244
Biodiesel	TJ	1.7	2.2	2.8	3.3	3.9	5.0	6.1	7.2	8.3	9.4
Bioethanol	TJ	0.023	0.046	0.069	0.092	0.11	0.18	0.25	0.31	0.38	0.45

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

The source category 1B1 Fugitive emissions from solid fuels includes nonexhaust emissions from coal handling only. There is no production of solid fuels in Switzerland.

Table 3-74: Specification of source category 1B1a Coal mining and handling.

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

Source category 1B1 Fugitive emission from solid fuels is not a key category.

3.3.1.2 Methodological issues for 1B1 – Fugitive emissions from solid fuels

Methodology (1B1)

There is no coal mining in Switzerland and therefore only nonexhaust particulate matter emissions from coal handling occur.

Based on the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from coal handling are determined by a Tier 2 method using technology-specific activity data and emission factors.

Emission factors (1B1)

Emission factors for TSP, PM10 and PM2.5 are based on the EMEP/EEA guidebook (EMEP/EEA 2019, table 3-6). No literature BC-factors are available for coal turnover. It is assumed that coal persists of 60 % of carbon and that the share is equal independent of its size.

Table 3-75: Emission factors in 1B1 Fugitive emissions from solid fuels in 2020.

1B1 Fugitive emissions attributed to solid fuels	Unit	PM2.5 nx	PM10 nx	TSP nx	BC nx
1B1a Coal handling, Other bituminous coal imported	g/t	0.3	3.0	7.5	0.18

Activity data (1B1)

Activity data are provided by the energy model as described in chapter 3.1.6.3 and are based on the total amount of other bituminous coal imported as published in Swiss overall energy statistics (SFOE 2021).

Table 3-76: Activity data in 1B1 Fugitive emissions from solid fuels.

1B1 Fugitive emissions from solid fuels	Unit	1990	1995	2000	2005	2010						
1B1a Coal handling, Other bituminous coal imported	t	534'938	286'007	210'347	232'974	248'060						
1B1 Fugitive emissions from solid fuels	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	1990 to 2020
1B1a Coal handling, Other bituminous coal imported	t	230'305	206'436	222'598	233'487	213'788	197'752	189'824	176'005	156'612	151'282	-72%

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

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

3.3.2 Source category 1B2a - Fugitive emissions from oil

3.3.2.1 Source category description for 1B2a

In Switzerland, oil production is not occurring. Crude oil is imported by underground pipelines only. Fugitive emissions from oil industry in Switzerland result exclusively from the refineries transforming crude oil into liquid fuels and the several gasoline handling stations and storage tanks. At the beginning of 2015, one of the two refineries ceased operation and there is only one refinery left.

Table 3-77: 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	SO ₂ emissions from Claus-units in refineries
1B2av	Distribution of oil products	Fugitive emissions caused by distribution and storage of gasoline

Table 3-78: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1B2a fugitive emissions from oil.

NFR code	Source category	Pollutant	Identification criteria
1B2aiv	Fugitive emissions oil: refining / storage	SO _x	T2
1B2av	Distribution of oil products	NM VOC	T1

3.3.2.2 Methodological issues for 1B2a

Methodology (1B2a)

1B2ai Exploration, production, transport of oil – pipeline transport: Following the decision tree, Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions reported under 1B2ai are estimated using a Tier 3 approach where emission estimates based on information from experts (Canton of Neuchâtel 2019).

1B2aiv Refining and storage - leakage and emissions from Claus-units in refineries: Following the decision tree, Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), NMVOC emissions due to leakage reported under 1B2aiv are estimated using a Tier 2 approach where technology-specific activity data and emission factors are available. This source category also encompasses the SO₂ 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 the EMEP/EEA guidebook (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 2022/1B2av Benzinumschlag Tanklager, EMIS 2022/1B2av 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 m³ air saturated with VOC are emitted per week and pig trap. This leads to negligible NMVOC emissions of 10-20 kg per year.

1B2aiv, NMVOC from leakage in refineries: The emission factor of NMVOC for 1B2aiv, leakage in refineries is country-specific and is documented in the EMIS database (EMIS 2022/1B2aiv_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 2022/1B2aiv). This emission factor is used for all the years until 1995. For the years 2007-2017 total NMVOC emissions from 1A1b, 1B2aiv and 1B2c correspond to those reported in the Swiss PRTR database (PRTR 2021), including data for the years up to 2019 from the two refineries. Therefore, emission factors in 1B2aiv are adapted to reach the total NMVOC emission reported in Swiss PRTR. Between the years 1995 and 2007 the emission factors are interpolated linearly.

1B2aiv, SO₂ 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. Emission factors for storage tanks are estimated by Carbura based on a study documented in Carbura 2021. Emission factors for gasoline vapour recovery systems at gasoline stations are provided by Weyer und Partner (Schweiz) AG until 2015 using a database of Swiss 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 3-79: NMVOC and SO₂ emission factors in 1B2a – Oil, for 2020. 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 leakage (per amount of crude oil imported)	g/t	75	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	10.4	NA

Activity data (1B2a)

As crude oil is transported per pipeline to the refineries in Switzerland, activity data for 1B2ai reflect the number of pipelines, which is equal to the number of pipelines and number of pig traps. Activity data for 1B2aiv refining and storage are the amount of crude oil imported.

These data are provided by Avenergy Suisse (Avenergy 2021) in their annual statistics and also reported in the Swiss overall energy statistics (SFOE 20210).

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 2021), corrected for consumption of Liechtenstein, as documented in the EMIS database (EMIS 2022/1B2av Benzinumschlag Tanklager, EMIS 2022/1B2av Benzinumschlag Tankstellen).

Table 3-80: Activity data of 1B2a – Oil.

1B2a Fugitive emissions attributed to oil	Amount of	Unit	1990	1995	2000	2005	2010
1B2ai Transport of crude oil by pipelines	Refineries	Number	2	2	2	2	2
1B2aiv Refining and storage	Crude oil	kt	3'127	4'657	4'649	4'877	4'546
1B2av Gasoline distribution	Gasoline sold	TJ	156'516	151'672	168'353	152'182	134'129

1B2a Fugitive emissions attributed to oil	Amount of	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	1990 to 2020
1B2ai Transport of crude oil by pipelines	Refineries	Number	2	2	2	2	1	1	1	1	1	1	-50%
1B2aiv Refining and storage	Crude oil	kt	4'452	3'455	4'935	4'975	2'836	3'006	2'889	3'076	2'789	2'857	-9%
1B2av Gasoline distribution	Gasoline sold	TJ	128'941	124'386	118'717	113'956	105'664	102'367	99'223	97'654	96'850	85'769	-45%

3.3.2.3 Category-specific recalculations for 1B2a - Oil

- 1B2a: Small recalculation in statistics for SFOE 2021 concerning the amount of crude oil imported in the year 2019.
- 1B2a: Small recalculation of total amount of gasoline sold and therefore of the amount of fugitive NMVOC and Pb emissions in 2019 from gasoline distribution.
- 1B2av: NMVOC emissions due to losses in gasoline storage tanks have been recalculated for the whole timeseries 1980-2019. The new calculations are based on the latest information regarding the number and type of gasoline storage tanks.
- 1B2aiv: NMVOC emission factors in 1B2aiv refinery leakage are adapted for the year 2019 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 3-81: 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 relevant for 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 occur in this source category.

Production of natural gas

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

Transport of natural gas

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

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

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

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

Emission factors (1B2b)

Production of natural gas

For natural gas production occurring in the years 1985-1994, NMVOC default emission factors are taken from the 2006 IPCC Guidelines (IPCC 2006) as documented in the internal emission database documentation (EMIS 2022/1B2b 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 2022/1B2b 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 3-82: Emission factors in 1B2b – Natural gas, for 2020.

1B2b Fugitive emissions attributed to natural gas	Unit	NMVOC
1B2b iv Natural gas distribution losses, Transit	g/GJ	1'399
1B2b iv Natural gas distribution losses, Distribution	g/GJ	1'399
1B2b iv Natural gas 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 2021)

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 2022/1B2b 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 2022/1B2b Diffuse Emissionen Erdgas).

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

- The calculated gas losses from the pipeline network depend on the length, material and pressure of the pipelines. Gas losses due to permanent leakiness, small-scale damages, network maintenance and the network components are evaluated separately. As no applicable loss rates are available for the network compounds in Switzerland (installed

control units, fittings, storage systems and gas meters), a fixed percentage is applied to the permanent gas losses. This amount is added to the permanent gas losses.

- Regarding the end users, gas losses from on-site and indoor pipelines as well as gas losses due to the permanent leakiness of gas appliances are evaluated. Pipeline loss rates apply to the number of households, industrial users and gas fuelling stations separately. Regarding the gas appliances, different loss rates are assigned to the number of gas heating systems, gas cooking stoves and gas fuelling stations.
- For some (earlier) years in the time series, sufficient input data are not available to calculate the gas losses. For these years, polynomial interpolations are applied to assess the activity data. Depending on the process, a second, third or fourth order polynomial interpolation is applied.

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

Table 3-83: Activity data of 1B2b – Natural gas.

1B2b Fugitive emissions attributed to natural gas	Fuel	Unit	1990	1995	2000	2005	2010
Gas production	Natural gas	GJ	130'000	NO	NO	NO	NO
Gas distribution losses, Transit	Natural gas	GJ	28'226	30'874	32'571	33'491	34'595
Gas distribution losses, Distribution	Natural gas	GJ	710'246	817'028	655'267	512'036	449'418
Gas distribution losses, Other	Natural gas	GJ	NO	NO	NO	NO	35'444

1B2b Fugitive emissions attributed to natural gas	Fuel	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	1990 to 2020
Gas production	Natural gas	GJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-
Gas distribution losses, Transit	Natural gas	GJ	34'569	34'483	34'852	35'125	35'468	35'743	35'884	35'809	36'096	36'079	28%
Gas distribution losses, Distribution	Natural gas	GJ	441'857	435'545	399'993	389'310	388'251	390'185	383'203	377'827	376'672	376'495	-47%
Gas distribution losses, Other	Natural gas	GJ	28'114	NO	NO	NO	NO	NO	NO	NO	NO	NO	-

3.3.3.3 Category-specific recalculations for 1B2b

- 1B2b: Small recalculation of natural gas consumption in the year 2019 leads also to recalculation of natural gas losses in 2019.
- 1B2bii, gas production, venting: the NMVOC emission factor newly relates to the upper value as given in the IPCC guidelines, chp. 4, Table 4.2.4 (Tier 1 method). Before, it was taken from the EMEP/EAA guidebook and resulted in a smaller value. This change affects NMVOC emissions from 1985 to 1994.

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

3.3.4.1 Source category description for 1B2c

This source category contains venting and flaring caused by two types of activities: oil production and refining and gas production. In Switzerland, oil production is not occurring, and only one production site for natural gas production was operational from 1985–1994. Therefore, emissions from flaring result primarily from the gas torches caused by oil refining, which were operational at the two refineries. Since 2015, there is only one refinery in operation. In addition, CO₂ emissions from H₂ production in one of the two refineries are also reported under 1B2c since 2005.

Table 3-84: Specification of source category 1B2c – Venting and flaring.

1B2c	Source category	Specification
1B2c	Venting and flaring (oil, gas, combined oil and gas)	The release/combustion of excess gas at the oil refinery Flaring of gas at gas production facility (only relevant for 1990-1994)

Table 3-85: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 1B2c - Fugitive emissions from venting and flaring (oil, gas, combined oil and gas).

NFR code	Source category	Pollutant	Identification criteria
1B2c	Venting and flaring (oil, gas, combined oil and gas)	NO _x	T2

Source category 1B2c, venting and flaring, is newly a key category for NO_x, for submission 2022 according to approach 2 trend assessment (see Table 1-11).

3.3.4.2 Methodological issues for 1B2c

Methodology (1B2c)

Following the decision tree, Figure 3-1 in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions reported under 1B2c are estimated using a Tier 3 approach where plant-specific activity data are available. In Switzerland, flaring only occurs in refineries and there is no venting. One of the two refineries in Switzerland ceased its operation at the beginning of 2015. Between 1990-1994, there was a gas production facility in Switzerland, where gas was flared.

Emission factors (1B2c)

Emission factors of 1B2c Venting and flaring are based on the following data:

- NO_x, NMVOC, SO₂ and CO emission factors are provided from the refining industry as documented in the EMIS database (EMIS 2022/1B2c Raffinerie Abfackelung). Since 2005 (with the exception of 2012), the refining industry provides annual data on the CO₂ emissions from flaring under the Federal Act on the Reduction of CO₂ Emissions (Swiss Confederation 2011) based on daily measurements of CO₂ emission factors of the flared gases. From these data, annual CO₂ emission factors are derived. Since 2005, the evolution of the other emission factors (NO_x, NMVOC, SO₂, CO) is assumed to be proportional to the CO₂ emission factor. Emission factors for 2020 are considered confidential and are available to reviewers upon request. The NMVOC emissions from flaring in the gas production facility (only occurring from 1990-1994) are calculated based on default emission factors provided in the 2006 IPCC Guidelines.
- PM/TSP exhaust, BC exhaust, heavy metals and PAH emission factors concerning gas venting and flaring for gas production and for oil refining stem from the EMEP/EEA guidebook (EMEP/EEA 2019). For the emission factors applicable at oil refineries, the values from EMEP/EEA (2019), originally in the unit of ton of gas burned, are recalculated per quantity of oil processed for the Swiss inventory. Since the quantity of gas burned per oil processed at refinery is confidential, therefore, the emission factor shown in Table 3-86 is confidential as well.
- The PCDD/PCDF emission factor for venting and flaring at gas production stems from Norway's Informative Inventory Report 2021 (Norwegian Environment Agency 2021). This emission factor is used from 1985 until 1994, when gas production stopped in Switzerland.

Table 3-86: Emission factors in 1B2c – Venting and flaring, for 2020.

1B2c Fugitive emissions attributed to venting and flaring	Unit	NO _x	NMVOG	SO ₂	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
1B2ci Flaring oil	g/t	C	C	C	C	C	C	C	C
1B2cii Flaring gas	g/t	NO	NO	NO	NO	NO	NO	NO	NO

1B2c Fugitive emissions attributed to venting and flaring	Unit	Pb	Cd	Hg	BaP	BbF	BkF	IcdP
1B2ci Flaring oil (per amount of crude oil imported)	g/t	C	C	C	C	C	C	C
1B2cii Flaring gas (per amount of natural gas produced)	g/t	NO	NO	NO	NO	NO	NO	NO

Activity data (1B2c)

1B2c Fugitive emissions from venting and flaring

Before 2005, the amount of flared gas in oil refineries (1B2ci) is assumed to be proportional to the amount of crude oil processed in the refineries. Since 2005, the industry provides bottom-up data on the amount of gas flared in the refineries. Activity data since 2014 are considered confidential and are available to reviewers on request.

For gas venting and flaring associated with gas production (only occurring from 1990-1994), the amount of gas flared under category 1B2cii is estimated based on the amount of gas produced.

Table 3-87: Activity data of 1B2c – Venting and flaring.

1B2c Fugitive emissions attributed to venting and flaring	Fuel	Unit	1990	1995	2000	2005	2010
1B2ci Flaring oil	Oil	kt	C	C	C	C	C
1B2cii Flaring gas	Gas	GJ	130'000	NO	NO	NO	NO

1B2c Fugitive emissions attributed to venting and flaring	Fuel	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	1990 to 2020
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

- 1B2c: As recommended by the expert review team in the stage 3 review in 2020, missing emission factors are now taken into account for the following pollutants: PM, PM10, PM2.5, BC, heavy metals and PAHs, using available emission factors from the EMEP/EAA guidebook 2019, expressed in this report per ton of refined crude oil.
- 1B2c: recalculation of the NMVOG emission factor for flaring gas in the refinery due to an error in the calculations using the conversion factor from g/L to g/t crude oil.
- 1B2cii, gas production, flaring: emission factors are now taken into account for additional pollutants and heavy metals, using emission factors for Tier 1 from the EMEP/EEA guidebook, when available. For dioxins, the emission factor is taken from Norway’s Informative Inventory Report 2021 (Norwegian Environment Agency 2021).

4 Industrial processes and product use

4.1 Overview of emissions

This introductory chapter gives an overview of major emissions from sector 2 Industrial processes and product use between 1990 and 2020 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 weaker decreasing trend afterwards. The trend until 2004 is mainly due to reductions in 2D Other solvent and product use and partially also due to reductions in 2G Other product use. For the entire time series, the NMVOC emissions are dominated by the emissions from 2D. Relevant emissions stem from 2G Other product use and 2H Other as well.

In 1990, source categories 2D3d Coating applications and 2D3g Chemical products contribute to more than half of the NMVOC emissions of source category 2D whereas all the other source categories account for the rest. In 2020, 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 2020, by emissions from paint application in construction and on wood.

The NMVOC emissions from the most important single source category 2D3a Household cleaning agents, cosmetics and toiletries increase between 1990 and 1996 then they drop until 2000 and since then they show a weaker decline until 2016. From 2017 onwards, the emissions are again increasing. Factors contributing to this trend are changes in the product use, product-specific NMVOC contents and population growth.

Within source category 2D, a significant reduction in emissions from 2D3g Chemical products and 2D3h Printing between 1990 and 2020 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 1990–2020. In addition, general technological improvements and post-combustion installations contribute to further emission reductions.

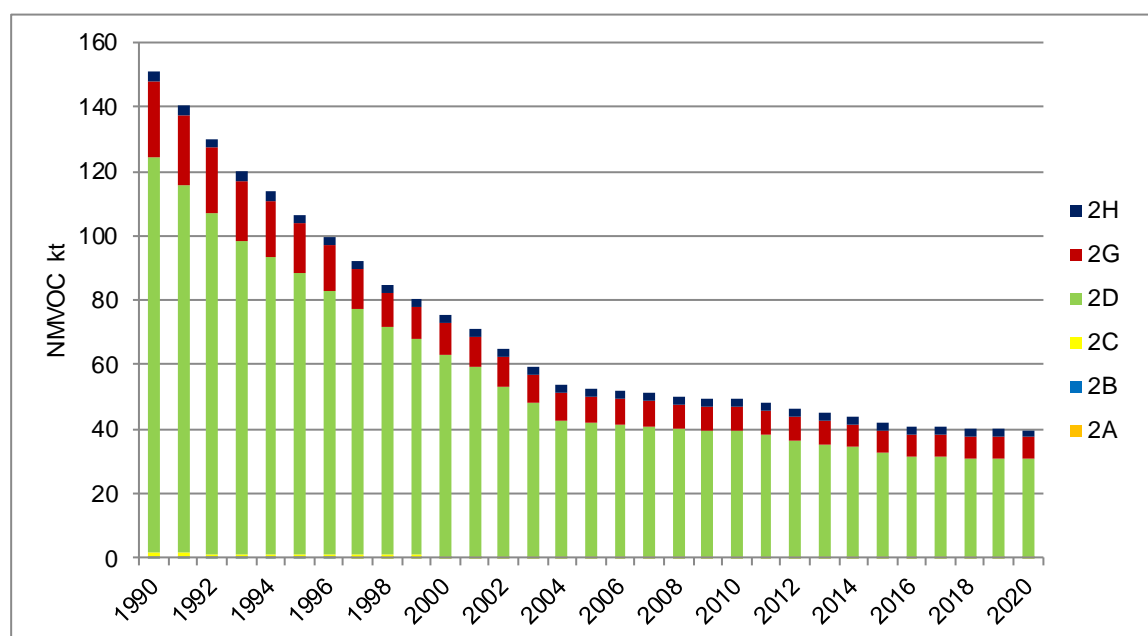


Figure 4-1: Switzerland's NMVOC emissions from industrial processes and product use by source categories 2A-2D and 2G-2H between 1990 and 2020. The corresponding data table can be found in Annex A7.3.

4.1.2 Overview and trend for SO₂

According to Figure 4-2 total SO₂ emissions from 2 Industrial processes and product use show an intermittent decrease of almost 70 % in the period 1990-2009. From 2010 to 2018, there is again an increase in SO₂ emissions followed by a decrease 2019-2020. In 1990, source category 2C Metal production shows the largest contribution to the total SO₂ emissions and other significant contributions are due to 2B Chemical industry. In 2020, the emissions are dominated by 2B Chemical industry. The emissions from 2A Mineral products are negligible over the entire time period and there are no emissions from 2D. The varying and even increasing SO₂ 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 2020. In 2020, it is by far the largest emission source within sector 2. The SO₂ 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 SO₂ emissions from 2G Other product use stems from the use of fireworks.

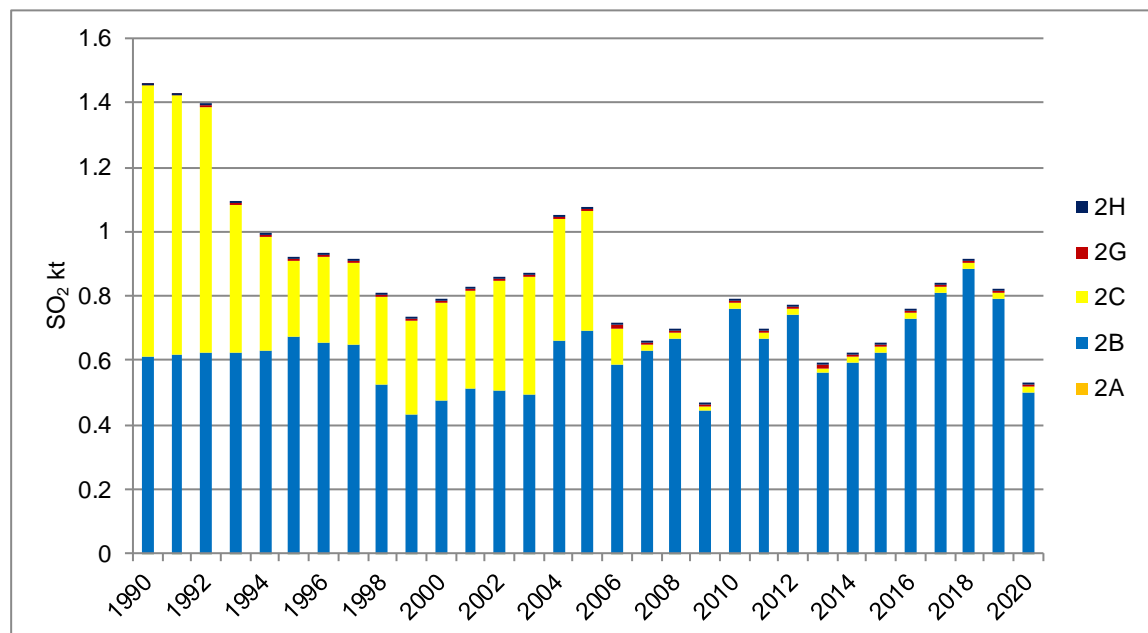


Figure 4-2: Switzerland's SO₂ emissions from industrial processes and product use by source categories 2A–2C and 2G-2H between 1990 and 2020. The corresponding data table can be found in Annex A7.3.

4.1.3 Overview and trend for PM_{2.5}

According to Figure 4-3, total PM_{2.5} 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 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 PM_{2.5} emissions.

In 2020, the highest contribution to the total PM_{2.5} emissions is due to the source categories 2A, 2G and 2H. The other source categories are of minor importance in 2020. PM_{2.5} 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, PM_{2.5} 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 1994 and 1999 and are almost exclusively responsible for the total PM_{2.5} emission reduction in this source category between 1990 and 2020. 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 PM_{2.5} emissions from 2G Other product use, i.e. from the use of fireworks and tobacco, remained about constant between 1990 and 2013 and show a decreasing trend since then. In 1990, 2G emissions were dominated by tobacco use. In 2020, tobacco use is still the major emission source but also the use of fireworks contributed considerable amounts. The emissions in 2H Other remain about constant since 1990 but with a slight decline in recent

years. In this source category, the main contributions arise from 2H1 Chipboard and fibreboard production.

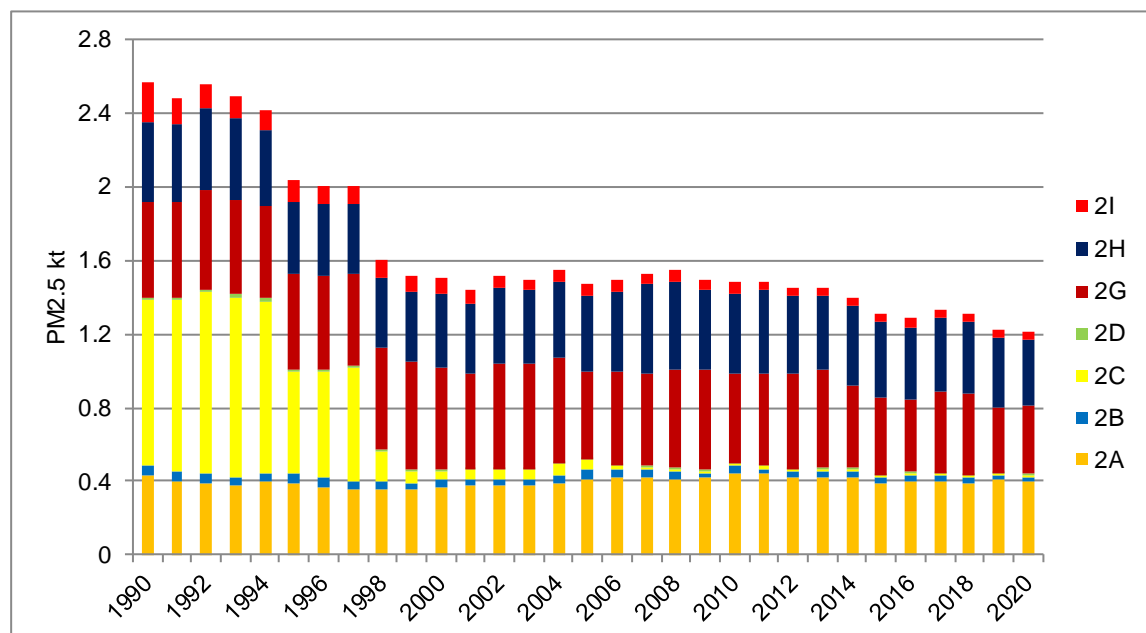


Figure 4-3: Switzerland's PM2.5 emissions from industrial processes and product use by source categories 2A-2D and 2G-2I between 1990 and 2020. The corresponding data table can be found in Annex A7.3.

4.2 Source category 2A – Mineral products

4.2.1 Source category description of 2A Mineral products

Table 4-1: Specification of source category 2A Mineral products in Switzerland.

2A	Source category	Specification
2A1	Cement production	Blasting operations of the cement production, Process emissions from calcination are reported in 1A2f
2A2	Lime production	Blasting operations of the lime production, Process emissions from calcination are reported in 1A2f
2A3	Glass production	Process emissions from glass production are reported in 1A2f
2A5a	Quarrying and mining of minerals other than coal	Gravel plants and blasting operations of the plaster production

Table 4-2: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 2A Mineral Products.

NFR code	Source category	Pollutant	Identification criteria
2A1	Cement production	PM2.5	L2, T2
2A1	Cement production	PM10	L1, L2
2A5a	Quarrying and mining of minerals other than coal	PM2.5	L1, T1, L2, T2
2A5a	Quarrying and mining of minerals other than coal	PM10	L1, T1, L2, T2

4.2.2 Methodological issues of 2A Mineral products

4.2.2.1 Cement production (2A1)

Methodology (2A1)

In Switzerland, there are six plants producing clinker and cement. The Swiss plants are rather small and do not exceed a capacity of 3'000 tonnes of clinker per day. All of them use modern dry process technology.

According to the EMEP/EEA guidebook (EMEP/EEA 2019), source category 2A1 Cement production comprises all emissions from operations other than pyroprocessing (kiln). Based on the decision tree Fig. 3.1 in chapter 2A1 Cement production of EMEP/EEA (2019), the emissions resulting from blasting operations during the digging of limestone are determined by a Tier 2 method using country-specific emission factors documented in EMIS 2022/2A1. 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 PM_{2.5} exh.) is taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.A.1, table 3.1).

Table 4-3: Emission factors for blasting operations of 2A1 Cement production in 2020.

2A1 Cement production	Unit	NO _x	NM _{VO} C	SO ₂					
Blasting operations	g/t clinker	3.3	8.6	0.14					
2A1 Cement production	Unit	PM _{2.5} ex	PM _{2.5} nx	PM ₁₀ ex	PM ₁₀ nx	TSP ex	TSP nx	BC ex	CO
Blasting operations	g/t clinker	0.51	50	0.86	77	0.86	110	0.015	3.3

Activity data (2A1)

Since 1990, data on annual clinker production are provided by the industry association (Cemsuisse) as documented in the EMIS database (EMIS 2022/2A1_Zementwerke übriger Betrieb). From 2008 onwards, they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

Table 4-4: Activity data of 2A1 Cement production.

2A1 Cement production	Unit	1990	1995	2000	2005	2010					
Clinker	kt	4'808	3'706	3'214	3'442	3'642					
2A1 Cement production	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Clinker	kt	3'587	3'368	3'415	3'502	3'195	3'296	3'279	3'239	3'227	3'129

4.2.2.2 Lime production (2A2)

Methodology (2A2)

There is only one producer of burnt lime in Switzerland. Based on the decision tree Fig. 3.1 in chapter 2A2 Lime production of the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from blasting operations in the quarry are determined by a Tier 2 method using country-specific emission factors (EMIS 2022/2A2). 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 , $\text{PM}_{2.5}$, PM_{10} , 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 (% $\text{PM}_{2.5}$) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.A.2, table 3.1).

Activity data (2A2)

Activity data on annual lime production is based on data from the only lime producer in Switzerland and is confidential but available to reviewers on request. From 2008 onwards, they are based on plant-specific annual monitoring reports from the Swiss Emissions Trading Scheme (ETS).

4.2.2.3 Glass production (2A3)

Process emissions from glass production in Switzerland, i.e. container and tableware glass as well as glass wool are reported together with the combustion emissions in source category 1A2f according to EMEP/EEA guidebook (EMEP/EEA 2019), since it is not straightforward to separate them. Therefore, emissions of NO_x , SO_x , $\text{PM}_{2.5}/\text{PM}_{10}/\text{TSP}$, 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 the EMEP/EEA guidebook (EMEP/EEA 2016), emissions from blasting operations as well as emissions of particulates from crushing and grinding work are determined by a Tier 2 method using country-specific emission factors (EMIS 2022/2A5a). 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 2020.

2A5a Quarrying and mining of minerals other than coal	Unit	NOx	NM VOC	SO ₂
Gravel plants	g/t gravel	NA	NA	NA
Plaster production	g/t rocks	5.6	14	0.24

2A5a Quarrying and mining of minerals other than coal	Unit	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO
Gravel plants	g/t gravel	NA	4	NA	8	NA	16	NA	NA
Plaster production	g/t rocks	0.9	150	1.4	300	1.4	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 latest year of the submission.

Table 4-6: Activity data of 2A5a Gravel plants and Plaster production.

2A5a Quarrying and mining of minerals other than coal	Unit	1990	1995	2000	2005	2010
Gravel plants	kt gravel	33'798	36'791	39'785	44'960	50'540
Plaster production	kt rocks	319	304	288	327	335

2A5a Quarrying and mining of minerals other than coal	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gravel plants	kt gravel	51'940	49'780	53'940	53'090	50'610	52'750	51'480	49'880	54'060	53'873
Plaster production	kt rocks	293	271	213	166	140	148	146	152	149	122

4.2.2.5 Construction and demolition (2A5b)

The emissions (from resuspension) of particulate matter (PM2.5, PM10 and TSP) from construction machinery are reported in source category 1A2gvii Mobile combustion in manufacturing industries and construction. Therefore, these emissions are indicated in the reporting tables as "IE".

4.2.3 Category-specific recalculations in 2A Mineral products

The following recalculations were implemented in submission 2022:

- 2A5a: The last year's extrapolated activity data of 2A5a Gravel plants for 2019 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, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 2B Chemical Industry.

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

4.3.2 Methodological Issues of 2B Chemical industry

4.3.2.1 Ammonia production (2B1)

Methodology (2B1)

In Switzerland, ammonia is produced in one single plant by catalytic reaction of nitrogen and synthetic hydrogen. Ammonia is not produced in an isolated reaction plant but is part of an integrated production chain. Starting process of this production chain is the thermal cracking of liquefied petroleum gas and light virgin naphtha yielding ethylene and a series of by-products such as e.g. synthetic hydrogen, which are used as educts in further production steps. According to the producer it is not possible to split and allocate the NMVOC emissions of the cracking process to each single product (ethylene, ammonia, cyanic acid etc.) within the integrated production chain. Therefore, the NMVOC emissions of the cracking process are allocated completely to the primary product ethylene (source category 2B10a). The only emissions reported under 2B1 Ammonia production are NH₃ emissions escaping from the flue gas scrubber.

Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions from 2B1 Ammonia production are calculated by a Tier 2 method using plant-specific emission factors documented in EMIS 2022/2B1.

Emission factors (2B1)

The NH₃ 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 2020.

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 1990-2020. 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 (HNO₃) which stopped production in spring 2018. Nitric acid was produced by catalytic oxidation of ammonia (NH₃) with air. At temperatures of 800°C nitric monoxide (NO) is formed. During cooling, nitrogen monoxide reacted with excess oxygen to form nitrogen dioxide (NO₂). The nitrogen dioxide reacted with water to form 60 % nitric acid (HNO₃). Today, two types of processes are used for nitric acid production: single pressure or dual pressure plants. In Switzerland a dual pressure plant was installed.

Thus, there resulted also some nitrogen oxide (NO_x) as an unintentional by-product. In the Swiss production plant abatement of NO_x was done by selective catalytic reduction (SCR, installed in 1988) which reduced NO_x to N₂ and O₂ (the SCR in this plant was also used for treatment of other flue gases and was not installed for the HNO₃ production specially). In 1990 an automatic control system for the dosing of ammonia to the SCR process was installed.

Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), NH₃ and NO_x emissions from 2B2 Nitric acid production are calculated by a Tier 2 method using plant-specific emission factors (see EMIS 2022/2B2).

Emission factors (2B2)

The emission factors for NO_x and NH₃ per tonne of nitric acid (100 %) are confidential but available to reviewers upon request. The emission factor values for NO_x and NH₃ 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 NH₃ slip in order to regulate ammonia dosage in the DeNO_x plant. Moreover, in 2013 the volume of the DeNO_x plant was duplicated. Consequently, the NH₃ emissions could be reduced significantly. Also, a slight reduction of NO_x occurred. From 2013 to 2018, emission factors were based on measurements provided by the plant.

Activity data (2B2)

Activity data on annual nitric acid (100 %) production was provided for the years 1990 to 2018 by the single production plant in Switzerland and is therefore considered as confidential. However, this information is available to reviewers. From 2013 to 2018, activity data were taken from annual monitoring reports from the Swiss Emission Trading Scheme (ETS).

4.3.2.3 Carbide production (2B5)

Methodology (2B5)

In Switzerland, only silicon carbide is produced in a single plant. It is produced together with graphite in a coupled process in an electric furnace at temperatures above 2000°C using the Acheson process. Therefore, emissions include those from the production of both silicon carbide and graphite. Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of SO₂, particulate matter and CO from 2B5 Silicon carbide production are calculated by a Tier 2 method using plant-specific emission factors (EMIS 2022/2B5).

Emission factors (2B5)

The emission factors of SO₂, particulate matter and CO are based on data from the production plant. The SO₂ emission factor is derived from the sulphur content of the feedstocks, i.e. petroleum coke and anthracite. The CO emission factor is calculated based on the carbon mass balance of the production process and exhaust measurements. The emission factors are expressed in g/t carbide but comprise the (unsplit) emissions from the coupled production process of silicon carbide and graphite. They are confidential but available to reviewers on request.

Table 4-10: Emission factor for 2B5 Carbide production in 2020.

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

Activity data (2B5)

Activity data on annual production of silicon carbide (and graphite) is provided by the production plant from 1995 onwards. For 1990–1994 they are estimates based on industry data. The activity data are considered confidential. However, this information is available to reviewers on request.

4.3.2.4 Chemical industry: Other (2B10a)

Methodology (2B10a)

Source category 2B10a Chemical industry: Other comprises emissions from production of acetic acid, ammonium nitrate (ceased in 2018), chlorine gas, ethylene, niacin, PVC (ceased in 1996) as well as sulphuric acid. Based on the decision tree Fig. 3.1 in chapter 2B Chemical industry in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from 2B10a Chemical industry are calculated by a Tier 2 method using plant-specific emission factors (EMIS 2022/2B10a).

Acetic acid production (2B10a)

In Switzerland there is only one plant producing acetic acid (CH₃COOH) 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 2022/2B10 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 2020.

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 2022/2B10 Essigsäure-Produktion. The data for acetic acid production are confidential since 2013 (only one manufacturer remaining) but available for reviewers on request.

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

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

2B10a Chemical industry: Other	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Ammonium nitrate production	kt	C	C	C	C	C	C	C	C	NO	NO
Chlorine gas production	kt	C	C	C	C	C	C	C	C	C	C
Acetic acid production	kt	18	12	C	C	C	C	C	C	C	C
Ethylene production	kt	C	C	C	C	C	C	C	C	C	C
Sulfuric acid production	kt	C	C	C	C	C	C	C	C	C	C
Niacin production	kt	C	C	C	C	C	C	C	C	C	C
PVC production	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Ammonium nitrate production (2B10a)

In Switzerland there was only one plant producing ammonium nitrate; it stopped production in 2018. In the production process emissions of NH₃ and particulate matter occurred.

Emission factors

The emission factors for NH₃ 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 2022/2B10 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 2022/2B10 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 2022/2B10 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 2022/2B10 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 2022/2B10 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 2022/2B10 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 2022/2B10 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 2022/2B10 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 (H₂SO₄) is produced by one plant only in Switzerland. From this production process SO₂ is emitted.

Emission factors

The emission factor for SO₂ 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 2022/2B10 Schwefelsäure-Produktion. Between 1990 and 2008 the mean value is applied. The SO₂ 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 2022/2B10 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 2022/2B10 PVC-Produktion).

Activity data

The annual amount of PVC produced is based on data from industry and expert estimates documented in EMIS 2022/2B10 PVC-Produktion (see Table 4-12).

4.3.3 Category-specific recalculations in 2B Chemical industry

The following recalculations were implemented in submission 2022:

- 2B5: Source category 2B5 Silicon carbide production was updated based on new detailed industry data and information yielding revised activity data for the years 1990-2012. Also, the so far missing CO emissions are newly reported.

4.4 Source category 2C – Metal production

4.4.1 Source category description of 2C Metal production

Table 4-13: Specification of source category 2C Metal production in Switzerland.

2C	Source category	Specification
2C1	Iron and steel production	Secondary steel production, iron foundries
2C3	Aluminium production	Production of aluminium (ceased in 2006)
2C7a	Copper production	Non-ferrous metal foundries
2C7c	Other metal production	Battery recycling, galvanizing plants

Table 4-14: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 2C Metal Production.

NFR code	Source category	Pollutant	Identification criteria
2C1	Iron and steel production	PM2.5	T1, T2
2C1	Iron and steel production	PM10	T1, T2

4.4.2 Methodological issues of 2C Metal production

4.4.2.1 Iron and steel production (2C1)

Methodology (2C1)

In Switzerland only secondary steel production from recycled steel scrap occurs. After closing of two steel plants in 1994 another two plants remain. Both plants use electric arc furnaces (EAF) with carbon electrodes for melting the steel scrap. The PCB emissions are

modelled within the disposal category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2. The PCB emission value of the air pollution control measurements in 2014 were included in the model.

Iron is processed in foundries only. There is no production of pig iron. Today, 14 iron foundries exist in Switzerland. About 75 % of the iron is processed in induction furnaces and 25 % in cupola furnaces.

Based on the decision tree Fig. 3.1 in chapter 2C1 in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions from 2C1 Iron and steel production are calculated by a Tier 2 method using country-specific emission factors (EMIS 2022/2C1).

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, SO₂, 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 NH₃ emission factor is taken from the Handbook on emission factors for stationary sources (SAEFL 2000).

The emission factor of BC (% PM2.5) is taken from EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.C.1, table 3.1).

Table 4-15: Emission factors 2C1 Iron and steel production in 2020. Unit of PCDD/PCDF is in I-TEQ.

2C1 Iron and steel production	Unit	NO _x	NMVOC	SO ₂	NH ₃	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO
Iron production,													
electric melting furnace	g/t iron	NA	33	NA	NA	7	NA	10	NA	13	NA	0.025	93
other processes	g/t iron	10	4'000	NA	70	NA	50	NA	130	NA	150	NA	4'000
Steel production,													
electric arc furnace	g/t steel	140	70	14	NA	6	NA	8	NA	9	NA	0.022	700
rolling mill	g/t steel	NA	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

2C1 Iron and steel production	Unit	Pb	Cd	Hg	PCDD/PCDF	BaP	BbF	BkF	IcdP	PCB
Iron production,										
electric melting furnace	mg/t iron	320	1.3	NA	0.00013	NA	NA	NA	NA	NA
other processes	mg/t iron	NA	NA	NA	0.0013	NA	NA	NA	NA	NA
Steel production,										
electric arc furnace	mg/t steel	200	4	40	0.00011	0.8	3.4	0.9	2.2	1.5
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	2010						
Iron production,												
electric melting furnace	kt	80	70	65	35	40						
other processes	kt	170	130	120	67	53						
Steel production,												
electric arc furnace	kt	1'108	716	1'022	1'159	1'218						
other processes	kt	1'108	716	NO	NO	NO						
rolling mill	kt	1'108	716	1'022	1'082	1'082						

2C1 Iron and steel production	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron production,											
electric melting furnace	kt	46	34	34	33	28	26	27	26	18	15
other processes	kt	61	46	45	43	37	34	35	34	24	20
Steel production,											
electric arc furnace	kt	1'322	1'252	1'231	1'315	1'296	1'238	1'270	1'291	1'130	1'125
other processes	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
rolling mill	kt	1'183	1'162	1'126	1'176	1'144	1'085	1'138	1'160	1'037	1'031

4.4.2.2 Aluminium production (2C3)

Methodology (2C3)

Today, there is no more primary aluminium production as the last production site closed in April 2006. Based on the decision tree Fig. 3.1 in chapter 2C3 in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from source category 2C3 are calculated by a Tier 2 method using country-specific emission factors (EMIS 2022/2C3).

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 2020.

Activity data (2C3)

From 1995 to 2006 data on aluminium production is based on data published regularly by the Swiss Aluminium Association (www.alu.ch). For earlier years, the data was provided directly by the aluminium industry. In April 2006, the last site of primary aluminium production (electrolysis) in Switzerland closed down.

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

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

2C3 Aluminium production	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

4.4.2.3 Copper production (2C7a)

Methodology (2C7a)

Source category 2C7a Copper production comprises one large and several small non-ferrous metal foundries, which are organized within the Swiss foundry association (GVS). In Switzerland, only casting and no primary production of non-ferrous metals occur.

Based on the decision tree Fig. 3.1 in chapter 2C7a in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from source category 2C7a are calculated by a Tier 2 method (EMIS 2022/2C7a) 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 2020. Unit of PCDD/PCDF is in I-TEQ.

2C7a Copper production	Unit	NMVOG	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO	Pb	Cd	PCDD/PCDF
Foundries of non-ferrous metals	g/t metal	50	95	100	100	0.095	240	0.30	0.05	0.00003

Activity data (2C7a)

Activity data on annual non-ferrous metal production is based on data from industry (1990 and monitoring reports of the Swiss ETS from 2006 onwards) and the Swiss foundry association (GVS, since 1996) as documented in the EMIS database.

Table 4-19: Activity data for 2C7a Foundries of non-ferrous metals.

2C7a Copper production	Unit	1990	1995	2000	2005	2010
Foundries of non-ferrous metals	kt	60	56	53	33	20

2C7a Copper production	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Foundries of non-ferrous metals	kt	12	6.6	6.4	9.5	8.9	9.0	8.0	6.8	6.4	5.1

4.4.2.4 Other metal production (2C7c)

Methodology (2C7c)

Source category 2C7c Other metal production comprises emissions from battery recycling and galvanizing plants. In Switzerland, there is one plant recycling batteries by applying the Sumitomo-process which started operation in 1992 and about a dozen of galvanizing plants. Based on chapter 2C7c in the EMEP/EEA guidebook (EMEP/EEA 2019), emissions from source category 2C7c are calculated by a Tier 2 approach (EMIS 2022/2C7c) 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, SO₂, 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, SO₂, TSP, CO, Pb, Cd, Hg and PCDD/PCDF are assumed constant based on air pollution control measurements from 2003 and 2012.

Emission factors of NMVOG and NH₃ 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 2020. Unit of PCDD/PCDF is in I-TEQ.

2C7c Other metal production	Unit	NO _x	NMVOC	SO ₂	NH ₃	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO
Galvanizing plants	g/t metal	NA	NA	NA	90	NA	15	NA	30	NA	37	NA	NA
Battery recycling	g/t battery	C	C	C	C	C	NA	C	NA	C	NA	NE	C

2C7c Other metal production	Unit	Pb	Cd	Hg	PCDD/PCDF
Galvanizing 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 2022/2C7c_Batterie-Recycling, EMIS 2022/2C7c_Verzinkereien).

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

Table 4-21: Activity data for 2C7c Other metal production: Battery recycling and Galvanizing.

2C7c Other metal production	Unit	1990	1995	2000	2005	2010
Galvanizing plants	kt	102	84	99	88	93
Battery recycling	kt	NO	C	C	C	C

2C7c Other metal production	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Galvanizing plants	kt	96	92	92	92	92	92	91	91	91	91
Battery recycling	kt	C	C	C	C	C	C	C	C	C	C

4.4.3 Category-specific recalculations in 2C Metal production

The following recalculations were implemented in submission 2022:

- 2C7c: Due to new projection figures for the metal processing industry (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of source category 2C7c Galvanizing plants have changed from 2013 onwards.

4.5 Source category 2D3 – Other solvent use

4.5.1 Source category description of 2D3 Other solvent use

Source category 2D3 comprises mainly NMVOC emissions from about 40 different solvent applications. From 2D3c Asphalt roofing and 2D3i Fat, edible and non-edible oil extraction (ceased in 2000) also particulate matter and CO and particulate matter, respectively, are emitted.

Table 4-22: Specification of source category 2D Other solvent use in Switzerland.

2D	Source category	Specification
2D3a	Domestic solvent use including fungicides	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, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 2D Other Solvent Use.

NFR code	Source category	Pollutant	Identification criteria
2D3a	Domestic solvent use including fungicides	NMVOG	L1, T1, L2, T2
2D3b	Road paving with asphalt	NMVOG	L1, T1, L2, T2
2D3d	Coating applications	NMVOG	L1, T1, L2, T2
2D3e	Degreasing	NMVOG	T1, T2
2D3g	Chemical products	NMVOG	L1, T1, L2, T2
2D3h	Printing	NMVOG	L1, T1
2D3i	Other solvent use	NMVOG	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 NMVOG emission sources, the use of household cleaning agents, cosmetics and toiletries is the largest single source in source category 2D3.

Based on the decision tree Fig. 3.1 in chapter 2D3a in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions are calculated by a Tier 2 method (EMIS 2022/2D3a) 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 consumption figures, NMVOC contents and emission fractions. About 75 % 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 in Germany (1996 and 2000).

For the latest submission a comprehensive study was conducted based on detailed sales figures of the years 2017-2020, NMVOC contents and application-specific emission factors. The sales figures came from a market research institute whereas information on product class-specific NMVOC contents were provided by a large retailer and production companies.

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 2020.

2D3a Domestic solvent use	Unit	NMVOC
Household cleaning agents	g/inhabitant	650
Domestic use of spray cans	g/inhabitant	360
Domestic use of pharmaceutical	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 (SF50 2021c).

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

2D3a Domestic solvent use	Unit	1990	1995	2000	2005	2010
	inhabitants	6'712'000	7'041'000	7'184'000	7'437'000	7'825'000

2D3a Domestic solvent use	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	inhabitants	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	8'638'000

4.5.2.2 Road paving with asphalt (2D3b)

Methodology (2D3b)

Based on the decision tree Fig. 3.1 in chapter 2D3b in the EMEP/EEA guidebook (EMEP/EEA 2019), the NMVOC emissions from 2D3b Road paving with asphalt are determined by a Tier 2 method based on country-specific emission factors as documented in EMIS 2022/2D3b. Other pollutants are not considered.

Emission factors (2D3b)

The emission factor for NMVOC emissions from 2D3b Road paving with asphalt comprises NMVOC emissions from the use of prime coatings and from the bitumen content in asphalt products (about 5 %). The NMVOC content in the bitumen has decreased considerably between 1990 and 2010. The values are based on industry data from 1990, 1998, 2007, 2010 and 2013. All other years are interpolated and complemented with expert estimates documented in the EMIS database. Emissions of particulate matter are not estimated so far.

Table 4-26: Emission factors of 2D3b Road paving with asphalt in 2020.

2D3b Road paving with asphalt	Unit	NMVOC	PM2.5 ex	PM10 ex	TSP ex	BC ex
Asphalt concrete	kg/t	0.54	NE	NE	NE	NE

Activity data (2D3b)

Activity data on the amount of asphalt products (so-called mixed goods) used for road paving is based on annual data from the association of asphalt production industry (SMI) for 1990 and from 1998 onwards and expert estimates for the years in between.

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

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

2D3b Road paving with asphalt	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Asphalt concrete	kt	5'300	4'770	4'770	5'260	4'850	4'710	5'260	5'180	5'210	4'910

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 the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions of NMVOC from Asphalt roofing are determined by a Tier 2 method based on country-specific emission factors as documented in EMIS 2022/2D3c. Emissions of PM2.5, PM10, TSP, BC and CO from the manufacture of asphalt sheeting are determined based on a Tier 1 method using default emission factors (EMEP/EEA 2019). In the past, four processes related to asphalt roofing were differentiated, i.e. production of sheeting, production of prime coat, laying of sheeting and use of prime coat. For submission 2018, these processes were aggregated and revised resulting in an implied emission factor for the entire asphalt roofing process.

Emission factors (2D3c)

The NMVOC emission factors from Asphalt roofing are based on information from the industry association, literature and expert estimates as documented in the EMIS database. Tier 1 emission factors of PM2.5, PM10, TSP, BC (% PM2.5) and CO from the manufacture of asphalt sheeting are taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 2.D.3.c, table 3.1).

Table 4-28: Emission factors of 2D3c Asphalt roofing in 2020.

2D3c Asphalt roofing	Unit	NMVOC	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
Asphalt roofing	kg/t sheeting	5.1	0.049	0.25	1.0	0.000005	0.0059

Activity data (2D3c)

Activity data is based on data from industry and expert estimates as documented in the EMIS database. From 2012 onwards, they are extrapolated on the basis of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020).

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

2D3c Asphalt roofing	Unit	1990	1995	2000	2005	2010
Asphalt roofing	kt sheeting	54	56	58	51	68

2D3c Asphalt roofing	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Asphalt roofing	kt sheeting	74	74	74	75	75	75	75	76	76	76

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 the EMEP/EEA guidebook (EMEP/EEA 2019), for 2D3d Coating applications a bottom-up Tier 2 method based on the consumption of paints, lacquers, glazes, thinners and related materials and their solvent content. Country-specific emission factors are used. In 2020, 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 2022/2D3d). 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 2020.

2D3d Coating applications	Unit	NMVOG
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	316
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 2022/2D3d). 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	2010
Paint application, construction	kt	60	43	33	42	54
Paint application, households	kt	12	13	13	12	11
Paint application, industrial	kt	20	21	21	8.8	8.3
Paint application, wood	kt	8.7	8.7	8.5	9.2	13
Paint application, car repair	kt	2.7	2.2	2.0	1.9	1.7

2D3d Coating applications	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Paint application, construction	kt	53	52	50	49	49	47	46	46	45	45
Paint application, households	kt	11	11	11	10	10	10	10	10	10	10
Paint application, industrial	kt	8.2	8.0	7.9	7.8	7.6	7.5	7.5	7.5	7.5	7.5
Paint application, wood	kt	13	13	13	11	10	9.5	9.3	9.2	9.0	9.0
Paint application, car repair	kt	1.5	1.4	1.2	1.1	0.97	0.85	0.85	0.85	0.85	0.85

4.5.2.5 Degreasing (2D3e)

Methodology (2D3e)

Source category 2D3e comprises emissions from degreasing of electronic components, metal and other industrial cleaning. Based on the decision tree Fig. 3.1 in chapter 2D3e in the EMEP/EEA guidebook (EMEP/EEA 2019), the NMVOC emissions from 2D3e Degreasing are calculated by a Tier 2 method (EMIS 2022/2D3e) using country-specific emission factors.

Emission factors (2D3e)

Emission factors for NMVOC are estimated based on data from industry surveys by swissmem (including VOC balance evaluations in 2004, 2007, 2012 and 2018) and expert estimates as documented in the EMIS database.

Table 4-32: Emission factors of 2D3e Degreasing in 2020.

2D3e Degreasing	Unit	NMVOC
Cleaning of electronic components	kg/t solvent	420
Degreasing of metal	kg/t solvent	500
Other industrial cleaning	kg/t solvent	500

Activity data (2D3e)

Activity data correspond to the annual consumption of solvents for degreasing and cleaning. They are based on survey data from the association of Swiss mechanical and electric engineering industries (swissmem) in 2004, 2007, 2012 and 2018, VOC balances of the most important companies, import statistics and expert estimates, documented in the EMIS database (EMIS 2022/2D3e).

In 1990 metal degreasing showed by far the highest activity data, i.e. consumption of solvents and NMVOC emissions but with a subsequent sharp decline until around 2004. Since then, other industrial cleaning and metal degreasing are of similar importance.

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

2D3e Degreasing	Unit	1990	1995	2000	2005	2010
Cleaning of electronic components	kt	1.7	1.5	1.3	1.0	0.78
Degreasing of metal	kt	13	9.0	5.9	2.5	2.1
Other industrial cleaning	kt	2.9	2.4	1.9	1.7	1.3

2D3e Degreasing	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cleaning of electronic components	kt	0.76	0.73	0.64	0.54	0.45	0.35	0.26	0.16	0.16	0.16
Degreasing of metal	kt	2.0	1.9	1.8	1.6	1.5	1.3	1.2	1.0	1.0	1.0
Other industrial cleaning	kt	1.3	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.5	1.5

4.5.2.6 Dry cleaning (2D3f)

Methodology (2D3f)

Based on the decision tree Fig. 3.1 in chapter 2D3f in the EMEP/EEA guidebook (EMEP/EEA 2019), the NMVOC emissions from 2D3f Dry cleaning are calculated by a Tier 2 method (EMIS 2022/2D3f) 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 2020.

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	2010
Solvent	kt	1.3	0.77	0.23	0.097	0.081

2D3f Dry cleaning	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Solvent	kt	0.076	0.074	0.072	0.072	0.071	0.071	0.070	0.070	0.069	0.069

4.5.2.7 Chemical products (2D3g)

Methodology (2D3g)

Based on the decision tree Fig. 3.1 in chapter 2D3g in the EMEP/EEA guidebook (EMEP/EEA 2019), for source category 2D3g Chemical products a Tier 2 method using country-specific emission factors is used for calculating the NMVOC emissions (EMIS 2022/2D3g).

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 2020.

2D3g Chemical products	Unit	NMVOC
Fine chemicals production	t/production index	3.4
Glue production	kg/t glue	0.51
Handling and storing of solvents	t/production index	1.5
Ink production	kg/t ink	5.0
Paint production	kg/t paint	3.0
Pharmaceutical production	kg/t pharmaceuticals	7.3
Polyester processing	kg/t polyester	50
Polystyrene processing	kg/t polystyrene	31
Polyurethane processing	kg/t polyurethane	3.0
PVC processing	kg/t PVC	4.0
Rubber processing	kg/tyres	0.14

Activity data (2D3g)

The activity data are mainly production or consumption data provided by industry associations, the Swiss Federal Office of Statistics and Swiss foreign trade statistics, i.e. for

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

For the other processes in source category 2D3g data are based on information from the industry and expert estimates as documented in the EMIS database. Activity data on handling and storage of solvents, production of fine chemicals and pharmaceuticals as well as production of inks, are extrapolated on the basis of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) from 2012 and 2017, respectively, onwards. Since 1994 no production of adhesive tape is occurring in Switzerland anymore. The last Swiss tannery ceased production in 2015.

Table 4-37: Activity data of 2D3g Chemical products.

2D3g Chemical products	Unit	1990	1995	2000	2005	2010
Fine chemicals production	prod. index	70	100	163	224	314
Glue production	kt	19	36	54	70	83
Handling and storing of solvents	prod. index	70	100	163	224	314
Ink production	kt	20	29	36	55	65
Paint production	kt	88	78	72	77	78
Pharmaceutical production	kt	16	21	20	28	30
Polyester processing	kt	11	7.0	6.5	6.9	3.4
Polystyrene processing	kt	20	19	19	24	35
Polyurethane processing	kt	17	35	45	54	54
Production of adhesive tape	kt	1.5	NO	NO	NO	NO
PVC processing	kt	94	94	78	64	52
Rubber processing	tyres	120'000	119'375	103'667	67'000	77'500
Tanning of leather	employees	110	108	102	88	65

2D3g Chemical products	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fine chemicals production	prod. index	299	297	296	294	293	291	290	288	287	285
Glue production	kt	86	89	91	94	97	100	102	105	106	107
Handling and storing of solvents	prod. index	299	297	296	294	293	291	290	288	287	285
Ink production	kt	63	62	60	52	43	35	35	36	36	37
Paint production	kt	75	72	69	66	63	60	60	60	60	60
Pharmaceutical production	kt	30	30	30	30	29	29	29	29	29	29
Polyester processing	kt	3.5	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Polystyrene processing	kt	36	34	30	29	27	23	24	22	23	23
Polyurethane processing	kt	40	40	38	38	37	37	36	36	35	35
Production of adhesive tape	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PVC processing	kt	55	40	38	37	36	35	34	32	31	30
Rubber processing	tyres	80'000	80'000	81'000	82'000	83'000	84'000	85'000	86'000	87'000	88'000
Tanning of leather	employees	54	44	33	22	11	NO	NO	NO	NO	NO

4.5.2.8 Printing (2D3h)

Methodology (2D3h)

The source category 2D3h Printing is differentiated into package printing and other printing industry. Based on the decision tree Fig. 3.1 in chapter 2D3g in the EMEP/EEA guidebook (EMEP/EEA 2019), a Tier 2 method using country-specific emission factors is used for calculating the NMVOC emissions from the ink applications (EMIS 2022/2D3h).

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 2020.

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. Activity data are extrapolated on the basis of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) from 2017 onwards.

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

2D3h Printing	Unit	1990	1995	2000	2005	2010
Printing	kt	13	13	14	12	8.3
Package printing	kt	5.9	5.9	5.5	9.1	13

2D3h Printing	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Printing	kt	8.2	8.1	8.0	7.8	7.7	7.5	7.5	7.4	7.4	7.4
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 the EMEP/EEA guidebook (EMEP/EEA 2019), a Tier 2 method using country-specific emission factors is applied for calculating the NMVOC emissions from the different solvent applications in source category 2D3i Other solvent use (EMIS 2022/2D3i). For the source category 2D3i Not-attributable solvent emissions, so-called direct emission data is available only.

Emission factors (2D3i)

Emission factors for NMVOC are based on data from industry and services, industry associations, retail trade, German studies on NMVOC emissions from solvent use (Theloke et al. 2000 and Theloke 2005), VOC balances and expert estimates, as documented in the EMIS database.

Table 4-40: Emission factors of 2D3i Other solvent use in 2020.

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	36
Production of textiles	kg/t solvent	175
Production of tobacco	kg/employee	12
Removal of paint and lacquer	kg/t removal agent	350
Scientific laboratories	kg/employee	15

Activity data (2D3i)

For some production processes and services – such as production of perfume and flavour and scientific laboratories – the activity data correspond to the number of employees in the respective industrial sectors (SFSO 2021d). 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); from 2012 onwards, they are extrapolated on the basis of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). For the production of textiles, the activity data is the solvent consumption based on VOC balances and industry data. For the removal of paint and lacquer, the activity data correspond to the amount of removal agent based on information from producers and retail trade.

Table 4-41: Activity data of 2D3i Other solvent use.

2D3i Other solvent use	Unit	1990	1995	2000	2005	2010					
Fat, edible and non-edible oil extraction	kt	40	38	12	NO	NO					
Production of cosmetics	employees	2'200	2'200	2'267	2'100	2'100					
Production of paper and paperboard	kt	1'510	1'560	1'780	1'750	1'540					
Production of perfume and flavour	employees	2'200	2'325	2'567	3'200	3'475					
Production of textiles	t solvent	600	498	396	294	192					
Production of tobacco	employees	3'300	2'988	2'733	2'700	3'200					
Removal of paint and lacquer	t	700	600	502	405	307					
Scientific laboratories	employees	10'194	18'604	23'217	23'000	23'000					
Vehicles dewaxing	employees	200'000	166'250	72'667	NO	NO					

2D3i Other solvent use	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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	1'380	1'365	1'350	1'335	1'319	1'304	1'289	1'274	1'259	1'244
Production of perfume and flavour	employees	3'500	3'521	3'542	3'563	3'583	3'604	3'625	3'646	3'667	3'688
Production of textiles	t solvent	197	201	206	210	215	219	224	223	221	220
Production of tobacco	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	288	268	249	229	210	190	190	190	190	190
Scientific laboratories	employees	23'000	23'083	23'167	23'250	23'333	23'417	23'500	23'583	23'667	23'750
Vehicles dewaxing	employees	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

4.5.3 Category-specific recalculations in 2D Other solvent use

The following recalculations were implemented in submission 2022:

- 2D3a: Source category 2D3a Domestic use of cleaning agents was completely updated based on detailed sales figures of the years 2017-2020, NMVOC contents and application-specific emission factors yielding revised values of the NMVOC emission factor from 1991 onwards.
- 2D3c: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of source category 2D3c Asphalt roofing have changed from 2012 onwards.
- 2D3e: Activity data and NMVOC emission factors of source category 2D3e Degreasing were revised for 1990-2019 based on a survey of the association of Swiss mechanical and electric engineering industries and VOC balances.
- 2D3g: Activity data and NMVOC emission factors of source category 2D3g Production of glue were updated from 2001 onwards based on industry data resulting in revised activity data and emission factors for 1991-2019 and 2000-2019, respectively.
- 2D3g: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of handling and storage of solvents, production of fine chemicals and pharmaceuticals as well as production of inks have changed from 2012 and 2017, respectively, onwards.
- 2D3h: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of source category 2D3h Printing have changed from 2017 onwards.
- 2D3i: Activity data and NMVOC emission factors of source category 2D3i Production of textiles were revised for 1990-2019 based on industry data and VOC balances.
- 2D3i: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of production of paper and paperboard have changed from 2012 onwards.

4.6 Source category 2G – Other product use

4.6.1 Source category description of 2G Other product use

Source category 2G Other product use includes about 20 sources releasing NMVOC. In addition, there are also emissions of NO_x, SO_x, NH₃, 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, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 2G Other product use.

NFR code	Source category	Pollutant	Identification criteria
2G	Other product use	NMVOC	L1, L2, T2
2G	Other product use	PM2.5	L1, T1, L2, T2
2G	Other product use	PM10	L1, L2

4.6.2 Methodological issues of 2G Other product use

4.6.2.1 Other product use (2G)

Methodology (2G)

Within source category 2G Other product use, the major NMVOC emission sources in 2020 are 2G Commercial and industrial use of cleaning agents and 2G Health care, other.

Based on the decision tree Fig. 3.1 in chapter 2G in the EMEP/EEA guidebook (EMEP/EEA 2019), for source category 2G Other product use Tier 2 methods using country-specific emission factors are applied for calculating the emissions from the different product applications and the use of fireworks and tobacco (EMIS 2022/2G).

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), VOC balances, post-combustion plants and expert estimates, as documented in the EMIS database.

Table 4-44: Emission factors of 2G Other product use in 2020.

2G Other product use	Unit	NMVOC
Application of glues and adhesives	kg/t solvent	382
Commercial and industrial use of cleaning agents	g/employee	400
Cosmetic institutions	kg/employee	28
De-icing of airplanes	kg/t de-icing agent	54
Glass wool enduction	g/t glass wool	124
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	114
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 2022/2G) 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, chp. 2.D.3.i, 2.G, table 3-15). The emission factor for PCDD/PCDF is according to the UK National Atmospheric Emissions Inventory (UK NAEI 2019).

Table 4-45: Emission factors of all pollutants other than NMVOC from 2G Other product use in 2020. Unit of PCDD/PCDF is in I-TEQ.

2G	Unit	NO _x	SO _x	NH ₃	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO
Fireworks	kg/t fireworks	0.26	4.1	NA	90	180	180	NE	7.4
Use of tobacco	kg/Mio cigarette eq.	1.8	NE	4.2	27	27	27	0.12	55

2G	Unit	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	IcdP
Fireworks	g/t fireworks	130	3.0	0.1	NE	NE	NE	NE	NE
Use of tobacco	g/Mio cigarette eq.	NE	5.4	NE	0.0000001	0.11	0.045	0.045	0.045

Activity data (2G)

For the production processes, such as enduction of glass and rock wool and part of the applications in services or agriculture, such as preservation of wood, pesticides and application of glues and adhesives the activity data are based on production volume or employed agents. For the other part of applications in services, such as house cleaning in services, commerce and industry and medical practices the activity data correspond to the respective number of employees. The quantity of NMVOC emission per employee originates from the bottom-up approach in these service sectors and the decentralized political structure in Switzerland. The determined NMVOC emissions of representative production sites or service institutions are referenced to the number of employees in order to calculate the Swiss total.

The activity data stem from industry, services, Swiss airports (since 2011 no VOC-containing agents are used for de-icing of airport surfaces anymore), industry associations, Swiss Federal Statistical Office, Swiss Federal Office for Agriculture (sales statistics of pesticides), VOC balances, foreign trade statistics and expert estimates. They are documented in the

EMIS database. Activity data for annual tobacco consumption and the annual firework sales are provided by the Swiss addiction prevention foundation (“Sucht Schweiz”) and the statistics of the Swiss federal office for police (FEDPOL 2021), respectively. Activity data for concrete additives are extrapolated from 2017 onwards, based on the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020).

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

2G Other product use	Unit	1990	1995	2000	2005	2010					
Application of glues and adhesives	kt solvent	4.8	4.0	3.2	2.7	2.5					
Commercial and industrial use of cleaning agents	employees	3'950'000	3'867'500	3'954'667	4'133'667	4'404'000					
Cosmetic institutions	employees	2'600	3'100	3'533	3'800	4'800					
De-icing of airplanes	kt	1.2	2.4	1.8	2.5	3.3					
De-icing of airport surfaces	kt	0.34	0.39	0.32	0.41	0.018					
Fireworks	kt	0.84	1.0	1.5	1.4	1.7					
Glass wool enduction	kt	24	24	31	37	36					
Hairdressers	employees	20'553	22'826	23'530	22'200	23'000					
Health care, other	employees	113'000	129'250	145'667	161'667	163'000					
Medical practices	employees	27'625	42'047	50'833	55'357	58'700					
Preservation of wood	kt	4.8	6.5	7.8	6.6	0.97					
Rock wool enduction	kt	38	40	51	46	56					
Underseal treatment and conservation of vehicles	kt	0.060	0.060	0.076	0.12	0.16					
Use of antifreeze agents in vehicles	Mio vehicle km	47'523	46'479	51'142	53'723	57'039					
Use of concrete additives	kt	24	25	29	36	41					
Use of cooling lubricants	kt	5.0	5.2	5.8	4.5	3.9					
Use of lubricants	kt	1.3	1.3	1.3	3.7	0.35					
Use of pesticides	kt	2.4	2.4	2.3	2.3	2.1					
Use of tobacco	Mio cigarette eq.	16'192	15'774	15'328	13'256	12'360					
2G Other product use	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Application of glues and adhesives	kt solvent	2.5	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3
Commercial and industrial use of cleaning agents	employees	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	4'500'000
Cosmetic institutions	employees	5'000	5'111	5'222	5'333	5'444	5'556	5'667	5'778	5'889	6'000
De-icing of airplanes	kt	2.6	3.8	3.1	2.3	2.3	2.3	2.3	2.4	2.4	2.4
De-icing of airport surfaces	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fireworks	kt	2.0	1.9	2.3	1.8	1.6	1.2	1.7	1.8	1.0	1.0
Glass wool enduction	kt	41	39	33	32	31	32	36	40	47	40
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	1.2	0.85	0.94	0.57	0.62	0.68	0.70	0.49	0.60	0.60
Rock wool enduction	kt	57	57	54	53	47	52	52	57	51	47
Underseal treatment and conservation of vehicles	kt	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Use of antifreeze agents in vehicles	Mio vehicle km	58'007	58'976	59'944	60'913	61'881	62'260	62'638	63'017	63'395	63'774
Use of concrete additives	kt	44	38	38	38	38	38	38	38	38	38
Use of cooling lubricants	kt	4.4	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0
Use of lubricants	kt	0.49	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Use of pesticides	kt	2.3	2.2	2.3	2.2	2.2	2.2	2.0	2.1	2.1	2.2
Use of tobacco	Mio cigarette	11'856	12'705	12'162	10'628	10'284	10'702	10'702	10'318	10'030	10'414

4.6.3 Category-specific recalculations in 2G Other product use

The following recalculations were implemented in submission 2022:

- 2G: For 2019, the NMVOC and NH₃ emission factors of 2G Glass wool enduction were revised based on industry data.
- 2G: Activity data and NMVOC emission factors of source category 2G Application of glue were revised for 1990-2019 based on industry data.
- 2G: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of use of concrete additives have changed from 2017 onwards.

4.7 Source categories 2H – Other

4.7.1 Source category description of 2H Other

Table 4-47: Specification of source category 2H Other in Switzerland.

2H	Source category	Specification
2H1	Pulp and paper industry	Production of fibreboards, chipboards and cellulose (ceased in 2008)
2H2	Food and beverages industry	Production of beer, spirits, wine, bread, sugar, smoked and roasted meat and mills
2H3	Other industrial processes	Blasting and shooting

Table 4-48: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 2H Other.

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

4.7.2 Methodological issues of 2H Other

4.7.2.1 Pulp and paper industry (2H1)

Methodology (2H1)

Today, the production of chipboard and fibreboard are the relevant industrial processes in the source category 2H1 Pulp and paper industry. In Switzerland, chipboard and fibreboard were produced in one and two plants, respectively, until 2019. Since 2020 only one plant is left. The cellulose production was closed down in 2008 and is not occurring anymore in Switzerland.

Based on the decision tree Fig. 3.1 in chapter 2H1 in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions are calculated by a Tier 2 method using country-specific emission factors (EMIS 2022/2H1).

Emission factors (2H1)

Emission factors are based on measurements of the chipboard production plant whereas constant emission factors are assumed for the fibreboard production, documented in the EMIS database. They are confidential but available to reviewers on request.

Table 4-49: Emission factors for 2H1 Pulp and paper industry in 2020. Unit of PCDD/PCDF is in I-TEQ.

2H1 Pulp and paper industry	Unit	NOx	NMVOC	SOx	PM2.5 nx	PM10 nx	TSP nx	BC nx	CO	PCDD/PCDF
Fibreboard production	g/t fibreboard	NE	C	NE	C	C	C	NE	NE	NA
Chipboard production	g/t chipboard	NE	C	NE	C	C	C	NE	NE	C

Activity data (2H1)

Activity data on annual chipboard production has been provided by the industry since 2005 and between 1990 and 2003 annual data are based on the annual statistics on forest and wood (SFSO/BUWAL 2004) as documented in the EMIS database.

Activity data on annual fibreboard production are provided by monitoring reports of the industry since 1996 as documented in the EMIS database.

Due to the production structure in Switzerland, i.e. one production site for cellulose (ceased in 2008), one for chipboard and two for fibreboard (one ceased in 2019), only the sum of the production volume of 2H1 Pulp and paper industry is provided, and since 2020 activity data are confidential. Detailed data can be accessed by reviewers on request.

Table 4-50: Activity data of 2H1 Pulp and paper industry.

2H1 Pulp and paper industry	Unit	1990	1995	2000	2005	2010					
Sum of chipboard, fibreboard and cellulose production	kt	604	593	641	693	602					
2H1 Pulp and paper industry	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Sum of chipboard, fibreboard and cellulose production	kt	564	533	510	516	519	503	507	502	460	C

4.7.2.2 Food and beverages industry (2H2)

Methodology (2H2)

Based on the decision tree Fig. 3.1 in chapter 2H2 in the EMEP/EEA guidebook (EMEP/EEA 2019), the emissions from the source category 2H2 Food and beverages industry, are calculated by a Tier 2 method using country-specific emission factors (EMIS 2022/2H2).

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 2022/2H2 Brot Produktion).

Table 4-51: Emission factors for 2H2 Food and beverages industry in 2020. Unit of PCDD/PCDF is in I-TEQ.

2H2 Food and beverages industry	Unit	NM VOC	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	274								
2H2 Food and beverages industry	Unit	PM2.5 ex	PM2.5 nx	PM10 ex	PM10 nx	TSP ex	TSP nx	BC ex	CO	PCDD/PCDF	
Breweries	g/m ³ beer	NA	NA	NA	NE	NA	NA	NA	NA	NA	
Spirits production	g/m ³ alcohol	NA	NA	NA	NE	NA	NA	NA	NA	NA	
Bread production	g/t bread	NA	NA	NA	NE	NA	NA	NA	NA	NA	
Meat smokehouses	g/t meat	350	NA	350	NE	350	NA	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 2021c) 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 2022/2H2 Brot Produktion).

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

2H2 Food and beverages industry	Unit	1990	1995	2000	2005	2010					
Breweries	m ³	436'814	401'555	366'956	342'085	357'435					
Spirits production	m ³	4'158	3'271	2'179	2'266	1'945					
Bread production	kt	336	352	359	372	386					
Meat smokehouses	kt	66	64	60	62	66					
Roasting facilities	kt	56	50	58	78	102					
Milling companies	kt	1'644	1'519	1'603	1'425	1'602					
Wine production	m ³	120'000	111'693	123'073	108'526	108'319					
Sugar production	kt	147	129	219	197	241					

2H2 Food and beverages industry	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Breweries	m ³	357'591	354'293	339'348	345'861	346'214	348'171	346'300	365'900	367'500	340'400
Spirits production	m ³	1'340	1'989	1'158	1'150	1'636	1'211	1'010	961	1'624	1'224
Bread production	kt	384	382	380	378	376	373	370	373	376	378
Meat smokehouses	kt	66	65	66	67	67	67	67	67	66	67
Roasting facilities	kt	110	110	120	119	125	127	131	141	148	161
Milling companies	kt	1'633	1'648	1'602	1'625	1'645	1'663	1'626	1'629	1'617	1'560
Wine production	m ³	102'522	98'621	108'564	99'556	99'859	90'174	88'116	90'404	95'742	96'107
Sugar production	kt	331	286	245	344	261	240	299	246	273	226

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 2020.

2H3 Other industrial processes	Unit	NO _x	NM VOC	SO ₂	NH ₃	PM2.5 ex	PM10 ex	TSP ex	BC ex	CO	Pb
Blasting and shooting	kg/t explosive	35	60	0.5	0.4	6.0	6.0	6.0	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	2010
Blasting and shooting	kt explosive	2.6	1.3	1.9	0.79	2.4

2H3 Other industrial processes	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Blasting and shooting	kt explosive	2.9	2.3	2.2	2.1	2.1	0.67	0.73	0.81	0.67	0.63

4.7.3 Category-specific recalculations in 2H Other

The following recalculations were implemented in submission 2022:

- 2H2 Meat smokehouses: Activity data for 2018 and 2019 have decreased by 2.15 % (-1'430 t) and 1.45 % (-960 t), respectively, due to changes in the underlying statistics for annual per capita meat consumption by the SFSO.
- 2H2 Milling companies: Activity data for 2019 has increased by 2.26 % (36'604 t), due to a change in the underlying statistics by the FOAG.
- 2H2 Sugar production: The emission factor for 2020 has been erroneously inserted in a previous year. It has now been deleted thus increasing the interpolated emission factors from 2008 to 2019.

4.8 Source categories 2I – Wood processing, 2K – Consumption of POPs and heavy metals and 2L – Other production, consumption, storage, transportation or handling of bulk products

4.8.1 Source category description of 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products

Table 4-55: Specification of source category 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products in Switzerland.

2I, 2K, 2L	Source category	Specification
2I	Wood processing	Wood processing
2K	Consumption of POPs and heavy metals	Emissions of PCBs from usage of PCBs in transformers, large and small capacitors, anti-corrosive paints and joint sealants as well as from demolition/renovation of PCB containing anti-corrosive paints and joint-sealants
2L	Other production, consumption, storage, transportation or handling of bulk products	Ammonia emissions from freezers (filling and storage)

Table 4-56: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products.

NFR code	Source category	Pollutant	Identification criteria
2I	Wood processing	PM2.5	L2, T2
2I	Wood processing	PM10	T1, L2, T2

4.8.2 Methodological issues of 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products

4.8.2.1 Wood processing (2I)

Methodology (2I)

Source category 2I includes particulate emissions of wood processing. Emissions from charcoal production are reported in 1A1c Manufacture of solid fuels and other energy industries. According to chapter 2I in the EMEP/EEA guidebook (EMEP/EEA 2019), the calculation of emissions is based on a Tier 1 method based on country-specific emission factors (EMIS 2022/2I Holzbearbeitung).

Emission factors (2I)

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

Table 4-57: Emission factors for 2I Wood processing in 2020.

2I Wood processing	Unit	PM2.5 nx	PM10 nx	TSP nx
Wood processing	g/t sawnwood	74	294	735

Activity data (2I)

Activity data of wood processing are the annual amount of sawnwood based on the yearbook forest and wood (FOEN 2021f).

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

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

2I Wood processing	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wood processing	kt sawnwood	670	606	564	634	626	622	578	597	598	623

4.8.2.2 Usage of PCBs (2K)

Methodology (2K)

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

A dynamic mass flow model was developed for the usage of PCBs in Switzerland for the time period 1930 to 2100 (Glüge et al. 2017). The model takes into account the entire life cycle, i.e. import, usage, export, treatment, disposal and accidental release of PCBs. A description of the model is given in Annex A2.2.

The emissions are calculated by multiplying the annual mass of PCBs involved in a source (e.g. tonnes of PCBs in use in joint sealants) with a source-specific emission factor (e.g. tonnes of PCBs emitted/tonnes of PCBs in use). This country-specific approach corresponds to a Tier 2 method according to the EMEP/EEA guidebook (EMEP/EEA 2019).

Emission factors (2K)

The PCB emission factors from the use of PCBs in transformers, small and large capacitors, anti-corrosive paints and joint sealants are expressed in units per tonnes of PCBs available in the respective application, see Table 4-59. 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 2020.

2K Usage of PCBs	Unit	PCB
Transformers	kg/t PCB	0.0022
Large capacitors	kg/t PCB	0.47
Small capacitors	kg/t PCB	0.47
Anti-corrosive paints	kg/t PCB	2.5
Joint sealants	kg/t PCB	2.5
Demolition and renovation	kg/t PCB	2.5

Activity data (2K)

The five usage categories are PCB stocks, which means that PCBs are stored in these applications and passed on through the system with a temporal delay (lifetime). In these cases, the activity data are the amounts of PCBs stored in the stock. The treatment category demolition and renovation is an instantaneous category. In this case, the activity data corresponds to the amount of PCBs treated in the respective year.

Table 4-60: Activity data for 2K Usage of PCBs.

2K Usage of PCBs	Unit	1990	1995	2000	2005	2010
Transformers	t PCB	1'257	840	501	265	123
Large capacitors	t PCB	356	235	139	73	33
Small capacitors	t PCB	361	213	108	47	17
Anti-corrosive paints	t PCB	209	196	178	156	128
Joint sealants	t PCB	209	196	178	156	129
Demolition and renovation	t PCB	2.4	4.0	6.2	8.5	10

2K Usage of PCBs	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Transformers	t PCB	104	87	73	60	50	41	33	27	22	18
Large capacitors	t PCB	28	24	20	16	13	11	9.0	7.3	5.8	4.7
Small capacitors	t PCB	14	11	8.6	6.7	5.2	4.0	3.1	2.4	1.8	1.3
Anti-corrosive paints	t PCB	123	117	110	104	98	92	86	80	73	68
Joint sealants	t PCB	123	117	110	104	98	92	86	80	73	68
Demolition and renovation	t PCB	11	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 database (EMIS 2022/2 F_2 L_NH3 aus Kühlanlagen). Emission factors are assumed constant over the entire time period (see Table 4-61).

Table 4-61: Emission factors for 2L Ammonia in freezers in 2020.

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 2022/2 F_2 L_NH3 aus Kühlanlagen) (see Table 4-62).

Table 4-62: Activity data of 2L Ammonia in freezers.

2L Ammonia from freezers	Unit	1990	1995	2000	2005	2010
Freezers filling	t	178	201	224	246	269
Freezers storage	t	1'100	1'100	1'200	1'200	1'200

2L Ammonia from freezers	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Freezers filling	t	273	278	283	287	292	295	298	301	304	307
Freezers storage	t	1'279	1'357	1'436	1'515	1'593	1'616	1'638	1'661	1'683	1'706

4.8.3 Category-specific recalculations in 2I Wood processing, 2K Consumption of POPs and heavy metals and 2L Other production, consumption, storage, transportation or handling of bulk products

The following recalculation was implemented in submission 2022:

- 2I Wood processing: The so far missing activity data of the years 1991-1994 were added as well as the data for 2019 were updated. Also, the emission factors of PM2.5, PM10 and TSP were adjusted for 2003, resulting in revised values for the years 1991-2019.

5 Agriculture

5.1 Overview of emissions

This introductory chapter contains an overview of emissions from sector 3 Agriculture. NO_x, NMVOC, NH₃, 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 1990-2020 (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 and thus N excretions, which decreased by 17 % between 1990 and 2020 (Kupper et al. 2022) with a similar pattern as overall NO_x emissions from the agriculture sector.

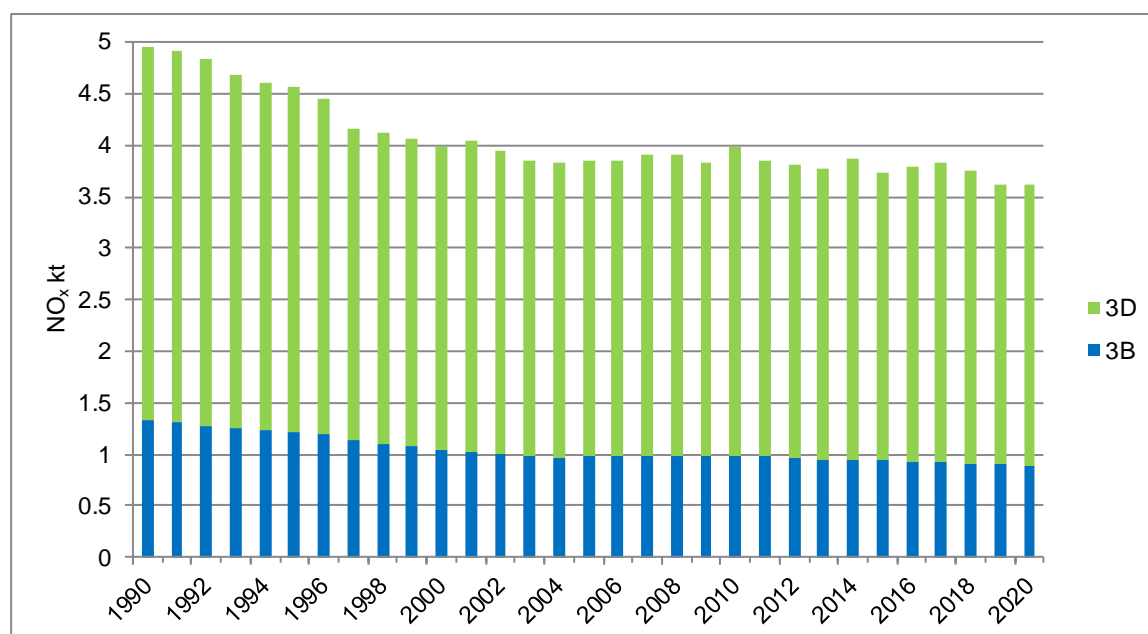


Figure 5-1: Switzerland's NO_x emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.1.

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, where emissions stem from cattle husbandry with silage feeding as dominant emission source. Emissions were stable between 1990 and 2000, before an increasing trend started between 2000 and 2008 due to a significant increase in the number of non-dairy cattle which predominately are fed by silage. Since 2014, the emissions have remained at about constant level.

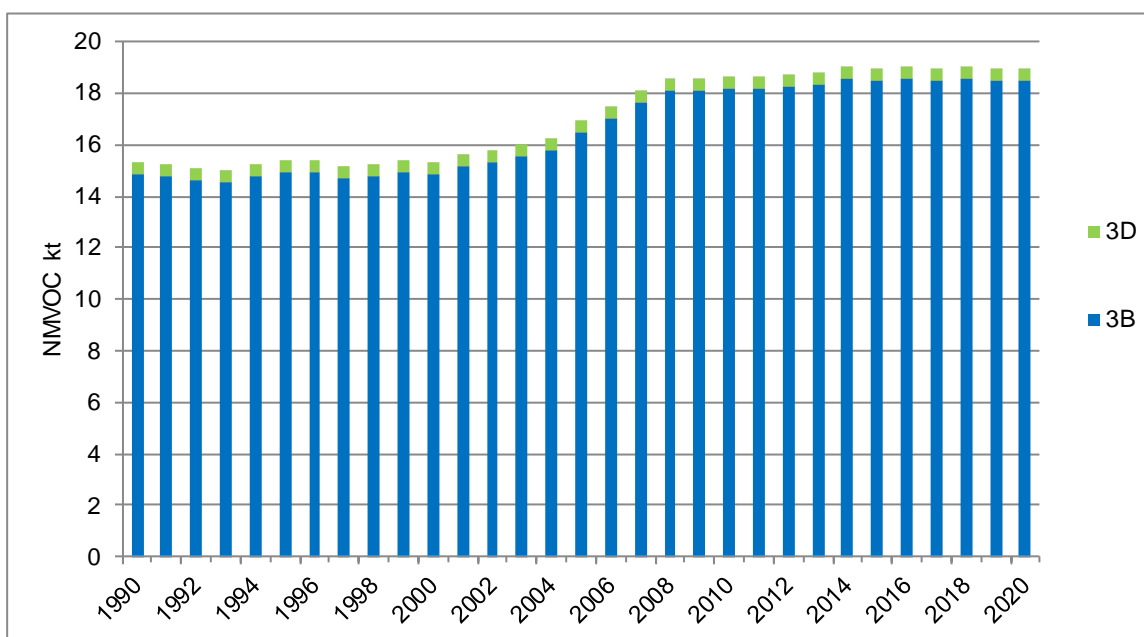


Figure 5-2: Switzerland's NMVOC emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.2.

5.1.3 Overview and trend for NH₃

Agriculture is the main source of NH₃ emissions in Switzerland (see Table 2-11). The trend of NH₃ emissions within agriculture is depicted in Figure 5-3. While category 3B Manure management is subject to little variation throughout the period 1990-2020, category 3D Crop production and agricultural soils shows a fluctuating and decreasing trend. Both categories are about equally important in the year 2020. 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 2007 and another decrease since then. This manifold trend results from a combination of changes in animal numbers, introduction of nutrient balance regulations for nitrogen, introduction of new housing systems and more grazing due to developments in animal welfare regulations, increase of animal productivity and changes in production techniques (Kupper et al. 2015, 2018, 2022). N excretions from livestock decreased by 17 % and N excretions of livestock going into the manure stream even by 27 % (Kupper et al. 2022). A further reason for the downward trend of agricultural NH₃ emissions is the growing importance of grazing due to animal welfare incentives. The share of soluble N (TAN) of excretions of livestock going to grazing increased from 8 % in 1990 to 17 % in 2020 (Kupper et al. 2022).

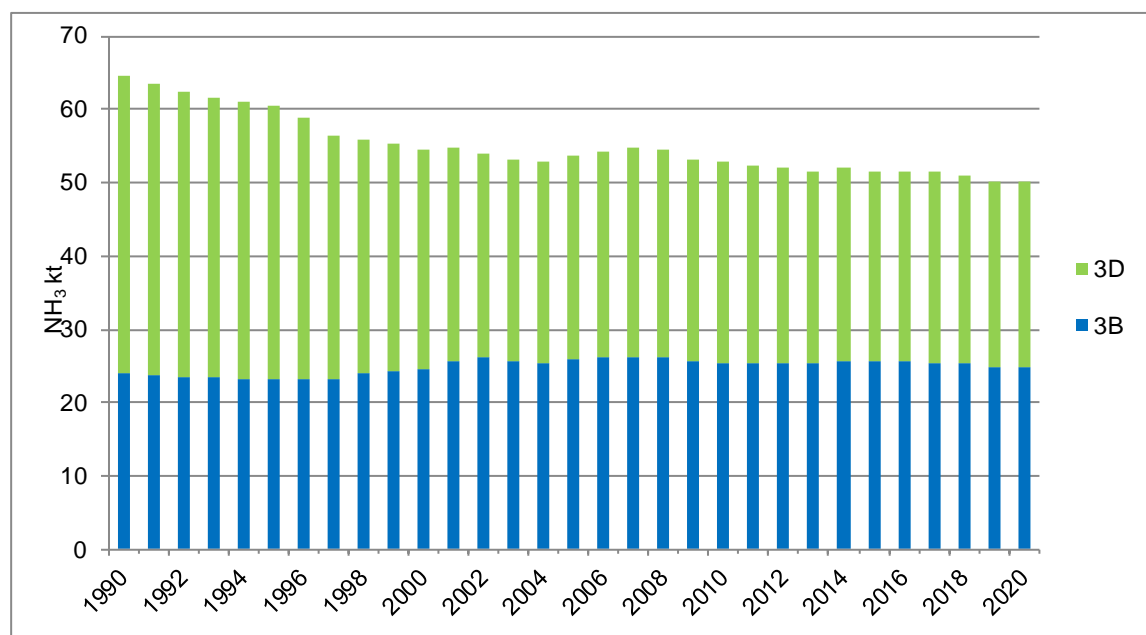


Figure 5-3: Switzerland's NH₃ emissions from agriculture by source categories 3B and 3D. The corresponding data table can be found in Annex A7.4.4.

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 NH₃ 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 management - Laying hens	
3B4gii	Manure management - Broilers	
3B4giii	Manure management - 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), bison (3B4hii)

Table 5-2: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 3B, Manure Management.

NFR code	Source category	Pollutant	Identification criteria
3B1a	Manure management - Dairy cattle	NMVOG	L1, T1, L2, T2
3B1a	Manure management - Dairy cattle	NH3	L1, T1, L2, T2
3B1b	Manure management - Non-dairy cattle	NMVOG	L1, T1, L2, T2
3B1b	Manure management - Non-dairy cattle	NH3	L1, T1, L2, T2
3B3	Manure management - Swine	NH3	L1, L2, T2
3B3	Manure management - Swine	PM10	L2
3B4gi	Manure management - Laying hens	PM10	L2
3B4gii	Manure management - Broilers	NMVOG	L2, T2
3B4gii	Manure management - Broilers	NH3	L2, T2
3B4gii	Manure management - Broilers	PM10	L2, T2

5.2.2 Methodological issues of 3B Manure management

Methodology (3B)

For calculating the ammonia emissions caused by manure management a country-specific approach is used according to the Tier 3 detailed methodology described in chapter 3B Manure management of the EMEP/EEA guidebook (EMEP/EEA 2019).

An internet-based model called AGRAMMON was developed in Switzerland allowing the calculation of ammonia emissions for single farms and for regions (<https://agrammon.ch>). The model simulates the nitrogen flow from animal feeding to excretion (in housing systems and during grazing), to manure storage and to manure application. In the 2018 revision of the model (Kupper et al. 2018) it was extended to cover not only NH₃ emissions but all nitrogen flows (including N₂O, NO_x and N₂).

For nitrogen flux calculations, AGRAMMON uses nitrogen excretions of different livestock categories according to the Swiss fertiliser guidelines (Richner et al. 2017). To take into account the varying milk yield level of dairy cattle, a linear correction factor also given in Richner et al. (2017) was applied. AGRAMMON considers important parameters on farm and manure management influencing the emissions of ammonia at the different levels of farm management. The Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL) collected data on farm and manure management at farm-level with a detailed representative questionnaire in 2002, 2007, 2010, 2015 and 2019. Each survey consisted of a representative stratified random sample covering approximately 2000 to 3000 farms (in total, in 2020 there were about 49'000 farms in Switzerland). The strata cover five different farm types, three regions of Switzerland and three altitude classes (valley zone, hill zone, mountain zone). The questionnaire contained detailed questions on livestock housing, feeding and grazing for different livestock categories, as well as manure storage and spreading, and fertilization. For each farm in the survey, farm-specific emission calculations were done with AGRAMMON. These results were then used to calculate livestock-category specific average emission factors for each strata group and the five respective survey years. For the national extrapolation of the emission data, the weighted average (according to share of the total livestock population of the respective livestock categories) input data on production of the different strata group was used. The emission time series from 2002 to 2019 was established with the calculated emission factors (2002, 2007, 2010, 2015, 2019), with interpolated emission factors for the years 2003-2006, 2008-2009, 2011-2014 and 2016-2018, and the known development of the number of animals in different livestock categories (activity data). Emission factors beyond 2019 are kept constant until new survey results are available. The experience gained from the detailed surveys between 2002 and 2019 and from the extrapolation of the single farm data to the totality of farms in Switzerland was used,

together with expert assumptions and available statistical data on farm management, to calculate the emissions between 1990 and 2002. The procedure is described in Kupper et al. (2018, 2022) which can be downloaded from the internet site of AGRAMMON (<https://agrammon.ch/en/downloads/> [09.03.2022]).

A comparison of the country-specificly calculated Tier 3 results (using the AGRAMMON version 2018) for N flows and NH₃ emissions from animal husbandry (3B Manure management, 3Da2a Animal manure applied to soils and 3Da3 Urine and dung deposited by grazing animals) with the results of the Tier 2 calculations based on the TFEIP N flow tool was performed for 2015 (at the time the last year with a representative survey on farm management). The comparison and discussion of the results are given in Annex A2.3. In the framework of the Stage 3 in-depth review of emission inventories in summer 2020 Switzerland provided detailed information on the development of the nitrogen (N) flow distribution to liquid and solid manure depending on management technique modelled within AGRAMMON. Table 5-3 shows that the share of the total N excretions from all agricultural livestock that went into the slurry flow decreased from 64 % to 56 % from 1990 to 2019. Table 5-4 shows that this was not the case for the N excretions of cattle (all categories together) that remained almost constant around 60 %. This probably was because the increase in grazing which reduced the share of N collected in the housing area compensated the increase of the share of N going to slurry in the housing area. The share of total N excretions of all livestock (Table 5-3) going to pasture, range and paddock roughly doubled because of animal welfare incentives and the considerable decrease of pig production. The share going to digesters increased from 0.6 % to 6.6 % and the share going to deep litter and poultry manure rose from 5.4 % to 8.4 % due to a strong growth of poultry production. The share going to solid manure decreased by nearly halve, mainly because of the shift from tied to loose housing systems for cattle. Table 5-5 shows the share of N excretions going to the liquid manure flow (including digesters) for the different livestock categories. The shares strongly increase for the cattle categories. For swine, which produce only liquid manure and for equids (horse, mules and asses), sheep, goats and poultry which produce only solid manure the values logically remained constant.

Table 5-3: Development of the share of the total N excretions from livestock (incl. cattle) going to the paths liquid slurry / solid manure / other (deep litter / poultry manure) / digesters / pasture, range and paddock in Switzerland from 1990 to 2019 (in % of total N excretions). Data based on representative surveys on farm management technique in 2002, 2007, 2010, 2015 and 2019; for 1990 and 1995 based on expert assumptions (Kupper et al. 2022).

Distribution of N excretion [%]	1990	1995	2002	2007	2010	2015	2019
Liquid / Slurry	63.8%	64.0%	58.7%	59.4%	58.8%	58.9%	55.8%
Solid manure	21.4%	20.3%	16.5%	14.0%	13.3%	11.7%	10.9%
Other (deep litter, poultry manure)	5.4%	5.2%	5.8%	6.8%	7.7%	7.5%	8.4%
Digesters	0.6%	0.5%	0.6%	1.5%	2.2%	4.2%	6.6%
Pasture, range and paddock	8.9%	9.9%	18.5%	18.2%	18.0%	17.9%	18.3%

Table 5-4: Development of the share of the N excretions from cattle (sum of all three categories) going to the paths liquid slurry / solid manure / other (deep litter) / digesters / pasture, range and paddock in Switzerland from 1990 to 2019 (in % of total N excretions). Data based on representative surveys on farm management technique in 2002, 2007, 2010, 2015 and 2019; for 1990 and 1995 based on expert assumptions (Kupper et al. 2022).

Distribution of N excretion [%]	1990	1995	2002	2007	2010	2015	2019
Liquid / Slurry	60.5%	61.8%	58.8%	61.7%	61.7%	63.1%	61.1%
Solid manure	26.9%	24.7%	18.7%	15.4%	14.4%	12.0%	11.3%
Other (deep litter)	1.3%	1.3%	1.3%	1.2%	1.4%	1.2%	1.2%
Digesters	0.5%	0.4%	0.5%	1.4%	2.0%	3.8%	6.0%
Pasture, range and paddock	10.7%	11.8%	20.7%	20.3%	20.4%	19.8%	20.4%

Table 5-5: Development of the share of N excretions going to the liquid phase of manure (including digestate) for the different livestock categories in Switzerland from 1990 to 2019 (in % of total N excretions of the respective category). Data based on representative surveys on farm management technique in 2002, 2007, 2010, 2015 and 2019; for 1990 and 1995 based on expert assumptions (Kupper et al. 2022).

% N excretion going to liquid phase	1990	1995	2002	2007	2010	2015	2019
Dairy cattle	66.2%	67.9%	66.0%	69.5%	70.7%	73.6%	74.2%
Non-dairy cattle	41.6%	39.0%	43.8%	55.2%	55.9%	58.4%	55.8%
Young cattle	50.0%	50.4%	45.8%	50.1%	50.7%	54.8%	55.6%
Sheep	0%	0%	0%	0%	0%	0%	0%
Swine	100%	100%	98.7%	99.0%	99.5%	99.8%	99.9%
Goats	0%	0%	0%	0%	0%	0%	0%
Horses	0%	0%	0%	0%	0%	0%	0%
Mules and asses	0%	0%	0%	0%	0%	0%	0%
Poultry (layers, broilers, turkey, growers)	0%	0%	0%	0%	0%	0%	0%

Additionally, a larger survey – but less detailed with respect to ammonia relevant farm data – was carried out in 2013 by the Swiss Federal Statistical Office at the national level covering a sample of about 17'000 farms. This allowed a plausibility check of the AGRAMMON data, which showed a good compatibility of the resulting national emissions between the two surveys. The difference in overall national emissions was about 1 %, although there were higher differences at the process- or farm-level, but these cancelled each other out (Kupper et al. 2018).

For the volatilisation of NO_x, which is also integrated in the AGRAMMON model, a Tier 2 approach based on emission factors from van Bruggen et al. (2014) was used.

The calculation of non-methane volatile organic compounds (NMVOC) and particulate matter (PM, except for all cattle categories) emissions was conducted with a Tier 1 approach using country specific and default Tier 1 emission factors from the EMEP/EEA guidebook (EMEP/EEA 2019). The PM emissions from all cattle categories (3B1) are calculated by a Tier 2 method using country specific emission factors based on literature data and expert judgement (Bühler and Kupper 2018).

A comprehensive literature study by Bühler and Kupper (2018) has shown that the data base of NMVOC emissions from animal husbandry is very scarce and the derived emission factors differ widely. The studies on which the emission factors in the EMEP/EEA guidebook (EMEP/EEA 2019) are based show several inconsistencies that could affect significantly the emission factors. It also remains unknown, how the emissions from the studies performed in the United States were adapted to European agricultural feeding conditions and how the corresponding emission factors were derived. Therefore, a study was conducted between 2018 and 2021 in order to measure NMVOC emissions from dairy cattle with and without silage feeding in an experimental dairy housing during summer, winter and transitional season and to derive emission factors that are representative for cattle husbandry in Switzerland (Schrade et al. 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 (Kupper et al. 2015, Kupper et al. 2018, Kupper et al. 2022). National standard N excretion rates are used (Richner et al. 2017), considering animal category specific correction factors for various feeding strategies as well as for milk yield of dairy cows (Kupper et al. 2022).

For the volatilisation of NO_x, which is also integrated in the AGRAMMON model, default values from van Bruggen et al. (2014) were used. Accordingly, it is estimated that 0.2 %, 0.5 %, 1.0 % and 0.1 % of the total nitrogen in liquid/slurry, solid storage, deep litter and poultry manure systems, respectively, are lost to the atmosphere in the form of NO_x. These values are considerably higher than the ones based on the EMEP/EEA guidebook (Table 3.10 and A1.8; EMEP/EEA 2019), especially for liquid/slurry systems which in 2020 account for about 70 % of the total N flow through manure storage (Kupper et al. 2022). In this context the management systems “anaerobic digestion” is treated as liquid/slurry system.

The resulting NH₃ and NO_x emission factors for the livestock categories are listed in Table 5-6 and Table 5-7. Each emission factor reflects the sum of the emissions from animal housing and manure storage. The emissions resulting from the application of manure to soils and from grazing are reported separately under category 3Da2a and 3Da3 and are not included in the emission factors listed in Table 5-6 and Table 5-7, but are given in the tables of chp. 5.3.2.

Table 5-6: Time series of NH₃ Emission factors for livestock categories. Note that the emissions from grazing and for the application of manure are not included in these emission factors (see chp. 5.3.2).

NH ₃ emission factors		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	kg/animal	11.9	12.6	15.9	17.5	17.5
3B1b	Non-dairy cattle	kg/animal	11.8	12.9	14.4	16.2	16.1
3B1c	Young cattle	kg/animal	4.8	5.0	5.3	5.6	5.7
3B2	Sheep	kg/animal	1.3	1.3	1.1	1.0	1.2
3B3	Swine	kg/animal	3.5	3.7	3.9	3.8	3.4
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	NO	NO	2.1	1.8	2.0
3B4c	Deer	kg/animal	3.4	3.7	3.3	3.1	3.6
3B4d	Goats	kg/animal	2.3	2.3	2.1	1.9	1.9
3B4e	Horses	kg/animal	9.1	9.1	8.3	8.0	8.1
3B4f	Mules and asses	kg/animal	3.3	3.3	3.2	3.0	2.9
3B4gi	Layers	kg/animal	0.32	0.31	0.27	0.26	0.22
3B4gii	Broilers	kg/animal	0.09	0.086	0.084	0.088	0.080
3B4giii	Turkey	kg/animal	0.31	0.31	0.29	0.30	0.28
3B4giv	Growers	kg/animal	0.17	0.16	0.13	0.11	0.083
3B4giv	Other poultry	kg/animal	0.17	0.17	0.17	0.17	0.17
3B4hi	Rabbits	kg/animal	0.23	0.23	0.23	0.23	0.23
3B4hii	Bisons	kg/animal	NO	6.8	7.0	6.4	6.3

NH ₃ emission factors		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3B1a	Dairy cattle	kg/animal	17.7	17.9	18.1	18.3	18.5	18.6	18.8	18.9	19.1	19.1
3B1b	Non-dairy cattle	kg/animal	16.2	16.3	16.3	16.4	16.5	16.3	16.1	15.9	15.7	15.7
3B1c	Young cattle	kg/animal	5.7	5.8	5.9	6.0	6.0	6.0	6.0	6.0	5.9	5.9
3B2	Sheep	kg/animal	1.2	1.2	1.2	1.2	1.1	1.1	1.2	1.2	1.2	1.2
3B3	Swine	kg/animal	3.4	3.3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	2.0	2.0	1.9	1.9	1.8	1.8	1.8	1.9	1.9	1.9
3B4c	Deer	kg/animal	3.5	3.5	3.5	3.4	3.3	3.4	3.4	3.5	3.5	3.5
3B4d	Goats	kg/animal	1.9	2.0	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7
3B4e	Horses	kg/animal	8.1	8.2	8.2	8.2	8.3	8.3	8.2	8.2	8.2	8.2
3B4f	Mules and asses	kg/animal	2.9	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
3B4gi	Layers	kg/animal	0.21	0.21	0.20	0.20	0.19	0.19	0.18	0.18	0.18	0.18
3B4gii	Broilers	kg/animal	0.076	0.073	0.070	0.067	0.063	0.063	0.064	0.064	0.064	0.064
3B4giii	Turkey	kg/animal	0.29	0.30	0.30	0.31	0.32	0.30	0.29	0.28	0.26	0.26
3B4giv	Growers	kg/animal	0.082	0.080	0.079	0.077	0.076	0.074	0.073	0.072	0.070	0.070
3B4giv	Other poultry	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	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	6.4	6.2	6.2	6.1	6.1	6.1	6.0	7.9	7.8	7.7

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

NO _x emission factors		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	g/animal	859	829	773	742	731
3B1b	Non-dairy cattle	g/animal	635	657	558	535	519
3B1c	Young cattle	g/animal	318	317	282	267	268
3B2	Sheep	g/animal	171	174	150	142	170
3B3	Swine	g/animal	94	92	73	63	61
3B4a	Buffalos	g/animal	IE	IE	IE	IE	IE
3B4b	Camels and llamas	g/animal	NO	NO	260	227	254
3B4c	Deer	g/animal	423	463	411	388	453
3B4d	Goats	g/animal	317	314	280	264	265
3B4e	Horses	g/animal	624	623	569	547	546
3B4f	Mules and asses	g/animal	229	229	223	209	202
3B4gi	Layers	g/animal	2.3	2.3	2.2	2.4	2.4
3B4gii	Broilers	g/animal	1.3	1.3	1.3	1.4	1.5
3B4giii	Turkey	g/animal	4.6	4.6	4.5	4.5	4.5
3B4giv	Growers	g/animal	1.1	1.1	1.1	1.0	1.0
3B4gvi	Other poultry	g/animal	1.8	1.8	1.8	1.8	1.8
3B4hi	Rabbits	g/animal	16	16	16	16	16
3B4hii	Bisons	g/animal	NO	433	446	407	399

NO _x emission factors		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3B1a	Dairy cattle	g/animal	729	726	723	721	718	716	714	712	709	707
3B1b	Non-dairy cattle	g/animal	515	511	507	503	499	498	498	498	497	495
3B1c	Young cattle	g/animal	267	264	262	261	259	257	255	254	251	251
3B2	Sheep	g/animal	166	164	161	156	152	153	156	157	159	159
3B3	Swine	g/animal	60	60	60	60	60	60	60	60	60	60
3B4a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	g/animal	251	247	243	236	229	228	230	230	233	234
3B4c	Deer	g/animal	444	436	434	423	412	419	424	431	436	437
3B4d	Goats	g/animal	270	272	272	274	269	263	258	253	248	248
3B4e	Horses	g/animal	549	552	556	560	565	562	558	555	552	552
3B4f	Mules and asses	g/animal	203	203	204	204	205	206	208	210	211	211
3B4gi	Layers	g/animal	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
3B4gii	Broilers	g/animal	1.4	1.4	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2
3B4giii	Turkey	g/animal	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
3B4giv	Growers	g/animal	1.0	1.0	0.98	0.98	0.97	0.97	0.97	0.96	0.96	0.96
3B4gvi	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	410	393	393	386	385	387	383	505	495	492

For all cattle categories country specific NMVOC emission factors are used based on a comprehensive study in which emission measurements were carried out in an experimental dairy housing (Schrade et al. 2022). NMVOC emissions from dairy cattle with and without silage feeding were measured during summer, winter and transitional season. For a representative determination of emissions from silage, measurements were carried out with three different silage rations. Based on these measurements, NMVOC emission factors were derived for dairy cattle with and without silage for the lowlands and mountain area, respectively. For silage feeding, emission factors of 25 kg/animal and 21 kg/animal resulted for dairy cattle in the lowlands and the mountain area, respectively. The values are higher than the default Tier 1 emission factor of 17.937 provided in the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 3B Manure management, Table 3.4). It should be noted that the weight of Swiss dairy cattle (660 kg, Richner et al. 2017) is higher than the one of dairy cattle in EMEP/EEA (2019) (600 kg, chp. 3B, Table A1.6). On the other hand, the emission factors without silage feeding of 1.5 kg/animal and 1.3 kg/animal for the lowlands and the mountain area, respectively, are considerably lower than the one given in EMEP/EEA (2019) (8.047 kg/animal). For non-dairy cattle the same emission factors are assumed whereas for young cattle categories, the emission factors were scaled with the ratio of the gross energy intake of the respective categories related to the one of dairy cattle. For the calculation of NMVOC emissions, the proportion of animals kept in the lowlands and mountain area as well as their proportion with and without silage feeding were taken into account, see Table 5-8. The proportions are derived from the on-farm surveys on farm and manure management conducted by HAFL (2002, 2007, 2010, 2015 and 2019) in connection with the AGRAMMON model, see chp. 5.2.2 (Kupper and Häni 2022). The relatively high proportion of dairy cattle that is fed without silage in Switzerland is due to the fact that unpasteurised milk is used for hard cheese production and that farms producing milk for hard cheese production are not allowed to produce and use silage for all cattle. Between 1990 and 2020, the share of dairy cattle receiving silage increased almost continuously, e.g. in the lowlands from 37 % to 61 %.

For all livestock categories other than cattle, the NMVOC emission factors are based on default Tier 1 emission factors (EMEP/EEA 2019, chp. 3B Manure management, Table 3.4). The resulting NMVOC emission factors for cattle categories and the default emission factors for all other animal categories are given in Table 5-9.

Table 5-8: Time series of the share of cattle categories kept in the lowlands as well as of animals receiving silage feeding in the lowlands and mountain area, respectively.

	1990	1995	2000	2005	2010
3B1a Dairy cattle					
Lowlands	62%	61%	60%	60%	60%
Silage feeding, lowlands	37%	41%	45%	53%	56%
Silage feeding, mountain area	30%	31%	33%	38%	39%
3B1b Non-dairy cattle					
Lowlands	62%	61%	58%	58%	58%
Silage feeding, lowlands	95%	95%	95%	95%	95%
Silage feeding, mountain area	95%	95%	95%	95%	95%
3B1c Young cattle					
Lowlands	51%	51%	55%	56%	56%
Silage feeding, lowlands	48%	52%	56%	64%	70%
Silage feeding, mountain area	43%	46%	43%	47%	58%

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3B1a Dairy cattle										
Lowlands	60%	60%	60%	60%	60%	60%	60%	60%	59%	59%
Silage feeding, lowlands	56%	56%	56%	56%	56%	57%	59%	60%	61%	61%
Silage feeding, mountain area	40%	40%	41%	42%	43%	42%	41%	41%	40%	40%
3B1b Non-dairy cattle										
Lowlands	58%	58%	57%	57%	57%	56%	56%	56%	56%	56%
Silage feeding, lowlands	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Silage feeding, mountain area	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
3B1c Young cattle										
Lowlands	56%	56%	56%	57%	57%	57%	57%	57%	57%	57%
Silage feeding, lowlands	71%	72%	72%	73%	73%	73%	73%	73%	73%	73%
Silage feeding, mountain area	58%	59%	59%	60%	60%	59%	59%	59%	59%	59%

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

NMVOC emission factors		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	kg/animal	9	10	10	12	12
3B1b	Non-dairy cattle	kg/animal	23	23	23	23	23
3B1c	Young cattle	kg/animal	4.8	5.1	5.2	5.6	6.2
3B2	Sheep	kg/animal	0.17	0.17	0.17	0.17	0.17
3B3	Swine	kg/animal	0.57	0.57	0.55	0.55	0.55
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	NO	NO	0.27	0.27	0.27
3B4c	Deer	kg/animal	0.045	0.045	0.045	0.045	0.045
3B4d	Goats	kg/animal	0.54	0.54	0.54	0.54	0.54
3B4e	Horses	kg/animal	4.3	4.3	4.3	4.3	4.3
3B4f	Mules and asses	kg/animal	1.5	1.5	1.5	1.5	1.5
3B4gi	Layers	kg/animal	0.17	0.17	0.17	0.17	0.17
3B4gii	Broilers	kg/animal	0.11	0.11	0.11	0.11	0.11
3B4giii	Turkey	kg/animal	0.49	0.49	0.49	0.49	0.49
3B4giv	Growers	kg/animal	0.17	0.17	0.17	0.17	0.17
3B4giv	Other poultry	kg/animal	0.49	0.49	0.49	0.49	0.49
3B4hi	Rabbits	kg/animal	0.059	0.059	0.059	0.059	0.059
3B4hii	Bisons	kg/animal	NO	3.6	3.6	3.6	3.6

NMVOC emission factors		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3B1a	Dairy cattle	kg/animal	12	13	13	13	13	13	13	13	13	13
3B1b	Non-dairy cattle	kg/animal	23	23	23	23	23	23	23	23	23	23
3B1c	Young cattle	kg/animal	6.3	6.4	6.4	6.4	6.4	6.4	6.4	6.3	6.3	6.3
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	0.54
3B4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	kg/animal	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
3B4c	Deer	kg/animal	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
3B4d	Goats	kg/animal	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
3B4e	Horses	kg/animal	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
3B4f	Mules and asses	kg/animal	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3B4gi	Layers	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
3B4gii	Broilers	kg/animal	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
3B4giii	Turkey	kg/animal	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
3B4giv	Growers	kg/animal	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
3B4giv	Other poultry	kg/animal	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
3B4hi	Rabbits	kg/animal	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
3B4hii	Bisons	kg/animal	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6

The particulate matter emission factors (PM_{2.5}, PM₁₀, and TSP) are listed in Table 5-10. They are based on a comprehensive literature study by Bühler and Kupper (2018). The emission factors of all cattle categories were derived from literature data and expert judgment distinguishing loose- and tied-housing systems. For dairy cattle, the emission factors are based on PM₁₀ emission measurements in a loose-housing system in Switzerland (Schrade 2009). For all livestock categories other than cattle, except for fattening pigs (TSP) and sheeps and goats (PM_{2.5} and PM₁₀) default Tier 1 emission factors from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 3B, Table 3.5) are used. For the mentioned exceptions other literature values are assumed. For camels/llamas, deer and bisons the same emission factors as for goats are assumed whereas for rabbits the emission factors of fur animals are applied. All these emission factors are kept constant over the entire time series, except for the emission factors of the aggregated category swine. For the animals outside agriculture, i.e. sheeps, goats, horses, mules and asses the same emission factors as for the corresponding agricultural animals are applied (see chp. 7.2.2).

Table 5-10: Emission factors of PM_{2.5}, PM₁₀ and TSP for livestock categories in year 2020 (based on measurements in Switzerland, literature data and EMEP/EEA 2019).

Emission factors		Unit	PM _{2.5}	PM ₁₀	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	4.5	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 2021, SFSO 2021a) for the time period 1990 to 2020 is shown in Table 5-11. 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 the EMEP/EEA guidebook (EMEP/EEA 2019). Thus, for fattening pigs over 25 kg and broilers also empty periods were taken into account. Data for horses, mules and asses were derived from background data of the gross nutrient balance of the Swiss Federal Statistical Office (SFSO 2021b).

Table 5-11: Time series of animal numbers for livestock categories (in thousand animals).

Activity data 3B		Unit	1990	1995	2000	2005	2010
3B1a	Dairy cattle	1'000 animals	783	740	669	621	589
3B1b	Non-dairy cattle	1'000 animals	12	23	45	78	111
3B1c	Young cattle	1'000 animals	1'060	986	874	856	891
3B2	Sheep	1'000 animals	395	387	421	446	434
3B3	Swine	1'000 animals	1'965	1'739	1'670	1'744	1'750
3B4a	Buffaloes	1'000 animals	IE	IE	IE	IE	IE
3B4b	Camels and llamas	1'000 animals	NO	NO	1.0	3.1	6.1
3B4c	Deer	1'000 animals	0.17	1.4	2.8	3.8	5.5
3B4d	Goats	1'000 animals	68	53	62	74	83
3B4e	Horses	1'000 animals	28	41	50	55	62
3B4f	Mules and asses	1'000 animals	5.9	7.6	12	16	20
3B4gi	Layers	1'000 animals	3'083	2'118	2'150	2'189	2'438
3B4gii	Broilers	1'000 animals	3'392	3'637	3'985	5'711	7'184
3B4giii	Turkey	1'000 animals	95	170	173	132	58
3B4giv	Growers	1'000 animals	719	714	832	868	926
3B4giv	Other poultry	1'000 animals	22	17	21	11	23
3B4hi	Rabbits	1'000 animals	61	41	28	25	35
3B4hii	Bisons	1'000 animals	NO	0.10	0.26	0.37	0.51

Activity data 3B		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3B1a	Dairy cattle	1'000 animals	589	591	587	587	583	576	569	564	555	546
3B1b	Non-dairy cattle	1'000 animals	111	114	117	118	118	121	123	125	128	131
3B1c	Young cattle	1'000 animals	877	859	854	857	853	859	852	854	842	837
3B2	Sheep	1'000 animals	424	417	409	403	395	397	398	403	400	398
3B3	Swine	1'000 animals	1'726	1'678	1'615	1'631	1'605	1'553	1'546	1'501	1'447	1'448
3B4a	Buffaloes	1'000 animals	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3B4b	Camels and llamas	1'000 animals	6.0	5.8	5.9	6.1	6.4	6.5	6.6	6.7	6.6	6.5
3B4c	Deer	1'000 animals	5.7	5.7	5.7	5.7	6.0	6.0	6.0	6.4	6.6	6.6
3B4d	Goats	1'000 animals	83	85	85	85	84	85	88	91	92	90
3B4e	Horses	1'000 animals	57	58	57	57	55	56	56	46	47	47
3B4f	Mules and asses	1'000 animals	19	20	20	20	20	20	21	34	34	33
3B4gi	Layers	1'000 animals	2'437	2'521	2'589	2'665	2'822	3'056	3'174	3'371	3'486	3'854
3B4gii	Broilers	1'000 animals	7'410	7'737	8'126	8'506	8'614	9'064	8'857	9'430	9'593	10'083
3B4giii	Turkey	1'000 animals	58	51	55	57	49	71	77	84	75	88
3B4giv	Growers	1'000 animals	970	1'076	1'055	1'196	1'033	959	1'084	1'078	1'242	1'150
3B4giv	Other poultry	1'000 animals	29	25	20	22	23	30	16	20	21	24
3B4hi	Rabbits	1'000 animals	34	28	28	27	25	25	22	22	21	19
3B4hii	Bisons	1'000 animals	0.51	0.52	0.50	0.53	0.56	0.56	0.57	0.54	0.46	0.46

5.2.3 Category-specific recalculations 3B Manure management

- 3B: A new representative stratified survey on farm management and structure was conducted at the end of 2019. A random sample of farms covering the five farmtypes, three geographical regions and three altitude classes (valley zone, hill zone, mountain zone) described in chapter 5.2.2 was drawn by the Federal Office for Statistics. A twelve-page questionnaire was sent to the selected 5'683 farms. Eventually the responses from 2'639 farms could be used for the data analysis (response rate 46.1 %). Thus, the analysed sample covered 11.3 % of the Swiss farms and 15.5 % of the agricultural livestock units.
- 3B: NH₃ and NO_x emissions from manure management were recalculated for the years 1990-2019 with the revised version of the AGRAMMON N-flow model (revision 2021; version 6.0.1). This revision did not include any changes of technical parameters, but only small optimisations in the calculation procedure like a linear instead of stepwise correction of housing emissions during grazing, more empirical (N-flow based) distribution of the TAN-flow in manure storage and a correction for horses as well as mules and asses for the time when the animals have access both to grazing and the exercise yard close to the housing. The impact of the changes on overall emissions are minimal.
- 3B: N excretion of livestock and NH₃ emissions were taken from the Swiss NH₃ emission inventory (Kupper et al. 2022) where they were compiled based on the calculation with the Tier 3 N-flow model AGRAMMON and the database on farming practice from the representative surveys 2015 and 2019. For the years 2016-2018 they were derived from an interpolation of the emission factors for 2015 and 2019, which were based on representative surveys on farming practice in the respective years.

- 3B: Activity data of source categories 3B3, 3B4e and 3B4gii were revised for the years 2017-2019 due to new background data of the SFSO for livestock population statistics for fattening pigs, horses and broilers.
- 3B: NH₃ and NO_x emissions from manure management were recalculated for the years 1990-2019. 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.
- 3B1: The NMVOC emission factors of all cattle categories were completely revised for the entire time series. The new factors are based on extensive measurements of NMVOC emissions from dairy cattle with and without silage feeding in an experimental dairy housing during summer, winter and transitional season. The associated uncertainties have been updated accordingly and significantly reduced.
- 3B4giv: The activity data were revised for the year 2019 due to an update of the number of other poultry.

5.3 Source category 3D – Crop production and agricultural soils

5.3.1 Source category description of 3D Crop production and agricultural soils

This chapter contains direct and indirect emissions from agricultural soils, from all fertilisers (mineral (inorganic N-) fertiliser, sewage sludge, compost and other residue fertilisers) and animal manure applied on these soils as well as excretions during grazing.

Note that the application of HCB as a fungicide is prohibited in Switzerland since 1972 and its application as a seed-dressing agent since 1978 (LUBW 1995). Emissions due to potential HCB impurities or by-products in certain pesticides (3Df) are not estimated.

Table 5-12: Specification of source category 3D Agricultural Soils.

3D	Source category	Specification
3Da1	Inorganic N-fertilizers	Application of urea-containing fertilizers and other inorganic fertilizers
3Da2a	Livestock manure applied to soils	Application of livestock manure to soils (dairy cattle, non-dairy cattle, sheep, swine, buffalos, goats, horses, mules/asses, laying hens, broilers, turkeys, growers, other poultry, other animals)
3Da2b	Sewage sludge applied to soils	Application of sewage sludge to soils (NO after 2009)
3Da2c	Other organic fertilisers applied to soils (including compost)	Application of compost derived from organic residues (incl. liquid and solid digestate)
3Da3	Urine and dung deposited by grazing livestock	Deposition of urine and dung by grazing livestock
3De	Cultivated crops	For particulate matter emissions: Soil cultivation and crop harvesting (operation of tractors and machinery). For NMVOC emissions: Crop production, differentiated for cropland, grassland and summering pastures.

Table 5-13: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 3D Agricultural Soils.

NFR code	Source category	Pollutant	Identification criteria
3Da1	Inorganic N-fertilizers (includes also urea application)	NO _x	L2, T2
3Da1	Inorganic N-fertilizers (includes also urea application)	NH ₃	T1, L2, T2
3Da2a	Animal manure applied to soils	NO _x	T1, L2, T2
3Da2a	Animal manure applied to soils	NH ₃	L1, T1, L2, T2
3Da2b	Sewage sludge applied to soils	NH ₃	T1
3Da2c	Other organic fertilisers applied to soils (including	NO _x	T2
3Da2c	Other organic fertilisers applied to soils (including	NH ₃	T1, T2
3Da3	Urine and dung deposited by grazing animals	NO _x	L2, T2
3Da3	Urine and dung deposited by grazing animals	NH ₃	T1, L2, T2
3De	Cultivated crops	PM10	L1, T1, L2, T2

5.3.2 Methodological issues of 3D Crop production and agricultural soils

Methodology (3D)

The emissions are calculated by Tier 3 (3Da2a, 3Da3 (NH₃)), Tier 2 (3Da1, 3De) and Tier 1 (3Da2b, 3Da2c, 3Da3 (NO_x)) methods based on the decision tree in Fig. 3.1 in chapter 3D Crop production and agricultural soils of the EMEP/EEA guidebook (EMEP/EEA 2019).

- 3Da1: For the application of nitrogen containing inorganic fertilisers the Tier 2 method and NH₃ emission factors according to the EMEP/EEA guidebook (EMEP/EEA 2019) were used. In 3Da1 only the agricultural use of inorganic fertilisers is reported, while private use is reported under 6Ac.
- 3Da2a: As described in chapter 5.2.2, emissions from livestock manure management are calculated with livestock specific emission factors multiplied by the number of livestock. Both the emission factors for 3B and 3D are generated from stratified samples considering different farm types, regions, height above sea level and application techniques (Tier 3). This category also includes emissions from digestate originating from agricultural biogas plants (at least 80 % of the substrate is livestock manure).
- 3Da2b/3Da2c: NH₃ 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 NH₃ from 3Da2c). For NH₃ 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: NH₃ emission from urine and dung deposited by grazing livestock are determined by multiplying animal specific emission factors (see chapter 5.2.2) with the number of animals. For NO_x emissions the Tier 1 method and emission factors described in the EMEP/EEA guidebook (EMEP/EEA 2019) were used.
- 3De: In this source category, NMVOC and particulate matter (PM_{2.5}, PM₁₀ and TSP) emissions from agricultural soils are reported based on a study by Bühler and Kupper (2018). The NMVOC emissions from agricultural soils are estimated with a Tier 2 approach according to the EMEP/EEA guidebook (EMEP/EEA 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, PM_{2.5}, 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 NH₃ emission factors from the EMEP/EEA guidebook (EMEP/EEA 2019, 3D Crop production and agricultural soils, Table 3.2) were used for the whole time series. The climate zone for Switzerland is "cool". Based on official fertiliser trade statistics (Agricura 2020) and an assessment of soil pH based on the Swiss agricultural soil use capability map (Frei et al. 1980), 54 % of fertilisers are used on soils with pH > 7.0 and 46 % on soils with pH < 7.0.

NH₃-emission factors for 3Da2c are based on Kupper et al. (2022; chp. 7.4.2). The emission factors used were 60 % of TAN for liquid residues and 80 % of TAN for solid residues.

Table 5-14 shows NH₃ 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 NO₂) is emitted per ton of nitrogen applied.

Table 5-14: NH₃ and NO_x emission factors 2020 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	39
3Da2c	Organic compost	kg / tN	18	148

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

Table 5-15: Time series of NH₃ emission factors for the application of animal manure to soils (3Da2a).

NH ₃ emission factors		Unit	1990	1995	2000	2005	2010					
3Da2a1a	Dairy cattle	kg/animal	26.0	25.7	23.1	23.0	22.6					
3Da2a1b	Non-dairy cattle	kg/animal	13.4	12.7	11.4	12.0	12.3					
3Da2a1c	Young cattle	kg/animal	6.6	6.5	5.6	5.4	5.3					
3Da2a2	Sheep	kg/animal	0.22	0.23	0.19	0.20	0.25					
3Da2a3	Swine	kg/animal	3.3	3.1	2.0	1.6	1.4					
3Da2a4a	Buffalos	kg/animal	IE	IE	IE	IE	IE					
3Da2a4b	Camels and llamas	kg/animal	NO	NO	0.23	0.19	0.23					
3Da2a4c	Deer	kg/animal	0.38	0.41	0.36	0.33	0.40					
3Da2a4d	Goats	kg/animal	0.44	0.44	0.33	0.50	0.41					
3Da2a4e	Horses	kg/animal	1.8	1.8	1.6	1.5	1.5					
3Da2a4f	Mules and asses	kg/animal	0.65	0.65	0.62	0.61	0.65					
3Da2a4gi	Layers	kg/animal	0.059	0.061	0.067	0.075	0.087					
3Da2a4gii	Broilers	kg/animal	0.063	0.064	0.053	0.054	0.063					
3Da2a4giii	Turkey	kg/animal	0.22	0.22	0.21	0.18	0.17					
3Da2a4giv	Growers	kg/animal	0.023	0.027	0.032	0.032	0.035					
3Da2a4giv	Other poultry	kg/animal	0.075	0.075	0.070	0.054	0.077					
3Da2a4hi	Rabbits	kg/animal	0.037	0.037	0.036	0.035	0.035					
3Da2a4hii	Bisons	kg/animal	NO	0.84	0.83	0.75	0.73					

NH ₃ emission factors		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3Da2a1a	Dairy cattle	kg/animal	22.3	22.0	21.8	21.5	21.3	21.3	21.2	21.2	21.2	21.2
3Da2a1b	Non-dairy cattle	kg/animal	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.5	11.5
3Da2a1c	Young cattle	kg/animal	5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0
3Da2a2	Sheep	kg/animal	0.24	0.23	0.22	0.21	0.20	0.20	0.21	0.21	0.22	0.22
3Da2a3	Swine	kg/animal	1.4	1.4	1.4	1.4	1.3	1.4	1.4	1.4	1.4	1.4
3Da2a4a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	kg/animal	0.22	0.22	0.21	0.21	0.20	0.20	0.20	0.19	0.19	0.20
3Da2a4c	Deer	kg/animal	0.39	0.38	0.38	0.37	0.36	0.36	0.36	0.36	0.36	0.36
3Da2a4d	Goats	kg/animal	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.44	0.44	0.44
3Da2a4e	Horses	kg/animal	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.5	1.5
3Da2a4f	Mules and asses	kg/animal	0.64	0.63	0.62	0.61	0.60	0.62	0.64	0.65	0.67	0.67
3Da2a4gi	Layers	kg/animal	0.089	0.091	0.093	0.095	0.096	0.096	0.095	0.094	0.094	0.094
3Da2a4gii	Broilers	kg/animal	0.060	0.057	0.054	0.051	0.048	0.049	0.049	0.049	0.050	0.050
3Da2a4giii	Turkey	kg/animal	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15
3Da2a4giv	Growers	kg/animal	0.036	0.037	0.038	0.039	0.040	0.037	0.033	0.030	0.027	0.027
3Da2a4giv	Other poultry	kg/animal	0.074	0.072	0.069	0.067	0.064	0.064	0.064	0.064	0.065	0.065
3Da2a4hi	Rabbits	kg/animal	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
3Da2a4hii	Bisons	kg/animal	0.75	0.72	0.72	0.71	0.70	0.71	0.70	0.92	0.90	0.90

Table 5-16: Time series of NO_x emission factors for the application of animal manure to soils (3Da2a).

NO _x emission factors		Unit	1990	1995	2000	2005	2010					
3Da2a1a	Dairy cattle	g/animal	1443	1427	1322	1305	1347					
3Da2a1b	Non-dairy cattle	g/animal	875	859	761	785	818					
3Da2a1c	Young cattle	g/animal	416	414	360	341	347					
3Da2a2	Sheep	g/animal	68	69	60	57	68					
3Da2a3	Swine	g/animal	200	192	136	110	112					
3Da2a4a	Buffalos	g/animal	IE	IE	IE	IE	IE					
3Da2a4b	Camels and llamas	g/animal	NO	NO	102	89	100					
3Da2a4c	Deer	g/animal	166	181	161	152	178					
3Da2a4d	Goats	g/animal	127	126	112	107	107					
3Da2a4e	Horses	g/animal	527	526	481	462	460					
3Da2a4f	Mules and asses	g/animal	194	194	189	178	171					
3Da2a4gi	Layers	g/animal	7.8	7.8	8.0	8.8	9.9					
3Da2a4gii	Broilers	g/animal	5.7	5.7	5.7	6.2	6.7					
3Da2a4giii	Turkey	g/animal	20	20	20	20	20					
3Da2a4giv	Growers	g/animal	3.5	3.6	4.0	3.9	4.1					
3Da2a4giv	Other poultry	g/animal	7.4	7.4	7.1	7.1	7.1					
3Da2a4hi	Rabbits	g/animal	13	13	13	13	13					
3Da2a4hii	Bisons	g/animal	NO	359	369	337	330					

NO _x emission factors		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3Da2a1a	Dairy cattle	g/animal	1349	1351	1354	1356	1359	1357	1355	1353	1351	1351
3Da2a1b	Non-dairy cattle	g/animal	817	816	815	814	813	810	806	803	799	799
3Da2a1c	Young cattle	g/animal	349	350	351	352	352	350	348	347	346	345
3Da2a2	Sheep	g/animal	67	66	65	63	61	61	62	63	64	64
3Da2a3	Swine	g/animal	112	110	110	110	110	111	110	110	111	111
3Da2a4a	Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da2a4b	Camels and llamas	g/animal	99	97	96	93	90	89	90	90	91	92
3Da2a4c	Deer	g/animal	175	171	170	166	162	164	166	169	171	171
3Da2a4d	Goats	g/animal	109	110	110	111	109	107	105	103	101	101
3Da2a4e	Horses	g/animal	462	465	468	471	476	473	470	467	464	464
3Da2a4f	Mules and asses	g/animal	172	172	172	172	173	174	176	178	179	179
3Da2a4gi	Layers	g/animal	9.9	10	10	10	10	10	10	10	10	10
3Da2a4gii	Broilers	g/animal	6.4	6.2	5.9	5.6	5.4	5.4	5.4	5.3	5.3	5.3
3Da2a4giii	Turkey	g/animal	20	20	19	19	19	19	20	20	20	20
3Da2a4giv	Growers	g/animal	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
3Da2a4giv	Other poultry	g/animal	7.1	7.1	7.0	7.0	7.0	7.0	7.1	7.1	7.1	7.1
3Da2a4hi	Rabbits	g/animal	13	13	13	13	13	13	13	13	13	13
3Da2a4hii	Bisons	g/animal	339	325	325	320	319	320	317	418	410	408

In the following, Table 5-17 and Table 5-18 list the emission factors for NH₃ and NO_x for N excretion on pasture and paddock during grazing. They are based on the livestock category specific N flow calculations with AGRAMMON (see chapter 5.2.2). The considerable increase between 1990 and 2010 (e.g. dairy cattle, young cattle (calves), sheep, goats, horses) was a consequence of a strong increase of grazing linked to animal welfare incentives.

Table 5-17: Time series of NH₃ emission factors for N excretion during grazing (3Da3) for different of livestock categories.

NH ₃ emission factors		Unit	1990	1995	2000	2005	2010
3Da31a	Dairy cattle	kg/animal	0.47	0.55	0.87	1.0	1.1
3Da31b	Non-dairy cattle	kg/animal	1.4	1.4	1.6	1.5	1.4
3Da31c	Young cattle	kg/animal	0.29	0.29	0.44	0.47	0.45
3Da32	Sheep	kg/animal	0.14	0.14	0.21	0.23	0.20
3Da33	Swine	kg/animal	NO	NO	0.004	0.010	0.005
3Da34a	Buffalos	kg/animal	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	kg/animal	NO	NO	0.38	0.36	0.29
3Da34c	Deer	kg/animal	0.43	0.47	0.59	0.61	0.52
3Da34d	Goats	kg/animal	0.092	0.091	0.17	0.19	0.19
3Da34e	Horses	kg/animal	0.34	0.34	0.54	0.63	0.64
3Da34f	Mules and asses	kg/animal	0.12	0.12	0.15	0.20	0.22
3Da34gi	Layers	kg/animal	NO	0.002	0.014	0.024	0.028
3Da34gii	Broilers	kg/animal	NO	0.001	0.001	0.002	0.001
3Da34giii	Turkey	kg/animal	NO	0.003	0.016	0.017	0.014
3Da34giv	Growers	kg/animal	NO	0.001	0.001	0.001	0.003
3Da34giv	Other poultry	kg/animal	NO	NO	0.006	0.005	0.006
3Da34hi	Rabbits	kg/animal	NO	NO	NO	NO	NO
3Da34hii	Bisons	kg/animal	NO	0.66	0.84	0.85	0.79

NH ₃ emission factors		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3Da31a	Dairy cattle	kg/animal	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3Da31b	Non-dairy cattle	kg/animal	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5
3Da31c	Young cattle	kg/animal	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.44
3Da32	Sheep	kg/animal	0.21	0.21	0.22	0.23	0.23	0.23	0.23	0.22	0.22	0.22
3Da33	Swine	kg/animal	0.004	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001
3Da34a	Buffalos	kg/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b	Camels and llamas	kg/animal	0.31	0.32	0.33	0.34	0.35	0.34	0.34	0.34	0.33	0.34
3Da34c	Deer	kg/animal	0.54	0.56	0.59	0.61	0.63	0.63	0.63	0.63	0.63	0.63
3Da34d	Goats	kg/animal	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.22	0.23	0.23
3Da34e	Horses	kg/animal	0.63	0.61	0.60	0.59	0.57	0.59	0.60	0.61	0.62	0.62
3Da34f	Mules and asses	kg/animal	0.22	0.22	0.22	0.22	0.21	0.21	0.20	0.20	0.19	0.19
3Da34gi	Layers	kg/animal	0.028	0.028	0.028	0.029	0.029	0.029	0.029	0.029	0.029	0.029
3Da34gii	Broilers	kg/animal	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3Da34giii	Turkey	kg/animal	0.015	0.017	0.019	0.020	0.022	0.022	0.022	0.022	0.022	0.022
3Da34giv	Growers	kg/animal	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004
3Da34giv	Other poultry	kg/animal	0.006	0.007	0.007	0.008	0.008	0.008	0.008	0.009	0.009	0.009
3Da34hi	Rabbits	kg/animal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da34hii	Bisons	kg/animal	0.82	0.79	0.79	0.78	0.79	0.78	0.76	0.99	0.96	0.95

Table 5-18: Time series of NO_x emission factors for N excretion during grazing (3Da3) for different livestock categories.

NO _x emission factors	Unit	1990	1995	2000	2005	2010
3Da31a Dairy Cattle	g/animal	150	176	280	333	342
3Da31b Non dairy Cattle	g/animal	455	455	532	482	451
3Da31c Young Cattle	g/animal	94	95	144	152	146
3Da32 Sheep	g/animal	41	41	63	69	59
3Da33 Swine	g/animal	NO	NO	0.38	1.1	0.49
3Da34a Buffalos	g/animal	IE	IE	IE	IE	IE
3Da34b Camels and llamas	g/animal	NO	NO	112	107	87
3Da34c Deer	g/animal	129	141	177	183	155
3Da34d Goats	g/animal	27	27	49	56	57
3Da34e Horses	g/animal	101	100	162	187	189
3Da34f Mules and Asses	g/animal	37	37	44	59	67
3Da34gi Layers	g/animal	NO	0.076	0.51	0.86	1.00
3Da34gii Broilers	g/animal	NO	0.028	0.043	0.076	0.035
3Da34giii Turkey	g/animal	NO	0.099	0.56	0.61	0.48
3Da34giv Growers	g/animal	NO	0.036	0.034	0.053	0.104
3Da34giv Other poultry	g/animal	NO	NO	0.22	0.16	0.20
3Da34hi Rabbits	g/animal	NO	NO	NO	NO	NO
3Da34hii Bisons	g/animal	NO	196	252	252	236

NO _x emission factors	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3Da31a Dairy Cattle	g/animal	340	338	335	333	331	333	334	335	337	337
3Da31b Non dairy Cattle	g/animal	450	450	450	449	449	456	462	469	476	476
3Da31c Young Cattle	g/animal	146	147	146	145	144	144	145	144	144	143
3Da32 Sheep	g/animal	61	64	66	67	69	68	68	67	66	66
3Da33 Swine	g/animal	0.42	0.35	0.29	0.220	0.155	0.141	0.125	0.108	0.093	0.092
3Da34a Buffalos	g/animal	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3Da34b Camels and llamas	g/animal	91	95	99	102	104	102	101	100	99	100
3Da34c Deer	g/animal	161	168	177	182	188	188	187	187	186	186
3Da34d Goats	g/animal	58	59	59	59	58	61	64	67	69	69
3Da34e Horses	g/animal	186	183	179	176	171	175	178	182	186	185
3Da34f Mules and Asses	g/animal	66	66	65	64	64	62	60	58	57	57
3Da34gi Layers	g/animal	1.00	1.00	1.01	1.01	1.0	1.0	1.0	1.0	1.0	1.0
3Da34gii Broilers	g/animal	0.032	0.029	0.026	0.023	0.020	0.023	0.026	0.030	0.033	0.033
3Da34giii Turkey	g/animal	0.54	0.60	0.66	0.72	0.78	0.78	0.78	0.78	0.78	0.78
3Da34giv Growers	g/animal	0.099	0.094	0.088	0.083	0.078	0.092	0.106	0.121	0.135	0.135
3Da34giv Other poultry	g/animal	0.22	0.24	0.26	0.27	0.29	0.30	0.30	0.31	0.31	0.31
3Da34hi Rabbits	g/animal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da34hii Bisons	g/animal	243	235	236	233	234	232	227	295	285	284

Emission factors (3De)

For the calculation of the NMVOC emissions from crop production and agricultural soils three types of agricultural areas are differentiated, i.e. cropland, grassland and summering pastures. The NMVOC emission factors for cropland and grassland are based on the values for wheat and grass (15°C), respectively, of Table 3.3 of the EMEP/EEA guidebook (EMEP/EEA 2019) taking into account country-specific values for the mean dry matter yield (Richner et al. 2017). For summering pastures, the same NMVOC emission value as of grass (15°C) and a fraction of the growing period of 0.3 (Bühler and Kupper 2018) are assumed using a country-specific value for the mean dry matter yield (Richner et al. 2017). The resulting NMVOC emission factors are constant for the entire time series and are given in Table 5-19.

The particulate matter emission factors consist of an operation-specific emission factor for soil cultivation or harvesting and a factor for the annual number of the respective agricultural operation. The crop- and operation-specific emission factors are based on the Tier 2 emission factors for wet conditions of the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 3D, Tables 3.5 and 3.7). The factors for the annual number of agricultural operations are country-specific and are based mainly on expert judgements (Bühler and Kupper 2018). Only for the number of grass harvests literature values are available (Richner et al. 2017) for five different altitude classes. In order to derive the emission factors of the aggregated source categories cropland and grassland, the emissions from the cultivation of each single type of crop and of grassland have to be calculated, summed up and then divided by the total area of the respective crop and grassland types. Since the relative shares of grassland in the valley and the alpine area remain about constant over the entire time period constant (aggregated) emission factors result for grassland.

Unfortunately, the guidebook provides emission factors for PM10 and PM2.5 only. A couple of European countries assume for TSP the same values as of PM10. But this assumption is not reasonable since particulate matter emissions from soil cultivation and harvesting have a large mass fraction in the coarse fraction. Therefore, the TSP emission factors have been estimated according to the Danish emission inventory (Danish Informative Inventory Report 2018) with a fraction of PM10/TSP of 10 %. The particulate matter emission factors are also given in Table 5-19.

Table 5-19: NMVOC and PM2.5 emission factors of 2020 for 3De Crop production and agricultural soils.

Emission factors		Unit	NMVOC	PM2.5	PM10	TSP
3De	Cropland	g/ha	376	40	754	7'539
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 2021, Agricura 2020, AGRAMMON 2018) as well as the amount applied with sewage sludge and compost (including solid and liquid digestate) derived from organic residues are shown in Table 5-20.

Activity data for emissions from N excretion resulting from the application of animal manure to soils (3Da2a) and from grazing (3Da3) are the livestock numbers for source category 3B Manure management which are given in Table 5-11. The application of sewage sludge to soils has been prohibited (too high heavy metal content), therefore the activity data is NO from 2009 onwards.

The underlying data for compost and digestate (liquid and solid) from non agricultural biogas plants are based on a study from the year 2017 (Schleiss 2017, covering the period from 1990 to 2015 and subsequent annual update) and on data from the statistics of renewable energies (SFOE 2021a), respectively, see description in chp. 6.3.2. Schleiss 2017 differentiates so-called back yard and industrial composting. The compost applied to soil as fertiliser in agriculture is part of the industrial compost.

Table 5-20: Time series of nitrogen amount applied on agricultural soils: synthetic N-fertilisers (urea-containing and other N-containing synthetic fertilisers), sewage sludge and compost (derived from organic residues in t N). Additionally, agricultural areas (in ha; cropland, grassland, summering pastures) are displayed.

Activity data of agricultural soils		Unit	1990	1995	2000	2005	2010					
3Da1	Urea containing fertiliser	tN	16'284	10'707	7'631	6'605	7'101					
3Da1	Other synthetic N-fertiliser	tN	50'391	47'652	43'042	43'478	45'986					
3Da2b	Sewage sludge	tN	4'815	4'942	3'356	1'054	NO					
3Da2c	Organic compost	tN	817	1'286	1'829	2'169	3'281					
3De	Cropland	ha	313'247	308'284	290'954	283'802	270'371					
3De	Grassland	ha	724'556	737'229	743'849	742'474	741'837					
3De	Summering pastures	ha	538'676	499'774	496'667	487'956	486'382					

Activity data of agricultural soils		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3Da1	Urea containing fertiliser	tN	6'517	5'378	5'793	7'942	7'223	8'872	9'250	8'326	7'753	7'395
3Da1	Other synthetic N-fertiliser	tN	40'213	39'771	37'924	41'393	36'521	37'531	40'113	37'446	32'403	33'680
3Da2b	Sewage sludge	tN	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3Da2c	Organic compost	tN	3'676	4'345	4'670	4'709	4'908	5'435	5'542	5'668	6'211	6'421
3De	Cropland	ha	267'683	267'531	269'820	269'337	270'092	269'536	270'557	270'146	266'207	267'462
3De	Grassland	ha	744'727	743'594	739'588	740'097	737'463	736'455	732'125	729'073	729'073	729'073
3De	Summering pastures	ha	483'414	481'379	479'745	475'690	474'575	472'465	472'618	470'837	469'280	466'163

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 2021i). In addition, for NMVOC emissions also the emissions from summering pastures (SFSO 2021b) are included where no agricultural crop operations take place. The activity data of these agricultural areas are also given in Table 5-20. While cropland and grassland are part of the agricultural farms (farmland), summering pastures are alpine land (usually at an altitude of more than 1000-2500 m) which is grazed for around 100 days per year by dairy cows (for mountain cheese production), heifers, sheep and goats.

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

- 3D: NH₃ emissions were taken from the Swiss NH₃ emission inventory (Kupper et al., 2022) where they were compiled based on the calculation with the Tier 3 N-flow model AGRAMMON and the database on farming practice from the representative surveys 2015 and 2019. For the years 2016-2018 they were derived from an interpolation of the emission factors for 2015 and 2019, which were based on representative surveys on farming practice in the respective years.
- 3D: For the calculation of NH₃ emissions the AGRAMMON model version 6.0.1 was used. Compared to the model versions 5.1.4 used for previous reportings the model version 6.0.1 contained some small optimisations in the calculation procedure but no changes in technical parameters (Kupper et al. 2022). The effect of these changes on the final results for the year were minimal.
- 3D: N excretion of livestock and NH₃ emissions were taken from the Swiss NH₃ emission inventory (Kupper et al., 2022) where they were compiled based on the calculation with the Tier 3 N-flow model AGRAMMON and the database on farming practice from the representative surveys 2015 and 2019. For the years 2016-2018 they were derived from an interpolation of the emission factors for 2015 and 2019, which were based on representative surveys on farming practice in the respective years.
- 3Da: Activity data of source categories 3Da2a and 3Da3 were revised for the years 2017-2019 due to new background data of the SFSO for livestock population statistics for fattening pigs, horses and broilers (relevant for 3Da manure application).
- 3Da: Activity data of source categories 3Da2a and 3Da3 were revised for the years 2018 and 2019 due to new estimates of the numbers for horses and mules and asses.
- 3Da: The activity data of source categories 3Da2a4giv and 3Da34giv were revised for the year 2019 due to an update of the number of other poultry.
- 3Da2c: Activity data of source category 3Da2c Other organic fertiliser applied to soils were revised for the years 2014-2019 due to updated amounts of compost. Therefore, the weighted mean NH₃ emission factor changed as well for 2014-2019.

5.4 Source category 3F – Field burning of agricultural residuals

Burning of crop residues in fields is prohibited in Switzerland. Only the burning of branches and twigs is allowed under certain conditions. These emissions are reported in source category 5C2 Open burning of agricultural waste.

6 Waste

6.1 Overview of emissions

In this introductory chapter, an overview of emissions, separated according to the most relevant pollutants, is presented. Trends and changes for individual source categories in the period between 1990 and 2020 are analysed and discussed. In absolute figures, processes in sector 5 Waste emit mainly NMVOC and NH₃. The contributions of PM_{2.5}, heavy metals (Pb and Hg) and PCDD/F are smaller in absolute terms, but larger relative to total national emissions.

The following source categories are reported:

- 5A Biological treatment of waste - Solid waste disposal on land
- 5B Biological treatment of waste - Composting and anaerobic digestion
- 5C Waste incineration and open burning of waste
- 5D Wastewater handling
- 5E Other waste

Please note that according to IPCC Guidelines (IPCC 2006) and EMEP/EEA guidebook (EMEP/EEA 2019) **all emissions from waste-to-energy, where waste material is used directly as fuel or converted into a fuel, are reported under the sector 1A Fuel combustion**. Therefore, the largest share of waste-related emissions in Switzerland is not reported in sector 5 Waste but in sector 1 Energy.

6.1.1 Overview and trend for NMVOC

Figure 6-1 depicts the NMVOC emissions in the waste related sectors since 1990. A clear and continuous increasing trend of total NMVOC emissions from 2006 to 2020 can be observed. The contribution of the waste sector is small in comparison to the national total. Therefore, there are no source categories from the waste sector that are key categories for NMVOC.

The main sources of NMVOC emissions are 5B Biological treatment of solid waste and 5C Incineration and open burning of waste. Nowadays the bulk emissions in this sector originate from 5B Biological treatment of solid waste. The reason for this development is the increase in industrial and commercial composting activities, particularly the digestion of organic waste. The latter has become economically more beneficial due to cost covering feed-in tariffs for electricity and due to additional revenues as CO₂ compensation projects. The increase in digested quantities is also linked to population growth.

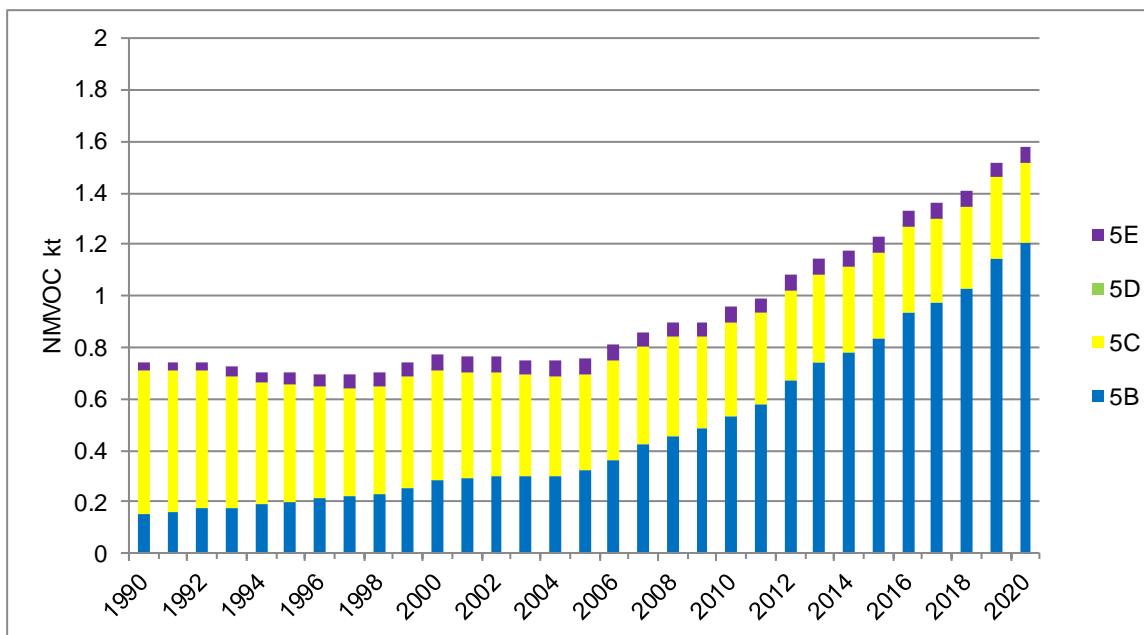


Figure 6-1: Switzerland's NMVOC emissions from the waste sector by source categories 5B-5E. The corresponding data table can be found in Annex A7.5.

6.1.2 Overview and trend for PM2.5

Figure 6-2 depicts the PM2.5 emissions in the waste related sectors since 1990. 5C Incineration and open burning of waste is significantly contributing to total PM2.5 emissions from the waste sector over the entire reporting period and thus key category.

Between 1990 and 2020 a continuous decrease of total PM2.5 emissions occurred that largely can be affiliated with the emission reductions achieved in 5C Waste incineration. This is mainly due to emission reductions from sewage sludge incineration, refurbishment of crematoriums, the cessation of burning cable insulation in 1995 as well as clinical waste incineration in 2002 as well as due to an overall decreasing trend in the open burning of natural residues in agriculture and households.

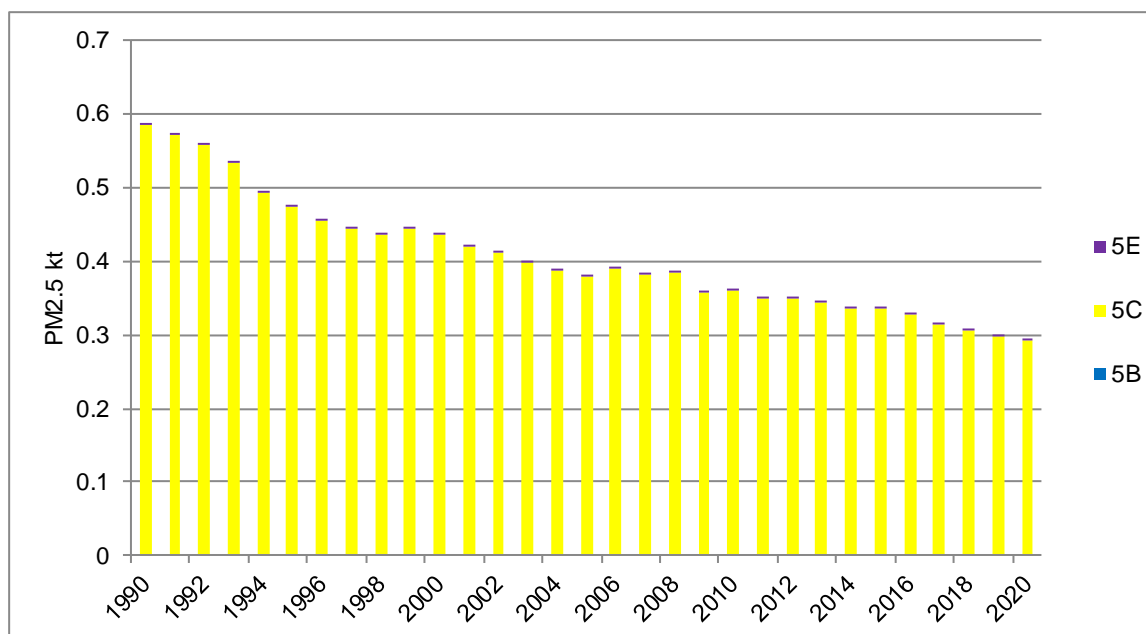


Figure 6-2: Switzerland's PM2.5 emissions from the waste sector by source categories 5B, 5C and 5E. Note that PM2.5 emissions from 5D are not occurring. The corresponding data table can be found in Annex A7.5.

6.2 Source category 5A – Biological treatment of waste - Solid waste disposal on land

6.2.1 Source category description of 5A Biological treatment of waste - Solid waste disposal on land

The source category 5A Biological treatment of waste - Solid waste disposal on land includes all emissions from solid waste handling on landfill sites. Since 1987 all deposited waste in Switzerland has been deposited on managed landfill sites.

In Switzerland, managed active landfill sites where organic material is degraded in biological processes are equipped to recover landfill gas (SFOE 2021a). The landfill gas is generally used in combined heat and power plants for the production of electricity and heat (reported under 1A Fuel combustion). A fraction of landfill gas is used to generate heat only. A very small fraction of the landfill gas is flared (reported under 5A).

Methane emissions are estimated by using a First Order Decay (FOD) model compliant with IPCC 2006 (see below). Following legal requirements and regulations it is assumed that open burning ceased after 1990 (Consaba 2016).

Table 6-1: Specification of source category 5A Biological treatment of waste - Solid waste disposal on land.

5A	Source category	Specification
5A	Solid waste disposal on land	Emissions from handling of solid waste on landfill sites

Source category 5A Biological treatment of waste - Solid waste disposal on land is not a key category.

6.2.2 Methodological issues of 5A Biological treatment of waste - Solid waste disposal on land

Methodology (5A)

The emission modelling corresponds to a Tier 2 approach. See decision tree in chapter 5A Biological treatment of waste – Solid waste disposal on land of the EMEP/EEA guidebook (EMEP/EEA 2019).

The main emission from landfills is the greenhouse gas CH₄, 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 CH₄ are calculated in several steps, the details are described in Switzerland’s National Inventory Report (FOEN 2021):

1. CH₄ emissions are modelled with the FOD model according to IPCC 2006.
2. The amount of CH₄ that is recovered and used as fuel for combined heat and power generation as well as for flaring is subtracted from the total CH₄ generated in landfills.
3. Emissions of air pollutants from burning methane in engines and torches are calculated. Their amount is proportional to the CH₄ 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 2022/1A1a & 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 2020 for 5A Biological treatment of waste - Solid waste disposal on land.

5A1 Solid waste disposal on land	Unit	NO _x	NM VOC	NH ₃	PM _{2.5} ex	PM ₁₀ ex	TSP ex	CO	PCB
Flaring	kg/t CH ₄ produced	1	0.082	NA	0.4	0.4	0.4	17	NA
Direct emission	kg/t CH ₄	NA	13	20	NA	NA	NA	NA	NA
Direct emission	g/t PCB	NA	NA	NA	NA	NA	NA	NA	11

Activity data (5A)

The main activity data for 5A Biological treatment of waste - Solid waste disposal on land are the waste quantities disposed on landfills that are used for calculating the amount of methane produced. Activity data are taken from EMIS 2022/1A1a & 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 2022/1A1a & 5A).

5A1 Solid waste disposal on land	Unit	1990	1995	2000	2005	2010					
Total waste quantity	kt	860	628	350	16	NO					
Municipal solid waste (MSW)	kt	650	540	292	14	NO					
Construction waste (CW)	kt	150	60	54	1.4	NO					
Sewage sludge (SS)	kt (dry)	60	28	4.2	0.98	NO					
Open burned waste	kt	NO	NO	NO	NO	NO					

5A1 Solid waste disposal on land	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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 CH₄ flared (see Table 6-4). The quantity of CH₄ 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	2010					
CH ₄ flared	kt	1.8	5.3	5.6	3.4	2.4					
PCB quantity available	kt	0.40	0.37	0.35	0.33	0.32					

5A1 Solid waste disposal on land	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CH ₄ flared	kt	2.1	1.8	1.6	1.4	1.4	1.4	1.4	1.4	1.4	1.4
PCB quantity available	kt	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30

The emissions from using methane as fuel for combined heat and power generation in engines are reported under 1A1a Energy industries.

6.2.3 Category-specific recalculations in 5A Biological treatment of waste - Solid waste disposal on land

The following recalculations were implemented in submission 2022:

- 5A1 Managed waste disposal sites: A new emission factor for direct emissions of NMVOC has been introduced based on EMEP Guidebook 2019 recommendations (5A Chapter 3.2.2). A fraction of 1.3 % of all VOC emissions (1.317 % of CH₄ emissions) occur as NMVOC. This has led to annual NMVOC emissions of 405-150 t.
- 5A1 Managed waste disposal sites: A new emission factor for emissions of NMVOC from flaring has been introduced based on a study on emissions from landfill gas installations (Butz 2003) suggesting NMVOC emissions equalling to 82.15 g/t CH₄ flared ± 10 %. This has led to annual NMVOC emissions of 510-110 kg.

6.3 Source category 5B - Biological treatment of waste - Composting and anaerobic digestion at biogas facilities

6.3.1 Source category description of 5B Biological treatment of waste - Composting and anaerobic digestion at biogas facilities

The source category 5B Biological treatment of waste comprises the emissions from 5B1 Composting and from 5B2 Anaerobic digestion at biogas facilities. Emissions from combined

heat and power generation using biogas from digestion are reported under 1A2gviii Other and 1A4a Commercial/Institutional.

5B1 Composting distinguishes between industrial composting and backyard composting. Industrial composting covers emissions from centralized composting activities with a capacity of more than 100 tonnes of organic matter per year as well as the composting of organic material at the border of agricultural fields. Backyard composting in private households or communities is common practice in Switzerland. Activity data and emission factors for industrial and backyard composting have been thoroughly reassessed in 2017, new data were gained and EMIS 2022/5B1 Kompostierung has been revised accordingly.

Within 5B2 Anaerobic digestion at biogas facilities two plant types are distinguished: (1) industrial biogas plants and (2) agricultural biogas plants. Biogas upgrading is treated as a separate process covered in this source category; however this only induces methane emissions due to leakage and is therefore not relevant for the CLRTAP Inventory. The digestion of organic waste takes place under anaerobic conditions. The digestate (solid and liquid output after completion of a process of anaerobic microbial degradation of organic matter) is composted or directly used as fertiliser, respectively. The biogas generated during the digestion process is used for combined heat and power generation or upgraded and used as fuel for cars or fed into the natural gas grid.

Table 6-5: 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)

A Tier 2 method is applied to estimate emissions from 5B1 Composting (see decision tree in chapter 5B1 Biological treatment of waste – Composting of the EMEP/EEA guidebook (EMEP/EEA 2019).

Emissions from 5B2 Anaerobic digestion are estimated by applying a Tier 2 method (see decision tree in chapter 5B2 Biological treatment of waste – Anaerobic digestion at biogas facilities of the EMEP/EEA guidebook (EMEP/EEA 2019).

Figure 6-3 depicts a schematic design of an industrial biogas plant. Six emission-relevant process steps are taken into account. For each process step separate activity data and emission factors are used:

- P1: Emissions from the storage of organic waste
- P2: Emissions from fermentation
- P3: Emissions from the interim storage of liquid digestate
- P4: Emissions from on site aerobic after treatment of solid digestate
- P5: Emissions from the utilisation of biogas in combined heat and power generation units
- P6: Emissions from flaring of biogas

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

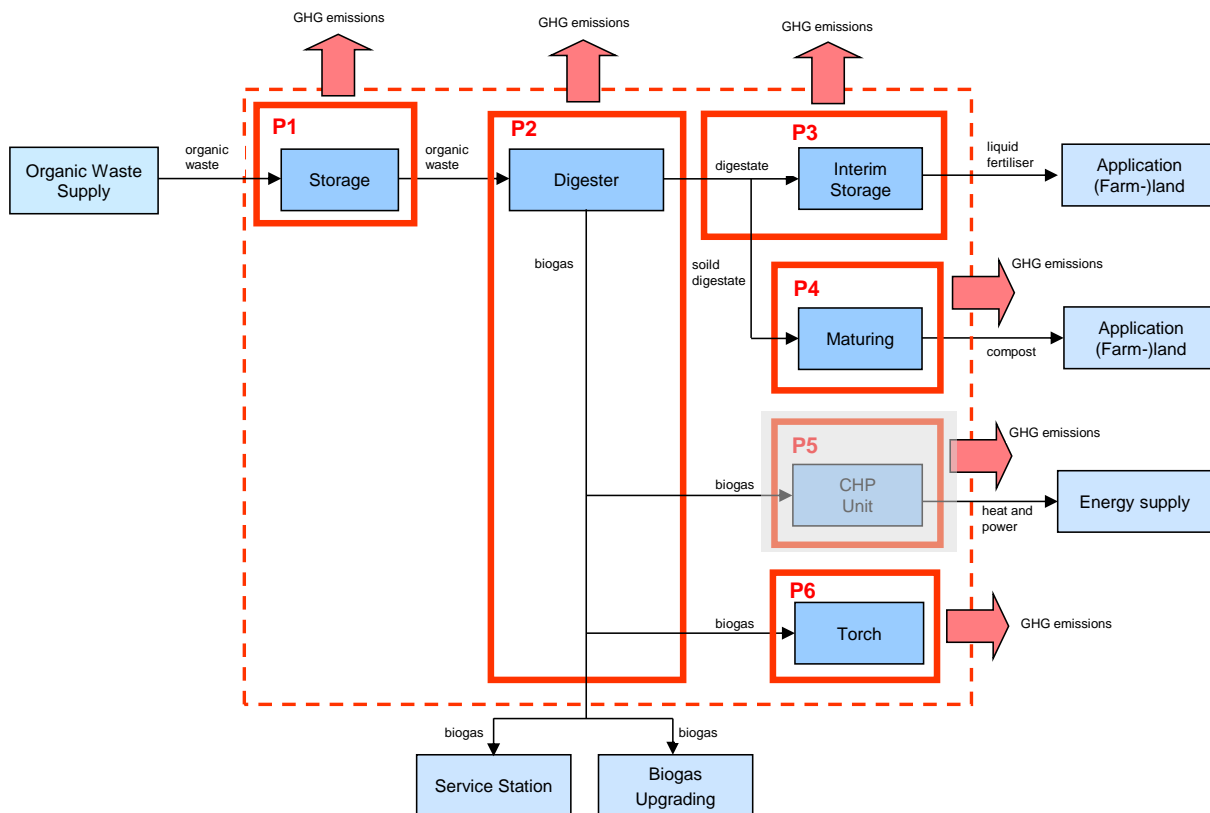


Figure 6-3: Schematic design of an industrial biogas plant.

Figure 6-4 depicts a schematic design of an agricultural biogas plant. It is very similar to the scheme of the industrial biogas plant described above. Seven process steps are distinguished where emissions might occur. For each process step separate activity data and emission factors are used:

- P1: Emissions from the intermediate storage of the waste from animal husbandry (liquid and solid manure) and the additional co-substrate.
- P2: Losses due to leakage from the fermenter, gas piping and overproduction
- P3: Emissions from the storage of liquid digestate
- P4: Emissions from aerobic after treatment of solid digestate
- P5: Emissions from the utilisation of biogas in combined heat and power generation units
- P6: Emissions from the utilisation of biogas in the gas boiler
- P7: Emissions from flaring of biogas

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

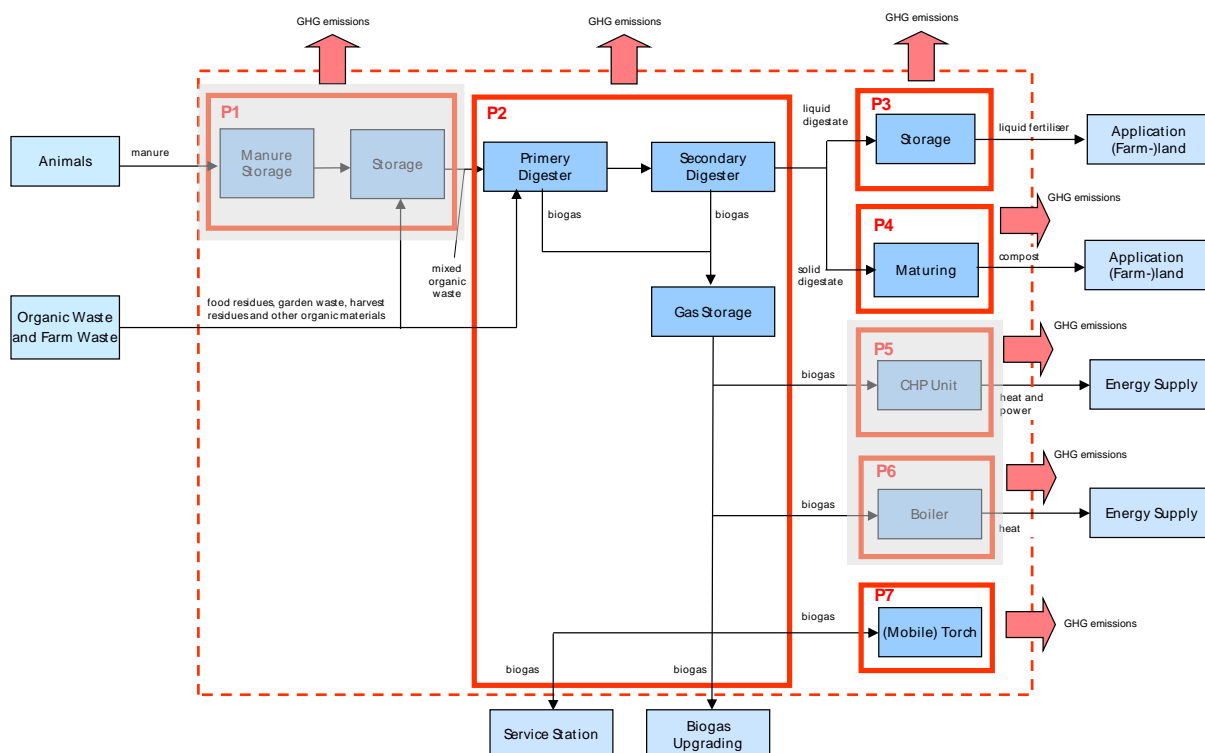


Figure 6-4: Schematic design of an agricultural biogas plant.

Emission factors (5B)

Emission factors for 5B1 Composting are country-specific based on measurements and expert estimates (EMIS 2022/5B1 Kompostierung). Emission factors are assumed to remain constant over the reporting period.

Emission factors for 5B2 Anaerobic digestion are country-specific based on measurements according to Edelmann and Schleiss (1999), Cuhls et al. (2010) and Butz (2003) as documented in comments to the database (EMIS 2022/1A2g and 5B2 Vergärung IG and EMIS 2022/1A4a and 5B2 Vergärung LW). Table 6-6 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 2020.

5B Composting and anaerobic digestion at biogas facilities	Unit	NOx	NM VOC	SO ₂	NH ₃	PM2.5 ex	PM10 ex	TSP ex	CO
Composting (industrial)	g/t composted waste	NA	550	NA	917	NA	NA	NA	NA
Composting (backyard)	g/t composted waste	NA	550	NA	917	NA	NA	NA	NA
Digestion (ind., digestable waste / storage)	g/t digestable waste	NA	70	NA	5.6	NA	NA	NA	NA
Digestion (ind., digested waste liquid / storage)	g/t digested waste (liquid)	NA	400	NA	80	NA	NA	NA	NA
Digestion (ind., digested waste solid / rotting)	g/t digested waste (solid)	NA	230	NA	104	NA	NA	NA	NA
Digestion (ind., flaring, CH ₄)	g/t CH ₄	4066	82	616	NA	37	37	37	2054
Digestion (agr., digested waste liquid / process water)	g/t digested waste (liquid)	NA	400	NA	80	NA	NA	NA	NA
Digestion (agr., digested waste solid / rotting)	g/t digested waste (solid)	NA	230	NA	104	NA	NA	NA	NA
Digestion (agr., flaring, CH ₄)	g/t CH ₄	4066	82	616	NA	37	37	37	2054

Activity data (5B)

Activity data for 5B Biological treatment of waste are extracted from EMIS 2022/5B1 Kompostierung, EMIS 2022/1A1a and 5B2 Vergärung IG and EMIS 2022/1A1a and 5B2 Vergärung LW. Activity data for digestion are based on reliable statistical data from the statistics of renewable energies (SFOE 2021a). Activity data for industrial and backyard composting are based on a study by Schleiss (2017) using data of the years 1989, 1993, 2000 and 2013, supplied by plant operators. From 2014 onwards, activity data for industrial composting are adopted from the annual statistical reports by the inspectorate system for the Composting and Fermentation Industry in Switzerland CVIS as recommended by Schleiss (2017). As of 2012, activity data for backyard composting are assumed to be constant as recommended by Schleiss (2017). Data on the amount of waste is provided in tonnes of wet matter. In order to comply with UNFCCC reporting guidelines, a factor 0.545 (CVIS 2019) is applied for the conversion of wet substance to dry substance.

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

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

5B Composting and anaerobic digestion at biogas facilities	Unit	1990	1995	2000	2005	2010					
Composting (industrial)	kt dry	131	196	283	287	289					
Composting (backyard)	kt dry	60	84	98	93	65					
Digestion (ind., digestable waste / storage)	kt wet	NO	27	60	108	289					
Digestion (ind., digested waste liquid / storage)	kt wet	NO	15	33	60	161					
Digestion (ind., digested waste solid / rotting)	kt wet	NO	9.4	20	37	99					
Digestion (ind., flaring, CH ₄)	kt	NO	0.037	0.10	0.18	0.51					
Digestion (agr., digested waste liquid / process water)	kt wet	113	94	125	181	569					
Digestion (agr., digested waste solid / rotting)	kt wet	5.9	4.9	6.5	10	30					
Digestion (agr., flaring, CH ₄)	kt	NO	NO	NO	NO	0.12					

5B Composting and anaerobic digestion at biogas facilities	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Composting (industrial)	kt dry	290	291	292	261	234	274	267	259	296	285
Composting (backyard)	kt dry	60	55	55	55	55	55	55	55	55	55
Digestion (ind., digestable waste / storage)	kt wet	372	508	561	590	650	695	712	729	770	792
Digestion (ind., digested waste liquid / storage)	kt wet	207	283	313	329	362	387	397	406	429	441
Digestion (ind., digested waste solid / rotting)	kt wet	127	174	192	201	222	237	243	249	263	270
Digestion (ind., flaring, CH ₄)	kt	0.63	0.84	0.91	0.90	0.95	1.0	1.0	1.0	1.0	1.0
Digestion (agr., digested waste liquid / process water)	kt wet	612	711	829	940	1053	1201	1290	1416	1619	1767
Digestion (agr., digested waste solid / rotting)	kt wet	32	37	44	50	55	63	68	75	85	93
Digestion (agr., flaring, CH ₄)	kt	0.13	0.16	0.20	0.23	0.26	0.29	0.31	0.34	0.40	0.43

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

The following recalculation was implemented in submission 2022:

- 5B1 Composting (industrial and backyard): The unit of activity data and emission factors are now reported as weight dry mass instead of wet mass. A transfer factor from wet to dry mass of 54.5 % has been suggested by CVIS (2019). Thus, activity data for the years 1980-2019 have decreased by 45.5 % while emission factors for NH₃ and NMVOC have increased by the same factor (increase of 83.5 %). This leads to small changes in emissions from 5B1 Composting, due to rounding effects.

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 burning of waste.

5C	Source category	Specification
5C1a	Municipal waste incineration	Emissions from illegal incineration of municipal solid wastes at home; Emissions from waste incineration at construction sites (open burning)
5C1bi	Industrial waste incineration	Emissions from incinerating cable insulation materials
5C1bii	Hazardous waste incineration	PCB emissions from combustion of PCB contaminated waste oil (transformers and large capacitors, ceased in 1999)
5C1biii	Clinical waste incineration	Emissions from incinerating hospital waste in hospital incinerators (ceased in 2002)
5C1biv	Sewage sludge incineration	Emissions from sewage sludge incineration plants
5C1bv	Cremation	Emissions from the burning of dead bodies
5C2	Open burning of waste	Emissions from field burning of agricultural waste. Burning of gardening residues from private households is also integrated (small contribution compared to agriculture).

Table 6-9 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, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 5C Waste incineration and open burning of waste.

NFR code	Source category	Pollutant	Identification criteria
5C1a	Municipal waste incineration	PM2.5	L1, L2
5C1a	Municipal waste incineration	PM10	L1

6.4.2 Methodological issues of 5C Waste incineration and open burning of waste

Methodology (5C)

For the calculation of the emissions from municipal waste incineration (illegal burning of municipal waste) a Tier 2 method is used (see decision tree in chapter 5C1a Municipal waste incineration, EMEP/EEA 2019).

For the calculation of the emissions from the incineration of insulation materials from cables a Tier 2 method is used (see decision tree in chapter 5C1b Industrial waste incineration including special waste and sewage sludge, EMEP/EEA 2019).

Until 1999, also PCB emissions from so-called open burning of PCB contaminated waste oil in outdoor fires (i.e. outside of a container) occurred in Switzerland. They are modelled within the disposal category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

For the calculation of the emissions from clinical waste incineration a Tier 2 method is used (see decision tree in chapter 5C1biii Clinical waste incineration, EMEP/EEA 2019).

For the calculation of the emissions from sewage sludge incineration plants a Tier 2 method is used (see decision tree in chapter 5C1b Industrial waste incineration including special waste and sewage sludge, EMEP/EEA 2019).

For the calculation of the emissions from cremation a Tier 2 method is used (see decision tree in chapter 5C1bv Cremation, EMEP/EEA 2019).

For the calculation of the emissions from burning of agricultural and private gardening waste a country-specific Tier 2 method is used (see decision tree in chapter 5C2 Open burning of waste, EMEP/EEA 2019).

Emission factors (5C)

Emission factors are country-specific based on measurements and expert estimates as documented in the EMIS database (EMIS 2022/5C1 Abfallverbrennung illegal, EMIS 2022/5C1 Kabelbrand, EMIS 2022/5C1 Spitalabfallverbrennung, EMIS 2022/5C1 Krematorien, EMIS 2022/5C1 Klärschlammverbrennung, EMIS 2022/5C2 Abfallverbrennung Land- und Forstwirtschaft).

The emission factor of dioxine for 5C1 Illegal waste incineration in particular is defined based on Wevers et al. (2004) and Lemieux et al. (2003). Emission factors for the other pollutants of 5C1 Illegal waste incineration are based on SAEFL (2000) and USEPA (1995, Chapter 2.5 Open Burning).

Emission factors for 5C2 Open burning of agricultural and private gardening waste were, upon recommendation by INFRAS (2014) taken from the EMEP/EEA guidebook (EMEP/EEA 2019, chp. 5.C.2, table 3-2). INFRAS (2014) concluded, that Tier 2 default emission factor for incineration of natural residues in forestry would best account for emission factors for incineration of natural residues in agriculture and private gardens as well, except for NH₃ (EMEP/EEA 2002), Hg (Sigler et al. 2003) and lcdP (USEPA 1998, Table 4.10.5-1 Open burning of Municipal Refuse).

The emission factors for 5C1b Sewage sludge incineration for the year 1990 are taken from SAEFL (2000). The emission factors for the year 2002 are based on emission declarations of plants in the region of Basel (accounting for about 1/3 of the national total quantities). Emission factors for 2015 have been re-investigated based on emission declarations of the same plants in the region of Basel. Based on 27 air pollution control measurement reports under the Ordinance on Air Pollution Control of 11 different sewage sludge incineration plants, emission factors have again been estimated for 2018 (TBF 2021). For documentation see EMIS 2022/5C1 (5C1biv UNECE) Klärschlammverbrennung. From 1990 to 2002 from

2002 to 2015 and from 2015 to 2018 emission factors are interpolated linearly. From 2018 onwards the emission factors are assumed to be constant.

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

Table 6-11: Emission factors for 5C Waste incineration and open burning of waste in 2020. Unit of PCDD/PCDF is in I-TEQ.

5C Incineration and open burning of waste	Unit	NOx	NM VOC	SO ₂	NH ₃	PM _{2.5} ex	PM ₁₀ ex	TSP ex	CO
Clinical waste incineration	g/t waste	1'500	300	1'300	NA	1'100	1'600	2'200	1'400
Illegal waste incineration	g/t waste	2'500	16'000	750	NA	14'400	16'000	20'000	50'000
Insulation material from cables	g/t cable	1'300	500	6'000	NA	62	410	510	2'500
Sewage sludge incineration	g/t sludge	400	189	162	19	28	40	40	97
Open burning of natural residues in agriculture	g/t wood	1'380	1'470	30	800	3'760	4'130	4'310	48'790
Open burning of natural residues in private households	g/t wood	1'380	1'470	30	800	3'760	4'130	4'310	48'790
Cremation	g/cremation	210	6.0	NA	NA	14	14	16	41

5C Incineration and open burning of waste	Unit	Pb	Cd	Hg	PCDD/ PCDF	BaP	BbF	BkF	lcdP
Clinical waste incineration	mg/t waste	25'000	1'100	16'000	0.46	NA	NA	NA	NA
Illegal waste incineration	mg/t waste	100'000	200	100	0.16	0.34	0.2	0.27	0.1
Insulation material from cables	mg/t cable	80'000	1'900	200	0.017	NA	NA	NA	NA
Sewage sludge incineration	mg/t sludge	280	33	200	0.00014	NA	NA	NA	NA
Open burning of natural residues in agriculture	mg/t wood	320	130	60	0.01	3'150	6'450	5'150	1'700
Open burning of natural residues in private households	mg/t wood	320	130	60	0.01	3'150	6'450	5'150	1'700
Cremation	mg/cremation	50	NA	100	0.0006	NA	NA	NA	NA

Activity data (5C)

The clinical waste incineration quantities are based on rough expert estimates (EMIS 2022/5C1 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 estimate the quantity of illegal waste, the percentage quotation is multiplied by the total amount of municipal solid waste and waste from construction work (EMIS 2022/5C1 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 2021c). 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 decreasing 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 2022/5C2 Abfallverbrennung Land- und Forstwirtschaft). As a consequence of the greenhouse gas inventory UNFCCC in-country review 2016, greenhouse gas emissions from open burning of natural residues in forestry (5C2ii) were moved to sector 4V in the greenhouse gas inventory. The corresponding air pollutant emissions have been moved to 11B Forest fires within the informative inventory report (chp. 7.3).

Table 6-12: 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	2010					
Total	kt	134	105	109	132	124					
Clinical waste incineration	kt	15	8.8	2.5	NO	NO					
Illegal waste incineration	kt	32	26	25	22	21					
Insulation material from cables	kt	7.5	NO	NO	NO	NO					
Open burning of PCB	kt	0.0011	0.00020	NO	NO	NO					
Sewage sludge incineration	kt dry	57	50	64	95	90					
Open burning of natural residues in agriculture	kt	16	15	14	13	12					
Open burning of natural residues in private households	kt	6.1	4.9	3.6	2.4	1.2					
Cremation	Numb.	37'513	40'968	44'821	48'169	52'813					
5C Incineration and open burning of waste	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	kt	116	108	126	124	129	130	132	128	129	126
Clinical waste incineration	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Illegal waste incineration	kt	20	20	20	19	19	19	18	18	17	17
Insulation material from cables	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Open burning of PCB	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge incineration	kt dry	83	75	94	93	97	99	102	98	100	97
Open burning of natural residues in agriculture	kt	11	11	11	11	11	11	11	11	10	10
Open burning of natural residues in private households	kt	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1
Cremation	Numb.	52'530	50'567	53'205	55'616	59'664	54'634	57'694	54'842	57'746	68'148

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 2022:

- 5C1biv sewage sludge incineration: Emission factors for all relevant air pollutants have changed from 2016 to 2020 in the framework of a study evaluating reports of emission measurements carried out in the period 2015-2020 on several sewage sludge incineration plants in Switzerland.

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 either individual cities or several cities and/or municipalities together. Wastewater in general is treated in three consecutive steps: 1. mechanical treatment, 2. biological treatment, and 3. chemical treatment. The treated wastewater flows into a receiving system (lake, river or stream). The wastewater treatment infrastructure in Switzerland is now virtually complete (FOEN 2017I). The vast majority of WWTP apply anaerobic sludge treatment with sewage gas recovery and use the sewage gas for combined heat and power production.

The source category 5D2 Industrial wastewater handling includes all emissions from liquid wastes and sludge from industrial processes such as food processing, textiles, car-washing places and electroplating plants as well as pulp and paper production. These processes may result in effluents with a high load of organics. Depending on the contaminants, an on-site pre-treatment is necessary in order to reduce the load of pollutants in the wastewater to meet the regulatory standards (which are in place to preclude disruptions of the municipal 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 municipal solid waste incineration plants (1A1a), Sewage sludge incineration plants (5C) or used as alternative fuel in the cement industry (1A2f).

The emissions from the use of sewage gas for combined heat and power generation as well as in boilers are reported in sector 1 Energy in source category 1A2gviii Other.

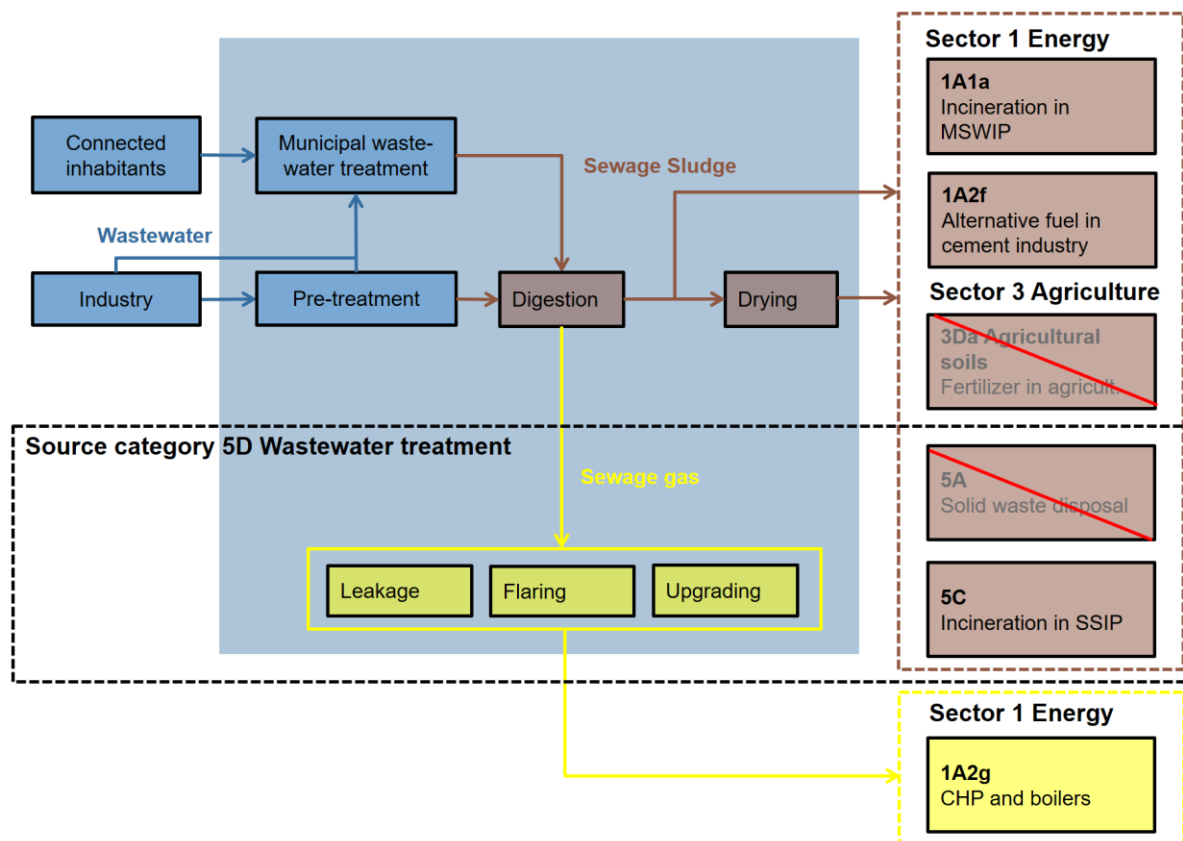


Figure 6-5: System boundaries of emissions related to wastewater handling. Abbreviations: CHP Combined Heat and Power Generation, MSWIP municipal solid waste incineration plant, SSIP sewage sludge incineration plant.

6.5.2 Methodological issues of 5D Wastewater handling

Methodology (5D)

For 5D1 Domestic wastewater handling and 5D2 Industrial wastewater handling, a Tier 2 method is used (see decision tree in chapter 5D Wastewater handling, EMEP/EEA 2019).

For 5D1 Domestic wastewater handling emission factors are calculated on the basis of the total emissions divided by the number of inhabitants (Swiss population, SFSO 2021c). 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 2022/5D1, EMIS 2022/5D2), see Table 6-14.

Table 6-14: Emission factors for 5D Wastewater handling in 2020.

5D Wastewater handling	Unit	NO _x	NM VOC	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	0.12	0.0024	0.00061	NA	0.061

Activity data (5D)

Activity data for 5D1 Domestic wastewater handling and 5D2 Industrial wastewater handling are the total number of inhabitants extracted from SF50 (2021c). 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 wastewater systems are indicated below for informational reason.

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

5D Wastewater handling	Unit	1990	1995	2000	2005	2010
Inhabitants	persons in 1000	6'712	7'041	7'184	7'437	7'825
Fraction connected to waste water treatment plants	%	90.0	93.7	95.4	96.8	97.2
Inhabitants connected	persons in 1000	6'041	6'597	6'854	7'199	7'606

5D Wastewater handling	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Inhabitants	persons in 1000	7'912	7'997	8'089	8'189	8'282	8'373	8'452	8'514	8'575	8'638
Fraction connected to waste water treatment plants	%	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3	97.3
Inhabitants connected	persons in 1000	7'698	7'781	7'871	7'968	8'058	8'147	8'224	8'284	8'343	8'405

6.5.3 Category-specific recalculations in 5D Wastewater handling

There were no recalculations implemented in submission 2022.

6.6 Source category 5E – Other waste, shredding

6.6.1 Source category description of 5E Other waste, shredding

In source category 5E only shredding of cars and electronic waste containing PCBs in small capacitors is considered.

Sewage sludge spreading is a drying process not occurring in Switzerland: In Swiss wastewater treatment plants, sewage sludge, after anaerobic digestion and generation of biogas, is stored in sludge tanks and in a first step, chemical and mechanical means are applied to dehydrate the sludge. Of the dehydrated sewage sludge, 70 – 80 % is incinerated in municipal solid waste incineration plants or in dedicated sewage sludge incineration plants. The remaining 20 – 30 % is used as alternative fuel in the cement industry (1A2f). For this purpose, the water content of the sludge has to be reduced to 10 %, which requires thermal drying processes. However in Switzerland, due to restrictions in available space, sludge spreading is not applied as a method for drying. The thermal drying predominantly occurs in large thermal drying plants equipped with flue gas treatment systems. Hence emission from sludge spreading (5E) is a process not applicable.

Table 6-16: 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, 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 2022/5E Shredder Anlagen). For all years, emission factors are considered to remain constant. The PCB emission factor expressed in units per tonnes of PCBs shredded is based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 6-17: Emission factors for 5E Other waste, car shredding and shredder in 2020. Unit of PCDD/PCDF is in I-TEQ.

5E Other waste	Unit	NMVOG	PM2.5 nx	PM10 nx	TSP nx	CO	Pb	Cd	PCDD/ PCDF	PCB
Car shredding	g/t scrap	200	5	10	12	5	0.022	0.0025	0.0000004	NA
Shredder	t/t PCB	NA	NA	NA	NA	NA	NA	NA	NA	0.071

Activity data (5E)

The quantities of shredded cars from 1990 are data provided by the Swiss shredder association. The data from 2003 and 2007 are taken from Swiss waste statistics. In between years are interpolated. From 2007 onwards the quantities are assumed to remain constant due to the lack of data (EMIS 2022/5E Shredder Anlagen). For PCB emissions, the activity data is the amount of PCBs shredded based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2. As a consequence of the legal ban of disposal of combustible waste in landfills, a sharp increase in shredding of small capacitors occurred in 1999 although they should have been treated as special waste from 1998 onwards.

Table 6-18: Activity data for car shredding (source EMIS 2022/5E Shredder Anlagen)

5E Other waste	Unit	1990	1995	2000	2005	2010
Car shredding	kt	280	300	300	300	300
Shredder	t PCB	3.0	3.3	10	3.5	0.71

5E Other waste	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Car shredding	kt	300	300	300	300	300	300	300	300	300	300
Shredder	t PCB	0.58	0.48	0.39	0.31	0.25	0.20	0.15	0.12	0.092	0.070

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

There were no recalculations implemented in submission 2022.

7 Other and natural emissions

7.1 Overview of emissions

In this introductory chapter, an overview of emissions, separated according to the most relevant pollutants is presented. Trends and changes for individual source categories in the period between 1990 and 2020 are analysed and discussed. In sectors 6 Other and 11 Natural emissions NH_3 , NO_x , $\text{PM}_{2.5}$ and NMVOC are the most relevant pollutants.

The following source categories are reported:

- 6Aa Humans
- 6Ab Pets
- 6Ac Fertilisers (private use)
- 6Ad Fire damages estates and motor vehicles
- 11B Forest fires and open burning of residues in forestry
- 11C Other natural emissions (NMVOC from forest stands)

Active volcanoes (11A) do not occur in Switzerland.

7.1.1 Overview and trend for NH_3

Figure 7-1 shows the trend of NH_3 emissions in sector 6 Other and natural emissions since 1990. The source category 6A Other sources is a key category for NH_3 . Total emissions fluctuate and have slightly increased within the reporting period. Emissions from source category 6Ab Pets, which includes livestock outside agriculture, contributes the largest share to total emissions; the emissions fluctuate due to the variability in the number of livestock outside agriculture. Emissions from the other two source categories 6Aa Humans and 6Ac Fertilisers have remained stable during past years, although 6Aa shows a very slight increase with the increasing trend in the population.

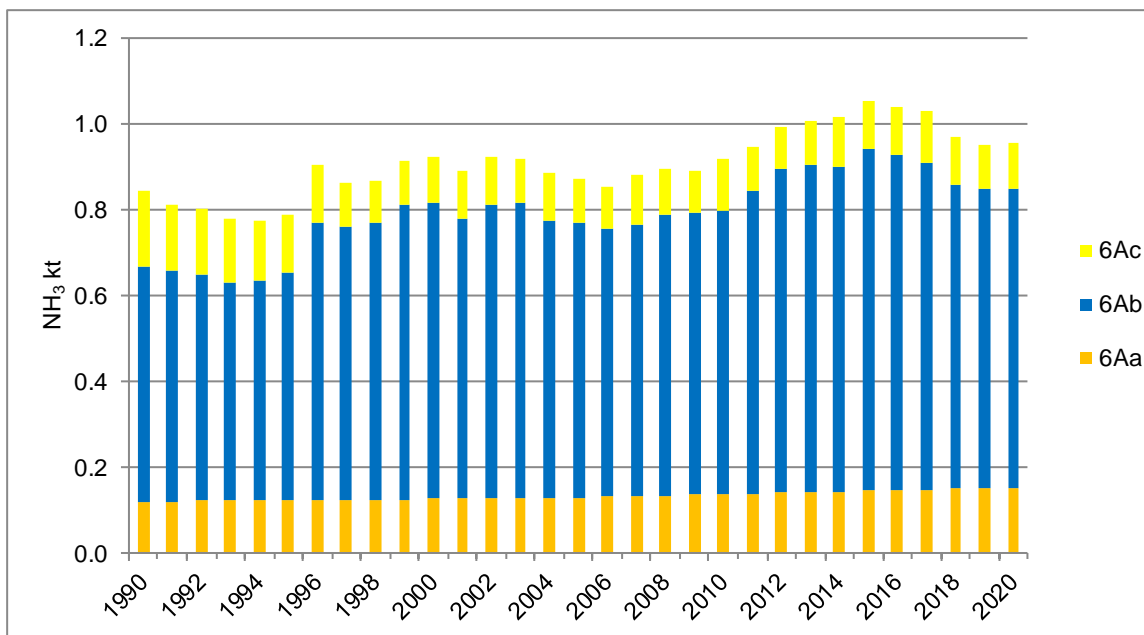


Figure 7-1: Switzerland’s NH₃ emissions from sector 6 Other and natural emissions by source categories 6Aa, 6Ab and 6Ac. The corresponding data table can be found in Annex A7.6.

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 2020 are summarised in Figure 7-2. The contribution of sector 6A is very small in comparison to the national total and is not a key category for NO_x. The overall emissions fluctuate due to changes in the number of livestock outside agriculture, which are included in 6Ab, but remain at about the same (low) level within the reporting period. For all years, 6Ab Pets and 6Ac Fertilizers contribute the bulk to total emissions. Emissions from 6Ac Fertilizers show a slight decrease during the reporting period. Emissions from 6Ad Fire damages estates and motor vehicles remained stable.

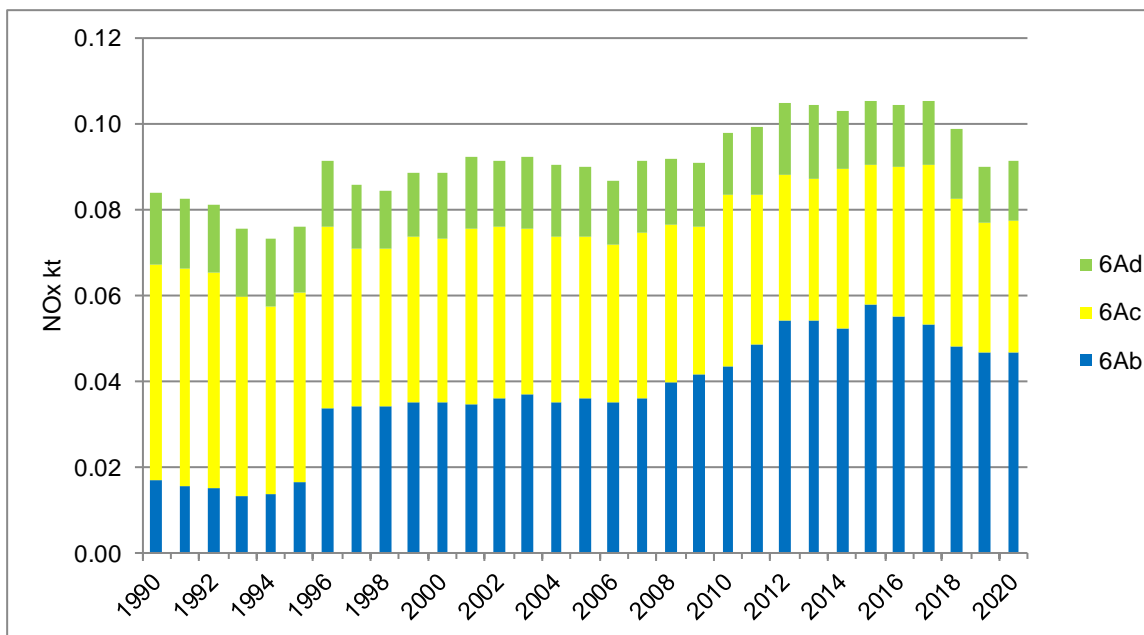


Figure 7-2: Switzerland's NO_x emissions from the sector 6 Other and natural emissions by source categories 6Ab, 6Ac and 6Ad. The corresponding data table can be found in Annex A7.6.

7.1.3 Overview and trend for PM_{2.5}

Figure 7-3 depicts the trend of PM_{2.5} emissions in sector 6 Other and natural emissions since 1990. The contribution of sector 6A is very small in comparison to the national total and is not a key category for PM_{2.5}. Emissions from source category 6Ab Pets, which includes livestock outside agriculture, fluctuate due to changes in the number of livestock outside agriculture and they show an increasing trend from 2008 to 2015. Emissions from 6Ad Fire damages estates and motor vehicles are the other relevant source category; they are relatively stable.

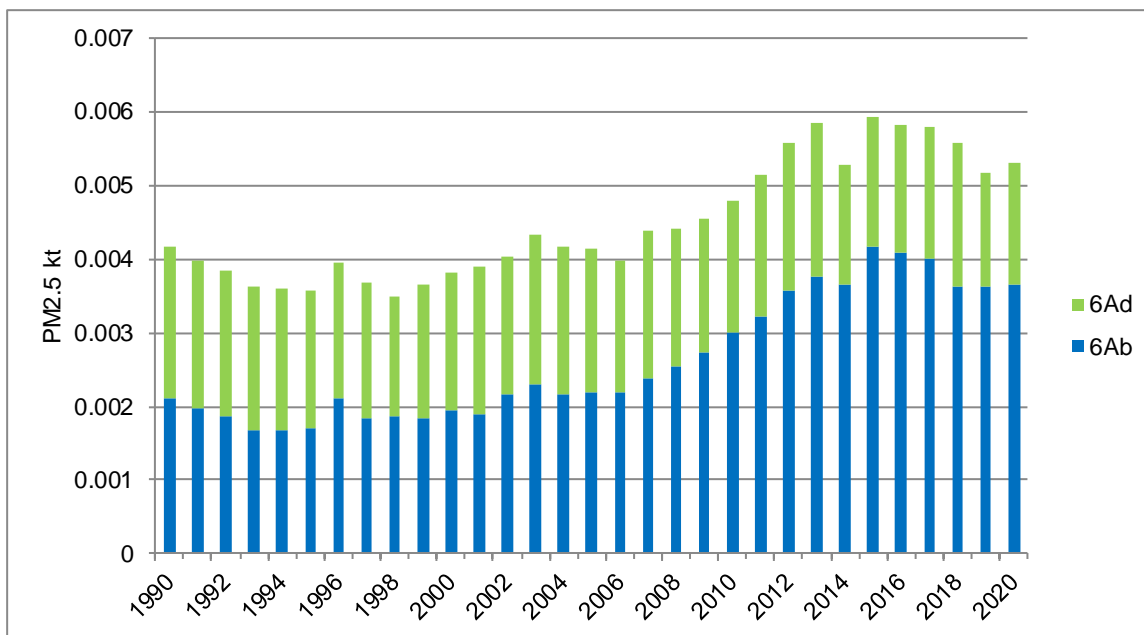


Figure 7-3: Switzerland's PM2.5 emissions from the sector 6 Other emissions. The corresponding data table can be found in Annex A7.6.

7.1.4 Overview and trend for NMVOC from Forests

Figure 7-4 depicts the trend of NMVOC emissions in the sector 11C Other natural emissions since 1990 for various tree species. The emissions stem predominantly from Norway spruce, fir and oak stands. They are considerably high in comparison to the national total of NMVOC emissions. However, sector 11C is reported as a memo item only and therefore not a key category for NMVOC. Total emissions in 1990 were 60.8 kt; they are increasing on average by 0.34 % per year. The annual fluctuations are due to the meteorological conditions, which influence the emission rates of the trees.

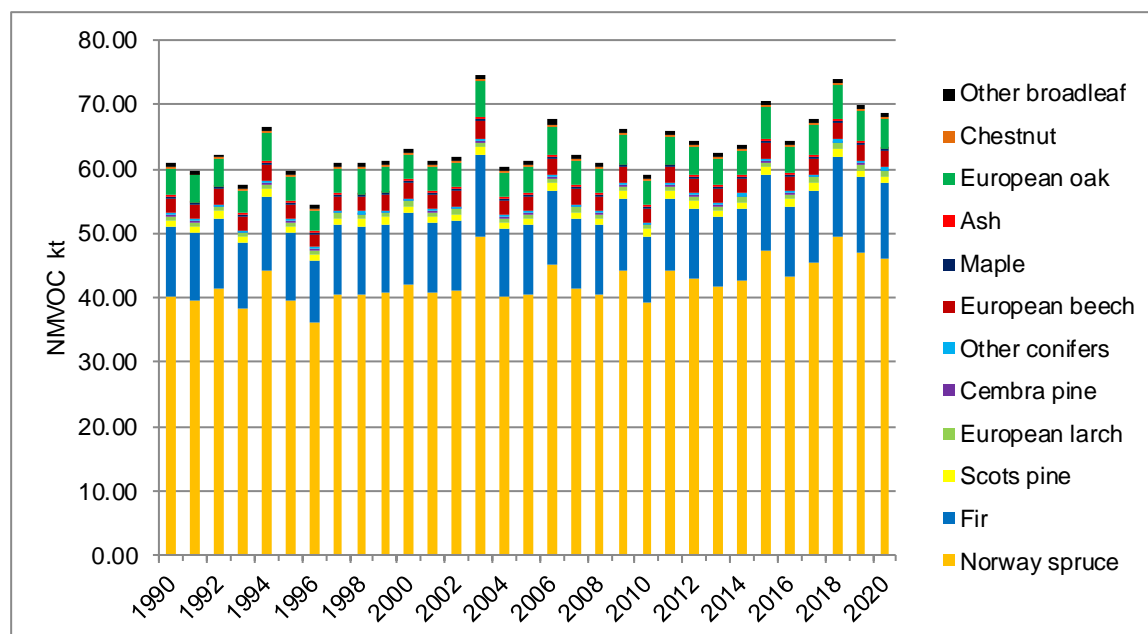


Figure 7-4: Switzerland’s NMVOC emissions from the sector 11C Other natural emissions (forest stands).

7.2 Source category 6 - Other emissions

7.2.1 Source category description of 6 Other emissions

Within the sector 6 Other emissions, emissions from the sources as shown in Table 7-1 are considered.

Table 7-1: Specification of sector 6 Other emissions.

6A	Source category	Specification
6Aa	Human emissions	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 and urea	NOx and ammonia emissions
6Ad	Fire damages and accidental PCB release	Emissions from fires in buildings and emissions from fires and fire damage in motor vehicles Emissions from accidental PCB releases by fire and to soil

Table 7-2: Key categories, approaches 1 and 2, level assessment 2020 (L1, L2) and trend assessment 1990-2020 (T1, T2) for source category 6A Other emissions.

NFR code	Source category	Pollutant	Identification criteria
6A	Other sources	NH3	L2, T2

7.2.2 Methodological issues of 6 Other emissions

Methodology (6A)

Human emissions (6Aa)

Other and natural emissions

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, NH₃ and particulate matter (PM_{2.5}, 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 NH₃ emissions from application of inorganic fertilisers in agriculture (source category 3Da1) is a Tier 2 approach of the EMEP/EEA guidebook (EMEP/EEA 2019) taking into account the specified list of fertilisers, climate zone and pH. This methodology is applied to source category 6Ac.

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

Emissions from fire damage in estates are calculated as follows: The fire insurance association of the cantons (Vereinigung kantonaler Feuerversicherungen, VKF) publishes the number of fire incidents in buildings each year and the total sum of monetary damage. Data from 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 2022/6A).

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 2022/6A). 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 accidental release category of the dynamic mass flow model developed for the usage of PCBs in Switzerland (Glüge et al. 2017), see Annex A2.2.

Emission factors (6A)

The emission factors for the source categories 6Aa to 6Ac are depicted in Table 7-3. Emission factors for fertiliser see also Table 5-14.

Ammonia emissions (6Aa-6Ac)

Emission factors for human ammonia emissions are extracted from Sutton et al (2000). Emission factors for pet 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).

NO_x, NMVOC, PM_{2.5}, PM₁₀ and TSP non-exhaust (6Ab)

The emission factors for NO_x, NMVOC, PM_{2.5}, 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 2020 in sector 6 Other emissions (source EMIS 2022/6A).

6 Other emissions	Unit	NO _x	NMVOC	NH ₃	PM _{2.5} non-exh.	PM ₁₀ 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	458	985	3'299	36	90	217
Cats	g/animal	NA	NA	90	NA	NA	NA
Dogs	g/animal	NA	NA	400	NA	NA	NA
Zoo animals	g/t	NA	NA	41'400	NA	NA	NA
6Ac Private application of synthetic fertilizer and urea							
Fertilizer, outside agriculture	kg/t	18	NA	61	NA	NA	NA

Fire damages (6Ad)

Fire damages estates: Emission factors for CO, NO_x and SO₂ 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 2022/6A “Brand- und Feuerschäden Immobilien”). The emission factors of Pb, Cd, and Hg are country-specific based on measurements of a study about a cable recycling company in Switzerland (Graf 1990). It is assumed that the PCDD/PCDF emission factor is the same as for illegal waste incineration. The emission factor for B(a)P is taken from USEPA 1998 (Table 4.10.5-1 Open burning of municipal refuse).

Fire damage motor vehicles: Emission factors for CO, NO_x and SO₂ are country-specific based on measurements and expert estimates originally derived for wire burn off, documented in EMIS 2022/6A Brand- und Feuerschäden Motorfahrzeuge”. The PCDD/PCDF emission factors for fire damage of motor vehicles are determined by USEPA 1998 (chp. 4.10.2 Open burning of scrap tires). It is assumed that the emission factor for B(a)P is slightly higher than the study-based emission factor for B(a)P of car scrap due to higher B(a)P emission factor values of car tires.

Table 7-4 presents the emission factors used. 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 2020 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	NMVOG	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 accidental release of PCBs (6Ad)

The PCB emission factors from accidental release of PCBs by fire and to soil are expressed in units per tonnes of PCBs incinerated and stored in soil, respectively, see Table 7-5. They are based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 7-5: PCB emission factors for accidental release of PCB by fire and to soil, respectively, reported under 6Ad Other emissions in 2020 as kg/t released PCB.

6Ad Accidental 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, NMVOG, 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 food⁵.

Emissions from private fertiliser use (6Ac)

For 6Ac only mineral fertilisers (no urea-based fertilisers) are used for private applications outside agriculture.

⁵Verband für Heimtiernahrung VHN (<http://www.vhn.ch/>)

Table 7-6: Activity data causing N emissions in sector 6 Other emissions.

6 Other emissions		Unit	1990	1995	2000	2005	2010					
6Aa Human emissions												
Human respiration	person		6'712'000	7'041'000	7'184'000	7'437'000	7'825'000					
Human transpiration	person		6'712'000	7'041'000	7'184'000	7'437'000	7'825'000					
Children <1y	person		83'939	82'203	78'458	72'903	80'290					
Children 1-3y	person		238'030	253'652	237'941	217'302	229'471					
Aged inhabitants	person		9'000	9'752	10'504	11'029	17'357					
6Ab Pets and livestock outside agriculture												
Livestock, outside agriculture	animals		16'326	18'649	88'285	89'276	95'332					
Cats	animals		1'164'786	1'205'000	1'379'000	1'417'000	1'507'000					
Dogs	animals		456'015	438'000	513'000	487'000	445'000					
Zoo animals	t		140	140	140	140	140					
6Ac Private application of synthetic fertilizer and urea												
Fertilizer, outside agriculture	t		2'778	2'432	2'111	2'087	2'212					
6 Other emissions		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
6Aa Human emissions												
Human respiration	person		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	8'638'000
Human transpiration	person		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	8'638'000
Children <1y	person		80'808	82'164	82'731	85'287	86'559	87'883	87'381	87'851	86'172	85'914
Children 1-3y	person		235'267	239'384	243'262	245'703	250'182	254'577	259'729	261'823	263'115	261'404
Aged inhabitants	person		17'393	17'972	18'389	18'679	19'278	19'244	19'793	20'337	20'661	19'804
6Ab Pets and livestock outside agriculture												
Livestock, outside agriculture	animals		102'848	113'853	111'397	108'866	120'094	113'379	109'783	107'715	103'135	102'173
Cats	animals		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	1'722'313
Dogs	animals		475'500	506'000	511'297	518'360	521'891	521'891	513'816	505'740	504'375	503'009
Zoo animals	t		140	140	140	140	140	140	140	140	140	140
6Ac Private application of synthetic fertilizer and urea												
Fertilizer, outside agriculture	t		1'947	1'881	1'822	2'056	1'823	1'933	2'057	1'907	1'673	1'711

Fire damages and accidental release of PCBs (6Ad)

Activity data for source category fire damages and accidental release of PCBs (6Ad) are given in Table 7-7. For accidental release of PCBs by fire and to soil, the activity data are the amounts of PCBs incinerated and stored in soil, respectively, based on the dynamic mass flow model for the usage of PCBs in Switzerland, see Annex A2.2.

Table 7-7: Activity data in source category 6Ad Fire damages: Burnt goods (source EMIS 2022/6A).

6Ad Fire damages		Unit	1990	1995	2000	2005	2010					
Fire damage estates	kt		8.0	7.3	7.3	7.6	6.8					
Fire damage motor vehicles	kt		0.48	0.52	0.58	0.64	0.68					
6Ad Accidental release of PCB												
by fire	t		2.4	1.7	1.1	0.70	0.43					
to soil	t		39	41	41	41	41					
6Ad Fire damages		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fire damage estates	kt		7.4	7.8	8.0	6.3	6.8	6.6	6.9	7.4	5.9	6.3
Fire damage motor vehicles	kt		0.69	0.71	0.72	0.73	0.75	0.76	0.77	0.77	0.78	0.79
6Ad Accidental release of PCB												
by fire	t		0.39	0.35	0.32	0.29	0.26	0.24	0.22	0.20	0.18	0.16
to soil	t		41	41	41	41	40	40	40	40	40	40

7.2.3 Recalculations in 6 Other emissions

The following recalculations were implemented in submission 2022:

- 6Aa: The activity “number of residents in nursing homes” in 2019 has increased by 0.15 % (31 people), due to changes in the underlying statistics by the SFSO.
- 6Ab: The activity data of source category 6Ab Livestock outside agriculture were revised for the years 2018 and 2019 due to new estimates of the numbers for horses, mules and asses yielding revised emission factors of all pollutants (NO_x, NMVOC, NH₃ and PM) as well.

- 6Ab: NO_x and NH₃ emission factors from manure management and agricultural soils of livestock outside agriculture were recalculated for 1990-2019 due to changes in N excretions and calculations of the new version of the AGRAMMON-model.
- 6Ad: Activity data for 2019 (amount of burnt material) decreased by 15.9 % (1'122t), due to a change in the underlying statistics by the fire insurance association (VKF).
-

7.3 Source category 11B - Forest fires

7.3.1 Source category description of 11B Forest fires

Within 11B Forest fires, emissions of NO_x, NMVOC, SO_x, NH₃, particulate matter, CO, Pb, Cd, Hg, PCDD/PCDF and PAH are reported.

Table 7-8: Specification of source category 11B Forest fires in Switzerland.

11B	Source category	Specification
11B	Forest fires	Emissions from natural wildfires on forest land and grassland; emissions from open burning of natural residues in forestry

Note that emissions are reported under 11B Natural emissions but are not accounted for in the national totals and are reported as memo item only.

As a consequence of the greenhouse gas inventory UNFCCC 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 2022/4VA1-11B-NFR_Waldbrände). Between 1900 and 1990, the available fuel on forest land, i.e. the mean biomass stocks, increased by a factor of 2.3 (Kurz et al. 1998). This information was used to calculate time series of the emission factors for most pollutants. For burnt grassland, the emission factors remain constant.

Emission factors for open burning of natural residues in forestry are taken from EMEP guidebook (EMEP/EEA 2019, chp. 5.C.2, table 3-2) and USEPA as documented in EMIS 2022/5C2 Abfallverbrennung Land- und Forstwirtschaft.

Table 7-9: Emission factors 2020 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	NM VOC	SO ₂	NH ₃	PM _{2.5}	PM ₁₀	TSP	CO
Forest fires	kg/ha	87	500	43	43	1'000	1'200	1'800	2'280
Burning grassland	kg/ha	13	34	3	3	110	140	210	373
Open burning of natural residues in forestry	g/t	1'380	1'470	30	800	3'760	4'130	4'310	48'790
11B Forest fires	Unit	Pb	Cd	Hg	PCDD/F	BaP	BbF	BkF	IcdP
Forest fires	kg/ha	NE	NE	0.0014	0.0000004	0.08	0.14	0.14	0.18
Burning grassland	kg/ha	NE	NE	0.0014	0.0000004	0.08	0.14	0.14	0.18
Open burning of natural residues in forestry	g/t	0.32	0.13	0.06	0.00001	3.2	6.5	5.2	1.7

Activity data (11B)

The area of forest land and grassland burnt is provided by swissfire, a database of wildfires managed by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL 2021) as documented in the EMIS database (EMIS 2022/4VA1-11B-NFR_Waldbrände). For the years since 1990, the swissfire database is also used in the GHGI (FOEN 2021). Burnt grassland areas also include woody grassland.

The activity data for burning of silvicultural residues is decreasing since 1990 since legal burning is more strongly restricted, especially since the last revision of the corresponding article in the Swiss Federal Ordinance on Air Pollution Control in the year 2009 (Swiss Confederation 1985 as of 1 January 2009). Activity data are documented in EMIS 2022/5C2 Abfallverbrennung Land- und Forstwirtschaft.

Table 7-10: Activity data of 11B Forest fires, grassland fires and open burning of natural residues in forestry.

11B Forest fires	Unit	1990	1995	2000	2005	2010					
Forest fires	ha	1'067	363	47	41	26					
Burning grassland	ha	637	82	22	20	1.3					
Open burning of natural residues in forestry	kt	29	25	20	16	12					
11B Forest fires	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Forest fires	ha	171	26	24	43	43	256	106	55	16	11
Burning grassland	ha	66	14	3.6	2.6	8.0	212	38	29	16	30
Open burning of natural residues in forestry	kt	11	11	11	11	11	11	11	11	10	10

7.3.3 Recalculations in 11B Forest fires

The following recalculations were implemented in submission 2022:

- 11B: The time series of wildfires on forest land and grassland were recalculated with updated activity data from the Swissfire database in the years 1993, 2011, 2013, 2015, 2018 and 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.

Table 7-11: Specification of source category 11C Other natural emissions in Switzerland.

11C	Source category	Specification
11C	Other natural emissions	Natural NMVOC emissions from forest trees; NMVOC emissions from natural grassland

7.4.2 Methodology of 11C Other natural emissions

The biogenic NMVOC emissions from forests were calculated for the years 1900-2020 and 2050 on the basis of monthly maps for the parameters temperature, vegetation period and for 12 different tree species (Meteotest 2019a, EMIS 2022/11C Wald). This corresponds to the simplified method according to chapter 11C in the EMEP/EEA guidebook (EMEP/EEA 2019) which represents a Tier 2 approach. With the method used, the emissions for isoprene, monoterpene and OVOC (Oxygenated VOC) could be modelled for each month with a spatial resolution of 100 x 100 m.

The NMVOC emission of natural grassland is 0.51 kt yr⁻¹ for all years according to SAEFL (1996a).

Emission factors (11C)

Emission factors for NMVOC emissions of different tree species are specified in the EMIS database (Table 7-12). They represent annual implied emission factors derived from the monthly emission maps. The values after 2018 are interpolated between the modelled years 2018 and 2050.

Table 7-12: Implied emission factors 2020 of 11C NMVOC for different tree species.

11C Tree species	Unit	NMVOC
Norway spruce	g/ha	79'065
Fir	g/ha	83'553
Scots pine	g/ha	21'212
European larch	g/ha	10'227
Cembra pine	g/ha	13'958
Other conifers	g/ha	110'549
European beech	g/ha	10'714
Maple	g/ha	21'153
Ash	g/ha	7'798
European oak	g/ha	182'110
Chestnut	g/ha	12'300
Other broadleaf	g/ha	10'632

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 2022/11C Wald).

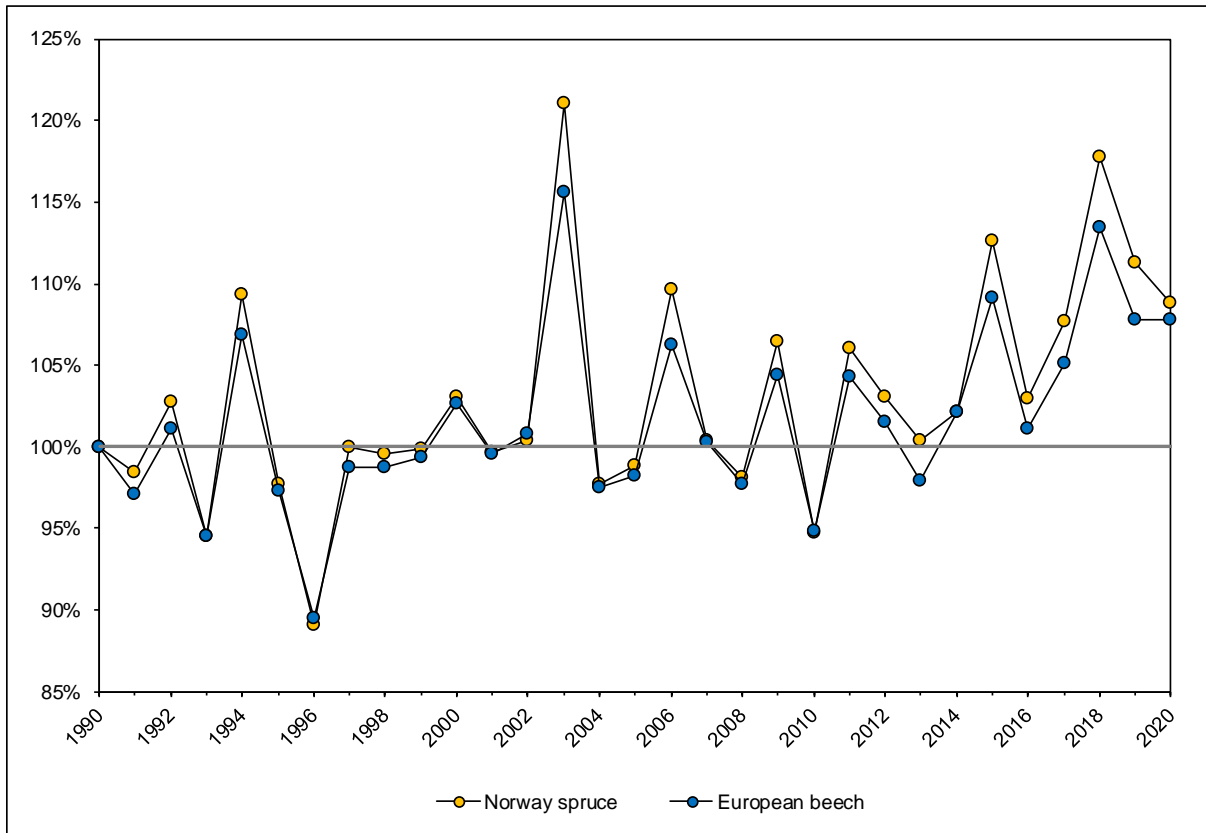


Figure 7-5: Relative trends of the (implied) NMVOC emission factors for two selected tree species 1990-2020.

Activity data (11C)

On the basis of several forest and area statistics, the area proportions of the various tree species and their temporal change over the years could be determined (Meteotest 2019a) as shown in Table 7-13.

Table 7-13: Activity data of 11C; forest areas covered by the twelve main tree species.

11C Tree species	Unit	1990	1995	2000	2005	2010
Total	ha	1'211'651	1'220'183	1'229'051	1'237'835	1'247'057
Total coniferous	ha	829'570	835'789	842'127	848'438	855'920
Norway spruce	ha	554'168	558'151	562'292	566'457	571'778
Fir	ha	138'196	138'374	138'497	138'634	138'930
Scots pine	ha	49'503	49'823	50'136	50'400	50'688
European larch	ha	73'421	74'919	76'432	77'933	79'282
Cembra pine	ha	11'025	11'261	11'502	11'745	11'964
Other conifers	ha	3'257	3'261	3'268	3'269	3'278
Total non-coniferous	ha	382'081	384'394	386'924	389'397	391'137
European beech	ha	226'751	227'722	228'738	229'799	230'716
Maple	ha	15'325	15'461	15'614	15'729	15'857
Ash	ha	28'555	28'655	28'782	28'911	28'991
European oak	ha	24'911	24'919	24'978	25'023	25'027
Chestnut	ha	26'877	27'097	27'353	27'578	27'674
Other broadleaf	ha	59'662	60'540	61'459	62'357	62'872

11C Tree species	Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	ha	1'248'869	1'250'769	1'252'632	1'254'489	1'256'307	1'258'136	1'260'026	1'261'840	1'263'687	1'265'518
Total coniferous	ha	857'434	859'020	860'557	862'131	863'641	865'167	866'724	868'212	869'778	871'331
Norway spruce	ha	572'877	574'022	575'109	576'243	577'328	578'465	579'544	580'618	581'777	582'896
Fir	ha	139'007	139'075	139'149	139'220	139'295	139'380	139'463	139'535	139'606	139'670
Scots pine	ha	50'755	50'820	50'870	50'939	51'002	51'056	51'119	51'163	51'219	51'269
European larch	ha	79'504	79'758	80'032	80'282	80'532	80'733	81'007	81'244	81'478	81'748
Cembra pine	ha	12'011	12'062	12'114	12'161	12'196	12'241	12'296	12'353	12'395	12'442
Other conifers	ha	3'280	3'283	3'283	3'286	3'288	3'292	3'295	3'299	3'303	3'306
Total non-coniferous	ha	391'435	391'749	392'075	392'358	392'666	392'969	393'302	393'628	393'909	394'187
European beech	ha	230'887	231'063	231'256	231'422	231'609	231'780	231'974	232'161	232'314	232'462
Maple	ha	15'891	15'926	15'953	15'982	16'007	16'039	16'067	16'095	16'125	16'158
Ash	ha	29'001	29'010	29'025	29'037	29'047	29'062	29'082	29'095	29'109	29'128
European oak	ha	25'030	25'031	25'035	25'039	25'040	25'041	25'043	25'047	25'051	25'052
Chestnut	ha	27'676	27'681	27'687	27'693	27'700	27'706	27'715	27'724	27'731	27'739
Other broadleaf	ha	62'950	63'038	63'119	63'185	63'263	63'341	63'421	63'506	63'579	63'648

7.4.3 Recalculations in 11C Other natural emissions

The following recalculation was implemented in submission 2022:

- 11C: Small recalculations of biogene NMVOC emissions originating from forests 2007-2018 are due to recalculations of activity data (forest areas). For 2019, the emissions were modelled with meteorological data of 2019 replacing the extrapolated values that were used in the previous submission.

8 Recalculations and improvements

8.1 Explanations and justifications for recalculation

Several recalculations had to be carried out due to improvements in several sectors. They are listed sorted by sector in the following enumerations. Improvements realised for this submission and leading to recalculations are described in chp. 1.4.1.

8.1.1 1 Energy

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

- 1A1: The shares of PM2.5 and PM10 in TSP for all wood combustion installations were changed from 87 % to 90 % and from 93 % to 95 %, respectively, based on a revaluation of measurement and literature data yielding revised emission factors of PM2.5 and PM10 for the entire time series.
- 1A1: Since the share of PM2.5 in TSP was changed for all wood combustion installations also the BC emission factors were revised for the entire time series.
- 1A1a: Activity data of plants for renewable waste from wood products have been revised for 2019 due to a small recalculation in the Swiss wood energy statistics (SFOE 2021b).
- 1A1a: There is a small recalculation of natural gas consumption in the year 2019.
- 1A1a: There are recalculations of gas oil use for the years 2011-2012.
- 1A1a: Activity data of incinerated municipal solid waste, construction waste and other & special waste have changed for 2019 due to updates in the underlying statistics by the FOEN. Municipal solid waste has decreased by 9'820 t (-0.34 %), construction waste and other & special waste have increased by 8'665 t (+1.7 %) and 1'155 t (+0.56 %), respectively.
- 1A1a: Emission factors for all relevant air pollutants of incinerated municipal solid waste have changed from 2014 to 2019 in the framework of a study evaluating reports of emission measurements carried out in the period 2015-2020 on all municipal solid waste incineration plants in Switzerland.
- 1A1a: Emission factors for all relevant air pollutants of incinerated special waste have changed from 2014 to 2019 in the framework of a study evaluating reports of emission measurements carried out in the period 2015-2020 on all special waste incineration plants in Switzerland.
- 1A1a: Small reallocation of gas oil use from 1A1aiii to 1A1ai (but no difference in total gas oil use in 1A1a).
- 1A1c: Activity data of charcoal production has changed for 2019 due to updated production of one of the charcoal production plants for the year 2019.

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

- 1A2: There was a recalculation of gas oil use in boilers in manufacturing industries and construction for the year 2019.
- 1A2: There was a small recalculation of natural gas consumption in the year 2019.
- 1A2f: The emission factor for NO_x for cement production has changed for the years 2016-2019. The Swiss cement industry has entered into an industry agreement to reduce its

NO_x emissions from 2016 to 2021 according to a defined reduction path. Emission data for monitoring compliance with the agreement were evaluated and the emission factor for NO_x was adjusted accordingly.

- 1A2gviii: A typing error in the HCB emission factor (2014) of some wood combustion installations was corrected yielding revised values for the years 2009-2019.
- 1A2gviii: The shares of PM2.5 and PM10 in TSP for all wood combustion installations were changed from 87 % to 90 % and from 93 % to 95 %, respectively, based on a revaluation of measurement and literature data yielding revised emission factors of PM2.5 and PM10 for the entire time series.
- 1A2gviii: Since the share of PM2.5 in TSP was changed for all wood combustion installations also the BC emission factors were revised for the entire time series.
- 1A2gviii: Activity data (wood, wood waste) of combustion installations in source category 1A2gviii have been revised for 1990-2019 due to recalculations in the Swiss wood energy statistics (SFOE 2021b). The biggest changes were in automatic boilers >50 kW after 2005.
- 1A2gviii: Activity data of sewage gas from industrial wastewater treatment used in boilers and in engines has changed (by less than 1 %) for the years 2015-2018. The data is taken from the national statistical report of renewable energies by SFOE and has been updated.
- 1A2gviii: Due to small recalculations of consumption of liquefied petroleum gas in the road transportation sector 2011-2019, the use of liquefied petroleum gas in 1A2gviii Other boilers has changed a little, too.

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

- 1A4: Activity data (wood, wood waste) of combustion installations in source categories 1A4ai, 1A4bi and 1A4ci have been revised for 1990-2019 due to recalculations in the Swiss wood energy statistics (SFOE 2021b). The biggest changes were in automatic boilers >50 kW after 2005.
- 1A4: The shares of PM2.5 and PM10 in TSP for all wood combustion installations were changed from 87 % to 90 % and from 93 % to 95 %, respectively, based on a revaluation of measurement and literature data yielding revised emission factors of PM2.5 and PM10 for the entire time series.
- 1A4: Since the share of PM2.5 in TSP was changed for all wood combustion installations also the BC emission factors were revised for the entire time series.
- 1A4: A typing error in the HCB emission factor (2014) of some wood combustion installations was corrected yielding revised values for the years 2009-2019 in 1A4ai, 1A4bi and 1A4ci.
- 1A4a: Due to recalculations of activity data in 1A2 Manufacturing and construction for gas oil and natural gas the activity data of boilers in 1A4a Commercial changed too.
- 1A4b: Due to recalculations of activity data in 1A2 Manufacturing and construction for gas oil and natural gas the activity data of boilers in 1A4b residential changed too.
- 1A4ci: Due to a mistake in the database, emissions of BaP für gas oil in greenhouses were not reported so far.

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

- 1A/1A3b: Due to recalculations in sector 1B2a of fugitive NMVOC emissions from gasoline storage tanks the total amount of gasoline used in sector 1A Fuel combustion activities changes a little for the years 1990-2019. This recalculation leads to changes for all pollutants for the years 1990-2019.
- 1A3b: There was no PCDD/PCDF emission factor set for natural gas engines in the road transportation model so far. A comparison with the German IIR 2021 (where an emission factor from Rentz et al. (2008) is used) and the emission factors in the EMEP/EEA guidebook (EMEP/EEA 2019) for small combustion was done and the emission factors from Rentz et al. (2008) were introduced in the Swiss Road transportation model for gas driven engines. This leads to a recalculation of the PCDD/PCDF emissions for the years 1990-2019.
- 1A3b: A comparison of the Zn exhaust emission factors so far used in HBEFA and the ones in the EMEP/EEA guidebook (EMEP/EEA 2019) led to a switch to the ones used in the EMEP/EEA guidebook. Also, because there was no reference available for the ones used in HBEFA so far. Due to this recalculation the Zn exhaust emissions for the years 1990-2019 from gasoline engines have reduced by 93 % and the ones from diesel oil by 97 % compared to the emissions in the previous submission.
- 1A3b: Due to a mistake, the cold start emissions were underestimated so far. The newly calculated energy consumption for cold start processes leads to 20 % higher emissions for Pb, Cd exhaust and SO₂ for the years 1990-2019.
- 1A3b: Based on newest available statistics some changes in the activity data have been done. This recalculation leads to changes for all pollutants for the years 1990-2019.
- 1A3b: Small recalculations for all pollutants for the years 1990-2019 due to newly defined roundings of activity data and emission factors.
- 1A3e: Emission factor for NO_x was higher in 2020 than for 2015. This was corrected and it is now constant from 2015 on (19g/GJ).
- 1A3: Small recalculation of diesel oil use in 1D2 International navigation (memo item) for all the years 1990-2019 leads to small recalculation in total diesel sold and therefore in activity data of diesel in tank tourism and statistical difference of 1A3b Road transportation looking at the fuel used approach in the reporting templates.

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.
- 1B2a: Small recalculation in statistics for SFOE 2021 concerning the amount of crude oil imported in the year 2019.
- 1B2a: Small recalculation of total amount of gasoline sold and therefore of the amount of fugitive NMVOC and Pb emissions in 2019 from gasoline distribution.
- 1B2av: NMVOC emissions due to losses in gasoline storage tanks have been recalculated for the whole timeseries 1980-2019. The new calculations are based on the latest information regarding the number and type of gasoline storage tanks.
- 1B2aiv: NMVOC emission factors in 1B2aiv refinery leakage are adapted for the year 2019 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: Small recalculation of natural gas consumption in the year 2019 leads also to recalculation of natural gas losses in 2019.
- 1B2bii, gas production, venting: the NMVOC emission factor newly relates to the upper value as given in the IPCC guidelines, chp. 4, Table 4.2.4 (Tier 1 method). Before, it was taken from the EMEP/EAA guidebook and resulted in a smaller value. This change affects NMVOC emissions from 1985 to 1994.
- 1B2c: As recommended by the expert review team in the stage 3 review in 2020, missing emission factors are now taken into account for the following pollutants: PM, PM10, PM2.5, BC, heavy metals and PAHs, using available emission factors from the EMEP/EAA guidebook 2019, expressed in this report per ton of refined crude oil.
- 1B2c: recalculation of the NMVOC emission factor for flaring gas in the refinery due to an error in the calculations using the conversion factor from g/L to g/t crude oil.
- 1B2cii, gas production, flaring: emission factors are now taken into account for additional pollutants and heavy metals, using emission factors for Tier 1 from the EMEP/EEA guidebook, when available. For dioxins, the emission factor is taken from Norway's Informative Inventory Report 2021 (Norwegian Environment Agency 2021).

8.1.2 2 Industrial processes and product use

8.1.2.1 Category-specific recalculations in 2A Mineral products

- 2A5a: The last year's extrapolated activity data of 2A5a Gravel plants for 2019 has been revised based on effective production data from the industry association.

8.1.2.2 Category-specific recalculations in 2B Chemical industry

- 2B5: Source category 2B5 Silicon carbide production was updated based on new detailed industry data and information yielding revised activity data for the years 1990-2012. Also, the so far missing CO emissions are newly reported for the entire time series.

8.1.2.3 Category-specific recalculations in 2C Metal production

- 2C7c: Due to new projection figures for the metal processing industry (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of source category 2C7c Galvanizing plants have changed from 2013 onwards.

8.1.2.4 Category-specific recalculations in 2D Other solvent use

- 2D3a: Source category 2D3a Domestic use of cleaning agents was completely updated based on detailed sales figures of the years 2017-2020, NMVOC contents and application-specific emission factors yielding revised values of the NMVOC emission factor from 1991 onwards.
- 2D3c: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of source category 2D3c Asphalt roofing have changed from 2012 onwards.
- 2D3e: Activity data and NMVOC emission factors of source category 2D3e Degreasing were revised for 1990-2019 based on a survey of the association of Swiss mechanical and electric engineering industries and VOC balances.
- 2D3g: Activity data and NMVOC emission factors of source category 2D3g Production of glue were updated from 2001 onwards based on industry data resulting in revised activity data and emission factors for 1991-2019 and 2000-2019, respectively.
- 2D3g: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of handling and storage of solvents, production of fine chemicals and pharmaceuticals as well as production of inks have changed from 2012 and 2017, respectively, onwards.
- 2D3h: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of source category 2D3h Printing have changed from 2017 onwards.
- 2D3i: Activity data and NMVOC emission factors of source category 2D3i Production of textiles were revised for 1990-2019 based on industry data and VOC balances.
- 2D3i: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of production of paper and paperboard have changed from 2012 onwards.

8.1.2.5 Category-specific recalculations in 2G Other product use

- 2G: For 2019, the NMVOC and NH₃ emission factors of 2G Glass wool enduction were revised based on industry data.
- 2G: Activity data and NMVOC emission factors of source category 2G Application of glue were revised for 1990-2019 based on industry data.
- 2G: Due to new projection figures (Swiss Energy Perspectives 2050+, Prognos/INFRAS/TEP/Ecoplan 2020), the interpolated activity data of use of concrete additives have changed from 2017 onwards.

8.1.2.6 Category-specific recalculations in 2H Other industry production

- 2H2 Meat smokehouses: Activity data for 2018 and 2019 have decreased by 2.15 % (-1'430 t) and 1.45 % (-960 t), respectively, due to changes in the underlying statistics for annual per capita meat consumption by the SFSO.

- 2H2 Milling companies: Activity data for 2019 has increased by 2.26 % (36'604 t), due to a change in the underlying statistics by the FOAG.
- 2H2 Sugar production: The emission factor for 2020 has been erroneously inserted in a previous year. It has now been deleted thus increasing the interpolated emission factors from 2008 to 2019.

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: The so far missing activity data of the years 1991-1994 were added as well as the data for 2019 were updated. Also, the emission factors of PM_{2.5}, PM₁₀ and TSP were adjusted for 2003, resulting in revised values for the years 1991-2019.

8.1.3 3 Agriculture

8.1.3.1 Category-specific recalculations in 3B Manure management

- 3B: A new representative stratified survey on farm management and structure was conducted at the end of 2019. A random sample of farms covering the five farmtypes, three geographical regions and three altitude classes (valley zone, hill zone, mountain zone) described in chapter 5.2.2 was drawn by the Federal Office for Statistics. A twelve page questionnaire was sent to the selected 5'683 farms. Eventually the responses from 2'639 farms could be used for the data analysis (response rate 46.1 %). Thus, the analysed sample covered 11.3 % of the Swiss farms and 15.5 % of the agricultural livestock units.
- 3B: NH₃ and NO_x emissions from manure management were recalculated for the years 1990-2019 with the revised version of the AGRAMMON N-flow model (revision 2021; version 6.0.1). This revision did not include any changes of technical parameters, but only small optimisations in the calculation procedure like a linear instead of stepwise correction of housing emissions during grazing, more empirical (N-flow based) distribution of the TAN-flow in manure storage and a correction for horses as well as mules and asses for the time when the animals have access both to grazing and the exercise yard close to the housing. The impact of the changes on overall emissions are minimal.
- 3B: N excretion of livestock and NH₃ emissions were taken from the Swiss NH₃ emission inventory (Kupper et al., 2022) where they were compiled based on the calculation with the Tier 3 N-flow model AGRAMMON and the database on farming practice from the representative surveys 2015 and 2019. For the years 2016-2018 they were derived from an interpolation of the emission factors for 2015 and 2019, which were based on representative surveys on farming practice in the respective years.
- 3B: Activity data of source categories 3B3, 3B4e and 3B4gii were revised for the years 2017-2019 due to new background data of the SFSO for livestock population statistics for fattening pigs, horses and broilers.
- 3B: NH₃ and NO_x emissions from manure management were recalculated for the years 1990-2019. 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.
- 3B1: The NMVOC emission factors of all cattle categories were completely revised for the entire time series. The new factors are based on extensive measurements of NMVOC emissions from dairy cattle with and without silage feeding in an experimental dairy

housing during summer, winter and transitional season. The associated uncertainties have been updated accordingly and significantly reduced.

- 3B4giv: The activity data were revised for the year 2019 due to an update of the number of other poultry.

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

- 3D: NH₃ emissions were taken from the Swiss NH₃ emission inventory (Kupper et al., 2022) where they were compiled based on the calculation with the Tier 3 N-flow model AGRAMMON and the database on farming practice from the representative surveys 2015 and 2019. For the years 2016-2018 they were derived from an interpolation of the emission factors for 2015 and 2019, which were based on representative surveys on farming practice in the respective years.
- 3D: For the calculation of NH₃ emissions the AGRAMMON model version 6.0.1 was used. Compared to the model versions 5.1.4 used for previous reportings the model version 6.0.1 contained some small optimisations in the calculation procedure but no changes in technical parameters (Kupper et al. 2022). The effect of these changes on the final results for the year were minimal.
- 3D: N excretion of livestock and NH₃ emissions were taken from the Swiss NH₃ emission inventory (Kupper et al., 2022) where they were compiled based on the calculation with the Tier 3 N-flow model AGRAMMON and the database on farming practice from the representative surveys 2015 and 2019. For the years 2016-2018 they were derived from an interpolation of the emission factors for 2015 and 2019, which were based on representative surveys on farming practice in the respective years.
- 3Da: Activity data of source categories 3Da2a and 3Da3 were revised for the years 2017-2019 due to new background data of the SFSO for livestock population statistics for fattening pigs, horses and broilers (relevant for 3Da manure application).
- 3Da: Activity data of source categories 3Da2a and 3Da3 were revised for the years 2018 and 2019 due to new estimates of the numbers for horses and mules and asses.
- 3Da: The activity data of source categories 3Da2a4giv and 3Da34giv were revised for the year 2019 due to an update of the number of other poultry.
- 3Da2c: Activity data of source category 3Da2c Other organic fertiliser applied to soils were revised for the years 2014-2019 due to updated amounts of compost. Therefore, the weighted mean NH₃ emission factor changed as well for 2014-2019.

8.1.4 5 Waste

8.1.4.1 Category-specific recalculations in 5A Biological treatment of waste - Solid waste disposal on land

- 5A1 Managed waste disposal sites: A new emission factor for direct emissions of NMVOC has been introduced based on EMEP Guidebook 2019 recommendations (5A Chapter 3.2.2). A fraction of 1.3 % of all VOC emissions (1.317 % of CH₄ emissions) occur as NMVOC. This has led to annual NMVOC emissions of 405-150 t.
- 5A1 Managed waste disposal sites: A new emission factor for emissions of NMVOC from flaring has been introduced based on a study on emissions from landfill gas installations (Butz 2003) suggesting NMVOC emissions equalling to 82.15 g/t CH₄ flared ± 10 %. This has led to annual NMVOC emissions of 510-110 kg.

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

- 5B1 Composting (industrial and backyard): The unit of activity data and emission factors are now reported as weight dry mass instead of wet mass. A transfer factor from wet to dry mass of 54.5 % has been suggested by CVIS (2019). Thus, activity data for the years 1980-2019 have decreased by 45.5 % while emission factors for NH₃ and NMVOC have increased by the same factor (increase of 83.5 %). This leads to small changes in emissions from 5B1 Composting, due to rounding effects.

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

- 5C1biv sewage sludge incineration: Emission factors for all relevant air pollutants have changed from 2016 to 2020 in the framework of a study evaluating reports of emission measurements carried out in the period 2015-2020 on several sewage sludge incineration plants in Switzerland.

8.1.4.4 Category-specific recalculations in 5D Wastewater handling

There were no recalculations implemented in submission 2022.

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: The activity “number of residents in nursing homes” in 2019 has increased by 0.15 % (31 people), due to changes in the underlying statistics by the SFSO.
- 6Ab: The activity data of source category 6Ab Livestock outside agriculture were revised for the years 2018 and 2019 due to new estimates of the numbers for horses, mules and asses yielding revised emission factors of all pollutants (NO_x, NMVOC, NH₃ and PM) as well.
- 6Ab: NO_x and NH₃ emission factors from manure management and agricultural soils of livestock outside agriculture were recalculated for 1990-2019 due to changes in N excretions and calculations of the new version of the AGRAMMON-model.
- 6Ad: Activity data for 2019 (amount of burnt material) decreased by 15.9 % (1'122t), due to a change in the underlying statistics by the fire insurance association (VKF).

8.1.5.2 Recalculations in 11B Forest fires

- 11B: The time series of wildfires on forest land and grassland were recalculated with updated activity data from the Swissfire database in the years 1993, 2011, 2013, 2015, 2018 and 2019.

8.1.5.3 Recalculations in 11C Other natural emissions

- 11C: Small recalculations of biogene NMVOC emissions originating from forests 2007-2018 are due to recalculations of activity data (forest areas). For 2019, the emissions were modelled with meteorological data of 2019 replacing the extrapolated values that were used in the previous submission.

8.1.6 Implications of recalculation for emission levels

Table 8-1 shows the effect of recalculations on the emission levels 2019 and 1990, based on the previous (2021) and latest (2022) submission. In 2019, recalculations cause a higher emission level by at least 3 % for CO emissions. A decrease due to recalculations by at least 3 % is observed for NMVOC, Pb, Cd, Hg and PCDD/PCDF. For all other pollutants, the difference in emissions 2019 due to recalculations does not exceed 1.6 %.

In 1990, recalculations do not cause an increase or a decrease of more than 3 % for any pollutant. The largest differences occur for CO and PM_{2.5} emissions (+2.3 % and +1.1 %, respectively), whereas the change for all other pollutants does not exceed 1.0 %.

Table 8-1: Recalculations: Implications for the emission levels 2019 and 1990. The values refer to the NFR submission 2021 (previous) and 2022 (latest). Differences are given in absolute and relative numbers for all pollutants.

Pollutant	Units	2019			
		previous subm. 2021	latest subm. 2022	difference (abs.)	difference (rel.) previous = 100%
NO _x	kt	61	61	-0.32	-0.52%
NMVOC	kt	81	78	-3.2	-4.0%
SO _x	kt	4.4	4.4	-0.013	-0.29%
NH ₃	kt	54	54	-0.14	-0.27%
PM2.5	kt	6.2	6.2	0.089	1.4%
PM10	kt	14	14	0.065	0.46%
TSP	kt	28	28	0.10	0.37%
BC	kt	1.2	1.2	-0.0091	-0.78%
CO	kt	161	169	8.0	5.0%
Pb	t	15	14	-0.90	-6.1%
Cd	t	0.69	0.59	-0.096	-14%
Hg	t	0.68	0.65	-0.030	-4.5%
PCDD/PCDF	g I-TEQ	16	15	-1.3	-8.4%
PAH (total)	t	2.7	2.7	-0.028	-1.0%
HCB	kg	0.36	0.36	0.0057	1.6%
PCB	kg	444	444	444	0.00000054%

Pollutant	Units	1990			
		previous subm. 2021	latest subm. 2022	difference (abs.)	difference (rel.) previous = 100%
NO _x	kt	145	145	-0.0061	-0.0042%
NMVOC	kt	305	302	-2.7	-0.89%
SO _x	kt	37	37	0.0013	0.0035%
NH ₃	kt	69	69	-0.055	-0.079%
PM2.5	kt	16	17	0.19	1.1%
PM10	kt	25	25	0.12	0.47%
TSP	kt	44	44	-0.0096	-0.022%
BC	kt	5.7	5.7	0.0085	0.15%
CO	kt	799	817	19	2.3%
Pb	t	380	380	0.18	0.047%
Cd	t	3.4	3.4	0.00081	0.024%
Hg	t	6.4	6.4	0.000051	0.00080%
PCDD/PCDF	g I-TEQ	194	194	-0.0025	-0.0013%
PAH (total)	t	8.1	8.1	-0.000037	-0.00046%
HCB	kg	173	173	0.00026	0.00015%
PCB	kg	2'332	2'332	2'332	-0.00000019%

The source categories with the most important recalculations implemented for main pollutants and PM2.5 in submission 2022 in terms of absolute emissions are listed in Table 8-2 and Table 8-3 for the years 2019 and 1990, respectively. The two most important recalculations for each year and each pollutant are the following:

NO_x

- For 2019, the most important recalculation concerning NO_x emissions occurs in category 1A2f Stationary combustion in manufacturing industries and construction: Non-metallic

minerals, precisely in cement production. The Swiss cement industry has entered into an industry agreement to reduce its NO_x emissions from 2016 to 2021 according to a defined reduction path. Emission data for monitoring compliance with the agreement were evaluated and the emission factor for NO_x was adjusted accordingly for the years 2016 to 2019.

- Another important recalculation concerns category 1A3b Road transportation, which can be mainly attributed to changes in activity data due to the newest available statistics (1990-2019) as well as to newly defined roundings of activity data and emission factors, which lead to minor changes for all pollutants for the years 1990-2019. For 2019, the largest changes occur for heavy duty vehicles and buses (1A3biii) and passenger cars (1A3bi), whereas for 1990 they are significantly smaller and biggest for light duty vehicles (1A3bii) and passenger cars (1A3bi).
- In addition, recalculations in the agriculture sector led to minor changes in NO_x emissions due to an update of the AGRAMMON model with revised values for the N excretions. The largest changes occur for the cattle categories (3B1a, 3Da2a and 3B1b, see Table 8-3).

NM VOC

- In 2019, the most important recalculation affecting NMVOC emissions occurred in category 2D3a Domestic solvent use including fungicides. The domestic use of cosmetics, toiletries, cleaning agents and care products was completely updated based on detailed sales figures, NMVOC contents and application-specific emission factors for the years 2017-2020, which also led to retrospective adjustments back to 1991.
- Other important recalculations in 2019 and 1990 concern the NMVOC emissions from 3B1 Manure management - Cattle. The NMVOC emission factors of all cattle categories were completely revised for the entire time series based on extensive measurements of emissions from dairy cattle with and without silage feeding in an experimental dairy housing during summer, winter and transitional season. For cattle with and without silage feeding, the new factors are slightly higher and significantly lower, respectively, than the so far used default Tier-1 emission factors (EMEP/EEA guidebook 2019).
- In addition, a recalculation in source category 1B2av Distribution of oil products lead to changes. This change is the result of several recalculations. On one hand, NMVOC emissions due to losses in gasoline storage tanks have been recalculated for the whole timeseries 1980-2019. The new calculations are based on the latest information regarding the number and type of gasoline storage tanks. On the other hand, a small recalculation in the national energy statistics concerning the amount of crude oil imported and another small recalculation concerning the total amount of gasoline sold had an impact on (fugitive) NMVOC emissions in the year 2019.

SO_x

- The most important recalculation for SO_x emissions in 2019 stems from source category 5C1biv Sewage sludge incineration. Emission factors for all relevant air pollutants have changed from 2016 to 2020 in the framework of a study evaluating reports of emission measurements carried out in the period 2015-2020 on several sewage sludge incineration plants (SSIP) in Switzerland, which leads to an emission reduction.
- Another important recalculation for the year 2019 concerns source category 1A1a Public electricity and heat production. SO_x emissions increased in 2019. Activity data of incinerated municipal solid waste, construction waste and other & special waste have changed for 2019 due to updates in the underlying statistics by the FOEN. Furthermore, emission factors for all relevant air pollutants of incinerated municipal solid waste as well as special waste have changed from 2014 to 2019 in the framework of a study evaluating

reports of emission measurements carried out in the period 2015-2020 on all municipal solid waste incineration plants in Switzerland.

- For the year 1990, recalculations led to minor changes in SO_x emissions. The most important recalculations concern category 1A3b Road transportation, where changes in activity data due to the newest available statistics as well as to newly defined roundings of activity data and emission factors lead to minor changes for all pollutants for all the years 1990-2019. For 1990, the largest recalculations occurred for heavy duty vehicles and buses (1A3biii) as well as passenger cars (1A3bi).

NH₃

- The most important recalculation of NH₃ emissions in 2019 and 1990 concern emissions from manure management of livestock (3B), especially of cattle (3B1) including animal manure applied to soils (3Da2a) due to an update of the AGRAMMON model based on new survey data on farm and manure management (2019) with revised values for the N excretions for the entire time series.

PM2.5

- The most important recalculations for PM2.5 emissions in 2019 and 1990 occurred in source categories 1A4ai Commercial/Institutional: Stationary, 1A4bi Residential: Stationary and 1A2gviii Stationary combustion in manufacturing industries and construction. The shares of PM2.5 in TSP were changed from 87 % to 90 % for all wood combustion installations for the entire time series based on a revaluation of measurement and literature data. Also, activity data (wood, wood waste) was revised due to recalculated Swiss wood energy statistics with biggest changes for automatic boilers >50 kW after 2005.
- Another important recalculation of PM2.5 emissions in 2019 concerns source category 2A5a Quarrying and mining of minerals other than coal. The so far extrapolated activity data of 2A5a Gravel plants for 2019 has been revised based on effective production data from the industry association.
- In addition, a recalculation in 1A3bi Road transportation: Passenger cars led to reduced emissions in 2019 and 1990. These differences can be mainly attributed to changes in activity data due to the newest available statistics as well as to newly defined roundings of activity data and emission factors, which lead to minor changes for all pollutants for the years 1990-2019.

Table 8-2: NFR categories with most important implications of recalculations on emission levels in 2019 in terms of absolute differences for the main pollutants and PM2.5. The values refer to the NFR submission 2021 and 2022. The list is ranked for each pollutant in terms of the absolute difference in emission levels due to recalculations.

NO _x (as NO ₂)		NMVOC		SO _x (as SO ₂)		NH ₃		PM _{2.5}	
kt		kt		kt		kt		kt	
1A2f_Stationary combustion in manufacturing industries and construction: Non-metallic minerals	-0.35	2D3a_Domestic solvent use including fungicides	-2.7	5C1biv_Sewage sludge incineration	-0.039	3Da2a_Animal manure applied to soils	0.45	1A4bi_Residential: Stationary	0.045
1A3biii_Road transport: Heavy duty vehicles and buses	-0.18	3B1b_Manure management - Non-dairy cattle	1.4	1A1a_Public electricity and heat production	0.025	3B1b_Manure management - Non-dairy cattle	-0.35	1A4ai_Commercial/Institutional: Stationary	0.033
1A3bi_Road transport: Passenger cars	0.11	3B1a_Manure management - Dairy cattle	-1.0	1A4ai_Commercial/Institutional: Stationary	0.0021	3B1a_Manure management - Dairy cattle	-0.30	1A2gviii_Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.018
1A4ai_Commercial/Institutional: Stationary	0.095	2D3e_Degreasing	-0.63	6A_Other (included in national total for entire territory) (please specify in the IIR)	-0.0011	3B3_Manure management - Swine	0.12	2A5a_Quarrying and mining of minerals other than coal	0.016
1A4bi_Residential: Stationary	0.070	1B2av_Distribution of oil products	-0.51	1A2gviii_Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.00072	3Da3_Urine and dung deposited by grazing animals	0.095	1A3bi_Road transport: Passenger cars	-0.014

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 2021 and 2022. The list is ranked for each pollutant in terms of the absolute difference in emission levels due to recalculations.

NO_x (as NO ₂)		NM VOC		SO_x (as SO ₂)		NH₃		PM_{2.5}	
kt		kt		kt		kt		kt	
1A3bii_Road transport: Light duty vehicles	-0.016	3B1a_Manure management - Dairy cattle	-3.4	1A3biii_Road transport: Heavy duty vehicles and buses	0.0028	3Da2a_Animal manure applied to soils	0.86	1A4bi_Residential: Stationary	0.16
3B1a_Manure management - Dairy cattle	-0.016	1B2av_Distribution of oil products	-2.5	1A3bi_Road transport: Passenger cars	-0.0018	3B1a_Manure management - Dairy cattle	-0.66	1A4ai_Commercial/Institutional: Stationary	0.017
3Da2a_Animal manure applied to soils	0.012	1A3bi_Road transport: Passenger cars	2.4	1B2c_Venting and flaring (oil, gas, combined oil and gas)	0.00078	3B1b_Manure management - Non-dairy cattle	-0.35	1A2gviii_Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.015
1A3bi_Road transport: Passenger cars	0.010	3B1b_Manure management - Non-dairy cattle	-1.2	1A3bii_Road transport: Light duty vehicles	-0.00052	3B3_Manure management - Swine	0.16	1A3bi_Road transport: Passenger cars	-0.0048
3B1b_Manure management - Non-dairy cattle	-0.0083	2G_Other product use (please specify in the IIR)	0.80	1A2gviii_Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.000026	3B4gii_Manure management - Broilers	-0.048	1A4ci_Agriculture/Fishing: Stationary	0.0028

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

The emission trends 1990–2019 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 NMVOC emissions, where the decreasing trend is 1 % stronger in the latest compared to the previous submission. For all other pollutants, the change of the trend due to recalculations is almost negligible (difference of maximum 0.2 %).

Table 8-4: Recalculations: Implications for the emission trends between 1990 and 2019 for the main pollutants. The values refer to the NFR submission 2021 and 2022.

Pollutant	Trend 1990-2019 (1990 = 100%)	
	previous subm. 2021 %	latest subm. 2022 %
NO _x	42	42
NMVOC	27	26
SO _x	12	12
NH ₃	78	78
PM2.5	38	38

8.2 Planned improvements

The following improvements are planned for the submission 2023:

General

- Uncertainty estimations: The code developed in Python to compute the uncertainty estimations, for approaches 1 and 2, will be made available on a public repository for the next submission.

Energy (stationary)

- 1A4 stationary combustion: based on a new data collection and model emissions from stationary engines and gas turbines will be reestimated for all the years.

Energy (mobile) no planned improvements

Energy (fugitive emissions)

- 1B2a fugitive emissions from gasoline distribution: results from the on-going study concerning fugitive emissions from gasoline handling in fuel stations will replace the existing emission estimates.

IPPU

- 2D3 and 2G: A comprehensive update of all NMVOC emissions from solvent and product use is on-going.

Agriculture no planned improvements

Waste no planned improvements

Other and Natural no planned improvements

9 Emission projections 2021–2030

9.1 Comments on projections

The emission projections of air pollutants in Switzerland have been fully revised in the course of the latest submission 2022 and a new “With Measures” (WM) scenario was elaborated. The data for the sectors energy, IPPU and waste are in accordance with the base scenario called “WWB” (which means “with existing measures”) of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). Note that:

- due to lack of detailed data for all sectors with non-road vehicles and machineries the exclusively calculated model used in the older energy scenarios (Prognos 2012a) was used with respecting the overall fuel use published in Prognos/INFRAS/TEP/Ecoplan (2020).
- for activity data based on population size the latest perspectives for Switzerland’s inhabitants are used (SFSO 2020p).
- for the agricultural sector, independent scenarios were developed according to the agricultural policy 2018-2021 (Swiss Confederation 2017).

Note also that emission data published in the submission table for the projections (“Annex IV A WM”) refer to the “national total” assessment based on the fuel sold principle for road transportation. All tables and figures in this chapter refer to the “national total for compliance” assessment based on fuel used principle (for details see chapter 1.4.2 and 3.1.6.1).

In the IIR on hand the air pollutant emissions in chps. 9.3 to 9.6 are shown for the “With Measures” (WM) scenario only. A “With additional Measures” (WaM) scenario was not elaborated for the latest submission.

9.2 Assumptions for projections for the WM scenario

9.2.1 Emission factors

Emission factors for the sector 1 Energy are mainly based on available emission measurements, EMEP/EEA guidebook (EMEP/EEA 2019), expert estimates as described in chapter 3 and assumptions about their future development. Where no such assumptions can be made, the emission factors are kept constant.

Emission factors for the sector 1 Energy are taken from the following reports:

- Fuel combustion / heating systems: Internal emission database (EMIS 2022)
- Road transportation: EMEP/EEA guidebook (EMEP/EEA 2019), INFRAS (2019)
- Domestic aviation: EMEP/EEA guidebook (EMEP/EEA 2019), FOCA (2006, 2006a, 2007a, 2008-2021)
- Non-road vehicles: EMEP/EEA guidebook (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 (EMEP/EEA 2019) as described in chapter 4 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. 2022), EMEP/EEA guidebook (EMEP/EEA 2019) and country-specific studies (Bühler and Kupper 2018, Schrade et al. 2022) as described in chapter 5 and kept constant as in 2019 due to uncertain assumptions about the evolution of production parameters (Kupper et al. 2022).

Emission factors for sector 5 Waste and sector 6 Other are taken from various literature sources and EMEP/EEA guidebook 2019 (EMEP/EEA 2019) as described in chapter 6 and 7.

9.2.2 Activity data

As described in chapter 9.1 and Table 9-1, activity data base mainly on the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) and the agricultural policy 2018-2021 (Swiss Confederation 2017). The base scenario called “WWB” (German for “Weiter wie bisher” meaning a continuation of existing energy and climate policy measures) of the Swiss Energy Perspectives 2050+ is calculated on energy consumption data from 2017 onwards. Note that therefore, no effect of the pandemic situation from COVID-19 in 2020 was projected. As a consequence, increasing trends in energy consumption after the latest submission year (2020) to the first displayed projection year (2025) can be observed in some sectors (especially in 1A3 Transportation) due to exceptional low fuel consumption during the pandemic situation. In general, from 2030 onwards, the actual projections of the Swiss Energy Perspectives 2050+ are used and data from 2021 to 2029 is linearly interpolated between past statistical data 2020 and projected data 2030. Due to the strong decline in air traffic by the pandemic situation in 2020 projections for the year 2025 are used for 1A3a Aviation and linearly interpolated in between (2021-2024). For 1A3b Road transportation, model data based on the Swiss Energy Perspectives 2050+ with an annual resolution is implemented. Due to the lack of detailed, disaggregated data in the Swiss Energy Perspectives 2050+ for processes in all non-road sectors, model data from the previous projections (Prognos 2012a) is used. The total amount of fuel used in non-road sectors is then subtracted from the projected overall fuel consumption in the Swiss Energy Perspectives 2050+, which has some influence on the allocation of fuel consumption to the different source categories, whereas the overall fuel consumption remains the same as projected in the Swiss Energy Perspectives 2050+.

Table 9-1 provides an overview of the respective sectoral references.

Table 9-1: Overview of sectoral underlying detailed scenarios in the WM scenario.

Sector	Scenario	Sectoral scenario	Reference
1 Energy	WM	Swiss Energy Perspectives 2050+ scenario "WWB" (with existing measures) updated with new national reference scenario for population ("A-00-2020"). Activity data in the nonroad sectors still base on assumptions of Prognos (2012a).	Prognos/INFRAS/TEP/Ecoplan 2020 SFSO 2020p Prognos 2012a
2 IPPU	WM	Scenario based on key parameters of the Swiss Energy Perspectives 2050+ but updated with new national reference scenario for population ("A-00-2020")	Prognos/INFRAS/TEP/Ecoplan 2020 SFSO 2020p
3 Agriculture	WM	Continuation of Agricultural policy 2018-2021	Swiss Confederation 2017 Mack and Möhring 2021
5 Waste	WM	Scenario based on key parameters of the Swiss Energy Perspectives 2050+ but updated with new national reference scenario for population ("A-00-2020")	Prognos/INFRAS/TEP/Ecoplan 2020 SFSO 2020p

Table 9-2 lists the key factors underlying the WM scenario and their assumed development between 2010 and 2030.

Table 9-2: Trend of underlying key factors of the WM scenario between 2010 and 2030 (SFSO 2021c and SFSO 2020p for population, INFRAS 2017 for vehicle km, and Prognos/INFRAS/TEP/Ecoplan 2020 for the rest).

Indicator	2010	2015	2020	2025	2030	2010-2030
Population (million)	7.83	8.28	8.64	9.02	9.39	20%
GDP (prices 2017, billion CHF)	603	648	713	760	805	33%
Oil price (prices 2017, USD/barrel)	88	-	75	88	96	9%
Gas price (prices 2017, CHF/MWh)	28	-	24	27	28	0%
Heating degree days	3'586	3'075	3'182	3'135	3'089	-14%
Cooling degree days	153	263	177	188	199	30%
Energy reference area (million m ²)	706	744	782	816	847	20%
Passenger cars (million vehicle km)	52'066	56'620	52'055	61'749	63'691	22%

Please note that the population data in the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020) do not match the official statistics used within the air pollutant (and greenhouse gas) inventory (SFSO 2020p).

For each sector, further specific methods and respective assumptions apply that are described below in more detail:

Sector 1 Energy

As mentioned above, energy consumption is based on the scenario “WWB” of the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). Main measures and underlying assumptions in the energy scenario “WWB” and the different source categories are described in detail in Prognos/INFRAS/TEP/Ecoplan (2020). The projections are based on an aggregation of various bottom-up models. Energy demand is determined using separate models for private households, industry, transportation, services/agriculture and electricity supply. Figure 9-1 depicts the total energy demand in recent years and as projected up to 2030 for each source category in the energy sector.

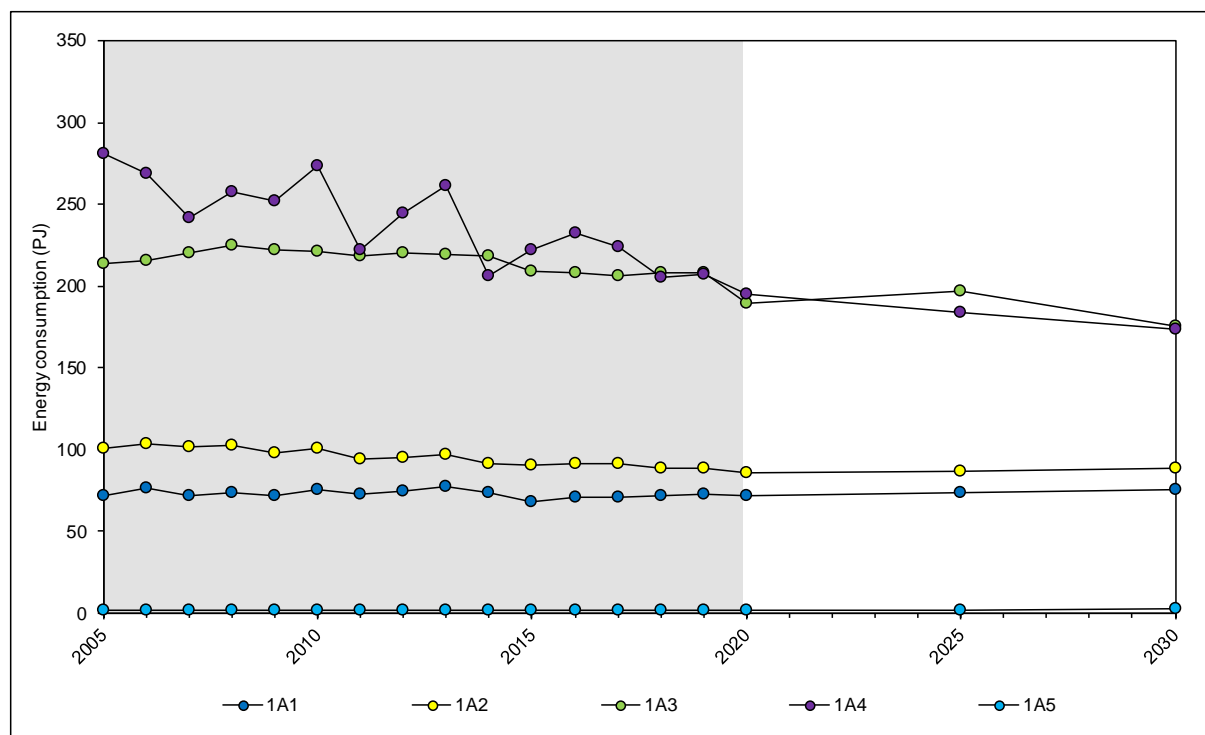


Figure 9-1: Energy demand in Switzerland as projected in the WM scenario in source categories 1A1 – 1A5 of the source category 1A Fuel combustion.

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

Fuel combustion in 1A2 Manufacturing industries and construction is modelled for the main fuel types based on a large number of industrial production processes, broken down by the most important industrial sectors, including a residual sector for all other industrial sectors. Also considered are the respective building and facility management processes as well as the use of biogas and sewage gas in boilers and engines. Energy consumption is then projected based on activity data for the sectors and specific energy use per process.

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

Energy demand in households is modelled based on energy use for heating, hot water, household appliances, lighting and other electrical equipment. The model consists of a dynamic building stock in various classes. The projection is then based on population growth, average floor space per person, average household size as well as technological developments of old and new buildings.

Energy demand from commercial and institutional buildings is based on energy use of heating, hot water, air conditioning, lighting, office appliances, engines and other uses, split for different energy sources, trades and services. Projections are then driven by gross value-creating activity, number of employees, energy reference area and technical standards.

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

The use of these bottom-up models allows to reproduce past developments and to derive the key drivers for particular segments of energy demand. Future energy demand is projected

based on assumptions on the evolution of the key drivers. The energy demand is then assigned to the relevant categories.

Source category 1A3 Transport

Activity data from transport activities are based on the same model as the one used to derive energy demand for the energy scenarios (see above). The main measures and underlying assumptions are:

- Implementation of measures such as efficiency targets set for light 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 and are represented in Prognos/INFRAS/TEP/Ecoplan (2020) and Swiss Confederation (2021).
- Non-road source categories: Projections of vehicle fleets, operating hours and expected fuel consumption (see Annex A2.1.2) serve as input for projecting the fuel consumption of non-road vehicles (FOEN 2015j, INFRAS 2015a, Prognos 2012a). In addition, (compressed) natural gas in non-road has been replaced with liquefied petroleum gas, which is a more accurate reflection of the situation in Switzerland.

Sector 2 Industrial processes and product use

Activity data of sector 2 Industrial processes and product use are inferred from the sectoral production data that were used in the Swiss Energy Perspectives 2050+ (Prognos/INFRAS/TEP/Ecoplan 2020). In particular, sectoral indices of production volumes for clinker, cement, iron and steel, non-iron metals, glass, food, construction, and so-called other industry have been used. For other processes, such as production of basic chemicals of source category 2B Chemical industry, the provided production index scenario is not consistent with the more or less stable production volumes of the past twenty years. Therefore, constant activity data at the level of the recent years have been assumed for these source categories. Furthermore, a few activity data are only scaled with population growth (SFSO 2020p). However, the Energy Perspectives 2050+ provide no appropriate key parameters or measures for a number of source categories mainly within solvent and product use. For these source categories, projections are thus estimates based on information from industry, industry associations or expert judgement.

Sector 3 Agriculture

The basis of the WM scenario is the continuation of the agricultural policy 2018–2021 (Swiss Confederation 2017). The new agricultural policy (AP22+) should have become effective in 2022 but it was rejected by the parliament. Thus, central elements of the policy will be implemented through a parliamentary initiative. Their effects were modelled by Mack and Möhring (2021) and they elaborated respective projections of animal populations, milk yields, cropping areas and fertiliser use. As the ordinances under the parliamentary initiative have not yet passed legislation, the reference scenario of Mack and Möhring (2021) was used as basis for the calculations of the WM scenario. Projections are thus based on data and information available by 2021 on (i) the development of the macroeconomical variables (gross domestic product, population, crop yields), (ii) the expected development of the domestic producer prices and (iii) the actual agricultural policy with the respective subsidy system. The main measures and underlying assumptions are:

- Livestock populations: Direct payments have been decoupled to a certain degree from cropping area and particularly from the number of animals living on the farms reducing incentives for intensification that would lead to negative environmental impacts (Swiss

Confederation 2009). Consequently, the animal population numbers are more directly dependent on price levels. The cattle population is projected to decline slightly, whereas the number of swine and poultry remains more or less constant. Dairy cows are projected to exhibit a further increase in milk yield. Beyond 2027 constant population numbers were assumed for all animal categories due to the lack of further projections.

- **Manure management:** the shares of manure excreted during grazing as well as the shares of the individual manure management systems cannot be predicted satisfactorily and are thus left constant since 2019 together with all other parameters affecting manure management.
- **Crops:** Important aspects of the further development of direct payments that influence the development of the crop cultures are an improved targeting of direct payments, particularly for the promotion of common goods and the securing of a socially acceptable development (Swiss Confederation 2009, FOAG 2011). In general, arable crop production is projected to slightly decline whereas feed production from grasslands will remain more or less constant. Beyond 2027, constant yields and areas were assumed due to the lack of further projections.
- **Fertilisers and fertiliser management:** Use of commercial fertilisers is projected to decrease slightly until 2027 (Mack and Möhring 2021). Beyond 2027, constant fertiliser use was assumed due to the lack of further projections.

Sector 5 Waste

Per capita waste generation is assumed to remain at the level of 2018 in the projections up to 2030. However, in agreement with the energy scenarios, digestion of organic waste is increasing according to the use of biogas and sewage gas in the energy scenarios. Landfilling of combustible waste is prohibited in Switzerland, and it is assumed that this will also be the case in the future.

9.3 Main pollutants and CO for the WM scenario

Overall projections of the emissions for NO_x, NMVOC, SO_x and CO indicate a significant decline between 2005 and 2030 while it is much weaker for NH₃ (Figure 9-2).

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

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 decrease very slightly compared to the current levels. The main driver for a decrease is in source category 1A Fuel combustion caused by improved emission abatement technology for road and non-road vehicles and machineries and a reduction of fuel consumption. Population growth and, to some extent, the stagnation of the effects of the VOC incentive tax (Swiss Confederation 1997) will lead to a slight increase of NMVOC emissions in sector 2 IPPU. In sector 5 Waste, an increase is based on the assumption that the production of biogas is likely to increase, in particular anaerobic digestion at biogas facilities under 5B2.

The SO_x emissions are projected to remain low, which is mainly due to the revision of the Ordinance on Air Pollution Control (Swiss Confederation 1985) in 2018, which included that eco-grade gas oil (with low sulphur content) is only allowed to be used in installations of a rated thermal input of less than 5 MW from 2023 onwards.

NH₃ emissions are projected to remain more or less on constant, but on a slightly lower level than in 2020 (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 in 1A3b Road transportation and 1A4 Other sectors driven by improved emission abatement technology for road vehicles, lower fuel consumption for heating because of better insulation of buildings and a higher share of solar heating and heat pumps.

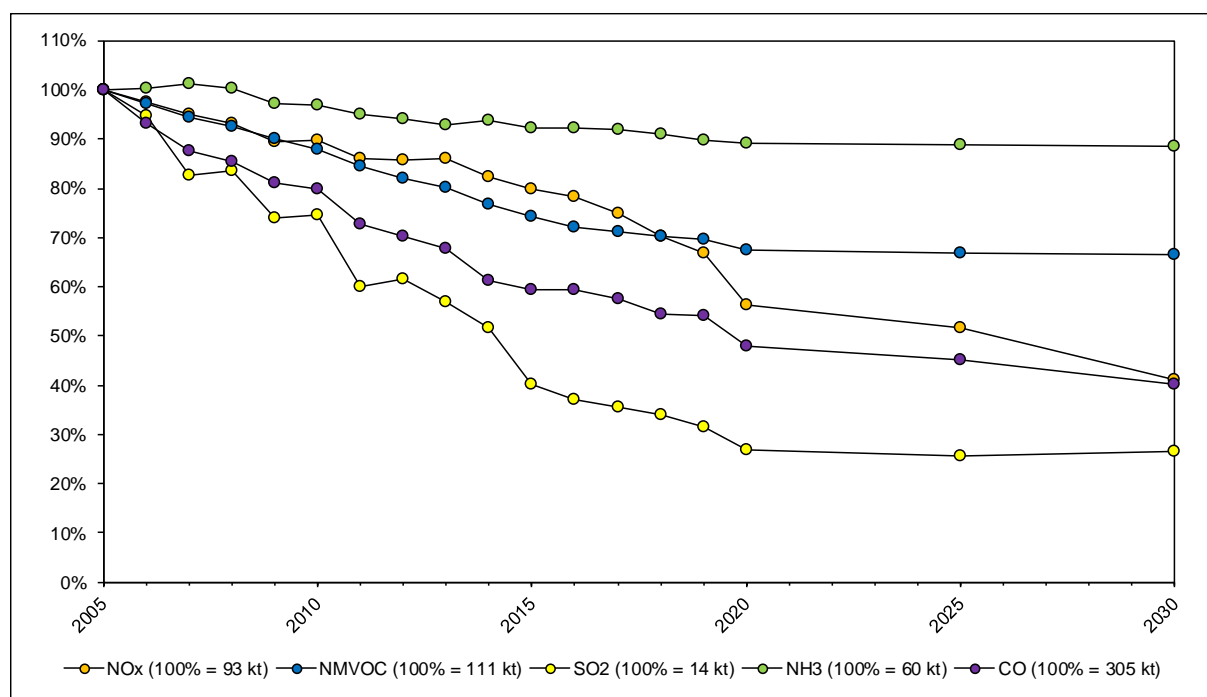


Figure 9-2: Relative trends for the total emissions of main air pollutants and CO in Switzerland as projected in the WM scenario. 100 % corresponds to the 2005 levels (base year of the Gothenburg Protocol).

Table 9-3: Main air pollutants and CO: Total emissions of the WM projections until 2030 in kt.

Year	NO _x	NM VOC	SO ₂	NH ₃	CO
	kt	kt	kt	kt	kt
2005	93	111	14	60	305
2010	83	98	10	58	244
2011	80	94	8.4	57	222
2012	80	91	8.6	56	215
2013	80	89	8.0	56	208
2014	76	86	7.3	56	187
2015	74	83	5.6	55	181
2016	73	80	5.2	55	182
2017	70	79	5.0	55	176
2018	65	78	4.8	54	166
2019	62	77	4.4	54	165
2020	53	75	3.8	53	146
2025	48	75	3.6	53	138
2030	38	74	3.7	53	123
2030 vs. 2020 (%)	-27%	-2%	-2%	-1%	-16%

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 Road transportation with the largest absolute contribution and the strongest relative decrease – but also in source categories 1A2 Manufacturing industry and construction and 1A4 Other sectors.

Reductions under 1A Fuel combustion are expected to be achieved by improved emission abatement technology and by improved in-use compliance under real driving conditions for road vehicles in source category 1A3b Road transportation (triggered by the Euro 6/VI standards and a reduction of fuel consumption (see Figure 9-1)) as well as by measures related to domestic and commercial heating in source category 1A4 Other sectors such as better insulation of buildings, higher share of solar heating and heat pumps or increased use of eco-grade gas oil (with low sulphur and nitrogen content). In source category 1A2 Manufacturing industry and construction, reductions of production volumes (e.g. cement industry and other non-metallic minerals) also contribute to the overall projected emission reduction until 2030. The slight emission increase of 1A1 is caused by growing amount of waste incinerated due to population growth. Compared to the energy sector, the other sectors are less relevant for the development of NO_x emissions. In sector 2 Industrial processes and product use, emissions in 2030 are projected to be lower than in the base year 2005 but to increase compared to the current (low) level in 2020. In sector 3 Agriculture, emissions are expected to be lower in 2030 than in 2005, but to remain constant on current levels. In sector 5 Waste, a decrease in emissions is expected until 2025 compared to 2005. From 2025 onwards, the trend levels off. In sector 6 Other, emissions are on a very low level and are expected to slightly increase until 2030 compared to 2005.

Table 9-4: WM projections: Relative trends of NO_x emissions per sector (2005 represents 100 %).

NO _x emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	89	55%	50%	39%
1A Fuel combustion	88	55%	50%	39%
1A1 Energy industries	2.9	82%	86%	89%
1A2 Manufacturing industries and constr.	14	51%	46%	41%
1A3 Transport	54	54%	49%	34%
1A4 Other sectors	16	55%	48%	43%
1A5 Other (Military)	0.60	66%	88%	91%
1B Fugitive emissions from fuels	0.29	0.6%	0.6%	0.6%
2 IPPU	0.32	73%	81%	89%
3 Agriculture	3.8	94%	94%	94%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.16	77%	77%	76%
6 Other	0.090	101%	104%	103%
National total	93	56%	52%	41%

9.3.2 Projections for NMVOC

The bulk of NMVOC emission reductions has been achieved until 2016, and a minor decrease of emissions is expected from 2020 up to 2030 (see Table 9-3 and Table 9-5). Although increase is projected in sector 2 IPPU, the most important source for NMVOC emissions, a reduction in the energy sector leads to the overall reduction.

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

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

NMVOC emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	40	36%	32%	28%
1A Fuel combustion	36	36%	32%	27%
1A1 Energy industries	0.22	81%	82%	83%
1A2 Manufacturing industries and constr.	2.1	44%	42%	41%
1A3 Transport	23	32%	27%	23%
1A4 Other sectors	10	43%	37%	33%
1A5 Other (Military)	0.11	58%	76%	79%
1B Fugitive emissions from fuels	4.5	37%	35%	33%
2 IPPU	53	75%	77%	78%
3 Agriculture	17	112%	111%	110%
4 LULUCF	NR	NR	NR	NR
5 Waste	1.0	166%	218%	271%
6 Other	0.19	105%	107%	107%
National total	111	68%	67%	66%

9.3.3 Projections for SO_x

The decreasing trend of SO_x emissions is expected to continue until 2025, thereafter is a very slight increase between 2025 and 2030 (see Table 9-3 and 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 CO₂ law, Swiss Confederation 2011). The slight increase in SO_x emissions between 2025 and 2030 is due to a projected increase of the use of residual fuel oil in source category 1A1b Petroleum refining. Only marginal emission reductions or stable levels are projected for all other source categories.

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

SO _x emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	13	25%	23%	23%
1A Fuel combustion	12	26%	24%	24%
1A1 Energy industries	1.7	17%	21%	25%
1A2 Manufacturing industries and constr.	4.1	45%	44%	44%
1A3 Transport	0.21	64%	121%	127%
1A4 Other sectors	6.3	14%	7.3%	6.7%
1A5 Other (Military)	0.037	84%	125%	133%
1B Fugitive emissions from fuels	0.51	3.3%	3.3%	3.3%
2 IPPU	1.1	49%	56%	64%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.063	47%	47%	46%
6 Other	0.011	95%	95%	95%
National total	14	27%	26%	26%

9.3.4 Projections for NH₃

Emission projections for NH₃ are highly dependent on sector 3 Agriculture. Overall, NH₃ emissions are expected to be more or less constant between 2020 and 2030, but on a slightly lower level in 2030 than in 2020 (see Table 9-3).

The emission projections for the sector 3 Agriculture up to 2030 are based on Swiss modelling studies covering the expected development of livestock numbers under specified economic and regulatory conditions (Mack and Möhring 2021). Projections are calculated with unchanged emission factors (except for dairy cattle, see chapter 9.2) resulting for different livestock categories on the basis of the detailed farm survey carried out in 2019 (see chapter 5.2.2). This is a conservative approach that does not include any further changes in housing systems and manure management techniques. Emission factors on the aggregated reporting level may change slightly due to changes in the projected animal numbers on lower disaggregated levels, as for example in the source category 3B3 Manure Management - Swine consisting of animal categories piglets, fattening pig, dry sows, nursing sows and boars with constant emission factors for each. Nonetheless, changes are expected to occur due to the further application of existing programs with incentives to introduce low-emission techniques or animal welfare programs. Agricultural NH₃ emissions between 2020 and 2030 are expected to decline very slightly due to the projected development of livestock numbers for cattle until 2027.

Ammonia emissions from all other sectors are of minor relevance in comparison with the agriculture sector. NH₃ emissions show slightly 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 levels is expected to occur in sector 5 Waste due to a growing population. In sector 6 Other, emissions have increased between 2005 and 2015, but have stabilized afterwards and are expected to remain about constant at the current level.

Table 9-7: WM projections: Relative trends of NH₃ emissions per sector (2005 represents 100 %).

NH ₃ emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	3.9	31%	31%	30%
1A Fuel combustion	3.9	31%	31%	30%
1A1 Energy industries	0.026	130%	139%	148%
1A2 Manufacturing industries and constr.	0.19	103%	104%	105%
1A3 Transport	3.5	24%	24%	24%
1A4 Other sectors	0.16	76%	72%	69%
1A5 Other (Military)	0.000039	103%	103%	103%
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	0.35	43%	40%	36%
3 Agriculture	54	93%	93%	92%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.93	95%	105%	117%
6 Other	0.88	109%	111%	112%
National total	60	89%	89%	89%

9.3.5 Projections for CO

For the next years, a continuous decreasing trend for total CO emissions is projected (see Figure 9-3 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)). For domestic and commercial heating, continuous better insulation of buildings, higher share of solar heating and heat pumps, continuous technological improvements of wood combustion installations and slight decrease in wood energy consumption in manually operated furnaces as well as further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves) are expected. Accordingly, the bulk of emission reductions occur in 1A Fuel combustion, particularly in 1A3 Transport 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 population growth and thereby an increase of waste incineration).

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

CO emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	295	46%	43%	38%
1A Fuel combustion	295	46%	43%	38%
1A1 Energy industries	0.96	59%	65%	70%
1A2 Manufacturing industries and constr.	21	74%	71%	69%
1A3 Transport	166	37%	35%	29%
1A4 Other sectors	106	55%	50%	46%
1A5 Other (Military)	0.92	82%	98%	101%
1B Fugitive emissions from fuels	0.089	0.6%	0.6%	0.6%
2 IPPU	8.1	103%	107%	109%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	1.9	76%	69%	62%
6 Other	0.76	82%	82%	82%
National total	305	48%	45%	40%

9.4 Suspended particulate matter

Projected trends for suspended particulate matter PM_{2.5}, PM₁₀, TSP and BC show an overall decline between 2005 and 2030 (see Figure 9-3 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 9-4 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. In 2020, due to the COVID-19 pandemic and thereby lower traffic volumes, non-exhaust PM emissions dropped (see Figure 9-4). Therefore, the overall trend for PM₁₀ and TSP (exhaust and non-exhaust) is increasing between 2020 and 2030.

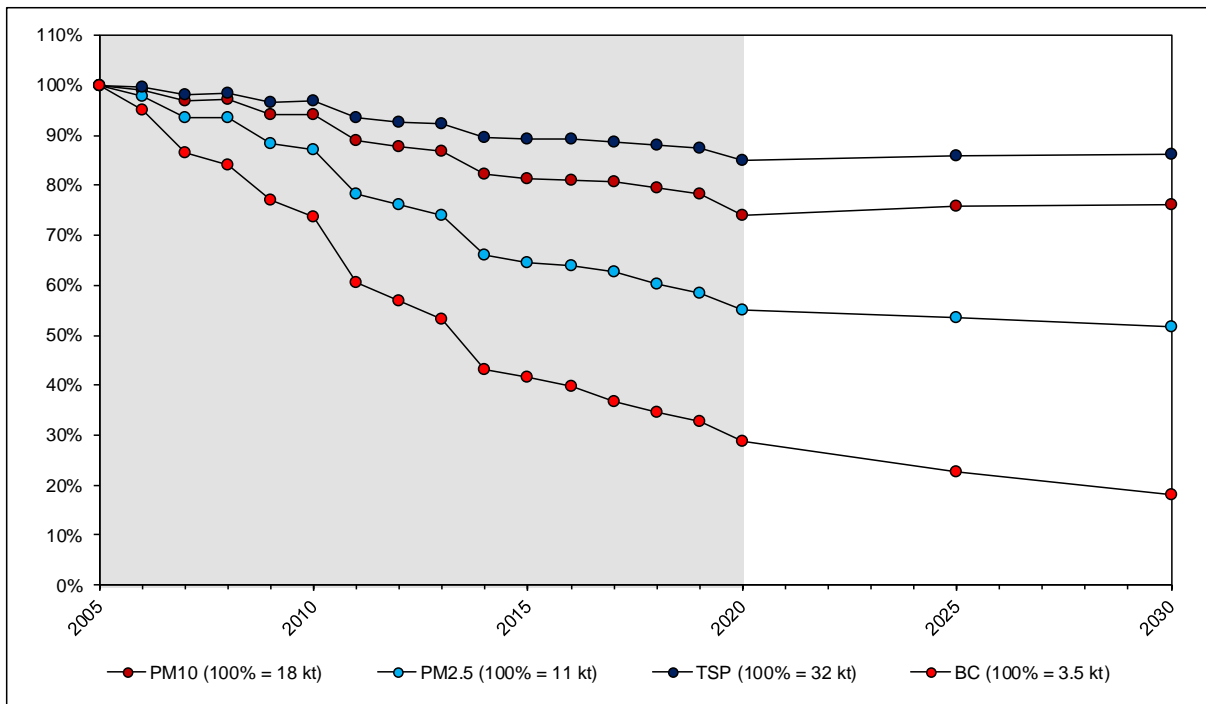


Figure 9-3: Projection of total emissions of suspended particulate matter PM2.5, PM10, TSP and BC in Switzerland of the WM (WEM) scenario (in percentage of 2005). The figure shows the sum of exhaust and non-exhaust particles.

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

Year	PM2.5	PM10	TSP	BC
	kt	kt	kt	kt
2005	11	18	32	3.5
2010	9.3	17	31	2.6
2011	8.3	16	30	2.1
2012	8.1	16	30	2.0
2013	7.9	16	30	1.9
2014	7.1	15	29	1.5
2015	6.9	15	29	1.5
2016	6.8	15	29	1.4
2017	6.7	15	28	1.3
2018	6.4	14	28	1.2
2019	6.2	14	28	1.2
2020	5.9	13	27	1.0
2025	5.7	14	28	0.81
2030	5.5	14	28	0.65
2030 vs. 2020 (%)	-6%	3%	2%	-37%

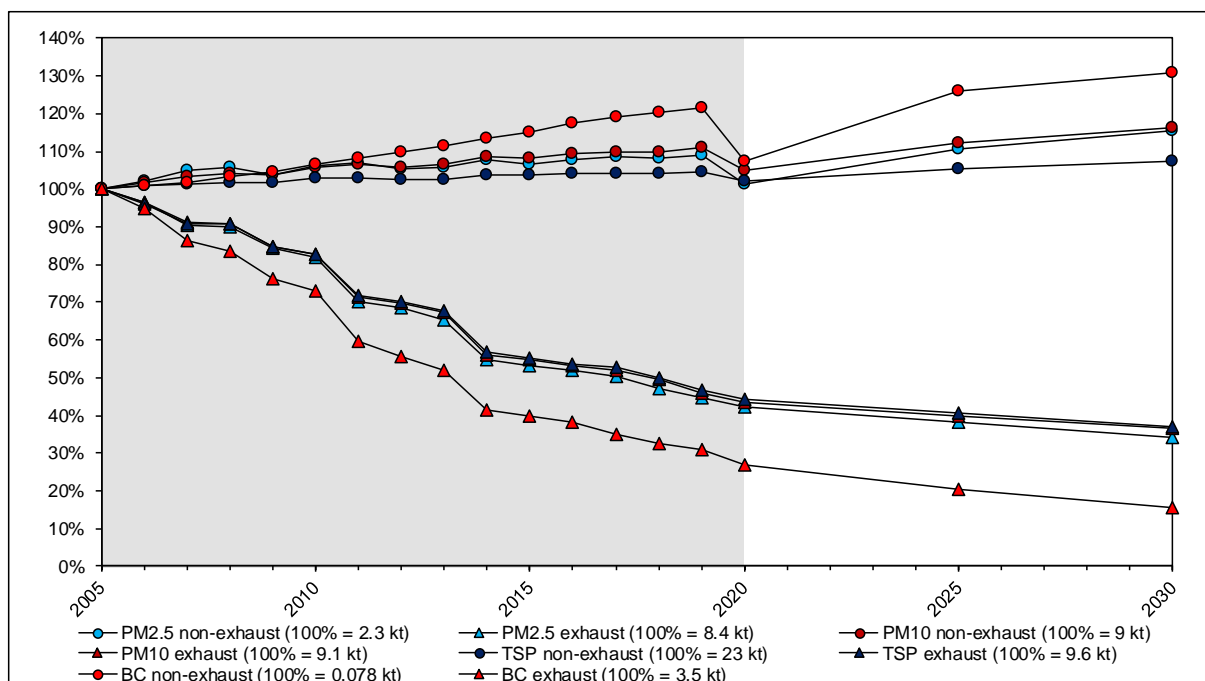


Figure 9-4: Projection of exhaust and non-exhaust emissions of suspended particulate matter PM2.5, PM10, TSP and BC in Switzerland of the WM scenario (in percentage of 2005).

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

Year	PM2.5 ex	PM10 ex	TSP ex	BC ex
	kt	kt	kt	kt
2005	8.4	9.1	9.6	3.5
2010	6.9	7.5	7.9	2.5
2011	5.9	6.5	6.9	2.1
2012	5.7	6.4	6.7	1.9
2013	5.5	6.1	6.5	1.8
2014	4.6	5.1	5.4	1.4
2015	4.5	5.0	5.3	1.4
2016	4.3	4.8	5.1	1.3
2017	4.2	4.8	5.1	1.2
2018	4.0	4.5	4.8	1.1
2019	3.7	4.2	4.5	1.1
2020	3.5	4.0	4.3	0.94
2025	3.2	3.6	3.9	0.71
2030	2.9	3.3	3.6	0.54
2030 vs. 2020 (%)	-19%	-16%	-16%	-42%

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

Year	PM2.5 nx	PM10 nx	TSP nx	BC nx
	kt	kt	kt	kt
2005	2.3	9.0	23	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	9.8	23	0.088
2015	2.4	9.8	23	0.089
2016	2.5	9.9	23	0.091
2017	2.5	9.9	23	0.092
2018	2.5	9.9	23	0.093
2019	2.5	10	24	0.094
2020	2.3	9.4	23	0.083
2025	2.5	10	24	0.098
2030	2.6	10	24	0.10
2030 vs. 2020 (%)	14%	11%	5%	22%

9.4.1 Projections for PM2.5

The overall decreasing trend of emissions from PM2.5 emissions is expected to continue until 2030 (see Figure 9-3 and Table 9-12).

The largest future reductions are expected to occur in 1A Fuel combustion, particularly in small combustion installations in source category 1A4, due to continuous technological improvements of wood combustion installations and a further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves), because they must comply with stricter air pollution control requirements from 2007 onwards as well as a continuous slight decrease in wood energy consumption in manually operated furnaces. Since emissions in source category 1A3b Road transportation have dropped in 2020 due to COVID-19, a potential reduction of total PM2.5 emission in this category is not visible anymore between 2020 and 2030. However, there are some reductions that will happen compared to the year 2019 (without “COVID-19 effect”): The Euro 6/VI standard, a reduction of fuel consumption (see Figure 9-1) and a limit value for particle number emissions for non-road vehicles (under the EU stage V emission standard starting in January 2019) will diminish future emissions. However, at the same time non-exhaust emissions are expected to increase with increasing activity (vehicle kilometres), which partially compensates the decrease of exhaust emissions. This effect is more relevant for the larger particles (TSP, PM10) and less for smaller fractions.

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

Table 9-12: WM projections: Relative trends of PM2.5 emissions per sector (2005 represents 100 %).

PM2.5 emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	8.7	48%	46%	44%
1A Fuel combustion	8.7	48%	46%	44%
1A1 Energy industries	0.18	33%	36%	39%
1A2 Manufacturing industries and constr.	1.5	41%	36%	34%
1A3 Transport	2.8	48%	52%	52%
1A4 Other sectors	4.1	52%	46%	41%
1A5 Other (Military)	0.057	79%	83%	83%
1B Fugitive emissions from fuels	0.00066	7%	8%	8%
2 IPPU	1.5	82%	87%	92%
3 Agriculture	0.13	112%	112%	112%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.38	77%	68%	58%
6 Other	0.0041	128%	132%	132%
National total	11	55%	54%	52%

9.4.2 Projections for PM10

PM10 emissions are expected to slightly increase until 2030 (see Figure 9-3 and Table 9-13).

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

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

Table 9-13: WM projections: Relative trends of PM10 emissions per sector (2005 represents 100 %).

PM10 emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	14	68%	70%	70%
1A Fuel combustion	14	68%	70%	70%
1A1 Energy industries	0.19	33%	36%	39%
1A2 Manufacturing industries and constr.	3.4	77%	76%	76%
1A3 Transport	5.4	75%	85%	88%
1A4 Other sectors	4.3	52%	46%	41%
1A5 Other (Military)	0.27	98%	99%	99%
1B Fugitive emissions from fuels	0.0013	35%	37%	38%
2 IPPU	2.3	85%	90%	94%
3 Agriculture	1.7	107%	107%	107%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.42	77%	68%	59%
6 Other	0.20	84%	84%	84%
National total	18	74%	76%	76%

9.4.3 Projections for TSP

TSP emissions show a similar projected development as PM10 emissions (see Figure 9-3 and Table 9-14, 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. Because of the drop of emissions in 2020 due to COVID-19, this increase appears even larger.

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

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

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

TSP total emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	15	72%	74%	74%
1A Fuel combustion	15	72%	74%	74%
1A1 Energy industries	0.20	32%	35%	38%
1A2 Manufacturing industries and constr.	4.5	84%	85%	85%
1A3 Transport	5.8	77%	87%	91%
1A4 Other sectors	4.6	52%	46%	41%
1A5 Other (Military)	0.39	100%	101%	101%
1B Fugitive emissions from fuels	0.0023	49%	50%	52%
2 IPPU	3.4	87%	90%	94%
3 Agriculture	13	101%	101%	101%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.52	77%	68%	58%
6 Other	0.25	86%	86%	86%
National total	32	85%	86%	86%

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

TSP exhaust emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	8.0	38%	33%	29%
1A Fuel combustion	8.0	38%	33%	29%
1A1 Energy industries	0.20	32%	35%	38%
1A2 Manufacturing industries and constr.	1.4	24%	18%	14%
1A3 Transport	1.9	19%	16%	13%
1A4 Other sectors	4.5	51%	45%	40%
1A5 Other (Military)	0.020	32%	42%	43%
1B Fugitive emissions from fuels	0.00059	1%	1%	1%
2 IPPU	0.85	73%	80%	88%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.51	77%	68%	58%
6 Other	0.23	83%	83%	83%
National total	9.6	44%	40%	37%

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

TSP non-exhaust emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	7.4	108%	118%	123%
1A Fuel combustion	7.4	108%	118%	123%
1A1 Energy industries	NA	NA	NA	NA
1A2 Manufacturing industries and constr.	3.0	113%	116%	119%
1A3 Transport	3.9	106%	121%	129%
1A4 Other sectors	0.12	87%	84%	82%
1A5 Other (Military)	0.37	104%	104%	104%
1B Fugitive emissions from fuels	0.0017	65%	67%	69%
2 IPPU	2.6	92%	94%	96%
3 Agriculture	13	101%	101%	101%
4 LULUCF	NR	NR	NR	NR
5 Waste	0.0036	100%	100%	100%
6 Other	0.017	129%	131%	130%
National total	23	102%	106%	107%

9.4.4 Projections for BC

The decreasing trend of emissions from PM_{2.5} and PM₁₀ is also reflected in the trends of BC emissions and is even more pronounced since the reduction measure mainly focus on combustion particles which largely consists of BC (see Figure 9-3 and Table 9-17). 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 PM_{2.5}: 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 projections: Relative trends of BC emissions per sector (2005 represents 100 %).

BC emissions	2005	2020	2025	2030
	kt	%	%	
1 Energy	3.5	28%	22%	18%
1A Fuel combustion	3.5	28%	22%	18%
1A1 Energy industries	0.012	25%	27%	29%
1A2 Manufacturing industries and constr.	0.32	14%	7%	4%
1A3 Transport	1.2	21%	17%	14%
1A4 Other sectors	1.9	36%	29%	23%
1A5 Other (Military)	0.0099	32%	42%	43%
1B Fugitive emissions from fuels	0.00018	15%	16%	16%
2 IPPU	0.0026	51%	51%	50%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.027	78%	69%	59%
6 Other	0.00014	84%	84%	84%
National total	3.5	29%	23%	18%

9.5 Priority heavy metals

Projected emissions for priority heavy metals Pb, Cd and Hg are shown in Figure 9-5 and Table 9-18. While Pb emissions are projected to decrease slightly between 2020 and 2030, Cd and Hg are considered to increase. For Pb, the slight reduction is due to technical improvements in 5C1biv Sewage sludge incineration from 2018 onwards. This yields a decrease by factor four in the emission factor of Pb and slightly decreasing emissions of Pb despite continuously increasing amounts of incinerated sewage sludge. For Cd, the increase is related to an increase in the amount of waste incinerated (1A1 Energy industries) and to increased traffic volumes, which leads to an increase in Cd non-exhaust emissions. For Hg, the increase is also partly related to an expected increase in the amount of waste incinerated (1A1 Energy industries).

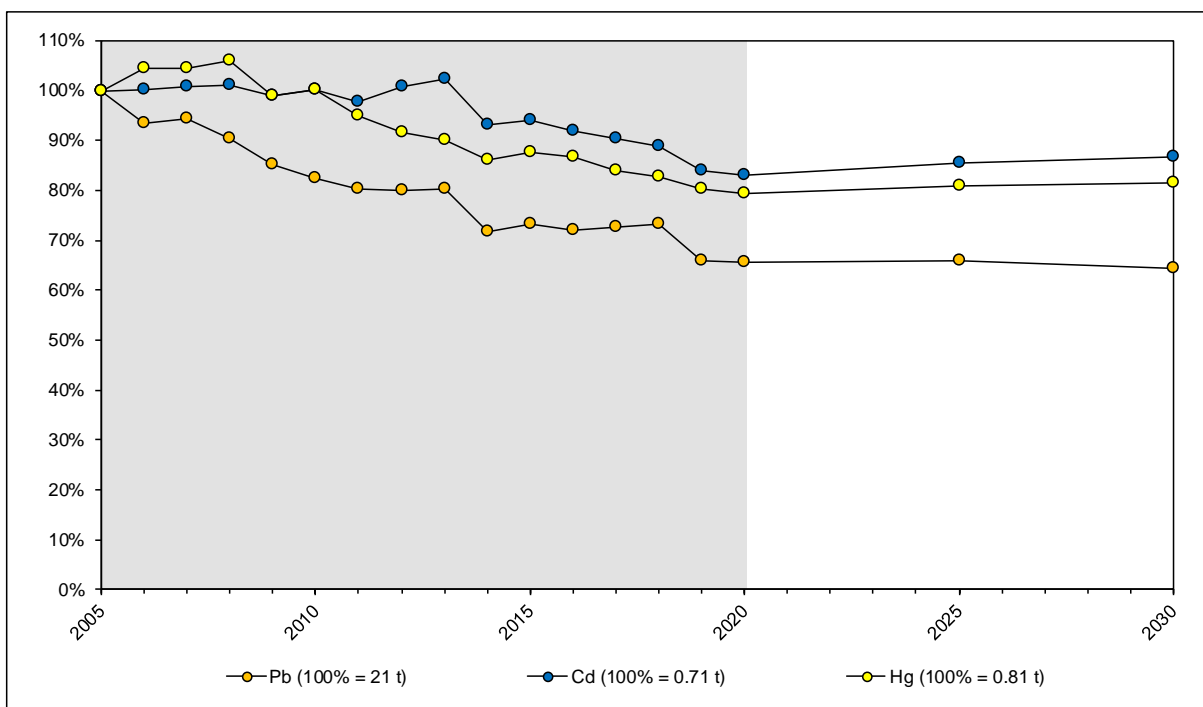


Figure 9-5: Projected emissions of priority heavy metals in Switzerland until 2030 of the WM scenario (in percentage of 2005 level).

Table 9-18: WM projected total emissions of priority heavy metal in tonnes.

Year	Pb	Cd	Hg
	t	t	t
2005	21	0.71	0.81
2010	17	0.71	0.81
2011	17	0.69	0.77
2012	17	0.71	0.74
2013	17	0.72	0.73
2014	15	0.66	0.70
2015	15	0.66	0.71
2016	15	0.65	0.70
2017	15	0.64	0.68
2018	15	0.63	0.67
2019	14	0.59	0.65
2020	14	0.59	0.64
2025	14	0.60	0.65
2030	13	0.61	0.66
2030 vs. 2020 (%)	-2%	4%	3%

9.5.1 Projections for lead (Pb)

The annual national total of lead emissions will presumably slightly decrease until 2030 compared to current levels (see Table 9-19 and Figure 9-5).

In the energy sector, emissions are expected to slightly increase from 2020 to 2030. On one hand, this increase is because of increasing emissions from source category 1A1 due to growing amount of waste incinerated. On the other hand, an increase is visible for source category 1A3b. However, this increase is caused by the drop of emissions in 2020 due to the COVID-19 pandemic. In the future – without the “COVID-effect” – Pb emissions from 1A3 Transport are projected to decrease due to the assumption that the share of diesel oil will continue to increase compared to gasoline.

The emissions from sector 2 Industrial processes and product use are projected to slightly increase. The reduction in the waste sector from 2020 compared to 2005 is to a major extent attributable to 5C1biv Sewage sludge incineration and 5C1bv Cremations. Technical improvements in emissions reductions technologies lead to significant reductions in Hg emissions from these incineration processes. Continuously increasing population numbers thereafter lead to a slight increase in emissions, although emissions in 2030 are remain considerably lower than in 2005. The projection for the major source 6Ad Fire damage estates and motor vehicles assumes that emission factor and activity data remain constant until 2030.

Table 9-19: WM projections: Relative trends of Pb emissions per sector (2005 represents 100 %).

Pb emissions	2005	2020	2025	2030
	t	%	%	
1 Energy	9.9	58%	61%	59%
1A Fuel combustion	9.9	58%	61%	59%
1A1 Energy industries	1.9	86%	88%	91%
1A2 Manufacturing industries and constr.	2.7	32%	32%	32%
1A3 Transport	4.3	60%	67%	63%
1A4 Other sectors	0.96	64%	58%	51%
1A5 Other (Military)	0.00045	86%	85%	84%
1B Fugitive emissions from fuels	0.0011	0.6%	0.6%	0.6%
2 IPPU	2.1	27%	30%	33%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	2.3	75%	64%	54%
6 Other	6.6	86%	86%	86%
National total	21	65%	66%	64%

9.5.2 Projections for cadmium (Cd)

Cadmium emissions are expected to increase until 2030 (see Table 9-20 and Figure 9-5). Responsible for this development of cadmium emissions is an expected increase of emissions in source category 1A1 Energy industries from waste incineration due to population growth as well as an increase of traffic volumes 1A3b Road transportation.

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

Cd emissions	2005	2020	2025	2030
	t	%	%	
1 Energy	0.43	83%	87%	89%
1A Fuel combustion	0.43	83%	88%	89%
1A1 Energy industries	0.18	88%	91%	94%
1A2 Manufacturing industries and constr.	0.10	64%	64%	63%
1A3 Transport	0.077	108%	126%	130%
1A4 Other sectors	0.068	73%	73%	73%
1A5 Other (Military)	0.00051	103%	103%	102%
1B Fugitive emissions from fuels	0.0015	0.001%	0.001%	0.001%
2 IPPU	0.092	87%	87%	88%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.021	42%	41%	40%
6 Other	0.16	86%	86%	86%
National total	0.71	83%	86%	87%

9.5.3 Projections for mercury (Hg)

Overall, the annual national total of mercury emissions is expected to increase until 2030 compared to 2020 (see Table 9-21 and Figure 9-5). 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 an expected increase in the amount of waste incinerated. Emissions

from sectors 5 Waste and 6 Other are on low levels and trends are projected to level off. Emissions from sector 2 Industrial processes and product use, which are very low compared to other sectors, are expected to be on a lower level in 2030 compared to 2005.

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

Hg emissions	2005	2020	2025	2030
	t	%	%	
1 Energy	0.59	85%	87%	88%
1A Fuel combustion	0.59	85%	87%	88%
1A1 Energy industries	0.34	88%	91%	94%
1A2 Manufacturing industries and constr.	0.12	77%	76%	74%
1A3 Transport	0.037	81%	85%	77%
1A4 Other sectors	0.085	90%	88%	86%
1A5 Other (Military)	0.000028	103%	102%	102%
1B Fugitive emissions from fuels	0.00025	0.0001%	0.0001%	0.0001%
2 IPPU	0.067	71%	76%	81%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.077	37%	36%	36%
6 Other	0.076	82%	82%	82%
National total	0.81	79%	81%	82%

9.6 Persistent organic pollutants (POPs)

Figure 9-6 shows projected emission trends for persistent organic pollutants (POP). More detailed figures on projections are given in Table 9-22. The emissions of all POPs are expected to decrease. The decrease of PCB emissions is higher than for the other pollutants.

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

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

For HCB, the slight increase mainly occurs due to an expected increase of the amount of waste incinerated 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 decrease due to technical improvements in wood furnaces under 1A4.

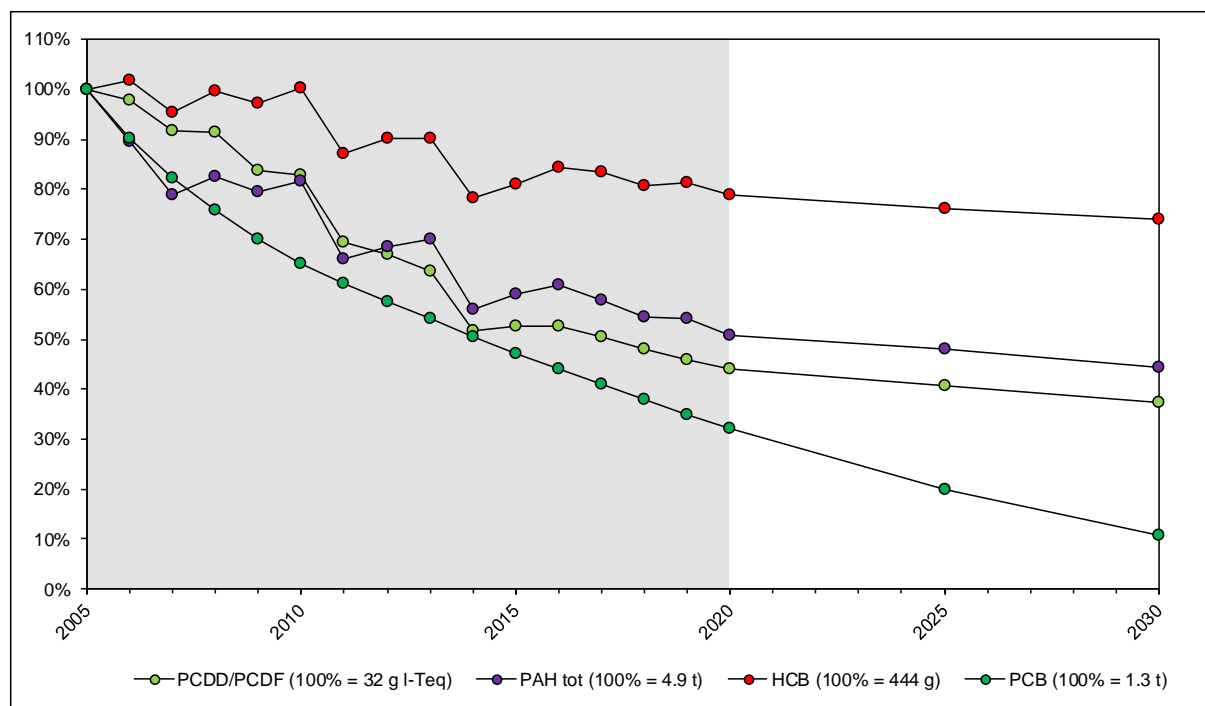


Figure 9-6: Emissions of POPs: PCDD/PCDF, PAH as the sum of benzo(a)pyrene), benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, and HCB in Switzerland in the WM scenario (in percent of 2005).

Table 9-22: 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	0.82	4.9	0.44	1.3
2010	27	1.3	1.3	0.77	0.70	4.0	0.45	0.83
2011	22	1.0	1.1	0.63	0.57	3.3	0.39	0.78
2012	21	1.0	1.1	0.65	0.59	3.4	0.40	0.73
2013	20	1.1	1.1	0.67	0.60	3.4	0.40	0.69
2014	17	0.84	0.89	0.54	0.48	2.8	0.35	0.64
2015	17	0.89	0.93	0.57	0.51	2.9	0.36	0.60
2016	17	0.91	0.96	0.59	0.53	3.0	0.38	0.56
2017	16	0.86	0.91	0.57	0.51	2.8	0.37	0.52
2018	15	0.81	0.86	0.54	0.48	2.7	0.36	0.48
2019	15	0.80	0.85	0.53	0.47	2.7	0.36	0.44
2020	14	0.76	0.80	0.50	0.44	2.5	0.35	0.41
2025	13	0.71	0.76	0.48	0.42	2.4	0.34	0.25
2030	12	0.65	0.71	0.44	0.38	2.2	0.33	0.14
2030 vs. 2020 (%)	-15%	-14%	-12%	-12%	-15%	-13%	-6%	-66%

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 9-6).

The major part of the emissions reduction is expected to happen in source category 1A4 Other sectors (1A4a Commercial and 1A4b Residential) due to continuous technical improvements in wood combustion installations, slight decrease in wood energy consumption in manually operated furnaces as well as further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). Furthermore, emission reductions are

expected in sector 5 Waste (mainly due to a reduction of illegally incinerated waste under 5C1a).

Table 9-23: WM projections: Relative trends of PCDD/PCDF emissions per sector (2005 represents 100 %).

PCDD/PCDF emissions	2005	2020	2025	2030
	g I-Teq	%	%	
1 Energy	23	36%	33%	30%
1A Fuel combustion	23	36%	33%	30%
1A1 Energy industries	5.2	18%	19%	19%
1A2 Manufacturing industries and constr.	2.8	33%	29%	25%
1A3 Transport	1.7	30%	25%	18%
1A4 Other sectors	13	44%	40%	36%
1A5 Other (Military)	0.00038	103%	102%	102%
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	2.1	33%	34%	35%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	4.3	70%	61%	51%
6 Other	2.5	86%	86%	86%
National total	32	44%	41%	37%

9.6.2 Projections for polycyclic aromatic hydrocarbons (PAH)

Overall, the annual national total of PAH emissions is expected to decrease until 2030 (see Table 9-24 and Figure 9-6). The main relevant source of PAH emissions remaining in the future are small wood combustion installations of source category 1A4.

The projected decrease of PAH emissions in 1A4 is due to continuous technical improvements in wood combustion installations, slight decrease in wood energy consumption in manually operated furnaces as well as further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In contrast, a significant emission increase is expected under 1A3 Transport. It is assumed that 1A3 will be a relevant source of PAH emissions in 2030. The reason for this increase is the rising share of diesel oil use under 1A3b.

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

PAHs emissions	2005	2020	2025	2030
	t	%	%	
1 Energy	4.1	54%	50%	46%
1A Fuel combustion	4.1	54%	50%	46%
1A1 Energy industries	0.0085	52%	53%	53%
1A2 Manufacturing industries and constr.	0.18	55%	61%	69%
1A3 Transport	0.17	155%	187%	187%
1A4 Other sectors	3.7	49%	44%	38%
1A5 Other (Military)	0.00073	94%	92%	91%
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	0.50	2.3%	2.4%	2.5%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	0.25	75%	75%	75%
6 Other	0.093	120%	120%	120%
National total	4.9	51%	48%	44%

9.6.3 Projections for hexachlorobenzene (HCB)

HCB emissions on national level are projected to decrease from 2020 until 2030 (see Table 9-25 and Figure 9-6).

The major part of the reduction is expected in the most relevant source category for HCB emissions, 1A4 Other sectors, due to continuous technical improvements of wood combustion installations, slight decrease in wood energy consumption in manually operated furnaces as well as further reduction in the number of emission intensive types of wood furnaces (e.g. cooking stoves). In contrast, HCB emissions will increase in source category 1A1a Electricity and heat production due to an increase of energy generation from waste incineration plants.

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

HCB emissions	2005	2020	2025	2030
	kg	%	%	
1 Energy	0.44	79%	76%	74%
1A Fuel combustion	0.44	79%	76%	74%
1A1 Energy industries	0.15	124%	128%	132%
1A2 Manufacturing industries and constr.	0.051	68%	59%	50%
1A3 Transport	NE	NE	NE	NE
1A4 Other sectors	0.24	53%	47%	42%
1A5 Other (Military)	NE	NE	NE	NE
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	NA	NA	NA	NA
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	NA	NA	NA	NA
6 Other	NA	NA	NA	NA
National total	0.44	79%	76%	74%

9.6.4 Projections for polychlorinated biphenyl (PCBs)

PCB emissions are expected to decrease considerably until 2030 (see Table 9-26 and Figure 9-6). Also in future, the main relevant PCB emission sources remain anti-corrosive paints and joint sealants (2K) which were applied on steel and in window frames, respectively, prior to the ban of PCBs in so-called open application in 1972. To a lesser extent, also accidental releases of PCB by fire and from soil due to former PCB spillages (6Ad) contribute to future PCB emissions. In 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 projections: Relative trends of PCB emissions per sector (2005 represents 100 %).

PCB emissions	2005	2020	2025	2030
	kg	%	%	
1 Energy	1.4	28%	27%	25%
1A Fuel combustion	1.4	28%	27%	25%
1A1 Energy industries	1.1	6.9%	4.9%	3.1%
1A2 Manufacturing industries and constr.	0.35	91%	92%	93%
1A3 Transport	0.00037	29%	23%	17%
1A4 Other sectors	0.0015	48%	45%	42%
1A5 Other (Military)	NE	NE	NE	NE
1B Fugitive emissions from fuels	NA	NA	NA	NA
2 IPPU	922	40%	24%	13%
3 Agriculture	NA	NA	NA	NA
4 LULUCF	NR	NR	NR	NR
5 Waste	254	3.3%	1.5%	0.9%
6 Other	93	33%	24%	18%
National total	1270	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: $0.1^\circ \times 0.1^\circ$ 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.

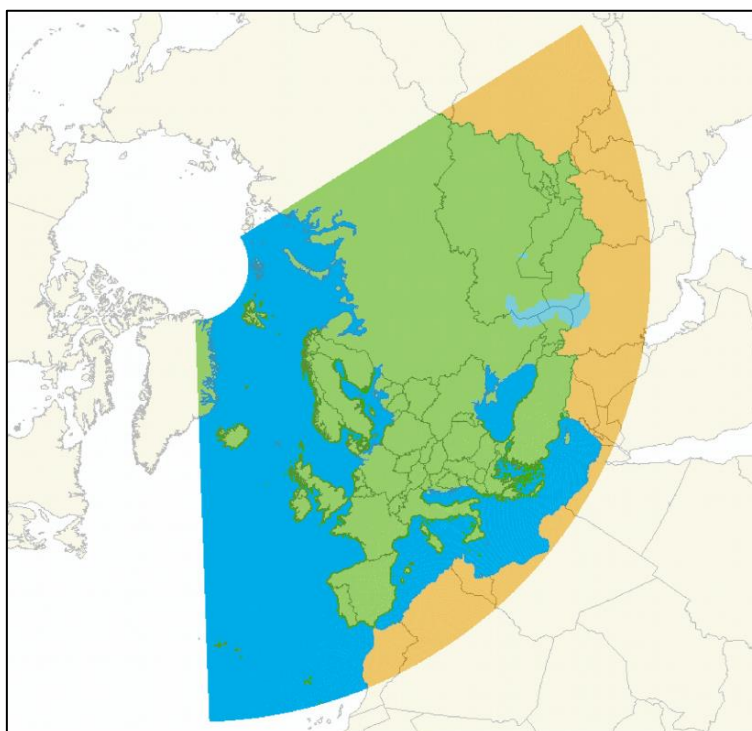


Figure 10-1: EMEP domain in the latitude-longitude projection (30°N - 82°N , 30°W - 90°E) (EMEP 2012a, <https://www.emep.int/grid/lonlatgrid.pdf>).

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 $0.5^\circ \times 0.5^\circ$ to $0.2^\circ \times 0.2^\circ$ (EMEP 2012a). This means, for instance, that in a 0.2° -based EMEP grid the cell size at 40°N (Italy) is $17 \times 22 \text{ km}^2$ whereas at 60°N (Scandinavia) the cell size is $11 \times 22 \text{ km}^2$. In total, a $0.2^\circ \times 0.2^\circ$ 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 $0.1^\circ \times 0.1^\circ$. This results in a spatial resolution at 40°N (Italy) of $9 \times 11 \text{ km}^2$ and $6 \times 11 \text{ km}^2$ at 60°N (Scandinavia). Figure 10-2 illustrates the EMEP grid resolution for Europe as used on local scales. In total, approximately 624'000 grid cells exist within the local EMEP domain.

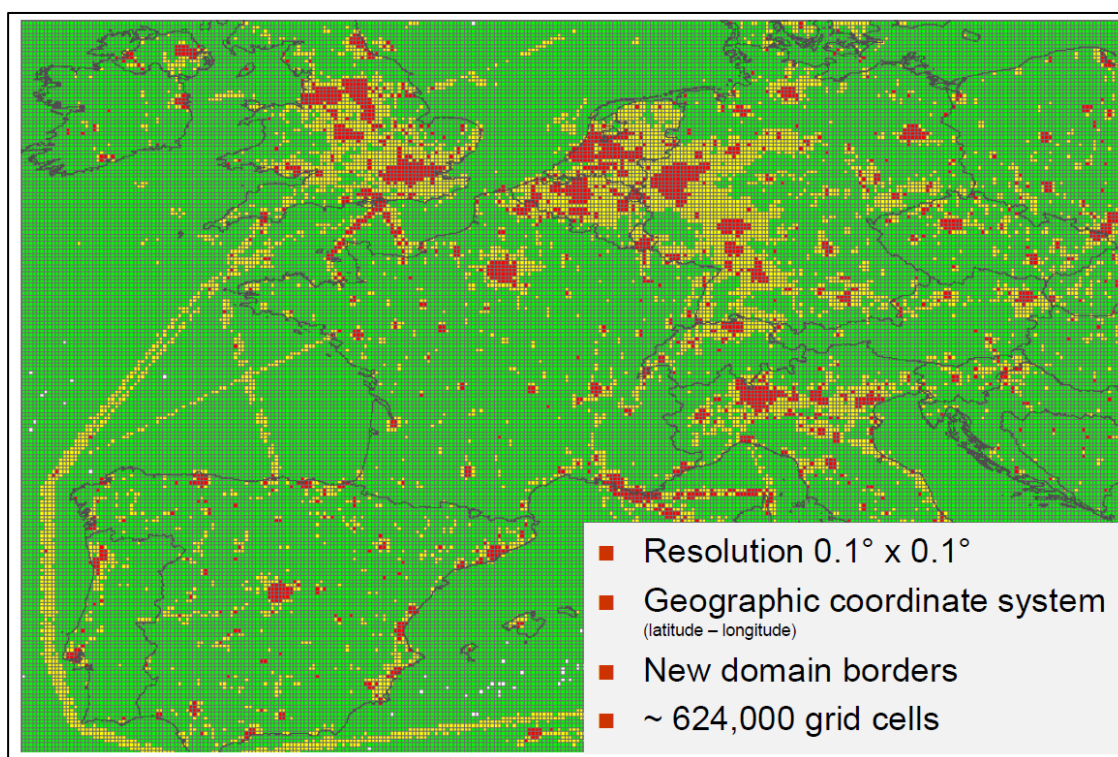


Figure 10-2: Resolution of the EMEP grid for Europe (EMEP 2012b).

In Switzerland's air pollution inventory of the latest submission 2022, the EMEP grid on local scale ($0.1^\circ \times 0.1^\circ$) is applied (see chapter 10.3) and contains 580 different grid cells. This includes also cells covering Lake of Constance. For grid cells outside Swiss borders no emissions are reported (see Figure 10-3).

The challenge in modelling on local scale ($0.1^\circ \times 0.1^\circ$) is the accurate allocation of emissions from the national total of emissions. Accordingly, emissions from national total should be processed to a resolution that is at least as fine as the resolution of the local-based EMEP grid. To achieve that, a separate study has been carried out which provides the allocation of the emissions sources within the local-scale EMEP grid (see Meteotest 2013 and 2021).

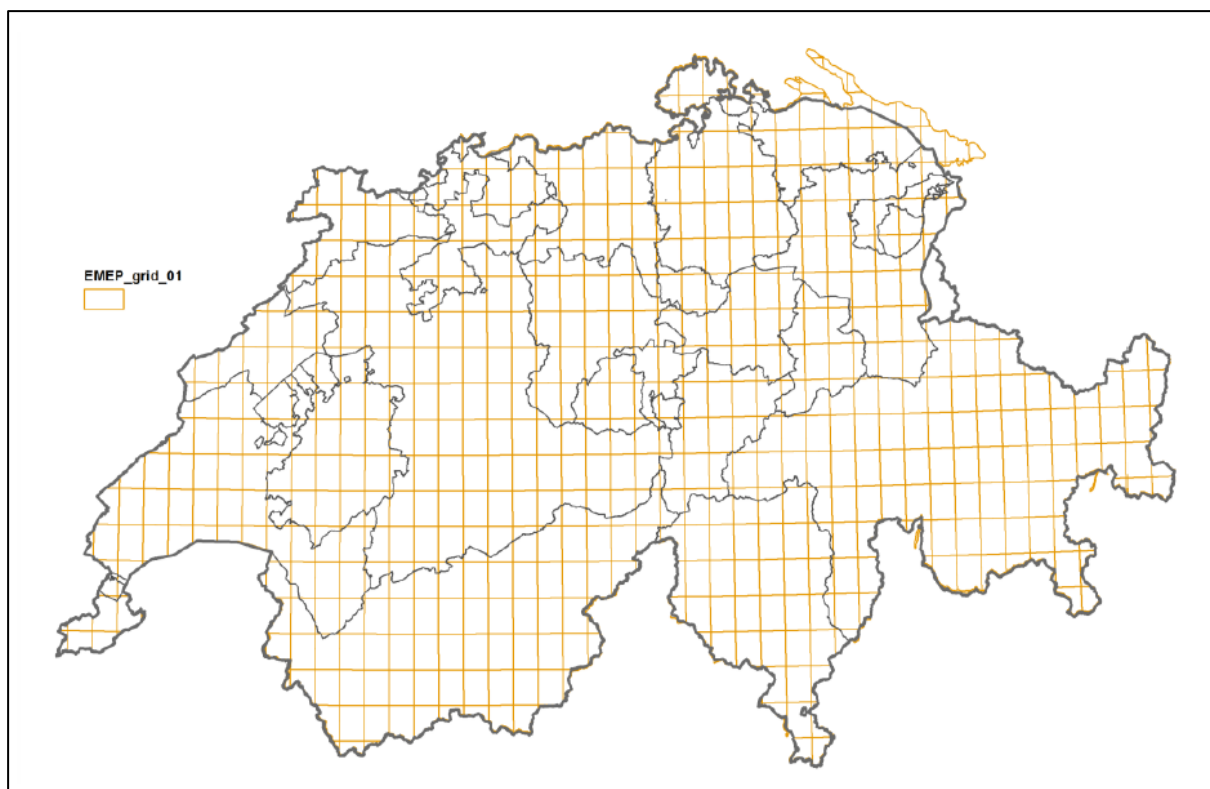


Figure 10-3: EMEP grid in Switzerland with 0.1° x 0.1° spatial resolution (from Meteotest 2013, downloaded from EMEP).

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 annex V (GNFR) of ECE 2014a). Table 10-1 shows the relative shares of the GNFR categories of Switzerland's total emissions (national total) in 2020 for all main air pollutants including PM_{2.5}.

Table 10-1: GNFR categories and their part (%) of total emissions in 2020 (national total) for the main air pollutants and PM2.5.

GNFR aggregated sectors	NO _x	NM VOC	SO _x	NH ₃	PM2.5
A_PublicPower	3.9%	0.22%	6.4%	0.063%	0.75%
B_Industry	11%	8.1%	64%	0.51%	18%
C_OtherStatComb	13%	4.2%	24%	0.23%	33%
D_Fugitive	0.0032%	2.2%	0.44%	NA	0.00083%
E_Solvents	0.036%	45%	0.11%	0.14%	6.3%
F_RoadTransport	52%	9.8%	2.1%	1.8%	20%
G_Shipping	1.8%	0.54%	0.034%	0.00040%	0.46%
H_Aviation	1.5%	0.12%	1.5%	NA	0.13%
I_Offroad	8.6%	2.3%	1.0%	0.0053%	13%
J_Waste	0.23%	2.3%	0.79%	1.7%	5.0%
K_AgriLivestock	1.7%	24%	NA	47%	1.7%
L_AgriOther	5.1%	0.60%	NA	47%	0.76%
M_Other	0.17%	0.27%	0.27%	1.8%	0.090%
Total	100%	100%	100%	100%	100%

10.2.2 Data availability for emission allocation

In order to allocate the emissions of each GNFR category, an adequate allocation key has to be determined. Numerous GNFR categories overlap with various source categories thus it is not possible to apply a single approach. Depending on the properties of each GNFR category, evaluation and identification of an appropriate allocation key is required. This ensures the adequate allocation of total emissions in the EMEP grid. For allocation purposes only relative shares of the national total emissions are relevant. Details of this work can be found in Meteotest 2013 and 2021.

For the latest submission 2022, Switzerland calculated gridded emissions for the entire time series 1980-2020. For the allocation process of the emissions various data sources were applied for the time intervals 1980-1989, 1990-1999, 2000-2009, 2010-2015, 2016-2019 and >2020. Table 10-2 illustrates the data source applied for each time interval.

Table 10-2: Applied data sources for gridded emission time series 1980-1989, 1990-1999, 2000-2009, 2010-2015, 2019-2019 and >2020 (Meteotest 2013 and 2021).

Data source	Distribution pattern	Applied data source for gridded emission time series					
		1980-89	1990-99	2000-09	2010-15	2016-19	> 2020
Population data	1990, 2000, annually from 2010	1990	1990	2000	2013	2017	2020
Census of enterprises sector 1	1996, 2000, 2005, 2008, annually from 2011	1996	1996	2005	2013	2017	2018
Census of enterprises sector 2+3	1995, 2000, 2001, 2005, 2008, annually from 2011	1995	1995	2005	2013	2017	2018
Land use statistics	1979/85, 1992/97, 2004/09, 2013/18	1979/85	1992/97	2004/09	2013/18	2013/18	2013/18
NO _x emission maps	1990, 2000, 2005, 2010, 2015	2005	2005	2005	2015	2015	2015
PM10 emission maps	2005, 2010, 2015	2005	2005	2005	2015	2015	2015
NH ₃ emission maps	1990, 2000, 2007, 2010 (manure management)	1990	2000	2007	2010	2010	2010
Aviation	annual passenger numbers	1985	1995	2005	2013	2017	2019
Refineries	number of refineries	2	2	2	2	1	1
Cement production	number of cement plants (1990, 1998, 2006, 2013)	1990	1998	2006	2013	2013	2013

Population Density

At first sight, most emissions originate where people live and occur proportional to population density in an area. Therefore, population density is one of the main factors to allocate emissions in the EMEP grid. Geo-referenced population data is available annually by the Federal Statistical Office. The most populated area in Switzerland is the Swiss Plateau and the largest cities with their agglomerations in particular (see Figure 10-4).

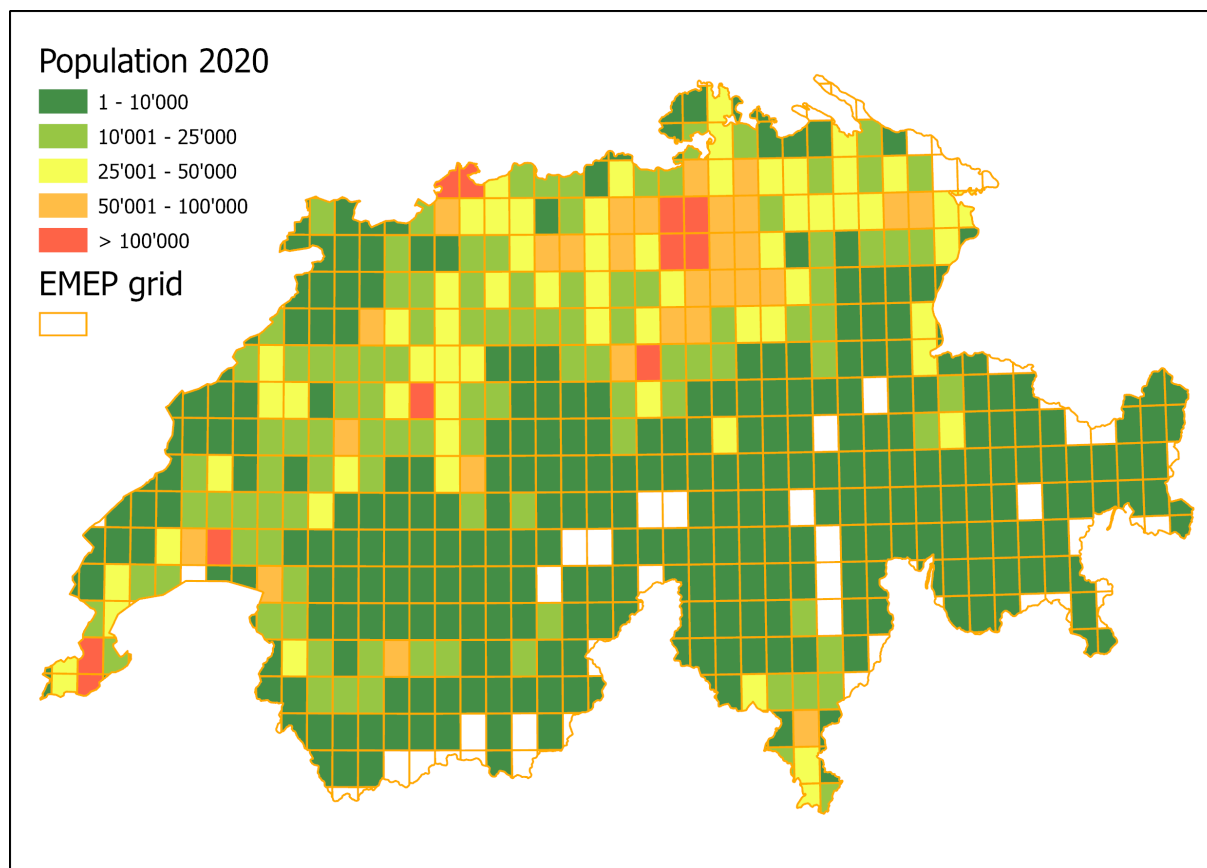


Figure 10-4: Population number per EMEP grid cell in Switzerland in 2020.

Census of enterprises/number of employees by economic sectors

Statistical surveys exist for enterprises, from which information about the specific economic use per hectare (100x100 m²) is derived. This data is provided annually by the Federal Statistical Office. For several GNFR categories covering industrial production, the number of employees per economic branch and per hectare combined with the information on the economic use per hectare is used for the allocation of the emissions in the EMEP grid.

Land Use Statistics

Switzerland’s Land Use Statistics allows determining specific land use characteristics on a hectare-scale (100x100 m²). According to the Land Use Statistics by the Federal Statistical Office 74 categories are available. They are aggregated to 9 main land use categories to apply them to the EMEP grid (Meteotest 2013). The 9 main land use categories are:

- Wooded areas
- Industrial buildings

- Industrial grounds
- Residential buildings
- Surroundings of residential buildings
- Agricultural buildings
- Agricultural areas
- Unspecified buildings
- Wastewater treatment plants

Air pollution 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 2011b, Meteotest 2020)
- NO_x: Emissions of navigation (FOEN 2011b, Meteotest 2020)
- NO_x: Emissions of construction machinery (FOEN 2011b, Meteotest 2020)
- NO_x: Emissions of industrial vehicles (FOEN 2011b, Meteotest 2020)
- PM10: Emissions of rail traffic (FOEN 2013a, Meteotest 2020)
- NH₃: Emissions of manure management - farming of animals without pasture (Meteotest 2019b)

10.2.3 Switzerland’s allocation of emissions for the EMEP grid

Method

The data sets described in 10.2.2 are available for the allocation of total emissions to the EMEP grid. The application of those data sets results in various spatial patterns of national emissions in each GNFR category. The attribution of GNFR categories to the patterns is given in the Table 10-3. This allocation method is applied for every pollutant (Meteotest 2014, 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:

$$\sum_{g=0}^{n_g} Emission_{gs} = Emission_{tot_s}$$

GNFR categories include by definition also Large Point Sources (LPS). The LPS for 2020 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 (2021).

Table 10-3: GNFR categories and their allocation indicators.

GNFR 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 (NO _x emission map for road transport)
G_Shipping	based on specific air pollution modelling data (NO _x emission map of navigation)
H_Aviation	based on the annual statistics of flight passengers of the six largest airports in Switzerland (excluding Basel since it lies on French territory)
I_OffRoad	based on selected land use categories, proportional to the number of employees in economic sector 2 and specific air pollution modelling data (NO _x emission map of construction machinery and industrial vehicles, PM10 emission map of rail transport). Emissions from military activities were uniformly distributed on areas below 1500 meters above sea level.
J_Waste	proportional to the population density, the land use categories industrial buildings, industrial grounds, residential buildings and unspecified buildings, to the number of employees in sector 2 and to the waste water treatment plants
K_AgriLivestock	based on specific air pollution modelling data (NH ₃ emission map of manure management – farming of animals without pasture)
L_AgriOther	based on the land use categories agricultural areas
M_Other	proportional to the population density

Emissions not included in national total emissions

The following GNFR categories are not part of the national total emissions for the EMEP grid domain. These emissions are, therefore, not allocated to the EMEP grid cells.

Table 10-4: GNFR categories not included in the EMEP grid domain (according to Meteotest 2013).

GNFR	NFR Code	Longname
K_CivilAviCruise	1 A 3 a ii (ii)	1 A 3 a ii (ii) Civil Aviation (Domestic Cruise)
T_IntAviCruise	1 A 3 a i (ii)	1 A 3 a i (ii) Civil Aviation (International Cruise)
z_memo	1 A 3 d i (i)	1 A 3 d i (i) International maritime Navigation
	1 A 3	Transport (fuel used)
	7 B	Other (not included in National Total for Entire Territory)
S_Natural	11 A	11 (11 08 Volcanoes)
	11 B	Forest fires
	11 C	Other natural emissions

10.3 EMEP grid results (visualizations)

10.3.1 Spatial distribution of Switzerland’s NO_x emissions 2020

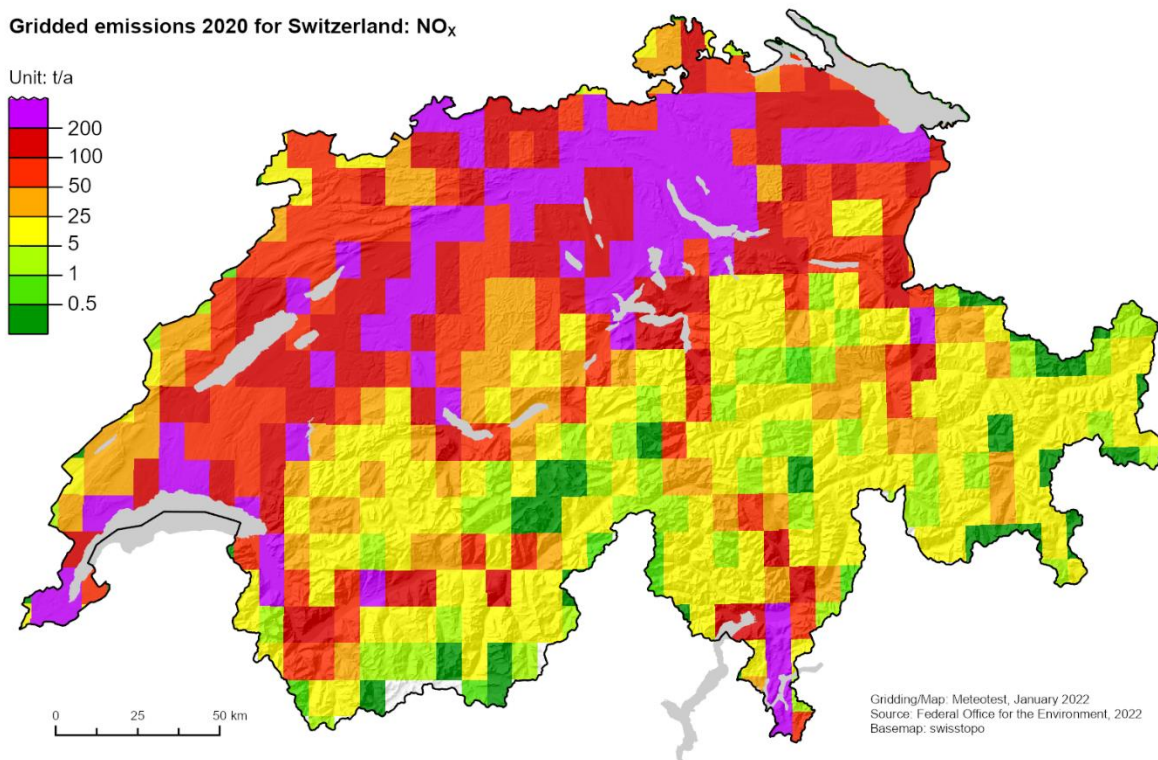


Figure 10-5: Spatial distribution of the NO_x emissions in Switzerland.

10.3.2 Spatial distribution of Switzerland's NMVOC emissions 2020

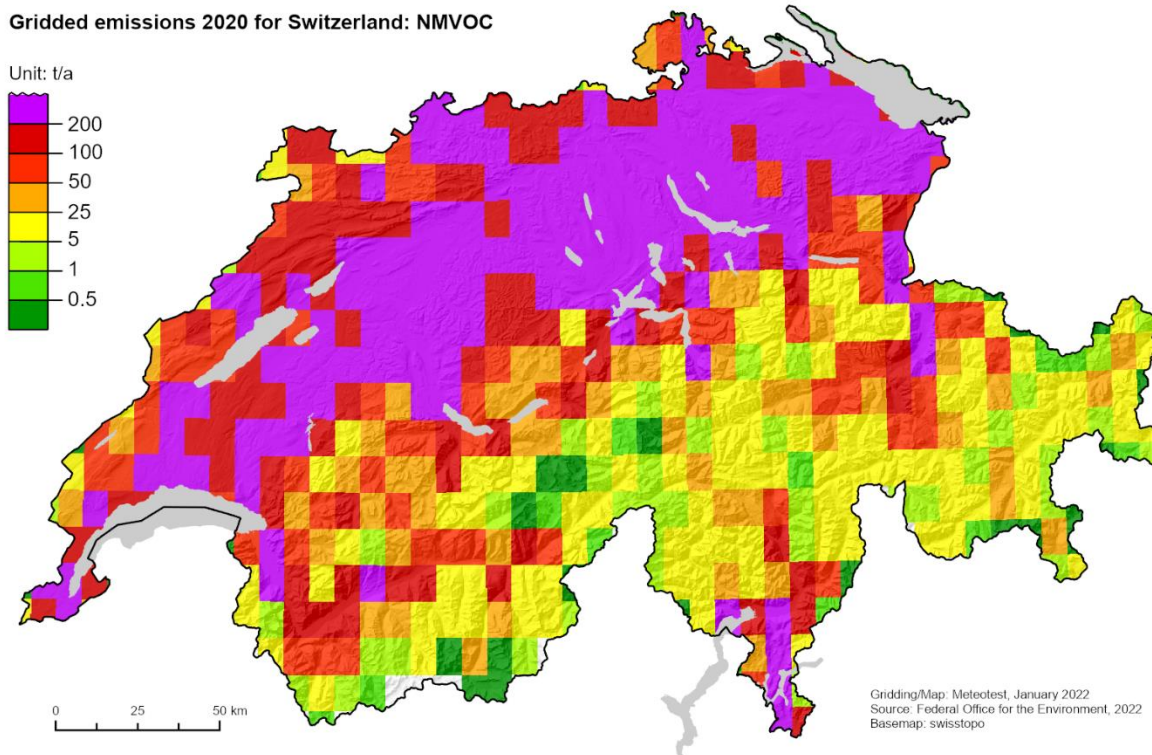


Figure 10-6: Spatial distribution of the NMVOC emissions in Switzerland.

10.3.3 Spatial distribution of Switzerland's SO_x emissions 2020

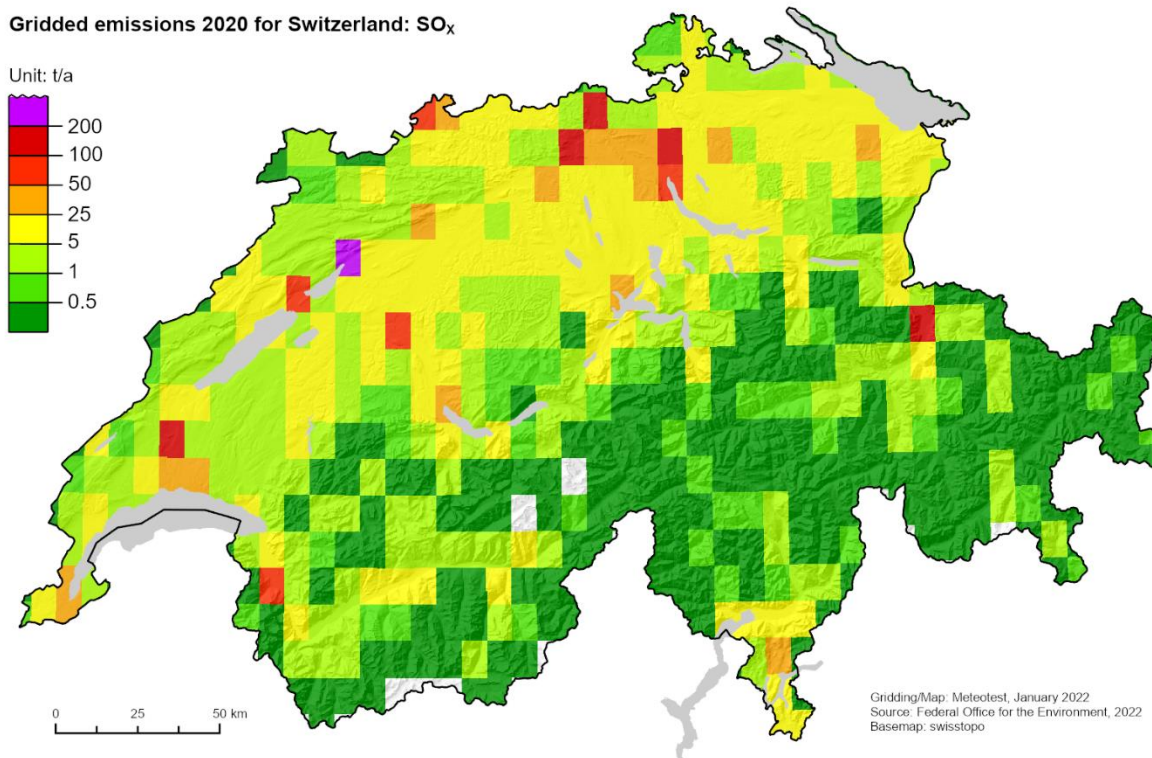


Figure 10-7: Spatial distribution of the SO_x emissions in Switzerland.

10.3.4 Spatial distribution of Switzerland's NH₃ emissions 2020

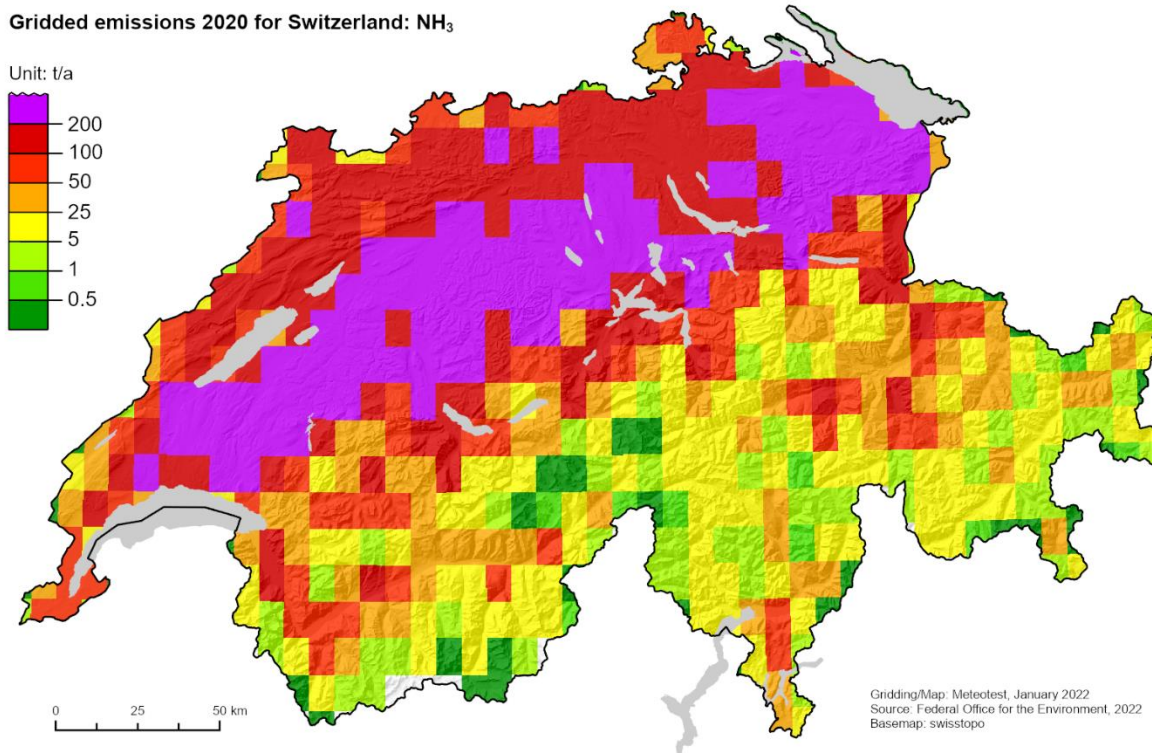


Figure 10-8: Spatial distribution of the NH₃ emissions in Switzerland.

10.3.5 Spatial distribution of Switzerland's PM_{2.5} emissions 2020

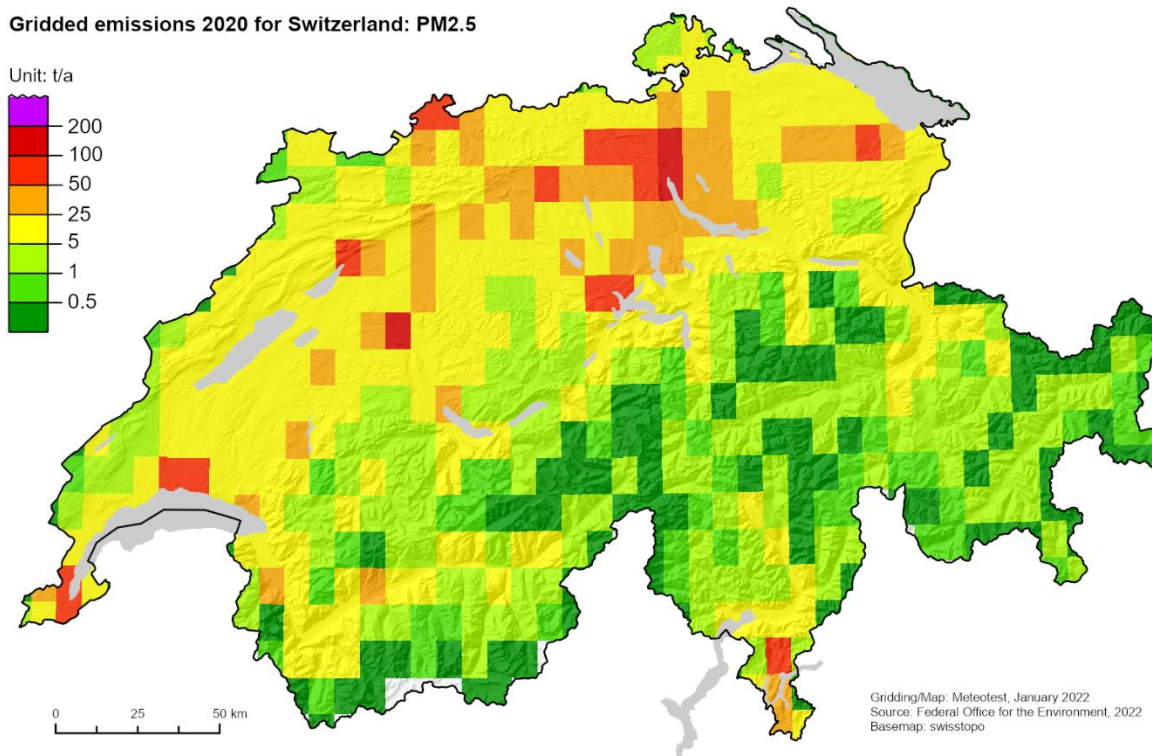


Figure 10-9: Spatial distribution of the PM_{2.5} emissions in Switzerland.

10.4 Large point sources (LPS)

Large Point Sources (LPS) are reported according to the definitions of the ECE Guidelines (ECE 2014). LPS are defined as facilities or installations whose emissions of at least one of 14 pollutants exceed the threshold value given in Table 1 of the ECE Guidelines (ECE 2014).

Facility designations, locations and emissions of Switzerland's LPS of the years 2007-2020 are reported based on the most recent data of the Swiss Pollution Release and Transfer Register (PRTR 2022). Data concerning air pollution release are reported annually by the facility operators and may be calculated based on periodic measurements, fuel consumption or other methods.

In 2020, 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 municipal solid waste incineration plants, followed by different facilities of the manufacturing industry such as steel production and chemicals (see Figure 10-10).

Information concerning the physical height of stack is reported as stack height class and the locations of the LPS are given in WGS 84 decimal coordinates, recalculated from Swiss grid coordinates (CH1903) as given in the Swiss PRTR.

The reported E-Swiss PRTR facility IDs correspond to the BER-Code (Business and Enterprise Register) of the Swiss Federal Statistical Office.

Large Point Sources 2020

Kategorie

- ◆ Cement Production
- ◆ Petroleum Refinery
- ◆ Steel Production
- ◆ Other Manufacturing Industry
- ◆ Municipal Waste Incineration

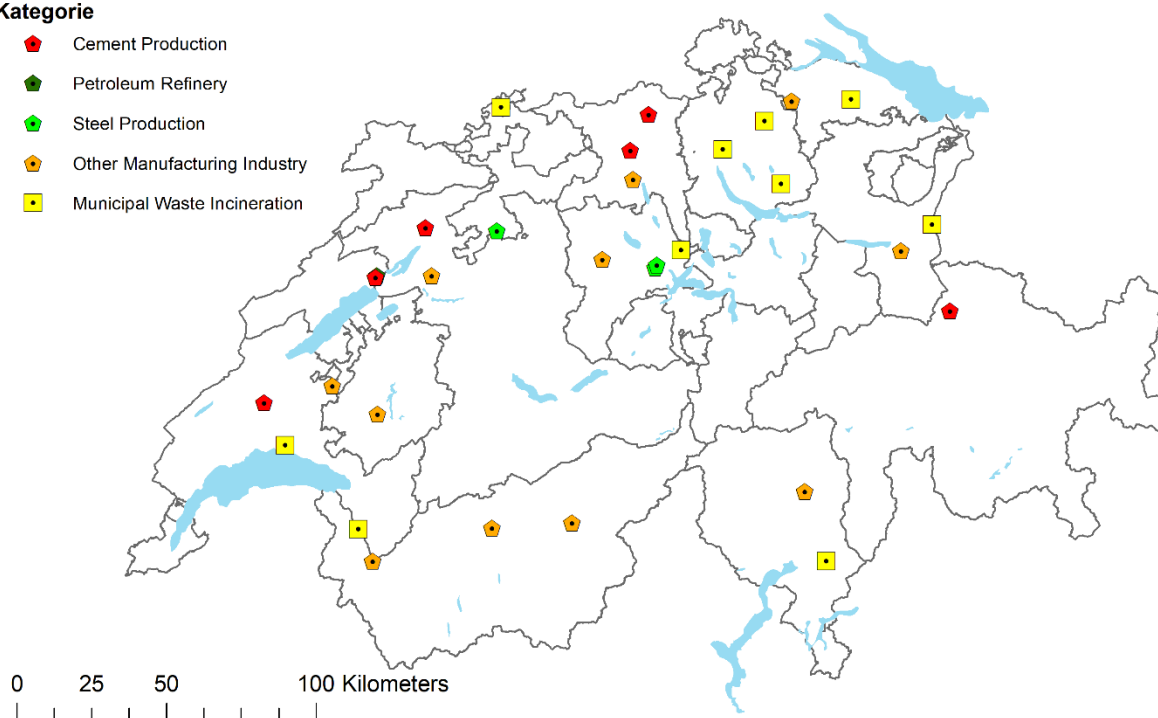


Figure 10-10: Spatial distribution of Switzerland's LPS in 2020.

11 Adjustments

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

12 References and assignments to EMIS categories

12.1 References

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12.2 Assignment of EMIS categories to NFR code

Table 12-1: Assignments of NFR Code to titles of EMIS database comments. For the CLRTAP Inventory the Code in [violet] are relevant.

NFR Code CRF [UNECE]	EMIS Title	NFR Code CRF [UNECE]	EMIS Title
1 A	Energiemodell***	2 D 3 a [2 D 3 g]	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 übrige**
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/biii/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	Schieneverkehr	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	Graströckung**	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]	Flächenenteisung Flughafen
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	Kalksteinrube*	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	Emissionen 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]	Waldbände
2 C 7 c	Battene-Recycling*	5 B 1	Kompostierung
2 D 1	Schmiermittel-Anwendung	5 B 2	Biogasaufbereitung (Methanverlust)
2 D 1	Schmiermittel-Verbrauch BZT	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]	NMVOE 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.

Annexes

Annex 1 Key category analysis (KCA)

A1.1 Overview

The following table provides an overview over the level (1990 and 2020) and trend (1990-2020) assessments based on approach 1 and approach 2 of the key category analysis. Note that the key category analysis is performed based on the approach “fuels used” (in contrast to “fuels sold”; for differentiation of the two approaches see chapter 3.1.6.1). Columns A to D in the following two tables are labelled according to Table 2-6 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 2, “Key category analysis and methodological choice 2019”.

Table A - 1: Summary of Switzerland's key category analysis, for the main pollutants, PM2.5 and PM10. L: level assessment (2020); T: trend assessment (1990-2020); 1: KCA approach 1; 2: KCA approach 2. Note that categories which are key for the level assessment for the base year only are not reported in this table.

SUMMARIES TO IDENTIFY KEY CATEGORIES							
A	B	C & D					
NFR code	Source category	NOx	NMVOC	SO2	NH3	PM2.5	PM10
1A1a	Public electricity and heat production	L1, L2		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: Other	L1, L2, T1, T2		L1, L2, T1, T2		T1, T2	T1, T2
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		L1	
1A3bi	Road transport: passenger cars	L1, L2, T1, T2	L1, L2, T1, T2	T1, T2			
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 and motorcycles		L2, T2				
1A3bv	Road transport: gasoline evaporation		L1, T1, T2				
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, T1		L1, L2, T1		L1, L2, T1, T2	L1
1A4bi	Residential: stationary plants	L1, L2	L1, L2	L1, L2, T1, T2		L1, L2, T1, T2	L1, L2, T1, T2
1A4ci	Agriculture/forestry/fishing: stationary					L1	
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	L1				L2	
1A5b	Other, mobile (including military, land-based and recreational boats)						L1
1B2aiv	Fugitive emissions oil: Refining / storage			T2			
1B2av	Distribution of oil products		T1				
1B2c	Venting and flaring (oil, gas, combined oil and gas)	T2					
2A1	Cement production					L2, T2	L1, L2
2A5a	Quarrying and mining of minerals other than coal					L1, L2, T1, T2	L1, L2, T1, T2
2B10a	Chemical industry: Other			L2, T2			
2B5	Carbide production			L1, L2, T1, T2			
2C1	Iron and steel production					T1, T2	T1, T2
2D3a	Domestic solvent use including fungicides		L1, L2, T1, T2				
2D3b	Road paving with asphalt		L1, L2, T1, T2				
2D3d	Coating applications		L1, L2, T1, T2				
2D3e	Degreasing		T1, T2				
2D3g	Chemical products		L1, L2, T1, T2				
2D3h	Printing		L1, L2, T1				
2D3i	Other solvent use		L1, L2				
2G	Other product use		L1, L2, T2			L1, L2, T1, T2	L1, L2
2H1	Pulp and paper industry					L1, L2, T1, T2	
2H2	Food and beverages industry		L1, L2, 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				L1, L2, T2		
3B4gi	Manure management - Laying hens						L2
3B4gii	Manure management - Broilers		T2		L2, T2		L2, T2
3Da1	Inorganic N-fertilizers (includes also urea application)	L2, T2			L2, T1, T2		
3Da2a	Animal manure applied to soils	L2, T1, T2			L1, L2, T1, T2		
3Da2b	Sewage sludge applied to soils				T1		
3Da2c	Other organic fertilisers applied to soils (including compost)	T2			T1, T2		
3Da3	Urine and dung deposited by grazing animals	L2, T2			L2, T1, T2		
3De	Cultivated crops						L1, L2, T1, T2
5C1a	Municipal waste incineration					L1, L2	L1
6A	Other sources				L2, T2		

Table A - 2: Summary of Switzerland's key category analysis, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. L: level assessment (2020); T: trend assessment (1990-2020); 1: KCA approach 1. No approach 2 analysis was conducted. Note that categories which are key for the level assessment for the base year only are not reported in this table.

SUMMARIES TO IDENTIFY KEY CATEGORIES											
A	B	C & D									
NFR code	Source category	TSP	BC	CO	Pb	Cd	Hg	PCDD/PCDF	PAHs total	HCB	PCBs
1A2gvii	Mobile Combustion in manufacturing industries and construction	L1, T1									
1A2gviii	Stationary combustion in manufacturing industries and construction: Other						L1, T1			T1	
1A3aii(i)	Civil aviation (domestic, cruise)				L1						
1A3bi	Road transport: passenger cars		L1	L1, T1	L1, T1		L1		L1, T1		
1A3bii	Road transport: light-duty vehicles		T1	T1							
1A3biii	Road transport: heavy-duty vehicles and buses	T1	T1								
1A3biv	Road transport: mopeds and motorcycles			L1							
1A3bvi	Road transport: automobile tyre and brake wear	L1, T1	L1, T1			L1, T1					
1A3c	Railways	L1, T1									
1A3dii	National navigation (shipping)			L1							
1A4ai	Commercial/institutional: stationary		L1, T1	L1, T1			L1	L1, T1	L1, T1	L1, T1	
1A4aii	Commercial/institutional: mobile			L1, T1							
1A4bi	Residential: stationary plants	L1, T1	L1, T1	L1, T1		L1	L1, T1	L1, T1	L1, T1	L1, T1	
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery		L1, T1	L1, T1							
2A5a	Quarrying and mining of minerals other than coal	L1									
2B10a	Chemical industry: Other						T1				
2B5	Carbide production			L1, T1							
2C1	Iron and steel production	T1			T1	T1	L1, T1	T1			
2C3	Aluminium production								T1		
2G	Other product use	L1				L1, T1					
2I	Wood processing	T1									
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)										L1, T1
3B3	Manure management - Swine	L1									
3B4gi	Manure management - Laying hens	L1									
3De	Cultivated crops	L1, T1									
5C1a	Municipal waste incineration				L1, T1			L1, T1			
5C1biii	Clinical waste incineration						T1	T1			
5C2	Open burning of waste								L1		
5E	Other waste										T1
6A	Other sources				L1, T1	L1, T1	L1, T1	L1, T1	T1		T1

A1.2 Detailed results of approach 1 assessment

The following tables report the detailed results for the key category analysis, approach 1, level and trend assessments, for the reporting year 2020 and the base year 1990. Columns labelled A to F for the level assessments correspond exactly to columns A to F from Table 2-1 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 2, "Key category analysis and methodological choice 2019". For the table reporting the trend assessment, columns labelled A to G correspond exactly to columns A to G from Table 2-5 from the same guidelines. Equations referenced hereafter are also from the same guidelines.

Explanations of headers for tables in this Annex are:

- $E_{x,t}$: emission estimate for the reporting year.
- $E_{x,0}$: emission estimate for the base year.
- $L_{x,t}$: level assessment for the reporting year (EMEP/EAA guidebook part A, chp. 2, equ. 1 for approach 1).
- $L_{x,0}$: level assessment for the base year (EMEP/EAA guidebook part A, chp. 2, equ. 1 for approach 1).
- Trend assessment: computed according to EMEP/EAA guidebook part A, chp. 2, equ. 2 for approach 1.

Table A - 3: Switzerland's key categories according to approach 1 level assessment for the year 2020, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 2020					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, t (t)	Lx, t (%)	Cumulative Total (%)
1A3bi	Road transport: passenger cars	NOx	17810	33.9	33.9
1A3bii	Road transport: light-duty vehicles	NOx	4823	9.2	43.1
1A4bi	Residential: stationary plants	NOx	4348	8.3	51.4
1A3biii	Road transport: heavy-duty vehicles and buses	NOx	4313	8.2	59.6
1A2f	Stationary combustion in manufacturing industries and construction: Other	NOx	3142	6.0	65.6
1A4ai	Commercial/institutional: stationary	NOx	2391	4.6	70.1
1A1a	Public electricity and heat production	NOx	2087	4.0	74.1
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	1894	3.6	77.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	1814	3.5	81.2
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	1675	3.2	84.3
3Da2a	Animal manure applied to soils	NOx	1457	2.8	87.1
2D3a	Domestic solvent use including fungicides	NMVOG	8984	11.9	11.9
3B1b	Manure management - Non-dairy cattle	NMVOG	8241	11.0	22.9
2D3d	Coating applications	NMVOG	8054	10.7	33.6
3B1a	Manure management - Dairy cattle	NMVOG	7140	9.5	43.1
2G	Other product use	NMVOG	6829	9.1	52.2
1A3bi	Road transport: passenger cars	NMVOG	3794	5.0	57.2
2D3h	Printing	NMVOG	3727	5.0	62.2
2D3g	Chemical products	NMVOG	3171	4.2	66.4
2D3b	Road paving with asphalt	NMVOG	2651	3.5	69.9
1A4bi	Residential: stationary plants	NMVOG	2499	3.3	73.3
2D3i	Other solvent use	NMVOG	2009	2.7	75.9
2H2	Food and beverages industry	NMVOG	1991	2.6	78.6
1A3bv	Road transport: gasoline evaporation	NMVOG	1901	2.5	81.1
2D3e	Degreasing	NMVOG	1317	1.8	82.9
3B4gii	Manure management - Broilers	NMVOG	1089	1.4	84.3
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NMVOG	1022	1.4	85.7
1A2f	Stationary combustion in manufacturing industries and construction: Other	SO2	1376	36.3	36.3
1A4bi	Residential: stationary plants	SO2	586	15.5	51.8
2B5	Carbide production	SO2	424	11.2	62.9
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	306	8.1	71.0
1A4ai	Commercial/institutional: stationary	SO2	244	6.4	77.5
1A1a	Public electricity and heat production	SO2	241	6.4	83.8
1A2c	Stationary combustion in manufacturing industries and construction:	SO2	137	3.6	87.4
3Da2a	Animal manure applied to soils	NH3	20359	38.2	38.2
3B1a	Manure management - Dairy cattle	NH3	10414	19.5	57.7
3B1b	Manure management - Non-dairy cattle	NH3	7030	13.2	70.9
3B3	Manure management - Swine	NH3	4876	9.1	80.0
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	2487	4.7	84.7
3Da3	Urine and dung deposited by grazing animals	NH3	1406	2.6	87.3
1A4bi	Residential: stationary plants	PM2.5	1410	24.1	24.1
1A3bvi	Road transport: automobile tyre and brake wear	PM2.5	817	13.9	38.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	393	6.7	44.7
2G	Other product use	PM2.5	375	6.4	51.1
1A4ai	Commercial/institutional: stationary	PM2.5	313	5.3	56.4
5C1a	Municipal waste incineration	PM2.5	245	4.2	60.6
2A5a	Quarrying and mining of minerals other than coal	PM2.5	234	4.0	64.6
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	229	3.9	68.5
1A3c	Railways	PM2.5	194	3.3	71.8
2H1	Pulp and paper industry	PM2.5	183	3.1	75.0
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM2.5	179	3.0	78.0
2H2	Food and beverages industry	PM2.5	165	2.8	80.8
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	162	2.8	83.6
2A1	Cement production	PM2.5	156	2.7	86.2
1A3bvi	Road transport: automobile tyre and brake wear	PM10	2401	17.9	17.9
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2344	17.5	35.4
1A4bi	Residential: stationary plants	PM10	1478	11.0	46.4
1A3c	Railways	PM10	1259	9.4	55.7
3De	Cultivated crops	PM10	1004	7.5	63.2
2G	Other product use	PM10	470	3.5	66.7
2A5a	Quarrying and mining of minerals other than coal	PM10	468	3.5	70.2
1A4ai	Commercial/institutional: stationary	PM10	333	2.5	72.7
2H2	Food and beverages industry	PM10	307	2.3	75.0
5C1a	Municipal waste incineration	PM10	272	2.0	77.0
1A5b	Other, mobile (including military, land-based and recreational boats)	PM10	261	1.9	78.9
2A1	Cement production	PM10	244	1.8	80.8
1A4ci	Agriculture/forestry/fishing: stationary	PM10	231	1.7	82.5
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM10	222	1.7	84.1
3B4gii	Manure management - Broilers	PM10	202	1.5	85.6

Table A - 4: Switzerland's key categories according to approach 1 level assessment for the year 1990, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 1990					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, 0 (t)	Lx, 0 (%)	Cumulative Total (%)
1A3bi	Road transport: passenger cars	NOx	43771	31.1	31.1
1A3biii	Road transport: heavy-duty vehicles and buses	NOx	29900	21.2	52.3
1A4bi	Residential: stationary plants	NOx	11630	8.3	60.6
1A2f	Stationary combustion in manufacturing industries and construction: Other	NOx	10535	7.5	68.1
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	6334	4.5	72.6
1A1a	Public electricity and heat production	NOx	6294	4.5	77.0
1A3bii	Road transport: light-duty vehicles	NOx	6197	4.4	81.4
1A4ai	Commercial/institutional: stationary	NOx	4696	3.3	84.8
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	NOx	4358	3.1	87.9
1A3bi	Road transport: passenger cars	NMVOc	55936	19.1	19.1
2D3d	Coating applications	NMVOc	40731	13.9	33.1
2D3g	Chemical products	NMVOc	27504	9.4	42.5
2G	Other product use	NMVOc	23727	8.1	50.6
2D3h	Printing	NMVOc	20354	7.0	57.5
1A3bv	Road transport: gasoline evaporation	NMVOc	16980	5.8	63.3
1B2av	Distribution of oil products	NMVOc	14669	5.0	68.4
2D3e	Degreasing	NMVOc	11166	3.8	72.2
2D3a	Domestic solvent use including fungicides	NMVOc	9195	3.1	75.3
1A4bi	Residential: stationary plants	NMVOc	8850	3.0	78.3
3B1a	Manure management - Dairy cattle	NMVOc	7075	2.4	80.8
1A3biv	Road transport: mopeds and motorcycles	NMVOc	5733	2.0	82.7
2D3i	Other solvent use	NMVOc	5470	1.9	84.6
3B1b	Manure management - Non-dairy cattle	NMVOc	5368	1.8	86.4
1A4bi	Residential: stationary plants	SO2	9208	25.1	25.1
1A1a	Public electricity and heat production	SO2	3587	9.8	34.9
1A2f	Stationary combustion in manufacturing industries and construction: Other	SO2	3530	9.6	44.5
1A4ai	Commercial/institutional: stationary	SO2	3426	9.3	53.8
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	3314	9.0	62.9
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SO2	3091	8.4	71.3
1A3biii	Road transport: heavy-duty vehicles and buses	SO2	1753	4.8	76.1
1A3bi	Road transport: passenger cars	SO2	1705	4.6	80.7
1A2c	Stationary combustion in manufacturing industries and construction: chemicals	SO2	1103	3.0	83.7
1A2e	Stationary combustion in manufacturing industries and construction: food processing, beverages and tobacco	SO2	985	2.7	86.4
3Da2a	Animal manure applied to soils	NH3	34567	50.4	50.4
3B1a	Manure management - Dairy cattle	NH3	9337	13.6	64.1
3B3	Manure management - Swine	NH3	6965	10.2	74.2
3B1b	Manure management - Non-dairy cattle	NH3	5191	7.6	81.8
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4258	6.2	88.0
1A4bi	Residential: stationary plants	PM2.5	5227	31.5	31.5
1A3biii	Road transport: heavy-duty vehicles and buses	PM2.5	1585	9.5	41.0
2C1	Iron and steel production	PM2.5	818	4.9	46.0
1A1a	Public electricity and heat production	PM2.5	772	4.7	50.6
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	4.4	55.0
1A3bvi	Road transport: automobile tyre and brake wear	PM2.5	689	4.2	59.2
1A3bi	Road transport: passenger cars	PM2.5	578	3.5	62.6
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM2.5	545	3.3	65.9
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	539	3.2	69.2
2G	Other product use	PM2.5	513	3.1	72.2
1A4ai	Commercial/institutional: stationary	PM2.5	506	3.0	75.3
5C1a	Municipal waste incineration	PM2.5	465	2.8	78.1
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM2.5	438	2.6	80.7
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	435	2.6	83.4
1A3bii	Road transport: light-duty vehicles	PM2.5	327	2.0	85.3
1A4bi	Residential: stationary plants	PM10	5500	21.8	21.8
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2173	8.6	30.3
1A3bvi	Road transport: automobile tyre and brake wear	PM10	2050	8.1	38.5
1A3biii	Road transport: heavy-duty vehicles and buses	PM10	1585	6.3	44.7
2C1	Iron and steel production	PM10	1485	5.9	50.6
3De	Cultivated crops	PM10	1054	4.2	54.8
1A1a	Public electricity and heat production	PM10	1034	4.1	58.9
1A3c	Railways	PM10	983	3.9	62.7
2I	Wood processing	PM10	864	3.4	66.2
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM10	833	3.3	69.5
2G	Other product use	PM10	588	2.3	71.8
1A3bi	Road transport: passenger cars	PM10	578	2.3	74.1
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM10	568	2.2	76.3
1A4ci	Agriculture/forestry/fishing: stationary	PM10	544	2.2	78.5
1A4ai	Commercial/institutional: stationary	PM10	533	2.1	80.6
5C1a	Municipal waste incineration	PM10	517	2.0	82.6
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM10	511	2.0	84.6
2A1	Cement production	PM10	374	1.5	86.1

Table A - 5: Switzerland's key categories according to approach 1 trend assessment for 1990-2020, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in orange have increased emissions in 2020 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 1 TREND ASSESSMENT 1990 - 2020								
A	B	C	D	E	F	G	H	
NFR code	Source category	Pollutant	Ex, 0 (t)	Ex, t (t)	Category trend (%)	Trend Assessment	Contribution to trend (%)	Cumulative Total (%)
1A3biii	Road transport: heavy-duty vehicles and buses	NOx	29900	4313	-86	0.05	36.8	36.8
1A3bii	Road transport: light-duty vehicles	NOx	6197	4823	-22	0.02	13.5	50.3
1A3bi	Road transport: passenger cars	NOx	43771	17810	-59	0.01	8.0	58.3
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	2338	1675	-28	0.01	4.3	62.6
1A2f	Stationary combustion in manufacturing industries and construction: Other	NOx	10535	3142	-70	0.01	4.2	66.9
3Da2a	Animal manure applied to soils	NOx	2075	1457	-30	0.00	3.7	70.5
1A4ai	Commercial/institutional: stationary	NOx	4696	2391	-49	0.00	3.4	74.0
1A3dii	National navigation (shipping)	NOx	1055	985	-7	0.00	3.2	77.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	6334	1814	-71	0.00	3.0	80.1
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	NOx	1261	42	-97	0.00	2.3	82.4
1A3ai(i)	Civil aviation (domestic, landing/take-off (LTO))	NOx	1214	779	-36	0.00	1.8	84.2
3Da3	Urine and dung deposited by grazing animals	NOx	243	416	71	0.00	1.7	85.9
1A3bi	Road transport: passenger cars	NMVOc	55936	3794	-93	0.04	18.2	18.2
3B1b	Manure management - Non-dairy cattle	NMVOc	5368	8241	54	0.02	11.8	30.1
2D3a	Domestic solvent use including fungicides	NMVOc	9195	8984	-2	0.02	11.4	41.5
3B1a	Manure management - Dairy cattle	NMVOc	7075	7140	1	0.02	9.2	50.7
2D3g	Chemical products	NMVOc	27504	3171	-88	0.01	6.7	57.4
1B2av	Distribution of oil products	NMVOc	14669	890	-94	0.01	5.0	62.3
1A3bv	Road transport: gasoline evaporation	NMVOc	16980	1901	-89	0.01	4.2	66.6
2D3d	Coating applications	NMVOc	40731	8054	-80	0.01	4.2	70.8
2D3e	Degreasing	NMVOc	11166	1317	-88	0.01	2.7	73.4
2D3h	Printing	NMVOc	20354	3727	-82	0.01	2.6	76.0
2H2	Food and beverages industry	NMVOc	1956	1991	2	0.01	2.6	78.6
2D3b	Road paving with asphalt	NMVOc	4895	2651	-46	0.00	2.4	81.0
1A3bii	Road transport: light-duty vehicles	NMVOc	4920	191	-96	0.00	1.9	82.9
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	NMVOc	46	1022	2101	0.00	1.7	84.6
3B4gii	Manure management - Broilers	NMVOc	366	1089	197	0.00	1.7	86.3
1A2f	Stationary combustion in manufacturing industries and construction: Other	SO2	3530	1376	-61	0.03	31.4	31.4
2B5	Carbide production	SO2	445	424	-5	0.01	11.7	43.1
1A4bi	Residential: stationary plants	SO2	9208	586	-94	0.01	11.3	54.4
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SO2	3091	3	-100	0.01	9.8	64.2
1A3biii	Road transport: heavy-duty vehicles and buses	SO2	1753	13	-99	0.00	5.2	69.4
1A1a	Public electricity and heat production	SO2	3587	241	-93	0.00	4.0	73.4
1A3bi	Road transport: passenger cars	SO2	1705	54	-97	0.00	3.8	77.2
1A4ai	Commercial/institutional: stationary	SO2	3426	244	-93	0.00	3.4	80.6
1A2e	Stationary combustion in manufacturing industries and construction: food processing, beverages and tobacco	SO2	985	18	-98	0.00	2.6	83.2
2C3	Aluminium production	SO2	696	0	-100	0.00	2.2	85.5
3Da2a	Animal manure applied to soils	NH3	34567	20359	-41	0.10	34.0	34.0
3B1a	Manure management - Dairy cattle	NH3	9337	10414	12	0.05	16.4	50.4
3B1b	Manure management - Non-dairy cattle	NH3	5191	7030	35	0.04	15.6	66.0
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	34	952	2700	0.01	4.8	70.8
3Da2b	Sewage sludge applied to soils	NH3	1169	0	-100	0.01	4.7	75.6
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4258	2487	-42	0.01	4.3	79.9
3Da3	Urine and dung deposited by grazing animals	NH3	761	1406	85	0.01	4.2	84.1
3B3	Manure management - Swine	NH3	6965	4876	-30	0.01	2.8	86.9
1A3bvi	Road transport: automobile tyre and brake wear	PM2.5	689	817	19	0.03	15.0	15.0
1A3biii	Road transport: heavy-duty vehicles and buses	PM2.5	1585	68	-96	0.03	12.9	27.9
1A4bi	Residential: stationary plants	PM2.5	5227	1410	-73	0.03	11.4	39.3
2C1	Iron and steel production	PM2.5	818	8	-99	0.02	7.4	46.7
1A1a	Public electricity and heat production	PM2.5	772	44	-94	0.01	6.0	52.6
2G	Other product use	PM2.5	513	375	-27	0.01	5.1	57.7
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	234	28	0.01	4.4	62.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	393	-46	0.01	3.5	65.7
1A4ai	Commercial/institutional: stationary	PM2.5	506	313	-38	0.01	3.5	69.2
1A3c	Railways	PM2.5	174	194	11	0.01	3.5	72.7
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM2.5	438	42	-91	0.01	3.0	75.7
2H1	Pulp and paper industry	PM2.5	236	183	-22	0.01	2.6	78.3
2H2	Food and beverages industry	PM2.5	188	165	-12	0.01	2.6	80.8
5C1a	Municipal waste incineration	PM2.5	465	245	-47	0.00	2.1	83.0
2A1	Cement production	PM2.5	240	156	-35	0.00	1.9	84.8
1A3bi	Road transport: passenger cars	PM2.5	578	141	-76	0.00	1.7	86.5
1A4bi	Residential: stationary plants	PM10	5500	1478	-73	0.06	14.3	14.3
1A3bvi	Road transport: automobile tyre and brake wear	PM10	2050	2401	17	0.05	13.0	27.3
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2173	2344	8	0.05	11.8	39.1
2C1	Iron and steel production	PM10	1485	12	-99	0.03	7.7	46.8
1A3biii	Road transport: heavy-duty vehicles and buses	PM10	1585	68	-96	0.03	7.7	54.4
1A3c	Railways	PM10	983	1259	28	0.03	7.3	61.7
1A1a	Public electricity and heat production	PM10	1034	44	-96	0.02	5.0	66.7
3De	Cultivated crops	PM10	1054	1004	-5	0.02	4.4	71.1
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM10	833	71	-91	0.01	3.7	74.8
2I	Wood processing	PM10	864	183	-79	0.01	2.7	77.5
2A5a	Quarrying and mining of minerals other than coal	PM10	367	468	28	0.01	2.7	80.2
1A3bi	Road transport: passenger cars	PM10	578	141	-76	0.01	1.6	81.9
3B4gii	Manure management - Broilers	PM10	68	202	197	0.01	1.6	83.5
2G	Other product use	PM10	588	470	-20	0.01	1.6	85.1

Table A - 6: Switzerland's key categories according to approach 1 level assessment for the year 2020, sorted by decreasing contribution, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 2020					
A	B	C	D	E	F
NFR code	Source category	Pollutant (unit)	Ex, t	Lx, t (%)	Cumulative Total (%)
3De	Cultivated crops	TSP (t)	10036	37.0	37.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	TSP (t)	3491	12.9	49.9
1A3bvi	Road transport: automobile tyre and brake wear	TSP (t)	2401	8.9	58.8
1A3c	Railways	TSP (t)	1674	6.2	65.0
1A4bi	Residential: stationary plants	TSP (t)	1549	5.7	70.7
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	917	3.4	74.1
3B4gi	Manure management - Laying hens	TSP (t)	732	2.7	76.8
3B3	Manure management - Swine	TSP (t)	632	2.3	79.1
2G	Other product use	TSP (t)	470	1.7	80.8
2I	Wood processing	TSP (t)	458	1.7	82.5
2H2	Food and beverages industry	TSP (t)	418	1.5	84.1
3B4gii	Manure management - Broilers	TSP (t)	403	1.5	85.6
1A4bi	Residential: stationary plants	BC (t)	483	47.6	47.6
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	102	10.0	57.7
1A4ai	Commercial/institutional: stationary	BC (t)	85	8.4	66.1
1A3bvi	Road transport: automobile tyre and brake wear	BC (t)	82	8.1	74.1
1A3bi	Road transport: passenger cars	BC (t)	63	6.2	80.3
1A3bii	Road transport: light-duty vehicles	BC (t)	58	5.7	86.0
1A3bi	Road transport: passenger cars	CO (t)	42279	31.0	31.0
1A4bi	Residential: stationary plants	CO (t)	26844	19.7	50.6
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	13143	9.6	60.2
1A4aii	Commercial/institutional: mobile	CO (t)	6635	4.9	65.1
1A3biv	Road transport: mopeds and motorcycles	CO (t)	6434	4.7	69.8
1A4ai	Commercial/institutional: stationary	CO (t)	6123	4.5	74.3
2B5	Carbide production	CO (t)	5712	4.2	78.5
1A3dii	National navigation (shipping)	CO (t)	4935	3.6	82.1
1A3bii	Road transport: light-duty vehicles	CO (t)	4360	3.2	85.3
6A	Other sources	Pb (kg)	5646	48.2	48.2
1A3bi	Road transport: passenger cars	Pb (kg)	1747	14.9	63.1
5C1a	Municipal waste incineration	Pb (kg)	1700	14.5	77.7
1A3aii(i)	Civil aviation (domestic, cruise)	Pb (kg)	704	6.0	83.7
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	Pb (kg)	547	4.7	88.3
6A	Other sources	Cd (kg)	141	35.5	35.5
1A3bvi	Road transport: automobile tyre and brake wear	Cd (kg)	79	19.8	55.2
2G	Other product use	Cd (kg)	74	18.7	73.9
1A4bi	Residential: stationary plants	Cd (kg)	25	6.4	80.3
1A2gvii	Mobile Combustion in manufacturing industries and construction	Cd (kg)	19	4.8	85.1
6A	Other sources	Hg (kg)	63	22.8	22.8
1A4bi	Residential: stationary plants	Hg (kg)	48	17.5	40.3
2C1	Iron and steel production	Hg (kg)	45	16.4	56.7
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	Hg (kg)	28	10.2	66.9
1A4ai	Commercial/institutional: stationary	Hg (kg)	25	9.2	76.1
1A3bi	Road transport: passenger cars	Hg (kg)	21	7.7	83.9
5C1biv	Sewage sludge incineration	Hg (kg)	19	7.1	91.0
1A4bi	Residential: stationary plants	PCDD/ PCDF (mg I-TEQ)	4596	35.6	35.6
5C1a	Municipal waste incineration	PCDD/ PCDF (mg I-TEQ)	2720	21.1	56.6
6A	Other sources	PCDD/ PCDF (mg I-TEQ)	2117	16.4	73.0
1A4ai	Commercial/institutional: stationary	PCDD/ PCDF (mg I-TEQ)	1175	9.1	82.1
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PCDD/ PCDF (mg I-TEQ)	695	5.4	87.5
1A4bi	Residential: stationary plants	PAHs total (kg)	1519	61.0	61.0
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	271	10.9	71.9
5C2	Open burning of waste	PAHs total (kg)	189	7.6	79.4
1A3bi	Road transport: passenger cars	PAHs total (kg)	187	7.5	87.0
1A4bi	Residential: stationary plants	HCB (g)	89	59.9	59.9
1A4ai	Commercial/institutional: stationary	HCB (g)	34	23.2	83.1
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	HCB (g)	22	14.5	97.7
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCBs (g)	366922	90.0	90.0

Table A - 7: Switzerland's key categories according to approach 1 level assessment for the year 1990, sorted by decreasing contribution, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Categories in grey are not key and are given for information only.

KCA APPROACH 1 LEVEL ASSESSMENT FOR 1990					
A	B	C	D	E	F
NFR code	Source category	Pollutant (unit)	Ex, 0	Lx, 0 (%)	Cumulative Total (%)
3De	Cultivated crops	TSP (t)	10540	25.3	25.3
1A4bi	Residential: stationary plants	TSP (t)	5819	14.0	39.3
2I	Wood processing	TSP (t)	4322	10.4	49.7
1A2gvii	Mobile Combustion in manufacturing industries and construction	TSP (t)	3023	7.3	57.0
2C1	Iron and steel production	TSP (t)	2686	6.5	63.4
1A3bvi	Road transport: automobile tyre and brake wear	TSP (t)	2050	4.9	68.4
1A3biii	Road transport: heavy-duty vehicles and buses	TSP (t)	1585	3.8	72.2
1A3c	Railways	TSP (t)	1298	3.1	75.3
3B3	Manure management - Swine	TSP (t)	915	2.2	77.5
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	685	1.6	79.1
5C1a	Municipal waste incineration	TSP (t)	646	1.6	80.7
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	TSP (t)	609	1.5	82.1
2G	Other product use	TSP (t)	588	1.4	83.6
3B4gi	Manure management - Laying hens	TSP (t)	586	1.4	85.0
1A3bi	Road transport: passenger cars	TSP (t)	578	1.4	86.4
1A4bi	Residential: stationary plants	BC (t)	3220	56.8	56.8
1A3biii	Road transport: heavy-duty vehicles and buses	BC (t)	793	14.0	70.8
1A4ai	Commercial/institutional: stationary	BC (t)	300	5.3	76.1
1A2gvii	Mobile Combustion in manufacturing industries and construction	BC (t)	256	4.5	80.6
1A3bi	Road transport: passenger cars	BC (t)	242	4.3	84.9
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	232	4.1	89.0
1A3bi	Road transport: passenger cars	CO (t)	425307	57.5	57.5
1A4bi	Residential: stationary plants	CO (t)	111864	15.1	72.6
1A3bii	Road transport: light-duty vehicles	CO (t)	72490	9.8	82.5
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	28368	3.8	86.3
1A3bi	Road transport: passenger cars	Pb (kg)	211214	66.4	66.4
2C1	Iron and steel production	Pb (kg)	59858	18.8	85.2
2C1	Iron and steel production	Cd (kg)	443	45.6	45.6
6A	Other sources	Cd (kg)	170	17.4	63.0
2G	Other product use	Cd (kg)	102	10.5	73.5
1A3bvi	Road transport: automobile tyre and brake wear	Cd (kg)	65	6.7	80.2
1A4bi	Residential: stationary plants	Cd (kg)	62	6.4	86.6
2C1	Iron and steel production	Hg (kg)	1108	49.7	49.7
2B10a	Chemical industry: Other	Hg (kg)	384	17.2	66.9
5C1biii	Clinical waste incineration	Hg (kg)	240	10.8	77.7
5C1biv	Sewage sludge incineration	Hg (kg)	211	9.5	87.1
1A4bi	Residential: stationary plants	PCDD/ PCDF (mg I-TEQ)	17673	31.3	31.3
2C1	Iron and steel production	PCDD/ PCDF (mg I-TEQ)	12419	22.0	53.3
5C1biii	Clinical waste incineration	PCDD/ PCDF (mg I-TEQ)	6900	12.2	65.6
5C1a	Municipal waste incineration	PCDD/ PCDF (mg I-TEQ)	5168	9.2	74.7
6A	Other sources	PCDD/ PCDF (mg I-TEQ)	2544	4.5	79.2
2G	Other product use	PCDD/ PCDF (mg I-TEQ)	2178	3.9	83.1
1A4ai	Commercial/institutional: stationary	PCDD/ PCDF (mg I-TEQ)	2112	3.7	86.8
1A4bi	Residential: stationary plants	PAHs total (kg)	5697	70.3	70.3
2C3	Aluminium production	PAHs total (kg)	940	11.6	81.9
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	516	6.4	88.2
1A4bi	Residential: stationary plants	HCB (g)	322	79.3	79.3
1A4ai	Commercial/institutional: stationary	HCB (g)	48	11.8	91.2
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCBs (g)	1525788	70.4	70.4
6A	Other sources	PCBs (g)	281955	13.0	83.4
5E	Other waste	PCBs (g)	215511	9.9	93.4

Table A - 8: Switzerland's key categories according to approach 1 trend assessment for 1990-2020, sorted by decreasing contribution, for TSP, BC, CO, priority heavy metals, PCDD/PCDF, PAHs total, HCB and PCBs. Categories in orange have increased emissions in 2020 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 1 TREND ASSESSMENT 1990 - 2020								
A	B	C	D	E	F	G	H	
NFR code	Source category	Pollutant (unit)	Ex, 0	Ex, t	Category trend (%)	Trend Assessment	Contribution to trend (%)	Cumulative Total (%)
3De	Cultivated crops	TSP (t)	10540	10036	-5	0.08	18.4	18.4
2I	Wood processing	TSP (t)	4322	458	-89	0.06	13.7	32.1
1A4bi	Residential: stationary plants	TSP (t)	5819	1549	-73	0.05	13.0	45.1
2C1	Iron and steel production	TSP (t)	2686	13	-100	0.04	10.1	55.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	TSP (t)	3023	3491	15	0.04	8.8	64.0
1A3bvi	Road transport: automobile tyre and brake wear	TSP (t)	2050	2401	17	0.03	6.2	70.2
1A3biii	Road transport: heavy-duty vehicles and buses	TSP (t)	1585	68	-96	0.02	5.6	75.8
1A3c	Railways	TSP (t)	1298	1674	29	0.02	4.8	80.7
2A5a	Quarrying and mining of minerals other than coal	TSP (t)	685	917	34	0.01	2.7	83.4
3B4gi	Manure management - Laying hens	TSP (t)	586	732	25	0.01	2.0	85.4
1A3biii	Road transport: heavy-duty vehicles and buses	BC (t)	793	35	-96	0.02	22.4	22.4
1A4bi	Residential: stationary plants	BC (t)	3220	483	-85	0.02	19.5	41.9
1A3bvi	Road transport: automobile tyre and brake wear	BC (t)	69	82	18	0.01	14.5	56.4
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	BC (t)	232	102	-56	0.01	12.6	69.0
1A4ai	Commercial/institutional: stationary	BC (t)	300	85	-72	0.01	6.6	75.6
1A3bii	Road transport: light-duty vehicles	BC (t)	161	58	-64	0.01	6.0	81.7
1A3bi	Road transport: passenger cars	BC (t)	242	63	-74	0.00	4.0	85.7
1A3bi	Road transport: passenger cars	CO (t)	425307	42279	-90	0.05	39.4	39.4
1A3bii	Road transport: light-duty vehicles	CO (t)	72490	4360	-94	0.01	9.8	49.2
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	CO (t)	28368	13143	-54	0.01	8.6	57.7
1A4bi	Residential: stationary plants	CO (t)	111864	26844	-76	0.01	6.7	64.5
1A4aii	Commercial/institutional: mobile	CO (t)	4117	6635	61	0.01	6.4	70.8
2B5	Carbide production	CO (t)	3780	5712	51	0.01	5.4	76.3
1A4ai	Commercial/institutional: stationary	CO (t)	11159	6123	-45	0.01	4.4	80.7
1A4bii	Residential: household and gardening (mobile)	CO (t)	3271	3911	20	0.00	3.6	84.3
1A2gvii	Mobile Combustion in manufacturing industries and construction	CO (t)	7253	4252	-41	0.00	3.2	87.4
1A3bi	Road transport: passenger cars	Pb (kg)	211214	1747	-99	0.02	34.2	34.2
6A	Other sources	Pb (kg)	6784	5646	-17	0.02	30.7	64.9
2C1	Iron and steel production	Pb (kg)	59858	230	-100	0.01	11.2	76.1
5C1a	Municipal waste incineration	Pb (kg)	3230	1700	-47	0.00	9.0	85.1
2C1	Iron and steel production	Cd (kg)	443	5	-99	0.18	45.5	45.5
6A	Other sources	Cd (kg)	170	141	-17	0.07	18.4	63.9
1A3bvi	Road transport: automobile tyre and brake wear	Cd (kg)	65	79	21	0.05	13.4	77.3
2G	Other product use	Cd (kg)	102	74	-27	0.03	8.4	85.7
2C1	Iron and steel production	Hg (kg)	1108	45	-96	0.04	26.0	26.0
6A	Other sources	Hg (kg)	80	63	-22	0.02	15.0	41.0
2B10a	Chemical industry: Other	Hg (kg)	384	0	-100	0.02	13.4	54.4
1A4bi	Residential: stationary plants	Hg (kg)	72	48	-34	0.02	11.1	65.5
5C1biii	Clinical waste incineration	Hg (kg)	240	0	-100	0.01	8.4	73.9
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	Hg (kg)	13	28	111	0.01	7.5	81.4
1A4ai	Commercial/institutional: stationary	Hg (kg)	14	25	82	0.01	6.7	88.1
2C1	Iron and steel production	PCDD/ PCDF (mg I-TEQ)	12419	152	-99	0.05	26.0	26.0
5C1biii	Clinical waste incineration	PCDD/ PCDF (mg I-TEQ)	6900	0	-100	0.03	15.3	41.3
5C1a	Municipal waste incineration	PCDD/ PCDF (mg I-TEQ)	5168	2720	-47	0.03	14.9	56.2
6A	Other sources	PCDD/ PCDF (mg I-TEQ)	2544	2117	-17	0.03	14.8	71.0
1A4ai	Commercial/institutional: stationary	PCDD/ PCDF (mg I-TEQ)	2112	1175	-44	0.01	6.7	77.7
1A4bi	Residential: stationary plants	PCDD/ PCDF (mg I-TEQ)	17673	4596	-74	0.01	5.3	83.0
2G	Other product use	PCDD/ PCDF (mg I-TEQ)	2178	1	-100	0.01	4.8	87.8
2C3	Aluminium production	PAHs total (kg)	940	0	-100	0.04	27.2	27.2
1A4bi	Residential: stationary plants	PAHs total (kg)	5697	1519	-73	0.03	21.8	49.0
1A3bi	Road transport: passenger cars	PAHs total (kg)	103	187	82	0.02	14.7	63.7
1A4ai	Commercial/institutional: stationary	PAHs total (kg)	516	271	-48	0.01	10.6	74.3
6A	Other sources	PAHs total (kg)	72	112	56	0.01	8.5	82.8
5C2	Open burning of waste	PAHs total (kg)	371	189	-49	0.01	7.0	89.8
1A4bi	Residential: stationary plants	HCB (g)	322	89	-72	0.07	50.0	50.0
1A4ai	Commercial/institutional: stationary	HCB (g)	48	34	-28	0.04	29.3	79.3
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	HCB (g)	29	22	-27	0.03	18.7	98.0
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	PCBs (g)	1525788	366922	-76	0.04	50.0	50.0
5E	Other waste	PCBs (g)	215511	5017	-98	0.02	22.3	72.3
6A	Other sources	PCBs (g)	281955	30844	-89	0.01	14.0	86.3

A1.3 Detailed results of approach 2 assessment

The following tables report the detailed results for the key category analysis, approach 2, level and trend assessments, for the reporting year 2020 and the base year 1990. Columns labelled A to F for the level assessments correspond exactly to columns A to F from Table 2-1 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 2, "Key category analysis and methodological choice 2019". For the table reporting the trend assessment, columns labelled A to G correspond exactly to columns A to G from Table 2-5 from the same guidelines. Equations referenced hereafter are also from the same guidelines.

Explanations of headers for tables in this Annex are:

- $E_{x,t}$: emission estimate for the reporting year.
- $E_{x,0}$: emission estimate for the base year.
- $L_{x,t}$: level assessment for the reporting year (EMEP/EAA guidebook part A, chp. 2, equ. 3 for approach 2).
- $L_{x,0}$: level assessment for the base year (EMEP/EAA guidebook part A, chp. 2, equ. 3 for approach 2).
- Trend assessment: computed according to the EMEP/EAA guidebook part A, chp. 2, equ. 4 for approach 2.

Table A - 9: Switzerland's key categories according to approach 2 level assessment for the year 2020, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, LEVEL ASSESSMENT FOR 2020					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, t (t)	Lx, t (%)	Cumulative Total (%)
1A3bi	Road transport: passenger cars	NOx	17810	44.3	44.3
1A3bii	Road transport: light-duty vehicles	NOx	4823	10.1	54.4
1A3biii	Road transport: heavy-duty vehicles and buses	NOx	4313	5.1	59.5
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	742	4.8	64.3
3Da2a	Animal manure applied to soils	NOx	1457	4.8	69.1
1A4bi	Residential: stationary plants	NOx	4348	3.8	72.9
1A2f	Stationary combustion in manufacturing industries and construction: Other	NOx	3142	3.5	76.4
1A1a	Public electricity and heat production	NOx	2087	2.9	79.3
3Da3	Urine and dung deposited by grazing animals	NOx	416	2.7	82.0
1A4ai	Commercial/institutional: stationary	NOx	2391	2.5	84.5
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	1675	1.9	86.4
2G	Other product use	NMVOC	6829	17.0	17.0
2D3a	Domestic solvent use including fungicides	NMVOC	8984	13.4	30.4
3B1b	Manure management - Non-dairy cattle	NMVOC	8241	9.4	39.9
3B1a	Manure management - Dairy cattle	NMVOC	7140	7.0	46.8
2D3d	Coating applications	NMVOC	8054	5.9	52.7
2D3g	Chemical products	NMVOC	3171	4.9	57.6
2D3i	Other solvent use	NMVOC	2009	4.7	62.3
2D3b	Road paving with asphalt	NMVOC	2651	4.0	66.3
1A3bi	Road transport: passenger cars	NMVOC	3794	3.2	69.5
2H2	Food and beverages industry	NMVOC	1991	3.0	72.5
1A3biv	Road transport: mopeds and motorcycles	NMVOC	709	2.8	75.3
1A4bi	Residential: stationary plants	NMVOC	2499	2.8	78.1
2D3h	Printing	NMVOC	3727	2.7	80.8
3B4gii	Manure management - Broilers	NMVOC	1089	2.7	83.5
3B3	Manure management - Swine	NMVOC	789	2.0	85.5
1A2f	Stationary combustion in manufacturing industries and construction: Other	SO2	1376	37.7	37.7
2B5	Carbide production	SO2	424	12.2	49.8
1A4bi	Residential: stationary plants	SO2	586	8.9	58.8
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	306	8.4	67.2
1A1a	Public electricity and heat production	SO2	241	8.3	75.5
2B10a	Chemical industry: Other	SO2	78	4.5	80.0
1A4ai	Commercial/institutional: stationary	SO2	244	3.5	83.5
1A4ci	Agriculture/forestry/fishing: stationary	SO2	68	2.7	86.2
3Da2a	Animal manure applied to soils	NH3	20359	24.1	24.1
3B1a	Manure management - Dairy cattle	NH3	10414	16.7	40.8
3B3	Manure management - Swine	NH3	4876	10.7	51.5
3B1b	Manure management - Non-dairy cattle	NH3	7030	10.5	62.0
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	2487	6.7	68.8
6A	Other sources	NH3	955	5.4	74.2
3Da3	Urine and dung deposited by grazing animals	NH3	1406	4.7	78.9
3B4gii	Manure management - Broilers	NH3	648	3.0	82.0
3B4gi	Manure management - Laying hens	NH3	676	3.0	85.0
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	952	2.8	87.7
1A4bi	Residential: stationary plants	PM2.5	1410	20.3	20.3
2A5a	Quarrying and mining of minerals other than coal	PM2.5	234	12.2	32.5
2H2	Food and beverages industry	PM2.5	165	8.6	41.1
1A3bvi	Road transport: automobile tyre and brake wear	PM2.5	817	7.7	48.9
2G	Other product use	PM2.5	375	6.7	55.6
2H1	Pulp and paper industry	PM2.5	183	5.3	60.9
1A4ai	Commercial/institutional: stationary	PM2.5	313	4.6	65.5
2A1	Cement production	PM2.5	156	4.5	70.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	393	3.7	73.8
5C1a	Municipal waste incineration	PM2.5	245	2.7	76.4
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	162	2.5	78.9
2I	Wood processing	PM2.5	46	2.4	81.3
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM2.5	179	2.2	83.5
1A4ci	Agriculture/forestry/fishing: stationary	PM2.5	229	1.9	85.4
3De	Cultivated crops	PM10	1004	12.2	12.2
2A5a	Quarrying and mining of minerals other than coal	PM10	468	10.4	22.6
1A3bvi	Road transport: automobile tyre and brake wear	PM10	2401	9.6	32.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2344	9.4	41.6
1A4bi	Residential: stationary plants	PM10	1478	9.0	50.6
2H2	Food and beverages industry	PM10	307	6.8	57.3
1A3c	Railways	PM10	1259	5.0	62.4
2I	Wood processing	PM10	183	4.0	66.4
2G	Other product use	PM10	470	3.6	70.0
3B4gii	Manure management - Broilers	PM10	202	3.3	73.3
2A1	Cement production	PM10	244	3.0	76.2
3B4gi	Manure management - Laying hens	PM10	154	2.5	78.8
3B3	Manure management - Swine	PM10	146	2.4	81.1
2H1	Pulp and paper industry	PM10	189	2.3	83.5
1A4ai	Commercial/institutional: stationary	PM10	333	2.1	85.5

Table A - 10: Switzerland's key categories according to approach 2 level assessment for the year 1990, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, LEVEL ASSESSMENT FOR 1990					
A	B	C	D	E	F
NFR code	Source category	Pollutant	Ex, 0 (t)	Lx, 0 (%)	Cumulative Total (%)
1A3bi	Road transport: passenger cars	NOx	43771	45.3	45.3
1A3biii	Road transport: heavy-duty vehicles and buses	NOx	29900	14.5	59.8
1A3bii	Road transport: light-duty vehicles	NOx	6197	5.4	65.2
1A2f	Stationary combustion in manufacturing industries and construction: Other	NOx	10535	4.9	70.0
1A4bi	Residential: stationary plants	NOx	11630	4.3	74.3
1A1a	Public electricity and heat production	NOx	6294	3.7	77.9
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1205	3.3	81.2
3Da2a	Animal manure applied to soils	NOx	2075	2.8	84.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	NOx	6334	2.2	86.2
2G	Other product use	NMVOc	23727	17.4	17.4
1A3bi	Road transport: passenger cars	NMVOc	55936	13.9	31.4
2D3g	Chemical products	NMVOc	27504	12.6	43.9
2D3d	Coating applications	NMVOc	40731	8.7	52.7
1A3biv	Road transport: mopeds and motorcycles	NMVOc	5733	6.7	59.4
2D3h	Printing	NMVOc	20354	4.3	63.7
2D3a	Domestic solvent use including fungicides	NMVOc	9195	4.0	67.8
2D3i	Other solvent use	NMVOc	5470	3.8	71.5
2D3e	Degreasing	NMVOc	11166	3.4	74.9
1A3bv	Road transport: gasoline evaporation	NMVOc	16980	3.2	78.1
1A4bi	Residential: stationary plants	NMVOc	8850	2.9	81.0
2D3b	Road paving with asphalt	NMVOc	4895	2.2	83.2
3B1a	Manure management - Dairy cattle	NMVOc	7075	2.0	85.2
2C3	Aluminium production	SO2	696	15.9	15.9
1A4bi	Residential: stationary plants	SO2	9208	14.6	30.4
1A1a	Public electricity and heat production	SO2	3587	12.9	43.3
1A2f	Stationary combustion in manufacturing industries and construction: Other	SO2	3530	10.1	53.4
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO2	3314	9.4	62.8
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SO2	3091	6.5	69.3
1A4ai	Commercial/institutional: stationary	SO2	3426	5.1	74.5
1B2aiv	Fugitive emissions oil: Refining / storage	SO2	419	3.5	77.9
1A3biii	Road transport: heavy-duty vehicles and buses	SO2	1753	2.6	80.6
1A3bi	Road transport: passenger cars	SO2	1705	2.6	83.1
2C1	Iron and steel production	SO2	144	2.0	85.1
3Da2a	Animal manure applied to soils	NH3	34567	33.9	33.9
3B3	Manure management - Swine	NH3	6965	12.6	46.5
3B1a	Manure management - Dairy cattle	NH3	9337	12.4	58.8
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4258	9.5	68.4
3B1b	Manure management - Non-dairy cattle	NH3	5191	6.4	74.8
6A	Other sources	NH3	846	4.0	78.8
3B4gi	Manure management - Laying hens	NH3	979	3.6	82.3
1A3bi	Road transport: passenger cars	NH3	1319	2.9	85.3
1A4bi	Residential: stationary plants	PM2.5	5227	31.0	31.0
2C1	Iron and steel production	PM2.5	818	7.0	38.0
2I	Wood processing	PM2.5	216	4.7	42.7
1A1a	Public electricity and heat production	PM2.5	772	4.3	47.0
2H2	Food and beverages industry	PM2.5	188	4.1	51.1
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	4.0	55.1
2G	Other product use	PM2.5	513	3.8	58.9
1A3biii	Road transport: heavy-duty vehicles and buses	PM2.5	1585	3.3	62.2
1A4ai	Commercial/institutional: stationary	PM2.5	506	3.1	65.3
2A1	Cement production	PM2.5	240	2.9	68.1
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	2.8	71.0
2H1	Pulp and paper industry	PM2.5	236	2.8	73.8
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM2.5	545	2.8	76.6
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM2.5	435	2.7	79.3
1A3bvi	Road transport: automobile tyre and brake wear	PM2.5	689	2.7	82.0
1A3bi	Road transport: passenger cars	PM2.5	578	2.6	84.6
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM2.5	438	2.2	86.8
1A4bi	Residential: stationary plants	PM10	5500	18.8	18.8
2I	Wood processing	PM10	864	10.7	29.6
2C1	Iron and steel production	PM10	1485	7.4	37.0
3De	Cultivated crops	PM10	1054	7.3	44.2
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2173	4.9	49.1
1A3bvi	Road transport: automobile tyre and brake wear	PM10	2050	4.6	53.8
2A5a	Quarrying and mining of minerals other than coal	PM10	367	4.6	58.4
2H2	Food and beverages industry	PM10	310	3.9	62.2
1A1a	Public electricity and heat production	PM10	1034	3.3	65.6
2A1	Cement production	PM10	374	2.6	68.2
2G	Other product use	PM10	588	2.5	70.7
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM10	833	2.4	73.1
1A3c	Railways	PM10	983	2.2	75.3
3B3	Manure management - Swine	PM10	213	2.0	77.3
1A3biii	Road transport: heavy-duty vehicles and buses	PM10	1585	1.9	79.2
1A4ai	Commercial/institutional: stationary	PM10	533	1.9	81.1
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery	PM10	511	1.8	83.0
2H1	Pulp and paper industry	PM10	244	1.7	84.7
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	PM10	568	1.7	86.3

Table A - 11: Switzerland's key categories according to approach 2 trend assessment for 1990-2020, sorted by decreasing contribution, for the main pollutants, PM2.5 and PM10. Categories in orange have increased emissions in 2020 compared to 1990. Categories in grey are not key and are given for information only.

KCA APPROACH 2, UNCERTAINTY APPROACH 2, TREND ASSESSMENT 1990 - 2020								
A	B	C	D	E	F	G	H	
NFR code	Source category	Pollutant	Ex, 0 (t)	Ex, t (t)	Category trend (%)	Trend Assessment	Contribution to trend (%)	Cumulative Total (%)
1A3biii	Road transport: heavy-duty vehicles and buses	NOx	29900	4313	-86	0.05	24.3	24.3
1A3bii	Road transport: light-duty vehicles	NOx	6197	4823	-22	0.02	15.9	40.3
1A3bi	Road transport: passenger cars	NOx	43771	17810	-59	0.01	11.2	51.5
3Da2a	Animal manure applied to soils	NOx	2075	1457	-30	0.00	6.8	58.3
3Da3	Urine and dung deposited by grazing animals	NOx	243	416	71	0.00	6.4	64.7
3Da1	Inorganic N-fertilizers (includes also urea application)	NOx	1205	742	-38	0.00	5.8	70.5
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	NOx	2338	1675	-28	0.01	2.7	73.2
1A2f	Stationary combustion in manufacturing industries and construction: Other	NOx	10535	3142	-70	0.01	2.7	75.9
1B2c	Venting and flaring (oil, gas, combined oil and gas)	NOx	213	2	-99	0.00	2.4	78.2
3Da2c	Other organic fertilisers applied to soils (including compost)	NOx	15	116	686	0.00	2.2	80.5
1A4ai	Commercial/institutional: stationary	NOx	4696	2391	-49	0.00	2.0	82.5
1A3dii	National navigation (shipping)	NOx	1055	985	-7	0.00	1.5	84.0
3B1b	Manure management - Non-dairy cattle	NOx	344	275	-20	0.00	1.5	85.5
2D3a	Domestic solvent use including fungicides	NMVOc	9195	8984	-2	0.02	14.6	14.6
1A3bi	Road transport: passenger cars	NMVOc	55936	3794	-93	0.04	13.2	27.8
3B1b	Manure management - Non-dairy cattle	NMVOc	5368	8241	54	0.02	11.6	39.4
2D3g	Chemical products	NMVOc	27504	3171	-88	0.01	9.0	48.3
3B1a	Manure management - Dairy cattle	NMVOc	7075	7140	1	0.02	7.7	56.0
1A3biv	Road transport: mopeds and motorcycles	NMVOc	5733	709	-88	0.00	4.5	60.5
3B4gii	Manure management - Broilers	NMVOc	366	1089	197	0.00	3.6	64.2
2H2	Food and beverages industry	NMVOc	1956	1991	2	0.01	3.3	67.4
2D3b	Road paving with asphalt	NMVOc	4895	2651	-46	0.00	3.1	70.5
2G	Other product use	NMVOc	23727	6829	-71	0.00	2.7	73.2
2D3d	Coating applications	NMVOc	40731	8054	-80	0.01	2.6	75.8
2D3e	Degreasing	NMVOc	11166	1317	-88	0.01	2.4	78.2
1A3bv	Road transport: gasoline evaporation	NMVOc	16980	1901	-89	0.01	2.4	80.5
2D3i	Other solvent use	NMVOc	5470	2009	-63	0.00	2.1	82.6
3B4gi	Manure management - Laying hens	NMVOc	509	636	25	0.00	1.8	84.5
3B3	Manure management - Swine	NMVOc	1126	789	-30	0.00	1.8	86.3
1A2f	Stationary combustion in manufacturing industries and construction: Other	SO2	3530	1376	-61	0.03	35.0	35.0
2B5	Carbide production	SO2	445	424	-5	0.01	13.7	48.7
1A2d	Stationary combustion in manufacturing industries and construction: pulp, paper and print	SO2	3091	3	-100	0.01	8.1	56.9
1A4bi	Residential: stationary plants	SO2	9208	586	-94	0.01	7.0	63.9
1A1a	Public electricity and heat production	SO2	3587	241	-93	0.00	5.6	69.6
2B10a	Chemical industry: Other	SO2	168	78	-54	0.00	4.4	74.0
1A3biii	Road transport: heavy-duty vehicles and buses	SO2	1753	13	-99	0.00	3.1	77.0
1B2aiv	Fugitive emissions oil: Refining / storage	SO2	419	14	-97	0.00	2.9	80.0
1A3bi	Road transport: passenger cars	SO2	1705	54	-97	0.00	2.2	82.2
1A4ai	Commercial/institutional: stationary	SO2	3426	244	-93	0.00	2.0	84.2
1B2c	Venting and flaring (oil, gas, combined oil and gas)	SO2	301	2	-99	0.00	2.0	86.2
3Da2a	Animal manure applied to soils	NH3	34567	20359	-41	0.10	21.4	21.4
3B1a	Manure management - Dairy cattle	NH3	9337	10414	12	0.05	14.0	35.4
3B1b	Manure management - Non-dairy cattle	NH3	5191	7030	35	0.04	12.4	47.8
3Da3	Urine and dung deposited by grazing animals	NH3	761	1406	85	0.01	7.6	55.4
3Da2c	Other organic fertilisers applied to soils (including compost)	NH3	34	952	2700	0.01	7.5	62.9
3Da1	Inorganic N-fertilizers (includes also urea application)	NH3	4258	2487	-42	0.01	6.2	69.1
3B4gii	Manure management - Broilers	NH3	305	648	112	0.01	5.3	74.4
6A	Other sources	NH3	846	955	13	0.00	4.7	79.1
3B3	Manure management - Swine	NH3	6965	4876	-30	0.01	3.3	82.4
5B1	Biological treatment of waste - Composting	NH3	175	311	78	0.00	2.7	85.0
2A5a	Quarrying and mining of minerals other than coal	PM2.5	183	234	28	0.01	14.3	14.3
1A4bi	Residential: stationary plants	PM2.5	5227	1410	-73	0.03	10.1	24.5
2C1	Iron and steel production	PM2.5	818	8	-99	0.02	9.5	33.9
1A3bvi	Road transport: automobile tyre and brake wear	PM2.5	689	817	19	0.03	8.8	42.7
2H2	Food and beverages industry	PM2.5	188	165	-12	0.01	8.4	51.1
2G	Other product use	PM2.5	513	375	-27	0.01	5.6	56.7
1A1a	Public electricity and heat production	PM2.5	772	44	-94	0.01	5.0	61.7
2H1	Pulp and paper industry	PM2.5	236	183	-22	0.01	4.7	66.5
1A3biii	Road transport: heavy-duty vehicles and buses	PM2.5	1585	68	-96	0.03	4.1	70.5
2A1	Cement production	PM2.5	240	156	-35	0.00	3.3	73.9
1A4ai	Commercial/institutional: stationary	PM2.5	506	313	-38	0.01	3.2	77.1
2I	Wood processing	PM2.5	216	46	-79	0.00	2.6	79.6
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM2.5	438	42	-91	0.01	2.2	81.9
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM2.5	729	393	-46	0.01	2.1	83.9
1A3c	Railways	PM2.5	174	194	11	0.01	2.0	86.0
1A4bi	Residential: stationary plants	PM10	5500	1478	-73	0.06	12.5	12.5
2C1	Iron and steel production	PM10	1485	12	-99	0.03	9.8	22.3
2I	Wood processing	PM10	864	183	-79	0.01	8.7	31.0
2A5a	Quarrying and mining of minerals other than coal	PM10	367	468	28	0.01	8.7	39.7
3De	Cultivated crops	PM10	1054	1004	-5	0.02	7.7	47.4
1A3bvi	Road transport: automobile tyre and brake wear	PM10	2050	2401	17	0.05	7.5	55.0
1A2gvii	Mobile Combustion in manufacturing industries and construction	PM10	2173	2344	8	0.05	6.8	61.8
2H2	Food and beverages industry	PM10	310	307	-1	0.01	4.5	66.2
1A3c	Railways	PM10	983	1259	28	0.03	4.2	70.5
1A1a	Public electricity and heat production	PM10	1034	44	-96	0.02	4.1	74.6
3B4gii	Manure management - Broilers	PM10	68	202	197	0.01	3.9	78.5
1A2f	Stationary combustion in manufacturing industries and construction: Other	PM10	833	71	-91	0.01	2.8	81.2
1A3biii	Road transport: heavy-duty vehicles and buses	PM10	1585	68	-96	0.03	2.4	83.6
3B4gi	Manure management - Laying hens	PM10	123	154	25	0.00	2.1	85.7

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 (2015a⁶), which is the data pool of FOEN (2015j). They can be queried by year, non-road family (see categories in Table A - 13), machine type, engine type (diesel, gasoline/2-/4-stroke, liquefied petroleum gas, gas oil), engine capacity (power class) and emission concept (standard), pollutant either at aggregated or disaggregated levels. The following table illustrates a query for the family 'construction machinery'.

Table A - 12: Excerpt of the non-road database INFRAS (2015a).

Construction machinery, 2010								
Machine type	Engine type	Engine capacity	Emission concept	Poll.	Op. hrs. (h/a)	EF (kg/h)	EF [w/o PF] (kg/h)	EF [100% PF] (kg/h)
Road finishing machines	diesel	18-37 kW	Nonr D PreEUB	PM	112.7	0.0074	0.0074	0.0007
Road finishing machines	diesel	18-37 kW	Nonr D EU2	PM	259.9	0.0045	0.0045	0.0005
Road finishing machines	diesel	18-37 kW	Nonr D EU3A	PM	305.8	0.0006	0.0046	0.0005
Road finishing machines	diesel	37-75 kW	Nonr D PreEUB	PM	130.1	0.0133	0.0133	0.0013
Road finishing machines	diesel	37-75 kW	Nonr D EU1	PM	248.6	0.0073	0.0073	0.0007
Road finishing machines	diesel	37-75 kW	Nonr D EU2	PM	327.8	0.0014	0.0047	0.0005
Road finishing machines	diesel	37-75 kW	Nonr D EU3A	PM	357.7	0.0005	0.0053	0.0005
Road finishing machines	diesel	75-130 kW	Nonr D PreEUB	PM	138.8	0.0129	0.0129	0.0013
Road finishing machines	diesel	75-130 kW	Nonr D EU1	PM	239.4	0.0096	0.0096	0.001
Road finishing machines	diesel	75-130 kW	Nonr D EU2	PM	332.7	0.0031	0.0062	0.0006
Road finishing machines	diesel	75-130 kW	Nonr D EU3A	PM	376.4	0.0007	0.007	0.0007
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D PreEUB	PM	131.7	0.0104	0.0104	0.001
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D EU1	PM	227.2	0.0077	0.0077	0.0008
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D EU2	PM	315.7	0.0025	0.005	0.0005
Hydraulic rammers of all types	diesel	75-130 kW	Nonr D EU3A	PM	357.2	0.0005	0.0048	0.0005
Rolling mill engines of all types	diesel	<18 kW	Nonr D PreEUB	PM	130.9	0.005	0.005	0.0005
Rolling mill engines of all types	diesel	<18 kW	Nonr D EU1	PM	250.1	0.0042	0.0042	0.0004
Rolling mill engines of all types	diesel	<18 kW	Nonr D EU2	PM	329.7	0.0032	0.0032	0.0003
Rolling mill engines of all types	diesel	<18 kW	Nonr D EU3A	PM	359.8	0.0029	0.0032	0.0003
Rolling mill engines of all types	diesel	18-37 kW	Nonr D PreEUB	PM	148.3	0.0077	0.0077	0.0008
Rolling mill engines of all types	diesel	18-37 kW	Nonr D EU2	PM	341.8	0.0046	0.0046	0.0005
Rolling mill engines of all types	diesel	18-37 kW	Nonr D EU3A	PM	402.3	0.0006	0.0047	0.0005
Rolling mill engines of all types	diesel	37-75 kW	Nonr D PreEUB	PM	168.8	0.0138	0.0138	0.0014
Rolling mill engines of all types	diesel	37-75 kW	Nonr D EU1	PM	322.6	0.0076	0.0076	0.0008
Rolling mill engines of all types	diesel	37-75 kW	Nonr D EU2	PM	425.3	0.0014	0.0048	0.0005
Rolling mill engines of all types	diesel	37-75 kW	Nonr D EU3A	PM	464.1	0.0005	0.0054	0.0005
Rolling mill engines of all types	diesel	75-130 kW	Nonr D PreEUB	PM	174.5	0.0133	0.0133	0.0013
Rolling mill engines of all types	diesel	75-130 kW	Nonr D EU1	PM	301	0.0099	0.0099	0.001
Rolling mill engines of all types	diesel	75-130 kW	Nonr D EU2	PM	418.3	0.0032	0.0064	0.0006
Rolling mill engines of all types	diesel	75-130 kW	Nonr D EU3A	PM	473.2	0.0007	0.0071	0.0007
Rolling mill engines of all types	diesel	130-300 kW	Nonr D PreEUB	PM	174.5	0.0279	0.0279	0.0028
Rolling mill engines of all types	diesel	130-300 kW	Nonr D EU2	PM	387.1	0.0068	0.0094	0.0009
Rolling mill engines of all types	diesel	130-300 kW	Nonr D EU3A	PM	467.7	0.001	0.0104	0.001
Mechanical vibrators	diesel	18-37 kW	Nonr D PreEUB	PM	100.6	0.0059	0.0059	0.0006
Mechanical vibrators	diesel	18-37 kW	Nonr D EU2	PM	232	0.0036	0.0036	0.0004
Mechanical vibrators	diesel	18-37 kW	Nonr D EU3A	PM	273	0.0004	0.0031	0.0003
Mechanical vibrators	diesel	37-75 kW	Nonr D PreEUB	PM	131.3	0.0108	0.0108	0.0011
Mechanical vibrators	diesel	37-75 kW	Nonr D EU1	PM	250.9	0.0059	0.0059	0.0006
Mechanical vibrators	diesel	37-75 kW	Nonr D EU2	PM	330.7	0.0011	0.0038	0.0004
Mechanical vibrators	diesel	37-75 kW	Nonr D EU3A	PM	361	0.0004	0.0036	0.0004
Mechanical vibrators	diesel	75-130 kW	Nonr D PreEUB	PM	140	0.0105	0.0105	0.0011
Mechanical vibrators	diesel	75-130 kW	Nonr D EU1	PM	241.6	0.0078	0.0078	0.0008
Mechanical vibrators	diesel	75-130 kW	Nonr D EU2	PM	335.8	0.0025	0.0051	0.0005
Mechanical vibrators	diesel	75-130 kW	Nonr D EU3A	PM	379.8	0.0005	0.0048	0.0005

⁶ <https://www.bafu.admin.ch/bafu/en/home/topics/air/state/non-road-datenbank.html> [04.02.2022]

A2.1.2 Activity data non-road vehicles

The following table gives an overview on the stock and the operating hours of non-road vehicles (FOEN 2015j).

Table A - 13: Number of vehicles, specific operating hours per year and total operating hours per year for all non-road families/categories (FOEN 2015j).

Category	1980	1990	2000	2010	2020	2030
	number of vehicles					
Construction machinery	63'364	58'816	52'729	57'102	60'384	62'726
Industrial machinery	26'714	43'244	70'671	69'786	69'757	70'083
Agricultural machinery	292'773	324'567	337'869	318'876	309'825	305'235
Forestry machinery	11'815	13'844	13'055	11'857	10'831	10'170
Garden-care / hobby appliances	1'198'841	1'539'624	1'944'373	2'322'737	2'464'323	2'499'627
Navigation machinery	94'866	103'383	93'912	95'055	97'522	99'104
Railway machinery	529	1'300	1'255	697	640	640
Military machinery	13'092	13'373	14'272	13'083	12'853	12'856
Total	1'701'994	2'098'151	2'528'136	2'889'193	3'026'135	3'060'441

Category	1980	1990	2000	2010	2020	2030
	Specific operating hours per year					
Construction machinery	247	322	406	417	424	429
Industrial machinery	666	670	684	680	675	671
Agricultural machinery	136	119	112	103	99	95
Forestry machinery	203	199	203	193	188	182
Garden-care / hobby appliances	12	17	20	64	77	81
Navigation machinery	39	38	38	36	35	35
Railway machinery	877	613	617	783	719	719
Military machinery	64	64	63	73	74	74

Category	1980	1990	2000	2010	2020	2030
	million operating hours per year					
Construction machinery	15.7	19	21.4	23.8	25.6	26.9
Industrial machinery	17.8	29	48.4	47.5	47.1	47
Agricultural machinery	39.9	38.8	37.7	33	30.6	29
Forestry machinery	2.4	2.8	2.6	2.3	2	1.9
Garden-care / hobby appliances	14.6	25.7	39.3	149.7	190.8	201.3
Navigation machinery	3.7	3.9	3.5	3.4	3.4	3.4
Railway machinery	0.5	0.8	0.8	0.5	0.5	0.5
Military machinery	0.8	0.9	0.9	0.9	0.9	0.9
Total	95.4	120.9	154.6	261.1	300.9	310.9

A2.2 Emissions due to former usage (2K) and subsequent disposal of polychlorinated biphenyls (1A1a, 2C1, 5A, 5C1, 5E, 6A)

A2.2.1 Mass flow and emission model of former use and disposal of PCBs

Polychlorinated biphenyls (PCBs) were used in Switzerland between 1946 and 1986. In 1986, a total ban was placed on any form of PCB use. The use in so-called 'open applications' was allowed until 1972. Open applications include joint (elastic) sealants, anti-corrosion coatings, paints and varnishes. All other uses were allowed until 1986.

An emission inventory based on a dynamic mass flow model was developed for PCBs for Switzerland for the time period 1930 to 2100. The model takes into account the import, usage, export, treatment, disposal and accidental release of PCBs, see Figure A - 1. PCB emissions to the environment occur from all stages of their lifecycle. A detailed documentation of the emission inventory is available in Glüge et al. 2017. Additionally, the underlying model is available in Microsoft Excel/VBA and can be downloaded.

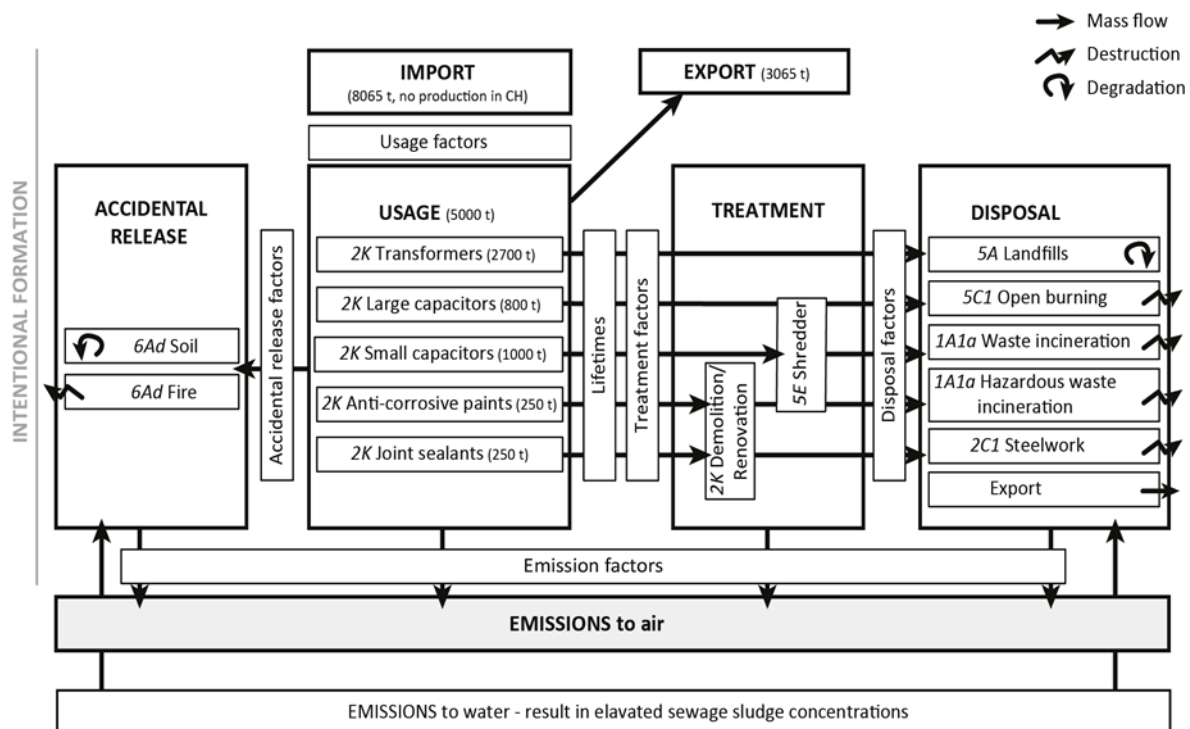


Figure A - 1: Model setup for the dynamic mass flow and emissions of PCBs taking into account the import, usage, export, treatment, disposal and accidental release. Emissions to air occur from usage, treatment, disposal, and accidental release. (Waste and hazardous waste incineration correspond to municipal solid waste and special waste incineration, respectively.)

Besides this intentional usage of PCBs, PCBs can also be emitted by unintentional formation, e.g. in combustion processes. Emissions from unintentional formation are not part of this mass flow model but are included in the air pollutant emission inventory for stationary combustion of solid and liquid fossil fuels as well as of wood and wood waste, see chps. 0 - 3.2.4.

Import and usage

PCBs have not been produced in Switzerland. Therefore, the chemicals enter the system solely through import (Figure A - 1, top part). The imported amounts are then distributed to the usage categories according to usage factors (Figure A - 1, middle part). The imported amounts, as well as the usage factors, vary over time. In this study, five usage categories that were identified to be important for Switzerland are included: transformers, large capacitors (> 1 kg), small capacitors (< 1 kg), anti-corrosive paints on steel and joint sealants. Other uses, such as PCBs in hydraulic oils (used in mining), plastics, or insecticides are considered as being of minor importance in Switzerland and are thus, not included in the model. For the time being, anti-corrosive paints and joint sealants are the predominant PCB emission sources (see Figure A - 3). The emissions from the five usage categories are reported in source category 2K Consumption of POPs and heavy metals.

Export

The exported amounts to other countries could have been estimated only roughly. PCBs were mainly exported in disposed PCB-containing transformers and capacitors and electronic waste, but also in old installations, such as for example hydraulic turbines with PCB-containing paints.

Disposal

When a PCB-containing product reaches its end of life it is disposed of. In the model, six disposal categories that have been relevant in Switzerland are included: landfills (5A), open burning (5C1), municipal waste incineration (1A1a), special waste incineration (1A1a), steelworks (2C1), and export (Figure A - 1, right part). For all usage categories, specific disposal factors, which vary over time, are applied to the six disposal categories and export. Here, open burning refers to combustion of PCB contaminated waste oil in outdoor fires (i.e. outside of a container). Open burning was ceased in 1999. Steelworks represent scrap metal that is melted in electric arc furnaces of secondary steel production plants. Thereby PCB-containing paint residues are combusted at temperatures of around 1600°C. Landfills are disposal sites where the waste is dumped. Since 2000, the incineration of combustible waste is mandatory in Switzerland, therefore, disposing of to landfills stopped. In landfills, PCBs are partly stored and partly degraded. When waste is exported, its emissions abroad are not included in the Swiss emission inventory. When combusted, PCBs are partly destroyed by high temperatures and partly emitted to the environment.

Treatment

Before disposal, some usage categories undergo specific treatment processes (Figure A - 1, right part). Two treatment categories are included in the model: Demolition/renovation of steel constructions and buildings containing PCBs in anti-corrosive paints and joint sealants, respectively (2K), as well as Shredding of electronic waste containing PCBs in small capacitors (5E).

Demolition/renovation can induce elevated emissions to the environment, as has been observed for buildings. Shredding of electronic waste occurs at fast rotation velocity that leads to increased temperature and dust production. As a consequence of the legal ban of disposal of combustible waste in landfills, a sharp increase in shredding of small capacitors occurred in 1999 although they should have been treated as special waste from 1998 onwards (see Figure A - 3). Shearing of steel constructions (heavy scrap), otherwise, is supposed to produce little dust and yield no evaporation of the substances in the coating. Therefore, no emissions to air from the shearing of steel constructions were assumed.

Accidental release

From each usage category, PCBs can be accidentally released (Figure A - 1, left part). The model includes two release categories: soil and fire (6Ad). When released to soil, PCBs are partly stored and partly degraded. In the case of fire, PCBs are partly destroyed by high temperatures and partly emitted to the environment.

Release to water

The release of PCBs to water bodies is only partly included in this model. Release to water bodies is important for anti-corrosive paints and to a smaller degree also for leachate from landfills. The measured PCB concentrations in sewage sludge and the total amount of produced sewage sludge per year was used to determine the mass of PCBs released to water. This approach overlooks emissions to natural water bodies, but it captures emissions to wastewater.

A2.2.2 Emission methodology

Emissions to air occur from the entire system: usage, treatment, disposal and accidental release. The emissions are calculated by multiplying the annual mass of PCBs involved in a source category (e.g. tonnes of PCBs in use in joint sealants) with a source-specific emission factor (e.g. tonnes of PCBs emitted/tonnes of PCBs in use). This country-specific approach corresponds to a Tier 2 method according to EMEP/EEA (2019).

The five usage categories as well as landfills and soils are PCB stocks, which means that PCBs are stored in these categories and passed on through the system with a temporal delay according to their lifetime or residence time. In these cases, the activity data are the amounts of PCBs stored in the stock. The treatment categories of renovation and shredder and all incineration categories (including fire) are instantaneous categories, where PCBs are not stored. In these cases, the activity data correspond to the amount of PCBs treated or incinerated in the respective year.

PCB emissions are sometimes reported as sum of the so-called indicator PCBs (iPCBs, i.e. PCB congeners 28, 52, 101, 138, 153, and 180), sometimes as sum of the dioxin-like PCBs (dl-PCBs, i.e. PCB congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189) and sometimes as sum of all 209 congeners. The emission model is run for all congeners, so emission numbers are available for all three sums. Where data such as typically emission factors are not available for all congeners, estimates are derived from the iPCBs using the chlorination degrees of the congeners. Please note that the PCB emissions reported in Switzerland's air pollutant emission inventory comprise the sum of all 209 congeners.

Figure A - 3 shows the resulting PCB emissions from all stages of the life cycle of PCB applications, i.e. usage, treatment, disposal and accidental release. Anti-corrosive paints and joint sealants are the predominant PCB emission sources for most of the time. Between 1975 and 1985 and around 2000, open burning and the above-mentioned shredding of small capacitors, respectively, were the dominant PCB sources. Only after 2040, emissions from soil due to former accidental releases to soil become the most important emission source. Mainly in the seventies and eighties, accidental release by fire, small and large capacitors and waste incineration were important emission sources as well.

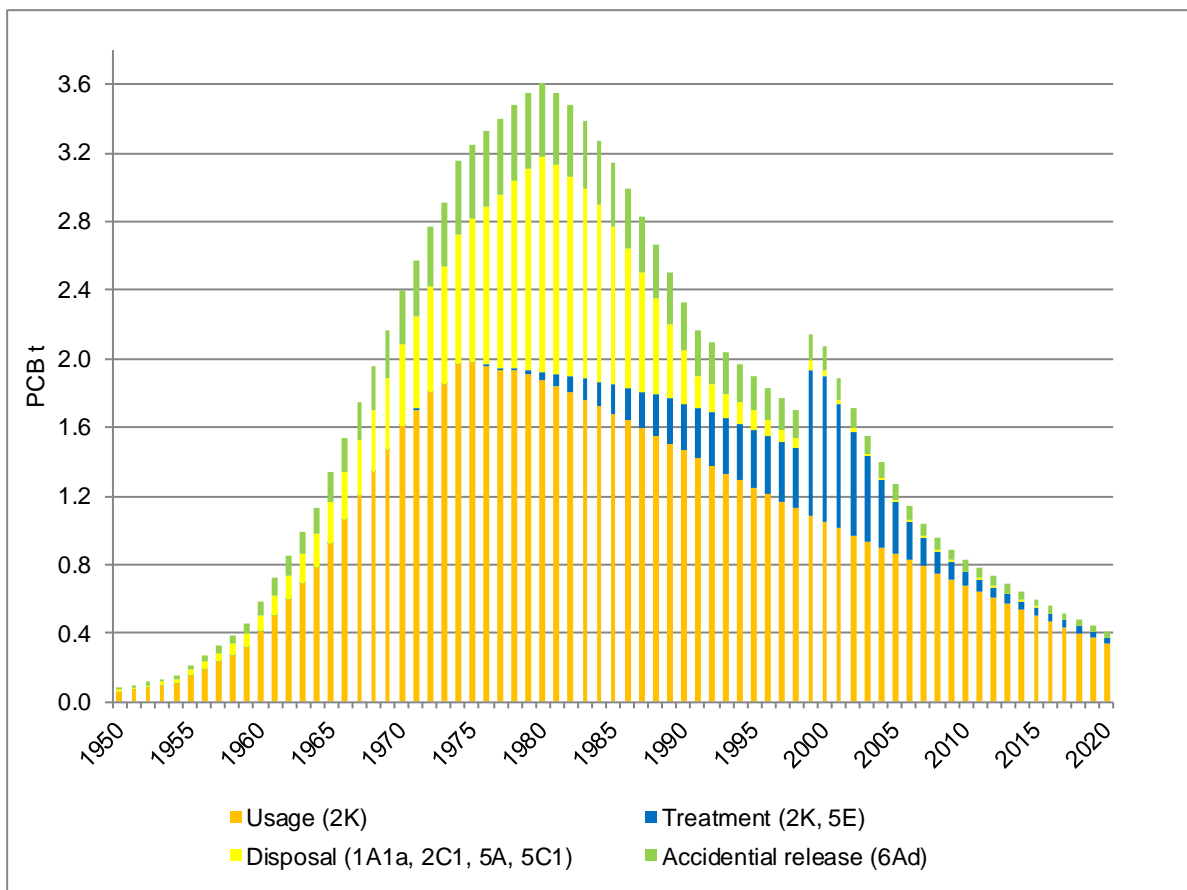


Figure A - 2: PCB emissions from usage (2K Transformers, large and small condensators, anti-corrosive paints and joint sealants), treatment (2K Demolition and renovation, 5E Shredder), disposal (1A1a Municipal solid waste and special waste incineration, 2C1 Secondary steel production, 5A Landfills, 5C1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

A2.3 Comparison of the country-specificly calculated Tier 3 results for N flows and NH₃ 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 emission factors as well as a comparison of the national emission factors and the Guidebook emission factors with a rationale of the discrepancies.” Because it is not only the emission factors that have a strong influence on the emission inventory calculations but also other assumptions like N excretions, length of housed period or percentage of TAN in the manure, it was decided to not only compare the emission factors but rather the total N flows and NH₃ emissions resulting from the calculations with the model AGRAMMON (see chp. 5.2.2) and the TFEIP N flow tool (downloaded from <https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/4-agriculture/manure-management-n-flow-tool/view>, version Jan 2021). The comparison was made for the year 2015, which at the time was the last year with data from a representative survey on farm and manure management, using the previous version of the AGRAMMON model (Kupper et al. 2018). The procedure and the results are summarized in an internal memo (Menzi 2022). An overview of the results is shown in Tables A-14 to A-16. The main results can be summarized as follows:

N excretions

- N excretions of livestock differ only 6 % between the two approaches (N-flow tool 94 % of AGRAMMON model).
- In both approaches N excretions from cattle make up nearly 80 % of total livestock N excretions and for swine about 10 %. Thus, these two main livestock categories are responsible for the decisive part of the comparison.
- Total N excretions of cattle compare quite well between the two approaches. Compared to the AGRAMMON model, they are 94 % as high in the N-flow model for dairy cattle, 92 % for non-dairy cattle and 91 % for young cattle. 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 (Richner et al. 2017) and in AGRAMMON.
- For swine, total N excretions calculated with the N-flow tool are 4 % lower than in the AGRAMMON model.
- For poultry, total N excretions are less than 2 % apart in the two approaches (higher in N-flow tool).
- For horses, N excretions differ less than 10 % between the two approaches. For mules and asses the AGRAMMON values are about 50 % lower than in the N-flow tool. This is probably because ponies are also included in this category.
- For livestock categories with grazing, the share of N excretions in the housing area and during grazing is considerably different between the two approaches. For example, the share of N excreted during grazing for dairy cattle is 16 % according to the AGRAMMON model 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 housing 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. In Switzerland, most cattle are also in the housing area during a large part of the day in the summer period (approx. May to October). For example, in 2015 (survey) dairy cattle 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 with the N-flow tool.

- 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 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 sheep and goats, the overestimation of N excretions during grazing in the N flow tool is considerably higher than for cattle because the housing period is assumed to be 30 days of 24 hours per year only (720 h) while the grazing period for sheep is around 200 days of about 10 hours according to the Swiss representative survey which gives a housing period of 6'760 h and for goats, the grazing period is 187 days of 6.8 h which gives a housing period of 7'488 h.

Total NH₃ emissions livestock

- Total NH₃ emissions (3B1, 3Da2a1, 3Da31) from all three cattle categories together are 7 % lower according to the N-flow tool compared to the AGRAMMON model.
- For dairy cattle, total NH₃ emissions agree quite well between the two approaches; the values according to the N-flow tool are 95 % of those from the AGRAMMON model. This implies that the underestimation of N excretions in the housing area and thus of the N flow through the manure management chain was largely compensated by the higher weight of the animals in AGRAMMON (660 kg) as compared to the N-flow tool (600 kg), the ratio between liquid and solid manure and the Tier 3 inputs considered in the AGRAMMON model, e.g. for feeding, covered slurry stores, slurry spreading technique etc.
- For non-dairy cattle the difference is larger than for dairy cattle (non-dairy cattle N-flow tool 87 % of AGRAMMON values; young cattle N-flow tool 69 % of AGRAMMON values). This is probably due to the high number of suckling cows in Switzerland. In the category non-dairy cattle, suckling cows were responsible for 27 % of the animal places and according to AGRAMMON 29 % of the N-excretions in 2015. In the category young cattle, suckling cow calves contributed 47% of the animal places and 52% of the N-excretions.
- For all livestock categories with grazing, NH₃ emissions from grazing according to the N-flow tool are considerably higher than in the AGRAMMON model because of the corresponding differences of the distribution of N excretion mentioned above.
- Total NH₃ emissions from all swine categories together in the N-flow tool are 97 % of those in the AGRAMMON model.
- Total NH₃ emissions from all poultry categories together in the N-flow tool are 131 % of those in the AGRAMMON model.

Distribution of NH₃ emissions to the stages of the manure management chain

- Manure application (3Da2a) is the largest contributor to NH₃ emissions from the manure chain (housing plus yard, manure storage, manure application, grazing) according to both the AGRAMMON model (42 %) and the N-flow tool (35 %). This considerable difference is a consequence of the assumptions on the time the animals spend outside for grazing in the two approaches (see above).

- Housing plus yard (3B) is the second largest contributor to NH₃ emissions from the manure chain both according to the AGRAMMON model (36 %) and the N-flow tool (32 %)
- Manure storage (3B) is the third most important emission source in the manure chain with a share of 17 % and 22 % according to the AGRAMMON model and the N-flow tool, respectively.
- Emissions from grazing (3Da3) are about 3.5 times higher according to the N flow tool as compared with the AGRAMMON model. Again, this is a consequence of the assumptions on the time the animals spend outside for grazing in the two approaches (see above).

A direct comparison of N flows or emission factors is impeded in various places by the differences between the models in the allocation of N flows. Important examples are:

- a) The N-flow tool differentiates between emission factors for liquid and solid manure in the housing area while AGRAMMON has only one emission factor for housing because a clear allocation of excreta and soiled surfaces to liquid and solid manure is not possible.
- b) For slurry storage, the emission factors are in percent of TAN in the N flow model and in g per m² slurry surface and day in AGRAMMON.
- c) AGRAMMON takes into account a different allocation of TAN excretions to liquid and solid manure. As urine (containing soluble N, which is potentially emitted) is primarily collected in the liquid manure, the emissions are higher than for a comparable N flow in the form of faeces, which primarily contain organic N and mostly go into solid manure.
- d) AGRAMMON takes into account the immobilisation of TAN and the release of TAN from the degradation of organic N in housing and during manure storage, which is not considered in the N flow tool.

The comparison of the two approaches shows that the Tier 2 approach can hardly cope with farm management conditions that differ strongly from the assumption in the N-flow tool and can only be transferred to the input variables with difficulty. If such detailed farm management data is available, it is more reliable and maybe even easier to use a country-specific Tier 3 approach.

Table A – 14: N flows in form of N excretions and NH₃ emissions for the different livestock categories according to the AGRAMMON model for the year 2015.

Aggrammon	Swiss reporting	dairy cows	non-d cattle	non-d cattle (calves)	cattle exc DC	cattle total	finishing pigs	sows	pigs total	sheep	goats	horses	hules+asses	equids	laying hen	broilers	turkeys	poultry tot	total
N excretion housing+yard	kt N	54.74	25.63	3.18	28.80	83.55	9.59	4.72	14.31	2.10	0.84	1.91	0.24	2.16	2.41	3.09	0.07	5.57	108.53
N excretion grazing	kt N	10.38	8.81	0.67	9.49	19.86	0.00	0.00	0.00	1.23	0.11	0.52	0.07	0.59	0.16	0.01	0.00	0.17	21.96
N excretion total	kt N	65.12	34.44	3.85	38.29	103.41	9.59	4.72	14.31	3.33	0.95	2.43	0.31	2.75	2.57	3.10	0.07	5.74	130.50
% category of total		49.9%	26.4%	3.0%	29.3%	79.2%	7.4%	3.6%	11.0%	3%	1%	1.9%	0.2%	2.1%	2.0%	2.4%	0.1%	4.4%	100.0%
% during grazing		16%	26%	17%	25%	19%	0%	0%	0%	37%	12%	21%	2%	21%	6%	0%	3%	9%	17%
Em housing	kt N	4.34	2.14	0.31	2.45	6.79	2.41	1.13	3.54	0.25	0.10	0.14	0.01	0.15	0.37	0.38	0.01	0.76	11.60
Em yard	kt N	1.55	1.33	0.10	1.43	2.98	-	-	-	-	-	0.11	0.02	0.13	-	-	-	-	3.11
Em housing&yards	kt N	5.89	3.47	0.41	3.88	9.77	2.41	1.13	3.54	0.25	0.10	0.25	0.03	0.28	0.37	0.38	0.01	0.76	14.71
emissions storage liquid	kt N	2.72	1.19	0.08	1.28	4.00	0.39	0.20	0.59	-	-	-	-	-	-	-	-	-	4.59
storage solid	kt N	0.80	0.70	0.19	0.89	1.69	-	-	-	0.17	0.06	0.14	0.02	0.16	0.12	0.06	0.00	0.19	2.27
storage total	kt N	3.53	1.89	0.27	2.16	5.69	0.39	0.20	1.22	0.17	0.06	0.14	0.02	0.16	0.12	0.06	0.00	0.19	7.48
application liquid	kt N	8.58	3.14	0.23	3.36	11.95	1.19	0.58	1.77	-	-	-	-	-	-	-	-	-	13.72
application solid	kt N	1.16	1.02	0.25	2.44	4.38	-	-	-	0.07	0.04	0.08	0.01	0.08	0.26	0.34	0.01	0.61	3.24
application total	kt N	9.75	4.16	0.48	4.64	14.38	1.19	0.58	1.77	0.07	0.04	0.08	0.01	0.08	0.26	0.34	0.01	0.61	16.96
emissions grazing	kt N	0.48	0.40	0.03	0.43	0.91	0.0002	0.0002	0.00	0.06	0.01	0.03	0.00	0.03	0.07	0.003	0.001	0.07	1.08
% of grazing emissions		44.2%	37.4%	2.9%	40.3%	84.5%	0.3%	0.0%	0.0%	0.06	0.01	2.4%	0.3%	2.7%	6.1%	0.3%	0.1%	6.5%	6.5%
% of total emissions		1.2%	1.0%	0.1%	1.1%	2.3%	0.0%	0.0%	0.0%	0.00	0.00	0.1%	0.0%	0.1%	0.2%	0.0%	0.0%	0.2%	0.2%
3B total	kt N	9.41	5.37	0.68	6.05	15.46	2.80	1.33	4.76	0.42	0.16	0.39	0.05	0.44	0.49	0.45	0.01	0.95	22.19
% category of total		42.4%	24.2%	3.1%	27.2%	69.7%	12.6%	6.0%	21.4%	2%	1%	1.8%	0.2%	2.0%	2.2%	2.0%	0.1%	4.3%	100.0%
3D total (manure)	kt N	10.22	4.56	0.51	5.07	15.29	1.19	0.58	1.77	0.14	0.04	0.10	0.01	0.11	0.33	0.35	0.01	0.68	18.03
% category of total		56.7%	25.3%	2.8%	28.1%	84.8%	6.6%	3.2%	9.8%	1%	0%	0.6%	0.1%	0.6%	1.8%	1.9%	0.0%	3.8%	100.0%
Emissions manure total	kt N	19.64	9.93	1.19	11.11	30.75	3.99	1.91	6.53	0.55	0.20	0.49	0.06	0.56	0.82	0.79	0.02	1.63	40.22
% category of total		48.8%	24.7%	3.0%	27.6%	76.5%	9.9%	4.7%	16.2%	1%	0%	1.2%	0.2%	1.4%	2.0%	2.0%	0.1%	4.1%	100.0%

Annexes: Other detailed methodological descriptions for individual source categories

Table A – 15: N flows in form of N excretions and NH₃ emissions for the different livestock categories according to the N-flow tool for the year 2015.

Tier 2 model	dairy cows	non-d cattle	calves	cattle total	finishing pigs	sows	pigs total	sheep	goats	horses	mules+ asses	equids total	laying hens	broilers	turkeys	poultry total	total
N excretion housing-yard	38.01	17.31	1.90	57.22	9.44	4.23	13.67	0.34	0.11	1.30	0.32	1.62	2.97	2.77	0.09	5.83	78.79
N excretion grazing	23.31	14.52	1.60	39.43	-	-	-	3.04	1.20	1.33	0.33	1.67	-	-	-	-	45.33
N excretion total	61.31	31.83	3.50	96.65	9.44	4.23	13.67	3.37	1.31	2.63	0.65	3.29	2.97	2.77	0.09	5.83	124.12
% category of total	49.4%	25.6%	2.8%	77.9%	7.6%	3.4%	11.0%	2.7%	1.1%	2.1%	0.5%	2.6%	2.4%	2.2%	0.1%	4.7%	100.0%
% during grazing	38%	46%	46%	41%	0%	0%	0%	90%	92%	51%	51%	51%	0%	0%	0%	0%	37%
emissions housing	2.08	1.49	0.15	3.72	1.78	1.04	2.82	0.03	0.01	0.17	0.04	0.21	0.42	0.41	0.02	0.85	7.65
em. yards	3.01	1.28	0.15	4.44	-	-	-	0.03	-	-	-	-	-	-	-	-	4.47
Em housing&yards	5.09	2.78	0.30	8.17	1.78	1.04	2.82	0.06	0.01	0.17	0.04	0.21	0.42	0.41	0.02	0.85	12.11
storage liquid	4.14	1.31	0.13	5.58	0.56	0.23	0.79	-	-	-	-	-	-	-	-	-	6.36
storage solid	0.46	0.66	0.03	1.16	-	-	-	0.02	0.01	0.15	0.03	0.18	0.13	0.46	0.01	0.60	1.97
storage total	4.60	1.97	0.16	6.73	0.56	0.23	0.79	0.02	0.01	0.15	0.03	0.18	0.13	0.46	0.01	0.60	8.33
application liquid	6.73	2.13	0.20	9.06	1.81	0.53	2.34	-	-	-	-	-	-	-	-	-	11.40
application solid	0.34	0.49	0.02	0.86	-	-	-	0.02	0.01	0.12	0.02	0.15	0.46	0.23	0.01	0.69	1.73
application total	7.08	2.62	0.23	9.92	1.81	0.53	2.34	0.02	0.01	0.12	0.02	0.15	0.46	0.23	0.01	0.69	13.14
grazing	1.96	1.22	0.13	3.31	-	-	-	0.14	0.05	0.28	0.07	0.35	-	-	-	-	3.85
% of grazing emissions	50.8%	31.7%	3.5%	86.0%	0.0%	0.0%	0.000%	3.5%	1.4%	7.3%	1.8%	9.1%	0.0%	0.0%	0.0%	0.0%	0.0%
% of total emissions	5.2%	3.3%	0.4%	8.8%	0.0%	0.0%	0.000%	0.4%	0.1%	0.7%	0.2%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%
3B total	9.70	4.75	0.46	14.90	2.35	1.26	3.61	0.08	0.02	0.32	0.07	0.39	0.55	0.87	0.03	1.45	20.45
% category of total	47.4%	23.2%	2.2%	72.9%	11.5%	6.2%	17.6%	0.4%	0.1%	1.6%	0.4%	1.9%	2.7%	4.2%	0.2%	7.1%	100.0%
3D total (manure)	9.03	3.84	0.36	13.24	1.81	0.53	2.34	0.16	0.07	0.40	0.09	0.50	0.46	0.23	0.01	0.69	16.99
% category of total	53.2%	22.6%	2.1%	77.9%	10.7%	3.1%	13.8%	0.9%	0.4%	2.4%	0.6%	2.9%	2.7%	1.3%	0.1%	4.1%	100.0%
Emissions manure total	18.73	8.59	0.82	28.14	4.16	1.79	5.95	0.24	0.09	0.72	0.17	0.89	1.00	1.09	0.04	2.14	37.44
% category of total	50.0%	22.9%	2.2%	75.2%	11.1%	4.8%	15.9%	0.6%	0.2%	1.9%	0.4%	2.4%	2.7%	2.9%	0.1%	5.7%	100.0%

Table A – 16: N flows in form of N excretions and NH₃ emissions for the different livestock categories according to the N-flow tool in percent of the corresponding values of the AGRAMMON model for the year 2015.

Tier 2 N-flow tool		In % of AGRAMMON														total			
		dairy cows	non-d cattle	calves	cattle exc.DC	cattle total	finishing pigs	sows	pigs total	sheep	goats	horses	hules+asses	equids&aying hens	broilers	turkeys	poultry tot		
N excretion housing+yard	kt N	69%	68%	60%	67%	68%	98%	90%	96%	16%	13%	68%	132%	75%	123%	90%	135%	105%	73%
N excretion grazing	kt N	225%	165%	237%	170%	198%	0%	0%	0%	246%	1091%	258%	469%	283%	0%	0%	0%	0%	206%
N excretion total	kt N	94%	92%	91%	92%	93%	98%	90%	96%	101%	137%	108%	208%	120%	116%	89%	131%	102%	95%
emissions housing	kt N	48%	70%	49%	67%	55%	74%	92%	80%	12%	12%	122%	359%	140%	113%	107%	223%	111%	66%
em. yards	kt N	194%	97%	146%	100%	149%	-	-	-	-	-	-	-	-	-	-	-	-	144%
Em housing&yards	kt N	86%	80%	73%	79%	84%	74%	92%	80%	22%	12%	69%	131%	76%	113%	107%	223%	111%	82%
storage liquid	kt N	1.52	1.10	1.48	1.12	1.39	1.44	1.13	1.33	-	-	-	-	-	-	-	-	-	139%
storage solid	kt N	0.57	0.95	0.18	0.79	0.68	-	-	-	15%	16%	1.04	1.58	1.11	1.08	7.11	3.25	0.00	87%
storage total	kt N	1.31	1.04	0.59	0.99	1.18	1.44	1.13	0.65	15%	16%	1.04	1.58	1.11	1.08	7.11	3.25	3.16	111%
emissions housing	kt N	78%	68%	90%	69%	76%	152%	91%	132%	-	-	-	-	-	-	-	-	-	83%
emissions housing	kt N	29%	48%	10%	#WERT!	35%	-	-	-	33%	33%	161%	296%	174%	174%	66%	154%	113%	54%
emissions housing	kt N	73%	63%	48%	61%	69%	152%	91%	132%	33%	33%	161%	296%	174%	174%	66%	154%	113%	77%
grazing	kt N	411%	303%	437%	313%	364%	0%	0%	0%	221%	982%	1084%	1969%	1190%	0%	0%	0%	0%	358%
3B total	kt N	103%	88%	67%	86%	96%	84%	95%	76%	19%	14%	81%	141%	88%	112%	194%	247%	153%	92%
3D total	kt N	88%	84%	72%	83%	87%	152%	91%	132%	119%	157%	396%	797%	438%	139%	65%	136%	101%	94%
Emissions manure total	kt N	95%	87%	69%	85%	91%	104%	94%	91%	43%	44%	146%	263%	160%	123%	138%	207%	131%	93%

Annex 3 Further elaboration of completeness use of IE and (potential) sources of air pollutant emissions excluded

Table A - 14: Explanation of the NE notation key in NFR table 2 Add Info from the latest 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
1A3dii	PCBs	no EF available
2A5a	BC	no EF available
2B5	BC	no EF available
2C3	Pb, Hg, PCDD/PCDF, HCB, PCBs	no EF available (production only from 1980 to 2006)
2C7c	BC	no EF available
2D3b	PM _{2.5} , PM ₁₀ , TSP, BC	Lack of data
2H1	NO _x , SO ₂ , BC, CO	no EF available
2H2	BC	no EF available
2H3	BC	no EF available
1A3di(i)	PCBs	no EF available
3Df	HCB	Lack of data
11B	BC, PCBs	no EF available

Table A - 15: Explanation of the IE Notation key in NFR table 2 Add Info from the latest submission.

NFR code	Substance(s)	Included in NFR code
1A1b	Activity Data "Gaseous Fuels"	1A1b - Activity Data "Liquid Fuels" (for the years 2017 onwards)
1A3bvii	TSP, PM ₁₀ , PM _{2.5} , BC, Cd	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	NMVOG	2B10a
2D3c	NMVOG	2D3i (for the years 1980-1989)
2D3e	NMVOG	2D3i (for the years 1980-1989)
2D3f	NMVOG	2D3i (for the years 1980-1989)
2D3g	NMVOG	2D3i (for the years 1980-1989)
2D3h	NMVOG	2D3i (for the years 1980-1989)
3B4a	NO _x , NMVOG, NH ₃ , PM _{2.5} , PM ₁₀ , TSP	3B1a
5D2	NO _x , NMVOG, SO _x , NH ₃ , CO	5D1 (for the years 1980-1989)

Table A - 16: List of sub-sources accounted for in reporting codes "other" in NFR table 2 Add Info from the latest submission.

NFR code	Substance(s) reported	Sub-source description
1A2gviii	NO _x , NMVOC, SO _x , NH ₃ , PM _{2.5} , PM ₁₀ , TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, HCB, PCB	Industrial combustion of wood and wood waste, other boilers and engines in industry, fibreboard production
1A3eii	-	NO
1A5a	-	NO
1A5b	NO _x , NMVOC, SO _x , NH ₃ , PM _{2.5} , PM ₁₀ , TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs	Military mobile only (aviation and nonroad)
1B1c	-	NO
1B2d	-	NO
2A6	-	NO
2B10a	NO _x , NMVOC, SO _x , CO, Hg (until 2016)	Acetic acid, ammonium nitrate (until 2018), chlorine gas, ethylene, formaldehyde (until 1989), PVC (until 1996), niacin and sulphuric acid
2C7c	NO _x , NMVOC, SO _x , NH ₃ , PM _{2.5} , PM ₁₀ , TSP, CO, Pb, Cd, Hg, PCDD/PCDF	Battery recycling, galvanizing plants, silicium production (until 1988)
2D3i	NMVOC	Removal of paint and lacquer, vehicles dewaxing (until 2001), production of perfume/arome, cosmetics, paper/paper board, tobacco products and textiles, extraction of oil and fat (until 2000) and scientific laboratories, unspecified commercial and industrial solvent emissions
2G	NO _x , NMVOC, SO _x , NH ₃ , PM _{2.5} , PM ₁₀ , TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs	Application of glues and adhesives, commercial and industrial use of cleaning agents, cosmetic institutions, de-icing of airplanes and air-port surfaces (until 2011), glass wool enduction, hairdressers, health care other, medical practices, preservation of wood, renovation of anti-corrosive coatings, rock wool enduction, underseal treatment and conservation of vehicles and use of concrete additives, cooling lubricants, fireworks, lubricants and pesticides
2H3	NO _x , NMVOC, SO _x , NH ₃ , PM _{2.5} , PM ₁₀ , TSP, CO, Pb	Blasting and shooting
2L	NH ₃	Use of NH ₃ as refrigerant
3B4h	NO _x , NMVOC, NH ₃ , PM _{2.5} , PM ₁₀ , TSP	Camels and Llamas (3B4b), Deer (3B4c), Rabbits (3B4hi), Bisons (3B4hii)
3I	-	NO
5E	NMVOC, PM _{2.5} , PM ₁₀ , TSP, CO, Pb, Cd, PCDD/F, PCBs	Car shredding
5C1bvi	-	NO
5D3	-	NO
6A	NO _x , NMVOC, SO _x , NH ₃ , PM _{2.5} , PM ₁₀ , TSP, BC, CO, Pb, Cd, Hg, PCDD/PCDF, PAHs, PCB	Human ammonia emissions (breath, transpiration, napkin), pet ammonia emissions, pet PM emissions (keeping of horses, sheep, goats and donkeys outside agriculture), domestic use of fertilizers, fire damages estates and motor vehicles
6B	-	NO
11C	-	NO

Table A - 17: Basis for estimating emissions from mobile sources as listed in NFR table 2 Add Info from the latest submission.

NFR code	Description	Fuel sold	Fuel used	Comment
1 A 3 a i (i)	International Aviation (LTO)	X		
1 A 3 a i (ii)	International Aviation (Cruise)	X		
1 A 3 a ii (i)	1 A 3 a ii Civil Aviation (Domestic, LTO)	X		
1 A 3 a ii (ii)	1 A 3 a ii Civil Aviation (Domestic, Cruise)	X		
1A3b	Road transport	(X)	X	"NATIONAL TOTAL" reported as "fuel sold", "COMPLIANCE TOTAL (CLRTAP)" as "fuel used"
1A3c	Railways		X	
1A3di (i)	International maritime Navigation	X		
1A3di (ii)	International inland waterways			NO
1A3dii	National Navigation	X		
1A4ci	Agriculture; stationary		X	
1A4cii	Off-road Vehicles and Other Machinery		X	
1A4ciii	National Fishing		IE	IE in 1A3dii
1 A 5 b	Other, Mobile (Including military)		X	

Annex 4 National energy balance

Swiss energy flow

The diagrams show a summary of the Swiss energy flow 2020 and 1990 in TJ as published by the Swiss Federal Office of Energy (SFOE 2021, SFOE 1991) in German and French.

Fig. 5 Detailliertes Energieflussdiagramm der Schweiz 2020 (in TJ)
Flux énergétique détaillé de la Suisse en 2020 (en TJ)

BFE, Schweizerische Gesamtenergiestatistik 2020 (Fig. 5)
OFEN, Statistique globale suisse de l'énergie 2020 (fig. 5)

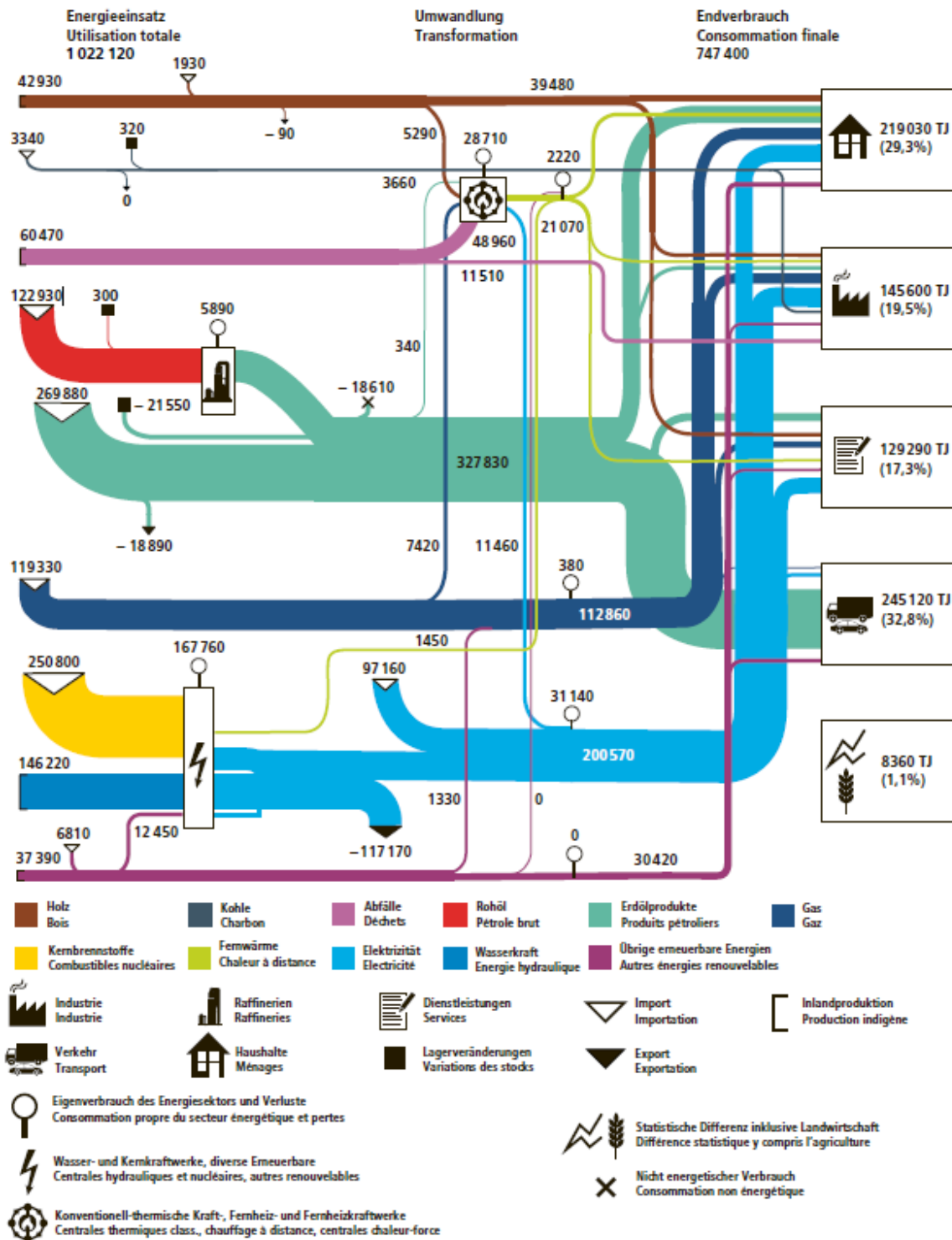


Figure A - 3: Energy flow in Switzerland 2020 (SFOE 2021, figure 5). Depicted values are in TJ.

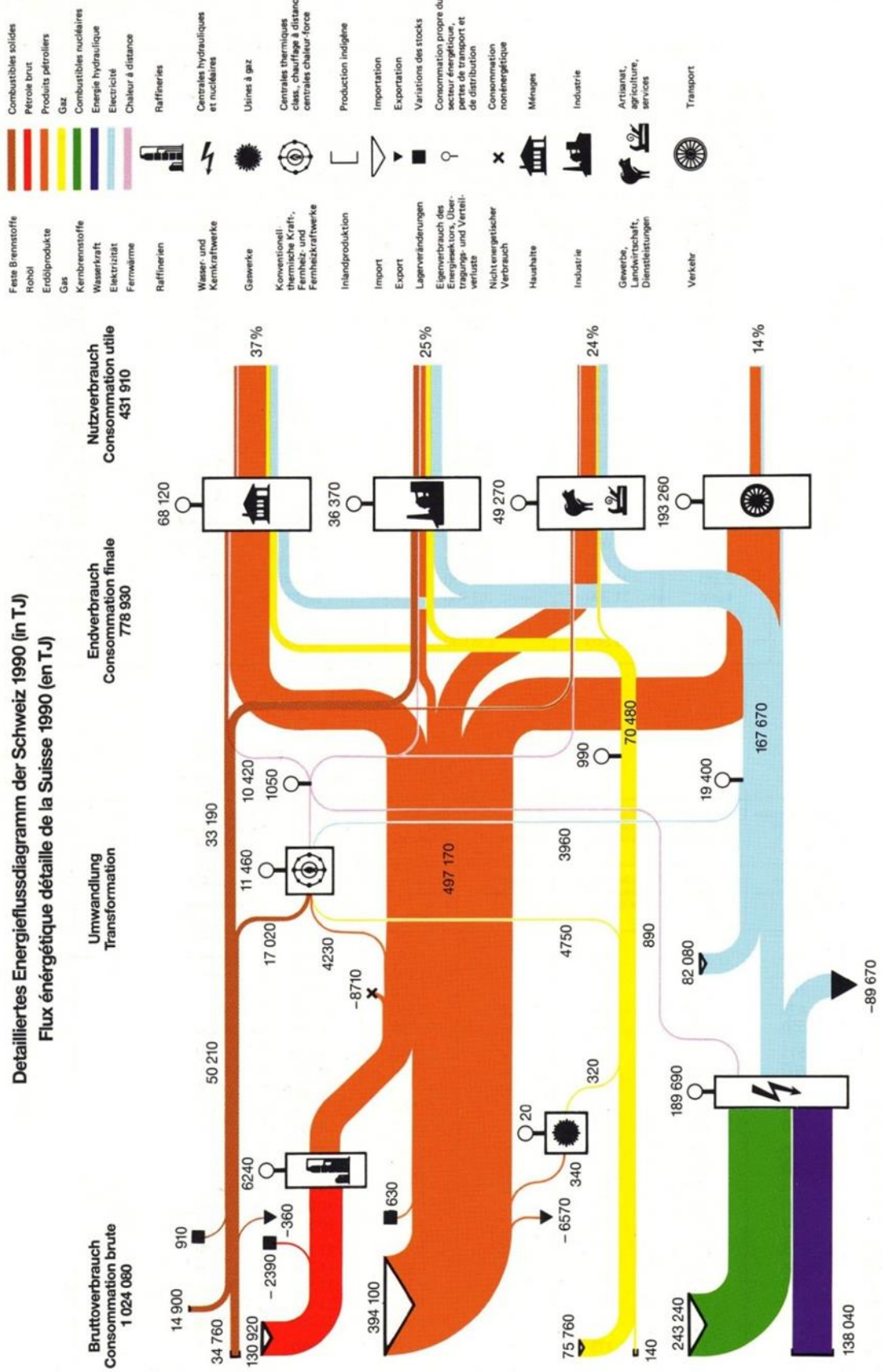


Figure A - 4: Energy flow in Switzerland 1990 (SFOE 1991). Depicted values are in TJ.

Table A - 18: Energy balance for Switzerland 2020 (table 4, Swiss overall energy statistics, SFOE 2021) in TJ.⁷

**Tab. 4 Energiebilanz der Schweiz für das Jahr 2020 (in TJ)
Bilan énergétique de la Suisse pour 2020 (en TJ)**

	Holzenergie		Kohle	Müll und Industrieabfälle		Rohöl	Erddprodukte	Gas	Wasserkraft	Kernbrennstoffe	Übrige erneuerbare Energien		Elektrizität	Fernwärme		Total
	Energie du bois	Charbon		Ord. mén. et déchets ind.	Pétrole brut						Produits pétroliers	Gas		Energie hydraulique	Combustibles nucléaires	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)				
Inlandproduktion	(a) 42930	-	60470	-	-	-	146220	-	37390	-	-	287 010	-	-	-	Production indigène
+ Import	(b) 1930	3340	-	122930	269880	119330	-	250800	6810	-	-	872 180	97160	-	-	+ Importation
+ Export	(c) -90	0	-	-	-18890	-	-	-	-	-	-	-136 150	-117170	-	-	+ Exportation
+ Lagerveränderung ¹	(d) -	320	-	300	-21550	-	-	-	-	-	-	-20 930	-	-	-	+ Variation de stock ¹
= Bruttoverbrauch	(e) 44770	3660	60470	123230	229440	119330	146220	250800	44200	-20010	0	1 002 110	-	-	-	= Consommation brute
+ Energieumwandlung:																+ Transformation d'énergie
- Wasserkraftwerke	(f) -	-	-	-	-	-	-146220	-	-	146220	-	0	146220	-	-	- Centrales hydrauliques
- Kernkraftwerke	(g) -	-	-	-	-	-	-	-250800	-	-	-	-166 590	82760	1450	-	- Centrales nucléaires
- konventionell-thermische Kraftwerke	(h) -3300	-	-48960	-	-340	-7420	-	-	-	-	-	-28 140	10040	21840	-	- Centrales thermiques dans, chauffage à distance, centrales chaleur-force
- Gaswerke	(i) -	-	-	-	-	-	-	-	-	-	-	0	-	-	0	- Usines à gaz
- Raffinerien	(j) -	-	-	-123230	123230	-	-	-	-	-	-	0	-	-	0	- Raffineries
- Diverse Erneuerbare	(k) -1990	-	-	-	-	1330	-	-	-13780	-	-	-1 740	12700	-	-	- Renouvelables div.
+ Eigenverbrauch des Energiesektors, Netzverluste, Verbrauch der Speicherrungen	(l) -	-	-	-	-5890	-380	-	-	-	-	-	-39 630	-31140	-2220	-	+ Consommation propre du secteur énergétique, pertes de réseau, pompage d'accumulation
+ Nichtenergetischer Verbrauch	(m) -	-	-	-	-18610	-	-	-	-	-	-	-18 610	-	-	-	+ Consommation non énergétique
= Endverbrauch	(n) 39480	3660	11510	0	327830	112860	0	0	30420	200570	21070	747 400	-	-	-	= Consommation finale
Haushalte	(o) 17100	100	-	-	59470	47350	-	-	17200	69470	8340	219 030	69470	8340	-	Ménages
Industrie	(p) 11720	3560	11510	-	11680	38090	-	-	1850	60070	7120	145 600	60070	7120	-	Industrie
Dienstleistungen	(q) 9700	0	-	-	27600	25090	-	-	3660	57630	5610	129 290	57630	5610	-	Services
Verkehr	(r) -	-	-	-	226720	1060	-	-	7260	10080	0	245 120	10080	0	-	Transport
Statistische Differenz inkl. Landwirtschaft	(s) 960	0	-	-	2360	1270	-	-	450	3320	0	8 360	3320	0	-	Différence statistique, y compris l'agriculture

¹ + Lagerabnahme
- Lagerzunahme

¹ + diminution de stock
- augmentation de stock

**BFE, Schweizerische Gesamtenergiestatistik 2020 (Tab. 4)
OFEN, Statistique globale suisse de l'énergie 2020 (tabl. 4)**

⁷ Note that Liechtenstein's consumption of liquid fuels is included in these numbers (see chp. 3.1.6.3).

Annex 5 Additional information concerning uncertainties

The tables in the following chapters provide information about the level and trend uncertainty analysis of all relevant air pollutant emissions in 1990 and 2020. Input data used for the uncertainty estimation are the same for approach 1 (uncertainty propagation) and approach 2 (Monte Carlo simulations) and listed in Annex A5.1. Uncertainty estimates obtained by approach 1 are given in the tables in Annex A5.2 and uncertainty estimates obtained by approach 2 are given in the tables in Annex A5.3.

Categories for which no emission is quantified for neither the base year nor the reporting year are not listed in the tables.

For tables reporting input uncertainties in Annex A5.1 and results from approach 1 in Annex A5.2, columns labelled A to M correspond exactly to columns A to M from Table 5-1 from the EMEP/EEA guidebook (EMEP/EEA 2019), part A, chp. 5, "Uncertainties 2019", or Table 3.2, chp. 3, from the IPCC guidelines (IPCC, 2006).

For tables reporting uncertainty results from approach 2, columns labelled A to J correspond exactly to columns A to J from Table 3.3, chp. 3, from the IPCC guidelines (IPCC, 2006).

A5.1 Uncertainty estimations: input data

Bibliographic references for tables of Annex A5.1:

EMEP/EEA 2019: Default values of EMEP/EEA 2019 and associated uncertainty ranges (activity data and emission factors).

EMIS: Uncertainties that are implemented in the EMIS database (activity data and emission factors).

GHGI: Uncertainty analysis of Switzerland's greenhouse gas inventory (FOEN 2022); mainly activity data.

France/Sweden: Uncertainties from France's or Sweden's Informative Inventory Reports (Citepa 2012, SEPA 2010); mainly emission factors.

UBA: Uncertainties for mobile sources from IFEU/INFRAS (2009), in which uncertainties are evaluated for road and non-road vehicles via Monte Carlo simulations (for emission factors).

UBA/INFRAS: PM10 emission factor uncertainties derived from raw data of IFEU/INFRAS (2009).

Kupper 2012: see References (chp. 12.1).

INFRAS 2017b: see References (chp. 12.1).

INFRAS 2021: see References (chp. 12.1).

Schleiss 2017: see References (chp. 12.1).

Table A - 19: Input uncertainties for NO_x for the year 2020, assigned to activity data (col. E) and emissions factors (col. F). The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. References: see p. 369.

A	B	E				F				Activity data	Emission factor
		Activity data uncertainty year 2020				Emission factor uncertainty year 2020					
		Distribu- tion type	(-)%	(+)%	Corr.	Distribu- tion type	(-)%	(+)%	Corr.		
1A1a	NOx	normal	10.0	10.0	no	normal	19.0	19.0	yes	GHGI	EMIS
1A1b	NOx	normal	1.3	1.3	no	normal	20.0	20.0	yes	GHGI	EMIS
1A1c	NOx	normal	5.0	5.0	no	normal	20.0	20.0	yes	EMIS	EMEP/EEA 2019
1A2a	NOx	normal	2.0	2.0	no	normal	27.0	27.0	yes	GHGI	EMIS
1A2b	NOx	normal	2.0	2.0	no	normal	20.0	20.0	yes	GHGI	EMIS
1A2c	NOx	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2d	NOx	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2e	NOx	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2f	NOx	normal	2.0	2.0	no	normal	17.0	17.0	yes	GHGI	EMIS
1A2gvii	NOx	normal	1.3	1.3	no	normal	13.0	13.0	yes	GHGI	UBA
1A2gviii	NOx	normal	2.1	2.1	no	normal	17.0	17.0	yes	GHGI	EMIS
1A3ai(i)	NOx	normal	1.3	1.3	no	normal	20.0	20.0	yes	GHGI	EMEP/EEA 2019
1A3aii(i)	NOx	normal	1.3	1.3	no	normal	20.0	20.0	yes	GHGI	EMEP/EEA 2019
1A3bi	NOx	normal	1.3	1.3	no	normal	38.2	38.2	yes	GHGI	UBA
1A3bii	NOx	normal	1.3	1.3	no	normal	32.2	32.2	yes	GHGI	UBA
1A3biii	NOx	normal	1.3	1.3	no	normal	18.0	18.0	yes	GHGI	UBA
1A3biv	NOx	normal	1.3	1.3	no	normal	36.0	36.0	yes	GHGI	UBA
1A3c	NOx	normal	1.3	1.3	no	normal	13.0	13.0	yes	GHGI	UBA
1A3dii	NOx	normal	1.3	1.3	no	normal	13.0	13.0	yes	GHGI	UBA
1A3ei	NOx	normal	2.0	2.0	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
1A4ai	NOx	normal	1.6	1.6	no	normal	16.0	16.0	yes	GHGI	EMIS
1A4aii	NOx	normal	1.3	1.3	no	normal	13.0	13.0	yes	GHGI	UBA
1A4bi	NOx	normal	3.7	3.7	no	normal	13.0	13.0	yes	GHGI	EMIS
1A4bii	NOx	normal	1.3	1.3	no	normal	30.0	30.0	yes	GHGI	EMIS
1A4ci	NOx	normal	21.2	21.2	no	normal	30.0	30.0	yes	GHGI	EMIS
1A4cii	NOx	normal	1.3	1.3	no	normal	13.0	13.0	yes	GHGI	UBA
1A5b	NOx	normal	1.3	1.3	no	normal	13.0	13.0	yes	GHGI	UBA
1B2c	NOx	normal	22.0	22.0	no	gamma	97.5	200.0	yes	EMIS	EMIS
2A1	NOx	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2A2	NOx	normal	2.0	2.0	no	gamma	100.0	500.0	yes	GHGI	EMEP/EEA 2019
2A5a	NOx	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019
2B2	NOx	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019
2B10a	NOx	normal	2.0	2.0	no	normal	60.0	60.0	yes	GHGI	EMEP/EEA 2019
2C1	NOx	normal	2.0	2.0	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
2C3	NOx	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2C7c	NOx	normal	5.0	5.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2G	NOx	normal	25.0	25.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2H3	NOx	normal	3.0	3.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
3B1a	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B1b	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B2	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B3	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4d	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4e	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4f	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4gi	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4gii	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4giii	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4giv	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3B4h	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3Da1	NOx	normal	5.0	5.0	no	normal	100.0	100.0	yes	GHGI	EMEP/EEA 2019
3Da2a	NOx	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
3Da2b	NOx	normal	6.4	6.4	no	normal	100.0	100.0	yes	GHGI	EMEP/EEA 2019
3Da2c	NOx	normal	20.0	20.0	no	normal	100.0	100.0	yes	Schleiss 2017	EMEP/EEA 2019
3Da3	NOx	normal	6.4	6.4	no	normal	100.0	100.0	yes	GHGI	EMEP/EEA 2019
5A	NOx	normal	10.0	10.0	no	normal	50.0	50.0	yes	GHGI	EMIS
5B2	NOx	normal	20.0	20.0	no	normal	100.0	100.0	yes	EMIS	EMEP/EEA 2019
5C1a	NOx	normal	50.0	50.0	no	normal	40.0	40.0	yes	EMIS	EMIS
5C1bi	NOx	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biii	NOx	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biv	NOx	normal	20.0	20.0	no	normal	50.0	50.0	yes	EMIS	EMIS
5C1bv	NOx	normal	5.0	5.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C2	NOx	normal	48.0	48.0	no	gamma	91.4	156.0	yes	EMIS	EMIS
5D1	NOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	EMIS	EMIS
5D2	NOx	normal	10.0	10.0	no	normal	10.0	10.0	yes	EMIS	EMIS
6A	NOx	normal	30.0	30.0	no	normal	50.0	50.0	yes	GHGI	EMIS

Table A - 20: Input uncertainties for NMVOC for the year 2020, assigned to activity data (col. E) and emissions factors (col. F). The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. References: see p. 369.

A	B	E				F					
		Activity data uncertainty year 2020				Emission factor uncertainty year 2020				Activity data	Emission factor
		Distribution type	(-)%	(+)%	Corr.	Distribution type	(-)%	(+)%	Corr.	Ref.	Ref.
1A1a	NMVOC	normal	10.0	10.0	no	normal	32.0	32.0	yes	GHGI	EMIS
1A1b	NMVOC	normal	1.3	1.3	no	normal	20.0	20.0	yes	GHGI	EMIS
1A1c	NMVOC	normal	5.0	5.0	no	normal	20.0	20.0	yes	EMIS	EMEP/EEA 2019
1A2a	NMVOC	normal	2.0	2.0	no	normal	18.0	18.0	yes	GHGI	EMIS
1A2b	NMVOC	normal	2.0	2.0	no	normal	19.0	19.0	yes	GHGI	EMIS
1A2c	NMVOC	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2d	NMVOC	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2e	NMVOC	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2f	NMVOC	normal	2.0	2.0	no	normal	30.0	30.0	yes	GHGI	EMIS
1A2g	NMVOC	normal	1.3	1.3	no	normal	34.0	34.0	yes	GHGI	UBA
1A2g	NMVOC	normal	2.1	2.1	no	normal	30.0	30.0	yes	GHGI	EMIS
1A3ai(i)	NMVOC	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
1A3ai(i)	NMVOC	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
1A3bi	NMVOC	normal	1.3	1.3	no	normal	52.2	52.2	yes	GHGI	UBA
1A3bii	NMVOC	normal	1.3	1.3	no	normal	45.7	45.7	yes	GHGI	UBA
1A3biii	NMVOC	normal	1.3	1.3	no	normal	22.0	22.0	yes	GHGI	UBA
1A3biv	NMVOC	normal	1.3	1.3	no	gamma	100.0	400.0	yes	GHGI	UBA
1A3bv	NMVOC	normal	1.3	1.3	no	normal	40.0	40.0	yes	GHGI	UBA
1A3c	NMVOC	normal	1.3	1.3	no	normal	34.0	34.0	yes	GHGI	UBA
1A3dii	NMVOC	normal	1.3	1.3	no	normal	34.0	34.0	yes	GHGI	UBA
1A3ei	NMVOC	normal	2.0	2.0	no	normal	50.0	50.0	yes	GHGI	EMEP/EEA 2019
1A4ai	NMVOC	normal	1.6	1.6	no	normal	56.0	56.0	yes	GHGI	EMIS
1A4aii	NMVOC	normal	1.3	1.3	no	normal	75.0	75.0	yes	GHGI	Sweden
1A4bi	NMVOC	normal	3.7	3.7	no	normal	68.0	68.0	yes	GHGI	EMIS
1A4bii	NMVOC	normal	1.3	1.3	no	normal	75.0	75.0	yes	GHGI	Sweden
1A4ci	NMVOC	normal	21.2	21.2	no	normal	75.0	75.0	yes	GHGI	EMIS
1A4cii	NMVOC	normal	1.3	1.3	no	normal	75.0	75.0	yes	GHGI	Sweden
1A5b	NMVOC	normal	1.3	1.3	no	normal	34.0	34.0	yes	GHGI	UBA
1B2ai	NMVOC	normal	30.0	30.0	no	normal	50.0	50.0	yes	None	EMEP/EEA 2019
1B2aiv	NMVOC	normal	30.0	30.0	no	normal	47.0	47.0	yes	EMEP/EEA 2019	EMIS
1B2av	NMVOC	normal	1.3	1.3	no	normal	26.0	26.0	yes	EMEP/EEA 2019	EMIS
1B2b	NMVOC	normal	22.0	22.0	no	normal	50.0	50.0	yes	EMIS	EMEP/EEA 2019
1B2c	NMVOC	normal	22.0	22.0	no	gamma	72.8	100.0	yes	EMIS	EMIS
2A1	NMVOC	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2A2	NMVOC	normal	2.0	2.0	no	gamma	100.0	500.0	yes	GHGI	EMEP/EEA 2019
2A5a	NMVOC	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019
2B10a	NMVOC	normal	2.0	2.0	no	normal	40.0	40.0	yes	GHGI	EMEP/EEA 2019
2C1	NMVOC	normal	2.0	2.0	no	gamma	72.8	100.0	yes	GHGI	EMEP/EEA 2019
2C3	NMVOC	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2C7a	NMVOC	normal	5.0	5.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2C7c	NMVOC	normal	5.0	5.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2D3a	NMVOC	normal	1.0	1.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2D3b	NMVOC	normal	5.0	5.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2D3c	NMVOC	normal	20.0	20.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2D3d	NMVOC	normal	20.0	20.0	no	normal	40.0	40.0	yes	EMIS	EMEP/EEA 2019
2D3e	NMVOC	normal	40.0	40.0	no	normal	50.0	50.0	yes	EMIS	EMEP/EEA 2019
2D3f	NMVOC	normal	20.0	20.0	no	normal	40.0	40.0	yes	EMIS	EMEP/EEA 2019
2D3g	NMVOC	normal	30.0	30.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2D3h	NMVOC	normal	20.0	20.0	no	normal	40.0	40.0	yes	EMIS	EMEP/EEA 2019
2D3i	NMVOC	normal	30.0	30.0	no	gamma	95.4	180.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2G	NMVOC	normal	25.0	25.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2H1	NMVOC	normal	30.0	30.0	no	gamma	97.5	200.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2H2	NMVOC	normal	10.0	10.0	no	gamma	72.8	100.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2H3	NMVOC	normal	3.0	3.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
3B1a	NMVOC	normal	6.4	6.4	no	normal	60.0	60.0	yes	GHGI	Agroscope/EMPA 2022, EMEP/EEA 2019
3B1b	NMVOC	normal	6.4	6.4	no	normal	70.0	70.0	yes	GHGI	Agroscope/EMPA 2022, EMEP/EEA 2020
3B2	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B3	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4d	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4e	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4f	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4gi	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4gii	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4giii	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4giv	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3B4h	NMVOC	normal	6.4	6.4	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
3De	NMVOC	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI (LULUCF)	EMEP/EEA 2019
5A	NMVOC	normal	10.0	10.0	no	normal	50.0	50.0	yes	GHGI	EMIS
5B1	NMVOC	normal	20.0	20.0	no	normal	100.0	100.0	yes	Schleiss 2017	EMIS
5B2	NMVOC	normal	20.0	20.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1a	NMVOC	normal	50.0	50.0	no	normal	50.0	50.0	yes	EMIS	EMIS
5C1bi	NMVOC	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biii	NMVOC	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biv	NMVOC	normal	20.0	20.0	no	normal	20.0	20.0	yes	EMIS	EMIS
5C1bv	NMVOC	normal	5.0	5.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C2	NMVOC	normal	48.0	48.0	no	gamma	91.4	156.0	yes	EMIS	EMIS
5D1	NMVOC	normal	1.3	1.3	no	normal	27.0	27.0	yes	EMIS	EMIS
5D2	NMVOC	normal	10.0	10.0	no	normal	20.0	20.0	yes	EMIS	EMIS
5E	NMVOC	normal	20.0	20.0	no	normal	23.5	23.5	yes	EMIS	EMIS
6A	NMVOC	normal	30.0	30.0	no	normal	50.0	50.0	yes	GHGI	EMIS

Table A - 21: Input uncertainties for SO_x for the year 2020, assigned to activity data (col. E) and emissions factors (col. F). The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. References: see p. 369.

A	B	E				F				Activity data	Emission factor		
		Activity data uncertainty year 2020				Emission factor uncertainty year 2020						Ref.	Ref.
		Distribution type	(-)%	(+)%	Corr.	Distribution type	(-)%	(+)%	Corr.				
1A1a	SOx	normal	10.0	10.0	no	normal	22.0	22.0	yes	GHGI	EMIS		
1A1b	SOx	normal	1.3	1.3	no	normal	20.0	20.0	yes	GHGI	EMIS		
1A2a	SOx	normal	2.0	2.0	no	normal	15.0	15.0	yes	GHGI	EMIS		
1A2b	SOx	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS		
1A2c	SOx	normal	2.0	2.0	no	normal	11.0	11.0	yes	GHGI	EMIS		
1A2d	SOx	normal	2.0	2.0	no	normal	14.0	14.0	yes	GHGI	EMIS		
1A2e	SOx	normal	2.0	2.0	no	normal	12.0	12.0	yes	GHGI	EMIS		
1A2f	SOx	normal	2.0	2.0	no	normal	19.0	19.0	yes	GHGI	EMIS		
1A2gvii	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A2gviii	SOx	normal	2.1	2.1	no	normal	19.0	19.0	yes	GHGI	EMIS		
1A3ai(i)	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3aii(i)	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3bi	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3bii	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3biii	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3biv	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3c	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3dii	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A3ei	SOx	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A4ai	SOx	normal	1.6	1.6	no	normal	10.0	10.0	yes	GHGI	EMIS		
1A4aii	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A4bi	SOx	normal	3.7	3.7	no	normal	10.0	10.0	yes	GHGI	EMIS		
1A4bii	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A4ci	SOx	normal	21.2	21.2	no	normal	18.0	18.0	yes	GHGI	EMIS		
1A4cii	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1A5b	SOx	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019		
1B2aiv	SOx	normal	30.0	30.0	no	normal	47.0	47.0	yes	EMEP/EEA 2019	EMIS		
1B2c	SOx	normal	22.0	22.0	no	normal	31.0	31.0	yes	EMIS	EMIS		
2A1	SOx	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019		
2A2	SOx	normal	2.0	2.0	no	gamma	100.0	500.0	yes	GHGI	EMEP/EEA 2019		
2A5a	SOx	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019		
2B5	SOx	normal	2.0	2.0	no	normal	20.0	20.0	yes	GHGI	EMEP/EEA 2019		
2B10a	SOx	normal	2.0	2.0	no	normal	40.0	40.0	yes	GHGI	EMEP/EEA 2019		
2C1	SOx	normal	2.0	2.0	no	gamma	72.8	100.0	yes	GHGI	EMEP/EEA 2019		
2C3	SOx	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019		
2C7c	SOx	normal	5.0	5.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019		
2G	SOx	normal	25.0	25.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019		
2H3	SOx	normal	3.0	3.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019		
5B2	SOx	normal	20.0	20.0	no	normal	100.0	100.0	yes	EMIS	EMIS		
5C1a	SOx	normal	50.0	50.0	no	normal	40.0	40.0	yes	EMIS	EMIS		
5C1bi	SOx	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS		
5C1biii	SOx	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS		
5C1biv	SOx	normal	20.0	20.0	no	normal	30.0	30.0	yes	EMIS	EMIS		
5C2	SOx	normal	48.0	48.0	no	gamma	85.5	133.0	yes	EMIS	EMIS		
5D1	SOx	normal	1.3	1.3	no	normal	37.0	37.0	yes	EMIS	EMIS		
5D2	SOx	normal	10.0	10.0	no	normal	20.0	20.0	yes	EMIS	EMIS		
6A	SOx	normal	30.0	30.0	no	normal	50.0	50.0	yes	GHGI	EMIS		

Table A - 22: Input uncertainties for NH₃ for the year 2020, assigned to activity data (col. E) and emissions factors (col. F). The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. References: see p. 369.

A NFR code	B Pollutant	E Activity data uncertainty year 2020				F Emission factor uncertainty year 2020				Activity data	Emission factor
		Distribu- tion type	(-)%	(+)%	Corr.	Distribu- tion type	(-)%	(+)%	Corr.	Ref.	Ref.
1A1a	NH3	normal	10.0	10.0	no	normal	20.0	20.0	yes	GHGI	EMIS
1A1b	NH3	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2a	NH3	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2b	NH3	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2c	NH3	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2d	NH3	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2e	NH3	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2f	NH3	normal	2.0	2.0	no	normal	9.0	9.0	yes	GHGI	EMIS
1A2gvii	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A2gviii	NH3	normal	2.1	2.1	no	normal	9.0	9.0	yes	GHGI	EMIS
1A3bi	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A3bii	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A3biii	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A3biv	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A3c	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A3dii	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A3ei	NH3	normal	2.0	2.0	no	normal	50.0	50.0	yes	GHGI	France
1A4ai	NH3	normal	1.6	1.6	no	normal	10.0	10.0	yes	GHGI	EMIS
1A4aii	NH3	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMIS
1A4bi	NH3	normal	3.7	3.7	no	normal	10.0	10.0	yes	GHGI	EMIS
1A4bii	NH3	normal	1.3	1.3	no	normal	10.0	10.0	yes	GHGI	EMIS
1A4ci	NH3	normal	21.2	21.2	no	normal	10.0	10.0	yes	GHGI	EMIS
1A4cii	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
1A5b	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	France
2B1	NH3	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019
2B2	NH3	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMEP/EEA 2019
2B10a	NH3	normal	2.0	2.0	no	normal	40.0	40.0	yes	GHGI	EMEP/EEA 2019
2C1	NH3	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2C7c	NH3	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019
2G	NH3	normal	25.0	25.0	no	normal	40.0	40.0	yes	EMIS	EMEP/EEA 2019
2H2	NH3	normal	10.0	10.0	no	gamma	100.0	500.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2H3	NH3	normal	3.0	3.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2L	NH3	normal	25.0	25.0	no	normal	100.0	100.0	yes	EMIS	EMEP/EEA 2019
3B1a	NH3	normal	6.4	6.4	no	normal	29.0	29.0	yes	GHGI	Infras 2021
3B1b	NH3	normal	6.4	6.4	no	normal	27.0	27.0	yes	GHGI	Infras 2021
3B2	NH3	normal	6.4	6.4	no	normal	87.0	87.0	yes	GHGI	Infras 2021
3B3	NH3	normal	6.4	6.4	no	normal	40.0	40.0	yes	GHGI	Infras 2021
3B4d	NH3	normal	6.4	6.4	no	normal	65.0	65.0	yes	GHGI	Infras 2021
3B4e	NH3	normal	6.4	6.4	no	normal	52.0	52.0	yes	GHGI	Infras 2021
3B4f	NH3	normal	6.4	6.4	no	normal	68.0	68.0	yes	GHGI	Infras 2021
3B4gi	NH3	normal	6.4	6.4	no	normal	82.0	82.0	yes	GHGI	Infras 2021
3B4gii	NH3	normal	6.4	6.4	no	normal	86.0	86.0	yes	GHGI	Infras 2021
3B4giii	NH3	normal	6.4	6.4	no	normal	93.0	93.0	yes	GHGI	Infras 2021
3B4giv	NH3	normal	6.4	6.4	no	normal	85.0	85.0	yes	GHGI	Infras 2021
3B4h	NH3	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	Infras 2021
3Da1	NH3	normal	5.0	5.0	no	normal	50.0	50.0	yes	GHGI	Kupper 2012
3Da2a	NH3	normal	6.4	6.4	no	normal	21.0	21.0	yes	GHGI	Infras 2021
3Da2b	NH3	normal	6.4	6.4	no	normal	50.0	50.0	yes	GHGI	Kupper 2012
3Da2c	NH3	normal	20.0	20.0	no	normal	50.0	50.0	yes	Schleiss 2017	Kupper 2012
3Da3	NH3	normal	6.4	6.4	no	normal	62.0	62.0	yes	GHGI	Infras 2021
5A	NH3	normal	10.0	10.0	no	normal	50.0	50.0	yes	GHGI	EMIS
5B1	NH3	normal	20.0	20.0	no	normal	100.0	100.0	yes	Schleiss 2017	EMIS
5B2	NH3	normal	20.0	20.0	no	normal	75.0	75.0	yes	EMIS	INFRAS 2014
5C1biv	NH3	normal	20.0	20.0	no	normal	50.0	50.0	yes	EMIS	EMIS
5C2	NH3	normal	48.0	48.0	no	normal	25.0	25.0	yes	EMIS	EMIS
5D1	NH3	normal	1.3	1.3	no	normal	50.0	50.0	yes	EMIS	EMIS
6A	NH3	normal	30.0	30.0	no	normal	100.0	100.0	yes	GHGI	EMEP/EEA 2019

Table A - 23: Input uncertainties for PM2.5 for the year 2020, assigned to activity data (col. E) and emissions factors (col. F). The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. References: see p. 369.

NFR code	Pollutant	E				F				Activity data	Emission factor
		Activity data uncertainty year 2020				Emission factor uncertainty year 2020					
		Distribu- tion type	(-)%	(+)%	Corr.	Distribu- tion type	(-)%	(+)%	Corr.		
1A1a	PM2.5	normal	10.0	10.0	no	normal	71.0	71.0	yes	GHGI	EMIS
1A1b	PM2.5	normal	1.3	1.3	no	normal	20.0	20.0	yes	GHGI	EMIS
1A1c	PM2.5	normal	5.0	5.0	no	normal	20.0	20.0	yes	EMIS	EMEP/EEA 2019
1A2a	PM2.5	normal	2.0	2.0	no	normal	28.0	28.0	yes	GHGI	EMIS
1A2b	PM2.5	normal	2.0	2.0	no	normal	30.0	30.0	yes	GHGI	EMIS
1A2c	PM2.5	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2d	PM2.5	normal	2.0	2.0	no	normal	33.0	33.0	yes	GHGI	EMIS
1A2e	PM2.5	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2f	PM2.5	normal	2.0	2.0	no	normal	65.0	65.0	yes	GHGI	EMIS
1A2gvii	PM2.5	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A2gviii	PM2.5	normal	2.1	2.1	no	normal	65.0	65.0	yes	GHGI	EMIS
1A3ai(i)	PM2.5	normal	1.3	1.3	no	normal	30.0	30.0	yes	GHGI	UBA/INFRAS
1A3aii(i)	PM2.5	normal	1.3	1.3	no	normal	30.0	30.0	yes	GHGI	UBA/INFRAS
1A3bi	PM2.5	normal	1.3	1.3	no	normal	57.3	57.3	yes	GHGI	UBA/INFRAS
1A3bii	PM2.5	normal	1.3	1.3	no	normal	48.3	48.3	yes	GHGI	UBA/INFRAS
1A3biii	PM2.5	normal	1.3	1.3	no	normal	27.0	27.0	yes	GHGI	UBA/INFRAS
1A3biv	PM2.5	normal	1.3	1.3	no	normal	54.0	54.0	yes	GHGI	UBA/INFRAS
1A3bvi	PM2.5	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A3c	PM2.5	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A3dii	PM2.5	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A3ei	PM2.5	normal	2.0	2.0	no	normal	27.1	27.1	yes	GHGI	UBA/INFRAS
1A4ai	PM2.5	normal	1.6	1.6	no	normal	78.0	78.0	yes	GHGI	EMIS
1A4bi	PM2.5	normal	3.7	3.7	no	normal	76.0	76.0	yes	GHGI	EMIS
1A4ci	PM2.5	normal	21.2	21.2	no	normal	39.0	39.0	yes	GHGI	EMIS
1A4cii	PM2.5	normal	1.3	1.3	no	normal	80.0	80.0	yes	GHGI	EMIS
1A5b	PM2.5	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1B1a	PM2.5	normal	30.0	30.0	no	normal	40.0	40.0	yes	EMEP/EEA 2019	EMIS
1B2c	PM2.5	normal	22.0	22.0	no	gamma	99.3	237.0	yes	EMIS	EMEP/EEA 2019
2A1	PM2.5	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2A2	PM2.5	normal	2.0	2.0	no	gamma	100.0	500.0	yes	GHGI	EMEP/EEA 2019
2A5a	PM2.5	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019
2B5	PM2.5	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2B10a	PM2.5	normal	2.0	2.0	no	normal	40.0	40.0	yes	GHGI	EMEP/EEA 2019
2C1	PM2.5	normal	2.0	2.0	no	gamma	82.9	125.0	yes	GHGI	EMEP/EEA 2019
2C3	PM2.5	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2C7a	PM2.5	normal	5.0	5.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2C7c	PM2.5	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019
2D3c	PM2.5	normal	20.0	20.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2D3i	PM2.5	normal	30.0	30.0	no	gamma	100.0	500.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2G	PM2.5	normal	25.0	25.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2H1	PM2.5	normal	30.0	30.0	no	gamma	97.5	200.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2H2	PM2.5	normal	10.0	10.0	no	gamma	100.0	500.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2H3	PM2.5	normal	3.0	3.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2I	PM2.5	normal	10.0	10.0	no	gamma	100.0	500.0	yes	EMEP/EEA 2019	EMEP/EEA 2019
3B1a	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B1b	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B2	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B3	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4d	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4e	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4f	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4gi	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4gii	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3B4giii	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3B4giv	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3B4h	PM2.5	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3De	PM2.5	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI (LULUCF)	EMEP/EEA 2019
5A	PM2.5	normal	10.0	10.0	no	normal	30.0	30.0	yes	GHGI	EMIS
5B2	PM2.5	normal	20.0	20.0	no	normal	100.0	100.0	yes	EMIS	EMIS
5C1a	PM2.5	normal	50.0	50.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1bi	PM2.5	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biii	PM2.5	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biv	PM2.5	normal	20.0	20.0	no	normal	34.0	34.0	yes	EMIS	EMIS
5C1bv	PM2.5	normal	5.0	5.0	no	normal	33.0	33.0	yes	EMIS	EMIS
5C2	PM2.5	normal	48.0	48.0	no	gamma	91.4	156.0	yes	EMIS	EMIS
5E	PM2.5	normal	20.0	20.0	no	normal	30.0	30.0	yes	EMIS	EMIS
6A	PM2.5	normal	30.0	30.0	no	normal	40.0	40.0	yes	GHGI	EMIS

Table A - 24: Input uncertainties for PM10 for the year 2020, assigned to activity data (col. E) and emissions factors (col. F). The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. References: see p. 369.

NFR code	Pollutant	E				F				Activity data	Emission factor
		Activity data uncertainty year 2020				Emission factor uncertainty year 2020					
		Distribu- tion type	(-)%	(+)%	Corr.	Distribu- tion type	(-)%	(+)%	Corr.		
1A1a	PM10	normal	10.0	10.0	no	normal	71.0	71.0	yes	GHGI	EMIS
1A1b	PM10	normal	1.3	1.3	no	normal	20.0	20.0	yes	GHGI	EMIS
1A1c	PM10	normal	5.0	5.0	no	normal	20.0	20.0	yes	EMIS	EMEP/EEA 2019
1A2a	PM10	normal	2.0	2.0	no	normal	28.0	28.0	yes	GHGI	EMIS
1A2b	PM10	normal	2.0	2.0	no	normal	30.0	30.0	yes	GHGI	EMIS
1A2c	PM10	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2d	PM10	normal	2.0	2.0	no	normal	33.0	33.0	yes	GHGI	EMIS
1A2e	PM10	normal	2.0	2.0	no	normal	10.0	10.0	yes	GHGI	EMIS
1A2f	PM10	normal	2.0	2.0	no	normal	65.0	65.0	yes	GHGI	EMIS
1A2gvii	PM10	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A2gviii	PM10	normal	2.1	2.1	no	normal	65.0	65.0	yes	GHGI	EMIS
1A3ai(i)	PM10	normal	1.3	1.3	no	normal	30.0	30.0	yes	GHGI	UBA/INFRAS
1A3aii(i)	PM10	normal	1.3	1.3	no	normal	30.0	30.0	yes	GHGI	UBA/INFRAS
1A3bi	PM10	normal	1.3	1.3	no	normal	57.3	57.3	yes	GHGI	UBA/INFRAS
1A3bii	PM10	normal	1.3	1.3	no	normal	48.3	48.3	yes	GHGI	UBA/INFRAS
1A3biii	PM10	normal	1.3	1.3	no	normal	27.0	27.0	yes	GHGI	UBA/INFRAS
1A3biv	PM10	normal	1.3	1.3	no	normal	54.0	54.0	yes	GHGI	UBA/INFRAS
1A3bvi	PM10	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A3c	PM10	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A3dii	PM10	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1A3ei	PM10	normal	2.0	2.0	no	normal	27.1	27.1	yes	GHGI	UBA/INFRAS
1A4ai	PM10	normal	1.6	1.6	no	normal	78.0	78.0	yes	GHGI	EMIS
1A4bi	PM10	normal	3.7	3.7	no	normal	76.0	76.0	yes	GHGI	EMIS
1A4ci	PM10	normal	21.2	21.2	no	normal	39.0	39.0	yes	GHGI	EMIS
1A4cii	PM10	normal	1.3	1.3	no	normal	80.0	80.0	yes	GHGI	EMIS
1A5b	PM10	normal	1.3	1.3	no	normal	50.0	50.0	yes	GHGI	UBA/INFRAS
1B1a	PM10	normal	30.0	30.0	no	normal	40.0	40.0	yes	EMEP/EEA 2019	EMIS
1B2c	PM10	normal	22.0	22.0	no	gamma	99.3	237.0	yes	EMIS	EMEP/EEA 2019
2A1	PM10	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2A2	PM10	normal	2.0	2.0	no	gamma	100.0	500.0	yes	GHGI	EMEP/EEA 2019
2A5a	PM10	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019
2B5	PM10	normal	2.0	2.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2B10a	PM10	normal	2.0	2.0	no	normal	40.0	40.0	yes	GHGI	EMEP/EEA 2019
2C1	PM10	normal	2.0	2.0	no	gamma	82.9	125.0	yes	GHGI	EMEP/EEA 2019
2C3	PM10	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI	EMEP/EEA 2019
2C7a	PM10	normal	5.0	5.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2C7c	PM10	normal	5.0	5.0	no	gamma	100.0	500.0	yes	EMIS	EMEP/EEA 2019
2D3c	PM10	normal	20.0	20.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2D3i	PM10	normal	30.0	30.0	no	gamma	100.0	500.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2G	PM10	normal	25.0	25.0	no	gamma	72.8	100.0	yes	EMIS	EMEP/EEA 2019
2H1	PM10	normal	30.0	30.0	no	gamma	97.5	200.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2H2	PM10	normal	10.0	10.0	no	gamma	100.0	500.0	yes	EMEP/EEA 2019 (E)	EMEP/EEA 2019
2H3	PM10	normal	3.0	3.0	no	gamma	97.5	200.0	yes	EMIS	EMEP/EEA 2019
2I	PM10	normal	10.0	10.0	no	gamma	100.0	500.0	yes	EMEP/EEA 2019	EMEP/EEA 2019
3B1a	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B1b	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B2	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B3	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4d	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4e	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4f	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4gi	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	EMIS
3B4gii	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3B4giii	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3B4giv	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3B4h	PM10	normal	6.4	6.4	no	gamma	100.0	300.0	yes	GHGI	None
3De	PM10	normal	5.0	5.0	no	gamma	97.5	200.0	yes	GHGI (LULUCF)	EMEP/EEA 2019
5A	PM10	normal	10.0	10.0	no	normal	30.0	30.0	yes	GHGI	EMIS
5B2	PM10	normal	20.0	20.0	no	normal	100.0	100.0	yes	EMIS	EMIS
5C1a	PM10	normal	50.0	50.0	no	normal	50.0	50.0	yes	EMIS	EMIS
5C1bi	PM10	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biii	PM10	normal	30.0	30.0	no	normal	30.0	30.0	yes	EMIS	EMIS
5C1biv	PM10	normal	20.0	20.0	no	normal	35.0	35.0	yes	EMIS	EMIS
5C1bv	PM10	normal	5.0	5.0	no	normal	33.0	33.0	yes	EMIS	EMIS
5C2	PM10	normal	48.0	48.0	no	gamma	91.4	156.0	yes	EMIS	EMIS
5E	PM10	normal	20.0	20.0	no	normal	30.0	30.0	yes	EMIS	EMIS
6A	PM10	normal	30.0	30.0	no	normal	40.0	40.0	yes	GHGI	EMIS

A5.2 Uncertainty estimations: results from approach 1

Table A - 25: Uncertainty analysis of NO_x emissions, approach 1, for 2020 and for the trend 1990-2020. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A NFR code	B Pollutant	C Emissions		D Emissions		E Emission combined uncertainty		F Category contribution to inventory variance		G Sensitivity if corr. (type A)	H Sensitivity if not corr. (type B)	I Contribution to inventory trend uncertainty from AD		J Contribution to inventory trend uncertainty from EF		K Contribution to inventory trend uncertainty from EM			
		1990	2020	2020	2020	2020		2020				(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
						(-)%	(+)%	(-)%	(+)%										
1A1a	NOx	6294.04	2086.67	21	21	0.728	0.728	0.002	0.015	0.210	0.210	0.035	0.035	0.045	0.045				
1A1b	NOx	494.17	318.51	20	20	0.015	0.015	0.001	0.002	0.004	0.004	0.019	0.019	0.000	0.000				
1A1c	NOx	0.01	0.04	21	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
1A2a	NOx	278.40	117.77	27	27	0.004	0.004	0.000	0.001	0.002	0.002	0.003	0.003	0.000	0.000				
1A2b	NOx	126.80	33.96	20	20	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000				
1A2c	NOx	1046.46	256.20	10	10	0.002	0.002	0.001	0.002	0.005	0.005	0.010	0.010	0.000	0.000				
1A2d	NOx	1260.62	41.59	10	10	0.000	0.000	0.003	0.000	0.001	0.001	0.030	0.030	0.001	0.001				
1A2e	NOx	743.24	244.47	10	10	0.002	0.002	0.000	0.002	0.005	0.005	0.002	0.002	0.000	0.000				
1A2f	NOx	10534.54	3141.83	17	17	1.048	1.048	0.006	0.022	0.063	0.063	0.095	0.095	0.013	0.013				
1A2gvii	NOx	6333.94	1814.17	13	13	0.204	0.204	0.004	0.013	0.023	0.023	0.051	0.051	0.003	0.003				
1A2gviii	NOx	2338.08	1675.34	17	17	0.298	0.298	0.006	0.012	0.035	0.035	0.097	0.097	0.011	0.011				
1A3a(i)	NOx	1214.30	779.06	20	20	0.088	0.088	0.002	0.006	0.010	0.010	0.046	0.046	0.002	0.002				
1A3a(ii)	NOx	153.76	34.60	20	20	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000				
1A3bi	NOx	43771.18	17810.00	38	38	168.159	168.159	0.011	0.126	0.230	0.230	0.401	0.401	0.214	0.214				
1A3bii	NOx	6196.89	4823.47	32	32	8.759	8.759	0.018	0.034	0.062	0.062	0.574	0.574	0.334	0.334				
1A3biii	NOx	29900.45	4312.68	18	18	2.196	2.196	0.048	0.031	0.056	0.056	0.873	0.873	0.764	0.764				
1A3biv	NOx	308.61	234.82	36	36	0.026	0.026	0.001	0.002	0.003	0.003	0.031	0.031	0.001	0.001				
1A3c	NOx	595.50	388.56	13	13	0.009	0.009	0.001	0.003	0.005	0.005	0.015	0.015	0.000	0.000				
1A3dii	NOx	1054.73	984.94	13	13	0.060	0.060	0.004	0.007	0.013	0.013	0.055	0.055	0.003	0.003				
1A3ei	NOx	145.60	10.26	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.016	0.000	0.000				
1A4ai	NOx	4695.68	2391.07	16	16	0.536	0.536	0.005	0.017	0.038	0.038	0.073	0.073	0.007	0.007				
1A4a(ii)	NOx	16.28	45.70	13	13	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000				
1A4bi	NOx	11629.86	4347.90	14	14	1.253	1.253	0.000	0.031	0.162	0.162	0.001	0.001	0.026	0.026				
1A4b(ii)	NOx	18.76	23.85	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000				
1A4ci	NOx	382.41	242.87	37	37	0.029	0.029	0.001	0.002	0.052	0.052	0.021	0.021	0.003	0.003				
1A4cii	NOx	4357.53	1894.28	13	13	0.222	0.222	0.002	0.013	0.025	0.025	0.025	0.025	0.001	0.001				
1A5b	NOx	882.99	395.33	13	13	0.010	0.010	0.000	0.003	0.005	0.005	0.006	0.006	0.000	0.000				
1B2c	NOx	212.79	1.71	100	201	0.000	0.000	0.001	0.000	0.000	0.000	0.054	0.110	0.003	0.012				
2A1	NOx	15.87	10.32	97	200	0.000	0.002	0.000	0.000	0.000	0.000	0.003	0.006	0.000	0.000				
2A2	NOx	0.27	0.24	100	500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000				
2A5a	NOx	1.79	0.68	100	500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
2B2	NOx	82.78	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000				
2B10a	NOx	8.93	17.64	60	60	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.006	0.000	0.000				
2C1	NOx	245.46	157.65	50	50	0.023	0.023	0.000	0.001	0.003	0.003	0.023	0.023	0.001	0.001				
2C3	NOx	17.41	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.004	0.009	0.000	0.000				
2C7c	NOx	0.00	1.59	73	100	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000				
2G	NOx	29.36	19.02	77	103	0.001	0.001	0.000	0.000	0.005	0.005	0.004	0.006	0.000	0.000				
2H3	NOx	91.00	22.12	98	200	0.002	0.007	0.000	0.000	0.001	0.001	0.008	0.017	0.000	0.000				
3B1a	NOx	672.42	386.29	50	50	0.137	0.137	0.001	0.003	0.025	0.025	0.048	0.048	0.003	0.003				
3B1b	NOx	344.36	274.82	50	50	0.070	0.070	0.001	0.002	0.018	0.018	0.052	0.052	0.003	0.003				
3B2	NOx	67.60	63.18	50	50	0.004	0.004	0.000	0.000	0.004	0.004	0.013	0.013	0.000	0.000				
3B3	NOx	185.29	86.68	50	50	0.007	0.007	0.000	0.001	0.006	0.006	0.006	0.006	0.000	0.000				
3B4d	NOx	21.62	22.34	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.000				
3B4e	NOx	17.58	25.94	50	50	0.001	0.001	0.000	0.000	0.002	0.002	0.007	0.007	0.000	0.000				
3B4f	NOx	1.35	6.99	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000				
3B4gi	NOx	7.19	9.41	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000				
3B4g(ii)	NOx	4.46	11.87	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000				
3B4g(iii)	NOx	0.44	0.39	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
3B4g(iv)	NOx	0.84	1.15	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
3B4h	NOx	1.03	4.92	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000				
3Da1	NOx	1204.92	742.28	100	100	2.002	2.002	0.002	0.005	0.037	0.037	0.208	0.208	0.045	0.045				
3Da2a	NOx	2075.01	1457.12	50	50	1.956	1.956	0.005	0.010	0.094	0.094	0.243	0.243	0.068	0.068				
3Da2b	NOx	87.01	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.023	0.023	0.001	0.001				
3Da2c	NOx	14.76	116.03	102	102	0.051	0.051	0.001	0.001	0.023	0.023	0.078	0.078	0.007	0.007				
3Da3	NOx	243.41	415.58	100	100	0.629	0.629	0.002	0.003	0.027	0.027	0.231	0.231	0.054	0.054				
5A	NOx	1.83	1.35	51	51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
5B2	NOx	NA	5.96	102	102	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.004	0.000	0.000				
5C1a	NOx	80.75	42.50	64	64	0.003	0.003	0.000	0.000	0.021	0.021	0.004	0.004	0.000	0.000				
5C1bi	NOx	9.75	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000				
5C1b(iii)	NOx	22.50	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000				
5C1b(iv)	NOx	114.00	38.97	54	54	0.002	0.002	0.000	0.000	0.008	0.008	0.001	0.001	0.000	0.000				
5C1b(v)	NOx	11.25	14.31	30	30	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000				
5C2	NOx	31.10	15.83	103	163	0.001	0.002	0.000	0.000	0.008	0.008	0.003	0.005	0.000	0.000				
5D1	NOx	25.35	4.82	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
5D2	NOx	0.25	1.05	14	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
6A	NOx	83.95	91.28	58	58	0.010	0.010	0.000	0.001	0.028	0.028	0.021	0.021	0.001	0.001				
Total						188.5	188.6							1.6	1.6				
Total		140810.5	52522.0	Emissions 2020 uncertainty (%):		13.7	13.7			Trend uncertainty (%):				1.3	1.3				

Table A - 27: Uncertainty analysis of SO_x emissions, approach 1, for 2020 and for the trend 1990-2020. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
				Emissions 1990	Emissions 2020	Emission combined uncertainty 2020				Category contribution to inventory variance 2020		Contribution to inventory trend uncertainty from AD	Contribution to inventory trend uncertainty from EF	Contribution to inventory trend uncertainty from EM	
						(-)%	(+)%			(-)%	(+)%			(-)%	(+)%
1A1a	SOx	3587.18	241.17	24	24	2.366	2.366	0.004	0.007	0.093	0.093	0.077	0.077	0.015	0.015
1A1b	SOx	660.41	47.08	20	20	0.062	0.062	0.001	0.001	0.002	0.002	0.012	0.012	0.000	0.000
1A2a	SOx	357.86	9.88	15	15	0.002	0.002	0.001	0.000	0.001	0.001	0.011	0.011	0.000	0.000
1A2b	SOx	63.56	1.21	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A2c	SOx	1102.74	137.15	11	11	0.164	0.164	0.001	0.004	0.011	0.011	0.007	0.007	0.000	0.000
1A2d	SOx	3091.28	2.72	14	14	0.000	0.000	0.009	0.000	0.000	0.000	0.121	0.121	0.015	0.015
1A2e	SOx	985.20	17.97	12	12	0.003	0.003	0.002	0.000	0.001	0.001	0.027	0.027	0.001	0.001
1A2f	SOx	3530.25	1375.50	19	19	48.101	48.101	0.028	0.037	0.106	0.106	0.523	0.523	0.285	0.285
1A2gvii	SOx	352.45	4.07	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.009	0.009	0.000	0.000
1A2gviii	SOx	3314.29	306.04	19	19	2.383	2.383	0.001	0.008	0.024	0.024	0.019	0.019	0.001	0.001
1A3a(i)	SOx	99.68	54.49	10	10	0.021	0.021	0.001	0.001	0.003	0.003	0.012	0.012	0.000	0.000
1A3a(ii)	SOx	24.94	3.05	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A3bi	SOx	1704.97	54.23	10	10	0.021	0.021	0.003	0.001	0.003	0.003	0.033	0.033	0.001	0.001
1A3bii	SOx	285.80	7.52	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.006	0.006	0.000	0.000
1A3biii	SOx	1752.53	12.81	10	10	0.001	0.001	0.005	0.000	0.001	0.001	0.046	0.046	0.002	0.002
1A3biv	SOx	28.33	1.06	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3c	SOx	25.50	0.18	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3dii	SOx	63.17	1.29	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
1A3ei	SOx	0.28	0.27	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	SOx	3425.52	243.56	10	10	0.423	0.423	0.003	0.007	0.015	0.015	0.030	0.030	0.001	0.001
1A4a(ii)	SOx	1.79	0.09	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4bi	SOx	9207.86	585.56	11	11	2.718	2.718	0.010	0.016	0.084	0.084	0.099	0.099	0.017	0.017
1A4b(ii)	SOx	1.34	0.06	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ci	SOx	306.40	68.30	28	28	0.251	0.251	0.001	0.002	0.056	0.056	0.018	0.018	0.003	0.003
1A4cii	SOx	290.19	2.49	10	10	0.000	0.000	0.001	0.000	0.000	0.000	0.007	0.007	0.000	0.000
1A5b	SOx	77.42	31.51	10	10	0.007	0.007	0.001	0.001	0.002	0.002	0.006	0.006	0.000	0.000
1B2aiv	SOx	419.02	14.29	56	56	0.044	0.044	0.001	0.000	0.017	0.017	0.037	0.037	0.002	0.002
1B2c	SOx	300.98	2.46	38	38	0.001	0.001	0.001	0.000	0.002	0.002	0.024	0.024	0.001	0.001
2A1	SOx	0.69	0.45	97	200	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
2A2	SOx	0.01	0.01	100	500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2A5a	SOx	0.08	0.03	100	500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B5	SOx	444.78	424.07	20	20	5.060	5.060	0.010	0.012	0.033	0.033	0.206	0.206	0.044	0.044
2B10a	SOx	168.00	78.09	40	40	0.681	0.681	0.002	0.002	0.006	0.006	0.066	0.066	0.004	0.004
2C1	SOx	144.04	15.75	73	100	0.091	0.173	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
2C3	SOx	696.30	NO	NO	NO	NO	NO	0.002	0.000	0.000	0.000	0.191	0.392	0.036	0.154
2C7c	SOx	0.00	0.02	73	100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2G	SOx	3.44	4.29	77	103	0.008	0.014	0.000	0.000	0.004	0.004	0.008	0.011	0.000	0.000
2H3	SOx	1.30	0.32	98	200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
5B2	SOx	NA	0.90	102	102	0.001	0.001	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000
5C1a	SOx	24.23	12.75	64	64	0.046	0.046	0.000	0.000	0.025	0.025	0.011	0.011	0.001	0.001
5C1bi	SOx	45.00	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
5C1b(ii)	SOx	19.50	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
5C1biv	SOx	74.10	15.78	36	36	0.023	0.023	0.000	0.000	0.012	0.012	0.007	0.007	0.000	0.000
5C2	SOx	0.68	0.34	98	141	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
5D1	SOx	0.13	0.02	37	37	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5D2	SOx	0.00	0.01	22	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6A	SOx	10.40	10.22	58	58	0.025	0.025	0.000	0.000	0.012	0.012	0.012	0.012	0.000	0.000
Total						62.5	62.6							0.4	0.5
Total		36693.6	3789.1	Emissions 2020 uncertainty (%):		7.9	7.9			Trend uncertainty (%):				0.7	0.7

Table A - 28: Uncertainty analysis of NH₃ emissions, approach 1, for 2020 and for the trend 1990-2020. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M		
				Emissions 1990	Emissions 2020	Emission combined uncertainty 2020				Category contribution to inventory variance 2020		Contribution to inventory trend uncertainty from AD	Contribution to inventory trend uncertainty from EF		Contribution to inventory trend uncertainty from EM	
						(-)%	(+)%			(-)%	(+)%		(-)%	(+)%	(-)%	(+)%
1A1a	NH3	4.64	33.38	22	22	0.000	0.000	0.000	0.000	0.007	0.007	0.009	0.009	0.000	0.000	
1A1b	NH3	0.01	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A2a	NH3	0.00	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A2b	NH3	0.11	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A2c	NH3	0.02	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A2d	NH3	0.02	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A2e	NH3	0.02	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A2f	NH3	147.02	163.47	9	9	0.001	0.001	0.001	0.002	0.007	0.007	0.006	0.006	0.000	0.000	
1A2g ^{vii}	NH3	1.00	1.54	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	
1A2g ^{viii}	NH3	17.01	35.14	9	9	0.000	0.000	0.000	0.001	0.001	0.001	0.003	0.003	0.000	0.000	
1A3bi	NH3	1318.90	795.27	50	50	0.557	0.557	0.003	0.012	0.021	0.021	0.169	0.169	0.029	0.029	
1A3bii	NH3	8.57	28.09	50	50	0.001	0.001	0.000	0.000	0.001	0.001	0.016	0.016	0.000	0.000	
1A3biii	NH3	4.55	28.37	50	50	0.001	0.001	0.000	0.000	0.001	0.001	0.018	0.018	0.000	0.000	
1A3biv	NH3	3.26	3.35	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	
1A3c	NH3	0.07	0.07	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A3dii	NH3	0.20	0.21	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A3ei	NH3	NA	0.32	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A4ai	NH3	19.07	26.30	10	10	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000	
1A4aii	NH3	0.01	0.02	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A4bi	NH3	184.16	95.36	11	11	0.000	0.000	0.001	0.001	0.007	0.007	0.007	0.007	0.000	0.000	
1A4bii	NH3	0.01	0.01	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A4ci	NH3	2.88	1.96	23	23	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	
1A4cii	NH3	0.76	0.83	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A5b	NH3	0.04	0.04	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
2B1	NH3	0.07	0.00	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
2B2	NH3	0.73	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
2B10a	NH3	7.73	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000	
2C1	NH3	11.90	1.42	97	200	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.023	0.000	0.001	
2C7c	NH3	9.19	8.23	100	500	0.000	0.006	0.000	0.000	0.001	0.001	0.002	0.008	0.000	0.000	
2G	NH3	203.15	74.73	47	47	0.004	0.004	0.001	0.001	0.039	0.039	0.049	0.049	0.004	0.004	
2H2	NH3	132.33	61.93	100	500	0.014	0.337	0.001	0.001	0.013	0.013	0.060	0.299	0.004	0.090	
2H3	NH3	1.04	0.25	98	200	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	
2L	NH3	2.38	3.72	103	103	0.000	0.000	0.000	0.000	0.002	0.002	0.003	0.003	0.000	0.000	
3B1a	NH3	9337.10	10414.11	30	30	33.668	33.668	0.046	0.152	1.384	1.384	1.331	1.331	3.687	3.687	
3B1b	NH3	5190.92	7029.68	28	28	13.394	13.394	0.044	0.103	0.934	0.934	1.177	1.177	2.260	2.260	
3B2	NH3	509.75	471.25	87	87	0.595	0.595	0.001	0.007	0.063	0.063	0.095	0.095	0.013	0.013	
3B3	NH3	6965.04	4876.22	41	41	13.730	13.730	0.008	0.071	0.648	0.648	0.317	0.317	0.521	0.521	
3B4d	NH3	158.13	157.71	65	65	0.037	0.037	0.001	0.002	0.021	0.021	0.033	0.033	0.002	0.002	
3B4e	NH3	256.31	385.05	52	52	0.143	0.143	0.003	0.006	0.051	0.051	0.141	0.141	0.022	0.022	
3B4f	NH3	19.65	100.34	68	68	0.017	0.017	0.001	0.001	0.013	0.013	0.084	0.084	0.007	0.007	
3B4gi	NH3	978.79	675.99	82	82	1.088	1.088	0.001	0.010	0.090	0.090	0.102	0.102	0.019	0.019	
3B4gii	NH3	304.87	647.51	86	86	1.097	1.097	0.006	0.009	0.086	0.086	0.515	0.515	0.273	0.273	
3B4giii	NH3	29.77	23.19	93	93	0.002	0.002	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.000	
3B4g ^{iv}	NH3	124.46	84.51	85	85	0.018	0.018	0.000	0.001	0.011	0.011	0.015	0.015	0.000	0.000	
3B4h	NH3	14.55	43.47	50	50	0.002	0.002	0.000	0.001	0.006	0.006	0.023	0.023	0.001	0.001	
3Da1	NH3	4258.37	2487.38	50	50	5.496	5.496	0.012	0.036	0.257	0.257	0.602	0.602	0.429	0.429	
3Da2a	NH3	34567.08	20358.71	22	22	70.346	70.346	0.095	0.297	2.706	2.706	1.994	1.994	11.299	11.299	
3Da2b	NH3	1169.36	NO	NO	NO	NO	NO	0.013	0.000	0.000	0.000	0.664	0.664	0.441	0.441	
3Da2c	NH3	34.00	951.99	54	54	0.925	0.925	0.014	0.014	0.393	0.393	0.675	0.675	0.611	0.611	
3Da3	NH3	760.92	1406.08	62	62	2.702	2.702	0.012	0.021	0.187	0.187	0.736	0.736	0.577	0.577	
5A	NH3	615.79	217.63	51	51	0.043	0.043	0.004	0.003	0.045	0.045	0.191	0.191	0.038	0.038	
5B1	NH3	175.00	311.18	102	102	0.354	0.354	0.003	0.005	0.128	0.128	0.255	0.255	0.082	0.082	
5B2	NH3	9.63	218.82	78	78	0.101	0.101	0.003	0.003	0.090	0.090	0.231	0.231	0.062	0.062	
5C1biv	NH3	5.70	1.85	54	54	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.000	0.000	
5C2	NH3	18.03	9.18	54	54	0.000	0.000	0.000	0.000	0.009	0.009	0.002	0.002	0.000	0.000	
5D1	NH3	90.61	126.07	50	50	0.014	0.014	0.001	0.002	0.003	0.003	0.041	0.041	0.002	0.002	
6A	NH3	845.54	955.34	104	104	3.499	3.499	0.004	0.014	0.592	0.592	0.434	0.434	0.538	0.538	
Total																
Total		68520.2	53317.3	Emissions 2020 uncertainty (%):		12.2	12.2			Trend uncertainty (%):				4.6	4.6	

Table A - 29: Uncertainty analysis of PM2.5 emissions, approach 1, for 2020 and for the trend 1990-2020. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M		
				Emissions 1990	Emissions 2020	Emission combined uncertainty 2020				Category contribution to inventory variance 2020		Contribution to inventory trend uncertainty from AD	Contribution to inventory trend uncertainty from EF		Contribution to inventory trend uncertainty from EM	
						(-)%	(+)%			(-)%	(+)%		(-)%	(+)%	(-)%	(+)%
1A1a	PM2.5	772.50	44.24	72	72	0.293	0.293	0.014	0.003	0.038	0.038	0.977	0.977	0.955	0.955	
1A1b	PM2.5	47.66	1.29	20	20	0.000	0.000	0.001	0.000	0.000	0.000	0.019	0.019	0.000	0.000	
1A1c	PM2.5	4.64	14.54	21	21	0.003	0.003	0.001	0.001	0.006	0.006	0.016	0.016	0.000	0.000	
1A2a	PM2.5	14.80	2.69	28	28	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000	
1A2b	PM2.5	20.38	1.00	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.011	0.000	0.000	
1A2c	PM2.5	40.75	5.37	10	10	0.000	0.000	0.001	0.000	0.001	0.001	0.005	0.005	0.000	0.000	
1A2d	PM2.5	149.61	0.23	33	33	0.000	0.000	0.003	0.000	0.000	0.000	0.105	0.105	0.011	0.011	
1A2e	PM2.5	25.68	1.39	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.000	0.000	
1A2f	PM2.5	437.58	41.54	65	65	0.212	0.212	0.007	0.003	0.007	0.007	0.442	0.442	0.196	0.196	
1A2g	PM2.5	728.86	392.77	50	50	11.233	11.233	0.008	0.024	0.043	0.043	0.408	0.408	0.168	0.168	
1A2g	PM2.5	544.76	178.51	65	65	3.923	3.923	0.001	0.011	0.031	0.031	0.054	0.054	0.004	0.004	
1A3ai(i)	PM2.5	92.40	6.03	30	30	0.001	0.001	0.002	0.000	0.001	0.001	0.048	0.048	0.002	0.002	
1A3aii(i)	PM2.5	22.68	1.56	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.012	0.000	0.000	
1A3bi	PM2.5	577.89	140.84	57	57	1.898	1.898	0.004	0.008	0.015	0.015	0.218	0.218	0.048	0.048	
1A3bii	PM2.5	327.15	83.81	48	48	0.477	0.477	0.002	0.005	0.009	0.009	0.092	0.092	0.009	0.009	
1A3biii	PM2.5	1585.35	68.19	27	27	0.099	0.099	0.030	0.004	0.007	0.007	0.799	0.799	0.638	0.638	
1A3biv	PM2.5	208.81	25.97	54	54	0.057	0.057	0.003	0.002	0.003	0.003	0.155	0.155	0.024	0.024	
1A3bvi	PM2.5	689.15	817.03	50	50	48.606	48.606	0.035	0.049	0.090	0.090	1.727	1.727	2.991	2.991	
1A3c	PM2.5	174.35	193.98	50	50	2.740	2.740	0.008	0.012	0.021	0.021	0.399	0.399	0.159	0.159	
1A3dii	PM2.5	59.09	27.08	50	50	0.053	0.053	0.000	0.002	0.003	0.003	0.019	0.019	0.000	0.000	
1A3ei	PM2.5	0.11	0.05	27	27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1A4ai	PM2.5	506.05	313.48	78	78	17.409	17.409	0.008	0.019	0.042	0.042	0.633	0.633	0.403	0.403	
1A4bi	PM2.5	5226.73	1409.82	76	76	334.944	334.944	0.026	0.085	0.446	0.446	1.987	1.987	4.149	4.149	
1A4ci	PM2.5	539.21	229.00	44	44	3.009	3.009	0.002	0.014	0.414	0.414	0.091	0.091	0.179	0.179	
1A4cii	PM2.5	435.10	162.27	80	80	4.906	4.906	0.001	0.010	0.018	0.018	0.042	0.042	0.002	0.002	
1A5b	PM2.5	86.95	44.82	50	50	0.146	0.146	0.001	0.003	0.005	0.005	0.043	0.043	0.002	0.002	
1B1a	PM2.5	0.16	0.05	50	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1B2c	PM2.5	0.44	0.00	102	238	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	
2A1	PM2.5	240.48	156.47	97	200	6.773	28.508	0.004	0.009	0.027	0.027	0.420	0.862	0.177	0.744	
2A2	PM2.5	7.21	6.55	100	500	0.012	0.312	0.000	0.000	0.001	0.001	0.024	0.120	0.001	0.015	
2A5a	PM2.5	183.33	233.83	100	500	15.954	397.885	0.010	0.014	0.100	0.100	1.018	5.092	1.047	25.940	
2B5	PM2.5	43.68	26.68	97	200	0.197	0.829	0.001	0.002	0.005	0.005	0.066	0.136	0.004	0.018	
2B10a	PM2.5	7.86	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.007	0.007	0.000	0.000	
2C1	PM2.5	817.90	7.87	83	125	0.012	0.028	0.017	0.000	0.001	0.001	1.401	2.114	1.964	4.468	
2C3	PM2.5	78.33	NO	NO	NO	NO	NO	0.002	0.000	0.000	0.000	0.162	0.333	0.026	0.111	
2C7a	PM2.5	5.66	0.48	98	200	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.018	0.000	0.000	
2C7c	PM2.5	1.53	1.42	100	500	0.001	0.015	0.000	0.000	0.001	0.001	0.005	0.026	0.000	0.001	
2D3c	PM2.5	4.00	3.75	99	201	0.004	0.017	0.000	0.000	0.006	0.006	0.014	0.028	0.000	0.001	
2D3i	PM2.5	12.00	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.026	0.128	0.001	0.016	
2G	PM2.5	512.78	375.41	77	103	24.275	43.583	0.012	0.023	0.799	0.799	0.851	1.170	1.364	2.009	
2H1	PM2.5	235.77	183.11	102	202	10.149	39.914	0.006	0.011	0.468	0.468	0.586	1.203	0.563	1.666	
2H2	PM2.5	187.99	164.91	100	500	7.995	197.970	0.006	0.010	0.140	0.140	0.593	2.967	0.372	8.825	
2H3	PM2.5	15.60	3.79	98	200	0.004	0.017	0.000	0.000	0.001	0.001	0.010	0.021	0.000	0.000	
2I	PM2.5	216.08	46.08	100	500	0.624	15.460	0.002	0.003	0.039	0.039	0.182	0.909	0.035	0.829	
3B1a	PM2.5	20.61	23.79	100	300	0.165	1.483	0.001	0.001	0.013	0.013	0.099	0.298	0.010	0.089	
3B1b	PM2.5	18.26	21.88	100	300	0.140	1.255	0.001	0.001	0.012	0.012	0.093	0.279	0.009	0.078	
3B2	PM2.5	0.79	0.80	100	300	0.000	0.002	0.000	0.000	0.000	0.000	0.003	0.009	0.000	0.000	
3B3	PM2.5	9.57	6.51	100	300	0.012	0.111	0.000	0.000	0.004	0.004	0.019	0.057	0.000	0.003	
3B4d	PM2.5	0.14	0.18	100	300	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	
3B4e	PM2.5	3.94	6.58	100	300	0.013	0.113	0.000	0.000	0.004	0.004	0.031	0.094	0.001	0.009	
3B4f	PM2.5	0.59	3.31	100	300	0.003	0.029	0.000	0.000	0.002	0.002	0.019	0.056	0.000	0.003	
3B4gi	PM2.5	9.25	11.56	100	300	0.039	0.350	0.000	0.001	0.006	0.006	0.050	0.150	0.003	0.023	
3B4gii	PM2.5	6.78	20.17	100	300	0.119	1.066	0.001	0.001	0.011	0.011	0.107	0.321	0.012	0.103	
3B4giii	PM2.5	1.89	1.77	100	300	0.001	0.008	0.000	0.000	0.001	0.001	0.007	0.020	0.000	0.000	
3B4giv	PM2.5	1.98	2.90	100	300	0.002	0.022	0.000	0.000	0.002	0.002	0.013	0.040	0.000	0.002	
3B4h	PM2.5	0.24	0.10	100	300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
3De	PM2.5	47.50	45.04	98	200	0.562	2.363	0.002	0.003	0.019	0.019	0.166	0.341	0.028	0.116	
5A	PM2.5	0.73	0.54	32	32	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	
5B2	PM2.5	NA	0.05	102	102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
5C1a	PM2.5	465.12	244.80	58	58	5.930	5.930	0.005	0.015	1.043	1.043	0.146	0.146	1.108	1.108	
5C1bi	PM2.5	0.47	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
5C1biii	PM2.5	16.50	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.011	0.011	0.000	0.000	
5C1biv	PM2.5	14.25	2.73	39	39	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005	0.000	0.000	
5C1bv	PM2.5	4.39	0.95	33	33	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	
5C2	PM2.5	84.75	43.12	103	163	0.577	1.442	0.001	0.003	0.176	0.176	0.073	0.124	0.036	0.046	
5E	PM2.5	1.40	1.50	36	36	0.000	0.000	0.000	0.000	0.003	0.003	0.002	0.002	0.000	0.000	
6A	PM2.5	4.16	5.31	50	50	0.002	0.002	0.000	0.000	0.014	0.014	0.009	0.009	0.000	0.000	
Total							503.6	1168.7							16.7	56.2
Total		16602.4	5861.5	Emissions 2020 uncertainty (%):			22.4	34.2			Trend uncertainty (%):				4.1	7.5

Table A - 30: Uncertainty analysis of PM10 emissions, approach 1, for 2020 and for the trend 1990-2020. The uncertainties are given considering a 95 % confidence interval and expressed as the distance from edge to mean, in percentage of the mean. AD: activity data; EF: emission factor; EM: emission; corr.: correlated.

A	B	C	D	G		H		I	J	K		L		M	
				Emission combined uncertainty 2020		Category contribution to inventory variance 2020				Contribution to inventory trend uncertainty from AD		Contribution to inventory trend uncertainty from EF		Contribution to inventory trend uncertainty from EM	
NFR code	Pollutant	Emissions 1990	Emissions 2020	(-)%	(+)%	(-)%	(+)%	Sensitivity if corr. (type A)	Sensitivity if not corr. (type B)	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%
1A1a	PM10	1034.30	44.24	72	72	0.056	0.056	0.020	0.002	0.025	0.025	1.417	1.417	2.008	2.008
1A1b	PM10	47.66	1.29	20	20	0.000	0.000	0.001	0.000	0.000	0.000	0.019	0.019	0.000	0.000
1A1c	PM10	4.89	15.32	21	21	0.001	0.001	0.001	0.001	0.004	0.004	0.010	0.010	0.000	0.000
1A2a	PM10	20.52	2.94	28	28	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.009	0.000	0.000
1A2b	PM10	29.24	1.05	30	30	0.000	0.000	0.001	0.000	0.000	0.000	0.017	0.017	0.000	0.000
1A2c	PM10	40.75	5.37	10	10	0.000	0.000	0.001	0.000	0.001	0.001	0.006	0.006	0.000	0.000
1A2d	PM10	166.57	0.23	33	33	0.000	0.000	0.003	0.000	0.000	0.000	0.115	0.115	0.013	0.013
1A2e	PM10	25.68	1.39	10	10	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.000	0.000
1A2f	PM10	832.63	71.03	65	65	0.118	0.118	0.015	0.003	0.008	0.008	0.953	0.953	0.909	0.909
1A2g	PM10	2173.23	2343.70	50	50	76.292	76.292	0.047	0.093	0.169	0.169	2.352	2.352	5.558	5.558
1A2g	PM10	567.79	187.68	65	65	0.827	0.827	0.004	0.007	0.022	0.022	0.292	0.292	0.086	0.086
1A3ai(i)	PM10	102.66	6.03	30	30	0.000	0.000	0.002	0.000	0.000	0.000	0.058	0.058	0.003	0.003
1A3aii(i)	PM10	25.20	1.56	30	30	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.014	0.000	0.000
1A3bi	PM10	577.89	140.84	57	57	0.362	0.362	0.007	0.006	0.010	0.010	0.376	0.376	0.142	0.142
1A3bii	PM10	327.15	83.81	48	48	0.091	0.091	0.004	0.003	0.006	0.006	0.172	0.172	0.029	0.029
1A3biii	PM10	1585.35	68.19	27	27	0.019	0.019	0.031	0.003	0.005	0.005	0.825	0.825	0.681	0.681
1A3biv	PM10	208.81	25.97	54	54	0.011	0.011	0.003	0.001	0.002	0.002	0.181	0.181	0.033	0.033
1A3bvi	PM10	2049.68	2400.92	50	50	80.062	80.062	0.052	0.095	0.173	0.173	2.594	2.594	6.760	6.760
1A3c	PM10	982.81	1259.22	50	50	22.023	22.023	0.029	0.050	0.091	0.091	1.458	1.458	2.134	2.134
1A3dii	PM10	59.09	27.08	50	50	0.010	0.010	0.000	0.001	0.002	0.002	0.008	0.008	0.000	0.000
1A3ei	PM10	0.11	0.05	27	27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A4ai	PM10	533.14	333.25	78	78	3.753	3.753	0.002	0.013	0.029	0.029	0.155	0.155	0.025	0.025
1A4bi	PM10	5499.56	1477.70	76	76	70.191	70.191	0.057	0.058	0.307	0.307	4.324	4.324	18.789	18.789
1A4ci	PM10	543.85	231.29	44	44	0.585	0.585	0.002	0.009	0.274	0.274	0.089	0.089	0.083	0.083
1A4cii	PM10	511.19	221.53	80	80	1.744	1.744	0.002	0.009	0.016	0.016	0.158	0.158	0.025	0.025
1A5b	PM10	286.52	261.46	50	50	0.949	0.949	0.004	0.010	0.019	0.019	0.216	0.216	0.047	0.047
1B1a	PM10	1.60	0.45	50	50	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
1B2c	PM10	0.44	0.00	102	238	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
2A1	PM10	374.35	243.58	97	200	3.131	13.178	0.002	0.010	0.027	0.027	0.173	0.355	0.031	0.127
2A2	PM10	14.41	13.08	100	500	0.010	0.237	0.000	0.001	0.001	0.001	0.021	0.107	0.000	0.012
2A5a	PM10	366.54	467.61	100	500	12.170	303.529	0.011	0.018	0.131	0.131	1.080	5.399	1.183	29.166
2B5	PM10	52.62	31.73	97	200	0.053	0.224	0.000	0.001	0.004	0.004	0.015	0.030	0.000	0.001
2B10a	PM10	17.07	NA	NA	NA	NA	NA	0.000	0.000	0.000	0.000	0.014	0.014	0.000	0.000
2C1	PM10	1485.46	11.78	83	125	0.005	0.012	0.031	0.000	0.001	0.001	2.544	3.838	6.473	14.729
2C3	PM10	113.15	NO	NO	NO	NO	NO	0.002	0.000	0.000	0.000	0.232	0.475	0.054	0.226
2C7a	PM10	5.96	0.51	98	200	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.021	0.000	0.000
2C7c	PM10	3.06	2.81	100	500	0.000	0.011	0.000	0.000	0.001	0.001	0.005	0.023	0.000	0.001
2D3c	PM10	19.98	18.73	99	201	0.019	0.079	0.000	0.001	0.021	0.021	0.031	0.064	0.001	0.005
2D3i	PM10	24.00	NA	NA	NA	NA	NA	0.001	0.000	0.000	0.000	0.050	0.252	0.003	0.063
2G	PM10	588.38	469.64	77	103	7.247	13.011	0.006	0.019	0.657	0.657	0.453	0.622	0.636	0.818
2H1	PM10	243.80	189.01	102	202	2.063	8.112	0.002	0.007	0.317	0.317	0.230	0.471	0.153	0.323
2H2	PM10	310.39	306.50	100	500	5.268	130.445	0.006	0.012	0.171	0.171	0.561	2.803	0.344	7.885
2H3	PM10	15.60	3.79	98	200	0.001	0.003	0.000	0.000	0.001	0.001	0.017	0.036	0.000	0.001
2I	PM10	864.32	183.09	100	500	1.880	46.548	0.011	0.007	0.102	0.102	1.090	5.450	1.199	29.716
3B1a	PM10	84.47	97.50	100	300	0.529	4.752	0.002	0.004	0.035	0.035	0.208	0.625	0.045	0.392
3B1b	PM10	74.85	89.69	100	300	0.448	4.021	0.002	0.004	0.032	0.032	0.197	0.593	0.040	0.352
3B2	PM10	19.76	19.92	100	300	0.022	0.198	0.000	0.001	0.007	0.007	0.037	0.112	0.001	0.013
3B3	PM10	213.16	145.99	100	300	1.187	10.654	0.001	0.006	0.053	0.053	0.130	0.390	0.020	0.155
3B4d	PM10	3.42	4.51	100	300	0.001	0.010	0.000	0.000	0.002	0.002	0.011	0.032	0.000	0.001
3B4e	PM10	6.20	10.34	100	300	0.006	0.053	0.000	0.000	0.004	0.004	0.028	0.084	0.001	0.007
3B4f	PM10	0.94	5.29	100	300	0.002	0.014	0.000	0.000	0.002	0.002	0.019	0.057	0.000	0.003
3B4gi	PM10	123.32	154.16	100	300	1.324	11.881	0.004	0.006	0.056	0.056	0.351	1.052	0.126	1.111
3B4gii	PM10	67.84	201.67	100	300	2.265	20.331	0.007	0.008	0.073	0.073	0.655	1.966	0.434	3.869
3B4giii	PM10	10.41	9.72	100	300	0.005	0.047	0.000	0.000	0.004	0.004	0.017	0.050	0.000	0.002
3B4giv	PM10	18.52	27.56	100	300	0.042	0.380	0.001	0.001	0.010	0.010	0.070	0.210	0.005	0.044
3B4h	PM10	0.50	0.83	100	300	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.007	0.000	0.000
3De	PM10	1053.99	1003.61	98	200	53.265	223.824	0.018	0.040	0.281	0.281	1.711	3.512	3.008	12.412
5A	PM10	0.73	0.54	32	32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5B2	PM10	NA	0.05	102	102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5C1a	PM10	516.80	272.00	71	71	2.054	2.054	0.000	0.011	0.761	0.761	0.005	0.005	0.579	0.579
5C1bi	PM10	3.08	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
5C1biii	PM10	24.00	NO	NO	NO	NO	NO	0.001	0.000	0.000	0.000	0.015	0.015	0.000	0.000
5C1biv	PM10	19.95	3.90	40	40	0.000	0.000	0.000	0.000	0.004	0.004	0.009	0.009	0.000	0.000
5C1bv	PM10	4.39	0.95	33	33	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000
5C2	PM10	93.09	47.37	103	163	0.133	0.332	0.000	0.002	0.127	0.127	0.007	0.013	0.016	0.016
5E	PM10	2.80	3.00	36	36	0.000	0.000	0.000	0.000	0.003	0.003	0.002	0.002	0.000	0.000
6A	PM10	203.81	166.69	50	50	0.386	0.386	0.002	0.007	0.280	0.280	0.093	0.093	0.087	0.087
Total						350.6	1051.4							51.8	139.4
Total		25283.4	13420.8	Emissions 2020 uncertainty (%):		18.7	32.4			Trend uncertainty (%):				7.2	11.8

A5.3 Uncertainty estimations: results from approach 2

Numeric results of the uncertainty estimations using Monte Carlo simulations are summarized in the tables in Annex A5.3.1. In these tables, columns labelled A to J correspond exactly to columns A to J from Table 3.3, chp. 3, from the IPCC guidelines (IPCC, 2006).

Results of the sensitivity analysis between input emissions from each category and inventory emission are depicted by tornado plots in the figures in Annex A5.3.2 (see also discussion in chp. 1.5.3).

Distributions of inventory emissions obtained from the 200'000 Monte Carlo simulations are shown as histograms, for each pollutant, for the base year, the reporting year and the trend, in the figures in Annex A5.3.3.

A5.3.1 Uncertainty estimations, approach 2, numeric results

Table A - 31: Uncertainty analysis of NO_x emissions, approach 2, for 2020 and for the trend 1990-2020. Monte Carlo simulations were run 200'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J		K
				Activity data uncertainty 2020		Emission factor uncertainty 2020		Emission combined uncertainty 2020				Emission contribution to variance 2020	Contribution to inventory trend, mean	
NFR	Pollutant	Emissions 1990	Emissions 2020	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%	Fraction
		t	t											
1A1a	NOx	6294.04	2086.67	10	10	19	19	21	21	0.004	-2.999	0.809	0.776	0.016
1A1b	NOx	494.17	318.51	1	1	20	20	20	19	0.000	-0.125	0.030	0.029	0.000
1A1c	NOx	0.01	0.04	5	5	20	20	20	20	0.000	0.000	0.000	0.000	0.000
1A2a	NOx	278.40	117.77	2	2	26	27	27	26	0.000	-0.115	0.035	0.033	0.000
1A2b	NOx	126.80	33.96	2	2	19	20	19	20	0.000	-0.066	0.016	0.015	0.000
1A2c	NOx	1046.46	256.20	2	2	10	10	10	10	0.000	-0.564	0.092	0.091	0.000
1A2d	NOx	1260.62	41.59	2	2	10	10	10	10	0.000	-0.869	0.141	0.138	0.001
1A2e	NOx	743.24	244.47	2	2	10	10	10	10	0.000	-0.356	0.059	0.056	0.000
1A2f	NOx	10534.54	3141.83	2	2	17	17	17	17	0.006	-5.269	1.069	1.058	0.029
1A2gvii	NOx	6333.94	1814.17	1	1	13	13	13	13	0.001	-3.222	0.577	0.563	0.008
1A2gviii	NOx	2338.08	1675.34	2	2	17	17	17	17	0.002	-0.473	0.108	0.105	0.000
1A3ai(i)	NOx	1214.30	779.06	1	1	20	19	20	20	0.000	-0.310	0.075	0.071	0.000
1A3aii(i)	NOx	153.76	34.60	1	1	19	20	20	20	0.000	-0.085	0.020	0.020	0.000
1A3bi	NOx	43771.18	17810.00	1	1	38	37	38	37	0.892	-18.303	4.782	5.029	0.618
1A3bii	NOx	6196.89	4823.47	1	1	32	31	32	31	0.046	-0.978	0.327	0.329	0.003
1A3biii	NOx	29900.45	4312.68	1	1	17	18	18	18	0.012	-18.211	3.370	3.343	0.287
1A3biv	NOx	308.61	234.82	1	1	36	35	36	35	0.000	-0.053	0.020	0.020	0.000
1A3c	NOx	595.50	388.56	1	1	13	13	13	13	0.000	-0.148	0.028	0.027	0.000
1A3dii	NOx	1054.73	984.94	1	1	13	13	13	13	0.000	-0.050	0.016	0.016	0.000
1A3ei	NOx	145.60	10.26	2	2	49	50	48	50	0.000	-0.097	0.049	0.049	0.000
1A4ai	NOx	4695.68	2391.07	2	2	15	16	16	16	0.003	-1.643	0.332	0.327	0.003
1A4aii	NOx	16.28	45.70	1	1	13	13	13	13	0.000	0.021	0.004	0.004	0.000
1A4bi	NOx	11629.86	4347.90	4	4	13	13	13	13	0.007	-5.192	0.947	0.948	0.023
1A4bii	NOx	18.76	23.85	1	1	30	29	29	30	0.000	0.004	0.001	0.001	0.000
1A4ci	NOx	382.41	242.87	21	21	29	29	36	36	0.000	-0.100	0.076	0.073	0.000
1A4cii	NOx	4357.53	1894.28	1	1	13	13	12	13	0.001	-1.757	0.320	0.308	0.003
1A5b	NOx	882.99	395.33	1	1	13	13	13	13	0.000	-0.348	0.064	0.061	0.000
1B2c	NOx	212.79	1.71	22	22	100	200	100	202	0.000	-0.151	0.304	0.151	0.002
2A1	NOx	15.87	10.32	2	2	100	199	100	199	0.000	-0.004	0.008	0.004	0.000
2A2	NOx	0.27	0.24	2	2	100	441	100	442	0.000	0.000	0.000	0.000	0.000
2A5a	NOx	1.79	0.68	5	5	100	442	100	441	0.000	-0.001	0.003	0.001	0.000
2B2	NOx	82.78	NO	NO	NO	NO	NO	NO	NO	NO	-0.059	0.010	0.009	0.000
2B10a	NOx	8.93	17.64	2	2	60	58	59	59	0.000	0.006	0.004	0.004	0.000
2C1	NOx	245.46	157.65	2	2	48	50	50	48	0.000	-0.063	0.032	0.032	0.000
2C3	NOx	17.41	NO	NO	NO	NO	NO	NO	NO	NO	-0.012	0.025	0.012	0.000
2C7c	NOx	0.00	1.59	5	5	83	98	82	99	0.000	0.001	0.001	0.001	0.000
2G	NOx	29.36	19.02	24	25	82	100	84	102	0.000	-0.007	0.011	0.008	0.000
2H3	NOx	91.00	22.12	3	3	100	200	100	200	0.000	-0.049	0.099	0.049	0.000
3B1a	NOx	672.42	386.29	6	6	49	49	49	50	0.001	-0.204	0.110	0.108	0.000
3B1b	NOx	344.36	274.82	6	6	49	49	50	49	0.000	-0.050	0.033	0.031	0.000
3B2	NOx	67.60	63.18	6	6	49	49	49	50	0.000	-0.003	0.005	0.004	0.000
3B3	NOx	185.29	86.68	6	6	49	49	50	49	0.000	-0.070	0.037	0.036	0.000
3B4d	NOx	21.62	22.34	6	6	49	49	49	50	0.000	0.001	0.001	0.002	0.000
3B4e	NOx	17.58	25.94	6	6	49	49	48	50	0.000	0.006	0.003	0.003	0.000
3B4f	NOx	1.35	6.99	6	6	50	48	50	49	0.000	0.004	0.002	0.002	0.000
3B4gi	NOx	7.19	9.41	6	6	49	49	49	50	0.000	0.002	0.001	0.001	0.000
3B4gii	NOx	4.46	11.87	6	6	48	50	49	50	0.000	0.005	0.003	0.003	0.000
3B4giii	NOx	0.44	0.39	6	6	48	49	49	50	0.000	0.000	0.000	0.000	0.000
3B4giv	NOx	0.84	1.15	6	6	49	49	49	49	0.000	0.000	0.000	0.000	0.000
3B4h	NOx	1.03	4.92	6	6	49	49	49	50	0.000	0.003	0.001	0.001	0.000
3Da1	NOx	1204.92	742.28	5	5	98	98	98	98	0.011	-0.329	0.327	0.332	0.003
3Da2a	NOx	2075.01	1457.12	6	6	49	48	49	50	0.010	-0.441	0.257	0.239	0.002
3Da2b	NOx	87.01	NO	NO	NO	NO	NO	NO	NO	NO	-0.062	0.062	0.061	0.000
3Da2c	NOx	14.76	116.03	20	20	100	97	99	102	0.000	0.072	0.073	0.075	0.000
3Da3	NOx	243.41	415.58	6	6	97	99	100	97	0.003	0.123	0.123	0.125	0.000
5A	NOx	1.83	1.35	10	10	49	49	50	50	0.000	0.000	0.000	0.000	0.000
5B2	NOx	NA	5.96	19	20	98	98	99	103	0.000	0.004	0.004	0.004	0.000
5C1a	NOx	80.75	42.50	50	48	41	38	60	65	0.000	-0.027	0.035	0.034	0.000
5C1bi	NOx	9.75	NO	NO	NO	NO	NO	NO	NO	NO	-0.007	0.003	0.003	0.000
5C1biii	NOx	22.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.016	0.007	0.007	0.000
5C1biv	NOx	114.00	38.97	20	19	49	49	52	54	0.000	-0.053	0.033	0.030	0.000
5C1bv	NOx	11.25	14.31	5	5	29	30	30	30	0.000	0.002	0.001	0.001	0.000
5C2	NOx	31.10	15.83	47	47	100	152	100	164	0.000	-0.011	0.025	0.013	0.000
5D1	NOx	25.35	4.82	1	1	10	10	10	10	0.000	-0.015	0.002	0.002	0.000
5D2	NOx	0.25	1.05	10	10	10	10	14	14	0.000	0.001	0.000	0.000	0.000
6A	NOx	83.95	91.28	29	29	50	48	56	58	0.000	0.005	0.027	0.029	0.000
Total, Monte Carlo simulations		140819.4	52526.7					13.4	13.6	1.0	-62.7	1.3	1.3	1.0
Total, inventory		140810.5	52522.0								-62.7			

Table A - 32: Uncertainty analysis of NMVOC emissions, approach 2, for 2020 and for the trend 1990-2020. Monte Carlo simulations were run 200'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C		D		E		F		G		H		I		J		Contribution to variance of inventory trend
		Emissions 1990	Emissions 2020	Activity data uncertainty 2020		Emission factor uncertainty 2020		Emission combined uncertainty 2020		Emission contribution to variance 2020	Contribution to inventory trend, mean	Contribution to inventory trend uncertainty						
				t	t	(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	Fraction	%	(-)%	(+)%	
1A1a	NMVOC	292.47	167.66	10	10	31	32	33	33	0.000	-0.043	0.021	0.020	0.000				
1A1b	NMVOC	6.95	4.55	1	1	20	20	20	20	0.000	-0.001	0.000	0.000	0.000				
1A1c	NMVOC	2.13	6.68	5	5	20	19	20	21	0.000	0.002	0.000	0.001	0.000				
1A2a	NMVOC	8.93	7.32	2	2	18	18	18	18	0.000	-0.001	0.000	0.000	0.000				
1A2b	NMVOC	53.59	5.73	2	2	19	19	19	19	0.000	-0.017	0.005	0.005	0.000				
1A2c	NMVOC	34.06	23.87	2	2	10	10	10	10	0.000	-0.004	0.001	0.001	0.000				
1A2d	NMVOC	29.85	4.11	2	2	10	10	10	10	0.000	-0.009	0.002	0.002	0.000				
1A2e	NMVOC	22.04	23.72	2	2	10	10	10	10	0.000	0.001	0.000	0.000	0.000				
1A2f	NMVOC	596.56	449.54	2	2	29	29	29	30	0.000	-0.051	0.020	0.020	0.000				
1A2gvii	NMVOC	1331.50	280.04	1	1	34	33	33	33	0.000	-0.365	0.152	0.146	0.000				
1A2gviii	NMVOC	278.83	111.10	2	2	29	29	29	30	0.000	-0.058	0.023	0.021	0.000				
1A3ai(i)	NMVOC	247.46	60.32	1	1	49	49	49	49	0.000	-0.065	0.036	0.035	0.000				
1A3ai(ii)	NMVOC	58.81	28.67	1	1	48	50	49	49	0.000	-0.010	0.006	0.006	0.000				
1A3bi	NMVOC	55936.00	3794.37	1	1	51	52	51	51	0.010	-17.862	8.398	8.447	0.221				
1A3bii	NMVOC	4919.59	191.26	1	1	45	44	44	45	0.000	-1.640	0.831	0.806	0.002				
1A3biii	NMVOC	3385.60	114.76	1	1	21	22	21	22	0.000	-1.135	0.365	0.357	0.000				
1A3biv	NMVOC	5733.49	709.25	1	1	100	383	100	383	0.020	-1.616	6.167	1.616	0.108				
1A3bv	NMVOC	16980.11	1901.29	1	1	39	39	39	39	0.001	-5.221	2.320	2.240	0.016				
1A3c	NMVOC	83.76	45.70	1	1	33	33	33	33	0.000	-0.013	0.005	0.005	0.000				
1A3dii	NMVOC	1640.55	412.60	1	1	33	34	33	34	0.000	-0.426	0.177	0.169	0.000				
1A3ei	NMVOC	0.06	0.05	2	2	49	50	50	49	0.000	0.000	0.000	0.000	0.000				
1A4ai	NMVOC	1131.40	583.07	2	2	55	55	55	55	0.000	-0.190	0.116	0.112	0.000				
1A4aii	NMVOC	1091.65	330.48	1	1	73	74	74	73	0.000	-0.264	0.209	0.202	0.000				
1A4bi	NMVOC	8849.57	2498.84	4	4	66	67	66	67	0.007	-2.197	1.555	1.498	0.007				
1A4bii	NMVOC	398.23	135.20	1	1	73	74	73	74	0.000	-0.091	0.072	0.069	0.000				
1A4ci	NMVOC	220.67	96.72	21	21	73	74	75	78	0.000	-0.043	0.040	0.036	0.000				
1A4cii	NMVOC	4369.08	888.26	1	1	73	73	72	75	0.001	-1.206	0.920	0.928	0.003				
1A5b	NMVOC	160.25	63.38	1	1	34	33	33	33	0.000	-0.034	0.014	0.014	0.000				
1B2ai	NMVOC	0.02	0.01	29	29	48	49	55	59	0.000	0.000	0.000	0.000	0.000				
1B2aiv	NMVOC	1344.61	214.28	30	29	46	46	53	56	0.000	-0.392	0.255	0.231	0.000				
1B2av	NMVOC	14668.85	890.13	1	1	25	25	25	26	0.000	-4.777	1.651	1.584	0.008				
1B2b	NMVOC	1056.51	577.19	21	22	49	48	53	54	0.000	-0.166	0.130	0.121	0.000				
1B2c	NMVOC	13.64	0.11	22	21	82	99	83	102	0.000	-0.005	0.005	0.004	0.000				
2A1	NMVOC	41.25	26.84	2	2	100	200	100	200	0.000	-0.005	0.010	0.005	0.000				
2A2	NMVOC	0.69	0.62	2	2	100	445	100	445	0.000	0.000	0.000	0.000	0.000				
2A5a	NMVOC	4.59	1.75	5	5	100	447	100	447	0.000	-0.001	0.004	0.001	0.000				
2B10a	NMVOC	608.61	15.21	2	2	40	39	39	40	0.000	-0.206	0.098	0.091	0.000				
2C1	NMVOC	1053.60	201.56	2	2	82	98	82	98	0.000	-0.295	0.302	0.245	0.000				
2C3	NMVOC	56.57	NO	NO	NO	NO	NO	NO	NO	NO	-0.020	0.039	0.020	0.000				
2C7a	NMVOC	2.98	0.25	5	5	100	199	100	199	0.000	-0.001	0.002	0.001	0.000				
2C7c	NMVOC	0.00	0.51	5	5	82	99	81	100	0.000	0.000	0.000	0.000	0.000				
2D3a	NMVOC	9195.44	8983.52	1	1	82	98	83	98	0.199	-0.073	0.087	0.066	0.000				
2D3b	NMVOC	4895.00	2651.40	5	5	83	98	83	99	0.017	-0.775	0.784	0.640	0.002				
2D3c	NMVOC	2430.00	384.18	20	19	82	99	83	101	0.000	-0.707	0.737	0.597	0.002				
2D3d	NMVOC	40731.00	8053.60	19	20	39	40	44	44	0.032	-11.271	5.368	5.092	0.087				
2D3e	NMVOC	11166.00	1317.20	39	40	49	48	60	65	0.002	-3.401	2.396	2.188	0.017				
2D3f	NMVOC	910.00	61.80	20	20	39	39	43	44	0.000	-0.294	0.152	0.143	0.000				
2D3g	NMVOC	27503.97	3171.13	29	30	81	99	85	103	0.028	-8.227	7.878	6.736	0.193				
2D3h	NMVOC	20353.80	3726.60	20	19	39	39	44	44	0.007	-5.751	2.897	2.729	0.025				
2D3i	NMVOC	5470.21	2008.57	29	30	100	179	100	183	0.034	-1.184	2.219	1.184	0.015				
2G	NMVOC	23727.29	6829.50	24	25	100	199	100	202	0.476	-5.424	9.902	5.424	0.289				
2H1	NMVOC	554.99	220.26	30	29	100	200	100	203	0.000	-0.116	0.247	0.116	0.000				
2H2	NMVOC	1955.66	1991.15	10	10	83	98	83	98	0.010	0.012	0.109	0.119	0.000				
2H3	NMVOC	156.00	37.92	3	3	100	200	100	200	0.000	-0.041	0.083	0.041	0.000				
3B1a	NMVOC	7074.65	7139.81	6	6	58	60	59	59	0.046	0.022	0.242	0.238	0.000				
3B1b	NMVOC	5367.84	8240.64	6	6	69	69	69	69	0.083	0.995	0.727	0.775	0.002				
3B2	NMVOC	66.79	67.33	6	6	100	200	100	200	0.000	0.000	0.003	0.003	0.000				
3B3	NMVOC	1126.15	788.98	6	6	100	201	100	201	0.006	-0.116	0.236	0.116	0.000				
3B4d	NMVOC	37.02	48.86	6	6	100	200	100	200	0.000	0.004	0.004	0.008	0.000				
3B4e	NMVOC	120.39	200.84	6	6	100	201	100	201	0.000	0.028	0.028	0.057	0.000				
3B4f	NMVOC	8.64	48.65	6	6	100	199	100	198	0.000	0.014	0.014	0.028	0.000				
3B4gi	NMVOC	508.70	635.91	6	6	100	200	100	199	0.004	0.044	0.044	0.092	0.000				
3B4gii	NMVOC	366.34	1089.00	6	6	100	198	100	199	0.012	0.251	0.251	0.506	0.001				
3B4giii	NMVOC	46.28	43.21	6	6	100	200	100	200	0.000	-0.001	0.003	0.002	0.000				
3B4giv	NMVOC	129.27	201.43	6	6	100	200	100	200	0.000	0.025	0.025	0.051	0.000				
3B4h	NMVOC	3.60	4.81	6	6	100	199	100	199	0.000	0.000	0.000	0.001	0.000				
3De	NMVOC	481.38	455.74	5	5	100	200	100	200	0.002	-0.009	0.027	0.013	0.000				
5A	NMVOC	405.68	143.43	10	10	49	49	50	50	0.000	-0.091	0.053	0.051	0.000				
5B1	NMVOC	104.96	186.64	20	19	98	97	100	101	0.000	0.028	0.030	0.034	0.000				
5B2	NMVOC	46.44	1022.11	20	20	29	29	34	37	0.000	0.339	0.137	0.153	0.000				
5C1a	NMVOC	516.80	272.00	49	49	49	49	67	71	0.000	-0.085	0.119	0.106	0.000				
5C1bi	NMVOC	3.75	NO	NO	NO	NO	NO	NO	NO	NO	-0.001	0.001	0.001	0.000				
5C1bii	NMVOC	4.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.002	0.001	0.001	0.000				
5C1biv	NMVOC	0.46	18.41	19	20	20	20	27	28	0.000	0.006	0.002	0.002	0.000				
5C1bv	NMVOC	1.20	0.41	5	5	29	30	30	30	0.000	0.000	0.000	0.000	0.000				
5C2	NMVOC	33.13	16.86	46	47	99	153	100	164	0.000	-0.006	0.013	0.007	0.000				
5D1	NMVOC	0.51	0.10	1	1	26	27	26	27	0.000	0.000	0.000	0.000	0.000				
5D2	NMVOC	0.01	0.02	10	10	20	20	22	22	0.000	0.000	0.000	0.000	0.000				
5E	NMVOC	28.00	60.00	19	20	23	23	30	31	0.000	0.011	0.006	0.006	0.000				
6A	NMVOC	186.62	202.46	29	30	49	49	55	60	0.000	0.006	0.029	0.031	0.000				
Total, Monte Carlo simulations		292518.1	75197.1					24.1	27.1	1.0	-74.2	4.4	4.5	1.0				
Total, inventory		292433.6	75191.5								-74.3							

Table A - 33: Uncertainty analysis of SO₂ emissions, approach 2, for 2020 and for the trend 1990-2020. Monte Carlo simulations were run 200'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C		D		E		F		G		H	I	J		Contribution to variance of inventory trend
		Emissions 1990	Emissions 2020	Activity data uncertainty 2020	Emission factor uncertainty 2020	Emission combined uncertainty 2020	Emission contribution to variance 2020	Contribution to inventory trend, mean	Contribution to inventory trend uncertainty							
NFR	Pollutant	t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%	Fraction		
1A1a	SO2	3587.18	241.17	10	10	22	21	23	24	0.038	-9.115	-2.029	2.050	0.145		
1A1b	SO2	660.41	47.08	1	1	19	20	20	19	0.001	-1.673	0.334	0.338	0.004		
1A2a	SO2	357.86	9.88	2	2	15	15	15	15	0.000	-0.949	0.153	0.148	0.001		
1A2b	SO2	63.56	1.21	2	2	10	10	10	10	0.000	-0.170	0.020	0.020	0.000		
1A2c	SO2	1102.74	137.15	2	2	11	11	11	11	0.003	-2.633	0.326	0.316	0.004		
1A2d	SO2	3091.28	2.72	2	2	14	14	14	14	0.000	-8.424	1.184	1.174	0.048		
1A2e	SO2	985.20	17.97	2	2	12	12	12	12	0.000	-2.638	0.341	0.345	0.004		
1A2f	SO2	3530.25	1375.50	2	2	18	19	19	19	0.769	-5.871	1.057	1.070	0.039		
1A2gvii	SO2	352.45	4.07	1	1	10	10	10	10	0.000	-0.950	0.108	0.111	0.000		
1A2gviii	SO2	3314.29	306.04	2	2	19	19	19	19	0.038	-8.198	1.488	1.467	0.076		
1A3ai(i)	SO2	99.68	54.49	1	1	10	10	10	10	0.000	-0.123	0.015	0.015	0.000		
1A3aii(i)	SO2	24.94	3.05	1	1	10	10	10	10	0.000	-0.060	0.007	0.007	0.000		
1A3bi	SO2	1704.97	54.23	1	1	10	10	10	10	0.000	-4.502	0.503	0.498	0.009		
1A3bii	SO2	285.80	7.52	1	1	10	10	10	10	0.000	-0.759	0.087	0.087	0.000		
1A3biii	SO2	1752.53	12.81	1	1	10	10	10	10	0.000	-4.745	0.533	0.524	0.010		
1A3biv	SO2	28.33	1.06	1	1	10	10	10	10	0.000	-0.074	0.009	0.009	0.000		
1A3c	SO2	25.50	0.18	1	1	10	10	10	10	0.000	-0.069	0.008	0.008	0.000		
1A3dii	SO2	63.17	1.29	1	1	10	10	10	10	0.000	-0.169	0.019	0.020	0.000		
1A3ei	SO2	0.28	0.27	2	2	10	10	10	10	0.000	0.000	0.000	0.000	0.000		
1A4ai	SO2	3425.52	243.56	2	2	10	10	10	10	0.007	-8.678	0.935	0.929	0.030		
1A4aii	SO2	1.79	0.09	1	1	10	10	10	10	0.000	-0.005	0.001	0.001	0.000		
1A4bi	SO2	9207.86	585.56	4	4	10	10	10	11	0.043	-23.502	2.293	2.199	0.175		
1A4bii	SO2	1.34	0.06	1	1	10	10	10	10	0.000	-0.003	0.000	0.000	0.000		
1A4ci	SO2	306.40	68.30	21	21	18	18	27	28	0.004	-0.649	0.218	0.209	0.002		
1A4cii	SO2	290.19	2.49	1	1	10	10	10	10	0.000	-0.785	0.091	0.089	0.000		
1A5b	SO2	77.42	31.51	1	1	10	10	10	10	0.000	-0.125	0.014	0.015	0.000		
1B2aiv	SO2	419.02	14.29	29	30	46	46	54	55	0.001	-1.104	0.629	0.584	0.013		
1B2c	SO2	300.98	2.46	21	22	30	31	36	38	0.000	-0.814	0.311	0.300	0.003		
2A1	SO2	0.69	0.45	2	2	100	200	100	200	0.000	-0.001	0.001	0.001	0.000		
2A2	SO2	0.01	0.01	2	2	100	448	100	448	0.000	0.000	0.000	0.000	0.000		
2A5a	SO2	0.08	0.03	5	5	100	443	100	443	0.000	0.000	0.001	0.000	0.000		
2B5	SO2	444.78	424.07	2	2	19	20	20	20	0.080	-0.056	0.035	0.034	0.000		
2B10a	SO2	168.00	78.09	2	2	39	39	39	40	0.011	-0.245	0.098	0.097	0.000		
2C1	SO2	144.04	15.75	2	2	82	99	83	98	0.003	-0.350	0.341	0.290	0.004		
2C3	SO2	696.30	NO	NO	NO	NO	NO	NO	NO	NO	-1.864	3.614	1.864	0.432		
2C7c	SO2	0.00	0.02	5	5	81	100	82	99	0.000	0.000	0.000	0.000	0.000		
2G	SO2	3.44	4.29	24	24	82	98	84	102	0.000	0.002	0.004	0.005	0.000		
2H3	SO2	1.30	0.32	3	3	100	199	100	199	0.000	-0.003	0.005	0.003	0.000		
5B2	SO2	NA	0.90	20	19	99	97	101	100	0.000	0.002	0.002	0.002	0.000		
5C1a	SO2	24.23	12.75	50	48	39	39	60	65	0.001	-0.031	0.041	0.038	0.000		
5C1bi	SO2	45.00	NO	NO	NO	NO	NO	NO	NO	NO	-0.123	0.053	0.050	0.000		
5C1biii	SO2	19.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.053	0.023	0.022	0.000		
5C1biv	SO2	74.10	15.78	20	20	29	29	35	36	0.000	-0.159	0.063	0.061	0.000		
5C2	SO2	0.68	0.34	47	47	96	130	97	142	0.000	-0.001	0.002	0.001	0.000		
5D1	SO2	0.13	0.02	1	1	36	36	36	36	0.000	0.000	0.000	0.000	0.000		
5D2	SO2	0.00	0.01	10	10	19	20	22	22	0.000	0.000	0.000	0.000	0.000		
6A	SO2	10.40	10.22	29	29	49	49	55	59	0.000	-0.001	0.012	0.012	0.000		
Total, Monte Carlo simulations		36693.9	3788.7					7.7	7.8	1.0	-89.7	0.7	0.7	1.0		
Total, inventory		36693.6	3789.1								-89.7					

Table A - 34: Uncertainty analysis of NH₃ emissions, approach 2, for 2020 and for the trend 1990-2020. Monte Carlo simulations were run 200'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C		D		E		F		G		H		I		J		Contribution to variance of inventory trend
		Emissions 1990	Emissions 2020	Activity data uncertainty 2020	Emission factor uncertainty 2020	Emission combined uncertainty 2020	Emission contribution to variance 2020	Contribution to inventory trend, mean	Contribution to inventory trend uncertainty									
NFR	Pollutant	t	t	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	Fraction	%	(-)%	(+)%	Fraction				
1A1a	NH3	4.64	33.38	10	10	20	20	21	23	0.000	0.042	0.011	0.011	0.000				
1A1b	NH3	0.01	0.01	1	1	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A2a	NH3	0.00	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A2b	NH3	0.11	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A2c	NH3	0.02	0.01	2	2	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A2d	NH3	0.02	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A2e	NH3	0.02	0.01	2	2	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A2f	NH3	147.02	163.47	2	2	9	9	9	9	0.000	0.024	0.007	0.007	0.000				
1A2gvii	NH3	1.00	1.54	1	1	49	49	49	49	0.000	0.001	0.000	0.000	0.000				
1A2gviii	NH3	17.01	35.14	2	2	9	9	9	9	0.000	0.027	0.004	0.004	0.000				
1A3bi	NH3	1318.90	795.27	1	1	48	50	48	50	0.004	-0.766	0.381	0.390	0.006				
1A3bii	NH3	8.57	28.09	1	1	48	49	49	49	0.000	0.029	0.014	0.015	0.000				
1A3biii	NH3	4.55	28.37	1	1	49	49	49	49	0.000	0.035	0.018	0.018	0.000				
1A3biv	NH3	3.26	3.35	1	1	49	48	50	48	0.000	0.000	0.000	0.000	0.000				
1A3c	NH3	0.07	0.07	1	1	49	49	48	50	0.000	0.000	0.000	0.000	0.000				
1A3dii	NH3	0.20	0.21	1	1	50	49	49	49	0.000	0.000	0.000	0.000	0.000				
1A3ei	NH3	NA	0.32	2	2	48	50	49	49	0.000	0.000	0.000	0.000	0.000				
1A4ai	NH3	19.07	26.30	2	2	10	10	10	10	0.000	0.011	0.002	0.002	0.000				
1A4aii	NH3	0.01	0.02	1	1	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A4bi	NH3	184.16	95.36	4	4	10	10	10	10	0.000	-0.130	0.024	0.023	0.000				
1A4bii	NH3	0.01	0.01	1	1	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
1A4ci	NH3	2.88	1.96	21	21	10	10	23	23	0.000	-0.001	0.001	0.001	0.000				
1A4cii	NH3	0.76	0.83	1	1	49	48	49	49	0.000	0.000	0.000	0.000	0.000				
1A5b	NH3	0.04	0.04	1	1	49	49	49	48	0.000	0.000	0.000	0.000	0.000				
2B1	NH3	0.07	0.00	2	2	10	10	10	10	0.000	0.000	0.000	0.000	0.000				
2B2	NH3	0.73	NO	NO	NO	NO	NO	NO	NO	NO	-0.001	0.000	0.000	0.000				
2B10a	NH3	7.73	NA	NA	NA	NA	NA	NA	NA	NA	-0.011	0.005	0.005	0.000				
2C1	NH3	11.90	1.42	2	2	100	200	100	200	0.000	-0.015	0.031	0.015	0.000				
2C7c	NH3	9.19	8.23	5	5	100	446	100	446	0.000	-0.001	0.006	0.001	0.000				
2G	NH3	203.15	74.73	24	24	39	39	45	47	0.000	-0.188	0.113	0.105	0.000				
2H2	NH3	132.33	61.93	10	10	100	445	100	445	0.002	-0.102	0.453	0.102	0.009				
2H3	NH3	1.04	0.25	3	3	100	200	100	200	0.000	-0.001	0.002	0.001	0.000				
2L	NH3	2.38	3.72	24	25	96	100	100	104	0.000	0.002	0.002	0.003	0.000				
3B1a	NH3	9337.10	10414.11	6	6	28	29	28	30	0.228	1.575	1.345	1.419	0.072				
3B1b	NH3	5190.92	7029.68	6	6	27	26	27	27	0.090	2.691	1.082	1.117	0.047				
3B2	NH3	509.75	471.25	6	6	84	86	86	85	0.004	-0.056	0.093	0.071	0.000				
3B3	NH3	6965.04	4876.22	6	6	39	39	40	40	0.093	-3.047	1.422	1.340	0.073				
3B4d	NH3	158.13	157.71	6	6	64	63	63	64	0.000	-0.001	0.023	0.023	0.000				
3B4e	NH3	256.31	385.05	6	6	50	51	51	52	0.001	0.189	0.103	0.113	0.000				
3B4f	NH3	19.65	100.34	6	6	67	67	67	68	0.000	0.118	0.081	0.082	0.000				
3B4gi	NH3	978.79	675.99	6	6	80	80	81	81	0.007	-0.444	0.388	0.366	0.005				
3B4gii	NH3	304.87	647.51	6	6	84	85	84	85	0.007	0.501	0.431	0.439	0.007				
3B4giii	NH3	29.77	23.19	6	6	92	90	91	91	0.000	-0.010	0.010	0.009	0.000				
3B4giv	NH3	124.46	84.51	6	6	82	84	83	84	0.000	-0.059	0.054	0.049	0.000				
3B4h	NH3	14.55	43.47	6	6	48	50	49	49	0.000	0.042	0.022	0.022	0.000				
3Da1	NH3	4258.37	2487.38	5	5	49	49	49	49	0.037	-2.586	1.315	1.271	0.063				
3Da2a	NH3	34567.08	20358.71	6	6	21	20	21	22	0.473	-20.680	4.059	4.101	0.630				
3Da2b	NH3	1169.36	NO	NO	NO	NO	NO	NO	NO	NO	-1.714	0.868	0.854	0.028				
3Da2c	NH3	34.00	951.99	20	20	49	49	52	54	0.006	1.346	0.722	0.753	0.021				
3Da3	NH3	760.92	1406.08	6	6	61	60	61	61	0.018	0.946	0.599	0.612	0.014				
5A	NH3	615.79	217.63	10	10	49	49	50	51	0.000	-0.583	0.314	0.304	0.004				
5B1	NH3	175.00	311.18	19	20	97	98	99	102	0.002	0.200	0.208	0.242	0.002				
5B2	NH3	9.63	218.82	19	20	73	73	75	78	0.001	0.307	0.233	0.246	0.002				
5C1biv	NH3	5.70	1.85	20	19	48	49	52	53	0.000	-0.006	0.003	0.003	0.000				
5C2	NH3	18.03	9.18	47	48	24	25	52	55	0.000	-0.013	0.015	0.014	0.000				
5D1	NH3	90.61	126.07	1	1	48	49	48	49	0.000	0.052	0.026	0.027	0.000				
6A	NH3	845.54	955.34	29	30	98	98	102	105	0.024	0.161	0.618	0.721	0.015				
Total, Monte Carlo simulations		68514.3	53316.3					11.9	11.9	1.0	-22.1	4.7	4.7	1.0				
Total, inventory		68520.2	53317.3								-22.2							

Table A - 35: Uncertainty analysis of PM2.5 emissions, approach 2, for 2020 and for the trend 1990-2020. Monte Carlo simulations were run 200'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C	D	E		F		G		H	I	J		K				
				Emissions 1990	Emissions 2020	Activity data uncertainty 2020		Emission factor uncertainty 2020				Emission combined uncertainty 2020			Emission contribution to variance 2020	Contribution to inventory trend, mean	Contribution to inventory trend uncertainty	
						t	t	(-)%	(+)%			(-)%	(+)%				(-)%	(+)%
1A1a	PM2.5	772.50	44.24	10	10	70	70	70	71	0.000	-4.448	3.386	3.205	0.040				
1A1b	PM2.5	47.66	1.29	1	1	20	19	20	20	0.000	-0.285	0.104	0.092	0.000				
1A1c	PM2.5	4.64	14.54	5	5	20	20	20	20	0.000	0.061	0.020	0.022	0.000				
1A2a	PM2.5	14.80	2.69	2	2	28	27	27	28	0.000	-0.074	0.030	0.029	0.000				
1A2b	PM2.5	20.38	1.00	2	2	30	29	29	30	0.000	-0.119	0.051	0.047	0.000				
1A2c	PM2.5	40.75	5.37	2	2	10	10	10	10	0.000	-0.218	0.070	0.061	0.000				
1A2d	PM2.5	149.61	0.23	2	2	33	32	33	32	0.000	-0.919	0.405	0.387	0.001				
1A2e	PM2.5	25.68	1.39	2	2	10	10	10	10	0.000	-0.149	0.048	0.042	0.000				
1A2f	PM2.5	437.58	41.54	2	2	63	64	64	64	0.000	-2.427	1.741	1.623	0.010				
1A2gvii	PM2.5	728.86	392.77	1	1	50	49	49	49	0.010	-2.060	1.173	1.105	0.005				
1A2gviii	PM2.5	544.76	178.51	2	2	63	64	63	64	0.003	-2.244	1.552	1.530	0.009				
1A3ai(i)	PM2.5	92.40	6.03	1	1	29	30	30	29	0.000	-0.531	0.227	0.207	0.000				
1A3aii(i)	PM2.5	22.68	1.56	1	1	30	29	30	29	0.000	-0.130	0.056	0.051	0.000				
1A3bi	PM2.5	577.89	140.84	1	1	56	56	56	56	0.002	-2.677	1.706	1.607	0.010				
1A3bii	PM2.5	327.15	83.81	1	1	48	47	48	47	0.000	-1.496	0.865	0.778	0.003				
1A3biii	PM2.5	1585.35	68.19	1	1	26	26	27	26	0.000	-9.316	3.552	3.324	0.045				
1A3biv	PM2.5	208.81	25.97	1	1	54	52	53	52	0.000	-1.123	0.687	0.660	0.002				
1A3bvi	PM2.5	689.15	817.03	1	1	49	49	49	50	0.041	0.784	0.423	0.461	0.001				
1A3c	PM2.5	174.35	193.98	1	1	48	50	49	49	0.002	0.121	0.068	0.074	0.000				
1A3dii	PM2.5	59.09	27.08	1	1	49	49	49	49	0.000	-0.197	0.115	0.110	0.000				
1A3ei	PM2.5	0.11	0.05	2	2	27	26	26	27	0.000	0.000	0.000	0.000	0.000				
1A4ai	PM2.5	506.05	313.48	2	2	77	76	76	76	0.015	-1.179	0.960	0.948	0.003				
1A4bi	PM2.5	5226.73	1409.82	4	4	75	74	74	75	0.285	-22.347	12.165	13.170	0.621				
1A4ci	PM2.5	539.21	229.00	21	21	38	38	43	44	0.003	-1.906	1.191	1.103	0.005				
1A4cii	PM2.5	435.10	162.27	1	1	80	77	80	77	0.004	-1.670	1.396	1.373	0.007				
1A5b	PM2.5	86.95	44.82	1	1	49	50	49	50	0.000	-0.259	0.150	0.145	0.000				
1B1a	PM2.5	0.16	0.05	29	29	39	40	47	51	0.000	-0.001	0.000	0.000	0.000				
1B2c	PM2.5	0.44	0.00	22	21	100	239	100	241	0.000	-0.003	0.007	0.003	0.000				
2A1	PM2.5	240.48	156.47	2	2	100	199	100	199	0.024	-0.508	1.006	0.508	0.004				
2A2	PM2.5	7.21	6.55	2	2	100	443	100	442	0.000	-0.004	0.018	0.004	0.000				
2A5a	PM2.5	183.33	233.83	5	5	100	444	100	443	0.342	0.294	0.294	1.317	0.007				
2B5	PM2.5	43.68	26.68	2	2	100	199	100	199	0.001	-0.104	0.211	0.104	0.000				
2B10a	PM2.5	7.86	NA	NA	NA	NA	NA	NA	NA	NA	-0.048	0.024	0.023	0.000				
2C1	PM2.5	817.90	7.87	2	2	95	121	93	123	0.000	-4.892	5.778	4.562	0.125				
2C3	PM2.5	78.33	NO	NO	NO	NO	NO	NO	NO	NO	-0.480	0.967	0.480	0.003				
2C7a	PM2.5	5.66	0.48	5	5	100	201	100	201	0.000	-0.032	0.065	0.032	0.000				
2C7c	PM2.5	1.53	1.42	5	5	100	444	100	444	0.000	-0.001	0.003	0.001	0.000				
2D3c	PM2.5	4.00	3.75	20	20	100	198	100	200	0.000	-0.002	0.012	0.009	0.000				
2D3i	PM2.5	12.00	NA	NA	NA	NA	NA	NA	NA	NA	-0.074	0.325	0.074	0.001				
2G	PM2.5	512.78	375.41	25	24	82	99	83	103	0.038	-0.836	1.465	1.063	0.007				
2H1	PM2.5	235.77	183.11	29	29	100	200	100	203	0.034	-0.319	1.126	0.640	0.003				
2H2	PM2.5	187.99	164.91	10	10	100	445	100	444	0.170	-0.132	0.654	0.171	0.002				
2H3	PM2.5	15.60	3.79	3	3	100	199	100	200	0.000	-0.073	0.147	0.073	0.000				
2I	PM2.5	216.08	46.08	10	10	100	443	100	444	0.013	-0.968	4.374	0.968	0.074				
3B1a	PM2.5	20.61	23.79	6	6	100	298	100	298	0.001	0.019	0.019	0.061	0.000				
3B1b	PM2.5	18.26	21.88	6	6	100	300	100	300	0.001	0.022	0.022	0.067	0.000				
3B2	PM2.5	0.79	0.80	6	6	100	301	100	301	0.000	0.000	0.001	0.001	0.000				
3B3	PM2.5	9.57	6.51	6	6	100	300	100	300	0.000	-0.019	0.057	0.019	0.000				
3B4d	PM2.5	0.14	0.18	6	6	100	302	100	303	0.000	0.000	0.000	0.001	0.000				
3B4e	PM2.5	3.94	6.58	6	6	100	302	100	302	0.000	0.016	0.016	0.049	0.000				
3B4f	PM2.5	0.59	3.31	6	6	100	299	100	299	0.000	0.017	0.017	0.050	0.000				
3B4gi	PM2.5	9.25	11.56	6	6	100	300	100	300	0.000	0.014	0.014	0.043	0.000				
3B4gii	PM2.5	6.78	20.17	6	6	100	301	100	301	0.001	0.082	0.082	0.248	0.000				
3B4giii	PM2.5	1.89	1.77	6	6	100	298	100	298	0.000	-0.001	0.003	0.001	0.000				
3B4giv	PM2.5	1.98	2.90	6	6	100	301	100	302	0.000	0.006	0.006	0.017	0.000				
3B4h	PM2.5	0.24	0.10	6	6	100	301	100	301	0.000	-0.001	0.003	0.001	0.000				
3De	PM2.5	47.50	45.04	5	5	100	200	100	200	0.002	-0.015	0.047	0.023	0.000				
5A	PM2.5	0.73	0.54	10	10	29	30	31	31	0.000	-0.001	0.001	0.001	0.000				
5B2	PM2.5	NA	0.05	19	20	98	98	98	103	0.000	0.000	0.000	0.000	0.000				
5C1a	PM2.5	465.12	244.80	49	49	29	29	56	58	0.005	-1.350	1.794	1.607	0.011				
5C1bi	PM2.5	0.47	NO	NO	NO	NO	NO	NO	NO	NO	-0.003	0.002	0.001	0.000				
5C1biii	PM2.5	16.50	NO	NO	NO	NO	NO	NO	NO	NO	-0.101	0.053	0.048	0.000				
5C1biv	PM2.5	14.25	2.73	20	20	33	34	38	39	0.000	-0.071	0.037	0.034	0.000				
5C1bv	PM2.5	4.39	0.95	5	5	33	32	33	32	0.000	-0.021	0.009	0.009	0.000				
5C2	PM2.5	84.75	43.12	49	46	100	153	100	165	0.001	-0.256	0.580	0.329	0.001				
5E	PM2.5	1.40	1.50	19	20	30	29	35	36	0.000	0.001	0.003	0.003	0.000				
6A	PM2.5	4.16	5.31	29	29	39	40	48	50	0.000	0.007	0.013	0.014	0.000				
Total, Monte Carlo simulations		16600.8	5861.0					30.7	34.0	1.0	-64.6	6.1	7.2	1.0				
Total, inventory		16602.4	5861.5								-64.7							

Table A - 36: Uncertainty analysis of PM10 emissions, approach 2, for 2020 and for the trend 1990-2020. Monte Carlo simulations were run 200'000 times. The reported uncertainties correspond to the borders of the narrowest 95.0 % confidence interval. Contributions to inventory trend (mean, uncertainties, columns I and J) are values normalised by the total inventory base year emission.

A	B	C		D		E		F		G		H		I		J		Contribution to variance of inventory trend
		Emissions 1990	Emissions 2020	Activity data uncertainty 2020		Emission factor uncertainty 2020		Emission combined uncertainty 2020		Emission contribution to variance 2020	Contribution to inventory trend, mean	Contribution to inventory trend uncertainty						
				t	t	(-)%	(+)%	(-)%	(+)%			(-)%	(+)%	Fraction	%	(-)%	(+)%	
1A1a	PM10	1034.30	44.24	10	10	70	69	71	70	0.000	-3.975	2.968	2.866	0.030				
1A1b	PM10	47.66	1.29	1	1	20	20	20	20	0.000	-0.187	0.066	0.061	0.000				
1A1c	PM10	4.89	15.32	5	5	20	20	20	20	0.000	0.042	0.014	0.015	0.000				
1A2a	PM10	20.52	2.94	2	2	27	28	28	27	0.000	-0.071	0.029	0.027	0.000				
1A2b	PM10	29.24	1.05	2	2	30	29	30	30	0.000	-0.114	0.048	0.044	0.000				
1A2c	PM10	40.75	5.37	2	2	10	10	10	10	0.000	-0.143	0.043	0.041	0.000				
1A2d	PM10	166.57	0.23	2	2	32	33	32	33	0.000	-0.671	0.287	0.283	0.000				
1A2e	PM10	25.68	1.39	2	2	10	10	10	10	0.000	-0.098	0.030	0.028	0.000				
1A2f	PM10	832.63	71.03	2	2	63	64	64	64	0.000	-3.063	2.068	2.098	0.016				
1A2gvii	PM10	2173.23	2343.70	1	1	49	49	49	49	0.072	0.684	0.379	0.407	0.001				
1A2gviii	PM10	567.79	187.68	2	2	64	63	64	63	0.001	-1.530	1.070	1.030	0.004				
1A3ai(i)	PM10	102.66	6.03	1	1	29	29	29	29	0.000	-0.390	0.160	0.153	0.000				
1A3aii(i)	PM10	25.20	1.56	1	1	30	29	29	30	0.000	-0.095	0.040	0.037	0.000				
1A3bi	PM10	577.89	140.84	1	1	56	57	56	57	0.000	-1.761	1.106	1.064	0.004				
1A3bii	PM10	327.15	83.81	1	1	47	48	47	48	0.000	-0.982	0.537	0.533	0.001				
1A3biii	PM10	1585.35	68.19	1	1	26	27	27	27	0.000	-6.117	2.305	2.224	0.018				
1A3biv	PM10	208.81	25.97	1	1	53	53	53	52	0.000	-0.738	0.446	0.432	0.001				
1A3bvi	PM10	2049.68	2400.92	1	1	49	49	50	48	0.076	1.411	0.756	0.770	0.002				
1A3c	PM10	982.81	1259.22	1	1	49	48	49	49	0.021	1.112	0.599	0.629	0.001				
1A3dii	PM10	59.09	27.08	1	1	49	49	49	49	0.000	-0.129	0.075	0.070	0.000				
1A3ei	PM10	0.11	0.05	2	2	27	27	27	27	0.000	0.000	0.000	0.000	0.000				
1A4ai	PM10	533.14	333.25	2	2	76	77	77	76	0.004	-0.804	0.670	0.631	0.002				
1A4bi	PM10	5499.56	1477.70	4	4	75	74	75	74	0.066	-15.706	9.947	10.269	0.372				
1A4ci	PM10	543.85	231.29	21	21	38	38	42	45	0.001	-1.260	0.785	0.724	0.002				
1A4cii	PM10	511.19	221.53	1	1	78	78	79	78	0.002	-1.165	0.984	0.936	0.003				
1A5b	PM10	286.52	261.46	1	1	49	49	49	50	0.001	-0.101	0.061	0.058	0.000				
1B1a	PM10	1.60	0.45	30	29	39	39	48	50	0.000	-0.005	0.003	0.003	0.000				
1B2c	PM10	0.44	0.00	22	21	100	237	100	239	0.000	-0.002	0.004	0.002	0.000				
2A1	PM10	374.35	243.58	2	2	100	200	100	200	0.013	-0.521	1.034	0.521	0.004				
2A2	PM10	14.41	13.08	2	2	100	445	100	445	0.000	-0.005	0.024	0.005	0.000				
2A5a	PM10	366.54	467.61	5	5	100	444	100	445	0.290	0.377	0.377	1.699	0.011				
2B5	PM10	52.62	31.73	2	2	100	200	100	200	0.000	-0.084	0.170	0.084	0.000				
2B10a	PM10	17.07	NA	NA	NA	NA	NA	NA	NA	NA	-0.069	0.034	0.032	0.000				
2C1	PM10	1485.46	11.78	2	2	93	123	93	123	0.000	-5.807	6.753	5.388	0.165				
2C3	PM10	113.15	NO	NO	NO	NO	NO	NO	NO	NO	-0.454	0.913	0.454	0.003				
2C7a	PM10	5.96	0.51	5	5	100	201	100	200	0.000	-0.022	0.044	0.022	0.000				
2C7c	PM10	3.06	2.81	5	5	100	445	100	444	0.000	-0.001	0.005	0.001	0.000				
2D3c	PM10	19.98	18.73	20	20	100	201	100	202	0.000	-0.005	0.037	0.030	0.000				
2D3i	PM10	24.00	NA	NA	NA	NA	NA	NA	NA	NA	-0.096	0.420	0.096	0.001				
2G	PM10	588.38	469.64	24	24	82	99	83	103	0.013	-0.477	1.083	0.804	0.003				
2H1	PM10	243.80	189.01	29	29	100	199	100	202	0.008	-0.219	0.789	0.418	0.002				
2H2	PM10	310.39	306.50	10	10	100	442	100	443	0.126	-0.014	0.384	0.321	0.001				
2H3	PM10	15.60	3.79	3	3	100	199	100	199	0.000	-0.048	0.096	0.048	0.000				
2I	PM10	864.32	183.09	10	10	100	442	100	441	0.044	-2.295	10.428	2.295	0.334				
3B1a	PM10	84.47	97.50	6	6	100	301	100	301	0.005	0.052	0.053	0.163	0.000				
3B1b	PM10	74.85	89.69	6	6	100	300	100	300	0.004	0.059	0.059	0.181	0.000				
3B2	PM10	19.76	19.92	6	6	100	301	100	301	0.000	0.001	0.012	0.014	0.000				
3B3	PM10	213.16	145.99	6	6	100	301	100	300	0.010	-0.266	0.799	0.266	0.002				
3B4d	PM10	3.42	4.51	6	6	100	300	100	301	0.000	0.004	0.004	0.013	0.000				
3B4e	PM10	6.20	10.34	6	6	100	301	100	301	0.000	0.017	0.017	0.051	0.000				
3B4f	PM10	0.94	5.29	6	6	100	302	100	302	0.000	0.018	0.018	0.053	0.000				
3B4gi	PM10	123.32	154.16	6	6	100	298	100	298	0.011	0.123	0.123	0.374	0.000				
3B4gii	PM10	67.84	201.67	6	6	100	302	100	302	0.019	0.535	0.535	1.619	0.009				
3B4giii	PM10	10.41	9.72	6	6	100	299	100	300	0.000	-0.003	0.011	0.005	0.000				
3B4giv	PM10	18.52	27.56	6	6	100	300	100	300	0.000	0.036	0.036	0.110	0.000				
3B4h	PM10	0.50	0.83	6	6	100	300	100	301	0.000	0.001	0.001	0.004	0.000				
3De	PM10	1053.99	1003.61	5	5	100	199	100	199	0.211	-0.195	0.602	0.326	0.001				
5A	PM10	0.73	0.54	10	10	29	30	31	31	0.000	-0.001	0.000	0.000	0.000				
5B2	PM10	NA	0.05	20	19	99	98	100	101	0.000	0.000	0.000	0.000	0.000				
5C1a	PM10	516.80	272.00	49	49	50	48	66	72	0.002	-0.986	1.368	1.226	0.006				
5C1bi	PM10	3.08	NO	NO	NO	NO	NO	NO	NO	NO	-0.012	0.006	0.006	0.000				
5C1biii	PM10	24.00	NO	NO	NO	NO	NO	NO	NO	NO	-0.097	0.050	0.046	0.000				
5C1biv	PM10	19.95	3.90	20	19	34	34	39	40	0.000	-0.065	0.034	0.031	0.000				
5C1bv	PM10	4.39	0.95	5	5	32	32	32	33	0.000	-0.014	0.006	0.006	0.000				
5C2	PM10	93.09	47.37	48	46	100	153	100	164	0.000	-0.184	0.415	0.236	0.001				
5E	PM10	2.80	3.00	20	20	29	30	35	36	0.000	0.001	0.003	0.003	0.000				
6A	PM10	203.81	166.69	29	29	39	40	47	50	0.000	-0.150	0.341	0.328	0.000				
Total, Monte Carlo simulations		25277.9	13421.8					28.7	32.2	1.0	-46.7	10.7	11.0	1.0				
Total, inventory		25283.4	13420.8								-46.9							

A5.3.2 Uncertainty estimations, approach 2, sensitivity results

Results for the sensitivity analysis between emissions from each category and inventory emission are given as tornado plots, in Figure A - 5 to Figure A - 10.

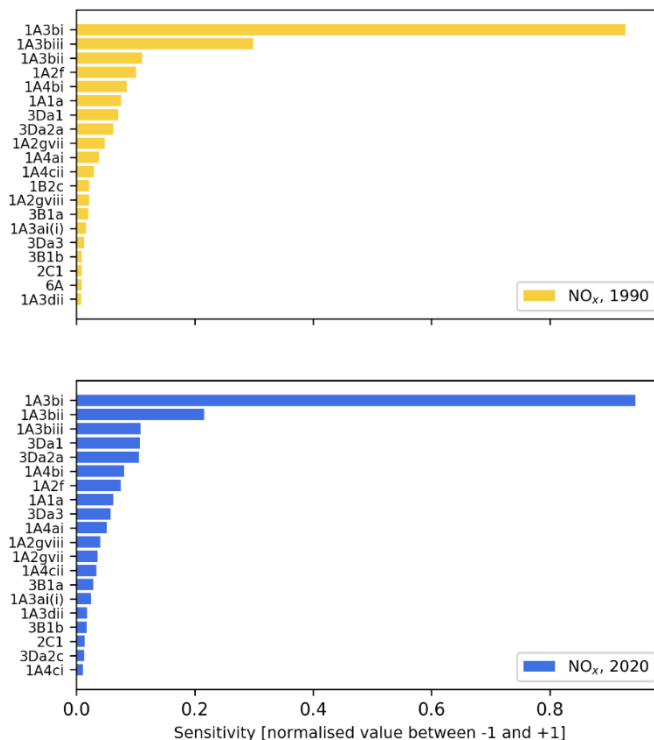


Figure A - 5: Results of the sensitivity analysis between emissions from each category and inventory emissions for NO_x, for the base year 1990 and the reporting year 2020. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

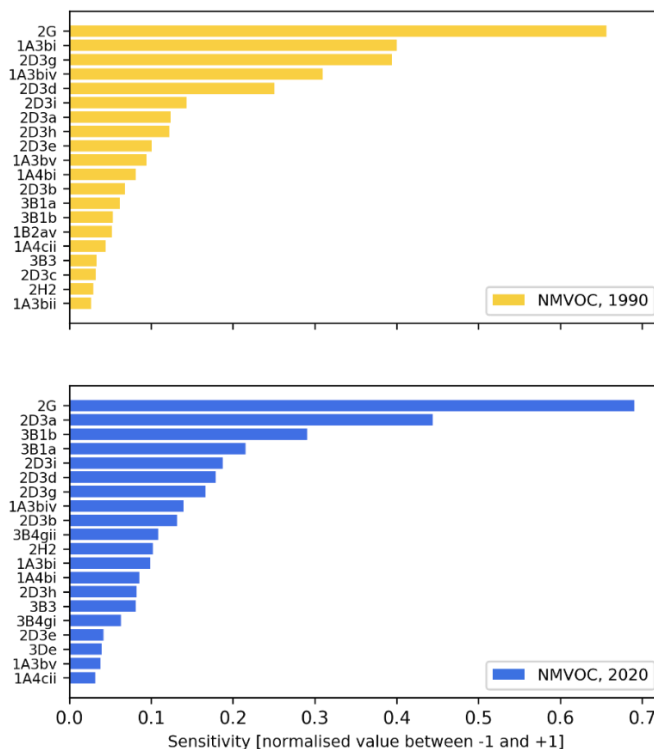


Figure A - 6: Results of the sensitivity analysis between emissions from each category and inventory emissions for NMVOC, for the base year 1990 and the reporting year 2020. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

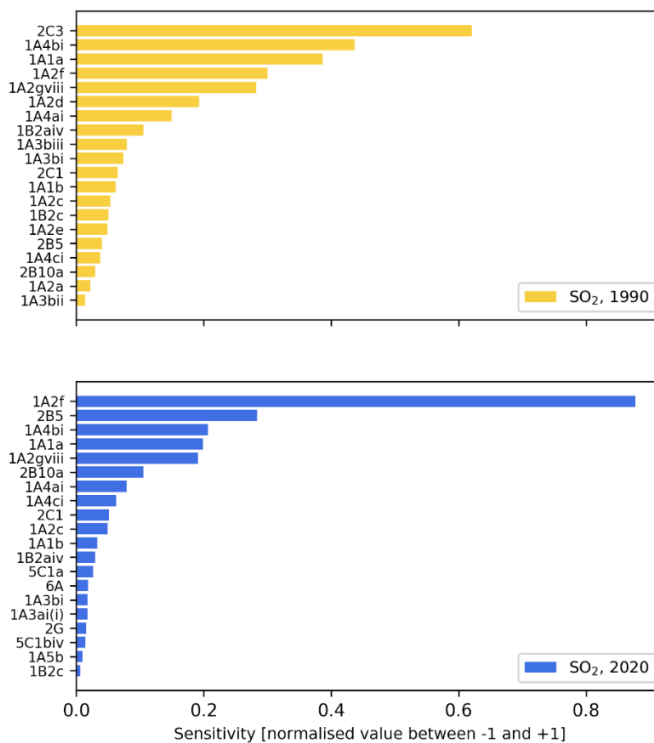


Figure A - 7: Results of the sensitivity analysis between emissions from each category and inventory emissions for SO_x (expressed as SO₂ equivalents), for the base year 1990 and the reporting year 2020. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

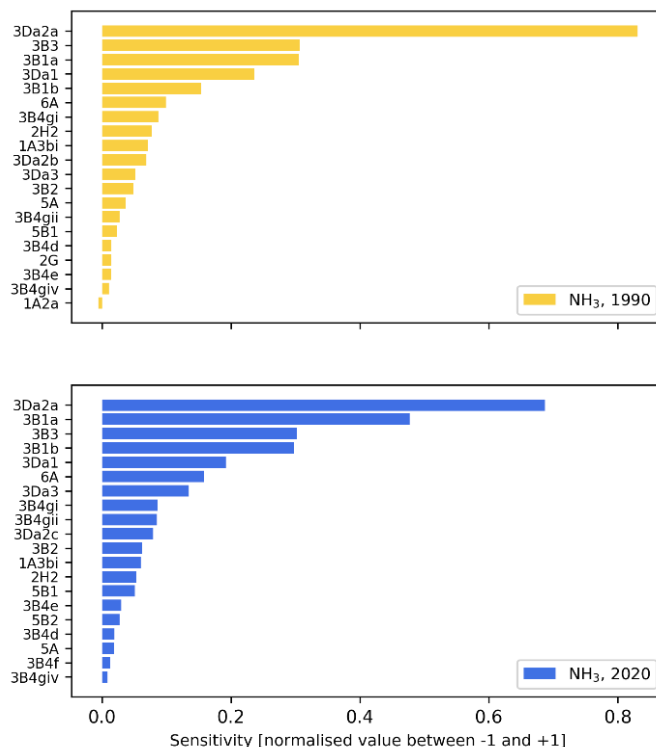


Figure A - 8: Results of the sensitivity analysis between emissions from each category and inventory emissions for NH₃, for the base year 1990 and the reporting year 2020. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

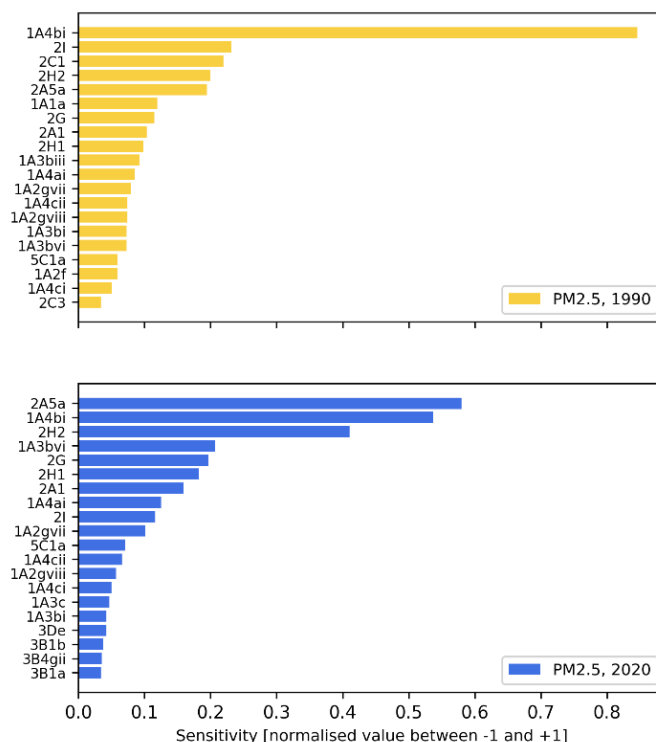


Figure A - 9: Results of the sensitivity analysis between emissions from each category and inventory emissions for PM_{2.5}, for the base year 1990 and the reporting year 2020. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

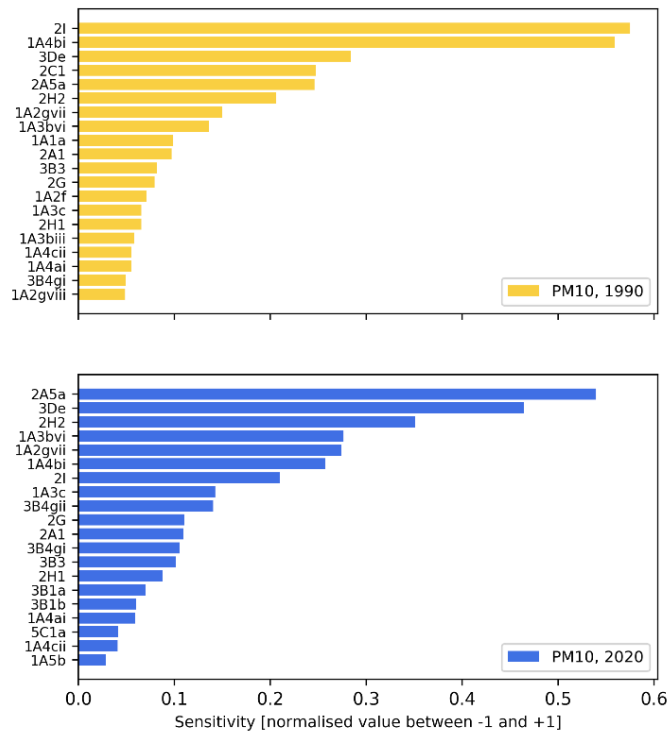


Figure A - 10: Results of the sensitivity analysis between emissions from each category and inventory emissions for PM10, for the base year 1990 and the reporting year 2020. Only the twenty categories ranked first are listed. See chp. 1.7 for details and compare also with Table 1-9 (results for the key category analysis approach 2, i.e. using uncertainties).

A5.3.3 Uncertainty estimations, approach 2, generated distributions for inventory emissions

The following figures present the probability distributions generated by Monte Carlo simulations for each pollutant, for the base year, the reporting year and the trend. Each distribution is fitted using a continuous, normal probability density function, whose integral (or total area) has a value of one, by definition. Therefore, for variables with a large uncertainty, the probability values, depicted on the y-axis, can be very low.

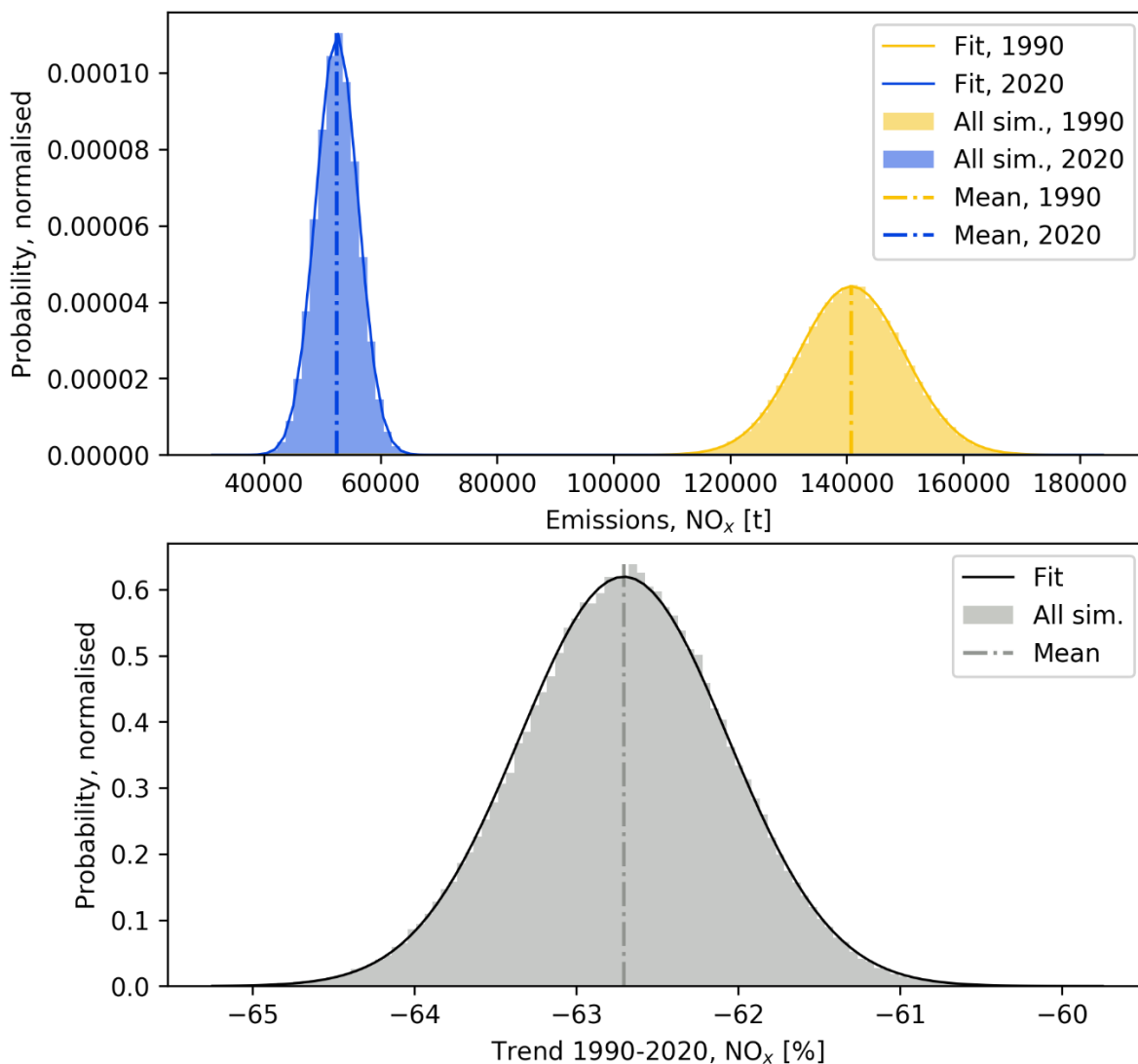


Figure A - 11: Monte Carlo simulations: Distributions obtained for the inventory mean emission for NO_x, for the base year 1990 (top panel, yellow), the reporting year 2020 (top panel, blue) and the trend 1990-2020 (bottom panel, grey). All sim.: all simulations (200'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

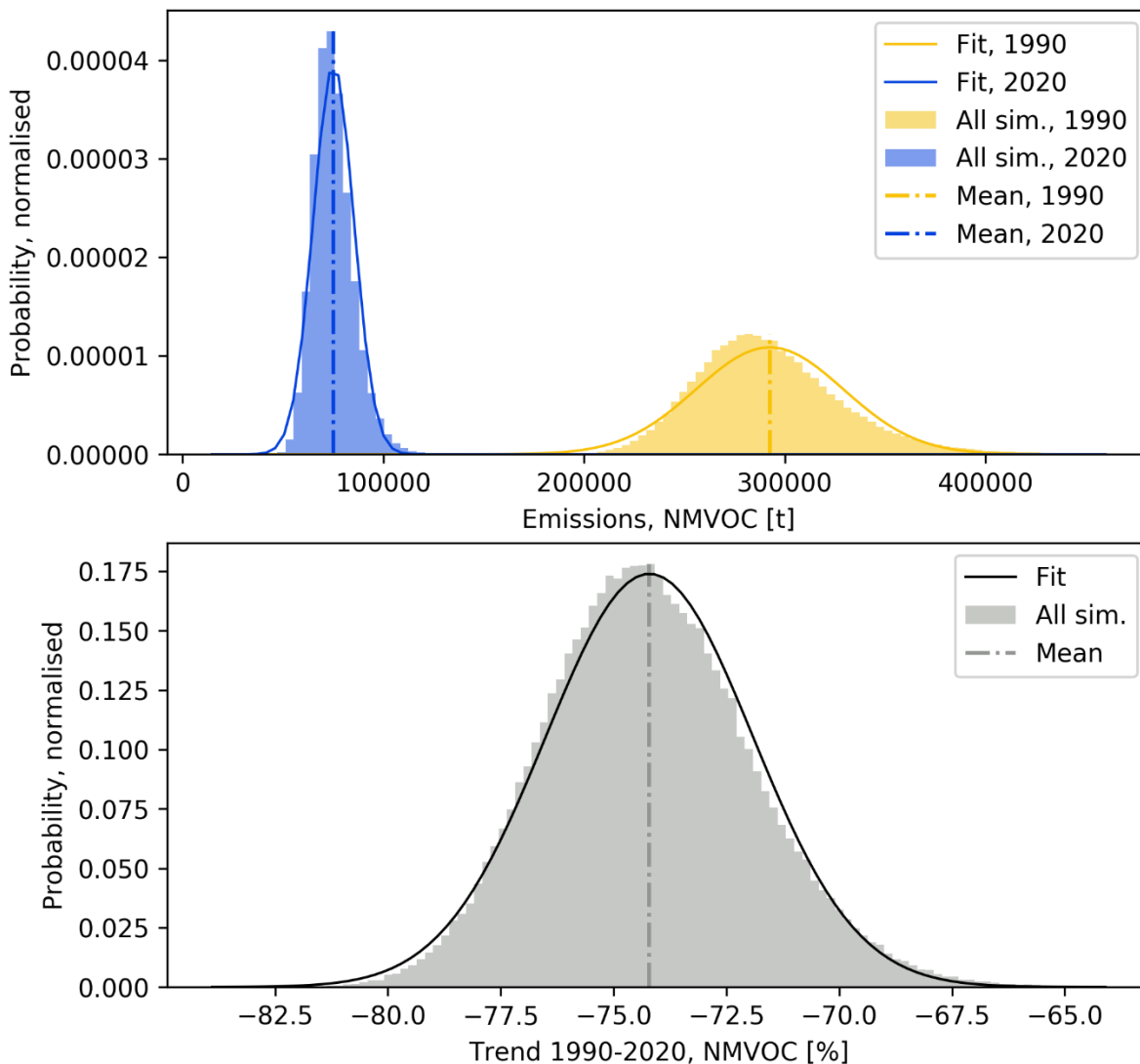


Figure A - 12: Monte Carlo simulations: Distributions obtained for the inventory mean emission for NMVOC, for the base year 1990 (top panel, yellow), the reporting year 2020 (top panel, blue) and the trend 1990-2020 (bottom panel, grey). All sim: all simulations (200'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

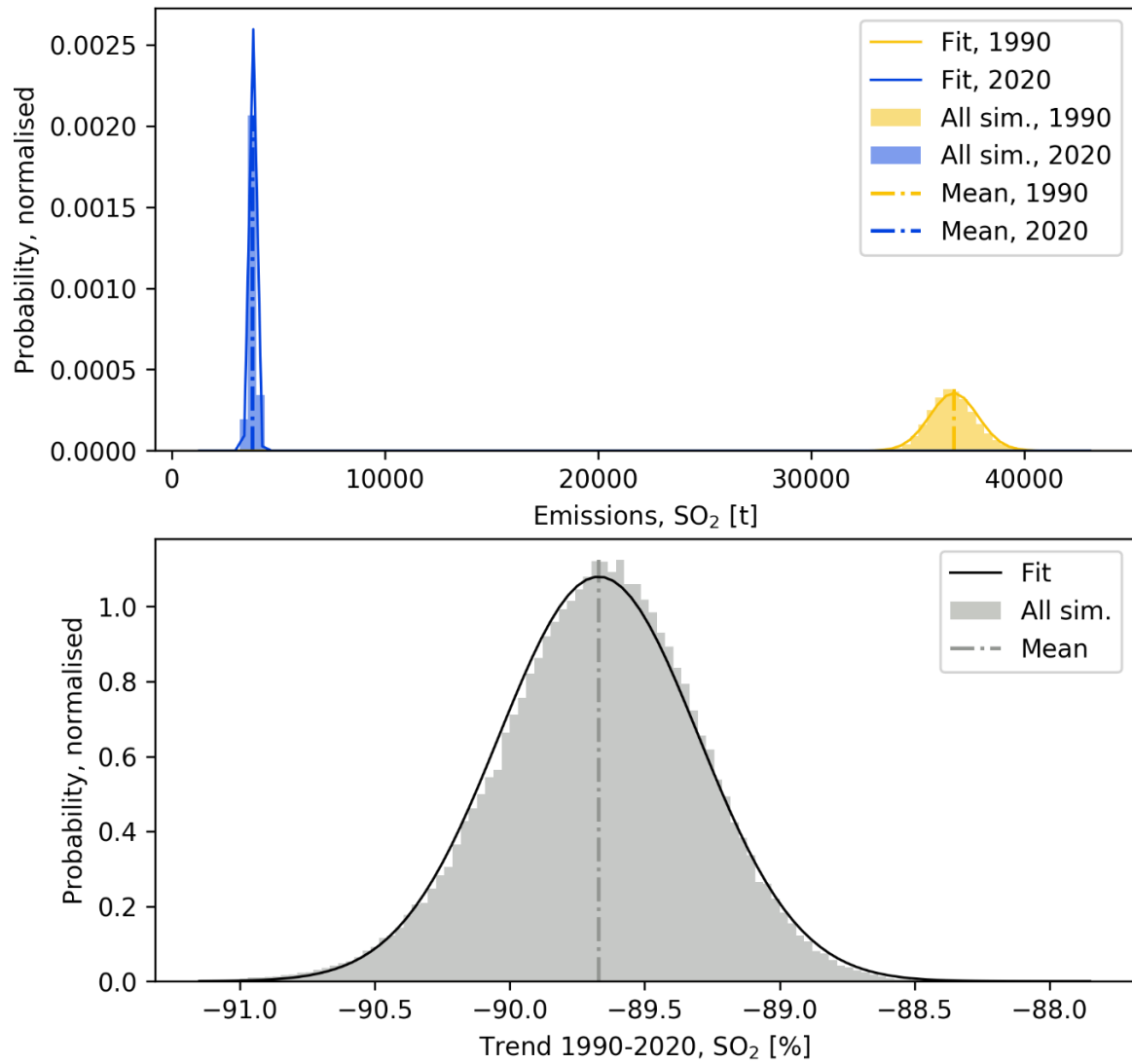


Figure A - 13: Monte Carlo simulations: Distributions obtained for the inventory mean emission for SO₂, for the base year 1990 (top panel, yellow), the reporting year 2020 (top panel, blue) and the trend 1990-2020 (bottom panel, grey). All sim: all simulations (200'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

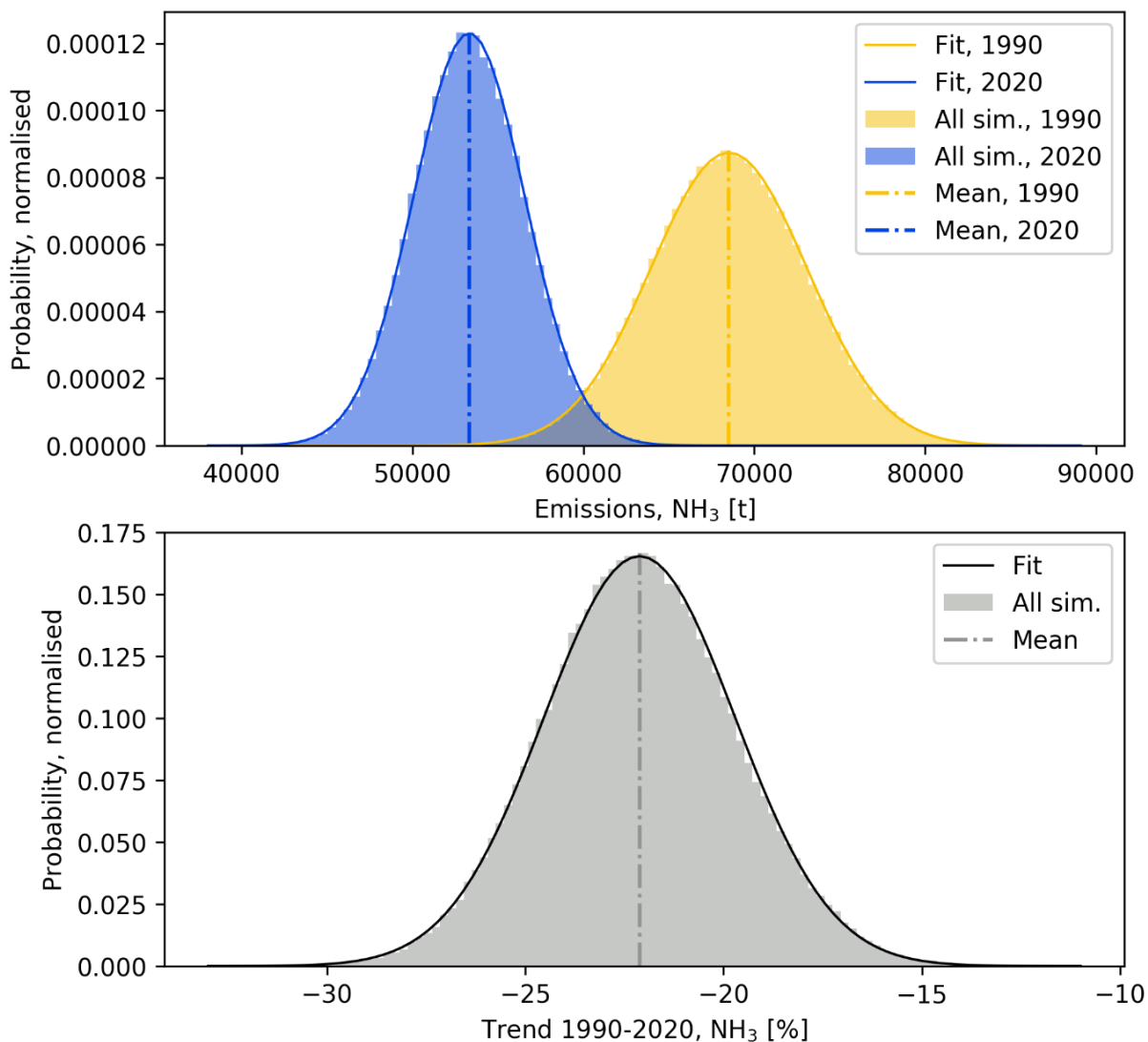


Figure A - 14: Monte Carlo simulations: Distributions obtained for the inventory mean emission for NH₃, for the base year 1990 (top panel, yellow), the reporting year 2020 (top panel, blue) and the trend 1990-2020 (bottom panel, grey). All sim: all simulations (200'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

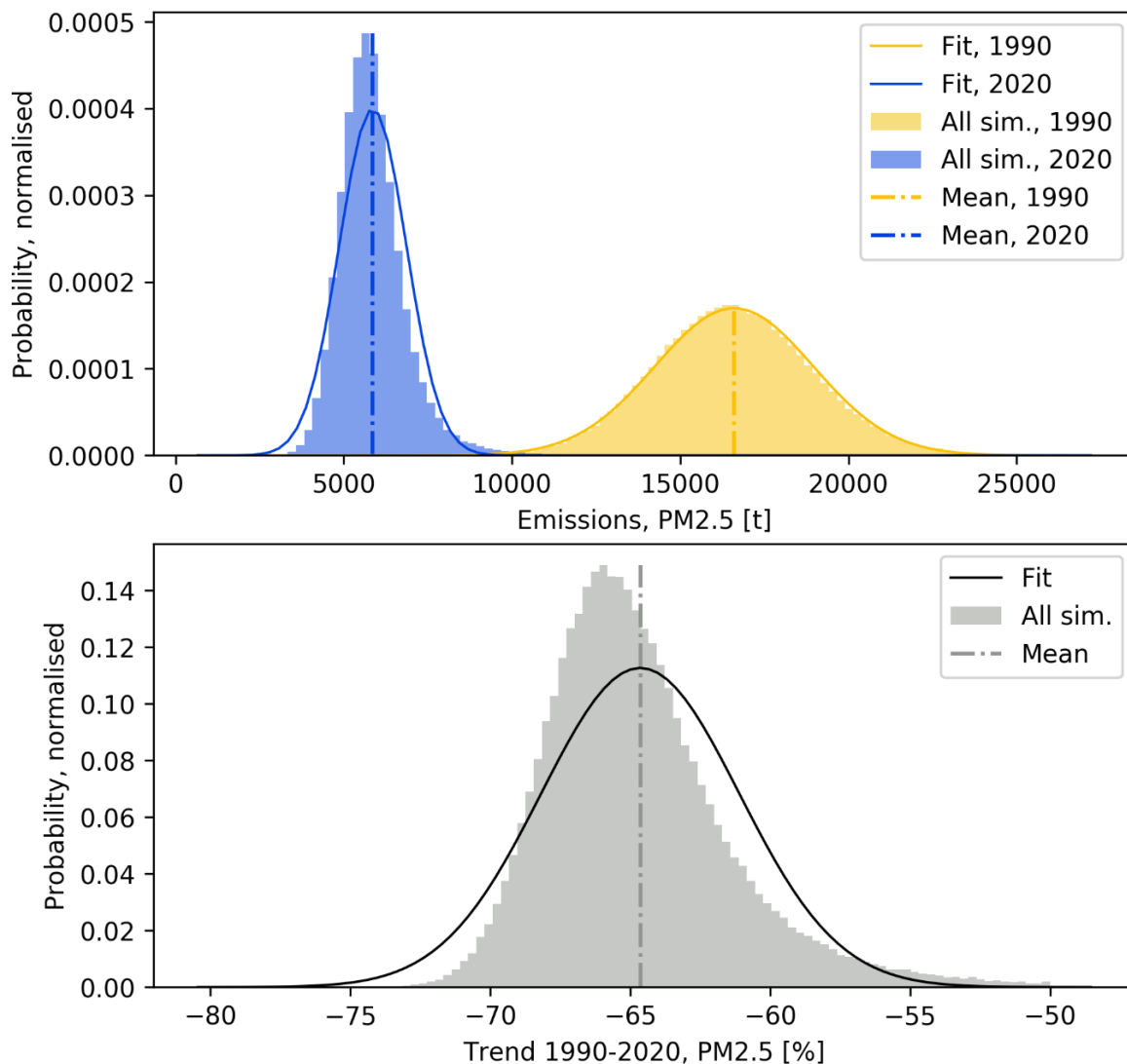


Figure A - 15: Monte Carlo simulations: Distributions obtained for the inventory mean emission for PM2.5, for the base year 1990 (top panel, yellow), the reporting year 2020 (top panel, blue) and the trend 1990-2020 (bottom panel, grey). All sim: all simulations (200'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

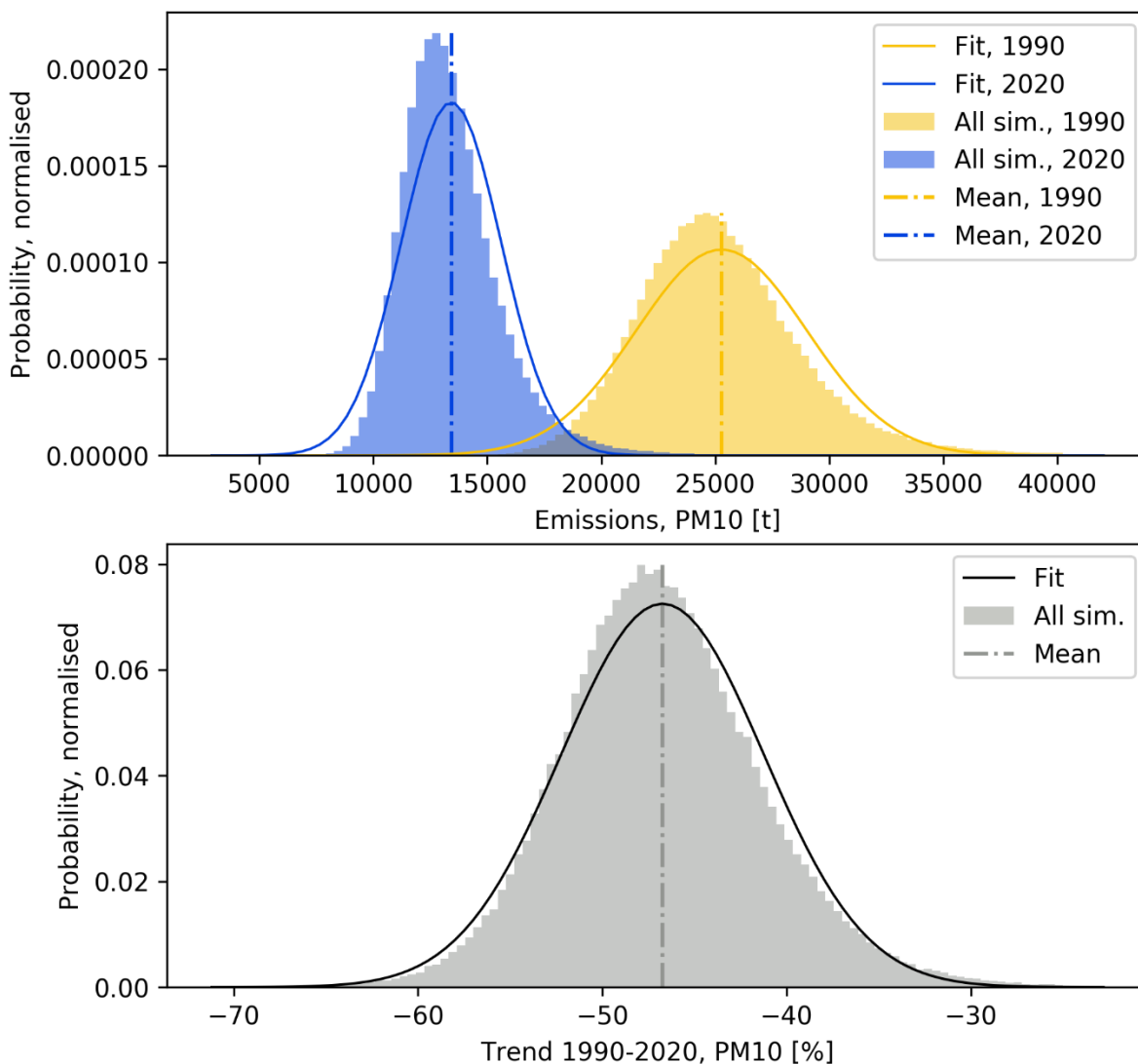


Figure A - 16: Monte Carlo simulations: Distributions obtained for the inventory mean emission for PM10, for the base year 1990 (top panel, yellow), the reporting year 2020 (top panel, blue) and the trend 1990-2020 (bottom panel, grey). All sim: all simulations (200'000 values for each distribution). Fit: fit of the distribution using a normal distribution. Mean: mean inventory emission obtained from the simulations.

Annex 6 Summary information on condensables in PM

Table A - 37: Inclusion/exclusion of the condensable component from PM10 and PM2.5 emission factors.

NFR codes	Source/sector name	PM emissions: the condensable		Emission factor reference and comments
		included	excluded	
1	Energy		X	With the exception of the source categories listed below, no condensables are included in the reported PM emissions.
1A2gvii, 1A3b-d, 1A4aii/bii/cii, 1A5	Road transportation, Nonroad machinery and vehicles	X		Considering the measuring procedure and the maximum temperature of 52°C, it can be assumed that PM condensables are also included in the measurements. The installed technology also plays a role in this context (petrol engines with/without catalytic converter, diesel engines with/without particulate filter, etc.).
1A4bi	Charcoal use, Bonfire	X		The emission factor of particulate matter of these two source categories are based on default Tier-2 emission factor of the EMEP/EEA Guidebook 2019 (chp. 1A4, Table 3-39). These emission factor values correspond to total particles which include both filterable and condensable PM.
2	IPPU		X	
3	Agriculture	NA	NA	
5	Waste		X	
6	Other		X	

A6.1 Emissions of PM condensable from wood energy combustion

The emissions from wood combustion in 1A Fuel combustion activities are calculated by a Tier 2 method using country-specific emission factors (chp. 3.2.1.1.2). For the previous submission of the inventory, the emission factor model was completely revised for the entire time series (including projections) by Zotter et al. (2022). It is based on a large number of air pollution control measurements, laboratory and field measurements, literature data (e.g. beReal, emission factors in the Nordic countries) and the EMEP/EEA guidebook (EMEP/EEA 2019) and takes into account various technology standards of combustion installations and operating influences. For automatic installations >50 kW (chip boilers, combined heat and power plants, plants for renewable waste from wood products), the emission factors of NO_x, NMVOC, TSP and CO were derived based on emission factors of the different operating phases and their effective combustion heat output, taking into account typical shares of the respective phases. Emission factor values were modelled for the years 1990, 2008, 2014, 2020 and 2035, i.e. 2008 and 2014 being the update years of the previous models. Years in between are linearly interpolated. So far, Switzerland's air pollutant emission inventory includes only PM exhaust emissions from wood energy combustion.

Besides the emission factors for PM exhaust, those for PM condensable were also derived. The condensable PM fractions were estimated based on literature data of the TSP/PMexhaust ratios (including measurements by Zotter et al. (2022) on some installation types relevant for Switzerland). The model differentiates between manually operated single room stoves / central heating boilers and (larger) automatic combustion installations, see Table A - 38. For information, the time series of the emission factors and the resulting emissions of PM2.5 condensable for the different installation types are given in Table A - 39 and Table A - 40, respectively.

Table A - 38: TSP/PMexhaust ratios for wood combustion installations (model values, Zotter et al. 2022)

1A Wood combustion	1990	2008	2014	2020
	TSP/PMexhaust			
Open fireplaces	3		2	
Closed fireplaces, log wood stoves				
Pellet stoves				
Log wood hearths				
Log wood boilers				
Log wood dual chamber boilers				
Automatic chip boilers < 50 kW	1.5		1.1	
Automatic pellet boilers < 50 kW				
Automatic chip boilers 50-300 kW w/o wood proc. companies				
Automatic pellet boilers 50-300 kW				
Automatic chip boilers 50-300 kW within wood proc. companies				
Automatic chip boilers 300-500 kW w/o wood proc. companies				
Automatic pellet boilers 300-500 kW				
Automatic chip boilers 300-500 kW within wood proc. companies				
Automatic chip boilers > 500 kW w/o wood proc. companies				
Automatic pellet boilers > 500 kW				
Automatic chip boilers > 500 kW within wood proc. companies				
Combined chip heat and power plants				
Plants for renewable waste from wood products				

Table A - 39: Emission factors of PM2.5 condensable for wood combustion installations in 1A Fuel combustion.

1A Wood combustion	1990	1995	2000	2005	2010
	g PM2.5 condensable/GJ				
Open fireplaces	360	298	235	173	120
Closed fireplaces, log wood stoves	360	293	225	158	108
Pellet stoves	NO	NO	120	90	63
Log wood hearths	540	440	340	240	180
Log wood boilers	360	285	210	135	81
Log wood dual chamber boilers	540	440	340	240	180
Automatic chip boilers < 50 kW	360	298	235	173	120
Automatic pellet boilers < 50 kW	NO	NO	23	12	4.7
Automatic chip boilers 50-300 kW w/o wood proc. companies	68	52	35	19	8.0
Automatic pellet boilers 50-300 kW	NO	NO	23	12	4.7
Automatic chip boilers 50-300 kW within wood proc. companies	68	52	35	19	8.0
Automatic chip boilers 300-500 kW w/o wood proc. companies	68	52	35	19	8.0
Automatic pellet boilers 300-500 kW	NO	NO	NO	12	4.7
Automatic chip boilers 300-500 kW within wood proc. companies	68	52	35	19	8.0
Automatic chip boilers > 500 kW w/o wood proc. companies	56	42	28	14	4.5
Automatic pellet boilers > 500 kW	NO	NO	NO	12	3.5
Automatic chip boilers > 500 kW within wood proc. companies	56	42	29	15	6.0
Combined chip heat and power plants	NO	17	11	4.6	0.61
Plants for renewable waste from wood products	45	34	23	12	3.4

1A Wood combustion	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	g PM2.5 condensable/GJ									
Open fireplaces	113	105	98	90	90	90	90	90	90	90
Closed fireplaces, log wood stoves	104	99	95	90	89	87	86	84	83	81
Pellet stoves	59	54	50	45	44	42	41	39	38	36
Log wood hearths	180	180	180	180	180	180	180	180	180	180
Log wood boilers	77	72	68	63	62	60	59	57	56	54
Log wood dual chamber boilers	180	180	180	180	180	180	180	180	180	180
Automatic chip boilers < 50 kW	113	105	98	90	89	87	86	84	83	81
Automatic pellet boilers < 50 kW	4.5	4.3	4.2	4.0	3.8	3.7	3.5	3.3	3.2	3.0
Automatic pellet boilers 50-300 kW	4.5	4.3	4.2	4.0	3.8	3.7	3.5	3.3	3.2	3.0
Automatic chip boilers 50-300 kW within wood proc. companies	7.5	7.0	6.5	6.0	5.8	5.7	5.5	5.3	5.2	5.0
Automatic chip boilers 300-500 kW w/o wood proc. companies	7.5	7.0	6.5	6.0	5.8	5.7	5.5	5.3	5.2	5.0
Automatic pellet boilers 300-500 kW	4.5	4.3	4.2	4.0	4.2	4.3	4.5	4.7	4.8	5.0
Automatic chip boilers 300-500 kW within wood proc. companies	7.5	7.0	6.5	6.0	5.8	5.7	5.5	5.3	5.2	5.0
Automatic chip boilers > 500 kW w/o wood proc. companies	3.7	2.9	2.2	1.4	1.3	1.2	1.2	1.1	1.0	0.90
Automatic pellet boilers > 500 kW	2.8	2.0	1.3	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Automatic chip boilers > 500 kW within wood proc. companies	5.5	5.0	4.5	4.0	3.8	3.7	3.5	3.3	3.2	3.0
Combined chip heat and power plants	0.47	0.33	0.18	0.040	0.038	0.037	0.035	0.033	0.032	0.030
Plants for renewable waste from wood products	2.6	1.8	1.0	0.20	0.19	0.18	0.17	0.15	0.14	0.13

Table A - 40: Emissions of PM2.5 condensable from wood energy consumption in 1A Fuel combustion.

1A Wood combustion, emissions of PM2.5 condensable	1990	1995	2000	2005	2010
Total	10'633	8'097	4'931	3'285	2'050
Open fireplaces	82	80	46	31	15
Closed fireplaces, log wood stoves	2'618	2'096	1'459	1'108	920
Pellet stoves	NO	NO	0.79	4.3	9.5
Log wood hearths	4'601	3'088	1'611	965	423
Log wood boilers	1'910	1'586	1'072	723	398
Log wood dual chamber boilers	1'060	782	332	115	49
Automatic chip boilers < 50 kW	86	129	129	130	121
Automatic pellet boilers < 50 kW	NO	NO	1.3	9.4	9.8
Automatic chip boilers 50-300 kW w/o wood proc. companies	31	44	41	35	22
Automatic pellet boilers 50-300 kW	NO	NO	0.08	1.3	2.8
Automatic chip boilers 50-300 kW within wood proc. companies	61	61	43	26	12
Automatic chip boilers 300-500 kW w/o wood proc. companies	16	27	25	19	12
Automatic pellet boilers 300-500 kW	NO	NO	NO	0.2	0.9
Automatic chip boilers 300-500 kW within wood proc. companies	28	29	21	12	5.3
Automatic chip boilers > 500 kW w/o wood proc. companies	18	46	48	34	20
Automatic pellet boilers > 500 kW	NO	NO	NO	0.1	0.7
Automatic chip boilers > 500 kW within wood proc. companies	78	93	69	42	18
Combined chip heat and power plants	NO	0.06	2.0	0.6	1.7
Plants for renewable waste from wood products	44	36	31	28	10

1A Wood combustion, emissions of PM2.5 condensable	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	1'529	1'565	1'573	1'136	1'199	1'225	1'140	1'022	998	890
Open fireplaces	9.7	8.9	8.1	5.5	5.8	6.2	6.0	5.6	5.6	5.2
Closed fireplaces, log wood stoves	720	771	813	614	659	684	645	582	573	516
Pellet stoves	7.9	8.8	9.4	7.2	7.9	8.3	7.9	7.3	7.0	6.3
Log wood hearths	292	282	262	176	181	179	162	143	137	121
Log wood boilers	282	275	263	178	183	182	167	148	144	125
Log wood dual chamber boilers	35	34	33	22	21	20	16	12	10	7.6
Automatic chip boilers < 50 kW	90	91	92	67	70	69	63	56	53	45
Automatic pellet boilers < 50 kW	8.1	9.3	10.5	8.4	9.1	9.6	9.2	8.5	8.5	7.5
Automatic chip boilers 50-300 kW w/o wood proc. companies	18	19	21	16	18	19	18	17	17	16
Automatic pellet boilers 50-300 kW	2.6	3.2	3.8	3.4	4.1	4.7	5.0	4.9	5.0	4.7
Automatic chip boilers 50-300 kW within wood proc. companies	9.9	10	10	7.7	8.2	8.4	8.2	7.6	7.3	6.8
Automatic chip boilers 300-500 kW w/o wood proc. companies	9.9	11	11	8.6	9.5	10	9.9	9.2	9.2	8.5
Automatic pellet boilers 300-500 kW	0.9	1.1	1.1	1.0	1.2	1.4	1.6	1.6	1.7	1.7
Automatic chip boilers 300-500 kW within wood proc. companies	4.4	4.4	4.4	3.4	3.5	3.6	3.4	3.3	3.2	3.0
Automatic chip boilers > 500 kW w/o wood proc. companies	15	15	13	6.9	7.6	8.1	7.7	6.9	6.7	6.0
Automatic pellet boilers > 500 kW	0.6	0.5	0.4	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Automatic chip boilers > 500 kW within wood proc. companies	14	14	13	10	10	10	9.2	8.3	8.0	7.3
Combined chip heat and power plants	1.8	1.6	1.0	0.2	0.1	0.1	0.2	0.2	0.2	0.2
Plants for renewable waste from wood products	7.5	5.4	3.5	0.7	0.6	0.8	0.8	0.7	0.6	0.6

Annex 7 Emission time series of main air pollutants, PM2.5 and BC for 1980–2020 and 2025–2050

A7.1 Emission time series by pollutant and aggregated sectors

A7.1.1 NO_x emission time series

Table A - 41: NO_x emissions by sector. The last column indicates the relative trend.

NO _x	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	151.9	147.0	140.8
2	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.1	0.9	0.7
3	4.7	4.8	4.8	4.8	4.8	4.8	4.9	4.9	4.9	4.9
5	0.8	0.8	0.8	0.9	0.9	0.8	0.7	0.6	0.5	0.4
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sum	164.4	163.9	162.7	163.0	164.7	165.0	162.2	158.5	153.4	147.0

NO _x	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	135.0	132.2	126.2	119.2	115.0	112.6	108.7	103.3	103.0	101.6
2	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3
3	4.9	4.9	4.8	4.7	4.6	4.6	4.4	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	140.8	137.9	131.8	124.6	120.4	117.8	113.7	108.1	107.7	106.3

NO _x	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	99.4	96.8	92.0	90.4	89.1	88.6	86.2	83.9	82.1	78.8
2	0.3	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.3
3	4.0	4.0	3.9	3.9	3.8	3.8	3.8	3.9	3.9	3.8
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	104.0	101.5	96.6	95.0	93.6	93.0	90.7	88.4	86.6	83.2

NO _x	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1	78.8	75.7	75.5	75.6	72.0	70.1	68.6	65.2	61.1	58.0	48.5	-45
2	0.4	0.4	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.2	0.2	-27
3	4.0	3.8	3.8	3.8	3.9	3.7	3.8	3.8	3.7	3.6	3.6	-6
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-23
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
Sum	83.4	80.2	79.9	80.0	76.5	74.4	73.0	69.6	65.3	62.1	52.5	-44

Table A - 42: NO_x emissions by sector (projection).

NO _x	2025	2030	2035	2040	2045	2050
	kt					
1	43.9	34.1	27.0	23.8	22.1	20.9
2	0.3	0.3	0.3	0.3	0.3	0.3
3	3.6	3.6	3.6	3.6	3.6	3.6
5	0.1	0.1	0.1	0.1	0.1	0.1
6	0.1	0.1	0.1	0.1	0.1	0.1
Sum	48.0	38.3	31.2	27.9	26.2	25.0

A7.1.2 NMVOC emission time series

Table A - 43: NMVOC emissions by sector. The last column indicates the relative trend.

NMVOC total	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	152.9	152.8	151.7	151.8	150.7	149.4	145.8	141.4	136.5	130.8
2	140.5	141.9	143.4	144.9	146.4	148.8	150.4	152.5	154.7	156.3
3	13.7	13.8	14.0	14.2	14.4	14.5	14.7	14.9	15.0	15.2
5	3.0	2.8	2.6	2.4	2.2	2.1	1.9	1.7	1.5	1.4
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sum	310.2	311.6	312.0	313.5	313.8	314.9	313.0	310.7	308.0	303.8

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	124.9	121.1	106.9	94.4	84.6	77.9	74.1	68.7	65.7	62.4
2	150.8	140.4	130.1	119.9	113.6	106.7	99.4	92.2	84.8	80.3
3	15.3	15.2	15.1	15.0	15.3	15.4	15.4	15.2	15.2	15.4
5	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sum	292.4	278.0	253.4	230.5	214.6	201.2	190.1	177.2	166.9	159.3

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	58.5	54.7	50.1	47.2	43.2	40.4	37.5	34.6	32.9	30.8
2	75.4	71.1	64.9	59.1	53.6	52.6	51.9	51.0	50.1	49.5
3	15.3	15.6	15.8	16.0	16.3	17.0	17.5	18.1	18.6	18.6
5	1.0	1.0	1.1	1.0	1.0	1.0	1.1	1.1	1.2	1.1
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sum	150.4	142.7	132.1	123.6	114.4	111.2	108.2	105.0	102.9	100.2

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1	28.5	25.9	24.7	23.5	21.1	19.9	18.9	18.1	17.3	16.5	14.6	-64
2	49.3	48.1	46.5	45.2	43.9	42.2	40.5	40.5	40.2	40.0	39.7	-25
3	18.6	18.6	18.7	18.8	19.0	19.0	19.0	19.0	19.0	19.0	19.0	12
5	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.7	66
6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	5
Sum	97.9	94.0	91.4	89.1	85.6	82.7	80.2	79.3	78.3	77.4	75.2	-32

Table A - 44: NMVOC emissions by sector (projection).

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
1	12.9	11.2	10.3	9.2	8.5	7.8
2	40.3	40.9	41.3	41.5	41.6	41.7
3	18.8	18.7	18.7	18.7	18.7	18.7
5	2.3	2.8	3.3	3.5	3.7	3.8
6	0.2	0.2	0.2	0.2	0.2	0.2
Sum	74.5	73.9	73.8	73.2	72.7	72.3

A7.1.3 SO_x emission time series

 Table A - 45: SO_x (as SO₂) emissions by sector. The last column indicates the relative trend.

SO2	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
1	111.5	98.6	87.4	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	101.6	90.3	83.8	80.7	73.8	68.0	62.8	55.3	45.5

SO2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
1	35.1	34.8	32.5	28.0	25.2	25.1	23.7	20.4	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	26.3	26.1	24.8	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	2020	05-20
	kt											%
1	9.6	7.7	7.8	7.3	6.6	4.9	4.4	4.1	3.8	3.6	3.2	-75
2	0.8	0.7	0.8	0.6	0.6	0.6	0.8	0.8	0.9	0.8	0.5	-51
3	NA	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	0.0	0.0	0.0	0.0	-53
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-5
Sum	10.5	8.4	8.6	8.0	7.3	5.6	5.2	5.0	4.8	4.4	3.8	-73

 Table A - 46: SO_x (as SO₂) emissions by sector (projection).

SO2	2025	2030	2035	2040	2045	2050
	kt					
1	2.9	3.0	2.8	2.8	2.7	2.6
2	0.6	0.7	0.7	0.7	0.7	0.7
3	NA	NA	NA	NA	NA	NA
5	0.03	0.03	0.03	0.03	0.03	0.03
6	0.01	0.01	0.01	0.01	0.01	0.01
Sum	3.6	3.7	3.6	3.5	3.4	3.4

A7.1.4 NH₃ emission time series

 Table A - 47: NH₃ emissions by sector. 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	60.8	60.9	61.0	61.2	61.7	62.3	62.8	63.3	63.8	64.2
5	2.3	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.4	1.2
6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Sum	64.8	64.8	64.9	64.9	65.3	65.7	66.3	66.9	67.5	68.0

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	63.4	62.5	61.5	61.0	60.5	58.9	56.5	56.0	55.2
5	0.9	0.9	0.9	0.9	0.8	0.8	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	68.5	67.5	66.9	66.0	65.6	65.4	64.2	61.9	61.6	61.2

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	4.9	4.9	4.7	4.4	4.1	3.9	3.6	3.4	3.3	3.0
2	0.4	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3
3	54.5	54.8	54.1	53.1	52.8	53.7	54.2	54.9	54.6	53.1
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	61.6	61.8	60.9	59.6	59.1	59.7	59.9	60.4	59.9	58.2

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1	2.8	2.5	2.3	2.0	1.8	1.6	1.6	1.5	1.4	1.4	1.2	-69
2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	-57
3	53.0	52.3	52.0	51.5	52.1	51.5	51.4	51.4	51.0	50.2	50.1	-7
5	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.9	0.8	0.9	0.9	-5
6	0.9	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0	1.0	9
Sum	57.9	56.9	56.3	55.6	56.0	55.2	55.1	55.0	54.4	53.6	53.3	-11

 Table A - 48: NH₃ emissions by sector (projection).

NH3	2025	2030	2035	2040	2045	2050
	kt					
1	1.2	1.2	1.1	1.1	1.0	0.9
2	0.1	0.1	0.1	0.1	0.1	0.1
3	49.8	49.6	49.6	49.6	49.6	49.6
5	1.0	1.1	1.2	1.2	1.3	1.3
6	1.0	1.0	1.0	1.0	1.0	1.0
Sum	53.1	53.0	53.0	53.0	52.9	52.9

A7.1.5 PM2.5 emission time series

Table A - 49: PM2.5 emissions by sector. 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	13.3
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	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
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	13.3	13.6	13.0	12.5	11.8	11.8	11.8	10.8	10.7	10.4
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	16.6	16.8	16.3	15.7	14.8	14.5	14.4	13.4	12.9	12.5

PM2.5	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	9.8	9.7	9.0	9.0	8.7	8.7	8.4	7.9	7.9	7.4
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	11.9	11.7	11.1	11.0	10.8	10.7	10.4	10.0	10.0	9.4

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1	7.3	6.4	6.2	6.0	5.2	5.1	5.0	4.9	4.7	4.6	4.2	-52
2	1.5	1.5	1.5	1.5	1.4	1.3	1.3	1.3	1.3	1.2	1.2	-18
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	12
5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-23
6	0.005	0.005	0.006	0.006	0.005	0.006	0.006	0.006	0.006	0.005	0.005	28
Sum	9.3	8.3	8.1	7.9	7.1	6.9	6.8	6.7	6.4	6.2	5.9	-45

Table A - 50: PM2.5 emissions by sector (projection).

PM2.5	2025	2030	2035	2040	2045	2050
	kt					
1	4.0	3.8	3.5	3.4	3.3	3.2
2	1.3	1.4	1.4	1.4	1.4	1.4
3	0.1	0.1	0.1	0.1	0.1	0.1
5	0.3	0.2	0.2	0.2	0.2	0.1
6	0.005	0.005	0.005	0.005	0.005	0.005
Sum	5.7	5.5	5.3	5.2	5.0	4.9

A7.1.6 BC emission time series

Table A - 51: BC emissions by sector. 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	5.27	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	5.71	5.96	5.64	5.46	5.03	5.08	5.13	4.59	4.52	4.36
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	5.76	6.00	5.69	5.50	5.07	5.11	5.17	4.63	4.55	4.40

BC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
1	4.05	3.97	3.69	3.70	3.56	3.52	3.34	3.04	2.95	2.71
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	4.08	4.01	3.72	3.73	3.59	3.55	3.37	3.07	2.98	2.73

BC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1	2.59	2.12	1.99	1.86	1.50	1.45	1.39	1.28	1.20	1.14	1.00	-72
2	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	-49
3	NA	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	0.02	-22
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	-16
Sum	2.61	2.15	2.02	1.89	1.53	1.47	1.42	1.30	1.23	1.16	1.02	-71

Table A - 52: BC emissions by sector (projection).

BC	2025	2030	2035	2040	2045	2050
	kt					
1	0.79	0.63	0.50	0.45	0.42	0.38
2	0.001	0.001	0.001	0.001	0.001	0.001
3	NA	NA	NA	NA	NA	NA
5	0.02	0.02	0.01	0.01	0.01	0.01
6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sum	0.81	0.65	0.52	0.47	0.43	0.40

A7.2 1 Energy

A7.2.1 1 Energy: NO_x

Table A - 53: NO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2. The last column indicates the relative trend.

NO _x	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	21	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	0.28	0.27	0.27	0.24
Sum	158	157	156	156	158	158	155	152	147	141

NO _x	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	22	20	19	20	19	18	16	16	16
1A3	83	81	76	72	69	67	64	63	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	113	109	103	103	102

NO _x	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	62	59	57	56	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	99	97	92	90	89	89	86	84	82	79

NO _x	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1A1	3.0	2.9	3.0	3.1	2.9	2.4	2.4	2.4	2.4	2.4	2.4	-18
1A2	12	11	11	11	10	9.4	9.2	8.8	8.2	7.9	7.3	-49
1A3	49	49	49	49	48	47	45	43	40	38	29	-46
1A4	14	12	12	13	11	11	11	11	9.8	9.7	8.9	-45
1A5	0.54	0.49	0.51	0.50	0.51	0.49	0.49	0.45	0.43	0.39	0.40	-34
1B2	0.11	0.093	0.062	0.074	0.090	0.051	0.0030	0.0023	0.0025	0.0017	0.0017	-99
Sum	79	76	75	76	72	70	69	65	61	58	48	-45

Table A - 54: NO_x emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2 (projection).

NO _x	2025	2030	2035	2040	2045	2050
	kt					
1A1	2.5	2.6	2.7	2.8	2.9	2.9
1A2	6.7	5.8	5.3	5.2	5.2	5.1
1A3	26	18	12	9.9	8.7	8.1
1A4	7.8	7.0	6.0	5.4	4.8	4.2
1A5	0.53	0.55	0.54	0.53	0.52	0.52
1B2	0.0017	0.0017	0.0017	0.00	0.0017	0.0017
Sum	44	34	27	24	22	21

A7.2.2 1 Energy: NMVOC

Table A - 55: 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	112	107	102	96
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	15	15	15	15	16	16	16
Sum	153	153	152	152	151	149	146	141	137	131

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	89	81	71	62	54	50	46	43	41	39
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	17	20	17	14	13	10	10	9	8	7.5
Sum	125	121	107	94	85	78	74	69	66	62

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	2.2	2.1	2.1	2.1	2.0	1.9	1.8	1.6
1A3	37	33	30	27	25	23	21	20	18	17
1A4	13	12	12	11	11	10	9.9	8.9	8.9	8.4
1A5	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.095	0.092
1B2	6.7	6.3	5.7	5.9	5.0	4.5	4.5	4.0	3.8	3.7
Sum	58	55	50	47	43	40	37	35	33	31

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1A1	0.20	0.18	0.18	0.17	0.16	0.16	0.17	0.17	0.18	0.19	0.18	-19
1A2	1.6	1.4	1.4	1.3	1.2	1.1	1.1	1.0	1.00	0.96	0.91	-56
1A3	16	15	13	12	11	11	10	9.6	9.2	8.7	7.3	-68
1A4	8.3	6.9	6.9	6.8	5.5	5.5	5.6	5.3	4.9	4.8	4.5	-57
1A5	0.090	0.082	0.082	0.080	0.079	0.075	0.076	0.070	0.068	0.062	0.063	-42
1B2	2.7	2.7	2.8	2.8	2.7	2.3	2.0	1.9	1.9	1.8	1.7	-63
Sum	29	26	25	23	21	20	19	18	17	17	15	-64

Table A - 56: NMVOC emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2 (projection).

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.18	0.18	0.19	0.20	0.20	0.21
1A2	0.85	0.83	0.81	0.81	0.79	0.78
1A3	6.3	5.2	4.6	4.2	3.7	3.3
1A4	3.9	3.4	2.9	2.7	2.5	2.3
1A5	0.083	0.086	0.086	0.085	0.084	0.083
1B2	1.6	1.5	1.6	1.3	1.2	1.1
Sum	13	11	10	9	8.5	7.8

A7.2.3 1 Energy: SO_x

Table A - 57: SO_x (as SO₂) 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	50	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	0.94	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	0.99	0.83	0.82	0.75	0.63	0.71	0.65	0.66	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	0.23
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	0.59	0.61	0.60	0.56	0.62	0.51	0.30	0.27	0.31	0.23
Sum	16	16	14	14	14	13	13	11	11	10

SO2	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											
1A1	1.7	1.5	1.9	1.8	2.1	0.82	0.39	0.39	0.32	0.29	0.29	-83
1A2	3.0	2.5	2.5	2.3	2.2	2.1	2.1	2.0	2.1	1.9	1.9	-55
1A3	0.23	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.26	0.26	0.13	-36
1A4	4.5	3.2	3.0	2.8	1.8	1.6	1.6	1.4	1.1	1.1	0.9	-86
1A5	0.037	0.033	0.035	0.036	0.037	0.036	0.038	0.034	0.034	0.030	0.032	-16
1B2	0.22	0.19	0.12	0.15	0.16	0.082	0.019	0.018	0.019	0.016	0.017	-97
Sum	9.6	7.7	7.8	7.3	6.6	4.9	4.4	4.1	3.8	3.6	3.2	-75

Table A - 58: SO_x (as SO₂) emissions from sector 1 Energy by source categories 1A1-1A5 and 1B2 (projection).

SO2	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.35	0.4	0.41	0.42	0.42	0.43
1A2	1.8	1.8	1.7	1.7	1.6	1.6
1A3	0.26	0.27	0.26	0.25	0.24	0.23
1A4	0.46	0.42	0.37	0.34	0.30	0.27
1A5	0.047	0.050	0.050	0.050	0.049	0.049
1B2	0.017	0.017	0.017	0.017	0.017	0.017
Sum	2.9	3.0	2.8	2.8	2.7	2.6

A7.2.4 1 Energy: NH₃

Table A - 59: NH₃ 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
1B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
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
1B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
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	0.17	0.16
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
1B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum	4.9	4.9	4.7	4.4	4.1	3.9	3.6	3.4	3.3	3.0

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1A1	0.035	0.037	0.040	0.042	0.033	0.031	0.031	0.033	0.032	0.033	0.033	30
1A2	0.24	0.23	0.22	0.21	0.24	0.21	0.23	0.22	0.21	0.21	0.20	2.8
1A3	2.4	2.1	1.9	1.6	1.4	1.3	1.2	1.1	1.0	1.0	0.9	-76
1A4	0.16	0.13	0.14	0.14	0.12	0.12	0.13	0.13	0.12	0.12	0.12	-24
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	3.4
1B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum	2.8	2.5	2.3	2.0	1.8	1.6	1.6	1.5	1.4	1.4	1.2	-69

Table A - 60: NH₃ emissions from sector 1 Energy by source categories 1A1-1A5 (projection).

NH3	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.036	0.04	0.04	0.04	0.04	0.04
1A2	0.20	0.20	0.20	0.20	0.19	0.19
1A3	0.86	0.83	0.80	0.74	0.67	0.58
1A4	0.12	0.11	0.10	0.09	0.087	0.080
1A5	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
1B	NA	NA	NA	NA	NA	NA
Sum	1.2	1.2	1.1	1.1	1.0	0.89

A7.2.5 1 Energy: PM2.5

Table A - 61: 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
1B2	0.000643	0.000625	0.000608	0.000590	0.000572	0.000589	0.000584	0.000574	0.000570	0.000505
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	0.61	0.57	0.55	0.52	0.45	0.44	0.37
1A2	2.0	2.0	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	6.7	7.1	6.6	6.4	5.8	5.9	6.0	5.3	5.2	5.0
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
1B2	0.000443	0.000658	0.000608	0.000671	0.000686	0.000653	0.000747	0.000699	0.000711	0.000714
Sum	13	14	13	13	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	1.7	1.7	1.6	1.6	1.6	1.5	1.5	1.4	1.3	1.2
1A3	3.2	3.1	2.9	2.9	2.8	2.8	2.8	2.7	2.6	2.5
1A4	4.5	4.6	4.2	4.3	4.1	4.1	3.9	3.6	3.7	3.6
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
1B2	0.000652	0.000691	0.000691	0.000652	0.000732	0.000593	0.000277	0.000274	0.000333	0.000236
Sum	9.8	9.7	9.0	9.0	8.7	8.7	8.4	7.9	7.9	7.4

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1A1	0.19	0.16	0.17	0.15	0.15	0.09	0.066	0.066	0.063	0.065	0.060	-67
1A2	1.1	0.93	0.88	0.82	0.71	0.71	0.70	0.68	0.66	0.64	0.62	-59
1A3	2.4	2.2	2.1	2.0	1.9	1.8	1.8	1.7	1.7	1.6	1.4	-52
1A4	3.6	3.0	3.0	2.9	2.4	2.4	2.5	2.4	2.2	2.2	2.1	-48
1A5	0.050	0.049	0.048	0.048	0.047	0.046	0.046	0.046	0.045	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	0.00005	-35
1B2	0.000236	0.000195	0.000130	0.000156	0.000190	0.000099	0.000006	0.000005	0.000005	0.000003	0.000004	-99
Sum	7.3	6.4	6.2	6.0	5.2	5.1	5.0	4.9	4.7	4.6	4.2	-52

Table A - 62: PM2.5 emissions from sector 1 Energy by source categories 1A1-1A5 and 1B1 (projection).

PM2.5	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.066	0.07	0.072	0.073	0.074	0.075
1A2	0.55	0.51	0.50	0.51	0.51	0.51
1A3	1.5	1.5	1.5	1.5	1.5	1.5
1A4	1.9	1.7	1.4	1.3	1.2	1.1
1A5	0.047	0.047	0.047	0.046	0.046	0.046
1B1	0.00005	0.00005	0.00005	0.00004	0.00004	0.00004
1B2	0.000004	0.000004	0.000004	0.000004	0.000004	0.000004
Sum	4.0	3.8	3.5	3.4	3.3	3.2

A7.2.6 1 Energy: BC

Table A - 63: 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	0.43	0.43	0.43	0.44	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
1B2	0.000154	0.000150	0.000146	0.000142	0.000137	0.000141	0.000140	0.000138	0.000137	0.000121
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	0.43	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	3.6	3.2	3.2	3.3	2.8	2.7	2.6
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
1B2	0.000106	0.000158	0.000146	0.000161	0.000165	0.000157	0.000179	0.000168	0.000171	0.000171
Sum	5.7	6.0	5.6	5.5	5.0	5.1	5.1	4.6	4.5	4.4

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	0.40	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	2.3	2.3	2.1	2.1	2.0	1.9	1.8	1.6	1.6	1.5
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
1B2	0.000156	0.000166	0.000166	0.000156	0.000176	0.000142	0.000066	0.000066	0.000080	0.000057
Sum	4.1	4.0	3.7	3.7	3.6	3.5	3.3	3.0	3.0	2.7

BC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
1A1	0.011	0.0098	0.010	0.0086	0.0082	0.0045	0.0034	0.0033	0.0032	0.0035	0.0029	-75
1A2	0.14	0.12	0.10	0.09	0.072	0.065	0.061	0.056	0.052	0.048	0.044	-86
1A3	0.92	0.83	0.71	0.62	0.56	0.49	0.42	0.37	0.37	0.33	0.26	-79
1A4	1.5	1.2	1.2	1.1	0.86	0.89	0.90	0.85	0.77	0.75	0.69	-64
1A5	0.0058	0.0050	0.0048	0.0044	0.0042	0.0038	0.0038	0.0035	0.0034	0.0031	0.0032	-68
1B1	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00003	0.00003	0.00003	0.00003	-35
1B2	0.000057	0.000047	0.000031	0.000037	0.000046	0.000024	0.000001	0.000001	0.000001	0.000001	0.000001	-99
Sum	2.6	2.1	2.0	1.9	1.5	1.4	1.4	1.3	1.2	1.1	1.0	-72

Table A - 64: BC emissions from sector 1 Energy by source categories 1A1-1A5 and 1B1 (projection).

BC	2025	2030	2035	2040	2045	2050
	kt					
1A1	0.0031	0.0033	0.0034	0.0034	0.0034	0.0034
1A2	0.021	0.012	0.010	0.010	0.010	0.010
1A3	0.21	0.17	0.16	0.15	0.15	0.14
1A4	0.55	0.44	0.33	0.29	0.25	0.22
1A5	0.0041	0.0042	0.0041	0.0039	0.0039	0.0038
1B1	0.00003	0.00003	0.00003	0.00003	0.00003	0.00002
1B2	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
Sum	0.79	0.63	0.50	0.45	0.42	0.38

A7.3 2 Industrial processes and product use

A7.3.1 2 Industrial processes and product use: NO_x

Table A - 65: 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.

NO _x	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

NO _x	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

NO _x	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

NO _x	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
2A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-17
2B	0.08	0.08	0.08	0.06	0.06	0.04	0.06	0.07	0.03	0.02	0.02	-77
2C	0.17	0.19	0.18	0.17	0.19	0.18	0.18	0.18	0.18	0.16	0.16	-8
2G	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-21
2H	0.08	0.10	0.08	0.08	0.07	0.07	0.02	0.03	0.03	0.02	0.02	-20
Sum	0.38	0.40	0.37	0.34	0.36	0.33	0.29	0.30	0.27	0.23	0.23	-27

Table A - 66: NO_x emissions from sector 2 Industrial processes and product use by source categories 2A-2C, 2G and 2H (projection).

NO _x	2025	2030	2035	2040	2045	2050
	kt					
2A	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
2C	0.17	0.18	0.18	0.18	0.18	0.18
2G	0.02	0.02	0.02	0.02	0.02	0.02
2H	0.04	0.05	0.07	0.07	0.07	0.07
Sum	0.26	0.28	0.30	0.30	0.30	0.30

A7.3.2 2 Industrial processes and product use: NMVOC

Table A - 67: 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	0.27	0.28	0.29
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	122.66	114.05	105.84	97.39	92.74	87.47	82.10	76.73	70.98	67.03
2G	23.73	22.08	20.41	18.79	17.24	15.70	13.99	12.23	10.71	10.14
2H	2.67	2.66	2.68	2.70	2.63	2.59	2.45	2.40	2.33	2.38
Sum	150.82	140.37	130.10	119.87	113.61	106.74	99.37	92.15	84.81	80.33

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	62.55	58.73	52.84	47.37	41.95	41.35	40.92	40.07	39.32	39.13
2G	9.63	9.28	8.99	8.69	8.61	8.36	8.04	7.93	7.71	7.51
2H	2.41	2.41	2.49	2.51	2.53	2.38	2.45	2.50	2.54	2.51
Sum	75.35	71.11	64.90	59.12	53.61	52.61	51.91	51.01	50.12	49.51

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
2A	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	-17
2B	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	-46
2C	0.35	0.39	0.32	0.31	0.31	0.29	0.27	0.28	0.28	0.22	0.20	-55
2D	39.05	37.72	36.25	35.08	33.90	32.33	30.86	30.97	30.70	30.63	30.36	-27
2G	7.30	7.34	7.37	7.33	7.18	7.10	7.03	6.93	6.85	6.84	6.83	-18
2H	2.55	2.55	2.47	2.43	2.43	2.41	2.28	2.28	2.28	2.28	2.25	-5
Sum	49.32	48.06	46.47	45.21	43.89	42.18	40.49	40.50	40.16	40.01	39.68	-25

Table A - 68: NMVOC emissions from sector 2 Industrial processes and product use by source categories 2A-2D, 2G and 2H (projection).

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
2A	0.03	0.03	0.03	0.03	0.03	0.03
2B	0.02	0.02	0.02	0.02	0.02	0.02
2C	0.21	0.22	0.22	0.22	0.22	0.22
2D	30.67	30.97	31.13	31.22	31.28	31.32
2G	6.91	6.99	7.07	7.08	7.09	7.09
2H	2.48	2.71	2.82	2.90	2.95	3.01
Sum	40.32	40.94	41.29	41.47	41.59	41.69

A7.3.3 2 Industrial processes and product use: SO_x

Table A - 69: SO_x (as SO₂) 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	0.67	0.66	0.65	0.53	0.43
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	0.91	0.93	0.91	0.80	0.73

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	0.51	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	0.82	0.85	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	2020	05-20
	kt											%
2A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-17
2B	0.76	0.67	0.74	0.56	0.59	0.62	0.73	0.81	0.89	0.79	0.50	-27
2C	0.02	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	0.00	-23
2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-20
Sum	0.79	0.69	0.77	0.59	0.62	0.65	0.76	0.83	0.91	0.81	0.52	-51

Table A - 70: SO_x (as SO₂) emissions from sector 2 Industrial processes and product use by source categories 2A-2C and 2G-2H (projection).

SO2	2025	2030	2035	2040	2045	2050
	kt					
2A	0.00	0.00	0.00	0.00	0.00	0.00
2B	0.58	0.67	0.69	0.69	0.69	0.69
2C	0.02	0.02	0.02	0.02	0.02	0.02
2G	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
Sum	0.60	0.69	0.72	0.72	0.72	0.72

A7.3.4 2 Industrial processes and product use: NH₃

Table A - 71: NH₃ 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	0.12	0.13
2L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.39	0.32	0.31	0.31	0.33	0.35	0.30	0.29	0.28	0.27

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
2B	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	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	0.01	-24
2G	0.09	0.08	0.09	0.07	0.07	0.06	0.06	0.07	0.08	0.08	0.07	-69
2H	0.10	0.13	0.11	0.09	0.12	0.09	0.08	0.09	0.07	0.08	0.06	-34
2L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41
Sum	0.21	0.23	0.21	0.17	0.20	0.16	0.16	0.18	0.16	0.17	0.15	-58

Table A - 72: NH₃ emissions from sector 2 Industrial processes and product use by source categories 2B, 2C, 2G, 2H and 2L (projection).

NH3	2025	2030	2035	2040	2045	2050
	kt					
2B	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
2G	0.07	0.07	0.07	0.07	0.06	0.06
2H	0.06	0.04	0.03	0.03	0.03	0.03
2L	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.14	0.12	0.11	0.10	0.10	0.10

AM7.3.5 2 Industrial processes and product use: PM2.5

Table A - 73: 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	0.14	0.14	0.12	0.11	0.12	0.10	0.09	0.09	0.09
Sum	2.57	2.49	2.56	2.49	2.42	2.04	2.00	2.00	1.60	1.52

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	0.09	0.07	0.06	0.05	0.06	0.06	0.07	0.06	0.06	0.06
Sum	1.51	1.44	1.52	1.50	1.54	1.47	1.49	1.53	1.54	1.49

PM2.5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
2A	0.44	0.44	0.42	0.43	0.42	0.39	0.40	0.40	0.39	0.41	0.40	-3
2B	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	-48
2C	0.01	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	0.00	55
2G	0.49	0.50	0.52	0.54	0.45	0.42	0.40	0.44	0.44	0.36	0.38	-22
2H	0.44	0.45	0.42	0.40	0.43	0.41	0.39	0.41	0.39	0.38	0.35	-13
2I	0.06	0.05	0.04	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.05	-27
Sum	1.48	1.49	1.45	1.45	1.40	1.31	1.28	1.33	1.31	1.23	1.21	-18

Table A - 74: PM2.5 emissions from sector 2 Industrial processes and product use by source categories 2A-2D and 2G-2I (projection).

PM2.5	2025	2030	2035	2040	2045	2050
	kt					
2A	0.40	0.40	0.40	0.40	0.40	0.40
2B	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
2D	0.00	0.00	0.00	0.00	0.00	0.00
2G	0.40	0.43	0.45	0.45	0.45	0.45
2H	0.39	0.43	0.45	0.46	0.47	0.47
2I	0.05	0.04	0.04	0.04	0.04	0.04
Sum	1.28	1.35	1.39	1.40	1.41	1.42

A7.3.6 2 Industrial processes and product use: BC

Table A - 75: 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	2020	05-20
	t											%
2A	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	-9
2C	0.03	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	0.00	55
2G	1.50	1.44	1.54	1.48	1.29	1.25	1.30	1.30	1.25	1.22	1.27	-21
Sum	1.59	1.53	1.63	1.56	1.38	1.33	1.38	1.38	1.33	1.30	1.34	-49

Table A - 76: BC emissions from sector 2 Industrial processes and product use by source categories 2A, 2C, 2D and 2G (projection).

BC	2025	2030	2035	2040	2045	2050
	t					
2A	0.05	0.05	0.05	0.05	0.05	0.05
2C	0.03	0.03	0.03	0.03	0.03	0.03
2D	0.00	0.00	0.00	0.00	0.00	0.00
2G	1.25	1.23	1.22	1.22	1.22	1.22
Sum	1.33	1.31	1.30	1.30	1.30	1.30

A7.4 3 Agriculture

A7.4.1 3 Agriculture: NO_x

Table A - 77: NO_x emissions from Sector 3 Agriculture by source categories 3B and 3D. The last column indicates the relative trend.

NO _x	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
3B	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
3D	3.4	3.4	3.4	3.5	3.5	3.5	3.5	3.6	3.6	3.6
Sum	4.7	4.8	4.8	4.8	4.8	4.8	4.9	4.9	4.9	4.9

NO _x	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
3B	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.1
3D	3.6	3.6	3.6	3.4	3.4	3.3	3.3	3.0	3.0	3.0
Sum	4.9	4.9	4.8	4.7	4.6	4.6	4.4	4.2	4.1	4.1

NO _x	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
3B	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3D	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.8
Sum	4.0	4.0	3.9	3.9	3.8	3.8	3.8	3.9	3.9	3.8

NO _x	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
3B	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	-8.2
3D	3.0	2.9	2.8	2.8	2.9	2.8	2.9	2.9	2.8	2.7	2.7	-4.8
Sum	4.0	3.8	3.8	3.8	3.9	3.7	3.8	3.8	3.7	3.6	3.6	-5.7

Table A - 78: NO_x emissions from Sector 3 Agriculture by source categories 3B and 3D (projection).

NO _x	2025	2030	2035	2040	2045	2050
	kt					
3B	0.9	0.9	0.9	0.9	0.9	0.9
3D	2.7	2.7	2.7	2.7	2.7	2.7
Sum	3.6	3.6	3.6	3.6	3.6	3.6

A7.4.2 3 Agriculture: NMVOC

Table A - 79: 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	13.1	13.3	13.5	13.7	13.9	14.0	14.2	14.4	14.5	14.7
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sum	13.7	13.8	14.0	14.2	14.4	14.5	14.7	14.9	15.0	15.2

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
3B	14.9	14.7	14.6	14.6	14.8	14.9	14.9	14.7	14.8	14.9
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sum	15.3	15.2	15.1	15.0	15.3	15.4	15.4	15.2	15.2	15.4

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
3B	14.8	15.2	15.3	15.6	15.8	16.5	17.1	17.6	18.1	18.1
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sum	15.3	15.6	15.8	16.0	16.3	17.0	17.5	18.1	18.6	18.6

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											
3B	18.2	18.2	18.3	18.3	18.6	18.5	18.6	18.5	18.6	18.5	18.5	12.1
3D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-3.1
Sum	18.6	18.6	18.7	18.8	19.0	19.0	19.0	19.0	19.0	19.0	19.0	11.7

Table A - 80: NMVOC emissions from Sector 3 Agriculture by source category 3B and 3D (projection).

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
3B	18.4	18.3	18.3	18.3	18.3	18.3
3D	0.5	0.5	0.5	0.5	0.5	0.5
Sum	18.8	18.7	18.7	18.7	18.7	18.7

A7.4.3 3 Agriculture: SO_x

There are no SO_x emissions from sector 3 Agriculture.

A7.4.4 3 Agriculture: NH₃

Table A - 81: NH₃ 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	22.9	22.8	22.8	22.7	22.9	23.1	23.3	23.4	23.6	23.7
3D	37.9	38.1	38.3	38.4	38.8	39.2	39.5	39.8	40.2	40.5
Sum	60.8	60.9	61.0	61.2	61.7	62.3	62.8	63.3	63.8	64.2

NH3	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
3B	23.9	23.7	23.5	23.4	23.3	23.2	23.2	23.3	24.0	24.4
3D	40.8	39.8	39.0	38.1	37.7	37.3	35.7	33.2	32.0	30.9
Sum	64.7	63.4	62.5	61.5	61.0	60.5	58.9	56.5	56.0	55.2

NH3	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
3B	24.7	25.7	26.1	25.7	25.5	26.0	26.2	26.3	26.2	25.7
3D	29.8	29.1	28.0	27.4	27.4	27.7	28.0	28.6	28.4	27.4
Sum	54.5	54.8	54.1	53.1	52.8	53.7	54.2	54.9	54.6	53.1

NH3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
3B	25.5	25.5	25.5	25.4	25.7	25.6	25.5	25.4	25.3	25.0	24.9	-4.0
3D	27.5	26.8	26.5	26.1	26.4	25.9	25.9	26.0	25.7	25.2	25.2	-9.1
Sum	53.0	52.3	52.0	51.5	52.1	51.5	51.4	51.4	51.0	50.2	50.1	-6.7

Table A - 82: NH₃ emissions from Sector 3 Agriculture by source categories 3B and 3D (projection).

NH3	2025	2030	2035	2040	2045	2050
	kt					
3B	24.7	24.6	24.6	24.6	24.6	24.6
3D	25.0	24.9	24.9	24.9	24.9	24.9
Sum	49.8	49.6	49.6	49.6	49.6	49.6

A7.4.5 3 Agriculture: PM2.5

Table A - 83: 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	2020	05-20
	kt											
3B	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	20.4
3D	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	-3.4
Sum	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	11.8

Table A - 84: PM2.5 emissions from Sector 3 Agriculture by source category 3B and 3D (projection).

PM2.5	2025	2030	2035	2040	2045	2050
	kt					
3B	0.10	0.10	0.10	0.10	0.10	0.10
3D	0.04	0.04	0.04	0.04	0.04	0.04
Sum	0.14	0.14	0.14	0.14	0.14	0.14

A7.5 5 Waste

A7.5.1 5 Waste: NO_x

Table A - 85: NO_x emissions from sector 5 Waste by source categories 5A-5D. The last column indicates the relative trend.

NO _x	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

NO _x	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

NO _x	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

NO _x	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
5A	0.002	0.002	0.002	0.002	0.001	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	0.006	702
5C	0.14	0.13	0.13	0.14	0.13	0.14	0.13	0.12	0.11	0.11	0.11	-27
5D	0.005	0.005	0.005	0.005	0.006	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	0.14	0.14	0.12	0.12	0.12	-23

Table A - 86: NO_x emissions from sector 5 Waste by source categories 5A-5D (projection).

NO _x	2025	2030	2035	2040	2045	2050
	kt					
5A	0.0012	0.0008	0.0005	0.0003	0.0001	NA
5B	0.009	0.013	0.016	0.018	0.019	0.020
5C	0.11	0.10	0.10	0.10	0.10	0.10
5D	0.01	0.01	0.01	0.01	0.01	0.01
Sum	0.12	0.12	0.13	0.13	0.12	0.12

A7.5.2 5 Waste: NMVOC

Table A - 87: 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	1.93	1.78	1.62	1.45	1.27	1.10	0.97	0.85	0.72	0.59
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	2.99	2.81	2.63	2.45	2.25	2.05	1.88	1.72	1.55	1.37

NMVOC total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
5A	0.41	0.36	0.36	0.33	0.30	0.30	0.30	0.29	0.28	0.28
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	1.15	1.10	1.10	1.06	1.01	1.01	0.99	0.99	0.99	1.02

NMVOC total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
5A	0.28	0.28	0.29	0.28	0.28	0.28	0.28	0.27	0.25	0.24
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	1.05	1.05	1.06	1.03	1.03	1.04	1.09	1.13	1.15	1.14

NMVOC total	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
5A	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.16	0.15	0.14	-49
5B	0.54	0.58	0.67	0.74	0.78	0.83	0.93	0.97	1.03	1.15	1.21	274
5C	0.36	0.35	0.35	0.35	0.34	0.34	0.33	0.33	0.32	0.31	0.31	-18
5D	0.0001	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	0.06	0
Sum	1.19	1.21	1.29	1.35	1.37	1.42	1.51	1.53	1.57	1.67	1.72	66

Table A - 88: NMVOC emissions from sector 5 Waste by source categories 5A-5E (projection).

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
5A	0.11	0.09	0.07	0.06	0.05	0.04
5B	1.82	2.43	2.92	3.23	3.40	3.56
5C	0.27	0.23	0.21	0.19	0.17	0.15
5D	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
Sum	2.26	2.81	3.26	3.54	3.68	3.81

A7.5.3 5 Waste: SO_x

Table A - 89: SO_x (as SO₂) 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	2020	05-20
	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	0.0009	702
5C	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.04	0.03	0.03	0.03	-54
5D	0.00002	0.00003	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	0.058	0.045	0.031	0.031	0.030	-53

Table A - 90: SO_x (as SO₂) emissions from sector 5 Waste by source categories 5A-5D (projection).

SO2	2025	2030	2035	2040	2045	2050
	kt					
5A	NA	NA	NA	NA	NA	NA
5B	0.001	0.002	0.002	0.003	0.003	0.003
5C	0.03	0.03	0.03	0.03	0.03	0.03
5D	0.00003	0.00003	0.00003	0.00003	0.00004	0.00004
Sum	0.030	0.029	0.029	0.029	0.029	0.028

A7.5.4 5 Waste: NH₃

Table A - 91: NH₃ 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	0.020	0.021	0.021	0.021	0.022	0.022	0.022	0.023	0.023	0.023
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	0.024	0.023	0.022	0.022	0.021	0.021	0.021	0.021	0.021	0.021
5D	0.091	0.093	0.094	0.096	0.098	0.099	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	0.021	0.021	0.021	0.023	0.025	0.025	0.026	0.026	0.027	0.028
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	2020	05-20
	kt											%
5A	0.35	0.34	0.32	0.31	0.29	0.28	0.27	0.26	0.24	0.23	0.22	-49
5B	0.40	0.40	0.42	0.44	0.42	0.41	0.46	0.47	0.47	0.53	0.53	42
5C	0.028	0.028	0.027	0.032	0.033	0.035	0.028	0.020	0.011	0.011	0.011	-56
5D	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	17
Sum	0.89	0.88	0.89	0.89	0.87	0.85	0.88	0.86	0.85	0.89	0.88	-4.8

Table A - 92: NH₃ emissions from sector 5 Waste by source categories 5A-5D (projection).

NH3	2025	2030	2035	2040	2045	2050
	kt					
5A	0.17	0.14	0.11	0.093	0.078	0.065
5B	0.66	0.80	0.91	0.99	1.03	1.07
5C	0.011	0.011	0.011	0.011	0.011	0.012
5D	0.13	0.14	0.14	0.15	0.15	0.15
Sum	0.98	1.08	1.18	1.24	1.27	1.30

A7.5.5 5 Waste: PM2.5

Table A - 93: 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	2020	05-20
	kt											
5A	0.0010	0.0009	0.0007	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	-60
5B	0.000023	0.000028	0.000037	0.000040	0.000041	0.000044	0.000047	0.000049	0.000051	0.000053	0.000054	702
5C	0.36	0.35	0.35	0.34	0.33	0.33	0.33	0.31	0.31	0.30	0.29	-23
5E	0.002	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	0.31	0.30	0.29	-23

Table A - 94: PM2.5 emissions from sector 5 Waste by source categories 5A-5C and 5E (projection).

PM2.5	2025	2030	2035	2040	2045	2050
	kt					
5A	0.00047	0.00034	0.00020	0.00011	0.00004	NA
5B	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002
5C	0.26	0.22	0.20	0.18	0.16	0.15
5E	0.002	0.002	0.002	0.002	0.002	0.002
Sum	0.3	0.2	0.2	0.2	0.2	0.1

A7.5.6 5 Waste: BC

Table A - 95: 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	0.0000001	0.0000001	0.0000002	0.0000003	0.0000005	0.0000006	0.0000007	0.0000010
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	2020	05-20
	kt											
5A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	702
5C	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-22
Sum	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-22

Table A - 96: BC emissions from sector 5 Waste by source categories 5B and 5C (projection).

BC	2025	2030	2035	2040	2045	2050
	kt					
5A	NA	NA	NA	NA	NA	NA
5B	0.000002	0.000003	0.000004	0.000004	0.000004	0.000004
5C	0.019	0.016	0.015	0.014	0.012	0.011
Sum	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 - 97: NO_x emissions from sector 6 Other by source categories 6Ab-6Ad. The last column indicates the relative trend.

NO _x	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
	kt									
6Ab	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
6Ac	0.044	0.045	0.046	0.047	0.047	0.048	0.048	0.049	0.049	0.050
6Ad	0.016	0.016	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Sum	0.078	0.079	0.080	0.081	0.081	0.082	0.082	0.083	0.083	0.084

NO _x	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	kt									
6Ab	0.017	0.016	0.015	0.013	0.014	0.017	0.034	0.034	0.034	0.035
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	0.081	0.076	0.073	0.076	0.091	0.086	0.084	0.089

NO _x	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	kt									
6Ab	0.035	0.035	0.036	0.037	0.035	0.036	0.035	0.036	0.040	0.042
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	0.089	0.092	0.091	0.092	0.090	0.090	0.087	0.091	0.092	0.091

NO _x	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											
6Ab	0.044	0.049	0.054	0.054	0.053	0.058	0.055	0.054	0.048	0.047	0.047	29
6Ac	0.040	0.035	0.034	0.033	0.037	0.033	0.035	0.037	0.034	0.030	0.031	-18
6Ad	0.015	0.016	0.017	0.017	0.013	0.015	0.014	0.015	0.016	0.013	0.014	-15
Sum	0.098	0.100	0.105	0.104	0.103	0.105	0.105	0.106	0.099	0.090	0.091	1

Table A - 98: NO_x emissions from sector 6 Other by source categories 6Ab-6Ad (projection).

NO _x	2025	2030	2035	2040	2045	2050
	kt					
6Ab	0.048	0.047	0.047	0.047	0.047	0.047
6Ac	0.032	0.032	0.032	0.032	0.032	0.032
6Ad	0.014	0.014	0.014	0.014	0.014	0.014
Sum	0.093	0.093	0.093	0.093	0.093	0.093

A7.6.2 6 Other: NMVOC

Table A - 99: 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	0.0644	0.0645	0.0647	0.0649	0.0638	0.0628	0.0618	0.0607	0.0597	0.0587
6Ad	0.1287	0.1287	0.1288	0.1288	0.1288	0.1288	0.1288	0.1289	0.1289	0.1289
Sum	0.1930	0.1933	0.1935	0.1937	0.1926	0.1916	0.1906	0.1896	0.1886	0.1876

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	2020	05-20
	kt											
	%											
6Ab	0.0913	0.0991	0.1096	0.1145	0.1103	0.1252	0.1225	0.1190	0.1011	0.1002	0.1006	44
6Ad	0.1109	0.1202	0.1261	0.1299	0.1018	0.1106	0.1078	0.1121	0.1205	0.0964	0.1019	-17
Sum	0.2022	0.2194	0.2357	0.2444	0.2120	0.2357	0.2304	0.2311	0.2216	0.1966	0.2025	5

Table A - 100: NMVOC emissions from sector 7 Other by source category 6Ab and 6Ad (projection).

NMVOC total	2025	2030	2035	2040	2045	2050
	kt					
6Ab	0.1044	0.1043	0.1043	0.1043	0.1043	0.1043
6Ad	0.1019	0.1019	0.1019	0.1019	0.1019	0.1019
Sum	0.2063	0.2062	0.2062	0.2062	0.2062	0.2062

A7.6.3 6 Other: SO_x

Table A - 101: SO_x (as SO₂) emissions from sector 6 Other by source category 6Ad. The last column indicates the relative trend.

SO ₂	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

SO ₂	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

SO ₂	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

SO ₂	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
		kt										
6Ad	0.0102	0.0109	0.0113	0.0116	0.0099	0.0106	0.0104	0.0108	0.0113	0.0098	0.0102	-5
Sum	0.0102	0.0109	0.0113	0.0116	0.0099	0.0106	0.0104	0.0108	0.0113	0.0098	0.0102	-5

Table A - 102: SO_x (as SO₂) emissions from sector 6 Other by source category 6Ad (projection).

SO ₂	2025	2030	2035	2040	2045	2050
		kt				
6Ad	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102
Sum	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102

A7.6.4 6 Other: NH₃

Table A - 103: NH₃ emissions from sector 6 Other by source categories 6Aa-6Ac. The last column indicates the relative trend.

NH ₃	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	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
6Ac	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.16	0.17	0.17
Sum	0.76	0.76	0.77	0.77	0.78	0.78	0.78	0.79	0.79	0.80

NH ₃	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	0.54	0.53	0.51	0.51	0.53	0.65	0.63	0.65	0.68
6Ac	0.18	0.16	0.15	0.14	0.14	0.14	0.13	0.10	0.10	0.10
Sum	0.85	0.81	0.80	0.78	0.78	0.79	0.90	0.86	0.87	0.91

NH ₃	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	0.69	0.65	0.68	0.69	0.65	0.64	0.63	0.63	0.66	0.66
6Ac	0.11	0.11	0.11	0.10	0.11	0.10	0.10	0.11	0.11	0.10
Sum	0.92	0.89	0.93	0.92	0.89	0.88	0.86	0.88	0.90	0.89

NH ₃	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	05-20
	kt											%
6Aa	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	16
6Ab	0.66	0.71	0.76	0.76	0.76	0.80	0.78	0.76	0.71	0.70	0.70	9
6Ac	0.12	0.10	0.10	0.10	0.12	0.11	0.11	0.12	0.11	0.10	0.10	-1
Sum	0.92	0.95	0.99	1.01	1.02	1.05	1.04	1.03	0.97	0.95	0.96	9

Table A - 104: NH₃ emissions from sector 6 Other by source categories 6Aa-6Ac (projection).

NH ₃	2025	2030	2035	2040	2045	2050
	kt					
6Aa	0.16	0.17	0.17	0.18	0.18	0.18
6Ab	0.71	0.71	0.71	0.71	0.71	0.71
6Ac	0.11	0.11	0.11	0.11	0.11	0.11
Sum	0.97	0.98	0.99	0.99	0.99	1.00

A7.6.5 6 Other: PM2.5

Table A - 105: 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	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	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	2020	05-20
		kt										
6Ab	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	68
6Ad	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	-16
Sum	0.005	0.005	0.006	0.006	0.005	0.006	0.006	0.006	0.006	0.005	0.005	28

Table A - 106: PM2.5 emissions from sector 6 Other by source categories 6Ab and 6Ad (projection).

PM2.5	2025	2030	2035	2040	2045	2050
		kt				
6Ab	0.004	0.004	0.004	0.004	0.004	0.004
6Ad	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