Informative Inventory Report Sweden 2021

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SWEDISH ENVIRONMENTAL
PROTECTION AGENCY

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EXECUTIVE SUMMARY

ES.1 Background information on the air pollutant emission inventory

Sweden has carried out inventories on air pollutants since the 1980's to meet the obligations of the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution (UNECE CLRTAP).

The inventory reports of air pollutants for the year 2020 is prepared in accordance with the 2016 Reporting Guidelines and the CLRTAP's revised Gothenburg Protocol as agreed by the parties to the Convention in Geneva, 2012. The inventory report is annually submitted to the UNECE Secretariat and to the EEA.

This report constitutes Sweden's IIR 2021 (inventory data 2019) for anthropogenic emissions of air pollutants: NO_X, CO, NMVOC, SO_2, NH_3, TSP, PM_{10} and $PM_{2.5}$, BC, heavy metals and other metals, dioxins, HCB, PCBs and PAH1-4 covering the years from 1980 to 2019. The report contains methodology, data sources, uncertainties, the quality assurance and quality control (QA/QC), activities carried out, and trend analyses for many pollutants. Data on estimated emissions and corresponding activity data are provided in NFR tables. Thermal values and emission factors are provided in Annex 2. The report also shows how Sweden follows the guidelines to ensure the transparency, consistency, accuracy, comparability, and completeness of the reported emission data.

Emission estimates are mainly based on official Swedish statistics, e.g. quarterly fuel statistics, agricultural statistics, environmental reports from industry and emission factors (nationally developed factors as well as internationally recommended ones). Sweden uses the Guidelines for Estimating and Reporting Emission Data for reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016[1] as methodological guidance. Sweden also uses methodologies in accordance to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[2].

Due to changes in the routines for handling data it was discovered that a higher degree of confidentiality is required for some activity data. This has affected some sub-sectors in the energy sector (NFR1A and 1B) which have been classified with the notation key Classified (C). Sweden works continuously on limiting the extent of confidentiality in inventory data.

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[1] http://www.eea.europa.eu/publications/emep-eea-guidebook-2016

[2] http://www.ipcc-nggip.iges.or.jp/public/2006gl/

ES.2 Overview of source category emission estimates and trends

The main sources of air pollutants have been divided into the following sectors: energy, industrial processes and product use, agriculture and waste. No air pollutant emissions have been estimated for the land use, land use change and forestry sector.

Emissions of pollutants regulated in the amended Gothenburg Protocol (SO_2, NO_X, NH_3, NMVOCs, PM_{10}, $PM_{2.5}$ and BC) have been reduced significantly since 1990. Other air pollutants, such as CO, poly aromatic hydrocarbons (PAH1-4), dioxins, HCB and priority heavy metals namely, cadmium (Cd), mercury (Hg) and lead (Pb) and other metals have also all been reduced since 1990.

Emission reduction of the air pollutants and heavy metals has been achieved through regulatory controls and application of better technologies in industry, energy, and transport sectors. Examples include switching from higher sulphur fuels to lower sulphur fuels, phasing out the use of leaded gasoline, catalytic converters on vehicles and other instruments such as the NO_X-fee.

Nitrogen oxides
The estimated emissions of nitrogen oxides (NO_X) were about 127 kt in 2019. The emissions have decreased by more than a half (54 %) since 1990 and by 7 % compared to the previous year.

The energy sector (NFR1) accounted for most of the NO_X emissions (about 80 %), of which transport was responsible for 43 % of the national total. The industrial processes and product use sector (NFR2) and the agriculture sector (NFR3) were responsible for about 10 % each. NO_X-emission from the waste sector (NFR5) is small.

Emissions from the transport sector (NFR1A3) have declined by almost two-thirds since 1990 and by about 14 % compared to the previous year mostly from road traffic and national navigation. Emissions from diesel passenger cars increased by about 850 % since 1990. On the contrary, emissions of NO_X from heavy-duty diesel vehicles declined by about 86 % since 1990 and decreased by 25 % compared to the previous year. The reduction is mainly due to the tightening of the EU road vehicle emission regulation standards.

Other important reasons for the general decline of NO_X emission is the increased use of district heating and the introduction of the NO_X-fee in 1992 which have resulted in a reduction of emissions from the manufacturing industries and construction (NFR1A2) and the energy industries sectors (NFR1A1).

Sulphur dioxide
Emissions of sulphur dioxide (SO_2) decreased from about 103 kt in 1990 to about 16.4 kt in 2019, a reduction of 84 %. Between 2018 and 2019 the emission decreased by 6 %. About a half (48 %) of the total SO_2-emission comes from the energy sector. The remaining emissions (52 %) are sourced to the industrial processes

and product use sector. SO_2-emission from the waste sector is very small. Among the largest sources of SO_2-emission are metal industry (NFR2C), 26 %, pulp and paper industry (2H1), 20 %, public electricity and heat production (NFR 1A1a), 15 % and manufacturing industries and construction (NFR 1A2), 18 %. Transport (NFR 1A3) was a major source of SO_2 in early 1990's but now is responsible for about 3 % of the total emission. The general reduction in these sectors, including the transport sector, are mainly due to a transfer from fuels with high sulphur content to low-sulphur fuels.

Ammonia

The total emissions of ammonia (NH_3) amounted to 53.4 kt in 2019. Compared to emission levels in 1990, the emissions were 11 % lower in 2019. The agriculture sector was the main source of NH_3 in 2019, accounting to 88 % of the total emissions. NH_3 is emitted from farm animals' dung and urine and the use of inorganic fertilizers. The rest of the emission originates mainly from pulp and paper industry and transport, mainly from urea in vehicles filters that release HN_3. The main drivers for the reduced emission within the agriculture sector are a decline in number of animals, reduced use of inorganic fertilizers, measures, and a more effective production.

Non-methane volatile organic compounds (NMVOCs)

In 2019, a total of about 134 kt of NMVOCs were emitted in Sweden. About 38 % of the NMVOC emissions comes from the solvent use (NFR2D3). The energy sector and the agriculture sector contributed with 34 % and 22 %, respectively.

The total emissions of NMVOCs have decreased by about 64 % since 1990 and by 2 % between 2018 and 2019. The decline is sharp in the energy sector (mainly from transport) and also in the solvent use sector, amounting to about 80 % and 43 %, respectively. The main reason for the sharp decrease in the transport sector during the last two decades are the increased energy efficiency in cars and the introduction of stricter emission standards in the EU-regulations for road vehicles.

Carbon monoxide

The aggregated emissions of carbon monoxide (CO) have decreased from about 1 Mton in 1990 to about 337 kt in 2019, declined by 70 %. Other energy sectors (NFR1A4) was the largest source for CO emission, accounting for about 57 % of the total emissions in 2019. Most of the emission come from biomass combustion in residential stationary plants, (NFR1A4b). Emissions have decreased by 26 % since 1990.

In 2019, the transport sector (1A3) was responsible for 27 % of the total emissions of CO. Emissions from the transport sector have decreased by 89 % since 1990, the main reason being the introduction of catalytic converters in passenger cars and light duty vehicles.

Particles Matter (PM_{10} and $PM_{2.5}$)

In 2019, the total emissions of PM_{10} and $PM_{2.5}$ in Sweden were about 37 and 18 kt, respectively. Compared to 1990, the emissions have been reduced by about 45 %

and 61 %, respectively. The transport sector is responsible for about 44 % and 22 %, respectively of the emission in 2019. The amount of emissions depends on total traffic work and the use of studded tires. The combined emissions of PM_{10} from road abrasion and tires- and brake wear show an increasing trend due to increased volume of traffic. Other sectors (residential and premises heating) cause large emissions of $PM_{2.5}$ too which accounted for 35 % of the total emissions in 2019. Emissions have decreased by 58 % since 1990, when district heating has become more common and that today's wood boilers are more effective in combustion than older ones.

Black Carbon

Emissions of back carbon (BC) have been reported for the years 2000 to 2019. The estimated emission was about 2.3 kt in 2019 and reduced by 58 % since 2000. The largest single source of BC emission is other energy sectors (NFR1A4) accounting for 43 % and have decreased by 47 % since 2000. The reduction is mainly due to a transition from wood combustion for residential and premises heating to district heating. The transport sector (NFR1A3) accounted for about 26 % of total BC emissions in 2019 where road traffic is the major contributor in the sector. Emissions from road transport have declined by about 73 % since 2000 due to stricter exhaust requirements.

Poly Aromatic Hydrocarbons

The total emissions of poly aromatic hydrocarbons (PAH1-4) were about 7 tons in 2019. The emissions have been reduced by 62 % since 1990. The largest source of emissions of PAH in Sweden is wood combustion for heating residential, commercial and public premises, as well as agricultural and forestry and fishing which accounted for 75 % of total emissions in 2019. Since 1990, emissions from this source have decreased by 55 % mainly due to a transition to district heating. However, emissions from heating of agricultural- forestry and premises have increased due to the increased use of biomass. The largest reduction of PAH1-4 emissions since 1990, about 79 %, has been achieved in the metal industry (NFR2C) through application of new technologies.

Hexachlorobenzene

The total emissions of hexachlorobenzene (HCB) were 2.7 kg in 2019. Emissions have decreased by 83 % since 1990. The largest single source of HCB emissions in 2019 was the electricity- and heat production (NFR1A1) which accounted for 37 % of the total emissions followed by metal industry (NFR2C) 26 %. Emissions from electricity- and heat production have been more than doubled since 1990, mainly due to increased use of biomass as a fuel. The increased HCB emission from iron and steel industry since 1990 is due to increased production volume. The largest increase of HCB in relative terms comes from the waste sector (incineration and open burning), which has increased by about 300 % since 1990, due to increased combustion of hazardous waste.

Priority Heavy Metals (Cd, Hg and Pb)

In 2019, the estimated emissions of Cd in Sweden were about 500 kg, a decrease of 79 % since 1990. The largest sources of Cd emissions in 2019 were electricity- and

heat production (NFR 1A1), 33 % and stationary combustion in the residential sector (NFR 1A4), 22 %. The industrial processes and product use contributed with 21 % of the emission and have decreased by more than 95 % since 1990, mainly due to better technologies applied in the metal industry.

In 2019, the estimated emissions of mercury (Hg) in Sweden were about 400 kg, a decrease of about 74 % since 1990. The largest sources of Hg emissions in 2019 were electricity- and heat production (NFR1A1) and metal industry (NFR2C) accounted for 40 % and 19 %, respectively of the total emission. The waste sector is also a significant source of Hg emission and accounted for 8 % of the total emission in 1919. Emissions from metal industry have decreased by 85 % since 1990, mainly due to application of better technologies in the metal industry.

The total emissions of lead (Pb) in Sweden were about 8 ton in 2019 and have decreased by 98 % since 1990. The largest source of Pb emissions in 2019 was metal industry (NFR2C) followed by electricity- and heat production (NFR 1A1) and accounted for 38 % and 26 %, respectively of the total emission. Emissions of Pb from the transport sector which contributed to 7 % of the emission in 2019 decreased by more than 99 % since 1990 due to the phasing out the use of leaded gasoline, while the large decrease from metal industry (96 %) is mainly due to application of better technologies.

1 Introduction

Reporting of emission data to the Executive Body of the Convention on Long-range Trans-boundary Air Pollution (CLRTAP) is required in order to fulfil obligations regarding strategies and policies in compliance with the implementation of Protocols under the Convention. Parties should use the reporting procedures and are required to submit annual national emissions of SO_2, NO_X, NMVOC, CO and NH_3, particulate matter, black carbon (BC), various heavy metals and POPs using the revised 2016[3] Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution[4]

This report constitutes Sweden's Informative Inventory Report (IIR) due by March 15 2021. The report contains information on Sweden's inventories for all years from 1980 to 2019 including descriptions of methods, data sources, QA/QC activities carried out, and a trend analysis. The inventory accounts for anthropogenic emissions of SO_2, NO_X, NH_3, NMVOC, CO, BC, TSP, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PAH, HCB and dioxins.

Emission estimates are mainly based on official Swedish statistics, e.g. quarterly fuel statistics, agricultural statistics, environmental reports from industry and emission factors (nationally developed factors as well as internationally recommended ones).

Sweden uses the Guidelines for Estimating and Reporting Emission Data for reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the 2016 EMEP/EEA Air Pollutant Emission Inventory Guidebook as methodological guidance[5]. Data are also reported under the EU National Emissions Ceiling Directive on emission of air pollutants to the European Commission.
Sweden also uses methodologies in accordance with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories[6] and methods that are in general in line with Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories IPCC-NGGIP (Good Practice Guidance[7]). Some parts of the methodologies are taken directly from the IPCC Guidelines, the Good Practice Guidance and the 2016 EMEP/EEA Air Pollutant Emission Inventory Guidebook.

1.1 Institutional arrangements

The national system is designed in compliance with UNFCCC decision 20/CP.7. Under the terms of Decision No. 280/2004/EC of the European Parliament and of the Council, the national system has to be in place by the end of 2005. The national

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[3] http://www.eea.europa.eu/publications/emep-eea-guidebook-2016

[4] http://www.ceip.at/fileadmin/inhalte/emep/2014_Guidelines/ece.eb.air.125_ADVANCE_VERSION_reporting_guidelines_2013.pdf

[5] http://www.eea.europa.eu/publications/emep-eea-guidebook-2013

[6] http://www.ipcc-nggip.iges.or.jp/public/2006gl/

[7] http://www.ipcc-nggip.iges.or.jp/public/gp/english/

system has to ensure the function of all the institutional, legal and procedural arrangements required to calculate emissions and removals of greenhouse gases.

The Swedish national system came into force on 1 January 2006 and its aim is to ensure that climate reporting to the secretariat of the Convention (UNFCCC) and the European Commission complies with specified requirements. This means, among other things,

- estimating and reporting anthropogenic GHG emissions and removals in accordance with the Kyoto Protocol,
- assisting Sweden in meeting its commitments under the Kyoto Protocol,
- facilitating the review of submitted information,
- ensuring and improving the quality of the Swedish inventory and
- guaranteeing that submitted data is officially approved.

The national system ensures annual preparation and reporting of the national inventory and of supplementary information in a timely manner and that the inventory fulfils all quality criteria, i.e. is transparent, accurate, consistent, comparable and complete.

The national system is, where applicable, used also for the reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE) and under the EU National Emissions Ceiling Directive on emission of air pollutants to the European Commission.

1.1.1 Legal arrangements

The ordinance (2005:626) concerning climate reporting has been updated and enlarged to fulfil all the reporting requirements under the EU Monitoring Mechanism Regulation 525/2013/EC. The new ordinance 2014/1434 concerning climate reporting came into force and replaced the old ordinance the 29th of December 2014 and have been operational since the preparation of submission 2015.

The ordinance on climate reporting (OCR) describes the roles and responsibilities of the relevant government agencies in this area. The ordinance ensures that sufficient capacity is available for reporting. It also includes other improvements needed on the national level.

Supplemental to the new ordinance, formal agreements between the Swedish Environmental Protection Agency (Swedish EPA) and other concerned national agencies have been signed, listing in detail what is required regarding content and timetable from each agency.

Sweden also has legislation indirectly supporting climate reporting efforts by providing a basis for estimating greenhouse gas emissions and removals. Environmental reports are submitted under the Environmental Code (SFS 1998:808), and the Official Statistics Act (SFS 2001:99) imposes an obligation for large industries to submit annual data. In addition, government agencies in Sweden must comply

by the Information and Secrecy Act (offentlighets- och sekretesslag) (SFS 2009:400).

The General Statistics Act (SFS 2001: 99) and the associated ordinance (2001:100) concerning official statistics impose an obligation on companies and other organizations to submit annual data. The data then serve as a basis for estimating greenhouse gas emissions and removals in several sectors.

There is legislation in Sweden that indirectly supports the work by providing a basis for the estimation of air pollutants. Under Chapter 26 Section 19 of the Environmental Code (1998:808), there is an obligation for annual environmental reports to be submitted for certain environmentally hazardous activities so that government agencies can undertake supervision.

The General Statistics Act (SFS 2001: 99) and the associated Ordinance (2001:100) Concerning Official Statistics impose an obligation on companies and other organizations to submit annual data. The data then serve as a basis for estimating air pollutants in several sectors.

According to Directive 2003/87/EC and national Act (2004:1199) on emission trading, emission data for plants included in the emission trading system should be reported annually. These data are used as a supplementary source within this air pollutant inventory.

1.1.2   Institutional arrangements

Where applicable, the same institutional arrangements are used as for the Greenhouse gas inventory:

The illustration in Figure 1-1 and Table 1-1 and the associated text below describe in broad terms which organizations are involved in the work of compiling documentation for the yearly inventory report and for other reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE) and under the EU National Emissions Ceiling Directive on emission of air pollutants to the European Commission.

Depending on the role of the government agencies in reporting activity, this responsibility may range for example from supplying data and producing emission factors/calorific values to carrying out calculations to estimate emissions or conducting a national peer review (in red). In addition to what is described in the OCR, the Swedish EPA engages the SMED consortium as consultants with expert skills to conduct the inventory and reporting in the area of air pollutants.
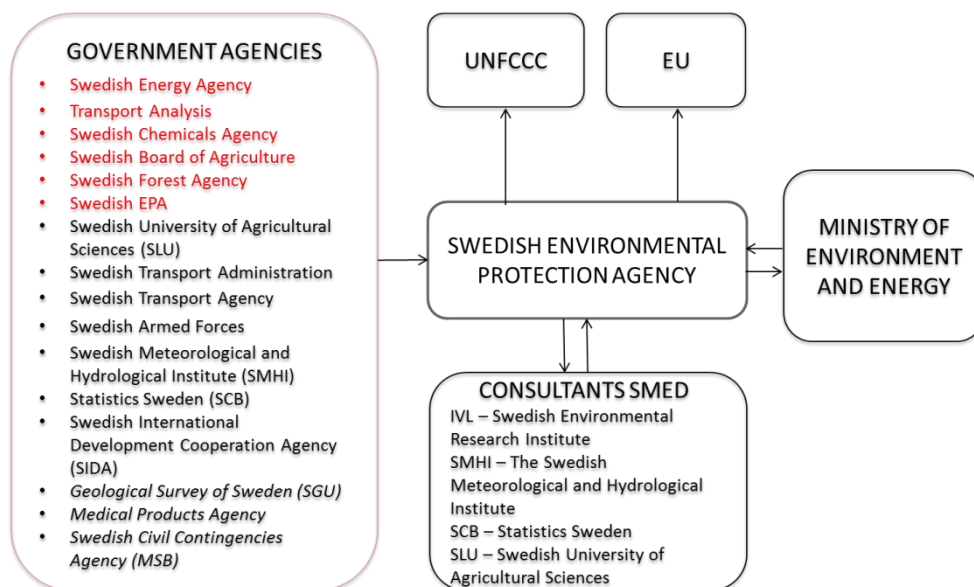
Figure 1-1   **The Swedish national system.**

1.1.2.1   RESPONSIBILITIES OF THE SWEDISH ENVIRONMENTAL
                PROTECTION AGENCY

The Swedish Environmental Protection Agency (Swedish EPA) is responsible for co-ordinating the activities for producing the inventory, maintaining the reporting system and also for the final quality control and quality assurance of the inventory. The Swedish EPA sends the inventory to Ministry of the Environment and – on behalf of the Ministry of the Environment and Energy – submits the inventory to the NEC directive/EU and to the CLRTAP/UNECE. Finally, the Swedish EPA is responsible for national publication of the air pollutants inventory.

1.1.2.2   RESPONSIBILITIES OF NATIONAL AGENCIES

Table 1-1 below shows the responsibilities of the Swedish agencies according to the Ordinance concerning climate reporting.

Table 1-1 Responsibilities according to the ordinance concerning climate reporting

Sector	Data and documentation provided by	Peer review conducted by
Energy	Swedish Energy Agency, the Swedish Transport Administration, the Swedish Transport Agency, Transport Analysis, the Swedish Armed Forces.	Swedish Energy Agency (energy sector excluding transports) Transport Analysis (transports)
Industrial Processes and Product Use	Swedish Chemicals Agency, Medical Products Agency.	The Swedish EPA (CO_2, CH_4 and N_2O) Swedish Chemicals Agency
Agriculture	Swedish Board of Agriculture, Statistics Sweden (SCB).	The Swedish Board of Agriculture
Land Use, Land-Use Change and Forestry Sector	Swedish University of Agricultural Sciences (SLU), Statistics Sweden (SCB), the Swedish Forest Agency, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish Board of Agriculture, Swedish Civil Contingencies Agency (MSB), the Geological Survey of Sweden (SGU).	Swedish Forest Agency The Swedish Board of Agriculture (agriculture related parts)
Waste		The Swedish EPA

1.1.2.3 THE SMED CONSORTIUM

The Swedish EPA engages consultants with expert skills to conduct the inventory and reporting in the area of climate change. During the spring of 2005, the Swedish EPA completed a negotiated procurement of services under the terms of the Public Procurement Act. After procurement had been completed, a framework contract was signed with the consortium Swedish Environmental Emissions Data (SMED)[8], consisting of the Swedish Meteorological and Hydrological Institute (SMHI), Statistics Sweden (SCB), the Swedish University of Agricultural Sciences (SLU) and the Swedish Environmental Research Institute (IVL). The contract between the Swedish EPA and SMED runs for nine years and thus covered the whole first commitment period under the Kyoto Protocol. During 2014 the contract with the consortium SMED was prolonged for another period (2015 – 2022). The structure of the consortium for the prolonged contract is a little bit different from since it is based on an agency agreement for the national agencies (SMHI, SCB and SLU) and a negotiated procurement of services under the terms of the Public Procurement Act for the IVL, this to be able to have the same setting for the consortium as during the former period.

SMED receives data and documentation from responsible authorities as described above and produces most of the data and documentation in the Swedish inventory. The regular inventory work is organized as a project involving all SMED organizations. The project is run by a project management team with one person from each organization. The SMHI is main responsible for production of gridded emission data. SCB is main responsible for the energy sector, the agriculture sector and parts of the waste sector, but is also involved in industrial processes since these are closely connected to the energy sector. The SLU is responsible for the LULUCF sector. The IVL is main responsible for the industrial process and product use sector and also parts of the waste sector and energy sector.

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[8] http://www.smed.se/

On behalf of the Swedish EPA, SMED also conducts specific projects necessary for improving the inventory.

1.2 Inventory planning, preparation and management

The present Swedish air pollutant inventory was compiled according to the recommendations for inventories set out in the Guidelines for Estimating and Reporting Emission Data for reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP[9]) and the 2016 EMEP/EEA Air Pollutant Emission Inventory Guidebook as methodological guidance[10] and also the UNFCCC reporting guidelines in accordance with the Doha Amendment to the Kyoto Protocol (1/CMP.8), the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC GPG, 2000[11]). Data are reported in the updated NFR format.

The inventory of air pollutants for reporting to the UNECE (CLRTAP) is integrated with the greenhouse gas inventory (for reporting to the UNFCCC and EU). This assures effective use of resources and consistency between the reporting to the UNFCCC and to the CLRTAP.

1.2.1   Quality system

In order to fulfil the obligations of reporting, the Swedish EPA has set up a quality system as part of the national system. The structure of the quality system follows the PDCA cycle (Plan, Do, Check, Act) illustrated in Figure 1-2 below. This is an adopted model for how systematic quality and environmental management activity is to be undertaken according to international standards to ensure that quality is maintained and developed.

The quality system includes several procedures such as training of staff, inventory planning and preparation, QA/QC procedures, publication, data storage, and follow-up and improvements. All QA/QC procedures are documented in a QA/QC plan[12]. The QA/QC plan also includes a scheduled time frame describing the different stages of the inventory from its initial development to final reporting. The quality system ensures that the inventory is systematically planned, prepared and followed up in accordance with specified quality requirements so that the inventory is continuously developed and improved.

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[9] http://www.ceip.at/fileadmin/inhalte/emep/2014_Guidelines/ece.eb.air.125_ADVANCE_VERSION_reporting_guidelines_2013.pdf

[10] http://www.eea.europa.eu/publications/emep-eea-guidebook-2013

[11] http://www.ipcc-nggip.iges.or.jp/public/gp/english/

[12] Swedish EPA, National Greenhouse Gas and Air Pollutants Inventory System in Sweden

Procedural Arrangements

Figure 1-2   **Structure of the quality system.**

The responsibilities of the Swedish EPA and the other government agencies for the quality system are described in Ordinance (2014:1434) Concerning Climate Reporting. Under Section 3, the Swedish EPA and other government agencies which take part in the inventory work have to ensure that the methodologies applied in the reporting and inventories of emissions attain the quality required for it to be possible for Swedish air pollutant reporting to be done in the correct manner and with correct information.

The governments agencies have to have internal routines to plan, prepare, check and act/follow up the quality work and consult one another with the aim of developing and maintaining a coordinated quality system.

The responsibility of SMED to maintain and develop an internal quality system is described in the framework contract between the Swedish EPA and SMED. The SMED quality system is described in a detailed manual including several appendices.[13] It is updated annually and lists all quality control steps that must be undertaken during inventory work (Tier 1 and where appropriate Tier 2). It also includes descriptions of roles and responsibilities, of databases and models, work manuals for each NFR category and documented procedures for uncertainty and key source analyses, as well as procedures for handling and responding to UNECE's review of the Swedish inventory. It also handles follow-up and improvement by procedures of non-conformity reporting and collection of improvement needs from all stages of the annual inventory cycle. This results in a planning document, which is used as a basis for planning and selecting further actions to improve the inventory.

The illustration in Figure 1-3 below shows a process description of the annual Swedish inventory for greenhouse gases which is largely applicable to the air pollutant inventory.

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[13] Manual for SMED:s Quality System in the Swedish Air Emission Inventories, available at www.smed.se

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Swedish Energy Agency				data for the energy sector available April 15th																				
Swedish Transport Administration, Swedish Transport Agency, National Maritime Administration, Swedish Armed Forces						data for the transport sector available June 18th																		
Annual Environmental Reports			data for industrial processes and waste sector available from March 31st																					
Trade associations and private companies					data for industrial processes available																			
Swedish Chemicals Agency								data for the solvents and other products use sector available August 15th																
Swedish Board of Agriculture								data for the agriculture sector available August 1st																
Statistics Sweden				data for the agriculture sector available April 15th																				
Trade associations					data for waste sector available																			
Swedish EPA, Statistics Sweden	data for waste sector (some intermittent) available																							
SMED	development projects																							
Swedish EPA	decision on and approval of results from development projects																							
SMED				data collection, calculations and internal QA/QC																				
SMED				preparation of report for peer review to EPA October 15th																				
Swedish Energy Agency, Transport Analysis, The Swedish EPA, Swedish Chemicals Agency, Swedish Board of Agriculture, National Board of Forestry									national peer review October 16th - October 31st															
SMED								finalization of report after peer review																
Swedish EPA								finalization of report after peer review publishing mid December															
Swedish EPA												submission to NEC directive EU December 31st												
Swedish EPA														submission to CLRTAP February 15th										
UNECE														International Review										

Figure 1-3   **Overview of inventory planning, preparation and management.**

1.2.2   Training, awareness and skills

Training, awareness and skills in air pollutant reporting are essential to maintain the level of quality required according to specified requirements. Skills are ensured for the Swedish EPA and the majority of the government agencies involved in the work by the government agency being the sector government agency with staff that have particular skills in different specialist areas.

Skills on the part of SMED are ensured in accordance with the requirements laid down in the framework contract between the Swedish EPA and the consultants. The levels of consultant's skills are continuously reviewed.

1.2.3   Inventory planning (PLAN)

Planning of the inventory for submission in year x starts in the fall of year x-2 when the Swedish EPA gets the preliminary budget for year x-1. General priorities for the coming year are set by the Swedish EPA based on

- new international and national requirements, decisions and guidelines
- recommendations from international review not yet implemented in the inventory
- recommendations from national peer review not yet implemented in the inventory
- key source analysis (focus on major sources)
- uncertainty analysis (focus on sources that contributes significantly to the uncertainty of the inventory)
- ideas from SMED and the Swedish EPA on how to improve quality and effectiveness of the inventory

Priorities are distributed to SMED approximately in October. Based on the priorities and on detailed information in the list on suggestions on improvements (see section 1.2.8 below), SMED compiles a list of suggested development projects for the coming years. The list of suggested development projects is discussed between SMED and the Swedish EPA. During the winter the Swedish EPA decides on what projects should be initiated.

From January to June (approximately) SMED is working with development projects. Reports on the results and recommendations for implementation in the inventory are delivered to the Swedish EPA who then decides how these new methods/activity data/emission factors should be implemented in the inventory. In order to be able to implement results in the current inventory with sufficient QA/QC, the Swedish EPA has to decide on implementation in June.

From time to time, there is a need to change data provided by responsible authorities as discussed above. The Swedish EPA each year contacts responsible authorities and discusses needs for updates.

1.2.4 Inventory preparation (DO)

SMED gather data and information from various government agencies, organisations and companies over the period from April to August with the aim of being able to carry out emission calculations. The calculations are performed in models, statistics programs and calculation programs in April to September. Over the period from September to October, the material is put together in a reporting format. A short description of data collection and processing for each sector is provided below. See sections 3-7 for a detailed description. Preparation of the inventory is documented in detailed work documentation, which serves as instructions for inventory compilers to ensure quality and consistency, and also serves as information in the national peer review process.

1.2.4.1 ENERGY- STATIONARY COMBUSTION

Energy industries: Data from quarterly fuel statistics, a total survey conducted by Statistics Sweden at plant level and by fuel type. For some petroleum refining plants, data from the European Union Emission Trading Scheme (ETS) is used.

Manufacturing industries: Data is mainly from the quarterly fuel statistics, a sample survey conducted by Statistics Sweden. In some cases data from the industrial Energy use in the manufacturing industry (ISEN) or ETS is used as a complement. All data is at plant level and by fuel type.

Other sectors: Data from official statistical reports prepared by Statistics Sweden at national level and by fuel type.

Activity data is multiplied by thermal values, mainly from Statistics Sweden, and emission factors provided by the Swedish Energy Agency and the Swedish EPA. Default emission factors from the EMEP/EEA 2016 Guidebook are used to complement the national estimates.

1.2.4.2 ENERGY- MOBILE COMBUSTION

Data on fuel consumption at national level and by fuel type is collected from Statistics Sweden and used in combination with emissions data and fuel data from the National Road Administration, the National Rail Administration, the Civil Aviation Administration and the Swedish Military. Activity data is multiplied by thermal values, mainly provided by Statistics Sweden, and emission factors provided by the responsible authorities. Default emission factors from the EMEP/EEA 2016 Guidebook are used to complement the national estimates.

1.2.4.3 ENERGY – FUGITIVE EMISSIONS

For handling of solid fuels, activity data from Statistical Sweden is used, together with national emission factors for coal and peat.

Emissions from coke production are partly compiled from the facilities' environmental reports, partly calculated via facility-specific activity data and default emission factors from the EMEP/EEA 2016 Guidebook.

For flaring in refineries and chemical industries, activity data from ETS are used for 2005 and later. In earlier years, data was collected through personal contacts with the facilities. Activity data from hydrogen production in oil refineries are taken from ETS. Regular emission factors for stationary combustion are used.

Activity data for transfer losses of gasworks gas are taken from the environmental reports provided by the facilities. Data on venting and flaring of gas in the national gas transmission network (natural gas and biogas) is reported by the operator. Emission factors for stationary combustion are used for flaring. Losses of gas during transmission, storage, venting and distribution are estimated using a national method and national data on typical gas compositions.

Fugitive emissions from refineries and from storage of petroleum products at storage depots are mainly compiled from the facilities' environmental reports. Estimates of fugitive emissions from gasoline stations are calculated from fuel data provided by the National Road Administration.

1.2.4.4   INDUSTRIAL PROCESSES AND PRODUCT USE

The reported data for industrial processes is mainly based on information from environmental reports. According to Swedish environmental legislation, operators performing environmentally hazardous activities that require a permit by law are required to compile and send an annual environmental report to their supervisory authority. The County Administrative Boards audit the data from the operators' environmental reports.

The data in the environmental reports refer to emissions derived from plant specific measurements or estimates such as mass balances. The use of default emission factors is limited.

In some cases, when there are a large number of smaller companies within a specific sector, and all the environmental reports are not available, a combination of information available from environmental reports and production statistics at national level is used to estimate national emissions. Emission factors used are usually derived nationally based on available information from some facilities in a specific sector and applied to the national level. Default emission factors from the EMEP/EEA 2016 Guidebook are used to complement the national estimates.

Data used for estimating emissions from solvent and other product use are based on emission factors and national activity data obtained from the Products Register kept by the Swedish Chemicals Agency.

1.2.4.5   AGRICULTURE

Data on livestock population, crop areas, crop yields, sales of manure, manure management systems and stable periods are taken from official statistical reports published by the Swedish Board of Agriculture and Statistics Sweden. Some complementary information is collected from organisations and researchers, such as the Swedish Dairy Association, SLU and the Swedish Institute of Agricultural and Environmental Engineering. Default emission factors from the EMEP/EEA 2016 Guidebook are used to complement the national estimates.

1.2.4.6   WASTE

Emissions reported for waste incineration are compiled from the facilities' annual environmental reports. Other reported data are mainly based on models and uses statistical sources as activity data and default emission factors from EMEP/EEA 2016 Guidebook.

1.2.5   QA/QC procedures and extensive review of emission inventory (CHECK)

1.2.5.1   QUALITY CONTROL

Quality control is the check that is made during the inventory on different types of data, emission factors and calculations that have been made. The quality control takes place according to general requirements (Tier 1) which apply to all types of data used as support material for the reporting, and specific requirements for quality control (Tier 2) which are applied to certain types of data and/or emission sources. In this inventory, general Tier 1 QC measures, according to Table 6.1 in 2006 IPCC Guidelines (2006), have been carried out as follows:

- Transcription errors in data input
- Calculations are made correctly
- Units and conversion factors are correct
- Integrity of database files
- Consistency in data between source categories
- Time series consistency
- Correct movement of inventory data between processing steps
- Recalculations, checked and documented
- Completeness check
- Comparison of last submission's estimates to previous estimates
- Documentation of changes that may influence uncertainty estimates

In addition, source specific Tier 2 QC procedures are carried out for several categories (Table 1-2).

QC activities are performed in line with the 2006 IPCC Guidelines. All QC measures performed are documented by SMED in work documentations and checklists for each NFR code or group of codes. When the reporting tables are completed by SMED, sector QC meetings are held between SMED and the Swedish EPA. During the meetings, emission data is analysed in terms of level, trend

and changes compared to previous submission. Before delivery of the inventory to the Swedish EPA, the SMED quality coordinator performs the final quality control. The QC meetings and the SMED quality coordinator checks serve as both quality control and quality assurance in accordance with the 2006 IPCC guidelines. In addition, the validation tool RepDab[14] is used to check the format, completeness and internal consistency of the submission.

Table 1-2 Source specific Tier 2 QC procedures carried out in the inventory.

CRF		Action
1A, 1B and parts of 2	Energy amounts	Analysis of differences between the CRF sectoral and reference approach. In order to check activity data and EF, several quality control projects have been carried out over time comparing the inventory data with information from environmental reports and EU ETS data.
2C1	Iron and steel production	Activity data are checked with fuel combustion data in order to avoid double counting of emissions or omissions. Activity data is also compared to trade statistics. IEF are compared to IPCC default values.

1.2.5.2   QUALITY ASSURANCE

The Swedish QA/QC system includes several QA activities outside the SMED QA/QC procedures. At the final stages of completion of the inventory, the Swedish EPA performs a peer review for each sector. In the 2020 submission, the Swedish EPA inventory compiler team consisted of seven members.

The Swedish QA/QC system also includes national peer reviews by sectoral authorities prior to inventory submission. The peer review is defined in the Ordinance on Climate Reporting (2014:1434) and thus includes only review of greenhouse gases. However, most underlying data is the same for the estimation of greenhouse gases and air pollutions, and thus, the national reviews serve as quality improvements also for the air pollution reporting. The national reviews include all sectors and are conducted by a person who has not taken part in the inventory preparation. The Swedish EPA is responsible for coordinating the peer reviews. From the 2016 submission, the national peer review is conducted in two steps:

- *Annual national review*. The aim of the review is to check the robustness of the national system and to guarantee that politically independent emissions data is reported. The review is performed by sectoral authorities prior to submission.

- *In-depth expert peer review*. Each year there is also an in-depth peer review of one sector or part of a sector. The choice of sector depends on the outcome of the results from the EU and UNFCCC reviews and if the national review has identified problems or other needs discovered by SMED or the Swedish EPA. The aim of the in-depth expert peer review is to improve the inventory data quality. The review is performed by sectoral authorities and other national and international experts.

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[14] http://www.ceip.at/check-your-inventory-repdab/

The annual national review is organised as a yearly meeting. Before the meeting the sectoral authorities have reviewed the NIR in terms of the functionality of the national system and a general overview of methodology and statistics used (chapter 1), emission trends (chapter 2) and changes in methods, if changed (chapter 8). Thereafter the reviewers will provide feedback on whether they find the inventory reliable and independent, the trends are correct and the national system functional. Any recommendations for improvements are recorded in the list of suggested improvements described in section 1.2.8.

The in-depth expert peer review includes methodologies, models, activity data and emissions factors. The reviewers also identify areas for improvement, which consolidates the basis for improvements in coming submissions. Results from the national peer review are documented in review reports. Recommendations from the review reports are collected to the list of suggested improvements described in section 1.2.8.

The UNECE secretariat administers an international peer review of Swedish reporting after submission approximately every fourth year. Recommendations from the review reports are collected to the list of suggested improvements described in section 1.2.8.

1.2.6 Finalization, publication and submission of the inventory

The Swedish Environmental Protection Agency informs the Ministry of the Environment and Energy about the air pollutants inventory report in mid-December. At the same time, the inventory is published nationally[15].

The Swedish EPA submits the inventory to the CLRTAP/UNECE and NEC Directive/European Commission on February 15th. Reported data in the submission of year X relates to emissions year X-2, in other words emissions which took place during 2018 are reported in early 2020.

1.2.7 Data storage

A system for handling emission data, entitled Technical Production System (TPS)[16], has been developed and was implemented for the first time in submission 2007. It supports data input from text files and Microsoft Excel sheets, and provides different types of quality gateways. For instance, the system makes it possible for multiple users such as the SMED consortium and the national peer reviewers to view data, plot time series and make comparisons between different years and submissions. For all NFR categories and sub-categories, time series from 1990 (sometimes 1980) onwards of emission data, activity data, and implied emission

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[15] www.naturvardsverket.se

[16] https://tps.naturvardsverket.se/

factors where relevant can be presented. The system also allows for different types of data output, e.g. to the NFR tables or to plain MS Excel. Finally, TPS is used for data archiving of each submission. For access to the TPS, login with password is requested.

In addition to TPS, documentation, data and all calculations for each submission are stored at each organization's servers and, for collective use and archiving, at two projects at Projectplace[17]. One project is for documents shared between Swedish EPA, other involved agencies and SMED and the other project is primarily for SMEDs use however the Swedish EPA also has access to the major part of the project. At Projectplace, all documents are stored in versions, in other words when documents are changed a new version is automatically created. This function ensures that important information is not lost and facilitates backtracking of changes. Login with password is requested for access to projects at Projectplace.

1.2.8 Follow-up and improvement (ACT)

Each year, all comments received from national and international reviews that are not already addressed and also ideas from SMED and the Swedish EPA are compiled into a list for suggestions on improvements. From this list, development projects are formed each year as describes in section 1.2.3. All suggestions not implemented one year is kept on the list for next year.

Each year, the Swedish EPA follows up on delivered data from responsible agencies to ensure correct and appropriate data for next submission.

Development of TPS such as additional functions etc. is organized in a similar way as for the inventory: Ideas are compiled into a list, and from this list issues to be implemented are prioritized.

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[17] www.projectplace.com

1.3   Key source categories

Key source categories are sources that together contribute with either 95 % of the level or 95 % of the overall trend of reported emissions in Sweden. In this inventory, level and trend assessments are carried out for the following pollutants: As, Cd, CO, Cr, Cu, dioxins/furans, Hg, NH_3, Ni, NMVOC, NO_X, PAH 1-4, Pb, $PM_{2.5}$, PM_{10}, Se, SO_2, TSP and Zn. The level and the trend assessment are done with both the approach 1 and the approach 2 methods. The results of the Swedish key source analysis for 2021 are presented in Annex 1 together with the methodology.

1.4   General uncertainty evaluation

In order to prioritise efforts and resources in subsequent years, expert judgments mainly by the inventory staff together with IPCC references on uncertainties in activity data and emission factors have been the basis for the IPCC Tier 1 uncertainty evaluation.

The complete results of the Swedish uncertainty analysis for 2019 are presented in Annex 1 together with the methodology. The summary table below (Table 1-3) show the uncertainty for the total emissions together with the uncertainty for the trend for all substances. The tables A1-1 to A1-19 in the annex show for all pollutants; estimated emissions 1990 and 2019, the uncertainty for the trend 1990-2019 and the uncertainty in national emissions 2019 together with the estimated uncertainty for the emission factor and for the activity data. For several of the substances the majority of the total variance derives from only a limited number of sources. For example, 73 % of the variance in total NO_X emissions derives from the application of mineral fertilisers. In general, the emission factors are more uncertain than the activity data.

Table 1-3 Summary of uncertainties in total inventory by pollutant in 2019 and trend uncertainties 1990-2019.

Pollutant	Uncertainty in total inventory 2019 (%)	Uncertainty introduced into the trend 1990-2019 (%)
As	83.5	11.1
Cd	34.5	6.1
CO	18.7	7.8
Cr	49.1	7.2
Cu	62.0	13.2
DIOX	133.7	104.8
Hg	72.2	3.8
NH_3	17.4	8.7
Ni	19.8	3.1
NMVOC	21.4	5.9
NO_x	27.3	8.7
PAH 1-4	680.7	32.1
Pb	25.0	0.5
$PM_{2.5}$	20.0	3.0
PM_{10}	15.6	4.4
Se	407.8	158.5
SO_2	8.4	1.3
TSP	16.6	5.5
Zn	268.3	75.1

1.5 General assessment of completeness

The Swedish inventory covers all air pollutants required and most relevant sources with some exceptions. The general completeness for each sector is discussed below.

Sources where pollutants not yet have been estimated, but may occur, include: 2C7d, Storage handling and transport of metal products; 2J, Production of POPs; 2K, Consumption of POPs and heavy metals; 3Da4, Crop residues applied to soils; 3Db, Indirect emissions from managed soils; 3Dd, Off-farm storage handling and transport of agricultural products.

For sources where PAH1-4 is estimated, usually benzo(a)pyrene is estimated separately but not always the other 3 specified PAH-substances due to lack of information. As a consequence, national totals for the 4 specified PAH species in relation to PAH1-4 may be misleading.

As a consequence of the in-depth review of the 2013 submission of the Swedish inventory under the CLRTAP and EU NEC directive, Sweden has implemented emission estimates for all missing sources and pollutants in the Swedish inventory where there are default emissions factors available and they can be considered to be representative of the national circumstances (first time in Submission 2016). In Table 1-4a and 1-4b those sources are listed that are not estimated in the Swedish emission inventory. For some of these, default emission factors are available in the

EMEP/EEA Guidebook 2016. For each of the sources in Table 1-4a and 1-4b, an explanation is given as to why emissions have not been estimated.

Table 1-4a Sources in the Swedish air pollutant inventory for which emissions have not been estimated – Main pollutants and particulates. Explanations are given below.

NFR Code	NO$_X$	NMVOC	SO$_X$	NH$_3$	PM$_{2.5}$	PM$_{10}$	TSP	BC	CO
1B1c				NE (3)				NE (3)	
2C1b				NE (3)					
2C1c				NE (3)					NE (3)
2C7b			NE (1)				NE (1)		
2C7d					NE (1)	NE (1)	NE (1)		
11B	NE (5)	NE (5)	NE (5)	NE (5)	NE (5)	NE (5)	NE (5)		NE (5)

Table 1-4b Sources in the Swedish air pollutant inventory for which no emissions have been estimated – Heavy metals and POPs. Explanations are given below.

NFR Code	Pb	Cd	Hg	As	Cr	Cu	Ni	PCDD/ PCDF	PAH 1-4	HCB	PCB
1B1c									NE (3)	NE (3)	NE (3)
1B2A1	NE (3)	NE (3)	NE (3)	NE (3)	NE (3)	NE (3)	NE (3)		NE (3)		
1B2A4									NE (3)		NE (3)
1B2C									NE (3)		NE (3)
2C1b									NE (2)	NE (3)	NE (2)
2C1c									NE (2)		
2C7a											NE (1)
2C7b							NE (1)				
2K			NE (2)								NE (2)

(1) Notation key should be IE (included in NFR 2), will be corrected in submission 2022.

(2) Default EF results in unreasonable emissions and is not applicable to Swedish conditions.

(3) Not possible to estimate with the country-specific methodology currently used.

(4) Notation key should be IE (included in NFR 5C1bii)

(5) Source is not mandatory.

1.5.1 Energy

Estimated emissions are considered to be complete for most sources. There might still be some incompleteness as regards in-house generated fuels in the chemical industry and in smaller companies.

Fugitive emissions, i.e. venting and flaring of liquid and gaseous fuels, are most likely not complete for smaller companies. However, all Swedish plants that flare gas and that are included in the European trading scheme for CO_2 from 2005, are included. For smaller plants, data might be reported in NFR1A instead of NFR1B. Hence lack of data on emissions from flaring is considered to be insignificant.

1.5.2 Industrial Processes and Product Use

For most sources, and particularly for the most important ones, the estimates are in accordance with the requirements concerning completeness as laid out in the EMEP/EEA air pollutant emission inventory guidebook – 2016. However, some exceptions do exist, mainly in terms of some heavy metal emissions and POPs from product use and consumption of POPs and heavy metals, where the default guidebook emission factors were judged inappropriate for Swedish conditions.

1.5.3 Agriculture

Emissions of NO_X and NH_3 from crop residues are currently not estimated, because neither a country specific method nor a default method in the guidebook exists. Beyond that all relevant agricultural emissions and sources are considered to be included in the inventory. For example, most of the country's horses do not belong to farms but are despite that included in the agricultural sector of the inventory. All sales of fertilizers are included, also quantities used in other sectors.

1.5.4 Waste

Emissions from incineration of Municipal Solid Waste (MSW) are included in 1A1a, as MSW is used for energy production. In NFR 5, emissions of some pollutants from hazardous waste incineration, cremation, landfill fires and garden burning/bonfires are included, but not complete. For hazardous waste incineration, emissions from one large plant are included, and there may be emissions from smaller plants that are not covered. The overall completeness for the waste sector is unknown, but the inventory can be considered as complete in terms of using the suggested methods in EMEP/EEA Guidebook 2016. The EMEP/EEA Guidebook 2019 has yet to be implemented.

2   Explanation of key trends.

2.1   Emissions of pollutants regulated in the amended Gothenburg Protocol

Emissions of pollutants regulated in the amended Gothenburg Protocol (SO_2, NO_X, NH_3, NMVOCs, $PM_{2.5}$ and BC) have been reduced since 1990 (Figure 2-1).
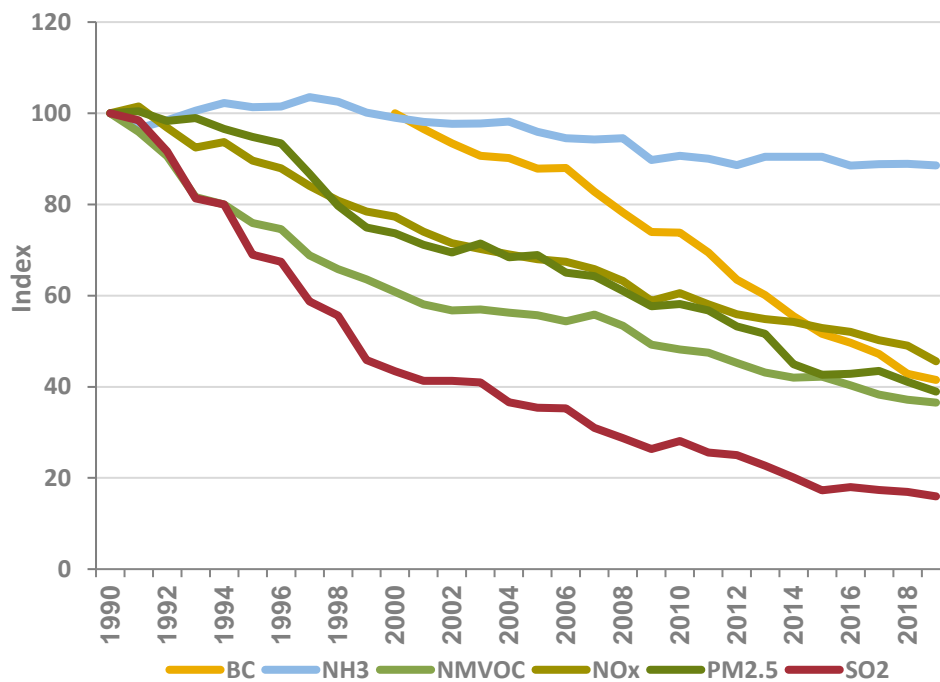
Figure 2-1   **Trends in emissions 1990-2019 for NO_X, SO_2, NH_3, NMVOC, $PM_{2.5}$ index year 1990=100 and BC index year 2000=100.**

2.1.1   Nitrogen oxides (NO_X)

Swedish emissions of NOX amounted to 127 kt in 2019. In total emissions have decreased by 54 % since 1990 and by 8 % since 2018. The different sectors' share

of the NOX emissions in Sweden 2019 is shown in Figure 2-2.
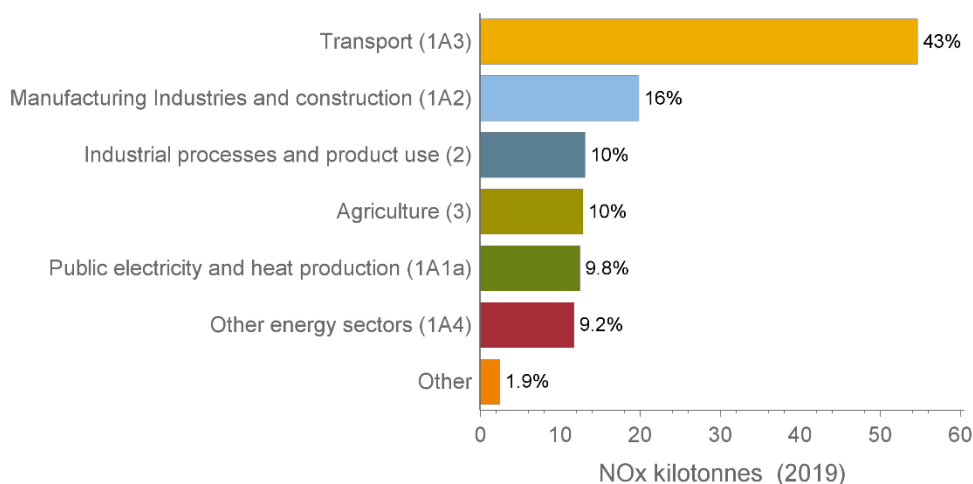
Figure 2-2   **Distribution of NO$_X$ emissions among major contributing sectors and subsectors in 2019.**

The largest source of NOX emissions in 2019 was the transport sector (NFR1A3), where emissions amounted to 55 kt, corresponding to 43 % of the total. Emissions from the transport sector have been reduced by 65 % since 1990 and by 14 % since 2018. Since 1990 the stricter emission requirements for new vehicles during the period can explain the reduction.

NOX emissions from passenger cars (NFR1A3b) were 65 % lower in 2019 compared to 1990 (Figure 2-3). Since 2006, NOX emissions from diesel passenger cars have increased from 6 kt to 20 kt. The combination of increased use of diesel due to the political ambition to reduce CO_2-emissions from cars and the problems with the large discrepancies between Euro standards and real driving emissions (RDE) from diesel cars are the main reasons for this development. Emissions of NOX from gasoline cars as well as heavy-duty vehicles continue to decrease. Emissions from heavy duty vehicles were reduced by 25 % between 2018 and 2019 and by 86 % since 1990.
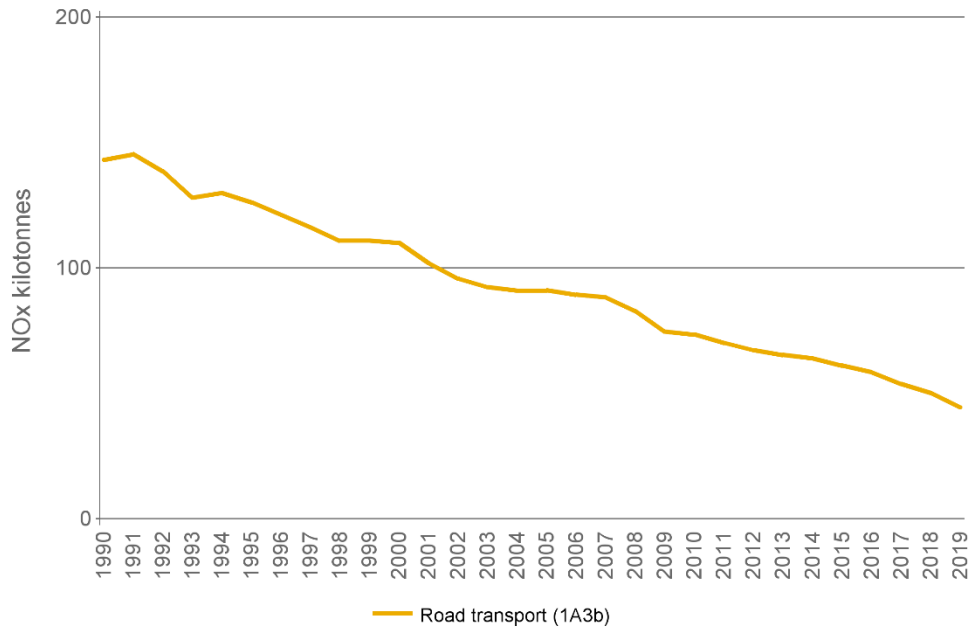
Figure 2-3   **Trend in NO_X emissions from transport (1A3b) 1990-2019.**

The second largest source of NOX emissions in 2019 was combustion in manufacturing industries and construction (NFR1A2) in which emissions were 20 kt, corresponding to 16 % of the total emissions. NOX emissions in the sector have been reduced by 49 % since 1990 and increased by 1 % since 2018 (Figure 2-4).

Emissions of NOX from electricity and heat generation (NFR1A1a) amounted to 12 kt in 2019, corresponding to 10 % of the total emissions. Emissions have varied during the period with decreasing emissions during the 1990's and increasing emissions between 2000 and 2010 (Figure 2-4). To some extent emissions depend on temperature and precipitation resulting in higher emissions during 1996 and 2010 which were exceptionally cold years.

In 1992, a NOX-fee were introduced where combustion plants (NFR1A1a and 1A2) with an output of more than 25 GWh per year are included. Since the introduction of the fee, NOX emissions per unit produced energy have been reduced to less than half. This is an important reason why emissions of NOX from combustion in manufacturing industries and construction and electricity and heat pro-duction have decreased despite increased energy production.

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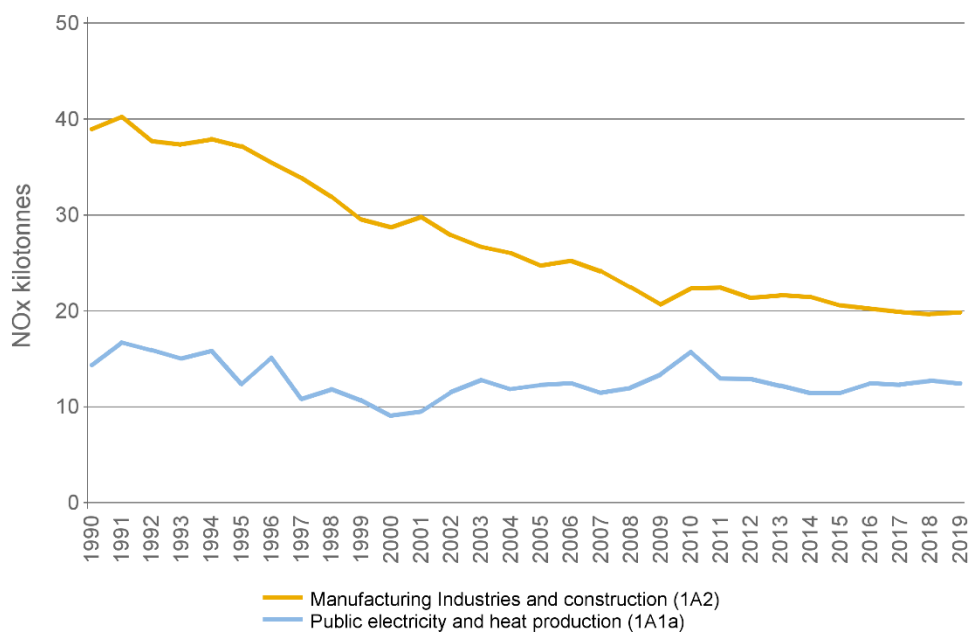
Figure 2-4   **Trends in emissions from Public electricity and heat production and Manufacturing industries and construction 1990-2019.**

Emissions of NOX from other sectors (NFR1A4) were 12 kt, corresponding to 9 % of the total emissions in 2019. These emissions have been reduced by 63 % since 1990 due to expanded district heating and increased use of heat pumps that have replaced oil heaters.

Agriculture sector and industrial processes sector contributed with 10 % respectively of the total emissions of NOX in 2019. Emissions from industrial processes have decreased by 15 % since 1990 and have stayed at the same level since 2010. The main part of the emissions originates from the pulp- and paper industry (NFR2H1).

2.1.2 Sulphur dioxide (SO₂)

Total emissions of SO2 have decreased by 84 % since 1990 and decreased by 6 % since 2018 and amounted to 16.4 kt in 2019. The different sectors share of the SO2 emissions in Sweden 2019 is shown in Figure 2-5.
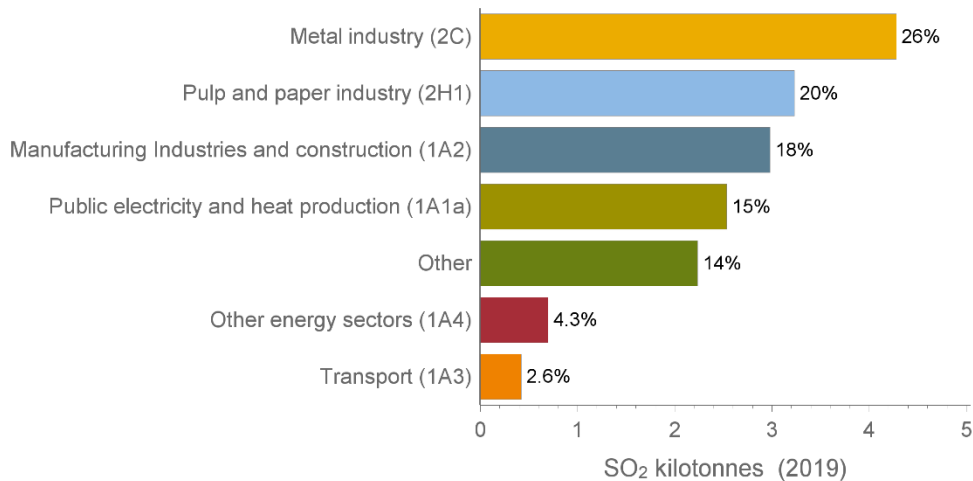
Figure 2-5   **Distribution of SO₂ emissions among major contributing sectors and subsectors in 2019.**

Industrial processes (NFR2) emitted 9 kt during 2019 and was the main contributor to the emissions of SO2. Processes within the metal industry (NFR2C) and pulp and paper industry (NFR2H1) generated 4.3 and 3.2 kt, respectively in 2019. Since 2018 emissions from the metal industry have decreased by 16 % and have overall been reduced by 56 % since 1990. Emissions from the pulp and paper industry decreased by 1 % since 2018 and 75 % since 1990.

Emissions from combustion in manufacturing industries and construction (NFR1A2) amounted to 3 kt in 2019, corresponding to 18 % of the total emissions. Emissions have been reduced by 85 % since 1990. The main reason for the large reduction since 1990 was a cut down in the use of oil in the sector and better pollution control.

Emissions from electricity and heat generation (NFRA1a) amounted to 2.5 kt in 2019. Emissions from the sector have been decreased by 84 % since 1990 due to reduced use of coal and oil and pollution control. Between 2018 and 2019 emissions decreased by 14 %.

Transport (NFR1A3) and other sectors (NFR1A4) amounted to 0.5 kt and 0.7 kt, respectively in 2019, each corresponding to roughly 3 and 4 %. Emissions in these

sectors have decreased by 95 % since 1990 due to reduced use of oil and reduced sulphur content in the oil used.
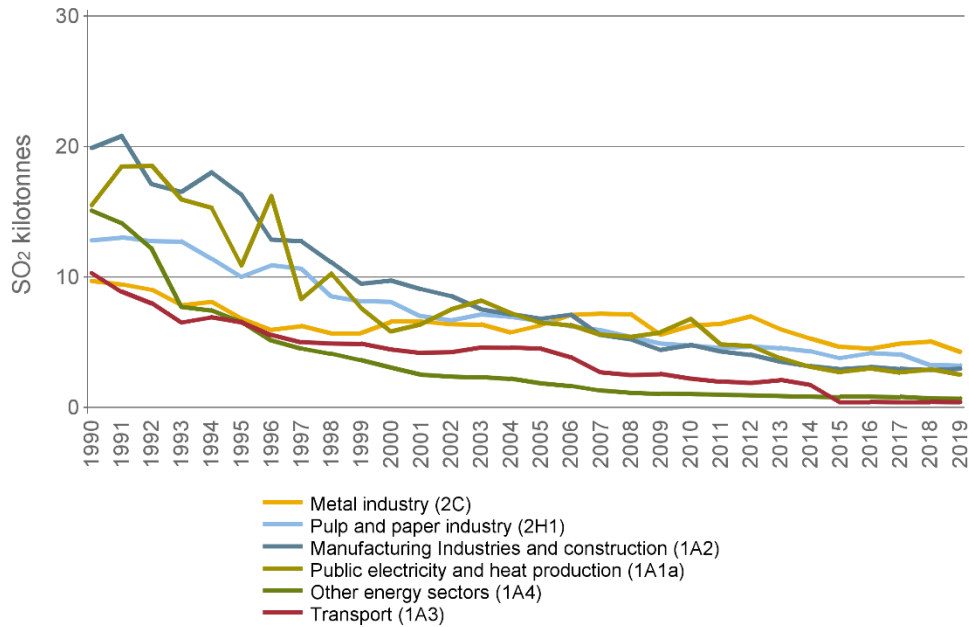
Figure 2-6   **Trends in SO$_2$ emissions from major sectors and subsectors 1990-2019.**

2.1.3 Ammonia (NH₃)

Total emissions of NH_3 in Sweden (53.4 kt) were 11 % lower in 2019 compared to 1990. Between 2018 and 2019 emissions decreased by 0.4 %. The different sectors' share of the NH_3 emissions in 2019 is shown in Figure 2-7.
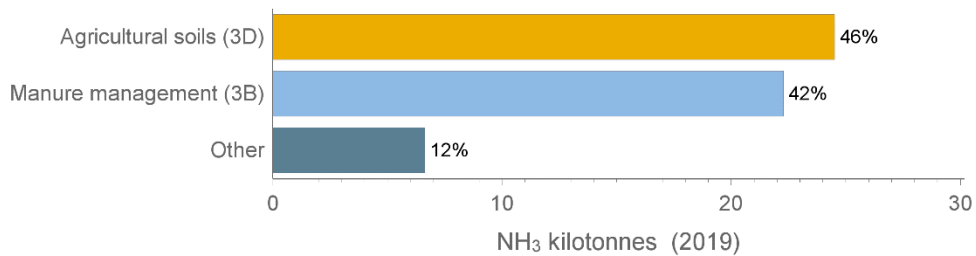
Figure 2-7   **Distribution of NH₃ emissions among major contributing sectors and subsectors in 2019.**

The agriculture sector (NFR3) was the main source for NH_3 emission in the inventory, amounted to about 47 kt in 2019. Ammonia is emitted from farm animals' dung and urine and during the spreading of animal manure and the use of inorganic fertilizers.

Emissions from agriculture soils (NFR3D) were 24.5 kt in 2019 and accounted for 46 % of total emissions. Within NFR3D, most of the emissions come from animal manure and inorganic fertilizers applied to soils. Emissions were 12 % lower in 2019 compared to 1990 and has been almost stable since 2005.

Manure management (NFR3B) contributed with about 22 kt or 42 % of total emission of NH_3 in 2019. The main shares came from non-dairy cattle, 9.7 kt followed by dairy cattle, 3.1 kt. Emissions from manure management were 16 % lower in 2019 compared to 1990 due to a decline in number of animals, lesser use of inorganic fertilizers, and a more effective production within the sector.

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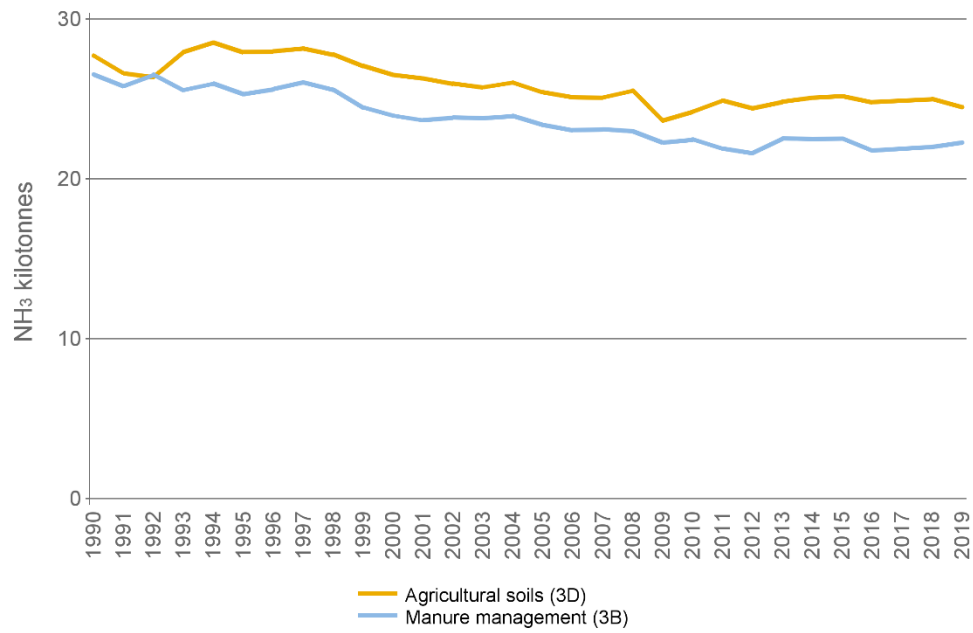
Figure 2-8   **Trend in NH₃ emissions from manure management (NFR3B) and Agricultural Soils (NFR3D) 1990-2019.**

2.1.4   NMVOC

Emissions of NMVOC which amounted to 134 kt in 2019 have decreased by 64 % since 1990 and by 2 % since 2018. The different sectors' share of the NMVOC emissions in Sweden 2019 is shown in Figure 2-9.


Bar chart titled "NMVOC kilotonnes (2019)":
- Solvent use (2D3): 38%
- Other: 18%
- Manure management (3B): 15%
- Other energy sectors (1A4): 12%
- Transport (1A3): 9.4%
- Fugitive emissions (1B): 7.7%
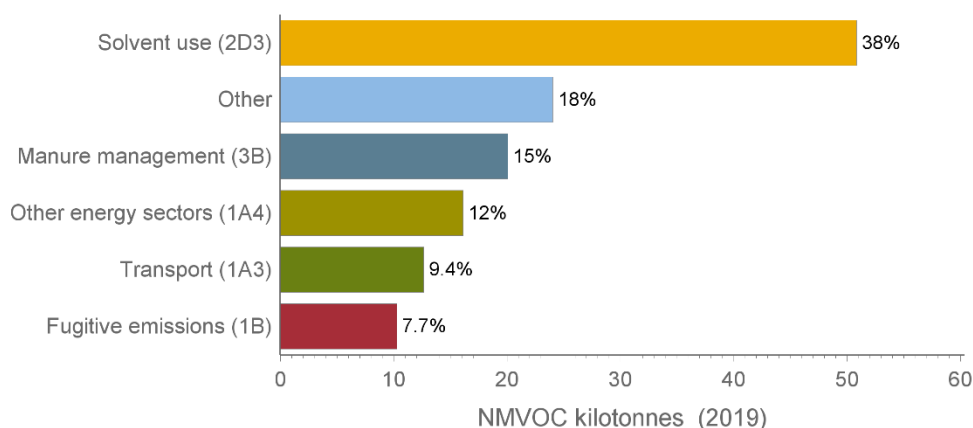
Figure 2- 9   Distribution of NMVOC emissions among major contributing sectors and subsectors in 2019.

Emissions of NMVOC from solvent use (NFR2D3) were 51 kt in 2019 and it was the dominant source contributing with 38 % to total emissions. Emissions from solvent use have decreased by 43 % since 1990. Important reductions occurred from coating applications (in sector NFR2D3) where emissions decreased by 77 % since 1990. Emissions from other non-specified (in sector NFR2D3) have more than doubled since 1990, from 13 kt to 30 kt.

Emissions from the transport sector (NFR1A3) which accounted for 13 kt, corresponding to 9 % of national totals in 2019, have decreased by 92 % since 1990 and by 5 % since 2018. The main part of the reduction since 1990 comes from passenger cars (NFR1A3b) since the cars have been more energy efficient and the introduction of new exhaust requirements. Emissions from gasoline evaporation (NFR1A3b) have been reduced by 95 % from 45 kt to 2.3 kt per year since 1990, due to emission control measures.
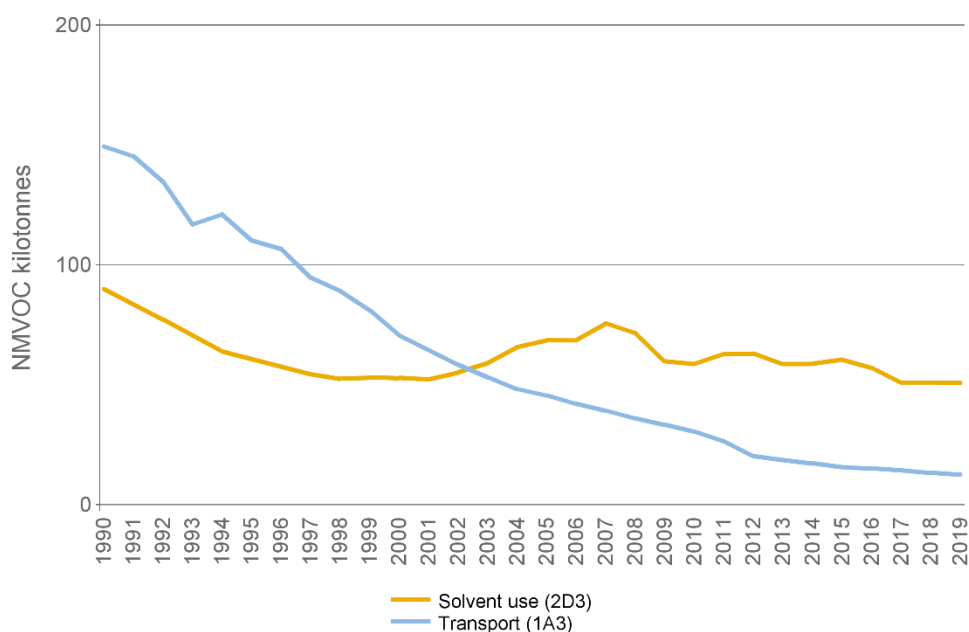
Figure 2-10   Trends in NMVOC emissions from solvent use (2D3) and transport (1A3) 1990-2019.

Emissions from other energy sectors (NFR1A4) amounted to 16.1 kt in 2019, cor-responding to 12 % to the total emissions. Since 1990 emissions have de-creased by 46 %. The main contribution, 11 kt or 8 % of total emissions, comes from the residential sector (NFR1A4b) where the sources are combustion of bio-mass and the use of gasoline in gardening equipment.

Emissions of NMVOC from manure management (NFR3B) were 20 kt in 2019, corresponding to 15 %. Fugitive emissions (NFR1B) of NMVOC were 10.3 kt in 2019 corresponding to 8 % of total emissions of NMVOC. The emissions have de-creased by 67 % since 1990. The main part, roughly 60 %, of fugitive emissions originates from total refinery areas and the main reduction can be observed in the emissions from gasoline distribution.

2.1.5 Particulate matter (PM$_{2.5}$)

Emissions of PM$_{2.5}$ were 17.7 kt in 2019 and have been reduced by 61 % since 1990 and decreased by 5 % since 2018. The different sectors' share of the PM$_{2.5}$ emissions in Sweden 2019 is shown in figure 2-11.

Figure 2-11   Distribution of PM$_{2.5}$ emissions among major contributing sectors and subsectors in 2019.

Other energy sectors (NFR1A4) were the largest source of PM$_{2.5}$ in 2019, accounting for 6.2 kt or 35 % of total emissions. Emissions were 59 % lower in 2019 compared to 1990. The main part of the emissions in the sector came from stationary biomass combustion in the residential sector (NFR1A4bi). Emissions from this sector, which have varied over the period, were 61 % lower in 2019 compared to 1990.

Emissions from road transport (NFR1A3b), the second largest source of PM$_{2.5}$, amounted to 4.3 kt in 2019. Emissions from road transport have decreased by 42 % since 1990. The main reason for reductions since 1990 is stricter standards resulting in lower emissions from heavy goods vehicles (92 % reduction since 1990) and buses (93 % reduction since 1990). Specific emissions of PM$_{2.5}$ from diesel passenger cars have been reduced by over 70 % since 1990. The emissions from automobile road abrasion, which depend on the total traffic work and the use of studded tires, increased with 30 % between 1990 and 2019.

Emissions from combustion in manufacturing industries and construction (NFR1A2) were 1.1 kt in 2019, accounted for 6 % of total emissions of PM$_{2.5}$. Emissions from the sector have been reduced by 76 % since 1990. Most of the

emissions in the sector originated from pulp, paper, and print (NFR1A2d) and other (NFR1A2g).

Emissions from electricity and heat generation (NFR1A1a) amounted to 0.9 kt in 2019. Emissions have decreased by 59 % since 1990. The reason for the reduction is improved pollution control. Emissions in 2019 were 4 % lower compared to 2018.

The pulp and paper (NFR2H1) and metal industries (NFR2C) are the two most important subsectors within industrial processes and product use (NFR2) where emissions were 1.9 and 0.9 kt, respectively in 2019. In the metal industries there was a large reduction in emissions between 2013 and 2014 much of which can be explained by a new electro filter at a large pellet plant. Between 2018 and 2019 emissions were decreased by 40 %. There has been a significant reduction, 79 %, in emissions from the pulp and paper industry between 1990 and 2019.
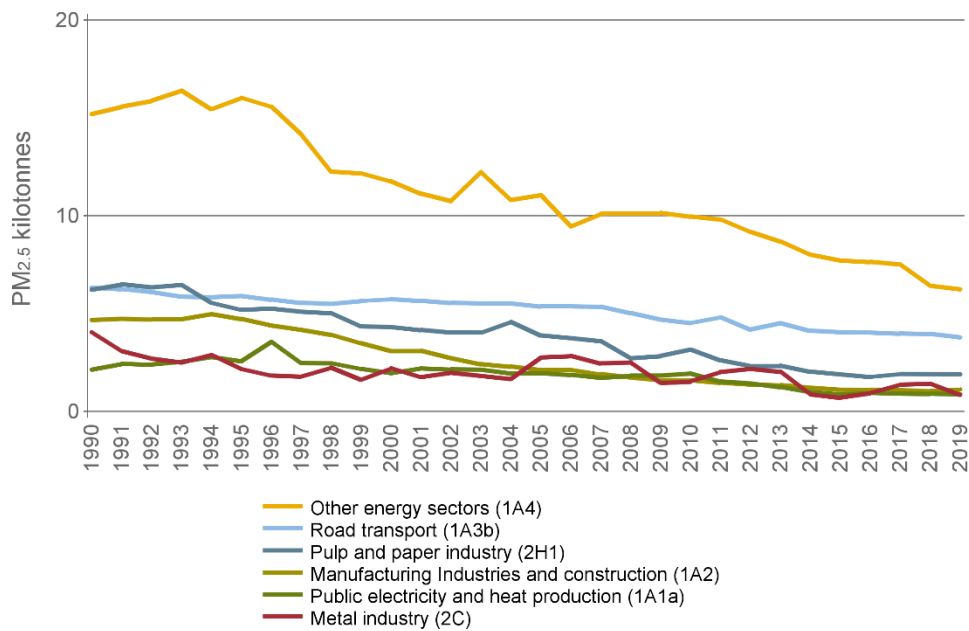
Figure 2-12   **Trends in PM$_{2.5}$ emissions from major sectors and subsectors 1990-2019.**

2.1.6   Black carbon (BC)

Total emissions of black carbon (BC) in Sweden 2019 were 2.3 kt in. Emissions have been reduced by 58 % since 2000 and by 3 % since 2018. The different sectors' share of the BC emissions in Sweden 2019 is shown in figure 2-13.
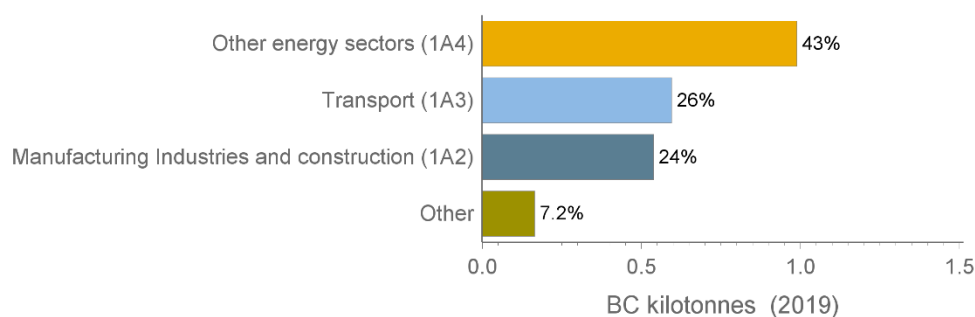
Figure 2-13   Distribution of BC emissions among major contributing sectors and subsectors in 2019.

The largest source of BC emissions in 2019 with 43 % of the emissions was other energy sectors (NFR1A4) where emissions amounted to 1 kt. The main part, 0.7 kt, originates from stationary biomass combustion.

The second largest source is the transport sector (NFR1A3) in which emissions amounted to 0.6 kt in 2019. The most important source was road transportation (NFR1A3b), contributing with 0.5 kt or 79 % of the emissions within the sector. Emissions from road transportation have been reduced by 76 % since 2000 and the most important contribution to the reduction comes from heavy duty vehicles (88 %) and passenger cars (81 %). The reductions are a result of stricter exhaust requirements.

Emissions from combustion in manufacturing industries and construction (NFR1A2) were 0.5 kt in 2019. Emissions were 53 % lower in 2019 compared to 2000. A majority originates from off-road vehicles and other machinery (NFR1A2g).
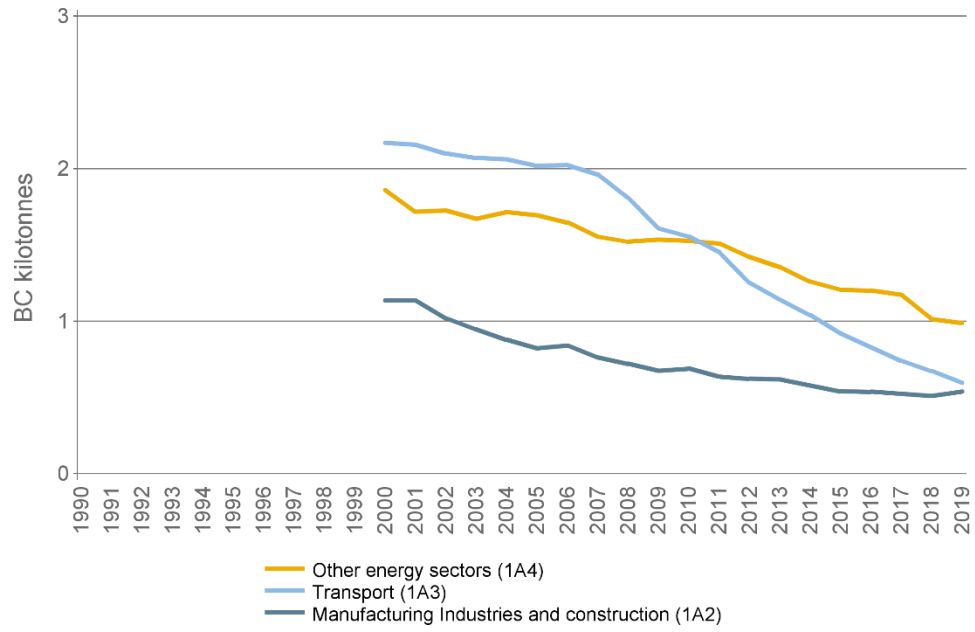
Figure 2-14   **Trends in BC emissions from major sectors and subsectors 1990-2019.**

2.2   CO, PM₁₀, PAH1-4, HCB & Dioxins

Emissions of CO, PM₁₀, PAH1-4, HCB and dioxins all show decreasing trends over the period (1990-2019). The reduction of emission of these pollutants was between 40 % and 83 % but emissions have varied over the period (figure 2-15).
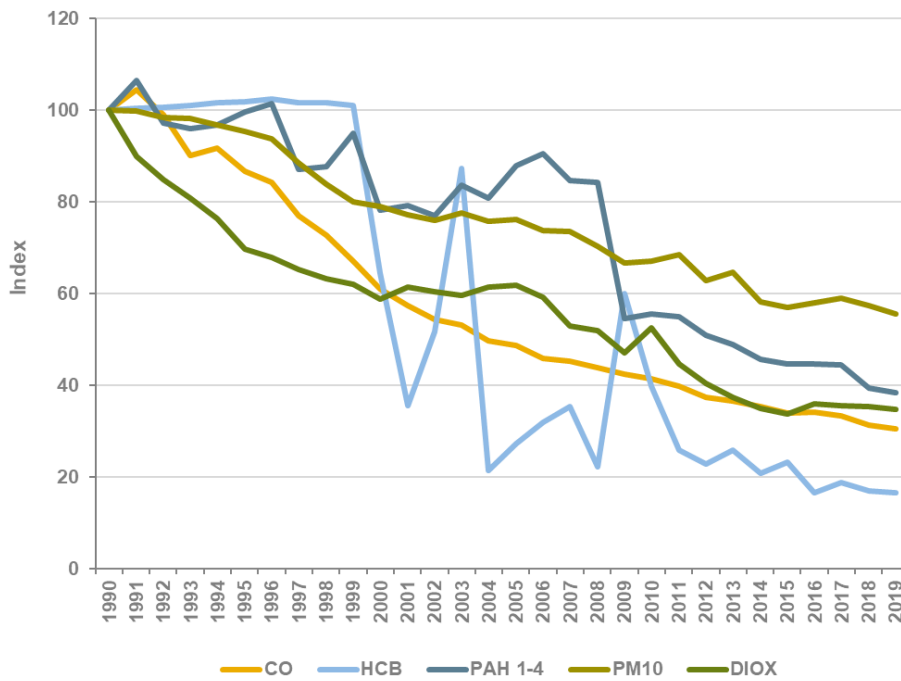
Figure 2-15   **Trends in emissions 1990-2019 for CO, PM₁₀, PAH1-4, HCB and dioxins. Index 1990=100.**

2.2.1 Carbon monoxide (CO)

The aggregated emissions of carbon monoxide (CO) have decreased from 1.1 Mt in 1990 to about 0.3 Mt in 2019, a decline of 70 %. The different sectors' share of the CO emissions in Sweden 2019 is shown in figure 2-16.
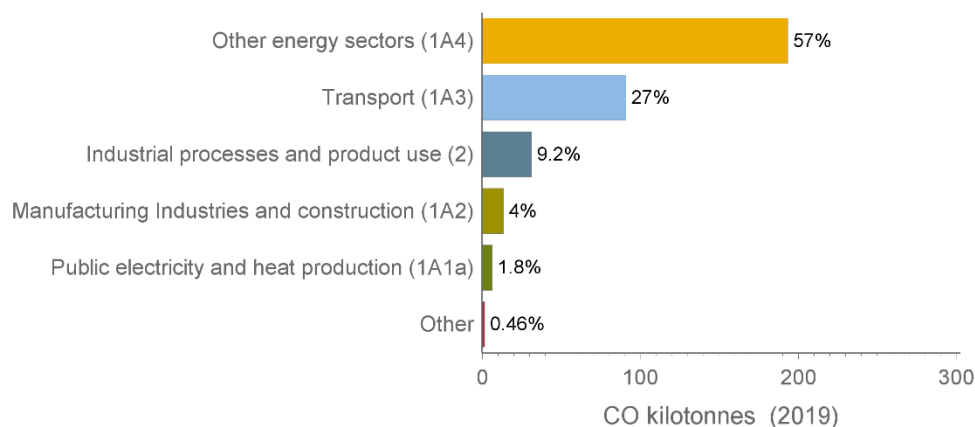
Figure 2-16   Distribution of CO emissions among major contributing sectors and subsectors in 2019.

Other energy sectors (NFR1A4) was the largest source for CO emission, accounting for about 57 % of the total emissions in 2019. Most of the emission was derived from biomass combustion in residential stationary plants, (NFR1A4bi). The rest were derived from other stationary combustion (NFR1A4ai), off-road vehicles and other machinery (NFR1A4aii and 1A4bii), and agriculture, forestry and fishing (NFR1A4c).

In 2019, the transport sector (1A3) was responsible for 27 % of the total emissions of CO. Emissions from the transport sector have decreased by 89 % since 1990, the main reason being the introduction of catalytic converters in passenger cars and light duty vehicles. Emissions of CO from passenger cars have decreased by 92 % and from light duty vehicles by 95 % since 1990.

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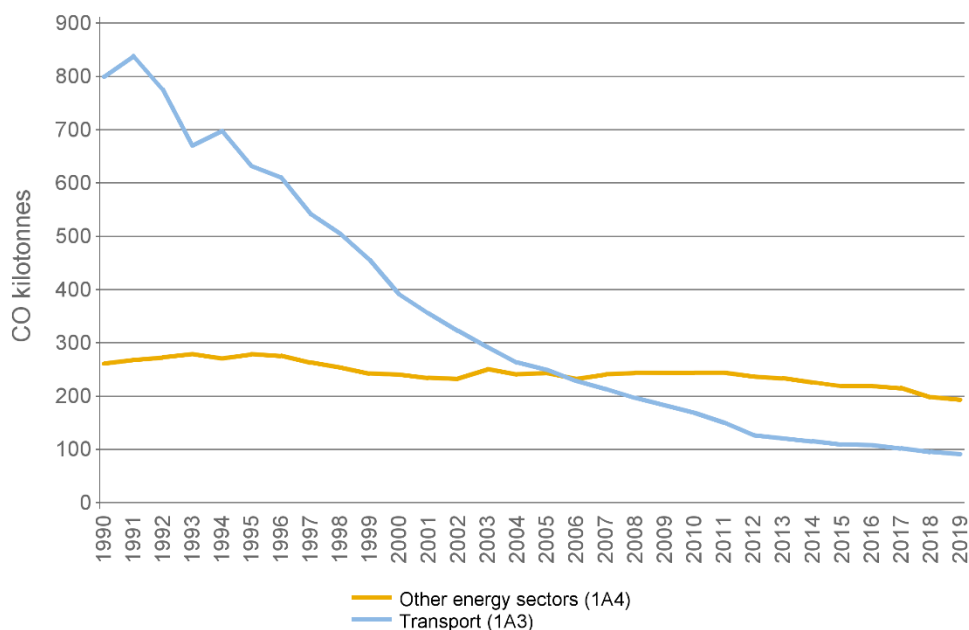
Figure 2-17 **Trends in CO emissions from other sectors (NFR1A4) and transport (NFR1A3) 1990-2019.**

Carbon monoxide emissions from the industrial processes and product use sector (NFR2) were 31 kt in 2019 contributing with 9 %. Emissions from industrial processes and product use have increased by about 42 % compared to 1990.
The total emissions derived largely from aluminum (NFR2C3) were emissions have increased with 87 % since 1990 and from the pulp and paper industry (NFR2H1) emissions which have increased with 31 % since 1990.

Carbone monoxide emissions from electricity- and heat generation (NFR1A1a) and combustion within manufacturing industries and construction (NFR1A2) amounted to 6.2 and 13.5 kt, respectively. Most of the emission in electricity- and heat generation is derived from biomass combustion and the emissions from the sector have increased by more than 800 % since 1990. Within the manufacturing industries (NFR1A2) the emissions originate mainly from off-road vehicles and other machinery (1A2gvii) contributing with 3 % of the national total emissions of CO.

2.2.2 Particulate matter (PM$_{10}$)

Emissions of PM$_{10}$ were about 37 kt in 2019 and have decreased by 45 % since 1990. The aggregated emission in 2019 has decreased by 3 % compared to 2018. The different sectors' share of the PM$_{10}$ emissions in Sweden 2019 is shown in figure 2-18.
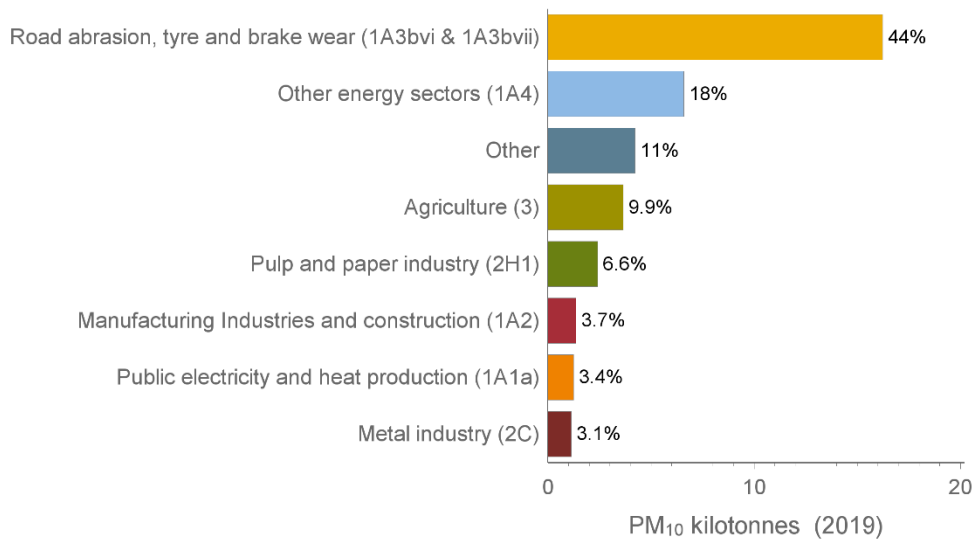
Figure 2-18   **Distribution of PM$_{10}$ emissions among major contributing sectors and subsectors in 2019.**

The main sources of PM$_{10}$ emissions in 2019 were automobile road abrasion, tyre, and brake wear (NFR1A3b), accounting for in 16 kt in which the major part (95 %) comes from automobile road abrasion. Emissions from automobile road abrasion, tyre, and brake wear were 30 % higher in 2019 than in 1990. The magnitude of PM$_{10}$ emission depends on total traffic work and the use of studded tires.

The second largest source of PM$_{10}$ emissions was other energy sectors (NFR1A4) which amounted to 6.6 kt or 18 % of the total emissions in 2019. Most of the emissions are derived from using biomass in residential stationary combustion (NFR1A4bi) with a total of 5.4 kt. The aggregated emissions from NFR1A4 in 2019 decreased by 3 % compared to 2018. (Figure 2-19).

Emissions from agriculture sector (NFR3) were 3.6 kt in 2019 or 10 % of the national total. Manure management (NFR3B) and agricultural soils (NFR3D) contributed with about 1.5 and 2.1 kt, respectively.

The aggregated emissions of PM$_{10}$ from industry (NFR2) were about 5.3 kt, 15 % of the national total. The pulp and paper industry (NFR2H1) accounts for the largest part of the sector emissions and contributes with 2.4 kt, 7 % of the national total

in 2019. Emissions in the sector have been reduced by 72 % since 1990. Large reductions in emissions have occurred in metal industry (NFR2C), 77 % since 1990, mainly due to installation of new flue gas treatment in pellets production (NFR2C1e).

Emissions of PM_{10} from combustion in manufacturing industries and construction (NFR1A2) amounted to 1.4 kt in 2019 and have been reduced by 77 % since 1990. Biomass combustion in pulp, paper, and print (NFR1A2d) contributed with about 0.4 kt in 2019.

Emissions from public electricity- and heat production (NFR1A1a) were about 1.2 kt, or 3 % of the total emission in 2019. Emissions have decreased by 53 % since 1990 mainly due to improved technology in large combustion plants (Figure 2-19).
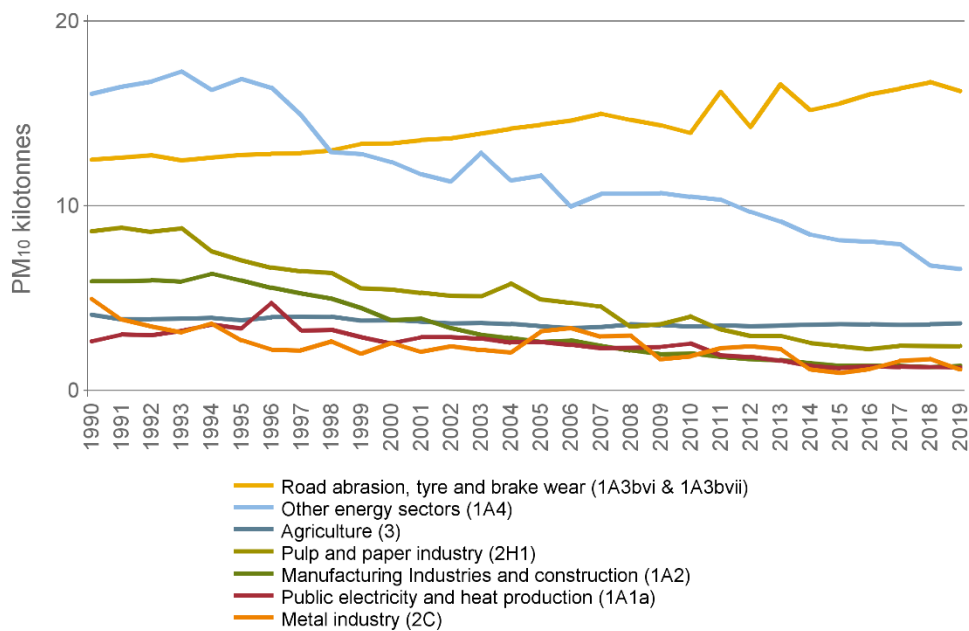
Figure 2-19 **Trends in PM_{10} emissions from major sectors and subsectors 1990-2019.**

2.2.3   Poly Aromatic Hydrocarbons (PAH1-4)

Emissions of poly aromatic hydrocarbons (PAH1-4) were about 7 t in 2019. Emissions have been reduced by about 62 % since 1990 and decreased by 2 % between 2018 and 2019. The different sectors' share of the emissions of PAH1-4 in Sweden 2019 is shown in Figure 2-20.
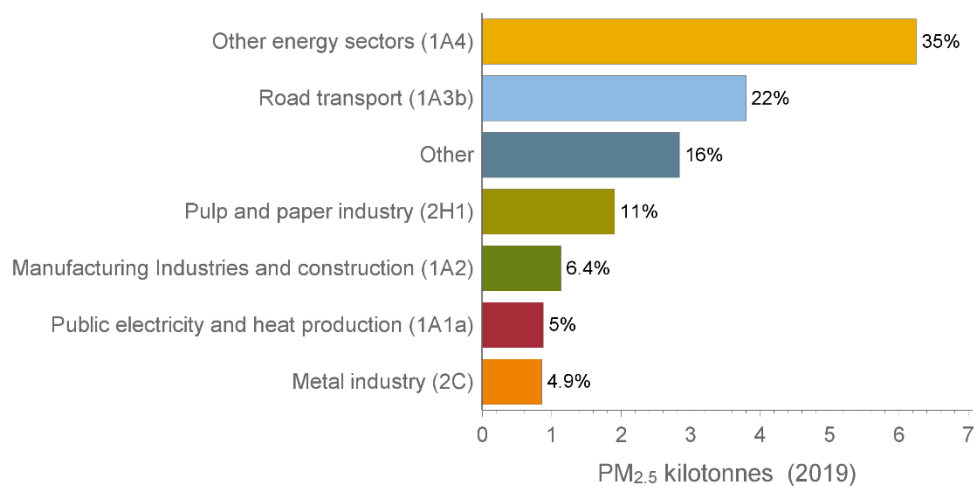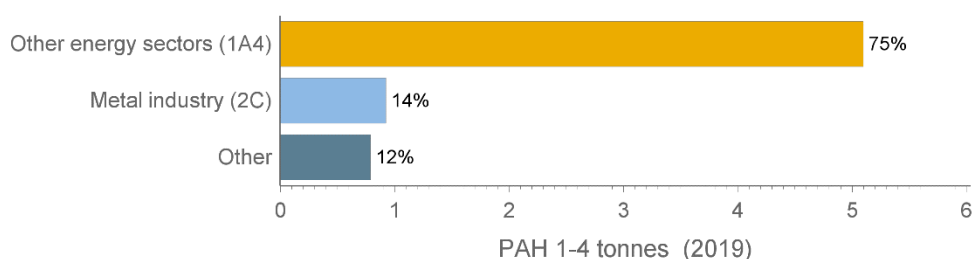

Figure 2-20   **Distribution of PAH1-4 emissions among major contributing sectors and subsectors in 2019.**

Other energy sectors (NFR1A4) was the largest source of PAH1-4 and contributed with about 5.1 t or 75 % of the total emissions in 2019. Most of the emission come from stationary combustion of solid biomass (NFR1A4b). Emissions from NFR1A4 were about 55 % lower compared to 1990 (Figure 2-21). The rest of the emissions, about 0.5 t, come from stationary combustion of biomass in agriculture, forestry and fishing (NFR1A4ci) and commercial/ Institutional (NFR1A4ai). Emission reduction in the sector is mainly due to increased proportion of district heating.

Metal industry (NFR2C) is also a significant source of PAH1-4 emissions which was responsible for 14 % (or 0.92 t) of the emission in 2019. Between 1990 and 2019 emissions have been reduced by about 79 % due to application of new technologies. Aluminium production (NFR2C3) was a key source of PAH1-4 emission in Sweden until 2008 and decreased strongly since then as all pot-lines operating the Söderberg technology were shut-down in 2008. This has resulted in emission reduction by more than 99 % between 2008 and 2009 (Figure 2-21). In 2019, the emission from aluminium production (NFR2C3) was about 14 kg.
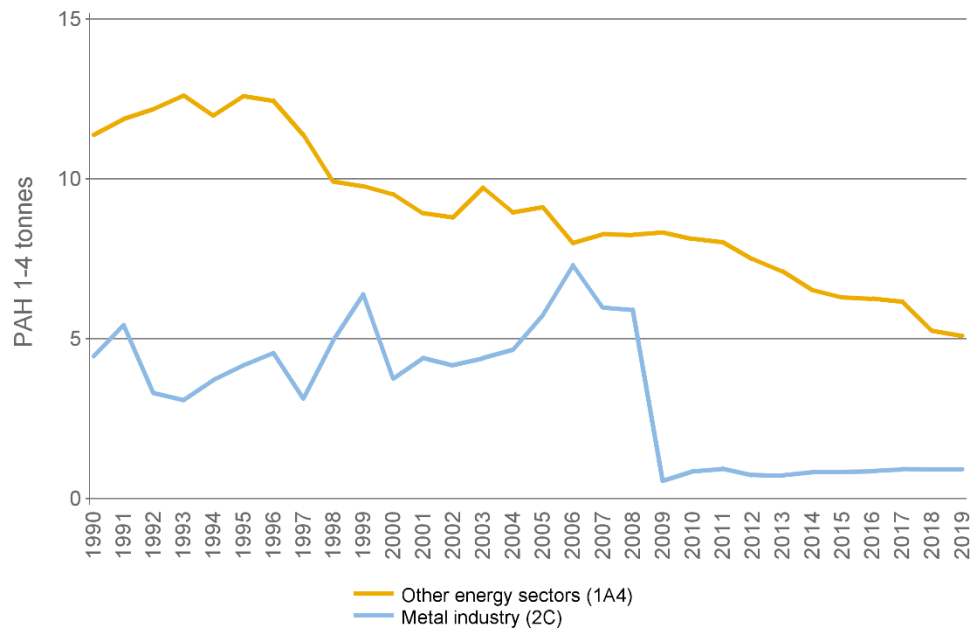
Figure 2-21   Trends in PAH1-4 emissions from major sectors and subsectors 1990-2019.

2.2.4 Hexachlorobenzene (HCB)

The total emissions of HCB in Sweden were about 2,74 kg in 2019. Emissions have decreased by 83 % since 1990. Compared to previous year, emissions were about 3 % lower in 2019. The different sectors' share of the HCB emissions in 2019 is shown in Figure 2-22.

Figure 2-22   **Distribution of HCB emissions among major contributing sectors and subsectors in 2019.**

Emissions of HCB from public electricity- and heat production (NFR1A1a) amounted to about 1 kg in 2019 or about 37 % of the total emission of which most of the emission was derived from biomass combustion. Emissions from NFR1A1a have more than doubled (138 %) since 1990, mainly due to increased biomass combustion in the energy production plants and also due to increased combustion of waste. Emission in 2019 was about 2 % lower compared to 2018. The annual HCB emission depends, to some extent, on temperature and precipitation conditions in Sweden. For example, the observed high emission peaks in 1996 and 2010 were particularly cold years (Figure 2-23).

Chemical industry (NFR2B) was the prime source of HCB in the Swedish inventory. Emissions are now reduced by about 99.9 % compared to 1990 due to improved technologies applied in the sector. Emissions of HCB from metal industry (NFR2C) were about 0.7 kg or 26 % of the total in 2019. Emissions are mostly derived from iron pellets production (NFR2C1e) which have increased largely since 1990 due to increased production. The economic recession between 2008 and 2009 is reflected by a dip in the emission trend (Figure 2-23).

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In 2019, about 0.4 kg or 15 % of HCB was derived from combustion within the manufacturing industries and construction sector (NFR1A2), mainly due to bio-mass combustion in pulp, paper and print (NFR1A2d) and other (NFR1A2g). Emissions have varied and were about 15 % higher in 2019 compared to 1990.

The waste sector (NFR5) is also a significant source of HCB emission and was responsible for about 0.28 kg or 10 % of the total emission in 2019. Most of the emission comes from incineration and open burning of waste (NFR5C). The emissions have increased by about 300 % since 1990 due to increased incineration of hazardous waste.

Emissions of HCB from Other Sectors (NFR1A4) were about 0.22 kg in or about 8 % of the national total in 2019. Most of the emission within (NFR1A4) comes from biomass combustion in residential stationary plants (NFR1A4bi). Emissions have increased by about 6 % since 1990.
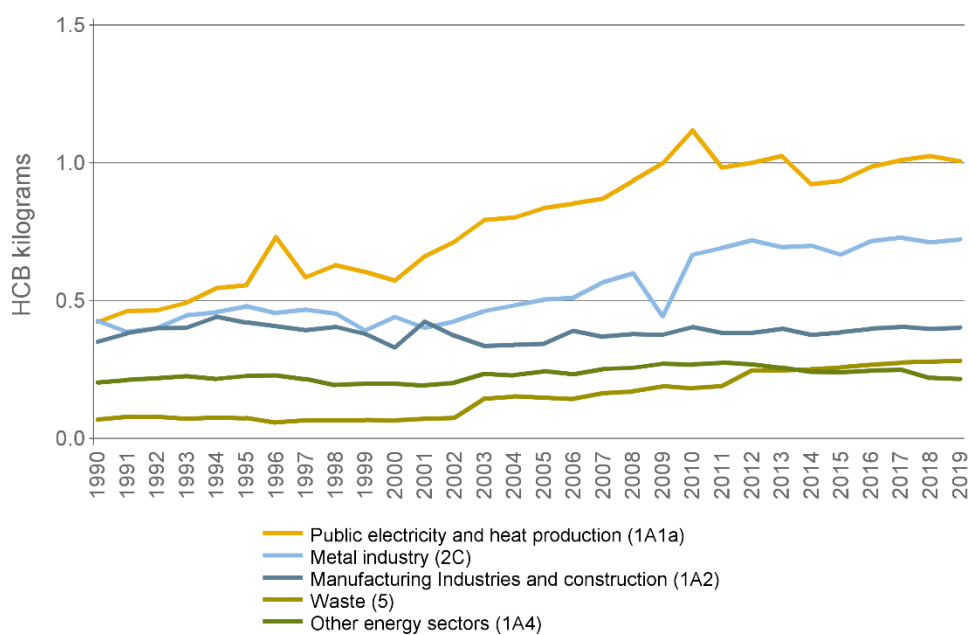
Figure 2-23   **Trends in HCB emissions from major sectors and subsectors 1990-2019.**

2.2.5 Dioxins - Polychlorinated dibenzodioxins and furans (PCDD/F)

The aggregated emissions of dioxins in Sweden were 24.3 g I-Teq in 2019. Emissions have decreased by 65 % since 1990. Compared to previous year, emissions were about 2 % lower in 2019. The share of different sectors' dioxins emissions in 2019 is shown in Figure 2-24.
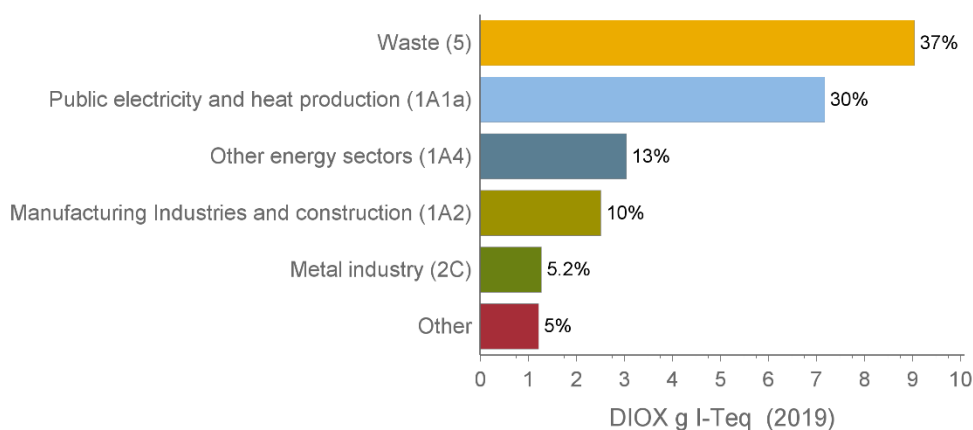
Figure 2-24 **Distribution of dioxins emissions among major contributing sectors and subsectors in 2019.**

Emissions of dioxins from the waste sector (NFR5) amounted to about 9 g I-Teq or about 37 % of the total emission in 2019. Most of the emissions came from house and car fires (NFR5E) and accounted for 34 % of the total national. The rest of emissions within the sector come mainly from combustion of hazardous waste (NFR5C). Since 1990 the emission has increased by 41 % mainly due to increased combustion of hazardous waste.

Emissions of dioxins from electricity- and heat production (NFR1A1a) amounted to about 7 g I-Teq or 30 % of the national emission in 2019. Most of the emission is derived from biomass combustion. Emissions from NFR1A1a decreased by about 54 % since 1990 due to improved technologies applied in the sector. The amount of dioxins emission from (NFR1A1a) depends to some extent on temperature and precipitation conditions in Sweden. The observed elevated emissions in 1996 and 2010 were particularly cold years (Figure 2-25).

In 2019, about 2.5 g I-Teq or 10 % of dioxins emission to air were derived from manufacturing industry and construction sector (NFR1A2), mostly due to biomass combustion in pulp, paper and print (NFR1A2d) and wood and wood products

(NFR1A2giv). Emissions from NFR1A2 have decreased by 72 % since 1990, due to improved technologies applied, especially in pulp, paper and print. Emission of dioxins from the metal industry (NFR2C) were less than 1.3 g I-Teq or 5 % of the national total in 2019. Since 1990, the emission decreased by more than 95 % mainly from iron and steel production due to use of better technologies.

The share of Other energy sectors (NFR1A4) was 13 % of the national emission in 2019. The emission has increased by 2 % since 1990 mainly from Agriculture, Forestry and Fishing (NFR1A4c) and Commercial and Institutional (NFR1A4ai) stationary combustion due to increased combustion of solid biomass.
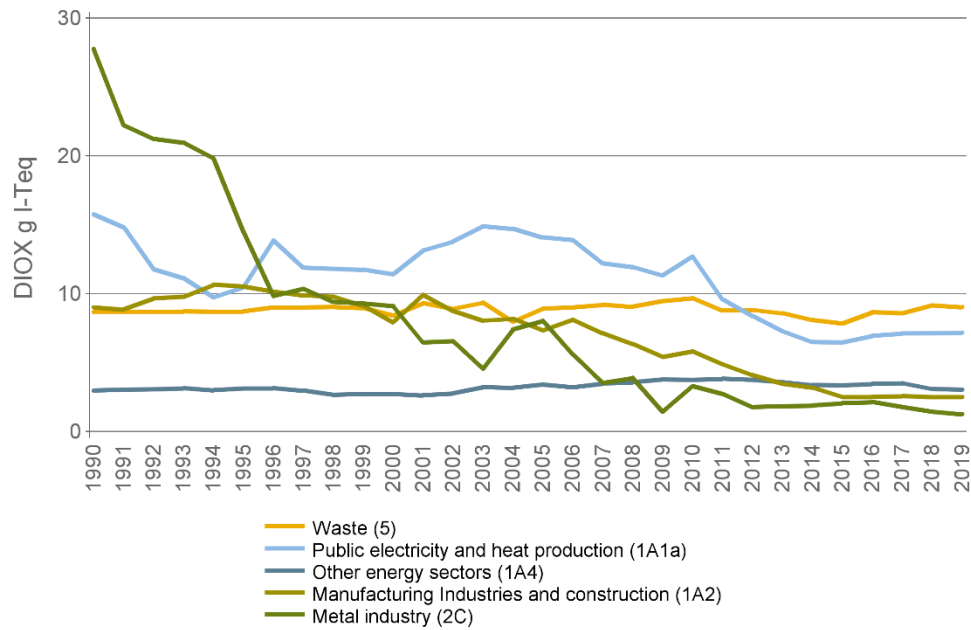
Figure 2-25   **Trends in dioxins emissions from major sectors and subsectors 1990-2019.**

2.3   Emissions of priority heavy metals

Emissions of cadmium (Cd), mercury (Hg) and lead (Pb) have all been reduced significantly since 1990 (Figure 2-26). The most significant reduction in emissions comes from Pb as it has been phased out from gasoline blends in the early 1990's. Lead emissions have since 1990 been reduced by about 98 %. In the early 1990's Cd emissions were also heavily reduced by 79 %, mainly due to efficient improvements in metal production. Hg emissions have been also reduced by nearly about 74 % since 1990 mostly due to improvements in metal processing and waste incineration.
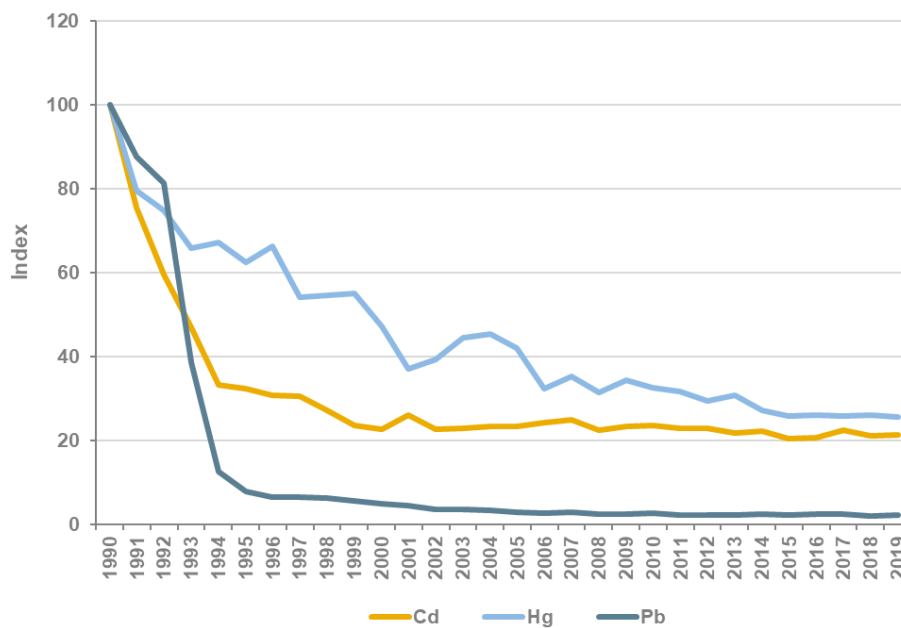
Figure 2-26   **Trends in emissions 1990-2019 for Cd, Hg and Pb. Index 1990=100.**

2.3.1   Cd

The aggregated emissions of Cd in Sweden were about 500 kg in 2019. Emissions have decreased by 79 % since 1990. Compared to previous year, emissions were about 2 % higher in 2019. Emission distribution of Cd between different sectors in 2019 is shown Figure 2-27.
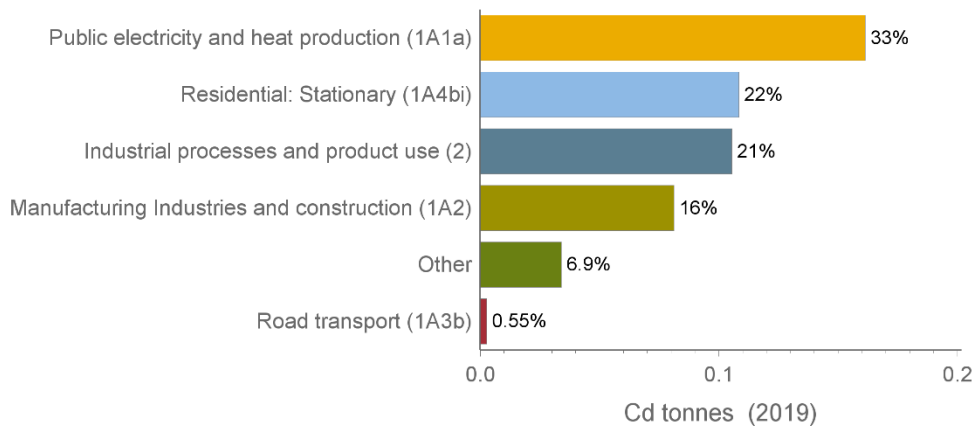
Figure 2-27   Distribution of Cd emissions among major contributing sectors and subsectors in 2019.

Electricity and heat production sector (NFR1A1a) was the largest source of Cd emissions and contributed with about 160 kg or 33 % of the total emissions in 2019. Emissions have increased by 57 % since 1990 due to intensified use of biomass in energy production (Figure 2-28). The amount of emission from this source depends to some extent on the weather condition and hence the demand on electricity and heat production. Year 1996 and 2010 were particularly cold which resulted in especially higher emissions for these years.

Stationary residential combustion (NFR1A4bi) was the second largest source of Cd emissions with a total of 111 kg in 2019, corresponding to 22 % of the total emissions. These emissions have decreased by 19 % compared to levels in 1990.
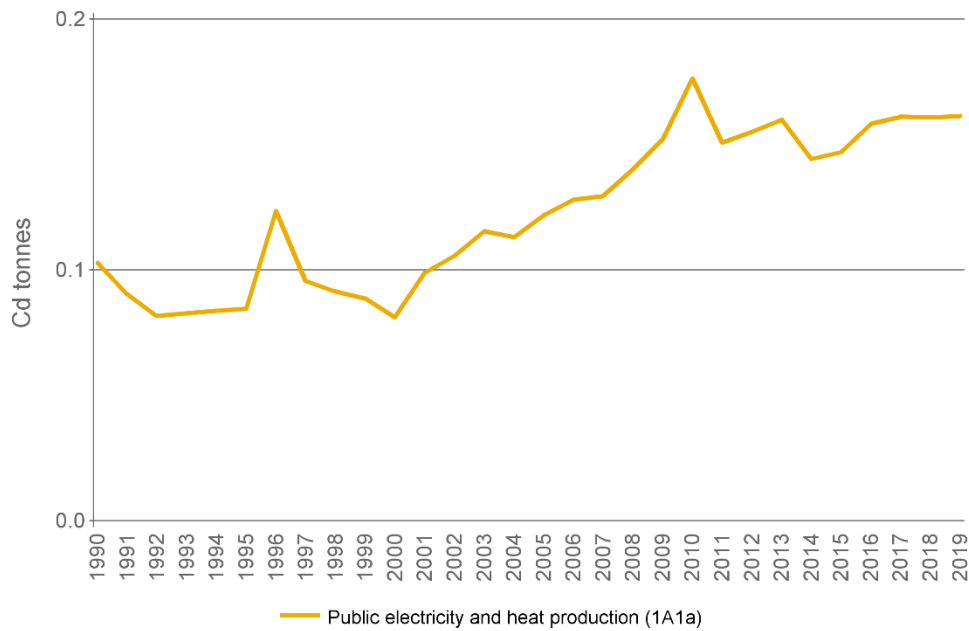
Figure 2-28   **Trend in emissions from electricity and heat production (1A1a) 1990-2019.**

Emission of Cd from industrial processes and product use sector (NFR2) accounted for about 100 kg or 21 % of the total emission in 2019. Most of these emissions come from metal industry (NFR2C) and pulp and paper industry (NFR2H1), accounted for 15 % and 6 %, respectively of total emissions. Emissions from various industries are shown in Figure 2-29. Emissions from industrial processes and product use have decreased by more than 90 % since 1990. The emissions have been reduced during the early 1990's and levels have been relatively stable since 2010.

Combustion in manufacturing industries and construction (NFR1A2) accounted for 16 %, or about 80 kg, of total Cd emissions in 2019. Emissions from this source have decreased by 36 % since 1990. Most of these emissions occurred in the pulp, paper and print industries (NFR1A2d). Emissions from combustion in manufacturing industries and construction have been relatively stable over the past twenty years.
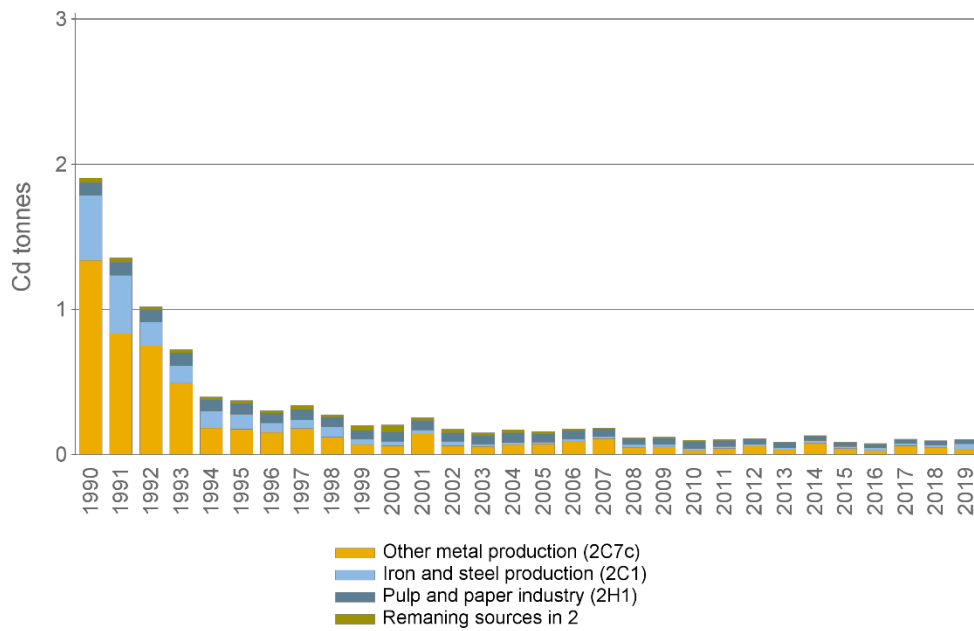
Figure 2-29   **Emissions of Cd from industrial processes and product use 1990-2019.**

Emissions from road traffic in the transport sector (NFR1A3b) accounted for less than 1 %, about 5 kg, of the Cd emissions in 2019 and emissions have been almost stable since 1990.

2.3.2   Hg

Total emissions of Hg in Sweden were about 400 kg in 2019 and decrease by 74 % since 1990. Emission distribution of Hg between different sectors in 2019 is shown in Figure 2-30.
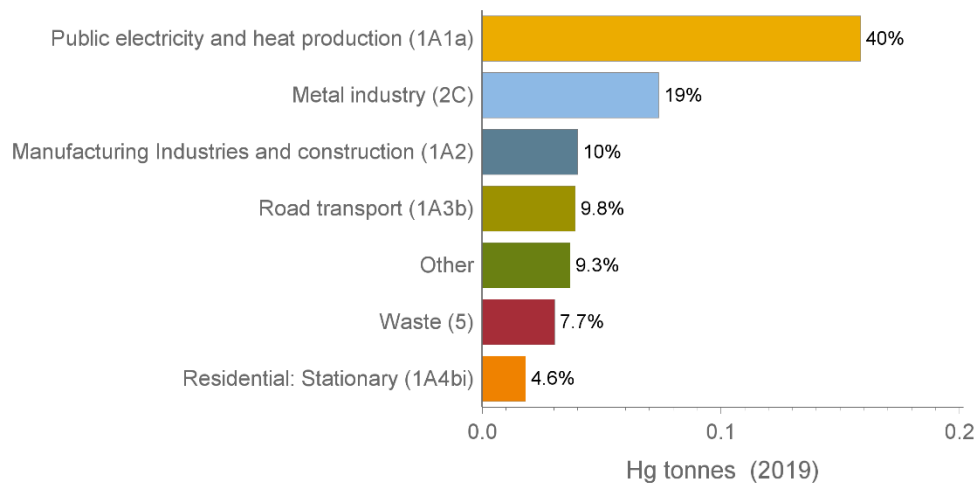
Figure 2-30   **Distribution of Hg emissions among major contributing sectors and subsectors in 2019.**

In 2019, about 40 % (or 156 kg) of Hg emissions were derived from electricity and heat production (NFR1A1a). Most of these emissions were derived from biomass combustion in combined heat and power generation plants. Hg emissions from this source have decreased by about 67 % since 1990 (Figure 2-31).
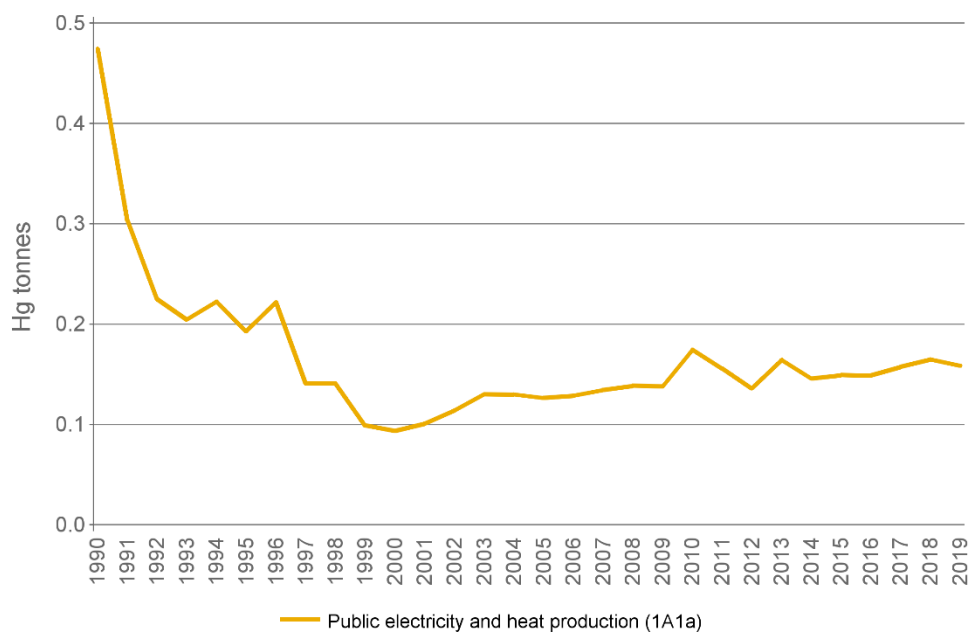
Figure 2-31 **Emissions of Hg in from Public electricity and heat generation (1A1a) 1990-2019.**

Metal industry (NFR2C) accounted for 19 % or about 70 kg of total Hg emissions in 2019. Emissions have been reduced by 85 % since 1990 mainly due to improved technologies.

In 2019, about 10 % (or 40 kg) of Hg emission come from combustion in manufacturing industries and construction (NFR1A2). Emissions have been reduced by about a half since 1990 mostly from non-metallic minerals (NFR1A2f) and pulp, paper and print (NFR1A2).

Emissions from road traffic in the transport sector (NFR1A3b) accounted for 10 % (or 39 kg) of the Hg emissions in 2019. Most of the emission came from passenger cars, with a total emission of nearly 27 kg in 2019. Emissions from transport sector have decreased by 9 % since 1990.

Emission from the waste sector accounted for about 8 % of the total emission in 2019, in which most of the emission came from crematories. Emissions in 2019 were 83 % lower than in 1990 due to improved technologies applied in the incineration plants.

2.3.3 Pb

The total emissions of lead (Pb) in Sweden were about 8 t in 2019 and decreased by 98 % since 1990. Emission distribution of Pb between different sectors in 2019 is shown in Figure 2-32.
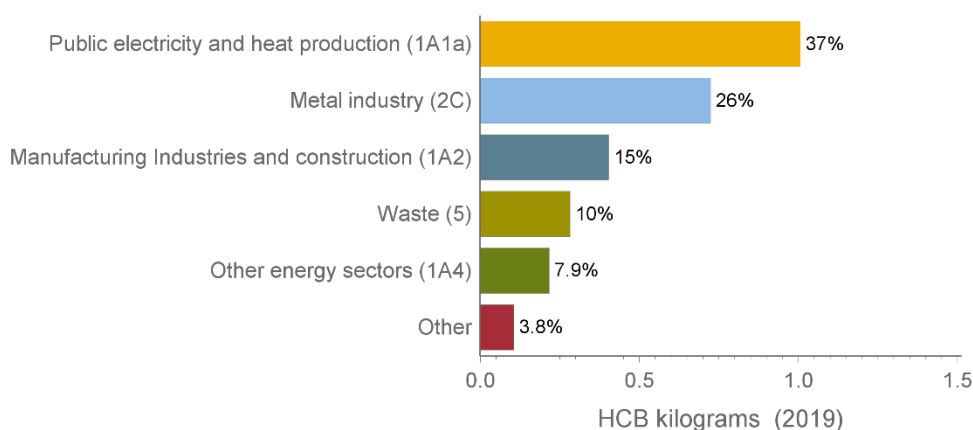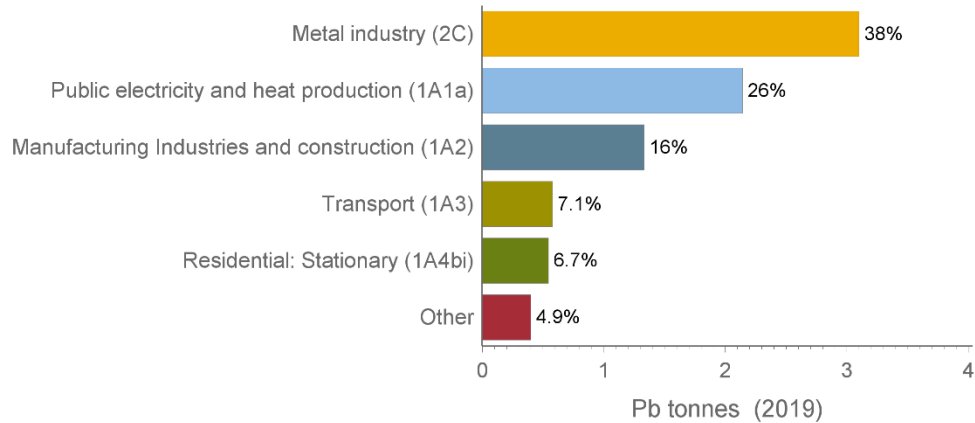

Figure 2-32   Distribution of Pb emissions among major contributing sectors and subsectors in 2019.

Emission of Pb from metal industry (NFR2C) accounted for about 38 % of the total emissions in 2019. These emissions were reduced by 96 % since 1990 mainly due to improved technologies. Emissions from this sector were reduced strongly be-tween 1990 and 1996 and since 2002 emissions have been leveled out with only slight variations between years, see Figure 2-33.
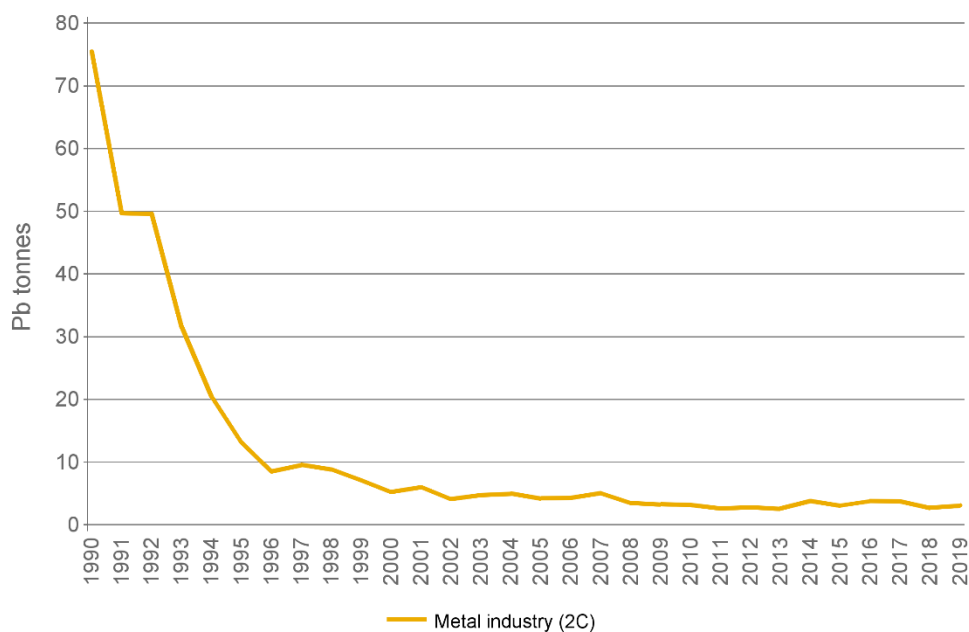
Figure 2-33   **Trend in emissions of Pb from Metal industry (2C) 1990-2019**.

About 26 % of the Pb emissions that come from public electricity and heat production (NFR1A1a) is mostly derived from biofuels combustion. The emissions have been reduced by 23 % compared to emission levels in 1990, see Figure 2-34. Emissions from manufacturing industries and construction (NFR1A2) accounted for 16 % of the Pb emissions in 2019. About one-half of these emissions come from the use of biofuels in pulp, paper and print industries (NFR1A2d). Since 1990, emissions from manufacturing industries and construction has reduced by one-third.
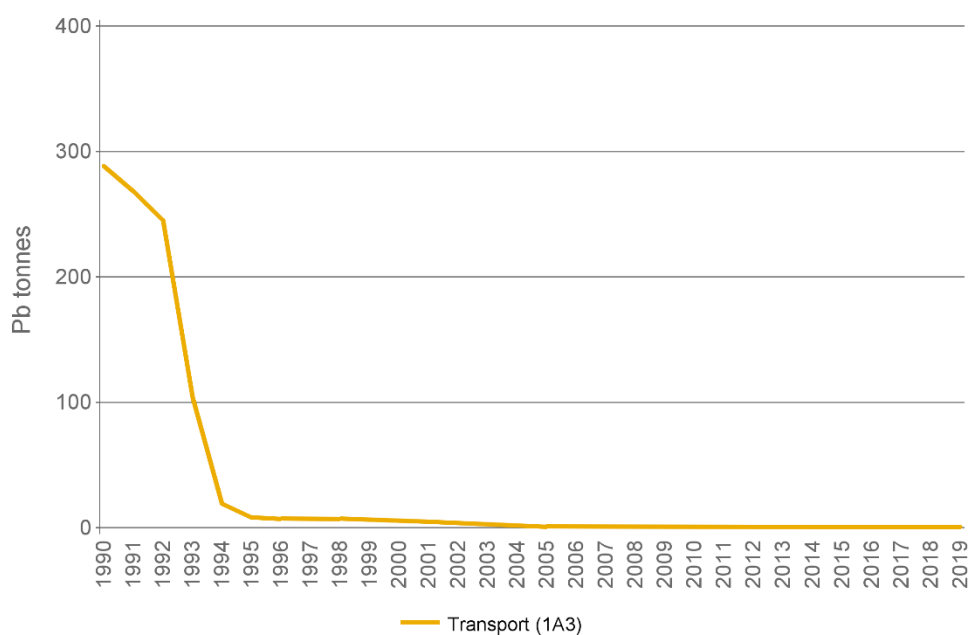
Figure 2-34.   **Trend in emissions of Pb from transport (1A3) 1990-2019.**

The transport sector (NFR1A3) contributed with about 7 % of Pb emissions in 2019. Lead emission is derived from gasoline use for in transportation (NFR1A3b). As Pb has been phased out from gasoline blends in the early 1990's, these emissions have been reduced by more than 99 %. In 1990 the emissions from passenger cars amounted to 246 t and in 2019 the emission is less than 1 t, see Figure 2-35.
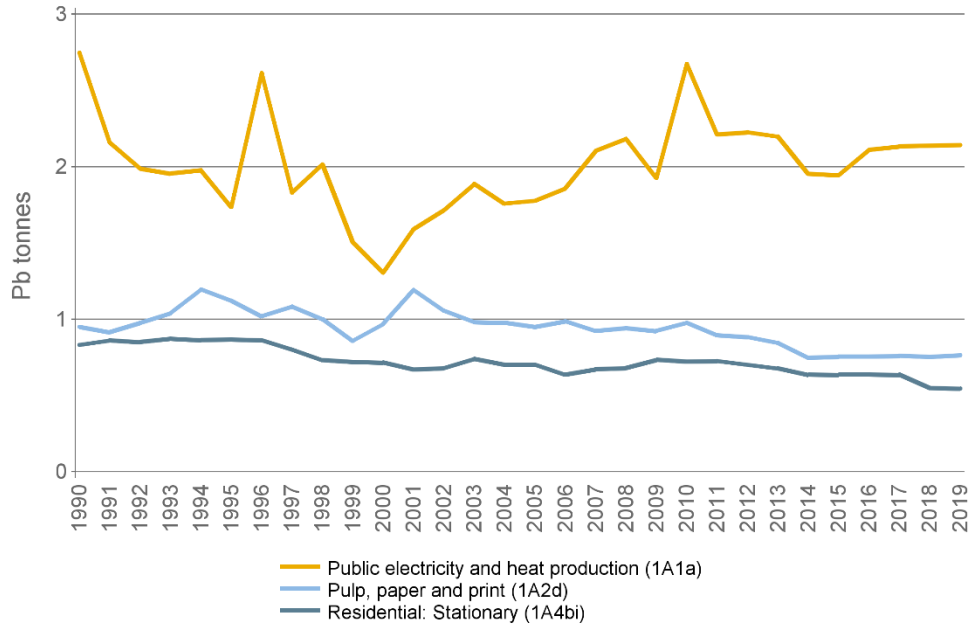
Figure 2-35   Trends in emissions from Public electricity (1A1a) and heat production, Pulp, paper and print (1A2d) and residential stationary (1A4bi) 1990-2019.

In 2019, almost 7 % of Pb emissions come from heating of the residential stationary sector (NFR1A4b) in which most of the Pb emission is related to biomass combustion. Emission decreased by 34 % since 1990 due to increased share of district heating.

3 Energy (NFR sector 1)

3.1 Overview

The energy sector includes emissions from fuel combustion (NFR1A) and fugitive emissions from fuel production and handling (NFR1B). Energy consumption per capita is high in Sweden compared to other OECD countries. This is because of the availability of natural resources such as forests and hydropower, which led to the early and rapid expansion of energy-intensive industries. Sweden's geographical location, with low mean annual temperatures also explains the high demand for energy for heating.

3.2 Fuel combustion, NFR1A

Emissions from fuel combustion, NFR1A, are allocated to a number of subsectors.

NFR1A1 energy industries, e.g. public electricity and heat production plants, combustion activities within oil refineries, and combustion related to solid fuel production, i.e. coke ovens.

NFR1A2 manufacturing industries, combustion-related emissions in manufacturing industries and construction and working machinery within the construction sector allocated to this subsector. Emissions from working machinery within the construction sector are allocated to NFR1A2, but apart from that, NFR1A2 includes only stationary combustion.

NFR1A3, emissions from domestic transport include aviation, road traffic, railways and navigation.

NFR1A4, emissions from other sectors, include stationary and mobile sources in households, service, agriculture, forestry and fisheries.

NFR1A5, emissions from other combustion include domestic military operations.

In addition, emissions from International aviation and international navigation (international bunkers) and multilateral operations, NFR1D, are not included in the national total.

Emissions from fuel combustion in Sweden are, if not specifically otherwise stated, determined as the product of fuel consumption, thermal value and emission factors (EF) as shown in the formula:

$$\text{Emission}_{fuel} = \text{Fuel consumption}_{fuel} * \text{Thermal value}_{fuel} * \text{EF}_{fuel}$$

Different tier methods are used for different sub-sectors as discussed in sections below. Activity data sources, thermal values and emission factors are described in detail in Annex 2.

Note that some fuel types are used in industrial processes rather than for energy purposes. This is the case for black liquor in the paper- and pulp industry and for coal and coke in the metal industry. Emissions from these fuels are thus accounted for under NFR2 and methods used are described in section 4.

3.2.1 Public electricity and heat production, NFR1A1a

3.2.1.1 SOURCE CATEGORY DESCRIPTION

Since 1980 the Swedish energy system has changed substantially. The dependence on fossil fuels (oil and coal), both for heating purposes and in industry, has decreased. During the period 1980-1990, the production of electricity from nuclear power plants increased from 26 TWh to 68 TWh. Another factor behind the decrease in fossil fuel use is the increased use of district heating. Use of biofuel (wood chips, bark) and incineration of municipal waste is common in district heating plants. The use of heat pumps both in district heating plants and in residential houses has increased since 1985. In the manufacturing industry the combustion of oil products has decreased from 1980 and has to a large extent been replaced by biofuels.

Swedish electricity production is characterized by large proportions of hydropower and nuclear energy. Sweden is also expanding its proportion of wind power, which is increasing every year. Wind power effects the electricity balance and is also affected by the weather. The power generated by wind power might need the use of reserve power in cases of limited wind. Only a small share of electricity production is based on fuels used in conventional power plants. Public electricity and heat use vary between years, mainly due to variations in ambient wintertime temperatures. In addition, production of electricity based on fuels depends to a large extent on the actual weather conditions. Years with dry weather and cold winters have a significant effect on the use of fuel in electricity production since less electricity can be produced by means of hydropower and more electricity is needed for heating. The largest emissions from electricity production were thus in 1996, due to very dry and cold weather. In Sweden, electricity and district heating are used to a large extent to heat homes and commercial premises. Increased use of district heating since 1990 to heat homes and commercial/industrial premises has led to increased energy efficiency and thus lower emissions. Electricity is an important energy source in the manufacturing industry, which is dominated by the pulp and paper industry and the steel industry.

Production of district heating is currently to a large extent based on biomass and waste. There has been a shift from fossil fuels towards biomass since 1990. In 1990, 25 % of fuels used were biomass including biogenic waste, and 6 % was fos-

sil waste. In 2019, 76 % of all fuels used for district heating were biomass (including the biogenic fraction of waste), while waste (fossil fraction) accounted for 13%[18]. These proportions have been quite similar during the last six years.
Since 1990, there has been a large increase in the use of district heating from 89 PJ (1990) to 181 PJ (50.2 TWh 2019)[19] but, due to the more frequent use of biomass, greenhouse gas emissions from district heating were lower in 2019 than in 1990.

The number and distribution of Swedish power stations in 2019 are presented in Table 3.1[19]. Changes in number of plants and their installed effect have been minor in the production of electricity, but due to growing wind power the number of plants in the electricity sector have increased.

Table 3-1 Number and distribution of Swedish energy stations 2019

Type of plants	Number of plants	Gross Production GWh	Gross Production TJ
Total power stations	49 081	168 422	606 319
Power generation not based on fuels	48 910	85 903	309 251
Wind power	3 976	19 847	71 449
Hydropower	990	65 393	235 415
Solar power	43 944	663	2 387
Power generation based on fuels	171	82 520	297 072
Nuclear power	3	66 130	238 068
Conv. thermal power	168	16 390	59 004

The trend in fuel consumption in this sector varies depending on the production of hydropower and climate variables. The greatest changes in fuel consumption are for biomass fuels, where the consumption has increased significantly due to, for instance, increased district heating. There was a significant increase in the use of natural gas in 2009 due to an increase in the number of gas fuelled facilities. In 2010, the production and use of district heating was unusually high due to the cold weather with unusually low temperatures in the beginning and the end of the year.

A summary of the latest key source analysis is presented in Table 3-2.

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[18] All numbers are according to data used in the greenhouse gas inventory this submission. The proportions given are calculated for heat production, and may include plants in both 1.A1.A.ii and 1.A.1.A.iii

[19] Statistics Sweden/Swedish Energy Agency EN11SM 2001 (Electricity supply, district heating and supply of natural and gasworks gas 2019.).

Table 3-2 Summary of key source analysis, NFR1A1a, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A1a	Biomass – *As, CO, Cd, Cr, Cu, DIOX, Hg, NMVOC, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*	Biomass – *As, CO, Cd, Cr, Cu, DIOX, Hg, NH3, NMVOC, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*
	Gaseous –	Gaseous –
	Liquid – *Ni, SO$_2$*	Liquid – *NOx, Ni, SO$_2$, Se*
	Solid – *As, Cr, Hg, SO2*	Solid – *As, Cr, DIOX, Hg, NOx, PM10, PM2.5, SO2, Se, TSP*
	Other – *As, Cd, Cr, DIOX, Hg, NOx, Ni, PM2.5, Pb, SO2, Se*	Other *As, Cd, Cu, DIOX, Hg, NOx, PM2.5, Pb, SO2, Se*
	Peat– *As, Hg, SO2*	Peat– *DIOX, Hg, NOx, Ni, PM10, PM2.5, SO2, Se, TSP*

3.2.1.1 METHODOLOGICAL ISSUES

A combined Tier 2 and 3 methods is used. Activity data for emissions in NFR1A1a are taken from quarterly fuel statistics. For this sector, the quarterly fuel statistics is sent to all companies registered as IIC 40 according to databases used by Statistics Sweden and the response rate is almost 100 %. This gives very good data to the inventory, accurate, complete and consistent and with very low uncertainties.

No emissions from the integrated iron and steel industry are allocated to NFR1A1a. However, emissions from steelwork gases sold to and combusted by ISIC 40 facilities are still allocated to NFR1A1a.

The reported emissions of particulate matter include the condensable fraction of particles.

3.2.1.2 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

For the energy sector, the largest uncertainties come from activity data for the 1980's and from emission factors. The uncertainties for stationary combustion are in submission 2021 on fuel group aggregation level. The activity data uncertainties are relatively low, 2 % all fuel groups except for other fossil fuels that are 3 %. The CO_2 emission factor uncertainties are 2-5 % for Liquid fuels, 10 % for Solid fuels and 30% for Other fossil fuels and Peat and 30 % for Biomass. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group.

Activity data uncertainty is relatively low for all fuel groups. Emission factor uncertainty is for some fuel groups very high. The fuel groups and EF that have highest uncertainty are:
- Biomass for As, DIOX, HCB, PCB and Zn
- Other fuels for As, Cr, Cu, DIOX, Ni, Se, Zn, Cd
- Other fuels for HCB, PAH, PCB
- Peat for PCB
- Solid fuels for Cd, Cu, HCB, PCB, Se

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.1.3 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Experts at the Swedish EPA conduct a review of the inventory estimates, methodologies and emissions factors used. The experts also identify areas of improvement, which constitute part of the basis for improvements in coming submissions.

All quality procedures according to the Swedish QA/QC plan (including the Manual for SMED's Quality System in the Air Emission Inventories) have been implemented during the work with this submission.

All Tier 1 general inventory level QC procedures and all QC procedures listed in GPG section 8.1.7.4 applicable to this sector are used. The activity data has been subject to QA/QC procedures prior to the publishing of quarterly fuel statistics. In addition, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, the consumption of these fuels is studied on facility level and if necessary, the staff responsible for the quarterly fuel survey is contacted for explanations. IEFs for all reported substances are calculated per fuel, substance and NFR-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable. Data has, when possible, been compared with information from companies' legal environmental reports and/or other independent sources[20], [21]. Remarks in reports from the UNFCCC and CLRTAP/NEC reviews have been carefully read and taken into account.

3.2.1.4 SOURCE-SPECIFIC RECALCULATIONS

In submission 2021, one additional incineration plant was included. The plant has operated since 2010 and the emissions are now included for the whole time series. The breakdown into fossil and biogenic share of the waste fuels were updated for 2018.

The largest effect of submission 2021 recalculations was in NO_x emissions. The emissions increased with 1.2 % (0.15 kt NO_x) and increased with 0.3% (0.04kt NO_X) in 2017 between submission 2020 and 2021 in the sector.

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[20] Backman & Gustafsson, 2006

[21] Nyström, 2007

3.2.1.5   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.2   Refineries, NFR1A1B

3.2.2.1   SOURCE CATEGORY DESCRIPTION

Refineries process crude oil into a variety of hydrocarbon products such as gasoline and kerosene. During the refining process, dissolved gases are separated, some of which may be leaked or vented during processing. There are five refineries in Sweden. Three of these produce fuel products such as gasoline, diesel and heating oils. The other two mainly produce bitumen products and naphthenic special oils. One facility has a catalytic cracker; two facilities have hydrogen production plants and four of the facilities have sulphur recovery plants. The fuel consumption in this sector is mainly based on refinery gas, which is a by-product in the refining process. The use has increased due to higher demand of refined products.

A summary of the latest key source analysis is presented in Table 3-3.

Table 3-3 Summary of key source analysis, NFR1A1b, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A1b	Liquid Fuels - *NOx, Ni, PM2.5, SO2*	Liquid Fuels - *NOx, Ni, PM10, PM2.5, SO2, TSP*
	Gaseous fuels–	Gaseous fuels–

3.2.2.2   METHODOLOGICAL ISSUES

The Tier 2 method is used. The statistics for NFR1A1b are based on a total of seven plants with the Swedish Standard Industrial Classification 192, petroleum refining. Five of these companies are real refineries which use more than 99% of the energy within the sector and thereby cause most of the emissions. The other two plants are oil companies, mainly involved in production of lubricating grease.

Activity data for the five refineries was collected directly from each company for 1990-1999, since the Energy use in the manufacturing industry (ISEN) and Quarterly fuel statistics (KvBr) did not account for all fuels produced within refineries during these years. The corresponding energy content of all fuels was also collected and individual thermal values were calculated for each operator and fuel. For 2000-2004, i.e. before the EU Emission Trading System (EU-ETS) was established, quarterly fuel statistics was used as the data quality was improved compared to the 1990's and is considered to be sufficient for these years.

Data from the EU-ETS are used for four refinery plants for 2005 and 2007[22]. For the fifth plant, data from environmental reports were used due to lack of transparency in ETS data in the early years. In 2008 and later years, the quality of EU-ETS data is considered to be very high for all five of the refineries, and thus this is the primary data source for the GHG inventory. However, most of the refineries report refinery gas and natural gas aggregated to the EU-ETS, and for these facilities, data from the environmental reports are used to allocate the proper amount of this fuel to gaseous fuels. Environmental reports are used for verification for all five refineries. For refinery gas, plant specific CO_2 emission factors reported to the EU-ETS[23] are used for 2008 and later, since they are considered to be more accurate than the older national emission factor. The CO_2 emission factors for refinery gas are generally quite stable for each of the refineries, but the differences between the refineries are large.

The reported emissions of particulate matter include the condensable fraction of particles.

3.2.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The use of so many different sources for this sector could of course lead to consistency problems. Data used in the inventory in earlier years has been analysed and no (significant) signs of inconsistency have been found. In recent years, environmental reports are used for verification.

The assigned uncertainties are based on information directly from the facilities. These are updated regularly but not annually. The uncertainty of the activity data is around 1.5%, but the uncertainty of the NCV is unknown, so the total uncertainty for the activity data was judged to 10%. Activity data uncertainty for the 1990's is also estimated to 10 %.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. The uncertainty of the activity data for Liquid fuels is around 2 %, but the uncertainty of the NCV is unknown, so the total uncertainty for the activity data was judged to 10 %. The activity data for Gaseous Fuels is lower, 2 %. Activity data uncertainty is relatively low for Gaseous fuels and higher for Liquid fuels. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty is Liquid fuels for all emissions often larger than 100%. EF for As, CO and NMVOC are larger than 100%. See Annex 1 for more details regarding uncertainties for activity data and emissions.

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[22] Backman & Gustafsson, 2006.

[23] Technically, the emission factors are implied emission factors since amounts of fuel, NCV:s and emissions are reported.

3.2.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for NFR 1A1b as for 1A1a described above. For each of the five refineries, EU-ETS data for the latest year are verified against the refineries' legal environmental reports. During the national peer review remarks have been made that gaseous fuels are reported as "NO" for 2003 and questioned if this is the correct notation key. Investigations of activity data files used in earlier submissions show that in 2001 to 2003, sweet gas (a by-product from the cryogen plant) was probably miscoded as natural gas in submission 2005. Data for 2003 has been revised in later submissions, i.e. sweet gas has been re-coded as refinery gas. Environmental reports show that natural gas has been used in NFR 1A1b in 2004 and later, but not in 2003, and hence "NO" is considered to be the correct notation key for 2003. The environmental reports for 2001-2002 are no longer available, and hence there is not enough information to re-code the natural gas reported in 2001 and 2002, even though it might be miscoded refinery gas.

3.2.2.5   SOURCE-SPECIFIC RECALCULATIONS

In submission 2021, one of the facilities energy consumption was corrected for emission year 2014. For another facility the use of liquefied natural gas was reallocated between NFR 1.A and NFR 1.B for emission years 2014 and 2016. In addition, the emission factors for NOx and SO_2 were revised for refinery gas and heating oil[24] for the whole time series. For more detail description, see the Annex.

The largest effect of submission 2021 recalculations was in NO_X emissions. The emissions decreased with -33.8 % (-0.42 kt NO_X) for year 2018 and 0.31% (0.04 kt NO_X) for year 2017 between submission 2021 and 2020 in the sector.

3.2.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.3   Manufacture of solid fuels and other energy industries, NFR1A1c

3.2.3.1   SOURCE CATEGORY DESCRIPTION

This category includes emissions from two plants belonging to one company, producing coke to be used in blast furnaces for production of iron. The plants are integrated into the iron and steel production industry[25]. The trend is related to the

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[24] Yaramenka, K., Josefsson Ortiz, C. Mawdsley, I. 2020. Förbättring av utsläppsrapportering från Sveriges raffinaderier – fokus på luftföroreningar och Non-Energy Use (NEU). SMED PM.

[25] Fuel combustion in manufacturing of nuclear fuels was included in NFR 1A1c in previous submissions, but for confidentiality reasons the very small emissions from these facilities have been included in NFR 1A1aiii instead.

amounts of iron and steel produced, and hence there was a dip in 2009. Since 2009, the production and the emissions have increased gradually, and in 2013 the emissions were about the same level as in the early 2000's.

A summary of the latest key source analysis is presented in Table 3-4.

Table 3-4 Summary of key source analysis, NFR1A1c, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A1c	*Solid fules – NOx, SO2*	*Solid fules – SO2, TSP*

3.2.3.2 METHODOLOGICAL ISSUES

The Tier 2 method is used. Emissions from fuel combustion in the manufacturing of solid fuels are reported under NFR1A1c, in line with IPCC Guidelines. This includes emissions from combustion in coke ovens in the iron and steel industry.

Activity data on coke production is taken from environmental reports. Emissions of NMVOC and CO are estimated with the Tier 2 methodology with national emission factors. Estimates of emissions of SO_2 and NO_X are available from environmental reports on an aggregate level, and these emissions are distributed over the different NFR codes (1A1c, 1A2a, 1B1c and 2C1, SO_2 also 2B5 and 1B1b) according to the activity data distribution.

Pollutants Cd, Hg, Pb, PCDD/F and PAHs are included under category 2C1. The emissions of POPs and heavy metals are included under category 2C1 because it is not possible to separate emissions between the IPPU and Energy sectors.

Activity data on combustion of coke oven gas and blast furnace gas in coke ovens is discussed in connection with other emissions from the iron- and steel industry in section 4.4 Metal production, NFR2C.

Since 1990, solid fuel consumption has increased slightly due to higher production of coke caused by higher demand of primary iron and steel. In 2009, however, solid fuel consumption decreased considerably due to lower production of coke, caused by a lower demand of primary iron and steel.

The reported emissions of particulate matter include the condensable fraction of particles.

3.2.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The time series is considered to be very consistent as all data on emissions from the coke producing plants has been collected directly from the facilities. The inter-annual variations in IEFs for solid fuels are caused by variations in the relative amounts of blast furnace gas and coke oven gas, respectively, between years. The composition of each gas is also quite variable, and this is another explanation to the

fluctuating IEF's. Solid fuel consumption decreased considerably in 2009 due to lower production of coke caused by lower demand of primary iron and steel. In 2010, the demand increased and thus the fuel consumption increased to about the same level as before 2009.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Liquid fuels for Cd, Cu, Hg, Pb, Se, Zn
- All fuels for Cr, Ni, PAH, SO_2, TSP and PM_{10} and $PM_{2.5}$

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The estimation of emissions from coke production is based on carbon balance calculations and the methodology is thoroughly described in chapter 4.

The improvements in methodology and allocation of emissions from the integrated iron and steel industry in submission 2010 were made based on a study[26] carried out in 2008 looking at emissions from several industrial plants, including the two largest iron and steel plants in Sweden, where inventory data from submission 2008 was compared with data from environmental reports. In 2010, activity data and emission factors for the chemical industry and the most important metal foundries were verified against data from environmental reports in a similar study[27].

3.2.3.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2021, there was a revision of the allocation of SO_2 emissions between NFR-codes which affects the emissions of SO_2 and NO_x.

Emissions of particles in submission 2021 are also corrected due to a change in the measurement method for one of the integrated iron and steel production plants. Until 2016 results from an old measurement based on corn size analyses was used for the particle fractions, but since 2014 the plant has started to measure the fractions with Andersen impactor for the determination of the fraction of small particles. The former method underestimated the fractions of PM10, PM2.5 and BC. The fractions are now for PM2.5 (19%) and PM10 (29%).

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[26] Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008.

[27] Gustafsson, T., Nyström, A-K., Gerner, A., 2010

The largest effect of submission 2021 recalculations was in PM10 emissions. The emissions decreased with -22.9 % (0.008 kt PM10) for year 2018 and -22.9 % (0.001 kt PM10) for year 2017 between submission 2021 and 2020 in the sector.

3.2.3.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.4   Iron and steel, NFR1A2a

3.2.4.1   SOURCE CATEGORY DESCRIPTION

A limited number of industries account for the majority of industrial energy use, i.e. the pulp and paper industry, iron and steel works and the chemical industry together account for about 65 % of the fuel used. Despite rising industrial production, oil consumption has fallen sharply since 1970. This has been possible due to increased use of electricity and improved energy efficiency.

In Sweden, there are three primary steel works that base their production on iron ore pellets producing either steel or iron powder. There are also 10 secondary steel plants producing steel based on scrap metal. In 2009, fuel consumption in the iron and steel industry fell sharply as a consequence of decreased production (2.8 Mt of steel) due to the global recession. In 2009, fuel consumption in the iron and steel industry fell sharply as a consequence of decreased production (2.8 Mt of steel) due to the global recession. In 2019, the production was 4.5 Mt[28], and increased with 1.4% compared to 2018. Emissions from iron and steel companies with less than 10 employees are allocated to NFR 1A2g because the model estimate of fuel consumption for these small companies is produced on an aggregate level and not separated by ISIC code.

The trend of the fuel combustion is increasing slightly since 1990 due to higher production of iron and steel products. In 2009 this trend was broken due to decreasing demand of iron and steel. In 2010, production and fuel consumption recovered to more "normal" levels.

A summary of the latest key source analysis is presented in Table 3-5.

Table 3-5 Summary of key source analysis, NFR1A2a, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A2a	Liquid – *NOx, Ni, SO2*	Liquid – *Ni, Se*
	Solid – SO_2	Solid – SO_2

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[28] The Swedish Steel Producers´ Association, 2020-11-22. Stålåret 2019 – en kort översikt. 2020. https://www.jernkontoret.se/sv/publicerat/stal-och-stalindustri/stalaret/

3.2.4.2   METHODOLOGICAL ISSUES

The Tier 2 method is used. During 2009, a new methodology was implemented for the two largest primary iron and steel works. Activity data for all other facilities is, if not otherwise stated, collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 onwards, further described in Annex 1.

Emissions reported from primary steel works and other iron and steel works are reported in NFR 1A1c, 1A2a, 1B1b, 1B1c and 2C1 since some emissions arise from fuel combustion and some from reducing agents in the process. The text in this section is hence closely connected to the text in section 4.4 Metal production, NFR2C. NFR2C1 (iron and steel production). Fuel combustion has increased slightly since 1990 due to higher production of iron and steel products. However, there was a significant decrease in solid fuel consumption in 2009 due to lower production of coke, caused by a lower demand of primary iron and steel.

The reported emissions of particulate matter include the condensable fraction of particles.

Due to confidentiality reasons liquid and biomass fuels are reported as C for energy consumption.

3.2.4.2.1 Primary iron and steel works

In Sweden, there are two plants for integrated primary iron and steel production, i.e. basing their production on iron ore pellets. The integrated iron and steel production consist of material flows between coke oven, blast furnace and steelworks, and in one plant, rolling mill (see Figure 4.4.1 in section 4.4 Metal industry (NFR2C). Emissions from fuel combustion (oils, LPG and recovered energy gases, i.e. coke oven gas and blast furnace gas) used in the rolling mills and for in-house power and heat production are allocated to this sub-sector in accordance with the IPCC Guidelines.

3.2.4.2.2 Secondary iron and steel works

Except for the primary iron ore based iron and steel works, this sector includes emissions from for instance electric arc furnaces plants, iron ore pellet plants and iron powder plants. For these facilities, data on fuel consumption for energy purposes is from the quarterly fuel statistics. National NCVs and emission factors are used.

3.2.4.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

For the two largest facilities, the time series is considered to be very consistent since the time series developed in 2009 was compiled in close cooperation with the facilities. For NFR1A2a in total, the time series is also considered to be consistent, despite the fact that the quarterly fuel survey is used for most years and the annual

industrial energy survey for some years. The quarterly fuel survey data is weighted to cover the same population as the yearly industrial energy survey. A discussion on the reasons for changing data sources can be found in Annex 2.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Liquid fuels for As, Cd, Cr, Cu, NH_3, Ni, Pb, Se, Zn
- Biomass for As
- All fuels for DIOX, PAH, PM_{10}, $PM_{2.5}$ SO_2

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for NFR1A2a as for 1A1a described above. In addition to this, fuel consumption for the year t-2 is verified against the annual industrial energy survey on an aggregate level to check that the weight factors for the year t-1 are reasonable. For the two largest facilities, all data is collected directly from the company.

3.2.4.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2021, there was a revision of the allocation of SO_2 emissions between NFR-codes which affects the emissions of SO_2 and NO_x.

Emissions of particles in submission 2021 are also corrected due to a change in the measurement method for one of the integrated iron and steel production plants. Until 2016 results from an old measurement based on corn size analyses was used for the particle fractions, but since 2014 the plant has started to measure the fractions with Andersen impactor for the determination of the fraction of small particles. The former method underestimated the fractions of PM10, PM2.5 and BC. The fractions are now for PM2.5 (19%) and PM10 (29%).

The largest effect of submission 2021 recalculations was in SO_2 emissions. The emissions decreased with -11.3 % (-0.04 kt SO_2) for year 2018 and -9.7 % (-0.04 kt SO_2) for year 2017 between submission 2021 and 2020 in the sector.

3.2.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.5   Non-Ferrous Metals, NFR1A2b

3.2.5.1   SOURCE CATEGORY DESCRIPTION

This source category covers combustion-related emissions from seven aluminium producers (ISIC 27420), six copper producers (ISIC 27440) and five facilities producing various other metals. More detailed descriptions are given in section 4.4.

As for all subcategories to NFR1A2, for companies with less than 10 employees the Tier 2 method is used since country specific emission factors are used. Emissions from companies with less than 10 employees are allocated to NFR1A2g.

Fuel consumption shows a decreasing trend for the period 1990-2002, but from 2003 onwards, the inter-annual variations in fuel consumption for energy production are relatively small. In recent years, the copper producers account for 40-50 % of the fuel consumption in 1.A.2.b and the aluminium producers account for 32-45 %. The most common fuel is LPG (44-61 % in recent years), followed by heating oils and natural gas.

A summary of the latest key source analysis is presented in Table 3-6.

Table 3-6 Summary of key source analysis, NFR1A2b, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A2b	Liquid –	Liquid –
	Solid –	Solid –

3.2.5.2   METHODOLOGICAL ISSUES

The Tier 2 method is used. Activity data is taken from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002 and from quarterly fuel statistics for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2.

The reported emissions of particulate matter include the condensable fraction of particles.

3.2.5.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for NFR1A2a, time series consistency despite the changes in activity data source is discussed in Annex 2.

Activity data uncertainties are assigned by expert judgements by staff at the energy statistics department of Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on

expert judgements made on fuel type that were aggregated to fuel group. The uncertainty of AD and CO_2 is 5 % for all fuel groups.

Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Solid fuels for Zn
- Liquid fuels for all emissions
- All fuels for As, DIOX
- Other fuels for PM_{10}, $PM_{2.5}$, TSP

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.5.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

The same QA/QC procedures are used for NFR1A2b as for 1A2a described above. In addition to this, a detailed quality study of the non-ferrous metal industry was performed in 2010[29].

3.2.5.5   SOURCE-SPECIFIC RECALCULATIONS

In submission 2021, there were no recalculations that affected the air pollutant emissions.

3.2.5.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.6   Chemicals, NFR1A2c

3.2.6.1   SOURCE CATEGORY DESCRIPTION

The chemical industry produces a number of different products such as chemicals, plastics, solvents, petrochemical products etc. In total, around 50 plants are included, of which ten uses more than 90 % of the energy according to the activity data used for emission calculations for this sector. The fuel consumption trend is increasing since 1990, especially for liquid fuels, mainly due to increased use within the basic plastic industry. For 2019, liquid fuels account for about 65 % of the energy, solid fuels for 7%, gaseous fuels for 15 %, other fossil fuels for 13% and biomass for 1%.

As in other subcategories of NFR1A2, emissions from companies with less than 10 employees are allocated to NFR1A2g.

A summary of the latest key source analysis is presented in Table 3-7.

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[29] Skårman et.al, 2008.

Table 3-7 Summary of key source analysis, NFR1A2c, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
1A2c	Biomass –	Biomass –
	Liquid – Ni	Liquid –
	Other Fuels – SO_2	Other Fuels – $PM_{2.5}$, SO_2

3.2.6.2   METHODOLOGICAL ISSUES

The Tier 2 method is used. Activity data is, with exceptions mentioned below, collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 and later. For more details on these surveys, and explanations of choice of data sources, see Annex 1.

Generally, plants classified as ISIC Division 24 according to ISIC Rev.3[30] in the Quarterly fuel statistics are included in this sector, as recommended in IPCC 2006 Guidelines.

In submission 2009, after careful studies of different data sources regarding activity data of consumption of other petroleum fuels in this sector, it was found that the fuel used is a by-product of the process in one facility, a gas that consists mainly of methane. Since no specific emission factors for methane and methane based gas mixtures are available, emission factors for natural gas are used as these fuels are considered to have similar properties, but of course fuel consumption and emissions are still reported under liquid fuels. As natural gas contains around 90 molar % methane, the emission factors are considered to be accurate also for methane-rich gas mixtures of liquid origin.

In a development project in 2010[31], the activity data time series 1990-2008 for all fuel types and all facilities within the chemical industry were thoroughly reviewed. Reported emissions and activity data in NFR1 and 2 were analysed on facility level and verified against environmental reports, and when necessary the facilities were contacted for explanations or complementary data. Most of the data reported in submission 2010 was concluded to be correct, and only a few revisions had to be made in submission 2011. A few erroneous activity data records were detected and revised. The errors include double-counting, input data errors and miscoding, e.g. biogenic ethanol that had been coded as natural gas or hydrogen coded as other petroleum fuels.

The project also resulted in revisions of a couple of emission factors. Emission factors for hydrogen, which were previously set equal to those of "other petroleum

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[30] United Nations Statistics Division, 2010

[31] Gustafsson, Nyström & Gerner, 2010

fuels" for all substances containing nitrogen, i.e. including NH_3, were corrected and set to zero for all substances except for NO_X.

The revision that had the largest impact on the emissions is the conclusion drawn that some (not all) of the natural gas consumption previously reported in NFR1A2c 2004 and onwards is actually used as feedstock and not for energy production, and hence no emissions from this activity should be reported in NFR1A2c.

Since submission 2020, all combustion of petrochemical by-products (i.e. the gas discussed above) is allocated to CRF 2. This allocation is made due to difficulties in separating emissions from processes from stationary combustion.

The reported emissions of particulate matter include the condensable fraction of particles.

In submission 2021, the combustion of carbide furnace gas was allocated to CRF 2B5 (IPPU sector), according to the results from a developing investigation regarding improvements of the methods from carbide production, with the aim to increase consistency, completeness and accuracy of the reporting, and assures compliance with the 2006 IPCC Guidelines[32].

For confidentiality reasons the fuel consumption of solid fuels and other fossil fuels are reported as C in NFR-tables for emission year 2019.

3.2.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainty in activity data is 1.5 % (2012) and the emission factor uncertainty is assumed to be 10 % based on the variation in plant specific values. The Activity data uncertainty for this fuel 2012 is as reported to the EU ETS. For the other fuels used and for all fuels for 1990, uncertainties are assigned by expert judgements by staff at the energy statistics department of Statistics Sweden.

The uncertainties for stationary combustion are revised on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. The uncertainty of AD is 2-5 % for all fuel groups except for Other Fossil Fuels that is 10 %. Uncertainty of CO_2 emission factor is high, 100 %, for Other Fossil Fuels, 30 % for Biomass and 5 % for the other fuel groups. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Biomass for As
- Liquid As, Cr, Cu, Hg, Ni, Se, Zn

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[32] Yaramenka, K., Danielsson, H., Josefsson Ortiz, C. 2020. Improvements in reporting of emissions from carbide production. SMED Report No 16 2020.

- Other fuels for As, Cr, Cu, Hg, Ni Pb, PAH
- Gaseous fuels for PAH, PM_{10}, $PM_{2.5}$

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.6.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for NFR A2c as for 1A2a and 1A2b described above. For the largest plants in terms of emissions and fuel consumption, both environmental reports and ETS data are used for verification of the estimates based on Quarterly fuel statistics.

3.2.6.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2021, the fuel consumption of carbide furnace gas was allocated from 1A2C to 2B5 (IPPU sector). The combustion of carbide furnace gas was not used all years in the time series, which means that the effect is seen only the years when it was used: 1990,1991, 1997, 1998, 2000-2012. The new allocation affected CO, NMVOC, NH_3, TSP, PM10 PM2.5 SO_2 and NO_X. The effect of the emissions are less than 2% in relation to respectively emissions in this sector for all years.

The largest effect of this new allocation was on particle emissions (TSP, PM10 and PM2.5) and SO_2. For TSP, PM10 and PM2.5 the largest decrease was in 2008 (0.003 Gg). For SO_2, the largest decrease was in 1990 with the magnitude of 0.05 Gg.

3.2.6.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.7 Pulp, Paper and Print, NFR1A2d

3.2.7.1 SOURCE CATEGORY DESCRIPTION

In 2019, there were 50 paper mill and pulp industry plants and 120 sawmills (production capacity >10 000 m^3/year) in Sweden. In total, they produced 9.6 Mt of paper, 18.6 Mm^3 of sawn timber and 12.1 Mt of pulp[33]. Since 1990, production has had an increasing trend, but not in the latest few years. There is no apparent trend in total fuel consumption since 1990, but in recent years, the share of energy from biomass fuels has increased, from 68 % of fuel consumption in 2007 to 84 % in 2019. As for NFR 1A2 in general, emissions from companies with less than 10 employees are allocated to NFR 1A2g.

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[33] The Swedish Forest Industries Federation, 2020-11-27. 2020. https://www.skogsindustri-erna.se/skogsindustrin/skogsindustrin-i-korthet/fakta--nyckeltal/

A summary of the latest key source analysis is presented in Table 3-8.

Table 3-8 Summary of key source analysis, NFR1A2d, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A2d	Biomass – *As, Cd, Cr, Cu, DIOX, Hg, NMVOC, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*	Biomass – *As, Cd, Cr, Hg, NMVOC, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*
	Liquid – *Cd, NOx, Ni, Pb, SO2*	Liquid – *NOx, Ni, PM10, PM2.5, SO2, Se*
	Solid Fuels –	Solid Fuels – *Hg, PM2.5, SO2, Se*
	Other Fuels –	Other Fuels –

3.2.7.2 METHODOLOGICAL ISSUES

The Tier 2 method is used. Emissions from processes in the Pulp, paper and print industry are reported under NFR2D1, see section 4.6 Other industrial processes and product use, NFR2H.

Activity data is, if not otherwise stated, collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2. There is no apparent trend in fuel consumption since 1990.

During 2009, an investigation of emissions of NO_X, SO_2 and particulate matter from the pulp and paper industry was performed. A comparison between the total emissions from the facilities calculated with national emission factors and the corresponding emissions reported in the environmental reports of the corresponding facilities showed that the use of national emission factors leads to an overestimation of the emissions. In the environmental reports, however, emissions are not reported per fuel type, and hence it was not possible to develop revised emission factors per fuel. Instead, emissions of NO_X, SO_2 and particulate matter from fuel combustion in pulp and paper production facilities are enumerated with the same mean factors for all fuels:

NO_X:	$EM = 0.736 * EF(NO_X) * AD$
SO_2	$EM = 0.565 * EF(SO_2) * AD$
$TSP/PM_{10}/PM_{2.5}$:	$EM = 0.686 * EF(TSP/PM_{10}/PM_{2.5}) * AD$;

EM= emission
EF= national emission factor, specific for each substance
AD= activity data in TJ.

The availability of environmental reports for the years before 2000 is very limited, why the correction factors quoted above are used only for the years 2000 and later. The investigation, and hence the correction factors, applies to the pulp and paper industry only, and not to the printing works. Emissions from combustion of sulphur

lyes are presently not reported in 1A2d as this activity has been considered as an industrial process.

The reported emissions of particulate matter include the condensable fraction of particles.

3.2.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for NFR1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. Activity data uncertainties are assigned by expert judgements made by persons in the energy statistics department at Statistics Sweden. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. The activity data uncertainty is lowest for Biomass and Other Fossil Fuels with 8-10 %. The N_2O emission factor uncertainty for wood is 40 % and the CO_2 emission factor for Liquid Fuels is 5 %.

Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:
- Biomass for As
- Gaseous fuels for As
- Liquid As, Cd, Cr, Cu, DIOX, Hg, Ni, Se, Zn
- Other fuels for As, Cr, Cu, Hg, Ni, Pb, Zn
- All fuels for PAH, PM_{10}, $PM_{2.5}$, TSP

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In general, the same QA/QC procedures are used for NFR1A2d as for 1A1a and 1A2a–c described above.

3.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

There were no recalculations that affected the emissions.

3.2.7.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission. Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.8 Food Processing, Beverages and Tobacco, NFR1A2e

3.2.8.1 SOURCE CATEGORY DESCRIPTION

The food and drink industry is the fourth largest branch of industry measured as production value and number of employees. There are about 3000 companies, of which only around 650 have more than 10 employees[34]. The largest number of companies and employees are found in the bakery industry, but the most energy intensive branch is the sugar industry which accounts for about 25 % of the fuel consumption in 1A2e. Dairies, breweries, producers of refined vegetable fats and potato products are other industries with significant fuel consumption (around 7-12 % each of the fuel consumption in 1A2e). The fuel consumption varies between years. A slight decrease can be observed since 1990. In later years, gaseous fuels account for 45-49 % and liquid fuels account for about 27-35 % of the total fuel consumption. As for NFR 1A2 in general, emissions from companies with less than 10 employees are allocated to NFR 1A2g.

A summary of the latest key source analysis is presented in Table 3-9.

Table 3-9 Summary of key source analysis, NFR1A2e, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
1A2e	Biomass –	Biomass –
	Liquid – *Ni*	Liquid – *NOx, Ni, SO2, Se*
	Other –	Other –

3.2.8.2 METHODOLOGICAL ISSUES

The Tier 2 method is used. Activity data is collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2.

The fuel consumption varies between years and decreased steadily during the years 1998-2008. Since 2008, the total annual fuel consumption in this sector is stable.

The reported emissions of particulate matter include the condensable fraction of particles.

3.2.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for NFR1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. The IEFs are slightly variable between years due to variations in fuel mix.

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[34] The Swedish Food Federation 2013-10-02

The uncertainty values are assigned by staff at Statistics Sweden and are based on expert judgements made on fuel type that were aggregated to fuel group. Emission factor uncertainties have been assigned by national experts on emissions from stationary combustion.

The uncertainties for stationary combustion are revised in submission 2020 and set on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is 5 % for all fuel groups except for Other Fossil Fuels which is 10 %. CO_2 emission factor uncertainty varies between the fuel groups with highest for Other Fossil Fuels, 100%, 30% for Biomass and 5 % for the other fuel groups. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Biomass for As, DIOX
- Gaseous fuels for As
- Liquid As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn
- Other fuels for As, Cr, DIOX, Cu, Hg, Ni, Pb, Zn
- All fuels for PAH, PM_{10}, $PM_{2.5}$, TSP

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.8.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1A2e as for other 1A2 categories described above.

3.2.8.5   SOURCE-SPECIFIC RECALCULATIONS

There were no recalculations that affected the emissions.

3.2.8.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.9   Non-Metallic Minerals, NFR1A2f

3.2.9.1   SOURCE CATEGORY DESCRIPTION

This source category includes stationary combustion of fuels in non-metallic mineral industries (ISIC 26). Cement production accounts for the major part of the emissions.

A summary of the latest key source analysis is presented in Table 3-10.

Table 3-10 Summary of key source analysis, NFR1A2f, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A2f	Biomass –*Cd*	Biomass –
	Liquid – *NOx, Ni, SO2*	Liquid – *NOx, Ni, SO2*
	Solid – *As, Hg, NOx, SO2*	Solid – *DIOX, Hg, NOx, PM10, PM2.5, SO2, Se*
	Other –	Other –

3.2.9.2   METHODOLOGICAL ISSUES

Tier 2 method is used for emissions from stationary combustion for NFR1A2f, because country-specific emission factors for the source category and fuel for each gas is used.

Activity data is collected from Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 and later. For 2008 and later, activity data for the three plants within the cement production industry is taken from the EU-ETS system, as this data source provides more detailed information on fuel types. The total amount of fuels combusted is consistent with the Quarterly fuel statistics (KvBr).

National emission factors are used. For more details on these surveys and emission factors see Annex 2.

For practical reasons, SO_2 and NO_X emission data available from environmental reports are reported in NFR2A1. All other energy related emissions for this facility are reported in NFR1A2f.

The reported emissions of particulate matter include the condensable fraction of particles.

Due to confidentiality reasons liquid and solid fuels are reported as C for energy consumption.

3.2.9.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As for NFR1A2 in general, time series are considered consistent despite the changes in activity data source as discussed in Annex 2. The IEFs are slightly variable between years due to variations in the fuel mix.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Biomass for As
- Gaseous fuels for As
- Liquid As, Cd, Cr, Cu, DIOX ox, Hg, Pb, Se, Zn
- Other fuels for As
- All fuels for DIOX, PM_{10}, $PM_{2.5}$, TSP

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.9.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

Generally, the same QA/QC procedures are applied for 1A2f as for other 1A2 categories described above. In some earlier submissions, extensive QA/QC and verification efforts have been made for the other sectors including the construction industry.

3.2.9.5   SOURCE-SPECIFIC RECALCULATIONS

There were no recalculations that affected the emissions.

3.2.9.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan. In addition, see also chapter 1.2.5 QA/QC procedures and extensive review of emission inventory.

3.2.10   Other industries, NFR1A2g

3.2.10.1   SOURCE CATEGORY DESCRIPTION

This source category is by nature heterogeneous, as both stationary and mobile emission sources are included. The stationary sources included are combustion within ISIC 10-37, except from the branches separately reported in 1.A.2.a-1.A.2.f, stationary combustion within all companies with less than 10 employees regardless of branch, and stationary combustion within the construction sector. The Quarterly fuel statistics (KvBr) is a cut-off survey including enterprises with ten or more employees. The estimation of emissions from enterprises with less than ten employees is based on activity data from the annual energy balances, i.e. a model estimate of aggregate fuel consumption in all small enterprises within the entire manufacturing industry. These emissions are reported in 1A2gviii.

The mobile emission source included in this sector is combustion by off-road vehicles and other machinery (working machinery) used in the construction and manufacturing industry. The emissions of air pollution from this sector are reported in 1A2gvii.

In terms of stationary fuel combustion and emissions, two branches of industry are dominating; manufacturing of wood products (ISIC 20), and mining industry (ISIC 13). In ISIC 20, however, biomass fuels are dominating and hence the emissions of

fossil CO_2 from this branch of industry are low. The construction industry also accounts for a significant share of fuel consumption and emissions. The fuel consumption varies between years, but for stationary combustion within 1A2g in total, it has decreased slightly since 1990. Liquid and biomass fuels account for most of the decrease. For mobile combustion, i.e. working machinery, the fuel consumption in 2019 has almost doubled (+ 97%) compared to 1990. The emissions of NOx, NMVOC and particles shows however a decreasing trend for the last 2-3 years, while the emissions of CO have levelled out.

A summary of the latest key source analysis is presented in Table 3-11.

Table 3-11 Summary of key source analysis, NFR1A2g, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A2g vii	Biomass – *Cu*	Biomass – *Cu*
	Liquid – *CO, Cd, Cu, NMVOC, NOx, PM10, PM2.5, TSP*	Liquid – *CO, Cd, Cu, NMVOC, NOx, PM10, PM2.5, SO2*
	Other –	Other –
1A2g viii	Biomass – *As, Cd, Cr, DIOX, Hg, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, Zn*	Biomass – *As, Cd, Cr, DIOX, Hg, NMVOC, Ni, PAH 1-4, PM10, PM2.5, Pb, Se, TSP, Zn*
	Liquid – *Cd, NOx, Ni, SO2*	Liquid – *NOx, Ni, PM10, PM2.5, SO2, Se*
	Solid – *As, Cr, DIOX, Hg, NOx, Pb, SO2, Se*	Solid – *As, Cr, DIOX, Hg, NOx, Ni, Pb, SO2, Se*
	Other –	Other –

3.2.10.2   METHODOLOGICAL ISSUES

All consumption of motor gasoline and diesel oil, including low blended biofuel, in manufacturing industries and construction is allocated to mobile combustion while all other fuels (heating oils, natural gas etc.) are allocated to stationary combustion.

3.2.10.2.1 Stationary combustion

For emissions from stationary combustion, the Tier 2 method is used. Emissions from stationary combustion in mining and quarrying and in the manufacturing of various products such as textiles, wearing apparel, leather, wood and wood products, rubber and plastics products, other non-metallic mineral products, fabricated metal products and manufacturing of different types of machinery, are calculated with activity data from the Energy use in the manufacturing industry (ISEN) for 1990-1996 and 2000-2002, and from the Quarterly fuel statistics (KvBr) for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2.

Emissions from all companies with less than 10 employees within the manufacturing industry are estimated and reported under NFR1A2g. Activity data are collected from the annual energy balances produced by Statistics Sweden[35]. The last emission year is estimated as a projection of the second last year by the trend from

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[35] Statistics Sweden, EN20SM 1990-2008. See also Annex 2.

the quarterly energy balances, as the annual energy balances for the last emission year are not ready in time for the emission calculations. Emissions are minor and with current data not possible to separate on different industry sectors.

Emissions from stationary combustion in the construction industry are calculated with activity data from Statistics Sweden[36] in the same way as for small companies described above.

The fuel consumption varies between years, but has totally decreased slightly since 1990, especially the consumption of liquid and biomass fuels.

Since 2002, for one glassworks plant, it is no longer possible to separate combustion emissions of SO_2 from process emissions. The reason is that the facility has restructured its environmental report, and only reports emissions of SO_2 on an aggregate level. The median value for the share of process-related SO_2 missions of the total SO_2 emissions is 2 % for the years 1990 - 2001. The emission data reported in the plants environmental report are considered to be more accurate than emissions calculated from fuel combustion with standard emission factors, and thus for practical reasons, all data that is available from environmental reports from this plant, namely SO_2 and NO_X, are reported in NFR2A7 and all other emissions are reported in NFR1A2F.

For 2008 and later, activity data for the three plants within the cement production industry is taken from the EU ETS system because the reporting of waste-like fuels to the Quarterly fuel statistics has shown to be partly incomplete for some years. In the CLRTAP stage 3 review of submission 2013 (and in earlier reviews) it was recommended that the emissions from the cement industry within NFR1A2f should be reported separately. This is however not possible, because data on emissions of NO_X, SO_2 and particulate matter from the cement industry are taken from environmental reports. In these reports, only the total emissions for each substance are reported, and it is not possible to isolate the combustion emissions. Because of this, all emissions of these substances from the cement industry are reported in NFR2A1. This means that the emissions reported under NFR1A2g in the NFR tables do not include combustion emissions from the cement industry. A table for the cement industry would hence show "IE" for the major pollutants.

The reported emissions of particulate matter include the condensable fraction of particles.

Due to confidentiality reasons liquid, solid, biomass and other fossil fuels are reported as C for energy consumption.

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[36] Statistics Sweden, EN20SM 1990-2008. See also Annex 2.

3.2.10.2.2 Mobile combustion

Emissions from mobile combustion in NFR1A2g ii refer to working machinery used in industry, including for example tractors, dumpers, cranes, excavators, generators and wheel loaders. A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions, except for SO_2 which is estimated according to Tier 2. The model is further explained in Annex 2.

Emissions from working machinery are also reported in NFR1A3e ii, 1A4a ii, 1A4b ii and 1A4c ii. See Table 3-12.

Table 3-12 Distribution of emissions from off-road vehicles and other machinery.

Category	NFR	Definition IPCC Guidelines
Industry	1A2g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1A3e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1A4c ii or 1A2g vii.
Commercial/ Institutional	1A4a ii	Garden machinery, e.g. lawn mowers and clearing saws, not used by private users, also tractors not used in industry ore forestry or agriculture.
Residential	1A4b ii	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1A4c ii	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.10.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

3.2.10.3.1 Stationary combustion

As for NFR1A2 in general, time series consistency despite the changes in activity data source is discussed in Annex 2. As for other categories in NFR1A2, the IEFs vary slightly between years due to variations in fuel mix. In earlier submissions, the EC (European Commission) has asked for clarification of the drop in wood consumption in 2000 compared to earlier years. This issue has not been prioritized, but since the annual wood consumption 2001-2009 is considerably lower than in the 1990s, there is no reason to believe that the activity data for 2000 is incorrect.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Biomass for As
- Gaseous fuels for As
- Liquid As, Cd, Cr, Cu, DIOX, Hg, Pb, Se, Zn
- Other fuels for As
- All fuels for DIOX, PM_{10}, $PM_{2.5}$, TSP

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.10.3.2 Mobile combustion

No recalculations have been performed for emissions in the mobile sector for the eighties, and thus there are inconsistencies in time series between the eighties and later years. Time series from mobile combustion in NFR1A4b ii have been reviewed for later years and are considered to be consistent.

Uncertainties for activity data and emissions reported for working machinery in NFR1A4b ii can be seen in Annex 1 to the IIR.

3.2.10.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

3.2.10.5   SOURCE-SPECIFIC RECALCULATIONS

3.2.10.5.1 Stationary combustion

In submission 2021, the AD was revised between 2013 and 2018. The preliminary AD for 2018 was revised with final AD data for that year. All fuel groups were revised between 2013 and 2018 due to than biomass fuels due to a reallocation between biomass fuels and biomass liquid fuels in the Energy Balance and error corrections. These revisions resulted at mostly an increase of AD in liquid fuels by 2.4% in 2015 years emissions. The revision of 2018 AD was made for solid fuels and biomass, resulting in an increase of solid fuel consumption with 0.1% and a decrease of biomass use of 0.1%.

The largest effect of submission 2021 recalculations was in benzo(k)fluoranthene emissions. The emissions increased with 87.9 % (0.007 t) for year 2018 and 85.5% (0.007 t) for year 2017 between submission 2021 and 2020 in the sector.

3.2.10.5.2 Mobile combustion

Top-down allocated fuel amounts to working machinery from remaining non-allocated gasoline and diesel volumes (see IIR annex 2.4 for more detailed explanations) have been revised. Emissions of SO_2, heavy metals and PAH have therefore been recalculated (see table below).

Table 3-13 Changes in emissions of SO₂, heavy metals and PAH in 2018 and between submission 2020 and submission 2021.

Gas	Change in emissions 2018	Change in emissions 2018 (%)
SO₂ (kt)	-8E-05	-3%
Cd (t)	-1E-04	-2%
Cr (t)	-7E-04	-2%
Cu (t)	-2E-02	-2%
Ni (t)	-9E-04	-2%
Se (t)	-1E-04	-2%
Zn (t)	-1E-02	-2%
B(a)p	-4E-04	-2%
B(b)f	-7E-04	-2%

3.2.10.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.11   Civil Aviation, NFR1A3a i-ii

3.2.11.1   SOURCE CATEGORY DESCRIPTION

Domestic aviation is defined as emissions from flights that depart and arrive in the same country. But for the reporting of air pollution according to the Long-Range Transboundary Air Pollution Convention (LRTAP), emissions from national and international aviation during the LTO cycle[37] *both* belong to the national totals. And emissions from *both* domestic and international aviation during the Cruise cycle[38] is reported separately as memo items and not included in national totals.

The national government administers 13 of 40 airports with regular and/or charted air traffic in Sweden, for which activity data is provided at present. The remaining 27 airports are private and/or administered by local governments[39].

The energy consumption from the LTO cycle, from both national and international aviation, decreased by 2 % between 1990 and 2019 and by 7% between 2018 and 2019. The energy consumption from the cruise cycle (national & international) on the other hand, increased by 65 % compared to 1990 but decreased by 6 % between 2018 and 219. (figure 3-1).

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[37] Landing and take-off.

[38] Cruise cycle: above 3000 feet.

[39] Transportstyrelsen, 2013.
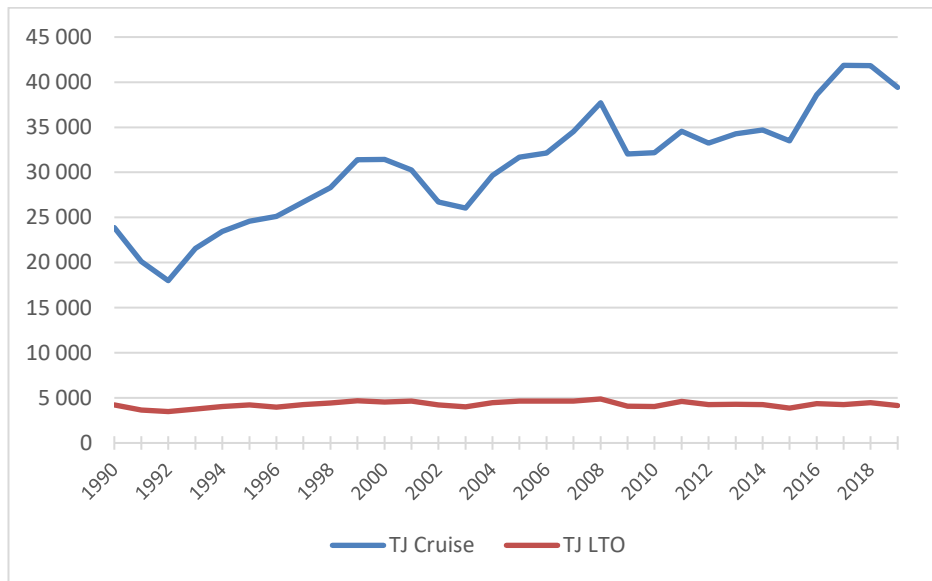
Figure 3-1. Energy use by aviation: LTO & Cruise cycle

The emissions of NO_X from both the Cruise and LTO cycle have fluctuated over the years, but while the emissions of NOx from the Cruise cycle have increased by 57% between 1990 and 2019, the emissions of NOx from LTO has decreased by 16% compared to 1990. The total emissions of NOx decreased by 4% between 2018 and 2019. The total emissions of particles have also decreased in the last year, both for the Cruise cycle and the LTO cycle.
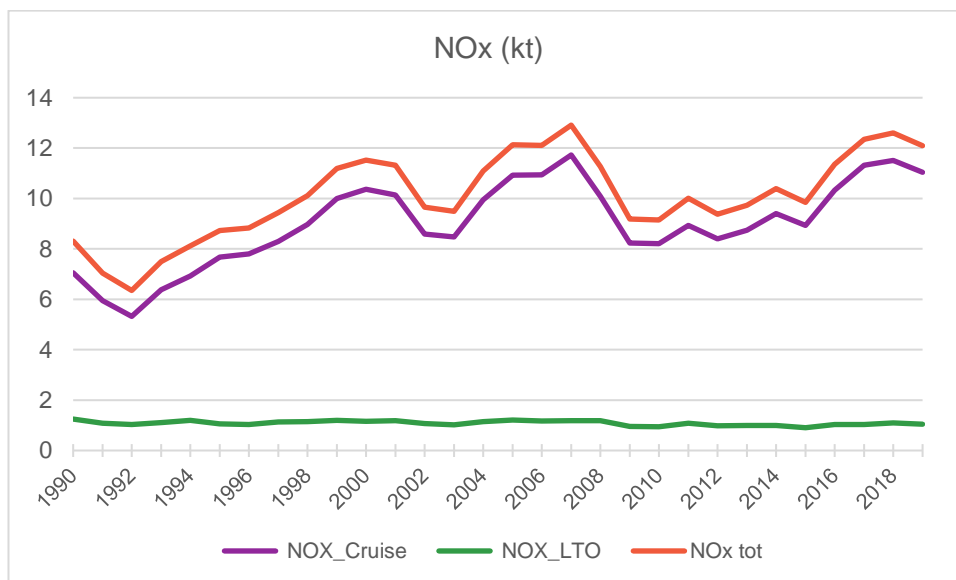
The emissions of CO fluctuate a lot, but was at its lowest in 2003. After a steady increase, the emissions of CO peaked in 2017. The decreasing trend since 2017 is due to a transition from Boeing to Airbus planes. The emissions of CO from both

the LTO and Cruise phase have decreased by 15% since 2018 and by 12-13 % since 1990.
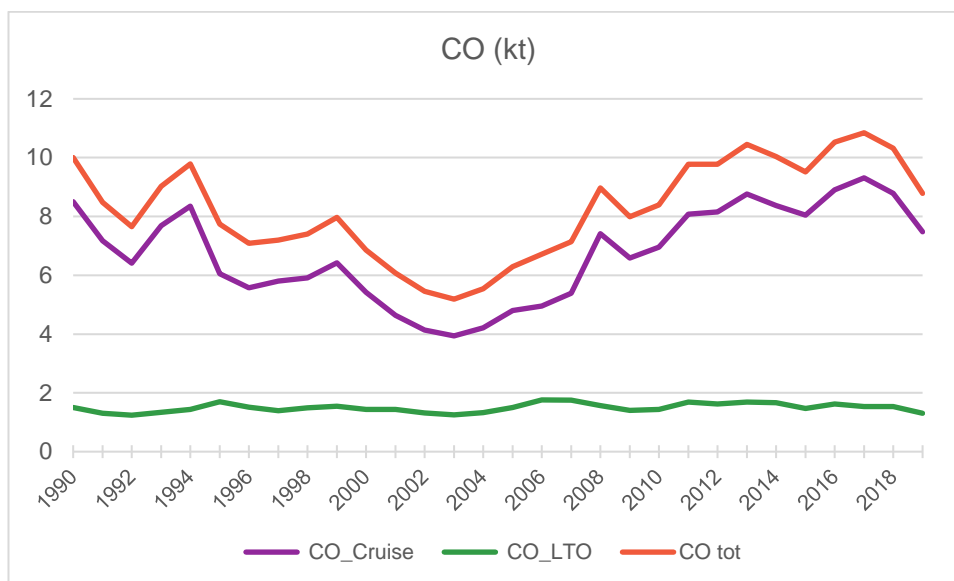
The emissions of NMVOC from the Cruise phase have a decreasing trend and the emissions have declined by 65% since 1990 and by 13 % in the last year. The emissions of NMVOC from the LTO phase have fluctuated for the whole time series and have decreased by 35% since 1990 and by 16 % from 2018 to 2019. The total emissions of NMVOC have a declining trend, which in the recent years is a result of phasing out a specific type of airplane (MD-80/82), which is a major contributor to these gases.

The emissions of SO_2 from the Cruise phase have increased for the whole time period from 1990 to 2018, due to an increased fuel consumption by aviation, but decreased by 6 % from 2018 to 2019. The emissions of SO_2 from the LTO phase have a more fluctuating trend. The emissions of Pb have a decreasing trend for both the Cruise and the LTO phase.

A summary of the latest key source analysis is presented in Table 3-14.

Table 3-14 Summary of key source analysis, NFR1A3a i-ii, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A3a	Aviation Gasoline - *Pb*	Aviation Gasoline - *Pb*
	Jet Kerosene −	Jet Kerosene − ,

3.2.11.2   METHODOLOGICAL ISSUES

Sweden uses Tier 2 to estimate emissions of SO_2 and NMVOC and Tier 3a to estimate the emissions of all other gases. Emissions from aviation used by agriculture and forestry are reported as civil aviation. Emissions from military use of aviation

fuels are reported under Other – mobile sources (NFR1A5b) or 1D2 Military oper-
ations abroad.

The Swedish Transport Agency (STAg) is responsible for reporting the emissions
from aviation. But the fuel consumption and emissions published by STAg are cal-
culated by the Swedish Defence Research Agency (FOI) by using an air emission
model. STAg provides FOI statistics for the model regarding:

- Airport of departure and arrival

- Type of aircraft

- Number of flights

- Number of LTO cycles

- Number of passengers

A database with information regarding 200 different types of aircraft is also used.
The emission data regarding different types of aircrafts in the database originates
from "ICAO Engine Exhaust Emission Data Bank". All this data is used to calcu-
late emissions and the amount of combusted fuel for the whole flights as well as
for aircraft movements below 3000 feet at the airports, the so called LTO cycle.
FOI has written a report which describes their method for estimating the emission
from aviation[40].

The model used to calculate the emissions from aviation underestimates the num-
ber of kilometres flown, as the model uses more direct flight routes in the calcula-
tions than the aircrafts do in reality. As a result, the consumption of fuel and emis-
sions are underestimated, and need to be adjusted to be in line with data on na-
tional delivery of aviation fuel from the monthly survey on supply and delivery of
petroleum products from Statistics Sweden (see Annex 2). The results from the
emission calculations are aggregated into four groups: domestic landing and take-
off (LTO), domestic cruise, international LTO and international cruise.

The methodology for calculating national emissions is the same for all years with a
few exceptions for earlier years. All emissions for 1990-1994 were calculated by
SMED in cooperation with the STAg due to the lack of activity data. Emissions of
CO for 1990-1994 were estimated by using the ratio between CO and CO_2 in 1995
(4.85 % of CO_2 emissions). Emissions of NO_X were calculated in a similar way.
The mean value of the ratio between NO_X and CO_2 emissions in 1995-2004 is used
for 1990-1994 (4.03 % of CO_2 emissions). Emissions of HC for 1990-1994 are cal-
culated by extrapolation.

From 1995 and onwards, emissions of SO_2, NO_X, CO and HC are estimated by FOI
as described above. The emissions of NMVOC and CH_4 are estimated based on the

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[40] Calculation of exhaust emissions from air traffic. T. Mårtensson, A. Hasselrot. FOI R 3677 mSE

model estimated emissions of HC and emission factors from EMEP/EEA air pollutant emission inventory guidebook. N_2O emissions from LTO are estimated using information from STAg on the number of LTO cycles together with emission factors from EMEP/EEA guidebook. Emissions of N_2O from cruise are based on emission factors from EMEP/EEA guidebook together with the fuel consumption for cruise activities as well as emissions of particles.

Due to the fact that the Swedish airports generally are smaller than international airports in other countries, taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well. Hence, traffic from Swedish airports needs less fuel and give rise to lower emissions compared to the International Civil Aviation Organization (ICAO) standards.[41] For international flights, ICAO standard taxi time has been used for the part of the LTO cycle occurring on international airports.[42]

The Swedish Transport Agency (STAg) includes the traffic from a number of non-governmental airports in their estimates from 2005 and from all Swedish airports from 2006. Since 2010 there is no separate reporting on emissions from governmental respectively private airports, instead a total is reported.

In 2006, the STAg responded to the governmental call to reduce response burden on statistical compilations. As a result, private aviation as well as educational training flights are no longer covered in the STAg reports on fuel consumption and emissions from aviation as from 2007. However, as the estimated emissions from aviation are adjusted to match the delivered amount of aviation fuels, the emissions from private aviation as well as from educational training flights will consequently be included.

3.2.11.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Data on domestic and international bunker fuel in the Monthly fuel, gas and inventory statistics has been found to be of good quality (See Annex 1 to IIR for more information). Regarding time-series consistency, see the Methodology section.

3.2.11.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

The activity data has been subject to QA/QC procedures.

3.2.11.5 SOURCE-SPECIFIC RECALCULATIONS

The activity data for aviation gasoline for 2018 was changed in submission 2021, which resulted in a slight decrease in the emissions from this fuel type.

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[41] Gustafsson, 2005.

[42] Näs, 2005.

3.2.11.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission

3.2.12   Road transport, NFR1A3b i-iv

3.2.12.1   SOURCE CATEGORY DESCRIPTION

Road Road traffic is the dominating mode for transport of both goods and people[43] and the Swedish citizens travelled more then 67 000 million of km by car on Swedish roads in 2019 (Table 3-14). This is an increase by approximately 20 % since 1990. For all trucks (LCV & HGV) there has been an increase in number of travelled km by 92 % since 1990 (Table -3-15). The Swedish road network comprised in 2019 of around 141,300 km of public roads[44].

Table 3-15 Million of km driven by different kinds of vehicles in 1990, 2000 and 2019.[45]

Year	Passenger cars	LCV	HGV	Motorcycles	Buses
1990	55 696	3 709	3 653	407	964
2000	58 555	4 574	4 310	670	917
2019	67 142	9 327	4 829	756	996

Road transport includes five vehicle categories: passenger cars, light commercial vehicles (LCV), heavy goods vehicles (HGV), buses and mopeds & motorcycles. The total number of trucks and passenger cars (in traffic) has increased by 116 % respectively 36 % since 1990[46] in contrast to the decrease in the emissions of NO_X and NMVOC. The emissions of NMVOC have decreased by 96 % respectively 93 % from trucks and passenger cars while the emissions of NO_X have decreased by 72% respectively 65 % from trucks and passenger cars since 1990. This is mainly a result of the introduction of three-way catalytic converters on passenger cars and trucks. Gasoline evaporation, automobile tyre and brake wear and automobile road abrasion are, beside combustion of fuel, also sources of air pollution caused by road traffic.

The emissions of CO and particles also show a downward trend for all years (1990-2019) as well as the emissions of SO_2, as the sulphur content in fuel has been heavily restricted over the years. The emissions of NH_3 shows an increasing trend, which peaks in 2001 and then decrease in the coming years.

Gasoline has previously been the most common fuel used for road transportation, but as from 2011 the amount of diesel used by road traffic as well as the emissions of GHG from diesel surpassed gasoline. The increasing consumption of diesel by

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[43] Ministry of the Environment, 2001

[44] Trafikverket, 2019. https://www.trafikverket.se/resa-och-trafik/vag/Sveriges-vagnat/

[45] Data from the road emission model HBEFA (Trafikverket).

[46] TRAFA 2019. Fordonsstatistik (scb.se)

road traffic is primarily explained by a shift from gasoline cars to diesel cars, but also by an increased consumption of diesel by HGV and LCV. The total consumption of diesel by HGV and LCV corresponds to 53 % of the total consumption of diesel by road traffic in 2019, while passenger cars consume around 46 % of the total diesel for road traffic.

The consumption of diesel by HGV increased by 65% between 1990 and 2007 but was only 9 % higher in 2019 than in 1990 due to a decreasing trend after 2007 (Figure 3-4).
The consumption of diesel by LCV has increased nine fold since 1990, but is lower than the consumption by both passenger cars and HGV. The consumption of diesel by passenger cars has increased steadily since 1990 but has slowed down in the last years.
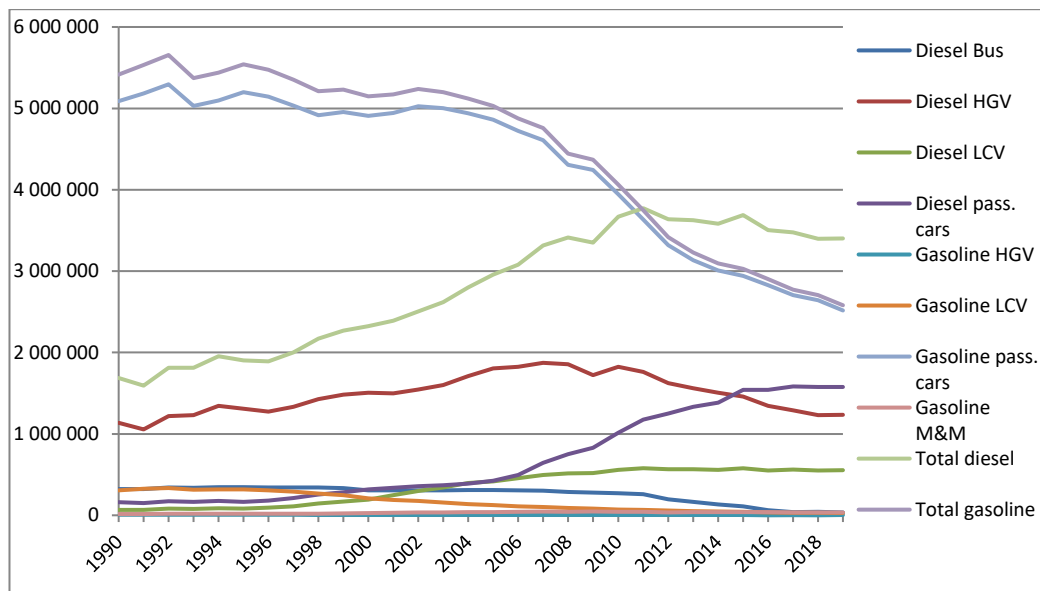
Figure 3-4. Consumption of diesel and gasoline by vehicle type 1990-2019 (m³).

The total use of liquid biofuels (FAME/HVO and ethanol/ETBE) has increased vastly since 2003, when large-scale blending of ethanol into petrol began (Figure 3-5). Advantageous policy regulations and tax reliefs for biofuels initiated the increasing production and use of biofuels[47]. The amount of biogas used by road traffic has also increased greatly since it was introduced on the market and has doubled every other to every third year between 1998 and 2008.

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[47] Swedish Energy Agency, 2013.
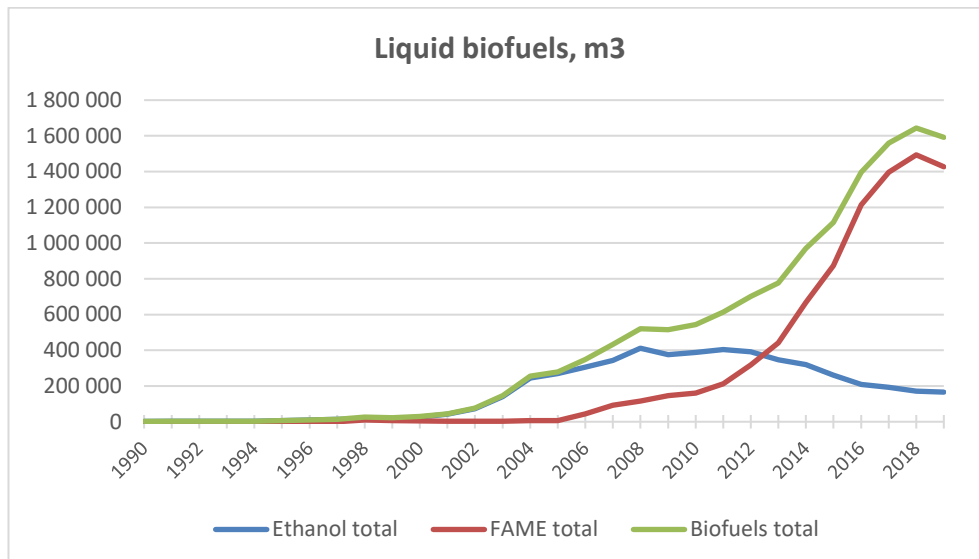
Figure 3-5. Consumption of biofuels 1990-2019 (m³).

The main part of ethanol used by road transportation in Sweden is used as a blending component for gasoline. Large-scale blending of ethanol into petrol began in 2003 and the total amount of ethanol used for road traffic nearly tripled between 2003 and 2011. Today, just about all petrol sold in Sweden contains around 5 % ethanol. As from 2012, the amount of low-blended ethanol in gasoline started to decline as a result of the shift from gasoline cars to diesel cars.

Ethanol is also used by ethanol buses and by E85 passenger cars (flexi fuel cars). The ethanol used by E85 cars increased until 2011 and then began to decline. The consumption of ethanol by buses follows the same trend (Figure 3-6).
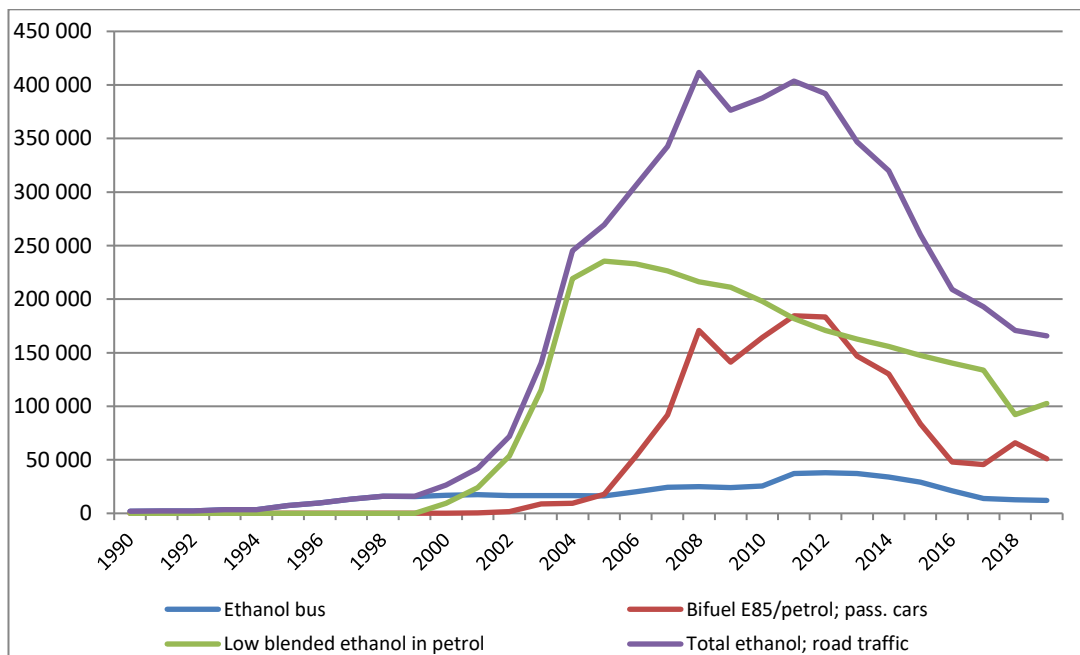
Figure 3-6. Consumption of ethanol by road traffic 1990-2019 (m³)

Large-scale blending of FAME into diesel began in 2007and of HVO in 2012. The amount of FAME/HVO used by road traffic increased by 32-51 % per year 2011-2016, but the upward trend slowed down in 2017 and then turned in 2018. (Figure 3-7). The sharp increase in biodiesel in 2011-2016 was mainly a result of a growing trend for diesel cars and a rising fraction of FAME/HVO blended into diesel.
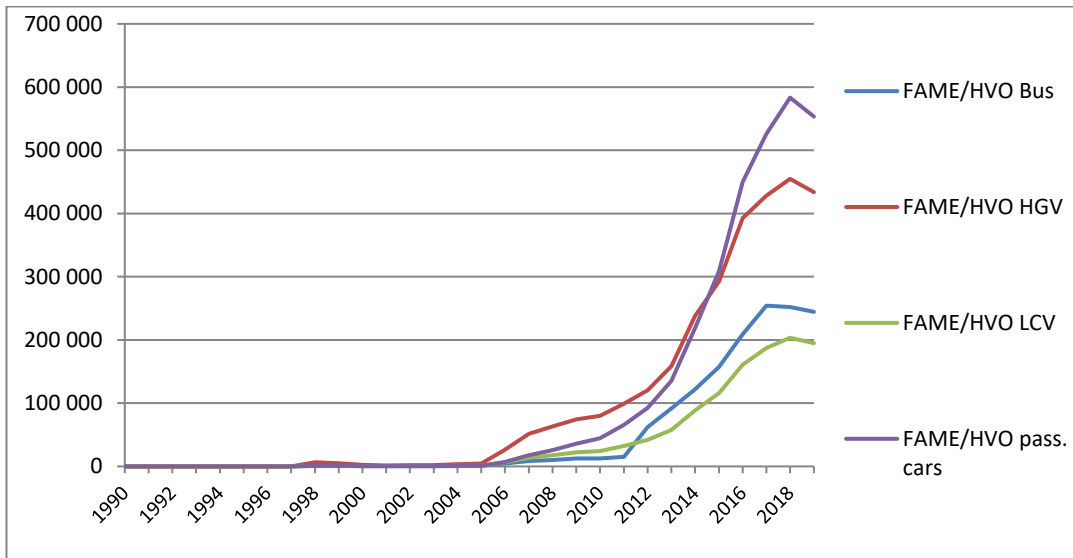
Figure 3-7. Consumption of FAME/HVO by road traffic 1990-2019 (m3).

A summary of the latest key source analysis in presented in Table 3-16.

Table 3-16 Summary of key source analysis, NFR1A3b i-v, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A3b i	Biomass – *CO, Hg, NOx,*	Biomass – *CO, Hg*
	Diesel oil – *CO, Hg, NOx, PM₂.₅*	Diesel oil – *Hg, NOx, PM₁₀, TSP*
	Gasoline – *CO, Hg, NH3, NMVOC, NOx*	Gasoline *CO, DIOX, Hg, NH3, NMVOC, NOx, Pb, SO2*
	Gasoline evaporation -	Gasoline evaporation –
1A3b ii	Biomass –	Biomass –
	Diesel oil – *NOₓ, PM₁₀ PM₂.₅*	Diesel oil – *NOₓ, Hg, PM₂.₅*
	Gasoline –	Gasoline – *CO, NMVOC, NOx, Pb*
1A3b iii	Biomass – *NOₓ*	Biomass – *Hg, NOₓ,*
	Diesel oil – *CO, Hg, NOx, PM10, PM2.5, TSP*	Diesel oil - *Hg, NMVOC, NOx, PM10, PM2.5, SO2, TSP*
	Gasoline –	Gasoline –
1A3b iv	Gasoline – *CO, NMVOC*	Gasoline – *CO*
1A3b v	Gasoline – NMVOC	Gasoline – NMVOC

3.2.12.2   METHODOLOGICAL ISSUES

The road emission model HBEFA is used by the Swedish Transport Administration (STA) to estimate the fuel consumption and the emissions from road traffic. The fuel consumption estimated by HBEFA is however adjusted to be in line with national fuel statistics. For 1990-2017, data from the survey "Monthly fuel, gas and inventory statistics" is used for this purpose. A revised version of the survey was introduced in 2018, but uncertainties regarding the quality of the statistics were detected and data from the survey was consequently not used for 2018. As a result, data collected and reported according to the "Swedish fuel quality act", regarding diesel, gasoline and biofuels, was instead used for 2018-2019.[48]

In the monthly survey "Monthly fuel, gas and inventory statistics", data is collected from all oil companies and other sellers who keep stocks of petroleum products and coal. The survey also collects stock data from companies with a large consumption of oil in the manufacturing industries and energy industries. As the same oil companies are obliged to collect and report fuel data under the "Swedish fuel quality act", which is used for 2018-2019, the time series is still considered consistent. The amount of diesel and gasoline collected and reported by the monthly survey and the "Swedish fuel quality act" has only differed around 1 percent for the last 3-4 years. Therefore, despite the change of data source for 2018-2019, the activity data used in submission 2021 is considered to be consistent and of good quality.[49]

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[48] https://www.energimyndigheten.se/en/sustainability/sustainable-fuels/fuel-quality-act/

[49] Eklund, V. et al. 2019. Analys och implementering av data från nya MåBra.

The fuel consumption and emissions are allocated by fuel type and five vehicle categories: Passenger cars, Light commercial vehicles (LCV), Heavy goods vehicles (HGV), Buses and Mopeds & Motorcycles. The road traffic emission model HBEFA is updated yearly with new information regarding emission factors, vehicle fleet, composition of the fuel and the current traffic work. The HBEFA model is administrated by the Swedish Transport Administration (STA) and IVL Swedish Environmental Research Institute.

Emissions of SO_2 are based on the fuel consumption per vehicle type and country specific thermal values and emission factors. The emission factors for SO_2 are based on the actual sulphur content for the different environmental classes of petrol and diesel fuel as from submission 2007. The thermal values and the country-specific emission factors for SO_2 are provided by SPBI[50]. Prior to submission 2007, emissions of SO_2 from diesel and gasoline were based on the maximum allowed sulphur content of different environmental classes. Data on maximum allowed sulphur content was provided by SPBI.

The emissions of CO, NO_X, NMVOC, NH_3, Pb and particles from road traffic are estimated by HBEFA. The emissions of Cd, Hg, As, Cr, Cu, Ni, Se and Zn were estimated for the first time in submission 2016, with default emission factors from EMEP/EEA Guidebook 2013. The emission factors did not change in the updated version of the guidebook from 2016. The reported emissions of particulate matter include most likely the condensable fraction of particles.

Road traffic emission factors for heavy metals were also updated in submission 2019 using EMEP EEA Guidebook 2016. This included Cd, Cr, Cu, Ni and Zn for all vehicle categories and fuel types. Heavy metal emissions from motorcycles were estimated for the first time in submission 2019, with emission factors from EMEP/EEA Guidebook 2016.

Activity data for natural gas is available from 1990, while reliable activity data for biogas exists from 1996 and for ethanol and FAME from 1998. Thermal values for biogas have been collected from the Swedish Biogas Association, for ethanol from SPBI and for FAME from the "Eco fuel" web page[51].

The bottom-up estimations of the fuel consumption by HBEFA differ slightly from fuel consumption reported to the UNFCCC (based on fuel delivery). According to IPCC Guidelines, the inventory should only account for emissions from fuel purchased in Sweden compared to the STA, who aims to describe what is emitted on Swedish roads, regardless of where the fuel was bought or the nationality of the vehicles. An overview of the two different objectives is presented in Table 3-17.

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[50] Swedish petroleum and biofuel institute

[51] http://www.ecobransle.se/

Table 3-17 Emissions from road transport reported by the STA and in the NFR.

Fuel bought in	Traffic on Swedish roads	Traffic in Sweden, not on roads	Traffic to/from other country	Traffic in other countries
Sweden	NFR1A3b i-iv STA	NFR1A3b i-iv	NFR1A3b i-iv* STA to the Swedish border	NFR1A3b i-iv *
Other country	STA	Not reported	STA to the Swedish border	Not reported

* Since the IPCC Guidelines do not consider international bunkers for road transportation, all emissions from road traffic and fuel bought in Sweden are considered to be domestic and thus reported under NFR1A3b.

Military transport emissions are reported under NFR1A5b. Military road transport is included in the road traffic emissions estimated by HBEFA. To subtract and separate emissions from military transport from emissions from civil road transport, emissions from HBEFA for each vehicle type are reduced by an amount equal to the weight of the fuel consumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport, according to the equation below:

$$A = B - \sum((C-D)/C*E_i)$$

A = Military transport emissions
B = Total HBEFA emissions
C = Total fuel consumption National Statistics
D = Military fuel consumption Swedish Armed Forces
E_i = HBEFA emissions per vehicle type

Data on particle emissions are lacking for the years 1981-1984 and 1986 and are therefore interpolated. It should also be noted that emissions of particles reported under NFR1A3b for the 1980s include military activities.

Emissions of dioxin from road transport were before submission 2008 not separated into different sub-sectors and were aggregated under Road Transportation (1A3b). In submission 2008 data from 1990 were updated since detailed background information (m3 gasoline and diesel) per vehicle category from the HBEFA model, has made it possible to report emitted dioxin separately for Passenger cars (1A3b i), Light duty vehicles (1A3b ii), Heavy duty vehicles (1A3b iii) and Mopeds & Motorcycles (1A3b iv). As from submission 2012, data from the HBEFA 3.1 model were used instead of data from the ARTEMIS model. The emission factors used are from Finstad et al (2001)[52].

Further, as from submission 2008 emissions of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene) were reported for 1A3b. As for dioxin, detailed data from the ARTEMIS model (submission 2008-2011)

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[52] Finstad et al, 2001

and HBEFA 3.1 (from submission 2012) regarding yearly mileages (km x 10^6) per vehicle and fuel category, as well as emission factors, have been used. Emission factors presented by Westerholm et al. (2001)[53] are used for the calculations of PAHs from Swedish environmental classified diesel (MK1) used in Heavy duty vehicles. Emission factors for MK1 diesel in Passenger cars and Light duty vehicles are calculated using the relationship Passenger car/Heavy duty vehicle and Light duty vehicle/Heavy duty vehicle in the EMEP-Corinair Guidebook and emission factors for Heavy duty vehicle according to Westerholm et al (2001)[53]. For MK1 diesel the emissions of benzo(k)fluoranthene are included in reported benzo(b)fluoranthene. All other emission estimates are based on emission factors in the EMEP-Corinair Guidebook. The emission factors used are shown in Table 3-18.

Table 3-18 Emission factors used for estimations of dioxin and PAH emissions from fuel combustion in NFR1 A 3 b i - iv.

	Gasoline		Diesel					
	Leaded	Un-leaded	Conventional			MK1		
			Passenger cars, Light duty vehicles		Heavy duty vehicles	Passenger cars, Light duty vehicles		Heavy duty vehicles
			Not DI	Direct injection		Not DI	Direct injection	
Dioxin (µg/Mg)	2.00	0.10	0.10					
Benzo(a)pyrene (µg/km)	0.48	0.32	2.85	0.63	0.90	0.95	0.21	0.30
Benzo(b)fluoranthene (µg/km)	0.88	0.36	3.30	0.60	5.45	0.09	0.18	1.60
Benzo(k)fluoranthene (µg/km)	0.30	0.26	2.87	0.19	6.09			
Indeno(1,2,3-cd)pyrene (µg/km)	1.03	0.39	2.54	0.70	1.40	0.36	0.10	0.20

Time series per vehicle category are calculated for dioxin and PAH1-4 from 1980, but data for 1980 - 1989 are not updated in the NFR-tables.

For the dioxin emission estimates, the share of leaded gasoline of the total amount of gasoline must be taken into consideration (Table 3-19). For the PAH calculations the share of diesel Passenger cars and diesel Light duty vehicles with direct injection must be estimated, since these emission factors differ from the emission factors for diesel vehicles without direct injection (Table 3-19). All Heavy duty vehicles are assumed to have direct injection. Also the share of MK1 diesel of the total amount of diesel used has to be known (Table 3-19).

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[53] Westerholm et al., 2001. Comparison of Exhaust Emissions from Swedish Environmental Classified Diesel Fuel (MK1) and European Program on Emissions, Fuels and Engine Technologies (EPEFE) Reference Fuel: A Chemical and Biological Characterization, with Viewpoints on Cancer Risk

Table 3-19 Distribution of vehicles with respect to fuel type and injection system.

Year	Gasoline		Without direct injection		With direct injection		Diesel type	
	Leaded	Un-leaded	Passenger cars	Light duty vehicles	Passenger cars	Light duty vehicles	MK1	Conven-tional
1980-1985	100%	0%	100%	100%	0%	0%	0%	100%
1990	50%	50%	100%	100%	0%	0%	0%	100%
1995	0%	100%	67%	100%	33%	0%	66%	34%
2000	0%	100%	30%	45%	70%	55%	94%	6%
2005	0%	100%	6%	20%	94%	80%	98%	2%
2010	0%	100%	0%	4%	100%	96%	99%	1%
2013	0%	100%	0%	0%	100%	100%	99%	1%

3.2.12.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

For the energy sector, the largest uncertainties come from activity data for the 1980's and from emission factors. No recalculations have been performed for emissions in the mobile sector for the eighties, and thus there are inconsistencies in time series between the eighties and later years.

Activity data for gasoline, diesel and natural gas is available from 1990, while reliable activity data for biogas exists from 1996, for ethanol from 1998 and for FAME from 1999.

One important basic parameter for the HBEFA model is vehicle-km, which is calculated through another model. This second model is based on the mileage driven by the vehicle noted at time of MOT (annual testing of the vehicle). A passenger car which goes through the MOT in the beginning of 2015, has done most of the mileage in 2014. If the development of traffic is without interruption, this issue is not a problem for the calculations. However if a sudden event occurs, such as a drop in the economy, it will not show as clearly in the development of the vehicle mileage as in statistics on fuel consumption.

In 2018 a revised version of the survey "monthly fuel, gas and inventory statistics" was introduced, but uncertainties regarding the quality of the statistics were identified and the data from the survey was consequently not used for 2018. As a result, data collected and reported according to the "Swedish fuel quality act", regarding diesel, gasoline and biofuels, is used for 2018-2019.[54] Despite the change of data source for 2018-2019, the activity data used in submission 2021 is considered to be consistent and of good quality. See section 3.2.12.2 for more information.

See Annex 1 for more details regarding uncertainties for activity data and emissions.

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[54] https://www.energimyndigheten.se/en/sustainability/sustainable-fuels/fuel-quality-act/

3.2.12.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

All Tier 1 general inventory level QC procedures and all QC procedures applicable to this sector are used. The activity data has been subject to QA/QC procedures. In addition to this, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, responsible staff is contacted for an explanation. IEFs are calculated per fuel, substance and NFR-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

3.2.12.5   SOURCE-SPECIFIC RECALCULATIONS

3.2.12.5.1 Updates in the HBEFA road emission model

The road traffic emission model HBEFA is updated yearly with new information regarding emission factors, vehicle fleet, composition of the fuel and the current traffic work.

In submission 2021, the road emission model HBEFA 3.3 has been updated to version 4.1. The main differences compared to version 3.3 are:

- Emission factors for cars and light trucks of emission class Euro 5 and newer, as well a class Euro VI heavy vehicles, have been updated. The updates are based on new and additional measurements.

- Updated emission factors for light vehicles due to revision of driving cycles and aging features.

- Updated temperature dependence for passenger cars and introduction of temperature dependence for light trucks.

- Updated representation of aerodynamic factors and rolling resistance for passenger cars. The model now takes extra equipment such as roof boxes and trailers into account to a greater extent, as well as different road surfaces.

- Updated description of heavy trucks with regard to average engine power and average weight.

- Addition of the CNG (Compressed natural gas) technology for light and heavy duty vehicles.

- The flexi-fuel technology (E85) has been added for the LCV vehicle category.

- The plug-in hybrid technology (Plug-in Diesel/Electric Vehicles, PHEV) has been added for passenger cars.

In addition to the updates made in HBEFA 4.1, an annual update of the vehicle fleet, the fuel composition and the traffic volume has been completed. These are the improvements to the Swedish input data which have been implemented in submission 2021:

- The traffic volume has been revised by the agency *Transport Analysis*.

- Adjustment of the distribution of traffic volumes between the categories coach and urban bus.

- Adjusted driving distances for new diesel and petrol cars which have not yet been inspected for the first time.

- Reduced lead content in unleaded petrol.

- Adjustment of subsegments to give them emission factors which they previously lacked.

The replacement of HBEFA 3.3 with HBEFA 4.1 as well as the adjustments of the Swedish input data to HBEFA have resulted in significant changes in the emissions of some gases for certain vehicle types and technologies between submission 2020 and 2021. But the changes are not as prominent when looking at the sector total, beside the emissions of NOx, PM2.5, BC and Pb which can be seen in the tables below.
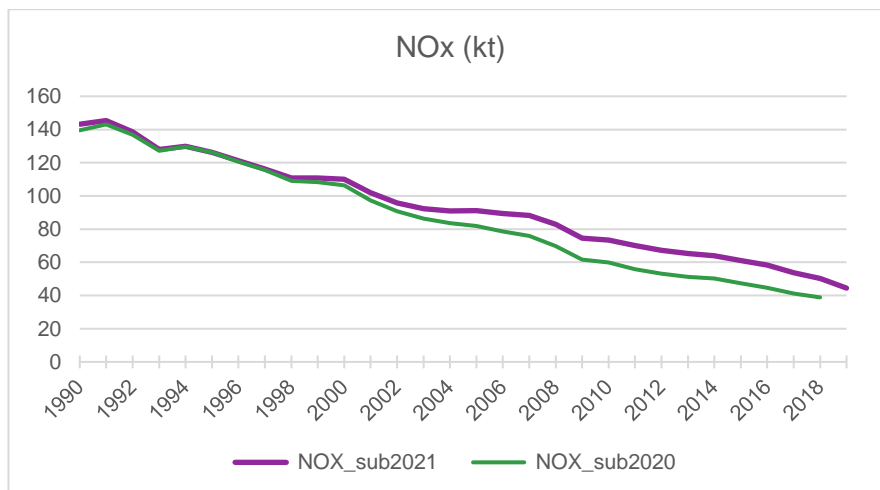
Figure 3-8. Emissions of NOx (kt) from road traffic 1990-2019 in sub2021 vs. sub2020.
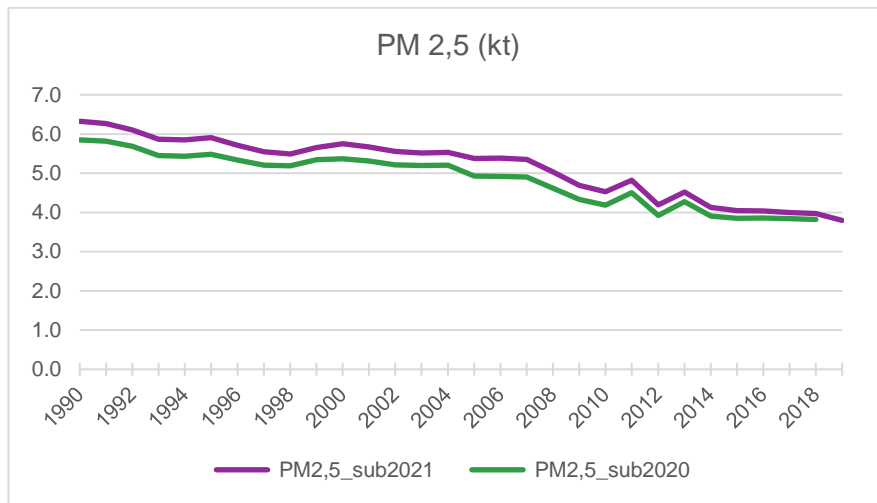
PM 2,5 (kt)

Figure 3-9. Emissions of PM2.5 (kt) from road traffic 1990-2019 in sub2021 vs. sub2020.
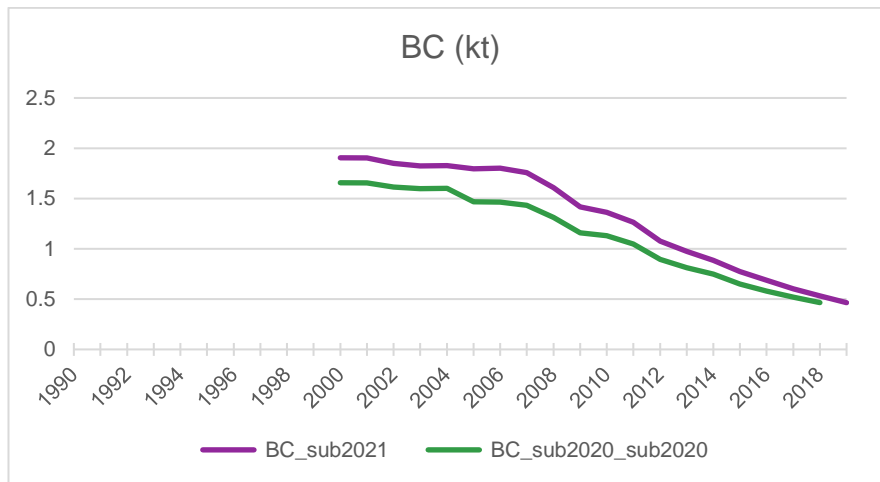
BC (kt)

Figure 3-10. Emissions of BC (kt) from road traffic 2000-2019 in sub2021 vs. sub2020.

3.2.12.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.13   Automobile tyre and brake wear, NFR1A3b vi, and automobile road abrasion, NFR1A3b vii

3.2.13.1   SOURCE CATEGORY DESCRIPTION

TSP emissions from tyre and brake wear have increased by 28 % since 1990. Emissions from tyre and brake wear are heavily dependent on the total amount of vehicle driven kilometres, which also have increased by 28 %.

A summary of the latest key source analysis is presented in Table 3-20.

Table 3-20 Summary of key source analysis, NFR1A3b vi-vii, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A3b vi	Automobile tyre and brake wear– *Cu, PM$_{10}$, PM$_{2.5}$, Pb, TSP, Zn*	Automobile tyre and brake wear– *Cu, PM$_{10}$, PM$_{2.5}$, Pb, TSP, Zn*
1A3b vii	Automobile road abrasion – *TSP, PM$_{10}$, PM$_{2.5}$*	Automobile road abrasion – *TSP, PM$_{10}$, PM$_{2.5}$*

3.2.13.2   METHODOLOGICAL ISSUES

From submission 2017 and onwards, a national model is used to estimate emissions from tyre and brake wear and road abrasion[55]. The national model takes into account several factors that have not been considered in previous estimates, such as meteorology, regional variations and measured PM$_{10}$ concentrations in urban street canyons for model verification. The new method has the advantage in that the emissions are calculated separately for eight regions in Sweden. Hence, the variability in both meteorological conditions and in the use of studded tyres is taken into account.

Activity data is obtained from the national model, divided by eight regions, and adjusted to fit activity data from the HBEFA 3.1 model.

3.2.13.2.1 *Particle emissions from Tyre and brake wear and road abrasion, NFR1A3b vi and 1A3bvii*

Emission factors for PM$_{10}$ for the years 2008-2014 have been calculated using the national model, for previous years and following years, averages of 2008-2014 have been used. TSP and PM$_{2.5}$ emissions have been estimated based on the PM$_{10}$ emission factor according to the EMEP/EEA Guidebook 2013 and other literature. As the modelled PM$_{10}$ emissions include both tyre and brake wear and road abrasion, the emission sources have been separated by assuming a constant emission factor for tyre and brake wear of 10 mg vkm^{-1}, according to literature values.

TSP emissions are separated further into tyre wear and brake wear and passenger cars, light duty vehicles, mopeds and motorcycles, based on the time series from previous years (1990-2014).

3.2.13.2.2 *PAH emissions from Tyre and brake wear, NFR1A3b vi*

The separation between particles from tyre wear and brake wear also makes it possible to calculate and report PAH1-4 from tyre wear and brake wear in 1A3b vi. The emission factors used for the calculations of PAH emissions from tyre wear and brake wear are as presented in the EMEP/EEA air pollutant emission inventory guidebook (detailed methodology). The emission factors used for the PAH calculations are presented in Table 3-21.

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[55] Mawdsley, I., Jerksjö, M., Andersson, S., Arvelius, J., Omstedt, G. 2015. New method of calculating emissions from tyre and brake wear and road abrasion. SMED report No 177 2015.

Table 3-21 Emission factors used for PAH emission calculations in 1A3b vi.

	Emission factors, TYRE WEAR (ppm wt.)				Emission factors, BRAKE WEAR (ppm wt.)			
	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Indeno (1,2,3-cd)pyrene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Indeno (1,2,3-cd)pyrene
All vehicle categories	3.9	-	-	-	0.74	0.42	0.62	-

3.2.13.2.3 Metal emissions from Tyre and brake wear, NFR1A3b vi

In Hjortenkrans et al. (2006)[56] mean metal concentrations in retread and non-retread tyre tread rubber are presented. As almost all tyres used on heavy duty vehicles are retread tyre tread rubber[56] and emissions calculated for heavy duty vehicles are based on an emission factor representing retread tyre tread rubber. For all other vehicle categories the calculations are based on emission factors for non retread tyre tread rubber (Table 3-22).

Table 3-22 Emission factors used for metal emission calculations from tyre wear in 1A3b vi.

Vehicle category	Emission factors, TYRE WEAR, (mg/kg)					
	Pb	Cd	Cr	Cu	Ni	Zn
Passenger cars	9.4	1.1	1.7	8.6	3.2	9 400
Light duty vehicles	9.4	1.1	1.7	8.6	3.2	9 400
Heavy duty vehicles*	9.5	0.86	1.3	7.4	2.9	12 000
Mopeds & Motorcycles	9.4	1.1	1.7	8.6	3.2	9 400

* retread tyres

Hjortenkrans et al. (2006)[57] also studied the metal content in both branded brake linings and those from independent suppliers. A similar study was made in the late 1990s[58] and the results show that there is a clear reduction of the Pb and Zn content in both branded linings and linings from independent suppliers. Also for Cu the metal content in linings from independent suppliers from 2005[59] is much lower

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[56] Hjortenkrans et al. 2006. Metallemission från trafiken i Stockholm – Däck. (in Swedish, results from a study on metal emissions from tyre wear)

[57] Hjortenkrans et al. 2006. Metallemission från trafiken i Stockholm – Bromsbelägg. (in Swedish, results from a study on metal emissions from brake linings)

[58] Westerlund, K.-G. 2001. Metal Emissions from Stockholm Traffics Wear of Brake Linings; Reports from SLB-analys, 2:2001; Environment and Health Protection Administration in Stockholm: Stockholm. 2001.

[59] Hjortenkrans et al. 2006. Metallemission från trafiken i Stockholm – Bromsbelägg. (in Swedish, results from a study on metal emissions from brake linings)

than in 1998[60]. For branded linings the results is the contrary, the Cu content in linings from 2005 is higher compared to linings from 1998. For the brake linings metal emission calculations the same assumption as both Hjortenkrans[59] and Westerlund[60] is made; 40 % of the traffic volume is related to new vehicles using branded linings and 60 % to older vehicles using linings from independent suppliers. For Pb, Cu and Zn the emission factors used are based on results presented by Westerlund[60] for the years 1980 - 1998, and on results presented by Hjortenkrans[59] for 2005 and onwards. The emission factors for 1999 - 2004 are interpolated. For Cd the same emission factor is set for the whole time series[57].

The emission factors used for calculating metal emissions from tyre wear and brake wear are presented in Table 3-23.

Table 3-23 Emission factors used for metal emission calculations from brake wear in 1A3b vi.

Vehicle category	Emission factors, BRAKE WEAR, branded (ppm wt.)				Emission factors, BRAKE WEAR, independent (ppm wt.)			
	Pb	Cd	Cu	Zn	Pb	Cd	Cu	Zn
1980 - 1998	13854	2.6	105070	20164	11381	0.445	61615	12447
1999	12090	2.6	108631	21855	9783	0.445	52835	11340
2000	10327	2.6	112193	23546	8185	0.445	44055	10233
2001	8563	2.6	115754	25237	6587	0.445	35275	9127
2002	6800	2.6	119316	26927	4989	0.445	26495	8020
2003	5037	2.6	122877	28618	3391	0.445	17715	6913
2004	3273	2.6	126439	30309	1793	0.445	8935	5807
2005 -	1510	2.6	130000	32000	195	0.445	155	4700

3.2.13.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The same method is used throughout the time series, which is considered consistent. Uncertainties for activity data and emissions reported for automobile tyre and brake wear (NFR 1A3b vi) and automobile abrasion (NFR 1A3b vii) can be seen in Annex 1 to the IIR.

3.2.13.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

3.2.13.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations in submission 2020.

3.2.13.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No planned improvements for this category.

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[60] Westerlund, K.-G. 2001. Metal Emissions from Stockholm Traffics Wear of Brake Linings; Reports from SLB-analys, 2:2001; Environment and Health Protection Administration in Stockholm: Stockholm. 2001.

3.2.14 Railways, NFR1A3c

3.2.14.1 SOURCE CATEGORY DESCRIPTION

The majority of all railway traffic in Sweden runs on electricity. Only a small part runs on diesel fuel and the emissions related to the use of electricity for railway should not be included in this sector. Production of electricity is accounted for in NFR1A1A, regardless of where it's consumed. The energy use by railways is very small compared to the total transport sector.

A summary of the latest key source analysis is presented in Table 3-24.

Table 3-24 Summary of key source analysis, NFR1A3c according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
1A3c	Liquid Fuels – NO_x	Liquid Fuels –

3.2.14.2 METHODOLOGICAL ISSUES

Both Tier 1 and Tier 2 methods are used to estimate emissions from diesel. The Swedish Transport Administration (STA) estimates the emissions of SO_2, NO_X, NMVOC and CO from railways, which are based on the consumption of diesel by railways[61] and default as well as country specific emission factors. The emission factors are described below.

The estimated diesel consumption is based on a survey carried out by the Swedish Transport Administration on behalf of the Swedish Energy Agency. The survey is a total survey and based on approximately 30 respondents for passenger traffic and rail infrastructure.

Emissions of SO_2 are based on country-specific thermal values and the actual sulphur content for diesel fuel.The threshold limits for CO and NOx are used as emission factors for all emissions from engines that comply with the EU emission standards Stage IIIA and Stage IIIB.[62] For engines introduced before the implementation of EU emissions standards, the emission factors from EMEP/EEA guidebook 2013 are used to estimate emissions of CO and NO_X.

The conversion of g/kWh to g/litre is based on the fuel consumption factors in Table 3-5 in the EMEP/EEA Guidebook 2013 and a diesel density of 816 g / litre. The same density is used for all years.

The emissions of NMVOC and particles are estimated with emission factors from EMEP/EEA guidebook 2013.

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[61] As of 2017, the Swedish Energy Agency took over the responsibility for data relating to energy consumption by railways; previously published by Traffic Analysis (TRAFA). SWEDISH OFFICIAL STATISTICS STATISTICAL NOTIFICATIONS EN0118 SM 1701.

[62] http://www.dieselnet.com/standards/eu/nonroad.php#rail

3.2.14.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The emissions for NFR1A3c are associated with low uncertainties. The estimate of diesel consumption based on the survey is considered to be of very high quality.

Uncertainties for activity data and emissions reported for working machinery in NFR1A4b ii can be seen in Annex 1 to the IIR

3.2.14.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

All Tier 1 general inventory level QC procedures and all QC procedures applicable to this sector are used. The activity data has been subject to QA/QC procedures.

3.2.14.5   SOURCE-SPECIFIC RECALCULATIONS

No source specific recalculations in submission 2021.

3.2.14.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

3.2.15   Navigation, NFR1A3d ii

3.2.15.1   SOURCE CATEGORY DESCRIPTION

Domestic navigation is defined as emissions from gasoline, diesel oil, domestic heating oil and residual fuel oil purchased and used in Sweden by commercial ships and leisure boats and the consumption of LNG used in Sweden by commercial ships. The energy consumption from all fuels by domestic navigation decreased by 1% between 2018 and 2019 and by 55% compared to 1990.

An amendment to Directive 2012/33/EU[63] introduced a mandatory use of marine fuels with a sulfur content of no more than 0.10% in sulfur control areas (SECA) from the 1'st of January 2015.[64]. In 2012 a decrease of the consumption of heavy fuel oils with a high level of sulphur could be noticed. However, with the introduction of hybrid fuels on the market, i.e. heavy fuel oils with a reduced sulphur content, the consumption of residual fuel oils didn't continue to decrease as anticipated.

In 2019, a shift from residual fuel oils to the LNG (liquid natural gas) can be noticed (see figure 3.19). The consumption of LNG started already in 2016, but for 2016-2018 the consumption of LNG could not be separated from the consumption of heavy fuel oil due to the lack of detailed data.

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[63] DIRECTIVE 2012/33/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels.

[64] https://eur-lex.europa.eu/eli/dir/2016/802/
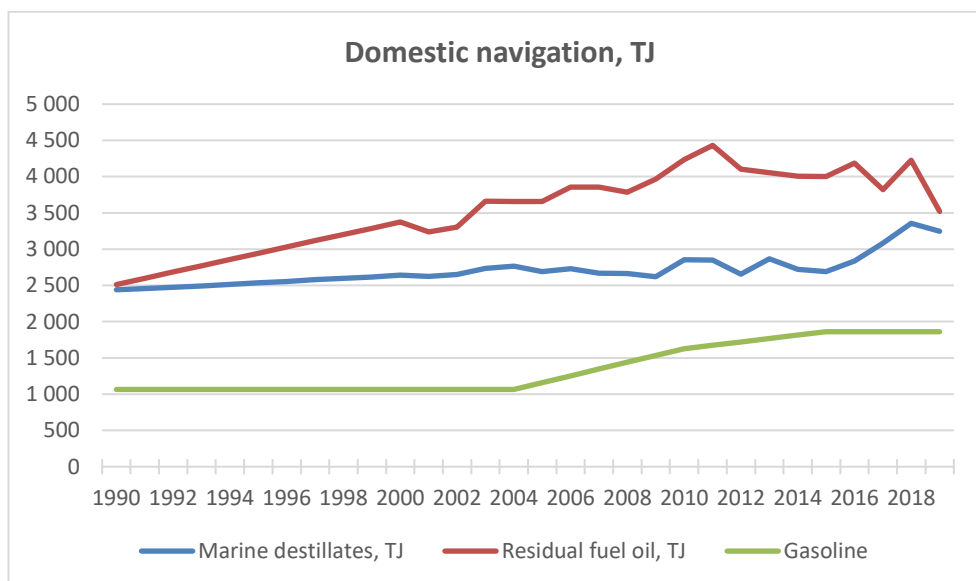
Figure 3.11. Fuel consumption by domestic navigation and by fuel type (including leisure boats) 1990-2019 (TJ)

A summary of the latest key source analysis is presented in Table 3-25.

Table 3-25 Summary of key source analysis, NFR1A3d ii, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
1A3d ii	Gas/diesel oil – *CO, NMVOC, NOx, PM₁₀, PM₂.₅, SO₂, TSP*	Gas/diesel oil – *CO, NMVOC, NOx, Ni, PM2.5*
	Residual oil – *As, NOx, Ni, PM10, PM2.5, SO2, TSP*	Residual oil – *As, NOx, Ni, PM2.5, SO2*

3.2.15.2   METHODOLOGICAL ISSUES

This source category covers domestic navigation and leisure boats. Domestic navigation is defined as emissions from gasoline, diesel oil, domestic heating oil and residual fuel oil purchased and used in Sweden and LNG used by commercial ships in Sweden. Emissions from fuels that are purchased in Sweden but used abroad are reported separately as international bunker emissions. The allocation of emissions from navigation is summarized in Table 3-26.

Table 3-26 Reporting of emissions from navigation, according to the Good Practice Guidance.

Fuel bought in	Traffic between Swedish harbours	Traffic between Swedish and international harbours	Traffic between two international harbours
Sweden	Domestic, 1A3d ii	International bunkers, 1A3d i (i)	International bunkers, 1A3d i (i)
Other country	Not included	Not included	Not included

The fuel consumption for both national and international navigation, except for leisure boats, has in previous submissions been based on the monthly survey on supply and delivery of petroleum products[65]. But it was difficult for the suppliers of fuel to separate the fuel used by national respectively international navigation. As the monthly survey of fuel supply statistics was revised[66], the fuel for national and international navigation was merged and only shows the total supply of fuel for navigation.

As from submission 2020, the fuel consumption by domestic shipping is based[67] on a methodology called Shipair as well as a maritime survey. Shipair was developed by the Swedish meteorological and hydrological institute (SMHI) and the model collects AIS data (Automatic Identification System) for ships which move between Swedish harbours. AIS data is used by ships to continuously transmit their identity and position information and consequently shows how the ships move between different ports. Information regarding the ships, such as size, engine power and type of vessel is also collected by the model and enables Shipair to estimate the amount of energy used by the ships.

Beside the Shipair model, the energy consumption from domestic navigation is based on a survey[68] of the largest shipping actors for national navigation, with the exception for cargo ships[69]. The survey collects data of the fuel consumption by fuel type since Shipair only estimates the total energy consumption by domestic navigation and does not know for sure which fuel type is used.

The consumption of LNG (liquid natural gas) by navigation was included in submission 2021 for year 2019. The data is based on a survey, which took place in 2020 and aimed to map the consumption of LNG by both national and international navigation[70]. The emission factors for LNG are based on a study from 2020.[71]

The Swedish Maritime Administration (SMA) provided the emissions factors for NOx, CO, NMVOC and SO_2 in 2005-2015. As from 2016, this is the responsibility of the Swedish Transport Agency (STA) in accordance with the Swedish climate legislation.

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[65] Statistic Sweden. Monthly fuel, gas and inventory statistics. See annex 2 for more information regarding different surveys.

[66] The revised monthly survey of fuel supply statistics was implemented in January of 2018.

[67] Excluding leisure boats.

[68] EN0118, Transportsektorns energianvändning (inrikes sjöfart). Eklund, V. et al. 2019. Analys och implementering av data från nya MåBra.

[69] The difference between the energy consumption estimated by Shipair and from the survey is assumed to be the energy consumption by cargo ships.

[70] Eklund, et al. 2020. Sjöfartens förbrukning av LNG.

[71] Hult, C. et al. 2020. Emission factors for methane engines on vehicles and ships

The emissions of NOx, CO, NMVOC, SO_2, metals, particles and PAH are estimated according to Tier 2 as the emission factors take into account the distribution of engine types and fuel types.

Emission factors for different engine/fuel combinations were originally divided into the following engine types: slow-speed diesel, medium-speed diesel, high-speed diesel, gas turbine and steam turbine in 2004[72]. These emission factors have since then been updated with new data, as the fuel qualities have developed. The distribution of the engine types for different ship categories is taken from a report by Chris Whall et al. (2002)[73]. AIS data for Swedish domestic navigation were used to distribute the fuel consumption into the different ship categories[74]. The distribution of the fuel consumption per ship category, together with the data on engine type distribution for ship categories and the emission factors per engine type, are used to produce effective emission factors for domestic navigation that can be used together with data on fuel consumption to obtain the emissions.

These effective emission factors also take into account the use of abatement measures in Swedish domestic navigation, most notably selective catalytic reduction to reduce NOx emission[75].

The emission factors for metals, particles and PAH:s were updated in submission 2018 by the Swedish Environmental Research Institute (IVL)[76]. The reported emissions of particulate matter include the condensable fraction of particles.

The Swedish Maritime Administration also report emissions from domestic navigation. These can however not be compared with emissions from the Swedish National Inventory, since the former include emissions from the whole Baltic Sea region.

The fuel consumption by leisure boats was reviewed in 2005, 2014 and 2018. The gasoline and diesel consumption by leisure boats in Sweden 1990-2004 is based on a survey regarding leisure boats from 2004 and a study carried out by SMED in 2005[77]. In 2010, there was a new leisure boat survey, which is the base for the gasoline and the diesel consumption by leisure boats in 2010-2014. An assessment of the survey was carried out by SMED in 2014[78] and revised in 2018, which resulted

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[72] Cooper and Gustafsson, 2004.

[73] Whall et al, 2002. Quantification of emissions from ships associated with ship movements between ports in the European Community. http://www.smed.se/luft/rapporter/rapportserie-smed?list_all

[74] Segersson and Fridell, 2012.

[75] Cooper and Gustafsson, 2004.

[76] Fridell, Mawdsley and Wisell, 2017.

[77] Gustafsson, 2005.

[78] Eklund V. 2014.

in an increased gasoline consumption and a decreased diesel consumption for 2006-2010.

In 2015 there was a third leisure boat study, which was assessed by SMED in 2018 and resulted in an increasing trend for the gasoline consumption and a slightly decreasing trend for the diesel consumption in 2010-2015. The consumption of gasoline and diesel in 2005-2009 and 2010-2014 has been estimated by interpolation.

Emissions of SO_2 from leisure boats are based on the fuel consumption and the same thermal values and emission factors as for civil road traffic regarding both gasoline and diesel. The emission of NO_X, NMVOC and CO from leisure boats are based on the estimated fuel consumption and emission factors provided and updated by the Swedish Environmental Research Institute (IVL) in submissions 2018[79]. The emission factors were in previous submissions taken from the EMEP/EEA guidebook 2009. The emissions from gasoline leisure boats also depend on the ratio between 2-stroke and 4-stroke engines and the ratio used is based on a study from 2005[80] and 2017[81]. The studies indicate that the share of 4-stroke engines is increasing over time. Based on information from the periodical publication "Fakta om Båtlivet i Sverige", the ratio has been determined for the years 2003, 2009 and 2015 and the ratio for 1990 has been estimated. For the years in between, the ratio has been interpolated, assuming that the change towards 4 stroke engines is gradual. The ratio for 2016 and 2017 is assumed to be the same as for 2015.

Emissions of particles from leisure boats have been estimated with the assumption that leisure boats generate the same amount of emissions per energy unit as for gasoline-run off road vehicles and other machinery for households[82].

3.2.15.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY
The fuel consumption by domestic navigation was before submissions 2020 based on the the "Monthly fuel, gas and inventory statistics" survey[83] and showed fluctuations for which it has been difficult to find natural explanations.[84] In submission 2020, the methodology for both national and international navigation was revised. The new methodology is based on the Shipair model and a maritime survey and is explained in section 3.2.15.2.

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[79] Fridell, E., Mawdsley, I., Wisell T. 2017.

[80] Statistics Sweden, 2005a.

[81] Fridell, E., Mawdsley, I., Wisell T. 2017.

[82] Kindbom and Persson. 1999

[83] Monthly fuel, gas and inventory statistics. http://www.scb.se/en/finding-statistics/statistics-by-subject-area/energy/energy-supply-and-use/monthly-fuel-gas-and-inventory-statistics/. See annex 2.

[84] Statistic Sweden. Monthly fuel, gas and inventory statistics. EN31SM.

Uncertainties for activity data and emissions reported for domestic navigation in NFR1A3d can be seen in Annex 1 to the IIR.

3.2.15.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

All Tier 1 general inventory level QC procedures and all QC procedures applicable to this sector are used. The activity data has been subject to QA/QC procedures.

3.2.15.5   SOURCE-SPECIFIC RECALCULATIONS

Beside the Shipair model, the fuel consumption from domestic navigation is based on a survey of the largest shipping actors for national navigation as mentioned. When the survey was conducted for the second time in 2020[85], it turned out that some of the fuels had been misclassified. This has been corrected in submission 2021.[86] The result is shown in the figures 3.12-14 below.
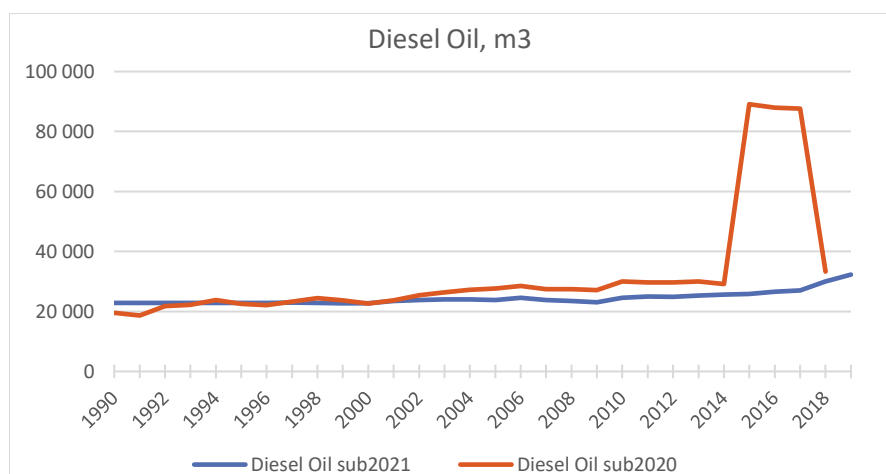
Figure 3.12. Diesel consumption by national navigation in sub2021 vs. sub2020 for 1990-2019

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[85] EN0118, Transportsektorns energianvändning (inrikes sjöfart).

[86]Eklund, V. 2020. Diesel inom sjöfarten.
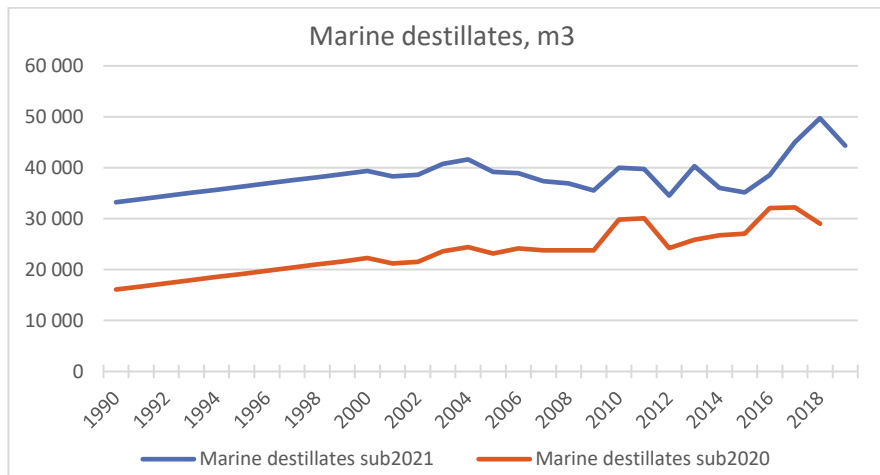
Figure 3.13. Consumption of marine distillates by national navigation in sub2021 vs. sub2020 for 1990-2019
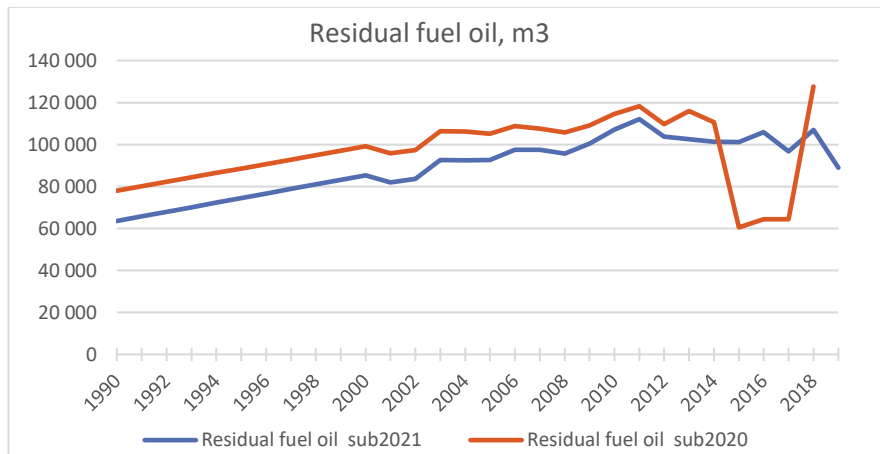
Figure 3.14. Consumption of residual fuel oils by national navigation in sub2021 vs. sub2020 for 1990-2019

The consumption of LNG (liquid natural gas) by navigation was included in sub-mission 2021 for year 2019. The LNG data is based on a survey, which aims to map the consumption of LNG by both national and international navigation[87]. The survey also showed a consumption of LNG by navigation in 2016-2018, but as the Shipair model (see section 3.2.15.2) include LNG for these years, it's reported as "IE" (included elsewhere) instead.

3.2.15.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the sub-mission as part of the national QA/QC plan.

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[87] Eklund, et al. 2020. Sjöfartens förbrukning av LNG.

3.2.16   Other transportation, NFR1A3e

3.2.16.1   SOURCE CATEGORY DESCRIPTION

The fuel consumption by working machinery in 1A3eii represent only 6 % of the fuel consumption from working machinery (in TJ). The consumption of diesel (including low blended biofuel) by working machinery had a decreasing trend in 2005-2014, but the consumption has turned and increased in the last three years. The emissions of CO, NOx, particles and NMVOC keep however decreasing.

A summary of the latest key source analysis is presented in Table 3-27.

Table 3-27 Summary of key source analysis, NFR1A3e ii, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A3e ii	*Diesel oil - NO$_X$*	*Diesel oil - NOx, PM10, PM2.5, TSP*

3.2.16.2   METHODOLOGICAL ISSUES

3.2.16.2.1 A Pipeline Transport (1.A.3.e.i)

The annual amount of transported natural gas in pipelines in Sweden is known for the whole reporting period 1990-2019. The amount of combusted natural gas for pipeline transport of natural gas in Sweden is only known for 2013 and for the following years, but not for 1990-2012. According to a national expert at Swedegas, the annual amount of natural gas used for pipeline transport is proportional to the total natural gas in the pipelines (about 0.12 % in 2013). Based on data for 2013, annual amounts of natural gas for combustion at pipeline transport were estimated for 1990-2012. The increase in the emissions in 2010 is a result of an increase in the import of natural gas due to a cold winter.

Annual national calorific values and national emission factors are applied to estimate the emissions of CO, NMVOC, NOx and SO$_2$. The emission factors used are the same as used for stationary combustion of natural gas in sector 1A4a.

3.2.16.2.2 Working machinery (1.A.3.e.ii)

A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions, except for SO$_2$ which are estimated according to Tier 2. The model is further explained in Annex 2.[88]

The consumption of gasoline and diesel, estimated by the model for off-road vehicles, is adjusted with regard to low-blended biofuel. The fuel consumption is also modified with a residual of gasoline and diesel. This residual arises as the volume of gasoline and diesel allocated to different sectors through a top-down approach is compared to the total volume of the gasoline and diesel consumed according to a

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[88] Annex 2: 1.6 Methodology for off-road vehicles and working machinery

bottom-up estimate. See Annex 2 for more information regarding the allocation of fuels for mobile combustion[89].

3.2.16.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

No recalculations have been performed for emissions in the mobile sector for the eighties, and thus there are inconsistencies in time series between the eighties and later years. Time series from mobile combustion in NFR1A3e ii have been reviewed for later years and are considered to be consistent.

The fuel and emission estimates of working machinery are based on a model that takes into consideration the emission regulations according to EU legislation in g/kWh, the differences between regulation and value measured at certification, the transient use[90], the emission deterioration with age and the differences between certification fuel and Swedish diesel of type "MK1". The model does not consider market fluctuations.

Uncertainties for activity data and emissions reported for working machinery in NFR1A3e ii can be seen in Annex 1 to the IIR

3.2.16.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

The model was implemented the first time in submission 2009. During 2010 the model underwent a second verification. Activity data and emissions factors were reviewed in 2012 and 2013. Time series are checked for consistency and recalculations are verified every year.

3.2.16.5   SOURCE-SPECIFIC RECALCULATIONS

Top-down allocated fuel amounts to working machinery from remaining non-allocated gasoline and diesel volumes (see IIR annex 2.4 for more detailed explanations) have been revised. Emissions of SO_2, heavy metals and PAH have therefore been recalculated (see table below).

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[89] See Annex 2. chapter "1.4 Allocation of fuels for mobile combustion" for more information."

[90] The difference between static test cycle and real use of the machine.

Table 3-28 Changes in emissions of SO$_2$, heavy metals and PAH in 2018 and between submission 2020 and submission 2021.

Gas	Change in emissions 2018	Change in emissions 2018 (%)
SO$_2$ (kt)	-1E-05	-2%
Cd (t)	-2E-05	-2%
Cr (t)	-9E-05	-2%
Cu (t)	-3E-03	-2%
Ni (t)	-1E-04	-2%
Se (t)	-2E-05	-2%
Zn (t)	-2E-03	-2%
B(a)p	-6E-05	-2%
B(b)f	-9E-05	-2%

3.2.16.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.17   Commercial/institutional, NFR1A4a

3.2.17.1   SOURCE CATEGORY DESCRIPTION

This category includes stationary combustion for heating of premises used for commercial and institutional activities as well as emissions from working machinery used in these activities.

3.2.17.1.1 Stationary combustion

Since 1990, the total consumption of fuels for heating of premises has decreased significantly due to the increased use of district heating. In the early 1990s, the total annual fuel consumption in this sector was around 35000 TJ, around year 2000 it had decreased to about 20000 TJ, and in 2019 it was around 7 500 TJ. Liquid fuels account for most of the decrease. The share of liquid fuels in 1990 was about 95 % and the corresponding share in 2019 was about 20 %.

A summary of the latest key source analysis is presented in Table 3-29.

3.2.17.1.2 Mobile combustion

The mobile emission source included in this sector is combustion by off-road vehicles and other machinery (working machinery), for example gardening machines for professional use and tractors that are not used in industry, farming or forestry. The emissions of air pollution from this sector are reported in 1A4aii.

The fuel consumption from working machinery in 1A4aii represent around 12 % of the fuel consumption from all working machinery and has increased by 43 % since 1990. But while the consumption of diesel (including low blended biofuel) has shown an increasing trend, the consumption of gasoline (including low blended biofuel) has stagnated or even shown a slightly decreasing trend as from 2011. The

emissions of NMVOC and NOx have a decreasing trend while the emissions of NH_3 show an increasing trend. The emissions of particles fluctuate throughout the time series and the emissions of CO peaked in 2013 and have decreased since then.

A summary of the latest key source analysis is presented in Table 3-29.

Table 3-29 Summary of key source analysis, NFR1A4a, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A4a	Biomass – *Cd, PM2.5, Zn*	Biomass – *Cd*
	Diesel oil – *NO$_x$, PM$_{2.5}$*	Diesel oil – *PM$_{2.5}$*
	Gasoline - *CO, NMVOC*	Gasoline - *CO, PM$_{2.5}$*
	Liquid fuels -	Liquid fuels - *NOx, Ni, PM10, PM2.5, SO2, Se, TSP*

3.2.17.2   METHODOLOGICAL ISSUES

3.2.17.2.1 Stationary combustion

For stationary combustion within NFR1A4a, all activity data and emission factors are on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 2. The data source for activity data is the annual energy balance, which for this sector is mainly based on premises statistics that is further described in in Annex 2. Since submission 2020, biomass activity data and emission factors are separated into traditional and modern small scale combustion technology for the whole time series[91]. Activity data for the latest emission year is preliminary as the annual energy balances are not published at the time when the emission calculations have to be finalized.

The reported emissions of particulate matter include the condensable fraction of particles.

The activity data and emission factors for CH_4, CO and NMVOC from biomass combustion within 1.A.4.a are separated into modern and traditional combustion technology for the whole time series in order to capture the phasing-out of old technology[92]. The revision is described more in detail in Annex 2.

3.2.17.2.2 Mobile combustion

Emissions from mobile combustion in NFR1A4a refer mainly to gardening machines for professional use and tractors that are not used in industry, farming or forestry. A national model is used to estimate emissions from all working machinery used in Sweden and it is considered to correspond to Tier 3 for all emissions,

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[91] Helbig, T. Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor. SMED rapport no 12 2019.

[92] Helbig, T., Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor. SMED rapport no 12 2019.

except for SO_2 which is estimated according to Tier 2. The model is further explained in Annex 2.

Emissions from working machinery are also reported in NFR1A2g vii, 1A3e ii, 1A4b ii and 1A4c ii. See Table 3-30.

Table 3-30 Distribution of emissions from off-road vehicles and other machinery

Category	NFR	Definition IPCC Guidelines
Industry	1A2g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1A3e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1A4c ii or 1A2g vii.
Commer-cial/ Institutional	1A4a ii	Garden machinery, e.g. lawn mowers and clearing saws, not used by private users, also tractors not used in industry ore forestry or agriculture.
Residential	1A4b ii	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1A4c ii	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.17.2.3 Verification of Estimation models and allocation methods for fuel in the other sectors

In submission 2005 and earlier, there were large uncertainties in estimation models and allocation methods for fuel in the Other sectors and NFR1A2f, construction. In 2005, a study was performed by SMED, aiming at identifying and analysing the methods and models applied for each sub-sector and determine whether they were in line with the IPCC guideline recommendations.[93] In addition, each fuel was traced back to its original source in order to determine whether it had been correctly allocated on stationary and mobile combustion.

The results from the study show good agreement with IPCC guideline recommendations. All fuels but biomass had little or no changes in methodologies, and where changes occurred, no significant inconsistencies in fuel consumption time series were detected. However, for biomass, several significant inconsistencies were identified leading to recalculations of activity data and emissions in NFR1A4a and 1A4b[94]. Due to these recalculations there are obvious inconsistencies between the national energy balances and the national emission inventory data.

Furthermore, all fuels proved to be correctly allocated on stationary and mobile combustion. In the Swedish air emission inventory, this means that all diesel oil

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[93] Gustafsson, et al. 2005.

[94] Paulrud et al. 2005.

and gasoline reported under Other sectors in the energy balances are used by mobile combustion, while all the other fuels are related to stationary combustion.

3.2.17.2.4 Activity data for stationary combustion in other sectors

Activity data for the latest emission year is preliminary as the annual energy balances are not published at the time when the emission calculations have to be finalized.

Since 2002, and in particular since 2004, the consumption of biomass fuels has increased in this sector. This is partly explained by the general shift from liquid to biomass fuels in recent years. However, a study carried out in 2013 had shown that the fuel consumption estimate used in the national energy balance and the emission inventory is more complete than the data reported to Eurostat.

Every year, there are revisions in the annual energy balances for years t-2 and t-3, that is, data published in 2010 contain revisions in fuel consumption in 2007 and 2008. These sometimes large revisions in the annual energy balances lead to large revisions of GHG inventory data as well as for air pollutants. In submission 2016, activity data and hence also emissions have been revised for 2012 and 2013.

In submission 2010 it was noted that the consumption of biomass, liquid fuels and gaseous fuels within this sector was higher in 2007 than in 2006 and 2008. In submission 2011, the activity data for 2007 and 2008 were revised as described above. The fuel consumption in 2007 is still relatively high. The input data to the energy balances for this sector has not been available for analysis. However, the activity data uncertainty is high in this sector and the time series 1990-2013 shows that inter-annual variations in total fuel consumption can be high.

3.2.17.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

3.2.17.3.1 Stationary combustion

The large activity data uncertainty in the stationary combustion is due to the use of data from the annual energy balances. The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group.

Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Biomass for As, Cd, Cu, HCB, PAH, PCB
- All fuels for Dioxin
- Liquid fuels for Cu, Hg, Cr
- Solid fuels for HCB, PCB

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.17.3.2 Mobile combustion

No recalculations have been performed for emissions in the mobile sector for the eighties, and thus there are inconsistencies in time series between the eighties and later years. Time series from mobile combustion in NFR1A4b ii have been reviewed for later years and are considered to be consistent.

Uncertainties for activity data and emissions reported for working machinery in NFR1A4b ii can be seen in Annex 1 to the IIR.

3.2.17.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

In submission 2005 and earlier, there were large uncertainties in estimation models and allocation methods for fuel in the other sectors. In 2005, a study was performed by SMED, aiming at identifying and analysing the methods and models applied for each sub-sector and determine whether they were in line with the IPCC guideline recommendations[95]. In addition, each fuel was traced back to its original source in order to determine whether it had been correctly allocated on stationary and mobile combustion.

The results from the study show good agreement with IPCC guideline recommendations. All fuels but biomass had little or no changes in methodologies, and where changes occurred, no significant inconsistencies in fuel consumption time series were detected. However, for biomass, several significant inconsistencies were identified leading to recalculations of activity data and emissions in NFR1A4a and 1A4b[96]. Due to these recalculations there are obvious inconsistencies between the national energy balances and the national emission inventory data for years before 2005. Furthermore, all fuels proved to be correctly allocated on stationary and mobile combustion. All diesel oil and gasoline reported under Other sectors in the energy balances is allocated to mobile combustion, while all the other fuels are related to stationary combustion.

3.2.17.5   SOURCE-SPECIFIC RECALCULATIONS
3.2.17.5.1 Stationary combustion

In submission 2021, activity data for 2013 to 2016 was revised.

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[95] Gustafsson, et al. 2005.

[96] Paulrud et al. 2005.

3.2.17.5.2 Mobile combustion

Top-down allocated fuel amounts to working machinery from remaining non-allocated gasoline and diesel volumes (see IIR annex 2.4 for more detailed explanations) have been revised. Emissions of SO_2, heavy metals and PAH have therefore been recalculated (see table below).

Table 3-31 Changes in emissions of SO_2, heavy metals and PAH in 2018 and between submission 2020 and submission 2021.

Gas	Change in emissions 2018	Change in emissions 2018 (%)
SO_2 (kt)	-5E-05	-3%
Cd (t)	-7E-06	-0.4%
Cr (t)	-3E-05	-0.4%
Cu (t)	-1E-03	-0.4%
Ni (t)	-5E-05	-0.4%
Se (t)	-7E-06	-0.4%
Zn (t)	-7E-04	-0.4%
B(a)p	-4E-06	-0.1%
B(b)f	-5E-05	-1%

3.2.17.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.18   Residential, NFR1A4b

3.2.18.1   SOURCE CATEGORY DESCRIPTION

In this category both stationary and mobile combustion occur.

3.2.18.1.1 Stationary combustion

Stationary combustion of fuels within residential decreased by 67 % between 1990 and 2019, mainly due to a continuous increase in district heating use[97]. In recent years, the use of heat pumps has also increased significantly[98]. Most of this change occurred before 2006; however, the use of heating oils is still decreasing while combustion of wood, wood chips and pellets has increased in recent years. In 2009-2010, fuel consumption increased due to the cold winters these years, especially in 2010. Despite this, the consumption of heating oil continued to decrease while consumption of wooden fuels and natural gas increased quite considerably. Emissions of CO_2, CH_4 and N_2O from the use of charcoal are included in this source category.

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[97] Swedish Energy Agency 2014a

[98] Swedish Energy Agency 2014b

3.2.18.1.2 Mobile combustion

Mobile combustion in NFR1A4bii refer to gardening machines used in households e.g. lawn mowers, hedged cutters, clearing saws and more. Snow mobiles and four wheelers not used for professional purposes are also allocated to NFR1A4bii. The emissions of CO, NMVOC, NH_3 and particles arise mainly from combustion of gasoline. This also applies to emissions of NOx after 2009. In 2019, the consumption of gasoline accounted for 46 % of the total gasoline consumption by working machinery, compared to 2 % of the consumption of diesel.

A summary of the latest key source analysis is presented in Table 3-32.

Table 3-32 Summary of key source analysis, NFR1A4b, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A4b	Biomass – *As, CO, Cd, Cr, DIOX, Hg, NMVOC, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*	Biomass – *As, CO, Cd, Cr, DIOX, Hg, NMVOC, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*
	Liquid – *CO, NMVOC, NOx, PM10, PM2.5*	Liquid CO, NH3, NMVOC, NOx, Ni, PM10, PM2.5, SO2, Se, TSP

3.2.18.2 METHODOLOGICAL ISSUES

3.2.18.2.1 Stationary combustion

The main data source is the annual energy balances. One- and two-dwellings statistics, Holiday cottages statistics and Multi-dwellings statistics are used as complementary data sources to get more details on biomass combustion. Biomass fuel consumption for heating residences are surveyed on the three most common combustion technologies: boiler, stoves and open fireplaces. Since 1998 biomass activity data is separated on wood logs, pellets/briquettes and wood chips/saw dust. Historical biomass data has been estimated by inter- and extrapolation. As of submission 2019, biomass activity data and emission factors for boilers and stoves are separated into traditional and modern small-scale combustion technology for the whole time series[99].

Estimation models and allocation methods for fuel in the Other sectors, as well as the use of preliminary data for stationary combustion in the Other sectors as discussed in section 3.2.17 also applies to NFR1A4b.

Emissions arising from the use of charcoal are estimated using national statistics and default 2006 IPCC guidelines EFs.

The reported emissions of particulate matter include the condensable fraction of particles. The emission factors were updated in submission 2019 from being based

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[99] Helbig, T., Gustafsson, T., Kindbom, K. Jonsson, M. 2018. Uppdatering av nationella emissionsfaktorer för övrig sektor (CRF/NFR 1A4). SMED rapport no 13 2018.

on measurements in hot flue gases to being based on measurements in diluted flue gases. The measurement method is described in Kindbom et al. 2017[100].

3.2.18.2.2 Mobile combustion

Emissions from mobile machinery used in households are included in NFR1A4bii. Machines included here are mainly different types of gardening machines e.g. lawn movers, hedge cutters and chain saws as well snow mobiles used by households, while emissions from gardening machines for professional use are reported in 1A4aii. Emissions from tractors not used in forestry, agriculture or industry are also reported in 1A4bii as well as emissions from generator sets and mobile freezers and chillers. A national model is used to estimate most emissions from working machinery used in Sweden and is considered to correspond to Tier 3 for all emissions, except SO_2 which is estimated according to Tier 2. The model is further explained in Annex 2.

Emissions from working machinery are also reported in NFR1A2g vii, 1A3e ii, 1A4a ii and 1A4c ii. See Table 3-33.

Table 3-33 Distribution of emissions from off-road vehicles and other machinery

Category	NFR	Definition IPCC Guidelines
Industry	1A2g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1A3e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1A4c ii or 1A2g vii.
Commercial/ Institutional	1A4a ii	Garden machinery, e.g. lawn mowers and clearing saws, not used by private users, also tractors not used in industry ore forestry or agriculture.
Residential	1A4b ii	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1A4c ii	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.18.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

3.2.18.3.1 Stationary combustion

The activity data and emission factor uncertainties for stationary combustion are 20 % and 1 % respectively. The large activity data uncertainty is due to the use of input data from the annual energy balances.

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[100] Kindbom, K.; Mawdsley, I.; Nielsen, O.; Saarinen, K.; Jónsson, K. and Aasestad, K., (2017): *Emission factors for SLCP emissions from residential wood combustion in the Nordic countries. Improved emission inventories of Short Lived Climate Pollutants (SLCP)*. TemaNord 2017:570

The time series for NFR1A4b is considered to be consistent as there haven't been any major changes in methodology or input data to the energy balances that affect this category.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Biomass for As, Cd, Cr, Cu, HCB, PAH, PCB, Zn
- Liquid fuels for Cd, Cr, Ni, PAH, Pb, Se, SO_2 and Zn
- Other fuels for PM_{10}, $PM_{2.5}$

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.18.3.2 Mobile combustion

No recalculations have been performed for emissions in the mobile sector for the eighties, and thus there are inconsistencies in time series between the eighties and later years. Time series from mobile combustion in NFR1A4b ii have been reviewed for later years and are considered to be consistent.

Uncertainties for activity data and emissions reported for working machinery in NFR1A4b ii can be seen in Annex 1 to the IIR.

3.2.18.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

All quality procedures according to the Swedish QA/QC plan (including the Manual for SMED's Quality System in the Air Emission Inventories) have been implemented during the work with this submission.

3.2.18.5 SOURCE-SPECIFIC RECALCULATIONS

3.2.18.5.1 Stationary combustion

In submission 2021, the preliminary charcoal activity data for 2018 used in previous submission was revised for 2018. In addition, the AD from the Energy balances was revised between 2013 and 2018, resulting in very small changes.

The largest effect of submission 2021 recalculations was in SO_2 emissions. The emissions increased with 0.12 % (0.0007 kt SO_2) and increased with 0.13% (0.0006 kt SO_2) in 2017 between submission 2020 and 2021 in the sector.

3.2.18.5.2 Mobile combustion

Top-down allocated fuel amounts to working machinery from remaining non-allocated gasoline and diesel volumes (see IIR annex 2.4 for more detailed explanations) have been revised. Emissions of SO_2, heavy metals and PAH have therefore been recalculated (see table below).

Table 3-34 Changes in emissions of SO_2, heavy metals and PAH in 2018 and between submission 2020 and submission 2021.

Gas	Change in emissions 2018	Change in emissions 2018 (%)
SO_2 (kt)	-4E-05	-4%
Cd (t)	+2E-05	+2%
Cr (t)	+8E-05	+2%
Cu (t)	+3E-03	+2%
Ni (t)	+1E-04	+2%
Se (t)	+2E-05	+2%
Zn (t)	+2E-03	+2%
B(a)p	+7E-05	+2%
B(b)f	+6E-05	+2%

3.2.18.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.2.19   Agriculture/Forestry/Fisheries, NFR1A4c i

3.2.19.1   SOURCE CATEGORY DESCRIPTION

This category includes emissions from stationary combustion for heating purposes and mobile combustion in working machinery within agriculture and forestry, and fishing vessels. The structure of the agricultural sector in Sweden is described in chapter 6. Changes in use of liquid and gaseous fuels in agriculture, fishing and forestry have been small since 1990. Due to availability of better data for the period 2003 and later years, there is a shift in the time series for biomass.

The consumption of both gasoline and diesel (including low blended biofuels) by working machinery used in agriculture and forestry has an increasing trend, but the consumption of diesel is dominant and correspond to 70 % of the total fuel consumption in 2019. Despite the smaller share of gasoline used by working machinery in 1A4c, the largest share of the emissions of CO and NMVOC stem from the combustion of gasoline. The emissions of CO from gasoline have an increasing trend compared to the emissions of CO from diesel, which have a decreasing trend.

The major part of the emissions of NO_x arise from the combustion of diesel (including biofuel) but have a decreasing trend. They have dropped by 74 % since 1990. The same applies for emissions of particles. The emissions of NMVOC from diesel also have a decreasing trend.

Combustion of solid fuels for stationary combustion within this sector has de-creased substantially since 1990.

A summary of the latest key source analysis is presented in Table 3-35.

Table 3-35 Summary of key source analysis, NFR1A4c i, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
1A4c i	Biomass – *CO, Cd, DIOX, NOx, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*	Biomass – *CO, Cd, Cr, Cu, DIOX, Hg, NMVOC, NOx, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn*
	Liquid – *CO, Cd, Cu, NMVOC, NOx, Ni, PM10, PM2.5, SO2, TSP*	Liquid – *CO, Cu, NMVOC, NOx, Ni, PM10, PM2.5, SO2, TSP*
	Solid –	Solid – *SO2, TSP*

3.2.19.2 METHODOLOGICAL ISSUES

In this sector both stationary and mobile combustion occur.

3.2.19.2.1 Stationary combustion

For stationary combustion, all activity data is on national level by fuel type and es-timated emissions are therefore considered to correspond to Tier2. Activity data is based on models and results from a survey from 1985 repeated in 2007 (see Other statistics from Statistics Sweden in Annex 2).

Estimation models and allocation methods for fuel in the Other sectors, as well as the use of preliminary data for stationary combustion in the Other sectors as dis-cussed in section 3.2.17, Commercial/institutional, NFR1A4a also applies to NFR1A4c. As a consequence, emissions from stationary combustion 2002-2006 were revised in submission 2009. Emissions for the most recent year will be re-vised in next submission when annual statistics are available. Note that as a conse-quence of this revision, emissions from biomass are inconsistent with a sharp in-crease to a higher level in 2003. There is no information available to improve data 2002 and earlier years. Emissions 1990 are considered to be of sufficient quality as the 1985 survey then was only five years old. Since submission 2020, biomass ac-tivity data and emission factors are separated into traditional and modern small scale combustion technology for the whole time series[101].

The reported emissions of particulate matter include the condensable fraction of particles.

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[101] Helbig, T. Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sek-tor. SMED rapport no 12 2019.

3.2.19.2.2 Mobile combustion

Mobile combustion in 1A4c refers to working machinery used in agriculture (e.g. tractors and combine harvesters), forestry (e.g. forwarders and harvesters) and fisheries. A national model is used to estimate emissions from all land based working machinery used in Sweden, considered to correspond to Tier 3 for all emissions, except SO_2 which is estimated according to Tier 2. The model is further explained in Annex 2.

Emissions from Fisheries, NFR1A4c, were first reported in submission 2006. The estimated fuel consumption is based on a survey on energy consumption within the fishing industry by Statistics Sweden[102] together with data on the Swedish fishing fleet's total installed effect in kW from the Swedish Agency for Marine and Water Management (SwAM). The estimate on fuel consumption provided by Statistics Sweden refer to 2005, and for the previous and following years the fuel consumption is estimated by adjusting the 2005 value according to the development in total installed effect. The fuel consumption by fisheries has decreased by 38 % since 1990 and by 2% between 2018 and 2019.

The emissions factors used to estimate emissions from Fisheries are based on a SMED study from 2005[103], producing emission factors for SO_2, NO_X and NMVOC, for 1990-2004. As from 2005, the estimates are based on the same consumption estimate and emission factors as for 2004. However, from 2007 and onwards the emission factors for SO_2 from fisheries are assumed to be the same as for domestic navigation, which are updated every year.

Emissions from fisheries are derived under the assumption that the fishing fleet operates using medium speed diesel engines running on marine distillate fuel. The emission abatement technologies used by the fleet (e.g. Selective Catalytic Reduction (SCR) for NO_X reduction) is assumed to be negligible.

Emissions from working machinery are also reported in NFR1A2g vii, 1A3e ii, 1A4a ii and 1A4b ii. See Table 3-36.

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[102] Statistics Sweden, 2006 ENFT0601.

[103] Cooper et al., 2005a.

Table 3-36 Distribution of emissions from off-road vehicles and other machinery

Category	NFR	Definition IPCC Guidelines
Industry	1A2g vii	Mobile machineries in industry that run on petroleum fuels, as for example tractors, dumpers, cranes, excavators, generators, wheel loaders, sorting works, pump units etc.
Other	1A3e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1A4c ii or 1A2g vii.
Commercial/ Institutional	1A4a ii	Garden machinery, e.g. lawn mowers and clearing saws, not used by private users, also tractors not used in industry ore forestry or agriculture.
Residential	1A4b ii	All emissions from mobile fuel combustion in households, as for example tractors, lawn movers, snow mobiles, forklifts, trimmers, chainsaws and forklifts
Agriculture, Forestry	1A4c ii	Emissions from mobile fuel combustion in agriculture and forestry, as for example loader-excavator, tractor, harvester, clearing saw etc. Highway agricultural transportation is excluded.

3.2.19.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

3.2.19.3.1 Stationary combustion

The sharp increase in use of biomass in stationary combustion in 2003 is due to a revision in submission 2009, where improved data was used for 2003 and later years. There is no information available to improve data from 2002 and earlier years. Emissions in 1990 are considered to be of a sufficient quality as they are based on the 1985 survey mentioned above, which was reasonably recent in 1990. The time series for liquid, solid and gaseous fuels are considered to be consistent. Solid fuels have not been used in this sector since 2000.

The uncertainties for stationary combustion are on fuel group aggregation level. The uncertainty values are assigned by staff at Swedish Statistics and are based on expert judgements made on fuel type that were aggregated to fuel group. Activity data uncertainty is relatively low for most fuel types. Emission factor uncertainty is for some fuels very high. The fuel groups and EF that have highest uncertainty are:

- Biomass for As, Cd, Cu, DIOX, HCB, PAH, PCB
- Liquid fuels for Cd, Cr, Cu, Ni, PAH, Pb, Se and Zn
- Solid fuels for As, DIOX, HCB, PAH, SO_2, Zn

See Annex 1 for more details regarding uncertainties for activity data and emissions.

3.2.19.3.2 Mobile combustion

No recalculations have been performed for emissions in the mobile sector for the eighties, and thus there are inconsistencies in time series between the eighties and later years. The time series from mobile combustion in NFR1A4c ii have been reviewed for later years and are considered to be consistent.

Uncertainties for activity data and emissions reported for working machinery in NFR1A4c ii can be seen in Annex 1 to the IIR.

3.2.19.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

In submission 2021, AD from the Energy balances were revised for biomass 2013 to 2018 all fuels. In addition, the preliminary consumption for liquid fuel in 2018 in submission 2020 was revised.

The largest effect of submission 2021 recalculations was in Ni emissions. The emissions decreased with -35 % (0.07 t Ni) and decreased with -2.5% (0.005 t Ni) in 2017 between submission 2020 and 2021 in the sector.

3.2.19.5 SOURCE-SPECIFIC RECALCULATIONS

3.2.19.5.1 Stationary combustion

For stationary combustion, the following revisions were made: The activity data for stationary combustion within NRF1A4c fisheries was revised for domestic heating oil and LPGs for the year 2017. Further, in submission 2020, activity data and emission factors for particulate matter, CO, NMVOC, PAHs from biomass combustion within NRF1A4c was separated into modern and traditional technology for the whole time series in order to capture the phasing-out of old technology[104]. The revision is described more in detail in Annex 2.

3.2.19.5.2 Mobile combustion

Top-down allocated fuel amounts to working machinery from remaining non-allocated gasoline and diesel volumes (see IIR annex 2.4 for more detailed explanations) have been revised. Emissions of SO_2, heavy metals and PAH have therefore been recalculated (see table below).

Table 3-37 Changes in emissions of SO_2, heavy metals and PAH in 2018 and between submission 2020 and submission 2021.

Gas	Change in emissions 2018	Change in emissions 2018 (%)
SO_2 (kt)	-7E-05	-3%
Cd (t)	-9E-05	-2%
Cr (t)	-5E-04	-2%
Cu (t)	-2E-02	-2%
Ni (t)	-7E-04	-2%
Se (t)	-9E-05	-2%
Zn (t)	-9E-03	-2%
B(a)p	-3E-04	-2%
B(b)f	-5E-04	-2%

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[104] Helbig, T. Kindbom, K. Jonsson, M. 2019. Uppdatering av nationella emissionsfaktorer för övrig sektor. SMED rapport no 12 2019.

3.2.19.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

3.2.20   Other stationary combustion, NFR1A5a

No emissions are reported in this category.

3.2.21   Military transport, NFR1A5b

3.2.21.1   SOURCE CATEGORY DESCRIPTION

NFR1A5b includes emissions from military transports. The fuel consumption and emissions have decreased over the years due to decreased activities.

A summary of the latest key source analysis is presented in Table 3-38.

Table 3-38 Summary of key source analysis, NFR1A5b according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1A5b	Liquid Fuels - NO_X	Liquid Fuels - NO_X

3.2.21.2   METHODOLOGICAL ISSUES

Emissions from military transport are based on data on fuel consumption, including all military activities, and are considered to correspond to Tier 1. Fuel consumption from some more administrative military activities, such as the Swedish Defence Material Administration (FMV), the Swedish Fortification Department (FORTV), the Swedish Defence Research Agency (FOI) and the National Defence Radio Institute (FRA), are not included in the calculations.

Emissions from military aviation are based on an average of LTO and cruise emission factors from civil aviation. Emissions from military navigation are estimated using emission factors from civil navigation. Emissions from the use of diesel oil by military stationed abroad is reported under multilateral operations, NFR1D2.

Emissions from military road transport are included in the emissions estimated by the road emission model HBEFA 3.3. The emissions by each vehicle type in HBEFA are consequently reduced by an amount, equal to the weight of the fuel consumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport. These emissions are allocated to military road transport.

To subtract and separate emissions from military road transport from civil road transport in HBEFA, the equation below is used:

$$A = B - \sum((C\text{-}D)/C*E_i)$$

A = Military transport emissions
B = Total HBEFA emissions
C = Total fuel consumption National Statistics
D = Military fuel consumption Swedish Armed Forces
E_i = HBEFA emissions per vehicle type

Please note that for 1980-1989, only emissions of particles from jet gasoline in military aviation are reported due to the lack of sufficient information for the other sub-sectors. Also, note that there was only a consumption of FAME for 1999-2002 and a consumption of Ethanol for 2007-2016 (with the exception of 2015).

3.2.21.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY
Uncertainties for activity data and emissions reported for military transport NFR1A5b can be seen in Annex 1 to the IIR.

3.2.21.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION
No source-specific QA/QC or verification is performed.

3.2.21.5   SOURCE-SPECIFIC RECALCULATIONS
No source-specific recalculations have been made.

3.2.21.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS
No major improvements are planned for the next submission.

3.2.22   Memo Items International bunkers, 1D, NFR1A3ai and 1A3dii
3.2.22.1   SOURCE CATEGORY DESCRIPTION
This sector includes emissions from bunker fuels, e.g. fuel bought in Sweden and used for international aviation and international navigation.

International Aviation is defined as emissions from flights that depart in one country and arrive in a different country. However, "Cruise emissions" from *both* domestic and international aviation should be reported separately as a memo items in NFR1A3ai and are not included in national totals. This applies according to the Long-Range Transboundary Air Pollution Convention (LRTAP). And emissions from *both* national and international aviation during the "LTO cycle" belong to the national totals.

International navigation is defined as fuels bought in Sweden, by Swedish or foreign registered ships, and used for transports to non-Swedish destinations, but excludes consumption by fishing vessels. Emissions from international navigation are not included in the national total, but are instead reported separately as a memo item in NFR1A3di. The division on international and domestic fuels for navigation is based on AIS data as from submission 2020. In previous submissions it was based on information from the monthly survey on supply and delivery of petroleum products[105]. More information regarding the change of methodology for navigation can be found in section 3.2.21.2.

A summary of the latest key source analysis is presented in Table 3-39.

Table 3-39 Summary of key source analysis, NFR1D according to approach 1.

| NFR | Key Source Assessment 2019 | |
	Level	Trend
1D International Aviation: Jet kerosene	NO_X	NO_X

3.2.22.2   METHODOLOGICAL ISSUES

International bunkers from aviation and navigation are defined as fuels bought in Sweden, by Swedish or foreign-registered airplanes or ships, and used for transport to non-Swedish destinations. Emissions from bunker fuels is reported separately as a memo items in NFR1A3ai respectively 1A3di.

3.2.22.2.1 INTERNATIONAL AVIATION, NFR1A3A I

International Aviation is defined as emissions from flights that depart in one country and arrive in a different country. However, "Cruise emissions" from *both* domestic and international aviation should be reported separately as a memo item in NFR1A3ai and not included in national totals. This applies according to the Long-Range Transboundary Air Pollution Convention (LRTAP). Emissions from *both* national and international aviation during the "LTO cycle" belong to the national totals.

The fuel consumption and emissions from both national and international aviation are calculated by the Swedish Defence Research Agency (FOI) by using an estimation model and data provided by Swedish Transport Agency (STAg) regarding:

- Airport of departure and arrival

- Type of aircraft

- Number of flights

- Number of passengers

- International or domestic flight

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[105] Statistic Sweden. http://www.scb.se/sv_/Hitta-statistik/Statistik-efter-amne/Energi/Tillforsel-och-anvandning-av-energi/Manatlig-bransle--gas--och-lagerstatistik/

A database with information regarding 200 different types of aircraft is also used. The emission data regarding different types of aircrafts in the database originates from "ICAO Engine Exhaust Emission Data Bank". All this data is used to calculate emissions and amounts of burnt fuel for total flight time as well as for aircraft movements below 3000 feet at the airports, the so called LTO cycle. The FOI has in a published report described their method for estimating the emission from aviation[106].

Due to the fact that the Swedish airports generally are smaller than international airports in other countries; taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow[107]. The traffic from Swedish airports consumes as a result less fuel and gives rise to less emission. The estimated fuel consumption and emissions are adjusted to match the statistics on delivered amount of aviation fuels from Statistics Sweden (see Annex 2).

The results from the emission calculations are aggregated into four groups; domestic landing and take-off (LTO), domestic cruise, international LTO and international cruise. The aggregation is based on estimated emissions from the LTO cycle & Cruise reported by STAg *and* the national/international (bunker) fuel consumption from the monthly survey on supply and delivery of petroleum products from Statistics Sweden.

The emissions of NO_X from the cruise phase peaked first in 2007 and then I 2018creased until 2017. The emissions of NOx from the Cruise cycle increased by 57% between 1990 and 2019, but decreased by 4% between 2018 and 2019. (see figure 3-15 below).

The emissions of CO fluctuate a lot, but was at its lowest in 2003. After a steady increase, the emissions of CO from the cruise phase peaked in 2017. The decreasing trend since 2017 is due to a transition from Boeing to Airbus planes. The emissions of CO from the Cruise phase have decreased by 15% since 2018 and by 12 % since 1990.

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[106] Mårtensson, T. & Hasselrot, A., 2013.

[107] Gustafsson, 2005.
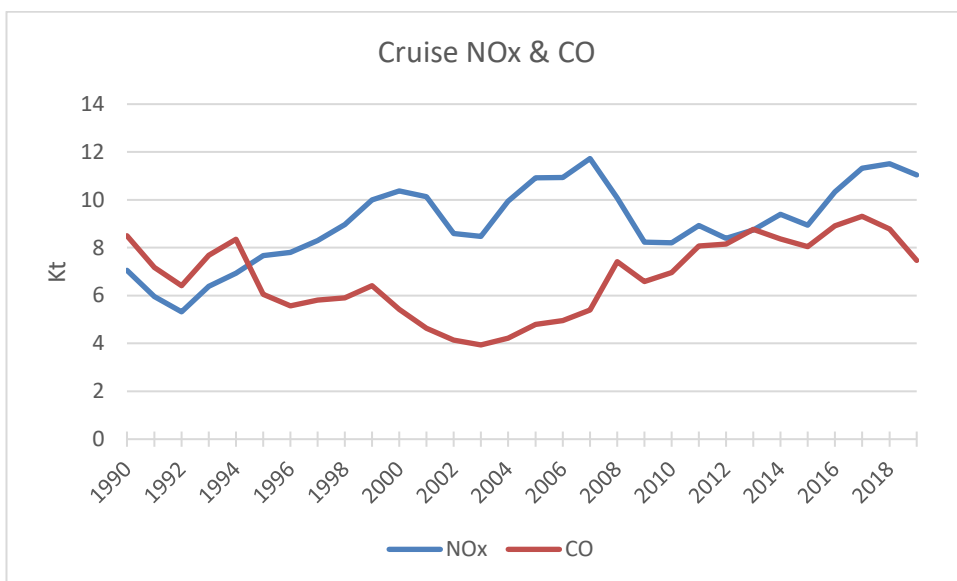
Figure 3-15. Emissions of NOx and CO from the cruise phase for aviation (CRF 1A3a & 1D) 1990-2019.

The emissions of NMVOC fluctuate but show a decreasing trend over time since 1990. In recent years this is the result of phasing out the MD-80/82 aircraft model. The emissions of Pb have decreased noticeably for the whole period, as leaded gasoline has been phased out (see figure 3-16 below). The emissions of Pb originate from the cruise phase in national aviation, since no aviation gasoline is used for international aviation.
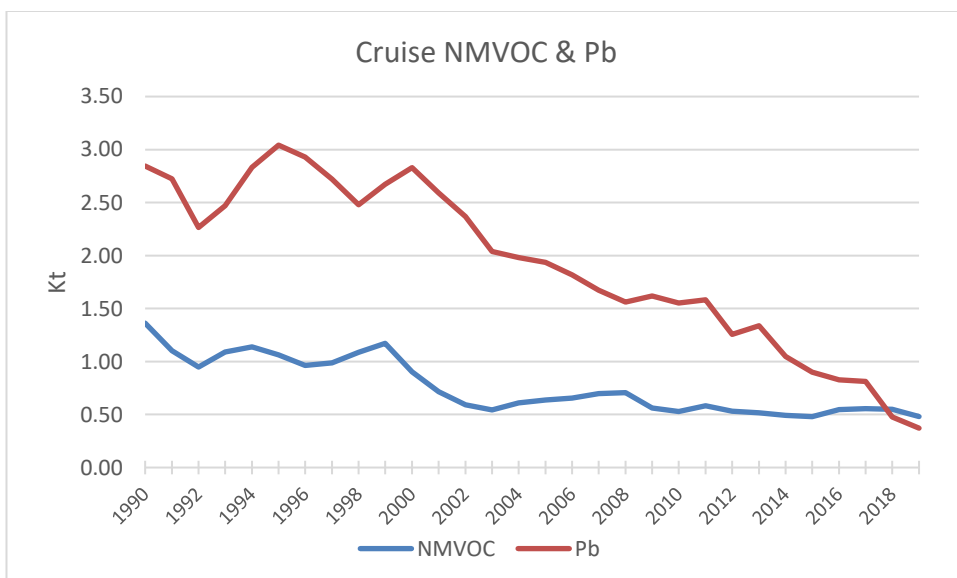
Figure 3-16. Emissions of NMVOC and Pb from the cruise phase for aviation (CRF 1A3a & 1D) 1990-2019.

3.2.22.2.2 INTERNATIONAL NAVIGATION, NFR1A3D I

International bunkers from navigation are defined as fuels bought in Sweden, by Swedish or foreign-registered ships and used for transport from Swedish destinations to non-Swedish destinations, but excludes consumption by fishing vessels. Emissions from international bunkers navigation are not included in the national total but instead reported separately as a memo item in NFR1A3di. The division on international and domestic fuels is based on information from the monthly survey on supply and delivery of petroleum products.

The emissions from international navigation are estimated applying Tier 2 methodology. The fuel consumption for international navigation has in previous submissions been based on the monthly survey on supply and delivery of petroleum products[108]. But it has been problematic for fuel suppliers to separate fuel distributed to national respectively international navigation. As the monthly survey of fuel supply statistics was revised in 2018, the reported fuel for national and international navigation was merged in the survey and represent as from 2018 the total fuel supply for navigation.

As a result of the described adjustments in the survey, the energy consumption from domestic shipping is mainly based on a methodology called Shipair as from submission 2020. The Shipair model is developed by the Swedish meteorological and hydrological institute (SMHI) and collects AIS data (Automatic Identification System) from ships, which they use to continuously transmit identity and position information. The AIS data shows how the ships move between Swedish ports. Information regarding the ships, such as size, engine power and type of vessel is also collected. This enables the Shipair model to estimate the amount of energy needed for the ships to move and the amount of fuel consumed.

Beside the Shipair model, the energy consumption from domestic navigation is based on information collected from the largest shipping actors for national navigation, with the exception for cargo ships.[109] Information regarding the fuel consumption, by fuel type, is collected as Shipair only estimate the energy consumption. Shipair does not know which fuel types are used and the amount of fuel by fuel type. The difference between the energy consumption estimated by Shipair and from collected data, is assumed to be the energy consumption by cargo ships.

The fuel consumption by international navigation is estimated as the difference between the energy consumption for national navigation and the total supply of fuel for navigation in the monthly survey of fuel supply statistics. The result from using the new methodology is a slightly lower consumption of fuel for international navigation.

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[108] Statistic Sweden. Monthly fuel, gas and inventory statistics. See annex 2 for more information regarding different surveys.

[109] Eklund, V. et al. 2019. Analys och implementering av data från nya MåBra.

Emission from multilateral operations are reported as a memo item in NFR1A3di. These emissions are derived from fuel purchased in Sweden and used abroad by Swedish forces participating in UN related operations. These emissions account for very small amounts.

3.2.22.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The fuel consumption by international navigation was in previous submissions based on the the "Monthly fuel, gas and inventory statistics" survey[110].

In submission 2020, the methodology for both national and international navigation has been revised to get a better allocation of the fuel used by national respectively international navigation for 1990-2018 and to reduce the uncertainty. The new methodology is explained in section 3.2.21.2.2.

Uncertainties for activity data and emissions reported for domestic navigation in NFR1A3d can be seen in Annex 1 to the IIR.

3.2.22.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

3.2.22.5 SOURCE-SPECIFIC RECALCULATIONS

The method to estimate the activity data (AD) for international navigation changed in submission 2020. In previous submissions, the AD was based on the monthly survey on supply and delivery of petroleum products[111] which specified fuel used by international navigation. As it was problematic to separate the fuel used by domestic respectively international navigation, the survey only present the total fuel consumption for navigation as from submission 2020. Activity data for international navigation is retrieved by deducting the fuel used by domestic navigation from the total deliveries of fuel used by navigation.

Due to incorrect reporting of the respondents to the survey, the microdata for residual fuel in 2018 was adjusted in submission 2021. This has led to a reduction in consumption of residual fuels by international navigation in 2018, which can be seen in figure 3-17.

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[110] Monthly fuel, gas and inventory statistics. http://www.scb.se/en/finding-statistics/statistics-by-subject-area/energy/energy-supply-and-use/monthly-fuel-gas-and-inventory-statistics/. See annex 2.

[111] Statistic Sweden. Monthly fuel, gas and inventory statistics. See annex 2 for more information regarding different surveys.
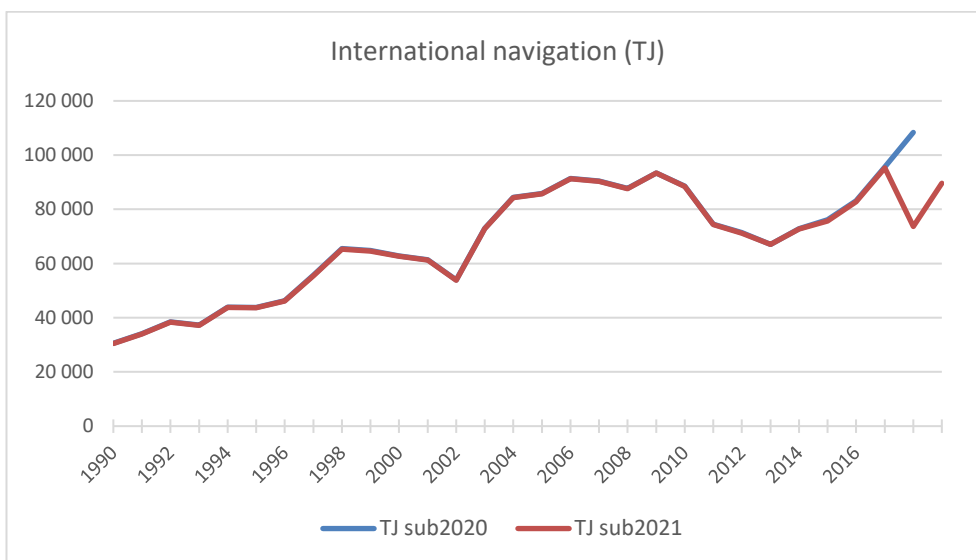
Figure 3-17. The fuel consumption by international navigation 1990-2019 (TJ).

3.2.22.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.3 Fugitive emissions from solid fuels and oil and natural gas, NFR1B

3.3.1 Coal mining and handling, NFR1B1a

3.3.1.1 SOURCE CATEGORY DESCRIPTION

There are no coal mines in Sweden and hence no fugitive emissions from coal mines occur (reported as NO).

3.3.2 Solid fuel transformation, NFR1B1b

3.3.2.1 SOURCE CATEGORY DESCRIPTION

NFR1B1b includes emissions of SO_2, HN_3, NMVOC, NO_x, Se and PAH from quenching and extinction at coke ovens. Particle emissions, also occurring from coke production, are allocated to NFR1A1c (industrial combustion). A summary of the latest key source analysis is presented in Table 3-40.

Table 3-40 Summary of key source analysis, NFR1B1b, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1B1b	*Se*	-

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3.3.2.2   METHODOLOGICAL ISSUES

Information on SO_2 emissions are retrieved from the companies' environmental reports and direct communication. PAH emissions from quenching and extinction at coke ovens are reported based on the measurement data from the environmental reports.

NH_3 and Se emissions from coke production are reported from submission 2016, NMVOC and NO_x emissions – from submission 2018 and onwards. Emission factors are obtained from EMEP/EEA Guidebook 2016 and applied to activity data. Activity data, produced amount of coke (Mton), has been acquired from the annual environmental reports for the two facilities producing coke (2001 and onwards), and for the earlier years – estimated via amounts of treated coking coal and the coke/coal ratio of 0.79, based on the data for the later years.

Fugitive emissions of particles from handling of coke have not been included since these emissions are included in the reporting of particle emissions from the industrial facilities that produce coke. These emissions are thus reported "IE". Separate calculations based on statistics on coke and petroleum coke, using emission factors for handling of coal from CEPMEIP results in a rough estimate of 300 t TSP/year. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

Emissions of As, Hg and dioxin occurring during coke production are reported in NFR2C1.

3.3.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for NFR1B1b are displayed in Annex 1. Uncertainties are expert estimates, except for HN_3, NMVOC, NO_x and Se, for which the emission factor uncertainties are calculated based on the intervals in the EMEP/EEA Guidebook 2016.

3.3.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

The improvements in methodology and allocation of emissions from the integrated iron and steel industry in submission 2010 were made based on a study[112] carried out in 2008 looking at emissions from several industrial plants, including the two largest iron and steel plants in Sweden, where inventory data from submission 2008 was compared with data from environmental reports.

3.3.2.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in submission 2021.

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[112] Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008.

3.3.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.3.3   Other, NFR1B1c

3.3.3.1   SOURCE CATEGORY DESCRIPTION

NFR1B1c includes emissions from flaring of coke oven gas at coke ovens handling (NO_X, CO, NMVOC, SO_2, TSP, PM_{10} and $PM_{2.5}$) and particle emissions from solid fuels handling (TSP, PM_{10} and $PM_{2.5}$). A summary of the latest key source analysis is presented in Table 3-41.

Table 3-41 Summary of key source analysis, NFR1B1c, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
1B1c	Solid Fuels – *PM10, TSP*	-

3.3.3.2   METHODOLOGICAL ISSUES

3.3.3.2.1 Flaring of coke oven gas

Table 1B1 is not really designed to include flaring, but since NFR1B2 only refers to liquid and gaseous fuels, it is not possible to report flaring from coke oven gas, blast furnace gas and steel converter gas in NFR Table 1B2.

The emissions from flaring of coke oven gas (COG – by-product gas at the integrated iron and steel plants) are calculated with Tier 2, i.e. with activity data directly from the plants, in the same way as for emissions from stationary combustion. All emissions, with the exception of SO_2, are calculated with the same emission factors as for stationary combustion because no other information is available for COG flaring in particular (emission numbers in the environmental reports are given for the coke ovens in total, including both flaring and industrial combustion of COG). For SO_2, one facility provides the emissions from COG flaring, whereas for the other total emissions from COG are distributed between NFR codes using the fuel amounts allocated to each code. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

Reported activity data is amounts of flared COG (Mton). The amounts vary considerably between years, and during some years (2009, 2015) they were unusually high, resulting in increasing emissions. According to environmental reports[113], COG is flared when the production is temporarily stopped because of urgent needs of reparation of equipment or other maintenance measures.

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[113] SSAB, 2008, 2009, 2015

3.3.3.2.2 Handling of solid fuels

Particulate emissions from handling of solid fuels have been calculated for all years since 1980. Emission factors used for handling of exported and imported fuels are those suggested in the CEPMEIP-project[114]. The TSP emission factor is 0.15 kg/t where PM_{10} constitutes 40 % and $PM_{2.5}$ 4 % of the total particulate emissions. The same emission factors have been used for the entire time series.

No production of coal occurs in Sweden but peat production does occur and from submission 2011 particulate emissions from production of milled peat is included in the estimates of particle emissions. Activity data (as m^3 produced peat) is available from official statistics from 1980 and onwards and is divided in peat used for energy purposes and peat used for agricultural purposes. Furthermore there are different methods for peat production. Most particle emissions arise from the production of milled peat.

Production data from official statistics divide peat used for energy purposes in milled peat and other types of peat. However, this split is not used when reporting production data for peat used for agriculture purposes. Milled peat is mostly used for energy purposes, but some may also be used for agricultural purposes, hence the production data for milled peat may be underestimated.

The TSP emission factors used for milled peat production are from Nuutinen *et. al.* (2007)[115] and the share of PM_{10} and $PM_{2.5}$ are from Tissari *et. al.* (2006)[116]. There are different methods that can be used when harvesting milled peat and the size of the particle emissions depends on which method is used. Since no information is available about the share between the different methods in Sweden an average emission factor is used, Table 3-42. Particle emissions are made up of only filterable particles since they origin from non-combustion processes.

Table 3-42 Particle emission factors for milled peat production.

Harvesting method	Particle emission factors (g/m^3) for peat production		
	TSP	PM_{10}	$PM_{2.5}$
HAKU method	0.09	0.042	0.030
Mechanical collector	0.14	0.066	0.046
Pneumatic collector	0.12	0.056	0.039
Average	**0.12**	**0.055**	**0.039**

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[114] CEPMEIP, 2001. TNO.
http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

[115] Nuutinen, J., Yli-Pirilä, P., Hytönen, K., Kärtevä, J., 2007, Turvetuotannon poly- ja melupäästöt sekä vaikutukset lähialueen ilmanlaatuun, Symo

[116] Tissari, J. M., Yli-Tuomi, T., Raunemaa, T. M., Tiitta, P. T., Nuutinen J. P., Willman, P. K., Lehtinen, K. E. J., Jokiniemi, J. K., 2006, Fine particle emissions from milled peat production, Boreal Environmental research 11:283-293, Helsinki 30 August 2006

Due to problems with data files on energy consumption in energy industries and manufacturing industries for 1980-1989, it has not been possible to recalculate emissions as has been done for different sectors for 1990 and onwards. Hence, time series for the eighties are not directly comparable with later years for NFR1B1c.

3.3.3.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time series reported in NFR1B1c have been reviewed in later years and are considered to be consistent. Uncertainties for emissions are mostly expert estimates. For COG flaring, uncertainties in activity data are high since the amount of flared gas are not measured as carefully as combusted gas (this statement is true for any plant). Uncertainties for particulate emissions from handling of solid fuels are ± 20% and based on expert judgement. More detailed information is to be found in Annex 1.

3.3.3.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

3.3.3.5   SOURCE-SPECIFIC RECALCULATIONS

Flaring of COG: small correction of SO_2 emissions in 2018 is made – 0.0001 kt.

Emissions of PM_{10} and $PM_{2.5}$ in 2007-2015 were revised in connection with changes of the reporting method at one of the facilities. As a result, emissions increased by <0.0002 kt for these years.

3.3.3.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.3.4   Hydrogen production plants at refineries, NFR1B2a i

3.3.4.1   SOURCE CATEGORY DESCRIPTION

NFR1B2a i includes emissions from hydrogen production at refinery facilities – NO_X, CO, NMVOC, SO_2, NH_3, TSP, PM_{10} and $PM_{2.5}$, BC, and dioxin. A summary of the latest key source analysis is presented in Table 3-43.

Table 3-43 Summary of key source analysis, NFR1B2a, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1B2a i,iv,v	Oil – *NMVOC, SO2*	Oil – *NMVOC, SO2*

3.3.4.2   METHODOLOGICAL ISSUES

Hydrogen production at one of the Swedish refinery plants occurred since 1980-es. At this facility, naphtha was used as raw material until 2011 and LNG – from 2011 and onwards. At another facility, hydrogen is produced since 2005 – from internal

off-gas and butane as feedstocks, and from 2014 – also from LNG. At the third facility, hydrogen production from LNG started in 2019. Emissions from these refineries are reported in NFR1B2a i in accordance with 2006 IPCC Guidelines.

The Tier 2 method is used. Activity data is reported as NA because one of the plants has changed reporting method so that activity data no longer represents amounts of feedstock. Instead, to calculate CO_2 emissions reported to EU ETS, the facility from now one will use amounts of so called 'PSA (pressure swing adsorption) gas' - energy-poor off-gas from the hydrogen production unit [117]. PSA gas is a good proxy for activity data for this particular plant with a complicated feedstock structure; however, it is not a feedstock and thus cannot be summed up with feedstock data (naphtha and LNG) from the other plant.

Emissions are calculated with plant-specific activity data and national emission factors. Due to lack of specific emission factors, "other petroleum fuels" emission factors are used for naphtha, and emission factors for refinery gas are used for PSA gas. For two of three facilities, emissions of NO_x and TPS are taken from the facility's environmental reports.

Within a development project during 2018-2019[118], efforts were made to investigate whether alternative emission factors can be used instead of currently used national emission factors for stationary combustion. The project work, performed in close cooperation with the refineries, resulted in better accounting of information available in environmental reports (often based on continuous measurements) in the emission inventories. In particular, NO_x emission factor for LNG/natural gas as feedstock was revised with respect to available (measurement) data. However, no relevant emission factors specific for hydrogen production were found in the literature.

The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

The emissions of SO_2 from hydrogen production ended in 2011 when naphtha was no longer used as a raw material in the production.

3.3.4.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY
Uncertainties for NFR1B2a i are displayed in Annex 1. Uncertainties are mostly expert estimates.

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[117] Ortiz, C., et al.. Överlappande mellan CRF 1 och 2, SMED memorandum, 2017

[118] Yaramenka et al. 2019

3.3.4.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

3.3.4.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in submission 2021.

3.3.4.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.3.5   Refineries, NFR1B2a iv

3.3.5.1   SOURCE CATEGORY DESCRIPTION

There are five refinery facilities in Sweden. Emissions from refineries reported in NFR1B2 i iv include:

- Fugitive emissions of NMVOC from the total refinery area (occur at all five facilities);
- SO_2 emissions from desulphurisation (occur at four facilities);
- Emissions from catalyst regeneration and make-up coke combustion (occur at three facilities) – NMVOC, NH_3, PAH, CO, NO_x, dioxin, SO_2, TSP, PM_{10}, $PM_{2.5}$, BC, and from submission 2020 – also heavy metals (Ni, Cr, Zn, Cu, Cd, Hg, and As).

A summary of the latest key source analysis is presented in Table 3-44.

Table 3-44 Summary of key source analysis, NFR1B2a according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1B2a i,iv,v	*Oil – NMVOC, SO₂*	*Oil – NMVOC, SO₂*

3.3.5.2   METHODOLOGICAL ISSUES

Sweden estimates emissions by using the Tier 2 method. The Tier 2 method requires data at plant level and Sweden uses data provided by the refineries in their annual environmental reports. Emissions are reported from catalyst regeneration and make-up coke combustion, desulphurization, and from the storage and handling of oil.

Since submission 2009, emissions from catalytic cracking and combustion of make-up coke in refineries are reallocated from the energy sector to NFR1B2a iv (hence the combustion is not carried out for energy purposes). This was based on a study performed by SMED[119]. The cracking reactions produce some carbonaceous material (referred to as *coke*) that deposits on the catalyst and very quickly reduces

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[119] Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008. Fortsättning av riktad kvalitetskontrollstudie av utsläpp från industrin i Sveriges internationella rapportering. SMED Report 2008

the catalyst reactivity. The catalyst is regenerated by burning off the deposited coke. Combustion of cracker coke occurs at three facilities. At one of the facilities, there is a large fluidized catalytic cracker (FCC), which contributes to over 95% of all the emissions from catalyst regeneration and make-up coke combustion.

Particle emissions from FCC have been obtained from the company's environmental reports from 2010 onwards (for $PM_{2.5}$, an assumption was made that it constitutes 85% of PM_5 specified in the environmental reports). These particles do not origin in the combustion processes but represent fine catalyst mass. The particle size distributions for 1990-2009 have been estimated with expert judgement. The assumed size distribution is 95% of TSP for PM_{10}, and 85% - for $PM_{2.5}$. BC emissions are estimated with a standard share specified in the EMEP/EEA Guidebook 2016. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases. Particle emissions from the other two facilities where catalyst regeneration occur are estimated with implied emission factors calculated for FCC. Amounts of make-up coke are taken from the company's reporting to the EU ETS system.

CO emissions from FCC are estimated based on the total facility's CO emissions (as specified in the environmental report) and the relative input of cracker feedstock to the total material input to the refinery processes. Implied emission factor calculated for FCC is further used to estimate CO emissions from the other two facilities with coke combustion and catalyst regeneration processes.

NO_x, SO_2 and heavy metal emissions from FCC are taken from the facility's environmental reports. Emissions of heavy metals are reported by the facility for the years from 2000, and for the earlier period estimated with implied emission factors and amounts of burnt make-up coke. For the other two facilities, default emission factors from the EMEP/EEA Guidebook 2016 are used for NO_x, and FCC-based implied emission factors – for SO_2 and for heavy metals. Emissions of heavy metals (Ni, Cr, Zn, Cu, Cd, Hg, and As) from refinery processes are reported starting from submission 2020.

Other emissions are calculated with the plant-specific activity data and either national emission factors (**PAH, dioxin**) or default emission factors specified in the EMEP/EEA Guidebook 2016 for the catalyst regeneration stage (**NH_3, NMVOC).**

Emissions of **SO_2 from desulphurization** decreased after 2001 and were between 0.18 and 0.44 Gg during 2011-2019.

Fugitive emissions of NMVOC from refineries include emissions from the process area as well as emissions from the refinery harbors when loading tankers. The estimates of NMVOC are mainly based on reported data from the facilities' envi-

ronmental reports and older reports from the Swedish EPA[120],[121],[122],[123] and Statistics Sweden[124]. The total numbers in the environmental reports most often cover NMVOC emissions from both evaporation (fugitive emissions) and flaring (NFR 1B2c) – fugitive emissions are thus calculated by subtracting flaring emissions from the totals for the entire time-series. For certain years, where emission data is missing, implied emission factors (emissions per tonne crude oil) are used.

Activity data reported is amount of processed crude oil (Mg), specified in the facilities' environmental reports.

3.3.5.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY
Uncertainties for NFR1B2a iv are displayed in Annex 1. Uncertainties are mostly expert estimates.

3.3.5.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION
No source-specific QA/QC or verification is performed.

3.3.5.5   SOURCE-SPECIFIC RECALCULATIONS
One of the facilities changed the method for estimating emissions of NMVOC from flaring, which, being used to correct estimates of fugitive NMVOC emissions, affected the entire time series. Besides, corrected calorific values of make-up coke at one of the facilities resulted in insignificant increase of emissions of all air pollutants calculated via emission factors for coke. The quantified effect of the recalculations on the emissions cannot be displayed due to confidentiality reasons.

3.3.5.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS
Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.3.6   Gasoline handling and distribution, NFR1B2a v
3.3.6.1   SOURCE CATEGORY DESCRIPTION
NFR1B2a v includes fugitive emissions of NMVOC from the storage of oil products (oil depots) and from gasoline handling at gasoline stations. A summary of the latest key source analysis is presented in Table 3-45.

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[120] Swedish EPA, 1990.

[121] Swedish EPA, 1994a.

[122] Swedish EPA, 1994b.

[123] Swedish EPA. 1995.

[124] Statistics Sweden. 1996 Emissions to air in Sweden of volatile organic compounds (VOC) 1988 and 1994.

Table 3-45 Summary of key source analysis, NFR1B2a, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1B2a i,iv,v	*Oil – NMVOC, SO$_2$*	*Oil – NMVOC, SO$_2$*

3.3.6.2 METHODOLOGICAL ISSUES

3.3.6.2.1 *Gasoline stations*

The calculation of the NMVOC time series for fugitive emissions from gasoline distribution, 1988-2019, is based on methods given by Concawe[125], including annual national gasoline consumption and assumptions on the share of gasoline evaporated at different stages of the handling procedure, as well as effects of applied abatement technology at gasoline stations[126]. The basic assumptions are presented in Table 3-46; ethanol both for use in blends with gasoline and for use unblended is included in the reported gasoline volumes.

Table 3-46 Assumptions for calculating fugitive emissions from the handling and distribution of gasoline.

Parameter	Assumption	
Density of gasoline	730 kg/m^3 1988 - 1996	
	750 kg/m^3 1997 -	
Distribution of gasoline to gas stations	0.16 %	of distributed volume
Spill	0.01 %	of distributed volume
Filling of car tanks	0.18 %	of filled volume
Measures at distribution to gas station	90 %	Efficiency of measures
Measures at filling cars	70 %	Efficiency of measures

The measures at distribution and filling were introduced over a period of time from 1991-1994, to the extent presented in Table 3-51. The amount of gasoline sold at large and small gas stations, respectively, was assumed to be 50/50 for the years 1988-1994. Data on the distributed amounts of gasoline is taken from national statistics from Statistics Sweden for submission 2016 and onwards, Table 3-47. For earlier submissions data on the distributed amounts of gasoline was taken from the HBEFA model.

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[125] Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

[126] Andersson, 2000.

Table 3-47 Fraction of gasoline stations with technical measures installed.

Year	Large gas stations >2000 m³	Small gas stations
1988 – 1990	0%	0%
1991	50%	0%
1992	75%	25%
1993	100%	75%
1994 -	100%	100%

3.3.6.2.2 Oil depots

Calculated fugitive emissions of NMVOC from the storage of oil products have been obtained from SPI[127] or from the environmental reports of the oil depots. The calculations are based on the amount of gasoline handled in the depots. The calculations cover the years 1990 and onwards and are based on methods given by Concawe 85/54[128] for the years 1990-2006 and on Concawe 03/07[129] for the years 2007 and onwards. More than 30 depots have been considered during later years. Gas recovery systems and the recovered amount of gas have been considered in the calculations. For five depots the reported NMVOC emissions are based on emission measurements in the depot areas and not on calculations based on the amount gasoline handled in the depots. For some years, for which no data was provided, emissions were by using interpolation. Handled amount of gasoline and fugitive emissions of NMVOC from depots and gasoline stations are presented in Table 3-48.

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[127] Per Brännström, 2009-, personal communication; Leif Ljung -2009, personal communications

[128] Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.

[129] Concawe Report No. 3/07, Air pollutant emission estimation methods for E-PRTR reporting by refineries

Table 3-48 Handled and distributed amount of gasoline and estimated fugitive emissions of NMVOC (Gg) from storage at depots and at gasoline stations.

Year	Volume of gasoline and ethanol m³	Fugitive emissions of NMVOC at depots Gg	Fugitive emissions of NMVOC at gasoline stations, Gg
1990	5 629 582	2.48	14.38
1995	5 762 693	1.93	3.37
2000	5 372 801	2.07	3.22
2005	5 508 187	2.31	3.30
2006	5 363 256	2.47	3.22
2007	5 253 617	2.36	3.15
2008	4 928 238	2.53	2.96
2009	4 861 776	2.42	2.92
2010	4 550 207	2.23	2.73
2011	4 222 863	2.49	2.53
2012	3 880 860	2.46	2.33
2013	3 685 278	2.21	2.21
2014	3 545 193	1.94	2.13
2015	3 471 386	2.03	2.08
2016	3 338 553	1.68	2.00
2017	3 198 811	1.74	1.92
2018	3 104 880	1.82	1.86
2019	C	C	C

3.3.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time series reported in NFR 1B2a v have been reviewed in later years and are considered to be consistent. Uncertainties for NMVOC emissions reported in NFR 1B2a v are ± 75% and based on Guidebook Quality Rating C. More detailed information is to be found in IIR Annex 1.

3.3.6.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

3.3.6.5 SOURCE-SPECIFIC RECALCULATIONS

Emissions of fugitive NMVOC emissions from gasoline distribution have been corrected in 2018 due to updated activity data. NMVOC emissions therefore increased in 2018 by 0,006 kt.

3.3.6.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.3.7 Transmission and distribution of natural gas and gasworks gas – fugitive emissions, 1B2b

3.3.7.1 SOURCE CATEGORY DESCRIPTION

NFR1B2b includes fugitive emissions of NMVOC from transmission and storage of natural gas and biogas (1B2b iv) and from distribution of natural gas, biogas and gasworks gas (1B2b v). A summary of the latest key source analysis is presented in Table 3-49.

Table 3-49 Summary of key source analysis, NFR1B2b, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1B2b	-	-

3.3.7.2 METHODOLOGICAL ISSUES

In 2013, a national method for estimating fugitive emissions of natural gas and gasworks gas was developed[130]. Emission of NMVOC from this subsector were for the first time reported in submission 2014.

3.3.7.2.1 Transmission and storage of natural gas 1B2b iv

Emission estimates for gas transmission and storage are based on information provided by Swedegas, the operator of the gas transmission pipeline and storage in Sweden.

The Swedish network for gas storage and transmission includes several different types of facilities: metering and regulation stations (M/R stations), compressor stations, ramification stations, valve stations, pig launcher & receiver stations, and a storage facility. According to Swedegas[131], many of the facilities are combined, e.g. valves located close to M/R stations. To enable biogas transmission in the network, two compressor stations were put into operation in 2014 – one combined with M/R station and one stand-alone facility.

In 2016, the method for estimating the emissions from the gas transmission network was revised since new measurements of methane emissions became available[132]. Methane leakage rates per hour have been measured at all major types of facilities. Estimated emission factors (see Table 3-50 below) have been applied to the number of facilities of each type.

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[130] Jerksjö M., Gerner A., Wängberg I. 2013

[131] Bjur & Lindsjö, 2016

[132] Jerksjö, M., Salberg, H. 2016. Mätningar av metanläckage längs svenska naturgasnätets stamledning, IVL report C202 (in cooperation with Fluxsense)

Table 3-50 Method for estimation of gas leakage from the national gas transmission network.

Facility type	CH$_4$ EF g/hour	Number of facilities in 2018	Comment
M/R station	91	43	Number of facilities is known for the whole time series
Storage	200	1	In operation since 2006
M/R + compressor station	222	1	In operation since 2014
Compressor station	100	1	In operation since 2014
Valve station	30	26	For the years 1990-2014, the number of facilities is assumed to be in direct proportion to the network's length (320 km in 1990, 620 km in 2017)
Pig launcher & receiver station	300	9	
Ramification station	30	39	

Methane emissions have been further calculated to NMVOC emissions by using parameters shown in Table 3-47. Information on gas composition was obtained from Swedegas and constitutes average values from the period 2006 to 2012.

Table 3-51 Composition and physical properties of natural gas.

Property	Unit	Value
Methane content in natural gas	% by weight	78.6
NMVOC content in natural gas	% by weight	19.0
Density of natural gas	kg/Nm^3	0.817
Density of methane	kg/Nm^3	0.716

As explained above, emissions of NMVOC are based on the amount of the different facility types within the national gas transmission network. The operator has been contacted in submission 2021 and confirmed that the amount of facility types has not changed since 2014, except that one additional M/R station was established in 2018.

Emissions earlier reported as gas leakage have been re-allocated to the sector *NFR1B2c Venting and flaring* since these emissions are controlled and associated with regular network maintenance work rather than with uncontrolled gas leakage.

3.3.7.2.2 *Natural gas distribution 1B2b v*

There are three types of gas networks for distribution of gas in Sweden.
1. The gas network for distribution of natural gas (since 2016 mixed with biogas)
2. Local biogas distribution network
3. Gasworks gas distribution network.

The gas network for distribution of natural gas is connected to the national transmission pipeline via M/R stations as mentioned above and had a total length of 2620 km in year 2012. This network delivers natural gas to the end users, which are industries or municipalities which in turn use the gas for energy production, to feed their town gas networks, etc. There are about 40 small local distribution networks for biogas in Sweden[133]. The total length was 146 km in 2012. The biogas is of similar quality as natural gas and is distributed in similar distribution pipes as natural gas.

Most of the gasworks gas networks use natural gas and their distribution system has been modernized and considered to be of the same standard as the distribution system for natural gas. However, the gasworks gas networks in Stockholm and Gothenburg (the two largest cities in Sweden) are different. These networks consist to a large part of old pipes with considerable high leaking rate. Between 1990 and 2011, a facility in Stockholm produced gasworks gas from cracking light petroleum. In 2011, they started to use a mixture of natural gas and air. The city of Gothenburg produced gasworks gas of a similar quality as that in Stockholm during the period 1990 – 1993. In 1993, the city of Gothenburg shifted to a mixture of natural gas and air. From the beginning of 2011, only pure natural gas was distributed in Gothenburg. From 2016 biogas has been mixed into the natural gas. Activity data in terms of leakage of gasworks gas has been obtained from the gasworks gas distributor in Stockholm for the years 2002-2012. For earlier years, only production data is available, and the average relation of leakage to production has been used to estimate leakage for the years 1990-2001. The emissions of NMVOC have been calculated with data on chemical composition of gas from cracking and natural gas/air mixture. The methodology is described in Jerksjö et al[134].

Since no measurement on fugitive methane emissions from distribution of gas has been made in Sweden, emission factors found in the literature were compared and examined. Information on the Swedish gas network was collected by contacting the operators. Based on this information an emission factor obtained from a Dutch investigation (Wikkerlink 2006[135]) was chosen. The emission factor is the result of an evaluation of data from measurements of gas leaks at several places in the Netherlands and is equal to 120 Nm^3 methane per km distribution line. According to net operators of new or renewed Swedish networks for natural gas, the networks in Sweden are of similar standard and design as those in the Netherlands. The Dutch emission factor is considered to be valid for pipes made from PVC and polyeth-

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[133] Jerksjö, M., Gerner, A., Wängberg, I. 2013. Development of method for estimating emissions of methane, NMVOC and carbon dioxide from natural gas, biogas and town networks in Sweden. SMED Report No: 121, 2013.

[134] Jerksjö, M., Gerner, A., Wängberg, I. 2013. Development of method for estimating emissions of methane, NMVOC and carbon dioxide from natural gas, biogas and town networks in Sweden. SMED Report No: 121, 2013.

[135] Wikkerlink. 2006.

ylene, etc., and can be used as an average value covering different pressure regimes. The emission factor from the Dutch study was adopted for estimating the methane emissions from Swedish gas networks 1. (Natural gas) and 2. (Biogas) and also gas networks in cities with new or renewed distribution systems.

Data on gas mixtures, sources of activity data and emission factors used for emission calculations in NFR1B2b v for each gas distribution network are summarized in Table 3-52.

Table 3-52 Summary of method for calculating emissions from Swedish gas distribution networks.

Gas distribution networks	Natural gas*	Local biogas	Gasworks gas – Stockholm
Gas mixture used	Natural gas	Biogas of similar quality as natural gas	Mixture of natural gas and air. Until 2011 – gasworks gas and mixture of natural gas and air
Source of activity data	Gas distribution companies	Grönmij. 2009	Stockholm gas environmental reports
Type of activity data	km length	km length	Nm^3 gas leakage
Emission factor for NMVOC	No emission factors are used. Emissions are calculated based on estimated methane emissions and the content of CO_2 and NMVOC in the natural gas.		No emission factors are used. Emissions are calculated based on the content of NMVOC in the gas mixtures considered

* Including a number of city gas distribution networks, for instance Gothenburg gas distribution network since 2011.

The gas distribution networks in Stockholm and Gothenburg constitute of both old and new or re-lined pipes. The old pipes have a relatively high leaking rate. During 1990 to January 2011 gasworks gas (i.e. from cracking of light petroleum) was produced and distributed in the Stockholm gas network. In January 2011 one started to use a mixture of natural gas and air. The city of Gothenburg produced gasworks gas of a similar quality as that in Stockholm during the period 1990 – 1993. In 1993, the city of Gothenburg shifted to a mixture of natural gas and air and since the beginning of 2011, pure natural gas. From 2016 biogas is mixed into the natural gas.

The fugitive emissions from distribution of gasworks gas in Stockholm and Gothenburg have been estimated from statistics on production of gasworks gas and natural gas air mixtures and leakage rates from Stockholm Gas. The content of NMVOC in gasworks gas and natural gas air mixture is shown in Table 3-53.

Table 3-53 NMVOC content in gasworks gas.

Property	Unit	Value
NMVOC in gasworks gas	kg/Nm^3	0.04
NMVOC in natural gas air mixture	kg/Nm^3	0.08

3.3.7.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Gas transmission: The associated emission uncertainty is ±50 % according to expert estimates. More detailed information is to be found in IIR Annex 1.

Gas distribution: Fugitive emissions from the distributing network in Stockholm constitute 80 – 90 % of the total emissions from gas distribution in Sweden. The emission data from the Stockholm distribution network is based on measurements provided by the operator and the associated uncertainty is estimated to ± 50 %. The total uncertainty concerning distribution of gas in Sweden is largely influenced by the contribution from the gas network in Stockholm, and is thus likewise estimated to ± 50 %. More detailed information is to be found in IIR Annex 1.

3.3.7.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

3.3.7.5   SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been performed in NFR1B2b in submission 2021.

3.3.7.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

3.3.8   Venting and flaring, NFR1B2c

3.3.8.1   SOURCE CATEGORY DESCRIPTION

NFR1B2c includes emissions of NMVOC from gas venting as well as emissions from flaring of gas and/or oil products at refineries and during the national gas network maintenance (NO$_X$, CO, NMVOC, SO$_x$, NH$_3$, TSP, PM$_{10}$, PM$_{2.5}$, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PAH and dioxin). A summary of the latest key source analysis is presented in Table 3-54.

Table 3-54 Summary of key source analysis, NFR1B2c, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
1B2c	*SO$_2$*	*SO$_2$*

3.3.8.2   METHODOLOGICAL ISSUES

For flaring of oil products and refineries during 1990-2004, activity data has been collected directly from the plant operators. For 2005 and onwards, activity data is mainly taken from the EU ETS system. Plant specific net calorific values are used when available. The reported activity data are amounts of flared gas mixture in TJ.

The same emission factors are used as for stationary combustion if no other emission factors or emissions are available. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

Within a development project during 2018-2019[136], flaring at refineries was investigated in detail. Efforts were made to find alternative emission factors to be used instead of national emission factors for stationary combustion. The project work, performed in close cooperation with the refineries, resulted in better accounting of facility-specific information available in environmental reports (often based on measurements) in the emission inventories. This data, where available, is prioritized in the inventory over estimates made with national emission factors for stationary combustion ("E-report" in Figure 3-18).

Pollutant	Refinery plant 1	Refinery plant 2	Refinery plant 3	Refinery plant 4
CO₂	EU ETS	EU ETS	EU ETS	EU ETS
SO₂	E-report	E-report	E-report	0.005 kg/GJ
NOₓ	E-report	E-report	0.076 kg/GJ	E-report
NMVOC	E-report (FCC) + 0.5%	E-report	0.5%	E-report
CO	0.01 kg/GJ	0.01 kg/GJ	0.01 kg/GJ	0.01 kg/GJ
TSP	0.06 kg/GJ	0.06 kg/GJ	0.06 kg/GJ	0.06 kg/GJ
NH3	0.002 kg/GJ	0.002 kg/GJ	0.002 kg/GJ	0.002 kg/GJ
CH₄	0.006 kg/GJ	0.006 kg/GJ	0.006 kg/GJ	0.006 kg/GJ
N₂O	0.0005 kg/GJ	0.0005 kg/GJ	0.0005 kg/GJ	0.0005 kg/GJ
PAH	Guidebook-defaults	Guidebook-defaults	Guidebook-defaults	Guidebook-defaults
Dioxin	0.0005 µg/GJ	0.0005 µg/GJ	0.0005 µg/GJ	0.0005 µg/GJ

Color-codes	National EF (same as in subm. 2019)	EU ETS	National EF (revised)	Guidebook-default

Figure 3-18. Methodology of the reporting of emissions from flaring at refineries

The emission factor for NMVOC from stationary combustion (implying 0.01% unburnt hydrocarbons) was replaced with the default emission factor from the EMEP/EEA Guidebook 2016 for refinery gas flaring, implying 0.5% unburnt hydrocarbons. Other improvements include revision of estimates made for the years 1990-2004 and better accounting of facility-specific shares of refinery gas, natural gas, LNG, sulphur-rich gases and hydrogen in the flared gas mixture. Emissions of dioxin, based on the national emission factors for stationary combustion, and emissions of PAH and heavy metals (Pb, Cd, Hg, As, Cr, Cu, Ni, Zn), based on the default emission factors from the EMEP/EEA Guidebook 2016, are included in the inventory from submission 2020.

The subcategory also includes occasional emissions from venting and flaring of natural gas during a network inspection at Swedegas. Network inspection conducted once in eight years (sometimes more often) requires so called piggning – emptying M/R stations, which means release of certain amounts of natural gas. A

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[136] Yaramenka et al. 2019

larger part of the released gas is flared but some is vented. From the years 2014 estimated amounts of gas vented during the inspections have been obtained from the operator. For the years 2006, 1998 and 1990 estimates were made based on the relation of the amount of vented gas to the number of M/R stations in 2014-2015. Emissions of NMVOC from piggning are well below 0.1 t.

Beside piggning operations, there is certain amount of gas annually vented to the atmosphere (earlier reported as diffuse emissions) from M/R stations – between 11 and 13 Nm^3 gas per station for recent years, or about 0.1 tonne NMVOC in total per year. Much higher and much more varying venting emissions come from the storage facility (put into operation in 2006) – from 0.1 to 17 t NMVOC per year, depending on how well the compressor worked. In 2013 the compressor failure[137] resulted in particularly high emissions.

3.3.8.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Estimates of emissions from natural gas venting are provided by the operator. The associated uncertainty is ± 50 % according to expert estimates. The activity data uncertainty for flaring of different fuels at refineries and other industrial facilities is as reported to EU ETS and is estimated to ±17.5 %. For gas and oil flaring, the total emission uncertainties are affected by uncertainties in the emission factors, which are the same as for industrial combustion. More detailed information is to be found in IIR Annex 1.

3.3.8.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

The coherence between environmental reports and ETS data is checked when possible, and when differences occur, the facilities are contacted for verification.

3.3.8.5   SOURCE-SPECIFIC RECALCULATIONS

Small correction in the calculation equation for 1990 – 2004 in submission 2021 results in changes of emissions of all air pollutants. Besides, one of the facilities changed the method for estimating emissions of NMVOC from flaring, which affected the entire time series. The quantified effect of the recalculations on the emissions cannot be displayed due to confidentiality reasons.

3.3.8.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

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[137] Hellström 2013-2015

3.3.9 Other fugitive emissions from energy production, NFR1B2d

3.3.9.1 SOURCE CATEGORY DESCRIPTION

NFR1B2d combines emissions from other sub-categories within NFR1B category – those that cannot be reported separately in the relevant sub-categories due to confidentiality issues. Emissions included in this category are NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, CO, and dioxin.

3.3.9.2 METHODOLOGICAL ISSUES

Sub-categories, emissions from which are considered as confidential and thus included in NFR 1B2d varies from year to year. For the years prior to 2015, all emissions in this category are reported as NO because no specific "other" activity actually does occur.

3.3.9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties are estimated for each of the included sub-categories separately.

3.3.9.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

Source-specific QA/QC and verification are conducted for each of the included sub-categories separately.

3.3.9.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculations are described for each of the included sub-categories separately.

3.3.9.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4 Industrial processes and product use (NFR sector 2)

4.1 Overview

For Sweden, the most important industries within the industrial sector have historically been base industries such as mining, iron and steel industry and pulp and paper industry. Other important industries when considering emissions from industrial processes include the cement industry, primary aluminum production and processes in the chemical industry.

Generally three sources of information concerning activity and emission data for the industrial process sector have been used:
- Emission data as reported annually by facilities in legally required environmental reports to the authorities.
- National production statistics or similar information at national level.
- Plant specific data collected by direct contacts with facilities.

Under Swedish environmental laws, operators performing environmentally hazardous activities that require a permit by law are obliged to compile and submit an annual environmental report to their supervisory authority. The environmental report consists of three parts:
- Basic identification information about the facility.
- Text section (for example, a description of the facility and the processes, the use of energy, chemicals and raw materials, emissions and conditions in the permit).
- Emission declaration (for example emission data and information on how emission data has been determined)

Data in the environmental reports often originate from measurements or mass balances. The use of default emission factors is limited. Operators that exceed the thresholds for the substances, listed in the Swedish environmental law concerning environmental reports[138], are obliged to compile the emission declaration.

The County Administrative Boards audit the data presented in the operators' environmental reports. Since the beginning of year 2007 environmental reports are submitted electronically via the Swedish Portal for Environmental Reporting (SMP)[139]. This database includes not only emissions, but also basic information

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[138] Swedish EPA, NFS 2016:8, Naturvårdsverkets föreskrifter om miljörapport för tillståndspliktiga miljöfarliga verksamheter.

[139] Swedish Portal for Environmental Reporting, Svenska Miljörapporteringsportalen. https://smp.lansstyrelsen.se/

about the facilities, such as their activity code (national code system, adjustment of NACE four digits), permit, location coordinates, etc.

The use of emission factors in the Swedish inventory for industrial processes is limited and, when used, they are nationally derived or specific for a facility. Where there are a large number of companies within a specific sector, and when all environmental reports are not available, a combination of information from environmental reports and production statistics on the national level, are used to estimate the sector's emissions on a national scale.

Emissions of PM_{10} and $PM_{2.5}$ are in many cases calculated as a fraction of TSP. An overview of the fractions that are used within the sector are included in Annex 3.2.

Sweden's emission inventory is in accordance with EMEP/ EEA Air Pollutant Emission Inventory Guidebook 2016[140], 2006 IPCC Guidelines[141], and the Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution[142].

4.2   Mineral products, NFR2A

4.2.1   Cement production, NFR2A1

4.2.1.1   SOURCE CATEGORY DESCRIPTION

Cement production occurs at three facilities in Sweden, with one being dominant. Emission data is taken from environmental reports and by direct contacts with the facilities. Calculation methods have been discussed with the industry.

The summary of the latest key source assessment is presented in Table 4.2.1.

Table 4.2.1 Summary of key source analysis, NFR2A1, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2A1	SO2	PM10, PM2.5, SO2, TSP

4.2.1.2   METHODOLOGICAL ISSUES

All three cement-producing facilities (owned by one company) are covered in the reported estimates and the emissions have been estimated based on direct information from the company or from environmental reports. NO_X emissions originate mainly from fuel combustion and less from industrial processes. Hence IE is reported for NO_x in NFR2A1 and emissions are reported in NFR1A2f.

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[140] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

[141] 2006 IPCC Guidelines for National Greenhouse Gas Inventories http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

[142] UNECE 2003, Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution. Air Pollution Studies No. 15.

SO_2 emissions are allocated to industrial processes. Reported SO_2 emissions for 2018 have slightly increased compared to 2017, however emissions since 1990 have decreased substantially. Emissions of TSP, PM_{10} and $PM_{2.5}$, also allocated to industrial processes and product use, have been estimated for the whole time period. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

Reported emissions of TSP, PM_{10} and $PM_{2.5}$ from 2010 onwards are substantially lower than average emissions in the 2000's. The decreased emissions are due to the installation of a new dust filter at the largest site in 2010. BC emissions are reported for 2000 onwards and are calculated as a fraction of $PM_{2.5}$ according to EMEP/EEA Guidebook 2016.

NH_3 emissions arise partly due to the selective non-catalytic reduction (SNCR) of NO_X where NH_3 is injected and partly from the raw material. Emissions have been included for the years that such an SNCR has been installed at respective plant. To ensure double reporting does not occur, reported emissions in the energy sector are subtracted from total NH_3 emissions reported by the company. There is a substantial variation in NH_3 emissions over the time series, which is due to variations in ammonia slip and the fact that emissions in the energy sector are subtracted from the total as reported by the company.

Emissions of heavy metals, PAH1-4 and dioxins from the fuels used are calculated based on Quarterly fuel statistics and reported in the energy sector (NFR1A2f).

Table 4.2.2 gives an overview of the allocation of pollutants from cement production.

Table 4.2.2 Allocation of pollutants from cement production.

Pollutant	NFR
NO_X	1A2f
NMVOC	1A2f
SO_2	2A1
NH_3	2A1 and 1A2f
$PM_{2.5}$	2A1
PM_{10}	2A1
TSP	2A1
BC	2A1
CO	1A2f
Metals	1A2f
PAH1-4	1A2f

4.2.1.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions are based on expert judgement. Assessed uncertainties for SO_2 and NH_3 are $\pm 20\%$ and $\pm 400\%$, respectively. For TSP, PM_{10} and $PM_{2.5}$,

uncertainties are estimated to ± 30% each. More information is given in IIR Annex 1.

Time series from cement production reported in NFR2A1 have been reviewed in later years and are considered to be consistent.

4.2.1.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.1.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2021.

4.2.1.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.2.2   Lime production, NFR2A2

4.2.2.1   SOURCE CATEGORY DESCRIPTION

In Sweden, quicklime, hydraulic lime and dolomite lime is produced at a number of facilities, owned by a few companies. Produced lime is, for instance, used in blast furnaces, in sugar and carbide production and in the pulp and paper industry to bind impurities and purify the produced material. The production of lime has increased since 1990 (about 440 kt) and peaked in 2005 (about 730 kt). In 2009 there was a large decrease in lime production due to the global economic recession. In 2017 and 2018, there was an increase in production compared to years 2014-2016, with quantities of around 625 kt, but slightly lower compared to years 2010-2013. Lime production in 2019 summed up to an a comparatively low amount of around 500 kt.
Emissions of SO_2, particulate matter and BC from lime production are reported in NFR2A2.
The summary of the latest key source assessment is presented in Table 4.2.3.

Table 4.2.3 Summary of key source analysis, NFR2A2, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2A2	$PM_{2.5}$, SO_2,	PM_{10}, $PM_{2.5}$, SO_2, TSP

4.2.2.2   METHODOLOGICAL ISSUES

Emissions of SO_2 from 1990 have been estimated for production of quick lime. The estimations from quick lime production are calculated using emission factors presented in environmental reports by one of the producers[143]. The emission factor provided by the lime producer is substantially higher for 2008 than for earlier

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[143] Nordkalk, http://www.nordkalk.com

years. This resulted in an increase of reported SO_2 emissions for 2008 compared to earlier years. However, in 2009 the reported SO_2 emissions were again on the same level as before 2008 due to less use of lime. For 2009-2018 the emission factor for 2008 has been used for the estimation of emissions of SO_2 due to lack of more recent information in the environmental reports.

Emissions of SO_2 from quick lime production intended for the pulp and paper industry are, as in earlier submissions, not included in the estimates reported in NFR2A2 but are reported in NFR2H1. SO_2 emissions from quick lime production within carbide production are from submission 2015 onwards included in NFR2A2.

Emissions of particles from lime production within conventional lime and sugar industries have been estimated using emission factors presented in environmental reports by one of the producers and the size fractions (PM_{10} and $PM_{2.5}$) are based on expert judgement. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

For particle emissions from quicklime production within carbide production, emissions are obtained from the company's environmental report.

BC emissions are included as of submission 2015 and are calculated as a fraction of $PM_{2.5}$ according to EMEP/EEA Guidebook 2016.

From 2005 onwards, facility-specific EU ETS data is used for activity data estimations, where the amount of burnt lime is calculated based on CO_2 emissions. In previous submissions, statistics from the Swedish Lime Association have been used for activity data for the entire time series, however, the statistics have not been produced in time, resulting in the need of an alternative data source. In a study carried out in 2015[144] different data sources were compared, and it was concluded that EU ETS data is the more reliable one. For 1990-2004, statistics from the Swedish Lime Association is used for activity data. Although different data sources are used over the time series, it was concluded that both sources provide similar results and the time series can be considered consistent.

4.2.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY
Uncertainties for emissions are based on expert judgement. Assessed uncertainty for SO_2 is ± 20% and ± 50% for TSP, PM_{10} and $PM_{2.5}$. More information is given in IIR Annex 1.

Time series from lime production reported in NFR code 2A2 have been reviewed in later years and are consistent.

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[144] Mawdsley, I. 2015. Change of activity data for lime production

4.2.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

Activity data reported in NFR2A2 has been compared with national statistics from Statistics Sweden[145] and from the Swedish Lime Industry[146]. The comparison (Figure 4.2.1) shows that national statistics from Statistics Sweden are more irregular but for early years the coherence is good. The differences are especially high in 1998, 1999 and from 2004 and onwards. Comparison between reported activity data and activity data from the Swedish Lime Industry shows good compliance and only has small differences for a few years.

National statistics are based on national surveys mainly aiming at collecting data for economic statistics. In these surveys not all facilities are included and for those the produced amounts are estimated, which might lead to over- or underestimations of, in this case, produced amounts of lime. This leads to larger fluctuations and higher uncertainties in the national statistics from Statistics Sweden compared to data from the Swedish Lime Association and the Swedish Lime Industry.

In a study conducted in 2013[147], Gustafsson and Gerner concluded that national statistics from Statistics Sweden would likely result in overestimated emissions, as imported quantities are likely included in the data.

In 2015 a review of NFR2A2 was made, where different data sources were compared and where it was determined that the best available data source for this source code is the EU ETS. The main reason being that data from the Swedish Lime Association often arrive too late for the ordinary reporting timeline.

As part of the QA / QC procedures, a comparison is made annually between activity data from the different data sources (EU-ETS, Statistics Sweden, the Swedish Lime Association) (Figure 4.2.1).

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[145] Statistics Sweden. Data from the Industrial production database: www.scb.se

[146] Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

[147] Gustafsson, T., Gerner A. 2013. Verification of activity data for lime production.
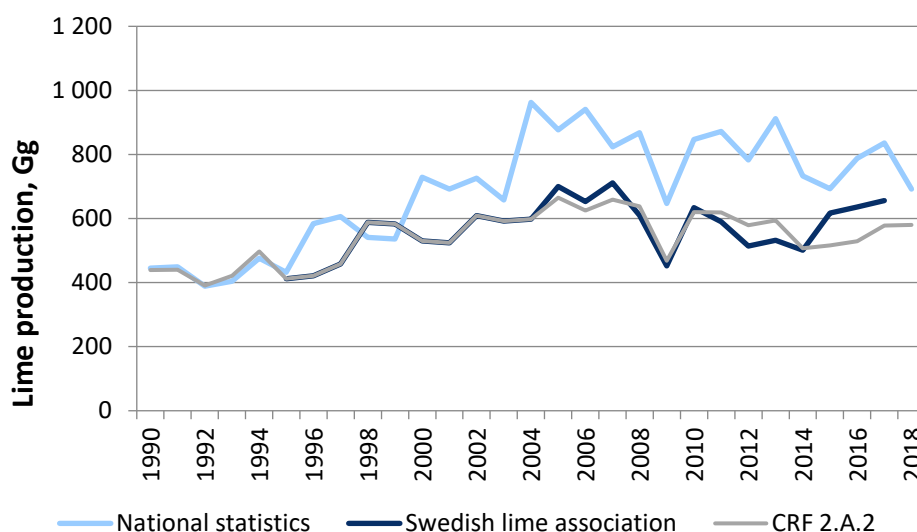
Figure 4.2.1 National total on produced amount of lime according to data from Statistics Sweden, the Swedish Lime Association and reported data in NFR2A2.

4.2.2.5   SOURCE-SPECIFIC RECALCULATIONS

Emission of SO_2, particulate matter and BC in 2018 have been recalculated due to corrected activity data. SO2 emissions decrease by about 0.06 kt, TSP, PM_{10} and $PM_{2.5}$ decrease by about 0.01 kt and BC decreases by less than 0.001 kt.

4.2.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.2.3   Glass production, NFR2A3

4.2.3.1   SOURCE CATEGORY DESCRIPTION

In Sweden there is one facility for container glass production and several small facilities for manual glass production. In addition, emissions from one glass wool producer are included. From glass wool production, emissions of NH_3, NMVOC, particles and BC are reported.

From the float glass production, the total emissions of SO_2 and NO_X from the glass furnace are allocated to 2A3 since a separation in energy-related and process-related emissions is not possible. From the container glass production, SO_2 emissions originating from the raw material and small amounts of NMVOC are reported. Emissions of Cu, Se and Ni from the float glass production and emissions of Se and Ni from the container glass production are reported from Submission 2016 onwards.

The only producer of float glass shut down in 2013. The shut-down of the float glass production facility resulted in very low emissions for 2013 as this is the only

source of NO_X emissions in NFR2A3. Also total emissions of SO_2 in 2A3 decreased to a small extent in 2013-2014 due to the ceased production of float glass. In 2014, NO_X emissions in 2A3 are reported "NA".

Emissions of particulate matter have been reported from the production of container and manual glass for the period 1990-2013, whereas particle emissions from float glass production are reported for the time period 1980–2012 until production shut down. BC emissions are reported for glass and glass wool production for year 2000 onwards and heavy metals from glass production are reported 1990-2019. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

No data regarding CO, dioxin, PAH and HCB emissions are available, and the time series from 1990 and onwards are thus reported NE, in accordance with EMEP/EEA Guidebook 2016.

All other emissions from the glass production facilities originate from combustion for energy purposes and are allocated to the Energy sector (NFR1). A summary of the latest keys source assessment is presented in Table 4.2.4.

Table 4.2.4 Summary of key source analysis, NFR2A3, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2A3	Ni, SO₂, Se	As, NH3, PM10, PM2.5, Se, TSP

4.2.3.2   METHODOLOGICAL ISSUES

The emission data sources for glass production are mixed. Some data derives from reports from the Swedish EPA and some have been received from the companies' environmental reports or from data bases containing data from the environmental reports. For earlier years in the time series emission data are from national reporting to HELCOM and from the Swedish EPA[148]. Data for missing years and parameters have been estimated or interpolated.

Emission factors for Ni, Se and Cu are obtained from EMEP/EEA Guidebook 2016 and applied to activity data. Activity data, produced amount of float and container glass, has been acquired from the annual environmental reports for the two major producing facilities and is presented in table 4.2.5. The facility producing float glass shut down in 2013, leading to significantly less glass production. However, activity data in 2A3 are reported NE in NFR since there are also small glass-producing facilities for which no activity data are provided. Activity data for glass wool production, are not available either.

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[148] Bjärborg, 1998.

Table 4.2.5 Production of float and container glass in Sweden.

Year	Production of float and container glass (ton)
1990	349 929
1995	364 049
2000	385 691
2005	399 322
2010	370 112
2011	407 166
2012	358 919
2013	156 537
2014	158 140
2015	156 524
2016	139 385
2017	172 346
2018	176 678
2019	172 587

Manual glass production used to be an important source of lead emissions. In the early 1990's emissions of lead from the production of manual glass represented roughly 80 % of the total reported lead emission from glass production. Ten years later, the manual glass production adds up to only around 10 % of the lead emissions from glass production. This reduction is probably due to the reduced production of lead crystal glass. Today no lead is used in the production of manual glass.

4.2.3.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions are based on the Guidebook 2016, Guidebook Quality Rating C or D or E and expert judgement. More detailed information is to be found in IIR Annex 1.

Time series from glass production reported in NFR code 2A3 have been reviewed in later years and are consistent.

4.2.3.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.3.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in NFR2A3 in submission 2021.

4.2.3.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.2.4 Quarrying and mining of minerals other than coal, NFR2A5a

4.2.4.1 SOURCE CATEGORY DESCRIPTION

Reported emissions include estimates for quarrying and mining of minerals other than coal. Emissions from five iron ore mines, located near three pellets plants, are reported in NFR 2.C.1 as the emissions from these mines are presented in the environmental reports together with the emissions from the pellet production. The number of metal ore mines in operation varies between years but a total of 16 mines are included in emissions reported in NFR2A5a. Particulate emissions from limestone quarrying, crushing and grinding are also included in NFR2A5a.

The dominating source for emissions of particulate matter in NFR2A5a are limestone quarrying, crushing and grinding. These emissions are based on national statistics on the amount quarried limestone and emission factors. The use of mining explosives causes emissions of mainly nitrogen oxides, NO_X[149]. Ore dressing plants are the dominating source of heavy metals. Data on emissions of NO_X, particulate matter and heavy metals from metal ore mining are mainly collected from the companies' environmental reports to the authorities.

The summary of the latest key source assessment is presented in Table 4.2.6.

Table 4.2.6 Summary of key source analysis, NFR2A5a,2A5b and 2A6, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2A5a, 2A5b, 2A6	PM10, PM2.5, TSP	As, Cd, Hg, PM10, TSP

4.2.4.2 METHODOLOGICAL ISSUES

NO_X emissions originating from the use of mining explosives are only reported for the years 2002 - 2019 due to lack of data for earlier years. Emissions of particles and metals are reported for the whole time period. Emissions of particles from limestone quarrying, crushing and grinding were re-allocated from NFR2A2 in Submission 2016.

4.2.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions of TSP, PM_{10}, $PM_{2.5}$ are based on expert judgement. Assessed uncertainties are $\pm 49\%$, $\pm 49\%$ and $\pm 50\%$, respectively.

Uncertainties for emissions for NO_X and metals are based on Guidebook Quality ratings C and D. Uncertainty for NO_X, Pb, Cd, Hg, As, Cu, Ni and Zn are $\pm 100\%$, $\pm 50\%$, $\pm 100\%$, $\pm 1000\%$, 100%, $\pm 50\%$, $\pm 50\%$ and $\pm 50\%$, respectively.

More information is given in IIR Annex 1.

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[149] Wieland, 2004.

Time series from quarrying and mining of minerals other than coal reported in NFR code 2A5a have been reviewed in later years and are consistent.

4.2.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.4.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed in submission 2020.

4.2.4.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.2.5 Construction and demolition, NFR2A5b

4.2.5.1 SOURCE CATEGORY DESCRIPTION

Reported emissions include estimates for construction and demolition (2A5b). Emissions of particles from construction work are reported. The basis for the calculations is national data on construction activity. Emission factors from EMEP/EEA Guidebook 2016 are used[150].

No data concerning the NMVOC emissions are available, and the time series from 1990 and onwards is thus reported NE, in accordance with EMEP/EEA Guidebook 2016. A summary of the latest key source assessment is presented in Table 4.2.7.

Table 4.2.7. Summary of key source analysis, NFR2A5a, 2A5b and 2A6, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2A5a, 2A5b, 2A6	-	-

4.2.5.2 METHODOLOGICAL ISSUES

The data chosen as a basis for the particle emission estimates from construction work are national statistics on building permits for housing and non-residential buildings (in m^2)[151], 1996 - 2019, and economic statistics on annual investments in construction-related activities[152], 1980 - 2002. As only information on economic investments used for construction work are available for the years 1980 - 1995 this

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[150] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

[151] Statistics Sweden. http://www.scb.se. Housing and construction, Statistics on building permits for housing and non-residential buildings

[152] The Swedish Construction Federation. http://www.bygg.org. Personal communication

information had to be transformed into a unit where emission factors can be used. For the calculations of the time series of emissions, the economic information was normalised to the 1995 level, and the costs per square meter was assumed to be constant through-out the time series. The investments in construction work in 2002 expressed in SEK and normalised to the 1995 level was used as the base year for the transformation of investment information into constructed square meters 1980 - 1995. The data is divided into three sub-groups; houses (detached single family, detached two family and single family terraced), apartments (all types) and non-residential construction (all construction except residential construction and road construction). Emission factors used for calculations of particulate matter from construction activities are all found in the EMEP/EEA Guidebook 2016[153]. In sub-mission 2020 the Tier 1 default approach from EMEP/EEA Guidebook 2016 have been used to calculate emissions from construction and demolition. It is necessary to use the "footprint area" for the different categories in order to calculate the emissions. In the EMEP/EEA Guidebook 2016 a conversion factor is presented only for the non-residential construction. In Sweden this conversion factor is used also for houses and apartments.

4.2.5.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions of TSP, PM_{10}, $PM_{2.5}$ are calculated with the EF from EMEP/EEA Guidebook 2016 (upper and lower). Assessed uncertainties for TSP are ± 146%, PM_{10} are ± 145% and for $PM_{2.5}$ are ± 151%.

More information is given in IIR Annex 1.

Time series from construction work reported in NFR code 2A5b have been re-viewed in later years and are consistent.

4.2.5.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.5.5   SOURCE-SPECIFIC RECALCULATIONS

Particle emissions for 1990-2018 for NFR2A5b Construction and demolition have been updated due to new activity data from Statistics Sweden, resulting in a change for TSP between -0.002 to 0.165 kt, PM_{10} between -0.0005 to 0.050 kt and for $PM_{2.5}$ between -0.00005 to 0.005 kt from the previous submission.

4.2.5.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the sub-mission as part of the national QA/QC plan.

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[153] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

4.2.6 Storage, handling and transport of mineral products, NFR2A5c

Emissions from the source category Storage, handling and transport of mineral products, NFR2A5c, have not been separated from the relevant mineral chapter and are included in respective source category, 2A1, 2A2, 2A3 or 2A5.

4.2.7 Other mineral products, NFR2A6

4.2.7.1   SOURCE CATEGORY DESCRIPTION

Reported emissions include estimates for other mineral products (2A6). In the source category other mineral products, emissions from battery manufacturing and mineral wool production are reported.

Under NFR2A6 "Other mineral products" emissions from battery manufacturing and mineral wool production are reported.

A summary of the latest key source assessment is presented in Table 4.2.8.

Table 4.2.8 Summary of key source analysis, NFR2A5a, 2A5b and 2A6, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2A5a, 2A5b, 2A6	-	-

4.2.7.1.1 Mineral wool production

Mineral wool has been produced at approximately 2-5 different facilities during the time period 1980-2013. Presently, glass and mineral wool production occurs at two facilities run by one company.

4.2.7.1.2 Batteries manufacturing

There is currently one battery producing facility in Sweden. This battery producer of NiCd-batteries previously used iso-propanol in their processes, which gave rise to emissions of NMVOC. The process was changed in 1998 and, since then, no NMVOC emissions occur from this source. Before 2000 another two battery producing facilities were included of which one was emitting NMVOC until 1991. Emissions of lead, cadmium and nickel are reported for the time period from 1990 and onwards.

4.2.7.2   METHODOLOGICAL ISSUES

4.2.7.2.1 Mineral wool production

For mineral wool production, the reported emission data on NMVOC consists of the sum of formaldehyde and phenol.

The data on particulate emissions from mineral wool production provided for the 1990´s and 2000 - 2019 are primarily based on measurements whereas for earlier

years, estimates made by the companies are based on known circumstances influencing emissions. Concerning the particle emissions, only the TSP emissions were provided by industry, and the fractions of TSP as PM_{10} and $PM_{2.5}$ were calculated from emission factors for production of glass fibers provided in the CEPMEIP study[154].

4.2.7.2.2 Batteries manufacturing

The time series from 1990 - 2018 is based on emission data representing three individual facilities. From 2000 there is only one active facility. Between 1988 and 1991 reported NMVOC represents emissions from two facilities. From 1992 to 1998 only NMVOC from one facility is included. This battery manufacturer of NiCd-batteries used isopropanol in their processes, which gave rise to emissions of NMVOC. The process was changed in 1998 and, since then, no NMVOC emissions occur from this source. The heavy metal emissions from the battery manufacture nowadays originate from one facility producing nickel-cadmium batteries. For some years information on emissions is not available, and data has been interpolated.

4.2.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions of NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$ from Mineral Wool Production are based on Guidebook Quality Rating D, E and expert judgements. Assessed uncertainties for are ± 400%, ± 400%, ± 49%, ± 49% and ± 50%, respectively. Uncertainties for emissions for metals are based on Guidebook Quality Rating C, D and expert judgement. Uncertainties for Pb, Cd, Hg, As, Cr, Cu, Ni and Zn are ± 50%, ± 100%, 1000%, ± 100%, ± 100%, ± 50%, ± 50% and ± 50%, respectively.

Uncertainties for emissions of NMVOC, Cd, Ni, Pb from Batteries manufacturing are based on Guidebook Quality Rating D, C and expert judgements. Uncertainties for NMVOC, Cd, Ni and Pb are ± 200%, ± 100%, ± 50% and ± 50%, respectively.

More information is given in IIR Annex 1.

Time series from construction work reported in NFR code 2A6 have been reviewed in later years and are consistent.

4.2.7.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.2.7.5 SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed during submission 2021.

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[154] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

4.2.7.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.3   Chemical industry, NFR2B

4.3.1   Ammonia production, NFR2B1

4.3.1.1   SOURCE CATEGORY DESCRIPTION

There is an annual production of about 5 Gg of ammonia in Sweden, according to UN statistics[155]. This is however not intentionally produced, but is a by-product in one chemical industry producing various chelates and chelating agents, such as EDTA, DTPA and NTA[156]. Emissions from this industry are included in NFR code 2B5. Ammonia production, 2B1, is thus reported as NO in the NFR-tables.

4.3.1.2   METHODOLOGICAL ISSUES

Emission data on NO_X and NH_3 originating from the nitric acid production has been obtained directly from the facilities and from official statistics. Emissions for all years, except 1991-1993, are as reported from the facilities. The reduction of the reported NO_X emissions in 2001 and 2002, compared to earlier years, is a result of one facility being shut down in late 2000 and a second one during 2001. The higher level of NO_X emissions in year 2004 is a result of a long lasting leakage of NO_X from one of the production units at the active facility. During year 2007 catalytic abatement was installed at one of the production units at the active facility and as a result the emissions of NO_X and NH_3 were reduced compared to previous years. According to the company the increased NH_3 emissions in 2010-2014 is a result of prioritizing low NO_X emissions. NH_3 is used as a reducing agent in the de-NO_X catalyst and hence lower NO_X implies more injected NH_3. NH_3 that do not react in the catalyst is emitted to the air. From 2007 emissions are continuously measured in one of the two production lines, from 2011 emissions are continuously measured in both production lines.

Documentation has been received from the facility concerning production data, production capacity and abatement measures, used emission factors and the method used for estimating emissions as well as uncertainty in emission estimates and measurements. However, this information is confidential.

4.3.1.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time series from industrial processes reported in NFR codes 2A-2H have been reviewed in later years and are consistent.

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[155] UN. Commodity Production Statistical Database. Department of Economic and Social Affairs, Statistics Division, as referred in FCCC Synthesis and Assessment report 2002 Part I.

[156] Kindbom, 2004.

4.3.1.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

Experts at the Swedish EPA conduct a review of the inventory, estimates, methodology and emissions factors used. The experts also identify areas of improvement, which constitute part of the basis for improvements in coming submissions.

All quality procedures according to the Swedish QA/QC plan (Manual for SMED's Quality System in the Air Emission Inventories, Kindbom et al. 2005) have been implemented during the work with this submission.

All Tier 1 general inventory level QC procedures and some specific Tier 2 QC procedures, listed in Good Practice Guidance section 8, have been performed and are documented in check-lists.

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable. Data have, when possible, been compared with information in environmental reports and/or other independent sources. Remarks in reports from the UNFCCC and CLRTAP/NEC reviews have been carefully read and taken into account.

According to the Good Practice Guidance, the method of calculating emissions at facilities should be documented. This is currently not done in most cases and will be improved in the future.

4.3.1.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been made.

4.3.1.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are currently planned.

4.3.2   Nitric acid production, NFR2B2

4.3.2.1   SOURCE CATEGORY DESCRIPTION

Production of nitric acid has taken place at three facilities in Sweden. One of these was shut down late 2000, and a second one was shut down during 2001. Therefore, there is currently only one facility producing nitric acid in Sweden. Data on emissions have been obtained directly from the facilities and from official statistics.

A summary of the latest key source assessment is presented in Table 4.3.1.

Table 4.3.1 Summary of key source analysis, NFR2B2, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2B2	-	NO_X

4.3.2.2   METHODOLOGICAL ISSUES

Emission data on NO_X and NH_3 originating from the nitric acid production has been obtained directly from the facilities and from official statistics. Emissions for all years, except 1991-1993, are as reported from the facilities. The reduction of the reported NO_X emissions in 2001 and 2002, compared to earlier years, is a result of one facility being shut down in late 2000 and a second one during 2001. The higher level of NO_X emissions in year 2004 is a result of a long lasting leakage of NO_X from one of the production units at the active facility. During year 2007 catalytic abatement was installed at one of the production units at the active facility and as a result the emissions of NO_X and NH_3 were reduced compared to previous years. According to the company the increased NH_3 emissions from 2010 and on is a result of prioritizing low NO_X emissions. NH_3 is used as a reducing agent in the de-NO_X catalyst and hence lower NO_X implies more injected NH_3. NH_3 that do not react in the catalyst is emitted to the air. From 2007 emissions are continuously measured in one of the two production lines, from 2011 emissions are continuously measured in both production lines. During 2019 a new production line was taken into operation. In connection with that, the oldest production line, with the highest emissions, was shut down.

Documentation has been received from the facility concerning production data, production capacity and abatement measures, used emission factors and the method used for estimating emissions as well as uncertainty in emission estimates and measurements. However, this information is confidential.

4.3.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time series from industrial processes reported in NFR codes 2A-2H have been reviewed in later years and are consistent. Uncertainties for emissions are based on information from the company. Assessed uncertainties for NO_X and for NH_3 are $\pm$ 5%. More information is given in IIR Annex 1.

4.3.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.3.2.5   SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been performed in submission 2020.

4.3.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are currently planned.

4.3.3   Adipic acid production, NFR2B3

No production of adipic acid occurs in Sweden, and thus NO is reported for NFR2B3.

4.3.4 Caprolactam, glyoxal and glyoxylic acid production (NFR2B4)

4.3.4.1 SOURCE CATEGORY DESCRIPTION

No production of caprolactam, glyoxal or glyoxylic acid occurs in Sweden, and thus NO is reported for NFR2B3.

4.3.5 Carbide production, NFR2B5

4.3.5.1 SOURCE CATEGORY DESCRIPTION

Carbide production occurs at only one facility in Sweden. Emissions of TSP, PM_{10}, $PM_{2.5}$ and BC are reported from carbide production and estimates are based on information from the company. The distribution of particulates between TSP, PM_{10} and $PM_{2.5}$ has been determined by expert judgement.

Silicium carbide production does not occur in Sweden.

A summary of the latest key source assessment is presented in Table 4.3.2.

Table 4.3.2 Summary of key source analysis, NFR2B5, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2B5	*PM2.5*	-

4.3.5.2 METHODOLOGICAL ISSUES

The time series of particle emissions from carbide production are considered complete and consistent in methodology. TSP, PM_{10}, $PM_{2.5}$ and BC emissions from carbide production are included and the dominating part of reported emissions arises from flaring of carbide oven gas. The amount of TSP from flaring is reported by the company. The partitioning of particles between TSP, PM_{10} and $PM_{2.5}$ has been done by expert judgement after discussions with the carbide producing company and the emitted mass of PM_{10} and $PM_{2.5}$ are estimated to constitute 90 % and 80% of the total TSP emission, respectively. Particle emissions from quicklime production in the carbide industry are included in NFR2A2. Emissions from flaring are allocated to 2B5 together with all other emissions from carbide production.

Amounts of produced carbide and used carbide (the latter are used for reporting of CO_2 emissions from the same category) are attributable to different processes with different emission factors, meaning that summarizing them in a one set of activity data would not be relevant. Activity data is therefore reported as not applicable, NA.

4.3.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time series from industrial processes reported in the NFR code 2B5 have been reviewed in later years and are consistent. Uncertainties for NFR2B5 are displayed in Annex I.

4.3.5.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.3.5.5 SOURCE-SPECIFIC RECALCULATIONS

No recalculations have been performed in submission 2021.

4.3.5.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are currently planned.

4.3.6 Titanium dioxide production, NFR2B6

No production of titanium dioxide occurs in Sweden, and thus NO is reported for NFR2B6.

4.3.7 Soda ash production, NFR2B7

In 2004[157] a study was carried out to collect data on soda ash use and calculate CO_2 emissions. From this study it became clear that no production of soda ash occurs in Sweden and is hence reported as NO in NFR2B7.

4.3.8 Other chemical industry, NFR2B10a

4.3.8.1 SOURCE CATEGORY DESCRIPTION

This sub-category includes various chemical industries, such as sulphuric acid production, the pharmaceutical industry, production of base chemicals for plastic industry, various organic and inorganic chemical productions, and other non-specified chemical production, which is not covered elsewhere. Approximately 70 larger industrial facilities are included in the emission estimates. Emissions of NO_X, CO, NMVOC, SO_2, NH_3 and TSP are reported. From submission 2020 onwards, emissions of $PM_{2.5}$, PM_{10} and BC from 18 plants are included in the inventory. Emissions from organic chemical processes include cracking and graphite production, inorganic chemical processes include production of carbon black, phosphate fertilizers, NPK and PVC. Also, emissions from production of base plastics such as PE and styrene are included. It is possible that some emissions of NMVOC reported in NFR2B10 should be reported in NFR2D3g (e.g. pharmaceutical industries), but since it has been difficult to make the distinction clear between process emissions and solvent use, all NMVOC emissions from these facilities are included in NFR2B10.

The mercury emissions reported originate from the chloralkali and the sulphuric acid industries. The dioxin emissions reported in 2001 originate from three facilities, in 2002 from four, and for 2003 from six facilities. Due to lack of information about emissions in earlier years, dioxin emissions are reported NE (Not Estimated) for 1980 – 2000.

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[157] Nyström, A-K. 2004. CO_2 from the use of soda ash. SMED report 61 2004.

From some chemical processes, emissions of Se, As and PAH may occur, according to EMEP/EEA Guidebook 2016 (e.g. arsenic from production of PVC and phosphate fertilizers). Data on these emissions are not available, and the time series from 1990 and onwards are thus reported NE.

Time series for HCB emissions has been included to the inventory as a result of a development project[158]. These emissions occur at one facility within inorganic chemical production and have significantly (by more than 90%) decreased between 1990 and 2016.

A summary of the latest key source assessment is presented in Table 4.3.3.

Table 4.3.3 Summary of key source analysis, NFR2B10a, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2B10	Hg, NMVOC, NOx, Pb, SO2	Hg, NH3, Pb, SO2

4.3.8.2   METHODOLOGICAL ISSUES

The primary information on emissions of NO_X, CO, NMVOC, SO_2, NH_3 and TSP are as reported by the companies in their environmental reports. A total of approximately 70 facilities are included, but not all of them report on all emissions. The time series have been reviewed and are considered to be consistent.

From submission 2020 onwards, emissions of TSP, PM_{10} and $PM_{2.5}$, and BC from 18 plants are included in the inventory. For six inorganic chemical processes, emission factors are based on particulate fractions as in EMEP/EEA Guidebook 2016 and applied to TSP emissions reported by facilities. Activity data on production of PVC and carbon black is obtained from the facilities' environmental reports. Activity data on production of phosphate fertilizers was obtained from FAOSTAT[159] for 1990-1995 and from Statistics Sweden database for 1996 onwards. TSP from one organic process (cracking) is obtained from the plant's environmental report and emission factors from EMEP/EEA Guidebook 2016 are used to calculate emissions of the remaining particle fractions. Particle emissions from the remaining plants and processes are calculated based on production data and tier 1 emission factors or tier 2 emissions factors where applicable (e.g styrene production). Particle emissions in this source category come from many different processes and for most of these processes it is not known whether the condensable component is included in the particle emission estimate.

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[158] Hagström, P. 2017, SMED memorandum on HCB emissions from Swedish industrial processes

[159] FAOSTAT http://faostat3.fao.org

Mercury emissions reported in 2B10a originate from processes in the chloralkali industry and from sulphuric acid production. Reported emissions of mercury were derived from information in the SMP database, from the industries' environmental reports or unpublished earlier estimates[160].

Hardly any information on dioxin emissions from the chemical industry has been available. There is only information on dioxin emissions available from a few facilities from 2001. In submission 2020, complete time series have been created by extrapolation.

The SO_2 emissions reported in 2B10a decreased dramatically in 2004 in comparison to earlier years. This is due to that in December 2003 one facility for production of viscose staple fiber was shut down. The yearly SO_2 emissions from this facility represented between 8 and 20 % of the totally reported SO_2 emission in NFR2 – Industrial Processes, 1990 - 2003. In 2007 the CO-emissions were very low from one facility producing PVC. NH_3 emissions decreased since 2007 due to that one facility are working on replacing NH_3 in the production process.

In 2010, emissions in this sub-category were reviewed as part of a quality control project carried out by SMED on behalf of the Swedish EPA, aiming at increasing the quality and reducing the uncertainties of the emissions of the most important substances from chemicals industries in Sweden[161]. Emissions reported in the environmental reports were compared to plant-specific data. Significant discrepancies were investigated, and recommendations were provided on feasible improvements for submission 2011 as well as recommendations on further investigations[162].

Overall, the QC-project showed that total reported emissions from the chemical industries in the Swedish inventory are in coherence with the emission data reported by the plants.

4.3.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY
Uncertainties for NFR2B10a are displayed in Annex I.

Time series for various chemical industries reported in NFR code 2B10a have been reviewed in later years and are considered to be consistent.

4.3.8.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION
Emissions reported in the plant-specific environmental reports are carefully studied annually to retrieve the most appropriate data.

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[160] Levander, 1989.

[161] Swedish EPA. 2010.

[162] Most recommendations on further investigations refer to the energy sector

4.3.8.5   SOURCE-SPECIFIC RECALCULATIONS

Emissions of PM_{10}, $PM_{2.5}$ and BC in 2018 have been recalculated due to updated data on fertilizer production, resulting in an insignificant increase of emissions. NMVOC emissions in 2016 and 2017 from one plant have been recalculated due to updated data provided in the plant's environmental report, resulting in a decrease of less than 0.001 kt or 0.01% of total NMVOC emissions reported in NFR 2B10a.

Table 4.3.4 Summary of performed recalculations in NFR2B10a and their effects on total emissions reported in NFR2 for 2017.

Gas	Value in submission 2019	Value in submission 2020	Change between submissions (%)	Change in relation to NFR2 total (%)
NO_x (kt)	0.747	0.748	0.1	0.01
TSP (kt)	0.018	0.023	27	0.06
PM_{10} (kt)	0.009	0.017	95	0.15
$PM_{2.5}$ (kt)	0.008	0.014	79	0.17
BC (kt)	0.003	0.003	3.7	0.18
NMVOC (kt)	1.73	1.74	0.6	0.02
Hg (t)	0.02	0.02	0.22	0.05

4.3.8.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are currently planned.

4.3.9   Storage, handling and transport of chemical products, NFR2B10b

Emissions from the source category Storage, handling and transport of chemical products, NFR2B10b, have not been separated from the relevant chemical production chapter and are included in respective source category, 2B1, 2B2, 2B5 or 2B10a.

4.4   Metal production, NFR2C

4.4.1   Iron and steel production NFR2C1

4.4.1.1   SOURCE CATEGORY DESCRIPTION

Processes that are included in this category are primary and secondary iron and steel production, direct reduced iron production, iron ore mining, dressing, sintering and iron ore pellets production. The summary of the latest key source assessment is presented in Table 4.4.1.

In Sweden, there are two primary iron and steel facilities equipped with blast furnaces, producing iron and steel products from virgin materials, one plant producing iron sponge and iron powder using direct reduction of iron ore pellets, and about ten secondary steel plants equipped with electric arc furnaces, producing iron and steel products from scrap and direct reduced iron. One of the facilities is using a shaft furnace process to produce stainless steel from recovered flue gas dust and

other waste products. In total, there are approximately 20 different facilities included in the different estimates. Processes occurring besides the primary processes and secondary steel production are rolling mills, pickling and other refinement processes. Emissions from five iron ore mines and from three facilities producing pellets in Sweden are reported in 2C1. Emissions from one sinter producing facility are reported in 2C1 until 1995, when the production closed down.

Table 4.4.1. Summary of key source analysis, NFR2C1, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
2C1	As, CO, Cd, Cr, Cu, DIOX, Hg, NOx, Ni, PAH 1-4, PM10, PM2.5, Pb, SO2, Se, TSP, Zn	Cd, Cr, Cu, DIOX, Hg, Ni, PAH 1-4, PM10, PM2.5, SO2, Se, TSP, Zn

4.4.1.1.1 Primary iron and steel production

There are two plants in Sweden that produce pig iron and steel as part of their integrated coke ovens, blast furnaces and steel converters. The basis of the production is iron ore pellets.

4.4.1.1.2 Secondary iron and steel production

There are about ten secondary steel plants equipped with electric arc furnaces, producing iron and steel products from scrap and direct reduced iron. One of the facilities is using a shaft furnace process to produce stainless steel from recovered flue gas dust and other waste products.

4.4.1.1.3 Direct reduced iron

There is one plant in Sweden which produces iron sponge and iron powder using direct reduction of iron ore pellets.

4.4.1.1.4 Sinter

Emissions from a sinter producing facility are also included in NFR2C1 between 1990 and 1995, when the production closed down.

4.4.1.1.5 Pellet

Emissions from five iron ore mines and three facilities producing pellets in Sweden are reported in NFR2C1.

4.4.1.2   METHODOLOGICAL ISSUES

Process emissions arising from reducing agents in the primary steel works and secondary iron and steel works are reported in NFR2C1. As the plants also generate emissions from fuel combustion (NFR1A1c and NFR1A2a) and fugitive emissions (NFR1B1b and NFR1B1c) the text in this section is closely connected to the text in the energy section.

In the Swedish inventory, emissions from primary iron and steel production and secondary steel production are estimated separately but reported together under 2C1 iron and steel production. In 2C1 also emissions from five major iron ore mines and three facilities producing pellets in Sweden are included.

4.4.1.2.1 *Primary iron and steel production*

Two plants reported in this sector are primary iron and steel producing plants as part of integrated coke ovens, blast furnaces and steel converters. The primary purpose of the use of coal and coke in the blast furnace is to secure oxidation and to act as reducing agents, and the associated emissions are reported as industrial processes from iron and steel production in NFR2C1, according to the 2006 IPCC Guidelines.

Figure 4.4.1 gives an overview of the input and output materials, the carbon flows between the different processes (plant stations), and the CO_2-emitting sources. Note that for non-CO_2 emissions, the different emission sources may vary considerably. The flow chart is however giving a general introduction to the two integrated iron and steel production plants in Sweden.

In the coke ovens (battery), coking coal is turned into coke through dry distillation. During the process, coke oven gas (COG) and by-products are formed. The coke oven gas is purified through several procedures and used as fuel in other plant stations, but smaller amounts are also flared. Produced amounts of coke are fed into the blast furnace together with injection coal to act as reduction agent when pig iron is produced from iron ore pellets. Limestone is added to extract slag and other by-products from the pig iron. Besides pig iron and by-products, blast furnace gas (BFG) is produced in the process. The main use for the blast furnace gas is to heat the cowpers (and in one plant used in the coke oven), but some excess gas is released through flaring.

In the steelworks, pig iron is transformed into various qualities of steel depending on the demand. Dolomite, pig iron, carbide, etc., are added depending on the different metallurgic processes. LD-gas is produced in the steel converter and used as fuel or flared. Some steel is treated in the rolling mills where LPG and different oils are used as fuel.
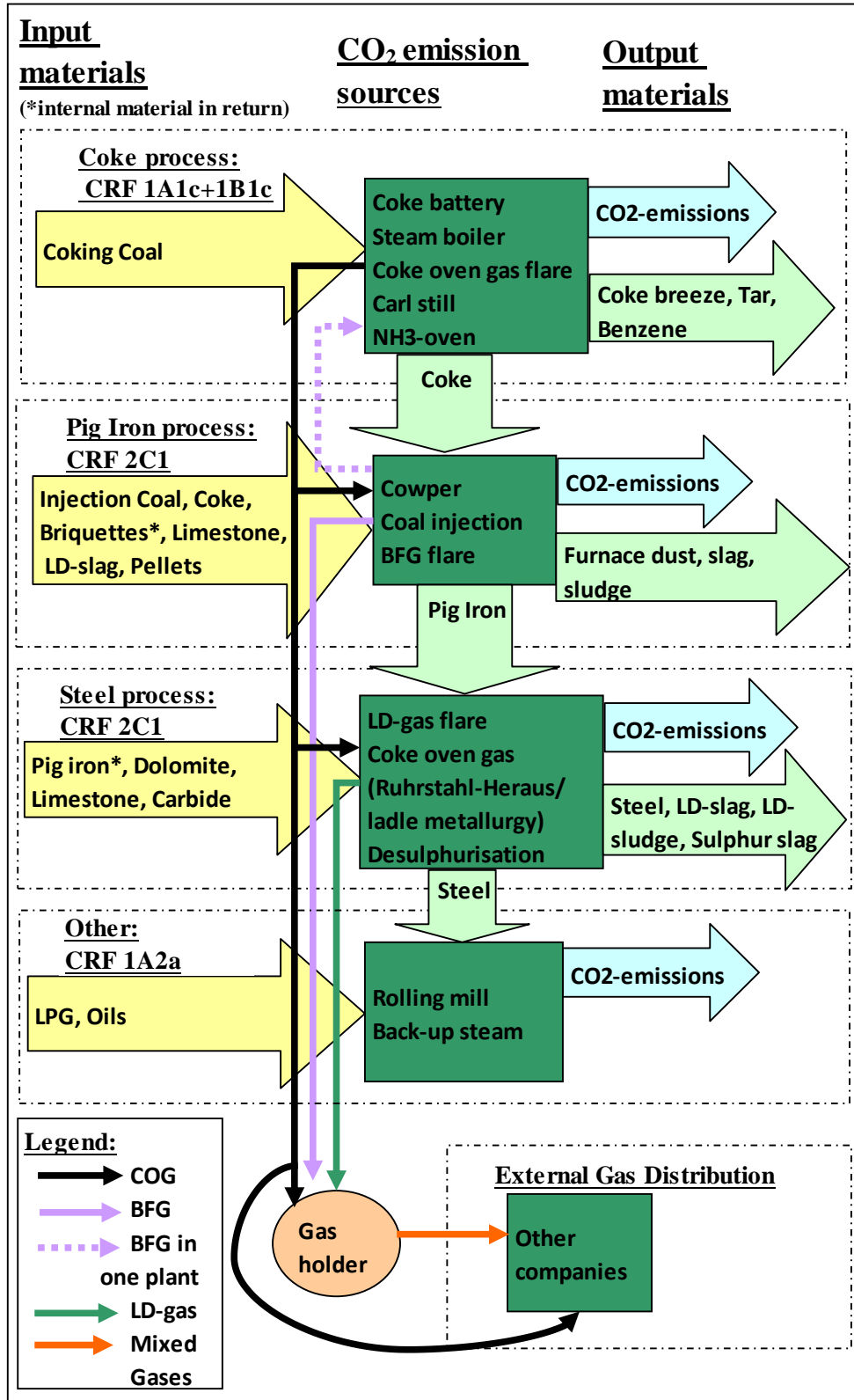
**Figure 4.4.1. Carbon flow chart of integrated primary iron and steel plants in Sweden.
CRF = NFR.**

Considerable amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) from the different processes are collected in a gas holder and sold to external consumers (mainly in NFR1A1a electricity and heat production). These amounts of gases and their associated emissions are allocated to the source category where they are consumed and thus not accounted for in the iron and steel production. This is in line with the 2006 IPCC Guidelines[163] where allocation of emissions from delivered gases is described. During the whole process from raw material to final product, emissions are released.

From 2003 onwards, the plant specific annual environmental reports consist of plant station data on consumed amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) and other fuels, emissions of NO_X, SO_2, several heavy metals, TSP and dioxin (one plant only), but lack information on emissions of NMVOC, CO and some heavy metals. In previous submissions, time series for several pollutants (NO_X, SO_2, NMVOC and CO) were based on information from various sources (e.g. Statistics Sweden and environmental reports). As of submission 2010, the inventory reporting of all emissions is based on information from the environmental reports and some additional information from direct contact with the plants. In order to achieve consistent time series and to estimate emissions of missing pollutants, different IPCC splicing techniques were applied.

Emissions of NO_X, SO_2 and TSP are derived from the environmental reports and direct contact with the plants for the entire time series. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases. The allocation of both plants' total emissions of NO_X, SO_2 and TSP on plant stations and consequently NFR category is presented in Table 4.4.2 for the year 2018.

Table 4.4.2 Allocation of NO_X, SO_2 and TSP emissions for 2019 in integrated primary iron and steel production.

NFR	Plant station	NO_X emissions (kt)	SO_2 emissions (kt)	TSP emissions (kt)
1A1c	Coke Oven	0.39	0.15	52
1A2a	Combustion in Rolling Mills + Power and Heat Production	0.31	0.35	22
1B1b	SO_2 from quenching and extinction at coke ovens		0.03	
1B1c	Flare in Coke Oven (COG)	0.004	0.01	0.13
2B5	Sulphuric acid production		0.01	
2C1	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	0.20	0.60	276
Total		**0.90**	**1.15**	**350**

NMVOC and CO emissions are estimated based on consumed amounts (including flared amounts) of energy gases multiplied by country specific emission factors

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[163] See 2006 IPCC Guidelines: Volume 3: Industrial Processes and Product Use, Box 1.1 (page 1.8)

(see Annex 2). Emissions of NMVOC and CO from coke oven gas, blast furnace gas and LD-gas in the blast furnace and steel converter are allocated to NFR2C1. Consumed amounts of different energy gases and other fuels 1990-2002 are derived by applying the Good Practice Guidance surrogate method using the average values 2003-2007 and CO_2 emissions as the surrogate parameter.

Inventory emissions of heavy metals and dioxin are mostly obtained from the environmental reports, except for selenium, which is included for the first time in submission 2016, calculated using default emission factor from EMEP/EEA Guidebook 2016. In some cases, especially for the early 1990's and for one of the plants, information on heavy metal emissions are lacking and thus estimated by extrapolation using IEF and TSP as a surrogate parameter. Emissions of heavy metals and dioxin are all reported under NFR2C1 although they comprise both process-related emissions and emissions originating in the energy sector (CRF 1.A.1.c).

The PM size fractioning has been made according to reported emissions of PM_{10} and $PM_{2.5}$ from one of the plants. From submission 2015, BC emissions are also reported from year 2000, calculated as a fraction of $PM_{2.5}$, according to the EMEP/EEA Guidebook 2016.

Reported activity data are amounts of pig iron produced (Mton).

4.4.1.2.2 Secondary iron and steel production

For reported emissions from secondary iron and steel production, the companies' environmental reports are the main source of information. NO_X, NMVOC and SO_2 emissions emitted from electric arc furnaces are reported in 2C1. NO_X emissions may also arise from pickling and acid regeneration and NMVOC emissions may arise from rolling mills. These sources are also included in the estimates.

The estimated TSP emissions are based on information from the different facilities. TSP data for missing years have been interpolated. The PM size fractioning has been made according to EMEP/EEA Guidebook 2016. From submission 2015 onwards, BC emissions are reported from secondary iron and steel production from 2000 onwards. Emissions are calculated as a fraction of $PM_{2.5}$ according to EMEP/EEA Guidebook 2016.

The estimated metal emissions from secondary iron and steel processes are based on produced amount of steel, published by the trade association[164], and emission factors, for the years 1990 - 2000. The emission factors used are based on compiled information from older trade specific reports made by the Swedish EPA for some years during the 1990's. Emission factors have been calculated for Cd, Cr; Cu, Hg, Ni, Pb and Zn. For years where the Swedish EPA did not provide trade specific re-

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[164] The Swedish Steel Producers Association. http://www.jernkontoret.se.

ports, or when the trade was not fully covered in the reports, data has been interpolated. Data on As emissions from iron and steel production is somewhat uncertain since reported data are scarce. From 2001 and onwards the emissions are mainly derived from the companies' environmental reports. For years when information is missing in the environmental reports, emissions are estimated using IEF for earlier years and production volumes or amounts of particles emitted.

Dioxin emissions have been compiled for the whole time series. According to the US-EPA[165], dioxin emissions from steel production are strongly dependent on a number of parameters, likely to vary between steel plants. Whether steel is produced from primary metals or from scrap metal is one very important factor, with the latter giving much higher dioxin emissions. Since the emission factors vary widely depending on several process factors, no straightforward calculations using an emission factor were made when compiling a time series of national dioxin emissions from the iron and steel industry. Instead, the estimates for the time period 1980 - 2000 are based on a combination of information concerning production data for scrap-based steel, results from dioxin measurements, earlier estimates and expert judgement in co-operation with the trade association[166]. From 2001 the information concerning the dioxin emissions were derived from the companies' environmental reports.

In submission 2016 emissions of PAH1-4 and PCB from secondary iron and steel processes were reported for the first time, based on national figures on produced amount of steel and emission factors from EMEP/EEA Guidebook 2016.

In submission 2020 and 2021 emissions from flaring of pilot fuel, that occur at several facilities, have been included. The emissions from flaring of pilot gas are calculated based on estimated constant fuel amounts, periodically checked with the facilities. This affected emissions from 1990 of: CO_2, Dioxin, NOx, NMVOC (from 1988) and CO. This also added emissions of CH_4, N_2O and NH_3 for the whole time series.

4.4.1.2.3 *Direct reduced iron*

For emissions estimates for the producer of iron ore based iron powder, almost all reported emissions are obtained from the plant's environmental reports and are verified by collecting and comparing the carbon contents in the amounts of coke, anthracite and output material. To be consistent with calculations of emissions from production of pig iron, limestone used in the production is included in the emissions from the production of iron powder in NFR2C1. Reported activity data is produced amount of direct-reduced iron (iron sponge). For estimation of PM_{10}, $PM_{2.5}$ and BC emissions, the same Tier 1 fractions of TSP or $PM_{2.5}$ as in EMEP/EEA Guidebook 2016 are used. The condensable component of the particle

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[165] U.S. Environmental Protection Agency, 1997.

[166] The Swedish Steel Producers Association. http://www.jernkontoret.se.

emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

Emissions of Se, HCB and PCB are reported, calculated with default Tier 1 emission factors from the EMEP/EEA Guidebook 2016.

4.4.1.2.4 Sinter

During 1990-1995 a sinter plant was in operation at one of the integrated primary iron and steel plants. SO_2 from the sulphur content in the ore were considered to be emitted from the facility. Also particles, heavy metals, dioxin, PAH1-4, PCB and HCB are reported for the facility. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

4.4.1.2.5 Pellet

There are currently five major iron ore mines and three facilities producing pellets reported in NFR2C1e. Emissions considered are SO_2 from the sulphur content in the ore and NO_X emitted as a result of the use of explosives. The use of mining explosives also causes emissions of carbon monoxide, CO. No data concerning the CO emissions are available and the time series from 1990 is thus reported NE[167]. Metals, dioxins and particles are reported for the time period from 1990.

The figures are mainly based on data reported by the companies in their environmental reports. For years with missing data figures have been interpolated or estimated, using expert judgement in cooperation with industry. For distributing the emission of particulates between TSP, PM_{10} and $PM_{2.5}$ for mining activities, the same ratio has been used as the ones presented in EMEP/EEA Guidebook 2016 (PM_{10} = 50% of TSP, $PM_{2.5}$ = 7% of TSP, NFR2A5a, Table 3.2). The distribution of particulates from pellets production are for one of the facilities based on information presented in their environmental report (PM_{10} = 85% of TSP, $PM_{2.5}$ = 80% of TSP). For the other two facilities PM_{10} and $PM_{2.5}$ are 100% of TSP. Content of heavy metals in particulate matter has been calculated using an analysis provided by the leading company. The analysed samples were from the pellets production, but in the emission estimates the factors have been used on the sum of produced sinter and pellets. BC emissions are reported from submission 2015 and are calculated as a fraction of $PM_{2.5}$ according to EMEP/EEA Guidebook 2019. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

In submission 2016 emissions of PAH1-4, PCB, HCB from sintering and iron ore pellets production are reported for the first time. For iron ore pellets production

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[167] Wieland, 2004

also emissions of selenium are reported for the first time. The estimates are based on produced amount and emission factors from EMEP/EEA Guidebook 2019.

The reported emissions of dioxins are based on an emission factor developed using measurements in 2001 and known production data for the same year. Since the production methodology and other circumstances have not changed significantly during the time period, this developed emission factor has been used to calculate the time series of dioxin emissions for the period 1980 - 2001. For 2002 onwards, data on dioxin emissions provided by the companies are reported.

4.4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time series from industrial processes reported in NFR codes 2C1 has been reviewed in later years and are consistent.

Uncertainties for NFR2C1 are displayed in Annex 1.

Primary iron and steel plants *(including direct reduced iron production):* Uncertainties are mostly expert estimates, except for Se, PCB and HCB, for which the emission factor uncertainties are calculated based on the intervals in the EMEP/EEA Guidebook 2016.

4.4.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.4.1.5 SOURCE-SPECIFIC RECALCULATIONS

4.4.1.5.1 *Primary iron and steel plants:*

Small corrections were made in the calculation equations (distribution of emissions between NFR codes) for 2017-2018 for NO_x, SO_2, TSP, PM_{10}, $PM_{2.5}$, BC, Cr, Cu and Ni. The corrections resulted in the emission change by -1% for particle fractions, -0.2% for Cr and Ni, -0.03% for Cu, +2% for NO_x and 4-5% for SO_2, compared to submission 2020.

4.4.1.5.2 *Secondary iron production:*

In submission 2020 emissions from flaring of pilot fuel, that occur at several facilities, was included. However, some emissions were not added in submission 2020 but is corrected in this submission. This added emissions of CH_4, N_2O and NH_3 for the whole time series. This also added emissions of dioxin (1990-2000) and NMVOC (1988-2000). These corrections resulted in the following changes compared to submission 2020: 0,0016 kt CH_4, 0,003 kt NH_3 och 0,00016 kt N_2O per year for the whole time series; 7,8 10^{-7} g I-Teq of Dioxin and 0,1 kt NO_x per year for 1990-2000 and 0,003 kt NMVOC per year for 1988-2000.

The emission of SO_2 during 2018 have been updated due to new information from one facility which resulted in an increase of 0,017 kt SO_2.

4.4.1.5.3 Direct reduced iron:

No source-specific recalculations have been performed in submission 2021.

4.4.1.5.4 Sinter

No source-specific recalculations have been performed in submission 2021.

4.4.1.5.5 Pellet

Minor correction of activity data for one facility in 2018 led to small changes of reported emissions of reported emissions of Se, PAH 1-4, HCB and PCB (-0.013, -0.0006, -0.021 and -0.062 ton, respectively).

4.4.1.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.4.2   Ferroalloy production NFR2C2

4.4.2.1   SOURCE CATEGORY DESCRIPTION

Ferroalloy production is reported for only one facility in Sweden. There is also ferroalloy production at another plant, but since the main production at this facility is of iron and steel, these emissions are reported in NFR2C1, Iron and steel production.

A summary of the latest key source assessment is presented in Table 4.4.4.

Table 4.4.4 Summary of key source analysis, NFR2C2, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
2C2	*Cr, PM2.5, SO2, Zn*	*Cr, PM2.5*

4.4.2.2   METHODOLOGICAL ISSUES

Emission data for SO_2 and NO_X has been obtained directly from the company for all years. Production of ferrosilicon leads to larger emissions of SO_2 compared to production of ferrochromium. From 2005 the production of ferrosilicon has been much reduced and during 2008 – 2011 and 2014 no ferrosilicon was produced. This led to a distinct decrease in SO_2 emissions during these years. In 2012 the production of ferrosilicon was relatively large compared to adjacent years, which resulted in high emissions of SO_2. Also, emissions of NO_X were higher in 2012 compared to years with no ferrosilicon production. In 2013 only small amounts of ferrosilicon was produced, resulting in lower emissions of SO_2 and NO_X compared to 2012.

TSP emissions for 1980-1999 have been calculated based on activity data provided by the company and emission factors derived from reported emissions of TSP in

the company's environmental reports in later years. The calculated average emission factor has been used for all years during the 1990's and was doubled for the period 1980-1989, as suggested by the company experts. From 2000, data on TSP emissions from the company's environmental report were used. $PM_{2.5}$ emissions are estimated from PM_{10} according to relationship in Guidebook 2016. Emissions of BC are estimated from $PM_{2.5}$ according to relationship in Guidebook 2016.

Metals emitted to air from ferroalloy production are primarily Cr, Pb, Ni and Zn. Chromium emission have been reported in the environmental reports to the emission database from 1992. The chromium (Cr) emissions in the database and the activity data obtained from the company have been used to derive emission factors. The average emission factor for 1992-1994 was used for 1990-1991. Zinc and lead emissions have only been sporadically reported to the database during the 1990's. In order to estimate emissions of Zn and Pb, information from older Swedish EPA reports were combined with the reported data on emissions to calculate emission factors for the 1990's. Emissions of Ni from ferroalloys production has been derived from the company's environmental reports or by information from the producer for the years 2003 – 2014. For earlier years no data is available and Ni emissions are hence reported NE (Not Estimated) for the time period 1980 – 2002.

Reported activity data are amounts of carbon in coke and electrode materials (kt).

4.4.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY
Time series from industrial processes reported in NFR codes 2C2 have been reviewed in later years and are consistent.

Uncertainties for NFR2C2 are displayed in Annex 1.

4.4.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION
No source-specific QA/QC or verification is performed.

4.4.2.5   SOURCE-SPECIFIC RECALCULATIONS
No source-specific recalculations are performed in submission 2021.

4.4.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS
No major improvements are currently planned.

4.4.3 Aluminium production, NFR2C3

4.4.3.1 SOURCE CATEGORY DESCRIPTION

The process included in this category is primary aluminium production (2C3).

There is one facility that produces primary aluminium in Sweden. The facility consists of two plants. One of the potlines (plant 1) includes 56 closed Prebake cells (CWPB), each of 150 kA. The other plant (plant 2) consisted of 262 cells and, until the beginning of 2008, operated three Prebake cells and 259 open cells with Söderberg anodes (VSS). The Söderberg anodes were produced in an electrode pulp factory at the facility.

In 2008 a project was started to convert the Söderberg ovens to ovens with Prebake cells. All pot-lines operating the Söderberg technology were shut-down by December 2008. By the end of December 2009, 120 of a total of 262 cells in plant 2 had been converted to the Prebake technology and the conversion to Prebake cells continued under 2010. In the beginning of December 2010 242 Prebake cells in plant 2 were in operation. At the end of December 2010, a power outage lead to big disturbances in plant 2 leading to both increased emissions and major production problems. On January 7, 120 Prebake cells were shut down as a direct result of the power outage. At the end of June 2011 all Prebake cells in plant 2 were restarted and in operation.

PAHs emissions occur in Söderberg plants due to the self-baking anode. Emissions of PAHs during the electrolysis process are small for Prebake plants but from submission 2018 these emissions are calculated from 2009 and onwards using emission factors emissions presented in EMEP/EEA Guidebook 2016.

A summary of the latest key source assessment is presented in Table 4.4.5.

Table 4.4.5 Summary of key source analysis, NFR2C3, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2C3	CO, PM2.5, SO2	CO, PAH 1-4

4.4.3.2 METHODOLOGICAL ISSUES

Primary aluminium production takes place in one facility, where historically both the Prebake and the Söderberg technologies have been used. All pot-lines operating the Söderberg technology were shut-down by December 2008.

The time series of emissions compiled for primary aluminium production include emissions of NO_X, CO, NMVOC and SO_2, particles and PAH. Reported production statistics and emissions data are based on information in the environmental reports or received directly from the company.

From submission 2019 emissions of dioxin from aluminium production are reported as NE since no emission factors for dioxin regarding primary aluminium production are available in EMEP/EEA Guidebook 2016.

Emissions of NO_X have been calculated from production statistics using emission factors defined by Swedish EPA[168]. NMVOC emissions have been calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC[166]. Closing down the Söderberg ovens also ended the need for anode production in late 2008. The shutdown of the anode production ended the tar emissions which meant that also the NMVOC emissions fell sharply. From 2009 and onwards, emissions of NMVOC are reported NE since no emission factor is specified in the EMEP / EEA Guidebook. CO emissions were reported for the first time in submission 2008 and are for 2002 - 2019 as reported in the company's environmental reports. For the period 1990 - 2001 the CO emissions are calculated using production statistics and emission factor provided by the company as also the SO_2 emissions, 1990 - 2005. For 2006 - 2019 SO_2 is as reported by the company in their environmental reports.

The elevated SO_2 emission in 2012 is primarily due to high sulphur content in delivered anodes. The desulfurization of flue gases in the flue gas treatment facilities was not sufficiently efficient. In 2014 the SO_2 emissions were lower than previous year due to improved abatement technology. The improved abatement technology is also shown in low SO_2 emissions from 2015. Also the CO emissions were higher for 2012 compared to previous years. The reason for this is, according to the company, that a new calculation method has been used from 2012 and onwards.

Information concerning production statistics and emissions of TSP and benzo(a)pyrene (BaP) were provided by industry, and only a few missing years have had to be interpolated. The reported emissions also include particles from the foundry located at the site of the primary production plant. The particle size fractions of PM_{10} and $PM_{2.5}$ have been assumed for the whole time period, as given in the CEPMEIP project[169] for primary aluminium production. For particles from the foundry the same particle size fractions of PM_{10} and $PM_{2.5}$ have been used. The assumption is thus that PM_{10} constitutes 95 % and $PM_{2.5}$ 43 % of the reported TSP emissions.

Emissions of benzo(a)pyrene and "PAH" have been reported from the facility as far back as 1984. It is not known which compounds are included in the term "PAH". In 1984 and 1986, benzo(a)pyrene emissions occurred from plant 1 and 2. From 1987 until 2008, emissions occurred only from plant 2, which represents the production of Söderberg anodes and anode baking in the so-called Söderberg ovens. Emissions of PAHs during the electrolysis process are small for Prebake plants

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[168] Ahmadzai, H. Swedish EPA. Personal communication. 2000.

[169] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

but to submission 2018 these emissions are calculated from 2009 and onwards using emission factors emissions presented in EMEP/EEA Guidebook 2016. For 1990 – 2008 emissions of benzo(a)pyrene are as reported by the facility and emissions of benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-de)pyrene are calculated based on information in EMEP/EEA Guidebook 2016.

According to UNEP[170] primary production of aluminium has no significant emissions of dioxins to air. This was confirmed by measurements made at the facility in the late 1970´s and early 1980´s. The measurements in the early 1980´s showed no detectable amounts.

4.4.3.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions are based on Guidebook Qualiaty Ratings. Uncertainty for SO_2, NO_X, NMVOC and particles are $\pm$ 30%, $\pm$ 50%, $\pm$ 75%, and $\pm$ 40%, respectively, and $\pm$ 100% for CO and PAH1-4.

More information is given in IIR Annex 1. Time series from aluminium production reported in NFR code 2C3 have been reviewed in later years and are consistent.

4.4.3.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.4.3.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed in aluminum production during submission 2021.

4.4.3.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.4.4   Magnesium production, NFR2C4

No production of magnesium occurs in Sweden, and thus NO is reported for NFR2C4.

4.4.5   Lead, Zinc, Copper and Nickel production, NFR2C5, 2C6, 2C7a and 2C7b

Production of lead, zinc, copper and nickel does occur in Sweden. However, since Swedish non-ferrous metal smelters produce several metals in the same process, emissions cannot be separated and are all included in NFR2C7c Other metal production. Thus IE is reported in NFR2C5, 2C6, 2C7a and 2C7b.

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[170] UNEP, 2001. Standardized Toolkit for Identification and Quantifications of Dioxin and Furan Releases. http://www.chem.unep.ch/pops/pdf/toolkit/toolkit.pdf

4.4.6   Other metal production, NFR2C7c

4.4.6.1   SOURCE CATEGORY DESCRIPTION

This sub-category includes emission estimates from one large smelter producing different non-ferrous metals such as copper, lead, zinc etc., one metal recycling company mainly producing lead and seven smaller smelters of various kinds. Emissions of particles have been obtained from the large smelter from 1980, for one facility from 1985 and for most of the smaller smelters from 1990. Time series of metal emissions are reported from 1990 and includes also the smaller facilities. In the dioxin time series reported emissions from the large smelter, from the metal recycling company and from two smaller smelters are included.

A summary of the latest key source assessment is presented in Table 4.4.6.

Table 4.4.6 Summary of key source analysis, NFR2C7c, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2C7c	*As, Cd, Cr, Cu, DIOX, Hg, Ni, Pb, SO2, Zn*	*As, Cd, Cr, Cu, Hg, Ni, PM10, PM2.5, Pb, SO2, TSP, Zn*

4.4.6.2   METHODOLOGICAL ISSUES

The reported emissions of SO_2 mainly originate from the sulphur content in the raw materials used in the large non-ferrous smelter, but also represent emissions from the metal recycling company and from one of the smaller smelters. Reported NO_X in 2C7c represents the same facilities. The SO_2 and NO_X time series are considered complete and consistent.

At the large smelter, a variety of processes occur, including both primary and secondary processes, and a number of products are produced. This facility has a long history of submitting environmental reports to the authorities, why emission estimates for all substances were readily available, except for the size fractions of emitted particles. Emission factors for PM_{10} and $PM_{2.5}$, as fractions of emitted TSP, have for the period before 1995 been assigned by expert judgement, in cooperation with company experts. Fractions range from 60 to 95 % for PM_{10} from 1980 until 2003 and from 30 to 80 % for $PM_{2.5}$ during the same period of time. The suggested emission factors according to CEPMEIP[171], valid for 1995, correspond to a value of 90 % for PM_{10} and 80 % for $PM_{2.5}$. For the years after 2003 the emission factors for PM_{10} and $PM_{2.5}$ are the same as for 2003.

Emissions of particles and metals from ten secondary non-ferrous metal smelters have been compiled. Emissions of TSP and metals are reported in the inventory as reported by the companies in environmental reports, and further into an emission database. The data in the database are for early years not complete and consistent,

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[171] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

and several instances of missing values have had to be interpolated in order to complete the time series. Emissions of PM_{10} and $PM_{2.5}$ are calculated by applying particle size fractions implied by Tier 2 emissions factors given in EMEP/EEA guidebook 2016. The applied particle size fraction applied for a plant therefore depends on the type of metal production of the plant.

Primary non-ferrous metal production is not associated with major dioxin emissions to air. From secondary processes, however, dioxin emissions are known to occur. Dioxin emissions from the large smelter, from the metal recycling company and from three smaller smelters are included for the whole time series, 1990 – 2019.

Emissions of PCB from the large smelter, one small smelter and the metal recycling plant are reported for the first time in submission 2019, using the EF from EMEP/EEA guidebook 2016.

Chrome and nickel emissions from copper production are reported from submission 2016 onwards according to Table 4.4.7 below. For the primary copper production facility, nickel emissions are obtained from environmental reports from 1999 onwards and chrome emissions are calculated based on the EMEP/EEA Guidebook 2016 and information from the facility operator regarding abatement efficiency. For one secondary copper production facility, nickel emissions are based on EMEP/EEA Guidebook 2016 with assumptions on applied abatement and chrome is reported as NE due to the lack of tier 2 EF. Activity data is acquired from the facilities' environmental reports. For two smaller smelters, almost all emission data are obtained from the environmental reports and interpolated/extrapolated to cover the period 1990-2010.

Table 4.4.7 Cr and Ni emissions from copper production (NFR2C7c) at four major facilities in Sweden – sources and emission factors used.

Facility	Type of production	Emissions of Ni		Emissions of Cr	
		Source	EF, g/Mg copper	Source	EF, g/Mg copper
1	Primary	Emissions from environmental reports available from 1999 onwards, extrapolation for earlier years		Facility production data and default EF from Guidebook 2016	0.315 (98.5% abatement efficiency according to facility operator)
2	Secondary	Facility production data and default EF from Guidebook 2016	1.3E-05 (abatement with 99.99% efficiency assumed)	Not estimated	No default Tier II EF in the Guidebook 2016
3	Secondary	Emissions from environmental reports available for 2014+extrapolation		Emissions from environmental reports available for 2008-2014+extrapolation	
4	Secondary	Facility production data and default EF from Guidebook 2016	1.3E-05 (abatement with 99.99% efficiency assumed)	Emissions from environmental reports available for 2006 and 2008 + interpolation/extrapolation	

4.4.6.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Time series from industrial processes reported in NFR codes 2C7c have been reviewed in later years and are consistent.

Uncertainties for NFR2C7c are displayed in Annex 1.

4.4.6.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.4.6.5   SOURCE-SPECIFIC RECALCULATIONS

CO emissions 1990-2000 have been recalculated, resulting in an increase of less than 0.001 kt or 0.2% of total reported CO emissions in NFR2C7c for these years.

4.4.6.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are currently planned.

4.4.7   Storage, handling and transport of metal products, NFR2C7d

Emissions from the source category Storage, handling and transport of metal products, NFR2C7d, have not been separated from the relevant metal production chapter and are included in respective source category, 2C1, 2C2, 2C3 or 2C7.

4.5 Other solvent and product use, NFR2D3

A summary of the latest key source assessment is presented in Table 4.5.1.

Table 4.5.1 Summary of key source analysis, NFR2D3, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2D3	*NMVOC*	*NMVOC*

4.5.1 Road paving with asphalt, NFR2D3b

4.5.1.1 SOURCE CATEGORY DESCRIPTION

In this source category, emissions from road paving with asphalt are included. Due to confidentially reasons emissions from asphalt roofing (NFR2D3c) are reported together with emissions from road paving.

Large changes have occurred in asphalt paving technology over the last decade, with a gradual change towards use of water-based emulsions instead of solvent-containing bitumen solutions. Industry representatives estimated that the naphtha content in the solutions used for road paving varied within the interval 17- 50 % during 2002-2014. In this inventory, NMVOC and particles emitted in the process of asphalt paving of roads are included. CO emissions have not been estimated due to lack of information and reported NE in accordance with EMEP/EEA Guidebook 2016.

4.5.1.2 METHODOLOGICAL ISSUES

NMVOC emission estimates for the late 1980s and early 1990s are taken from investigations and inventories made in the early 1990s. Data from 2002 onwards has been calculated based on information from the asphalt producers on the average amount of solvent (naphtha) in the mixtures used for road paving. The producers have also provided figures on the total amount of road paving mixtures delivered in Sweden. It is assumed that all solvents in the solvent-based bitumen are emitted when used. In the calculations, emissions from imported solvent-based bitumen are not included. The amount of imported solvent-based bitumen is most likely very small. Emissions of NMVOC reported for the years in mid- and late 1990s were interpolated. For the years 2014 - 2019, data on amount of road paving mixtures delivered in Sweden was unavailable, and estimates are made based on the asphalt statistics[172] and an implied emission factor for the latest year when this data is available (2013). Since production data regarding the total amount of road paving mixtures delivered in Sweden is only available with a lag of one year, production data and emissions for 2018 are updated. As for 2019, activity data has been set equal to 2018 and will be updated in submission 2022.

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[172] Asphalt in figures https://eapa.org/asphalt-in-figures/ available 2020-01-15

The emissions of NMVOC in 2005 were much higher than adjacent years. This is due to that the production of solvent-based bitumen in 2005 was extremely high, since it was used to repair roads that had been damaged by a severe storm ("Gudrun") that hit large areas of southern Sweden in early 2005.

Particle emissions from road paving with asphalt are reported from submission 2016 onwards. Activity data is obtained from asphalt statistics[173]. Emissions factors are obtained from EMEP/EEA Guidebook 2016. According to the Guidebook, there are two main types of asphalt production technologies – batch mix and drum mix technologies – with different emission factors for particle fractions. Both technologies are applied in Sweden, but the exact proportion is not known. In particle emissions calculations, it is assumed that 50 % of all the asphalt is produced with batch mix technology and another 50 % with drum mix technology. Based on personal communication with branch representatives[174], it is also assumed that all the facilities use fabric filters to catch major part of the particles.

Reported activity data are amounts of produced asphalt in kt.

4.5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions are based on expert judgement. Assessed uncertainties for emissions, from Road paving with asphalt and Asphalt roofing, of CO, NMVOC, TSP, PM_{10} and $PM_{2.5}$ are $\pm$ 216%, $\pm$ 191%, $\pm$ 109%, $\pm$ 97%, and $\pm$ 100%, respectively. More information is given in IIR Annex 1.

Time series from road paving with asphalt reported in NFR code 2D3b have been reviewed in later years and are considered to be consistent.

4.5.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC has been performed.

4.5.1.5 SOURCE-SPECIFIC RECALCULATIONS

Since production data regarding the total amount of road paving mixtures delivered in Sweden is only available with a lag of one year, production data and emissions for 2018 are updated in submission 2021. However, the reported data for 2018 was the same as estimated in submission 2020 which led to no recalculation in submission 2021 for road paving with asphalt.

4.5.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are currently planned.

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[173] Asphalt in figures http://www.eapa.org/asphalt.php available 2016-10-15

[174] Jan Wikström and Lorentz Lundqvist, NCC Roads AB

4.5.2 Asphalt roofing, NFR2D3c

4.5.2.1 SOURCE CATEGORY DESCRIPTION

In this source category, emissions from asphalt roofing are included. Due to confidentially reasons emissions from asphalt roofing are reported together with emissions from road paving (NFR2D3b).

Emissions to air linked to the asphalt roofing industry consist mainly of particles, CO and non-methane volatile organic compounds (NMVOC), which are emitted from asphalt storing tanks and blowing stills, as well as from coater-mixer tanks and coaters. Since the end of the 1990's there have only been two companies in Sweden producing asphalt-saturated felt. Production and emission data provided by the manufacturers have been used for developing emission factors for estimations of the NMVOC and particle emissions. CO emissions are estimated with the default emission factors from EMEP/EEA Guidebook 2016. No measurements or estimations on Ni, Pb, Cd or Cr emissions have been performed by the industry and are consequently reported NE for the whole time-series, in accordance with EMEP/EEA Guidebook 2016.

4.5.2.2 METHODOLOGICAL ISSUES

Data on the total Swedish production of asphalt-saturated felt was provided by the producing companies. Emission factors for NMVOC and particles are based on measurements and calculations made by the manufacturers[175]. The NMVOC emissions from the production of asphalt-saturated felt originate from the felt saturation and coating processes. In submission 2018 new information and measurements from both companies were presented leading to new calculations of NMVOC emissions for the whole time series. The new information also showed that no NVMOC emissions came from leakage from the asphalt storage tanks. The NMVOC and TSP emissions, 1990-2008, for one company are calculated by emission factors based on measurements in 2009. The NMVOC and TSP emissions for 2009-2019 are based on measurements. For the other company the NMVOC emissions, 1990-2015, are calculated by an emission factor based on the measurements in 2016. The factor used for estimating the TSP emission for the other company includes particles emitted from the mineral surfacing process as well as from storage and handling of the mineral products (0.005 kg/Mg) and are based on data from 1997. Emission factors for CO are obtained from EMEP/EEA Guidebook 2016. CO emissions from Swedish production of asphalt-saturated felt are reported from submission 2016 onwards. The notation key for activity data is C (classified). However, emissions from asphalt roofing are reported in 2D3 Road paving with asphalt due to confidentially reasons.

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[175] Danielsson, 2004.

4.5.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions are based on expert judgement. Assessed uncertainties for emissions, from Road paving with asphalt and Asphalt roofing, of CO, NMVOC, TSP, PM_{10} and $PM_{2.5}$ are $\pm 216\%$, $\pm 191\%$, $\pm 109\%$, $\pm 97\%$, and $\pm 100\%$, respectively. More information is given in IIR Annex 1.

Time series from asphalt roofing have been reviewed in later years and are considered to be consistent.

4.5.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No SOURCE-specific QA/QC has been performed.

4.5.2.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations are performed in submission 2021.

4.5.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are currently planned.

4.5.3   Solvent use, NFR2D3a, NFR2D3d, NFR2D3e, NFR2D3f, NFR2D3g, NFR2D3h and NFR2D3i

4.5.3.1   SOURCE CATEGORY DESCRIPTION

Use of solvents and products containing solvents result in emissions of non-methane volatile organic compounds (NMVOC). The model used for estimating the NMVOC emissions reported in the various solvent use categories is described in more detail in Annex 3.1 and is fully described in Skårman et al., 2016[176].

Emission estimates reported for solvent use in NFR2D3 include emissions from the source groups NFR2D3a "Domestic solvent use" (all domestic use except use of coatings), NFR2D3d "Coating applications" (industrial coating, domestic coating, non-industrial coating), NFR2D3e "Degreasing" (use of degreasing in industry), NFR2D3f "Dry cleaning" (non-domestic dry cleaning), NFR2D3g "Chemical product use" (vehicle industry, rubber industry, paint industry, textile industry, leather industry), NFR2D3h "Printing" (printing industry) and NFR2D3i "Other solvent and product use" (all other use of solvents).

NMVOC emissions from asphalt blowing are included in NFR 1B2A4 as this process step occurs at Swedish refineries that produce bitumen for the market. Emissions are not possible to separate from other NMVOC emissions from the plant. For other emissions from asphalt blowing, the Guidebook EFs are judged to be too uncertain to be used as these lack references and would result in fairly high emissions.

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[176] Skårman et al., 2016. Swedish method for estimating emissions from Solvent Use. Further development of the calculation model. SMED report 192.

Emissions of NMVOC from solvents and products containing solvents have decreased by 40 % from 84 kt NMVOC in 1990 to 51 kt NMVOC in 2019. This can largely be explained by the reduced use of solvents in coating application due to a shift to water-based paints.

NMVOC emissions from "Coating applications" (NFR2D3d) have decreased by 78 % from 35 kt NMVOC in 1990 to 8 kt NMVOC in 2019. The largest source of NMVOC from solvents reported in NFR2D3 is, in later years, NFR2D3i "Other product and solvent use". In this sub-sector an increase of emitted NMVOC from 1990 (13 kt) to 2019 (30 kt) can be observed.

4.5.3.1.1 NFR2D3a "Domestic solvent use"

Domestic solvent use is a moderate source of NMVOC but increases over time. This increase, starting in 2002, is due to an increased use of the product groups "washer fluid", "degreasing agents", "diluents and thinners" and "ignition fluids". However, a decrease in emissions from the use of ignition fluids and diluents and thinners can be seen for later years.
Two different emission factors are used for NFR2D3a "Domestic solvent use" for the whole time series:
- Diluted 0.275 (product groups that are used diluted in water)
- Not diluted 0.95 (product groups that are not used diluted in water)
The separation between diluted and not diluted products is a new approach compared to the old calculation model.

4.5.3.1.2 NFR2D3d "Coating applications"

Coating applications is a moderate source of NMVOC and has decreased over time. Coating in industry is the dominating source, followed by domestic coating, and that non-industry coating is of less importance. Emissions of NMVOC from coating application have decreased for the whole time series from 1990. The decrease is both due to reduced use of paints containing solvents and more efficient abatement technologies as indicated in available environmental reports.

4.5.3.1.3 NFR2D3e "Degreasing"

Degreasing within the industry is a minor source of NMVOC and has decreased over time. The estimates are based on abatement efficiency factors given in EMEP/EEA guidebook and the distribution between different abatement technologies has been based on information available in the GAINS-model (scenario: EGEO_Baseline_CLE) for 1995, 2000, 2005 and 2010. Emissions of NMVOC have decreased from 1990, mainly due to a decreased use of degreasing products, but also a shift in technology, i.e. lower emission factors for the later years.

4.5.3.1.4 NFR2D3f "Dry cleaning"

Dry cleaning is a minor source of NMVOC. The time series for emissions of NMVOC from dry cleaning has decreased from 1990 mainly due to less use of dilution and thinner products.

4.5.3.1.5 NFR2D3g "Chemical product use"

Chemical product use is a minor source of NMVOC. The vehicle industry is the predominant source of emissions for chemical product use. The emissions are decreasing over time. The decrease during the 90's is both due to reduced solvent content in used products, as well as more efficient abatement technologies according to information available in environmental reports for the rubber and vehicle industry. The largest sources in Chemical product use are:

- Vehicle industry
- Rubber industry
- Paint industry
- Textile and leather industry

4.5.3.1.6 NFR2D3h "Printing industry"

Printing industry is a minor source of NMVOC. A steady decrease in the emissions of NMVOC from 1990 depends on a reduced use of solvent products within the industry as well as a technology shift.

4.5.3.1.7 NFR2D3i "Other solvent and product use"

Other solvent and product use is a major source of NMVOC and has increased from 1990 to 2015. The increased emissions for the activity are mainly due to a greater use of the product groups "preservatives", "refrigerants", "metal mordants/etchants" and "coolant agents". From 2002 these products account for between around 40 to around 60% of reported emissions in NFR2D3i. From 2016 and onwards the emissions of NMVOC in NFR2D3i are on a somewhat lower stable level.

4.5.3.2 METHODOLOGICAL ISSUES

Activity data regarding all solvent use sub-categories for year 1995 and onwards has been obtained from the Product register at the Swedish Chemicals Agency.

The Products Register does not provide reliable data for the period 1990-1994 for most industry categories. Data from reported time series compiled in a dedicated study on NMVOC emissions carried out by SMED in 2002 (Kindbom et. al, 2004) has been used for the estimations of emissions for 1990 for most sources. Exceptions are the emissions for 1990 for NFR2D3e "Degreasing", "Vehicle industry" (included in NFR2D3g) and NFR2D3i "Other solvent and product use". The 1990 emissions for "Degreasing" have been calculated with activity data from the GAINS-model and emission factors from EMEP/EEA. The 1990 emissions for the

"Vehicle industry" are based on the information that the number of produced vehicles was around 22% lower in 1990 than in 1995, and this information has been used to calculate the NMVOC emissions for 1990. The 1990 emissions for "Other product and solvent use" are based on the correlation between GDP (gross domestic product) (Ekonomifakta, 2016) and emissions from 1995 to 2013. From known GDP for 1990 and the mathematical function for the correlation between emissions and GDP, emissions of NMVOC have been calculated.

The emissions for 1991-1994 have been interpolated based on the available information for1990 and the known data for 1995.

In submission 2020, the model used for estimating NMVOC emissions has been updated[177]. Up until submission 2019, emissions have been calculated over a running average of three years. From submission 2020 on, emissions from solvent use are distributed over three consecutive years based on the assumption that products containing solvents are seldomly used entirely within the same year they have been purchased. More detailed information about the methodology update is given in IIR Annex 3.1.4.

Emission factors given in the literature, for example the EMEP/EEA Guidebook 2016, EU legislations, and other countries IIR´s, have been compiled and included in the model. The used emission factors are presented in Annex 3.1. The model has been developed in order to enable to test different datasets of emission factors. Two emission factors have been developed for each activity; one for solvents used as raw material and one for the remaining quantities. The emission factors for raw material have been set to 0.001 for all SNAP codes, since most of the solvents will end up in the product and will not be emitted during production.

Sweden reports NA for mercury for NFR2D3a since applying the default emission factor of 5.6 mg Hg/capita from the EMEP/EEA Guidebook 2016 would result in emissions of 56.8 kg. Compared to the national total emissions of 0.41 t, this would lead to an increase of emissions by 14%. Sweden estimates emissions to be much lower since fluorescent tubes are handled as electronic waste with hazardous components and are collected and treated according to a national directive enforced in 2014. 97% of households in Sweden consider returning electronic waste to recycling sites as important according to a study conducted within a project aiming to improve the emission inventory carried out in 2017. If Sweden was to estimate Hg emissions from this source, national statistics that are not readily available, has to be compiled in the future.

A new emission factor for products used diluted in water or removed with water has been introduced in the new model for NFR 2D3a and 2D3i. The new emission

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[177] Helbig, T., Danielsson, H. Uppdatering av utsläppsberäkningen i lösningsmedelmodellen, SMED memorandum, 2019.

factor is set to 0.275 and it has been calculated as average of 0.05 and 0.5 according to the information in the EMEP/EEA Guidebook 2016 for NFR 2D3a section 3.2.4. In the previous estimates these products were not treated separately and consequently the emission factor of 0.95 was used also for water diluted products. Activity data and emission factors for the individual SNAP codes 060412i (not diluted), 060412i (not diluted, raw material), 060412ii (diluted) and 060412ii (diluted, raw material) are given in Annex 3.1.

The country specific emission factors have been developed in order to adjust to the old time series 1990-2001, developed by SMED in 2002 (Kindbom et. al., 2004). However, for some activities, errors have been identified in previously reported data for 1990, and consequently those emissions have been corrected. Furthermore, application techniques, available information in the environmental reports for specific industries, as well as other pathways of release (e.g. water), have been considered when developing the country specific emission factors.

4.5.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Reported time series are considered to be consistent, except for the last year (2019) where activity data for the previous year (2018) has been applied for emission calculations. This practice has been questioned by the ERT several times. The reason for Sweden to apply activity data with a delay of one year is due to the fact that activity data from the Product Register is not provided in sufficient time data to be able to perform the calculations and report in a timely manner. Sweden is undertaking efforts to receive data earlier and hence being able to report emissions accordingly. Agreements on the data delivery timeframe from the Product Register by the Swedish Chemicals Agency might be updated in 2021 with the aim for inventory compilers to receive relevant data in time.

Uncertainties for NMVOC emissions for NFR2D3a, NFR2D3d, NFR2D3e, NFR2D3f, NFR2D3e, NFR2D3f, NFR2D3h and NFR2D3i are ± 25% for years 1990-1994 and ± 15% for 1995 and onwards. More detailed information is to be found in IIR Annex 1.

The uncertainties have been discussed and assigned in co-operation with the Swedish Chemicals Agency. Uncertainty estimates for the emission factors were estimated by expert judgement. Information available in environmental reports, in the GAINS model and in the EMEP/EEA guidebook has been taken into account when developing the emission factors.

4.5.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

4.5.3.5   SOURCE-SPECIFIC RECALCULATIONS

Activity data from the Swedish Chemicals Agency is only available with a one-year-delay. In submission 2021 activity data for 2018 is updated. The effect of the update per NFR is presented below.

	NFR2D3a	NFR2D3d	NFR2D3e	NFR2D3f	NFR2D3g	NFR2D3h	NFR2D3i
2018	-0.261	-0.103	0.002	-0.001	0.081	-0.529	2.623

4.5.3.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.6   Other product use, NFR2G4

4.6.1   Source category description

NFR2G4 includes emissions from tobacco smoking and use of fireworks.

4.6.1.1   TOBACCO SMOKING

Emissions of NO_X, CO, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, Ni, Zn, Ni, Dioxin and individual PAHs from tobacco smoking calculated using emission factors from EMEP/EEA Guidebook 2016. For calculation of emissions of Pb, Cd, Hg, As, Cr and Cu from tobacco smoking, emission factors presented in the Norwegian IIR submission 2015 are used.

4.6.1.2   FIREWORKS

Emissions of NO_X, SO_X, CO, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni and Zn from use of fireworks are calculated using emission factors from EMEP/EEA Guidebook 2016.

A summary of the latest key source assessment is presented in Table 4.6.1.

Table 4.6.1 Summary of key source analysis, NFR2G, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2G	*Cu, Ni, PM10, PM2.5, TSP*	*Cu, Ni, PM2.5*

4.6.2   Methodological issues

Emissions of NO_X, SO_X, NMVOC, NH_3, CO, particles, BC, most heavy metals, dioxins and PAH from tobacco smoking and use of fireworks are included in NFR2G4. Emissions from tobacco smoking are based on activity data from official statistics on sold amounts of tobacco for the whole time series from 1990. Activity data include only "legal" purchases of tobacco products in Sweden; products that

are purchased through tax-free and cross-border trading are not included. For fire-works, activity data is based on national statistics available at Statistics Sweden's website on imported and exported amounts of fireworks. No significant production of fireworks occurs in Sweden. Emission factors from EMEP/EEA Guidebook 2016[178] are used for estimates of emissions from fireworks. The emission factors for particles are the default factors from EMEP/EEA Guidebook 2016, which does not specify whether the condensable component is included or not.

Emission factors and activity data for the two sources are listed in Table 4.6.2 and in Table 4.6.3. In Table 4.6.4 the corresponding emissions are shown.

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[178] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

Table 4.6.2 Emission factors for tobacco smoking and use of fireworks.

Pollutant	Tobacco smoking		Fireworks	
	Emission factor	Reference	Emission factor	Reference
NO_X	1.8 kg/ton	EMEP/EEA 2016	0.26 kg/ton	EMEP/EEA 2016
SO_X	NE	-	3.02 kg/ton	EMEP/EEA 2016
CO	55.1 kg/ton	EMEP/EEA 2016	7.15 kg/ton	EMEP/EEA 2016
NMVOC	4.84 kg/ton	EMEP/EEA 2016	NE	-
NH_3	4.15 kg/ton	EMEP/EEA 2016	NA	-
TSP	27 kg/ton	EMEP/EEA 2016	109.83 kg/ton	EMEP/EEA 2016
PM_{10}	27 kg/ton	EMEP/EEA 2016	99.92 kg/ton	EMEP/EEA 2016
$PM_{2.5}$	27 kg/ton	EMEP/EEA 2016	51.94 kg/ton	EMEP/EEA 2016
BC	0.45 % of $PM_{2.5}$	EMEP/EEA 2016	NA	-
Pb	0.05 g/ton	Norwegian IIR, 2015	NE	-
Cd	0.1 g/ton	Norwegian IIR, 2015	1.48 g/ton	EMEP/EEA 2016
Hg	0.1 g/ton	Norwegian IIR, 2015	0.057 g/ton	EMEP/EEA 2016
As	0.159 g/ton	Norwegian IIR, 2015	1.33 g/ton	EMEP/EEA 2016
Cr	0.354 g/ton	Norwegian IIR, 2015	15.6 g/ton	EMEP/EEA 2016
Cu	0.152 g/ton	Norwegian IIR, 2015	444 g/ton	EMEP/EEA 2016
Ni	2.7 g/ton	EMEP/EEA 2016	30 g/ton	EMEP/EEA 2016
Zn	2.7 g/ton	EMEP/EEA 2016	260 g/ton	EMEP/EEA 2016
Dioxin	0.1 ug/ton	EMEP/EEA 2016	NA	-
B(a)P	0.111 g/ton	EMEP/EEA 2016	NA	-
B(b)F	0.045 g/ton	EMEP/EEA 2016	NA	-
B(k)F	0.045 g/ton	EMEP/EEA 2016	NA	-
I(1,2,3-cd)P	0.045 g/ton	EMEP/EEA 2016	NA	-

Table 4.6.3 Activity data for tobacco smoking and use of fireworks.

Year	Amount consumed tobacco	Amount used fireworks
	ton	ton
1990	8 475	987
1995	6 688	1 696
2000	5 599	2 581
2005	5 719	2 347
2010	4 324	1 778
2011	4 417	1 653
2012	4 154	1 405
2013	3 993	1 564
2014	4 068	1 576
2015	3 863	1 341
2016	3 826	1 326
2017	3 649	1 245
2018	C	C
2019	C	C

Table 4.6.4a Emissions from tobacco smoking.

										Tobacco smoking											
Year	NOₓ, ton	CO, ton	NMVOC, ton	NH₃, ton	TSP, ton	PM₁₀, ton	PM₂.₅, ton	BC, ton	Pb, kg	Cd, kg	Hg, kg	As, kg	Cr, kg	Cu, kg	Ni, kg	Zn, kg	Dioxin, mg	B(a)P, kg	B(b)F, kg	B(k)F, kg	I(1,2,3-cd)P, kg
1990	15	467	41	35	229	229	229		0.42	0.85	0.85	1.3	3.0	1.3	23	23	0.85	0.94	0.38	0.38	0.38
1995	12	369	32	28	181	181	181		0.33	0.67	0.67	1.1	2.4	1.0	18	18	0.67	0.74	0.30	0.30	0.30
2000	10	308	27	23	151	151	151	0.68	0.28	0.56	0.56	0.89	2.0	0.85	15	15	0.56	0.62	0.25	0.25	0.25
2005	10	315	28	24	154	154	154	0.69	0.29	0.57	0.57	0.91	2.0	0.87	15	15	0.57	0.63	0.26	0.26	0.26
2006	9.7	297	26	22	146	146	146	0.66	0.27	0.54	0.54	0.86	1.9	0.82	15	15	0.54	0.60	0.24	0.24	0.24
2007	8.8	269	24	20	132	132	132	0.59	0.24	0.49	0.49	0.78	1.7	0.74	13	13	0.49	0.54	0.22	0.22	0.22
2008	7.5	229	20	17	112	112	112	0.51	0.21	0.42	0.42	0.66	1.5	0.63	11	11	0.42	0.46	0.19	0.19	0.19
2009	7.8	238	21	18	117	117	117	0.53	0.22	0.43	0.43	0.69	1.5	0.66	12	12	0.43	0.48	0.19	0.19	0.19
2010	7.8	238	21	18	117	117	117	0.53	0.22	0.43	0.43	0.69	1.5	0.66	12	12	0.43	0.48	0.19	0.19	0.19
2011	8.0	243	21	18	119	119	119	0.54	0.22	0.44	0.44	0.70	1.6	0.67	12	12	0.44	0.49	0.20	0.20	0.20
2012	7.5	229	20	17	112	112	112	0.50	0.21	0.42	0.42	0.66	1.5	0.63	11	11	0.42	0.46	0.19	0.19	0.19
2013	7.2	220	19	17	108	108	108	0.49	0.20	0.40	0.40	0.63	1.4	0.61	11	11	0.40	0.44	0.18	0.18	0.18
2014	7.3	224	20	17	110	110	110	0.49	0.20	0.41	0.41	0.65	1.4	0.62	11	11	0.41	0.45	0.18	0.18	0.18
2015	7.0	213	19	16	104	104	104	0.47	0.19	0.39	0.39	0.61	1.4	0.59	10	10	0.39	0.43	0.17	0.17	0.17
2016	6.9	211	19	16	103	103	103	0.46	0.19	0.38	0.38	0.61	1.4	0.58	10	10	0.38	0.42	0.17	0.17	0.17
2017	6.6	201	18	15	99	99	99	0.44	0.18	0.36	0.36	0.58	1.3	0.55	9.9	9.9	0.36	0.40	0.16	0.16	0.16
2018	6.4	C	17	15	97	97	97	0.43	0.18	0.36	0.36	0.57	1.3	0.54	9.7	9.7	0.36	0.40	0.16	0.16	0.16
2019	6.3	C	17	14	94	94	94	0.42	0.17	0.35	0.35	0.55	1.2	0.53	9.4	9.4	0.35	0.39	0.16	0.16	0.16

Table 4.6.4b Emissions from the use of fireworks.

Year	NOₓ, ton	SOₓ, ton	CO, ton	TSP, ton	PM₁₀, ton	PM₂.₅, ton	Cd, kg	Hg, kg	As, kg	Cr, kg	Cu, kg	Ni, kg	Zn, kg
					Use of fireworks								
1990	0.26	3.0	7.1	108	99	51	1.5	0.056	1.3	15	438	30	257
1995	0.44	5.1	12	186	169	88	2.5	0.097	2.3	26	753	51	441
2000	0.67	7.79	18	283	258	134	3.8	0.147	3.4	40	1146	77	671
2005	0.61	7.09	17	258	235	122	3.5	0.134	3.1	37	1042	70	610
2006	0.63	7.34	17	267	243	126	3.6	0.139	3.2	38	1080	73	632
2007	0.81	9.43	22	343	312	162	4.6	0.178	4.2	49	1387	94	812
2008	0.50	5.83	14	212	193	100	2.9	0.110	2.6	30	857	58	502
2009	0.42	4.92	12	179	163	85	2.4	0.093	2.2	25	723	49	423
2010	0.46	5.37	13	195	178	92	2.6	0.101	2.4	28	789	53	462
2011	0.43	4.99	12	182	165	86	2.4	0.094	2.2	26	734	50	430
2012	0.37	4.24	10	154	140	73	2.1	0.080	1.9	22	624	42	365
2013	0.41	4.72	11	172	156	81	2.3	0.089	2.1	24	694	47	407
2014	0.41	4.76	11	173	157	82	2.3	0.090	2.1	25	700	47	410
2015	0.35	4.05	9.6	147	134	70	2.0	0.076	1.8	21	595	40	349
2016	0.34	4.00	9.5	146	132	69	2.0	0.076	1.8	21	589	40	345
2017	0.32	3.8	8.9	137	124	65	1.8	0.071	1.7	19	553	37	324
2018	0.29	3.35	C	122	111	58	1.6	0.063	1.5	17	492	33	288
2019	0.28	3.24	C	118	107	56	1.6	0.061	1.4	17	476	32	279

Generally, emissions from tobacco smoking have decreased during the years. Emissions from the use of fireworks show an increasing trend during the years 1990 to 2007. The reported emissions for 2008 – 2019 have decreased compared to 2007 since fewer fireworks were imported.

4.6.3 Uncertainties and time-series consistency

Uncertainties for all estimates based on EF from EMEP/EEA Guidebook 2016 are based on information on upper/lower EFs. For other estimates, Guidebook Quality Rating D is used. More information is given in IIR Annex 1.

Time series from tobacco smoking and use of fireworks reported in NFR code 2G4 have been reviewed in later years and are consistent.

Uncertainties for NFR2G4 are displayed in Annex 1.

4.6.4 Source-specific QA/QC and verification

No source-specific QA/QC or verification is performed.

4.6.5 Source-specific recalculations

Minor recalculations for emissions of As, CO, Cd, Cr, Cu, Hg, NO_x, Ni, PM_{10}, $PM_{2.5}$, SO_2, TSP and Zn have been performed for the emission years 2000-2016 and 2018 due to updated activity data for the use of fireworks from Statistics Sweden.

4.6.6 Source-specific planned improvements

No major improvements are currently planned.

4.7 Pulp and paper industry, NFR2H1

4.7.1 Source category description

NFR2H1 includes emissions from pulp and paper.

The pulp and paper industry in Sweden is an important source of industrial process emissions. Emissions from 44 individual pulp and paper facilities are included in the inventory. Of those, six facilities only have energy related emissions which are reported in NFR1A2d. Of the facilities included with process related reported in NFR2H1 one shut down in 2004, two in 2008 and one in 2012. For 2019 emissions from 33 individual pulp and paper facilities are included in reported emissions. The Kraft process (sulphate) dominates in Sweden but there are also emissions from sulphite facilities and facilities that are mainly CTMP (Chemo Thermo Mechanical Pulp) or TMP (Thermo Mechanical Pulp) facilities reported in NFR2H1.

Reported emissions from the pulp and paper industry are for SO₂, NOₓ and TSP based on information in the companies' environmental reports, while other air pollutants are calculated using nationally derived emission factors.

A summary of the latest key source assessment is presented in Table 4.7.1.

Table 4.7.1 Summary of key source analysis, NFR2H1, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2H1	*As, CO, Cd, Cr, DIOX, Hg, NH3, NMVOC, NOx, Ni, PM10, PM2.5, Pb, SO2, TSP*	*As, CO, Cd, Cu, DIOX, Hg, NH3, NMVOC, NOx, Ni, PM10, PM2.5, Pb, SO2, TSP*

4.7.2 Methodological issues

Reported SO₂, NOₓ and TSP emissions from the pulp and paper industry are primarily based on information on production (Figure 4.7.1) and emissions in the companies' environmental reports. The industrial organisation within this sector has for several years co-operated closely with its members in developing sector-specific methods of measuring and calculating emissions, which have resulted in high-quality emissions data. The condensable component of the particle emissions is most likely excluded since emission factors/estimates in general are based on measurements in the flue stack, i.e. not in diluted flue gases.

The emission factors that are used for the other pollutants are derived from national measurements and from international literature. The reported emissions of NMVOC do not include terpenes.
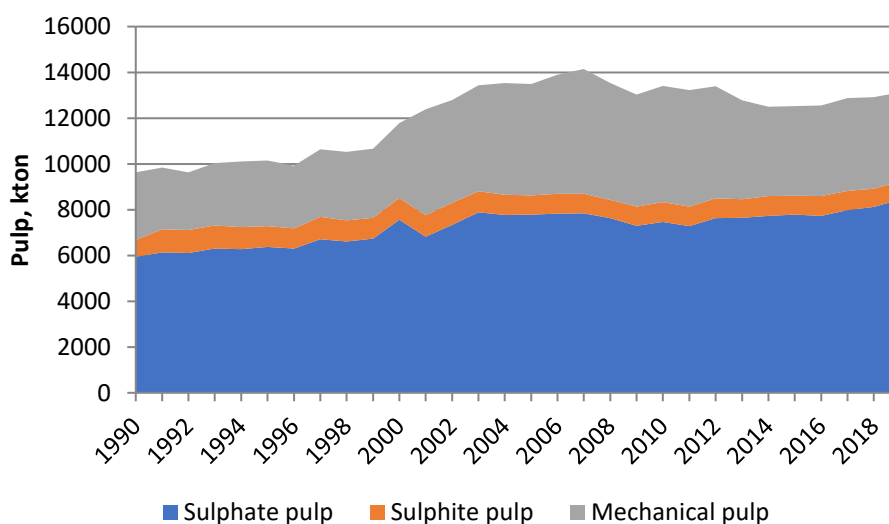
Figure 4.7.1 Production of pulp in Sweden 1990-2019 in kton.

4.7.3 Uncertainties and time-series consistency

Uncertainties for emissions are based on Guidebook Quality Ratings and expert judgement. For TSP, PM, NH_3 as well as heavy metals information from a national good practice guidance project is taken into account. More detailed information is to be found in IIR Annex 1.

Time series from industrial processes for pulp and paper industries reported in NFR codes 2H1 have been reviewed in later years and are consistent.

4.7.4 Source-specific QA/QC and verification

No source-specific QA/QC or verification is performed.

4.7.5 Source-specific recalculations

Exclusion of energy related NO_X emissions for one facility 2003 - 2018, correction of process related NO_X emissions for one facility 2003 and for another facility for 2016 and 2017. The corrections made led to decreased emissions 2003 - 2018 between 0.033 and 0.049 kton yearly.

Exclusion of energy related SO_X emissions for one facility 2003 - 2018, correction of SO2 emissions for one facility 2006, for one facility 2014 - 2016. These minor corrections led to changes of reported emissions between -0.012 and +0.079 kton yearly. Correction of SO_X emissions 2017 and 2018 led to increased emissions of 0.25 and 0.22 kton, respectively.

Updated pulp production for two facilities producing mechanical pulp for 2018 led to decreased emissions of NMVOC of less than 0.0007 kton.

The time series of process related dust emissions have been reviewed and facilities with emission data missing data for some years have been estimated using data for adjacent years. The update led to increased TSP emissions between 0.07 and 0.50 kton yearly for 2002 - 2018. The update of TSP emissions also affects emissions of PM_{10}, $PM_{2.5}$, BC and metals.

4.7.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.8 Food and beverages industry, NFR2H2

4.8.1 Source category description

NFR2H2 includes emissions from the food and beverages industry. The food and drink industry is a moderate source of NMVOC in Sweden. The industry consists of beer, wine and liquor producers, bread, sugar, yeast and margarine and solid cooking fat producers, coffee roasters and animal feed producers.

4.8.2 Methodological issues

Estimations of NMVOC emissions are based on activity data from different official statistics. For wine the estimation of NMVOC emissions are based on data on sold amount[179] together with figures on import and export[180]. NMVOC emissions from beer production are based on the Swedish annual total production of beer[181]. NMVOC emissions originating from the production of liquors, bread, sugar, yeast, margarine and solid cooking fat, coffee roasters and animal feeds are all based on statistics from Statistics Sweden[180]. For the NMVOC emission estimations emission factors presented in Table 4-25 were used. Emission factors from EMEP/EEA that was used in 2H2 can be found at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/2-industrial-processes/2-h-other-industry-production/2-h-2-food-and-drink.

Table 4.8.1 NMVOC emission factors for the reported production activities in NFR2H2 - Food and drink.

Production activity	Emission factor	Unit	Reference EF (footnote)
Liquors	0.6	kg/1000 litres	EF based on emission and activity data from one producer, 2001
Wine	0.08	kg/1000 litres	EMEP/EEA Guidebook 2016
Beer	0.035	kg/1000 litres	EMEP/EEA Guidebook 2016
Bread (sponge dough)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Bread (white)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Bread (wholemeal and light rye)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Bread (dark rye)	0.45	kg/Mg	EMEP/EEA Guidebook 2016
Cakes	0.1	kg/Mg	EMEP/EEA Guidebook 2016
Biscuits	0.1	kg/Mg	EMEP/EEA Guidebook 2016
Breakfast cereals	0.1	kg/Mg	EMEP/EEA Guidebook 2016
Sugar	1	kg/Mg	EMEP/EEA Guidebook 2016
Yeast	1.8	kg/Mg	EMEP/EEA Guidebook 2016
Margarine and solid cooking fats	1	kg/Mg	EMEP/EEA Guidebook 2016
Coffee roasting	0.055	kg/Mg	EMEP/EEA Guidebook 2016
Animal feed	0.1	kg/Mg	EMEP/EEA Guidebook 2016

4.8.3 Uncertainties and time-series consistency

Uncertainties for emissions are based on Guidebook 2016. Assessed uncertainties for NMVOC are ± 200%. More information is given in IIR Annex 1.

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[179] Systembolaget. Försäljningsstatistik. http://www.systembolaget.se

[180] Statistics Sweden. http://www.scb.se. Data from the Industrial production database.

[181] Bryggeriföreningen. http://sverigesbryggerier.se

Time series from industrial processes for food and beverages industries reported in NFR codes 2H2 have been reviewed in later years and are consistent.

4.8.4 Source-specific QA/QC and verification

No source-specific QA/QC or verification is performed.

4.8.5 Source-specific recalculations

Activity data, thus affecting reported NMVOC emissions, have been updated, due to new information for statistics from Statistics Sweden, for 1996-2018. The recalculations resulted in a yearly change in NMVOC emissions between -0.0001 to +0.509 kt.

4.8.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

4.9 Wood processing, NFR2I

4.9.1 Source category description

TSP emissions from wood processing are included for the first time in submission 2016. Emissions from production of plywood, MDF boards and fiber boards are included in NFR2I Wood processing. The number of companies, as well as the amount of produced wood products have decreased over the time series, with 18 companies in 1990 producing around 670 kt to three companies in 2016, producing around 390 kt.

A summary of the latest key source assessment is presented in Table 4.9.1.

Table 4.9.1 Summary of key source analysis, NFR2I, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
2I	TSP	

4.9.2 Methodological issues

Activity data is retrieved from Trä- och Möbelföretagen[182], a Swedish trade organisation for wood and furniture products. For the years 1991-1999, production quantities are interpolated as there is no available data for those years. Reported activity data are amounts of wood products in kt.

TSP emissions are calculated using activity data and the emission factor from EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016. Particle emissions

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[182] http://www.tmf.se/english_1/about_tmf_1

are made up of only filterable particles since they origin from non-combustion processes.

4.9.3 Uncertainties and time-series consistency

The time series reported in the NFR code 2I has been reviewed and is consistent. Uncertainties for emissions of TSP are ± 900%. More detailed information is to be found in IIR Annex 1.

4.9.4 Source-specific QA/QC and verification

No source-specific QA/QC or verification is performed.

4.9.5 Source-specific recalculations

As data was not available in time for submission, emissions for 2018 have been updated in submission 2021. Emissions of TSP increase therefore by about 0.002 kt.

4.9.6 Source-specific planned improvements

No major improvements are currently planned.

4.10 Production of POPs, NFR2J

To the knowledge of the Swedish inventory compilers, there is no production of POPs in Sweden. Thus no emissions are reported from the source category NFR2J.

4.11 Consumption of POPs and heavy metals, NFR2K

Emissions from consumption of POPs and heavy metals are not included in the Swedish emission inventory. Calculations have been made using default emission factors from the EEA/EMEP Guidebook 2016, however resulting emissions were judged to be unreasonably high for Swedish conditions[183].

4.12 Other production, consumption, storage, transportation or handling of bulk products, NFR2L

No other production, consumption, storage, transportation or handling of bulk products occur in Sweden, thus no emissions are reported in NFR2L.

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[183] Yaramenka, K., Mawdsley, I., Gustafsson, T. 2014. Utveckling av rapportering till CLRTAP NFR 1B, 2 och 5 map EMEP Guidebook, steg 1. SMED rapport nr 161 2014 (available in Swedish)

5 Agriculture (NFR sector 3)

5.1 Overview

In the agriculture sector, emissions of NH_3, NMVOC, NO_X and particulate matter (TSP, PM_{10} and $PM_{2.5}$) are reported. The general trend for all emissions is a continuous decline. One of the driving forces to this is a decreasing agricultural sector in Sweden, which has resulted in a decrease of agriculture land and decreasing livestock populations. Over the past 50 years, the agriculture in Swedish has undergone radical structural changes and rationalisations. One fifth of the Swedish arable land cultivated in the 1950s is no longer farmed. Closures have mainly affected small holdings and those remaining are growing larger. Livestock farmers predominately engage in milk production and the main crops grown in Sweden are grain and fodder crops. The decrease of total agricultural land area has continued since Sweden joined the European Union in 1995, but the acreages of land for hay and silage has increased. From 1990 there has been a steady decrease in the number of dairy cows. However, milk yield per head has increased.

Field burning of crop residues is prohibited in Sweden[184]. Dispensation can be given for pest control reasons only. According to an inquiry sent out by the Swedish Board of Agriculture field burning only occurs to a very limited extent in Sweden and therefore notation key NO is used for emission from 3F Field burning of crop residues.

5.2 Manure management, NFR 3B

5.2.1 Source category description

Manure management and housing of livestock give rise to emissions of ammonia, NMVOC, NO_X and particulate matters. Emissions of ammonia derive from storage, handling and application of stable manure. Emissions from application of manure are calculated here but reported under sector 3D. NMVOC emissions from animal husbandry originate from feed, especially silage, degradation and decomposition of feed in the rumen and in the manure. In the Swedish inventory, emissions of NMVOC from manure management from dairy cattle is the main contributor. Nitric oxide is formed through biological oxidation (i.e. nitrification) of ammonia or ammonium by aerobic bacteria. Nitric oxide is emitted from the surface layers of stored manure, during application of manure to soil and from deposition of excreta during grazing. The same processes also result in emissions of nitrous oxide (N_2O). These emissions are accounted for in the reporting to the UNFCCC. Housing of livestock causes emissions of particulate matter. The emissions originate mainly from feed, but bedding materials such as straw or wood shavings can also give rise to airborne particulates.

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[184] SJVFS 2018:40, §15

A summary of the latest key source assessment is presented in Table 5-1.

Table 5-1 Summary of key source analysis, NFR 3B, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
3B1 Dairy cattle	*NH3, NMVOC, PM10, PM2.5, TSP*	*NH3, NMVOC, PM2.5*
3B1 Non-dairy cattle	*NH3, NMVOC, PM10, PM2.5, TSP*	*NH3, NMVOC, PM2.5, TSP*
3B3 Swine	*NH3, NMVOC, PM10, PM2.5, TSP*	*NH3, PM2.5*
3B4 Fur-bearing animals		*NH3*
3B4 Horses	*NH3, NMVOC*	*NH3, NMVOC*
3B4 Poultry	*NH3, NMVOC, PM10, PM2.5, TSP*	*NH3, NMVOC, PM10, PM2.5, TSP*
3B4 Sheep	*NH₃*	*NH₃*

5.2.2   Methodological issues

5.2.2.1   ACTIVITY DATA

One of the main sources of activity data used in the agriculture inventory is the survey "Use of fertilisers and animal manure in agriculture"[185]. This survey has been performed by Statistics Sweden every second or third year since 1988. The latest was for 2018/2019. In this survey data was collected from 5 150 agricultural holdings, which was an increase of about 1500 holdings since 2013. Detailed information about the design of the survey can be found in the report series MI 30 SM[186]. It is from this survey we receive data on, distribution of different manure management systems (solid manure, liquid manure and deep litter) for each different kind of animal manure, design of manure containers (e.g. with or without a roof), time and method of manure application, timespan before mulching of manure and data on stable periods. Since dairy cows regularly are stabled at nights and also spend time in the stables during milking, the data on stable periods is combined with the assumption that 38% of the dairy cows manure is produced in the stable during the grazing period.

Another important source of activity data is the farm register from the Swedish Board of Agriculture. From this register, data on livestock population is obtained for most animal categories (table 5-2 and 5-3). However, other sources are used for slaughter chicken, horses, reindeers, and furred animals. Concerning horses, the farm register underestimates the number of horses because only horses on farms are included in the sampling frame (i.e. not horses for leisure activities). Three separate surveys[187] have estimated total number of horses in Sweden in 2004, 2010 and 2016. These estimates are used in the inventory instead. To estimate the number of slaughter chickens we use the Swedish official slaughter statistics together

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[185] Statistics Sweden, report series MI 30 SM.

[186] http://www.scb.se/mi1001

[187] Swedish Board of Agriculture, report series JO 25 SM http://www.scb.se/jo0107

with timespan between production rounds to estimate the average annual population. The number of minks is provided by the Swedish Furred Animals Association.

Data on manure and nitrogen excretion for different animals are compiled by the Swedish board of agriculture and based on nutrient balance calculations. The underlying data are based on a variety of sources. The data for the most significant animal groups (i.e. cattle and swine) are from public reports produced by the Swedish Board of Agriculture. Some of the data for the less significant animal groups are based on expert opinions.

Data on milk yield for dairy cows, which affects the amount of nitrogen and manure excreted, is obtained from the Swedish board of agriculture (table 5-3).

Table 5-2 Population size of different animal groups (1000s heads).

Year	Dairy cows	Non-Dairy Cattle				Swine				Sheep	
		Suckler cows	Heifers	Bulls and steers	Calves	Sow	Pig for meat production	Piglet	Boar	Sheep	Lamb
1990	576	75	337	206	524	221	1 276	758	8.6	162	244
1995	482	157	370	226	542	237	1 300	768	7.6	195	266
2000	428	167	365	224	500	202	1 146	566	4.2	198	234
2005	393	177	327	200	508	185	1 085	538	2.7	222	249
2010	348	197	322	191	479	154	937	427	2.3	273	292
2015	340	184	311	178	467	140	830	384	1.5	289	306
2017	322	208	307	193	472	140	836	385	1.6	301	305
2018	319	214	306	192	475	130	901	361	1.5	296	291
2019	306	210	310	190	451	128	943	383	1.5	280	269

Table 5-2 (continued).

Year	Horses	Goats		Other		Poultry			
	Horse	Goat	Kid	Reindeer	Fur-bearing animals	Laying hen	Turkey	Chicken	Slaughter Chicken
1990	316	2.8	2.8	271	297	6 400	122	2 200	4 476
1995	316	2.8	2.8	253	254	6 100	122	1 800	7 055
2000	316	2.8	2.8	221	276	5 700	122	1 700	7 896
2005	323	3.7	3.7	261	290	5 100	122	1 700	8 453
2010	363	5.2	5.2	250	180	6 061	130	1 647	9 159
2015	363	6.8	6.8	250	210	7 571	156	1 842	11 044
2017	356	7.7	7.7	254	200	7 294	131	1 994	11 723
2018	356	7.8	7.8	249	200	7 699	131	1 927	11 568
2019	356	8.1	8.1	241	200	8 909	127	2 067	12 211

Table 5-3 Activity data used for estimating the emissions from dairy cattle.

Year	Total milk delivered* (kt)	Average fat content (%)	Average protein content (%)	Yield per cow, kg ECM/yr	Feed intake (MJ/day)
1990	3 432	4.31	3.36	6 503	270.8
1995	3 243	4.33	3.34	7 352	291.2
2000	3 297	4.18	3.28	8 240	309.8
2005	3 163	4.25	3.38	8 734	319.6
2010	2 862	4.23	3.41	8 928	320.7
2015	2 933	4.25	3.42	9 401	329.9
2017	2 817	4.21	3.47	9 518	332.7
2018	2 760	4.2	3.46	9 385	329.5
2019	2 704	4.24	3.5	9 686	336.8

* Including on farm consumption.

Table 5-4 Livestock grazing periods (percent).

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Swine	Sheep, Goats	Reindeer	Horses	Poultry
1990	24.8	48.3	45.8	36.7	35.0	NO	50	100	50	NO
1995	24.8	48.3	45.8	36.7	35.0	NO	50	100	50	NO
2000	24.8	51.7	49.2	36.7	36.7	NO	50	100	50	NO
2005	26.1	58.9	53.7	30.2	36.6	NO	50	100	50	NO
2010	25.0	54.1	51.7	26.4	31.4	NO	50	100	50	NO
2015	24.5	52.1	49.7	18.6	31.7	NO	50	100	50	NO
2017	24.4	54.3	51.1	23.6	32.9	NO	50	100	50	NO
2018	24.4	54.3	51.1	23.6	32.9	NO	50	100	50	NO
2019	25.3	57.4	52.7	23.9	35.7	NO	50	100	50	NO

Table 5-5 Liquid waste management systems (percent)

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats, horses, reindeer and fur-bearing	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	22.6	15.5	16.3	19.0	19.5	44.0	44.0	0.0	25.0	0.0
1995	30.6	21.0	22.0	25.8	26.5	63.0	63.0	0.0	25.0	0.0
2000	39.0	12.5	13.2	16.4	16.4	80.5	25.8	0.0	25.0	0.0
2005	50.8	5.9	19.6	22.5	18.9	91.3	31.8	0.0	20.8	0.0
2010	57.1	11.2	22.3	28.6	16.8	91.2	60.4	0.0	12.0	0.0
2015	60.4	10.0	24.9	31.4	16.1	81.1	49.5	0.0	9.3	0.0
2017	64.2	10.7	25.8	38.0	20.7	83.1	53.6	0.0	8.9	0.0
2018	63.7	10.6	25.6	37.7	20.6	81.8	52.8	0.0	8.9	0.0
2019	64.1	9.8	24.2	36.7	16.9	80.3	46.8	0.0	6.9	0.0

Table 5-6 Solid waste management systems (percent)

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats	Reindeer	Fur-bearing animals	Horses	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	51.9	28.9	30.3	35.5	36.4	54.0	45.0	50.0	0.0	100.0	33.0	55.0	0.0
1995	43.8	23.4	24.5	28.7	29.4	35.0	26.0	50.0	0.0	100.0	33.0	55.0	0.0
2000	35.3	28.0	29.5	36.7	36.7	18.0	67.0	50.0	0.0	100.0	33.0	55.0	0.0
2005	22.4	19.0	16.7	27.2	22.8	6.2	45.6	50.0	0.0	100.0	33.0	72.6	0.0
2010	16.4	20.1	15.2	25.8	22.0	5.2	30.4	50.0	0.0	100.0	33.0	88.0	0.0
2015	10.8	19.9	11.9	25.3	16.1	3.4	36.0	50.0	0.0	100.0	33.0	78.1	0.0
2017	7.2	14.7	9.4	13.4	14.3	2.2	19.9	50.0	0.0	100.0	33.0	89.8	0.0
2018	7.2	14.7	9.3	13.4	14.3	2.2	19.9	50.0	0.0	100.0	33.0	89.8	0.0
2019	5.1	10.3	7.9	10.6	12.0	2.3	23.8	50.0	0.0	100.0	33.0	89.9	0.0

Table 5-7 Deep litter waste management systems (percent).

Year	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Sheep, goats, reindeer, Fur-bearing animals	Horses	Laying Hens, Chickens	Slaughter Chickens, Turkeys
1990	0.8	7.2	7.6	8.9	9.1	2.0	11.0	0.0	2.0	20.0	100
1995	0.8	7.2	7.6	8.9	9.1	2.0	11.0	0.0	2.0	20.0	100
2000	0.8	7.7	8.1	10.1	10.1	1.0	7.0	0.0	2.0	20.0	100
2005	0.4	16.0	9.8	19.9	21.6	1.3	22.1	0.0	2.0	6.6	100
2010	0.8	14.5	10.5	18.8	29.5	0.9	7.4	0.0	2.0	0.0	100
2015	0.9	17.1	11.9	22.4	34.5	1.5	6.0	0.0	2.0	12.6	100
2017	0.8	19.3	12.1	22.5	30.3	0.7	17.5	0.0	2.0	1.3	100
2018	0.8	19.3	12.1	22.5	30.3	0.7	17.5	0.0	2.0	1.3	100
2019	1.0	21.3	13.3	25.6	33.5	1.0	19.8	0.0	2.0	3.2	100

Table 5-8. On-farm anaerobic digestion treatment and composting systems (percent). Affects only cattle, swine and horses.

Year	Anaerobic digestion in on-farm digesters							Composting
	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine	Horses
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0
2000	0.0	0.0	0.0	0.0	0.0	0.2	0.1	15.0
2005	0.1	0.0	0.0	0.1	0.1	0.4	0.1	15.0
2010	0.2	0.1	0.1	0.1	0.1	0.9	0.6	15.0
2015	1.2	0.3	0.6	0.8	0.5	4.8	2.9	15.0
2017	1.2	0.3	0.6	0.8	0.6	4.8	3.1	15.0
2018	1.3	0.4	0.6	0.9	0.6	5.0	3.2	15.0
2019	1.4	0.4	0.6	1.0	0.6	5.2	3.1	15.0

Table 5-9. Anaerobic digestion treatment in co-digesters (percent). This fractions of the manure are for storage accounted in the waste sector.

Year	Anaerobic digestion in co-digesters						
	Dairy cattle	Suckler cows	Heifers	Bulls and steers	Calves	Pigs for meat production	Other swine
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.1	0.0	0.0	0.1	0.1	0.4	0.1
2005	0.2	0.1	0.1	0.1	0.1	0.9	0.3
2010	0.5	0.1	0.2	0.3	0.2	1.9	1.2
2015	2.2	0.6	1.1	1.5	1.0	9.2	5.6
2017	2.2	0.7	1.1	1.6	1.1	9.3	6.0
2018	2.7	0.8	1.3	1.9	1.3	10.4	6.7
2019	3.0	0.8	1.3	2.1	1.3	11.1	6.5

5.2.2.2 EMISSIONS OF AMMONIA (TIER 2) AND EMISSIONS OF NITRIC OXIDE

To estimate the emission of ammonia from 1990 to 2004, and the emission of NO_X for the complete time series, Sweden use a slightly modified version of the default tier 2 model described in the EMEP/EEA guidebook 2016. The ammonia emissions from 2005 and onwards are instead estimated with a country specific model (described in detail below). The main modification of the tier 2 model is that we use total N instead of TAN to estimate the emissions from stable ventilation and manure storage. The reason is that the country specific emissions factors we use are developed in that way. The emission factors we use in the tier 2 model are the same as in the country specific model but here aggregated to match the calculation level used in the default model (e.g. aggregated to different animal categories instead of different spreading methods as we use in the CS model). The rationale for not using the default emission factors is that the climate in Sweden is considerable cooler then the European average and this has a profound effect on the average annual ammonia emission factors[188].

The default tier 2 methodology for both ammonia and NOx follows the same step-wise procedure from the guidebook. This methodology is utilized for all the livestock categories described in table 5-2 and 5-3. To ensure consistency with the greenhouse gas inventory, the same parameters are used in both inventories. The manure management systems taken into account are liquid systems, solid systems, deep litter, anaerobic digesters and composting. The digesters are divided into on-

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[188] Swedish Institute of Agricultural and Environmental Engineering (JTI) 2002

farm digesters and co-digesters. Emissions from on-farm digesters are allocated to the agriculture sector while emissions from co-digesters are during storage accounted for in the waste sector while emissions during ventilation are accounted for in the agriculture sector. Emissions during application of digest from co-digesters are also accounted in the agriculture sector as other organic fertilisers.

Step 1
By using the annual nitrogen excretion rates (table 5-12) combined with the distribution of different manure management systems (MMS) (table 5-5 to 5-8) and stable periods (table 5-4) we calculate the amount of total-N that is excreted in the stables and on the grazing grounds.

I.e. $m_{build\_MMS\_N}$ and $m_{graz\_N.}$

Step 2
Here we calculate the NH_3-N losses from the livestock buildings by multiplying the amount of excreted nitrogen with the emission factor for all the different manure management systems (table 5-10).

$E_{build\_MMS}NH_3\text{-}N = m_{build\_MMS\_N} \times EF_{build\_MMS}$

Step 3
In this step, we estimate the amount of total-N in the manure that remains after the ventilation losses. This estimate the amount of N stored in the different manure management systems.

$m_{storage\_MMS\_N} = m_{build\_MMS\_N} - E_{build\_MMS}NH_3\text{-}N$

Step 4
Here we estimate the nitrogen losses that occur from emissions of NH_3 as well as NO_X during storage. In Sweden, no manure is spread directly without being stored before application so this shortens the calculations slightly compared to the guidebook. The emission factors used can be seen in table 5-11. To estimate the emissions of NO_X we have used the default solid manure emission factors for solid manure, deep litter and compost (1%). For liquid manure and digestate we have used the default EF for slurry (0.01%). These values are used together with the country specific values of the proportion of total N that is ammoniacal nitrogen (TAN) (table 5-12).

$E_{storage\_MMS}NH_3\text{-}N = m_{storage\_MMS\_N} \times EF_{NH3}$

$E_{storage\_MMS}NO\text{-}N = m_{storage\_MMS\_N} \times TAN_{MMS} \times EF_{NOx}$

Step 5

In this step, we calculate the amount of N that is available for application on agricultural soil. That is, subtracting the amount of nitrogen lost during storage.

$$m_{applic\_MMS\_N} = m_{storage\_MMS\_N} - E_{storage\_MMS}NH_3\text{-}N$$

Step 6

Emissions of ammonia from application of manure are estimated. First, the available total N is translated to amount of TAN, because the country specific emission factors we use are expressed as fraction of TAN lost as ammonia (table 5-12).

$$E_{applic\_MMS}NH_3\text{-}N = m_{applic\_MMS\_N} \times TAN_{MMS} \times EF_{Applic\_MMS}$$

Step 7

The emissions of NO_X from application of manure are estimated based on total amount of nitrogen in manure applied to agricultural soils. The emissions are reported under NFR category 3.D. The emission factor used is the default one from the guidebook.

$$EM_{applic\_NO2} = \sum (m_{applic\_MMS\_N}) \times 0.04$$

Step 8

Here we calculate the emissions of ammonia from grazing (although reported under NFR 3D). See table 5-15 for the emission factors.

$$E_{graz}NH_3\text{-}N = m_{graz\_N} \times EF_{grazing}$$

Step 9

In this final step, the different emissions are aggregated to the relevant NFR categories and converted to the mass of the specific compounds.

Reported per animal (m) in 3B, manure management

$$EM_{3.B.m}NH_3 = \sum (E_{build\_MMS}NH_3\text{-}N + E_{storage\_MMS}NH_3\text{-}N) \times 17/14$$

$$EM_{3.B.m}NO_2 = \sum (E_{storage\_MMS}NO\text{-}N) \times 46/14$$

Reported as a sum for all animals in 3Da2a, animal manure applied to soils

$$EM_{3.D.a.2.a}NH_3 = \sum (E_{applic\_MMS}NH_3\text{-}N) \times 17/14$$

Reported as a sum for all animals in 3Da3, urine and dung deposited by grazing animals

$$EM_{3.D.a.3}NH_3 = E_{graz}NH_3\text{-}N \times 17/14$$

5.2.2.3   EMISSIONS OF AMMONIA (COUNTRY SPECIFIC MODEL)

Additionally, Sweden has developed a country specific methodology to estimate emissions of ammonia from agriculture. The methodology[189,190] was developed in collaboration between the Swedish EPA, Statistics Sweden, the Swedish Board of Agriculture and the Swedish Institute of Agricultural and Environmental Engineering. Several of the questions to the farmers in the Statistics Sweden's field investigation among farmers are designed to provide this model with relevant and accurate activity data. It is only possible to use the model from 2005 and onwards. The reason being that before this year it is not possible to acquire the detailed micro data from the Statistics Sweden's field investigation among farmers that is needed as activity data in the model. However, when 2005 is Sweden's base year for ammonia reduction commitments in the EU national emission ceilings directive (NEC) and the Gothenburg protocol this is the most important part of the time series. Hence, the only available alternative strategy, i.e. to use the default tier 2 model for the complete time series, would result in a less accurate monitoring of these commitments.

The Swedish method estimates the emissions separately from all four stages of the manure handling chain; stable ventilation, storage, manure application and grazing. The emission factors that describe the share of nitrogen lost as ammonia during the different stages of the manure handling are developed by the Swedish University of Agricultural Sciences and the Swedish Institute of Agricultural and Environmental Engineering (JTI)[191]. The main difference between the country specific model and the tier 2 model is that the former considers more variables when estimating the emissions from storage and application of manure. For example, whether the manure is stored with or without a roof (and if so, type of roof), application method as well as timespan between spreading and mulching.

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[189] Swedish Environmental Protection Agency 1997

[190] Swedish Institute of Agricultural and Environmental Engineering (JTI) 2002

[191] Swedish Institute of Agricultural and Environmental Engineering (JTI) 2002

The calculations are carried out as:

$$NH_3\ N_{Ventilation} = D \times N \times P \times EF_1$$
$$NH_3\ N_{Storage} = D \times N \times P \times (1 - EF_1) \times EF_2$$
$$NH_3\ N_{Application} = D \times N \times P \times (1 - EF_1) \times (1 - EF_2) \times EF_3$$
$$NH_3\ N_{Grazing} = D \times N \times (1 - P) \times EF_4$$

Where, D = number of animals, N = yearly production of nitrogen per type of animal, P = stable period, EF_1 = nitrogen losses through ventilation (fraction of total nitrogen content), EF_2 = nitrogen losses during storage (fraction of total nitrogen content), EF_3 = nitrogen losses during application of animal manure (fraction of ammonium nitrogen content) and EF_4 = nitrogen losses during grazing (fraction of total nitrogen content). In table 5-10 and 5-13 to 5-15 all the emission factors used in the calculations are presented.

The ammonia emissions per animal from 3B manure management are then calculated as:

$$NH_3 = (NH_3N_{Ventilation} + NH_3N_{Storage}) \times {^{17}/_{14}}$$

Ammonia emissions from application of manure and grazing are also calculated with this methodology but instead reported under 3D, crop production and agricultural soils. Concerning grazing, the length of the grazing periods for cattle are obtained from the field investigation among farmers, while the grazing period is fixed to 6 months for horses, sheep and goats, and to 12 months for reindeers.

Table 5-10 Emission factors (EF$_1$) used to calculate emissions of ammonia from stable ventilation (% of total N) in both the tier 2 and the country specific model.

Animal category	EF solid manure*	EF liquid manure*	EF deep litter*	EF digesters**	EF composting**
Cattle	4%	4%	20%	4%	-
Swine	10%	14%	25%	14%	-
Sheep	4%	-	15%	-	-
Goats	4%	-	15%	-	-
Horses	4%	-	15%	-	4%
Laying hens	10%	10%	35%	-	-
Chickens	10%	10%	20%	-	-
Slaughter Chickens	-	-	10%	-	-
Turkeys	10%	10%	35%	-	-
Fur-bearing animals	10%	-	-	-	-

* Statistics Sweden. 1998. Beräkningsunderlag och metodik till "Utsläpp till luft av ammoniak 1997".
** Same as for liquid manure. *** Same as for solid manure.

Table 5-11 Emission factors used to calculate emissions of ammonia from manure storage (% of total N) in the tier 2 model.

Animal category	EF solid manure*	EF liquid manure*	EF deep litter*	EF digesters**	EF composting***
Dairy Cows	18%	3%	30%	2.86%	-
Suckler cows	17%	3%	30%	2.86%	-
Heifers	18%	3%	30%	2.86%	-
Bulls and steers	17%	3%	30%	2.86%	-
Calves	18%	3%	30%	2.86%	-
Sows	18%	4%	30%	2.86%	-
Boars	18%	4%	30%	2.86%	-
Pigs for meat production	18%	4%	30%	2.86%	-
Piglets	18%	4%	30%	2.86%	-
Sheep	25%	-	-	-	-
Goats	25%	-	-	-	-
Horses	25%	-	33%	-	0.25%
Laying hens	12%	4%	20%	-	-
Turkeys	20%	-	20%	-	-
Chickens	12%	4%	20%	-	-
Slaughter Chickens	5%	-	5%	-	-
Fur-bearing animals	30%	-	-	-	-
Reindeer*	-	-	-	-	-

* This EF:s are based on the same EF:s as in the country specific model but here aggregated to match the calculation level used in the tier 2 model. See paragraph 5.2.2.2.
** Same as for liquid manure. *** Same as for solid manure.

Table 5-12 Nitrogen excretion, proportion of TAN and emission factors (% of TAN) used for ammonia emissions from application of manure in the tier 2 model.

Animal groups	Nitrogen kg/year/head	TAN in liquid manure and digestate	TAN in solid manure and compost	TAN in deep litter	EF for application of liquid manure and digestate	EF for application of solid manure and compost	EF for application of deep litter
Dairy Cows* (Milk production 6,000 kg/yr)	97						
Dairy Cows* (Milk production 8,000 kg/yr)	117	60%	51%	10%	33%	38%	41%
Dairy Cows* (Milk production 10,000 kg/yr)	137						
Suckler cows	63	60%	52%	10%	32%	39%	46%
Heifers	47	60%	51%	10%	32%	38%	47%
Bulls and steers	47	60%	52%	10%	32%	39%	46%
Calves	28	60%	51%	10%	33%	39%	47%
Sows**	22.5	70%	51%	10%	30%	35%	48%
Boars	13	70%	51%	10%	29%	34%	46%
Pigs for meat production**	10.8	70%	51%	10%	29%	35%	44%
Piglets	1.2	70%	51%	10%	29%	35%	48%
Sheep	14	25%	25%	-	-	43%	-
Goats	13	25%	25%	-	-	43%	-
Horses	48	24%	25%	10%	-	43%	47%
Laying hens	0.60	75%	60%	40%	29%	40%	56%
Turkeys	0.69	40%	40%	40%		39%	39%
Chickens	0.22	75%	60%	40%	30%	41%	56%
Slaughter Chickens	0.29	40%	40%	40%	-	41%	41%
Fur-bearing animals	4.59	100%	100%	-	-	40%	-
Reindeer***	6	-	-	-	-	-	-

*For dairy cows the nitrogen excretion is estimated from milk production. **Due to a more intense swine production the nitrogen production for sows and pigs for meat production was updated in 2002. For the years prior to 2002, the values 18.5 and 9.5 kg are used. *** Data from the Norwegian university of life sciences (Karlengen et al. (2012).

Table 5-13 Emission factors (EF$_2$) used to calculate emissions of ammonia from storage (% of total N) in the country specific model.

Type of manure, handling	Cattle	Swine	Sheep/g oats/hor ses	Laying hens/ chicken	Slaugh- ter chicken	Turkeys	Fur- bearing animals
Liquid manure, uncovered							
Filled from underneath	6%	8%		8%			
Filled from above	7%	9%		9%			
Liquid manure, covered							
Filled from underneath:							
Roof	1%	1%		1%			
floating crust	3%	4%		4%			
Other	2%	2%		2%			
Filled from above:							
Roof	1%	1%		1%			
floating crust	4%	5%		5%			
Other	3%	3%		3%			
Urine, uncovered							
Filled from underneath	37%	37%					
Filled from above	40%	40%					
Urine, with cover							
Filled from underneath:							
Roof	5%	5%					
floating crust	17%	17%					
Other	10%	10%					
Filled from above:							
Roof	5%	5%					
floating crust	20%	20%					
Other	12%	12%					
Solid manure	20%	20%	25%	12%			30%
Deep litter manure	30%	30%	33%	20%	5%	20%	
Anaerobic digesters*	2.86%	2.86%					
Composting**				25%			

Except for digesters and composting all EF:s are from the report "Swedish Institute of Agricultural and Environmental Engineering 2002: Översyn av statistiska centralbyråns beräkningar av ammo-niakavgången i jordbruk, JTI, 2002.
** Default EF:s from EMEP/EEA Guidebook 2016. *** Same EF as for solid manure.

Table 5-14 Emission factors (EF₃) used to calculate emissions of ammonia from spreading (% of TAN) in the country specific model.

Tillage timing	Spreading strategy	Season	EF solid manure, deep litter and compost	EF urine	EF liquid manure, slurry and digestate
Immediately	Broadcast	Early autumn	20%	15%	5%
Immediately	Trailing hoses	Early autumn		10%	3%
Mulching within 4 h	Broadcast	Early autumn	35%	23%	18%
Mulching within 4 h	Trailing hoses	Early autumn		18%	9%
Mulching within 5-24 h	Broadcast	Early autumn	50%	30%	30%
Mulching within 5-24 h	Trailing hoses	Early autumn		25%	15%
After 24 hours or no mulching on un-seeded ground	Broadcast	Early autumn	70%	45%	70%
After 24 hours or no mulching on un-seeded ground	Trailing hoses	Early autumn		30%	40%
Immediately	Broadcast	Late autumn	10%	10%	5%
Immediately	Trailing hoses	Late autumn		4%	3%
Mulching within 4 h	Broadcast	Late autumn	15%	15%	8%
Mulching within 4 h	Trailing hoses	Late autumn		11%	4%
Mulching within 5-24 h	Broadcast	Late autumn	20%	20%	10%
Mulching within 5-24 h	Trailing hoses	Late autumn		18%	5%
After 24 hours or no mulching on un-seeded ground	Broadcast	Late autumn	30%	25%	30%
After 24 hours or no mulching on un-seeded ground	Trailing hoses	Late autumn		25%	15%
After 24 hours or no mulching on un-seeded ground	Broadcast	Winter	20%	40%	30%
After 24 hours or no mulching on un-seeded ground	Trailing hoses	Winter		30%	20%
Immediately	Broadcast	Spring	15%	8%	10%
Immediately	Trailing hoses	Spring		7%	5%
Mulching within 4 h	Broadcast	Spring	33%	14%	15%
Mulching within 4 h	Trailing hoses	Spring		14%	8%
Mulching within 5-24 h	Broadcast	Spring	50%	20%	20%
Mulching within 5-24 h	Trailing hoses	Spring		20%	10%
After 24 hours or no mulching on pasture	Broadcast	Spring	70%	35%	40%
After 24 hours or no mulching on pasture	Trailing hoses	Spring		25%	30%
Immediately	Shallow injection	Spring		8%	15%
After 24 hours or no mulching on grain	Broadcast	Spring	70%	11%	20%
After 24 hours or no mulching on grain	Trailing hoses	Spring		10%	15%
After 24 hours or no mulching on pasture	Broadcast	Summer	90%	60%	70%
After 24 hours or no mulching on pasture	Trailing hoses	Summer		40%	50%
Immediately	Shallow injection	Summer		15%	30%
After 24 hours or no mulching on grain	Broadcast	Summer	90%	10%	20%
After 24 hours or no mulching on grain	Trailing hoses	Summer		10%	7%

All EF:s are from the report "Swedish Institute of Agricultural and Environmental Engineering 2002: Översyn av statistiska centralbyråns beräkningar av ammoniakavgången i jordbruk, JTI, 2002.

Table 5-15 Emission factors (EF₄) used to calculate emissions of ammonia from grazing animals (% of total N) in both the tier 2 and the country specific model.

Animal category	EF Grazing
Cattle	8%
Horses	8%
Sheep	4%
Goats	4%
Reindeer	4%

Statistics Sweden. 1998. Beräkningsunderlag och metodik till "Utsläpp till luft av ammoniak 1997".

5.2.2.4   NON-METHANE VOLATILE ORGANIC COMPOUNDS (NMVOCS)

The emissions of NMVOC from manure management are estimated with the tier 2 methods described in the EMEP/EEA guidebook 2016. The emissions are calculated as the sum of six different sources:

- from feeding of silage
- from silage stores
- from housing (feeding beside silage)
- from outdoor manure stores
- from manure application (reported in 3D)
- from sewage sludge application (reported in 3D)
- from grazing animals (reported in 3D)

The calculation methodology differ slightly between cattle and other animals. For cattle the methodology is based on feed intake, instead of excreted volatile substance as for the other animals. That is, the factor MJ_i is replaced with kg VS_i (kg volatile solids excreted).

The emissions from cattle for the different subcategories are calculated as:

Feeding of silage:

$$E_{NMVOC,silage\_feeding\_i} = AAP_i \times MJ_i \times x_{house\_i} \times EF_{NMVOC,silage\_feeding\_i} \times Frac_{silage\_i}$$

Silage stores:

$$E_{NMVOC,silage\_store\_i} = E_{NMVOC,silage\_feeding\_i} \times Frac_{silage\_store}$$

Housing (feeding beside silage):

$$E_{NMVOC,house\_i} = AAP_i \times MJ_i \times x_{house\_i} \times EF_{NMVOC,house\_i}$$

Outdoor manure stores:

$$E_{NMVOC,manure\_store\_i} = E_{NMVOC,house\_i} \times (E_{NH3,storage\_i} / E_{NH3,house\_i})$$

Finally, the total emission of NMVOC reported in 3B, manure management, is:

$$\sum_i \left[E_{NMVOC,silage_{feeding_i}} + E_{NMVOC,silage_{store_i}} + E_{NMVOC,house_i} + E_{NMOC,manure_{store_i}} \right]$$

where;

AAP_$_i$ is the annual average population of animal i, MJ_$_i$ is the annual gross feed intake for animal i. The estimated gross feed is country specific and the same ones as used in the reporting of greenhouse gases to the UNFCCC. X_{house_i} is country specific data on the share of time an animal i spends in the animal house in a year. The value is corrected for that part of the manure is deposited in the stables also during the grazing period when dairy cows return to the stables for milking. Frac-$_{silage\_store}$ is the share of the emission from the silage store compared to the emission from the feeding table in the barn. The default tentative value of 0.25 from the guidebook is used. The emission factors used are from the EMEP/EEA guidebook 2016. $E_{NH3,storage\_i}$, $E_{NH3,house\_i}$ and $E_{NH3,appl\_i}$ are the emissions of ammonia from storage of manure, stables and application of manure for animal category i, respectively. The values are taken from the Swedish ammonia inventory.

When no country specific emission factors on emissions of NMVOC exists in Sweden the default emission factors from the EMEP/EEA guidebook 2016 are used. See table 5-16 for a list of the factors used in the calculations of NMVOC from manure management.

Table 5-16 Parameters and emission factors used for estimating emissions of NMVOC from manure management.

Source	Feed intake (MJ/day)	Fraction silage feeding	Silage feeding (kg NMVOC/MJ feed intake)	Housing (kg NMVOC/MJ feed intake)
Dairy cows	*	0.76	0.0002002	0.0000353
Suckler cows	217.0	0.59	0.0002002	0.0000353
Bulls and steers	165.5	0.63	0.0002002	0.0000353
Heifers	143.9	0.81	0.0002002	0.0000353
Calves	91.5	-	0.0002002	0.0000353
Source	**Feed intake (kg VS /day)**	**Fraction silage feeding**	**Silage feeding (kg NMVOC/kg VS excreted)**	**Housing (kg NMVOC/kg VS excreted)**
Sows and boars	0.69	-	-	0.007042
Pigs for meat production	0.37	-	-	0.001703
Piglets	0.04	-	-	0.001703
Sheep	0.4	0.68	0.01076	0.001614
Horses	2.13	1	0.01076	0.001614
Goats	0.3	0.67	0.01076	0.001614
Laying hens and chickens	0.02	-	-	0.005684
Slaughter chickens	0.01	-	-	0.009147
Turkeys	0.07	-	-	0.005684
Reindeers	0.39	-	-	0.001614
Fur-bearing animals	0.14	-	-	0.005684

* see table 5-3.

5.2.2.5   PARTICULATE MATTER

The default tier 1 methodology from the EMEP/EEA guidebook 2016 is used for all animal categories. Concerning cattle and swine we have used the EF:s from the annex in the guidebook where the EF:s are divided into different housing types. Only housed animals are included in the calculation. All used emission factors are presented in table 5-17 and 5-18.

Table 5-17 Tier 2 emission factors used to estimate the emissions from cattle and swine (kg/AAP/year).

Sub-stance	Housing type	Dairy cows	Beef cows	Steers and bulls	Heifers	Calves	Pigs for meat pro-duction	Piglets	Sows and boars
TSP	Slurry	1.81	0.69	0.69	0.69	0.34	0.70	0.36	1.36
	Solid	0.94	0.52	0.52	0.52	0.35	0.83	0.00	1.77
PM_{10}	Slurry	0.83	0.32	0.32	0.32	0.15	0.31	0.16	0.61
	Solid	0.43	0.24	0.24	0.24	0.16	0.37	0.00	0.80
$PM_{2.5}$	Slurry	0.54	0.21	0.21	0.21	0.10	0.06	0.03	0.11
	Solid	0.28	0.16	0.16	0.16	0.10	0.07	0.00	0.14

Table 5-18 Tier 1 emission factors used to estimate emissions from other animals (kg/AAP/year).

Substance	Sheep	Horses	Goats	Poultry (layers)	Poultry (broilers)	Poultry (turkeys)	Fur-bearing animals
TSP	0.14	0.48	0.14	0.19	0.04	0.11	0.018
PM_{10}	0.06	0.22	0.06	0.04	0.02	0.11	0.008
$PM_{2.5}$	0.02	0.14	0.02	0.003	0.002	0.02	0.004

5.2.3   Uncertainties and time-series consistency

As described above it was not possible to apply the Swedish country specific ammonia model for the years before 2005. To minimize the time series break between the default tier 2 model (1990-2004) and the country specific model (2005 and onwards) we use the country specific emission factors also in the tier 2 model. However, when the emissions are estimated on different levels in the two models, it was necessary to aggregate the country specific emission factors so to be able to use them in the tier 2 model. For example, the Swedish model use much more disaggregated emissions factors for application of animal manure (i.e. table 5-13). From these we have calculated weighted country specific averages that fit the default tier 2 model (i.e. table 5-11).

Between 1995 and 1996 there was an increase in the number of sows by 13%. The reason for this sudden increase was that as from this year also uncovered gilts are included in the group. Due to more intense swine production, the nitrogen production for sows and pigs for meat production were updated in 2002. Since no estimate on the number of horses exists before 2004, the value for 2004 is used for all preceding years.

The calculations are to a large degree based on information from farmers collected in Statistics Sweden's field investigation; these results are afflicted with statistical errors. Hence, all results must be considered with caution regarding the uncertainty in the input data. The emission factors are also encumbered with significant uncertainties. The emission factor uncertainties are likely more substantial than the activity data uncertainties. We estimate the uncertainty interval for the activity data for a specific emission category in 3B is some 20%. The uncertainty intervals for the different emission factor are estimated as: NH_3 50%, NMVOC 200%, NO_X 80%. PM 150%-200%.

5.2.4 Source-specific QA/QC and verification

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they agree. We conduct regular meetings with the different authorities that provide activity data to the inventory to ensure that the quality of the data is of satisfactory quality and that they in turn use appropriate QC methods.

5.2.5 Source-specific recalculations

In this submission a corrections has been made regarding NH_3 emissions from housing for the part of the manure treated in co-digesters. The correction effect emissions from dairy cattle, non-dairy cattle and swine.

5.2.6 Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the submission as part of the national QA/QC plan.

5.3 Crop production and agricultural soils, NFR 3D

5.3.1 Source category description

From the subsector, "crop production and agricultural soils", Sweden report emissions of ammonia, NMVOC, NO_X and particulate matters. The most significant source of ammonia is emissions from application of animal manure. Other sources of ammonia are the use of inorganic fertilisers, grazing animals, applications of sewage sludge and use of other organic fertilisers. The same sources also give rise to emissions of nitric oxide. Emissions of NMVOC from crop can arise to attract pollinating insects, eliminate waste products or as a means of losing surplus energy. Factors that can influence the emissions of NMVOC include temperature and light intensity, plant growth stage, water stress, air pollution and senescence. The main source from crop production in Sweden is emissions from ley. Particulate matters are emitted during production of crops, and the main sources are soil culti-

vation and crop harvesting. These emissions originate from the operation of tractors and other machinery and are thought to consist of a mixture of organic fragments from the crops, soil minerals and organic matter.

Table 5-19 Summary of key source analysis, NFR 3D, according to approach 1.

| NFR | Key Source Assessment 2019 | |
	Level	Trend
3Da1 Inorganic N fertilizers	NH_3, NOx	NH_3, NOx
3Da2a Animal manure applied to soils	NH_3, NMVOC, NOx	NH_3, NMVOC, NOx
3Da2b Sewage sludge applied to soils	-	NH_3
3Da2c Other organic fertilizers applied to soils	NH3, NOx	NH_3
3Da3 Urine and dung deposited by grazing animals	NH_3, NOx	NH_3, NOx
3Dc Farm-level agricultural operations	PM_{10}, $PM_{2.5}$	PM_{10}, $PM_{2.5}$
3De Cultivated crops	NMVOC	NMVOC

5.3.2 Methodological issues

5.3.2.1 ACTIVITY DATA

To estimate the emissions of ammonia and nitric oxide, data on applied nitrogen is needed for a number of different sources. To ensure consistency with the greenhouse gases inventory the same data are used in both inventories. The data on total nitrogen content in different types of mineral fertilisers are from the Swedish Board of Agriculture's sales statistics in Sweden (table 5-24). Application of sludge and nitrogen content in sludge are collected intermittently by Statistics Sweden and the Swedish EPA from sewage treatment plants. The nitrogen content in other organic fertilisers applied to soils is estimated from Statistics Sweden's survey on "Use of fertilisers and animal manure in agriculture" excluding substrate from manure. Nitrogen content in applied animal manure is estimated as the amount remaining after ventilation and storage losses calculated above in category 3B.

The formula used to calculate N content in animal manure applied to soils (F_{AM}) is:

$$F_{AM} = \sum_T N_T \times Nex_T \times (1 - Frac_{LossMS}) \times (1 - Frac_{PRP})$$

Where N_T is the number of heads of livestock in category T in Sweden, Nex_T is the annual average excretion of N per head of category T, $Frac_{LossMS}$ is the amount of N lost before application. $Frac_{PRP}$ is the fraction of the nitrogen in pasture, range and paddock manure. The amount of nitrogen in grazing manure is also calculated above under 3B.

To estimate emissions of particulate matter and NMVOC from crop production, statistics on crop areas is needed. This statistics is produced by the Swedish Board of Agriculture[192].

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[192] Swedish Board of Agriculture, JO 10-series

Emission of hexachlorobenzene (HCB) is estimated from pesticides that have HCB as an impurity or by-product. In Sweden one active substance, Pecloram, contains HCB, it is in used since 2011, se table 5-20.

Table 5-20 Annual sale of active substance, picloram (ton).

Year	Picloram
1990	0.0
1995	0.0
2000	0.0
2005	0.0
2010	0.0
2015	0.6*
2017	1.0
2018	1.8
2019	1.4

Statistics on picloram are from Swedish Chemicals Agency, https://www.kemi.se/en/statistics/quantities-of-sold-pesticides.

* Assumed values using linear alteration.

5.3.2.2 EMISSIONS OF AMMONIA

For a methodological description of the emissions from application of manure and grazing animals, see paragraph 5.2.2.2 and 5.2.2.3 above. To estimate the ammonia emissions from mineral fertilisers we have used the default tier 2 methodology from the EMEP/EEA guidebook 2016. The amount of nitrogen that volatilise as ammonia differs between different types of fertilisers[193] (table 5-21). The amount of nitrogen in sold ammonia-emitting products are shown in table 5-22.

To estimate the emissions from the relatively small sources, sewage sludge and other organic fertilisers, we have used the average nitrogen loss from application of animal manure as an approximation.

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[193] EMEP/EEA air pollutant emission inventory guidebook 2016

Table 5-21. Emissions of ammonia from different fertiliser types.

Fertiliser	Volatilised as ammonia (g NH_3/kg N)
Anhydrous ammonia	19
Ammonium nitrate (AN)	15
Ammonium phosphate	50
Ammonium sulphate (AS)	90
Calcium ammonium nitrate (CAN)	8
Ammonium solutions (AN)	98
NK mixtures	15
NP mixtures	50
NPK mixtures	50
Other straight N compounds	10
Urea	155

Table 5-22. Amount of nitrogen in applied inorganic fertilisers (t).

Year	Anhydrous ammonia	Ammonium nitrate (AN)	Ammonium phosphate	Ammonium sulphate (AS)	Calcium ammonium nitrate (CAN)	Ammonium solutions (AN)	NK mixtures	NP mixtures	NPK mixtures	Other straight N compounds	Urea	Fraction of N emitted as NH_3
1990	0	28 877	0	3 797	65 151	913	2 221	15 596	56388	48828	2 729	0.0218
1995	0	25 507	0	3 354	57 548	806	1 962	13 776	51319	43129	899	0.0211
2000	0	18 429	0	1 966	58 474	1 101	2 216	11 440	50957	44516	301	0.0203
2005	68	6 561	574	653	76 931	27	1 636	7 954	59030	7895	239	0.0219
2010	0	10 511	0	513	93 535	669	1 390	2 540	52815	5565	462	0.0193
2015	0	15 266	0	902	106 196	30	767	991	60259	4933	856	0.0191
2017	0	12 155	1 616	1 386	104 022	1 319	625	39	63588	13185	525	0.0197
2018	0	12 199	1 690	2 014	93 159	1 296	618	37	61415	10600	1 159	0.0210
2019	0	11 056	1 029	2 203	96 376	1 306	697	25	58620	11074	255	0.0199

Statistics on fertilisers are from Swedish Board of Agriculture.

5.3.2.3 EMISSIONS OF NON-METHANE VOLATILE ORGANIC COMPOUNDS (NMVOCS)

As described in the guidebook, the estimated emissions of NMVOC from housing are used as the basis for estimating the emissions from manure application. See above in paragraph 5.2.3.3, for a description of how $E_{NMVOC,house}$ is calculated.

Emissions from animal manure applied to soils (3Da2a):

$$E_{NMVOC,appl\_i} = E_{NMVOC,house\_i} \times (E_{NH3,appl\_i} / E_{NH3,house\_i})$$

For emissions from application of sewage sludge no methodology is described in the guidebook. As an approximation of the NMVOC emissions, we have used the

same emission factor as for manure from pasture, range and paddock and assume the same volatile solid content as for swine.

Emissions from sewage sludge applied to soils (3Da2b):

$$E_{NMVOC,Sludge} = N_{sludge} \times Frac_{VS\_swine} \times EF_{NMVOC,graz}$$

Emissions from urine and dung deposited by grazing animals (3Da3):

$$E_{NMVOC,graz\_i} = AAP_i \times MJ_i \text{ (or kg VS}_i) \times (1 - x_{house\_i}) \times EF_{NMVOC,graz\_i}$$

To estimate the emissions from crop production we have used the tier 2 method described in the 2016 guidebook. Country specific data have been used (see table 5-23) in combination with the default parameters found in table 3.3 in the EMEP/EEA Guidebook 2016. Concerning grass there is a temperature effect in the model. The emissions are assumed to increase if the temperature is above 25 °C. Data from the Swedish Meteorological and Hydrological Institute indicate that this occurs on average 20 days per year in Sweden. However, when the default EFs describe the emissions per hour, we have assumed that the temperature is above 25 °C half the time on these days.

Table 5-23. Activity data used to estimate emissions of NMVOC from crops production.

Year	Yield				Normalised fraction				Weighted EF, kg NMVOC/ha/ year
	Wheat	Rye	Rape	Grass	Wheat	Rye	Rape	Grass	
1990	5 451	3 873	2 252	5 989	0.24	0.05	0.09	0.62	0.47
1995	5 053	4 420	1 899	4 448	0.18	0.03	0.06	0.73	0.34
2000	5 080	4 610	2 559	4 429	0.28	0.02	0.03	0.67	0.33
2005	5 447	4 516	2 298	4 046	0.25	0.01	0.05	0.69	0.33
2010	4 608	4 174	2 337	4 697	0.25	0.02	0.07	0.67	0.35
2015	6 171	5 426	3 501	5 209	0.29	0.01	0.06	0.64	0.44
2017	5 961	5 645	3 036	5 110	0.30	0.01	0.07	0.62	0.43
2018	3 657	3 858	2 016	3 767	0.25	0.01	0.06	0.67	0.29
2019	6 332	5 710	3 337	5 236	0.29	0.02	0.06	0.63	0.46

Table 5-24. Parameters and emission factors used to estimate emissions of NMVOC from grazing.

Source	Grazing (kg NMVOC/ MJ feed intake)
Dairy cows	0.0000069
Beef cows	0.0000069
Steers and bulls	0.0000069
Heifers	0.0000069
Calves	0.0000069
Sows and boars	-

Source	Grazing (kg NMVOC/kg VS excreted)
Pigs for meat production and piglets	-
Sheep	0.00002349
Horses	0.00002349
Goats	0.00002349
Laying hens and chickens	-
Slaughter chickens	-
Turkeys	-
Reindeers	0.00002349
Fur-bearing animals	-

5.3.2.4   NITROGEN OXIDES

The estimate of NO_X emissions from crop production and agricultural soils are based on the default tier 1 methodology when no tier 2 methodology yet exists in the guidebook.

To estimate these emissions the annual sum of all nitrogen applied to soil is required. That is, the sum of all applied nitrogen in: inorganic fertilisers, animal manure, sewage sludge, other organic fertilisers and excreta from grazing animals (table 5-25). This value is multiplied with the default tier 1 emission factor of 0.04 kg of NO_2[194] per kg of fertiliser-N applied.

Table 5-25. Amount of nitrogen applied from different sources (t/year).

Year	Amount of nitrogen in inorganic fertilizers	Amount of nitrogen in animal manure applied to soils	Amount of nitrogen in sewage sludge applied to soils	Amount of nitrogen in other organic fertilisers applied to soils	Amount of nitrogen in urine and dung deposited by grazing animals
1990	224 500	76 628	1 180	1 700	43 160
1995	198 300	79 788	2 304	1 700	45 647
2000	189 400	75 488	1 758	1 800	45 838
2005	161 568	73 787	1 053	1 834	46 533
2010	168 000	72 219	2 224	2 921	44 253
2015	190 200	71 254	2 802	5 966	42 206
2017	198 460	70 909	3 454	5 810	43 547
2018	184 187	70 646	3 983	6 753	43 518
2019	182 641	68 875	3 983	6 536	44 258

5.3.2.5   PARTICULATE MATTER

Emissions from agricultural crop operations are estimated with the tier 2 method. Activity data are statistics on crop areas and data on agricultural crop operations. The frequency of soil cultivation, harvesting, cleaning and drying has been set to

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[194] In the EMEP/EEA Guidebook 2016, the EF is incorrectly specified as amont of NO/kg N instead of NO_2/kg N as it is specified in the reference to the EF.

one time per year for all crops except for grass for hay making. For this category, soil cultivation is assumed to take place every third year and harvest on average 2.4 times per year. Average number of harvests is estimated based on the survey "Nitrogen and phosphorus balances for agricultural land"[195].

Table 5-26 Tier 2 emission factors used to estimate emissions from crop production (kg/ha/year).

Substance	Crop operation	Winter wheat	Spring wheat	Winter rye	Triticale	Mixed grain	Winter barley	Spring barley	Oats	Pasture ground	Other crops	Ley
PM$_{10}$	Soil cultivation	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Harvesting	0.49	0.49	0.37	0.37	0.37	0.41	0.41	0.62	NA	NA	0.25
	Cleaning	0.19	0.19	0.16	0.16	0.16	0.16	0.16	0.25	NA	NA	0
	Drying	0.56	0.56	0.37	0.37	0.37	0.43	0.43	0.66	NA	NA	0
PM$_{2.5}$	Soil cultivation	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
	Harvesting	0.02	0.02	0.015	0.015	0.015	0.016	0.016	0.025	NA	NA	0.01
	Cleaning	0.009	0.009	0.008	0.008	0.008	0.008	0.008	0.0125	NA	NA	0
	Drying	0.168	0.168	0.111	0.111	0.111	0.129	0.129	0.198	NA	NA	0

5.3.2.6   HEXACHLOROBENZENE

Emissions of HCB are estimated with the tier 1 default approach. Activity data are statistics on annual sales of active substances and proposed maximum concentration (impurity factor) of 50 mg/kg from guidebook 2016. In Sweden two active substances are in use that have impurity of HCB, picloram and tefluthrin but tefluthrin is used in such a way that it is not emission-relevant. The amount of HCB emissions from picloram is computed using the data on annual sale multiplied with the proposed impurity factor. The emission factor is set to 1 or 100% as all HCB appears to volatilize during the first 24 hours according to guidebook 2016.

5.3.3   Uncertainties and time-series consistency

There was a decrease in the amount of sold fertilisers in 2009. The reason was an overconsumption in 2008 due to a dropped tax on fertilisers. Statistics on the use of sewage sludge has been published irregularly and in different reports, and the time series for the earlier years in the time series has been created through interpolation/extrapolation and certain assumptions. Gradually the quality of the data has increased and is now of adequate quality.

We estimate the uncertainty interval for the activity data for a specific emission category in 3D is 20%-35%. Uncertainty intervals for the different emission factor are estimated as: NH$_3$ 50%, NMVOC 200%, NO$_X$ 80%-400%. PM 150%-200%.

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[195] Statistics Sweden MI40SM series

5.3.4   Source-specific QA/QC and verification

Annual increase or decrease is verified for the whole time series for all sub sources to decide that all annual changes are reasonable. We compare the times series for the emission with the time series for the activity data to confirm that they agree. Every year we ask experts from the Swedish board of agriculture to conduct expert peer reviews of the methods used. Regular meetings are held with the authorities that provide activity data to the inventory to ensure that the quality of the data is of satisfactory quality and that they in turn use appropriate QC methods.

5.3.5   Source-specific recalculations

In this submission emissions from digest of manure from co-digestion is included in other organic fertilizers from 1997 and onwards. There is also an update in the timeserie on other organic fertilizers (exkluding manure) because of an improved calculation method, 2005 and onwards. Finally there is an updated in the number of reindeers in 2018.

5.3.6   Source-specific planned improvements

Category-specific improvements will be decided after the finalization of the sub-mission as part of the national QA/QC plan.

6 Waste (NFR sector 5)

6.1 Overview

Emission estimates from the waste sector include emissions from solid waste disposal on land, biological treatment of waste, waste-water handling, incineration of hazardous waste (including cremation) and various types of fires such as landfill fires, house and car fires, bonfires and open burning of garden waste. Combustion of municipal waste is accounted for in the energy sector, since it is used as fuel for energy production. Emission estimates also includes emissions from sludge spreading (mechanical dewatering of digested sludge) and pets.

6.2 Solid waste disposal on land, NFR 5A

This category includes Solid waste disposal on land (NFR 5A).

6.2.1.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting of emissions of NMVOC, TSP, PM_{10} and $PM_{2.5}$. Emissions of NH_3, Hg and CO are reported as not estimated (NE). Other emissions are reported as not applicable (NA).

Table 6-1 Summary of key source analysis, NFR 5A, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
5A	-	-

6.2.1.2 METHODOLOGICAL ISSUES

6.2.1.2.1 Emission factors

Tier 1 default emission factors from the EMEP/EEA Emission Inventory Guidebook 2016 are used for NMVOC, TSP, PM_{10} and $PM_{2.5}$. See further information in Table 6-2 below.

Table 6-2 Emission factors used for NFR 5A Solid waste disposal on land.

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	5.65	g/m³ landfill gas	1.81	10.86	UK inventory (2004)
TSP	0.463	g/Mg waste	0.006	2.21	US EPA (2006)
PM_{10}	0.219	g/Mg waste	0.003	1.05	US EPA (2006)
$PM_{2,5}$	0.033	g/Mg waste	0.0004	1.16	US EPA (2006)

6.2.1.2.2 Activity data

Activity data on emissions of landfill gas is used for emissions of NMVOC. The data is calculated from emission data on methane from solid waste disposal on land, reported to UNFCCC.

For TSP, PM$_{10}$ and PM$_{2.5}$, activity data on landfilled waste at landfills for municipal solid waste is used. The data has been compiled and published by the association Swedish Waste Management (RVF/Avfall Sverige).

Table 6-3 Activity data used for NFR 5A Solid waste disposal on land.

Year	Emission of landfill gas* (m³) (AD used for NMVOC)	Landfilled waste at landfills for municipal solid waste* (t, wet weight) (AD used for TSP, PM$_{10}$ and PM$_{2.5}$)
1990	**381 513 038**[1]	7 000 000[2]
1991	**387 325 314**[1]	6 770 000
1992	**387 440 535**[1]	6 540 000
1993	**374 396 920**[1]	6 310 000
1994	**358 913 227**[1]	6 080 000[3]
1995	**357 976 710**[1]	5 340 000[3]
1996	**354 903 980**[1]	5 050 000[3]
1997	**351 430 403**[1]	4 750 000[3]
1998	**345 702 109**[1]	4 800 000[3]
1999	**330 900 990**[1]	4 900 000[3]
2000	**320 485 283**[1]	4 450 000[3]
2001	**314 665 020**[1]	4 240 000[3]
2002	**293 879 439**[1]	3 770 000[3]
2003	**277 121 981**[1]	2 940 000[3]
2004	**274 360 927**[1]	2 480 000[3]
2005	**255 200 701**[1]	1 940 000[3]
2006	**245 123 805**[1]	1 830 000[3]
2007	**223 208 499**[1]	1 994 000[3]
2008	**192 264 966**[1]	1 670 000[3]
2009	**180 652 305**[1]	1 618 500
2010	**168 392 368**[1]	1 567 000
2011	**154 759 432**[1]	1 515 500[4]
2012	**140 552 981**[1]	1 555 300[4]
2013	**129 894 408**[1]	1 391 900[4]
2014	**116 403 233**[1]	1 432 200[4]
2015	**105 153 682**[1]	1 662 200[4]
2016	**95 128 880**[1]	1 983 400[5]
2017	**88 579 667**[1]	2 117 300[6]
2018	**82 307 573**[1]	2 043 310[7]
2019	**70 631 575**[1]	2 649 310[8]

*Data in bold are compiled data, other data is extrapolated or interpolated.

1) Swedens reporting on greenhouse gases to UNFCCC, submission 2021, 2) Swedish Association of Waste Management 1990, 3) Swedish Waste Management 2009, 4-8) Swedish Waste Management 2016-2020

6.2.1.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The used uncertainties are presented below.

NMVOC
Emission factor:
1.81-10.86 g/m³ landfill gas
(Default).

Activity data "Emission of landfill gas":
± 64 % (1990),
± 55 % (2019),
(Expert judgement).

TSP, PM$_{10}$ and PM$_{2.5}$
Emission factor <u>TSP</u>:
0.006-2.21 g/Mg waste
(Default).

Emission factor <u>PM$_{10}$</u>:
0.003-1.05 g/Mg waste
(Default).

Emission factor <u>PM$_{2.5}$</u>:
0.0004-0.16 g/Mg waste
(Default).

Activity data "Landfilled waste at landfills for municipal solid waste":
± 15 % (1990),
± 10 % (2019),
(Expert judgement).

The time series in the waste sector are calculated consistently. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

6.2.1.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

6.2.1.5   SOURCE-SPECIFIC RECALCULATIONS

Recalculations has been done for NMVOC from NFR 5A Solid waste disposal on land for the years 2009-2018. The reasons for doing the recalculations was:
-implementation of newly published[196] activity data on landfilled waste for the year 2018.
-implementation of newly available[197] estimates on DOC values for year 2012 and year 2014.
-interpolations of the activity data and DOC values above.

The emission estimates decreased from 0.06% to 5.56%.

6.2.1.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

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[196] Swedish EPA, 2020

[197] SMED (Sundqvist & Szudy), 2020

6.3 Biological treatment of waste, NFR 5B

This category includes Composting (NFR 5B1) and Anaerobic digestion at biogas facilities (NFR 5B2). Emissions from both composting and anaerobic digestion at biogas facilities are calculated. The emissions from anaerobic digestion at biogas facilities were reported for the first time in submission 2020.

6.3.1 Composting, NFR 5B1

6.3.1.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting of emissions of NH_3 (from covered composting and windrow composting) and CO (from windrow composting). Emissions of NO_X, NMVOC, TSP, PM_{10}, $PM_{2.5}$ and BC are reported as not estimated (NE). Other emissions are reported as not applicable (NA).

Table 6-4 Summary of key source analysis, NFR 5B1, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
5B1	-	*NH3*

6.3.1.2 METHODOLOGICAL ISSUES

6.3.1.2.1 Emission and abatement factors used

When composting food waste and household waste in Sweden, the composting process is normally covered. Tier 2 default emission factors from the EMEP/EEA Emission Inventory Guidebook 2016 are used for NH_3 from compost production (covered composting).

The abatement factor from the EMEP/EEA Emission Inventory Guidebook 2016 is used in from year 2005. From year 1994 to 2005, this factor is estimated to be gradually increasing from zero to the default factor due to reflect an increasing degree of practicing abatement techniques. See further in the tables below.

Table 6-5 Emission factor used for NFR 5B1 Composting (covered composting).

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NH_3	0.24	kg/Mg organic waste	0.1	0.7	Guidebook (2016)

Table 6-6 Abatement factor used for NFR 5B1 Composting (covered composting).

Abatement technology	Pollutant	Efficiency Default value	95 % confidence interval		Reference
			Lower	Upper	
Biofilter	NH_3	90 %	70 %	97 %	Guidebook (2016)

Tier 2 default emission factors from the EMEP/EEA Emission Inventory Guidebook 2016 are used for NH_3 and CO (from windrow composting of garden and park waste). See further in the table below.

Table 6-7 Emission factors used for NFR 5B1 Composting (windrow composting)

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
CO	0.56	kg/Mg waste	0.05	1	Boldrin et al. (2009)
NH_3	0.66	kg/Mg waste	0.05	1	Boldrin et al. (2009)

6.3.1.2.2 Activity data used

Activity data on composted waste (covered composting and windrow composting) is used for emissions of CO and NH_3. The data has been compiled and published by the association Swedish Waste Management (RVF/Avfall Sverige).

Table 6-8 Activity data used for NFR 5B1 Composting.

Year	Composted waste* (t, wet weight) (AD used for NH_3 from covered composting)	Composted waste* (t, wet weight) (AD used for CO and NH_3 from windrow composting of garden and park waste)
1990	**50 000**[1]	**20 000**[1]
1991	44 940	60 460
1992	39 880	100 920
1993	34 820	141 380
1994	29 760	181 840
1995	**24 700**[2]	**222 300**[2]
1996	43 350	197 650
1997	**62 000**[3]	**173 000**[3]
1998	72 333	185 167
1999	82 667	197 333
2000	**93 000**[4]	**197 000**[4]
2001	102 492	193 271
2002	**111 984**[5]	**189 546**[5]
2003	**108 745**[5]	**273 215**[5]
2004	**99 950**[5]	**289 430**[5]
2005	**234 640**[6]	**225 190**[6]
2006	**248 230**[7]	**204 160**[7]
2007	**261 450**[8]	**253 840**[8]
2008	**278 000**[9]	**290 700**[9]
2009	**284 940**[10]	**345 560**[10]
2010	**297 180**[11]	**269 030**[11]
2011	**257 110**[12]	**432 990**[12]
2012	**246 680**[13]	**312 150**[13]
2013	**211 260**[14]	**317 210**[14]
2014	**197 140**[15]	**270 780**[15]
2015	**208 430**[16]	**209 910**[16]
2016	**181 047**[17]	**295 091**[17]
2017	**152 744**[18]	**297 618**[18]
2018	**137 191**[19]	**214 564**[19]
2019	**123 114**[20]	**231 716**[20]

*Data in bold are compiled, other data is extrapolated or interpolated.

1) Swedish Association of Waste Management 1990, 2) Swedish EPA 1995, 3) Swedish Association of Waste Management 1998, 4) Swedish Association of Waste Management 2001, 5) Swedish Association of Waste Management 2005, 6-20) Swedish Waste Management 2006-2020

6.3.1.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The used uncertainties are presented below.

NH_3 (from covered composting)

Emission factor:
0.1-0.7 kg/Mg organic waste
(Default).

Abatement factor:
70%-97%
(Default).

Activity data "Composted waste":
± 15 % (1990),
± 10 % (2019),
(Expert judgement).

NH_3 and CO (from windrow composting)
Emission factor (NH_3):
0.05-1 kg/Mg waste
(Default).

Emission factor (CO):
0.05-1 kg/Mg waste
(Default).

Activity data "Composted waste":
± 20 % (1990),
± 15 % (2019),
(Expert judgement).

The time series in the waste sector are calculated consistently. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

6.3.1.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

6.3.1.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculation has been done for NFR 5B1 Composting.

6.3.1.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.3.2 Anaerobic digestion at biogas facilities, NFR 5B2

6.3.2.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting of emissions of NH_3 from anaerobic digestion at biogas facilities. Emissions of NO_X, CO, NMVOC, TSP, PM_{10}, $PM_{2.5}$, BC, HCB, Pb, Cd, Hg, Cr, Zn, HCH, PCBs, PCDD/F, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3,-cd)pyrene are reported as not estimated (NE). Other emissions are reported as not applicable (NA).

Table 6-9 Summary of key source analysis, NFR 5B2, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	**Trend**
5B2	-	-

6.3.2.2 METHODOLOGICAL ISSUES

Emissions of NH_3 occurs from anaerobic co-digesters and farm-based plants, where the emissions from the co-digesters are allocated to NFR 5B2. The emission from the farm-based plants are allocated to NFR sector 3 Agriculture (NFR 3D2c).

6.3.2.2.1 Emission factors used

The Tier 1 emission factor for NH_3-N from the EMEP/EEA Emission Inventory Guidebook 2016 are used with the factor 17/14 for NH_3.

Table 6-10 Emission factor used for NFR 5B2 Anaerobic digestion at biogas facilities.

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	**Upper**	
NH_3-N	0.0286	kg NH_3-N per kg N in feedstock	0.0163	0.0501	Guidebook (2016)

6.3.2.2.2 Activity data used

Activity data on N in feedstock is used for the emissions of NH_3. The data is compiled from data sources on feedstock quantities by various categories of feedstocks treated by anaerobic digestion, and factors of N content for each category of feedstock. The categories of feedstocks are:

-Municipal organic waste

-Manure

-Food waste (from food processing)

-Slaughterhouse waste

-Energy crops

-Other waste

The result is a national total quantity of N in feedstock to anaerobic digestion (as presented in the table below).

Table 6-11 Activity data used for NFR 5B2 Anaerobic digestion at biogas facilities.

Year	N in feedstock (t) (AD used for NH₃ from anaerobic digestion at biogas facilities)
1990	**12**[1]
1991	13
1992	266
1993	267
1994	267
1995	**312**[2]
1996	551
1997	790
1998	1 028
1999	1 267
2000	1 506
2001	1 744
2002	1 983
2003	2 222
2004	2 461
2005	**2 699**[3]
2006	**3 219**[4]
2007	**4 273**[5]
2008	**3 684**[6]
2009	**5 373**[7]
2010	**6 497**[8]
2011	**6 269**[9]
2012	**7 436**[10]
2013	**8 296**[11]
2014	**10 602**[12]
2015	**13 289**[13]
2016	**13 139**[14]
2017	**12 934**[15]
2018	**13 880**[16]
2019	**15 119**[17]

*Data in bold are compiled, other data is extrapolated or interpolated.
1-2) Szudy, Ek, Linné, Olshammar, 2017, 3-17) Swedish Energy Agency, 2007-2020

The data sources for the early years are rather scarce, but from year 2005, a survey on biogas production and utilization by the Swedish Energy has been published annually. The survey presents not only produced and utilized quantities of biogas but also the feedstock used for the biogas production.

The factors of N content in the feedstocks are from both EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016 and from national reports.

6.3.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The used uncertainties are presented below.

NH$_3$ from anaerobic digestion at biogas facilities

Emission factor:
0.0163-0.0501 kg NH$_3$-N per kg N in feedstock
(Default).

Activity data "N in feedstock":
± 20 % (1990),
± 10 % (2019),
(Expert judgement).

The time series in the waste sector are calculated consistently. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

6.3.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

6.3.2.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculation has been done for NFR 5B2 Anaerobic digestion at biogas facilities.

6.3.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.4   Waste incineration, NFR 5C

6.4.1   Incineration of municipal waste, industrial waste, clinical waste and sewage sludge, NFR 5C1a, 5C1bi, 5C1biii and 5C1biv

Emissions from these sources reported for one plant in Sweden and included in NFR 5C1bii. Since 2003, also MSW incineration occurs at the plant.

Table 6-12 Summary of key source analysis, NFR5C1 according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
5C1	As, DIOX, Hg	DIOX, Hg

6.4.2   Incineration of hazardous waste, NFR 5C1bii

6.4.2.1   SOURCE CATEGORY DESCRIPTION

Emissions from incineration of hazardous and industrial waste and since 2003 also MSW, from one large plant are reported in NFR 5C1bii. In NFR 5C1bv emissions

of mercury, dioxin, benzo(a)pyrene and PAH1-4 from cremation are reported, and from submission 2016 onwards also NO_X, SO_2, NMVOC, CO, HCB, PCB, heavy metals other than mercury, and PAH other than benzo(a)pyrene are included in the reporting. Particulate matter from cow and sheep burn using air curtain incinerator is also reported in NFR 5C1bv starting from submission 2016. CO, SO_2, NO_x, NMVOC, particulate matter, heavy metals, dioxines and PAH1-4 from domestic open waste burning, such as garden fires, are reported in 5C2.

Regarding incineration of medical waste, no national activity and emission data for this source category is available.

6.4.2.2   METHODOLOGICAL ISSUES

Incineration of hazardous waste, other than cremation, occurs at nine plants in Sweden. There is one major plant for handling and destruction of hazardous waste, which is the only one for which emission data is available. For 2004 around 88 % of the total amount of incinerated hazardous waste was incinerated at this plant. The emissions from the plant are reported in 5C1bii. Emissions from incineration of hazardous waste not reported in 5C1bii are included in 1A1a and in 1A2c, d, e and f.

The facility included in 5C1bii was operated with an electrostatic precipitator (ESP) from the start in 1983 until 1990, when a textile filter with coal injection replaced the ESP. During 2000, wet flue gas cleaning was installed after the textile filter.

Reported emissions are for the whole time series obtained from the facility's environmental report or directly from the facility on request. Reported emissions are NO_X, SO_2, NMVOC, CO, NH_3, particulate matter, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PAH1-4, B(a)P, B(b)F, B(k)F, I(cd)P, HCB, PCB and dioxin. SO_2, NO_X, CO, particulate matter and Hg are continuously measured in the flue gases. Dioxins in flue gases have been measured by spot tests but are continuously collected and analysed once a week since June 2001. Emissions of NH_3 have been obtained from the facility from 2008 and onwards. For 2003 – 2007 reported NH_3 emissions are calculated based on implied emission factor for 2008. The estimates for Se, PAH1-4, B(a)P, B(b)F, B(k)F, I(cd)P, HCB, PCB and Zn are based on the amount of incinerated waste and emission factors from EMEP/EEA Guidebook 2016.

Reported activity data are amounts of incinerated waste (kt). The activity has increased over time. In 1995 the plant combusted about 22 000 t and in 2002 the corresponding value was about 33 000 t. In 2003 the capacity of the plant was increased substantially by taking a new incinerator into operation. In this new incinerator, the facility incinerates a mixture of MSW, industrial waste and hazardous waste. As a consequence of increased capacity, emissions from 2003 are increased compared to earlier years.

6.4.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions continuously measured in the flue gases are expected to be quite low, $\pm$ 30%. Uncertainties for emissions calculated with emission factors from EMEP/EEA Guidebook 2016 are based on data in the Guidebook. For other emissions, measured by spot tests, the uncertainties are set to $\pm$ 50%.

More information is given in IIR Annex 1.

Time series for incineration of hazardous waste reported in NFR code 5C1bii have been reviewed in later years and considered to be consistent.

6.4.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No SOURCE-SPECIFIC QA/QC has been performed.

6.4.2.5   SOURCE-SPECIFIC RECALCULATIONS

Specified in the facility's environmental reports values of CO, SO_2, NO_x and particles are based on stack measurements and for the years 2017-2019 are most probably underestimated, since the IED recommends to determine hourly and daily average values (to be compared to ELV) after having subtracted the value of the confidence interval (10-30%). However, this subtraction must not be applied in the context of reporting annual emissions. To follow the reviewers' recommendations, in submission 2021 these emissions are re-adjusted (increased up to the levels before subtraction of the confidence interval) to avoid potential underestimation.

Activity data for 2016-2018 (shares of fossil and biogenic waste) was adjusted in accordance with the numbers in the facility's environmental reports. This resulted in slight (0.1-3%) increase of HCB and PAH-4 emissions occurring from combustion of mixed, mostly hazardous, waste, and 9-16% decrease of emissions of Se, Zn, B(a)P, B(b)F, B(k)F, and I(cd)P, occurring from combustion of household, mostly biogenic, waste.

Hg emissions in 1990, earlier reported as NE, are assumed to be the same as in 1991 (0.007 Mg).

6.4.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.4.3   Cremation, NFR 5C1bv

6.4.3.1   SOURCE CATEGORY DESCRIPTION

In NFR 5C1bv emissions of mercury, dioxin, benzo(a)pyrene and PAH1-4 from cremation are reported, and from submission 2016 onwards also NO_X, SO_2, NMVOC, CO, HCB, PCB, heavy metals other than mercury, and PAH other than benzo(a)pyrene are included in the reporting.

Particulate matter from cow and sheep burn using air curtain incinerator is reported in NFR 5C1bv from submission 2016 onwards.

6.4.3.2   METHODOLOGICAL ISSUES

Reported activity data is the number of cremations.

Estimates of emissions of PAH1-4, benzo(a)pyrene and dioxin from cremation have been calculated based on national emission factors and statistics on the number of annual cremations. In submission 2016 emissions of NO_X, TSP, PM_{10}, $PM_{2.5}$, SO_2, NMVOC, CO, As, Cr, Cu, Ni, Pb, Se, Zn, PCB, HCB, B(b)F, B(k)F, and I(cd)P from cremation are reported for the first time. The estimates are made with emission factors from EMEP/EEA Guidebook 2016, which does not specify whether the condensable component of the particles is included or not. Emissions from PAH1-4 have been adjusted with respect to available estimates for B(b)F, B(k)F and I(cd)P. BC emissions have not been estimated due to lack of information and reported NE in accordance with EMEP/EEA Guidebook 2016.

The emissions of mercury are estimated using a methodology presented by Wängberg (2013)[198]. From the late 1990´s, abatement techniques have been considered in the estimations. The method is based on statistics on the annual amount of cremations at each of the Swedish crematories in combination with information on installation of emission control, i.e. filter with activated carbon. The implied emission factors for 1980 - 2015 are given in Table 6-13.

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[198] Wängberg, I. 2013. PM Utredning nr 7 Hg från krematorier

Table 6-13. Implied emission factors for Hg emission estimates 1980 – 2019. All represents kg per cremated body.

Year	IEF for Hg emissions
1980	0.00300
1985	0.00300
1990	0.00296
1995	0.00287
2000	0.00167
2001	0.00103
2002	0.00100
2003	0.00099
2004	0.00093
2005	0.00087
2006	0.00077
2007	0.00073
2008	0.00071
2009	0.00072
2010	0.00071
2011	0.00064
2012	0.00059
2013	0.00051
2014	0.00038
2015	0.00034
2016	0.00034
2017	0.00034
2018	0.00033
2019	0.00033

Emission factors used to calculate benzo(a)pyrene emissions from cremation are from USEPA[199] and for dioxin a suggested emission factor from the European Dioxin Inventory[200] was used. UNEP[201] presents emission factors for dioxins in the range 0.4 – 90 µg TEQ/cremation, while an earlier Swedish Inventory[202] suggested 6-12 µg TEQ/cremation, referred to in the European Dioxin Inventory. An average of 9 µg TEQ/cremation has been used in the present emission estimates. This agrees with a recent experimental study that recommends 6-13 µg TEQ/cremation[203]. The number of annual cremations has increased from 47000 in 1980 to more than 73000 in 2019, and associated dioxin emissions have thus increased from 0.42 g TEQ to approximately 0.66 g TEQ during the same period.

Emissions of particulate matter (TSP, PM_{10} and $PM_{2.5}$) from cow and sheep burn using air curtain incinerator are for the first time reported in submission 2016. The estimates are made with emission factors from EMEP/EEA Guidebook 2016, which does not specify whether the condensable component of the particles is included or not. Cow and sheep burn using air curtain incinerator occurs rather sel-

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[199] USEPA. 1998. Locating and Estimating Air Emissions from Sources of Polycyclic organic matter. EPA-454/R-98-014. Office of Air Quality Planning and Standards, USA

[200] Quass et al., 2001. http://europa.eu.int/comm/environment/dioxin/pdf/stage1/cremation.pdf

[201] UNEP, 2001. www.chem.unep.ch/pops/pdf/toolkit/toolkit.pdf

[202] deWit. 1993, unpublished

[203] Wang, 2003.

dom in Sweden; according to the Swedish Farming Services – the company responsible for collection and handling of cadavers – this only happens when there is a significant risk of infection, otherwise alternative utilization methods are used. The company estimates that only a few animals are burned with air curtain incinerator annually[204].

6.4.3.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for NFR 5C1bv are displayed in Annex 1.

Time series for emissions from cremations reported in NFR code 5C1bv have been reviewed in later years and considered to be consistent.

6.4.3.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No SOURCE-SPECIFIC QA/QC has been performed.

6.4.3.5   SOURCE-SPECIFIC RECALCULATIONS

Small correction in activity data for 2018 resulted in insignificant (0.001%) decrease of emissions of all estimated air pollutants.

6.4.3.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.4.4   Garden burning and bonfires, NFR 5C2

6.4.4.1   SOURCE CATEGORY DESCRIPTION

CO, SO_2, NOx, NMVOC, particulate matter, heavy metals, dioxines and PAH1-4 from domestic open waste burning, such as garden fires, are reported in 5C2.

Table 6-14 Summary of key source analysis, NFR5C2 according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
5C2	-	-

6.4.4.2   METHODOLOGICAL ISSUES

In order to estimate emission of PAH from burning of garden waste, emission factors from USEPA were used, while emission factors for open burning of waste from Guidebook 2016 were used to estimate emissions of CO, SO_2, NOx, NMVOC, TSP, PM_{10} and $PM_{2.5}$. Emission factors presented in EMEP/EEA Guidebook 2016[205], chapter "Small-scale waste burning" represents emissions from open burning of agricultural waste. A study in 2004[206] reveals that it is very rare that the

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[204] Mikael Lidholm, Svensk Lantbrukstjänst AB

[205] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/5-waste/5-c-2-open-burning

[206] Wikström, H. and Adolfsson, R. 2004. Field Burning of Crop Residues.

farmers practice field burning in Sweden. According to the Swedish Board of Agriculture and the Swedish Regulation regarding direct support (SJVFS 2014:41) it is forbidden to burn crop residue in Sweden for any farmer who wants support from EU. However, there is an exception if the farmer needs to make any plant protection measures due to e.g. fungal disease. Then the farmer may apply for permission by the County Administration. The issue was discussed with the Swedish Board of Agriculture (2020-05-25), who made a thorough investigation about this in 2017. The Swedish Board of Agriculture made the conclusion that it is very unusual that crop residues are burnt in Sweden. Based on the results from the investigation by the Swedish Board of Agriculture we consider that the emissions from open burning of farming/plantation waste small-scale waste are under considered insignificant for Sweden.

In submission 2016 emissions of Pb, Cd, As, Cr, Cu, Se, Zn and dioxines from burning of garden waste are reported for the first time for 1996 and onwards. The estimates are calculated with emission factors from EMEP/EEA Guidebook 2016.In submission 2019 activity data were updated which led to that emissions could be reported for all years.

As there are no national statistics regarding the extent of garden burning and bonfires, instead statistics on number of small houses have been used. The data should be considered as indicative levels of emissions from these sources.

6.4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions of TSP, PM_{10}, $PM_{2.5}$ are calculated according to Guidebook 2016. Assessed uncertainties for are ± 200%, ± 200% and ± 200%, respectively. Uncertainties for emissions for dioxin and metals are calculated according to Guidebook 2016. Uncertainty for DIOX, Pb, Cd, As, Se, Zn, Cr and Cu are ± 200%, ± 200%, ± 200%, 200%, ± 200%, ± 200%, ± 250% and ± 200%, respectively. Uncertainties for emissions for CO, SO_2, NO_x and NMVOC are calculated according to Guidebook 2016. Uncertainty for CO, SO_2, NO_x and NMVOC are ± 200%, ± 200%, ± 200% and 200%. Uncertainty for emissions for PAH is calculated according to Guidebook Quality Rating E. Uncertainty for PAH is ± 1000%.

More information is given in IIR Annex 1.

Time series for particles and PAH from garden burning and bonfires reported in NFR code 5C2 have been reviewed in later years and considered to be consistent.

6.4.4.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source specific QA/QC has been performed.

6.4.4.5 SOURCE-SPECIFIC RECALCULATIONS

In submission 2021 no recalculations have occurred

6.4.4.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.5   Waste-water handling, NFR 5D

6.5.1   Domestic wastewater handling, NFR 5D1

6.5.1.1   SOURCE CATEGORY DESCRIPTION

Sweden is reporting emissions of NMVOC (from municipal wastewater treatment plants) and NH_3 (from latrines).

Emissions of TSP, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn are reported as not estimated (NE). Other emissions are reported as not applicable (NA).

Table 6-15 Summary of key source analysis, NFR 5D1, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
5D1	-	-

6.5.1.2   METHODOLOGICAL ISSUES

6.5.1.2.1 Emission factors used

Tier 1 default emission factor from the EMEP/EEA Emission Inventory Guidebook 2016 are used for NMVOC (from wastewater handling at municipal wastewater treatment plants). See further in the table below.

Table 6-16 Emission factor used for NFR 5D1 Domestic wastewater handling (at municipal wastewater treatment plants).

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	15	mg/m^3 waste water	5	50	Atasoy et al. (2004)

Tier 2 default emission factor from the EMEP/EEA Emission Inventory Guidebook 2016 are used for NH_3 (from latrines). See further in the table below.

Table 6-17 Emission factor used for NFR 5D1 Domestic wastewater handling (latrines).

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NH_3	1.6	kg/person/year	0.8	3.2	Guidebook (2006)

6.5.1.2.2 Activity data used

Activity data on discharged volumes of treated wastewater is used for NMVOC emissions, compiled and published by Statistics Sweden for Swedish EPA.

Data on population with latrines has been estimated in a study[207] on availability of data on latrines in Sweden. Good quality data on collected latrine is available from 2012 and onwards from Swedish Waste Management. By assuming an average generation rate of urine and faeces of 1.53 kg/person/day[208], an average population equivalent of 2 000 persons has been calculated. The estimate of 2 000 persons is used for the years 1990-2019.

Table 6-18 Activity data used for NFR 5D1 Domestic wastewater handling.

Year	Discharged volumes of treated wastewater* (1000 m³) (AD used for NMVOC from wastewater handling at municipal wastewater treatment plants)	Population with latrines* (persons) (AD used for NH₃ from latrines)
1990	**1 305 000**[1]	2 000
1991	1 276 050	2 000
1992	**1 247 100**[2]	2 000
1993	1 263 600	2 000
1994	1 280 100	2 000
1995	**1 296 600**[3]	2 000
1996	1 315 067	2 000
1997	1 333 533	2 000
1998	**1 352 000**[4]	2 000
1999	1 357 459	2 000
2000	**1 362 917**[5]	2 000
2001	1 295 459	2 000
2002	**1 228 000**[6]	2 000
2003	1 206 612	2 000
2004	**1 185 223**[7]	2 000
2005	1 212 514	2 000
2006	**1 239 805**[8]	2 000
2007	1 249 172	2 000
2008	**1 258 539**[9]	2 000
2009	1 222 653	2 000
2010	**1 186 767**[10]	2 000
2011	1 227 949	2 000
2012	**1 269 131**[11]	2 000
2013	1 243 112	2 000
2014	**1 217 093**[12]	2 000
2015	1 147 873	2 000
2016	**1 078 652**[13]	2 000
2017	1 089 548	2 000
2018	**1 100 444**[14]	2 000
2019	1 100 444	2 000

*Data in bold are compiled, other data is extrapolated or interpolated.

1) Statistics Sweden 1992, 2) Statistics Sweden 1994, 3) Statistics Sweden 1997, 4-11) Statistics Sweden 2014, 12) Statistics Sweden 2016, 13) Statistics Sweden 2018, 14) Statistics Sweden 2020.

Population with latrines is estimated from data on collected latrine 2012-2017, Swedish Waste Management 2013-2018.

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[207] Ejhed, Hellsten, Olshammar, Szudy, 2018

[208] Rose et al., 2015

6.5.1.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The used uncertainties are presented below.

NMVOC (from municipal wastewater treatment plants)
Emission factor:
5-50 mg/m^3 wastewater
(Default).

Activity data "Discharged volumes of treated wastewater":
± 10 % (1990),
± 10 % (2019),
(Expert judgement).

NH$_3$ (from latrines)
Emission factor:
0.8-3.2 kg/person/year
(Default).

Activity data "Population with latrines":
± 30 % (1990),
± 20 % (2019),
(Expert judgement).

The time series in the waste sector are calculated consistently. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

6.5.1.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

6.5.1.5   SOURCE-SPECIFIC RECALCULATIONS

Recalculations has been done for NMVOC from NFR 5D1 Domestic wastewater handling for the years 2017-2018. The reasons for doing the recalculations was:
-implementation of newly published[209] activity data on discharged volumes of treated wastewater for the year 2018.
-interpolations of the activity data above.

The emission estimates increased from 0.99% to 2.04%.

6.5.1.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

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[209] Statistics Sweden, 2020

6.5.2 Industrial wastewater handling, NFR 5D2

6.5.2.1 SOURCE CATEGORY DESCRIPTION

Sweden is reporting of emissions of NMVOC. Emissions of NH_3, TSP, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn are reported as not estimated (NE). Other emissions are reported as not applicable (NA).

Table 6-19 Summary of key source analysis, NFR 5D2, according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
5D2	-	-

6.5.2.2 METHODOLOGICAL ISSUES

6.5.2.2.1 Emission factors used

Tier 1/Tier 2 default emission factor from the EMEP/EEA Guidebook 2016 is used for NMVOC (from wastewater treatment in industry).

Table 6-20 Emission factor used for NFR 5D2 Industrial wastewater handling.

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	15	mg/m³ waste water	5	50	Atasoy et al. (2004)

6.5.2.2.2 Activity data used

Activity data on discharged volumes of treated wastewater is used for emissions of NMVOC. The data has been compiled and published by Statistics Sweden.

Table 6-21 Activity data used for NFR 5D2 Industrial wastewater handling (NMVOC).

Year	Discharged volumes of treated wastewater* (1000 m³)
1990	933 056
1991	933 056
1992	933 056
1993	933 056
1994	933 056
1995	**933 056**[1]
1996	930 496
1997	927 936
1998	925 375
1999	922 815
2000	**920 255**[2]
2001	931 282
2002	942 310
2003	953 337
2004	964 365
2005	**975 392**[3]
2006	988 232
2007	1 001 072
2008	1 013 911
2009	1 026 751
2010	**1 039 591**[4]
2011	1 010 917
2012	982 242
2013	953 568
2014	924 893
2015	**896 219**[5]
2016	896 219
2017	896 219
2018	896 219
2019	896 219

*Data in bold are compiled, other data is extrapolated or interpolated.

1) Statistics Sweden 1996, 2) Statistics Sweden 2001, 3) Statistics Sweden 2007, 4) Statistics Sweden 2011, 5) Statistics Sweden 2016

6.5.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The used uncertainties are presented below.

NMVOC (from industrial wastewater handling)
Emission factor:
5-50 mg/m³ wastewater
(Default).

Activity data "Discharged volumes of treated wastewater":
± 50 % (1990),
± 50 % (2019),
(Expert judgement).

The time series in the waste sector are calculated consistently. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

6.5.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

6.5.2.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculation has been done for NFR 5D2 Industrial wastewater handling.

6.5.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.6   Other waste, NFR 5E

The NFR category 5E Other waste, includes emissions from:
-Sludge spreading (mechanical dewatering of digested sludge)
-Landfill fires
-House and Car fires
-Pets

Table 6-22 Summary of key source analysis, NFR5E according to approach 1.

NFR	Key Source Assessment 2019	
	Level	Trend
5E	*As, Cd, DIOX, Hg, NH$_3$, PM$_{10}$, PM$_{2.5}$, TSP*	*As, Cd, DIOX, Hg, NH$_3$, PM$_{10}$, PM$_{2.5}$, TSP*

6.6.1   Other waste, sludge spreading, NFR 5E

6.6.1.1   SOURCE CATEGORY DESCRIPTION

Sweden is reporting of emissions of NH$_3$ from sludge spreading (mechanical de-watering of digested sludge at wastewater treatment plants).

6.6.1.2   METHODOLOGICAL ISSUES

6.6.1.2.1   Emission factors used

Tier 2 default emission factor from the EMEP/EEA Emission Inventory Guidebook 2016 are used for NH$_3$ (from sludge spreading). See further in the table below.

Table 6-23 Emission factor used for NFR 5E Other waste, Sludge spreading.

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NH$_3$	50	g/kg NH$_3$ in the sludge	10	150	Guidebook (2006)

6.6.1.2.2 *Activity data used*

Table 6-24 Activity data used for NFR 5E Other waste, Sludge spreading.

Year	Quantity of N in anaerobically digested sludge* (t) (AD used for NH_3 from sludge spreading)
1990	8 073
1991	8 073
1992	8 073
1993	8 073
1994	8 073
1995	**8 073**[1]
1996	8 296
1997	8 518
1998	**8 741**[2]
1999	8 656
2000	**8 571**[3]
2001	8 878
2002	**9 185**[4]
2003	8 802
2004	**8 419**[5]
2005	8 565
2006	**8 710**[6]
2007	8 908
2008	**9 105**[7]
2009	9 038
2010	**8 971**[8]
2011	8 948
2012	**8 925**[9]
2013	8 989
2014	**9 053**[10]
2015	**8 919**[11]
2016	**9 259**[12]
2017	9 489
2018	**9 720**[13]
2019	9 720

*Data in bold are compiled, other data is extrapolated or interpolated.

1) Statistics Sweden 1997, 2) Statistics Sweden 1999, 3-9) Statistics Sweden 2014, 10) Statistics Sweden 2016, 11) Sweden's reporting according to the Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. 12) Statistics Sweden 2018, 13) Statistics Sweden 2020.

6.6.1.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The used uncertainties are presented below.

NH_3 (from mechanical dewatering of digested sludge)
Emission factor:
10-150 g/kg N in the sludge
(Default).

Activity data "Quantity of nitrogen in anaerobically digested sludge":
± 10 % (1990),
± 2 % (2019),
(Expert judgement).

The time series in the waste sector are calculated consistently. When statistics are not produced annually, interpolation and extrapolation have been necessary tools for imputation.

6.6.1.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC or verification is performed.

6.6.1.5 SOURCE-SPECIFIC RECALCULATIONS

Recalculations has been done for NH_3 from NFR 5E Other waste, Sludge spreading (mechanical dewatering of digested sludge at wastewater treatment plants) for the years 2017-2018. The reasons for doing the recalculations was:
-implementation of newly published[210] activity data on quantity of N in anaerobically digested sludge for the year 2018.
-interpolations of the activity data above.

The emission estimates increased from 2.5% to 5.0%.

6.6.1.6 SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.6.2 Other waste, landfill fires, NFR 5E

6.6.2.1 SOURCE CATEGORY DESCRIPTION

In the sector 5E Other waste, emissions of dioxin, PAH1-4 and Hg from landfill fires (1996 and onwards) are included.

6.6.2.2 METHODOLOGICAL ISSUES

All emissions from landfill fires are in this submission based on the frequency and duration of fires in Sweden[211] and emission factors derived from measurements performed during landfill fires[212]. The fires were classified as "underground fires" (> 48 hours) or "surface fires" (< 48 hours) depending on the duration of the fire. In Table 6-25, the emission factors used are presented, and in Table 6-26, the reported emissions of Hg, dioxin and PAH1-4 from landfill fires are presented.

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[210] Statistics Sweden, 2020

[211] The Swedish Civil Contingencies Agency, personal communication

[212] Pettersson et al., 1996.

Table 6-25 Emission factors used for estimation of Hg, dioxin and PAH emissions from landfill fires.

Fire category	Hg g/hour	Dioxin g/hour	PAH benzo(a) pyrene g/hour	benzo(b) fluoranthene g/hour	benzo(k) fluoranthene g/hour	Indeno(1,2,3-cd)-pyrene g/hour
Surface	1.30	200×10^{-6}	0.15	0.24	NE	0.09
Underground	0.031	12.6×10^{-6}	------	------	------	------

Table 6-26.   Number of hours of landfill fires and estimated Hg, dioxin and PAH emissions in Sweden 1996 – 2019.

Year	Surface fire, no. of hours	Underground fire, no. of hours	Hg emissions, kg	Dioxin emissions, g	Total PAH emissions, kg
1996	1284	966	1.7	0.27	0.62
1997	1108	1772	1.5	0.24	0.53
1998	654	1174	0.9	0.15	0.31
1999	733	2563	1.0	0.18	0.35
2000	969	717	1.3	0.20	0.46
2005	1799	1506	2.4	0.38	0.86
2006	1983	2783	2.7	0.43	0.95
2007	1683	2695	2.3	0.37	0.81
2008	1680	3110	2.3	0.38	0.81
2009	1540	1143	2.0	0.32	0.74
2010	1032	1604	1.4	0.23	0.50
2011	1574	922	2.1	0.33	0.76
2012	1043	1218	1.4	0.22	0.50
2013	1542	2782	2.1	0.34	0.74
2014	494	414	0.7	0.10	0.24
2015	460	541	0.6	0.10	0.22
2016	507	930	0.7	0.11	0.24
2017	309	2429	0.5	0.09	0.15
2018	364	7559	0.7	0.17	0.17
2019	458	1033	0.6	0.10	0.22

6.6.2.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions of DIOX, Hg and PAH are based on Guidebook Quality Rating E and they are ± 1000% each.

More information is given in IIR Annex 1.

Time series for landfill fires reported in NFR code 5E have been reviewed in later years and considered to be consistent.

6.6.2.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC has been performed.

6.6.2.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations have been performed during submission 2021.

6.6.2.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.6.3   Other waste, house and car fires, NFR 5E

6.6.3.1   SOURCE CATEGORY DESCRIPTION

Since submission 2016 also emissions of $PM_{2.5}$, PM_{10}, TSP, Pb, Cd, Hg, As, Cr, Cu and dioxin from House/car fires are included in 5E (1990 and onwards).

6.6.3.2   METHODOLOGICAL ISSUES

Emissions of $PM_{2.5}$, PM_{10}, TSP, Pb, Cd, Hg, As, Cr, Cu and dioxin from house and car fires are reported for the first time in submission 2016. The emissions are based on the frequency and duration of fires in Sweden[213] and emission factors (Tier 2) from EMEP/EEA Guidebook 2016. Used activity data are: car fires, detached and undetached house fires, apartment building fires and industrial building fires. Statistics for 1990-1997 are missing, and therefore the average amount of fires for 1998-2003 is used instead. In Table 6- 27, the emission factors used are presented and in Table 6- 28, the reported emissions of TSP, PM, metals and dioxin emissions from house and car fires are presented. In submission 2019 new activity data were present and the whole time series was updated.

Table 6-27 Emission factors used for estimation of TSP, PM, metals and dioxin emissions from house and car fires.

Fire category	TSP kg/fire	PM_{10} kg/fire	$PM_{2.5}$ kg/fire	Pb g/fire	Cd g/fire	Hg g/fire	As g/fire	Cr g/fire	Cu g/fire	Dioxin mg/fire
Cars	2.3	2.3	2.3	NE	NE	NE	NE	NE	NE	0.048
Detached house	143.82	143.82	143.82	0.42	0.85	0.85	1.35	1.29	2.99	1.44
Undetached house	61.62	61.62	61.62	0.18	0.36	0.36	0.58	0.55	1.28	0.62
Apartment building	43.78	43.78	43.78	0.13	0.26	0.26	0.41	0.39	0.91	0.44
Industrial building	27.23	27.23	27.23	0.08	0.16	0.16	0.25	0.24	0.57	0.27

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[213] www.msb.se

Table 6-28 Emissions of TSP, PM, metals and dioxin emissions from house and car fires in Sweden 1990 – 2019.

Year	TSP kt	PM$_{10}$ kt	PM$_{2.5}$ kt	Pb t	Cd t	Hg t	As t	Cr t	Cu t	PCDD/F g
1990	0.80	0.80	0.80	0.002	0.005	0.005	0.007	0.007	0.016	8.1
1995	0.80	0.80	0.80	0.002	0.005	0.005	0.007	0.007	0.016	8.1
2000	0.74	0.74	0.74	0.002	0.004	0.004	0.007	0.006	0.015	7.5
2005	0.77	0.77	0.77	0.002	0.004	0.004	0.007	0.007	0.016	7.8
2006	0.77	0.77	0.77	0.002	0.005	0.005	0.007	0.007	0.016	7.9
2007	0.80	0.80	0.80	0.002	0.005	0.005	0.007	0.007	0.017	8.1
2008	0.78	0.78	0.78	0.002	0.005	0.005	0.007	0.007	0.016	8.0
2009	0.83	0.83	0.83	0.002	0.005	0.005	0.008	0.007	0.017	8.4
2010	0.86	0.86	0.86	0.002	0.005	0.005	0.008	0.008	0.018	8.7
2011	0.76	0.76	0.76	0.002	0.004	0.004	0.007	0.007	0.016	7.7
2012	0.77	0.77	0.77	0.002	0.005	0.005	0.007	0.007	0.016	7.9
2013	0.74	0.74	0.74	0.002	0.004	0.004	0.007	0.007	0.015	7.5
2014	0.71	0.71	0.71	0.002	0.004	0.004	0.007	0.006	0.015	7.2
2015	0.68	0.68	0.68	0.002	0.004	0.004	0.006	0.006	0.014	6.9
2016	0.76	0.76	0.76	0.002	0.004	0.004	0.007	0.007	0.016	7.7
2017	0.76	0.76	0.76	0.002	0.004	0.004	0.007	0.007	0.015	7.7
2018	0.81	0.81	0.81	0.002	0.005	0.005	0.007	0.007	0.017	8.2
2019	0.80	0.80	0.80	0.002	0.005	0.005	0.007	0.007	0.017	8.2

6.6.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions from house and care fires reported in NFR 5E for TSP, PM$_{10}$ and PM$_{2.5}$ are based on data from the Guidebook 2016 and they are ± 67 % each. Uncertainties for emissions of DIOX and metals are calculated according to Guidebook 2016. Assessed uncertainties for DIOX, Cd, Hg, As, Cr, Cu and Pb are ± 66 %, ± 67 %, ± 67 %, ± 68 %, ± 70 %, ± 68 % and ± 74 %, respectively. More information is given in IIR Annex 1.

Time series for house and car fires reported in NFR code 5E have been reviewed in later years and considered to be consistent.

6.6.3.4 SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC has been performed.

6.6.3.5 SOURCE-SPECIFIC RECALCULATIONS

Activity data for Detached house fire" for 2016-2018, "Industrial building fire" for 2016-2018, "Car fire" for 2017-2018 and "Apartment building fire" for 2016 and 2018 have been updated due to new information. The updates resulted in an increase of emission for TSP, PM$_{10}$ and PM$_{2.5}$ by approximately 0.003 – 0.000002 kt. The increase in emissions of dioxin was 0.03-0.00002 g due to the update. For Pb the increase was approximately 0,001-0,008 kg, for Cu, Cd, Hg, As and Cr the update resulted in an increase in emissions of approximately 0.00001 – 0.06 kg due to updated activity data.

6.6.3.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

6.6.4   Other waste, pets, NFR 5E

6.6.4.1   SOURCE CATEGORY DESCRIPTION

Emissions of NH_3 from cats and dogs are also included in NFR 5E Other waste (1990 and onwards).

6.6.4.2   METHODOLOGICAL ISSUES

The estimates of emissions of ammonia from cats and dogs are based on a calculation made in the beginning of the nineties and the same value (0.5 kt NH_3) has been used for the whole time period from 1990[214]. The calculation is based on data on the number of cats and dogs and an estimated value on the amount of emissions from cats and dog relative to emissions from humans.

6.6.4.3   UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for emissions of NH_3 from cats and dogs are based on Guidebook Quality Rating D. Assessed uncertainties for NH_3 are ± 200%. More information is given in IIR Annex 1.

Time series for pets reported in NFR code 5E have been reviewed in later years and considered to be consistent.

6.6.4.4   SOURCE-SPECIFIC QA/QC AND VERIFICATION

No source-specific QA/QC has been performed.

6.6.4.5   SOURCE-SPECIFIC RECALCULATIONS

No source-specific recalculations were performed during submission 2021.

6.6.4.6   SOURCE-SPECIFIC PLANNED IMPROVEMENTS

No major improvements are planned for the next submission.

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[214] Statistics Sweden, MI 37 SM 0901. Emissions of ammonia to air in Sweden in 2007.

7   Other (NFR sector 6)

No other sectors are included in the Swedish emission inventory, the sector is reported "Not occurring".

8 Recalculations and Improvements

In this submission, recalculations are explained under each sector and NFR-code.

As requested by the EEA, a copy of table 2 and table 3 of the latest NECD Review report, which is 2020 Final Review Report with recommendations from TERT and comments on the status of implementation are included in Table 8-1 and in Table 8-2 for NO$_X$, NMVOC, SO$_2$, NH$_3$, PM$_{2.5}$, and Table 8-3 and Table 8-4 for POPs and heavy metals, Table 8-5 for LPS and Table 8-6 for gridded data.

Table 8-1 Recommendations from the NECD Review 2017 and 2019 for NO$_X$, NMVOC, SO$_2$, NH$_3$, PM$_{2.5}$ that had not been implemented in the inventory submission 2020

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE or TC in 2018	RE, TC or PTC in 2019	Tier 1 used for Key Category
2017 (3)	SE-1A3b-2017-0001	Yes	1A3b Road transport, NO$_X$, NMVOC, 1990-2018	No	TC	No
Recommendation made in previous review report Following a previous recommendation from the 2017 NECD Review, SE-1A3b-2017-0001, the TERT noted that the HBEFA version (3.3) used in the 2018 submission is not compatible with the 2016 EMEP/EEA Guidebook for all road transport sub-sectors. Specifically, in response to questions raised during the review, Sweden confirmed that HBEFA version 3.3 is not fully in-line with the 2016 EMEP/EEA Guidebook, although it is acknowledged that updated emissions factors for some categories have already been implemented (NO$_X$ from Euro IV and Euro VI passenger cars). Sweden also stated that HBEFA will be updated from version 3.3 to 4.1 in the fall of 2018 and the result will be implemented in submission 2020; the new version of HBEFA is expected to have updated emission factors in-line with the 2016 EMEP/EEA Guidebook for all road transport sub-categories (for example, updated NO$_X$ emission factors from light duty vehicles are expected to be included). The TERT welcomes the plan of Sweden to switch to HBEFA version 4.1 and recommends that Sweden clarifies these issues in the next IIR, providing also implied emission factors (IEFs) used for 1A3b Road Transport broken down by vehicle type, fuel type and Euro standard for comparability and transparency purposes.						
Assessment of the implementation of the initial recommendation The TERT notes with reference to NFR tables and IIR pages 87-100 and 1A3b Road Transport, all fuels and NO$_X$, NMVOC for all years that there may be an under-estimate of emissions. This was raised during the 2017, 2018 and 2019 NECD reviews. This is caused by the lack of update of the Handbook Emission Factors for Road Transport (HBEFA). In response to a question raised during the review, Sweden responded that it would use HBEFA 4.1 in submission 2021. This would bring Sweden in line with the reporting requirements. **The TERT recommends that Sweden calculates emissions from 1A3bi-iv using a Tier 2 or Tier 3 method consistent with the 2019 EMEP/EEA Guidebook for inclusion in next years' inventory submission.**						
Comment on implementation and reference to IIR section/chapter (if relevant) The new version of HBEFA 4.1 is implemented in submission 2021, with revised emission factors and emission estimates of several pollutants; such as NOx, MNVOC, particles etc.						

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE or TC in 2018	RE, TC or PTC in 2019	Tier 1 used for Key Category
2017 (3)	SE-1A3b-2017-0009	Yes	1A3b Road Transport, NH$_3$, 1990-2018	No	No	No

Recommendation made in previous review report

Following a recommendation from the previous 2017 NECD Review, SE-1A3b-2017-0009, related to the revision of NH$_3$ emission factor assumptions for Euro V and VI heavy duty vehicles, the TERT noted that this issue has not been addressed in the 2018 submission, but there is a plan for this to be addressed in the fall of 2018 (IIR, Table 8.1, p. 241). In response to questions raised during the review, the following issues were clarified with Sweden: 1) Current emission factors for NH$_3$, sector 1A3biii, used by Sweden, are the same for all Euro classes and do not reflect the increase in Euro V and Euro VI vehicles (see 2016 EMEP/EEA Guidebook, "1A3bi-iv Road transport 2016 - July 2017.pdf", Table 3.21, p. 33-34, and Table 3.73, p. 88), which was the main point of discussion during the 2017 review. This will be resolved with the next version of HBEFA. 2) The value of the emission factor used by Sweden, as reported in the IIR, should be corrected from 0.003 mg/km to 3 mg/km. 3) Regarding the year of submission that this improvement will take effect, Sweden mentioned that the emission factors will be adjusted in the next version of HBEFA, which will be available in the late fall of 2018, and it will be too late for Sweden to implement the result in submission 2019. Sweden cannot adjust the emission factors themselves in HBEFA, as this is done on a central level by INFRAS and TUG. As the emissions of NH$_3$ from road traffic are estimated by HBEFA, Sweden will not be able to implement the result from the updated emission factors for NH$_3$ in submission 2019. As a result of the above, the TERT recommends that this observation is checked again in the next submission 2019 and that Sweden improves the NH$_3$ emission factors in order to be in line with the 2016 EMEP/EEA Guidebook.

Assessment of the implementation of the initial recommendation

For 1A3b Road Transport, all fuels and NH$_3$ for all years, the TERT noted that there is a lack of transparency regarding the used emission factor, which is from HBEFA 3.3, which is not in line with 2016 EMEP/EEA Guidebook. This does not relate to an over- or under-estimate of emissions. This was raised during the 2017, 2018 and 2019 NECD review. In response to a question raised during the review, Sweden explained that HBEFA 4.1 (which is in line with 2016 EMEP/EEA Guidebook) will be used for 2021 submission.

The TERT recommends that Sweden updates the road transport model to HBEFA 4.1, in order to be ensure the accuracy of the emission estimates.

Comment on implementation and reference to IIR section/chapter (if relevant)

The new version of HBEFA 4.1 is implemented in submission 2021, with revised emission factors for NH$_3$ for Euro V and Euro VI heavy duty trucks.

Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC or PTC in 2019	Tier 1 used for Key Category
SE-3B1a-2019-0001	Yes	3B1a Manure management - Dairy cattle, NO$_x$, NH$_3$, 1990-2018	PTC	No

Assessment of the implementation of the initial recommendation

For 3B1a Manure Management – Dairy Cattle for NH_3 emissions, the TERT noted that there is a lack of transparency regarding how the country specific (CS) NH_3 EF were established as they are very low compared to the usual values encountered. This does not relate to an over- or under-estimate of emissions. This was raised during the 2019 NECD review. In response to a question raised during the review, Sweden acknowledged that their CS IEF are lower than other, but they intend to use the EFs most appropriate for Swedish conditions. The same EFs are used in the Swedish inventory as the ones used by the VERA tool which is a calculation tool developed by the organisation "Focus on Nutrients", and used for plant nutrient balances, manure quantities, fertilizer plans, climate footprints and energy consumptions. "Focus on Nutrients" is a collaboration between The Swedish Board of Agriculture, The County Administration Boards, The Federation of Swedish Farmers and a number of companies in the farming business (http://greppa.nu/om-greppa/om-projektet/in-english.html). VERA is the primary tool used to advise farmers in Sweden on increased nutrient management efficiency. Moreover, Sweden indicated that it could be reasonable that the emissions in Sweden are one third of the average emissions in Europe as the average annual temperature is only +3°C. Sweden mentioned that to further investigate and validate the CS EFs the inventory team will cooperate with "Focus on Nutrients" and the Swedish board of agriculture.

The TERT recommends that Sweden further investigates the CS EF and include all the relevant information needed in its IIR for the next submission in order to justify the low level of NH_3 emissions compared to other countries.

Comment on implementation and reference to IIR section/chapter (if relevant)

The CS EF for housing is currently under review by The Swedish Board of Agriculture and The Swedish University of Agricultural Sciences. The plan is to implement these EF in the next submission.

Table 8-2 Additional recommendations made during the NECD Review 2020 for NO$_X$, NMVOC, SO$_2$, NH$_3$, PM$_{2.5}$

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2020 (1)	SE-3B-2020-0001	Yes	3B Manure Management, NH$_3$, 2000-2018	N/A	No	No

Recommendation

For 3B Manure Management and NH$_3$ emission for all years, the TERT noted that there is a lack of transparency regarding the percentage of implementation of abatement techniques and the progress of implementation over time. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Sweden explained that the data used for the different manure management techniques are from the Statistical survey "Use of fertilisers and animal manure in agriculture" http://www.scb.se/mi1001-en, performed by Statistics Sweden. Moreover, Sweden indicated that from 2005 the calculation is done for each of the eight Swedish production areas, meaning that there is a lot of data, not manageable to publish in the IIR. The TERT understands the difficulty to present the detailed information in the IIR. However, the TERT assumes that presenting aggregated results of the implementation of abatement techniques will help understanding of the current state and progress of implementation of those abatement techniques.

The TERT recommends that Sweden include aggregated results of the implementation of abatement techniques in the IIR for the next submission in order to transparently show the progress of implementation of those abatement techniques.

Comment on implementation and reference to IIR section/chapter (if relevant)

Tables over the implementation of abatement techniques has not been added in the IIR as they are presented in detailed in the report Use of fertilisers and animal manure in agriculture. Tables that present time series of abatement techniques are for example table 10.1 Manure management systems for cattle and pigs, table 11.1 Liquid manure and urine tanks without covering, share of livestock units by method of filling up, table 11.2 Liquid manure and urine tanks with covering, share of livestock units by method of filling up, table 8.1 Spreading methods for liquid manure and urine and table 7. Incorporation time for manure.

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2020 (1)	SE-3Da2a-2020-0001	Yes	3Da2a Animal Manure Applied to Soils, NO$_X$, NH$_3$, 2000-2018	N/A	No	No

Recommendation

For 3Da2a Animal Manure Applied to Soils, for NH_3 and NO_X emissions for the years 2000-2018, the TERT noted that the inclusion of the new manure management systems (anaerobic digestion and composting) led to a downward revision of emissions with a stronger decrease at the end of the period. However, the TERT assumed that the manure attributed to anaerobic digestion was mainly liquid before and the EF used looked almost identical to the EF used for liquid. In response to a question raised during the review Sweden explained that the manure that is attributed to co-digester is spread on fields, but that there has been a misunderstanding regarding which sector has to report the emissions after the digestion in co-digester leading to the under-estimate noticed. Sweden indicated that they would try to solve this in the submission 2021. The TERT noted that the issue is below the threshold of significance for a technical correction.

The TERT recommends that Sweden correctly reports the NH_3 and NO_X emissions from manure previously treated in anaerobic digester and include associated explanations in its IIR for the next submission.

Comment on implementation and reference to IIR section/chapter (if relevant)

In submission 2021 the emission from manure that is attributed to co-digesters are, during housing and spreading, accounted for in the agricultural sector whereas emissions during storage are accounted for in the waste sector.

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2020 (1)	SE-3Da2c-2020-0001	No	3Da2c Other Organic Fertilisers Applied to Soils, NO_X, NH_3, 2000-2018	N/A	No	No

Recommendation

For 3Da2c Other Organic Fertilisers Applied to Soils (including compost) for NH_3 and NO_X emissions, the TERT noted that there is a lack of transparency regarding how Sweden is ensuring that no double counting is made between 3Da2a Animal Manure Applied to Soils and 3Da2c, as part of the manure is treated in anaerobic digestion. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Sweden explained that other organic fertilizers consist of digestate from biogas production (for example residues from the food industry) and that the substrate from manure is excluded in order to avoid double counting.

The TERT recommends that Sweden includes more information in its IIR for next submission on how the reporting of emissions from digested manure is handled in the inventory in order to avoid double-counting.

Comment on implementation and reference to IIR section/chapter (if relevant)

Clarifications are included in IIR section 5.2.2.2 and section 5.3.2.1.

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category

2020 (1)	SE-5-2020-0001	No	5A Biological Treatment of Waste - Solid Waste Disposal on Land, PM$_{2.5}$, 1990-2018	N/A	No	No

Recommendation

For PM$_{2.5}$ emissions from 5A Solid Waste Disposal on Land for all years, the TERT noted that Sweden does not include all waste disposed in landfill and especially waste handling of construction/demolition waste. In the 2019 EMEP/EEA Guidebook, chapter 5.A table 3-A, the particulate emission factors reference is US EPA 2006. In the US EPA Guidebook (chapter 13.2.4 Miscellaneous sources/aggregate handling and storage piles/table), the activity data used to estimate the PM emission factor is amount of waste handled (especially mineral waste). The definition of this term is provided and includes handle of construction/demolition waste (sand, clay, misc. fill materials. Consequently, it is important to collect data on total amount of waste handled (including the amount of mineral waste, such as construction and demolition, ash etc.) and not only waste disposed at municipal solid waste disposal sites. In response to a question raised during the review, Sweden explained that they have used the good quality data from landfills for municipal solid waste, well aware of the fact that the activity data are in some regard under-estimates since there are other kinds of landfill activities in Sweden. The TERT noted that the issue is below the threshold of significance for a technical correction.

The TERT recommends that Sweden corrects its estimate of PM$_{2.5}$ emissions from 5A using the total amount of waste landfilled as AD.

Comment on implementation and reference to IIR section/chapter (if relevant)

The recommendation given was not implemented in submission 2021, as the recommendation reached Sweden too late to be resolved.

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2020 (1)	SE-5-2020-0002	No	5C Waste Incineration, SO$_2$, NO$_X$, NMVOC, PM$_{2.5}$, 1990-2018	N/A	No	No

Recommendation

For category 5C Waste Incineration and NO$_X$, SO$_2$, CO and PM$_{2.5}$ emissions for all years, the TERT noted that emissions are based on stack measurements from just one facility. In the context of comparing their emissions to Emission Limit Values (ELV) specified in the IED, the IED recommends combustion plants to determine the validated hourly (and daily) average values after 'having subtracted the value of the confidence interval' (which maximum value is specified in a dedicated table). As a result, operators make a subtraction of, at a maxima, 20% of SO$_2$, 20% of NO$_X$, 30% of dust 30%...). However, this subtraction must not be applied in the context of reporting annual emissions. This was raised during the 2017 and 2018 NECD Review. Sweden, in the IIR (p247) indicates that 'The reported emissions CO, SO$_2$, NO$_X$ and particles are adjusted in accordance to IED by the facility'. Consequently, the TERT notes an under-estimate of the emissions. This under-estimate does not have an impact on total emissions that is above the threshold of significance.

The TERT recommends that Sweden estimates the emissions without subtraction of the value of the confidence interval since the date of implementation of the continuous measurement. In response to the draft review report, Sweden informed the TERT that corrections have been made and will be reported in the 2021 submission.

Comment on implementation and reference to IIR section/chapter (if relevant)

In submission 2021, emissions are recalculated (adjusted to the pre-subtraction levels) to avoid underestimation.

Table 8-3 Recommendations from the NECD Review 2019 of POPs and heavy metals that had not been implemented in the inventory submission 2020

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2019 (2)	SE-3Df-2019-0001	No	3Df Use of Pesticides, HCB, 1990-2018	No	RE	No

Assessment of the implementation of the initial recommendation

For 3Df Use of Pesticides for HCB emissions for all years, the TERT noted that Sweden did not report emissions and used the notation key 'NO'. However, no explanation could be found in the IIR. This was raised during the 2019 NECD review. In response to a question raised during the review, Sweden explained that national experts on pesticides indicated that only two products containing Picloram have permits since a few years back. The other substances listed in the EMEP/EEA Guidebook do not have permits to be used in Sweden. Sweden provided revised estimates for years 2011-2018. The TERT agreed with the revised estimate provided by Sweden.

The TERT recommends that Sweden includes the revised estimates in its 2021 NFR and IIR submission.

Comment on implementation and reference to IIR section/chapter (if relevant)

HCB emissions has been included in submission 2021 and explanation are added in IIR section 5.3.2.1 and 5.3.2.6.

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2019 (2)	SE-5C1bii-2019-0001	No	5C1bii Hazardous Waste Incineration, Hg, 1990	No	RE	No

Assessment of the implementation of the initial recommendation

For Hg from 5C1bii Hazardous Waste Incineration, the TERT noted that emissions have not been reported for the year 1990. This was raised during 2019 NECD review. In response to a question raised during the review, Sweden explained that Hg value for 1991 should also be applied for 1990 in order to avoid underestimation. Sweden provided a revised estimates for 1990 and stated that it will be included in the next submission. The TERT agreed with the revised estimate provided by Sweden.

The TERT recommends that Sweden includes the revised estimate in its 2021 NFR and IIR submission.

Comment on implementation and reference to IIR section/chapter (if relevant)

Hg value for 1990 is in submission 2021 is the same as for 1991.

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2019 (2)	SE-2A3-2019-0001	No	2A3 Glass Production, Cu, 1990-2018	No	No	No
Assessment of the implementation of the initial recommendation For 2A3 Glass Production, the TERT noted that Sweden reported AD for glass production as 'NE', and also emissions of Cu as 'NE', even though the 2016 EMEP/EEA Guidebook provides emission factors. The issue of the AD was raised during the 2019 NECD review. In response to a question raised during the review Sweden replied that they had missed to follow up on this issue. The TERT noted that the issue is below the threshold of significance for a technical correction. **The TERT recommends that Sweden includes values for AD as well as emissions for all pollutants for which an EF is provided in the EMEP/EEA Guidebook.**						
Comment on implementation and reference to IIR section/chapter (if relevant) AD on glass production has been added in submission 2021 in IIR chapter 4.2.3.2. Sweden will review the Cu Tier1 emission factor provided in 2019 EMEP/EEA Guidebook and consider implementing Cu emission calculations in submission 2022.						
Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2018 (3)	SE-2C3-2018-0001	No	2C3 Aluminium Production, HCB, 1990-2018	No	No	No
Assessment of the implementation of the initial recommendation For category 2C3 Aluminium Production and emissions of HCB for all years, the TERT noted that this is a potential under-estimate, since the 2016 EMEP/EEA Guidebook provides default EFs for a Tier 2 methodology. This was raised during the 2018 and 2019 NECD review. In response to a question raised during the review Sweden informed the TERT that they have started investigations and found that the use of hexachloroethane as a degassing agent in secondary aluminium smelters has been banned in Sweden since 1998, which means that from 1998 onwards, no emissions from this source are possible. Sweden suggested that they will need more time to investigate when the ban came into force, and also will investigate emissions for 1990-1997, as they believe that the default EF is higher than what is to be expected from the processes used. The TERT noted that the issue is below the threshold of significance for a technical correction. **The TERT recommends that Sweden investigates further and include calculation of emissions from 1990-1997 in their next submission and provide information on the EF used in their next IIR.**						
Comment on implementation and reference to IIR section/chapter (if relevant) Unfortunately, Sweden has not had the opportunity to prioritize this work to submission 2021.						

Table 8-4 Additional recommendations made during the NECD Review 2020 for POPs and heavy metals

Review year of initial recommendation (number of years it has been recommended)	Observation	Key Category	NFR, Pollutant(s), Year(s)	RE, TC, or UPTC in 2019	RE, TC, or UPTC in 2020	Tier 1 used for Key Category
2020 (1)	SE-3F-2020-0001	No	3F Field Burning of Agricultural Residues, SO_2, NO_X, NH_3, NMVOC, $PM_{2.5}$, BaP, PAHs, PCBs, HCB, Cd, Hg, Pb, PCDD/F, PM_{10}, CO, BC, 2000-2018	N/A	No	No
Recommendation						
For 3F Field Burning of Agricultural Residues, the TERT noted that there is a lack of transparency regarding the use of the notation key 'NO' as no explanation is provided in the IIR. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Sweden explained that burning of crop residues is prohibited in Sweden, and that a clarification will be included in IIR. **The TERT recommends that Sweden includes this information in its IIR for the next submission including whether the legislation allows for dispensations from the general ban.**						
Comment on implementation and reference to IIR section/chapter (if relevant)						
National experts have been contacted and a clarification is added in IIR section 5.1.						

Table 8-5 All recommendations made during the NECD Review 2020 for LPS data

Review year of initial recommendation (number of years it has been recommended)	Observation	GNFR sector, Pollutant(s), Year(s)	RE or UPTC in 2020
2020 (1)	SE-LPS-GEN-2020-0004	General, 2015	No

Recommendation

For LPS ID 0181-81-003 and 0181-81-009, the TERT noted that there is a lack of transparency regarding the fact that the two plants has the same name, stack height and coordinates being reported. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Sweden explained that one of the reported lines (0181-81-009) should have been allocated to GNFR J_Waste rather than A_PublicPower.

The TERT recommends that Sweden corrects this in the next submission.

Comment on implementation and reference to IIR section/chapter (if relevant)

For facility (0181-81-009/ 10014121.Facility) the coordinates have been corrected (i.e. no longer identical with the location of facility 0181-81-003/ 10014118.Facility). The Annex 1 activity code has been checked with the competent authority and has shown to be correct (i.e. 1.(c)) and consequently the previously reported GNFR code (A_PublicPower) for the facility is correct (see section 10.2.4)

Review year of initial recommendation (number of years it has been recommended)	Observation	GNFR sector, Pollutant(s), Year(s)	RE or UPTC in 2020
2020 (1)	SE-LPS-GEN-2020-0001	General, $PM_{2.5}$, PCBs, HCB, 2015	No

Recommendation

For the LPS reporting, the TERT noted that Sweden did not report emissions of $PM_{2.5}$, PCBs and HCB. In response to a question raised during the review Sweden explained that no facilities had emissions of PCBs and HCB above the reporting threshold. For $PM_{2.5}$, Sweden explained that this is not reported under PRTR. However, the TERT notes that reporting of $PM_{2.5}$ is mandatory if above the reporting threshold. The TERT noted that the issue is below the threshold of significance for a technical correction.

The TERT recommends that Sweden assess whether any LPS have a $PM_{2.5}$ emission above the reporting threshold, e.g. by considering the particle size distribution derived from the EMEP/EEA Guidebook and report $PM_{2.5}$ emissions form LPS, if relevant.

Comment on implementation and reference to IIR section/chapter (if relevant)

$PM_{2.5}$ emissions have been included in the LPS reporting for all E-PRTR facilities exceeding the threshold for PM_{10} (see section 10.2.3 and 10.2.4).

Review year of initial recommendation (number of years it has been recommended)	Observation	GNFR sector, Pollutant(s), Year(s)	RE or UPTC in 2020
2020 (1)	SE-LPS-GEN-2020-0006	General, SO$_2$, NO$_X$, NH$_3$, NMVOC, PM$_{2.5}$, BaP, PAHs, PCBs, HCB, Cd, Hg, Pb, PCDD/F, PM$_{10}$, CO, BC, 2015	No

Recommendation
For the LPS reporting, the TERT noted that there is a lack of transparency regarding the LPS emissions and the links to the national inventory. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Sweden explained that the documentation will be improved in the 2021 submission.
The TERT recommends that Sweden includes more documentation of the LPS emissions in the next submission, e.g. by including information on whether the LPS emissions are used directly in the inventory, the share of national emissions covered by LPS emissions and any differences between the LPS reporting and the reporting under PRTR.

Comment on implementation and reference to IIR section/chapter (if relevant)
The IIR has been updated with a section about LPS (description, methodology, improvements etc). (see section 10.2)

Table 8-6. **All recommendations made during the NECD Review 2020 for gridded data**

Review year of initial recommendation (number of years it has been recommended)	Observation	GNFR sector, Pollutant(s), Year(s)	UPTC in 2020
2020 (1)	SE-GRID-GEN-2020-0001	General, Pb, 2015	No

Recommendation

The TERT notes, with reference to Pb emissions for the year 2015, an issue in the Gridding submission which may relate to an over-estimate of emissions. This over-estimate may have an impact on total emissions that is above the threshold of significance. The TERT found the over-estimate was related to Pb emissions from F_RoadTransport. In response to a question raised during the review, Sweden explained it had looked into the issue and found that in the NFR submission, Pb emissions from flexifuel ethanol passenger cars had accidentally been replaced with a 'NA' notation key. Therefore, the gridded data do not contain an over-estimate but the NFR submission contains an under-estimate of emissions. The TERT recommends that for the next submission, Sweden ensures this issue is resolved and the reported gridded data are consistent with the national inventory (NFR tables).

In case differences remain, the TERT recommends Sweden to clearly describe the reasons for any discrepancies in the IIR chapter on gridded emissions.

Comment on implementation and reference to IIR section/chapter (if relevant)

In submission 2021, this error has been corrected and the emissions of Pb in gridded NFR are the same as in NFR F_RoadTransport.

Review year of initial recommendation (number of years it has been recommended)	Observation	GNFR sector, Pollutant(s), Year(s)	UPTC in 2020
2020 (1)	SE-GRID-GEN-2020-0002	General, SO_2, NO_X, NH_3, NMVOC, PAHs, Cd, Hg, PCDD/F, PM_{10}, CO, 2015	No

Recommendation

For the pollutants SO_2, NO_X, NH_3, NMVOC, PAHs, Cd, Hg, PCDD/F, PM_{10} and CO, the TERT noted that there are a number of locations (grid cells) where gridded and LPS data are inconsistent. The TERT had compared gridded emissions for each grid cell with LPS emissions (allocated to the respective grid cell), where several inconsistencies were found where LPS emissions exceed gridded emissions. In response to a question raised during the review Sweden explained that the information is based on two different systems, since LPS is based on E-PRTR reporting and gridded data on the national inventory. Sweden explained that in some cases it had found that, since E-PRTR only records emissions at facility level, for larger facilities the exact emission location (e.g. stack) may be in another grid cell compared to the E-PRTR location, which would explain part of the observed inconsistencies.

The TERT recommends Sweden to improve the consistency between gridded and LPS data to the extent possible, and reports in the IIR on the level of consistency between these two datasets and the attempts undertaken to improve the consistency.

Comment on implementation and reference to IIR section/chapter (if relevant)

We are working on a solution for this. See section planned improvement in gridded emission for more information

Review year of initial recommendation (number of years it has been recommended)	Observation	GNFR sector, Pollutant(s), Year(s)	UPTC in 2020
2020 (1)	SE-GRID-D-2020-0001	D Fugitive, PAHs, 2015	No

Recommendation

For the 2015 gridded emissions, the TERT noted that total emissions per GNFR category are different compared to the national inventory (NFR table). At the national total however, this difference is not found, therefore the issue does not relate to an over- or under-estimate of emissions at national level. In particular, the TERT noted that no gridded data are reported in categories D_Fugitives and M_Other, while emissions are reported in the national inventory for NFR categories which are part of these GNFR categories. In response to a question raised during the review, Sweden explained that certain aggregations of data had to be made as a result of confidentiality of data and Swedish law preventing the release of emission data that could be traced back to individual companies, unless specific consent is given. Sweden explained it is in the process of collecting these consents, reducing the number of confidentiality cases. For gridded data however, Sweden explained this is difficult due to the geographical dimension that is added to the data.

The TERT recommends that Sweden clearly documents this issue, explaining the reasons for the discrepancies of gridded GNFR emissions compared to the NFR tables in the IIR chapter on gridded and LPS emissions.

Comment on implementation and reference to IIR section/chapter (if relevant)

The IIR has been updated with a section about LPS (description, methodology, improvements etc). (see section 10.2). In addition, a new section with the methodology of the gridded NFR is also updated and described in order to clarify the main differences between LPS and NFR gridded data.

9   Projections

The most recent projections were produced in 2021 and are based on historical data according to submission 2021. The projections include emissions of NO_X, SO_2, NMVOC, NH_3, $PM_{2.5}$ and BC covering the years 2020, 2025, 2030, 2035, 2040, 2045 and 2050.

The projections are based on year 2018. However, since emissions for 2019 are estimated in submission 2021, it is verified that projections are in line with emissions for 2019. The methodologies used for projections are in general based on the methodologies that are used for the respective sector and category in the historical emission inventory. See respective chapter of the IIR for more information on methodologies.

There are many data sources contributing to the projections, some of the most important being energy projections by the Swedish Energy Agency, road traffic projections by the Swedish Transport Administration and projections by the Swedish Board of Agriculture. Projections in the energy sector are based on projections on economic development produced by the National Institute of Economic Research, using the general equilibrium model EMEC[215].

9.1   Stationary combustion

Projections for activity data is based on the long-term energy projections by the Swedish Energy Agency that are modified to fit the NFR format. The energy system model Times-Nordic[216] is used to estimate the projected energy supply for production of electricity and district heating. For the other sectors, results from the Times-Nordic model are combined with expert assessments.
For energy use in industry, an Excel-based model is used that links energy use to economic factors and energy prices. This is harmonized with contacts with energy-intensive companies and industry organisations as well as the results from the Times-Nordic model.

Emission factors for projections are in general based on expert judgments based on expected trends and current legislation. Some emission factors are projected to decrease whereas some are assumed to be constant in the projections.

Emission factors and projections for small-scale wood combustion were updated in 2018. Different emission factors were specified for modern and older types of

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[215] https://www.konj.se/english/about-nier/environmental-economics/general-equlibrium-modelling---emec.html

[216] https://www.profu.se/times.htm

stoves and boilers and projections for the use of different technologies were developed[217, 218].

9.2 Mobile combustion

9.2.1 Road transport

Projections for road transport are produced by the Swedish Transport Administration. These projections are in turn based on projected vehicle kilometres from the Swedish Energy Agency and emission factors from HBEFA. Energy use for road traffic is based on evaluation on future transport demand and the development of the vehicle fleet. For passenger cars, demography, fuel prices and household income are important factors for transport demand whereas economic development and oversees trade are the basis for the demand for freight transport. The development of the vehicle fleet is based on fuel allocation and annual efficiency which is a result of existing instruments and historical trends.

9.2.2 Other mobile combustion

Projections for mobile combustion are based on energy projections developed by the Swedish Energy Agency. These projections are adjusted to fit the NFR format as well as to correspond to national fuel deliveries.

Emission factors for projections are based on expert judgements. Most emission factors are the same as in previous projections or updated as necessary, e.g. when emission factors for inventory data are lower than previously estimated projection emission factors. The emission factors for navigation were updated in 2020 to reflect decided regulations on fuel's sulphur content and on emissions of nitrogen oxides as well as the anticipated use of abatement technologies such as scrubbers and selective catalytic reduction[219]. Emission factors for mobile machinery were also updated in 2020, assuming that Stage V emission standards are met by all mobile machinery that is in use by 2040 and adjusting the emission factors accordingly[220].

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[217] Gustafsson, T., Helbig, T. (2018) Förbättrade nationella beräkningsunderlag för utsläpp av PM2,5, BC, EC/OC, CH4, NMVOC och CO från småskalig biobränsleeldning. SMED Prememoria 2018-02-28. Available in Swedish.

[218] Helbig, T., Gustafsson, T., Kindbom, K., Jonsson, M. (2018) Uppdatering av nationella emissionsfaktorer för övrig sektor (CRF/NFR 1A4). SMED Rapport Nr 13 2018. Available in Swedish.

[219] Fridell, E., Winnes, H., Eklund, V. (2020) Emission factors for shipping scenarios. SMED Report No 11 2020

[220] Mawdsley, I., Jerksjö, M. (2020) SMED Promemoria 2020-12-18 (Available in Swedish)

9.3   Fugitive emissions

Activity data is based on energy projections from the Swedish Energy Agency that are adjusted to fit the NFR format. Emission factors or implied emission factors are used to calculated emission projections.

9.4   Industrial processes and product use

The larger emission sources are identified and handled in more detail than smaller sources, which are assumed to have constant emissions in the projections.

Activity data for NFR sources 2A, 2B and 2C is based on trend analysis of historical emissions and information from industry companies and organisations.

Where national or default emission factors are used in the emission inventory, emission projections are calculated based on these. In other cases, where emissions correlate to activity data historically, implied emission factors are calculated on a plant-level basis and used to calculate emission projections. If emissions do not correlate to activity data historically, constant emissions are assumed unless there is other available information.

For NFR 2H1 pulp and paper, a new method for estimating projections of NOx, SO_2 and particles was developed in 2020(refer to report). Production volumes are assumed to correlate to the development of black liquor projected by the Swedish Energy Agency. Emission factors for NOx, SO_2 and particles are assumed to be equivalent to the higher end of the Associated Emission Levels (AEL) of the BAT Conclusions for the Production of Pulp, Paper and Board, or lower if emissions are below the AEL. Emission factors used to calculate historical emissions are used to calculate other air pollutants.

For NFR sources 2D, 2G, 2H2 and 2H3, constant emissions are assumed.

9.5   Agriculture

Emission projections are based on projections by the Swedish Board of Agriculture. The Swedish Board of Agriculture applies a Swedish Agricultural Model (SASM) to produce projections for activity data for the years 2020, 2030 and 2045. These activity data projection model considers availability, prices on input material, processing of products, demand on food, and transportation costs. The model projects the development of the Swedish agriculture assuming the best economic outcome based on the input parameters.

For emission projections, activity data for 2025, 2035, 2040 and 2050 are interpolated or extrapolated. Some types of activity data that are not included in the projections by the Swedish Board of Agriculture are estimated in other ways. This includes amounts of harvested products of certain crops and number of some swine categories.

The emission factors are assumed to stay constant compared to inventory year 2019.

9.6 Waste

NMVOC emissions from NFR 5A landfilling, NH_3 emissions from NFR 5B1 and NH_3 emissions from NFR 5B2 are assumed to follow corresponding projections for CH_4 emissions. For landfilling, a model developed by IPCC is used, modified to suit Swedish conditions. Data on historical amounts of landfilled waste, the organic content of the waste and gas potential of different waste types are used in the model.

Emission projections for PM2.5 for NFR 5A are assumed to be constant. NFR categories 5D1, 5D2 and 5E are assumed to be constant.

9.7 Consistency with inventory data

During the last few years, the process of producing projections have been more synchronised with the system for emission inventory. For example, calculations for projections have been integrated in the same data models as for the emission inventory when possible, and data is stored on the same aggregation level and in the same database as inventory data. This has helped to ensure that projection data is consistent with inventory data.

10 Reporting of gridded emissions and LPS

Gridded emission data gives information of the geographical distribution of emissions and is used for control purpose and serves as an important input data for atmospheric dispersion modelling.

10.1 Gridded emissions

10.1.1 Scope

Swedish gridded emissions were last reported to UNECE in 2017. The years 1990, 2000, 2005, 2010 and 2015 were included in the submission for the following components: NO_X, NMVOC, SO_X, NH_3, $PM_{2.5}$, PM_{10}, BC, CO, Pb, Cd, Hg, PCDD/PCDF (dioxins/furans), PAHs, HCB and PCB.

The gridded emissions were aggregated into GNFR-sectors: A_PublicPower, B_Industry, C_OtherStationaryComb, E_Solvents, F_RoadTransport, G_Shipping, H_Aviation, I_Offroad, J_Waste, K_AgriLivestock and L_AgriOther. Due to data confidentiality it has not been possible to report the GNFR-sector D_Fugitive as a separate sector; these emissions have been included in the sector B_Industry.

The new EMEP grid resolution of $0.1° \times 0.1°$, introduced in the 2014 Reporting Guidelines, was implemented in the last reported gridded emissions in 2017. The previous gridded emissions reported in 2012 followed the old EMEP grid resolution of $50 \text{ km} \times 50 \text{ km}$.

10.1.2 Methodology

Both top-down and bottom-up approaches are used in order to calculate gridded emissions in Sweden. The methodology to allocate emissions into grid cells is schematically described below:

- For some emissions sources, the emissions are allocated with a bottom-up approach:

    o Emissions from large point sources are allocated directly into the appropriate grid cells.

    o Emissions from road transport are allocated to grid cells using a national road database (NVDB) containing the Swedish road network, vehicle kilometers and vehicle compositions.

    o Emissions from national shipping are allocated to grid cells with a system that uses AIS-data.

- For other emission sources where the emissions are not known for every grid cell, a top-down approach is used:

    - For many emission sources, activity data (or surrogate data) on an aggregated geographical level (for example municipality level) is used together with geographical data, in order to create a proxy. For example, emissions from civil aviation (LTO) are allocated with a proxy containing the numbers of LTOs per Swedish airport as activity data and the locations of the airports as the geographical data. Another example is emissions from manure management that are allocated with a proxy containing the numbers of animals per municipality as activity data and agriculture areas as the geographical data.

    - For some emission sources, activity data is only available on national level. For such emissions, only geographical data is used as a proxy. One example is emissions of NH_3 from pets; these emissions are allocated with population density as a proxy/surrogate data.

Description of methodology for each sector in the gridded emissions

A_PublicPower

Public electricity and heat production, 1A1a
Different methodologies are used for estimation of gridded emissions for 1990-2000 and from 2005, respectively. In 1990 and 2000, the availability of administrative information about various facilities within one company and the connection between the observation id and the identity of the specific combustion identity was low. Therefore, the emissions in these years are estimated at municipality level and distributed over areas according to 2005.

Activity data is the same as the one used for estimating the annual emissions to CLRTAP - Quarterly fuel statistics (KvBr) - which is a total survey regarding the public electricity and heat production. The emissions are aggregated at id-level and all of the administrative variables are kept in order to add the respective coordinates. Register variables are merged with the following geographical data:

- Real estate and addresses from register
- Real estate from real estate maps with assessment
- Information about the real estate maps
- The facilities' boundary line
- The working places of the Statistical Business Register
- Municipality borders
- Borders of urban areas
- Grid net 1 km × 1 km

Each facility in the activity data has a specific administrative number that is used in order to merge with coordinates. In those cases where the merge cannot be done due to lack of administrative number, information about real estate, urban areas are used to add coordinates to the facility.

In some of the observations, the emissions represent more than one emission source. The observations are in those cases divided and assigned different coordinates which enable the facilities to be located at different municipalities. Real estate coordinates are matched and controlled with information from EU-ETS data base. In submission 2021, there are 10 observations from the Quarterly fuel statistics that include 75 multiple facilities.

The quality of the gridded emissions in the Public electricity and heat production sector is rather good, since the public electricity and heat production sector in the quarterly fuel statistics is a total survey, which includes all the facilities. Information about fuel boilers in each observation might be limited, which increases the uncertainty at grid level. In addition, the uncertainty increases due to that some of the observations include several facilities. In general, the emissions are estimated with emission factors for each fuel combusted and are deemed to be certain at national level. However, for certain municipalities the uncertainty might be of significance since it cannot be expected that the facilities in each municipality have the same combustion technique. Uncertainties of emission factors for some emissions, e.g heavy metals are large. Regarding these emissions, the trend is more reliable. The uncertainties are also larger for the emissions in year 1990 and 2000, since emissions are not estimated at facility level (estimated at municipality level and distributed according to 2005 methodology).

B_Industry

Since submission 2018, various industry sectors are aggregated into a larger industry sector. The reason for this large aggregation of several sectors is due to confidential activity data which cannot be revealed according to the Swedish regulations for the emission years 2015 and forward. In order to keep a consistent methodology, this aggregation is applied for the whole time series. The aggregated industry sector includes the following sources:
- Petroleum refining (1A1b)
- Fuels combustion within the manufacturing industry for energy purposes (1A2)
- Industrial processes: Mineral, chemistry, metal, paper and pulp, use of fluorinated gases and other sectors (2)
- Fugitive emissions from fuel management (1B)

Petroleum refining, 1A1b

There are five large and a few smaller refineries in Sweden, which generate pollutant emissions to air. The five large facilities represent 99.9% of the fuel combusted, generating emissions to air.

Emissions from the large refineries are gathered from the EU-ETS database for CO_2-emissions. Other emissions are based on the fuel consumption reported in EU-ETS. EU-ETS data is used from 2007 and forward. For previous years 1990, 2000, 2005 and 2006, specific facility level activity data is used. The quality of the EU-ETS data base is considered to be high for all the refineries. Also, the facility level data used before 2005 is considered to be of high quality.

Manufacture of solid fuels and other energy industries, 1A1c

Activity data on coke production is collected from environmental reports. Emissions of NMVOC and CO are estimated with the Tier 2 methodology with national emission factors. Estimates of emissions of SO_2 and NO_X are available from environmental reports on aggregate level, and these emissions are distributed over the different NFR codes (1A1c, 1A2a, 1B1c and 2C1, SO_2 also 2B5 and 1B1b) according to the activity data distribution. The gridded emissions are estimated as 1A1a.

Iron and steel, 1A2a

National emissions from this sector are mainly based on the Quarterly fuel statistics for the years 2005 and forward and for 1990 and 2000 the main source is the Energy use in the manufacturing industry (ISEN). The gridded emissions follow the same method as in 1A1.

The quality of the gridded emissions is considered to vary between municipalities. Data in municipalities with few larger facilities are often of higher quality.

Non-Ferrous Metals, 1A2b

See 1A2a.

Chemicals, 1A2c

See 1A2a.

Pulp, Paper and Print, 1A2d

See 1A2a.

Food Processing, Beverages and Tobacco, 1A2e

See 1A2a.

Non-metallic minerals, 1A2f

Divided between counties proportional to the number of construction permits issued. Within each county distributed according to population density (1.A.2.f.i.ii).

Other Industries, 1A2g

National emissions from this sector are mainly based on the Quarterly fuel statistics for the years 2005 and forward and for 1990 and 2000 the main source is the Energy use in the manufacturing industry (ISEN). The gridded emissions follow the same method as in 1A1, except for the small industries, due to that the AD for this category is aggregated and there is no administrative information at facility level. These emissions are distributed according to a list of smaller industry companies, which is revised each 5 to 10 years.

The quality of the gridded emissions is considered to vary between municipalities. Data in municipalities with few larger facilities are often of higher quality. However, in municipalities with a large proportion of aggregated emissions, the uncertainty is higher.

Coal mining and handling. 1B1a

Sweden has no emissions from this sector.

Solid fuel transformation, 1B1b

The code covers coke production from coking coal occurring at two facilities. Emissions are linked to the geographical coordinates of the facilities.

Other, 1B1c

The code covers two activities:

- Flaring of coke oven gas occurring at two facilities. Emissions are linked to the geographical coordinates of the facilities.
- Milling of peat on peat extractions also are included. Emissions are distributed over areas with marshland and are weighted by county according to statistics on concession area for peat extraction

Hydrogen production plants at refineries, 1B2ai

Hydrogen production occurs at three refining facilities. Emissions are linked to the geographical coordinates of the facilities.

Refining/storage, 1B2aiv

The code covers desulphurization, make-up coke burning, catalyst regeneration, and fugitive emissions (evaporation from tanks) within Swedish refining facilities. Emissions are linked to the geographical coordinates of the facilities.

Gasoline handling and distribution, 1B2av

Emissions from petrol handling from the more than 3,000 fuel stations in Sweden, are distributed over the number of fuel stations per km (data from the Swedish Agency for Growth Policy Analysis (Tillväxtanalys)).

Transmission and distribution of natural gas and gasworks gas – fugitive emissions, 1B2b

Fugitive emissions of methane that occur in distribution of natural gas is distributed over 68 measuring stations, line valve stations, inspection stations and branches per km along the Swedish natural gas network. The emissions are distributed in proportion to the capacity of the lines measured in gas pressure.

Venting and flaring, 1B2c

The code covers three activities:

- Venting of natural gas in the distribution network. A major part of venting (up to 98% of the total vented amounts) occurs at the large storage facility– these emissions are linked to the facility's coordinates. The remaining emissions are distributed over 68 measuring stations, line valve stations, inspection stations and branches per km along the Swedish natural gas network, in proportion to the capacity of the lines measured in gas pressure.
- Flaring of natural gas in the distribution network. The emissions are distributed over 68 measuring stations, line valve stations, inspection stations and branches per km along the Swedish natural gas network, in proportion to the capacity of the lines measured in gas pressure.
- Flaring of refinery gas and other gases (hydrogen, sulphur anhydride) at refineries occurring at four facilities. Emissions are linked to the geographical coordinates of the facilities.

Cement production, 2A1

Emissions from cement production are linked to the geographical coordinates of the facilities.

Lime production, 2A2

Major part of the emissions from lime production is linked to the geographical coordinates of the facilities. The remaining emissions are are evenly distributed across industrial areas.

Glass production, 2A3

Most emissions are linked to the geographical coordinates of the facilities. Emissions from small-scale manual glass production are are evenly distributed across industrial areas.

Quarrying and mining of minerals other than coal, 2A5a

Emissions from use of explosives are evenly distributed over total mining areas including 165-170 mining sites. Emissions from limestone mining are distributed over limestone mining facilities.

Construction and demolition, 2A5b

Emissions from construction and demolition activities are evenly distributed across industrial areas.

Other mineral products, 2A6

The code covers production of batteries and production of mineral wool. Emissions from both activities are linked to the geographical coordinates of the facilities.

Nitric acid production, 2B2

Emissions from nitric acid production are linked to the geographical coordinates of the facilities.

Carbide production, 2B5

Emissions from calcium carbide production are linked to the geographical coordinates of the facility.

Other chemical industry, 2B10a

Emissions from a variety of chemical plants are linked to the geographical coordinates of the facilities.

Iron and steel production, 2C1

Emissions from production of iron and steel (primary and secondary steel production, production of sponge iron) are linked to the geographical coordinates of the facilities.

Ferroalloy production, 2C2

Emissions from production of ferroalloys are linked to the geographical coordinates of the facilities.

Aluminum production, 2C3

Emissions from aluminum production are linked to the geographical coordinates of the facilities.

Other metal production, 2C7c

The code includes emissions from all production of non-ferrous metals. Emissions are linked to the geographical coordinates of the facilities.

Road paving and asphalt, 2D3b

Geographical distribution of emissions is made after traffic work from SIMAIR / the Swedish Transport Administration (Trafikverket) for asphalting of roads

Asphalt roofing, 2D3c

Geographical distribution of emissions is done according to industrial areas for the production of roofing with asphalt

Pulp and paper industry, 2H1

Emissions from pulp and paper mills are linked to the geographical coordinates of the facilities.

Food and beverages industry, 2H2

Emissions from food and beverage producers are evenly distributed across industrial areas.

Wood processing, 2I

Emissions from sawmills are evenly distributed across industrial areas.

Consumption of POPs and heavy metals, 2K

Emissions from the use of fluorinated gases are distributed according to population density.

C_OtherStationaryComb
NFR Codes: 1A4ai, 1A4bi, 1A4ci

Commercial/Institutional Stationary combustion, 1A4ai

This sector refers to heating of commercial and public premises. Energy statistics for premises have been used for the distribution of fuel consumption and emissions per fuel type and temperature zone. Temperature zone has been selected because the data material is not adapted for reporting on finer geographical level than that. Because the necessary data for geographical distribution is only available for the years 2005, 2006 and 2008, the shares for other years have been calculated as follows: 1990 and 2000 = same distribution as 2005. 2010, 2015 and 2019 = same distribution as 2008. A division has been made between refined and unprocessed fuel and between modern and traditional technology for the whole time series.

Residential Stationary combustion, 1A4bi

This sector contains emissions from all small-scale heating systems in detached houses, holiday houses and apartment buildings. The data consists of model estimates from the annual energy balances. The distribution of emissions is made at a municipal level and is based on:

- Statistics from The Swedish Civil Contingencies Agency (MSB) on the number of fireplaces (wood boilers, local fireplaces, pellet boilers and oil boilers) per municipality /emergency services.

- The energy needs of small houses have been calculated with the ENLOSS energy balance model to find the energy requirement for an average meteorological year.

- Assumptions about heating habits and share of fuel, which are made from the outside experience from other studies and surveys as well as knowledge on the number of detached houses connected to district heating networks per municipality.

- Emission factors per type of fireplace and efficiency.

For the distribution keys, separation has been made of wood boilers with ceramic fireplace, where these emissions are calculated with emission factors for environmentally approved boilers. While those without a ceramic fireplace have been calculated with emission factors for non-environmentally approved wood boilers. Within each municipality, the emissions are then distributed by living area per square kilometers for each house type. The living areas are taken from the property register. The district heating supply in each urban area has been calculated from statistics from the Swedish Energy Markets Inspectorate's (Ei) register of district heating networks. In this way, emissions within each urban area are reduced by a factor that depends on number of detached houses connected to district heating networks according to this register. Thus emissions increase in urban areas that are less connected to district heating.

Agriculture/Forestry/Fishing: Stationary combustion, 1A4ci

This sector includes emissions that arise at stationary combustion in areal industries, such as agricultural and forestry premises. The data consists of model estimates from the annual energy balances, and the distribution of emissions from these fixed installations is evenly distributed over living space for agriculture. A division has been made between refined and unprocessed fuel and between modern and traditional technology for the whole time series.

D_Fugitives (Are included in B_Industry)

E_Solvents
NFR Codes: 2D3a, 2D3d, 2D3e, 2D3f, 2D3g, 2D3h, 2D3i, 2G4

Domestic solvent use, 2D3a

Households' use of solvents consists of about 1/3 of the emissions from the total use of solvents. Emissions are calculated based on national statistics from Swedish Chemicals Agency (KEMI). The emissions are distributed according to population density for each year.

Coating applications, 2D3d

Households' use of ink consists of about 1/3 of the emissions from the total use of ink. Emissions are calculated based on national statistics from Swedish Chemicals Agency (KEMI). The issues are distributed according to population density for each year. The use of ink in businesses is evenly distributed over industrial areas.

Degreasing, 2D3e

The source refers to emissions of volatile organic compounds from use of degreasing in industry. The emissions are evenly distributed across industrial areas.

Dry cleaning, 2D3f

The source refers to emissions of volatile organic substances from dry cleaners. The emissions are distributed according to population density for each year.

Chemical product use, 2D3g

The source refers to emissions of volatile organic compounds from use of solvents and chemical products in industry. The emissions are evenly distributed across industrial areas.

Printing, 2D3h

The source refers to emissions of volatile organic compounds from printing works. The emissions are evenly distributed across industrial areas.

Other solvent and product use, 2D3i

The source refers to emissions of volatile organic compounds from others activities, which are dominated by agriculture and forestry (approx. 25%) and other non-industrial (approx. 38%). The emissions are distributed by population density Another emission in this source is carbon dioxide from the use of urea in SCR catalysts (SCR = Selective catalytic reduction) Reported carbon dioxide emissions from urea use are based on national statistics from the Swedish Chemicals Agency (KEMI), and on emission factors from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The emissions of carbon dioxide from the use of urea in catalysts are distributed across industrial land for the year 1990 and after traffic work for the year 2000 and onwards.

Other product use, 2G4

This sector includes air pollutants from tobacco smoking and fireworks. Emissions are calculated using emission factors and statistics quantities of sold tobacco products (excluding snus) and national statistics on the import of fireworks. The emissions are distributed according to population density. Another emission originates from the use of products as anesthesia, firefighting equipment, aerosol cans and other nitrous oxide use. These emissions are distributed geographically according to population density.

F_RoadTransport
NFR Codes: 1A3bi, 1A3bii, 1A3biii, 1A3biv, 1A3bv, 1A3bvi, 1A3bii

Road transport: Passenger cars, 1A3bi

Road traffic emissions are calculated by the SIMAIR air quality system. Emission factors used for exhaust and evaporative emissions are from HBEFA 3.3.

Roads in Sweden is a combined system with a nationwide network maintained by the Swedish transport administration, complemented by local roads maintained by each municipality, and private roads. All roads are classified by its role in the traffic system on a 10-grade scale called FVK, going from 0 for the back-bone highway links connecting the major cities or abroad to 9 that ends e.g. in an agricultural

field with almost no traffic demand. The national roads undergo systematic traffic counts such that each road has a count somewhere in the last few years. To get a total coverage picture of the traffic activity simulations of the national roads are performed to adopt a consistent flow that is as well adopted to all counts.

At municipal level traffic counts are also performed but not on all roads, and not all counts are reported to the Swedish transport administration. Roads with traffic counts are included in the traffic activity simulation for the part of the road it is considered to be a good estimate. Apart from the roads considered in the traffic activity simulation the nation is divided in thousands of areas and within these areas the remaining demand for transport both the first/last piece of a travel going to or from a larger road and transports within the area is estimated by a model. This transport demand is distributed among all roads with no previous estimate from the traffic simulation by the simple assumption that each grade on the FVK is a tenfold in traffic amount for all vehicle types.

Road transport: Light duty vehicles, 1A3bii
Same methodology as for passenger cars.

Road transport: Heavy duty vehicles and buses, 1A3biii
Same methodology as for passenger cars.

Road transport: Mopeds & motorcycles, 1A3biV
Same methodology as for passenger cars.

Road transport: Gasoline evaporation, 1A3bv
Same methodology as for passenger cars.

Road transport: Automobile tyre and brake wear, 1A3bvi
Regional emission factors are calculated for each of the 6 regions used by the Swedish transport administration. At points with well-known traffic situations and measurements of PM10 emissions are estimated by the combined mechanical wear emission and resuspension model developed at the Swedish Meteorological and Hydrological Institute. Road transport activity is calculated as for the exhaust emissions and distributed in time according to an hourly distribution over a week and a monthly distribution over the year for each vehicle type on a road, then particle emissions are calculated hour by hour over the year including meteorological premises and compared to measured values. Using these calculations, a regional emission factor is calculated. Emissions for the whole region is calculated by applying this emission factor to the transport activity on all roads in the region.

Road transport: Automobile road abrasion, 1A3bvii
See NFR code 1A3bvi for methodology.

G_Shipping
NFR Codes: 1a3dii

National Navigation, 1A3dii
Emissions from national navigation are divided into leisure boats and other domestic navigation. Domestic navigation refers to the traffic between Swedish ports. The calculation system Shipair developed by Swedish Meteorological and Hydrological Institute (SMHI) and the Swedish Maritime Administration (SMA) is used as the basis for the distribution of emissions from other domestic navigation. The system includes a bottom-up model for ship emissions that combines data from Automatic Identification System (AIS) with detailed ship characteristics. If the characteristics of a ship are known, the positions from AIS can be used to calculate energy and fuel consumption between two moment. Depending on the ship's cruise status, different emission factors are used. Cruise status refers to whether the vessel is in normal operation, maneuvering or standing still at a normal quay, electrically powered dock or at anchor. Distribution keys have been produced in Shipair for the years 2010-2019 (for the years before 2010 the distribution key is used for 2010) The distribution of emissions from leisure boats is done separately for the coast and inland. Most boats are located on the coast and their emissions can be distributed with the help of aerial and satellite photos. For each square kilometer box, the number of wharfs within a distance of 10 km is used as a measure of the traffic. Within the hinterland, there is no wharf inventory and the boats are instead distributed evenly over the watercourses weighting with municipal population. For the distribution of leisure boats over Sweden's inland and coastal areas materials are used from several different sources: Statistics Sweden (SCB), The Swedish Mapping, Cadastral and Land Registration Authority (Lantmäteriet), Norrbotten and Stockholm County Administrative Boards, and Swedish Meteorological and Hydrological Institute (SMHI)

H_Aviation
NFR codes: 1A3a i-ii

Civil Aviation, 1A3a i-ii
This sector includes all civil aviation below an altitude of 1000 m (LTO, "Landing and Take-Off") for both domestic and international travel. But since the methodology for domestic aviation over 1000 meters (domestic cruise) are produced in the same way, this is also included here.
The distribution of emissions is based on landing statistics for Swedish airports from the Swedish Transport Agency (STAg) in combination with actual flight movements, and takes place according to the following steps:

1. Calculation of a representative geographically distributed flight pattern between each domestic airport and aviation to/from a domestic airport to all international airports.

2. Calculation of total emissions for each airport pair and aircraft type based on annual landing statistics. The emissions are then distributed over the airport couple's representative flight pattern.

3. Summary of the above issues to a total distribution over Swedish territory.

Landing statistics for Sweden's airports are obtained from STAg for the year 2005 and onwards, for 1990 and 2000, landing statistics are missing, so for these years the same distribution key is used as in 2005.

The geographically distributed flight patterns are based on data collected over four weeks in 2015. Data were collected from Automatic Dependent Surveillance – Broadcast (ADS-B), Multilateration (MLAT), and radar over Swedish territory from aircraft during the LTO phase and cruise. These flight movements were then used to create a representative flight pattern and flight distance between each pair of airports.

For the aircraft's emission factors, the calculation tools available with the EMEP/EEA Guidebook for emissions (European Environment Agency, 2016, 1.A.3.a Aviation) are used. These are used to calculate the emission factors for different long flight distances, as well as separate emissions from the LTO phase divided into taxi out, take off, climb out, landing and taxi in. In this way, emission factors are produced for 40 of the most common types of aircraft for Cruise, and for 33 of the most common types of aircraft for LTO. All aircraft that do not have specific emission factors are assigned values from an aircraft with similar characteristics.

The total emissions are then calculated for each airport pair and aircraft type according to the STAg:s landing statistics. LTO emissions are distributed according to activity in the flight pattern between 0 and 1000 meters altitude and cruise emissions are distributed according to activity at altitudes above 1000 meters (domestic cruise). The results are then summed up in a total distribution pattern over Swedish territory.

I_OtherMobile
NFR codes: 1A2gvii, 1A3c, 1A3e, 1Aeii, 1A4aii, 1A4bii, 1A4cii, 1A5b

Among the subsectors to 1.A.2.g.vii the emissions are divided according to the amount of fuels consumed derived from a model run.

Mobile combustion: Construction, 1A2gvii
Divided between counties proportional to the number of construction permits issued. Within each county distributed according to population density.

Mobile combustion: Road construction, 1A2gvii
Distributed along the road network proportional to the traffic work.

Mobile combustion: Industry, 1A2gvii
Distributed over areas of land use industrial.

Mobile combustion: Iron and steel, 1A2gvii
Distributed among the facilities weighted by the number of employees according to the trade association Jernkontoret.

Mobile combustion: Forestry, 1A2gvii
Divided between counties proportional to the amount logged forest according to the Swedish Forest Agency. Within each county distributed over areas of land use industrial.

Mobile combustion: Mines, 1A2gvii
Divided between the production facilities proportional to the amount of gangue mined. Evenly distributed over the area of each facility.

Railway, 1A3c
Emissions are from diesel powered engines for shunting and long haul and MTUs and rail cars for passenger traffic. Emissions are divided to 70 % shunting and 30 % on the lines. Shunting emissions are divided into marshalling yards proportional to the number of carriage movements. For each marshalling yard the emissions are distributed on land tagged land use rail in OpenStreetMap within a 10 km radius from the central coordinates of the yard. Emissions on the lines are distributed according to the traffic counts for diesel powered engines, MTUs and railcars.

Other transportation: Pipeline, 1A3e
Distributed along the pipeline system for natural gas according to the number of regulatory stations where distribution nets with lower pressure is attached.

Other transportation: Railways, 1A3eii
Divided between the national railway system and the local tram systems that are running regular traffic proportional to their maintenance budgets. In each tram system the emissions are distributed evenly along all rail. In the national railway system the emissions are distributed proportional to the traffic counts of engines for each part of the system.

Other transportation: Airport, 1A3eii
Divided between airports proportional to the number of landings according to the Swedish Transport Agency. Evenly distributed over the area of the airport according to OpenStreetMap.

Other transportation: Harbors, 1A3eii
Distributed on harbor areas, divided between the harbors proportional to the number of arrivals according to the Swedish Maritime Administration.

Commercial/Institutional: Mobile, 1A4aii
Distributed as floor area of apartment buildings.

Residential Mobile: AWD, 1A4bii

Divided between municipalities according to the number of registered vehicles. Within each municipality distributed as the floor area of detached houses, semi-detached houses and vacation houses.

Residential Mobile: Household/Garden, 1A4bii

Distributed as the floor area of detached houses, semi-detached houses and vacation houses.

Off-road vehicles and other machinery: Agriculture, 1A4cii

Divided between municipalities proportional to the total motor power for all tractors registered in the municipality. Within each municipality distributed on farmland.

Off-road vehicles and other machinery: Forestry, 1A4cii

Evenly distributed on areas subject to actual logging determined from differences in satellite pictures.

Off-road vehicles and other machinery: National fishing, 1A4cii

Emissions calculated by an emission model for ships, Shipair, developed by SMHI. Emissions are calculated from ship movements in AIS data and properties of the ships provided directly from the AIS data as well as two other databases with ship properties. About 350 of the 1300 Swedish fishing ships are using AIS transponders but are considered representative for the whole fleet.

Other mobile: Military traffic, 1A5b

Evenly distributed among military training areas.

Other mobile: Military navigation, 1A5b

Evenly distributed among naval bases.

Other mobile: Military aviation, 1A5b

Evenly distributed among wings.

J_Waste

NFR codes: 5A, 5B1, 5B2, 5C1bii, 5C1bv, 5C2, 5D1, 5D2, 5E

Solid Waste disposal on land, 5A

The data for the distribution consists of municipal landfills from Swedish Waste Management's reports with landfills quantities of household waste, park waste and municipal sewage sludge. Deposited quantities have been collected from several years: 1994, 2000 and 2001, in order to even out variations between them. For biological industrial waste, the distribution has been made according to information on industry-specific waste in Swedish Waste Management's reports. The information

about recovered methane gas has been obtained from Swedish Waste Managements and the distribution is made separately for each type of waste.

Composting, 5B1

The sector includes emissions of nitrous oxide and methane from composting plants. To distribute these emissions, information is taken from Swedish Waste Managements for the year 2005 and 2008-2017. Available data have been composting per municipality (tons of waste per year). The remaining post from all other municipality is evenly distributed over the remaining municipalities. Within each municipality the emissions is distributed across industrial land.

Anaerobic digestion at biogas facilities, 5B2

The sector includes emissions of nitrous oxide and methane from so-called co-digestion plants, i.e. digestion at biogas plants. To distribute these emissions, information is taken from Swedish Waste Managements for the year 2005 and 2008-2017. Available data have been rotting per municipality (tons of waste per year). The remaining post from all other municipality is evenly distributed over the remaining municipalities. Within each municipality the emissions is distributed across industrial land.

Incineration of hazardous waste, 5C1bii

This sector consists of the combustion carried out at Fortum's facility (SAKAB) in Kumla municipality, i.e. all emissions are facility specific.

Cremation, 5C1bv

The emissions from incineration at the crematorium are distributed on Swedish crematoria. The emissions have either been reported by the crematorium or calculated using a standard value based on the number of cremated per facility. Statistics have been obtained from Swedish environmental reporting portal (SMP) and the Swedish Cemetery and crematorium associations (SKKF). Cadaver incineration is also included in the national total for this sector.

Garden burning and bonfires, 5C2

Emissions from garden fires, may fires and equivalent, are distributed proportional to living space detached houses and holiday house.

Domestic waste-water handling, 5D1

The emissions are partly distributed by emissions of total nitrogen from all major and smaller municipal treatment plants in the country, and partly on individual sewers. Emissions from the individual sewers are distributed according to the population, within the parts of the country that have a population density that is less than 10 inhabitants per square kilometer. To determine the proportion of emissions allocated to individual sewers, the same methodology is used as within the international reporting of Sweden's total emissions.

The emissions of NH3 and NMVOC are separately reported for latrines (temporarily portable toilet). Distribution of these emissions takes place according to statistics from Swedish Waste Managements of weighted amount of waste (tons) per municipality. As there is too much uncertainty in the data from individual years, an average value for the years 2012-2017 is used, thus the same activity data is used throughout the time series. The emissions within municipalities are then distributed according to population density for each year.

Industrial waste-water handling, 5D2
The emissions from treatment of waste water from industries (not connected to municipal sewage treatment plants) is distributed over industrial land per square kilometer.

Other waste: Sludge spreading, 5E
The emissions are distributed over municipal sewage treatment plants.

Other waste: Landfill fires, 5E
The same distribution as NFR 5A - Solid waste disposal on land.

Other waste: House and car fires, 5E
Emissions from house and car fires include emissions of particles, heavy metals and dioxin for various types of fires; car fires, house fires (isolated and non-insulated houses), apartment fires and industrial building fires. The emissions are distributed according to municipal statistics on fires from Swedish Civil Contingencies Agency (MSB) The fires are divided into categories (cars, detached houses, chain houses, apartment buildings and industrial buildings) on which the emissions is calculated according to associated emission factors. Different distribution keys are then used within the municipalities depending on the type of building in which the fires took place:

- For car fires, emissions within municipalities are distributed over living space apartment buildings per square kilometer, as a significant part of the fires take place in multi-dwelling areas.

- For fires in detached houses and chain houses, the emissions are distributed within municipalities over living space detached houses per square kilometer.

- For fires in apartment buildings, the emissions within municipalities are distributed over living space apartment buildings per square kilometer.

- For fires in industrial buildings, the emissions are distributed within municipalities over the share of industrial land per square kilometer.

Other waste: Pets, 5E
Emissions from small-animal feces are weighted according to population density.

K_AgriLivestock
NFR codes: 3B1a, 3B1b, 3B2, 3B3, 3B4d, 3B4e, 3B4g, 3B4h

Manure management: Dairy cattle, 3B1a + Non-dairy cattle, 3B1b

The emissions from cattle manure are distributed according to the number of animals per municipality / county and are placed on pasture. For municipalities that have classified information on the number of animals, the difference between the total number of animals at county level, and the sum of the municipalities for which there is information is calculated. This difference is then distributed between the municipalities that have classified information according to the same situation that prevailed between these municipalities a year when the information was not covered by confidentiality. For municipalities that have had secrecy for all years, the rest is evenly distributed instead.

Since the number of animals per municipality is updated only every third year, while county statistics are updated every year, annual statistics on the number of animals at county level are also used. The county totals are distributed in the intermediate years according to the same municipal conditions as the closest year for which there is municipal statistics.

Manure management: Sheep, 3B2

The emissions from sheep manure are distributed according to municipal statistics on the number of sheep per municipality, according to the same methodology as for cattle. Within the municipalities the emissions are distributed by number of animal places per holding.

Manure management: Swine, 3B3

The geographical distribution is made by weighting the emissions by the number of swine per municipality / county, according to the same methodology as for cattle. The distribution within the municipalities is then based on production location per holding. Data on the number of animals per municipality / county are of higher quality than holding-specific data, so by basing the distribution on holding-specific data, and then weighted with reviewed data, a certain quality assurance is obtained without losing the available holding data. The emissions are then distributed over the living area for agricultural properties.

Manure management: Goats, 3B4d

The emissions from goat manure are distributed according to municipal statistics on the number of goats per municipality, according to the same methodology as for cattle. Within the municipalities, the emissions are distributed according to the number of animal places per holding.

Manure management: Horses, 3B4e

The emissions from horse manure are distributed according to the number of horses per municipality, according to the same methodology as for cattle. Within the municipalities, the emissions are distributed over pasture land.

Manure management: Poultry, 3B4g

Emissions are produced by weighting according to statistics from the Swedish Board of Agriculture (Jordbruksverket) / Statistics Sweden (SCB) on the number of poultry per municipality, according to the same methodology as for cattle. Within the municipalities, the emissions are then distributed according to the number of poultry places per holding.

Manure management: Other Animals, Reindeer, 3B4h

Emissions for reindeer manure are evenly distributed over all land in the counties where reindeer occur.

L_AgriOther

NFR codes: 3Da1, 3Da2a, 3Da2b, 3Da2c, 3Da3 , 3Da4, 3Da5, 3Da6, 3Db, 3Dc, 3De

Inorganic N-fertilizers (includes also urea application), 3Da1

The code includes emissions from fertilizers on arable land. These emissions are distributed on arable land and weighted by the amount of nitrogen per county that comes from artificial fertilizers (the amounts of nitrogen added from commercial fertilizers according to Statistics Sweden's (SCB) statistics). For counties that do not have large amount of agricultural land, the data may for some years be so small that the information is classified. In these cases, data is used from other available years (without confidentiality) to geographical distribution these counties. The use of urea is evenly distributed over arable land.

Animal manure applied to soils, 3Da2a

For animal manure applied to soils, emissions are generated by weighting the total nitrogen supply per animal species. The activity data is the number of animals per municipality. Manure from grazing animals is distributed over grazing land and weighted by the number of animals per municipality / county.

Sewage sludge applied to soils, 3Da2b

The emissions from sewage sludge applied to soils are evenly distributed over arable land.

Other organic fertilizers applied to soils, 3Da2c

The emissions of other organic fertilizers are geographically distributed on arable land and weighted by the amount of nitrogen per county that comes from commercial fertilizers.

Urine and dung deposited by grazing animals, 3Da3

The emissions for fertilization from grazing animals are produced by weighting based on total nitrogen supply per animal species. Activity data used is the number

of animals per municipality. Manure from grazing animals is distributed over grazing land and weighted by the number of animals per municipality / county.

Crop residues applied to soils, 3Da4
The emissions of nitrous oxide from the use of crop residues as fertilizer, are added to arable land and weighted by the total harvest in the county (tons per year) for all crops from the Swedish Board of Agriculture (Jordbruksverket). For counties that do not have large amount of agricultural land, the data may for some years be so small that the information is classified. In these cases, data is used from other available years (without confidentiality) to geographical distribution these counties.

Mineralization/immobilization associated with loss/gain of soil organic matter, 3Da5
The emissions of nitrous oxide from the processing of mineral soil are distributed over the agricultural land and weighted by the mineral soil areas at county level.

Cultivation of organic soils, 3Da6
The emissions of nitrous oxide are distributed on arable land and weighted with the help of organic soil areas on county level. Information on organic soil areas has been obtained from Swedish University of Agriculture (SLU).

Indirect emissions from managed soils, 3Db
This sector contains indirect emissions of nitrous oxide to the atmosphere, nitrogen leakage and drainage. Emissions to the atmosphere are distributed over agricultural land. The emissions from nitrogen leakage and drainage are distributed over the arable land.

Farm-level agricultural operations, 3Dc
The code includes emissions of particles from the storage, handling and transport of agricultural products. These emissions are distributed over the living space for agricultural properties.

Cultivated crops, 3De
The emissions of NMVOC from crop cultivation are evenly distributed over arable land.

10.1.3   Recent improvements
A summary of the major improvements of the gridded emissions reported in 2021, in comparison with gridded emissions reported in 2017, is given below:

- IIR has been updated with a detailed distribution methodology for each NFR code in the different GNFR sectors.

- Emissions from national shipping have been updated with an improved system for AIS-data. See NFR Codes 1a3dii for methodology.

- The methodology for gridding emissions from national and international aviation (LTO) have been updated to use DS-B, MLAT and radar data. See NFR code 1A3a i-ii for methodology.

- The database used for gridding emissions from road transport has been updated with a new year (2018). The traffic flow simulations for this new year has been updated and reveals higher and more realistic transport demands for travels internally within each of the model areas (see sec F_RoadTransport for methodology). This is reflected in that regions divided in large model areas (low density of roads) is estimated with larger traffic than for previous years. Emissions from traffic estimated as transport demand within such areas are now distributed to the roads instead of the even distribution over the area use earlier.

- The activity data for the number of animals per municipality in the agricultural sector has been updated so that municipalities that were previously set to zero due to confidentiality, now gets a more representative number of animals. Another improvement in activity data for the number of animals is the use of annual statistics at county level now. See NFR code 3B1a for methodology.

- The distribution key for population density has been updated. Previously, two distribution keys were used for the entire time series, based on population density for two single year. Now individual distribution keys have been created for each year based on population density grids from Statistics Sweden (SCB) with a resolution of 100 m × 100 m.

- Mines now have a geographical distribution. Previously all emissions from mines were placed on a coordinate, now the mine's emissions are distributed over all grids where mine's distribution extends.

10.1.4   Planned improvements

Potential major improvements for the next reported gridded Swedish emissions (in 2025) is given below:

- An investigation will be made to explain why the reported emissions of gridded and LPS data are inconsistent regarding a number of grid cells. If it is possible, improvements of the geographical distribution may become relevant in order to reduce these differences in the future

- Distribution keys for road traffic will be developed with new methodologies for the previous year's 2007, 2015 and 2018, in order to make the data consistent through all years.

- Geographical distributed scenario years will likely be developed for the year 2030, and possibly 2040.

- The quality of the geographical distribution may be improved by utilizing new open geodata regarding land use.

10.2 LPS

The text in this section has been updated with information for submission 2021.

10.2.1 Description

Every four years from 2017 onward, parties are required to provide data on Large Point Sources (LPS). The Guidelines for Reporting Emissions and Projections Data (ECE/EB.AIR/125) states that as far as possible, reported LPS data should be consistent with emissions data available under the European Pollutant Release and Transfer Register (E-PRTR). However, the E-PRTR Regulation does not cover all information that is requested for LPS. This concerns emissions of $PM_{2.5}$, information on stack height and the facilities GNFR code.

From release year 2018 the requested information according to the E-PRTR Regulation is separated into two different dataflows, i.e. the EU Registry on industrial sites and the Integrated E-PRTR/LCP. The EU Registry on industrial sites includes administrative information (national facility ID, facility name, coordinates) about facilities that are covered by E-PRTR, whereas the E-PRTR/LCP dataflow includes information on emissions.

Information about LPS is used in the inventory for quality assurance and allocation of emissions between different sectors (for example energy and industry).

10.2.2 Completeness

The Swedish LPS data is consistent with the national officially reported data according to the E-PRTR Regulation (166/2006/EC) for 2019. When preparing the LPS data according to Annex VI, Sweden uses officially reported data according to the Integrated E-PRTR/LCP data flow and as well as the EU Registry on industrial sites for 2019.

None of the reported Swedish facilities that are included in E-PRTR for 2019 reports emissions of HCB and PCB. Information on stack height is not mandatory for LPS according to the reporting guidelines (ECE/EB.AIR/125) nor to the E-PRTR Regulation. Information on stack hight is not available for the Swedish E-PRTR facilities. Consequently, information on stack height is not included in Annex VI for Sweden.

10.2.3 Methodology

Information on $PM_{2.5}$ and GNFR is mandatory for LPS according to the reporting guidelines (ECE/EB.AIR/125). However, this information is not mandatory according to the E-PRTR Regulation and therefor this information is not reported by the operators of the Swedish E-PRTR facilities. Consequently, this information has been prepared by the inventory team and are included in Annex VI for Sweden.

10.2.3.1 GNFR

Each facility has been given a GNFR code based on its reported activity code according to Annex I of the E-PRTR Regulation. The TFEIP's revised reporting

codes table (TFEIP, 2019), that is available on the CEIP's webpage, has been used for the mapping between Annex I activity code and GNFR.

10.2.3.2 $PM_{2.5}$

Emissions of $PM_{2.5}$ have been calculated based on the operators reported emissions of PM_{10} as follows:

1. Based on reported emissions of PM_{10} and $PM_{2.5}$ in the NFR tables for GNFR "B_Industry" the average ratio of $PM_{2.5}$ to PM_{10} has been calculated. Some NFR codes (2D3b, 2C3, 2A5a and 2A5b) have not been included in the calculation, since no facilities with the corresponding Annex 1 activity code are reported in the Swedish E-PRTR data for 2019.

2. Based on the facilities' reported PM_{10} emissions according to E-PRTR, the calculated average ratio (83%) has been used to calculate $PM_{2.5}$ emission for LPS:s.

10.2.4   Recent improvements

In line with the recommendations that were put forward during the 2020 NECD review, the following improvements have been performed since the last reporting of LPS:

- The IIR has been updated with a section about LPS (description, methodology, improvements etc).
- For facility (0181-81-009/ 10014121.Facility) the coordinates have been corrected (i.e. no longer identical with the location of facility 0181-81-003/ 10014118.Facility). The Annex 1 activity code has been checked with the competent authority and has shown to be correct (i.e. 1.(c)) and consequently the previously reported GNFR code (A_PublicPower) for the facility is correct.
- $PM_{2.5}$ emissions have been included in the LPS reporting for all E-PRTR facilities exceeding the threshold for PM_{10}.

10.2.5   Planned improvements

No major improvements are currently planned.

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