Informative Inventory Report

Emissions of air pollutants in Iceland from 1990 to 2019

Submitted under the Convention on Long-range Transport of Atmospheric Pollutants

2021

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Preface

The Convention on Long-Range Transboundary Air Pollution (CLRTAP) was adopted in 1979 and entered into force in 1983. The Convention has been extended by eight Protocols, of which Iceland has ratified the Protocol on Persistent Organic Pollutants. Furthermore, in 2009 the national emission ceilings directive (NECD) 2001/81/EC was incorporated to the EEA agreement, with national emission targets set for Iceland for SO_2, NO_x, NMVOC and NH_3, for the year 2010.

According to Article 8 of the Convention, Parties shall exchange information on emissions of pollutants. To comply with this requirement and with the NECD, Iceland prepares an Informative Inventory Report (IIR) each year. The IIR together with the associated Nomenclature for Reporting tables (NFR tables) is Iceland's contribution to this round of reporting under the Convention. This report emphasizes emissions of Persistent Organic Pollutants as Iceland has only ratified the Protocol on Persistent Organic Pollutants (POPs) under the CLRTAP. Emissions of the indirect greenhouse gases (NO_x, CO and NMVOC), NH_3 and SO_2 are provided in the NFR tables as they are calculated to comply with the reporting requirements of the NECD and the United Nations Framework Convention on Climate Change (UNFCCC). Emission estimates for particulate matter (PM), black carbon (BC) and heavy metals (HM) are provided for several emission sources. A description of the trends and the calculation method for the pollutants are given in this report. Further estimates for SO_2, $PM_{2.5}$ and PM_{10} for the volcano Eyjafjallajökull that erupted in 2010, the volcano Grímsvötn that erupted in 2011 and the Holuhraun eruption in 2014 and 2015 are provided.

The IIR is written by staff at the Environment Agency of Iceland (EA).

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Executive Summary

1.1 Background

The Convention on Long-Range Transboundary Air Pollution (CLRTAP) entered into force in 1983. The Convention has been extended by eight Protocols, of which Iceland has ratified the Protocol on Persistent Organic Pollutants (POPs). The Protocol on Persistent Organic Pollutants entered into force in 2003. According to Article 8 of the Convention, Parties shall exchange information on emissions of pollutants. In 2009, the national emission ceilings directive (NECD) 2001/81/EC was incorporated to the EEA agreement, with national emission targets set for Iceland for SO_2, NO_x, NMVOC and NH_3 for the year 2010. At the time of writing, work is underway by the Icelandic government to evaluate and work at the incorporation of the new National Emissions Ceiling directive (Directive 2016/2284) into the EEA agreement. In 2020 the International Institute for Applied Systems Analysis (IIASA) carried out an analysis of reduction potentials for Iceland for NO_x, SO_2, NMVOC, NH_3 and $PM_{2.5}$, which was done in a way comparable to the analysis done by IIASA for the EU Member States (see also TSAP Report no 16[1]) .

To comply with the requirements of the Convention and of the national emission ceilings directive, Iceland prepares an Informative Inventory Report (IIR) annually. The IIR together with the associated Nomenclature for Reporting tables (NFR tables) is Iceland's contribution to this round of reporting under the Convention and covers emissions in the period 1990 – 2019. This report emphasizes on anthropogenic emissions of Persistent Organic Pollutants (Dioxin, PAH4, HCB and PCB), as Iceland has only ratified the Protocol on Persistent Organic Pollutants. Anthropogenic emissions of the indirect greenhouse gases (NO_x, CO and NMVOC) and SO_2 are provided in the NFR tables as they are calculated to comply with the reporting requirements of the UNFCCC and of the NECD. For this submission emission estimates for ammonia (NH_3), particulate matter (PM), black carbon (BC) and heavy metals (HM) are provided for emission sources where default emission factors are available from the EMEP/EEA 2019 Guidebook.

This report and the NFR tables are available on the Centre on Emission Inventories and Projections (CEIP) webpage:

https://www.ceip.at/status-of-reporting-and-review-results/2021-submission

1.2 Responsible institution

The Environment Agency of Iceland (EA), an agency under the Ministry for the Environment and Natural Resources, is responsible for the annual preparation and submission of the Icelandic informative inventory report (IIR) and Nomenclature for Reporting tables (NFR tables) to the Convention on Long-Range Transboundary Air Pollution. The EA participates in meetings under the United Nations Economic Commission for Europe (UNECE) Task Force on Emission Inventories and Projections (TFEIP) and related expert panels, where parties to the convention prepare the guidelines and methodologies on inventories.

[1] http://www.iiasa.ac.at/web/home/research/researchPrograms/air/policy/TSAP_16b.pdf

1.3 Overview of POPs emissions

All sources of POPs emissions fall under the energy, the industry and the waste sector; activities belonging to the agriculture sector and occurring in Iceland do not generate POPs emissions.

Dioxin (PCDD/PCDF) emissions decreased substantially over the reported time period (Figure ES. 1), due to a significant decrease in the occurrence of open burning of waste. Open burning of waste was a common waste management practice in Iceland pre-2004. However, an increase in the amount of waste incinerated in incineration plants without energy recovery occurred in 2004 while a reduction of the amount of waste burned in the open occurred in that same year. Whilst open burning of waste is still the second largest contributor to the national total in the most recent year of the time series (after accidental fires), the amount emitted yearly in recent years is less than one percent of the 1990 level.

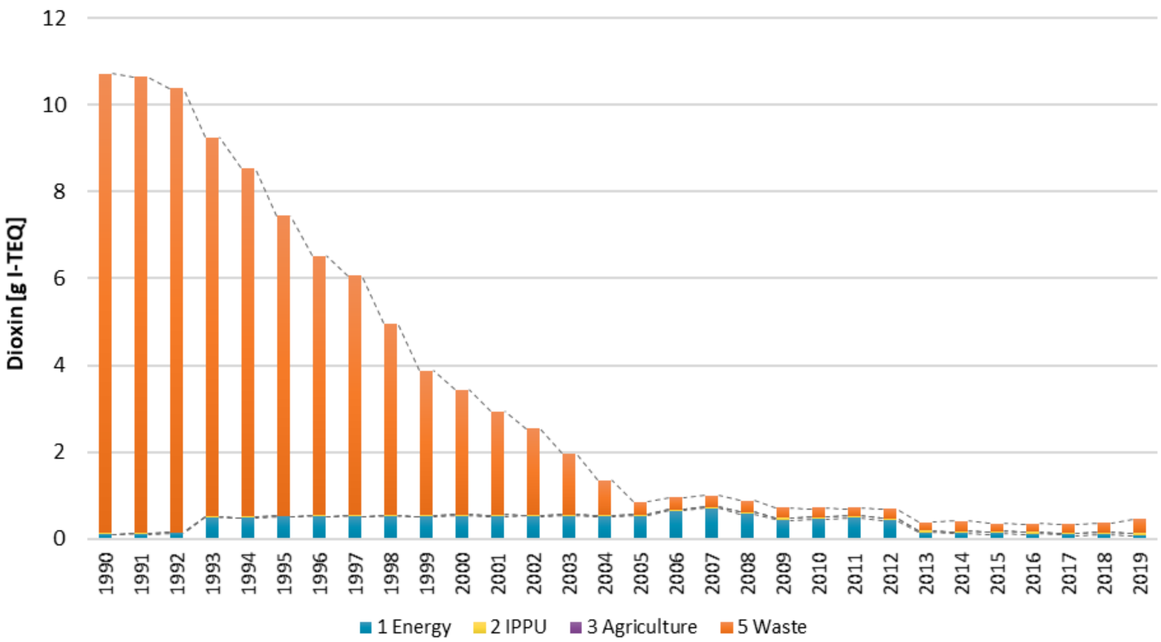

Figure ES. 1 Trends in dioxin emissions by source, since 1990

PAH4 (Benzo(a)pyrene - BaP, Benzo(b)fluoranthene – BbF, Benzo(k)fluoranthene - BkF, Indeno(1,2,3-cd)pyrene - IPy) emissions from 1990 to the most recent year of the time series also decreased substantially (Figure ES. 2), for the same reason as described above for dioxin emissions. The largest contributors of PAH4 emissions in Iceland in recent years are open burning of waste (Waste sector) and the metal industry (Industry sector).

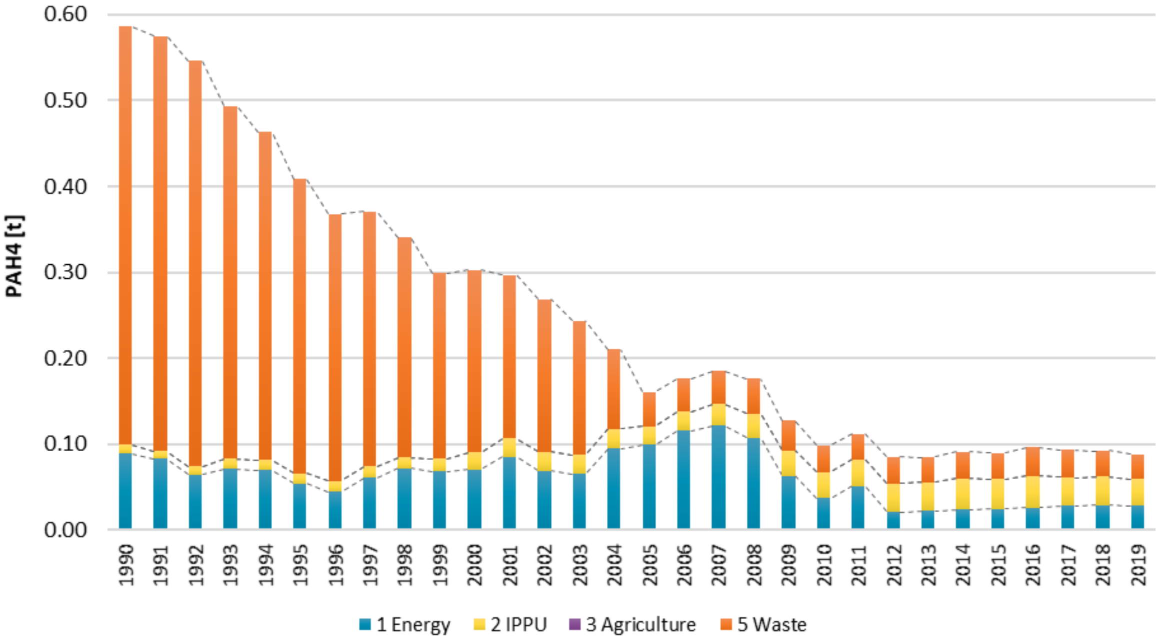

Figure ES. 2 Trends in PAH4 emissions by source, since 1990

The estimated hexachlorobenzene (HCB) emissions decreased markedly over the reported time series (Figure ES. 3). The largest contributor of HCB emissions in Iceland in recent years has been clinical waste incineration followed by emissions originating from fishing (energy sector) and metal production (IPPU sector). HCB emissions from the industry sector increased in 2004, following the opening of a secondary aluminium plant. Open burning of waste was a common waste management practice in Iceland pre-2004. However, an increase in the amount of waste incinerated in incineration plants without energy recovery occurred in 2004 while a reduction of the amount of waste burned in the open occurred in that same year. The increase in emissions from the waste sector in 2014 are linked to an increased quantity of clinical waste incinerated.

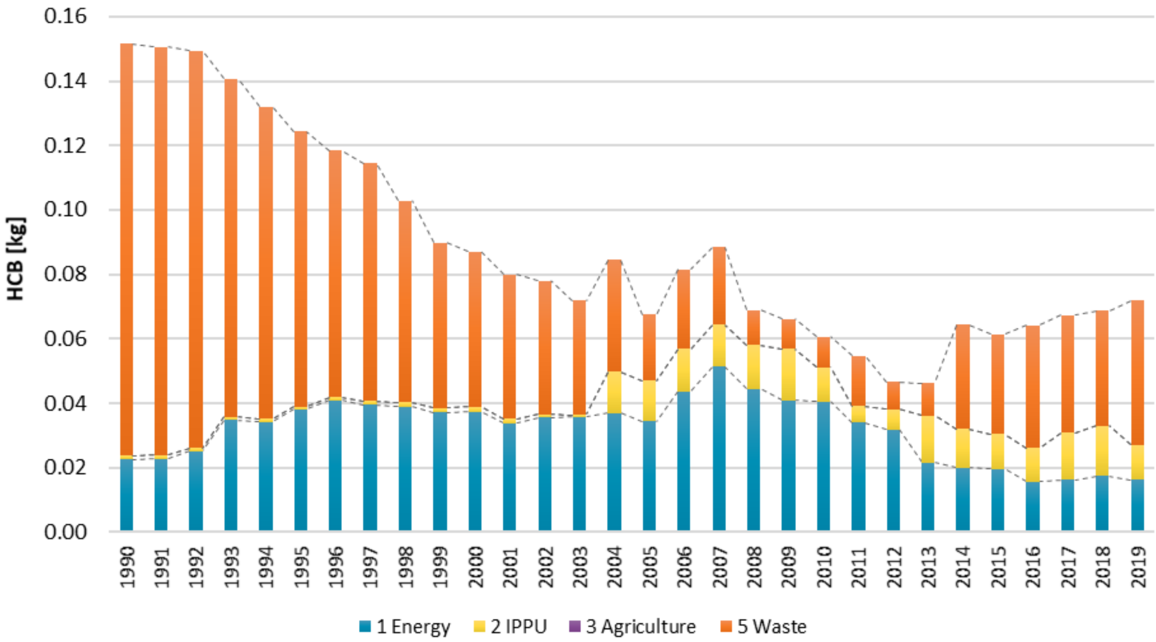

Figure ES. 3 Trends in HCB emissions by sector, since 1990.

Polychlorinated biphenyl (PCB) emissions have decreased across the time series (Figure ES. 4). The largest contributor of PCB emissions in Iceland in recent years is the fishing fleet. The only source of PCB estimated from industrial processes is secondary steel production (2C1), which occurred only for three years (2014 - 2016). Open burning of waste was a common waste management practice in Iceland pre-2004. However, an increase in the amount of waste incinerated in incineration plants without energy recovery occurred in 2004 while a reduction of the amount of waste burned in the open occurred in that same year.

Interpretations of the total PCB trend analysis should be undertaken with care as emissions factors are not available for all sources.

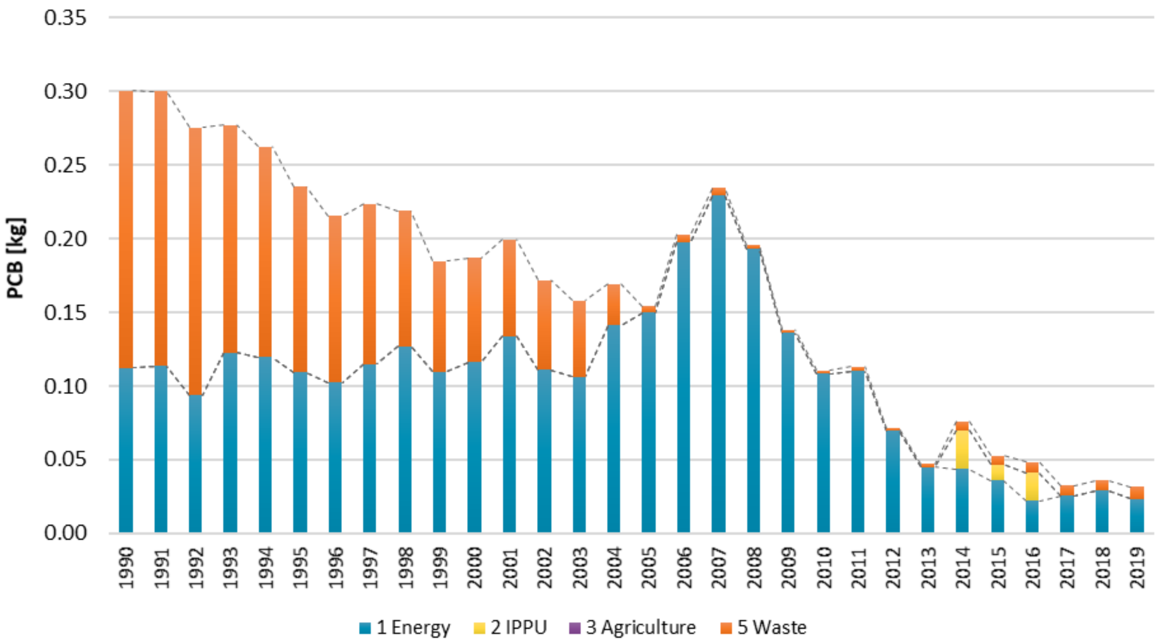

Figure ES. 4 Trends in PCB emissions by sector, since 1990.

1 Introduction

1.1 Background Information

The 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP) was signed by Iceland on 13 November 1979 and ratified in May 1983. The Convention entered into force in August 1983. One of the requirements under the Convention is that Parties are to report their national emissions by sources.

The Convention has been extended by eight Protocols, of which the Protocol on Persistent Organic Pollutants (POP-Protocol) was ratified by Iceland in May 2003 and entered into force in October 2003.

In 2009, Directive 2001/81/EC[2] was incorporated into the Agreement on the European Economic Area (The EEA Agreement), with national emission targets set for Iceland for SO_2, NO_x, NMVOC and NH_3. The targets set were 90 kt, 27 kt, 31 kt and 8 kt, respectively, to be reached by 2010. In December 2016, Directive (EU) 2016/2284[3] (National Emission Ceilings Directive, NECD) entered into force in the EU, repealing the previous NEC Directive 2001/81/EC. The new NECD includes the same pollutants as the directive it replaces, with the addition of CO, Cd, Hg, Pb, POPs (Dioxins/furans, PAH, HCB, PCBs), $PM_{2.5}$, PM_{10} and BC if available as obligatory reporting and TSP, As, Cr, Cu, Ni, Se and Zn as voluntary reporting. At the time of writing, work is underway at the EA and the Icelandic government to evaluate and work towards the incorporation of the new National Emissions Ceiling Directive (2016/2284) into the EEA agreement; Iceland-specific targets are yet to be determined. In 2020 the International Institute for Applied Systems Analysis (IIASA) carried out an analysis of reduction potentials for Iceland for NO_x, SO_2, NMVOC, NH_3 and $PM_{2.5}$, which was done in a way comparable to the analysis done by IIASA for the EU Member States (see also TSAP Report no 16[4]). Work is underway to assess the report produced by IIASA.

The present report together with the associated NFR (Nomenclature for Reporting) tables are Iceland's contribution to the 2021 reporting under the Convention. A description of the trends and calculation methods is given. Anthropogenic emissions of the indirect greenhouse gases (NO_x, CO, NMVOC), NH_3 and SO_2 are provided in the NFR tables, as they are calculated to comply with the reporting requirements of the UNFCCC and of the NECD. Emission estimates for particulate matter (PM), black carbon (BC) and heavy metals (HM) are provided for some emission sources. A short description of the trends and the calculation methods for those pollutants are given in this report.

Estimates for SO_2, $PM_{2.5}$ and PM_{10} for the volcano Eyjafjallajökull which erupted in 2010, the volcano Grímsvötn which erupted in 2011 and Holuhraun eruption in 2014 and 2015 are also provided (Chapter 7).

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[2] Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants.

[3] Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC

[4] http://www.iiasa.ac.at/web/home/research/researchPrograms/air/policy/TSAP_16b.pdf

1.2 Protocol on Persistent Organic Pollutants

The Protocol on Persistent Organic Pollutants (POPs) was adopted on 24 June 1998. It entered into force on 23 October 2003. It focuses on a list of 16 substances that have been singled out according to agreed risk criteria. The substances comprise eleven pesticides, two industrial chemicals and three by-products/ contaminants. The ultimate objective is to eliminate any discharges, emissions, and losses of POPs. The Protocol bans the production and use of some products outright (aldrin, chlordane, chlordecone, dieldrin, endrin, hexabromobiphenyl, mirex and toxaphene). Others are scheduled for elimination at a later stage (DDT, heptachlor, HCB, PCB). Finally, the Protocol severely restricts the use of DDT, HCH (including lindane) and PCBs. The Protocol includes provisions for dealing with the wastes of products that will be banned. It also obliges Parties to reduce their emissions of dioxins, furans, PAHs, and HCB below their levels in 1990 (or an alternative year between 1985 and 1995). For the incineration of municipal, hazardous, and medical waste, it lays down specific limit values. Aldrin, chlordane, chlordecone, dieldrin, endrin, hexabromobiphenyl, mirex and toxaphene have never been produced in Iceland. Of these chemicals only aldrin has been used in Iceland, though not since 1975. DDT and heptachlor have not been used in Iceland since 1975 and were banned with a regulation in 1996. Lindane (HCH) was used in Iceland until the early nineties. Sales statistics exist for 1990 to 1992, and the use of lindane was banned in 1999. PCB was banned in Iceland in 1988.

1.3 Institutional Arrangements for Inventory Preparation

Article 36 of the Icelandic Act on public health and pollution control no 7/1988 (Lög um hollustuhætti og mengunarvarnir) establishes the responsibility of the Environment Agency of Iceland (EA), an agency under the auspices of the Ministry for the Environment and Natural Resources, for the annual preparation and submission of the national inventory to the UNECE-LRTAP Convention. This act also authorises the EA to collect all necessary data and information from authorities, institutions and companies. Figure 1.1 illustrates the flow of information and allocation of responsibilities. The methodologies and data sources used for different sectors are described in more details in the respective sectoral chapters.

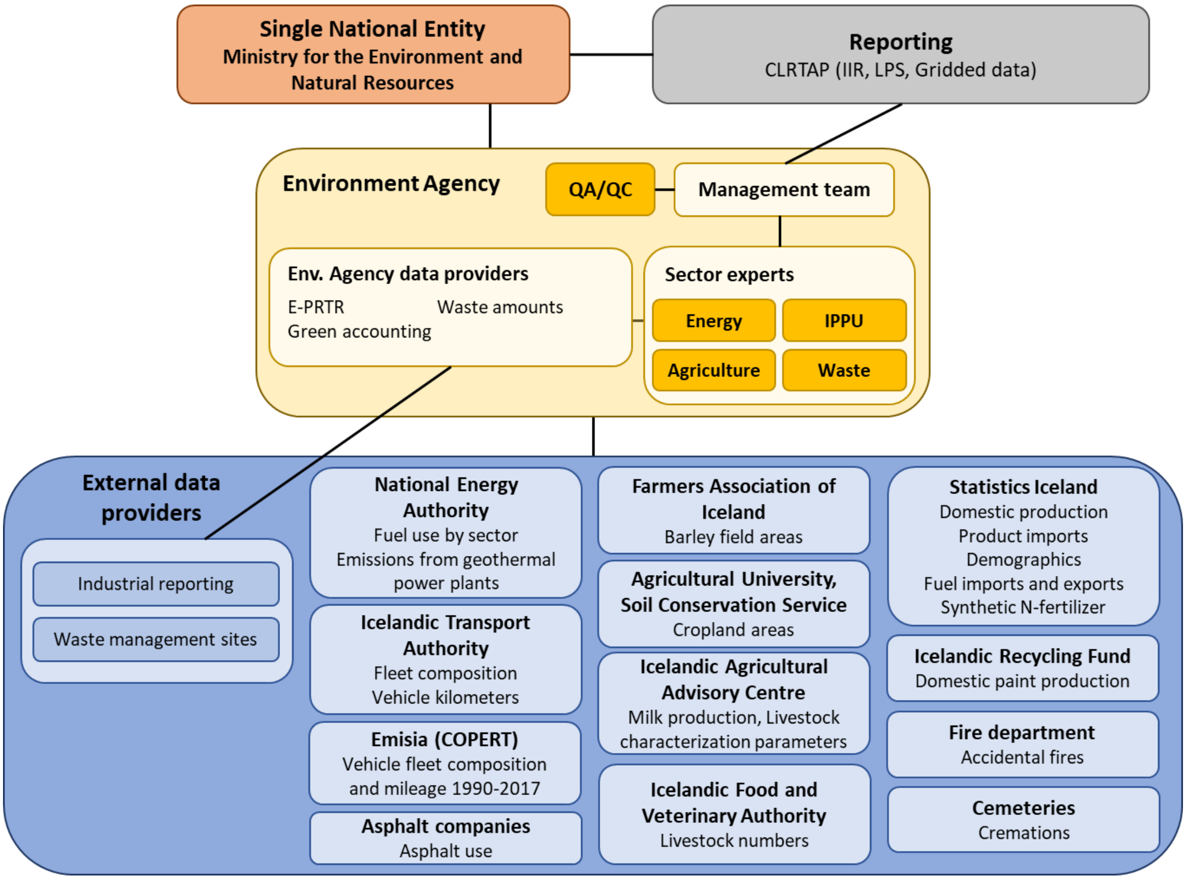

Figure 1.1 Information flow and distribution of responsibilities in the Icelandic emissions inventory system for reporting to the CLRTAP.

1.4 Inventory Preparation

The EA collects the bulk of data necessary to calculate yearly emissions, i.e. activity data and emission factors. Activity data is collected from various institutions and companies. In most cases, the same activity data information is used both for the air pollutants inventory (as per this report) and for the National Greenhouse gas Inventory. Data is gathered according to Icelandic Regulation No. 520/2017 on data collection for the greenhouse gas inventory, as well as provided by various teams within the EA:

1. The National Energy Authority (NEA) collects annual information on fuel sales from the oil companies. This information was until 2008 provided on an informal basis. From 2008 and onwards, Act No. 48/2007 enables the NEA to obtain sales statistics from the oil companies.
2. Until 2011 the Farmers Association of Iceland (FAI), on behalf of the Ministry of Agriculture, was responsible for assessing the size of the animal population each year, when the Food and Veterinary Authority took over that responsibility. On request from the EA, the FAI assisted the development of a method to account for young animals that are mostly excluded from national statistics on animal population. Animal statistics have been further developed to better account for replacement animals in accordance with recommendations from the Expert Review Team (ERT) that came to Iceland for an in-country review in 2011.
3. Statistics Iceland provides information on population, GDP, food and beverages, imports of solvents and other products, import of fertilizers and on import and export of fuels.

4. The EA- collects various additional data through the annual emission reports reported under the European Emissions Trading System (EU ETS (Directive 2003/87/EC) as implemented into Icelandic legislation with Act No. 70/2012 on Climate Change), European Pollutant Release and Transfer Register (E-PRTR (Regulation (EC) no 166/2006, as implemented into Icelandic legislation with Regulation No. 990/2008), Green Accounting reports from industry submitted under Icelandic Regulation No. 851/2002.
5. Data for using the transport model COPERT originates from EMISIA SA[5] and used for emission estimates from road transport (NFR 1A3b) (see more details in the energy sector).
6. Aviation emissions for 2005-2019 are reported using the Eurocontrol dataset.
7. Emission factors are mainly taken from the EMEP/EEA *Emission Inventory Guidebook* (2019; 2016; 2013)*,* the *Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases* (UNEP, 2005), *Annual Danish Informative Inventory Report to UNECE* (NERI, 2016), *Emissions of Black carbon and Organic carbon in Norway 1990-2011* (Aasestad, 2013) as well as the Norwegian reports *Utslipp til luft av dioksiner i Norge – Dokumentasjon av metode og resultater*[6] (Statistics Norway, 2002) and *Utslipp til luft av noen miljögifter i Norge - Dokumentajon av metode og resultater*[7] (Statistics Norway, 2001).
8. The EA also collects activity data on waste amounts split by treatment pathways.
9. Dioxin was measured at several locations in Iceland in 2011, including waste incineration plants, aluminium plants and the ferrosilicon plant. PAH4 was also measured at one aluminium plant and the ferrosilicon plant. The results from dioxin measurements from the waste incineration plant have been used for waste incineration emission estimates since the 2012 submission. Results from the measurements at industrial sites have been used since the 2013 submission.

The annual inventory cycle (Figure 1.2) describes individual activities performed each year in preparation for next submission of the emission estimates.

[5] https://www.emisia.com/utilities/copert-data/
[6] Utslipp til luft av dioksiner i Norge: Air emissions of dioxins in Norway – Documentation of methods and results
[7] Utslipp til luft av noen miljögifter i Norge – Dokumentasjon av metode og resultater: Air emissions of several pollutants in Norway - Documentation of methods and results.

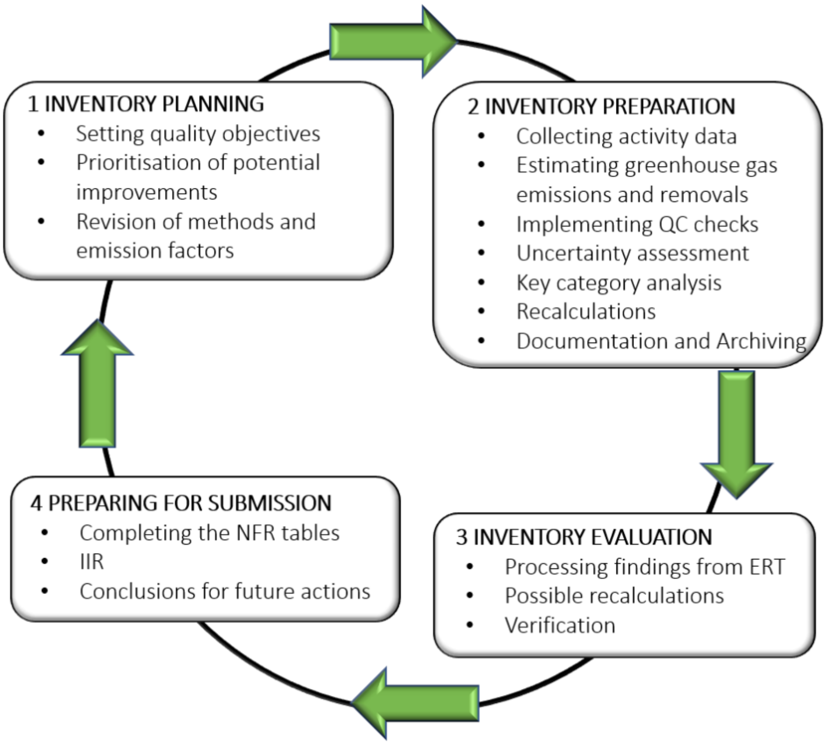

Figure 1.2 The annual inventory cycle.

A new annual cycle begins with an initial planning of activities for the inventory cycle by the inventory team and major data providers as needed, taking into account the outcome of the internal and external review. The initial planning is followed by a period assigned for compilation of the national inventory and improvement of the National System.

After compilation of activity data, emission estimates are calculated, and quality checks performed to validate results.

A series of internal review activities are carried out annually to detect and rectify any anomalies in the estimates, e.g. time series variations, with priority given to key source categories and those categories where data and methodological changes have recently occurred.

1.5 Key Category Analysis (KCA)

A key category is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of a given pollutant in terms of the absolute level of emissions, the trend in emissions, or both. Total emissions from the key categories amount to 80% of the total emissions included in the inventory. The KCA has been undertaken based on Approach 1 outlined in the 2019 EMEP Guidelines. A KCA has been performed for each pollutant, calculating both the level assessment for the base year (1990) and the most recent inventory year (2019) as well as the trend assessment (1990-2019). Memo items are excluded from the KCA.

Table 1.1, Table 1.2 and Table 1.3 present the results of the key category analysis for main pollutants, POPs and heavy metals, respectively, for the year 2019. The KCA for the above-mentioned pollutant categories in 1990 as well as the 1990-2019 trend assessment are presented in Annex II: KCA Results for 1990 and Trends 1990-2019.

Table 1.1 Key category analysis for reported main pollutants in 2019.

Component	Key categories (Sorted from high to low from left to right and top to bottom)					Total (%)
NO_x	*National fishing* *NFR 1A4ciii* 61.7%	*Ferroalloy production* *NFR 2C2* 6.5%	*National navigation* *NFR 1A3dii* 6.3%	*Road transport: Heavy duty vehicles* *NFR 1A3biii* 4.7%	*Road transport: Passenger cars* *NFR 1A3bi* 4.6%	83.9%
NMVOC	*Domestic solvent use including fungicides* *NFR 2D3a* 12.5%	*Manure management: horses* *NFR 3B4e* 10.8%	*Manure management - Non-dairy cattle* *NFR 3B1b* 9.3%	*Manure management - Dairy cattle* *NFR 3B1a* 9.0%	*National fishing* *NFR 1A4ciii* 8.6%	82.0%
	Food and beverages industry *NFR 2H2* 7.8%	*Solid Waste disposal on land* *NFR 5A* 6.5%	*Coating applications* *NFR 2D3d* 5.6%	*Distribution of oil products* *NFR 1B2av* 4.9%	*Road transport: Passenger cars* *NFR 1A3bi* 3.7%	
	Manure management - Sheep *NFR 3B2* 3.4%					
SO_x	*Other fugitive emissions from energy production (Geothermal energy)* *NFR 1B2d* 71.7%	*Aluminium production* *NFR 2C3* 18.0%				89.7%
NH_3	*Animal manure applied to soils* *NFR 3Da2a* 29.0%	*Urine and dung deposited by grazing animals* *NFR 3Da3* 18.6%	*Manure management - Sheep* *NFR 3B2* 15.6%	*Manure management - Dairy cattle* *NFR 3B1a* 13.5%	*Manure management - Non-dairy cattle* *NFR 3B1b* *9.9%*	86.6%
PM2.5	*National fishing* *NFR 1A4ciii* 26.3%	*Road transport: Automobile road abrasion* *1A3bvii* 24.5%	*Aluminium production* *NFR 2C3* 16.6%	*Ferroalloy production* *NFR 2C2* 5.6%	*National navigation (shipping)* *NFR 1A3dii* 3.4%	82.3%
	Road transport: Automobile tyre and brake wear *NFR 1A3bvi* 3.3%	*Quarrying and mining of minerals other than coal* *NFR 2A5a* 2.6%				

Component	Key categories (Sorted from high to low from left to right and top to bottom)					Total (%)
PM10	*Aluminium production* *NFR 2C3* 16.7%	*Road transport: Automobile road abrasion* *1A3bvii* 16.7%	*National fishing* *NFR 1A4ciii* 15.5%	*Quarrying and mining of minerals other than coal* *NFR 2A5a* 14.0%	*Construction and demolition* *NFR 2A5b* 12.7%	82.3%
	Farm-level agricultural operations including storage, handling and transport of agricultural products *NFR 3Dc* 3.4%	*Road transport: Automobile tyre and brake wear* *NFR 1A3bvi* 3.3%				
TSP	*Construction and demolition* *NFR 2A5b* 25.0%	*Road transport: Automobile road abrasion* *NFR 1A3bvii* 19.6%	*Quarrying and mining of minerals other than coal* *NFR 2A5a* 16.8%	*Aluminium production* *NFR 2C3* 11.8%	*National fishing* *NFR 1A4ciii* 9.1%	82.2%
BC	*National fishing* *NFR 1A4ciii* 54.6%	*Road transport: Passenger cars* *NFR 1A3bi* 12.5%	*Mobile combustion in manufacturing industries and construction* *1A2gvii* 6.2%	*National navigation (shipping)* *1A3dii* 6.0%	*Road transport: Heavy duty vehicles and buses* *1A3biii* 5.5%	84.7%
CO	*Aluminium production* *NFR 2C3* 94.3%					94.3%

Table 1.2 Key category analysis for reported POPs in 2019

Component	Key categories (Sorted from high to low from left to right)				Total (%)
DIOX	*Accidental fires*	*Open burning of waste*	*Road transport: Passenger cars*	*National fishing*	82.9%
	NFR 5E	*NFR 5C2*	*NFR 1A3bi*	*NFR 1A4ciii*	
	45.7%	22.2%	8.4%	6.5%	
PAH4	*Open burning of waste*	*Aluminium production*	*Ferroalloys production*	*Road transport: Passenger cars*	82.6%
	NFR 5C2	*NFR 2C3*	*NFR 2C2*	*NFR 1A3bi*	
	29.2%	19.5%	17.8%	16.1%	
HCB	*Clinical waste incineration*	*National fishing*	*Aluminium production*		90.8%
	NFR 5C1biii	*NFR 1A4ciii*	*NFR 2C3*		
	55.4%	20.3%	15.1%		
PCB	*National fishing*	*National navigation (shipping)*			87.9%
	NFR 1A4ciii	*NFR 1A3dii*			
	62.8%	25.1%			

Table 1.3 Key category analysis for reported heavy metals in 2019

Component	Key categories (Sorted from high to low from left to right and top to bottom)				Total (%)
Pb	*Other product use (Fireworks, tobacco)*	*Road transport: Automobile tyre and brake wear*			86.6%
	NFR 2G	*NFR 1A3bvi*			
	68.3%	18.4%			
Cd	*Ferroalloy production*	*National fishing*	*Other product use (Fireworks, tobacco)*	*Road transport: Automobile tyre and brake wear*	82.7%
	NFR 2C2	*NFR 1A4ciii*	*NFR 2G*	*NFR 1A3bvi*	
	33.6%	30.3%	11.2%	7.6%	
Hg	*Clinical waste incineration*	*National fishing*	*Cremation*	*Road transport: Passenger cars*	87.9%
	NFR 5C1biii	*NFR 1A4ciii*	*5C1bv*	*NFR 1A3bi*	
	38.8%	30.9%	9.9%	8.3%	
As	*Fishing*	*National navigation (shipping)*			87.7%
	NFR 1A4ciii	*NFR 1A3dii*			
	75.4%	12.3%			

Component	Key categories (Sorted from high to low from left to right and top to bottom)				Total (%)
Cr	*Road transport: Automobile tyre and brake wear* *NFR 1A3bvi* 47.2%	*National fishing* *NFR 1A4ciii* 32.8%	*Other product use (Fireworks, tobacco)* *NFR 2G* 9.5%		89.5%
Cu	*Road transport: Automobile tyre and brake wear* *NFR 1A3bvi* 65.2%	*Other product use (Fireworks, tobacco)* *NFR 2G* 17.0%			82.2%
Ni	*National fishing* *NFR 1A4ciii* 83.5%				83.5%
Se	*Fishing* *NFR 1A4ciii* 82.4%				82.4%
Zn	*Road transport: Automobile tyre and brake wear* *NFR 1A3bvi* 37.7%	*National fishing* *NFR 1A4ciii* 22.3%	*Other product use (Fireworks, tobacco)* *NFR 2G* 14.0%	*Accidental fires* *NFR 5E* 10.7%	84.8%

1.6 Quality Assurance & Quality Control (QA/QC)

The objective of QA/QC activities in national inventories is to improve transparency, consistency, comparability, completeness, accuracy, confidence and timeliness.

1.6.1 Background information on Iceland’s QA/QC activities

Quality aspects of Iceland's Climate Change and Air Quality Measurement, Reporting and Verification (MRV) system are stored in the QA/QC Hub. The Hub is an online solution, and forms part of its Air Quality and Climate Change Data Portal. The QA/QC Hub provides a centralized basis for the inventory team to design, manage and record its QA/QC activities. The use of the QA/QC hub started in the fall of 2019 and has not yet been fully operationalised; it is expected that it will be fully implemented for the next submission. It is used for reporting on greenhouse gas emissions as well as on air pollutant emissions.

The Hub is focused around three interconnecting elements:

- a record of comments produced by previous review processes
- an area for planning and tracking improvement work; and
- an area for planning QA/QC activities.

The interaction of these elements is outlined in Figure 1.3 below.

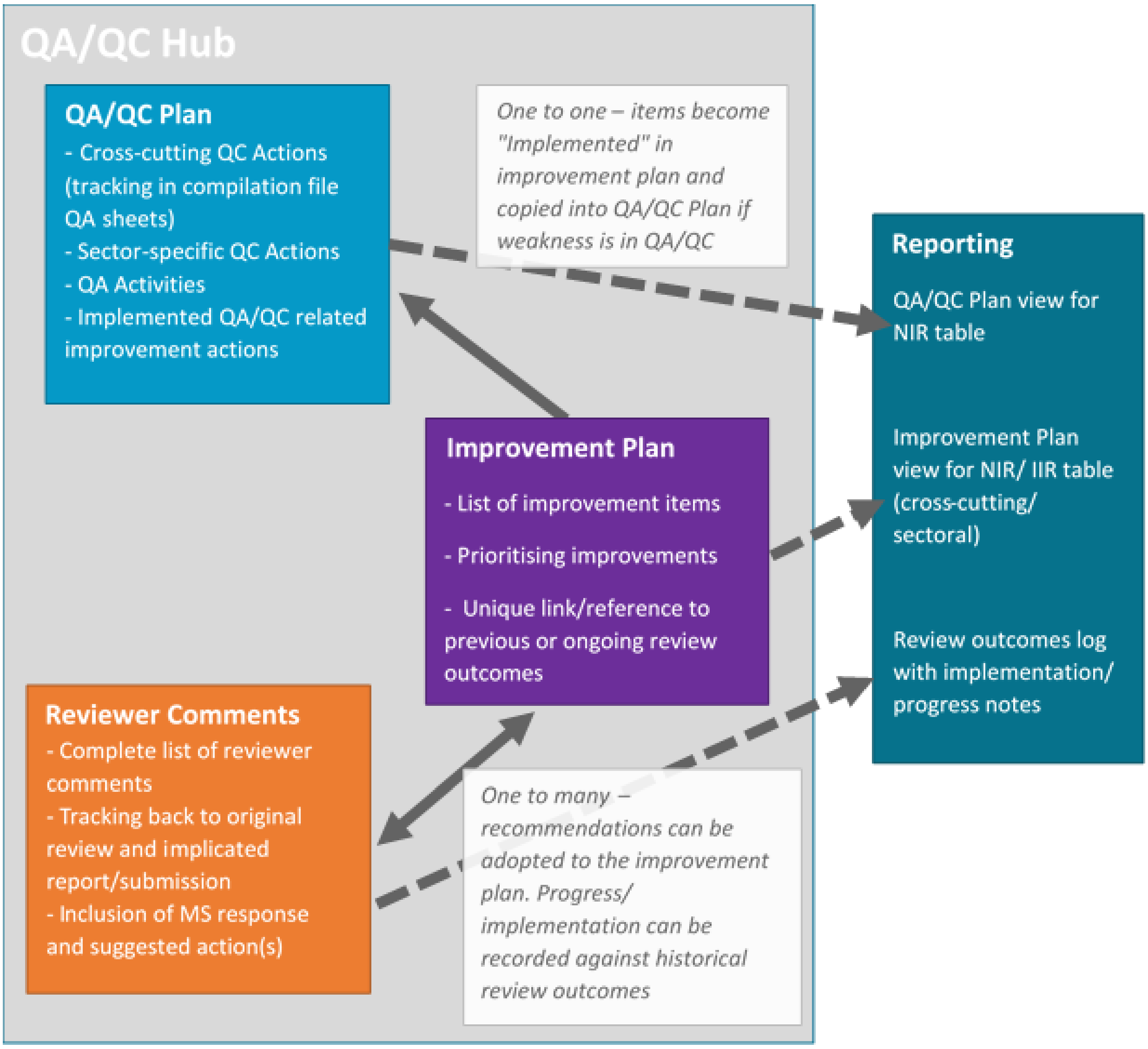

Figure 1.3 Schematic overview of the elements included in the QA/QC hub

The logic of this design is that it will enable the inventory team to link its ongoing review outcomes and internal development ideas to its 'live' improvements list and QA/QC activities. This should ensure that over time, Iceland's inventory submissions continue to evolve in terms of quality. Importantly, the inventory team will be able to provide transparent evidence to the way it handles and prioritizes its inventory improvements and QA/QC activities.

The live improvements and QA/QC lists can be viewed and recorded at sectoral or cross-cutting level. Crucially, all activities are designed to be time-bound and signed off as part of the annual inventory cycle. This enables the inventory team to provide an ongoing record of sector-specific and cross-cutting activities through its national inventory reporting. Once fully operationalised, the QA/QC Hub will lead to:

- enhanced transparency of inventory compilation and reporting
- increased documentation and understanding of Iceland's inventory improvement prioritization (taking into account national capacity and feasibility)
- improved response to, and engagement with, the international inventory review processes

The QA/QC Hub also acts as a centralized document library for relevant training material (to identify and track the engagement of key experts and stakeholders with the inventory team); and for the storage of internal document templates and specific QA/QC guidance for e.g. data collection, review and analysis.

1.6.2 Roles and responsibilities overview

The same inventory team takes care of the greenhouse gas (GHG) inventory and the air pollutant inventory. Sectoral experts thus calculate emissions from their respective sector both for GHG and air pollutants.

In the past, the Icelandic inventory team has operated with sectoral lead individuals, supported by a inventory manager. This has been effective at delivering a primarily complete inventory to the required reporting obligations. During the 2018/19 cycle, Iceland made minor alterations to its inventory team roles and responsibilities. The changes were made to reflect the growing importance and prioritization of effectively managing and reporting on inventory QA/QC activities. The ambition is to ensure that Iceland's national inventory reporting be not only complete, but shown to be timely, accurate and transparent, whilst future proofing the inventory against known limitations e.g. due to loss of institutional memory (through staff turnover) and economic / staff capacity.

At a simple level, the inventory will now operate under the inventory project manager. The project manager has overall responsibility for the completion of QA/QC activities and improvements planning. The roles and key responsibilities are outlined below:

- Inventory project manager: overall responsibility for the accurate and timely production and submission of the inventory, according to the rules and deadlines specified in relevant domestic and international legislation; The inventory project manager is responsible for the communication with the Icelandic government and with data providers, as well as communication with EU and UNFCCC experts/expert review teams.
- Data manager - responsible for making sure that data acquisition, processing and entry into the CRF portal is done timely
- QC manager - responsible for the annual design and timely implementation of QC activities.
- Sectoral experts - sectoral experts are the main knowledge holders on individual inventory sectors. They are responsible for completion of day-to-day data processing and QC activities. Each sector comprises 2 to 3 sectoral experts; prior to each submission cycle, it is decided how roles are divided between the sectoral experts, making sure that QC activities are done by someone other than the individual who did the calculations. In addition, each NIR chapter is proof-read by one of the experts not involved in the writing of the chapter.

1.6.3 Quality Assurance (QA)

Iceland’s air pollutant inventory was subjected to a Stage 3 review under CLRTAP in 2020. Iceland submitted several revised estimates which have all been included in this submission.

In many categories, activity data used for the air pollutant inventory are the same as those used for the greenhouse gas inventories. Regular reviews of the GHG inventory thus also contributes to increased quality of the air pollutant inventory.

Further Quality Assurance is provided by Iceland’s collaboration with consultants at Aether Ltd., who assist with and review sector-specific methodological choices and calculations. As part of this collaboration, the calculations for the Agriculture and Waste sectors were revised and improved in recent years, whereas the calculations for the Energy sector were revised in 2018.

Furthermore, Iceland participates in a Nordic inventory experts workgroup, funded by the Nordic Council of Ministers, where inventory compilers from Norway, Sweden, Finland, Denmark and Iceland meet regularly (one physical meeting once a year, as well as several teleconferences) and discuss various aspects of the inventory compilation, with a strong focus on harmonizing emission factors used across the various Nordic countries.

1.6.4 Quality Control (QC)

The team uses standardised notation protocols in the calculation files to document changes, possible issues and necessary improvements. This is done via an excel tool ("Q Comments"), which allows the documentation of changes and flagging of issues by use of comments starting with hashtags including the initials of the inventory compiler/QC reviewer, the date, and one or more flags pertaining to the type of issue (such as, for instance, potentially identified issue, transparency issue, or reason for change). A summary of all comments can be generated for each calculation file, enabling for instance someone performing QC checks to track and verify changes made to the file, as well as check the status of flagged issues. The issues can then either be marked as resolved, addressed immediately or added to the improvement plan, depending on the type of issue. This tool is an important source of information needed QC activities are performed.

Aether also assists Iceland in the development of QA/QC activities and provided Iceland with several tools running checks on the latest inventory. Those checks include:

- **Recalculation check** - comparing the values reported in the current and previous versions of the inventory.
- **Negative and zero values checks** - to highlight the occurrence of negative values and zero values in the inventory.
- **Notation keys check** - to summarise the occurrence of each notation key to ensure consistency and accuracy in the inventory.
- **PAHs sum check** - to ensure that the sum of the four reported PAHs equals the reported "total" PAH emissions.
- **Particulate Matter check** - to ensure that reported TSP emissions are greater than or equal to PM_{10}, and similarly that reported PM_{10} emissions are greater than or equal to $PM_{2.5}$.

In all cases, the findings of the checks are reviewed, not only to identify where corrections may be required, but also to consider whether there are any steps of the inventory compilation process that need improvement. In addition, reviewing the results also provides information on whether the individual checks are well designed and comprehensive. This ensures that all results from the QC process feed back into the continuous improvement programme. Further details are available under Annex II.

Other QC activities include the following:

- Are appropriate activity data, methods, calculations, units, emission factors and notation keys used?
- Are all data sources well referenced/documented?
- Are the emission estimate files consistent with summary files and NFR outputs?
- Are there recalculations since the last submission, and if so, are they properly documented?

As the QA/QC procedure is still being implemented, sector- and subsector specific guidelines on nature and frequency of QC checks are in the process of being developed.

1.6.5 Planned improvements for QA/QC activities

The configuration of roles and responsibilities mentioned in section 1.6.2 above is still being implemented, as well as the new QC procedures mentioned above. In the year 2021 the inventory team at the EA is expected to grow, and more time will be spent on finalising and fully implementing the new QA/QC procedures. A review and possible expansion of sector-specific QA and QC activities is planned for future submissions. In the future, it is also planned to fully document the results of QC activities for each sector and providing evidence of such activities by including screenshots of the Q Comments tool discussed under 1.6.4.

Furthermore, it is planned to interlink QA/QC activities with the key category analysis and the uncertainty analysis in order to prepare a prioritised improvement plan at the sectoral level as well as for the inventory work in general.

1.7 Uncertainty Evaluation

The uncertainty analysis is being developed and will be included in future submissions.

1.8 General Assessment of Completeness

The aim is to make, in the highest possible level of disaggregation, estimates of all known emissions to air in the informative inventory report. The inventory is generally complete, however there are some pollutants and/or categories that have not been estimated at all or only for part of the time series. The activities/pollutants not included in the present submission were not estimated due to lack of emission factors in tables provided in the EMEP/EEA Guidebook, lack of data, and/or that additional work was impossible due to time constraints in the preparation of the emission inventory.

1.8.1 Categories not estimated (NE):

In the 2020 Stage 3 review the ERT pointed out to Iceland that NE has a different meaning in the Guidebook and in the NFR tables and that NA is the correct notation key if it is not the responsibility of Iceland that the emissions are not estimated. Therefore, during this submission, Iceland started reviewing all notation keys and this work will continue for the next submission.

Table 1.4 List of pollutants not estimated by sector

NFR code	NFR category	Pollutants not reported (NE)	Reason
1A3ai(i)	International aviation LTO (civil)	NH_3, B(a)P, B(b)f, B(k)f, Ipy PAHs	No T1 EF in GB 2019
1A3aii(i)	Domestic aviation LTO (civil)	NH_3, B(a)P, B(b)f, B(k)f, Ipy, PAHs	No T1 EF in GB 2019
1A3bvi	Road transport: Automobile tyre and brake wear	B(a)P, B(b)f, B(k)f, Ipy, PAH, dioxins	No T1 EF in GB 2019
1A3bvii	Road transport: Automobile road abrasion	B(a)P, B(b)f, B(k)f, Ipy, PAH, Heavy metals	No T1 EF in GB 2019
5C1bii	Hazardous waste incineration	NH_3, B(a)P, B(b)f, B(k)f, Ipy, Cr, Cu, Se, Zn	No EF in GB 2019
5C1biii	Clinical waste incineration	NH_3, $PM_{2.5}$, PM_{10}, B(a)P, B(b)f, B(k)f, Ipy; Se, Zn	No EF in GB 2019

NFR code	NFR category	Pollutants not reported (NE)	Reason
5C1biv	Sewage sludge incineration (2014-2017)	NH_3, B(a)P, B(b)f, B(k)f, Ipy, Cr, Cu, Se, Zn	No EF in GB 2019
5C1bv	Cremation	BC	No EF in GB 2019
5D1	Domestic wastewater handling	NMVOC	No relevant activity data
5D2	Industrial wastewater handling	NMVOC	No relevant activity data
5D3	Other wastewater handling	NMVOC	No relevant activity data
5E	Other waste (please specify in IIR)	BC, Se, HCB, PCBs	No EF in GB 2019

1.8.2 Categories reported as Included Elsewhere (IE)

The table below indicates the categories where the notation key IE has been used in the reporting for some or all pollutants.

Table 1.5 Categories included elsewhere.

NFR code	NFR category	Pollutants included elsewhere (IE)	Reported under	
			NFR code	NFR category
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals (Cement)	SO_x	**2A1**	Cement production
1A3eii	Transport: Other	all reported pollutants	**1A2gvii**	Mobile combustion in manufacturing industries and construction
1A4bii	Residential: Household and gardening (mobile)	all reported pollutants	**1A2gvii**	Mobile combustion in manufacturing industries and construction
2B1	Ammonia production	NO_x	**2B10a**	Chemical Industry: Other (Fertilizer production)
5C1bi	Industrial waste incineration	Dioxin	**5C1a**	Municipal waste incineration
5C1bii	Hazardous waste incineration	Dioxin	**5C1a**	Municipal waste incineration
5C1biii	Clinical waste incineration	Dioxin	**5C1a**	Municipal waste incineration
5C1biv	Sewage sludge incineration (2014-2017)	Dioxin	**5C1a**	Municipal waste incineration

1.9 Recalculations

A recalculation file is used to identify and document all recalculations. This QC file compares Year x-3 (2018) and the base year (1990) for the current and previous submissions for all pollutants. The data has been compiled to enable any changes in the data to be easily identified and justifications for changes provided where required. As far as possible, the recalculation check includes all reported sectors.

The main sector-specific recalculations and improvements done for this submission are mentioned below for each sector, and all recalculations are described in more details in each subsector in the relevant chapter.

1.9.1 Energy

The main improvements and recalculations in the energy sector are listed below.

- A comprehensive review of all input data for the energy sector for 1990-2002 was performed which caused several recalculations for some subsectors. However, the changes included mainly a re-attribution of fuel use to various subsectors, based on the newest available data from the National Energy Authority, but total fuel use remains mostly unchanged.
- All pollutant emissions from road transport were recalculated with COPERT v5.4.36. Now COPERT model is used for all calculations of pollutants for road transport for the whole timeseries. However, TSP, $PM_{2.5}$, PM_{10} and BC from studded tyres are calculated separately, for the first time, as there is not an option to include studded tyres in COPERT, see chapter 3.5.2.
- Country specific carbon content has been acquired and utilized for gasoline and diesel oil.
- Improvements have been made in collaboration with the Icelandic Transport Authority to make more precise allocation of the vehicle fleet to specific Euro Standards based on the model year of vehicles.
- Data from the NEA has now been further discerned between categories. This has caused reallocation of significant amounts of fuel from 1A2gvii to specific mobile combustion categories that are relevant to the NEA discernment, i.e., mobile machinery in construction (1A2gv) and Off-road vehicles and other machinery in Agriculture/Forestry and Fishing (1A4cii).
- For previous submission electrode waste from the cement factory was reported un 1A2f. However, it was concluded for this submission that this activity data was for electrode waste which was exported as waste but not used for combustion. Therefore, electrode waste was removed from the inventory. This caused recalculations for 1990-2001 and 2007-2010.

1.9.2 Industrial processes and product use (IPPU):

The main recalculations and improvements for Industrial processes and product use are:

- In 2D3a, Domestic solvent use including fungicides, Hg was not estimated due to uncertainty around the releases according to the 2019 EMEP/EEA Guidebook.
- In 2C2, ferroalloy production, PM_{10}, $PM_{2.5}$ and BC emissions from Si production for the year 2018 were calculated as a percentage of TSP using the same ratios as in Table 3.1 in the EMEP/EEA Guidebook (EEA, 2019). Since the year 2018 the TSP emission factors are based on information from the factory instead of EMEP/EEA Guidebook.
- In 2D3c and 2G there are recalculations in the dioxin emissions for the whole time series due to a unit error occurred for the last submission.

1.9.3 Agriculture

The main recalculations and improvements in the Agriculture sector include:

- For the current 2021 submission, parameters, e.g. emission factors used in the N-flow methodology were updated from the 2016 EMEP/ EEA Air Pollution Inventory Guidebook to its newest 2019 edition. This affects the pollutants NH_3 and NO_x. These changes affect the categories 3B and 3D2a and 3Da3.
- The gross energy (GE) for mature dairy cattle was changed for the years 2013-2017 to avoid a step change between 2017 and 2018. The previous data collection of feed digestibility parameters referred to the year 2012 and the new data to the year 2018. This recalculation affects the Nex rate and therefore all emissions connected to the Nex rate of mature dairy cattle.

- Regarding NMVOCs the emission factor for rabbits as per 2019 EMEP EEA Guidebook was used for the whole time series while in the past submission these emissions were calculated using the emission factor of fur animals.
- Particulate emissions under 3Dc show recalculations for the whole timeseries due to changes in the cropland areas as communicated by the data provider Soil Conservation Service of Iceland.

1.9.4 Waste

The main recalculations include:

- In accordance with the 2020 Stage 3 review comment (IS_Waste_2020_Q6_5C1bv) Iceland submitted a revised estimate. There was a unit error in the calculations of emissions of IPy which cause an 1000x overestimations of the emissions. This was corrected for this submission for all years.
- During the 2020 Stage 3 review Iceland submitted a revised estimate for dioxin emissions from open pit burning for 1990-2003. It was recommended that Iceland uses an emission factor of 400 µg/t for 1990-1995 which is presented in Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases from 2012. This caused recalculations for 1990-1995, and also for 1996-2002 as those years are extrapolated from 1995.

1.10 Planned improvements

Various improvements are planned to increase the overall quality of the inventory and the report. Those include:

- Adding a comprehensive uncertainty analysis
- Improving the workflow pertaining to keeping track and acting upon comments received by reviewers
- Review and update all relevant emission factors with the 2019 EMEP/EEA Guidebook values
- Reviewing and updating the overall workflow for preparing the inventory, including more quality checks and cross-checks between data sources
- Review the layout of the Informative Inventory Report

Furthermore, several sector-specific improvements are planned. The main improvements are mentioned below for each sector, and all planned improvements are described in more details in each subsector in the relevant chapter.

1.10.1 Energy

For future submissions there is need to harmonize energy data processing between various organizations (such as EA, the National Energy Authority and Statistics Iceland), produce a complete uncertainty analysis, as well as update the IIR text. Moreover, plans are underway to make emission calculations for national navigation, fishing and aviation tier 2 for future submissions.

1.10.2 Industrial processes and product use

The main improvement planned for the IPPU sector consists of harmonising the reporting under CLRTAP with the reports under the E-PRTR Regulation (E-PRTR, according to Icelandic Regulation No. 990/2008, which implements Regulation (EC) no 166/2006 concerning the establishment of a European Pollutant Release and Transfer Register).

1.10.3 Agriculture

No major improvements are planned in this category a part of improving activity data collection.

1.10.4 Waste

The main planned improvements in the waste sector are to review all emission factors for incineration of waste for next submission. For future submissions it is planned to add further information on the methodological information to the IIR, update the uncertainty analysis, improve activity data and estimates for wastewater handling and review methodology to estimate emissions from accidental fires.

2 Trends in Emissions

2.1 Emission Profile in Iceland

The emissions profile for Iceland differs from that seen for other European countries for a range of reasons:

- Emissions from generation of **electricity and space heating** are very low owing to the use of renewable energy sources. Almost all electricity in Iceland is produced with hydropower (around 70%) and geothermal power (around 30%), with wind power and fossil fuel-derived power accounting for less than 0.1%.
- **Geothermal energy** is used for space heating in over 90% of all homes. It should be noted, though, that significant amounts of sulphur as hydrogen sulphide (H_2S) are emitted from geothermal power plants.
- Around 90% of the fuel used in the energy sector is used by **mobile sources** (transport, mobile machinery and fishing vessels).
- Emissions from **industrial processes**, especially from non-ferrous metal production, have a higher share in Iceland than in most other countries. This can be seen in the fact that around 75% of the electricity produced in Iceland in 2019 was used in the metal production industry. The production capacity has increased considerably since 1990.

The emissions profile in Iceland is further influenced by the fact that Iceland was severely hit by the economic downturn in 2008, when its three largest banks collapsed. During the years prior to the crisis the economy experienced a significant upswing, resulting among other things in an increase in fuel consumption. The crisis resulted in a serious contraction of the economy and as a result, oil consumption decreased. The result of this can be seen in several pollutants associated with fuel consumption, with a clear peak in 2007, or the year preceding the crisis. In recent years the economy has been experiencing an upswing and the number of tourists to the country has increased significantly, leading to rising fuel consumption.

2.2 Emission Trends for NO_x, NMVOC, SO_x, NH_3, Particulate Matter, BC and CO

The total amount of SO_x, NO_x, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$, TSP and BC emissions in Iceland in 1990 and 2019 is presented in Table 2.1, and an overview of all key categories for these pollutants is included in Annex III.

Nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), ammonia (NH_3) and particulate matter (TSP, PM_{10}, $PM_{2.5}$) have an adverse effect on human health and the environment. Iceland implemented the National Emission Ceiling Directive 2001/81/EC into its legislation in 2009, with emission target reductions for NO_x, SO_x, NMVOC and NH_3, to be reached by 2010. These pollutants are reported here. Furthermore, emissions of NO_x, CO, NMVOC and SO_2 are also calculated to comply with the reporting requirements of the UNFCCC. A short description of the trends of those pollutants is given in the following section.

Table 2.1 Emissions of SO_x, NO_x, NH_3, NMVOC, CO and PM in 1990 and 2019.

	NO_x [kt] NO_2	NMVOC [kt]	SO_x [kt] SO_2	NH_3 [kt]	$PM_{2.5}$ [kt]	PM_{10} [kt]	TSP [kt]	BC [kt]	CO [kt]
1990	30.89	9.55	23.98	4.97	1.27	2.33	4.43	0.43	70.60
2019	21.01	5.22	58.39	4.51	1.25	2.34	3.97	0.31	106.49
Change 1990-2019	**-32%**	**-45%**	**143%**	**-9%**	**-2%**	**0.1%**	**-11%**	**-28%**	**51%**

The emission trends of the total NOx, NMVOC, SO_2, NH_3, CO, $PM_{2.5}$, PM_{10}, TSP and BC emissions relative to 1990 levels is shown in Figure 2.1. The emissions of SO_2 have increased significantly since 1990 levels. This includes H_2S from geothermal plants - all sulphur species emitted are to be reported, as SO_2 equivalents. CO emissions have approximately doubled since 1990. The most significant decrease in emissions are NMVOC emissions which have roughly halved since 1990 levels.

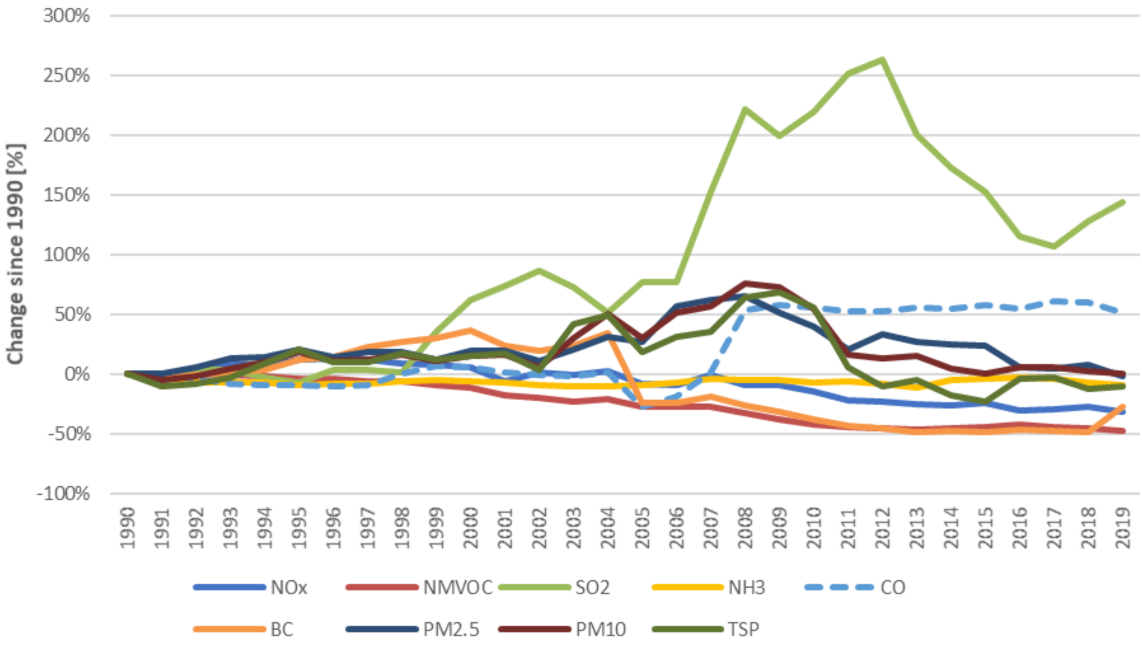

Figure 2.1 Trends in NO_x, NMVOC, SO_2, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC and CO emissions (% of 1990 emissions).

For the current inventory year, the emissions of all pollutants included in the NECD 2001/81/EC were below the emission maxima set by the 2001 NECD: For SO_2, the target was 90 kt and has not exceeded during the reporting period; For NO_x, the maximum allowed is 27 kt, and the emissions have been below that value since 2008; For NMVOC, the maximum allowed is 31 kt, and the emissions have been decreasing steadily since 1994, where the maximum NMVOC emissions occurred (15 kt in that year). The NH_3 emissions have been stable between 5 and 6 kt since 1990, below the maximum allowed of 8 kt. As of April 2020, no emission targets have been set yet for Iceland for 2030 and the incorporation of the new NECD (Directive 2016/2284) into the EEA is still pending.

2.2.1 Trends in sulphur oxides (SO_x (SO_2)) emissions

In 2019, total sulphur emissions in Iceland, calculated as SO_2 but including all sulphur species (such as H_2S), were 143% above the 1990 level. The key categories for sulphur emissions are geothermal energy and metal production. Figure 2.2 shows the sectoral emission trends since 1990. The main sources for SO_x include:

- **Geothermal energy (NFR 1B2d):** Geothermal energy exploitation is the largest source of sulphur emissions in Iceland. Sulphur is emitted from geothermal power plants in the form of H_2S and the emissions have increased substantially since 1990 due to increased activity in this field, with electricity production at geothermal power plants increasing approximately 15-fold since 1990. However, in recent years the SO_2 emissions have started decreasing following the onset in 2014 of a sulphur capture and storage project (Sulfix) at one of the geothermal power plants (Hellisheiði Power Plant).
- **Metal production (NFR 2C):** Emissions from industrial processes are dominated by metal production. Until 1996 industrial process SO_2 emissions were relatively stable. Since then, the metal industry has expanded which has led to substantially increased emissions of SO_2. Sulphur comes mostly from impurities in the carbon reductants used in the metal production process.

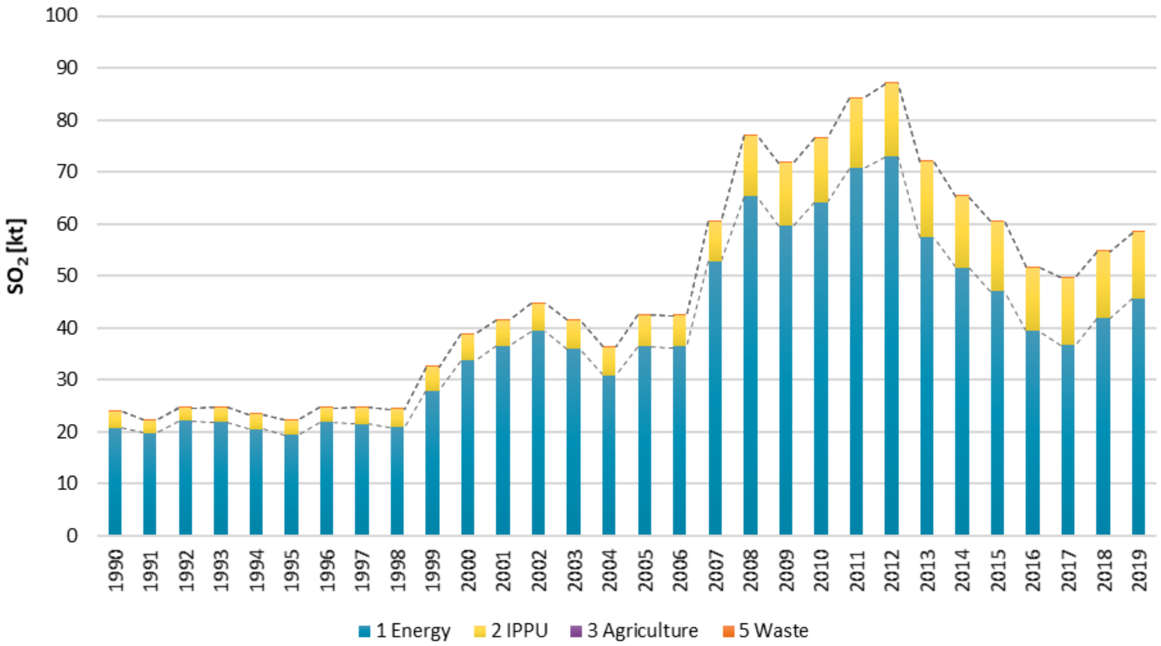

Figure 2.2 SO_2 emissions by sector, since 1990.

Volcanic eruptions contribute significantly to sulphur emissions, and emissions from this source are reported as a memo item for the years during which eruptions occurred, the last three eruptions since 2010 are:

- 2010: Eyjafjallajökull. The eruption lasted from 14 April until 23 May. During that time 127 kt of SO_2 were emitted or 71% more than total anthropogenic emissions in Iceland in 2010.
- 2011: Grímsvötn. The eruption lasted from 21 until 28 May. During that time 1000 kt of SO_2 were emitted or 12 times more than total anthropogenic emissions in 2011.
- 2014-2015: Holuhraun. A large eruption started on 29 August 2014 and ended on 27 February 2015 in the north of the Vatnajökull ice sheet. It was the biggest eruption in Iceland since the Laki eruption 1783. Total SO_2 emission from this eruption was estimated to be around 12000 kt.

2.2.2 Trends in nitrogen oxides (NO_x) emissions

In 2019, total NO_x emissions in Iceland were 32% below the 1990 level. The main sources of nitrogen oxides (NO_x) in Iceland are fishing, metal production, transport and mobile combustion in machinery, construction and other off-road vehicles. Figure 2.3 shows the sectoral emission trends since 1990.

- **Fishing (NFR 1A4ciii):** Emissions from fisheries rose from 1990 to 1996 because a substantial portion of the fishing fleet was operating in unusually distant fishing grounds. Since 1996, the emissions have generally been decreasing, with however large annual variations due to changes in fish stock size and location. Emissions remain though below 1990 levels.
- **Transport (NFR 1A3):** NO_x emissions from transport come mostly from road transport. These emissions decreased rapidly after the use of catalytic converters in all new vehicles became obligatory in 1995, even though fuel consumption has significantly increased. However, a significant increase in the vehicle fleet in the past few years has had a negative impact on NO_x emissions, with emissions again on the rise.
- **Metal production (NFR 2C):** Since 1990 the production capacity of the metal factories has seen a significant increase, and the NO_x emissions have increased accordingly.

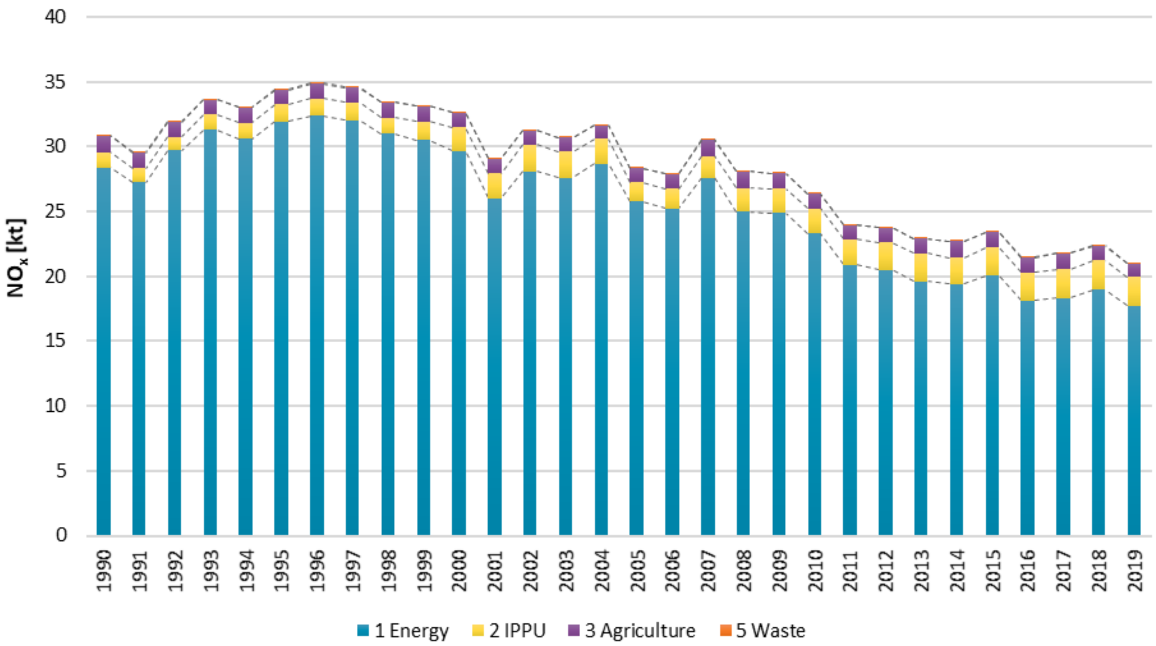

Figure 2.3 NO_X emissions by sector, since 1990.

2.2.3 Trends in particulate matter (PM) and BC emissions

In 2019, TSP emissions were ca. 11% lower than the 1990 level. PM_{10} increased by 0.1% and $PM_{2.5}$ decreased by 2%, compared to 1990 levels. The main sources of PM emissions are fishing, mineral industry, in particular quarrying and mining of minerals other than coal and construction and demolition, metal production and transport. Volcanic activity is also a significant contributor, but these emissions do not count towards the national totals and are reported under memo items. Figure 2.4, Figure 2.5 and Figure 2.6 show the sectoral emission trends in total suspended particulate (TSP), PM_{10} and $PM_{2.5}$ since 1990.

- **Fishing (NFR 1A4ciii):** Emissions from fisheries rose from 1990 to 1996 because a substantial portion of the fishing fleet was operating in unusually distant fishing grounds. From 1996, the emissions decreased again reaching 1990 levels in 2001. Emissions increased again by 10% between 2001 and 2002. In 2003 emissions again reached the 1990 level. Emissions remain below 1990 levels, however there are large annual variations due to the inherent nature of fisheries.
- **Metal production (NFR 2C):** Production capacity in the metal production sector has increased substantially, leading to an increase in PM emissions.
- **Transport (NFR 1A3):** Fluctuations in PM emissions result from the combination of changes in the pollution control standards with increase in vehicle fleet size.
- **Mineral Products (NFR 2A):** The categories quarrying and mining of minerals other than coal (2A5a) and construction and demolition (2A5b) have been added for the current submission. These two categories account for 43% of total TSP emissions, 30% of PM_{10} emissions and 7% of $PM_{2.5}$ emissions.

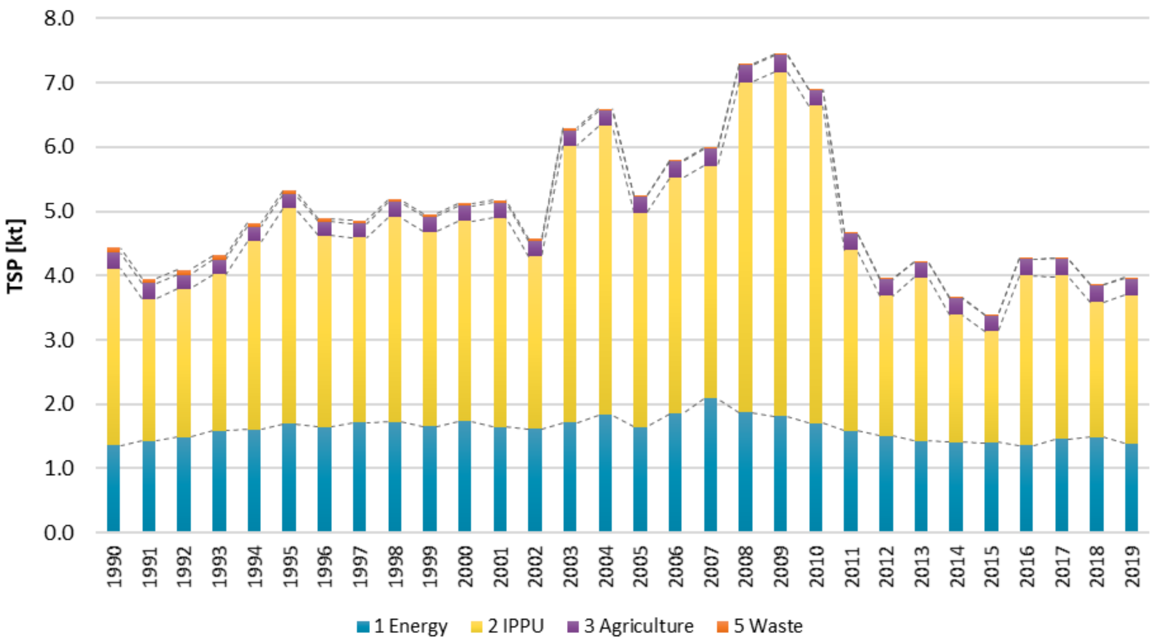

Figure 2.4 TSP emissions by sector, since 1990.

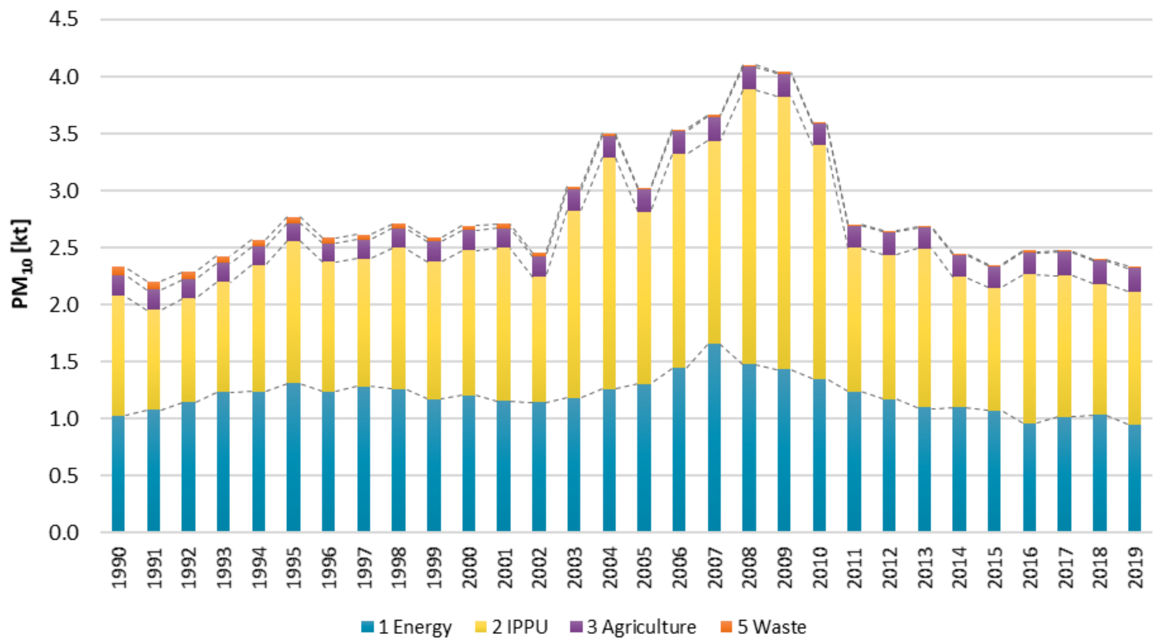

Figure 2.5 PM_{10} emissions by sector, since 1990.

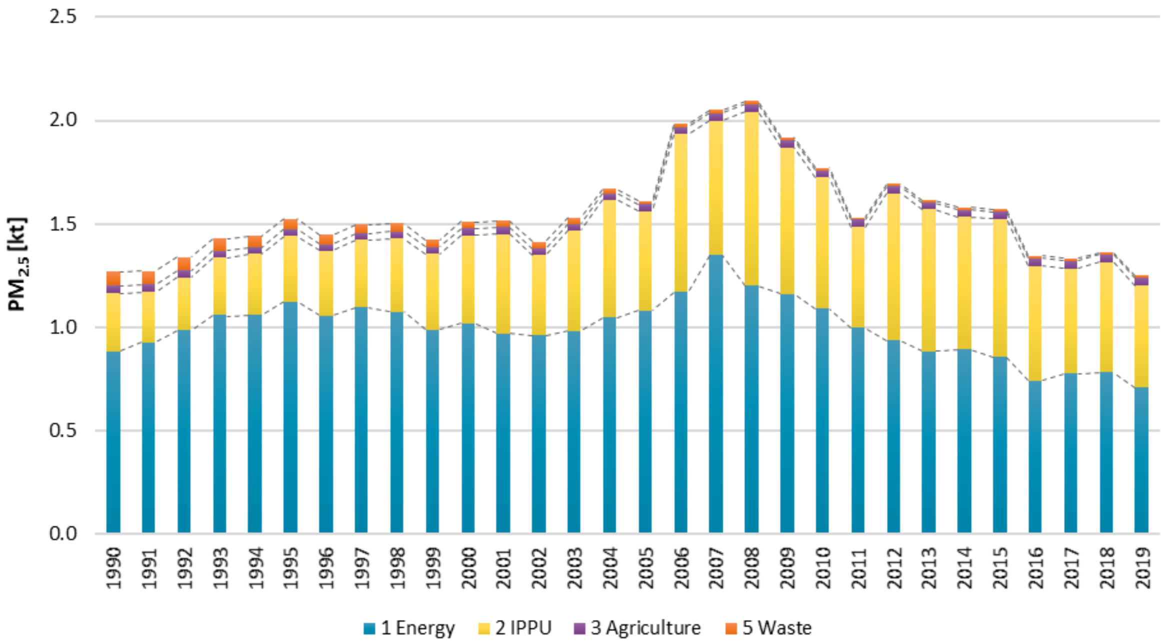

Figure 2.6 $PM_{2.5}$ emissions by sector, since 1990.

Black carbon emissions since 1990 have been estimated for several subsectors (see Figure 2.7), in particular within the Energy sector (public electricity and heat production, aviation, fishing/navigation, road transport) and within the Waste sector (Waste incineration). For the Energy sector, commercial fishing is the dominant source of BC emissions, with road transport a significant contributor. BC emissions from waste have been decreasing since 1990, approximately halving since 1990, due to the decrease in open burning of waste.

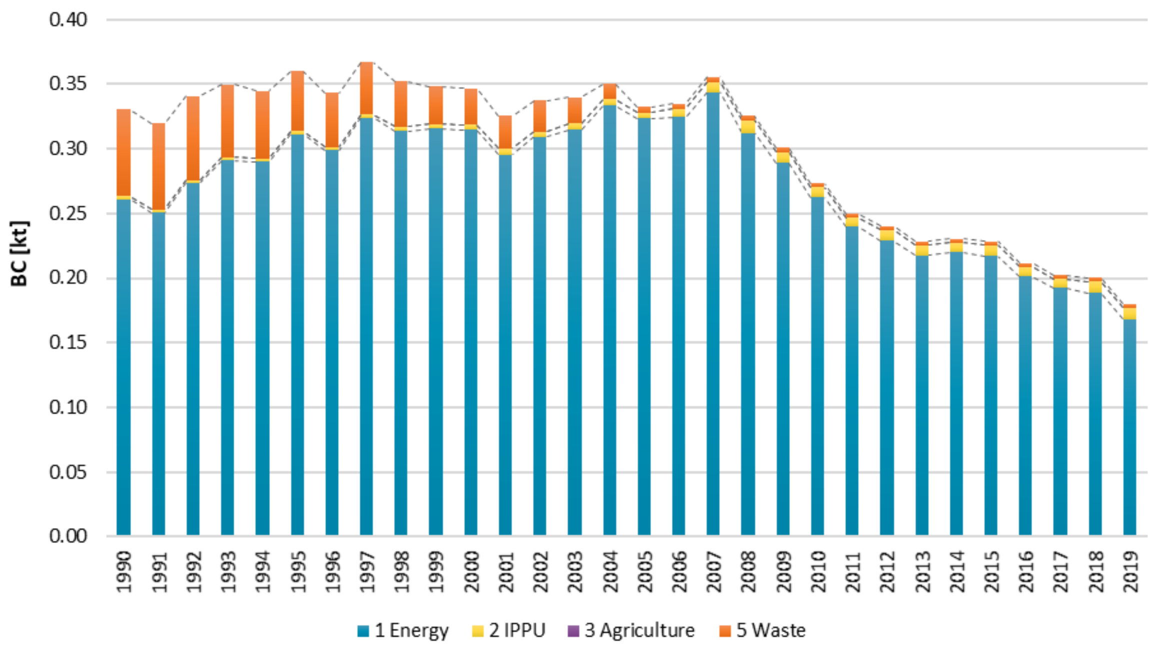

Figure 2.7 Black Carbon (BC) emission by sector, since 1990.

Volcanic eruptions contribute significantly to particulate matter emissions, and emissions from this source are reported as a memo item for the years during which eruptions occurred, eruptions from 2010 onwards are the following:

- 2010: Eyjafjallajökull. The eruption lasted from 14 April until 23 May. During that time around 6,000 kt of PM_{10} were emitted or around 10,000 times more than total estimated man-made emissions in 2010.
- 2011: Grímsvötn. The eruption lasted from 21 until 28 May. The eruption at Grímsvötn was much larger than at Eyjafjallajökull, and it has been estimated that during the first day more sulphur and particulates were emitted than during all the Eyjafjallajökull eruption. An estimate of the total particulates emitted has not been estimated but the EA has scaled the emissions of particulates using the ratio of sulphur emissions from the two eruptions (1000/127). This gives an approximate estimate of around 47,000 kt PM_{10} and 13,000 kt of $PM_{2.5}$. As these emissions from volcanos are natural, they are not included in national totals.
- 2014-2015: Holuhraun. A large eruption started on 31 August 2014 and ended on 27 February 2015 in the north of the Vatnajökull ice sheet. Unlike the eruptions in Eyjafjallajökull and Grímsvötn, which were phreatomagmatic eruptions, the eruption in Holuhraun was an effusive eruption i.e. the lava steadily flowed out of the volcano without explosive activity. Ash production was negligible and emissions of PM_{10} and $PM_{2.5}$ were not estimated.

2.2.4 Trends in ammonia (NH_3) emissions

In 2019, total NH_3 emissions in Iceland were 9% below the 1990 level. Ammonia emissions are mostly from the agriculture sector (NFR 3). Figure 2.8 shows the sectoral emission trends since 1990.

- **Agriculture (NFR 3): Animal manure applied to soils,** manure management and manure deposition of grazing animals on pastures are the main sources. Emissions have been fluctuating between 5 and 6 kt NH_3 since 1990. The main driver behind the general trend and its oscillations is the trend in livestock population. Sheep and cattle are the main sources of ammonia emissions, constituting around two thirds of total NH_3 emissions. NH_3 emissions from fertilizer application play only a minor role.

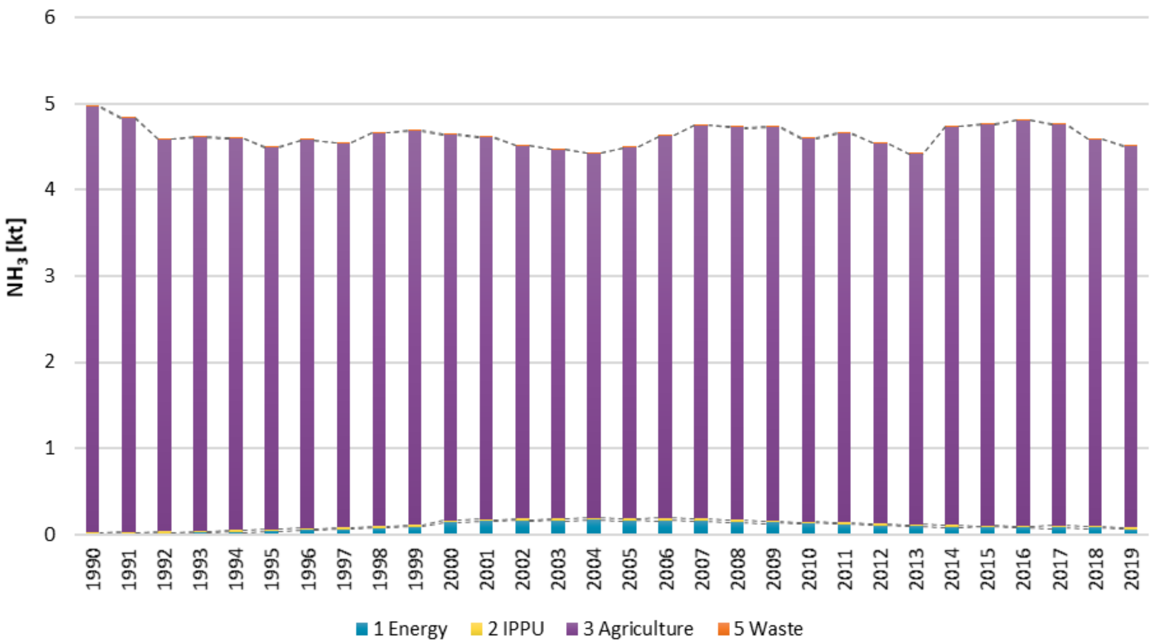

Figure 2.8 NH_3 emissions by sector, since 1990.

2.2.5 Trends in non-methane volatile organic compounds (NMVOC) emissions

In 2019, total NMVOC emissions in Iceland were 45% below the 1990 level. Many sources contribute to the total emissions, and the main sources are manure management, solvent use (domestic solvent use and coating application), fishing, and food and beverage industry. Figure 2.9 shows the sectoral emission trends since 1990.

- **Manure management (NFR 3B):** Horse and cattle manure management systems are responsible for close to 30% of NMVOC emissions in Iceland. The variations over the years are mostly linked to livestock population fluctuations.
- **Solvent use (NFR 2D3):** The main source of NMVOC linked to solvent use is domestic solvent use, which in turn are linked to population size. The population in Iceland has been increasing steadily since 1990.
- **Fishing (NFR 1A4ciii):** Emissions from commercial fishing rose in the years 1990 to 1996 when a substantial portion of the fishing fleet was operating in distant fishing grounds. From 1996 emissions decreased, reaching the 1990 levels in 2001. Emissions rose again in 2002 but have declined since with exception of 2009 due to less fuel consumption. Emissions in the current emission year were around a third lower than the 1990 level. Annual changes are inherent to the nature of fisheries.

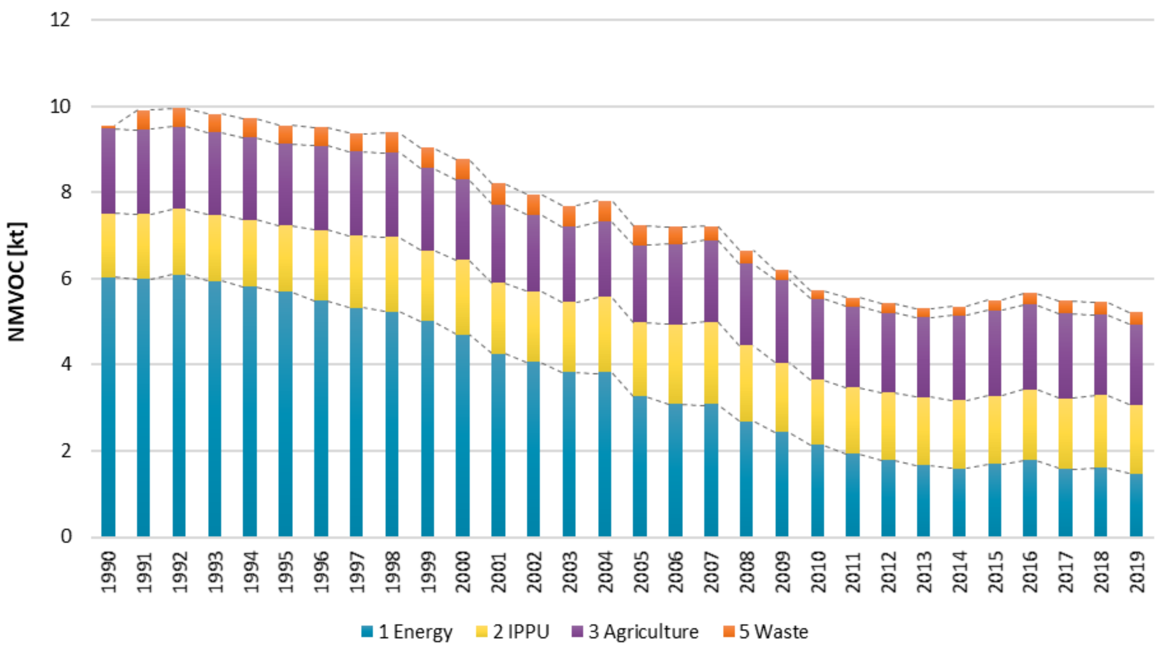

Figure 2.9 NMVOC emissions by sector, since 1990.

2.2.6 Trends in carbon monoxide (CO) emissions

In 2019, total CO emissions in Iceland were approximately double the 1990 level. Industrial Processes were the most prominent contributor to CO emissions in Iceland. Figure 2.10 shows the sectoral emission trends since 1990.

- **Metal production (NFR 2C):** The main source of CO is primary aluminium production. The various increases correspond to expansions in production capacity.
- **Road transport (NFR 1A3b):** In the earlier part of the time series, more than half of the total CO emissions were originating from road transport. Emissions from road transport have been steadily decreasing since 1990 due to advances in pollution control equipment in road vehicles, and in 2019 they amounted to less than 4% of the total emissions.
- **Aviation (Landing and Take-off):** An apparent sudden decrease in CO emissions from the energy sector between 2004 and 2005 is an artefact of the use of different data sets; for the years 1990-2004, emissions are estimated using fuel sales statistics and Tier 1 emission factor from the 2019 EMEP/EEA Guidelines; for the years 2005-2019, emissions are reported as provided by Eurocontrol.

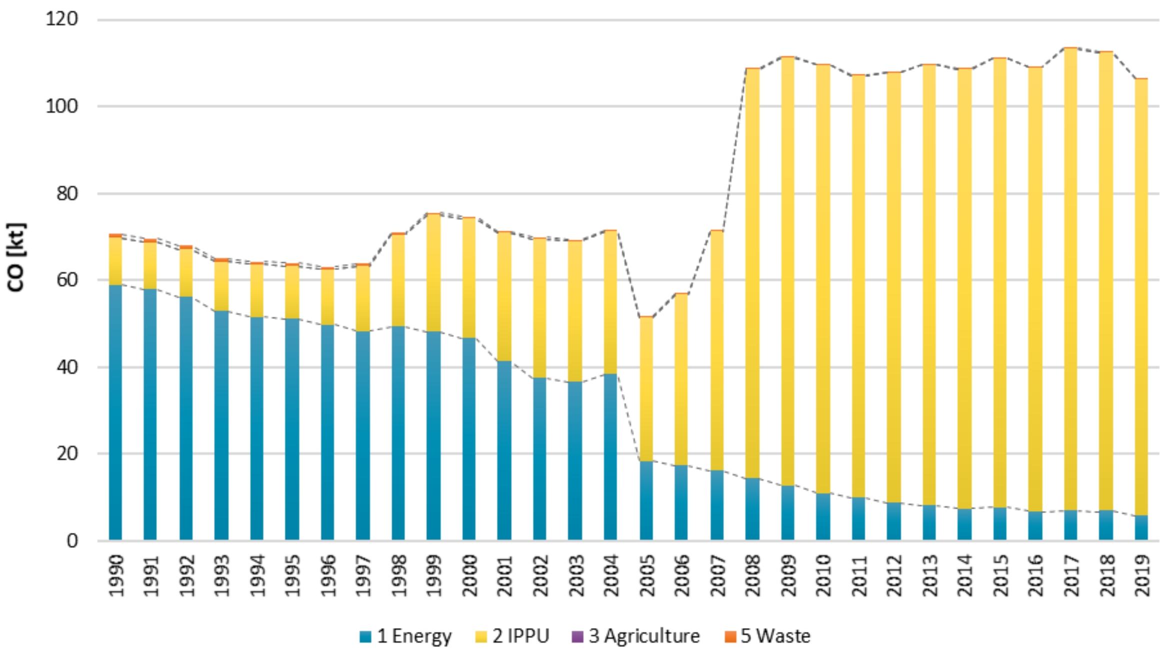

Figure 2.10 CO emissions by sector, since 1990.

2.2.7 Trends in SO_2, NO_x, NH_3, NMVOC, CO, PM and BC by main source sectors

- **Energy sector:** Figure 2.11 shows emission trends for SO_2, NO_x, NMVOC, CO, PM and BC in the energy sector as a percentage of the 1990 levels. The contribution of the energy sector in the total SO_2 emissions has, however, remained relatively stable at around 80% until 2012 due to a similar increase in the emissions in the industrial sector over the same period of time. Since 2012, the SO_2 emissions from geothermal energy have decreased due to reinjection of geothermal sulphur into the subsurface. However, they have started increasing again in the past two years. Emissions of NO_x, NMVOC, BC and CO have been generally decreasing in the energy sector since 1990, as has the contribution of this sector to the total emissions of these pollutants. Mobile fuel combustion (fishing, transport and machinery) is by far the largest pollutant source within the energy sector (apart from sulphur emissions from the geothermal industry).

- **NH_3 emission trends:** The trend of NH_3 emissions from the energy sector can be seen in Figure 2.12. These emissions increased significantly from 1990 and peaked in 2004. Since then they have been decreasing again. This is due to high emissions factors for Euro 1 and Euro 2 vehicles in the road transport sector.

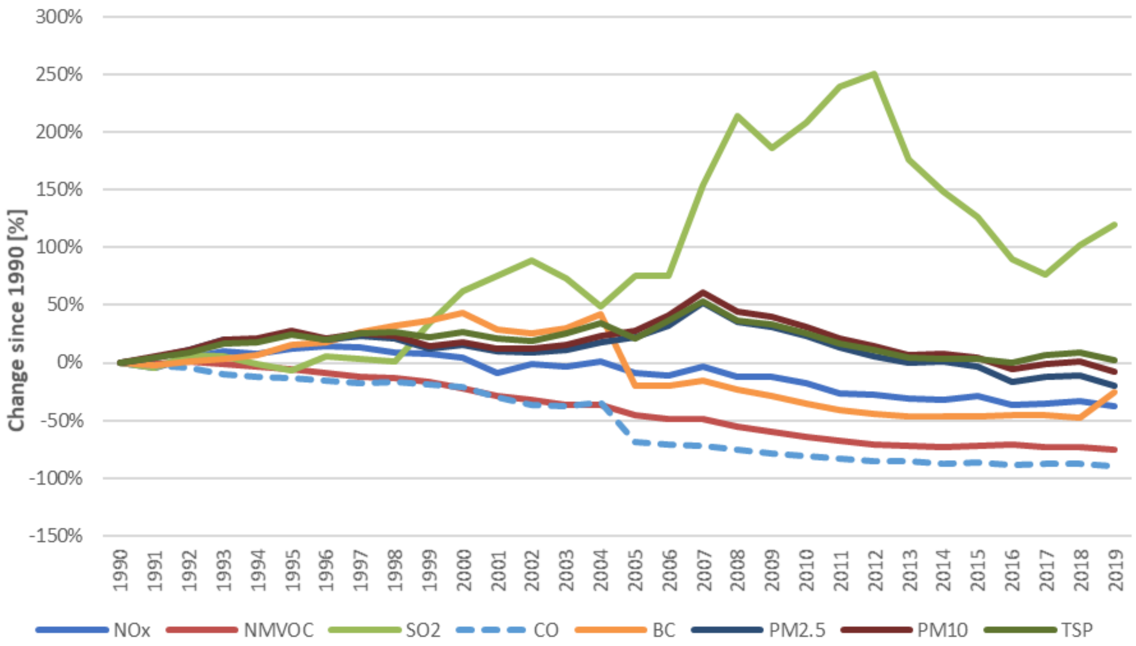

Figure 2.11 Trends in NO_X, NMVOC, SO_2 and CO, BC, $PM_{2.5}$, PM_{10}, and TSP emissions from the energy sector (% of 1990 levels).

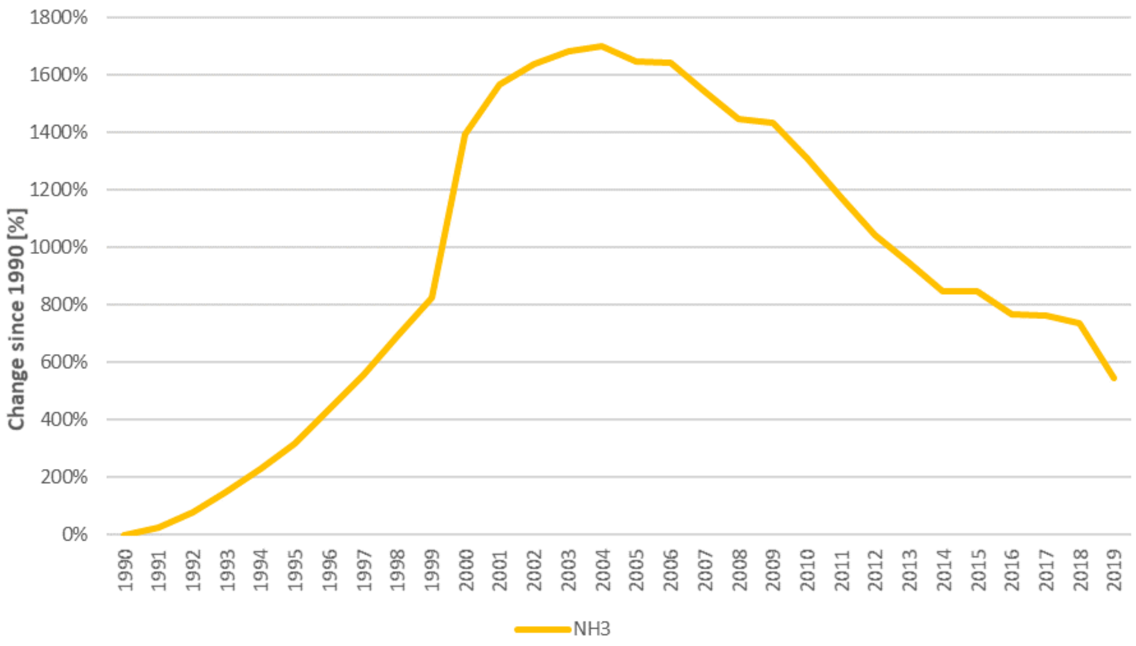

Figure 2.12 Trends in NH_3 emissions from the energy sector (% of 1990 levels).

- **Industrial processes and product use sector:** Figure 2.13 shows trends in the emissions of SO_2, NO_x, NH_3, NMVOC, CO, PM and BC in the industrial sector as a percentage of the 1990 levels. The industrial sector contributions to the total non-POPs pollutants emissions in 2019 are 10% for NO_x, 30% for NMVOC, 22% for SO_2, 94% for CO, 40% for $PM_{2.5}$, 50% for PM_{10}, 58% for TSP and 5% for BC. The large increase in CO emissions from the industrial sector (linked to the expansion in metal production capacity) has made this sector the dominant contributor of CO emissions in Iceland. Emissions of all the reported non-POPs emissions have increased in the industrial sector since 1990, with the exception of NH_3 which has decreased. Contributions of the industrial sector to the total emissions has also increased over that same period.

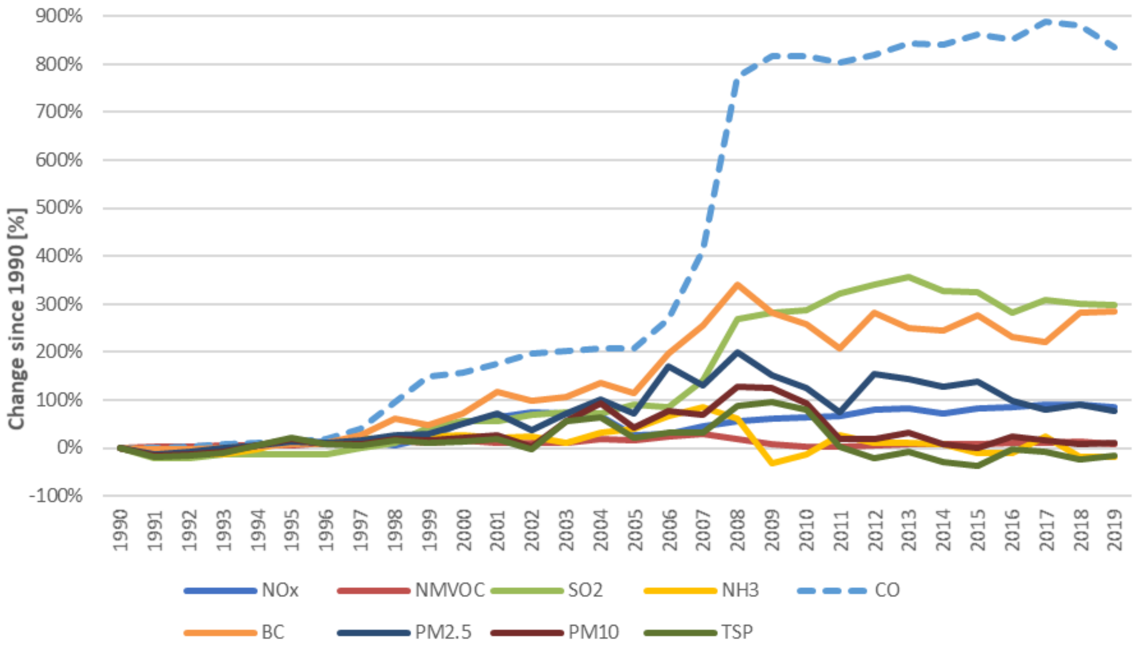

Figure 2.13 Trends in NO_x, NMVOC, SO_2, NH_3, CO, BC, $PM_{2.5}$, PM_{10} and TSP emissions from the industrial sector (% of 1990 levels).

- **Agricultural sector:** Figure 2.14 shows trends in the emissions of SO_2, NO_x, NH_3, NMVOC, CO, PM and BC in the agricultural sector as a percentage of the 1990 levels. The agricultural sector contribution to the total emissions in 2019 is 5% for NO_x, 35% for NMVOC, 98% for NH_3, 3% for $PM_{2.5}$, 9% for PM_{10} and 7% for TSP. The contribution of other non-POPs emissions to the total emissions is zero (not applicable or not estimated). No significant decrease in emissions have occurred in this sector since 1990. NO_x emissions have been fluctuating around the 1990 levels with a relatively high amplitude but still remains a small contributor (< 5%) to the total NO_x emissions throughout the period.

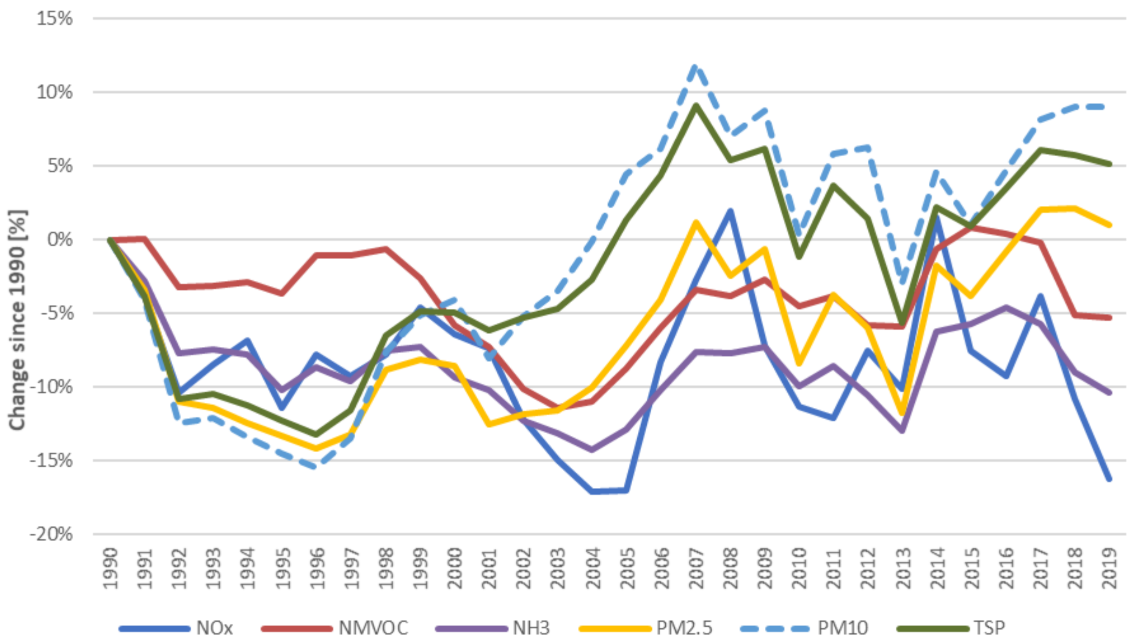

Figure 2.14 Trends in NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10} and TSP emissions from the agricultural sector (% of 1990 levels).

- **Waste sector:** Figure 2.15 shows trends in the emissions of SO_2, NO_x, NH_3, NMVOC, CO, PM and BC in the waste sector as a percentage of the 1990 levels. The waste sector contribution to the total emissions in 2019 is 7% for NMVOC; NO_x, SO_2, NH_3 and CO emissions from the waste sector contribute to less than 0.5% of the total emissions for each pollutant. Changes occurring in 2003 are due to the move from open burning of waste to municipal waste incineration. The prominent peaks in SO_2 emissions in 2004 and 2014 are due to major fires in a recycling company (2004) and in an industrial laundry service (2014).

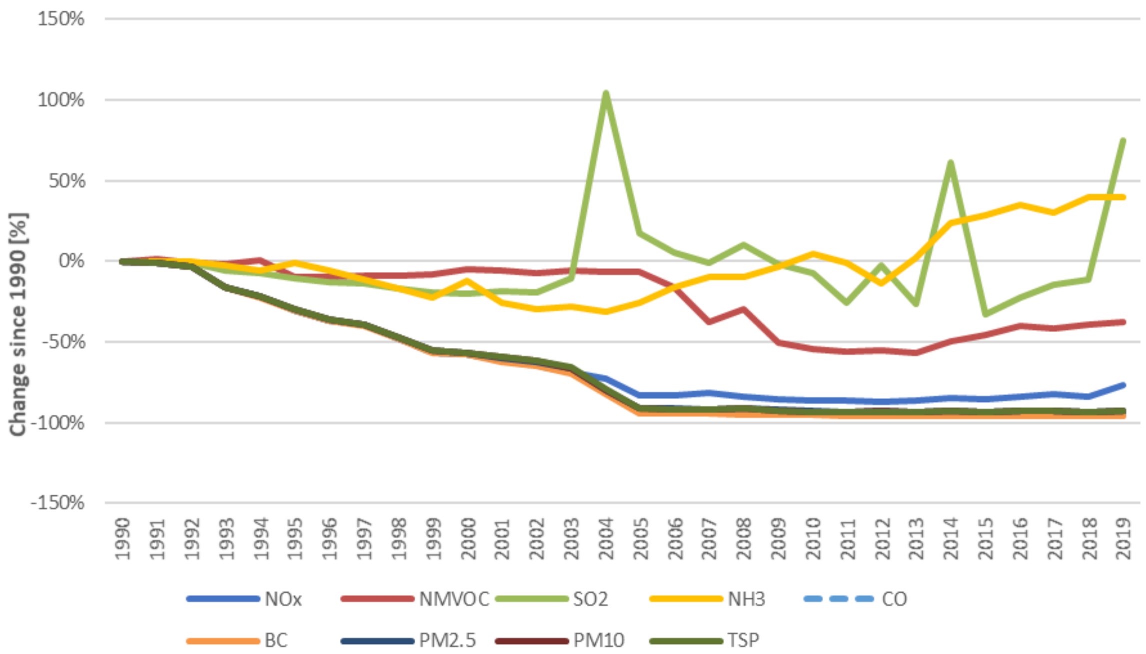

Figure 2.15 Trends in in NO_x, NMVOC, SO_2, NH_3, CO, BC, $PM_{2.5}$, PM_{10} and TSP emissions from the waste sector (% of 1990 levels).

2.3 Emission Trends for Persistent Organic Pollutants (POPs)

The total amount of dioxins, PAH4, HCB and PCB emitted in Iceland in 1990 and 2019 is presented in Table 2.2. Emissions of all POPs have significantly decreased since 1990.

Table 2.2 Emissions of POPs in Iceland 1990 and 2019.

Year	Dioxin [g I-TEQ]	PAH4 [t]	HCB [kg]	PCB [kg]
1990	10.72	0.302	0.046	0.169
2019	0.46	0.088	0.029	0.025
Trend	**-96%**	**-71%**	**-36%**	**-85%**

2.3.1 Trends in dioxin emissions

In 1990, the total emissions of dioxins in Iceland were 10.7 g I-TEQ. In 2019 total emissions were 0.46 g I-TEQ. This amounts to a decrease of more than 90% over that time period. Figure 2.16 shows the dioxin emissions by source from 1990.

Dioxins form a family of toxic chlorinated organic compounds that share certain chemical structures and biological characteristics. Dioxins are members of two closely related families: the polychlorinated dibenzo(p)dioxins (PCDDs; 75 congeners) and polychlorinated dibenzofurans (PCDFs; 135 congeners). Dioxins bio-accumulate in humans and wildlife due to their fat solubility and 17 of these compounds are especially toxic. Dioxins are formed during combustion processes such as commercial or municipal waste incineration and from burning fuels like wood, coal or oil. Dioxins can also be formed in natural processes such as forest fires. Dioxins also enter the environment through the production and use of organochlorine compounds, chlorine bleaching of pulp and paper, certain types of chemical manufacturing and processing and other industrial processes that create small quantities of dioxins. Cigarette smoke also contains small amounts of dioxins.

Emissions of dioxins are presented in g I-TEQ (International Toxic Equivalents). 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is the most toxic of the dioxin congeners. Other congeners (or mixtures thereof) are given a toxicity rating from 0 to 1, where TCDD is 1. The total dioxin toxic equivalence (TEQ) value expresses the toxicity as if the mixture were pure TCDD.

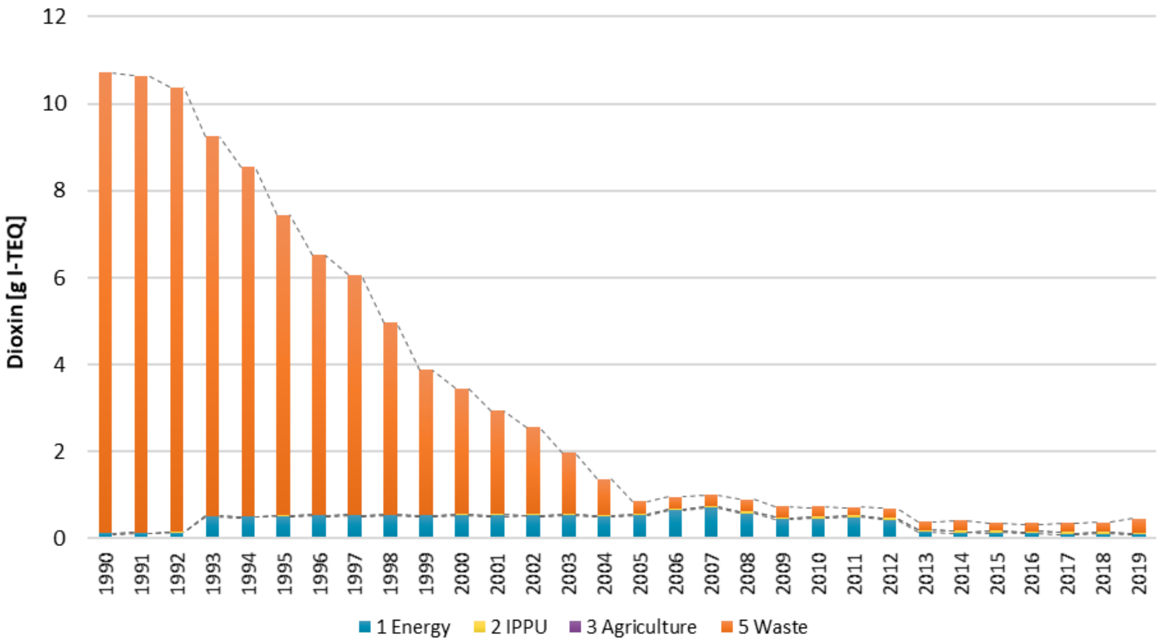

Figure 2.16 Dioxin emissions by sector, since 1990.

The main reason for the significant reduction of dioxin emissions is a significant decrease in waste incineration between 1990 and 2004. In recent years the main contributors to dioxin emissions have been accidental fires (reported under NFR 5E) and bonfires (reported under NFR 5C2 open burning of waste), and, to a lesser extent, transport and fishing (energy sector) and aluminium production (industry).

- **Waste sector (NFR 5):** Practices of waste disposal treatment have undergone a radical change in Iceland since 1990. This is one of the main reasons for the substantial decline in dioxin emissions since 1990. Below are described various factors that have influenced the dioxin emission profile from the waste sector:
    - Open pit burning that used to be the most common means of waste disposal outside the capital area, has gradually decreased since 1990. Open pit burning is practically non-existent today, the last site was closed by the end of 2010;
    - In recent years, those incineration plants have been closed. Currently, there is only one incineration plant operating in Iceland. The incineration plant is called Kalka and it does not recover energy. Emissions from bonfires around New Year celebrations are included in the waste incineration sector. Emissions from bonfires have decreased since 1990, due to the fact that bonfires are fewer and better controlled. Guidelines for bonfires, published in 2000, include restrictions on size, burnout time and the material allowed.
    - The total amount of waste being incinerated has decreased;
    - A peak in emissions from accidental fires occurred in 2004 when a major fire broke out at a recycling company (Hringrás). In the fire 300 tonnes of tires, among other separated waste materials, burned. A fire broke out in the same company in 2011 and was estimated to be 10% the size of that in 2004. In 2014, a major fire broke out in an industrial laundry service when, among other materials, around 60-80 tons of asphalt roll roofing burned.

- **Energy sector (NFR 1A):** Over the time series, the main source of dioxin emissions were from waste burning with energy recovery, which occurred in Iceland between 1994 and 2012. Other sources within the energy sector contributing to dioxin emissions since 2013 are passenger cars and fishing, but in general the emissions from those sources are decreasing.

2.3.2 Trends in polycyclic aromatic hydrocarbons (PAHs) emissions

In 1990, the total emissions of PAH4 in Iceland were 590 kg. In 2019 total emissions were 87 kg. This shows a decrease of 85% over the time period. Figure 2.17 shows the emissions by source from 1990 to 2019.

The polycyclic aromatic hydrocarbons (PAH) are molecules built up of benzene rings which resemble fragments of single layers of graphite. PAHs are a group of approximately 100 compounds. Most PAHs in the environment arise from incomplete burning of carbon-containing materials like oil, coal, wood or waste. Fires can produce fine PAH particles; they bind to ash particles and sometimes move long distances through the air. Thus, PAHs have been ubiquitously distributed in the natural environment for thousands of years. The four compounds benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene are used as PAH indicators for the purposes of emission inventories, as specified in the POP - Protocol.

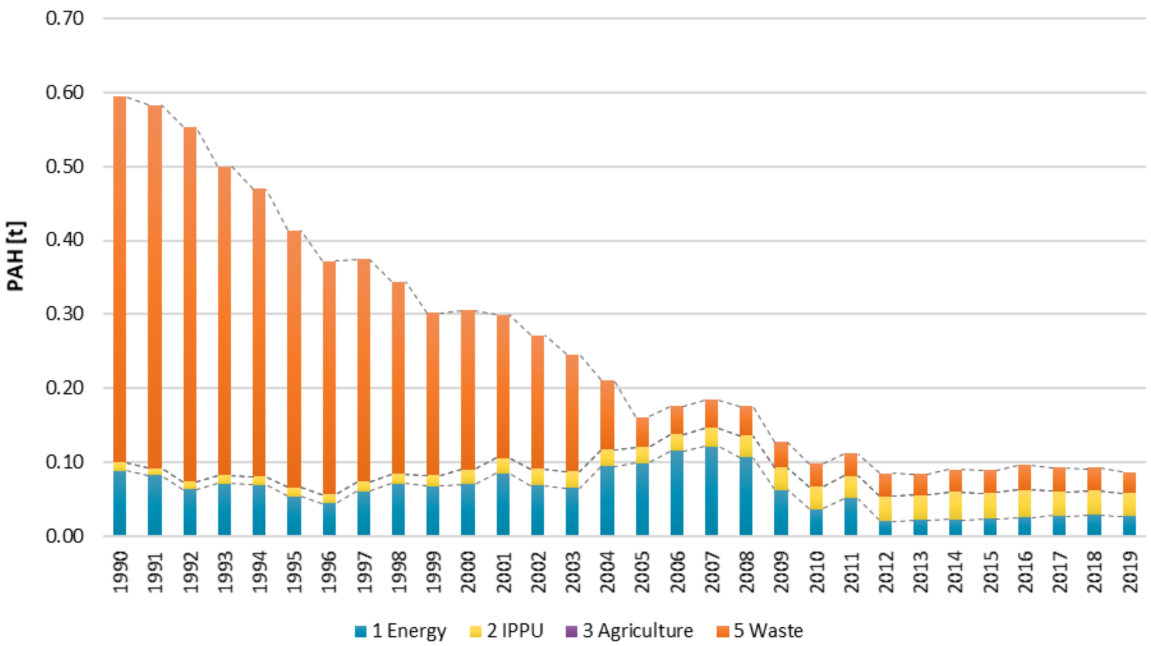

Figure 2.17 PAH4 emissions by sector, since 1990.

The main reason for the significant reduction of PAH4 emissions since is a significant decrease in waste incineration between 1990 and 2004, as discussed above for dioxin. The key sectors leading to PAH4 emissions are waste, metal production, accidental fires and road transport.

- **Waste (NFR 5):** PAH4 emissions from the waste incineration have decreased by around 92% since 1990, partly because outdated incineration plants and open pit burning have been closed down. See a more detailed description of the decrease in waste incineration in section 2.3.1 on dioxin above.

- **Metal production (NFR 2C):** Since 2005 PAH4 emissions from industrial processes (Industry) have increased due to substantially increased production capacity in the metal production sector. The contribution of the sector to the total PAH4 emissions has been steadily increasing from 2% in 1990 to around 35% in 2019. The main increase in emissions happened in the years 1998-2000 as well as in 2006-2008. Between 1998 and 2000 the increase in emissions was due to increased production capacity both in the aluminium and the ferrosilicon industry. In the years 2006-2008 the cause was increased production capacity in the aluminium industry.
- **Transport (NFR 1A3):** Road transport is also an important source of PAH4 emissions in Iceland. PAH4 emissions from this sector are estimated to have increased by approx. 68% since 1990.

2.3.3 Trends in hexachlorobenzene (HCB) emissions

Total HCB emissions in 2019 are 72 g compared to 152 g in 1990. There have been significant changes in HCB emissions during the period 1990-2019, as can be seen in Figure 2.18.

Hexachlorobenzene (HCB) or perchlorobenzene is a chlorocarbon with the molecular formula C_6Cl_6. HCB is a fungicide that was first introduced in 1945 for seed treatment, especially for control of bunt of wheat. HCB is currently emitted as a by-product in the manufacture of several chlorinated solvents. Overall, processes resulting in dioxin formation also result in HCB emissions. HCB is considered to be probable human carcinogen. HCB is a very persistent environmental chemical due to its chemical stability and resistance to biodegradation.

Analysis of trends in HCB emissions in Iceland must be interpreted with care as only few sources have been estimated, which reflects the lack of emission factors in the 2019 EMEP/EEA Guidebook. For instance, open pit burning was occurring between 1990 and 2003 but the 2019 EMEP/EEA Guidebook does not provide emission factors for HCB for open burning, thus HCB emissions estimates from the waste sector are almost non-existent until 2003. In 2004 the incineration plant Kalka opened and emission factors for HCB emissions from incineration are reported in the 2019 EMEP/EEA Guidebook, and are therefore reported from 2004 and onwards.

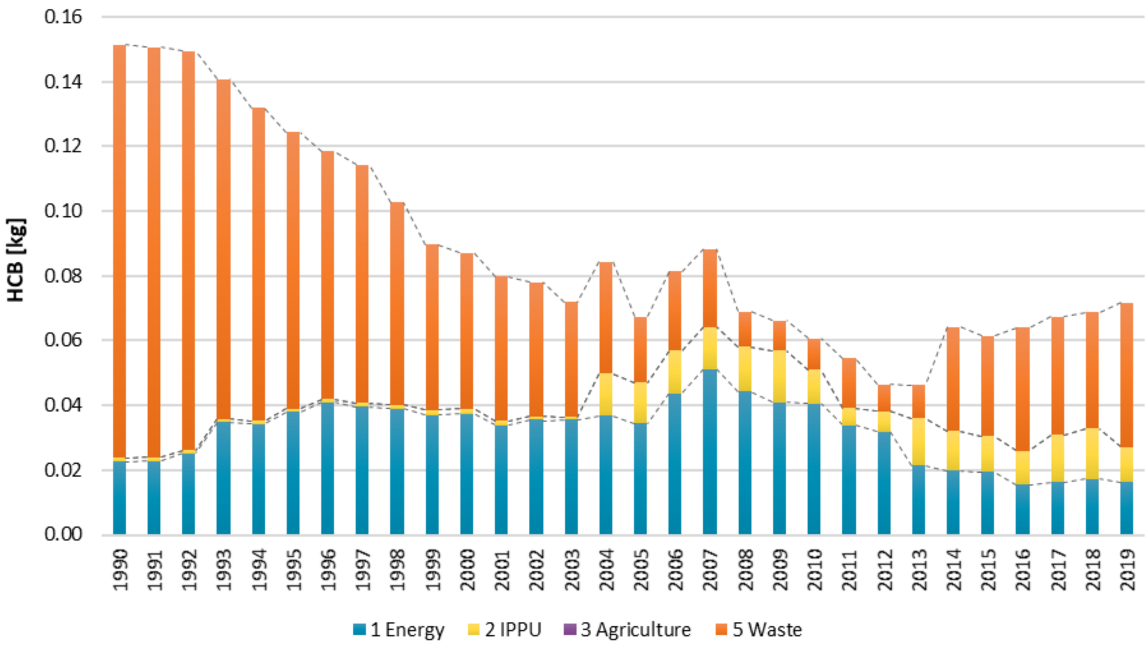

Figure 2.18 HCB emissions by sector, since 1990.

The main sources of estimated HCB emissions are clinical waste incineration, incineration with energy recovery (occurring in the years 1993-2012, and reported under Energy production 1A1a), fishing and secondary aluminium production.

- **Waste incineration (NFR 5C):** As shown in Figure 2.18, waste was responsible for 62% of the estimated HCB emissions in Iceland in 2019. Emission decreased from 1990 to 2005 because of a reduction in waste incineration, as discussed for dioxin and PAH4 above. The increase in HCB emissions between 2013 and 2014 is due to an increase in incineration of clinical waste.
- **Fishing (NFR 1A4ciii):** Emissions from commercial fishing rose in the years 1990 to 1996 when a substantial portion of the fishing fleet was operating in distant fishing grounds. Since then emissions have been following a generally decreasing trend, but with fluctuations due to changed conditions in the fishing industry (renewing of fishing fleet, status of fish stocks, etc), as well as different ratios of use of marine gas oil versus heavy fuel oil.
- **Waste incineration with energy recovery (NFR 1A1a):** This activity occurred in Iceland between the years 1993 and 2012 and contributed to HCB emissions for those years.
- **Metal production (NFR 2C):** A sudden increase in HCB emissions from industrial processes is seen in 2004 when a secondary aluminium production plant was established. From 2009, production started decreasing, until 2013 where another secondary production plant opened, reversing the decreasing trend.

2.3.4 Trends in polychlorinated biphenyl (PCB) emissions

In the early years of the time series, one of the main source of PCB in Iceland was waste incineration, following a decreasing trend between 1990 and 2004 as seen above for the other POPs. The other main sources contributing to the PCB emission trends are within the energy sector (1A2 manufacturing and construction, 1A1 energy industries (waste incineration with energy recovery) and 1A4 fishing). The only source of PCB estimated from industrial processes is secondary steel production (2C1). The only secondary steel plant in Iceland started its activities in 2014 and closed in 2016.

Analysis of trends in PCB emissions in Iceland must be interpreted with care as only few sources have been estimated, which reflects the lack of emission factors in the 2019 EMEP/EEA Guidebook.

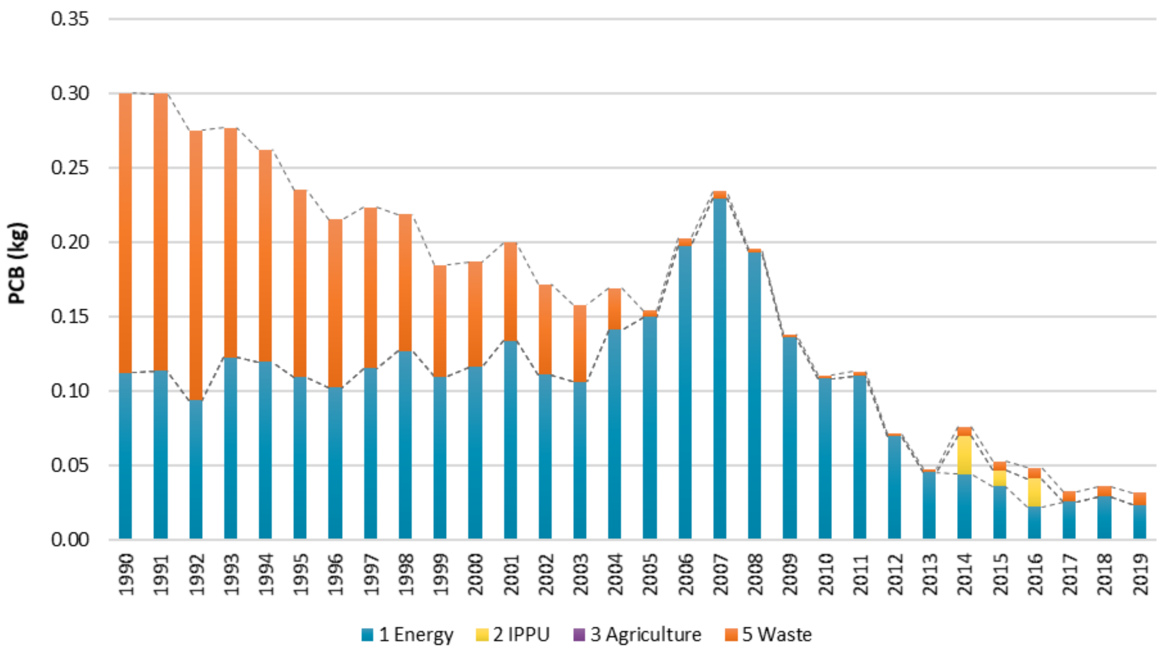

Figure 2.19 PCB emissions by sector, since 1990.

- **Waste (NFR 5):** As shown in Figure 2.19, waste was responsible for 26% of the estimated PCB emissions in Iceland in 2019. Emissions are only calculated for waste incineration. Open pit burning was occurring between 1990 and 2003. In 2004 the incineration plant Kalka opened and emission factors for PCB emissions from incineration are smaller than from open burning, therefore there is a significant decrease in emissions from waste from 2005.
- **Waste incineration with energy recovery (NFR 1A1a):** This activity occurred in Iceland between the years 1993 and 2012 and contributed to PCB emissions for those years.
- **Fishing (NFR 1A4ciii):** Emissions from commercial fishing rose in the years 1990 to 1996 when a substantial portion of the fishing fleet was operating in distant fishing grounds. Since then emissions have been following a generally decreasing trend, but with fluctuations due to changed conditions in the fishing industry (renewing of fishing fleet, status of fish stocks, etc), as well as different ratios of use of marine gas oil versus heavy fuel oil. Those two fuel types have very different emission factors for PCB. Fishing was the largest contributor of PCB in 2019, accounting for approximately 63% of total PCB emissions.
- **Metal production (NFR 2C):** The only PCB emissions reported from the Industrial processes and product use sector are from secondary steel production, which only took place during three years (2014 to 2016). Fluctuations in PCB emissions during these years from this activity reflects fluctuations in yearly production.

2.3.5 Trends in persistent organic pollutants (POPs) by main source sectors

Analysis of trends in POP emissions in Iceland must be interpreted with care as only few sources have been estimated, which reflects the lack of emission factors in the 2019 EMEP/EEA Guidebook.

- **Energy sector:** POPs emissions trends in the energy sector are shown in Figure 2.20 as a percentage of the 1990 levels. In 2019 the energy sector contributed to 21% and 33% of total dioxin and PAH4 emissions, respectively. The increase in dioxin emissions in the years 1993-2012 is due to the occurrence, during those years, of waste incineration with energy recovery.

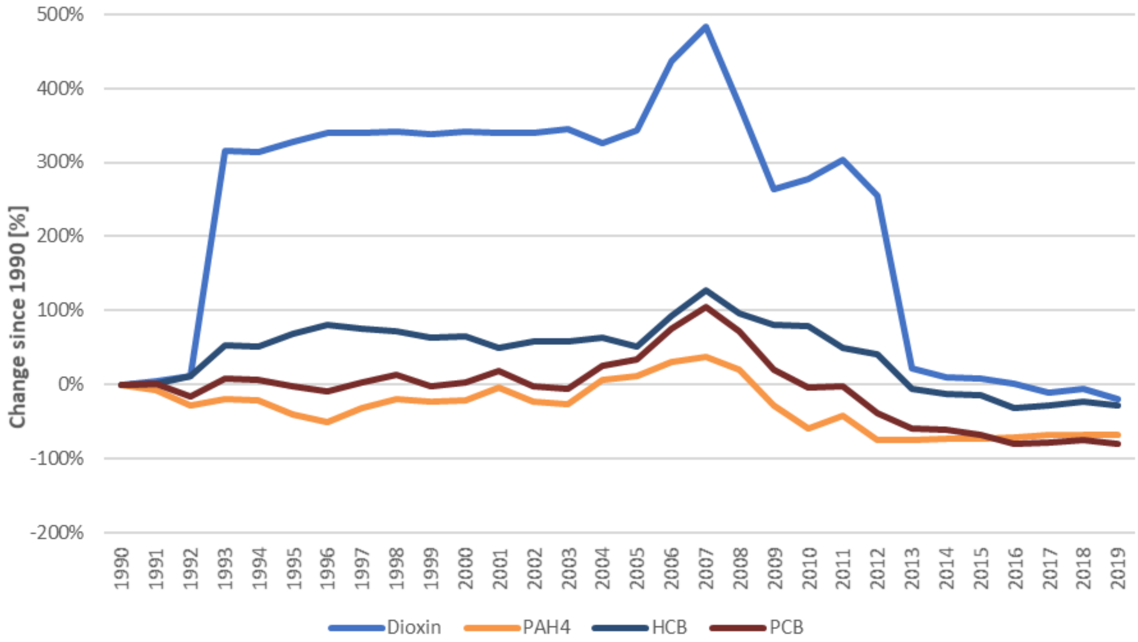

Figure 2.20 Trends in POPs emissions from the energy sector (% of 1990 levels).

- **Industrial sector:** POPs emissions trends in the industrial sector are shown in Figure 2.21 as a percentage of the 1990 levels. The industrial sector has not reduced its emissions of any POPs pollutant since 1990. In 2019 the industrial sector contributed 35% of total PAH4 emissions, 15% of total HCB emissions, 9% of total dioxin emissions and 0% of total PCB emissions (the latter due to the closure of the only PCB source in the industrial sector, which was a secondary steel production facility which operated from 2014 to 2016). The main source of HCB is secondary aluminium production, and the large fluctuations for HCB in the graph below reflect fluctuations in secondary aluminium production.

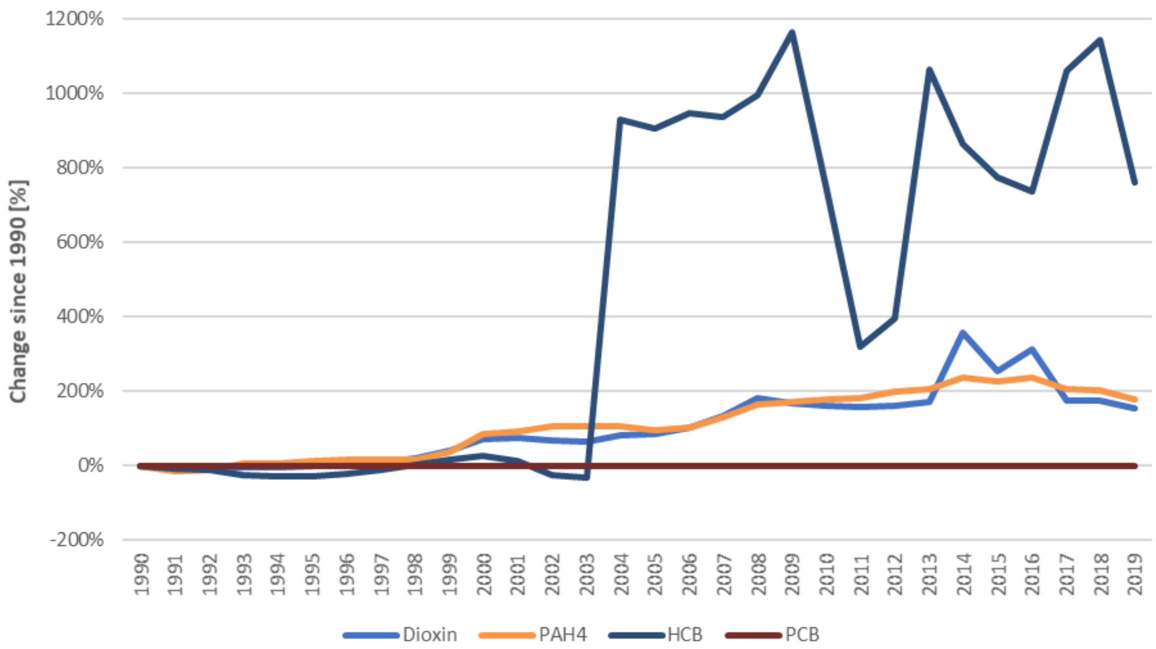

Figure 2.21 Trends in POPs emissions from the industrial sector (% of 1990 levels).

- **Agricultural sector:** No POPs emissions are occurring in Iceland from categories belonging to the agricultural sector.
- **Waste sector:** POPs emissions trends in the waste sector are shown in Figure 2.22 as a percentage of the 1990 levels. In 2019 the waste sector contributed to 62% of total HCB emissions, 70% of total dioxin emission, 33% of total PAH4 emissions and 26% of total PCB emissions.

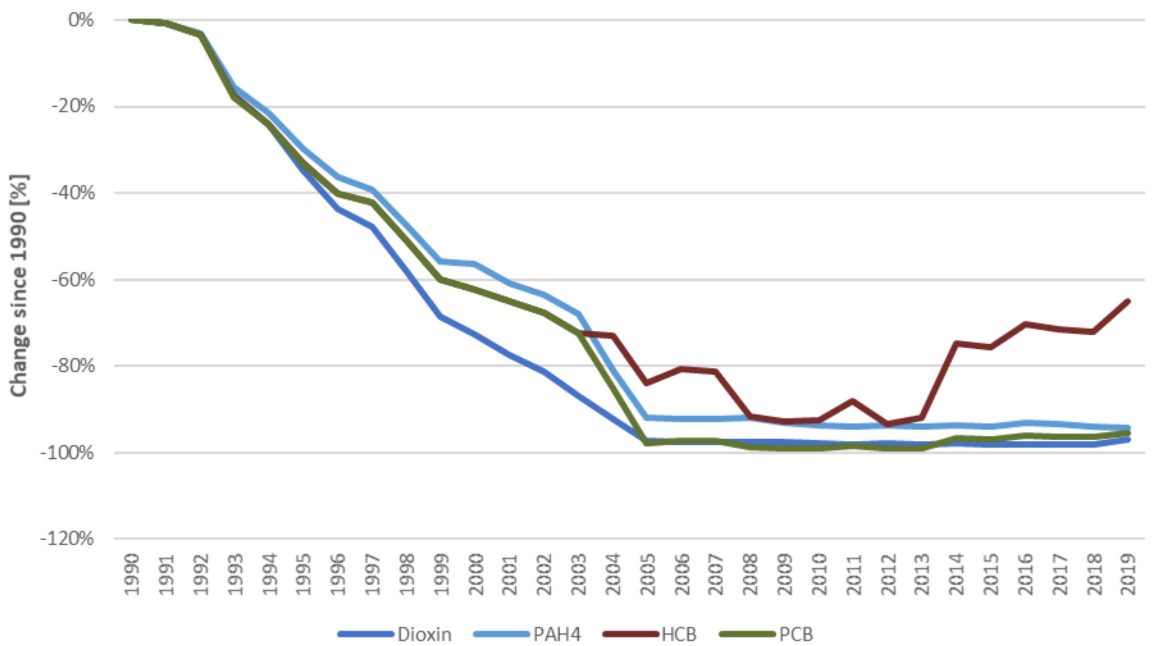

Figure 2.22 Trends in POPs emissions from the waste sector (% of 1990 levels).

2.4 Emission trends for Heavy Metals

Analysis of trends in heavy metal emissions in Iceland must be interpreted with care as only few sources have been estimated, which reflects the lack of emission factors in the 2019 EMEP/EEA Guidebook. A complete list of categories not estimated can be found in Table 1.4. Emission estimate for 1990 and 2019 shown in Table 2.3.

Table 2.3 Estimated emissions of heavy metals, 1990 and 2019.

	Pb [t]	Cd [t]	Hg [t]	As [t]	Cr [t]	Cu [t]	Ni [t]	Se [t]	Zn [t]
1990	0.38	0.0065	0.043	0.046	0.068	0.66	1.54	0.033	1.15
2019	0.58	0.0063	0.009	0.030	0.077	1.21	1.15	0.023	0.87
Change 1990-2019	**51%**	**-4%**	**-78%**	**-34%**	**14%**	**83%**	**-25%**	**-29%**	**-24%**

2.4.1 Trends in priority Heavy Metals (Pb, Cd, Hg)

Figure 2.23, Figure 2.24 and Figure 2.25 show emission trends for Pb, Cd and Hg per sector. The main sectors contributing to the emissions are energy, industrial processes and waste. In 1993, waste incineration with recovery of energy (included in the Energy sector under NFR 1A1a Public electricity and heat production) started in Iceland, leading to an increase in Pb, Cd and Hg. The amount of waste burned with recovery of energy peaked in 2007, and after that decreased until 2013 after which year this activity stopped. Aside from the emissions from waste incineration with energy recovery, a prominent contributor to the Pb trend (Figure 2.23) is the use of fireworks (under IPPU), and the steady increase since 1990 reflects the growing popularity of fireworks use in Iceland (mostly around New Years). A peak in the year 2007 reflects the peak in economic growth that year, before the economy collapse of 2008. For Hg (Figure 2.25), emissions in the early part of the time series are dominated by emissions from waste incineration, which decreased steadily from 1990 til 2004 with changes in practices in open burning and waste incineration (see also discussion on POPs, in particular dioxin, in chapter 2.3.1).

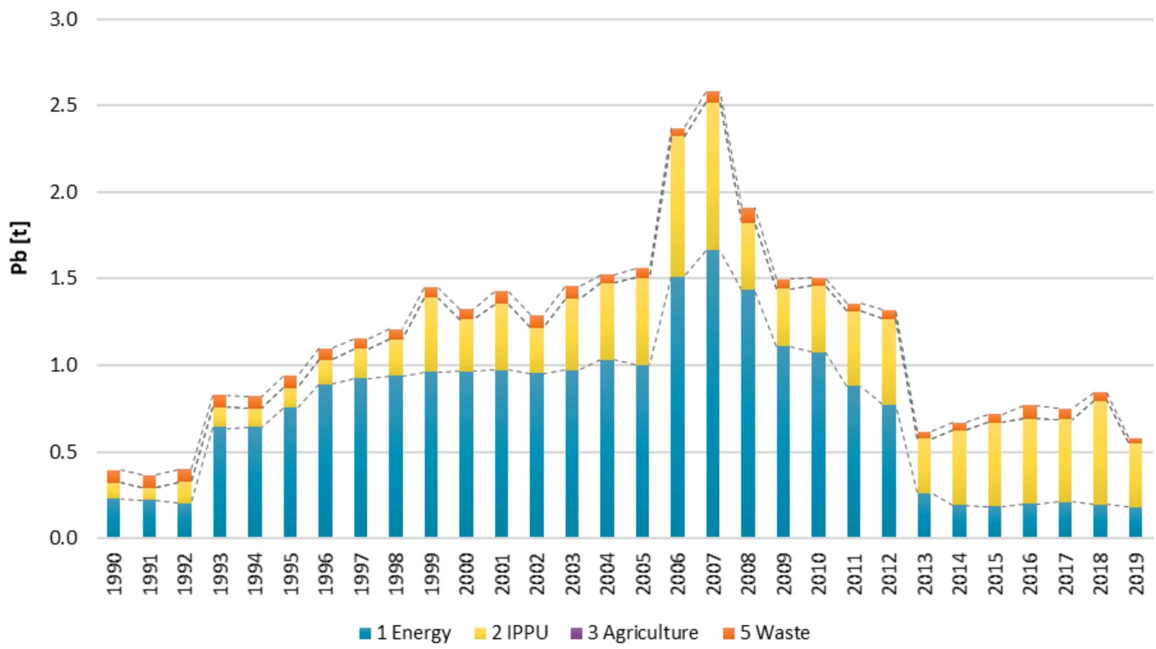

Figure 2.23 Pb emissions by sector, since 1990.

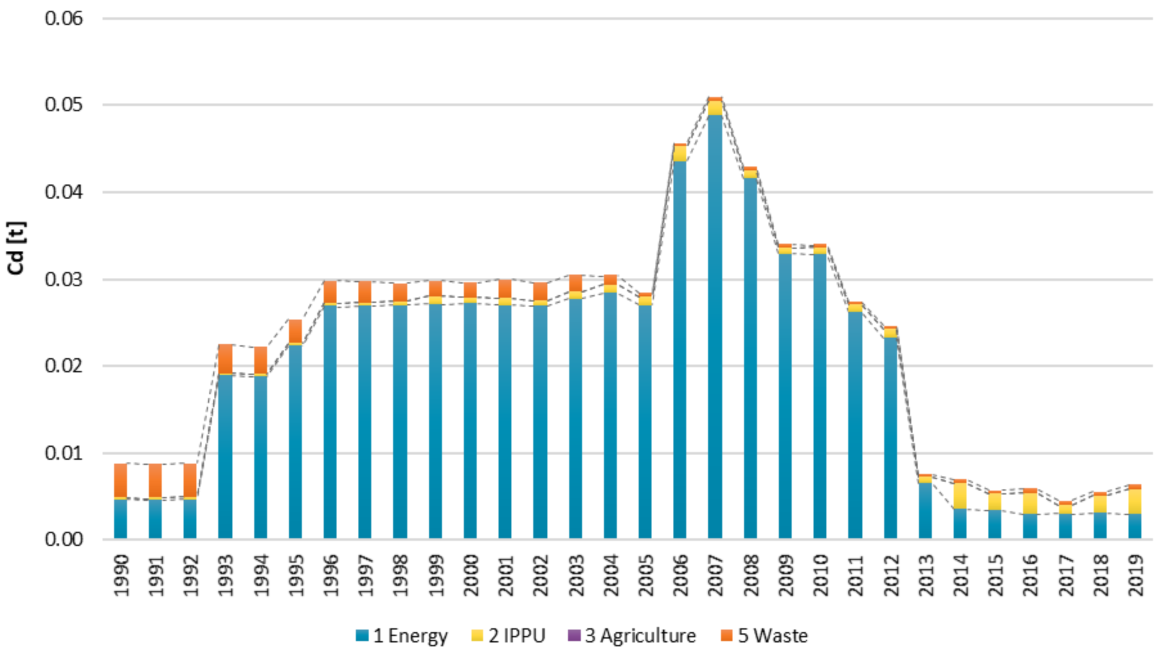

Figure 2.24 Cd emissions by sector, since 1990.

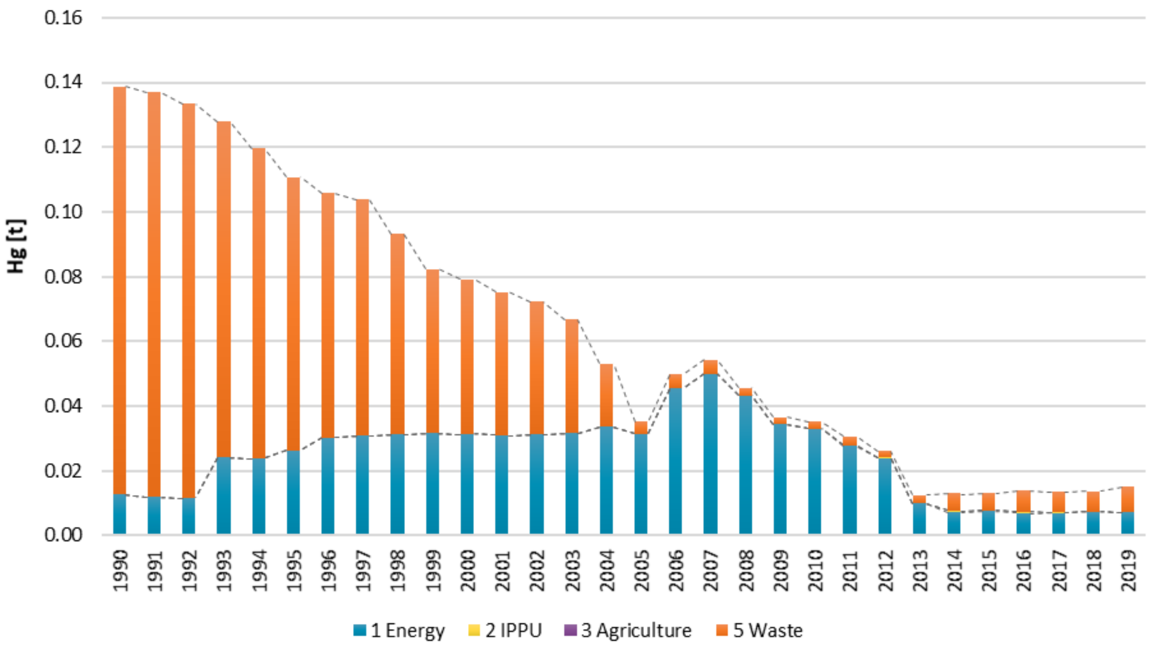

Figure 2.25 Hg emissions by sector, since 1990.

2.4.2 Trends in additional Heavy Metals (As, Cr, Cu, Ni, Se, Zn)

Figure 2.26 to Figure 2.31 show emission trends for As, Cr, Cu, Ni, Se and Zn per sector. Except for Zn, the trends are overall dominated by emissions from the energy sector. Fishing causes emissions of all heavy metals; Arsenic emissions are influenced by waste incineration with energy recovery, whereas Cr, Cu and Zn are influenced by automobile tyre and brake wear. In the industrial sector, the main source of As emissions is metal production. All other non-priority heavy metals are largely produced by fireworks, with sharp peaks in emission in 2007 where fireworks sales reached an all-time maximum. In the waste sector, heavy metal emissions come mostly from waste incineration, followed by accidental fires. The emission pattern for Zn is different (Figure 2.31), with the main contribution being automobile tyre and brake wear, as well as waste incineration (fireworks contribute also, albeit to a lesser extent). As waste incineration decreased between the years 1990-2004 (as discussed above in the POPs trends), heavy metals associated with it also decreased, as can be seen for As, Se and most notably Zn.

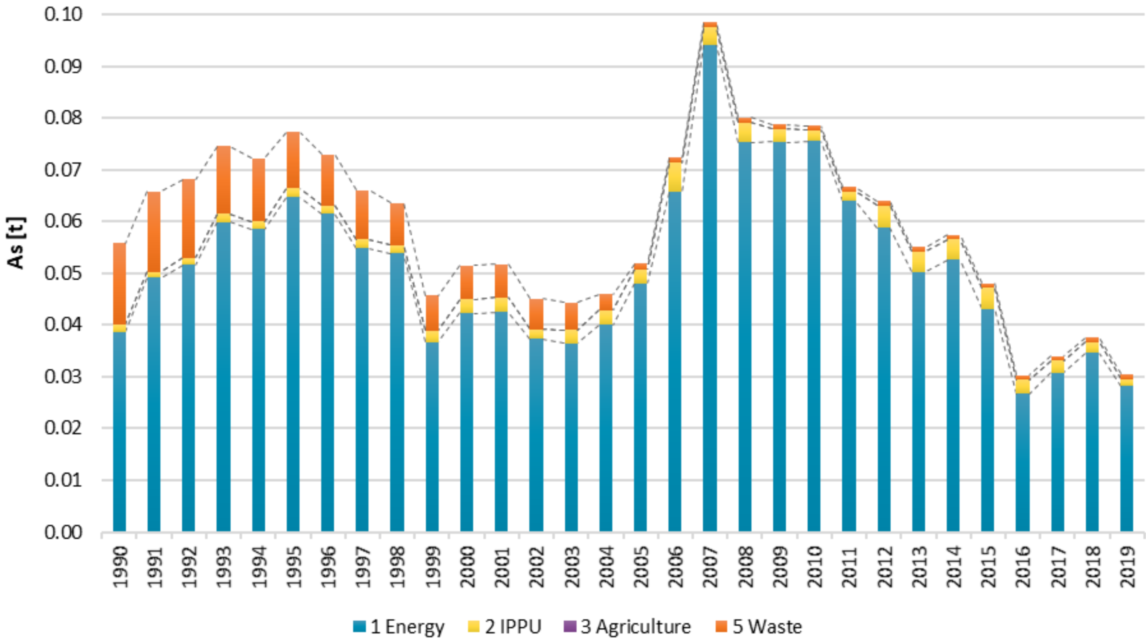

Figure 2.26 As emissions by sector, since 1990.

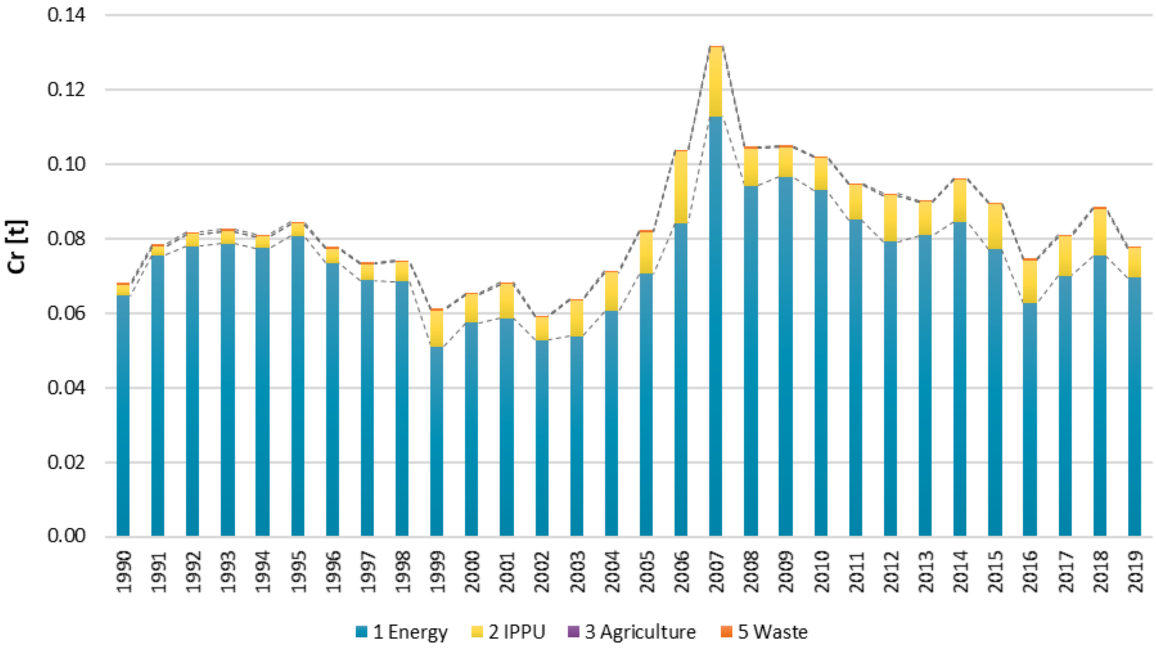

Figure 2.27 Cr emissions by sector, since 1990.

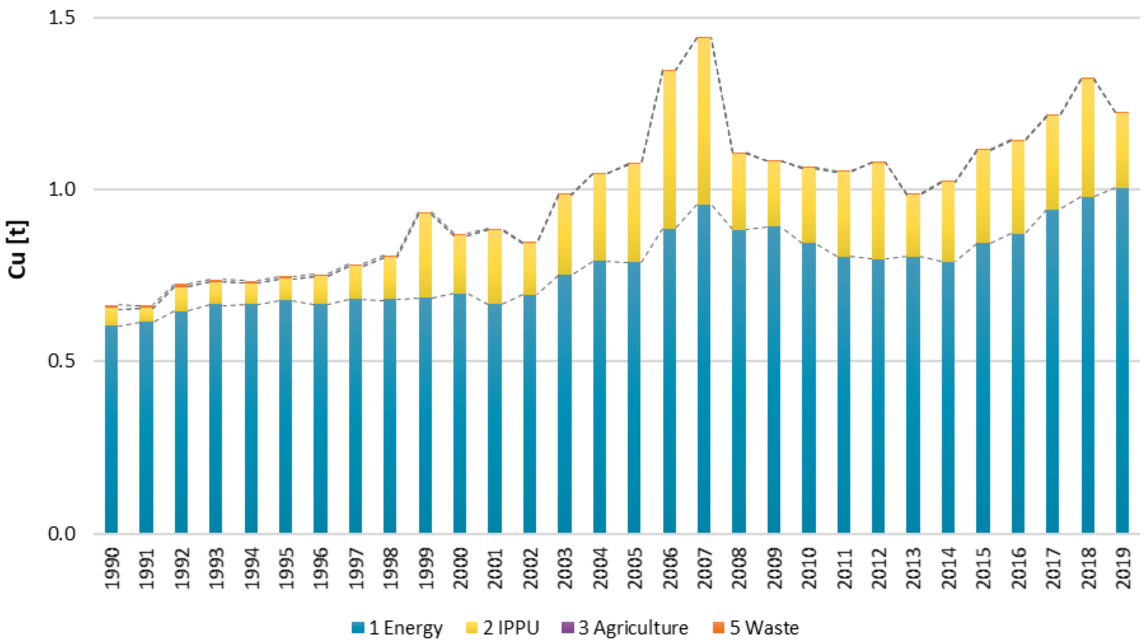

Figure 2.28 Cu emissions by sector, since 1990.

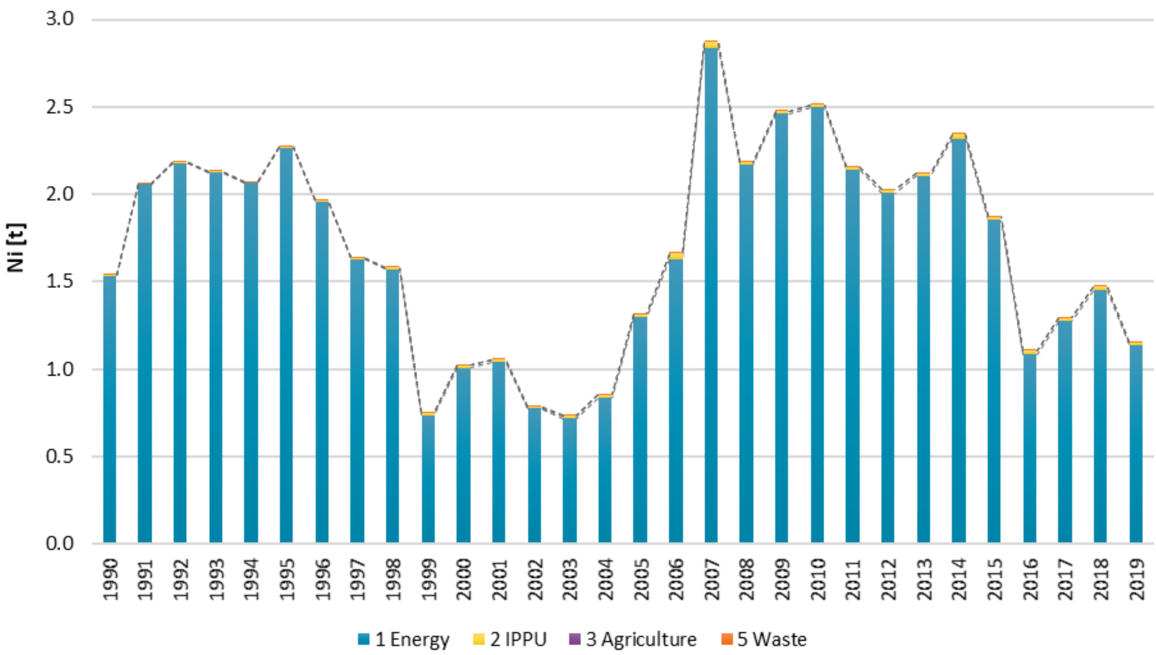

Figure 2.29 Ni emissions by sector, since 1990.

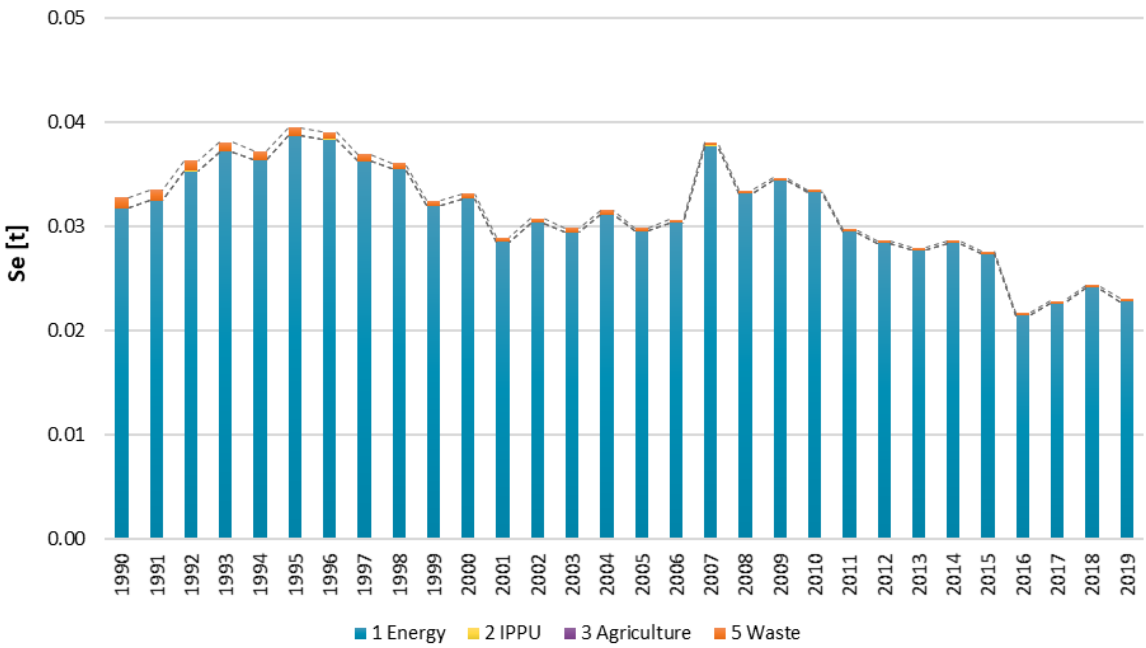

Figure 2.30 Se emissions by sector, since 1990.

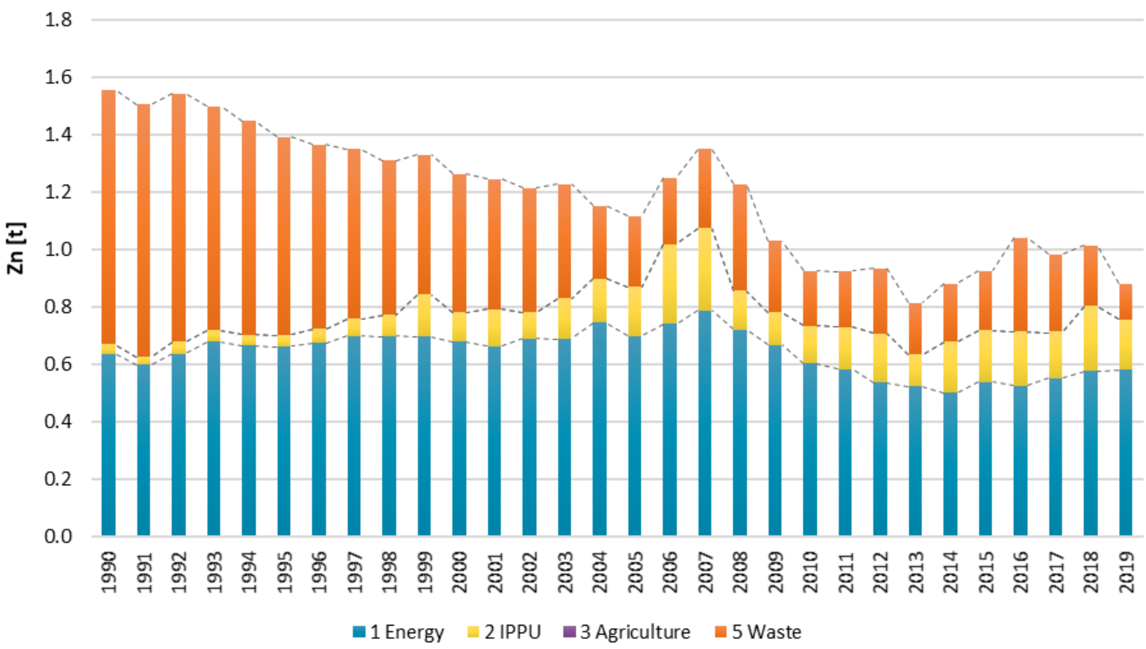

Figure 2.31 Zn emissions by sector, since 1990.

3 Energy (NFR sector 1)

3.1 Overview

The energy sector in Iceland is unique in many ways. Iceland ranks first among Organisation for Economic Co-operation and Development (OECD) countries in the per capita consumption of primary energy. However, the proportion of domestic renewable energy in the total energy budget is approx. 85%, which is a much higher share than in most other countries. The cold climate and sparse population call for high energy use for space heating and transport. Also, key export industries such as fisheries and metal production are energy intensive. The metal production industry uses around three-quarters of the total electricity produced in Iceland. Iceland relies heavily on its geothermal energy sources for space heating (over 90% of all homes) and electricity production (approx. 30% of the electricity) and on hydropower for electricity production (70% of the electricity). Thus, atmospheric pollutant emissions in the energy sector originate predominantly from mobile sources: road transport, fishing and off-road machinery including construction, as well as waste incineration with energy recovery (occurring from 1993-2012). One exception to this is the emission of H_2S from geothermal powerplants, which is by far the largest key category in Iceland´s inventory for sulphur (calculated as SO_2-equivalent).

The EA has been working with a consulting company (Aether ltd.) since 2015 to improve the Icelandic inventory, and in 2018 a complete review and restructuring of the Energy sector took place in collaboration with experts from Aether, including updating/redesigning calculation spreadsheets as well as checking all emission factors across the sector and replacing by default values where appropriate. Further work is planned, in collaboration with the National Energy Authority, the Icelandic Transport Authority and Statistic Iceland in order to harmonize all datasets used. Additionally, work is underway with the EA team responsible for the surveillance of fuel imports in order to develop country-specific fuel specifications, in particular liquid fuels.

The energy sector is divided into the following subsectors:

- Energy industries (NFR 1A1)
- Manufacturing Industries and Construction (NFR 1A2)
- Transport (NFR 1A3)
- Other sectors (NFR 1A4)
- Other (NFR 1A5)
- Fugitive emissions (NFR 1B2) (including emissions from geothermal utilization)

3.1.1 Sectoral trends – POP's

Summary tables for the POP's emissions from the energy sector is shown in Table 3.1.

Table 3.1 Overview of emissions of POPs from the energy sector in 2019 (NA – Not applicable, NE – Not estimated; NO - Not occurring).

		Dioxin [g I-TEQ]	B(a)P [t]	B(b)F [t]	B(k)F [t]	IPy [t]	PAH4 [t]	HCB [kg]	PCB [kg]
1A1	**Energy industries**	3.39E-05	NA/NO	NA/NO	NA/NO	0.000	1.00E-04	NA/NO	NA/NO
1A2	**Manufact. industries and construction**	0.0022	5.82E-04	0.0010	3.10E-05	2.43E-05	0.0016	NA/NO	NA/NO
1A3	**Transport**	0.064	0.0043	0.0067	0.0058	0.0045	0.021	0.0017	0.0032
1A4	**Other sectors**	0.031	0.0006	0.0025	0.0019	3.79E-04	0.0054	0.015	0.020
1A5	**Other**	3.23E-05	4.38E-08	3.43E-07	3.97E-08	3.51E-08	4.62E-07	NA/NO	NA/NO
1B2	**Fugitive emissions f. distribution of oil production and energy production**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
Energy, Total		**0.097**	**0.006**	**0.010**	**0.008**	**0.005**	**0.028**	**0.016**	**0.023**

Trends in POP's emission estimates are shown in Figure 3.1 through Figure 3.4 by subsector.

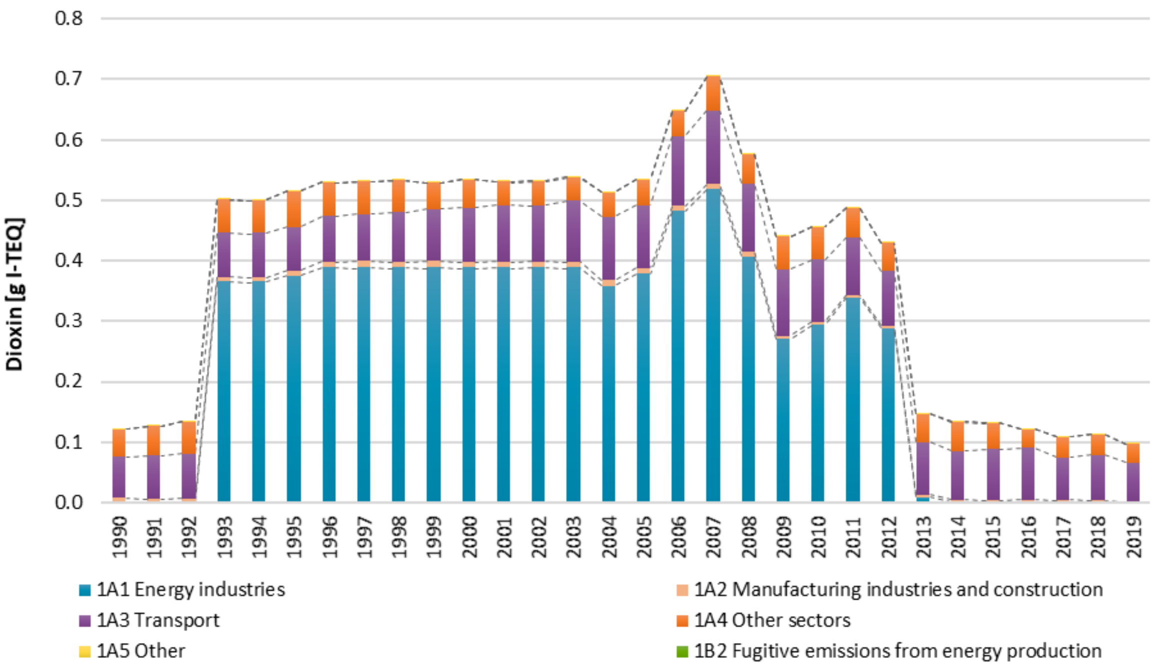

Figure 3.1 Dioxin emissions from the energy sector, since 1990.

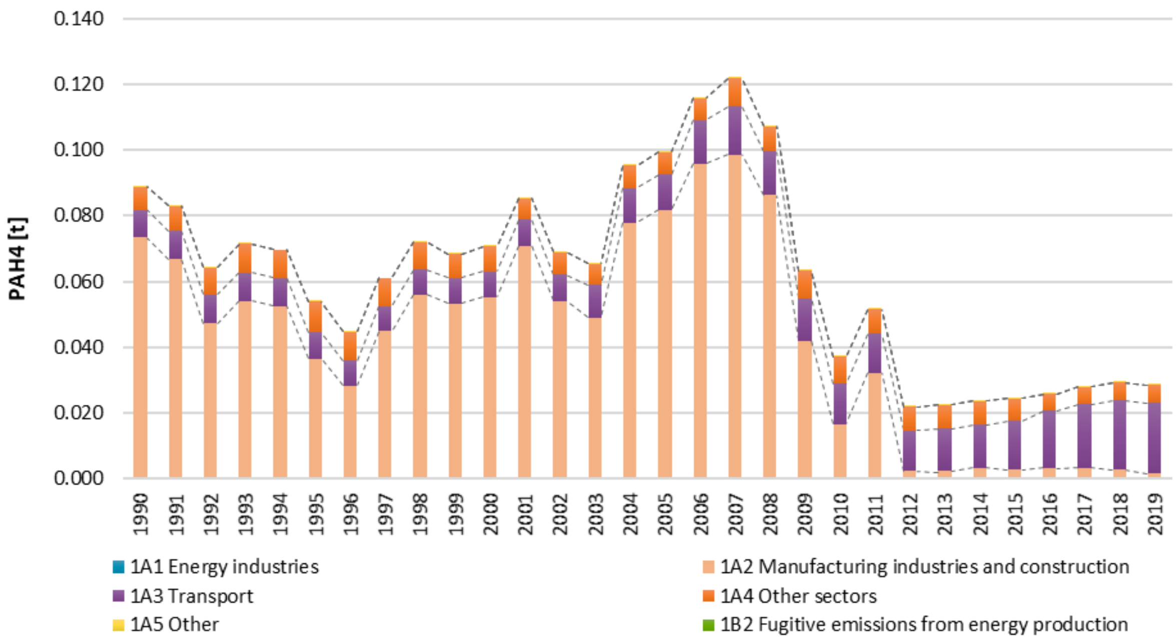

Figure 3.2 PAH4 emissions from the energy sector, since 1990.

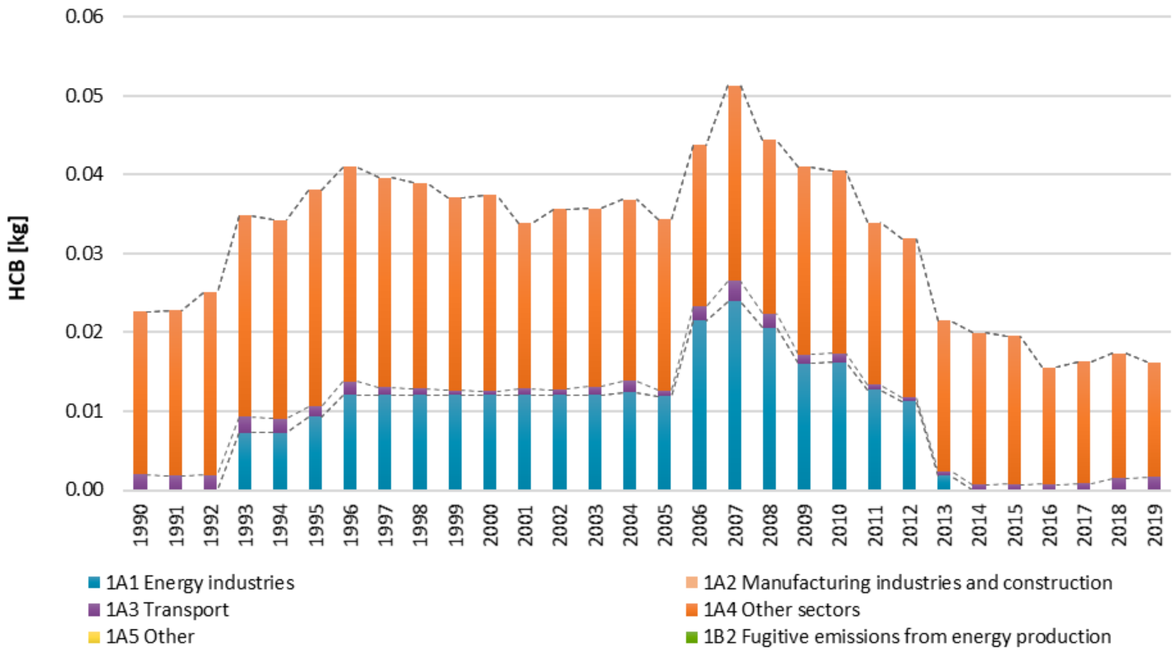

Figure 3.3 HCB emissions from the energy sector, since 1990.

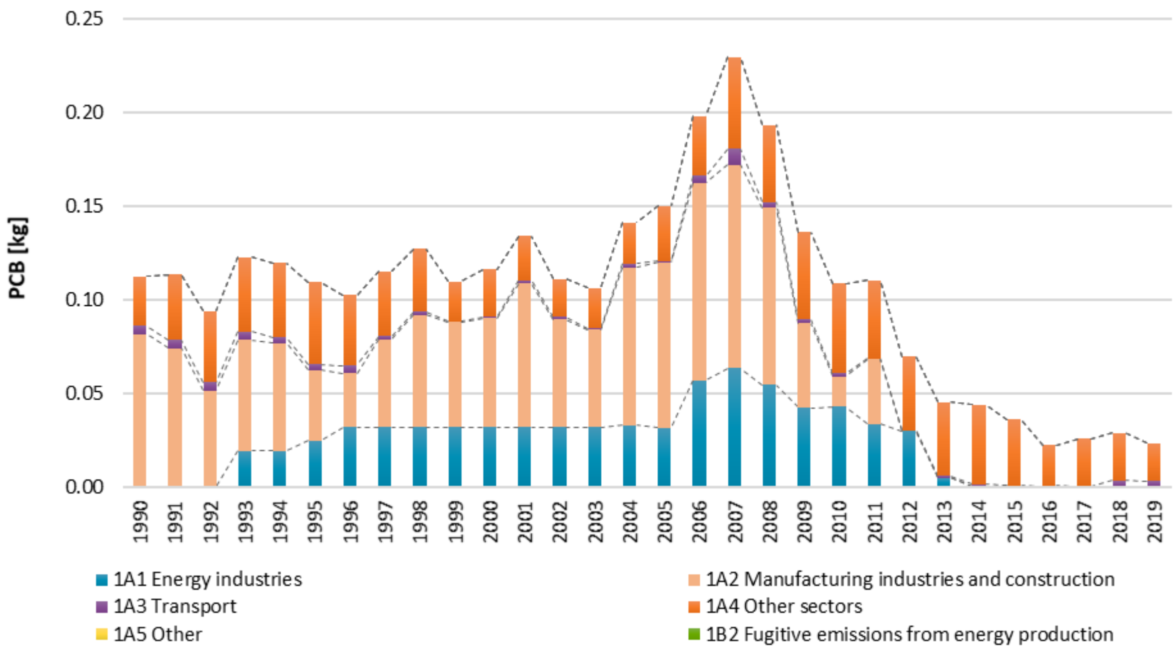

Figure 3.4 PCB emissions from the energy sector, since 1990.

3.1.2 Sectoral trends – Other pollutants

Summary tables for the non-POP's emissions from the energy sector is shown in Table 3.2.

Table 3.2 Overview of emissions of pollutants other than POP's in 2019 (NA – Not applicable, NE – Not estimated, NO - Not occurring).

		NO_X [kt NO_2]	NMVOC [kt]	SO_X [kt SO_2]	NH_3 [kt]	$PM_{2.5}$ [kt]	PM_{10} [kt]	TSP [kt]	BC [kt]	CO [kt]
1A1	**Energy industries**	0.0044	6.51E-05	0.018	NA/NO	5.42E-05	2.17E-04	4.40E-04	0.000	0.0011
1A2	**Manufact. industries and construction**	0.738	0.069	0.188	0.00014	0.043	0.043	0.043	0.026	0.212
1A3	**Transport**	3.993	0.668	0.362	0.060	0.311	0.526	0.965	0.049	4.294
1A4	**Other sectors**	13.028	0.478	3.287	0.000060	0.352	0.381	0.381	0.093	1.288
1A5	**Other**	0.012	5.90E-04	0.0021	NA/NO	4.55E-04	0.000	4.55E-04	2.54E-04	0.0015
1B2	**Fugitive emissions f. distribution of oil production and energy production**	NA/NO	0.258	41.851	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
Energy, Total		**17.776**	**1.473**	**45.707**	**0.060**	**0.707**	**0.952**	**1.390**	**0.168**	**5.797**

	(Table continued)	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
		[t]	[t]	[t]	[t]	[t]	[t]	[t]	[t]	[t]
1A1	**Energy industries**	2.76E-04	9.21E-05	9.21E-05	1.23E-04	9.21E-05	1.84E-04	9.21E-05	4.60E-04	1.23E-04
1A2	**Manufact. industries and construction**	0.039	1.79E-04	8.71E-05	2.19E-05	8.20E-05	9.27E-05	2.01E-05	4.15E-05	0.0095
1A3	**Transport**	0.102	0.0009	0.0023	0.0050	0.043	0.840	0.173	0.0032	0.370
1A4	**Other sectors**	0.039	0.0020	0.0046	0.023	0.026	0.165	0.966	0.019	0.203
1A5	**Other**	1.83E-06	1.37E-07	3.24E-06	7.77E-07	4.55E-06	5.00E-06	1.94E-07	2.55E-06	0.0007
1B2	**Fugitive emissions f. distribution of oil production and energy production**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
Energy, Total		**0.181**	**0.0031**	**0.0072**	**0.028**	**0.069**	**1.006**	**1.139**	**0.023**	**0.583**

3.2 General Methodology

Emissions from fuel combustion activities are estimated at the sector level based on methodologies suggested by the 2006 IPCC Guidelines and the 2019 EEA/EMEP Guidebook. They are calculated by multiplying energy use by source and sector with pollutant specific emission factors. Activity data is provided by the National Energy Authority (NEA), which collects data from the oil companies on fuel sales by sector.

For this submission, emissions from Road Transportation are estimated using COPERT 5.4.36. which follows the methodology presented in 2019 EEA/EMEP Guidebook. For the last submission the COPERT model was used for estimating emissions for 2000-2017 but for this submission it is used for the whole timeseries 1990-2019. More detailed description can be seen in chapter 3.5.2.

For the 2020 submission a comprehensive review was performed on how the fuels sales data from the NEA is attributed to IPCC/NFR sectors. For this submission the review only included the years 2003-2019 because the methodology used to collect the data by the NEA changed between 2002 and 2003. For this submission the same attribution of fuels to IPCC categories for 1990-2002 was performed with a review of the sales statistics. Consequently, the whole time series has been reviewed and methodologies harmonised from 1990 and onwards. The aim of the review of the fuel sales data from the NEA in 2020 was to make the adjustments from the sales statistics to the IPCC categories more transparent. This is what was done for each IPCC/NFR category to achieve the following:

- 1A1 Energy Industries – sales statistics are used directly and no adjustments are needed
- 1A2 Manufacturing Industries – adjustments are needed to transform sales statistics into IPCC/NFR categories (detailed description below)
- 1A4a and b Commercial/Residential combustion - sales statistics are used directly and no adjustments are needed
- 1A5 Other – all fuels that are categorized as *Other* in sales statistics without any explanation of use are attributed to this category.

Due to insufficient split in the sales statistics between fuel used for different manufacturing industries that belong to IPCC category 1A2 some adjustments are needed. To try to have this input data as accurate as possible:

- It is assumed that Green Accounting reports (and EU ETS Annual Emission Reports from 2013) are correct for each company and that data is used for 1A2a, 1A2b, 1A2c and 1A2f – this is the known usage.
- Because these fuels are purchased from domestic oil companies, they will be subtracted from the sales statistics received from the NEA.
- The difference between known usage and sales statistics is attributed to the category 1A2gviii Other Industry.

These adjustments are described in Figure 3.5. For some fuel types and years, the subtraction of known use from sales statistics does result in a negative number indicating that usage was more than what was sold. It is considered more likely that some data is missing from sales statistics and therefore these values will be input as zero. This will cause more fuel used than what is in the sales statistics, and a possible overestimate of emissions. This is however a very low amount compared to the total energy emissions.

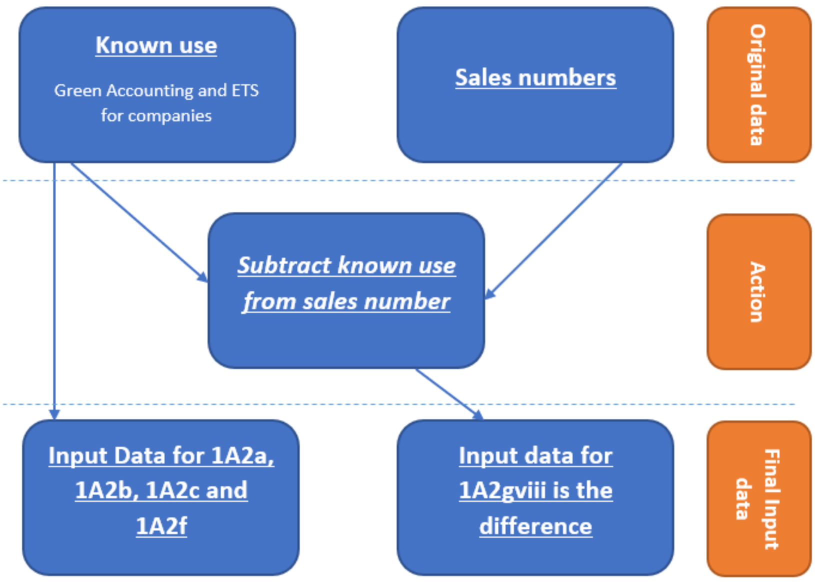

Figure 3.5 Description of adjustments in input data for NFR category 1A2

In the sales statistics received from the NEA there are unspecified categories for all fuels, labelled as "Other". These fuels are accounted for in CRF category 1A5. For future submissions the EA will work with the NEA to aim to attribute these fuels to specific categories.

3.3 Energy Industries (NFR 1A1)

Energy Industries include emissions from electricity and heat production. Iceland has extensively utilized renewable energy sources for electricity and heat production, thus emissions from this sector are low. For dioxin, PAH4, SO_2 and NMVOC waste incineration with energy recovery is the main source of emissions for this category. However, waste incineration with energy recovery has not been occurring in Iceland since 2013. Activity data on fuel use for the energy industries are based on data provided by the NEA and adjusted by EA, see chapter 3.2. Activity data on waste is collected by EA directly from the plants.

3.3.1 Electricity & heat (NFR 1A1a)

The main sources of electricity in Iceland are hydropower and geothermal energy. In recent years, wind power development has taken place. As can be seen in Table 3.3, only a very small fraction of electricity is produced with fuel combustion: electricity was produced with fuel combustion at two locations that are located far from the distribution system (two sparsely populated islands, Grimsey and Flatey); furthermore, some public electricity facilities have emergency backup fuel combustion power plants which are used when problems occur in the distribution system. Those plants are, however, very seldom used, apart from testing and during maintenance.

Table 3.3 Electricity production in Iceland (GWh).

	1990	1995	2000	2005	2010	2015	2018	2019
Hydropower	4,159	4,677	6,350	7,015	12,592	13,781	13,813	13,461
Geothermal	283	288	1,323	1,658	4,465	5,003	6,010	6,018
Fuel combustion	5.6	8.4	4.5	7.8	1.7	3.9	1.9	2.7
Wind power	NA	NA	NA	NA	NA	10.9	4.4	6.6
Total (GWh)	**4,447**	**4,974**	**7,678**	**8,681**	**17,059**	**18,799**	**19,829**	**19,489**

Geothermal energy was the main source of heat production in 2019. Some district heating facilities, that lack access to geothermal energy sources, use electric boilers to produce heat from electricity. They depend on curtailable energy. These heat plants have backup fuel combustion in case of electricity shortages or problems in the distribution system. Three district heating facilities burned waste to produce heat and were connected to the local distribution system, however since 2013 no more waste burning with energy recovery is occurring in Iceland. Emissions from these waste incineration plants are reported under Energy Industries.

3.3.1.1 *Activity data*

Activity data for electricity and heat production with fuel combustion and waste incineration are given in Table 3.4. No fuel consumption for heat production was reported by the NEA for 2010, 2011, 2018 and 2019. Biomethane was used for electricity production in 2003-2007. The use of residual fuel oil for electricity production in 2007 was much higher than in surrounding years. In 2007 a new aluminium plant was established in Iceland. Because the Kárahnjúkar hydropower project (hydropower plant built for this aluminium plant) was delayed, the aluminium plant was supplied with electricity for a while from the distribution system. This led to electricity shortages for the district heating system and industry depending on curtailable energy leading to increased fuel combustion. The different fuel composition from year to year (waste, fuel) effects the IEF (Implied Emission Factor). For example, the IEF for dioxin in this sector is higher in years when fuel combustion is low and the sector is dominated by waste incineration. The following years have been unusual: 1995 (issues in the electricity distribution system caused by snow avalanches in northwest Iceland (the Westfjords) and icing in the northern part of the country), 1997/1998 (unfavourable weather conditions for hydropower plants during the winter) and 2007 (explained above).

Table 3.4 Fuel combustion and waste incineration (kt) for electricity and heat production.

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil (electricity)	1.30	1.09	1.07	0.021	1.01	1.19	0.74	1.24
Residual fuel oil (electricity)	NO	NO	NO	NO	NO	NO	NO	NO
Biodiesel (electricity)	NO	NO	NO	NO	NO	NO	0.016	NO
Biomethane (electricity)	NO	NO	NO	0.29	NO	NO	NO	NO
Residual fuel oil (heat)	2.99	3.08	0.12	0.20	NO	0.14	NO	NO
Solid waste (heat)	NO	4.65	6.05	5.95	8.11	NO	NO	NO

Emission factors are Tier 1 factors taken from the 2019 EMEP/EEA Guidebook (Chapter 1.A.1. Energy Industries, Tables 3-4 (Gaseous fuels), 3-5 (Fuel oil) and 3-6 (Gas oil)). Emission factors for the burning of waste with energy recovery are taken from Table 3-2 of chapter 5C1a of the 2019 EMEP/EEA Guidebook. Due to the lack of emission factors given in the 2019 Guidebook the following pollutants are not estimated:

- Gas oil: NH_3, PCBs, HCB, BaP, BbF, BkF.
- Residual fuel oil: NH_3, PCBs, BaP, HCB.
- Gaseous fuels (biomethane): NH_3, PCBs, HCB.

3.3.1.2 *Recalculations and improvements*

1A1ai: Electricity Generation: Recalculations were performed for this sector for the whole time series. This entailed adding biodiesel too the calculations for several air pollutants. This caused an underestimation in last years submission of several air pollutants for 2018. Furthermore, the NEA reviewed the allocations of gas/diesel oil to electricity generation which caused a 7% decrease in activity data in 1990 with subsequent decrease in emissions in the base year.

1A1aiii: Heat Plants: Recalculations were performed for this sector for the time period 1996-2002. This was due to the review of the activity data which now includes fuel sold. This changed the amount of residual fuel oil used in heat plants.

Due to the review of all input data for the energy sector for 2002-2017 (see chapter 3.2) there were recalculations for all pollutants in sector 1A1a for that time period. Changes in sector 1A1a were because for previous submissions the fuel used for electricity had been calculated based on electricity production. For this submission fuel sold to energy production is used, which is a part of the official sales statistics from the NEA.

The degree of recalculations varied between pollutants, but in the year 2018 there was an increase of 2.1% for SOx, particulate matter, all heavy metals and IPy. For the base year 1990 activity data for electricity generation was reduced by 7% with a reduction in all estimated air pollutants by between 0.17 – 4.8% dependent on each air pollutant’s share in the category 1A1a.

Planned improvements

For future submissions work is underway to review the emission data from geothermal power plants with respect to heavy metals in particular.

3.4 Manufacturing Industries & Construction (NFR 1A2)

3.4.1 Manufacturing industries, stationary combustion (NFR 1A2a-g)

3.4.1.1 *Activity Data*

Information on the total amount of fuel used by the manufacturing industries was obtained from the NEA and attributed to the various subsectors by EA (see chapter 3.2) as well as using data reported under the Green Accounting and EU ETS for the larger companies. Fuel consumption in the fishmeal industry from 1990 to 2002 was estimated from production statistics, but the numbers for 2003 and onwards are based on official sales statistics from the NEA.

The difference between the given total for the sector and the sum of the fuel use of the reporting industrial facilities are categorized as 1A2gviii other non-specified industry. The total fuel consumption per fuel type can be seen in Table 3.5. Emissions from fuel use in the ferroalloys production is reported under 1A2a. Emissions from the cement industry (the single operating cement plant was closed down in 2011) and the mineral wool production are reported under 1A2f. For PAH4, emissions from the mineral wool production are not estimated, and for dioxin, emissions from the cement industry are reported under industrial processes (2A1).

Table 3.5 Fuel use (kt), stationary combustion in the manufacturing industry.

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil	5.07	1.13	8.92	15.20	4.04	3.36	0.61	2.77
Residual fuel oil	55.90	56.17	46.15	25.01	13.21	9.86	5.42	2.68
LPG	0.41	0.31	0.86	0.93	1.05	0.81	1.04	1.52
Other bituminous coal	18.60	8.65	13.26	9.91	3.65	NO	NO	NO
Petroleum coke	NO	NO	NO	NO	NO	0.028	0.037	0.039
Waste oil	NO	4.99	6.04	1.82	1.36	1.59	1.25	0.70

3.4.1.2 *Emission factors*

PAH and dioxin emission factors for liquid fuels are taken from table 3-4 (Tier 1 EF for 1A2 combustion in industry using liquid fuels) from chapter 1.A.2 of the 2019 EMEP/EEA Guidebook. However, it is assumed that the PAH emission factors given in the Table 3-4 should be in µg/GJ rather than mg/GJ (after comparison with Table 3-37, Volume 1.A.4). PAH and dioxin emission factors for gaseous fuels are taken from table 3-3 in the same chapter of the EMEP/EEA Guidebook.

The emission factors for dioxin and PAH4 are presented in Table 3.6.

Table 3.6 Emission factors for dioxin and PAH4 from stationary combustion in manuf. industry.

	Dioxin [µg I-TEQ/GJ]	B(a)P [µg/GJ]	B(b)F [µg/GJ]	B(k)F [µg/GJ]	IPy [µg/GJ]	PCB [µg/GJ]	HCB [µg/GJ]
Gas/Diesel Oil	0.0014	1.9	15	1.7	1.5	NE	NE
Residual fuel oil	0.0014	1.9	15	1.7	1.5	NE	NE
LPG	0.0005	0.72	2.9	1.1	1.08	NE	NE
Electrodes residues	IE*	45500	58900	23700	18500	170	0.62
Other Bituminous Coal	IE*	45500	58900	23700	18500	170	0.62
Petroleum coke	IE*	45500	58900	23700	18500	170	0.62
Waste oil	0.0014	1.9	15	1.7	1.5	NE	NE

*Coal, electrodes residues and petroleum coke are only used in the cement plant; all dioxin emissions from the cement plant are reported under 2A1. PR: profile ratio.

SO_x, NO_x, CO and NMVOC emission factors are taken from the 2019 EMEP/EEA Guidebook. Sulphur emissions from use of petroleum coke occur in the cement industry. Further waste oil has mainly been used in the cement industry and for fishmeal production. Emission estimates for SO_x for the cement industry are based on measurements.

This inventory includes emissions of Particulate Matter and Heavy Metal emissions for all fuel types, based on Tier 1 emission factors taken from Tables 3-2 (solid fuels), 3-3 (gaseous fuels) and 3-4 (liquid fuels) in the 2019 EMEP/EEA Guidebook on 1A2.

Due to the lack of emission factors given in the 2019 Guidebook the following pollutants are not estimated:

- All liquid fuels and LPG: NH_3, PCB, HCB
- Other bituminous coal: NH_3

3.4.1.3 *Recalculations and improvements*

- For 1990-2002 some fuels were moved from 1A2gvii to 1A5 because of lack of reference of where these fuels were used. This does not increase the total emissions from the energy sector.
- For previous submission electrode waste from the cement factory was reported un 1A2f. However, it was concluded for this submission that this activity data was for electrode waste which was exported as waste but not used for combustion. Therefore, electrode waste was removed from the inventory. This caused recalculations for 1990-2001 and 2007-2010.
- LPG was removed from 1A2gviii according to NEA's revision of data. This caused a decrease in activity data by 0.1% in category 1A2 with respective decreases in air pollutant emissions.

3.4.1.4 *Planned improvements*

There are no planned improvements.

3.4.2 Manufacturing industries, mobile combustion (NFR 1A2gvii)

3.4.2.1 *Activity data*

Activity data for mobile combustion in off-road vehicle and machinery is provided by the NEA. In previous submissions, activity data and information available from the National Energy Authority did not allow to separate fuels sold to machinery in construction, agriculture or other uses for the entire time series, but provided data on fuel sold from fuel delivery trucks (as opposed to fuel sold at petrol stations). Thus category 1A2gvii off-road vehicles and other machinery included all emissions derived from fuels sold to off-road machinery, including Agriculture/Forestry/Fishing: Off-road vehicles and other machinery (1A4cii) as well as transport activities not reported under road transport such as ground activities in airports and harbours (1A3eii). The latter two categories are marked as "IE" in the NFR tables and are all included under 1A2gvii. However, in this submissions the data on off-road vehicles and machinery, provided by the NEA has been separated for the newest inventory year between construction, agriculture and other. Activity data for fuel combustion are given in Table 3.7.

Table 3.7 Fuel use (kt), mobile combustion in the construction industry.

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil	37.98	46.74	61.89	67.78	32.23	33.08	31.44	24.84
Other Kerosene	NO	NO	NO	0.02	1.17	0.16	0.027	0.029
Biodiesel	NO	NO	NO	NO	NO	NO	0.028	0.028

3.4.2.2 *Emission factors*

Emission factors for dioxins from this sector are taken from “Utslipp til luft av dioxiner i Norge” (Statistics Norway, 2002). They are 0.1 µg/t fuel. BaP and BbF emissions are estimated from this source with 2019 EMEP/EEA Guidebook default emission factors from table 3-1 in chapter 1A4 Non-road mobile machinery. SO_x emissions are calculated from the S-content of the fuels. Emission factors for NO_x, CO, NMVOC, particles as well as BC are the default values from the 2019 EMEP/EEA Guidebook (Table 3-1, chapter 1A4).

3.4.2.3 *Recalculations and improvements*

As a part of the review of activity data fuel used for mobile machinery has now been separated in too three categories. These are mobile machinery in agriculture, construction and other. Therefore, activity data that was in 1A2gviii in previous submissions has decreased significantly in 2018. However, this has not caused a decrease in emissions from the energy sector as a portion of this fuel has been reallocated to 1A4cii and 1A2gv. Planned improvements

3.4.2.4 *Planned improvements*

For future submissions it is planned to extrapolate data regarding the distribution of fuel between the three categories, 1A2gv, 1A2gviii and 1A4cii. This is now only represented in 2019 as the NEA suggests in their dataset.

3.5 Transport (NFR 1A3)

3.5.1 Civil aviation (NFR 1A3a)

Emissions from aviation are divided into four groups: International Landing and Take-Off (LTO) (1A3ai(i)), Domestic LTO (1A3aii(i), International cruise (1A3ai(ii) and Domestic cruise (1A3aii(ii)). As defined by Eurocontrol “LTO” includes taxi out, take off, climb out (up to a height of 3000 ft.), final approach (from a height of 3000 ft.), landing and taxi in. “Cruise” includes climb from a height of 3000 ft. up to the cruise level, cruise, and descent down to a height of 3000 ft. Emissions occurring during LTO of both domestic and international flights are included in national totals, whereas emissions occurring during the cruise part of the flights are reported as “memo” item and are thus not counted in the national totals.

Emissions for the years 2005-2019 are taken directly from the Eurocontrol dataset for Iceland, which differentiates between Domestic, International, LTO and Cruise emissions. The pollutants reported from the Eurocontrol dataset include NO_x, SO_x, CO, NMVOC, TSP, PM_{10} and $PM_{2.5}$.

For the years 1990-2004, emissions were estimated based on fuel type (jet kerosene vs. aviation gasoline), and fuel use attributed to either LTO or Cruise using a ratio calculated from the Eurocontrol dataset (see below), with sales data allowing the distinction between international and domestic use.

Because of different methodologies being used for the two time periods, there are big changes in emissions of some pollutants between 2004 and 2005.

3.5.1.1 *Activity data*

Activity data is provided by the NEA, which collects data on fuel sales by sector. This data distinguishes between national and international usage. In Iceland, there is one main airport for international flights, Keflavík Airport. Under normal circumstances almost all international flights depart and arrive from Keflavík Airport, except for flights to Greenland, the Faroe Islands, and some flights with private airplanes which depart/arrive from Reykjavík airport. Domestic flights sometimes depart from Keflavík airport in case of special weather conditions. Oil products sold to Keflavík airport are reported as international usage. The deviations between national and international usage are believed to level out. Activity data stems from different data sources depending on the year:

- 1990-2004: Use of jet kerosene and aviation gasoline is based on the NEA's annual sales statistics for fossil fuels.
- 2005-2019: Fuel activity data is included in the Eurocontrol dataset. However, the dataset only includes total amount of fuel burnt (in kt), without differentiating between jet kerosene and aviation gasoline. Since these two types of fuel have slightly different NCV´s (44.3 TJ/kt for aviation gasoline, 44.1 TJ/kt for jet kerosene), in order to obtain total fuel activity data in TJ, the NEA´s annual sales statistics were used as an approximation of the ratio of aviation gasoline to jet kerosene to calculate a weighted-average NCV, which was used to convert the total burnt fuel reported by Eurocontrol into TJ.

Activity data for fuel sales for domestic and international aviation are given in Table 3.8 and Table 3.9. Note that these are the sales statistics provided by the NEA, and do not include information from Eurocontrol.

Table 3.8 Fuel sales (kt.), domestic aviation.

	1990	1995	2000	2005	2010	2015	2018	2019
Jet Kerosene	8.92	8.41	7.87	7.39	6.07	5.99	7.45	8.44
Aviation gasoline	1.68	1.13	1.10	0.87	0.65	0.50	0.35	0.37

Table 3.9 Fuel sales (kt), international aviation.

	1990	1995	2000	2005	2010	2015	2018	2019
Jet Kerosene	69.40	74.64	129.15	133.20	119.52	213.74	407.54	303.31
Aviation gasoline	0.20	0.18	0.03	0.40	0.01	0.01	NO	NO

3.5.1.2 *Emission factors*

1990-2004: Total emissions (LTO + Cruise) were calculated using following emissions factors:

- Emission factors for dioxin were taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005) and from “Utslipp til luft av dioxiner i Norge” (Statistics Norway, 2002).
- PAH4 emissions were not estimated as no emission factors are included in the 2019 EMEP/EEA Guidebook, nor are those emissions estimated by Eurocontrol.
- SO_x, NO_x, CO and NMVOC emissions were calculated using a tier 1 emission factor from table 3-3 in the 2019 EMEP/EEA guidebook.
- No emission factors are reported for particulate matter in the 2019 EMEP/EEA guidebook and therefore these emissions are NE for this time period.

In order to allocate emissions to LTO and Cruise, respectively, a distribution factor was calculated using the 2005 Eurocontrol data for fuel use, and this factor was applied to the 1990-2004 fuel sales statistics from the NEA. Emissions were then calculated from that fuel for LTO and cruise.

2005-2017: Emissions were taken from the Eurocontrol dataset without further calculations, with the exception of dioxin and BC for which estimates were not provided in that dataset. Dioxin was therefore calculated in the same way as for the period 1990-2004. BC was estimated for 2005-2017 using the fraction 15% of TSP, which is presented in the 2019 EMEP/EEA guidebook.

The emission factors for the period 1990-2004 are presented in Table 3.10.

Table 3.10 Emission factors for dioxin, NO_x, CO and NMVOC by fuel type - 1990-2004 (Except dioxin, where EF apply for 1990-2016)

	Dioxin [µg I-TEQ/t fuel]	NO_x [kg/t fuel]	CO [kg/t fuel]	NMVOC [kg/t fuel]
Jet Kerosene	0.06	4	1200	19
Aviation gasoline	2.2	4	1200	19

3.5.1.3 *Recalculations and improvements*

Recalculations were done for this sector as a part of the activity data review for 1990-2002 which caused an increase in emissions. This did not cause an increase in emissions for the total energy sector because this was kerosene fuel that had previously been reported under 1A4.

3.5.1.4 *Planned improvements*

Planned improvements are to enhance this category to tier 2 in future submissions.

3.5.2 Road transport (NFR 1A3b)

This sector covers the emission estimates from exhaust emissions from various types of road transportation vehicles.

3.5.2.1 *Methodology*

The transport model COPERT 5.4.36 (developed by Emisia SA) was used to produce emission estimates for all pollutants for the whole timeseries. The following text is taken from the COPERT website regarding the applied methodology[8]:

> *"The COPERT methodology is part of the EMEP/EEA air pollutant emission inventory Guidebook for the calculation of air pollutant emissions."*

Data acquired from Emisia was used to estimate emissions for the years 1990-2019, except data for average temperature and fuel consumption in road transport where data from the Icelandic Met Office and the National Energy Authority was used.

For other input parameters in COPERT, the same data as for 2018 was used for 2019, except for numbers of vehicles where country specific data was obtained from the Icelandic Transport Authority. Moreover, country specific fuel data has now been added on the ratio of carbon to hydrogen to oxygen in gasoline and diesel.

Calculations of SO_x emissions in COPERT are based on country specific sulphur content in fuels, where it is assumed that all sulphur is converted to SO_x. Country specific measurements are only available from 2006, so for previous years the maximum allowed sulphur content according to European regulations was used as an approximation.

Results from COPERT model was adjusted to calculate the emission $PM_{2.5}$, PM_{10}, TSP and BC within automobile road abrasion because of studded tyre use.

3.5.2.2 *Activity data*

A comprehensive dataset for COPERT was purchased from Emisia for the years 1990-2019. This data was used where country specific data was not available. The country specific data that was used was;

- Average temperature values were obtained from the Icelandic Met Office.

[8] https://www.emisia.com/utilities/copert/

- Vehicle stock numbers for 2017-2019 were obtained from the Icelandic Transport Authority.
- Measurements collected by the EA for energy content, density and sulphur content were used where available.
- Total fuels sales were obtained from sales statistics collected by the NEA for the whole timeseries

In Table 3.11 the total use of diesel oil, gasoline and biofuels can be seen. They are based on the NEA's annual sales statistics for fuels in road transport.

Table 3.11 Fuel use (kt), road transport.

	1990	1995	2000	2005	2010	2015	2018	2019
Gasoline	127.81	135.60	142.60	156.73	148.21	132.47	127.10	118.74
Diesel oil	36.57	36.86	47.46	83.48	106.43	126.37	178.91	180.86
Biomethane	NO	NO	0.006	0.039	0.595	2.18	1.38	1.49
Biodiesel	NO	NO	NO	NO	NO	11.92	15.29	14.88
Biogasoline/Bioethanoll	NO	NO	NO	NO	NO	1.93	6.09	6.24
Hydrogen	NO	NO	NO	0.00001	0.002	NO	0.001	0.001

Data for 1990-2016 from COPERT included numbers of vehicle and kilometres driven for each vehicle category. Total fuels sales from the NEA were input into COPERT, which then estimates fuel use for each vehicle category based on numbers of vehicle and kilometres driven.

Dataset about usage of studded tyres (for $PM_{2.5}$, PM_{10}, TSP and BC emissions within automobile road abrasion) was obtained from the city of Reykjavík (for 2000-2019) and the city of Akureyri (for 1990-2019).

3.5.2.3 *Emission factors*

All emission factors in COPERT are based on the Tier 3 methodology in the 2019 EMEP/EEA Guidebook which are presented in chapter 3.4 in the guidebook.

Emission factors for automobile road abrasion due to studded tyres are based on a Swedish research on studded tyre wear from pavement (Gustafsson, et al., 2005). Emission factors for studded tyres of passenger cars and light duty trucks and 50 times higher than for non-studded tyres for PM_{10}.

The same particle size fraction factors and BC fraction factors based on 2019 EMEP/EEA Guidebook are used for both studded and non-studded tyres.

The use of studded tyres of passenger cars and light duty trucks is 25% based on following information and assumptions:

- Studded tyres are banned from April 15th to October 31st each year. During this period the usage is assumed to be zero.
- The usage during other times is based on studded tyres counting in two municipalities, one in the capital area and one in Akureyri, in the north.
- Since 1990 the population living in the capital area has been 62% on average. The other 38% are living outside the capital region. There, the studded tyre usage is assumed to be the same as in Akureyri.

Studded tyre usage of heavy duty trucks, buses and motorcycles is very low and considered to be zero in this estimation.

3.5.2.4 *Recalculations and improvements*

Recalculations in 1A3b are mainly due to updated input data from COPERT and/or updated assumptions in the COPERT model. However, default values for *mean activity,* i.e. kilometres driven per vehicles type, changed. This caused some vehicle types to drive more and others to drive less which changed the emissions. The most significant change in the base year was 66TJ withdrawn from heavy-duty trucks while 65TJ were added to light-duty vehicles. In the latest year 213 TJ were withdrawn from light duty vehicles whilst 196 TJ were added to passenger cars. Net change in allocated energy to the vehicle fleet was <0.001% in both the base year and the latest year.

Calculation of $PM_{2.5}$, PM_{10}, TSP and BC emission from studded tyres is now included in this submission for 1.A.3.b.vii (Automobile road abrasion). This caused significant recalculations of the beforementioned pollutants. The increase was approximately 62%, 68%, 75% and 26% for $PM_{2.5}$, PM_{10}, TSP and BC for 1A3b, respectively.

3.5.2.5 *Planned improvements*

For future submissions it is planned, in collaboration with the Icelandic Transport Authority, to develop procedures to obtain enhanced data on vehicle stock and mileage data for COPERT.

3.5.3 National navigation (NFR 1A3dii)

Emissions are calculated by multiplying energy use with a pollutant specific emission factor.

3.5.3.1 *Activity data*

Total use of residual fuel oil and gas/diesel oil for national navigation is based on the NEA's annual sales statistics for fossil fuels. Activity data for fuel combustion are given in Table 3.12.

Table 3.12 Fuel use (kt), national navigation.

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil	11.75	7.04	3.43	6.20	8.46	7.89	8.46	11.88
Residual fuel oil	7.17	4.76	0.54	0.88	2.61	0.44	5.21	4.82

3.5.3.2 *Emission factors*

Emission factors for all pollutants are T1 emission factors from the 2019 EMEP/EEA Guidebook on navigation (Shipping), Tables 3.1 (bunker fuel oils) and 3.2 (marine diesel/gas oil). All emission factors are presented in Table 3.13.

Table 3.13 Emission factors for national navigation emissions.

	Dioxins µg/t fuel	BbF g/t fuel	HCB mg/t fuel	PCB mg/t fuel	Pb g/t fuel	Cd g/t fuel	Hg g/t fuel
Marine diesel oil	0.13	NE	0.08	0.038	0.13	0.01	0.03
Bunker fuel oil	0.47	NE	0.14	0.57	0.18	0.02	0.02

	As g/t fuel	Cr g/t fuel	Cu g/t fuel	Ni g/t fuel	Se g/t fuel	Zn g/t fuel	SO_2 kg/t fuel
Marine diesel oil	0.04	0.05	0.88	1	0.1	1.2	20
Bunker fuel oil	0.68	0.72	1.25	32	0.21	1.2	20

	NO_x kg/t fuel	NMVOC kg/t fuel	CO kg/t fuel	TSP kg/t fuel	PM10 kg/t fuel	PM2.5 kg/t fuel	BC % of TSP
Marine diesel oil	78.5	2.8	7.4	1.5	1.5	1.4	31%
Bunker fuel oil	79.3	2.7	7.4	6.2	6.2	5.6	12%

3.5.3.3 *Recalculations and improvements*
There are no recalculations.

3.5.3.4 *Planned improvements*
There are no planned improvements.

3.5.4 International navigation (memo item - NFR 1A3di(i))
The reported fuel use numbers are based on fuel sales data from the retail suppliers. The retail supplier divides their reported fuel sales between international navigation and national navigation based whether the vessel is sailing to an Icelandic or a foreign harbor (regardless of flag).

The emission factors used to estimate emissions from international navigation are the same as those used for national navigation and can be found in Table 3.13.

3.5.5 Transport: Other (NFR 1A3eii)
Emissions from other transport activities not reported under road transport, such as ground activities in airports and harbor, are included in Mobile construction in manufacturing industries and construction (1A2gvii) since currently available activity data from the National Energy Authority do not allow to allocate fuels sold to machinery besides agricultural machinery and machinery for construction.

3.6 Other Sectors (NFR 1A4)

3.6.1 Commercial, institutional & residential fuel combustion (NFR 1A4a, 1A4b)
Since Iceland relies largely on its renewable energy sources, fuel use for residential, commercial, and institutional heating is low. Residential heating with electricity is subsidized and occurs in areas far from public heat plants. Two waste incineration plants used waste to produce heat. One of them used the heat for heating a swimming pool and a school building (Skaftárhreppur, closed down in December 2012), and the other one used the heat for heating a swimming pool (Svínafell, closed down in 2010). Commercial/Institutional fuel combustion also includes the heating of swimming pools with gas oil, but only a few swimming pools in the country are heated with oil.

3.6.1.1 *Activity data*
Activity data for fuel use is provided by the NEA, which collects data on fuel sales by sector. EA adjusts the data provided by the NEA as further explained in chapter 3.2. Activity data for waste incineration are collected by the EA directly. Activity data for fuel combustion and waste incineration in the Commercial/Institutional sector are given in table Table 3.14 and activity data for fuel combustion in the Residential sector is given in Table 3.15.

Table 3.14 Fuel use (kt), commercial/institutional sector.

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil	1.80	1.60	1.60	1.00	0.30	0.30	0.15	0.29
LPG	0.78	0.83	0.46	0.50	0.17	0.37	0.08	0.10
Solid waste	NO	0.45	0.58	0.58	0.35	NO	NO	NO

Table 3.15 Fuel use (kt), residential sector.

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil	8.82	6.94	6.03	3.24	1.34	0.99	0.85	0.66
LPG	NO	NO	0.72	0.93	1.42	0.93	1.58	1.67

3.6.1.2 *Emission factors*

Emission factors (EFs) for stationary combustion are taken from 2019 EMEP/EEA Guidebook except EFs for dioxin from stationary combustion of LPG and waste oil which are taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). They are 0.06 µg/t fuel for LPG (Liquified Petroleum Gas) and 4 µg/t for waste oil.

Emissions from waste incineration with recovery, where the energy is used for swimming pools/school buildings are reported here. The IEF for dioxin in the sector shows fluctuations over the time series. From 1994 to 2012 (as stated above one plant was closed down in 2010 and the other one in 2012) waste was incinerated to produce heat at two locations (swimming pools, school building). The IEF for dioxin for waste is considerably higher than for liquid fuel. Further waste oil was used in the sector from 1990 to 1993. This combined explains the rise in IEF for the whole sector.

3.6.1.3 *Recalculations and improvements*

1A4a: Recalculations were done for this sector as a part of the activity data review for 1990-2002. The recalculations for 1990-1993. This was due to waste oil being reported in previous submissions for those years. When the activity data was reviewed for this submission, no reference for this waste oil was found and it is not included in the official sales statistics from the NEA. Therefore, this fuel was removed from the inventory. Moreover, LPG was reallocated to 1A4ai according to NEA's input data from other sectors. This caused a 20% increase in liquid fuels in the sub-sector. Overall effects, in the base year, of these changes decreased the emissions from 1A4ai by 60-169% except for SOx where the decrease amounted to approximately 362%.

Recalculations in 2018 were done for TSP which was due to a revised emission factor for TSP from diesel in table 3-9 in 2019 and 2016 EMEP guidebook. This caused an increase of TSP in 2018 by 4.6%.

1A4b: Recalculations were done for the whole timeseries for 1A4bi due to revised input data from the NEA. Liquid fuel decreased by 10% in the base year and increased by 1.9% in 2018 from this sector with subsequent effects on all relevant pollutants.

In addition to the review of activity data, there were recalculations for dioxins for this sector (1A4). The reason was that there was an error in units in the calculation sheets where g was said to be mg. This was corrected and therefore emissions of dioxins decreased significantly. This effected the whole timeseries.

3.6.1.4 *Planned improvements*

There are no planned improvements.

3.6.2 Agriculture, forestry & fishing (NFR 1A4c)

Emissions from fuel use by machinery and off-road vehicles in agriculture and forestry are included in Mobile construction in manufacturing industries and construction (1A2gvii) since currently available activity data from the National Energy Authority do not allow to allocate fuels sold to machinery to the various subsectors. Thus, emissions reported here only stem from the fishing fleet. Emissions from commercial fishing are calculated by multiplying energy use with a pollutant specific emission factor.

3.6.2.1 *Activity data*

Total use of residual fuel oil and gas/diesel oil for the commercial fishing is based on the NEA's annual sales statistics for fossil fuels and includes both national and international fishing. Fuel sales data provided by the NEA allows the correct attribution of fuel sold to fishing vessels vs. international ships for the time period 1995 to the current year. However, during the years 1990 to 1994 fuel sales statistics were recorded differently and fuel sold for international use was recorded without information on whether it was used for a fishing vessel or another type of ship. Therefore, the share of fuel use by fishing vessels had to be approximated for the years 1990-1994. This was done by averaging the percentage of fuel sold to fishing vessels relative to total fuel sales over the years 1995 to 1999, for diesel oil and fuel oil; this percentage was then applied to the fuel sales for the years 1990 to 1994.

Activity data for fuel combustion in the fishing sector are given in Table 3.16.

Table 3.16 Fuel use (kt), fishing sector.

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil	199.94	231.81	256.85	199.94	158.25	142.52	136.16	136.60
Residual fuel oil	32.62	57.15	22.27	32.61	69.89	52.45	35.33	25.84
Biodiesel	NO	NO	NO	NO	NO	0.09	NO	0.034

3.6.2.2 *Emission factors*

Emission factors for all pollutants are T1 emission factors from the 2019 EMEP/EEA Guidebook on navigation (Shipping), Tables 3.1 (bunker fuel oils) and 3.2 (marine diesel/gas oil). All emission factors are the same as those used for national navigation and are presented in Table 3.13 in the discussion pertaining to national navigation.

3.6.2.3 *Recalculations and improvements*

Minor recalculations were in National fishing (1A4ciii) which where due to a 0.6% increase in liquid fuels in the base year. This change is between the years 1990-1994 and are due to allocation of fuel between national and non-national fishing ships between 1990-1994, see chapter 3.6.1.1.Planned improvements and improvements

Work is scheduled to attempt to move from Tiers 1 to Tiers 2 for all pollutants for which Fishing is a key category (Dioxin, HCB, PCB, PAH, NO_x, NMVOC, Particulate matter and most heavy metals).

3.7 Other (NFR 1A5)

For this submission sector 1A5 is being reported for the second time for the timeseries 2003 and onwards as a part of the review of the energy input data (see chapter 3.2). For previous submissions these emissions have been reported under NFR category 1A2gvii but after a review of the sales statistic no justification was found for that attribution. Therefore, all fuels categorized as *"Other"* in sales statistics without any explanation of type of use, was allocated to CRF/NFR category 1A5. For future submissions the EA will work with the NEA to try to investigate where these fuels were used so they can be attributed to correct categories.

3.7.1 Stationary (NFR 1A5a)

The emissions from this sector are calculated by multiplying energy use with a pollutant specific emission factor from the 2019 EMEP/EEA guidebook.

3.7.1.1 *Activity data*

Activity data is provided by the NEA, which collects data on fuel sales by sector. All fuels categorized as *"Other"* in sales statistics without any explanation of which sector it is used in, was allocated to NFR category 1A5. For the timeseries 1990-2002 these fuels are still attributed to NFR category 1A2gvii.

Table 3.17 Fuel use (in kt) from sector 1A5 Other

	1990	1995	2000	2005	2010	2015	2018	2019
Gas/Diesel oil	NO	0.46	1.39	8.93	2.73	NO	NO	0.39
Residual Fuel Oil	0.04	0.052	0.067	NO	1.63	NO	NO	0.075
Kerosene	NO	NO	NO	0.15	0.047	0.029	0.030	0.064
LPG	NO	NO	NO	NO	NO	0.032	0.14	NO
Biodiesel	NO	NO	NO	NO	NO	NO	0.040	0.022
Biomethane	NO	NO	NO	NO	NO	NO	0.045	NO

3.7.1.2 *Emission factors*

All emission factors are the same as for 1A2 which are presented in chapter 3.4.1.2

3.7.1.3 *Recalculations and improvements*

This sector is being reported for the second time for this submission. Some recalculations were done for the sector due to the review of 1990-2002 activity data. This was done in relation to reallocation of fuel statistics between sectors where it was unclear to which sector fuel should have been allocated.

3.7.1.4 *Planned improvements*

For future submissions the EA will work with the NEA to try to investigate where these fuels are used so they can be attributed to correct categories.

3.8 Fugitive Emissions (NFR 1B2)

In Iceland, fugitive emissions occur only from two sources: Distribution of oil products (1B2av) and Geothermal energy production (1B2d).

3.8.1 Distribution of oil products (NFR 1B2av)

NMVOC emissions from distribution of oil products are estimated by multiplying the total imported fuel with an emission factor.

3.8.1.1 *Activity data*

The calculations are based on yearly fuel import data provided by Statistics Iceland.

3.8.1.2 *Emission factors*

The emission factor is taken from Table 4.2.4 2006 IPCC Guidelines Tanker Trucks and Rail Cards and is 0.00025 Gg per 1000 m^3 total oil transported.

3.8.1.3 *Recalculations and improvements*

No recalculations were performed for this sector.

3.8.1.4 *Planned improvements*

No improvements are planned for this sector.

3.8.2 Geothermal energy (NFR 1B2d)

Iceland relies heavily on geothermal energy for space heating and to a significant extent for electricity production (27% of the total electricity production in 2016). Geothermal energy is generally considered to have a relatively low environmental impact. Emissions of CO_2 are commonly considered to be among the negative environmental effects of geothermal power production, even though they have been shown to be considerably less extensive than from fossil fuel power plants, or 19 times less (Baldvinsson, 2011). Very small amounts of methane, but considerable quantities of sulphur in the form of hydrogen supplied (H_2S) are emitted from geothermal power plants. The H_2S values are stoichiometrically converted to SO_2 and reported as such.

3.8.2.1 *Activity data and emissions*

The H_2S concentration in the geothermal steam is site and time-specific and can vary greatly between areas and the wells within an area as well as by the time of extraction. The total emissions estimate of H_2S is based on direct measurements. The enthalpy and flow of each well are measured and the H_2S concentration of the steam fraction determined at the wellhead pressure. The steam fraction of the fluid and its H_2S concentration at the wellhead pressure and the geothermal plant inlet pressure are calculated for each well. Information about the period each well discharged in each year is then used to calculate the annual H_2S discharge from each well and finally the total H_2S is determined by adding up the H_2S discharge from individual wells.

The CarbFix project, located at the Hellisheiði Power Plant, has been pioneering CO_2 capture and reinjection on site into the basaltic subsurface, and has proven rapid and complete reaction to calcium carbonate precipitates (Matter, et al., 2016). A sister project, SulFix, consists of separating H_2S from the steam and also reinjecting the gas into the subsurface and mineralizing on contact with the basalt host rock. Injection of H_2S started in 2014 at Hellisheiði. This project has had a significant impact on sulphur emissions from geothermal power production at Hellisheiði, with a decrease of H_2S emissions by 63 kt in 2019.

Table 3.18 shows the electricity production with geothermal energy and the total Sulphur emissions (calculated as SO_2).

Table 3.18 Electricity production and emissions from geothermal energy in Iceland.

	1990	1995	2000	2005	2010	2015	2018	2019
Electricity production (GWh)	282.91	288.18	1322.66	1655.03	4465.32	5002.98	6009.83	6018.14
Sulphur emissions (as SO_2, kt)	13.33	11.01	26.02	30.31	58.68	42.37	37.81	41.85

3.8.2.2 *Recalculations and improvements*

No recalculations were done for this sector.

3.8.2.3 *Planned improvements*

For future submissions the plan is to differentiate between emissions linked to electricity production and those linked to district heating.

4 Industrial Processes and Product Use (IPPU) (NFR sector 2)

4.1 Overview

As a result of the expansion of the industrial sector, the contribution of this sector to the total emissions has been increasing since 1990. By far the main contributor to the emissions from this sector is metal production (aluminium, ferrosilicon alloy, and silicon metal in recent years). The emission trends of the various pollutants closely match the opening and closing of various facilities.

While most of the air pollutant emissions from the industrial processes sector can be traced back to the metal production industry, exceptions include NMVOC and Hg, which mostly originate from solvents and product use, NH_3 which comes from the mineral wool industry, and most heavy metals other than Hg that are emitted during the use of fireworks and tobacco (2G Other solvent and product use).

The Industrial Processes and Product Use (IPPU) sector is divided into the following subsectors:

- Mineral Industry (NFR 2A)
- Chemical Industry (NFR 2B)
- Metal Production (NFR 2C)
- Solvent and Product Use (NFR 2D)
- Other solvent and product use (NFR 2G)
- Food & Beverages Industry (NFR 2H2)

4.1.1 Sectoral trends - POPs

The emissions from the industrial processes sector in 2019 are shown below in Table 4.1, and the trends since 1990 are shown for Dioxin, PAH4, HCB and PCB in Figure 4.1 to Figure 4.4.

Table 4.1 Dioxin, PAH4, HCB and PCB emissions from industrial processes, 2019 (NA – Not applicable, NE – Not estimated, NO – Not occurring)

		Dioxin [g I-TEQ]	B(a)P [t]	B(b)f [t]	B(k)f [t]	IPy [t]	PAH4 [t]	HCB [kg]	PCB [kg]
2A	**Mineral industry**	6.3E-05	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
2B	**Chemical industry**	NO	NO	NO	NO	NO	NO	NO	NO
2C	**Metal production**	0.040	0.0024	0.020	0.0058	0.0021	0.030	1.1E-02	NA/NO
2D	**Solvent and product use**	0.0017	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
2G	**Other solvent and product use**	2.1E-05	2.4E-05	9.6E-06	9.6E-06	9.6E-06	5.3E-05	NA	NA
2H	**Other industry production**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
Industrial Processes, Total		**0.042**	**0.0024**	**0.020**	**0.0058**	**0.0022**	**0.030**	**1.1E-02**	**NA/NO**

The main source of POPs is the metal production industry (2C). In 2019, three primary aluminium smelters, one secondary aluminium production facility, one ferrosilicon plant as well as one silicon plant were operating in Iceland. A secondary steel plant was operating from 2014 to 2016, and closed down officially in February 2017, however no production occurred in the first weeks of 2017. Other solvent and product use (2D, 2G) also emit POPs, but to a very small extent compared to the metal production industry.

Figure 4.1 shows the dioxin emissions from the industrial sector. The increases in 1998-1999 and in 2007-2008 correspond to the opening of two new primary aluminium smelters, and the increase in 2014 corresponds to the opening of a secondary steel production facility, whose production was fluctuating from year to year leading to fluctuations in dioxin emissions. The dioxin emissions from 2A mineral industry mostly originated from a cement factory that ceased production in 2011.

PAH4 emissions, shown in Figure 4.2, also originate almost exclusively from the metal production industry. As for dioxin, the stepwise increase in emissions corresponds to the expansion of the industry.

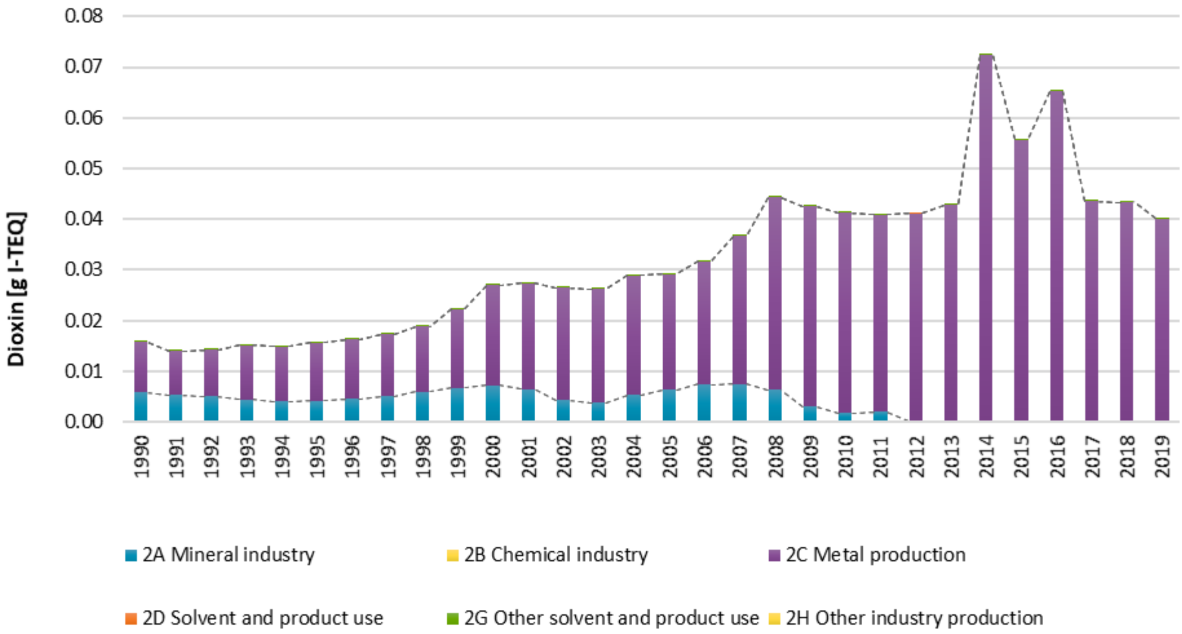

Figure 4.1 Dioxin emissions from the industrial sector, since 1990.

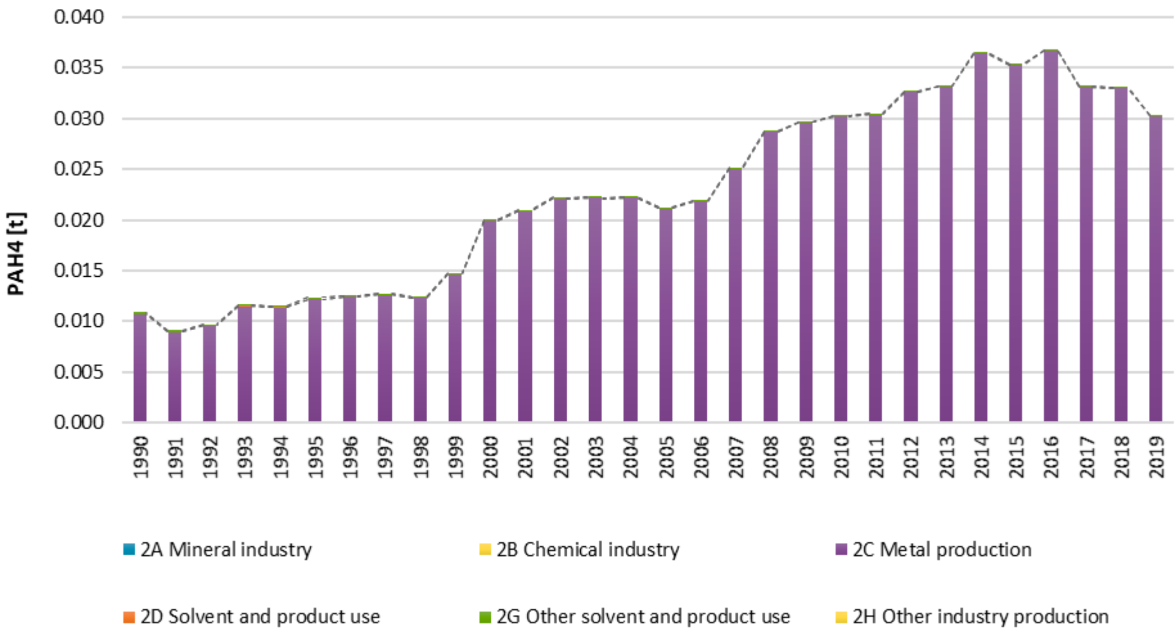

Figure 4.2 PAH4 emissions from the industrial sector, since 1990.

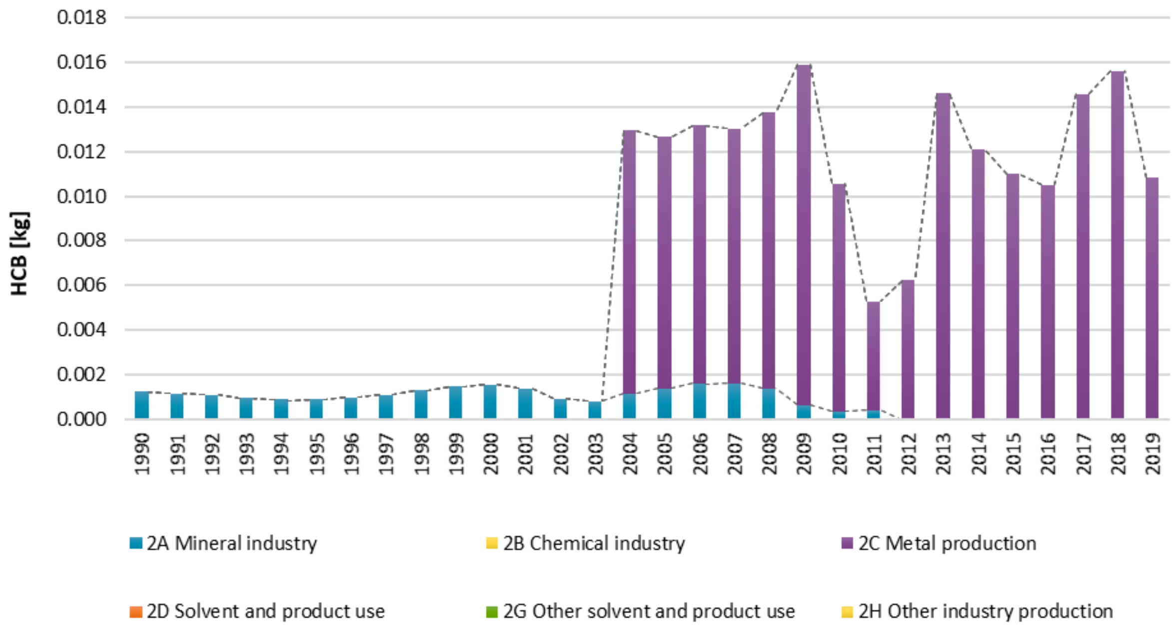

Figure 4.3 HCB emissions from the industrial sector, since 1990

Figure 4.3 shows HCB emission trends. The main HCB source was the cement industry until 2004 when a secondary aluminium production facility opened leading to an increase in HCB emissions. In 2010, this facility started stepping down the production, with a corresponding decrease in HCB emissions. In 2013, another secondary aluminium plant opened, leading to a new increase in production. HCB emissions from primary aluminium production, solvents and other product use are not estimated due to the fact that there is no emission factor available in the 2019 EMEP/EEA Guidebook.

Figure 4.4 shows the PCB emissions. Only one PCB source is estimated for this sector, which is the secondary steel production industry. Operations at the plant started in 2014, and the fluctuation in emissions directly reflect fluctuations in production. The facility stopped production at the end of 2016. No other sources are estimated in the IPPU sector, mostly because no PCB emissions are expected from most sources within the sector, with the exception of some solvents and product use for which there are no available emission factors in the 2019 EMEP/EEA Guidebook.

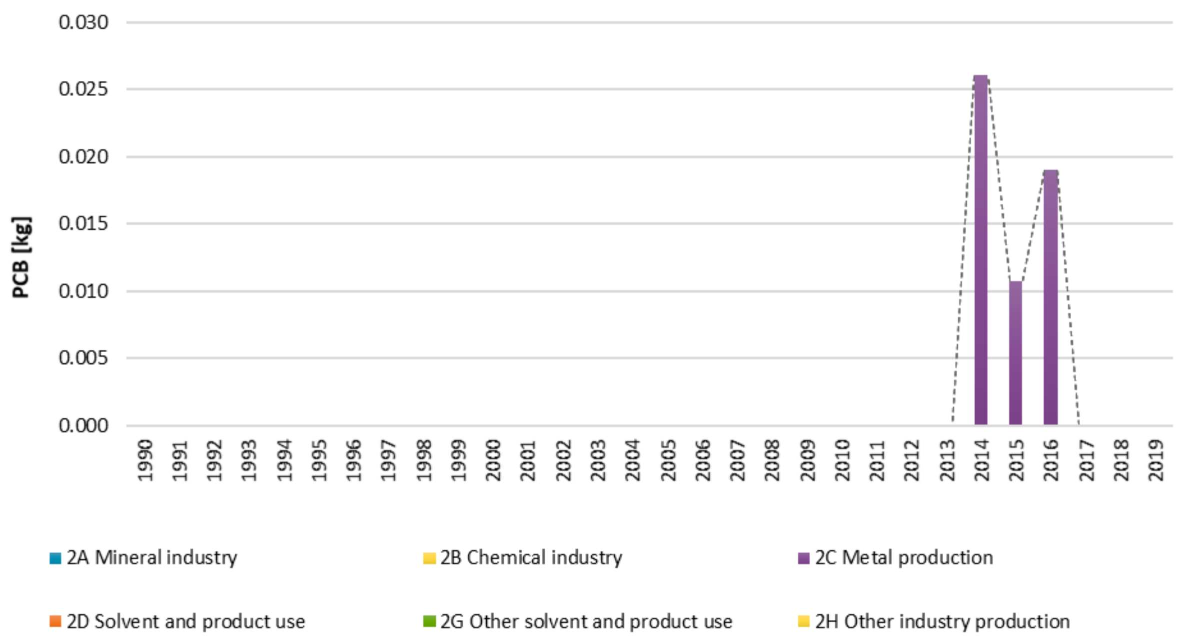

Figure 4.4 PCB emissions from the industrial sector, since 1990.

Overall, the POPs emissions have been increasing since 1990, with a clear correlation between the emissions and the opening and closing of various facilities.

4.1.2 Sectoral trends - other pollutants

Table 4.2 and Table 4.3 show the 2019 emissions for NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC and CO, as well as heavy metals. Figures showing the evolution of the emissions since 1990 for each pollutant, by subsector, are shown in Annex IV.

Table 4.2 NO_x, NMVOC, SO_x, NH_3, PM and CO emissions from industrial processes, 2019 (NA – Not applicable, NE – Not estimated, NO – Not occurring).

		NO_X [kt] NO_2	NMVOC [kt]	SO_X [kt] SO_2	NH_3 [kt]	$PM_{2.5}$ [kt]	PM_{10} [kt]	TSP [kt]	BC [kt]	CO [kt]
2A	**Mineral industry**	NA/NO	NA/NO	3.94E-05	0.014	0.087	0.66	1.7	4.7E-04	0.027
2B	**Chemical industry**	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C	**Metal production**	2.19	0.0045	12.66	NA/NO	0.38	0.47	0.55	0.0081	101
2D	**Solvent and product use**	NA/NO	1.19	NA/NO	NA/NO	1.42E-04	0.0011	0.0050	8.1E-06	NA/NO
2G	**Other solvent and product use**	5.07E-04	0.0010	0.0014	8.88E-04	0.030	0.053	0.057	2.6E-05	0.015
2H	**Other industry production**	NA	0.41	NA/NO	NA/NO	NA/NO	NA/NO	NE/NO	NA/NO	NA/NO
Industrial Processes, Total		**2.19**	**1.60**	**12.66**	**0.015**	**0.50**	**1.2**	**2.3**	**0.0086**	**101**

Table 4.3 Heavy metal emissions from industrial processes, 2019 (NA – Not applicable, NO - Not occurring)

		Pb [t]	Cd [t]	Hg [t]	As [t]	Cr [t]	Cu [t]	Ni [t]	Se [t]	Zn [t]
2A	**Mineral industry**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
2B	**Chemical industry**	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C	**Metal production**	0.0020	0.0021	NE/NO	7.9E-04	5.9E-04	0.0092	NA/NO	NA/NO	0.052
2D	**Solvent and product use**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
2G	**Other solvent and product use**	0.37	7.0E-04	2.9E-05	6.6E-04	0.0074	0.21	0.014	2.1E-06	0.12
2H	**Other industry production**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
Industrial Processes, Total		**0.37**	**0.0028**	**2.9E-05**	**0.0015**	**0.0079**	**0.22**	**0.014**	**2.1E-06**	**0.17**

The metal production subsector accounts for most of the NO_x, SO_x, PM, BC and CO emissions within the sector, whereas solvent and product use as well as other industry production are the biggest source of NMVOC and heavy metals. A large share of heavy metal emissions in Iceland comes from fireworks use.

In general, emissions of most pollutants have increased since 1990, mirroring the expansion of the industry, the population growth (41% between 1990 and 2019), with dips of varying magnitude after 2007 following a major financial crisis that drastically affected the Icelandic economy.

4.2 General methodology

Methodology is generally based on the most recent EMEP/EEA air pollutant emission inventory Guidebook (EEA, 2019). In most cases, emissions are calculated by multiplying the quantity of production or product use with pollutant-specific emissions factors. Emissions factors are also taken from the Standardized Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs (UNEP, 2013), Utslipp til luft av dioxiner I Norge (Statistics Norway, 2002), the 2006 IPCC Guidelines for Greenhouse Gas Inventories (IPCC, 2006) as well as plant-specific emission factors derived from direct measurements at the plants. Activity data is collected from data reported under the EU ETS (as per Directive 2003/87/EC of the European Parliament and of the Council), Statistics Iceland, Green Accounting or directly from the operators. Detailed, activity-specific methodology for emission estimates is described for each subsector. Work is underway to harmonise this reporting with data reported under the E-PRTR Regulation (Regulation (EC) No 166/2006).

4.3 Mineral Industry (NFR 2A)

4.3.1 Cement production (NFR 2A1)

The single cement plant in Iceland produced cement from shell sand and rhyolite in a rotary kiln using a wet process. The raw material calcium carbonate, which came from shell sand, was calcinated in the production process. The resulting calcium oxide was heated to form clinker and then crushed to form cement.

The production at the cement plant in Iceland slowly decreased after 2000. The construction of the Kárahnjúkar hydropower plant (building time from 2002 to 2007) along with increased activity in the construction sector (from 2003 to 2007) increased demand for cement, and the production at the cement plant increased again between 2004 and 2007, although most of the cement used in the country was imported. In 2011, clinker production at the plant was 69% less than in 2007, due to the collapse of the construction sector. Late 2011 the plant ceased operation.

4.3.1.1 *Activity data*

Process specific data on cement production, clinker production and amounts of coal were collected by the EA directly from the cement production plant.

4.3.1.2 *Emission factors*

Emission factor for dioxin is taken from the Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2013). The factor applies for wet kilns, with ESP/FF temperature < 200°C and is 0.05 µg I-TEQ/t cement. The HCB emission factor is based on the chapter Sources of HCB emissions from the Emission Inventory Guidebook (EEA, 2007). Emission factors for TSP, PM_{10} and $PM_{2.5}$ are based on measurements and the BC emission factor (3% of $PM_{2.5}$) is based on the 2019 EMEP/EEA Guidebook. Emission estimates for SO_2 are based on measurements from the plant but include both process-related and combustion-related emissions, and the total SO_2 emissions are reported under 2A1 Cement production. Emissions of PAH, NO_x, CO and NMVOC originate mainly from combustion and are reported under 1A2f (Stationary combustion in manufacturing industries and construction: non-metallic minerals); process-related emissions for those pollutants are not applicable. All emission factors used are summarized in the table below.

Table 4.4 Emission factors for cement production

	Dioxin [µg/t I-TEQ]	HCB [µg/t]	TSP [kg/kt]	PM_{10} [kg/kt]	$PM_{2.5}$ [kg/kt]	BC % of PM2.5
Cement production	0.05	11	220	200	100	3%

4.3.1.3 *Recalculations and improvements*

No recalculations were made to cement production (2A1) for this submission.

4.3.1.4 *Planned improvements*

No improvements are currently planned for this subsector.

4.3.2 Lime production (NFR 2A2)

This activity does not occur in Iceland.

4.3.3 Glass production (NFR 2A3)

This activity does not occur in Iceland.

4.3.4 Quarrying and mining of minerals other than coal (NFR 2A5a)

This category was added for the first time in the current submission. The activity data was retrieved from Statistics Iceland who provided a timeseries from 2004-2017 of aggregates with no further distinction of size, used by the Icelandic Road and Coastal Administration for road construction and by the main power company who uses material from quarries to build dams for hydropower plants. Currently no data is available prior to 2004, so the data from 2004 has been used for the years 1990-2003. Data for 2018 and 2019 is also not available, therefore the value from 2017 is used. The methodology follows Tier 1 of the 2019 EMEP/EEA Guidebook and the applied emission factors are taken from Table 3.1. Only particulate matter emissions, that is TSP, PM_{10} and $PM_{2.5}$ arise from this category.

4.3.5 Construction and demolition (NFR 2A5b)

This category was added for the first time in the current submission. To retrieve activity data, the building stock per construction year, subdivided by the type of houses (terraced, detached, semi-detached, apartment buildings, non-residential buildings) was obtained from Registers Iceland for the time series 1990-2019. Data about road construction is retrieved from the Icelandic Road and Coastal Administration for the years 2003-2019 and for the remaining time series is estimated as average 2003-2011. The methodology follows Tier 1 of the 2019 EMEP/EEA Guidebook. Default values from the Guidebook are used for the duration of construction (houses 0.5, apartment buildings 0.75, non-residential 0.83 and roads 1.00 years), for the control efficiency (houses -, apartment buildings -, non-residential 0.5, roads 0.5), silt content is assumed to be 20% and the Thornthwaite Precipitation-Evaporation Index was calculated with precipitation and temperature data recorded at a weather station in Reykjavík. Only particulate matter emissions, that is TSP, PM_{10} and $PM_{2.5}$ arise from this category.

4.3.6 Storage, Handling and Transport of mineral products (NFR 2A5c)

This activity is currently not estimated. It is planned to include this within the mineral production chapter.

4.3.7 Mineral wool production (NFR 2A6)

There is one mineral wool production plant in operation in Iceland. Although it is an activity falling under Annex I of Directive 2003/87/E (ETS Directive), it is excluded from the EU ETS scheme following the conditions described in Article 27 of the ETS Directive. The operator submits annual emission reports to the EA, using the same template as the companies reporting within the EU ETS scheme.

4.3.7.1 *Activity data*

Activity data for the mineral wool plant originates from the annual emission reports mentioned above, as well as annual Green Accounting reports.

4.3.7.2 *Emission factors*

Emissions of dioxins are calculated from the amount (weight) of electrodes used in the production process. The emission factor is taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002) and is 1.6 µg I-TEQ/t electrodes. PAH emissions are not applicable. Emissions of SO_2 are calculated using the S content of the electrodes used. Emission factors of CO, NH_3 and TSP were calculated based on measurements at the factory. In the case of NH_3 and TSP, measurements were available every second year from 2009. For those years the actual measurements were used to derive a year-specific emission factor. For the years in between, the average of the emission factor of the previous year and of the following year was used. For all years prior to 2009, the average of available measurements was used. Since 2018 yearly total emissions for NH_3 are communicated from company directly. PM_{10} and $PM_{2.5}$ were calculated from TSP using the TSP vs. PM_{10} vs. $PM_{2.5}$ ratios given in table 3.5 in chapter 2.A.3 the EMEP/EEA Guidebook (EEA, 2019). BC was calculated using the ratio to $PM_{2.5}$ given in the EMEP/EEA Guidebook (EEA, 2019). NO_x and NMVOC emissions originate from combustion and are reported under sector 1A2gviii. Table 4.5 shows the emission factors used for mineral wool production.

Table 4.5 Emission factors for mineral wool production (TSP: Values are EF averages for 1990-2019. NH_3: Values are EF averages for 1990-2017).

	NH_3	CO	TSP	PM_{10}	$PM_{2.5}$	BC	Dioxin
	[t/kt]	[t/kt]	[t/kt]	% of TSP	% of TSP	% of PM2.5	[µg/t I-TEQ/t]
Mineral wool production	2.65	2.66	2.49	88%	78%	2%	1.6

4.3.7.3 *Recalculations and improvements*
No recalculations were made to mineral wool production (2A6) for this submission.

4.3.7.4 *Planned improvements*
No improvements are currently planned for this subsector.

4.4 Chemical Industry (NFR 2B)

4.4.1 Ammonia production (NFR 2B1)
Ammonia was produced amongst other fertilizers during the period 1990-2001. The associated emissions are marked as Included Elsewhere under 2B1 Ammonia Production and are included in the emissions reported under 2B10a other: Fertilizer Production. The emission estimation methodology associated with ammonia production is also described there.

4.4.2 Nitric acid production (NFR 2B2)
This activity does not occur in Iceland.

4.4.3 Adipic acid production (NFR 2B3)
This activity does not occur in Iceland.

4.4.4 Carbide production (NFR 2B5)
This activity does not occur in Iceland.

4.4.5 Titanium dioxide production (NFR 2B6)
This activity does not occur in Iceland.

4.4.6 Soda ash production (NFR 2B7)
This activity does not occur in Iceland. Emissions from the use of soda ash in the silica (diatomite) industry (NFR 2B10a; reported until 2004) are reported under that NFR code.

4.4.7 Chemical industry: Other (NFR 2B10a)
The only chemical industry that existed in Iceland was the production of fertilizer and silica/diatomite. The fertilizer production plant ceased its operations in 2001 and the diatomite production plant was closed down in 2004. This industry is not considered to be a source of POPs nor heavy metals.

A fertilizer production plant was operational until it exploded in 2001. In the early days of the factory, only one type of fertilizer was produced (a nitrogen fertilizer), whereas at the end of its production phase it was producing over 20 different types of fertilizers. CO_2 and CH_4 emissions are considered insignificant, as the fertilizer plant used H2 produced on-site by electrolysis. Methodology NO_x and N_2O emissions were reported directly by the factory to the EA.

4.4.7.1 *Activity data*

When the fertilizer production plant was operational it reported its emissions of NO_x and N_2O to the EA. At the diatomite production plant, silica containing sludge was burned to remove organic material. Emissions of CO_2 and NO_x were estimated on the basis of the C-content and N-content of the sludge provided by the operator. Activity data for both industries are presented in Table 4.6.

Table 4.6 Production data for 1990, 1995 and 2000 for fertilizer and silica production (in kt).

	1990	1995	2000	
Fertilizer production [kt]	63.73	58.52	41.54	Facility closed in 2001
Diatomite production, [kt]	26.11	28.14	27.61	Facility closed in 2004

4.4.7.2 *Emission factors*

For diatomite production, emissions of CO_2 and NO_x were estimated based on the C-content and N-content of the sludge provided by the operator. Average NO_x implied EF for the period 1990-2004 was 15.6 t NO_x/kt Si production. Other emissions from soda ash use were not estimated and are considered to be small.

For the fertilizer production, the average implied EF for NO_x for the period 1990-2001 was 0.296 t NO_x/kt fertilizer production. As there is no data readily available about the types of fertilizers produced at the time, no other pollutants were estimated for this industry.

4.4.7.3 *Recalculations and improvements*

No recalculations were made for this submission.

4.4.7.4 *Planned improvements*

No improvements are currently planned for this subsector.

4.5 Metal Production (NFR 2C)

4.5.1 Iron and steel production (NFR 2C1)

From 2014 to 2016 a secondary steelmaking facility was operating. It produced steel from scrap iron and steel from the aluminium smelters. Carbonates and slags were added to the smelting process, which occurred in an electric arc furnace.

4.5.1.1 *Activity data*

Activity data used to estimate emissions from secondary steel production are total steel production, which is obtained from yearly Green Accounting reports submitted by the facility to the EA.

4.5.1.2 *Emission factors*

All emissions are calculated using Tier 2 emission factors for electric arc furnaces (Table 3.15 in chapter 2.C.1 (EEA, 2019)), with the exception of HCB for which there is no Tier 2 estimate. In this case we used the Tier 1 emission factor, which is unrelated to technology.

Table 4.7 shows all emission factors used.

Table 4.7 Emission factors for secondary steel production.

	NO_x [kg/t]	NMVOC [kg/t]	SO_2 [kg/t]	TSP [kg/t]	PM_{10} [kg/t]	$PM_{2.5}$ [kg/t]	BC % of PM2.5	CO [kg/t]
Secondary steel	0.13	0.046	0.06	0.03	0.024	0.021	0.36 %	1.7
	Dioxin [µg I-TEQ/t]	**HCB [mg/t]**	**PCB [mg/t]**					
Secondary steel	3	0.03	2.5					
	As [g/t]	**Cd [g/t]**	**Cr [g/t]**	**Cu [g/t]**	**Hg [g/t]**	**Ni [g/t]**	**Pb [g/t]**	**Zn [g/t]**
Secondary steel	0.015	0.2	0.1	0.02	0.05	0.7	2.6	3.6

4.5.1.3 *Recalculations and improvements*

No recalculations were made for this submission.

4.5.1.4 *Planned improvements*

No improvements are currently planned for this subsector.

4.5.2 Ferroalloys production (NFR 2C2)

As of 2018, two factories were producing Ferroalloys in Iceland. Both operators are under the EU Emission Trading Scheme (as per Directive 2003/87/EC). In both factories, raw ore, carbon material and slag forming materials are mixed and heated to high temperatures for reduction and smelting. For the production of FeSi75 electric (submerged) arc furnaces with consumable Söderberg electrodes are used. The furnaces are semi-covered.

Waste gases are cleaned via dry absorption units (bag-house filters). When the temperature inside the units gets too high, emergency bypass of the bag-house filters is induced. The operating permit for the ferrosilicon plant contains provisions on the maximal duration of such incidences (in percent over the year).

4.5.2.1 *Activity data*

The consumption of reducing agents and electrodes are collected by the EA directly from the single operating ferroalloys production plant. Further information on total production is given. Activity data for raw materials and products and the resulting emissions are given in Table 4.8.

Table 4.8 Raw materials use (kt) and production (kt), ferrosilicon and silicon production.

	1990	1995	2000	2005	2010	2015	2018	2019
Electrodes	3.83	3.88	5.73	6.00	4.79	4.86	4.82	4.59
Coking coal	45.12	52.38	73.20	86.87	96.10	115.10	144.31	142.36
Coke oven coke	24.92	30.14	46.63	42.59	30.26	30.85	21.29	21.17
Charcoal	NA	NA	NA	2.08	NA	NA	0.65	3.41
Wood	16.65	7.73	16.20	15.55	11.29	27.20	57.81	78.14
Limestone	NA	NA	0.47	1.62	0.50	2.19	1.89	1.83
Production (FeSi, Si)	62.79	71.41	108.70	110.96	102.21	117.95	122.19	119.44
Microsilica	14.02	15.94	22.70	25.84	18.12	22.18	22.39	20.77
Slag	NA	NA	NA	NA	NA	NA	NA	NA

4.5.2.2 *Emission factors*

4.5.2.2.1 FeSi production:

In 2011, emissions of dioxin and PAH4 (BaP, BaF, BkF, IPy) were measured at the ferrosilicon plant. These measurements were used to obtain plant specific emission factors per tonne of production that were used for the whole time series. Emission factors for CO, NO_X and NMVOC were taken from Table 8.18 of the BREF document for the non-ferrous metals industries (Cusano, et al., 2017). In the case where a range was given, the highest value of the range was chosen. The emission factors are presented in Table 4.9. Sulphur emissions were calculated from S-content of the reducing agents for the time period 1990-2002 and were taken directly from Green Accounting reports submitted yearly by the factory since 2003.

Emissions of particulates for the period 1990-2011 are calculated by adding up the emissions from filtered exhaust and the amount of particulates that are released during emergency bypass of the exhaust. Emission factor for filtered exhaust is taken from Table 8.12 of the BREF document for Best Available Techniques for the non-ferrous metals industries (Cusano, et al., 2017). It is 5 mg/Nm^3. This factor is then multiplied with the plant specific yearly amount of exhaust (in Nm^3). To calculate the bypass emissions, first the total Microsilica, fine (collected and sold e.g. to cement producers) and coarse (cyclone dust) are added up and divided by the hours per year (8760 hrs.) to get Microsilica production rate per hour. This is known for all years since 2005. The production rate is then multiplied with the bypass time per furnace and the ratio of the FeSi production per furnace of the total FeSi production each year. The bypass rate is known since 2002 and taken from Green Accounts, submitted in accordance with Regulation No 851/2002. The bypass rate for previous years was calculated as the average of the years 2002 to 2006. Microsilica (fine and coarse) production rate and production per furnace were extrapolated for the years 1990 to 2001 based on total produced FeSi at the plant each year. Since 2012, TSP are obtained from the yearly Green Accounting report submitted to EA. The emission factor for BC is taken from the Norwegian IIR (Norwegian Environment Agency, 2016).

4.5.2.2.2 Si production:

Emission factors for Particulate Matter are Tier 1 default values as published in the 2019 EMEP/EEA Guidebook and for years where available Tier 3 plant specific. The NO_x emission factor is taken from the BREF document on non-ferrous minerals (Cusano, et al., 2017). SO_2 emissions are reported by the operator to the EA in the annual Green Accounting report. Emissions from the other pollutants are not estimated due to lack of available information in the EMEP/EEA Guidebooks and in the BREF document cited above.

All emission factors used for calculating emissions from FeSi and Si production are presented in the table below.

Table 4.9 2019 emission factors from FeSi and Si production.

	NO_x [kg/t prod.]	**NMVOC [kg/t prod.]**	**CO [kg/t prod]**	**TSP [kg/t prod.]**	**PM10 % of TSP**	**$PM_{2.5}$ % of TSP**
FeSi	11	0.045	2.5	0.00067	95%	95%
Si	13	NA	NA	0.62	85%	60%
	BC % of PM2.5	**Dioxin [µg/t FeSi]**	**B(a)P [mg/t FeSi]**	**B(b)F [mg/t FeSi]**	**B(k)F [mg/t FeSi]**	**IPy [mg/t FeSi]**
FeSi	0.23%	0.114	2.79	102.22	29.68	9.39
Si	10%	NA	NA	NA	NA	NA

Several heavy metals (As, Cd, Cr, Cu, Hg, Pb and Zn) were measured in silicon dust in the ferrosilicon plant in 2014. These measurements were used in combination with the emitted TSP to calculate heavy metals emissions since 1990. Hg was found to be below detection (i.e. < 9 mg/kg silicon dust) in all samples. The heavy metal contents in silica dust are shown in Table 4.10.

Table 4.10 Heavy metal contents in silica dust in 2014 (mg metal / kg dust).

	As [mg/kg]	Cd [mg/kg]	Cr [mg/kg]	Cu [mg/kg]	Hg [mg/kg]	Pb [mg/kg]	Zn [mg/kg]
Content in silicon dust	11.8	0.46	8.8	10.8	< 9	8.7	25.2

4.5.2.3 *Recalculations and improvements*

PM_{10}, $PM_{2.5}$ and BC emissions from Si production for the year 2018 were calculated as a percentage of TSP using the same ratios as in Table 3.1 in the EMEP/EEA Guidebook (EEA, 2019). Since the year 2018 the TSP emission factors are based on information from the factory instead of EMEP/EEA Guidebook.

4.5.2.4 *Planned improvements*

It is planned to revise the particulate matter estimates in future submissions, and to harmonise this reporting with the E-PRTR reports.

4.5.3 Primary aluminium production (NFR 2C3)

In 2019 aluminium was produced at three primary aluminium plants in Iceland. Best Available Technology (BAT) is used at all plants, i.e. closed prebake systems with point feeding of alumina, efficient process control, hoods covering the entire pot and efficient collection of air pollutants.

Primary aluminium production results in emissions of dioxins, PAH4, NO_x, CO, particulate matter and SO_2. Emissions originate from the consumption of electrodes during the electrolysis process.

4.5.3.1 *Activity data*

The EA collects annual process specific data from the three operators through EU ETS and Green Accounting reports. The total production of the three aluminium plants is given in Table 4.11.

Table 4.11 Primary Aluminium production (kt).

	1990	1995	2000	2005	2010	2015	2018	2019
Primary Al production	87.8	100.2	226.4	272.5	818.9	857.3	876.0	835.7

4.5.3.2 *Emission factors*

In 2011 emissions of dioxin were measured at one of the aluminium plants. The same plant also measured PAH4 in 2002 and in 2011, and the average emission factors from these two measurements were calculated. The measurements were used to obtain plant specific emission factors per tonne of production that were used for the whole time series. Of the total pot gases 98.5 % are collected and cleaned via dry adsorption unit. Thus, 1.5% of the pot gases leak unfiltered to the atmosphere. Both dioxin and PAH4 are below detection limit in the cleaned gas. Emission factors are derived from the concentration of dioxin and PAH4 in the raw gas. They are presented Table 4.12.

NO_x and CO were taken from Table 3.2 of (EEA, 2019). Particulate matter was calculated from information on particulates per tonne of produced aluminium that the aluminium plants report in their Green Accounting reports submitted to the EA. Ratios of TSP:PM_{10}:$PM_{2.5}$ as well as the BC emission factor were also taken from the 2019 EMEP/EEA Guidebook. Emissions of SO_2 are estimated from S-content of alumina and electrodes for the time prior to reporting of SO_2 emission in the Green

Accounts (2003-2013, depending on the company), and from SO_2 emission calculations reported in the Green accounts in the later years. All emission factors are presented in Table 4.12.

Table 4.12 Emission factors, primary aluminium production.

	Dioxin [µg/t Al]	PAH4 [mg/t Al]	B(a)P % of PAH4	B(b)F % of PAH4	B(k)F % of PAH4	IPy % of PAH4
Emission factors	0.0329	0.0189	13%	61%	18%	8%
	CO [kg/t Al]	**NO_x [kg/t Al]**	**PM10 % of TSP**	**PM2.5 % of TSP**	**BC % of PM2.5**	
Emission factors	120	1	78%	67%	2.3%	

4.5.3.3 *Recalculations and improvements*
No recalculations were made for this submission.

4.5.3.4 *Planned improvements*
All emission factors used in Iceland are in the process of being compared with those used in other Nordic countries, as part of a Nordic cooperation project that was funded by Nordic Working Group for Climate and Air (NKL) under the Nordic Council of Ministers, and started in 2016. As a result of the project, it will be reassessed whether some emission factors should be changed. Furthermore, work is underway to harmonise this reporting with the E-PRTR reports.

4.5.4 Secondary aluminium production (NFR 2C3)
Secondary aluminium production started in 2004. In 2012, a second facility opened. At the end of 2014 the facilities merged and only one production area is active now. The plant recycles aluminium skimmings' and scrap aluminium from two primary aluminium plants by melting scrap metal in batches in a rotary kiln. The re-melt process is carried out under a layer of salt and the resulting salt slag traps part of the contaminants. The scrap aluminium is not treated with organic material such as paints, lacquers, oils, and greases prior to recycling and comes directly from the primary aluminium plants.

4.5.4.1 *Activity data*
All activity data, consisting of produced secondary aluminium, is obtained in Green Accounting reports submitted yearly to the EA.

Table 4.13 Secondary aluminium production (kt).

	1990	1995	2000	2005	2010	2015
Secondary Al production	NO	NO	NO	2.25	2.04	2.20

4.5.4.2 *Emission factors*
Emissions of dioxin, HCB and PM are estimated. The dioxin emission factor comes from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2013). The lowest value (0.5 µg/t aluminium) for secondary aluminium production was chosen as the plant only recycles scrap metal from primary aluminium plants and no coated aluminium, so organic compounds in the input material is minimum. Also, no chlorine is added in the process and further oxy-fuel burners are used. The TSP, PM_{10}, $PM_{2.5}$ and BC emission factors are taken from the Table 3.4 in the EMEP/EEA Guidebook (EEA, 2019). Measurements of dioxin at the plant in 2012, showed that the EF of 0.5 µg/t represents the plant well.

The emission factor for HCB was chosen as a value in the lower range (0.04-40 mg/t) given in Table 5-9 and Figure 5-18 of BiPRO (2006). As the recycled scrap material is directly coming from the primary aluminium smelters, contamination with organic substances in form of paintings or lacquers is expected to be insignificant and subsequently emissions of organochloride are expected to be low as well. A comparison across Nordic Countries shows that the used emissions factors are 1.365 mg/t in Finland, 1.7 mg/t in Norway and 20 mg/t in Denmark (from the IIR of the respective countries).

Table 4.14 Emission factors, secondary aluminium production.

	Dioxin [µg/t Al]	HCB [mg/t Al]	TSP [kg/t]	PM_{10} [kg/t]	$PM_{2.5}$ [kg/t]	BC % of $PM_{2.5}$
Emission factors	0.5	5	2	1.4	0.55	2.3 %

4.5.4.3 *Recalculations and improvements*

No recalculations were made for this submission.

4.5.4.4 *Planned improvements*

No improvements are currently planned for this subsector.

4.6 Solvent and Product Use (NFR 2D)

Activities related to 2D Solvent and product use mostly generate NMVOC. When volatile chemicals are exposed to air, emissions are produced through evaporation of the chemicals. The use of solvents and other organic compounds in industrial processes and households is an important source of NMVOC evaporation. Emissions of other pollutants than NMVOC were only estimated from road paving with asphalt (2D3b - Dioxin, PM and BC), Domestic solvent use (2D3a - Hg) and other solvent use (Creosotes - 2D3i - PAH). The categories Paint Application, Degreasing, and Other NMVOC emissions from printing and other product use have in common that their activity data consists of data about imported goods. This data was received from Statistics Iceland.

Emission factors for all subcategories of 2D3 are presented in Table 4.15 below. References and more details about individual emission factors are included in the respective under chapters.

Table 4.15 Emission factors for sector 2D3.

	unit	NMVOC [g/unit]	TSP [kg/unit]	PM_{10} [kg/unit]	$PM_{2.5}$ [kg/unit]	BC [% of $PM_{2.5}$]
2D3a Domestic solvent use	head	1800	-	-	-	-
2D3b Road paving with asphalt	t asphalt	16	14	3	0.4	5.7%
2D3d Coating applications	kg paint	230	-	-	-	-
2D3e Degreasing	kg cleaning product	460	-	-	-	-
2D3f Dry cleaning	kg textile treated	177	-	-	-	-
2D3g Chemical products - paint manufacturing	kg product	11	-	-	-	-
2D3h Printing	kg ink	500	-	-	-	-
2D3i Creosotes	kg creosote	105	-	-	-	-
2D3i Organic solvent-borne preservatives	kg preservative	945	-	-	-	-

	unit	Dioxin [µg I-TEQ/unit]	BaP [mg/unit]	BbF [mg/unit]	BkF [mg/unit]	Ipy [mg/unit]
2D3a Domestic solvent use	head	-	-	-	-	-
2D3b Road paving with asphalt	t asphalt	0.007	-	-	-	-
2D3d Coating applications	kg paint	-	-	-	-	-
2D3e Degreasing	kg cleaning product	-	-	-	-	-
2D3f Dry cleaning	kg textile treated	-	-	-	-	-
2D3g Chemical products - paint manufacturing	kg product	-	-	-	-	-
2D3h Printing	kg ink	-	-	-	-	-
2D3i Creosotes	kg creosote	-	1.05	0.53	0.53	0.53
2D3i Organic solvent-borne preservatives	kg preservative	-	-	-	-	-

	unit	Hg [mg/unit]
2D3a Domestic solvent use	head	5.6
2D3b Road paving with asphalt	t asphalt	-
2D3d Coating applications	kg paint	-
2D3e Degreasing	kg cleaning product	-
2D3f Dry cleaning	kg textile treated	-
2D3g Chemical products - paint manufacturing	kg product	-
2D3h Printing	kg ink	-
2D3i Creosotes	kg creosote	-
2D3i Organic solvent-borne preservatives	kg preservative	-

4.6.1 Domestic solvent use including fungicides (NFR 2D3a)

Domestic solvent use is calculated using a default per capita value, as per Tier 1, Table 3.1 Chapter 2.D.3.a of the Guidebook (EEA, 2016).

4.6.1.1 *Activity data*

Activity data consists of the Icelandic population and is given by Statistics Iceland.

4.6.1.2 *Emission factors*

The emission factor for NMVOC for western Europe was used, or 1.8 kg NMVOC/capita from Table 3.1, Chapter 2.D.3.a (EEA, 2019).

4.6.1.3 *Recalculations and improvements*

Hg was not estimated due to uncertainty around the releases according to the 2019 EMEP/EEA Guidebook (EEA, 2019).

4.6.1.4 *Planned improvements*

No improvements are currently planned for this subsector.

4.6.2 Road paving with asphalt (NFR 2D3b)

Asphalt road surfaces are composed of compacted aggregate and asphalt binder. Gases are emitted from the asphalt plant itself, the road surfacing operations, and subsequently from the road surface.

4.6.2.1 *Activity data*

Information on the amount of asphalt produced comes from Statistics Iceland until 2011, and directly from the companies producing asphalt since 2012.

4.6.2.2 *Emission factors*

The emission factors for NMVOC and BC are taken from Table 3.1 in Chapter 2.D.3.b, Tier 1, in the EMEP/EEA Guidebook (EEA, 2019). Emissions factors for TSP are based on measurements from the second-largest asphalt production plant. $PM_{2.5}$ and PM_{10} emission factors are then calculated by using the same ratio to TSP as given in Table 3.1, chapter 2.D.3.b in the Guidebook (EEA, 2019). Emissions of SO_2, NO_x, and CO are expected to originate mainly from combustion and are therefore not estimated here but accounted for under sector 1A2g.

4.6.2.3 *Recalculations and improvements*

Unit corrections were made for dioxin that applied to the whole timeseries.

4.6.2.4 *Planned improvements*

No improvements are currently planned for this subsector.

4.6.3 Coating applications (NFR 2D3d)

The emissions in this category stem from paint applications. Only NMVOC emissions are estimated; emissions from other pollutants are either considered minimal or non-existent.

4.6.3.1 *Activity data*

The EMEP/EEA Guidebook (EEA, 2016) provides emission factors based on amounts of paint applied. Data exists on imported paint since 1990 (Statistics Iceland) and on domestic production of paint since 1998 (Icelandic Recycling Fund, 2019). The total amount of solvent based paint is multiplied with the emission factor. For the time before 1998 no data exists about the amount of solvent based paint produced domestically. Therefore, the domestically produced paint amount of 1998, which happens to be the highest of the time period for which data exists, is used for the period from 1990-1997.

4.6.3.2 *Emission factors*

The Tier 1 emission factor from the EMEP/EEA Guidebook (EEA, 2019) refers to all paints applied, e.g. waterborne, powder, high solid and solvent based paints. The existing data on produced and imported paints, however, makes it possible to narrow activity data down to conventional solvent based paints. Therefore, Tier 2 emission factors for conventional solvent based paints could be applied. The activity data does not allow for a distinction between decorative coating application for construction of buildings and domestic use of paints. Their NMVOC emission factors, however, are identical: 230 g/kg paint applied.

4.6.3.3 *Recalculations and improvements*
No recalculations were made for this submission.

4.6.3.4 *Planned improvements*
No improvements are currently planned for this subsector.

4.6.4 Degreasing & dry cleaning (NFR 2D3e & f)
Degreasing and dry cleaning only generate NMVOC emissions. Emissions related to degreasing were estimated by Tier 1, based on amounts of cleaning products used, and those related to dry cleaning by Tier 2, based on the default amount of textile cleaned per capita. Since there is an overlap in chemicals used for these two activities, they are discussed in the same chapter.

4.6.4.1 *Activity data*
There is data on the amount of cleaning products imported provided by Statistics Iceland. Of the chemicals listed by the EMEP/EEA Guidebook, activity data is available for: methylene chloride (MC), tetrachloroethylene (PER), trichloroethylene (TRI) and xylenes (XYL). In Iceland, though, PER is mainly used for dry cleaning (expert judgement). In order to estimate emissions from degreasing more correctly without underestimating them, only half of the imported PER was allocated to degreasing. Emissions from dry cleaning are estimated without using data on solvents used (see below). The use of PER in dry cleaning, though, is implicitly contained in the method. In Iceland, xylenes are mainly used in paint production (expert judgement). Furthermore, only half of the imported xylenes were allocated to degreasing. Emissions from paint production are estimated without using data on solvents used but xylene use is implicitly contained in the method. In addition to the solvents mentioned above, 1,1,1-trichloroethylene (TCA), now banned by the Montreal Protocol, is added for the time period during which it was imported and used. Another category included is paint and varnish removers.

Emissions from dry cleaning were calculated using the Tier 2 emission factor for open-circuit machines provided by the EMEP/EEA Guidebook (EEA, 2019). Activity data for calculation of NMVOC emissions is the amount of textile treated annually, which is assumed to be 0.3 kg/head, default value from (EEA, 2019) and calculated using demographic data.

4.6.4.2 *Emission factors*
The amount of imported solvents for degreasing was multiplied with the NMVOC Tier 1 emission factor from EMEP/EEA Guidebook (EEA, 2019) for degreasing: 460 g/kg cleaning product.

The NMVOC emission factor for open-circuit machines is 177 g/kg textile treated. Since all dry cleaning machines used in Iceland are conventional closed-circuit PER machines, the emission factor was reduced using the respective EMEP/EEA Guidebook reduction default value of 0.89.

4.6.4.3 *Recalculations and improvements*
No recalculations were made for this submission.

4.6.4.4 *Planned improvements*
No improvements are currently planned for this subsector.

4.6.5 Chemical products (NFR 2D3g)
The only activity identified for the subcategory chemical products, manufacture and processing is manufacture of paints. NMVOC emissions from the manufacture of paints were calculated using Tier 2 of the Guidebook (EEA, 2019).

4.6.5.1 *Activity data*
The activity data consists of the amount of paint produced domestically as discussed above in chapter 4.7.2 Coating Applications.

4.6.5.2 *Emission factor*
NMVOC emissions from the manufacture of paints were calculated using the 2019 EMEP/EEA Guidebook (EEA, 2019) Tier 2 emission factor of 11 g/kg product.

4.6.5.3 *Recalculations and improvements*
No recalculations were made for this submission.

4.6.5.4 *Planned improvements*
No improvements are currently planned for this subsector.

4.6.6 Printing (NFR 2D3h)

4.6.6.1 *Activity data*
Import data on ink was received from Statistics Iceland.

4.6.6.2 *Emission factors*
NMVOC emissions for printing were calculated using the 2019 EMEP/EEA Guidebook (EEA, 2019). Tier 1 emission factor of 500 g/kg ink used.

4.6.6.3 *Recalculations and improvements*
No recalculations were made for this submission.

4.6.6.4 *Planned improvements*
No improvements are currently planned for this subsector.

4.6.7 Other product use (NFR 2D3i)
Wood is preserved to protect it against fungal and insect attack and also against weathering. There are three main types of preservative: creosote, organic solvent-based (often referred to as ‘light organic solvent-based preservatives’ (LOSP)) and water borne. Creosote is oil prepared from coal tar distillation. Creosote contains a high proportion of aromatic compounds such as polycyclic aromatic hydrocarbons (PAHs). In Iceland, creosotes were used from 1990 to 2010, and have been banned since 2011. Other wood preservation substances used in Iceland are organic solvent-borne preservatives.

4.6.7.1 *Activity data*
Activity data consists of annual import of creosotes and organic solvent-borne preservatives, and the assumption that all these products are applied during the year of import. Import data on both wood preservatives was received from Statistics Iceland.

4.6.7.2 *Emission factors*
Emission factors for PAH are taken from chapter 2.D.3.i, 2.G of the Emission Inventory Guidebook (EEA, 2019). They are 1.05 mg BaP per kilogramme of creosote, 0.53 mg per kilogramme creosote of the other 3 PAH: BbF, BkF and IPy. NMVOC emissions from wood preservation were calculated using the EMEP/EEA Guidebook Tier 2 emission factors for creosote preservative type (105 g/kg creosote) and organic solvent borne preservative (945 g/kg preservative).

4.6.7.3 *Recalculations and improvements*
No recalculations were made for this submission.

4.6.7.4 *Planned improvements*
No improvements are currently planned for this subsector.

4.6.8 Other solvent and product use (NFR 2G)

The two emission sources estimated in this category are use of tobacco and fireworks.

Tobacco smoking is a minor source of dioxins, PAH and other pollutants including heavy metals, whereas fireworks are the most significant source of heavy metals in the industrial processes sector. The yearly imported amount of tobacco shows a downward trend over the timeseries, which is reflected also in the emission. Firework imports follow in general the economic development of the country. A prominent peak around 2007 is due to a very sharp rise in the economy leading to the financial collapse of 2008.

4.6.8.1 *Activity data*

Activity data consist of all smoking tobacco and all fireworks imported and are provided by Statistics Iceland.

4.6.8.2 *Emission factors*

For tobacco use, emission factors for NO_x, CO, NH_3, TSP, PM, BC, NMVOC, dioxin and PAH4 were taken from Table 3-15 in Chapter 2.D.3.i, 2.G in the 2019 EMEP/EEA Guidebook (EEA, 2019). Emission factors for heavy metals are taken from the Danish IIR (Nielsen, et al., 2016), which uses emission factors derived from burning of wood.

For firework use, emission factors for SO_2, CO, NO_x, TSP, PM and heavy metals were taken from Table 3-14 in Chapter 2.D.3.i, 2.G of the 2019 EMEP/EEA Guidebook (EEA, 2019). It should be noted that the heavy metal emission factors presented in the 2016 EMEP/EEA Guidebook (2016), in particular that for Pb, might not represent the legislation currently in place, which generally bans lead (Pb) in fireworks. For lack of a better emission factor value Iceland estimates the Pb emissions using the available default value, however this might represent a substantial overestimation of Pb emissions from fireworks. All emission factors are presented in Table 4.16.

Table 4.16 Emission factors for use of tobacco and of fireworks, per mass unit of imported goods

	NO_x [kg/t]	NMVOC [kg/t]	SO_2 [kg/t]	NH_3 [kg/t]	TSP [kg/t]	PM_{10} [kg/t]	$PM_{2.5}$ [kg/t]	BC % of PM2.5	CO [kg/t]
Tobacco	1.8	4.84	NA	4.15	27	27	27	0.45 %	55.1
Fireworks	0.26	NA	3.02	NA	109.83	99.92	51.94	NA	7.150
	Dioxin [ng I-TEQ/t]	**B(a)P [g/t]**	**B(b)F [g/t]**	**B(k)F [g/t]**	**IPy [g/t]**				
Tobacco	100	0.111	0.045	0.045	0.045				
Fireworks	NA	NA	NA	NA	NA				

	As [g/t]	Cd [g/t]	Cr [g/t]	Cu [g/t]	Hg [g/t]	Ni [g/t]	Pb [g/t]	Se [g/t]	Zn [g/t]
Tobacco	0.159	0.02	0.152	0.35	0.01	0.03	0.64	0.01	1.61
Fireworks	1.33	1.48	15.6	444	0.057	30	784	NA	260

4.6.8.3 *Recalculations and improvements*

Unit corrections were made for dioxin that applied to the whole timeseries.

4.6.8.4 *Planned improvements*

Heavy metal emission factor for firework use will be reassessed and revised where necessary.

4.7 Food & Beverages Industry (NFR 2H2)

The only other industry production occurring in Iceland is the food and beverages industry. The only pollutant emitted in this industry is NMVOC.

4.7.1 Activity data

Production statistics were obtained by Statistics Iceland for beer, fish, meat and poultry for the whole time series. Statistics for coffee roasting and animal feed were available for the years 2005 to 2017. The numbers for 2018 and 2019 were estimated from historical data. Production statistics were extrapolated for the years 1990 to 2004. Further production of bread, cakes and biscuits was estimated from consumption figures.

4.7.2 Emission factors

Emission factor for NMVOC were taken from the 2019 EMEP/EEA Guidebook (EEA, 2019), and are presented in Table 4.17.

Table 4.17 NMVOC emission factors for the production of various food and beverage products

	NMVOC **kg/t produced**
Meat, fish and poultry	0.3
Cakes, biscuits and breakfast cereals	1
Beer and malt	0.035
Bread (European)	4.5
Coffee roasting	0.55
Animal feed	1

4.7.3 Recalculations and improvements

No recalculations were made for this submission.

4.7.4 Planned improvements

No improvements are currently planned for this subsector.

5 Agriculture (NFR sector 3)

5.1 Overview

Iceland is self-sufficient in all major livestock products, such as meat, milk, and eggs. Traditional livestock production is grassland based and most farm animals are native breeds, i.e. dairy cattle, sheep, horses, and goats, which all are of ancient Nordic origin, one breed for each species. These animals are generally smaller than the breeds common elsewhere in Europe. Beef production, however, is partly through imported breeds, as is most poultry and all pork production. There is not much arable crop production in Iceland, due to a cold climate and short growing season. Cropland in Iceland consists mainly of cultivated hayfields, but barley and rapeseed are grown on limited acreage.

The main pollutant emitted from the agriculture sector is ammonia (NH_3) and the largest source is manure management. NH_3 emissions from the agriculture sector represent 98% of all of Iceland's NH_3 emissions across all sectors. Furthermore, one third of all NMVOC emissions come from this sector. This can be seen in Table 5.1 below.

Table 5.1 Contribution from the agriculture sector to the national total for the year 2019.

	NH_3	NO_x	TSP	PM10	PM2.5	NMVOC	SO_x
National total kt	4.59	22.35	3.15	2.04	1.17	5.45	4.59
Agriculture total kt	4.49	1.12	0.26	0.20	0.037	1.87	4.49
Agriculture part %	98	5.0	8.4	10	3.2	34	98

Emission estimates from the agriculture sector include emission estimates from the following sources:

- Manure Management (NFR 3B)
- Crop Production & Agricultural Soils (NFR 3D)
- Agriculture Other Including Use of Pesticides (NFR 3Df and 3I)

Each of these sources are described in more detail in sections 5.3 to 5.5.

Ammonia, nitric oxide, NMVOC and particulate matter emissions are estimated for animal husbandry and manure management (3B) as well as crop production and agricultural soils (3D).

Dioxin, PAH4, HCB, PCB and Heavy Metals emissions are not applicable, not occurring or not estimated. Summary tables for the emissions from the agriculture sector are shown below in Table 5.2 and Table 5.3.

Buffalos, mules and asses are not farmed in Iceland and therefore these animal categories are "NO" (not occurring) in the Icelandic inventory.

5.1.1 Sectoral trends – POPs

Emissions of POPs from the agriculture sector are either not occurring or not applicable as seen in Table 5.2 below.

Table 5.2 Dioxin, PAH4, HCB and PCB emissions from the agriculture sector, 2019 (NA – Not applicable, NO – Not occurring).

		Dioxin [g I-TEQ]	B(a)P [t]	B(b)F [t]	B(k)F [t]	IPy [t]	PAH4 [t]	HCB [kg]	PCB [kg]
3B	Manure management	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
3D	Crop production and agricultural soils	NA	NA	NA	NA	NA	NA	NA	NA
3F, 3I	Field burning of agricultural wastes and Agriculture other sectors	NO	NO	NO	NO	NO	NO	NO	NO
Agriculture, Total		**NA/NO**	**NA/NO**	**NA/NO**	**NA/NO**	**NA/NO**	**NA/NO**	**NA/NO**	**NA/NO**

5.1.2 Sectoral trends – other pollutants

Ammonia, nitric oxides (expressed as NO_x), NMVOC and particulate matter emissions are estimated for animal husbandry and manure management (3B) as well as crop production and agricultural soils (3D). The estimated emissions are presented below in Table 5.3.

Table 5.3 NO_x, NMVOC, SO_x, NH_3, PM, BC and CO emission estimates from the agriculture sector, 2019 (NA – Not applicable, NE – Not estimated, NO – Not occurring).

		NO_X [kt] NO_2	NMVOC [kt]	SO_X [kt] SO_2	NH_3 [kt]	$PM_{2.5}$ [kt]	PM_{10} [kt]	TSP [kt]	BC [kt]	CO [kt]
3B	Manure management	0.043	1.865	NA/NO	2.133	0.033	0.124	0.183	NA/NO	NA/NO
3D	Crop production and agricultural soils	1.011	6.19E-08	NA	2.289	0.0034	0.080	0.080	NA	NA/NO
3F, 3I	Field burning of agricultural wastes and Agriculture other sectors	NO	NO	NO	NO	NO	NO	NO	NO	NO
Agriculture, Total		**1.053**	**1.865**	**NA/NO**	**4.422**	**0.037**	**0.204**	**0.263**	**NA/NO**	**NA/NO**

Emission trends of estimated pollutants from 1990 - 2019 can be seen in Figure 5.1 - Figure 5.5 and in Table 5.4 and in Table 5.5 for ammonia and PM10, respectively.

NH_3 (Ammonia): The agriculture sector is the biggest contributor of ammonia emissions with 98% of the total emissions in Iceland (Table 5.1). The bulk of the ammonia emissions derive from manure management (48% in 2019) and are directly connected to the livestock numbers. Ammonia applied to soils, from animal manure or directly deposited by grazing animals contribute with 52% to the total emissions in the agriculture sector in 2019. The contribution from synthetic N-fertilizers to the ammonia emission is relatively low with 3% in 2019. Trends in NH_3 emissions from agriculture can be seen in Table 5.4. The trend in NH_3 emissions is relatively steady which is driven by relatively little overall variability in livestock numbers.

Table 5.4 Total NH_3 emissions from the Agriculture sector (kt)

	1990	1995	2000	2005	2010	2015	2018	2019
3B Manure Management - total	2.46	2.12	2.16	2.08	2.13	2.24	2.17	2.13
3B1a Dairy cattle	0.68	0.65	0.60	0.57	0.59	0.64	0.61	0.61
3B2 Sheep	0.94	0.78	0.79	0.77	0.80	0.80	0.73	0.70
3Da1 Inorganic N fertilizer (incl. urea)	0.15	0.14	0.16	0.12	0.13	0.14	0.15	0.13
3Da2 Animal manure applied to soils	1.41	1.28	1.28	1.22	1.27	1.33	1.33	1.31
3Da2b Sewage sludge	NO	NO	NO	NO	NO	1.05E-04	0.0020	6.18E-04
3Da2c Other organic fertilizers applied to soils	NO	NO	NO	NO	0.01	1.30E-02	0.0144	1.49E-02
3Da3 Urine and Dung from grazing animals	0.91	0.89	0.88	0.88	0.91	0.92	0.83	0.84
Total	4.93	4.43	4.47	4.30	4.44	4.65	4.49	4.42

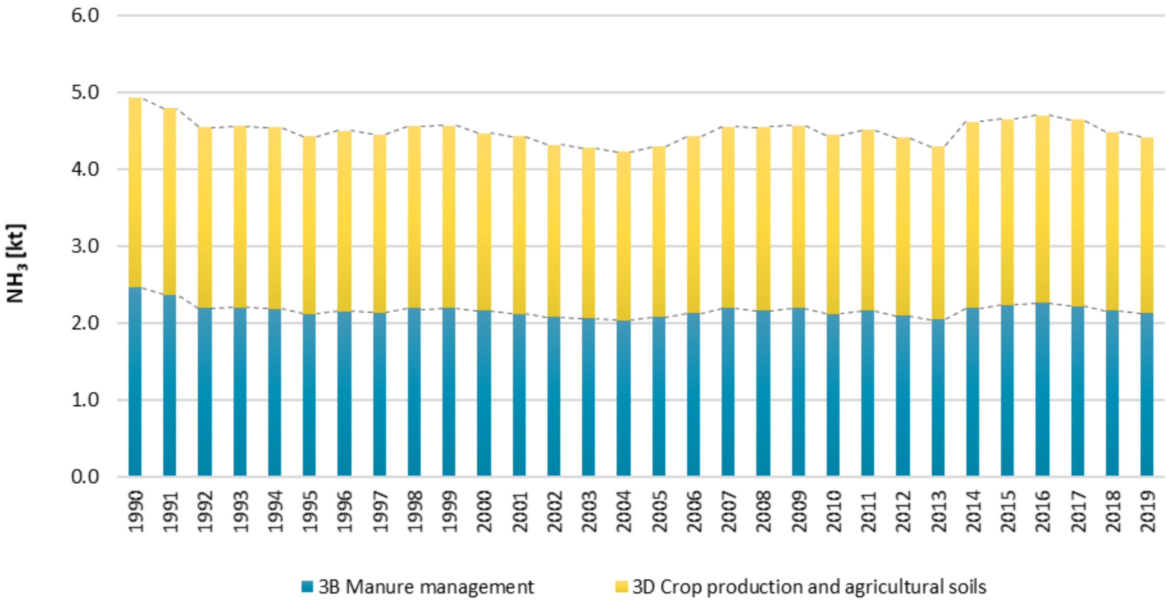

Figure 5.1 NH_3 emissions in the agriculture sector, since 1990.

Particulate matter: PM emissions, in terms of PM_{10} from the Agriculture sector contribute with 10% to the national total emissions (Table 5.1). The emissions arise mainly from Manure Management (61% in 2019) and the biggest emitters therein are poultry. Laying hens and broilers contribute with 35% to the total PM_{10} emissions. Farm level agricultural operations including storage, handling and transport of agricultural products contribute with 39% to the total emissions in 2019 (Table 5.5). Figure 5.2 and Figure 5.3 show little variation in particulate matter ($PM_{2.5}$ and PM_{10}) emissions from the agriculture sector over the time series.

Table 5.5 PM10 emissions from the Agriculture sector (kt)

	1990	1995	2000	2005	2010	2015	2018	2019
3B Manure Management - total	0.109	0.082	0.098	0.110	0.102	0.111	0.124	0.124
3B1a Dairy cattle	0.020	0.019	0.017	0.015	0.015	0.017	0.016	0.016
3B4gi Laying hens	0.026	0.020	0.023	0.018	0.017	0.014	0.028	0.024
3B4gii Broilers	0.031	0.013	0.023	0.042	0.034	0.040	0.044	0.047
3Dc Farm-level agr. operations	0.078	0.078	0.082	0.085	0.086	0.078	0.080	0.080
Total	**0.187**	**0.160**	**0.180**	**0.196**	**0.188**	**0.189**	**0.204**	**0.204**

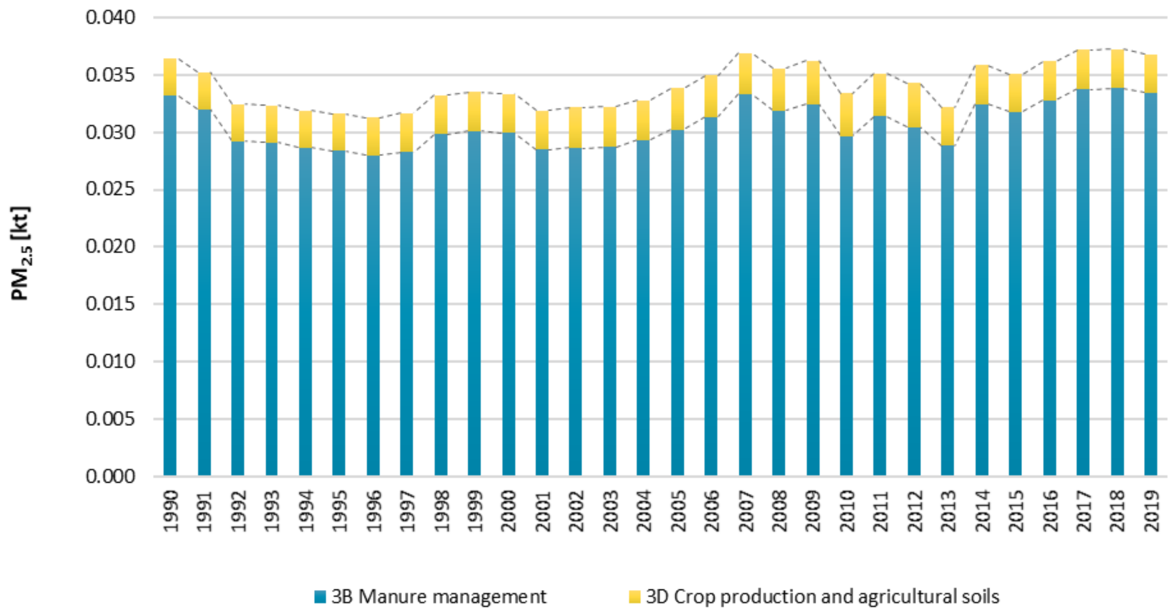

Figure 5.2 $PM_{2.5}$ emissions in the agriculture sector, since 1990.

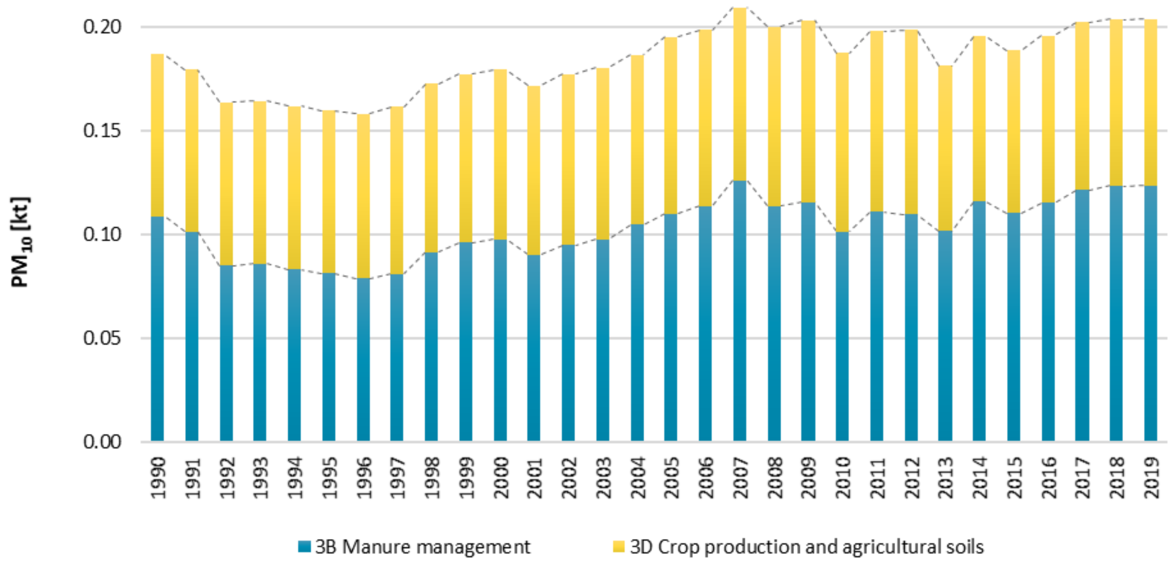

Figure 5.3 PM_{10} emissions in the agriculture sector, since 1990.

NO_x: The agriculture sector is not a main contributor of NO_x and only 5% from the national total is emitted in the agricultural sector (Table 5.1). NO_x emissions occur predominantly from 3D crop production and agricultural soils with peaks in emissions in 2008 and 2014 as can be seen in Figure 5.4.

NMVOC: Trends in NMVOC emissions from agriculture can be seen in Figure 5.5. NMVOC emissions mainly arise from manure management. A significant reduction in emissions occurred between 2001-2003, which was mainly caused by a drop in the population of dairy cows.

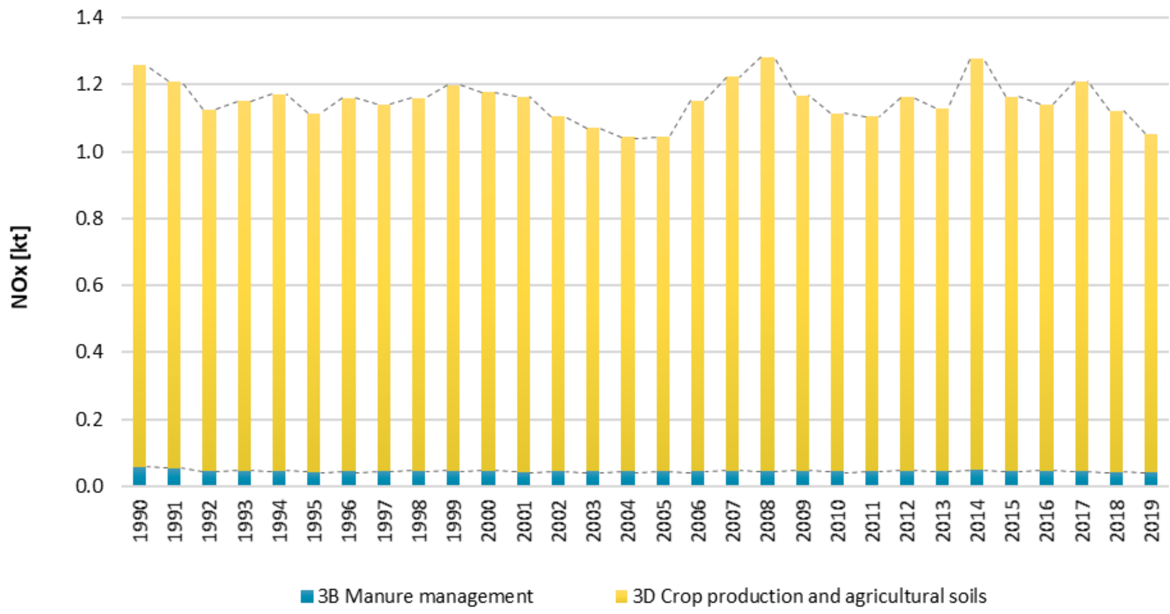

Figure 5.4 NO_x emissions in the agriculture sector, since 1990.

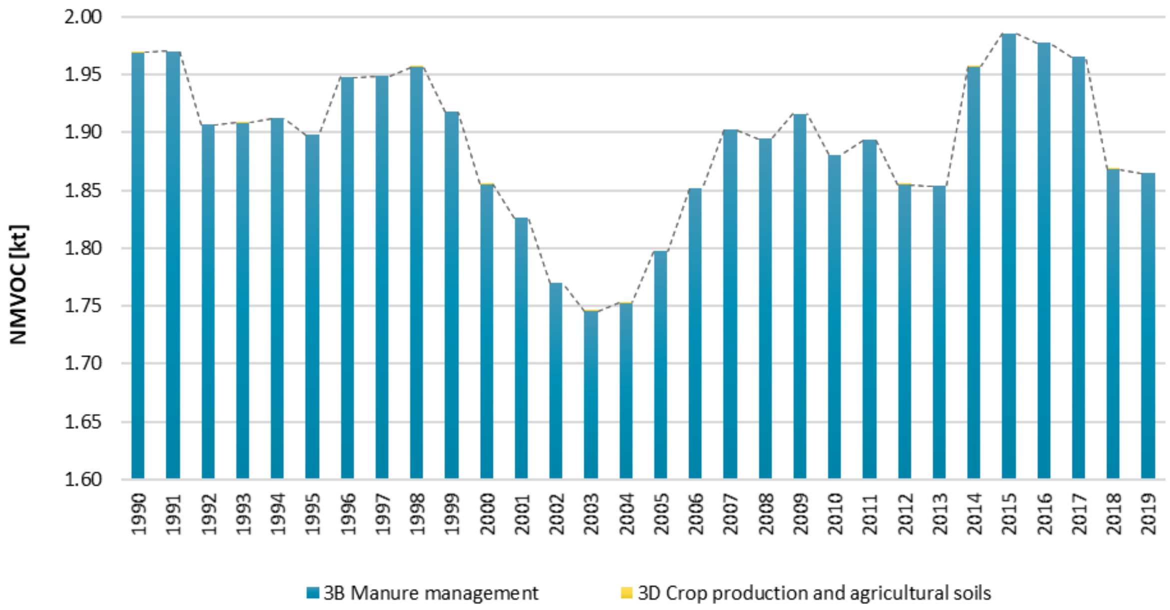

Figure 5.5 NMVOC emissions in the agriculture sector, since 1990.

Heavy metals: According to the 2019 EMEP/EEA Guidebook, heavy metal emissions in the agriculture sector only arise from the burning of crop residues. Since this activity does not occur in Iceland, there are no heavy metal emissions from the agriculture sector.

5.2 General Methodology

The methodology is based on chapters 3B and 3D of the EMEP/EEA air pollutant emission inventory Guidebook (EEA, 2016; EEA, 2019). All equations as well as the majority of emission factors and other parameters stem from the Guidebook chapters correspondingly. For brevity the Guidebook is referred to as the EMEP GB with the corresponding year (2016 or 2019).

Ammonia, nitric oxide, TSP, PM_{10} and $PM_{2.5}$ emissions are estimated with Tier 2 methods. In the absence of higher tiers for 3D, NO and NMVOC emissions are estimated with Tier 1 e.g. horses in solid storage.

For estimating emissions of NH_3 and NO_x in 3B manure management, the flow approach is used as outlined in the EMEP GB. This considers the flow of total ammoniacal N (TAN) through the manure management system. In the EMEP GB this flow is modelled by a series of equations that considers the amount of TAN and losses at all different stages of the manure management process. The set of equations provided by the EMEP GB was applied to more disaggregated livestock categories than the NFR methodology demands as can be seen in Table 5.6. The resulting emissions were then aggregated to the respective NFR categories.

NH_3 and NO_x emissions from grazing animals are part of this N flow approach and are therefore calculated in this context, although they are reported under agricultural soils (3D). Similarly, the manure that is available as organic fertilizer for application to land is determined from the N flow approach and is used as an input term in estimating the NH_3 and NO_x. Activity data, emission factors and other parameters used in these calculations will be discussed in the following chapters.

The Tier 2 methodology for PM emissions consists of the multiplication of livestock populations with default emission factors for slurry and solid manure applied to the time animals spent in housing.

5.3 Manure Management (NFR 3B)

5.3.1 Activity data

Animal population numbers are directly retrieved from the livestock database (www.bustofn.is) of the Ministry of Industry and Innovation (MII) and annual average populations (AAP) calculated according to IPCC Guidelines. Since the data from the annual census of MII represents livestock populations at a certain point in time (during winter) it does not reflect their seasonal changes, e.g. animals with a life spanning only one summer. Also, for some livestock categories, it does not include data on young animals, e.g. fattening pigs. Therefore, the number of animals not included in the census is estimated using information on fertility rates, number of offspring, number of animals slaughtered, etc. The inclusion of young animals leads to livestock populations being considerably higher for some categories than the ones published by the MII or by other public sources such as Statistics Iceland[9]. For the complete methodology of calculating the AAP and a comparison with published livestock numbers please refer to Iceland´s 2020 National Inventory Report on Greenhouse Gas Emissions[10].

Livestock data is available on a more disaggregated level than requested by the reporting requirements as can be seen in Table 5.6. Therefore, the emissions are estimated on a more disaggregated level and then combined to the NFR categories.

[9] https://hagstofa.is/talnaefni/atvinnuvegir/landbunadur/bufe-og-uppskera/
[10] https://unfccc.int/documents/225487

Table 5.6 Livestock as reported in NFR tables and as calculated in the Icelandic Inventory on a more disaggregated level.

NFR code		Disaggregation in Icelandic Inventory
3B1a	**Dairy cattle**	Mature Dairy Cattle
3B1b	**Non-dairy cattle**	Beef Cattle Calves Heifers 18-27 months Steers for producing meat 12-27 months
3B2	**Sheep**	Ewes Young female 12 months Rams Lambs
3B3	**Swine**	Piglets Sows
3B4a	**Buffalo**	NO
3B4d	**Goats**	Goats
3B4e	**Horses**	Horses
3B4f	**Mules and asses**	NO
3B4gi	**Laying hens**	Laying hens
3B4gii	**Broilers**	Broilers Chickens Pullets
3B4giii	**Turkeys**	Turkeys
3B4giv	**Other poultry**	Geese Ducks
3B4h	**Other (fur animals)**	Minks Foxes Rabbits

Table 5.7 shows the AAP of Icelandic livestock categories for selected years since 1990. The most prominent trends in the development of livestock populations since 1990 are a decrease in the dairy cattle and sheep populations and an increase in non-dairy, swine and poultry population.

Table 5.7 Annual average population of livestock according to NFR categorization in Iceland.

		1990	1995	2000	2005	2010	2015	2018	2019
3B1a	**Dairy cattle**	32,249	30,428	27,066	24,488	25,379	27,441	26,477	26,217
3B1b	**Non-dairy cattle**	43,299	42,771	45,078	41,482	47,130	51,335	55,096	54,678
3B2	**Sheep**	860,988	719,530	729,387	710,953	748,431	745,832	658,211	632,937
3B3	**Swine**	29,768	30,746	32,242	39,350	38,032	42,542	40,278	38,314
3B4a	**Buffalo**	NO	NO	NO	NO	NO	NO	NO	NO
3B4d	**Goats**	485	511	548	657	1,015	1,476	2,177	2,148
3B4e	**Horses**	73,867	80,246	75,630	76,629	78,849	79,429	69,702	72,449
3B4f	**Mules and asses**	NO	NO	NO	NO	NO	NO	NO	NO
3B4gi	**Laying hens**	214,975	164,402	193,097	152,217	144,429	119,811	231,881	205,091
3B4gii	**Broilers**	454,305	188,812	338,756	613,643	485,829	586,256	634,554	684,757
3B4giii	**Turkeys**	3,625	3,044	10,908	8,146	8,196	11,810	8,911	11,006
3B4giv	**Other poultry**	5,806	5,270	2,498	1,772	1,347	1,057	851	835
3B4h	**Other (fur animals)**	49,592	37,893	41,431	37,093	39,904	48,038	19,502	14,325

5.3.2 Emission factors and associated parameters

NH_3 and NO Tier 2 emissions depend on the total amounts of nitrogen and total ammoniacal nitrogen (TAN) in manure. Total N is calculated by multiplying livestock AAP with the nitrogen excretion rate per animal. TAN is calculated by multiplying total N with livestock specific TAN fractions provided in the EMEP GB. The nitrogen excretion (Nex) rate per livestock category is calculated using default values from the 2006 IPCC guidelines (Volume 4, chapter 10) (IPCC, 2006) that take animal weight and therefore the smaller size of Icelandic breeds into account. For most animal categories the animal parameters are not changing over the timeseries, and the Nex rate is also constant. Exceptions are mature dairy cattle, calculated by the Tier 2 approach, and those animal categories for which the Nex rate has been calculated on a more disaggregated level and reported as a weighted average in relation to the population data (growing cattle, horses, poultry). The calculation method for the Nex rate for mature dairy cattle follows the Tier 2 methodology from the 2006 IPCC Guidelines (Volume 4, chapter 10) by applying Equation 10.31, Equation 10.32 and Equation 10.33 for dairy cows. Detailed calculations and explanations can be found in the newest edition of the National Inventory Report of Iceland.

Total N and TAN have to be allocated to either slurry or solid manure management. Fractions for slurry and solid manure management are country specific and identical to the ones used in Iceland´s National Inventory Report. The same is valid for the fractions of the year spent inside. Two more parameters used in the calculation of TAN mass flow are the amount of straw used in animal housing and the amount of N contained in it (only for solid manure management). These amounts (for sheep, goats, and horses) are based on 2019 EMEP GB default data (Table 3.7) of hay used per day adjusted for the time periods animals stay inside. As an example, sheep have a default housing period of 30 (Table 3.7 of the GB) but in Iceland it is 200 days. So, the default straw value of 20 kg/yr is multiplied by 200/30 to obtain 133.3 kg/yr. The above-mentioned parameters are summarized in Table 5.8 aTable 5.9 All manure is assumed to be stored before spreading. Emission factors for animal manure either managed as slurry or solid manure during housing, storage, spreading, and grazing are given as shares of TAN by livestock category in the EMEP GB. In the absence of default values for sheep slurry, EMEP GB default values for cattle were used instead.

Table 5.8. Parameters used in calculation in the N-flow calculations.

Livestock sector (NFR)		Mean NEX [kg head^{-1} yr^{-1}] 2019	Prop. TAN (of N)	Fraction slurry	Fraction solid	Housing period [days]	Straw [kg/yr]
3B1a	**Dairy cattle**	95 (87-101)[1]	0.6	1	0	265	
3B1b	**Non-dairy cattle**	45 (29-60)[2]	0.6	1	0	243[6]	
3B2	**Sheep**	17 (7-29)[3]	0.5	0.35	0.65	150	133
3B3	**Swine -fattening pigs**	8	0.7	1	0	365	
3B3	**Swine -Sows**	23	0.7	1	0	365	
3B4d	**Goats**	20	0.5	0	1	200	133
3B4e	**Horses**	19.3 (6-36)[4]	0.6	0	1	51	141
3B4gi	**Laying hens**	1.4	0.7	0	1	365	
3B4gii	**Broilers**	1.6	0.7	0	1	365	
3B4giii	**Turkeys**	1.4	0.7	0	1	365	
3B4giv	**Other poultry**	0.8 (0.2-1.2)[5]	0.7	0	1	365	
3B4h	**Other (fur animals)**	8 (5-12)[6]	0.6	0	1	365	

[1] Range for time period due to increase in milk production; [2] Range given for subcategories (cows and steers used for producing meat, heifers, and young cattle); [3] Range given for subcategories (ewes, rams, animals for replacement, and lambs); [4] Range given for subcategories (mature horses, young horses, and foals); [5] Range given for subcategories (ducks, chickens, pullets and geese); [6] Range given for subcategories (foxes, minks, and rabbits);[6]Average given: non-dairy mature cattle 30 days, heifers 245 days, steers 330 days, calves 365 days.

Table 5.9 Emission factors for NH_3, NO and N_2O used in the N-flow methodology.

Livestock sector (NFR)		MMS	EF NH_3-N Housing	EF NH_3-N storage	EF NH_3-N application	EF NO-N storage	EF N_2O-N storage
3B1a	**Dairy cattle**	slurry	0.24	0.25	0.55	0.0001	0.01
		solid	0.08	0.32	0.68	0.01	0.02
3B1b	**Non-dairy cattle**	slurry	0.24	0.25	0.55	0.0001	0.01
		solid	0.08	0.32	0.68	0.01	0.02
3B2	**Sheep**	slurry				0.0001	0.001
		solid	0.22	0.32	0.9	0.01	0.02
3B3	**Swine -fattening pigs**	slurry	0.27	0.11	0.4	0.0001	0
		solid	0.23	0.29	0.45	0.01	0.01
3B3	**Swine -Sows**	slurry	0.35	0.11	0.29	0.0001	0
		solid	0.24	0.29	0.45	0.01	0.01
3B4d	**Goats**	solid	0.22	0.28	0.9	0.01	0.02
3B4e	**Horses**	solid	0.22	0.35	0.9		
3B4gi	**Laying hens**	slurry	0.41	0.14	0.69	0.0001	
		solid	0.20	0.08	0.45	0.01	0.02
3B4gii	**Broilers**	solid	0.21	0.3	0.38	0.01	0.002
3B4giii	**Turkeys**	solid	0.35	0.24	0.54	0.01	0.002
3B4giv	**Other poultry**	solid	0.24	0.24	0.54	0.01	0.002
3B4h	**Other (fur animals)**	solid	0.27	0.09	*	0.01	0.002

** The emission factor is zero in the Guidebook and Iceland does not have a country specific emission factor.*

NMVOC emissions are calculated using the Tier 1 methodology from the 2019 EMEP/EEA Guidebook, applying the default emission factors from Table 3.4. When default emission factors with silage feeding are available, these are used. All used emission factors are reported in

Table 5.10.

Table 5.10 Emission factors for NMVOC emissions, Tier 1, taken from Table 3.4 to the 2019 EMEP/EEA Guidebook, when available emission factors with silage feeding are used.

Livestock sector (NFR)		EF NMVOC kg $AAP^{-1}a^{-1}$
3B1a	**Dairy cattle**	17.937
3B1b	**Non-dairy cattle**	8.902
3B2	**Sheep**	0.279
3B3	**Swine -fattening pigs**	0.551
3B3	**Swine -Sows**	1.704
3B4d	**Goats**	0.624
3B4e	**Horses**	7.781
3B4gi	**Laying hens**	0.165
3B4gii	**Broilers**	0.108
3B4giii	**Turkeys**	0.489
3B4giv	**Other poultry (ducks and geese)**	0.489
3B4h	**Other (fur animals)**	1.941
3B4h	**Other (rabbits)**	0.059

Tier 2 calculations of particulate matter emissions are based on information on the amount of time livestock spends in housing and the fractions of manure either managed as slurry or as solid manure (see Table 5.8 above). The applied emission factors are reported in Table 5.11 and derive from the 2019 EMEP GB and from the 2013 EMEP GB. In the case of turkeys, the Tier 1 emission factors are applied.

Table 5.11 Emission factors used for calculating the particulate emissions, Tier 2.

Livestock sector (NFR)		MMS	EF TSP kg $AAP^{-1}a^{-1}$	EF PM10 kg $AAP^{-1}a^{-1}$	EF PM2.5 kg $AAP^{-1}a^{-1}$	Source
3B1a	**Dairy cattle**	slurry solid	1.81 0.94	0.83 0.43	0. 54 0.28	Table A1.7 2019 EMEP GB
3B1b	**Beef Cattle**[1]	slurry solid	0.69 0.52	0.32 0.24	0.21 0.16	Table A1.7 2019 EMEP GB
3B1b	**Calves**	slurry solid	0.34 0.35	0.15 0.16	0.1 0.1	Table A1.7 2019 EMEP GB
3B2	**Sheep**	slurry solid	/ 0.14	/ 0.056	/ 0.017	Table A1.7 2019 EMEP GB
3B3	**Swine -fattening pigs**	slurry solid	0.7 0.83	0.31 0.37	0.06 0.07	Table A3-4 2013 EMEP GB
3B3	**Swine -Sows**	slurry solid	1.36 1.77	0.61 0.8	0.11 0.14	Table A3-4 2013 EMEP GB
3B4d	**Goats**	solid	0.139	0.056	0.017	Table A1.7 2019 EMEP GB
3B4e	**Horses**	solid	0.48	0.22	0.14	Table A1.7 2019 EMEP GB
3B4gi	**Laying hens**	solid	0.119	0.119	0.023	Table A3-4 2013 EMEP GB
3B4gii	**Broilers**	solid	0.069	0.069	0.009	Table A3-4 2013 EMEP GB
3B4giii	**Turkeys**	solid	0.52	0.52	0.07	Table 3.3 2013 EMEP GB
3B4giv	**Other poultry ducks**	solid	0.14	0.14	0.018	Table A1.7 2019 EMEP GB
3B4giv	**Other poultry geese**	solid	0.24	0.24	0.032	Table A1.7 2019 EMEP GB
3B4h	**Other (fur animals)**	solid	0.018	0.0081	0.004	Table A1.7 2019 EMEP GB

[1] Beef cattle and calves are calculated separately and aggregated in the category 3B1b Non-Dairy Cattle

5.3.3 Emissions

NH_3 emissions reported under 3B manure management exclude emissions from manure deposited on fields by grazing animals, which are reported under 3D agricultural soils. Total ammonia (NH_3) emissions from manure management have decreased slightly, from 2.46 kt in 1990 to 2.13 kt in 2019. This decrease is mostly due to decreasing emissions from sheep. Sheep account for roughly a third of total NH_3 emissions and cattle for approximately half. Around a third of emissions occur during livestock housing, a quarter during manure storage and 2/5 after spreading of manure. The described trends and fractions can be seen in Figure 5.6.

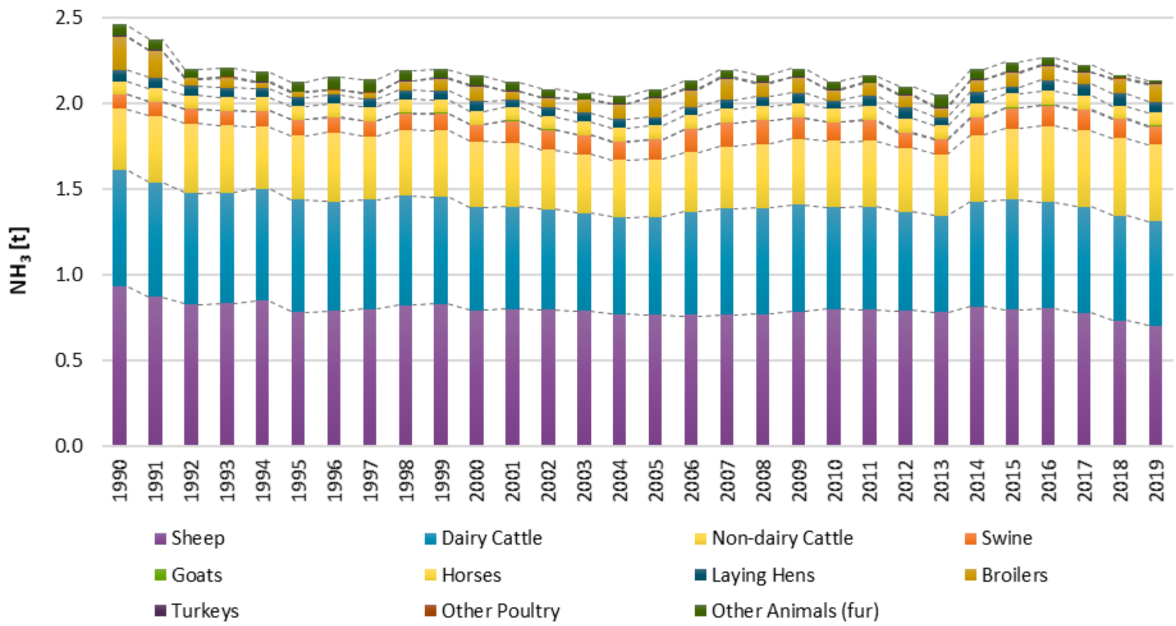

Figure 5.6 Ammonia (NH_3) emissions from animal husbandry and manure management in tonnes.

Nitric oxide emissions, in contrast to ammonia emissions, occur only during storage. They have been decreasing from 59 tonnes in 1990 to 43 tonnes in 2019, or by 28%. This decrease is mainly due to the decrease in sheep population already mentioned above. NO emissions from sheep constitute 66% of total NO emissions from livestock. NO emissions from poultry amount to 24% of total NO emissions. Other livestock categories with considerable shares are fur animals (2%) and horses (5%). Cattle and swine emissions constitute negligible amounts due to the fact that their manure is stored as slurry, which gives rise to considerably lower emissions than solid manure management systems.

NMVOC emissions in 1990 were 1.97 kt for manure management and have decreased slightly since then and are now 1.86 kt. The largest source of NMVOC emissions are cattle 51%, horses 30% and sheep 9%.

PM_{10} emissions increased from 109 tonnes in 1990 to 124 tonnes in 2019 (14%). Emissions were highest in 2007 at 126 tonnes. Both the general increasing trend since 1990 and the decrease since 2007 are almost exclusively due to variations in the broiler population, which quintupled between 1996 and 2007. Other livestock categories that emit substantial shares of total PM_{10} emissions from animal husbandry (besides broilers with 38%) are laying hens (20%), cattle (19%), swine (10%) and sheep (7%) in 2019.

Over the times series, 1990-2019, total $PM_{2.5}$ emissions varied between minimum 28 t and 34 t show no clear trend. In the latest year, emissions from cattle constituted 45% of total emissions followed by broilers (18%) and laying hens (14%).

TSP emissions have been increasing from 172 t in 1990 to 183 t in 2019, the increase is mostly due to poultry and swine. Biggest contributors are cattle (28%) followed by broilers (26%), swine (16%) and laying hens (13%).

5.3.4 Recalculations and improvements

For the current 2021 submission, parameters, e.g. emission factors used in the N-flow methodology were updated from the 2016 EMEP/ EEA Air Pollution Inventory Guidebook to its newest 2019 edition. In particular, emission factors for the NH_3-N emissions in the different stages of manure management systems (housing, storage, application and grazing) and for the manure types slurry and solid changed for some animal categories. Some emission factors increased, some decreased, and some remained unchanged. As the N-flow methodology is a mass balance, changes in the emission factors for NH_3 also affect emissions of NO_x. The TAN content of manure is increased or decreased due to higher or lower NH_3 emissions upstream in the process, and therefore the NO_x emissions increase or decrease downstream even though the emission factor has not been changed.

In addition, the gross energy (GE) for mature dairy cattle was changed for the years 2013-2017 to avoid a step change between 2017 and 2018. The previous data collection of feed digestibility parameters referred to the year 2012 and the new data to the year 2018. This recalculation affects the Nex rate and therefore all emissions connected to the Nex rate of mature dairy cattle.

Regarding NMVOCs the emission factor for rabbits as per 2019 EMEP EEA Guidebook was used for the whole time series while in the past submission these emissions were calculated using the emission factor of fur animals.

5.3.5 Planned Improvements

As suggested by the 2020 Step 3 review, it is planned to change from Tier 1 to Tier 2 calculation for NMVOC emissions. As a first step, a detailed investigation will be made about which data are easily available in Iceland and which data need to be collected specifically for this task.

5.4 Crop Production & Agricultural Soils (NFR 3D)

5.4.1 Activity data

Activity data for NH_3, NO and NMVOC emissions consists of the amount of fertilizer nitrogen applied to agricultural soils (Table 5.12). For NH_3 this amount is divided into type of fertilizer N. The total amount of N in fertilizer is provided in the annual reports of the IFVA[11]. No data exists that provides information on the types of N fertilizer. However, it is known that

- N in fertilizer applied in Iceland is mainly contained in calcium ammonium nitrate
- the two other fertilizer types of importance are ammonium nitrate and other NK
- less than one per cent of nitrogen is contained in urea (Bjarnason, written communication)

Calcium ammonium nitrate, ammonium nitrate and other NK have identical EF. Therefore, their share of total fertilizer was set to 99%. Urea has a considerably higher EF. Its share was set to one per cent.

Table 5.12 Total amount of synthetic N-fertilizers applied to agricultural soils

	1990	1995	2000	2005	2010	2015	2018	2019
N content in inorganic N fertilizer, kt N	12.47	11.20	12.68	9.78	10.88	11.65	11.74	10.38

Activity data for particulate matter emissions consists of the areas of crops cultivated as can be seen in Table 5.13. The total amount of cropland is recorded in the Icelandic geographic land use database (IGLUD), which is maintained by the Soil Conservation Service of Iceland. Data regarding the area of barley fields comes from the Farmers Association of Iceland[12] and Bragason (written communication). The area of grass fields is calculated by subtracting the area of barley fields from the total cropland area. Barley fields are cultivated and harvested once a year and the produce is cleaned and dried. Grass fields are cultivated about once every 10 years and hay is cut twice per year on average (Brynjólfsson, written communication).

Table 5.13 Areas of cropland in Iceland, distinguished by barley cultivation and grassland for haymaking.

	1990	1995	2000	2005	2010	2015	2018	2019
Area Barley cultivation (ha)	200	500	2,000	3,636	4,295	1,558	2,473	2,517
Area Grass cultivation (ha)	147,800	146,200	143,400	140,464	138,505	139,942	138,247	137,943

5.4.2 Emission factors

NH_3 emission factors were taken from Table 3.2 in the 2019 EMEP/EEA Guidebook. 2019. These emission factors depend on the mean spring air temperature, i.e. the mean temperature of the three-month period following the day when accumulated day degrees since 1 January have reached 400 °C. According to this definition the mean spring temperature in Iceland is about 9 °C, therefore the emission factors for cool climate and normal pH are applied as can be seen in Table 5.14.

[11] https://www.mast.is/is/um-mast/utgefid-efni/skyrslur
[12] http://www.bondi.is/

Table 5.14 Emission factors for NH_3 emissions from fertilizers for cool climate and normal pH

	EF NH_3 g [NH_3/ kg N applied]
Ammonium sulphate	90
Ammonium nitrate	15
Calcium ammonium nitrate	8
Anhydrous ammonia	19
Urea	155
Ammonium phosphates	50
Other NK and NPK	33 (average between NK mixtures and NPK mixtures)

The emission factors for NO, NMVOC and NH3 are taken from the 2019 EMEP/EEA Guidebook and are reported in Table 5.15 with the respective sources and NFR codes.

Table 5.15 Emission factors for NO, NMVOC and NH3 in NFR category 3D.

	NFR code	EF	Unit	Source
NH_3 from sewage sludge	**3Da2b**	0.13	kg NH_3 (kg N applied)$^{-1}$	Annex 1 2019 EMEP GB
NH_3 from other organic wastes	**3Da2c**	0.08	kg NH_3 (kg N applied)$^{-1}$	Table 3.1 2019 EMEP GB
NO from N applied in fertilizer, manure, and excreta	**3Da1, 3Da2a, 3Da3**	0.40	kg NO_2 (kg fertilizer and manure N applied)$^{-1}$	Table 3.1 2019 EMEP GB
NO from sewage sludge	**3Da2b**	0.04	kg NO_2 (kg sewage sludge)$^{-1}$	Annex 2 A2.3 2019 EMEP GB
NO from other organic wastes	**3Da2c**	0.04	kg NO_2 (kg organic waste)$^{-1}$	Table 3.1 2019 EMEP GB
NMVOC from standing crops	**3De**	0.86	kg ha^{-1}	Table 3.1 2019 EMEP GB

PM_{10} and $PM_{2.5}$ emission factors for barley and grass were taken from Tables 3.5 and 3.7 of the EMEP GB 2019 and are reported in Table 5.16.

Table 5.16 Emission factors for agricultural crop operations, PM_{10} and $PM_{2.5}$ in wet climate conditions from 2019 EMEP GB

	Crop	Soil Cultivation	Harvesting	Cleaning	Drying
PM_{10} [kg/ha]	**Barley**	0.25	2.3	0.16	0.43
PM_{10} [kg/ha]	**Grass**	0.025	0.025	0	0
$PM_{2.5}$ [kg/ha]	**Barley**	0.015	0.016	0.008	0.129
$PM_{2.5}$ [kg/ha]	**Grass**	0.015	0.01	0	0

5.4.3 Emissions

Total NH_3 emissions for crop production and agricultural soils varied between 2.47 and 2.29kilotonnes between 1990 and 2019. In 2019 57% of emissions originate from animal manure applied to soils, 37% originate from manure deposited by livestock during grazing and 6% from inorganic N-fertilizers. Total emissions do not show any discernible trend over time, primarily because the size of (and thus emissions from) the sheep population decreases with time, while the horse population increases.

The emission development of NO and NMVOC are linearly dependent on the application of fertilizer and therefore show the same development with a peak in 2008 with 0.6 kilotonnes and a decline since then. In 2019 NO emissions amounted to 1 kilotonnes and NMVOC emissions from crop production and agricultural soils were 62 grams.

In the current submission, other organic fertilizers in the form of bone meal and compost were added to the inventory. Research showed that the organic fertilizers have been applied since 2009 especially for land reclamation purposes carried out by the Soil Conservation Service of Iceland; the resulting NH_3 are between 5 and 16 tonnes over this period and the NO emissions are 2 between 2 and 8 tonnes.

PM_{10} emissions vary between 78 tonnes in 1990 and 80 tonnes in 2019. $PM_{2.5}$ emissions are fairly steady over the time series and were 3.2 tonnes in 1990 and 3.4 tonnes in 2019.

5.4.4 Recalculations and improvements

The update of parameters used in the N-flow methodology from the 2016 to the 2019 EMEP EEA Guidebook affects also subcategories in 3D, Agricultural Soils. This can be seen in 3D2a Animal manure applied to soils and in 3Da3 Urine and Dung deposited from grazing animals for NO_x and NH_3. In the category 3Da2b Sewage sludge applied to soils and update of activity data for the whole time series lead to recalculations for NO_x and NH_3.

5.4.5 Planned Improvements

There are no planned improvements in this category.

5.5 Agriculture Other Including Use of Pesticides (NFR 3Df and 3I)

The POP-protocol focuses on a list of 16 substances, 11 of which are pesticides. A number of pesticides, however, had already been banned in Iceland in 1996 in order to conform to EU legislation (Iceland is part of the European Economic Area). The only pesticide of the ones listed in chapter 3Df of the EMEP GB not banned until 2009 is lindane, a gamma-Hexachlorocyclohexane (HCH). The last recorded sale of lindane took place in 1992 when 1 kg was sold. In 1990 and 1991, 2 and 16.2 kg were sold, respectively. It is assumed that the lindane sold was applied during the same year. An EF of 0.5 as listed in Table 3.1 of the chapter 3Df of the 2013 edition of the EMEP/EEA Guidebook was applied to these values resulting in HCH emissions of 1, 8, 1, and 0.5 kg for the years 1990-1992. HCH is no longer included in the reporting obligations which explains the use of an emission factor from the 2013 Guidebook. Table 5.17 gives an overview of the use of pesticides in Iceland.

Table 5.17 Pesticide use and regulation in Iceland.

Pesticide	Last recorded use	Year of ban
Aldrin	1975	1996
Chlordane	No recorded use	1996
DDT	1975	1996
Dieldrin	No recorded use	1996
Endrin	No recorded use	1996
Heptachlor	1975	1996
Hexachlorobenzene (HCB)	No recorded use	1996
Mirex	No recorded use	1998
Toxaphene	No recorded use	1998
Pentachlorophenol (PCP)	No recorded use	1998
Lindane	1992	2009

6 Waste (NFR sector 5)

6.1 Overview

During most of the 20th century solid waste disposal sites (SWDS) in Iceland were numerous, small and located close to the locations of waste generation so that the waste did not have to be transported far for disposal. In 1967 the waste disposal site in Gufunes started operating and most of the waste of the capital´s population was landfilled there. Prior to that year, the waste of the capital area was landfilled in smaller SWDS.

Until the 1970s the most common form of waste management outside the capital area was open burning of waste. In some communities, waste burning was complemented with landfills for bulky waste and ash. The existing landfill sites did not have to meet specific requirements regarding location, management and aftercare before 1990 and were often just holes in the ground. Some communities also disposed of their waste by dumping it into the sea. Akureyri and Selfoss, two of the biggest communities outside the capital area opened municipal SWDS in the 1970s and 1980s.

Before 1990 three waste incinerators were opened in Keflavík, Húsavík and Ísafjörður. In total they burned around 15,000 tonnes of waste annually. They operated at low or varying temperatures and the energy produced was not recovered. Waste incineration in Iceland as such started in 1993 with the opening of the incineration plant in Vestmannaeyjar, an archipelago to the south of Iceland. In 2004 the incineration plant Kalka located at the southwest part of Iceland opened and this facility is currently the only waste incineration plant in Iceland. Open burning of waste was banned in 1999. The last place to burn waste openly was the island of Grímsey which stopped doing so by the end of 2010.

Recycling and biological treatment of waste started on a larger scale in the beginning of the 1990s. Their share of total waste management has increased rapidly since then.

Reliable data about waste composition does not exist until recent years. In 1991 the waste management company Sorpa ltd. started serving the capital area and has gathered data about the waste composition of landfilled waste since 1999. For the last few years the waste sector has had to report data about amounts and kinds of waste landfilled, incinerated, and recycled.

The special treatment of hazardous waste did not start until the 1990s, i.e. hazardous waste was landfilled or burned like non-hazardous waste. Special treatment started with the reusing of waste as an energy source. In 1996 the Hazardous waste committee (Spilliefnanefnd) was founded and started a collection scheme for hazardous waste. The collection scheme included fees on hazardous substances that were refunded if the substances were delivered to hazardous waste collection points. Hazardous substances collected included oil products, organic solvents, halogenated compounds, isocyanates, oil-based paints, printer ink, batteries, car batteries, preservatives, refrigerants, and more. After collection, these substances were destroyed, recycled or exported for further treatment. The Hazardous waste committee was succeeded by the Icelandic recycling fund in late 2002.

Clinical waste has been incinerated in incinerators either at hospitals or at waste incineration plants. Kalka is currently the only incineration plant in Iceland.

The trend in waste management practices has been toward managed SWDS as municipalities have increasingly cooperated with each other on running waste collection schemes and operating joint landfill sites. This development has resulted in larger SWDS and enabled the shutdown of a number of small sites. Currently a large majority of landfilled waste is being disposed of in managed SWDS. Recycling of waste has increased due to efforts made by the government, local municipalities, recovery companies and others. Composting started in the mid-1990s and has increased since then.

Emission estimates from the waste sector include emissions from the following sources:

- Solid waste disposal on land (NFR 5A)
- Biological treatment of solid waste (NFR 5B)
- Waste incineration without energy recovery (NFR 5C)
- Wastewater treatment and discharge (NFR 5D)
- Other waste (NFR 5E)

Each of these sources is described in more detail in sections 6.3 to 6.8. Emission estimates for waste incineration without energy recovery are included in this section, while emission estimates for waste incineration with energy recovery are reported under sector 1A.

6.1.1 Sectoral trends – POP's

A summary of emission estimates for the waste sector is provided in Table 6.1 for POP´s pollutants.

Table 6.1 Overview of POPs emissions in 2019 (NA – Not applicable, NE – Not estimated).

		Dioxin [g I-TEQ]	B(a)P [t]	B(b)F [t]	B(k)F [t]	IPy [t]	PAH4 [t]	HCB [kg]	PCB [kg]
5A	**Solid waste disposal on land**	NA	NA	NA	NA	NA	NA	NA	NA
5B1	**Composting**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
5C	**Waste incineration**	0.112	0.0040	0.0079	0.010	0.0022	0.024	0.045	0.0084
5D	**Wastewater handling**	NA	NA	NA	NA	NA	NA	NA	NA
5E	**Other waste**	0.210	9.05E-04	0.0017	0.0012	0.0012	0.0050	NE	NE
Waste, Total		**0.322**	**0.0049**	**0.010**	**0.011**	**0.0034**	**0.029**	**0.045**	**0.0084**

Trends in POP's emission estimates are shown in Figure 6.1 through Figure 6.4 by subsector.

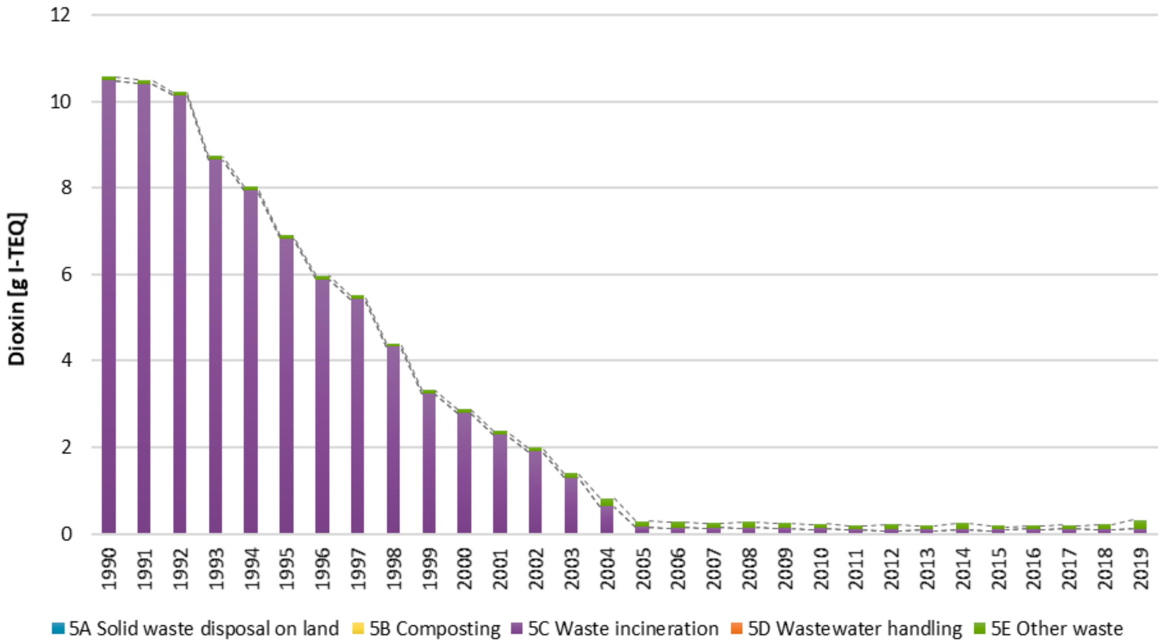

Figure 6.1 Dioxin emissions from the waste sector, since 1990.

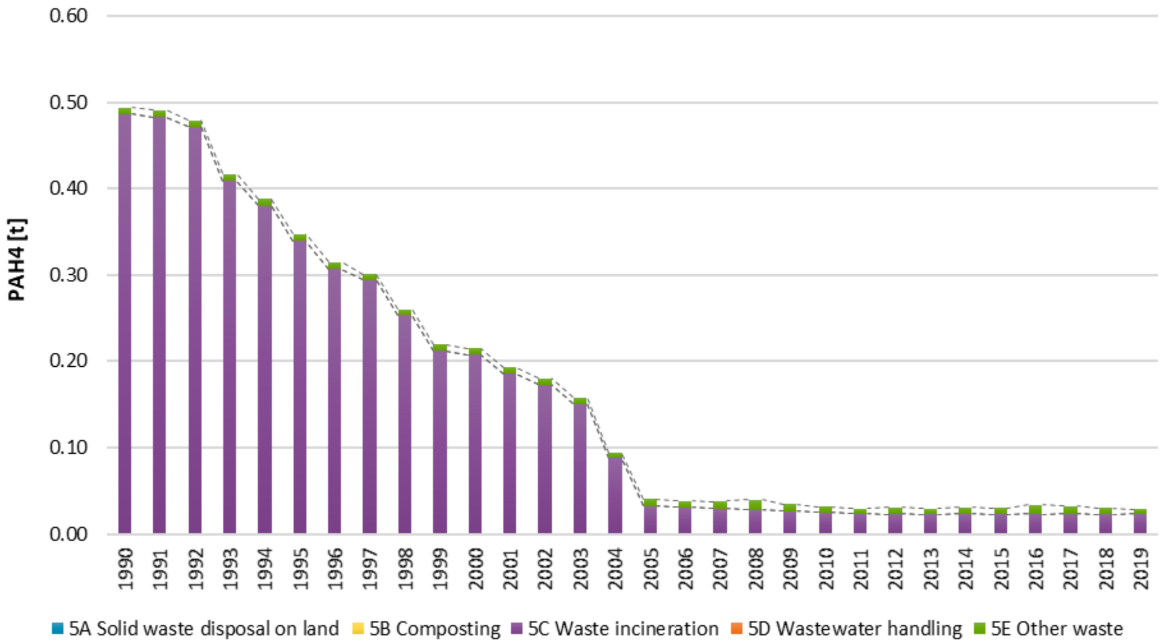

Figure 6.2 PAH4 emissions from the waste sector, since 1990.

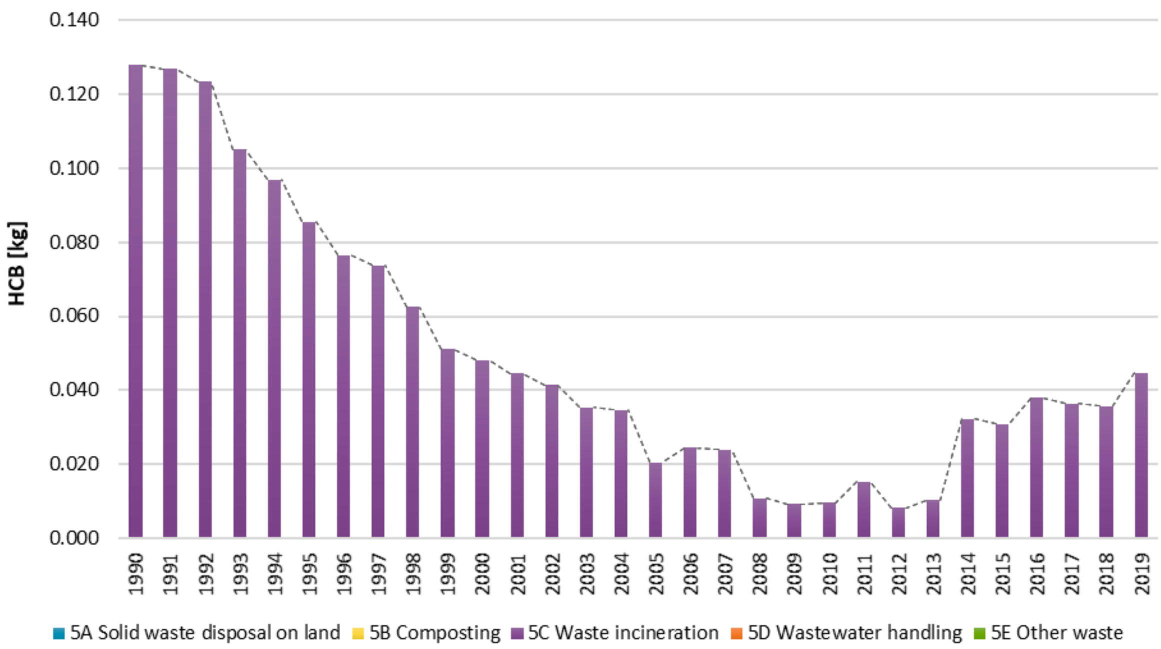

Figure 6.3 HCB emissions from the waste sector, since 1990.

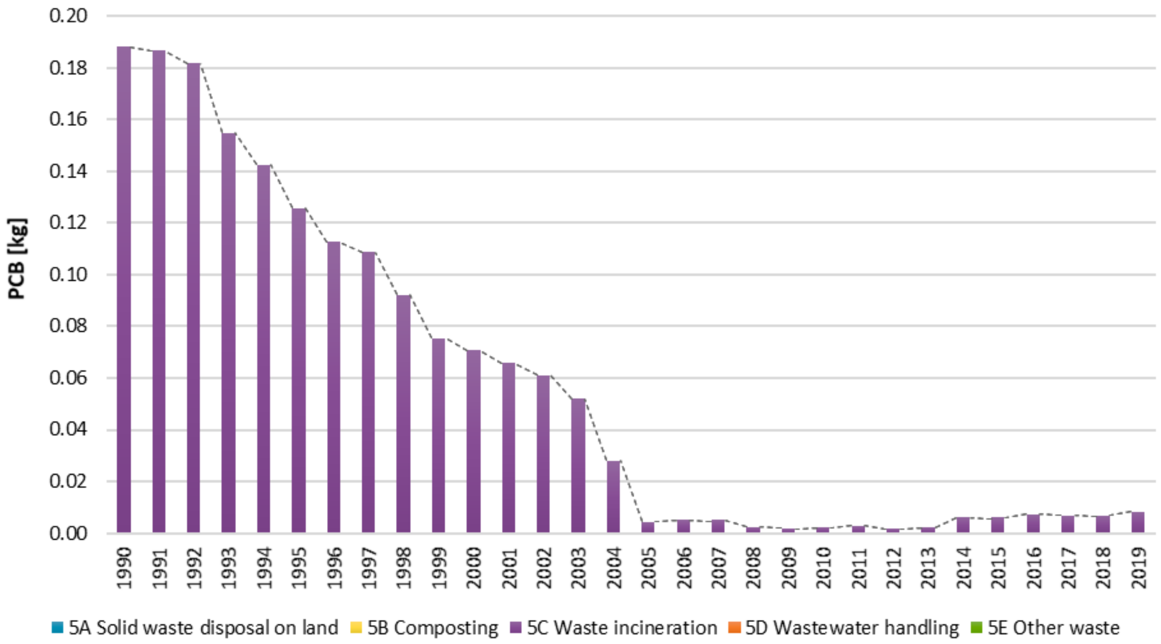

Figure 6.4 PCB emissions from the waste sector, since 1990.

In 2004 the incineration plant Kalka was opened which rapidly moved management practices away from open burning and into incineration with abatement technologies. Kalka has been the only incineration plant operating in Iceland since 2014 and no municipal solid waste has gone to open burning since 2011. This causes the significant reduction in HCB and PCP emissions between 2003-2004 and onwards.

6.1.2 Sectoral trends – Other emissions

A summary of emission estimates for other pollutants than POP's is provided in Table 6.2 and Table 6.3 for the year 2019.

Table 6.2 Overview of NO_x, NMVOC, SO_x, NH_3, PM and CO emissions from the waste sector in 2019.

		NO_X [kt] NO_2	NMVOC [kt]	SO_X [kt] SO_2	NH_3 [kt]	$PM_{2.5}$ [kt]	PM_{10} [kt]	TSP [kt]	BC [kt]	CO [kt]
5A	**Solid waste disposal on land**	NA	0.341	NA	NE	7.E-06	5.E-05	1.E-04	NA	NA
5B1	**Composting**	NE/NO	NE/NO	NE/NO	0.0057	NE/NO	NE/NO	NE/NO	NE/NO	0.013
5C	**Waste incineration**	0.027	0.017	0.0021	0.0023	0.0072	0.0078	0.0080	0.0030	0.096
5D	**Wastewater handling**	NA	NE	NA	NE	NA	NA	NA	NA	NA
5E	**Other waste**	0.0013	0.006	0.019	NA	0.0052	0.0052	0.0052	NE	0.019
Waste, Total		**0.029**	**0.363**	**0.022**	**0.008**	**0.012**	**0.013**	**0.013**	**0.0030**	**0.128**

Table 6.3 Overview of heavy metals emissions from the waste sector in 2019.

		Pb [t]	Cd [t]	Hg [t]	As [t]	Cr [t]	Cu [t]	Ni [t]	Se [t]	Zn [t]
5A	**Solid waste disposal on land**	NA	NA	NA	NA	NA	NA	NA	NA	NA
5B1	**Composting**	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO	NA/NO
5C	**Waste incineration**	0.0044	4.5E-04	0.0077	8.90E-04	3.22E-04	5.93E-04	7.27E-04	3.44E-04	0.0304
5D	**Wastewater handling**	NA	NA	NA	NA	NA	NA	NA	NA	NA
5E	**Other waste**	0.024	7.37E-05	2.42E-05	4.64E-05	1.48E-04	8.72E-04	8.15E-05	NE	0.093
Waste, Total		**0.028**	**5.21E-04**	**7.8E-03**	**9.4E-04**	**4.7E-04**	**0.0015**	**8.1E-04**	**3.4E-04**	**0.124**

6.2 General Methodology

The methodology is mainly based on EMEP air pollutant emission inventory Guidebook (EMEP, 2019). Emissions estimates are calculated by multiplying relevant activity data by source with pollutant specific emissions factors. Emissions factors are taken from the Emissions Inventory Guidebook (EEA, 2019), the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005), Annual Danish Informative Inventory Report to the UNECE (National Environmental Research Institute, 2011) and measurements at incineration plants.

The activity data used for the emission estimates is mainly based on treated waste in Iceland which is reported annually to the EA. This follows an exclusion of waste being treated outside of Iceland and its associated emissions. In addition to data on treated waste in Iceland, activity data for accidental fires, cremation and bonfires is used for estimating emissions from these sources.

6.3 Sector specific QA/QC

The QC activities include general methods such as accuracy checks on data acquisition and calculations as well as the use of approved standardized procedures for emission calculations, archiving information and reporting. Further information can be found in Chapter 1.6 on Quality Assurance and & Quality Control.

6.4 Solid waste disposal (NFR 5A)

For most of the 20th century solid waste disposal sites (SWDS) in Iceland were numerous, small and located close to the locations of waste generation so that the waste did not have to be transported far for disposal. In 1967 the waste disposal site in Gufunes started operating and most of the waste generated in the capital area was landfilled there. Prior to that year, the waste of the capital area was landfilled in smaller SWDS.

The trend in waste management practices has been toward managed SWDS as municipalities have increasingly cooperated with each other on running waste collection schemes and operating joint landfill sites. This development has resulted in larger SWDS and enabled the shutdown of a number of small sites. Currently a large majority of landfilled waste is being disposed of in managed SWDS. Recycling of waste has increased due to efforts made by the government, local municipalities, recovery companies, and others. Composting started in the mid-1990s and has increased since then.

6.4.1 Methodology

Tier 1 approach of the 2019 EMEP/EEA guidelines is used for the emission estimates for all estimated pollutants. Thus, the total mass of waste disposed of in all landfill sites in Iceland is multiplied with its pollutant specific emission factor.

6.4.2 Activity data

Total mass of waste landfilled in Iceland is used for the emission estimates. Further information on the annual mass of waste landfilled and the source of data can be found in Iceland's National Inventory Report on Greenhouse Gas Emissions.

6.4.3 Emission factors

Emission factors from the tier 1 approach of the 2019 EMEP/EEA Guidebook are used for estimating emissions from solid waste disposal and are presented in Table 6.4. Emission factors are assumed constant for all the years in the calculations. This section discusses the emission estimates from solid waste disposal on land and covers the emissions of NMVOCs, TSP, PM_{10} and $PM_{2.5.}$

The 2019 EMEP/EEA Guidebook mentions the possibility of small quantities of NO_x, NH_3 and CO being emitted from this activity. However, no emission factors are provided in the Guidebook and these emissions have not been estimated in Iceland. Other pollutants are considered not applicable in accordance with that same table.

Table 6.4 Emission factors used in solid waste disposal (NFR 5A).

		NMVOC [kg/t waste]	TSP [g/t waste]	PM10 [g/t waste]	$PM_{2.5}$ [g/t waste]
5A	**Solid waste disposal**	1.56	0.463	0.219	0.033

6.4.4 Emissions

From 1990 the emissions from 5A were increasing in proportion with increased amount of landfilled waste. This amount peaked in 2005, and therefor also the emissions. From 2006 emissions decreased but from 2013 they have slowly been increasing again.

Table 6.5 Emissions from 5A Solid Waste Disposal

	1990	1995	2000	2005	2010	2015	2018	2019
NMVOC [kt]	0.53	0.49	0.53	0.54	0.26	0.31	0.34	0.34
TSP [kt]	1.6.E-04	1.5.E-04	1.6.E-04	1.6.E-04	7.6.E-05	9.1.E-05	1.0.E-04	1.0.E-04
PM10 [kt]	7.5.E-05	6.9.E-05	7.5.E-05	7.6.E-05	3.6.E-05	4.3.E-05	4.7.E-05	4.8.E-05
PM2.5 [kt]	1.1.E-05	1.0.E-05	1.1.E-05	1.1.E-05	5.4.E-06	6.5.E-06	7.1.E-06	7.2.E-06

6.4.5 Recalculations and improvements

No recalculations were done for solid waste disposal (5A) for this submission.

6.4.6 Planned improvements

For future submissions it is planned to update the uncertainty analysis for the waste sector and add further information on the methodological information regarding solid waste disposal by e.g. adding details on sources of data.

6.5 Biological treatment of solid waste (NFR 5B)

6.5.1 Composting (NFR 5B1)

6.5.1.1 *Methodology*

Recycling and biological treatment of waste started on a larger scale in the middle of the 1990s. Their share of total waste management increased rapidly since then. Emission estimates are calculated by multiplying waste amounts with relevant pollutant specific emission factors.

6.5.1.2 *Activity data*

Compost production as a means of waste treatment started in Iceland in 1995 and the EA receives the amount of waste going to compost production facilities annually. Reliable data about waste composition does not exist until recent years. In 1991 the waste management company Sorpa ltd. started serving the capital area and has gathered data about the waste composition of landfilled waste since 1999. For the last few years the waste sector has had to report data about amounts and kinds of waste landfilled, incinerated, and recycled.

6.5.1.3 *Emission factors*

For composting, tier 2 emission factors from the 2019 EMEP/EEA Guidebook are used for estimating NH_3 and CO emissions. Emission factors for other pollutants are not provided in the 2019 EMEP/EEA Guidebook. The emission factors are presented Table 6.4. and are assumed constant for all the years in the calculations.

Table 6.6 Emission factors used in composting (NFR 5B1).

		NH_3 [kg/t waste]	CO [kg/t waste]
5B1	**Composting**	0.24	0.56

6.5.1.4 *Emissions*

Emissions from composting have been increasing in proportion to the amount of waste composted.

Table 6.7 Emissions from 5B1 Composting

	1990	1995	2000	2005	2010	2015	2018	2019
NH_3 [kt]	NO	4.8.E-04	4.8.E-04	0.0012	0.0037	0.0051	0.0058	0.0057
CO [kt]	NO	0.0011	0.0011	0.0028	0.0085	0.0119	0.0134	0.0134

6.5.1.5 *Recalculations and improvements*

No recalculations were done for composting (5B1) for this submission.

6.5.1.6 *Planned improvements*

No planned improvements for this sector.

6.5.2 Anaerobic digestion at biogas facilities (NFR 5B2)

Anaerobic digestion at biogas facilities is currently a non-occurring activity in Iceland.

6.6 Waste incineration and open burning (NFR 5C)

This section discusses the emission estimates from burning of waste which falls under the subcategories; Waste incineration (NFR 5C1) and Open burning of waste (NFR 5C2). Waste incineration covers the emission estimates from waste incineration plants without energy recovery[13] and not from waste incineration with energy recovery. Emission estimates for waste incineration with energy recovery are reported in the relevant subsector under NFR sector 1A1 (Chapter 3.3.1). Waste incineration is separated further into Municipal Waste Incineration (NFR 5C1a), Industrial Waste Incineration (NFR 5C1bi), Hazardous Waste Incineration (NFR 5C1bii), Clinical Waste Incineration (NFR 5C1biii), Sewage Sludge Incineration (NFR 5C1biv), Cremation (NFR 5C1bv) and Other Waste Incineration (NFR 5C1bvi).

Open burning of waste covers the emission estimates from open-pit burning facilities and bonfires.

The scope of this section does not include the emissions from waste incinerated outside of Iceland as this would lead to double counting of the emission estimates in a common international emission estimate inventory. Activity data on waste incinerated outside Iceland is provided to the EA annually by the waste burning facilities. Data on waste generation and waste management practices is published by Statistics Iceland.

For the next submission there will be an internal review of the methodology and calculations files used to calculate emissions from 5C waste incineration and open burning.

6.6.1 Waste incineration (NFR 5C1)

6.6.1.1 *Municipal Waste Incineration (NFR 5C1a)*

Incineration of waste in incineration plants without energy recovery started in 2001 in Iceland.

6.6.1.1.1 Methodology

The total amount of waste incinerated in all waste incineration plants without energy recovery in Iceland is multiplied with its pollutant specific emission factor as given in the 2019 EMEP/EEA Guidebook.

[13] A quantitative definition of waste incineration with energy recovery is found in Annex IV of regulation 1040/2016 (IS).

6.6.1.1.2 Activity data

Activity data on incinerated waste from major incineration plants have been collected by the EA since the year 2000. Waste incineration in incineration plants started in 1993 and currently there is a single operating waste incineration plant (Kalka) in Iceland. Waste incineration in incineration plants apart from Kalka and a small one in Tálknafjörður is considered open burning of waste. Kalka opened in 2004 which resulted in a decrease of open burning of waste (5C2) and an increase in waste incineration (5C1). Because of that there is a sharp change in emissions for most pollutants pre-2004 and post-2004 where emissions from 5C1 increased and emissions from 5C2 decreased.

Historic data which was not reported to the EA was estimated using the assumption of 500 kg of waste per inhabitant in communities where waste is known to have been incinerated.

6.6.1.1.3 Emission factors

Emission factors (T1) for all pollutants for the incineration plant Kalka are taken from table 3-1 in the chapter 5.C.1.a Municipal waste incineration in the 2019 EMEP/EEA Guidebook. Kalka has the following abatement technologies: dry cleaning process, hydrated lime, combustion is at approximately 1100°C, particle abatement (bag filters with capacity 50 kg/hr) and, therefore, lower emission factors were used for Kalka than for other incineration plants.

For other incineration plants (there was only one other, in Tálknafjörður, which falls under this category), Tier 2 emission factors from table 3-2 in the 2019 EMEP/EEA Guidebook is used for all pollutants except for NH_3, Se and Indeno(1,2,3-cd)pyrene. For NH_3, Se and Indeno(1,2,3-cd)pyrene, where tier 1 emission factors from table 3-1 of the 2019 EMEP/EEA Guidebook are used. The reason for this is the lack of emission factors given for these pollutants in table 3-2 of the Guidebook.

Emission factors for dioxins from waste incineration are either based on measurements when they are available or taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005).

From 2014 only one incineration plant (Kalka) handling MSW has been operating in Iceland. The emission factor of 0.5 μg TEQ/t MSW was taken from Table 14 in Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005).

6.6.1.1.4 Recalculations

No recalculations were done for this sector.

6.6.1.1.5 Planned improvements

For future submissions, there is a need to acquire more detailed technology stratification to account for abatement technologies in the Tier 2 methodology of the EMEP/EEA 2019 Guidebook. An uncertainty analysis is furthermore in progress.

6.6.1.2 *Industrial Waste Incineration (NFR 5C1bi)*

6.6.1.2.1 Methodology

Slaughterhouse waste is the only type of waste that is assumed to be constituting industrial waste incineration for the year 2019. Total reported slaughterhouse waste is multiplied by pollutant specific emission factors to estimate these emissions.

6.6.1.2.2 Activity data

Activity data for this category has only been included for the years 2014-2019 while for all other years it is included in 5C1a.

6.6.1.2.3 Emission factors

Industrial waste incineration, which only occurs at Kalka, assumes the same emission factors which are used for municipal solid waste incinerated at Kalka (NFR 5C1a).

6.6.1.2.4 Recalculations
No recalculations were done for this sector.

6.6.1.2.5 Planned improvements
It´s planned to acquire data for the years 1990-2013, review emission factors currently used and add emission estimates for those pollutants where the EMEP/EEA Guidebook provides emission factors.

6.6.1.3 *Hazardous Waste Incineration (NFR 5C1bii)*

6.6.1.3.1 Methodology
Total amount of hazardous waste is multiplied by a pollutant specific emission factor from the Tier 1 approach of the EMEP/EEA Guidebook.

6.6.1.3.2 Activity data
Activity data for incinerated hazardous waste exists from 2006 and is currently being reported to the EA.

6.6.1.3.3 Emission factors
Emission factors are taken from Table 3-1 of chapter 5C1b of the EMEP/EEA 2019 Guidebook.

6.6.1.3.4 Recalculations
No recalculations were done for this sector.

6.6.1.3.5 Planned improvements
No planned improvements for hazardous waste incineration (5C1bii).

6.6.1.4 *Clinical Waste incineration (NFR 5C1biii)*

6.6.1.4.1 Methodology
Total amount of clinical waste is multiplied by a pollutant specific emission factor from the Tier 1 approach of the 2019 EMEP/EEA Guidebook.

6.6.1.4.2 Activity data
Activity data for incinerated clinical waste under this sector is from 2001.

6.6.1.4.3 Emission factors
Emission factors are taken from table 3-2 of chapter 5Cbiii of the EMEP/EEA 2019 Guidebook. Abatement technology (rotary kiln) is in place at the incineration plant Kalka and, therefore, abatement efficiencies from table 3-4 are used for NO_x, CO, SO_x, TSP, Cd, Cr, Cu, Hg, Ni from the year 2004 when Kalka opened. Prior to that no abatement technology is assumed.

6.6.1.4.4 Recalculations and planned improvements
No recalculations were done for this sector.

6.6.1.4.5 Planned improvements
No planned improvements for clinical waste incineration (5C1bii).

6.6.1.5 *Sewage Sludge incineration (NFR 5C1biv)*

6.6.1.5.1 Methodology
Total amount of sewage sludge is multiplied by a pollutant specific emission factor from the Tier 1 approach of the EMEP/EEA Guidebook.

6.6.1.5.2 Activity data
Activity data for sewage sludge incineration was included in NFR sector 5C1a until 2014.

6.6.1.5.3 Emission factors
Emission factors are taken from table 3-1 of chapter 5C1b of the 2019 EMEP/EEA Guidebook.

6.6.1.5.4 Recalculations and planned improvements

No recalculations were done to sewage sludge incineration for this submission.

6.6.1.5.5 Planned improvements

Review of data for this sector is necessary. Some historic data exists for sewage sludge which need to be introduced until 2014.

6.6.1.6 *Cremation (NFR 5C1bv)*

6.6.1.6.1 Methodology

Total number of bodies incinerated is multiplied by a pollutant specific emission factor from the tier 1 approach of the 2019 EMEP/EEA Guidebook.

6.6.1.6.2 Activity data

Cremation is performed at a single facility located in Reykjavik where human bodies are incinerated along with the coffin. Activity data used is the total number of bodies incinerated and this data is taken from the facility available online.

6.6.1.6.3 Emission factors

Emission factors are taken from Table 3-1 of chapter 5C1bv of the 2019 EMEP/EEA Guidebook.

6.6.1.6.4 Recalculations and planned improvements

Two recalculations were done for this sector:

- Emissions for 2018 for all pollutants were recalculated, due to updated activity data value for 2018. This caused a 70% increase of all pollutants from this sector.
- In accordance with the 2020 Stage 3 review comment (IS_Waste_2020_Q6_5C1bv) Iceland submitted a revised estimate. There was a unit error in the calculations of emissions of IPy which cause an 1000x overestimations of the emissions. This was corrected for this submission for all years.

6.6.1.6.5 Planned improvements

No planned improvements.

6.6.1.7 *Other Waste Incineration (NFR 5C1bvi)*

Data for other waste incineration is not available for the time being.

6.6.2 Open burning of waste (NFR 5C2)

Open burning of waste includes combustion in nature and open dumps as well as combustion in incineration devices that do not control the combustion air to maintain adequate temperature and do not provide sufficient residence time for complete combustion. Incineration devices on the other hand are characterized by creating conditions for complete combustion. Therefore, the burning of waste in historic incineration devices that did not ensure conditions for complete combustion is allocated to open burning of waste. Open pit burning was a common procedure in the early nineties. In general, open pit burning results in poor combustion conditions due to inhomogeneous and poorly mixed fuel material, chlorinated precursors, humidity or catalytically active metals, but all these factors influence the dioxin formation. It can therefore be hard to come up with reasonable emission factors. In addition to that the activity data is quite uncertain as well, as no official statistics are available.

It is a tradition to light up bonfires at New Year's Eve in Iceland. These are quite common throughout the country. In the early nineties, there were no restrictions and no supervision with these bonfires. In the early nineties, some surveillance officers from the Environmental and Public Health Offices (Local Competent Authority) started to control these fires, by informing the bonfire personnel. In

2000 the EA, Iceland Fire Authority and National Commissioner of Iceland Police published guidelines for bonfires. They include restrictions on size, burnout time and the material allowed. Since that time only wood and paper are allowed on bonfires. Also, the Environmental and Public Health Offices supervise all bonfires. Now they are fewer and better organized.

6.6.2.1 *Methodology*

The total amount of waste incinerated in all waste open pit burning facilities in Iceland is multiplied with its pollutant specific emission factor as given in the EMEP/EEA 2019 Guidebook. This applies to most reported pollutants except for dioxin, where the emission estimates are based on technology specific emission factors from the Standardized toolkit for the identification of Dioxin and Furan releases (UNEP, 2005). The same methodology is used for emission estimates from bonfires, with dioxin being calculated differently. See more detailed descriptions in the following sections.

6.6.2.2 *Activity data*

Historic data on open pit burning was estimated with the assumption that 500 kg of waste have been incinerated per inhabitant in the communities where waste is known to have been incinerated in 1990, 1995 and 2000 and interpolated in the years between. These communities were mapped by the EA in the respective years. The date is known at the EA, at which sites, where open pit burning has been performed have been closed and other means of waste disposal have been found. Open pit burning is likely to occur still at various rural sites, but this has not been estimated. The amount of waste burned in open pits has decreased rapidly since the early 1990s, when more than 30 thousand tonnes of waste were burned. Between 2005 and 2010 there was only one site left burning waste openly, on the island of Grímsey. This site was closed by the end of 2010. It was assumed that around 50 tonnes of waste were burned there annually.

For bonfires, activity data is not easily obtained. In 2011 the EA along with the municipality of Reykjavík decided to weigh all the material of a single bonfire. Then the piled material was photographed and its height, width and length measured. The weight was then correlated to the more readily measurable parameters pile height and diameter. The Environmental and Public Health Offices were asked to measure height and diameter of the bonfires in their area, take pictures and send to the EA. From this information the total weight of bonfires was estimated for the whole country. The amount was further extrapolated back to 1990, in cooperation with an expert from one Environmental and Public Health Office that has been involved with this field of work for a long time.

6.6.2.3 *Emission factors*

For open pit burning, the dioxin emission factor is taken from table 54 in the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005), it is 300 µg per tonne waste (given for uncontrolled domestic waste burning). Emission factors for the majority of other pollutants are taken from Table 3.1 in chapter 5C2 of the 2019 EMEP/EEA Guidebook. Tier 2 emission factors, which are taken from Table 3.2 5.C.1.a. Municpial Waste Incineration in the 2019 EMEP/EEA Guidebook , are used for NH3, Hg, Ni, I(1, 2, 3-cd)P, HCB and PCB emissions however.

For bonfires, the dioxin emission factor has been estimated historically based on assumptions. From 2003 onwards an emission factor of 60 µg/t is used. This factor is taken from table II.6.5 of the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2012) and is given for open burning of wood. For 1990 to 1995 an emission factor of 400 µg per tonne burnt material was used. This factor is taken from table II.6.5 of the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2012) and is given for accidental fires in houses.

This relates to the fact that the burning material was very miscellaneous at that time. It was common practice to burn tires, kitchen interior and even boats at the bonfires. Furthermore, some businesses used the opportunity to get rid of all kind of wastes. Therefore, it was considered suitable for open pit burning. The emission factor was then interpolated from 400 µg to 60 µg per tonne burned material from 1996 to 2003. The emission factors for other pollutants than dioxin are taken from table 3-1 in chapter 5C2 of the 2019 EMEP/EEA Guidebook.

6.6.2.4 *Recalculations and planned improvements*

During the 2020 Stage 3 review Iceland submitted a revised estimate for dioxin emissions from open pit burning for 1990-2003. It was recommended that Iceland uses an emission factor of 400 µg/t for 1990-1995 which is presented in Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases from 2012. This caused recalculations for 1990-1995, and also for 1996-2002 as those years are extrapolated from 1995. The recalculations can be seen in Table 6.8:

Table 6.8 Recalculations for dioxins emissions from 5C2

		1990	1995	1997	1999	2001	2003
2020 submission	**Emission factor [µg/t]**	600	600	465	330	195	60
	Emissions [g]	2.5	2.3	1.6	1.0	0.55	0.15
2021 submission	**Emission factor [µg/t]**	400	400	315	230	145	60
	Emissions [g]	1.7	1.6	1.1	0.68	0.41	0.15
	Difference [g]	-0.850	-0.776	-0.514	-0.296	-0.141	0
	% difference	-33%	-33%	-32%	-30%	-26%	0

6.6.2.5 *Planned improvements*

No planned improvements.

6.7 Wastewater handling (NFR 5D)

According to the EMEP/EEA Guidebook (EEA, 2019) wastewater will be an insignificant source for air pollutants. However, in urban areas, NMVOC emissions from wastewater treatment plants can be of local importance. Activities considered within this sector are biological treatment plants and latrines (storage tanks of human excreta, located under naturally ventilated wooden shelters).

In Iceland, most wastewater is discharged into the sea either untreated or after primary treatment. Only a small amount of wastewater is treated with secondary treatment and latrines are not occurring. Therefore, non-GHG emissions have not been estimated from wastewater handling.

6.7.1 Methodology

No methodology is used due to the lack of relevant activity data.

6.7.2 Activity data

No relevant activity data.

6.7.3 Emission factors

No emission factors used.

6.7.4 Recalculations and improvements

No recalculations were done for wastewater handling (5D) for this submission.

6.7.5 Planned improvements

Acquire relevant activity data and estimate whether there might occur NMVOC emissions.

6.8 Other waste (NFR 5E)

This section discusses the emission estimates from other waste and Iceland estimates from accidental house and vehicle burning. Emission estimates for all reported pollutants is provided except for NH_3, BC, Se, HCB and PCB where emission factors have not been found or are considered not applicable.

6.8.1 Methodology

For accidental house fires, emission estimates are calculated as the number of fire events times a pollutant specific emission factor from the Tier 2 approach of chapter 5E in the 2019 EMEP/EEA Guidebook and the Danish IIR of 2015.

For accidental vehicle fires, emission estimates are calculated as the mass of vehicles burned times a pollutant specific emission factor from the Danish IIR 2015. Weight of different types of vehicles are used in the calculations and taken from table 6-26 of the Danish IIR 2015. The assumption is made that 70% of the total mass is burned.

6.8.2 Activity data

Activity data for vehicle and building fires were obtained for the years 2003 to 2019 from the Capital District Fire and Rescue Service (CDFRS). Building fires are classified by duration of response into small, medium and large fires. The data is presented in Table 6.9. As 2/3 of the Icelandic population lives in the capital area, it is assumed that the CDFRS serves 2/3 of the incidents in Iceland. In Table 6.10, data on vehicle and building fires, extrapolated for Iceland, is presented. As the emission factors used comply for full scale building fires, the activity data is scaled as a full scale equivalent where it is assumed that a medium and a small fire leads to 50% and 5% of a large fire respectively, and that a large fire is a full scale fire. Table 6.9 and Table 6.10 show the total scaled building fires. This scaling is similar to the scaling used in the 2011 Danish Informative Inventory Report, although the scaling in Denmark is based on response activity rather than response time. It does though seem appropriate to scale the fires in this way for the Icelandic data. It is further assumed that 10% of the building fires every year, are industrial building fires.

In 2004 a major industrial fire broke out at a recycling company (Hringrás). In the fire 300 tonnes of tires, among other separated waste materials, burned. In 2011 a fire broke out at the same company, but that fire is assumed to have been about 10% of the size of the one in 2004. In 2014 a major fire incident occurred when fire broke out in an industrial laundry service. The house had a thick layer of asphalt roll roofing with an estimated weight of around 80 tonnes.

For the year 1990 to 2002 an average of the total scaled building fires (38) and the vehicle fires (60) was used. The possibility to obtain better data for 1990 to 2002 has been further explored. However, the reports on accidental fires for that period are in completely different form, making them both difficult to obtain and interpret. As the extra information gained would not be of that much importance it is not thought to be priority to further explore this subject.

The activity data is calculated as a yearly combusted mass by multiplying the number of different vehicles fires with the average weight of the given vehicle type. As it is not registered at the CDRFS which types of vehicles are caught in fires, the average Danish (2011 Danish Informative Inventory Report) ratio of vehicle fires per vehicle type were taken per vehicle type, excluding motorcycles, as motorcycle fires are very rare in Iceland (passenger cars 83%; buses 8%; light duty vehicles 3%; heavy duty vehicles 7%). The total amount of vehicle mass involved in fires is then calculated from the number of vehicle fires and the average weights of the different vehicle types (also Danish weight, as information was not available). It is assumed that 70% of the total vehicle mass involved in a fire actually burns.

Table 6.9 Vehicle and building fires, capital area.

Year	Vehicle fires	<60 min	Building fires 60-120 min	>120 min	Total scaled building fires
2005	43	141	24	11	30
2010	34	118	17	9	23
2015	37	88	14	3	14
2018	38	74	11	11	20
2019	24	71	17	13	25

Table 6.10 Vehicle and building fires scaled for Iceland

Year	Vehicle fires	<60 min	Building fires 60-120 min	>120 min	Total scaled building fires
2005	65	212	36	17	46
2010	51	177	26	14	36
2015	54	132	23	5	24
2018	57	111	17	17	32
2019	51	107	26	20	38

At the major industrial fire at Hringrás in 2004, an estimated amount of 300 tonnes of tires, among other separated waste materials, burned.

For the major industrial fire in 2014, the estimated weight of the asphalt roll roofing burned down was estimated to be around 80 tonnes and was assumed to be a large part of the emissions from this particular fire.

6.8.3 Emission factors

Emission factor for undetached houses is used for all building fires except industrial building fires. This is due to the fact that Icelandic regulation demand more fire resistance than the regulations in the Scandinavian countries. Emission factors for detached building fires are taken from table 3-4 of chapter 5E of the 2019 EMEP/EEA Guidebook for all estimated pollutants provided in the Guidebook except for dioxin which is taken from the 2015 Danish Informative Inventory Report (IIR) to the UNECE. Other non-estimated sources of the Guidebook are taken from the Danish 2015 IIR table 6.20. No emission factors are provided for BC, Ni, Se, Zn, HCB and PCB. NH_3 is considered not applicable as the Guidebook suggests.

Similarly, for industrial house fires, emission factors from table 3-6 of chapter 5E of the 2019 EMEP/EEA Guidebook is used except for dioxin which is taken from the 2015 Danish Informative Inventory Report (IIR) to the UNECE. Other non-estimated sources of the Guidebook are taken from the Danish 2015 IIR table 6.20. No emission factors are provided for BC, Ni, Se, Zn, HCB and PCB. NH_3 is considered not applicable as the Guidebook suggests.

For vehicle fires, the burned mass is then multiplied with a pollutant specific emission factor taken from table 6-29 of the Danish IIR 2015.

For the major industrial fire at Hringrás in 2004, an emission factor of 220 µg/(t of tires) from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005), was taken. Using this factor, this single fire scaled like about 16 industrial building fires and PAH4 emissions were scaled accordingly.

Asphalt roll roofing was assumed to emit dioxin levels comparable to scrap tires which has the emission factor of 220 µg/(t of tires) given in the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005). Dioxin emissions from other materials that burned were included by assuming such that the fire was comparable to 5 industrial buildings. Thus the emissions from this particular fire corresponds to 5 industrial building fires plus the special assessment of the asphalt roll roofing, in total around 9 industrial fires. Other POP's emission estimates were calculated by using emission factors from table 6-20 of the Annual Danish Informative Inventory Report to the UNECE (National Environmental Research Institute, 2011) for industrial buildings, scaled according to the estimation of corresponding industrial building fires. Emission factors for NO_x, NMVOC, SO_2 and CO are also taken from the Danish IIR table 6-20. Other reported pollutants are taken from the 2019 EMEP/EEA Guidebook table 3-6. No emission factors are provided for BC, Ni, Se, Zn, HCB and PCB. NH_3 is considered not applicable as the Guidebook suggests.

6.8.4 Recalculations and improvements

No recalculations were done for this submission.

6.8.5 Planned improvements

Review of data used for 1990-2002 for the number of accidental house and vehicle fires. General data improvement needed. There were two larger fires in 2018, which have yet to be researched further. The Environment Agency has been in touch with the Capital´s Fire Department and the large fires are included here under the category "building fires <120 min". A further collaboration is being set up with the Iceland Building Authority with the aim of providing better estimates of emissions from building fires.

7 Natural Sources (NFR 11)

7.1 Volcanoes (NFR 11A)

Volcanic emissions are frequent in Iceland and modern techniques allow a good estimation of associated emissions. While the following chapters describe the three latest eruptions (from 2010) in detail, the Table 7.1 reports the emissions for the whole time series and the respective sources of information. As emissions from these eruptions are natural, they are reported in this chapter and in the NFR Tables under Memo Item 11A but are not included in national totals.

Table 7.1 Volcanic eruptions and associated SOx and particulate emissions from 1990.

		Emissions (kt)			
Year	**Volcano**	**SOx**	**PM2.5**	**PM10**	**Measurement method/ Source**
1991	Hekla	230			Satellite Nimbus-7 TOMS, https://volcano.si.edu/volcano.cfm?vn=372070&vtab=Emissions
1996	Grimsvötn	10			Satellite Aura OMI https://volcano.si.edu/volcano.cfm?vn=373010&vtab=Emissions
2000	Hekla	183			Satellite Earth Probe TOMS https://volcano.si.edu/volcano.cfm?vn=372070&vtab=Emissions
2004	Grimsvötn	30			Satellite Aura OMI https://volcano.si.edu/volcano.cfm?vn=373010&vtab=Emissions
2010	Eyjafjallajökull	127	1,673	5,970	See Chapter 0
2011	Grimsvötn	300	13,184	47,039	Satellite Aura OMI https://volcano.si.edu/volcano.cfm?vn=373010&vtab=Emissions
2014	Holuhraun	10,880			See Chapter 7.1.3
2015	Holuhraun	1,126			See Chapter 7.1.3

The last three volcanic eruptions are reported in more detail in the following chapters. These eruptions are: Eyjafjallajökull eruption, April-May 2010; Grímsvötn eruption, May 2011; and Holuhraun eruption, September 2014-February 2015.

7.1.1 Eyjafjallajökull eruption 2010

The Eyjafjallajökull eruption lasted from 14 April until 23 May 2010. For this eruption emissions of sulphur dioxide (SO_2) and particulate matter were estimated and reported. The emissions estimates are based on satellite observation on a daily basis during the eruption[14] and amounted to approx. 127 kt of SO_2, 6000 kt of PM_{10} and 1700 kt. of $PM_{2.5}$. These 6000 kt of PM_{10} were around 3500 times more than total estimated man-made PM_{10} emissions in Iceland in 2010.

Figure 7.1 Eyjafjallajökull eruption at its peak in April 2010 (Photo: Þorsteinn Jóhannsson).

[14] https://wiki.met.no/emep/emep_volcano_plume

7.1.2 Grímsvötn eruption 2011

Grimsvötn volcano lays below the biggest glacier in Iceland, Vatnajökull in the southeast of the country, and reaches 1725 m above sea level. It is one of the most active volcanoes, erupting in recent time in 1934, 1983, 1996, 1998, 2004 and 2011.

The Grímsvötn eruption lasted from 21 May until 28 May 2011. The eruption at Grímsvötn was much larger than that of Eyjafjallajökull the year before, and it has been estimated that during the first day more sulphur and particulates were emitted than during all the Eyjafjallajökull eruption. SO_2 emissions from Grímsvötn have been estimated to be around 1000 kt. An estimate of the total particulates emitted has not been estimated but the EA has scaled the emissions of particulates using the ratio of Sulphur emissions from the two eruptions (1000/127). This gives an approximate estimate of 47,000 kt PM_{10} and 13,000 kt of $PM_{2.5}$. Figure 7.2, a NASA MODIS satellite image acquired at 05:15 UTC on 22 May, 2011 shows the plume from Grímsvötn casting shadow to the west.

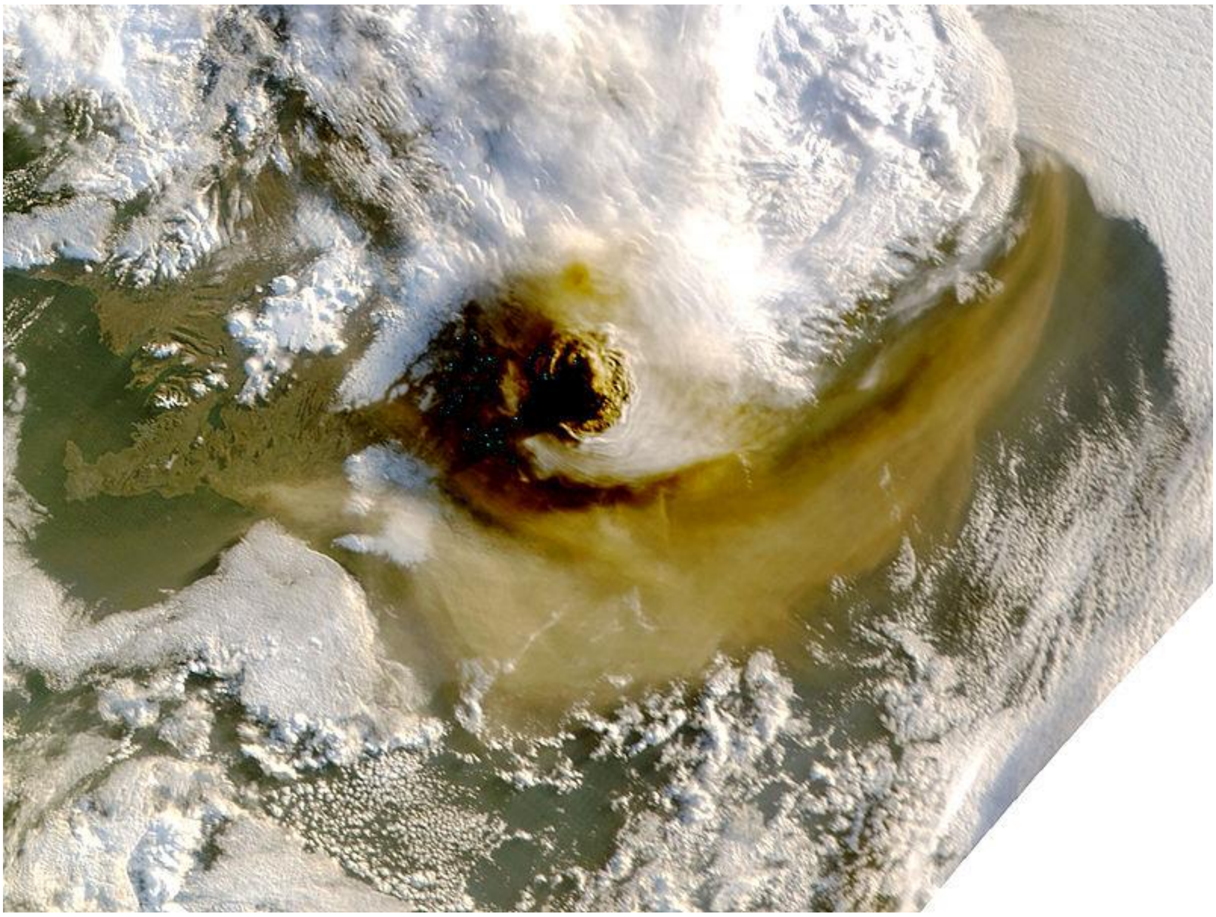

Figure 7.2 Grímsvötn eruption in May 2011. (Photo NASA/GSFC/Jeff Schmaltz/MODIS Land Rapid Response Team).

7.1.3 Holuhraun eruption 2014 - 2015

The eruption in Holuhraun began on 31 August 2014 and ended on 27 February 2015. It was the biggest eruption in Iceland since the Laki eruption 1783.

Emission estimates in the Holuhraun eruption were done by the volcanic hazard team at the Icelandic Met Office. According to information from Sara Barsotti and Melissa Anne Pfeffer the estimates were done as follows: The emission rate of SO_2 was calculated using wind parameters provided by the HARMONIE numerical prediction model and column concentrations of SO_2 detected with different types of DOAS measurements. The DOAS techniques used include two NOVAC scanning DOAS instruments (Galle, et al., 2010): one installed 7 km from the main degassing vent, Baugur, but moved during the eruption due to the advancing lava to 10 km from the main vent; and a second scanning DOAS installed 10 km from the main vent, but damaged by advancing lava two weeks after the start of the eruption; campaign DOAS traverses, made as close to the main vent as conditions allowed; and ring road DOAS traverses (Gíslason, 2015). All measurements were analysed closely to remove the data most impacted by scattering. For all techniques, the good quality measurements were used to calculate daily averages of SO_2 emission rate. On days when good quality data was acquired from more than one DOAS technique, the larger value was used, and then these daily values were used to calculate the monthly averages. Some minor degassing from the cooling lava continued after the end of the eruption (maximum 3 kg/s; Simmons et al., 2016); this contribution to the emissions is not included here.

Total SO_2 emission from this eruption was estimated 12,006 kt, as communicated in 2016 by the Icelandic meteorological office. Divided on calendar years 10,880 kt of SO_2 were emitted in the year 2014 and 1,126 kt of SO_2 in the year 2015. To put these numbers in in perspective it can be said that the total SO_2 emission from all the European Union countries for the year 2012 was 4,576 kt. So the emission from the eruption in the year 2014 i.e. from 29 August 2014 to 31 December 2014 was more than twice the total SO_2 emission from all the European Union countries for whole year. For September alone, during the most intensive period of the eruption, the SO_2 emission from the eruption was similar to the annual emission of the European Union.

Emissions of ash were negligible and therefore, have not been estimated. Further information about SO_2 emissions from the eruption are in Table 7.2 below. As these emissions are natural they are not included in national totals.

Table 7.2 Monthly emission rates (Pfeffer (Icelandic Meteorological Office), 2016, email communication).

	Average monthly emission rates [kg/s]	**SO_2 per month [kt]**
August 2014	124	332
September 2014	1708	4427
October 2014	1051	2815
November 2014	1143	2963
December 2014	128	343
January 2015	304	814
February 2015	129	312

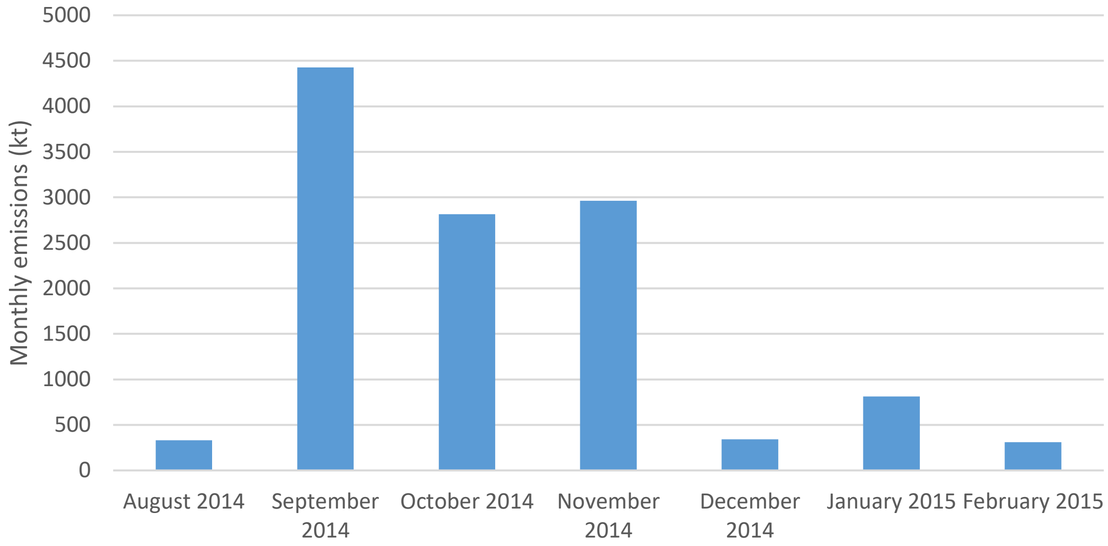

Figure 7.3 Monthly emission from Holuhraun during the eruption.

The eruption caused widespread SO_2 pollution all over Iceland and also in other countries in Europe. During the eruption, various institutions were in charge of disseminating information to the public. The Icelandic Met Office used the CALPUFF modelling system to simulate and forecast the dispersal and concentration of the SO_2 gas at ground level. The forecast was three-day long and was updated twice a day. SO_2 dispersion during the whole eruption modelled by CALPUFF are presented in Figure 7.4 as the frequency of hourly concentrations higher than the EU one hour limit value for SO_2 that is 350 µg/m^3. The values corresponding to each contour show how many times this concentration has been exceeded at each location during this period. During the eruption, gas pollution was extensive across all of Iceland. The NE part of the country suffered the highest impact from the eruption. The model suggests that the area within 50 km NE of the eruption site exceeded 350 µg/m^3 for up to 20 % of the time (about 30 days in total). The northern part of Vatnajökull and the eastern part of Hofsjökull glaciers were frequently exposed to high ground-level concentrations of SO_2 for up to 15 days.

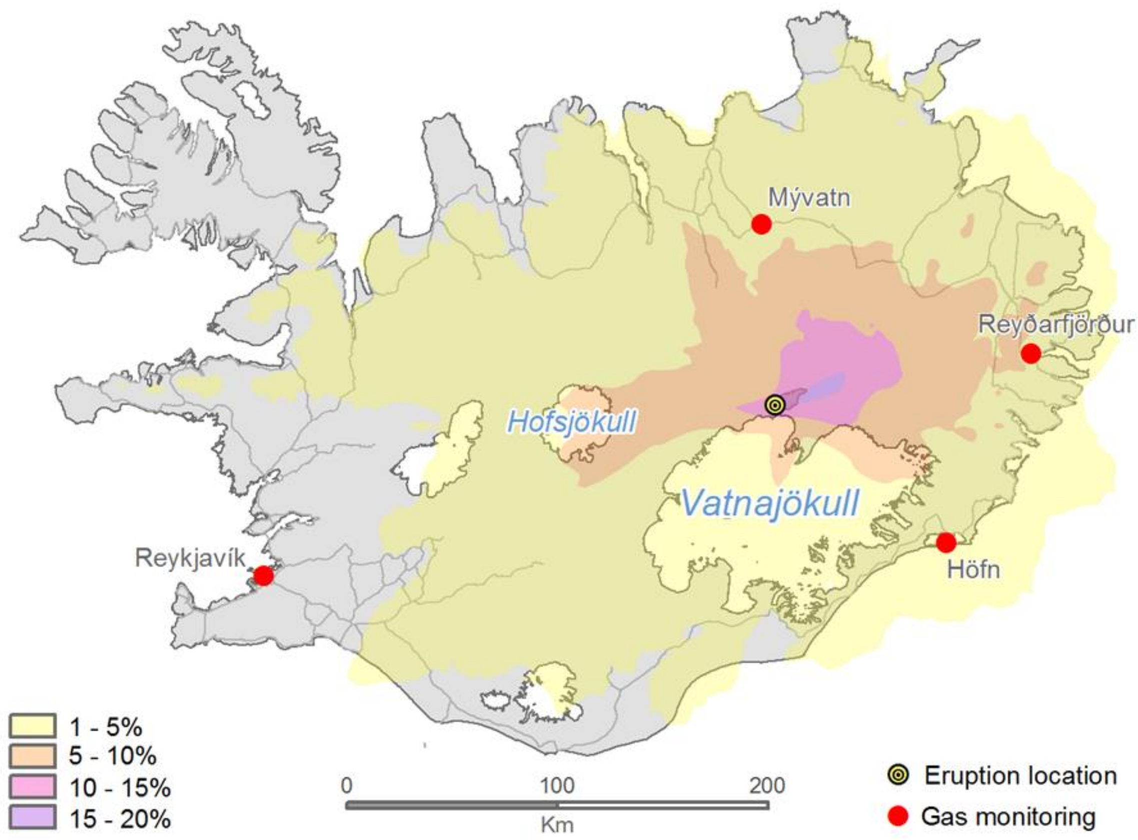

Figure 7.4 SO_2 dispersion during the eruption modelled by CALPUFF, presented as frequency of hourly concentrations higher than the 350 µg/m³ health limit. The monitoring stations mentioned in the text and in Figure 7.5 are also shown (Gíslason, 2015)

To inform the public about ground level concentration of SO_2 the Environmental Agency of Iceland shared information from SO_2 monitoring stations. At the beginning of the eruption the ambient air concentration of SO_2 was measured at 11 permanent stations across Iceland recording 10 and 60 minutes average concentration. Seven of the stations continuously streamed the results to the website[15] of the Environmental Agency of Iceland. By late January 2015 the number of these stations had risen to 21. All these instruments where trace level (ppb) SO_2 analysers equipped with pulsed fluorescence spectroscopy meters. In addition to these accurate measuring stations around 50 hand held SO_2 meters was distributed throughout the country and they were usually operated by the local police. So, the total number of SO_2 monitoring devices was 71, distributed in agglomerations all around the country.

Prior to the Holuhraun eruption, the ground–level concentration of atmospheric SO_2 in Iceland had never been recorded as exceeding the 350 µg/m³ hourly limit. During the eruption, predicted and measured values repeatedly exceed this limit (see Figure 7.4 and Figure 7.5). Much higher SO_2 peaks, lasting shorter than one hour, were frequently measured on handheld sensors, the highest being 21,000 µg/m³ in Höfn (SE of the country). Continuous measurements started 28 October 2014 in Höfn as shown in Figure 7.5. There the hourly averaged concentration reached a maximum of 3050 µg/m³ on 11 January 2015. Over the monitoring periods shown in Figure 7.5, SO_2 exceeded the one hour 350 µg/m³ threshold 2.0 % of the time at Mývatn (NE) (for 17 consecutive hours and a total of

[15] http://airquality.is

86 hours), 1.4 % in Reyðarfjörður (E) (for 10 consecutive hours and a total of 58 hours), 1.4 % in Reykjavík (for 8 consecutive hours and a total of 59 hours) and 4.2 % of the time in Höfn (for 16 consecutive hours and a total of 124 hours). The last unambiguous detection of the volcanic plume was at the Mývatn station on 18 February.

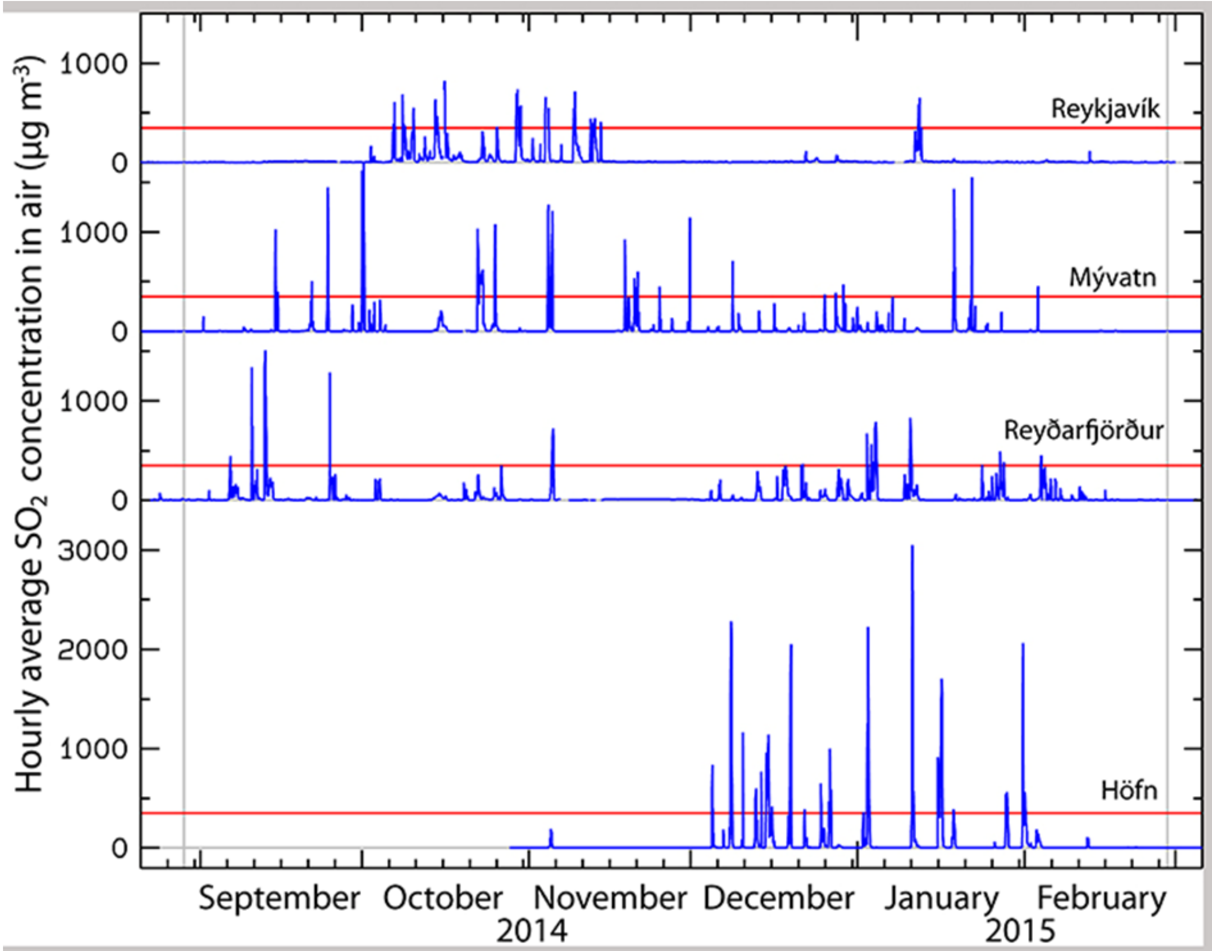

Figure 7.5 The SO_2 concentration in air at four of the permanent gas monitoring stations presented in Figure 7.4. The 350 µg/m^3 health limit is shown by the red horizontal line. The grey vertical lines mark the eruption period. Permanent SO_2 monitoring started at Höfn 28 October 2014. (Gíslason, 2015)

Gas emissions from the Holuhraun eruption resulted in an increase in ground–level SO_2 concentrations in the UK and Ireland during two occasions in September 2014 (Schmidt, 2015). Examples of the highest peaks during these events are shown from two monitoring stations in Ireland in Table 7.3 (Gíslason, 2015), along with examples from monitoring stations in the Netherlands, Belgium, and Austria. These stations are equipped with pulsed fluorescence spectrometers with similar detection limits and uncertainty as the Icelandic stations. During the 22 September the ground-level concentrations were highest in Austria at 235 µg/m^3. The Masenberg station in Austria is a background station at a high elevation and far away from local emission sources and rarely records SO_2 concentrations in excess of 30 µg/m^3. On this day unusually high concentrations were measured at most of the 30 monitoring stations in Austria. (Gíslason, 2015).

Table 7.3 Highest one hour SO_2 peak by country (Gíslason, 2015)

Country	Station name	Latitude	Longitude	Height above sea level	Date	Distance from the eruption	Highest one hour SO_2 peak
Ireland	Ennis	52.84	-9	16 m	06.09.2014	1407 km	498 µg/m^3
Ireland	Portlaoise	53.04	-7.29	98 m	06.09.2014	1420 km	343 µg/m^3
Netherlands	Philippine	51.29	3.75	5 m	22.09.2014	1905 km	82 µg/m^3
Belgium	Ghent region	51.15	3.81	12 m	22.09.2014	1931 km	87 µg/m^3
Britain	Wicken Fen	52.3	0.29	3 m	22.09.2014	1701 km	96 µg/m^3
Austria	Masenber	47.35	15.89	1210 m	22.09.2014	2754 km	235 µg/m^3

Figure 7.6 Holuhraun eruption in September 2014. The height of the lava fountains was around 100 m (Photo: Ólafur F. Gíslason).

8 Spatially Distributed Emissions on Grid

Note: Spatially distributed emissions on grid have not been updated in Iceland since the new requirement of the new 0.1°x0.1°EMEP grid came. Work is in progress to report gridded data in accordance with the requirements and will be available for the 2022 submission. The information below is given for reference only and has not been updated since the 2016 submission.

This chapter includes results of the Icelandic geographically distributed emissions for the years 1990, 1995, 2000, 2005 and 2010 for PAH4 and dioxin. Emission data have been disaggregated to the standard EMEP grid with a resolution of 50 km x 50 km. The reported emissions include gridded data for sector totals as well as national totals. Emissions for aviation, navigation and fishing have not been gridded.

When gridding the data all industrial sources and waste incineration sites (open pit burning and incineration plants) have been mapped with coordinates and projected on the grid. Other emissions like emissions from road transport, accidental fires, and bon fires have been divided on the grid based on population data. Some minor sources like emissions from tobacco smoking have been located where the populations density is highest, i.e. the capital area.

Update of gridded data, including actualisation to the new 0.1°x0.1°EMEP grid, is being considered and will be available for future submissions.

8.1 PAH4 Emissions in 1990, 1995, 2000, 2005 and 2010

Figures 8.1 to 8.5 show national total emissions of PAH4 within the EMEP-Grid in 1990, 1995, 2000, 2005 and 2010.

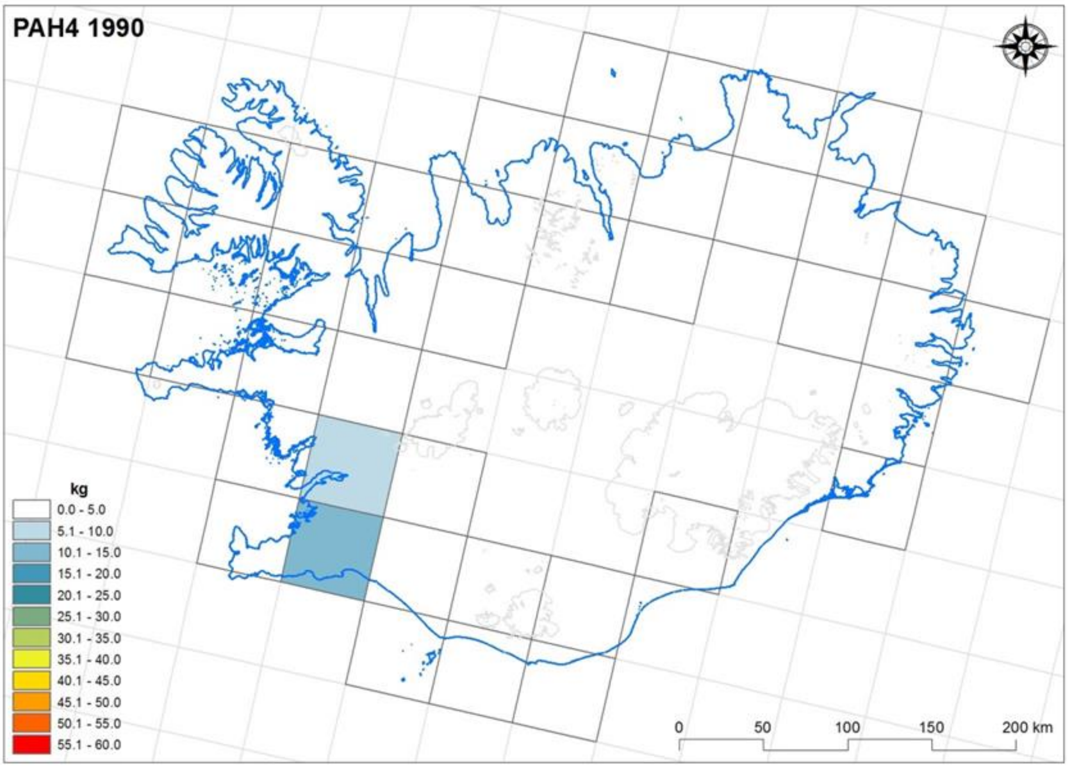

Figure 8.1 Emissions of PAH4 within the EMEP-Grid in 1990.

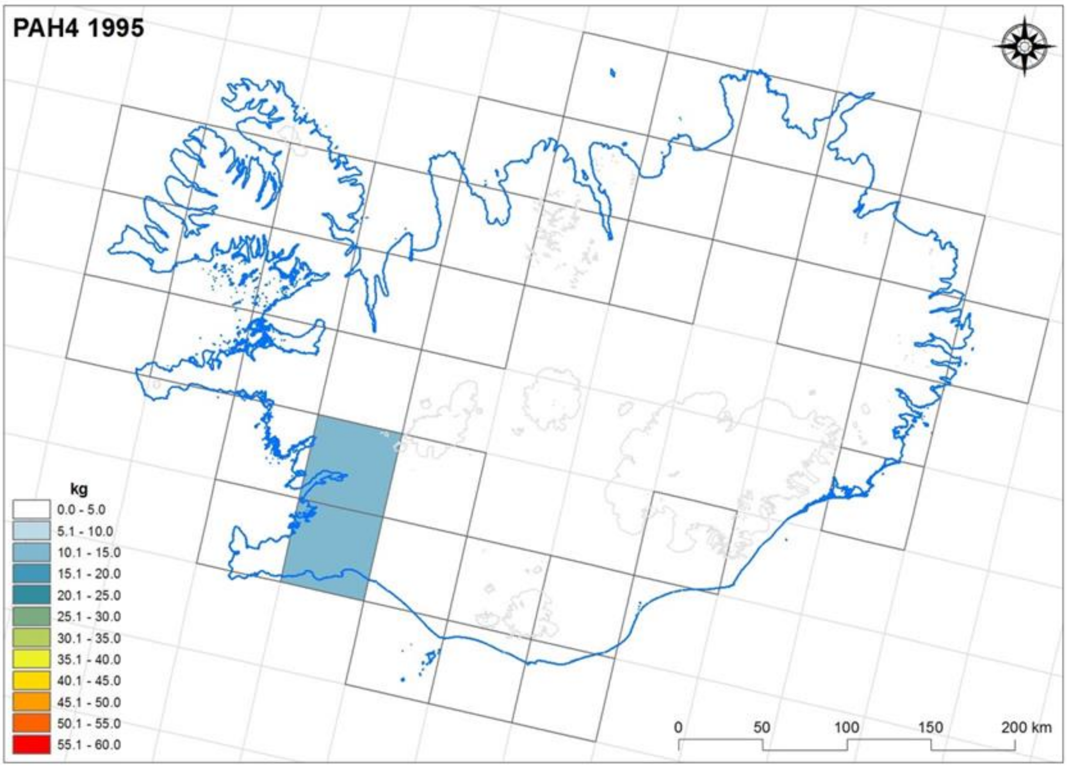

Figure 8.2 Emissions of PAH4 within the EMEP-Grid in 1995.

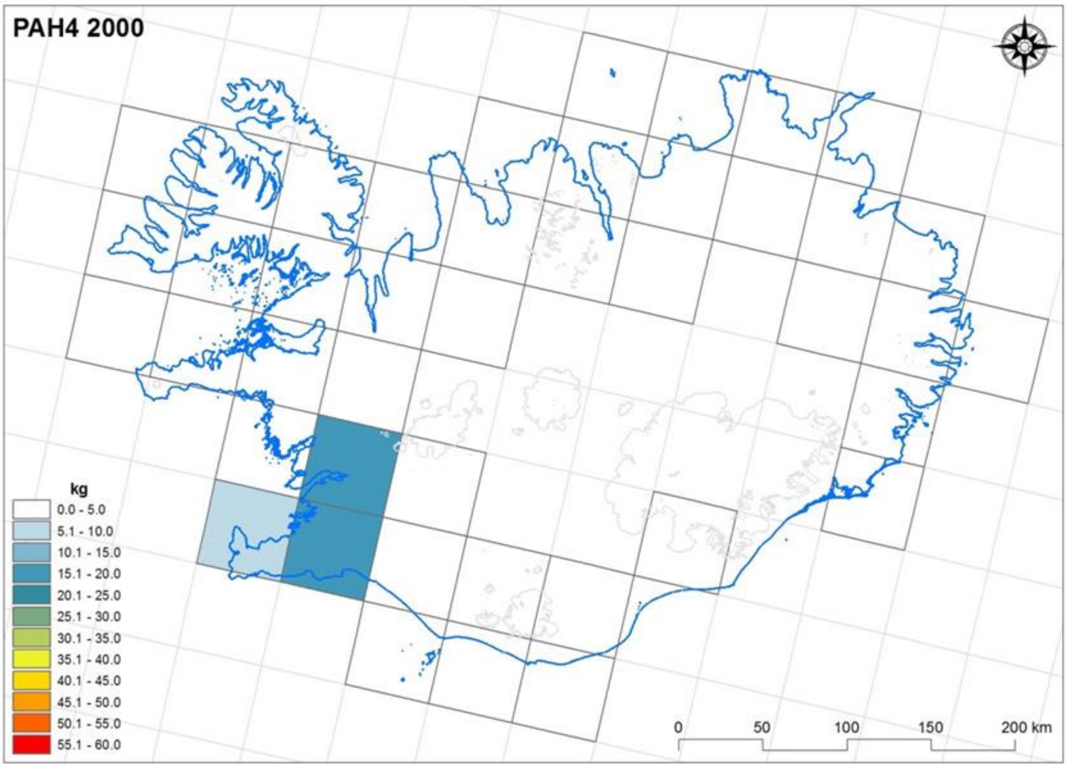

Figure 8.3 Emissions of PAH4 within the EMEP-Grid in 2000.

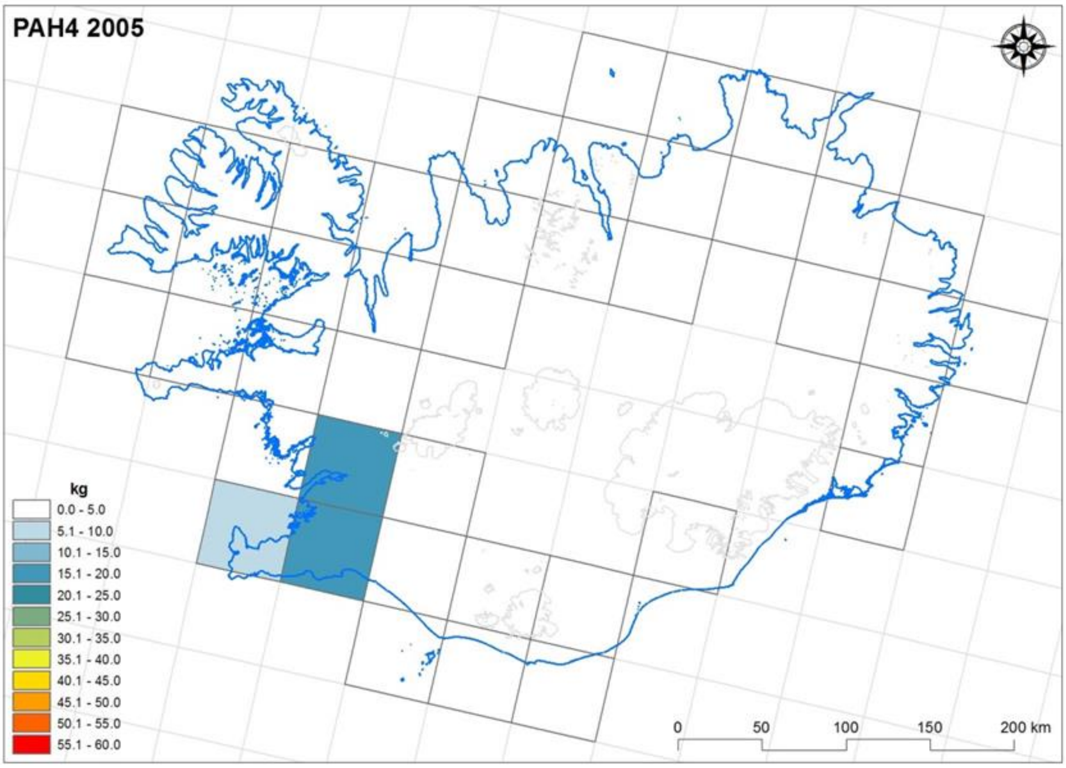

Figure 8.4 emissions of PAH4 within the EMEP-Grid in 2005.

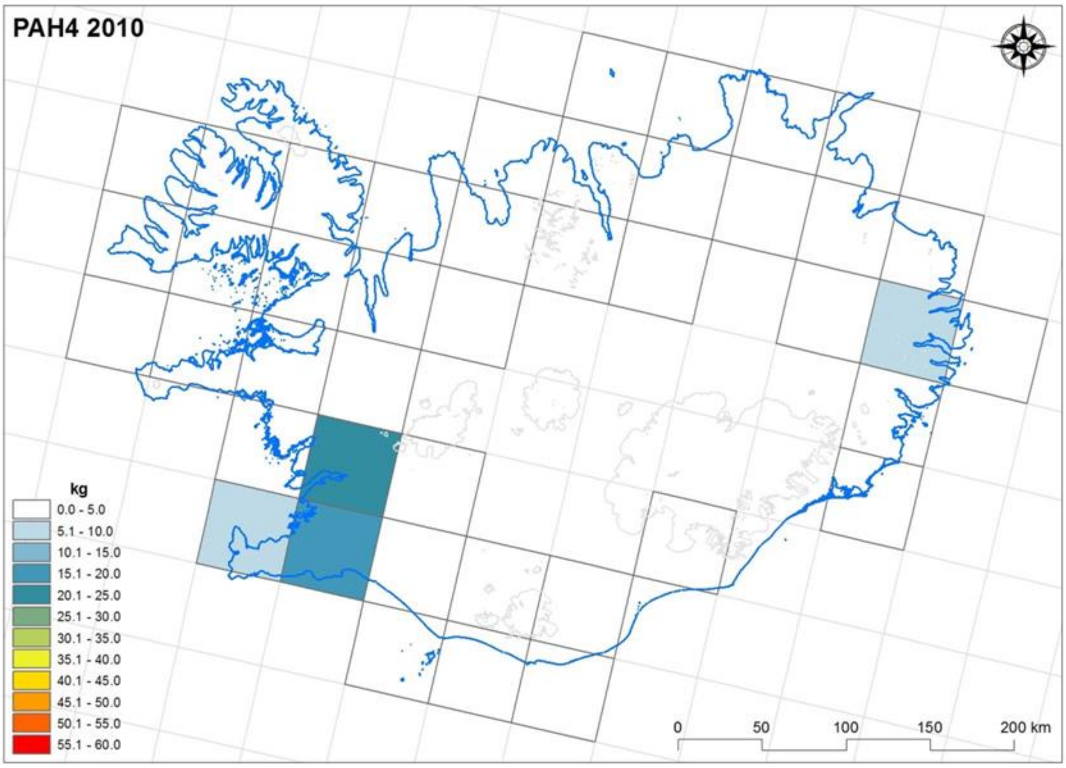

Figure 8.5 Emissions of PAH4 within the EMEP-Grid in 2010.

8.2 Dioxin Emissions in 1990, 1995, 2000, 2005 and 2010

For the distributed national totals, spatial patterns from the major sectors are recognisable. For dioxin the influence of closing down sites for open pit burning results in lower emissions over time. Further the malfunctioning of the incineration plant at Ísafjörður (north-west Iceland, Westfjords) results in higher emissions in 2010 than in the years before. Figures 8.6 to 8.10 show the national total emissions of dioxin within the EMEP-Grid in 1990, 1995, 2000, 2005 and 2010.

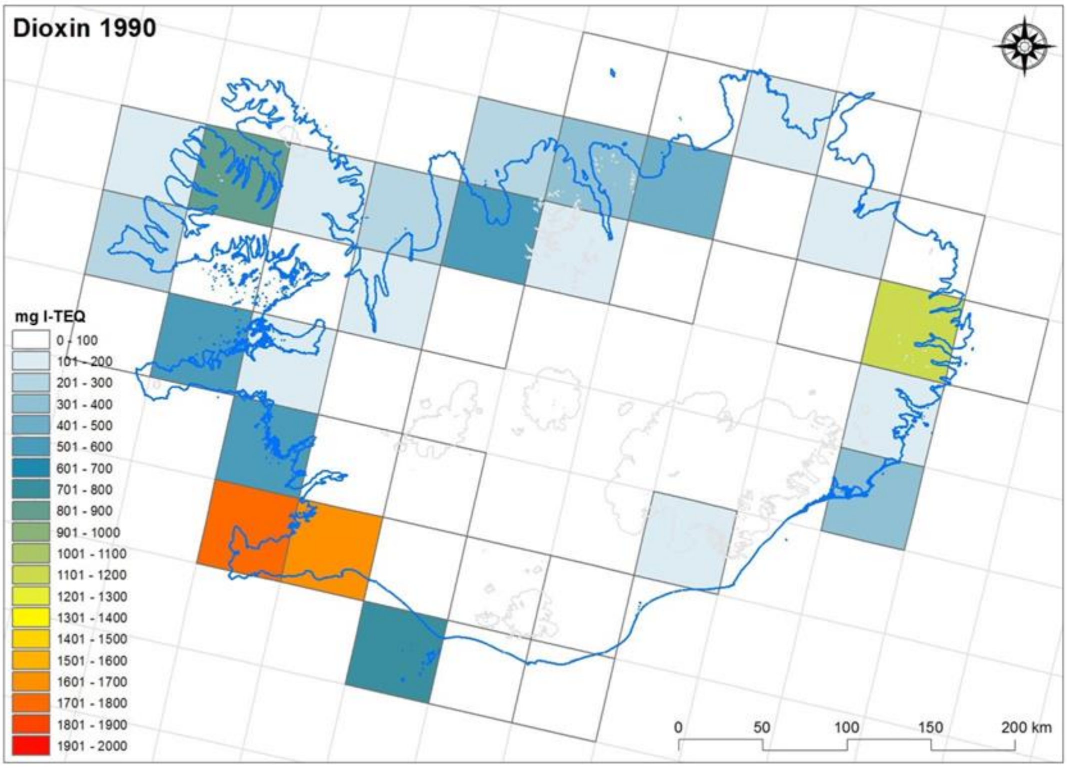

Figure 8.6 Dioxin emissions within the EMEP-Grid in 1990.

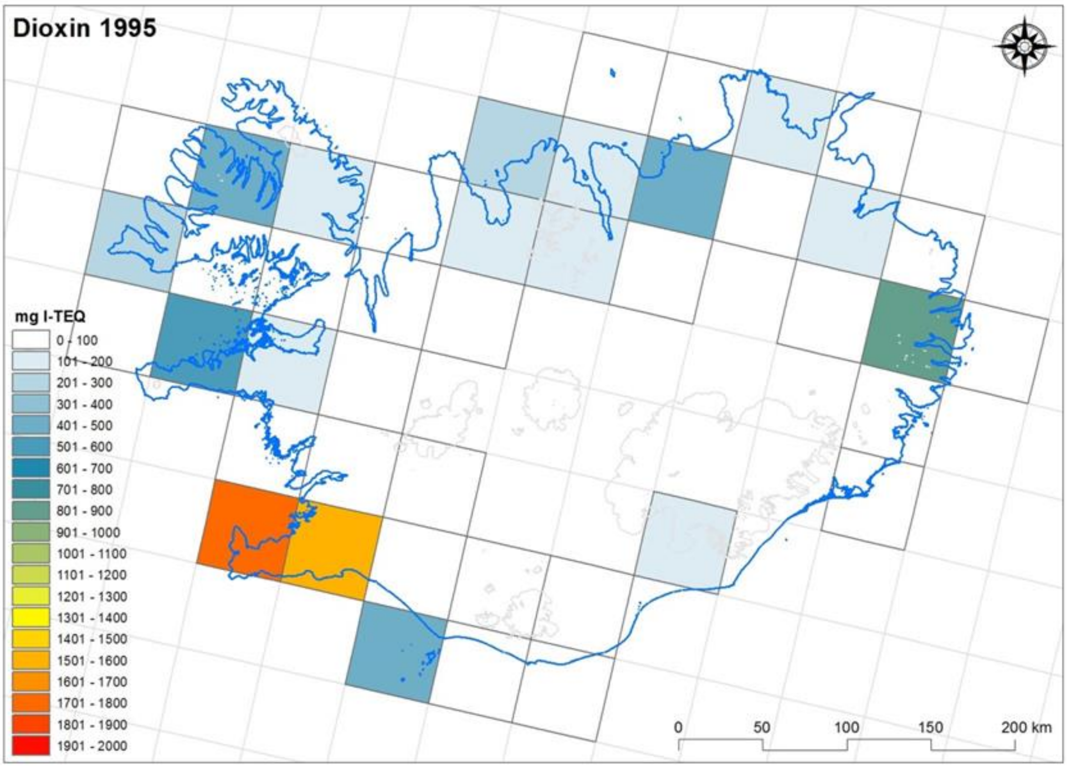

Figure 8.7 Dioxin emissions within the EMEP-Grid in 1995.

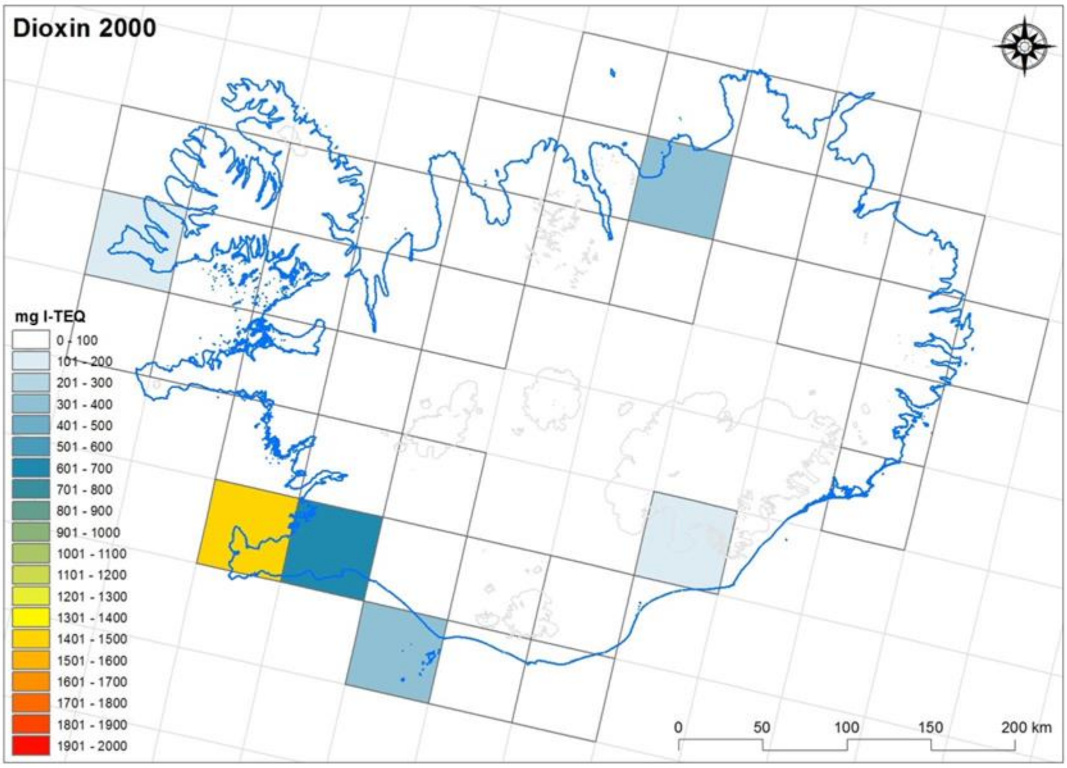

Figure 8.8 Dioxin emissions within the EMEP-Grid in 2000.

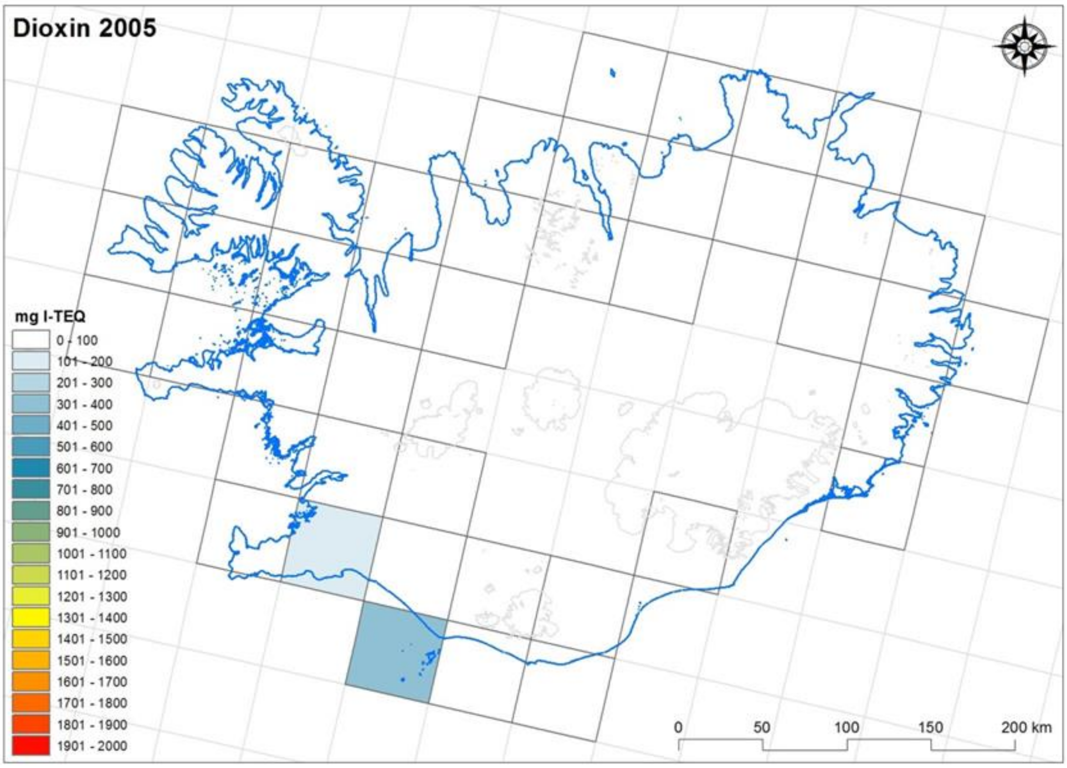

Figure 8.9 Dioxin emissions within the EMEP-Grid in 2005.

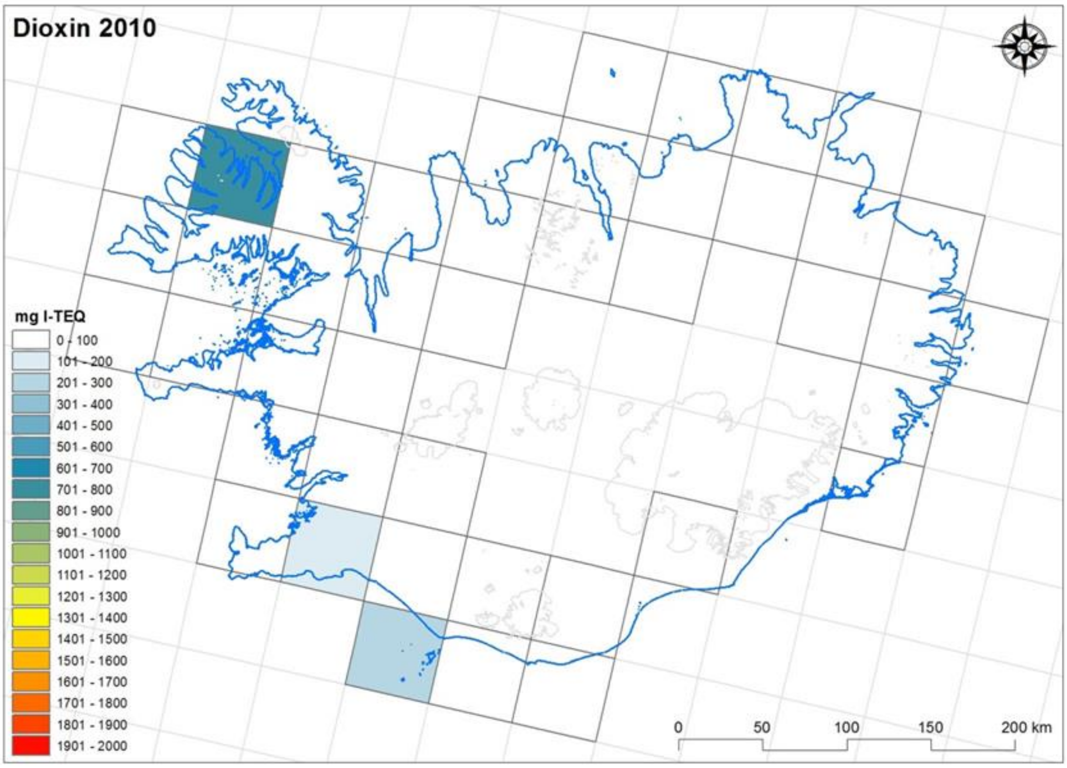

Figure 8.10 Dioxin emissions within the EMEP-Grid in 2010.

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Annex I: Iceland QA/QC checks

A range of QAQC checks have been performed on the Icelandic inventory:

- **Recalculation check** - comparing the values reported in the current (2021) and previous (2020) versions of the inventory for the base year (1990) and the most recent year covered by both versions (2018).
- **Negative and zero values checks** - to highlight the occurrence of negative values (LULUCF is not included) and zero values in the inventory.
- **Notation keys check** - to summarise the occurrence of each notation key to ensure consistency and accuracy in the inventory.
- **PAHs sum check** - to ensure that the sum of the four reported PAHs equals the reported "total" PAH emissions.
- **Particulate Matter check** - to ensure that reported TSP emissions are greater than or equal to PM_{10}, and similarly that reported PM_{10} emissions are greater than or equal to $PM_{2.5}$.

In all cases, the findings of the checks are reviewed, not only to identify where corrections may be required, but also to consider whether there are any steps of the inventory compilation process that need improvement. In addition, reviewing the results also provides information on whether the individual checks are well designed and comprehensive.

This ensures that all results from the QAQC process feed back into the continuous improvement programme.

Recalculation Check

A recalculation file has been used for the 2021 submission. This QAQC file compares the emissions between the current and previous submissions, for 2018 and 1990 (the base year). The data has been compiled to enable changes in the data to be easily identified and justifications for change provided where required. The current recalculation check considers all of the reported pollutants and activity data.

The recalculations check calculates the actual difference between the current and previous submission. If one or both values are notation keys, and are not the same in both submissions, then this is highlighted. If the values in both submissions are numeric but not equal, then the difference in submissions as a percentage of the current submissions is also shown. In addition, where differences occur the cells are highlighted for ease of reference. This process of identifying recalculation changes and the documentation of changes is in line with Chapter 4 of the 2016 EMEP guidelines regarding the reporting of recalculations. Where a recalculation change occurs, it is necessary to check that the underlying reasons are understood and considered reasonable.

At present, the recalculations QAQC check only considers the base year and latest year included in both the current and previous submissions. Iceland recognises that the inclusion of additional years as an improvement which will be implemented in subsequent submissions.

Negative and Zero Values Check

Checks were performed to identify whether any negative or zero values occur in the NFR Annex I submission file. No negative or zero values occurred and therefore no further action was needed.

Notation Keys Check

The number of occurrences of notation keys (NA, NE, NO and IE) in the NFR Annex I submission file are presented. This QAQC check is used to ensure that notation keys are applied consistently and accurately within the inventory. The occurrence of notation keys is presented as a count for each NFR code for the years 2004 – 2019 with highlighted cells for ease of reference.

A more complete check of the entire time series will be considered for future versions of the inventory.

PAH Sum Check

This is a sum check to identify whether the sum of the reported emissions for benzo(a) pyrene, benzo(b) fluoranthene, benzo(k) fluoranthene and Indeno (1,2,3-cd) pyrene equals the reported emissions for “total” four PAHs. This check is performed for each reported NFR code and year for the current submission. Where the sum of the PAHs does not equal the “total”, cells are highlighted for ease of reference and where required the cause for differences are documented.

Particulate Matter Check

This check identifies any categories where the emissions reported for TSP are less than PM_{10} emissions and where PM_{10} emissions are less than $PM_{2.5}$ emissions. This enables the identification of errors in reported PM emissions based on the assumption that TSP $\geq PM_{10} \geq PM_{2.5}$. This check is performed for each reported NFR code and year for the current submission. Where errors in reported PM emissions are identified, cells are highlighted for ease of reference and where required documentation is provided.

Annex II: KCA Results for 1990 and Trends 1990-2019

NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC and CO:

Key categories for NO_x, NMVOC, SO_x, NH_3, PM2.5, PM10, TSP, BC and CO, 1990

Component	Key categories (Sorted from high to low from left to right and top to bottom)					Total (%)
NO_x	*Fishing*	*Road transport: Passenger cars*	*National navigation*	*Mobile combustion in manufacturing industries and construction*		82.8%
	NFR 1A4ciii	*NFR 1A3bi*	*NFR 1A3dii*	*NFR 1A2gvii*		
	59.1%	14.9%	4.8%	4.0%		
NMVOC	*Road transport: Passenger cars*	*National fishing*	*Manure management - Horses*	*Manure management - Dairy cattle*	*Biological treatment of waste - Solid waste disposal on land*	81.7%
	NFR 1A3bi	*NFR 1A4ciii*	*NFR 3B4e*	*NFR 3B1a*	*NFR 5A*	
	37.6%	*6.4%*	*5.7%*	*5.6%*	*5.3%*	
	Coating applications	*Domestic solvent use including fungicides*	*Road transport: Gasoline evaporation*	*Manure management - Non-dairy cattle*	*Food and beverages industry*	
	NFR 2D3d	*NFR 2D3a*	*NFR 1A3bv*	*NFR 3B1b*	*NFR 2H2*	
	5.1%	*4.6%*	*4.3%*	*3.8%*	*3.2%*	
SO_x	*Other fugitive emissions from energy production (Geothermal energy)*	*National fishing*	*Ferroalloys production*			82.7%
	NFR 1B2d	*NFR 1A4ciii*	*NFR 2C2*			
	55.6%	19.4%	7.7%			
NH_3	*Animal manure applied to soils*	*Manure management - Sheep*	*Urine and dung deposited by grazing animals*	*Manure management - Dairy cattle*	*Manure management - Non-dairy cattle*	86.2%
	NFR 3Da2a	*NFR 3B2*	*NFR 3Da3*	*NFR 3B1a*	*NFR 3B1b*	
	28.3%	18.8%	18.3%	13.6%	*7.1%*	
PM2.5	*National fishing*	*Open burning of waste*	*Road transport: Automobile road abrasion*	*Ferroalloy production*	*Mobile combustion in manufacturing industries and construction*	82.4%
	NFR 1A4ciii	*NFR 5C2*	*NFR 1A3bvii*	*NFR 2C2*	*NFR 1A2gvii*	
	32.6%	11.2%	6.8%	6.7%	5.6%	
	Construction and demolition	*Aluminium production*	*National navigation (shipping)*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*	*Road transport: Heavy duty vehicles and buses*	
	NFR 2A5b	*NFR 2C3*	*NFR 1A3dii*	*NFR 1A2f*	*NFR 1A3biii*	
	4.3%	4.1%	4.0%	3.7%	3.4%	

Component	Key categories (Sorted from high to low from left to right and top to bottom)					Total (%)
PM10	*Construction and demolition*	*National fishing*	*Quarrying and mining of minerals other than coal*	*Road transport: Automobile road abrasion*	*Open burning of waste*	82.5%
	NFR 2A5b	*NFR 1A4ciii*	*NFR 2A5a*	*1A3bvii*	*NFR 5C2*	
	24.4%	20.0%	8.6%	7.1%	6.8%	
	Ferroalloy production	*Mobile combustion in manufacturing industries and construction*	*Farm-level agricultural operations including storage, handling and transport of agricultural products*	*Aluminium production*	*National navigation (shipping)*	
	NFR 2C2	*NFR 1A2gvii*	*NFR 3Dc*	*NFR 2C3*	*NFR 1A3dii*	
	3.8%	3.2%	3.1%	2.9%	2.5%	
TSP	*Construction and demolition*	*National fishing*	*Quarrying and mining of minerals other than coal*	*Road transport: Automobile road abrasion*	*Open burning of waste*	81.8%
	NFR 2A5b	*NFR 1A4ciii*	*NFR 2A5a*	*1A3bvii*	*NFR 5C2*	
	44.6%	10.9%	9.6%	7.7%	3.8%	
	International aviation LTO (civil)	*Ferroalloy production*				
	NFR 1A3ai(i)	*NFR 2C2*				
	3.0%	2.2%				
BC	*National fishing*	*Open burning of waste*	*Mobile combustion in manufacturing industries and construction*	*Road transport: Passenger cars*	*Road transport: Heavy duty vehicles and buses*	83.4%
	NFR 1A4ciii	*NFR 5C2*	*NFR 1A2gvii*	*NFR 1A3bi*	*NFR 1A3biii*	
	34.7%	19.8%	14.7%	7.1%	7.1%	
CO	*Road transport: Passenger cars*	*Aluminium production*	*International aviation LTO (civil)*			81.3%
	NFR 1A3bi	*NFR 2C3*	*NFR 1A3ai(i)*			
	54.4%	14.7%	12.3%			

Key categories for NO_x, NMVOC, SO_x, NH_3, PM2.5, PM10, TSP, BC and CO, Trend 1990-2019

Component	**Key categories (Sorted from high to low from left to right and top to bottom)**					**Total (%)**
NO_x	*Road transport: Passenger cars* *NFR 1A3bi* 30.0%	*Ferroalloy production* *NFR 2C2* 12.5%	*Aluminium production* *NFR 2C3* 10.9%	*Mobile combustion in manufacturing industries and construction* *NFR 1A2gvii* 8.4%	*Fishing* *NFR 1A4ciii* 7.7%	80.6%
	Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco *NFR 1A2e* 6.5%	*International aviation LTO (civil)* *NFR 1A3ai(i)* 4.7%				
NMVOC	*Road transport: Passenger cars* *NFR 1A3bi* 41.7%	*Domestic solvent use including fungicides* *NFR 2D3a* 9.8%	*Manure management - Non-dairy cattle* *NFR 3B1b* 6.7%	*Manure management - Horses* *NFR 3B4e* 6.2%	*Food and beverages industry* *NFR 2H2* 5.6%	80.6%
	Manure management - Dairy cattle *NFR 3B1a* 4.1%	*Distribution of oil products* *NFR 1B2av* 3.7%	*National fishing* *NFR 1A4ciii* 2.7%			
SO_x	*Other fugitive emissions from energy production (Geothermal energy)* *NFR 1B2d* 28.4%	*National fishing* *1A4ciii* 24.3%	*Aluminium production* *NFR 2C3* 21.9%	*Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco* *1A2e* 10.7%		85.3%
NH_3	*Manure management - Sheep* *NFR 3B2* 25.9%	*Manure management - Non-dairy cattle* *NFR 3B1b* 22.5%	*Manure management - Broilers* *NFR 3B4gii* 13.6%	*Manure management - Other animals* *NFR 3B4h* 7.9%	*Road transport: Passenger cars* *NFR 1A3bi* 6.5%	82.2%
	Animal manure applied to soils *NFR 3Da2a* 5.7%					

Component	Key categories (Sorted from high to low from left to right and top to bottom)					Total (%)
PM2.5	*Aluminium production*	*Open burning of waste*	*Road transport: Automobile road abrasion*	*National fishing*	*Mobile combustion in manufacturing industries and construction: Non-metallic minerals*	82.7%
	NFR 2C3	*NFR 5C2*	*NFR 1A3bvii*	*NFR 1A4ciii*	*NFR 1A2f*	
	28.3%	14.8%	13.6%	8.7%	6.2%	
	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	*Road transport: Heavy duty vehicles and buses*	*Mobile combustion in manufacturing industries and construction: Food processing, beverages and tobacco*			
	NFR 1A2f	*NFR 1A3biii*	*NFR 1A2e*			
	5.1%	3.3%	2.8%			
PM10	*Aluminium production*	*Construction and demolition*	*Road transport: Automobile road abrasion*	*Open burning of waste*	*Quarrying and mining of minerals other than coal*	80.4%
	NFR 2C3	*NFR 2A5b*	*1A3bvii*	*NFR 5C2*	*NFR 2A5a*	
	20.5%	17.4%	14.3%	9.7%	8.0%	
	National fishing	*Mobile combustion in manufacturing industries and construction*				
	NFR 1A4ciii	*NFR 1A2gvii*				
	6.7%	3.8%				
TSP	*Construction and demolition*	*Road transport: Automobile road abrasion*	*Aluminium production*	*Quarrying and mining of minerals other than coal*	*Open burning of waste*	82.6%
	NFR 2A5b	*NFR 1A3bvii*	*NFR 2C3*	*NFR 2A5a*	*NFR 5C2*	
	29.6%	17.9%	14.9%	10.9%	5.5%	
	International aviation LTO (civil)					
	NFR 1A3ai(i)					
	3.7%					
BC	*National fishing*	*Open burning of waste*	*Mobile combustion in manufacturing industries and construction*	*Road transport: Passenger cars*	*Aluminium production*	80.1%
	NFR 1A4ciii	*NFR 5C2*	*NFR 1A2gvii*	*NFR 1A3bi*	*NFR 2C3*	
	28.5%	25.5%	12.2%	7.6%	6.2%	
CO	*Aluminium production*	*Road transport: Passenger cars*				82.8%
	NFR 2C3	*NFR 1A3bi*				
	50.0%	32.9%				

Persistant Organic Pollutants (POPs)

Key categories for POPs, 1990

Component	Key categories (Sorted from high to low from left to right)		Total (%)
DIOX	*Open burning of waste* *NFR 5C2* 97.9%		97.9%
PAH4	*Open burning of waste* *NFR 5C2* 82.8%		82.8%
HCB	*Open burning of waste* *NFR 5C2* 84.3%		84.3%
PCB	*Open burning of waste* *NFR 5C2* 62.6%	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals* *NFR 1A2f* 27.1%	89.8%

Key categories for POPs, Trend 1990-2019

Component	Key categories (Sorted from high to low from left to right)					Total (%)
DIOX	*Open burning of waste* *NFR 5C2* 50.7%	*Accidental fires* *NFR 5E* 30.1%				80.8%
PAH4	*Open burning of waste* *NFR 5C2* 41.0%	*Aluminium production* *NFR 2C3* 14.7%	*Ferroalloys production* *NFR 2C2* 12.4%	*Road transport: Passenger cars* *NFR 1A3bi* 11.6%	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals* *NFR 1A2f* 9.0%	88.7%
HCB	*Open burning of waste* *NFR 5C2* 91.4%					91.4%
PCB	*Open burning of waste* *NFR 5C2* 40.9%	*National fishing* *NFR 1A4ciii* 35.3%	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals* *NFR 1A2f* 17.3%			93.5%

Priority heavy metals (Pb, Cd, Hg) and additional heavy metals (As, Cr, Cu, Ni, Se, Zn)

Key categories for heavy metals, 1990

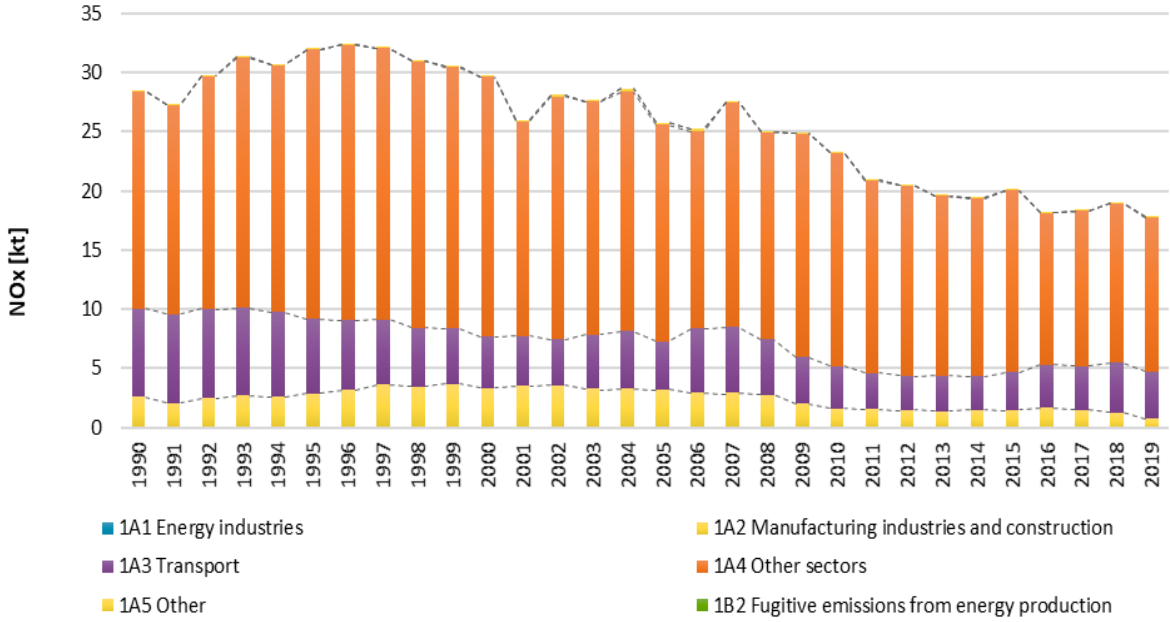
Component	Key categories (Sorted from high to low from left to right and top to bottom)					Total (%)
Pb	*Other product use (Fireworks, tobacco)*	*Mobile Combustion in manufacturing industries and construction*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*	*Other waste*	*Road transport: Automobile tyre and brake wear*	85.8%
	NFR 2G	*NFR 1A2gvii*	*NFR 1A2f*	*NFR 5E*	*NFR 1A3bvi*	
	22.7%	21.6%	16.3%	14.2%	11.0%	
Cd	*Open burning of waste*	*National fishing*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*			82.8%
	NFR 5C2	*NFR 1A4ciii*	*NFR 1A2f*			
	43.0%	30.0%	9.8%			
Hg	*Open burning of waste*					90.7%
	NFR 5C2					
	90.7%					
As	*National fishing*	*Open burning of waste*				82.1%
	NFR 1A4ciii	*NFR 5C2*				
	54.1%	28.0%				
Cr	*National fishing*	*Road transport: Automobil tyre and brake wear*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*			82.1%
	NFR 1A4ciii	*NFR 1A3bvi*	*NFR 1A2f*			
	49.1%	23.5%	9.5%			
Cu	*Road transport: Automobil tyre and brake wear*	*National fishing*				85.1%
	NFR 1A3bvi	*NFR 1A4ciii*				
	52.5%	32.6%				
Ni	*National fishing*					80.6%
	NFR 1A4ciii					
	80.6%					
Se	*National fishing*	*National navigation (shipping)*				85.8%
	NFR 1A4ciii	*NFR 1A3dii*				
	78.0%	7.8%				
Zn	*Open burning of waste*	*National fishing*	*Accidental fires*	*Road transport: Automobil tyre and brake wear*		84.3%
	NFR 5C2	*NFR 1A4ciii*	*NFR 5E*	*NFR 1A3bvi*		
	24.2%	22.8%	19.0%	12.7%	8.4%	

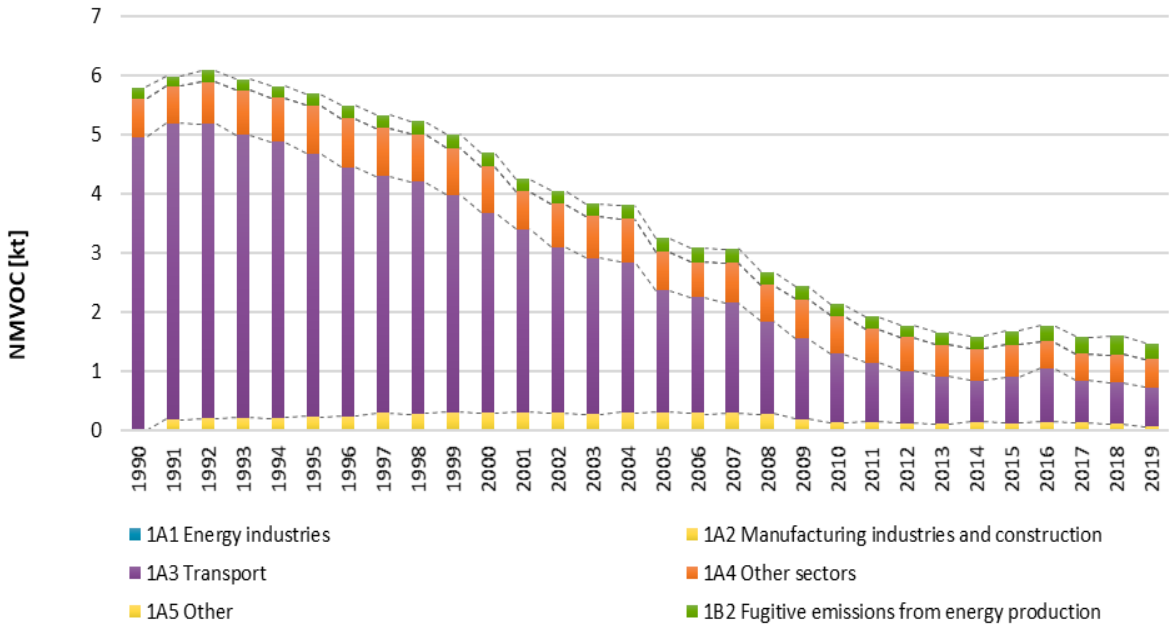
Key categories for heavy metals, trend 1990-2019

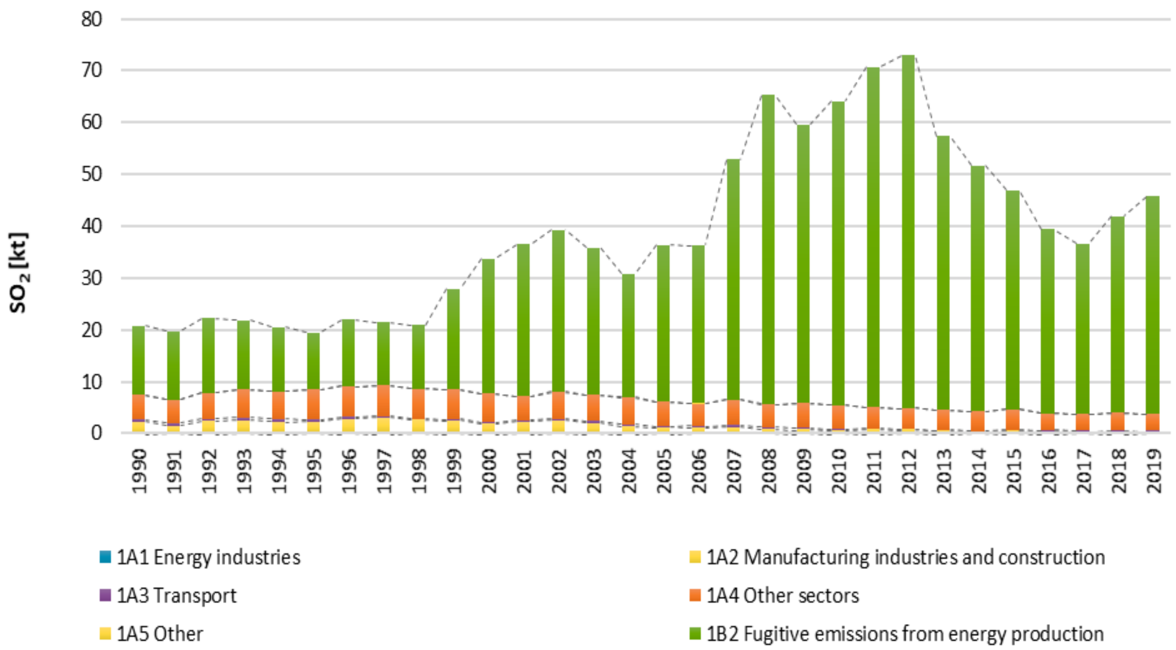
Component	Key categories (Sorted from high to low from left to right and top to bottom)				Total (%)
Pb	*Other product use (Fireworks, tobacco)*	*Mobile Combustion in manufacturing industries and construction*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*	*Other waste*	84.4%
	NFR 2G	*NFR 1A2gvii*	*NFR 1A2f*	*NFR 5E*	
	42.6%	17.4%	15.2%	9.2%	
Cd	*Open burning of waste*	*Ferroalloy production*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*	*Other product use (Fireworks, tobacco)*	88.0%
	NFR 5C2	*NFR 2C2*	*NFR 1A2f*	*NFR 2G*	
	38.4%	31.5%	9.3%	8.8%	
Hg	*Open burning of waste*	*National fishing*			80.6%
	NFR 5C2	*NFR 1A4ciii*			
	62.6%	18.0%			
As	*Open burning of waste*	*Fishing*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*		85.1%
	NFR 5C2	*NFR 1A4ciii*	*NFR 1A2f*		
	43.4%	36.0%	5.8%		
Cr	*Road transport: Automobil tyre and brake wear*	*National fishing*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*	*Other product use (Fireworks, tobacco)*	87.2%
	NFR 1A3bvi	*NFR 1A4ciii*	*NFR 1A2f*	*NFR 2G*	
	36.7%	25.3%	14.7%	10.5%	
Cu	*National fishing*	*Road transport: Automobil tyre and brake wear*	*Other product use (Fireworks, tobacco)*		88.0%
	NFR 1A4ciii	*NFR 1A3bvi*	*NFR 2G*		
	42.0%	26.5%	19.6%		
Ni	*National fishing*	*Public electricity and heat production*	*National navigation (shipping)*	*Other product use*	81.8%
	NFR 1A4ciii	*NFR 1A1a*	*NFR 1A3dii*	*NFR 2G*	
	33.5%	22.8%	14.0%	11.4%	
Se	*Open burning of waste*	*National fishing*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*	*Road transport: Automobil tyre and brake wear*	84.1%
	NFR 5C2	*NFR 1A4ciii*	*NFR 1A2f*	*NFR 1A3bvi*	
	36.4%	22.4%	12.7%	12.6%	
Zn	*Open burning of waste*	*Road transport: Automobil tyre and brake wear*	*Other product use (Fireworks, tobacco)*	*Stationary combustion in manufacturing industries and construction: Non-metallic minerals*	80.8%
	NFR 5C2	*NFR 1A3bvi*	*NFR 2G*	*NFR 1A2f*	
	37.1%	26.6%	11.3%	5.8%	

Annex III: Emission trends 1990-2019 per sector, non-POPs pollutants.

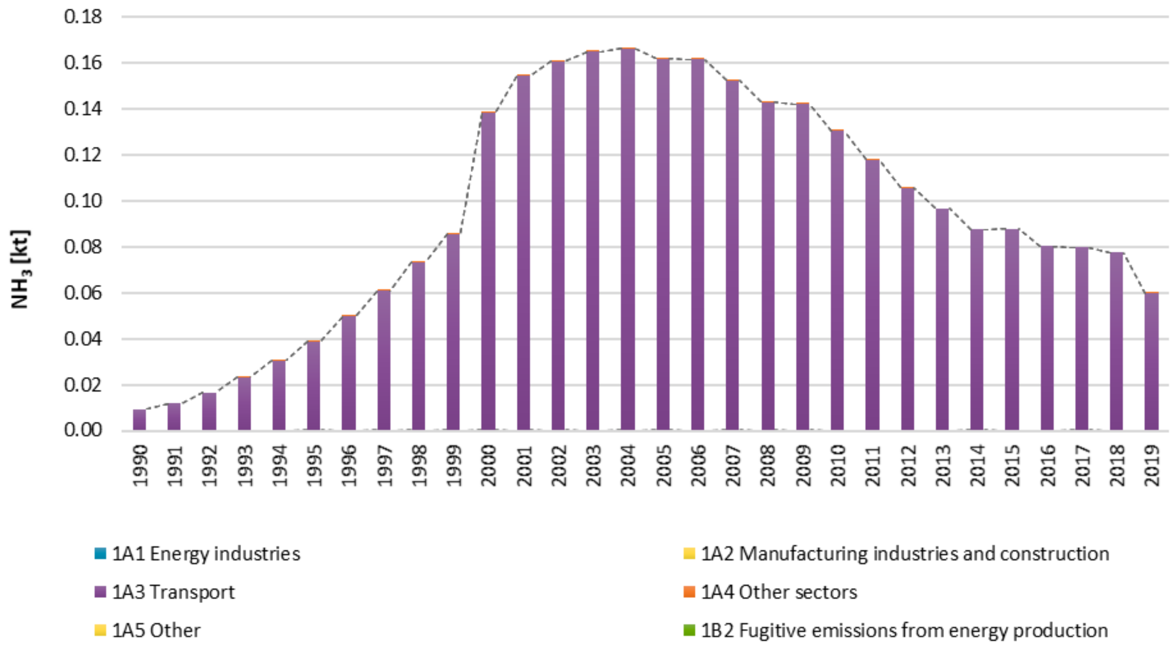
Energy: NO_x, NMVOC, SO_2, NH_3, CO and PM



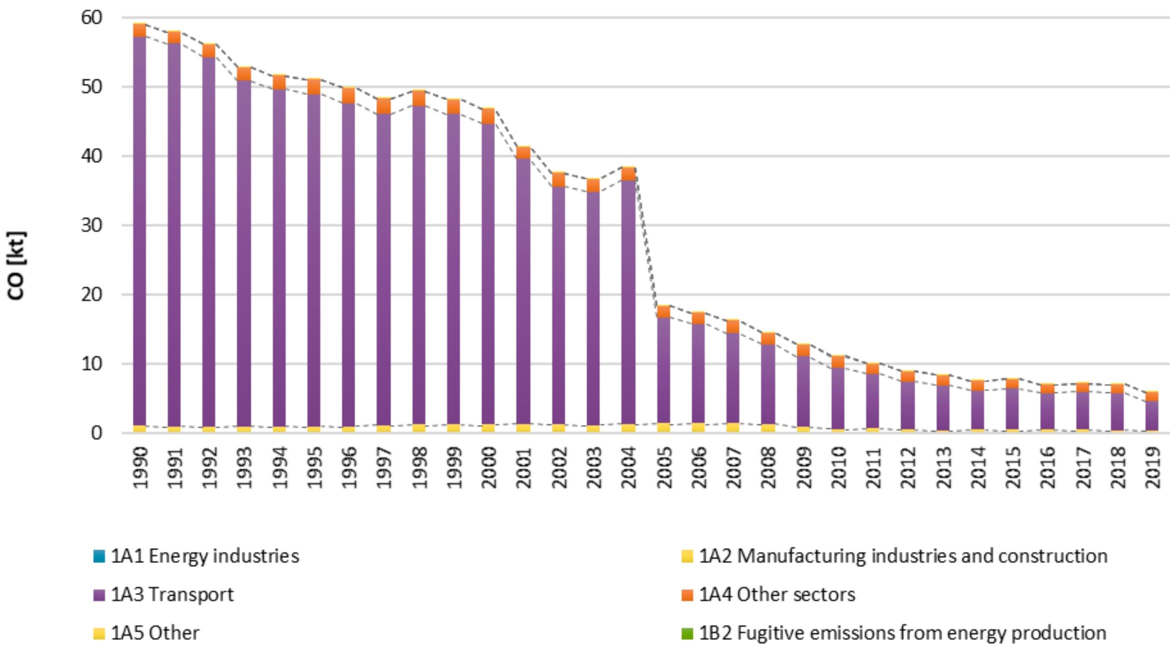




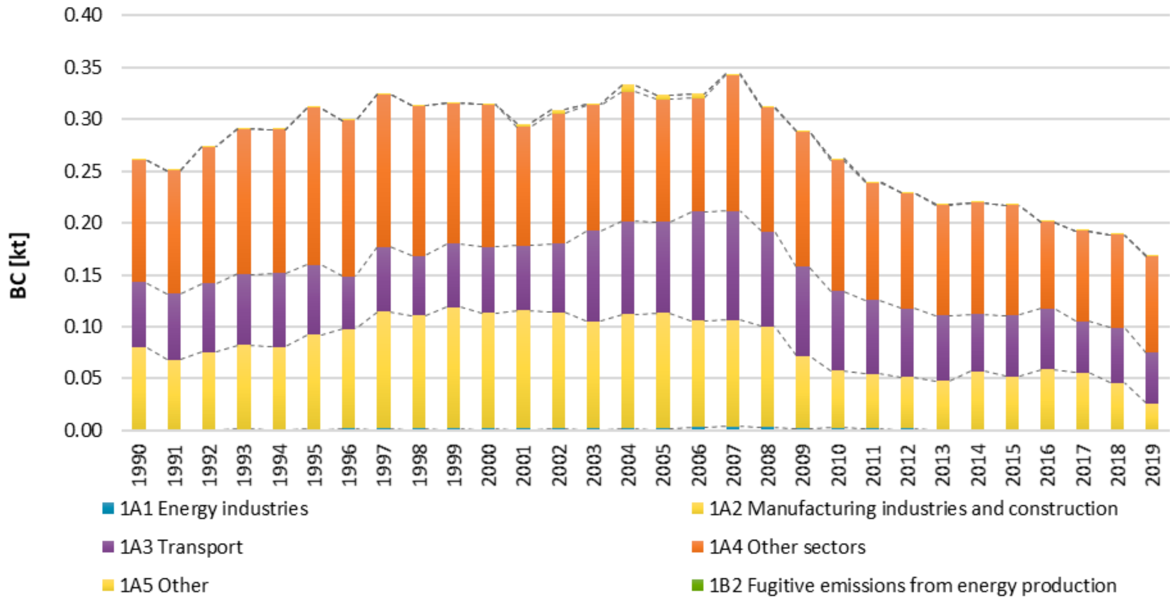
SO2 [kt]
80
70
60
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production



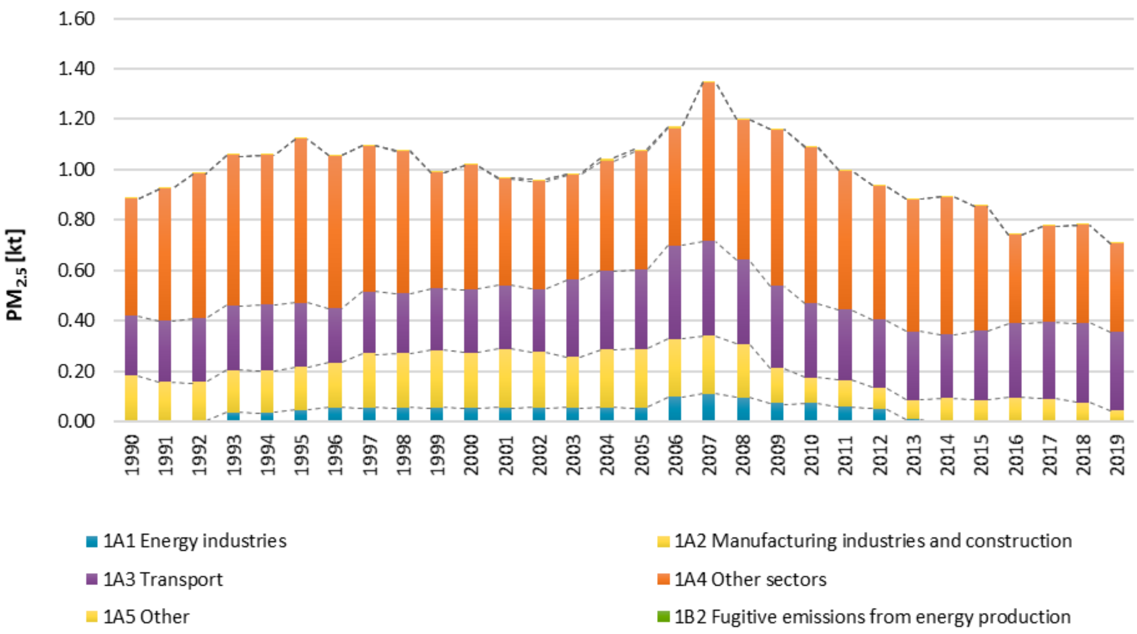
NH3 [kt]
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

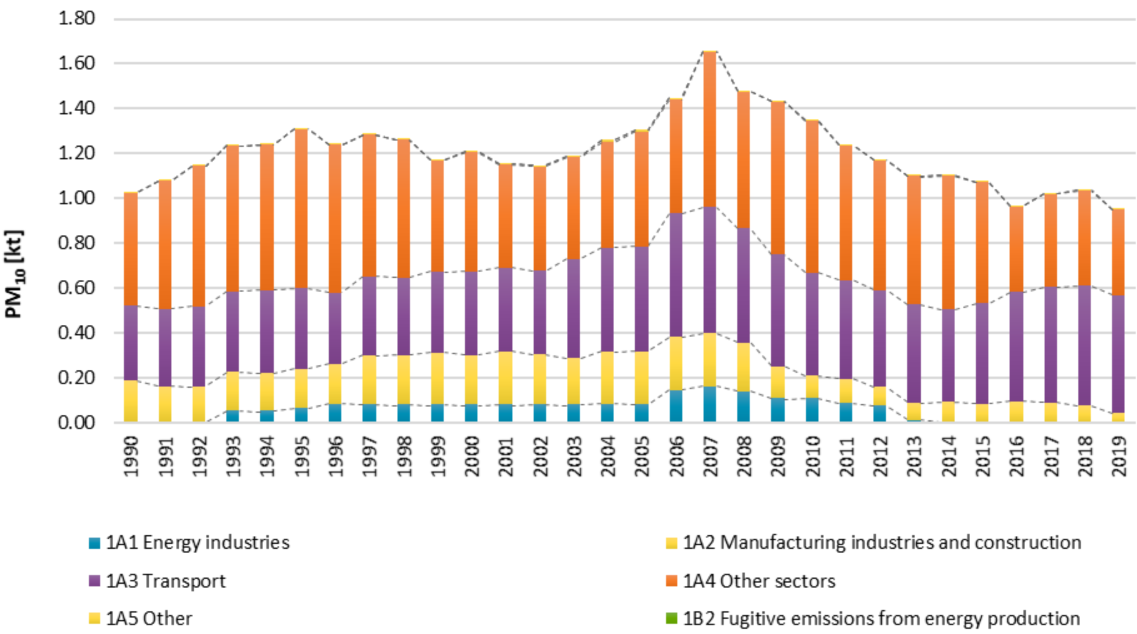


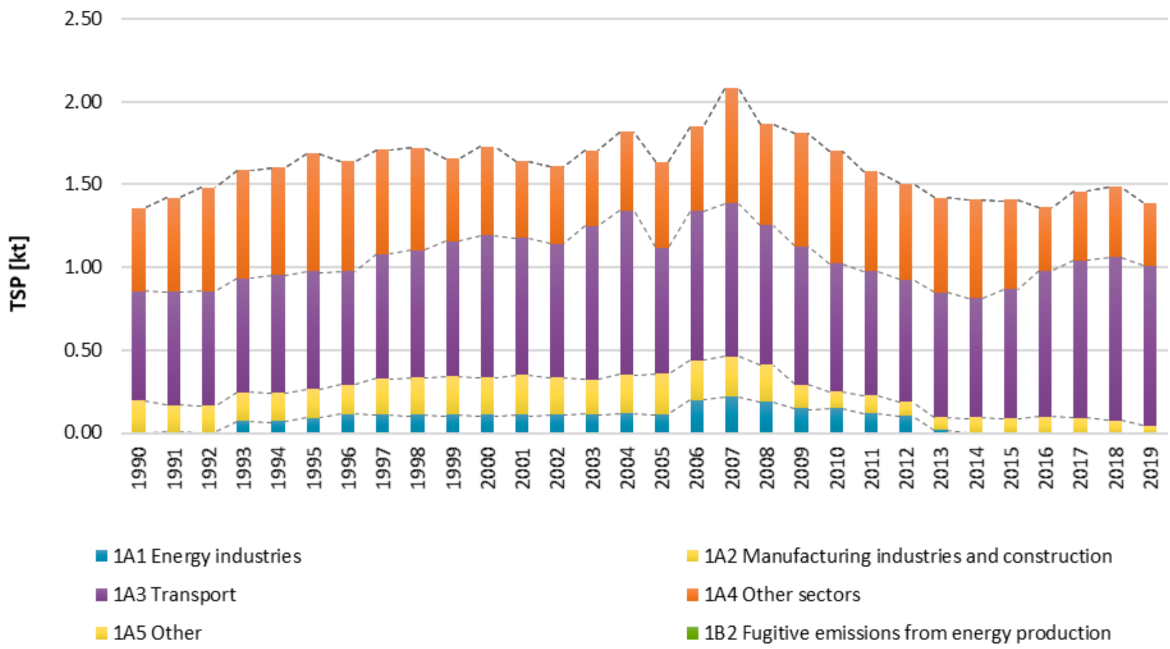
CO [kt]
60
50
40
30
20
10
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production



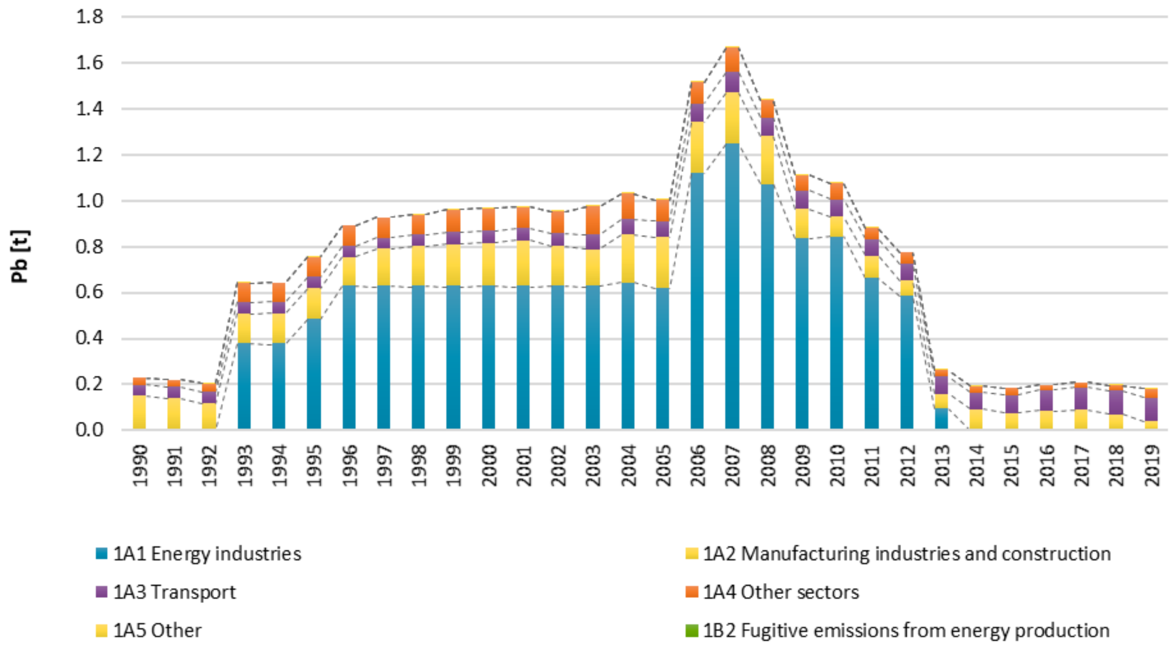
BC [kt]
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

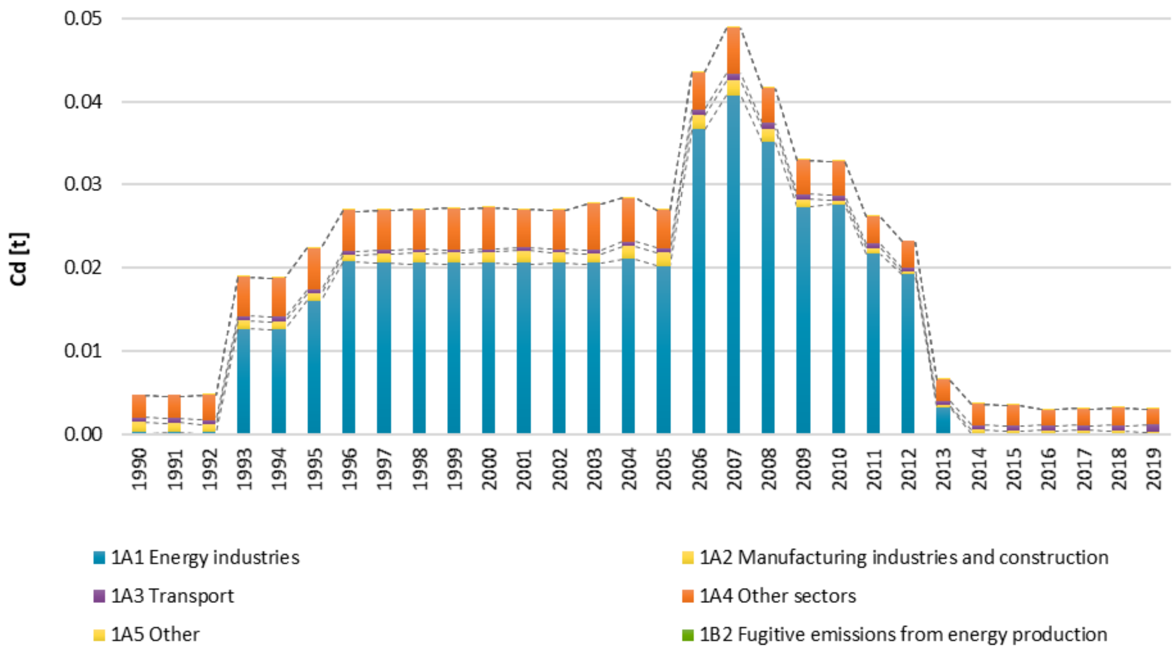

PM2.5 [kt]
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

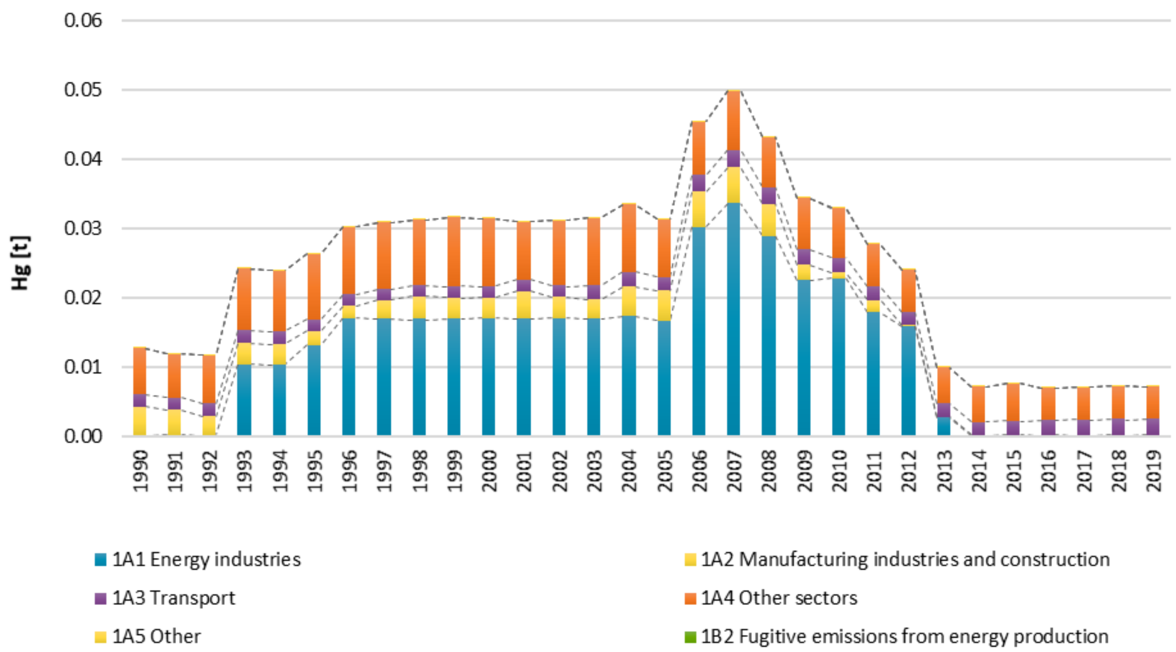

PM10 [kt]
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

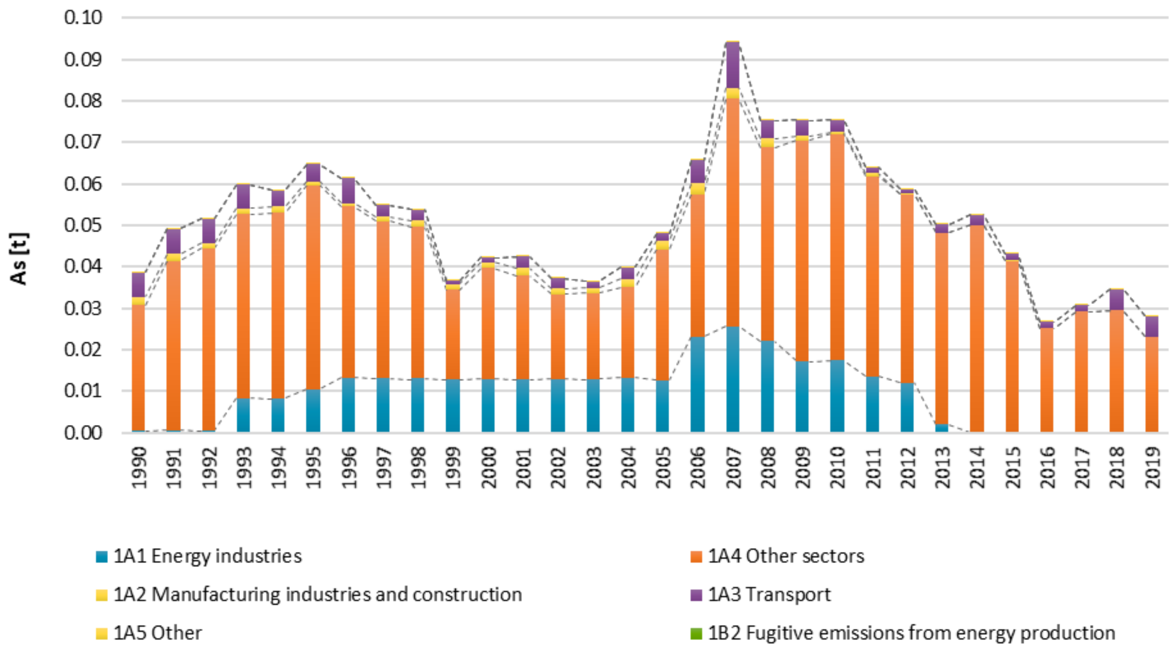


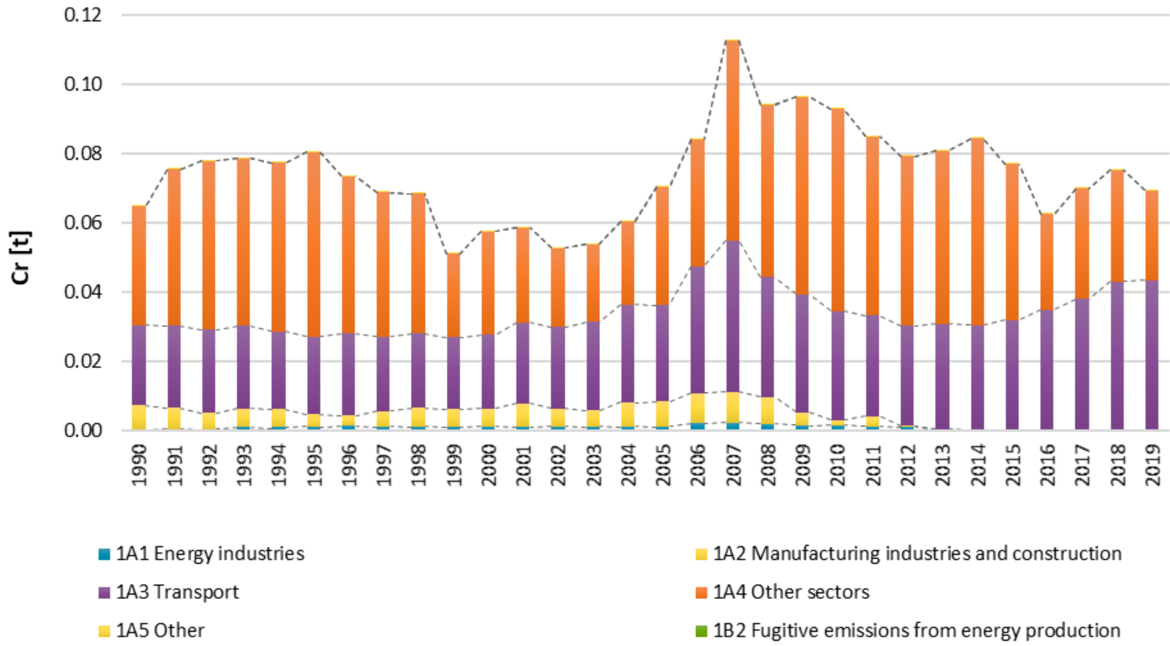
Energy: Heavy metals

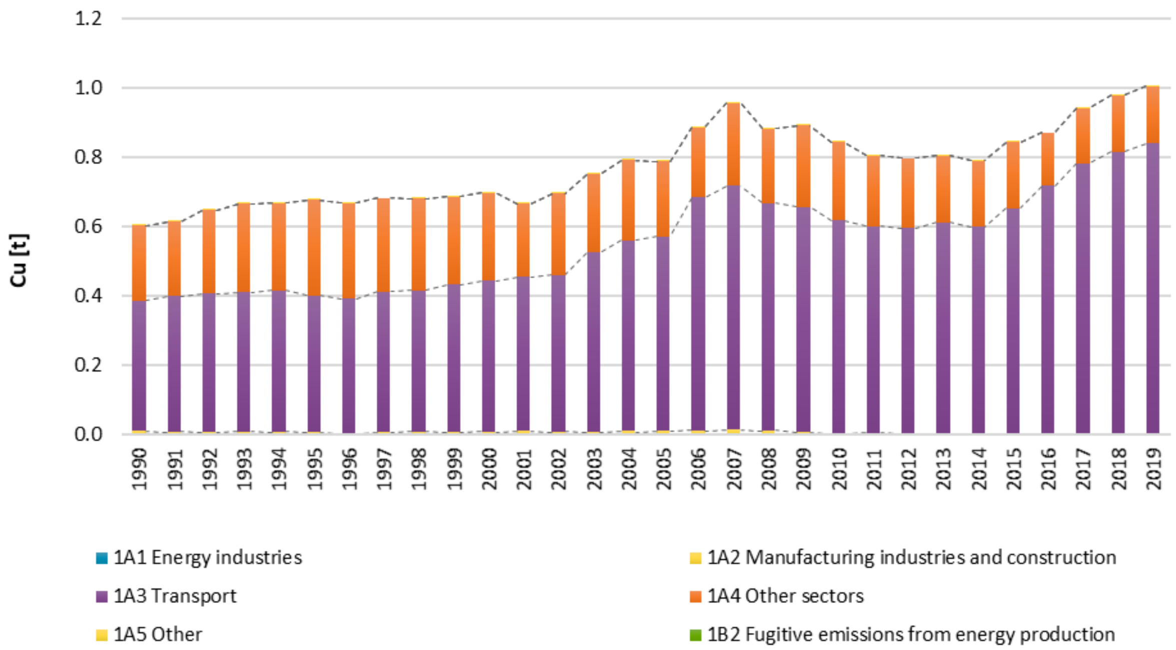


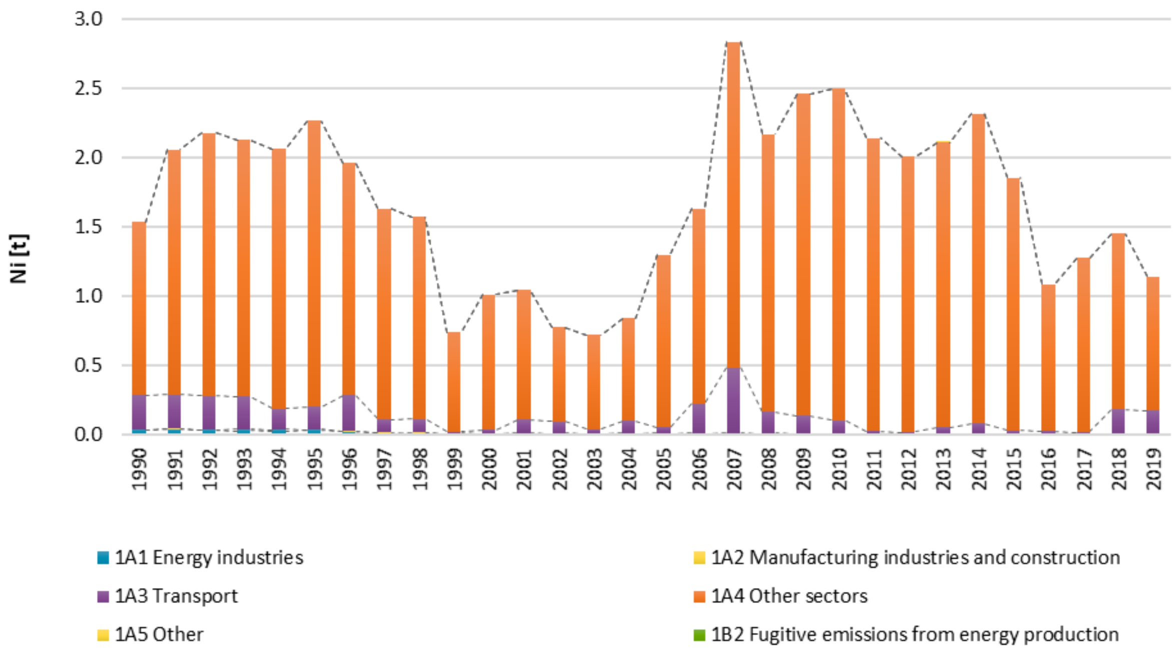

Cd [t]
0.05
0.04
0.03
0.02
0.01
0.00
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

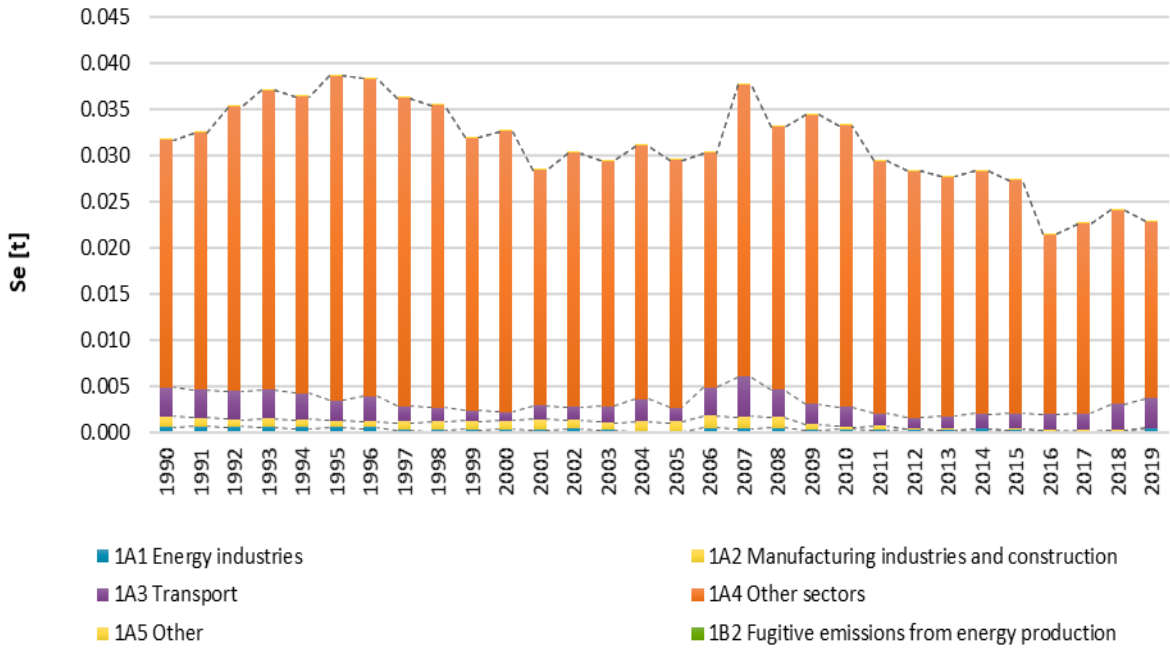

Hg [t]
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

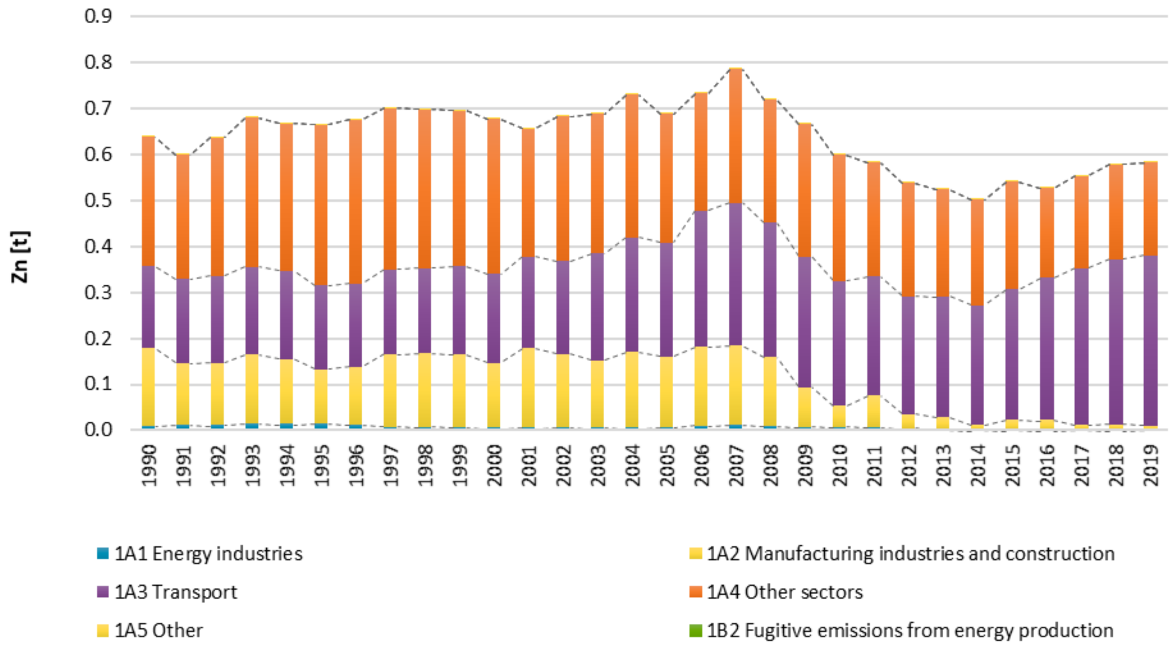

As [t]
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A4 Other sectors
1A2 Manufacturing industries and construction
1A3 Transport
1A5 Other
1B2 Fugitive emissions from energy production


Cr [t]
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

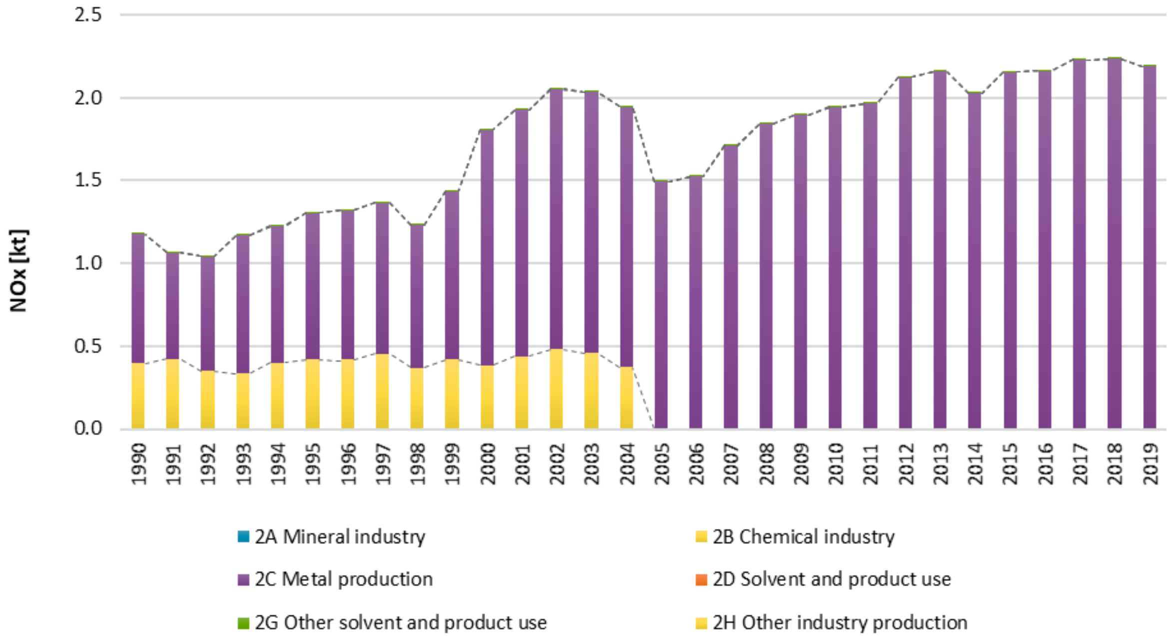

Cu [t]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

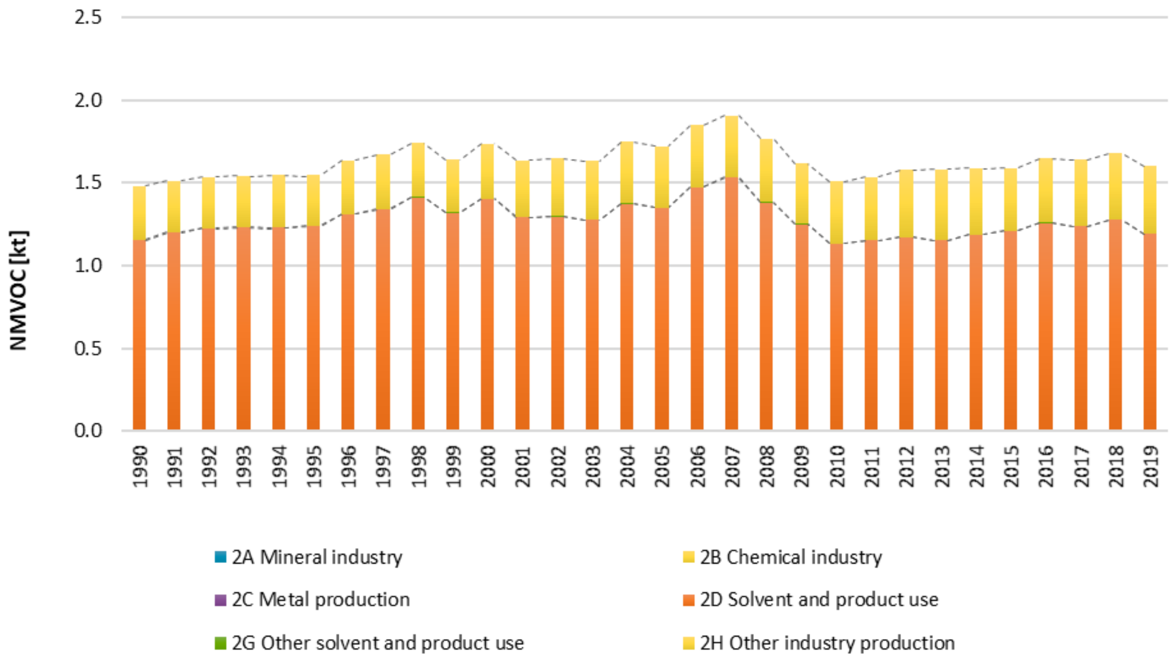

Ni [t]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

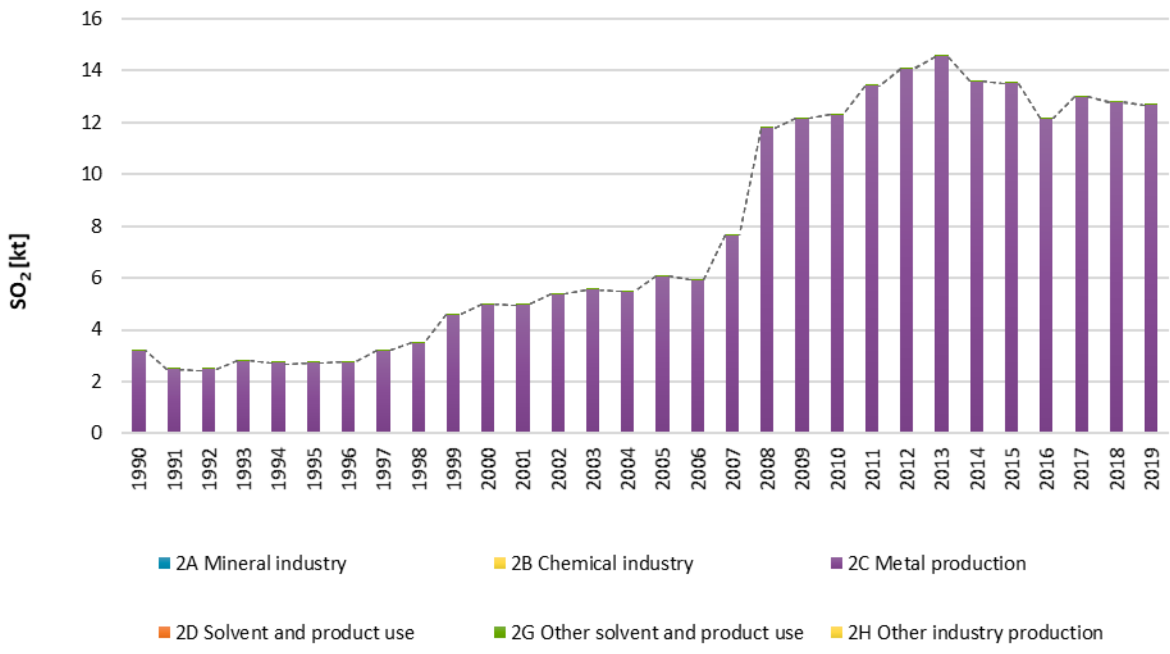

Se [t]
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production


Zn [t]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
1A1 Energy industries
1A2 Manufacturing industries and construction
1A3 Transport
1A4 Other sectors
1A5 Other
1B2 Fugitive emissions from energy production

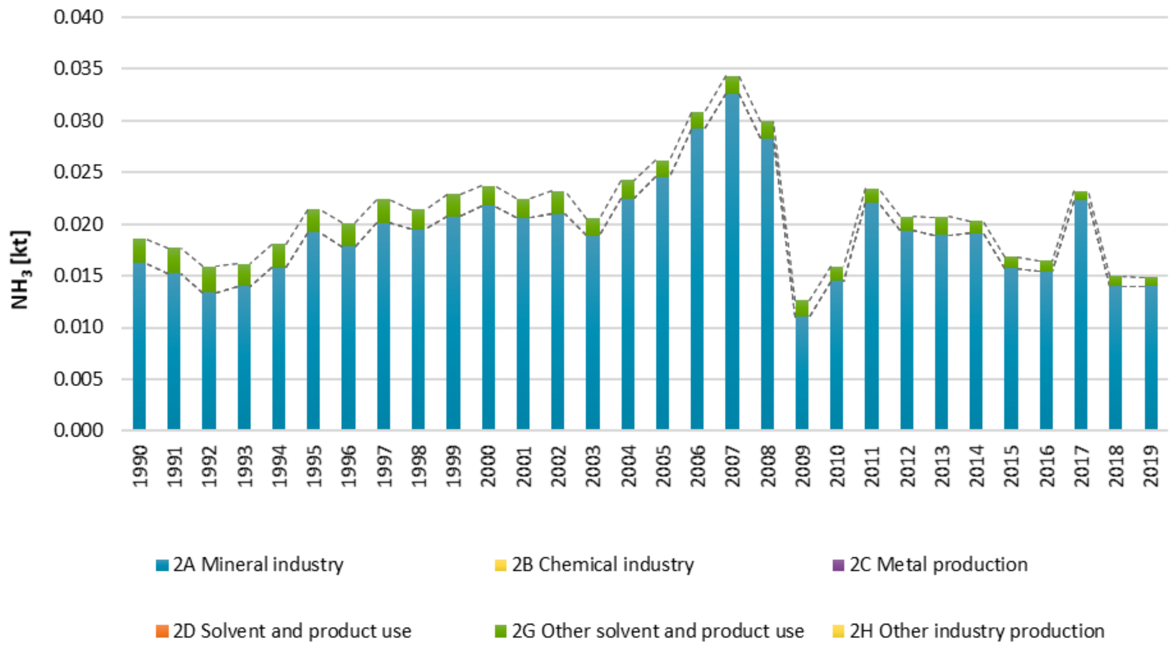
Industry: NO_x, NMVOC, SO_2, NH_3, CO and PM



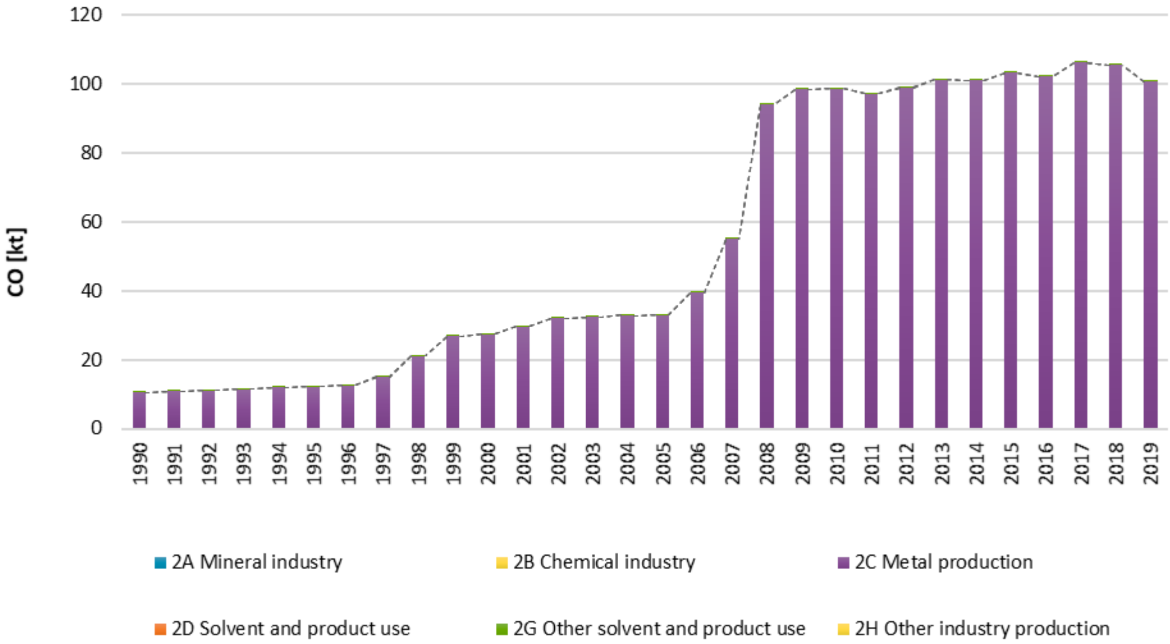


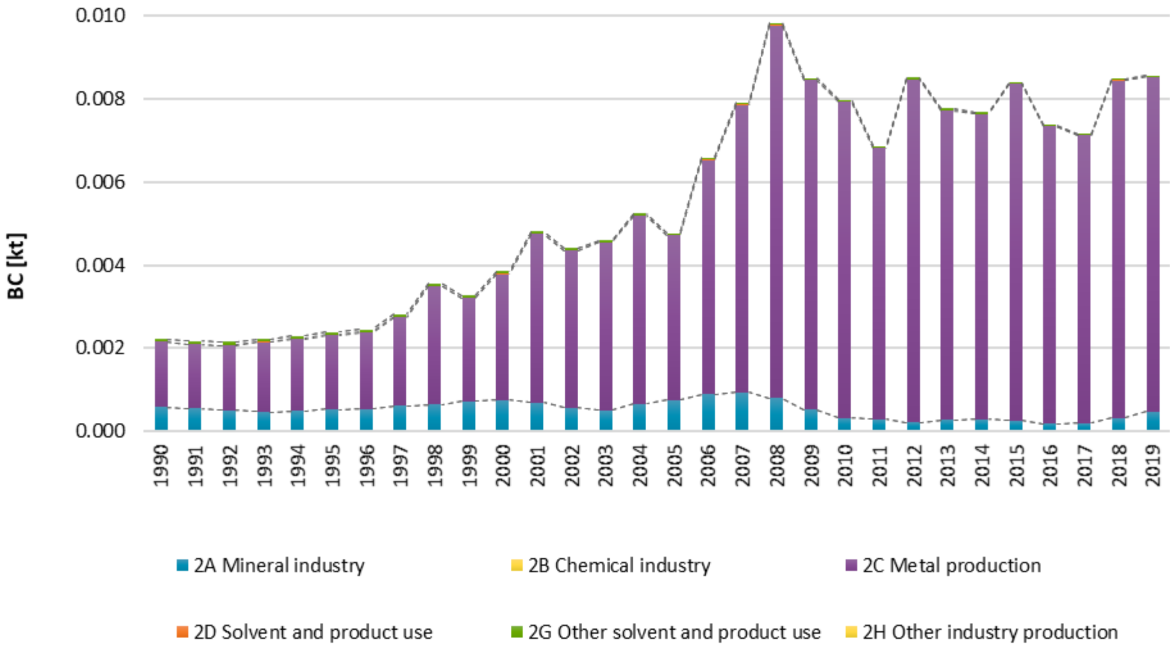


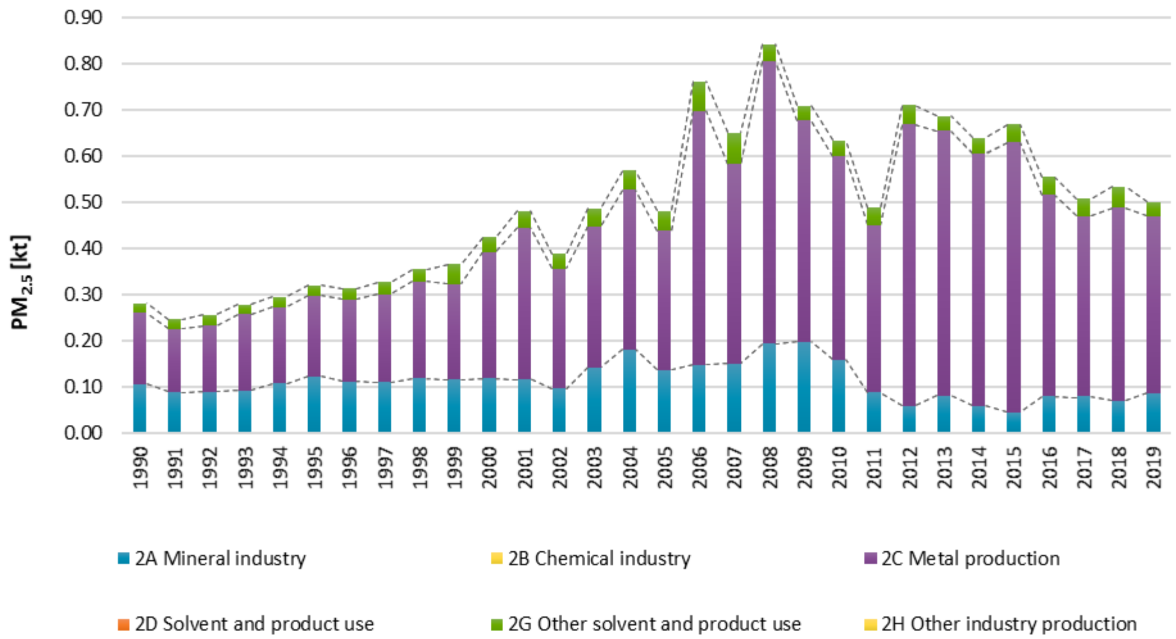
SO2 [kt]
16
14
12
10
8
6
4
2
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production

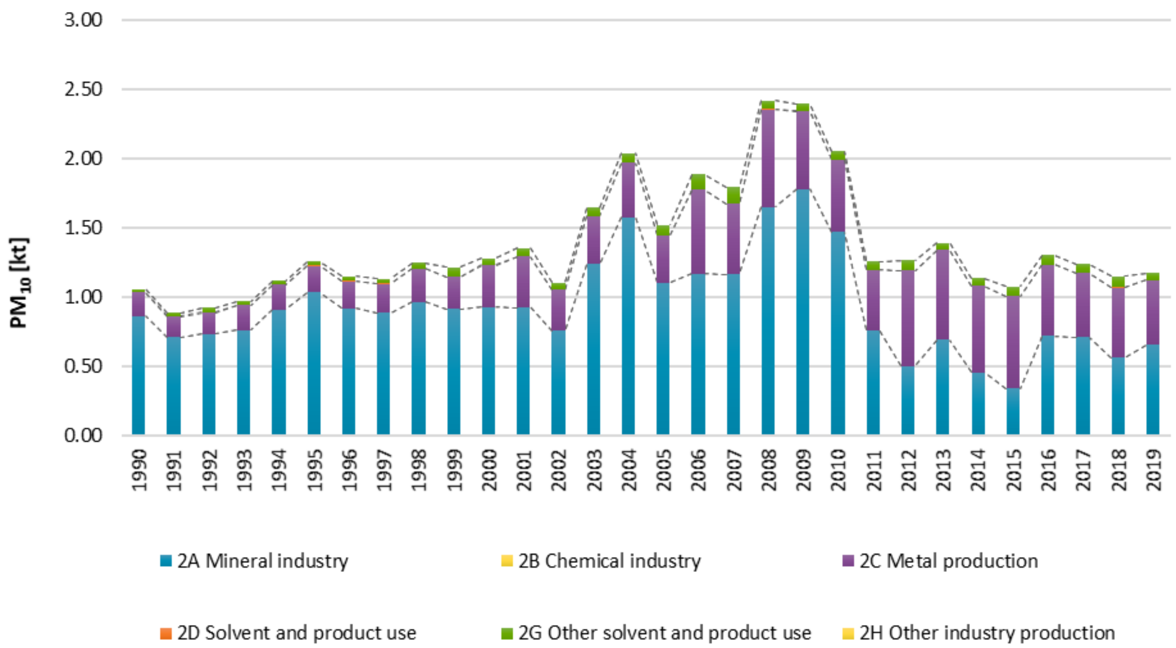


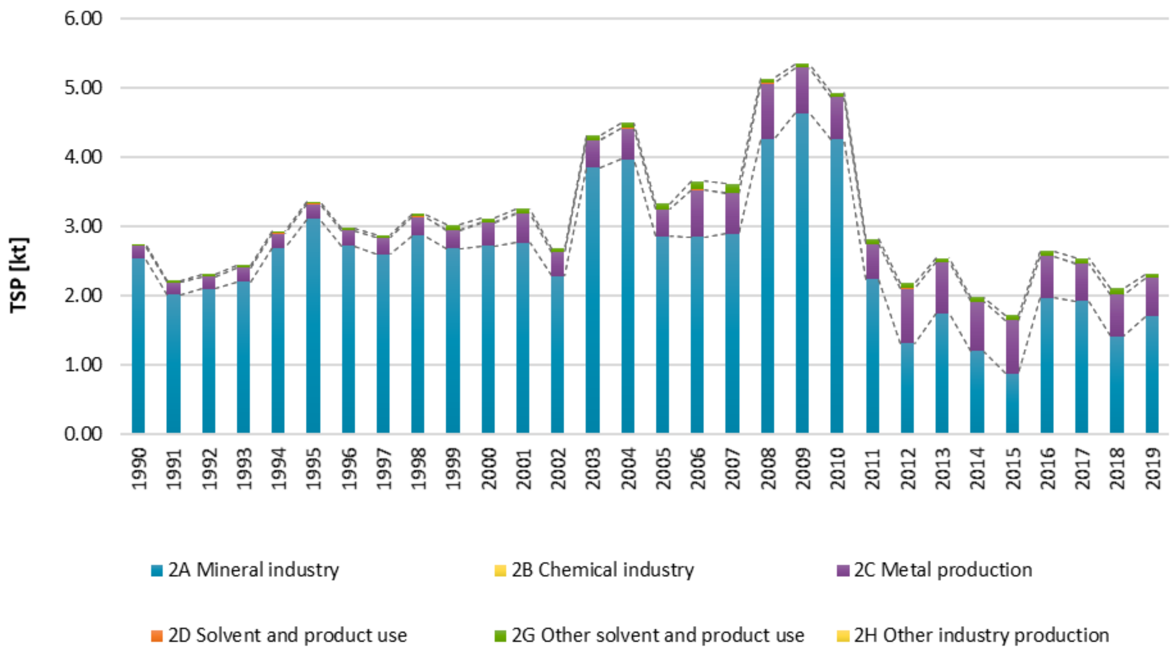
NH3 [kt]
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production


CO [kt]
120
100
80
60
40
20
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production

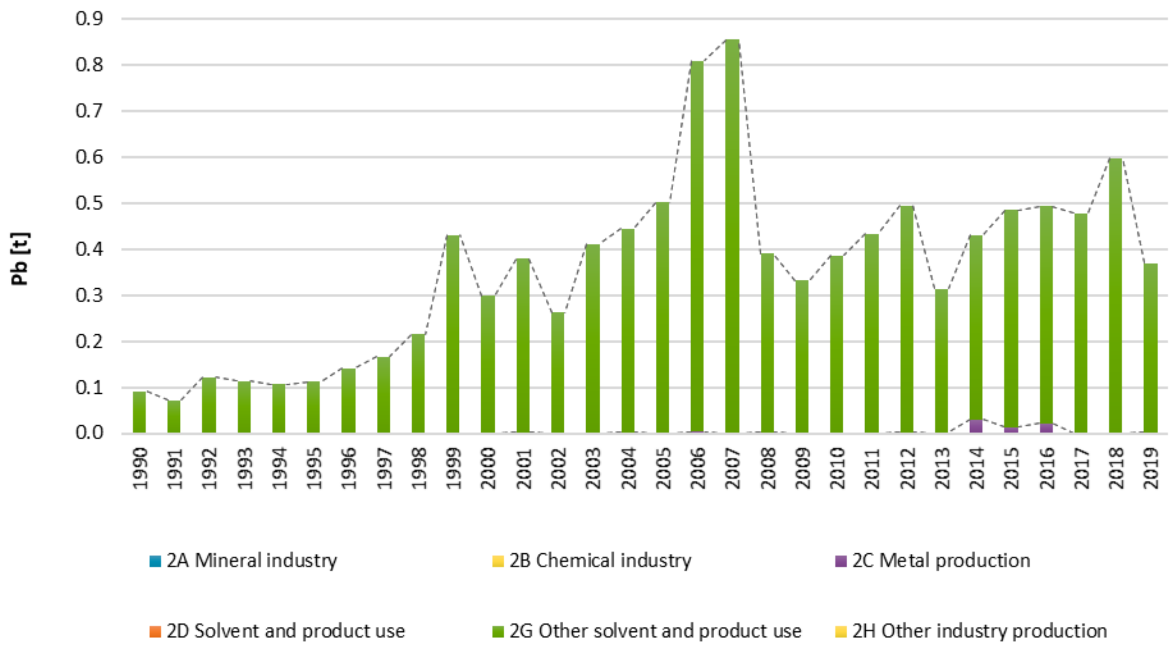

BC [kt]
0.010
0.008
0.006
0.004
0.002
0.000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production

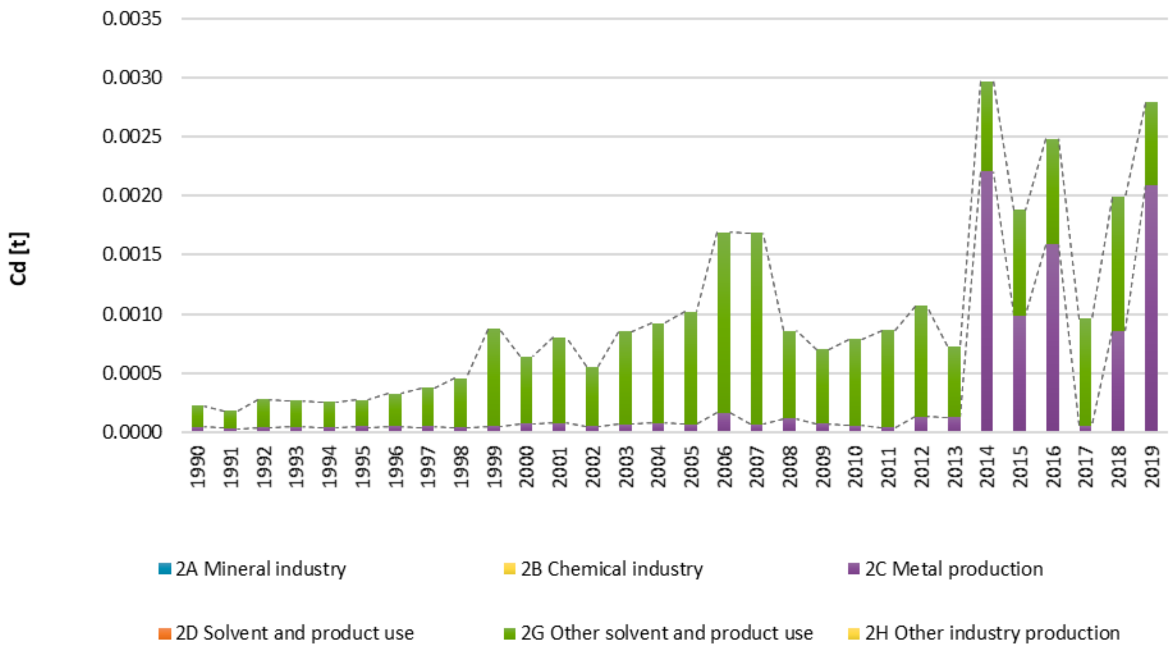

PM2.5 [kt]
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production


PM10 [kt]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production

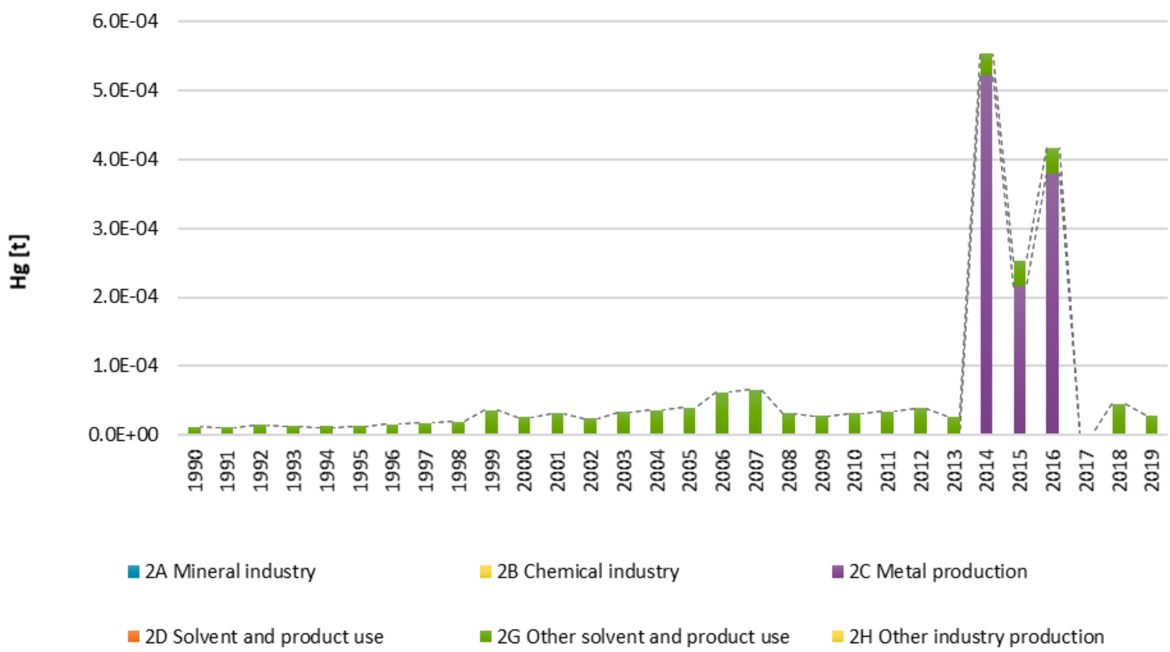


Industry: Heavy Metals

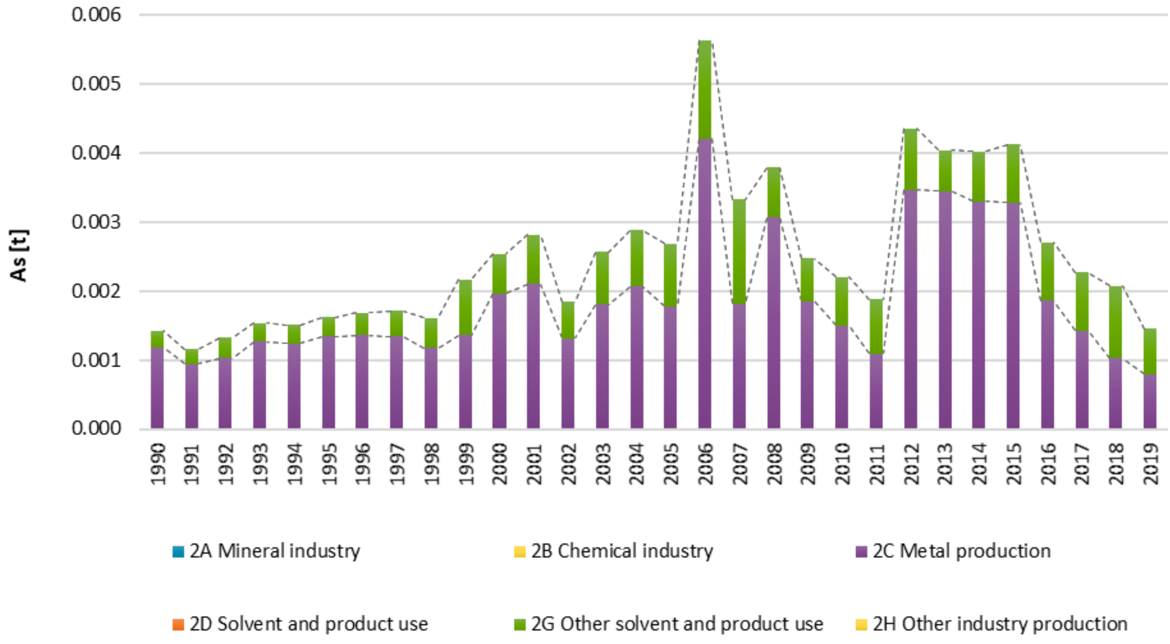


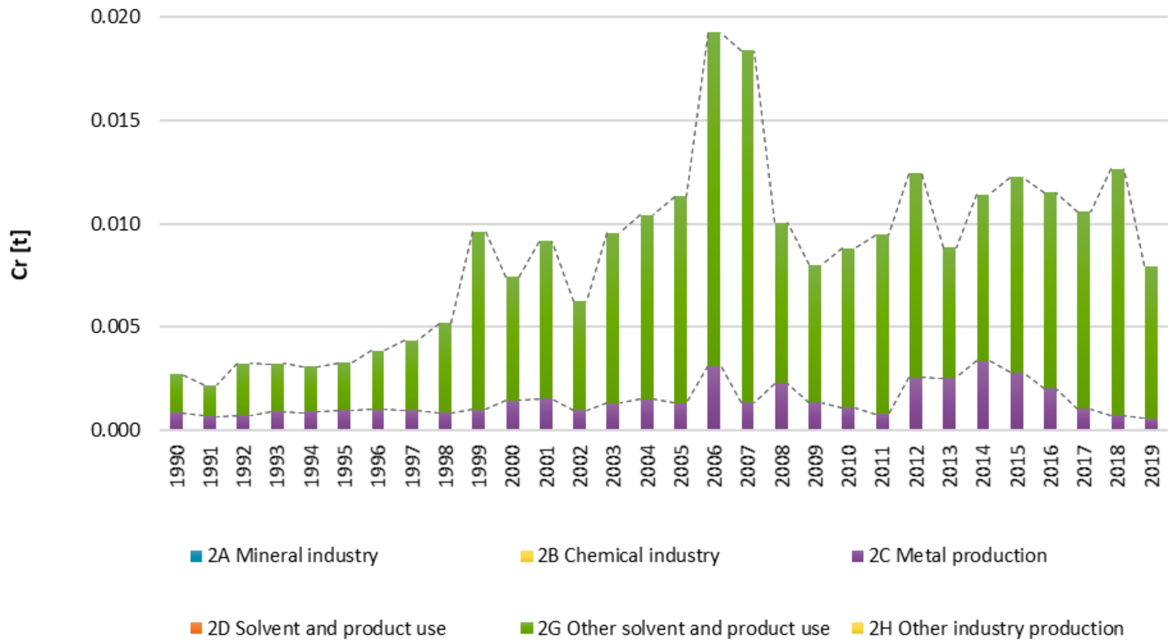


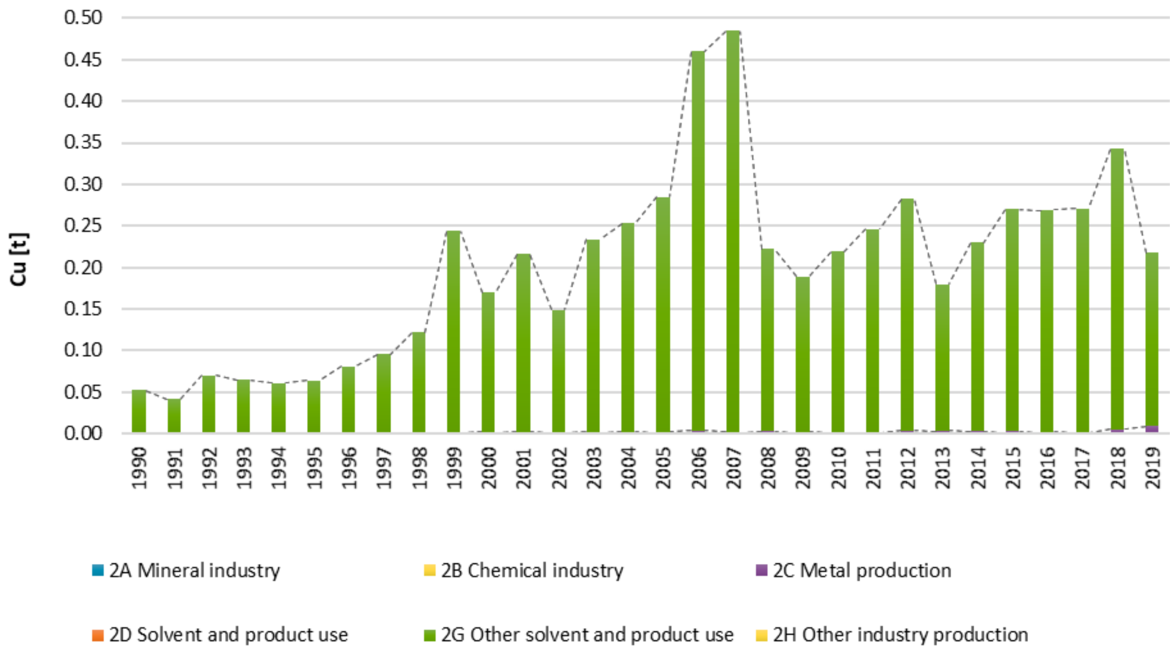
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
Cd [t]
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production

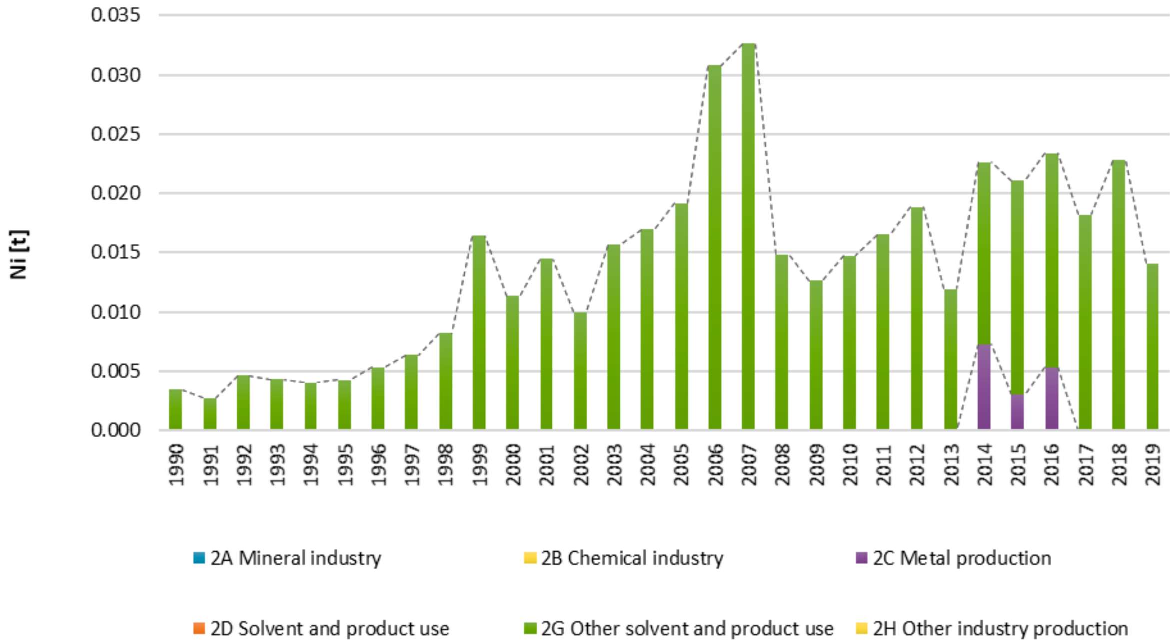


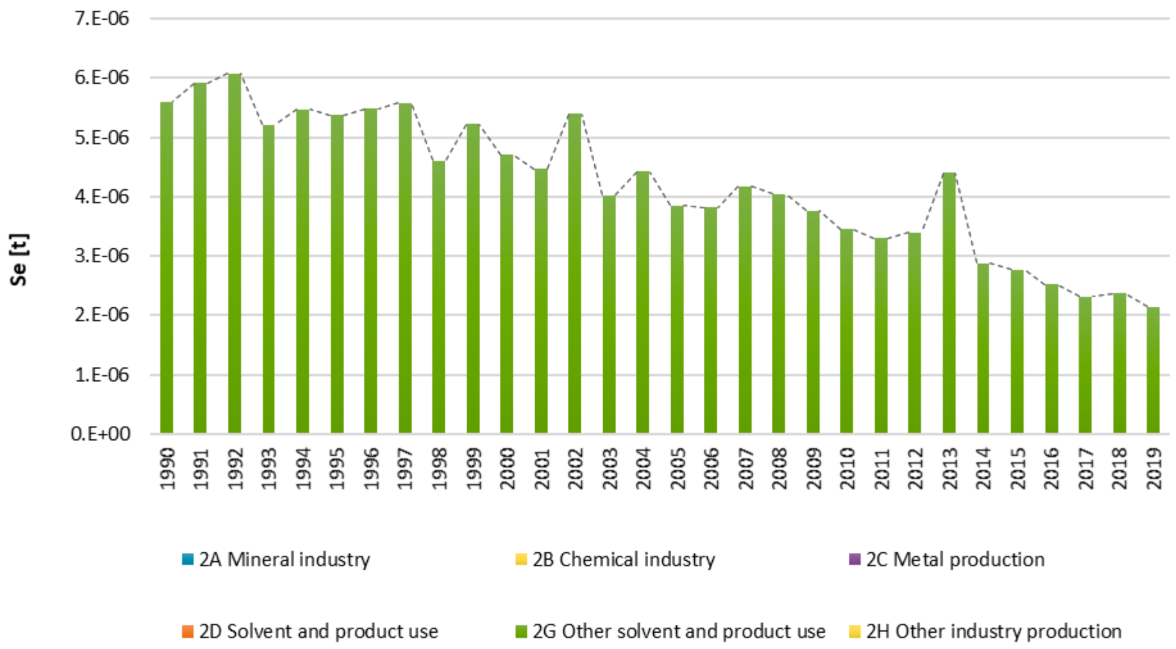
6.0E-04
5.0E-04
4.0E-04
3.0E-04
2.0E-04
1.0E-04
0.0E+00
Hg [t]
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production


As [t]
0.006
0.005
0.004
0.003
0.002
0.001
0.000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production


Cr [t]
0.020
0.015
0.010
0.005
0.000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production


Cu [t]
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production


Ni [t]
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production


7.E-06
6.E-06
5.E-06
4.E-06
3.E-06
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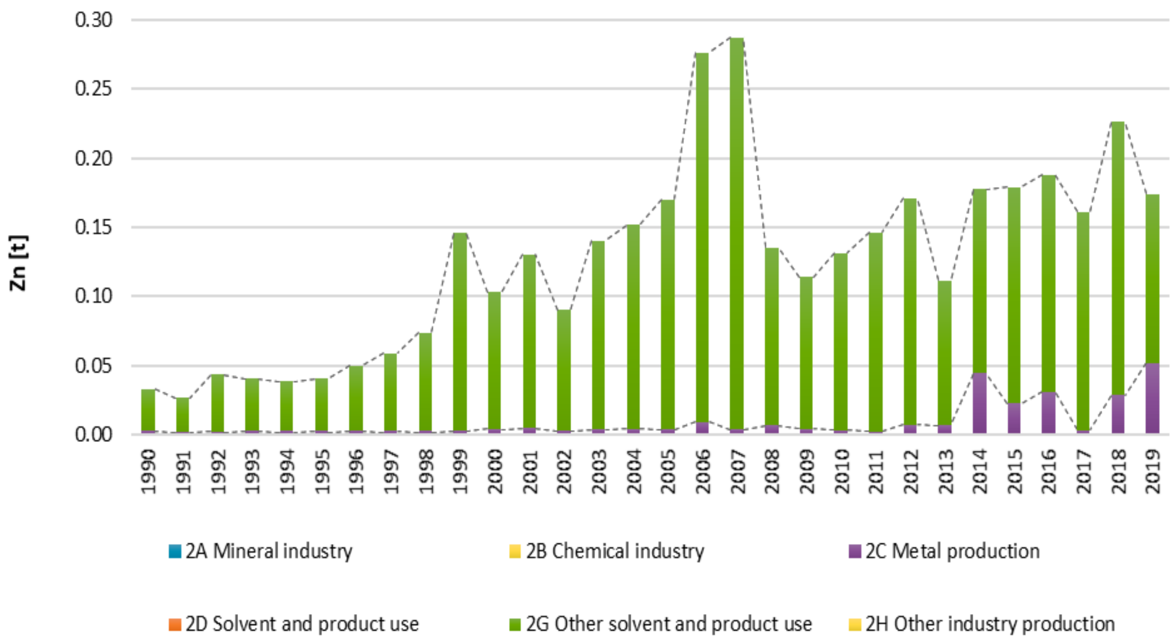
1.E-06
0.E+00
Se [t]
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production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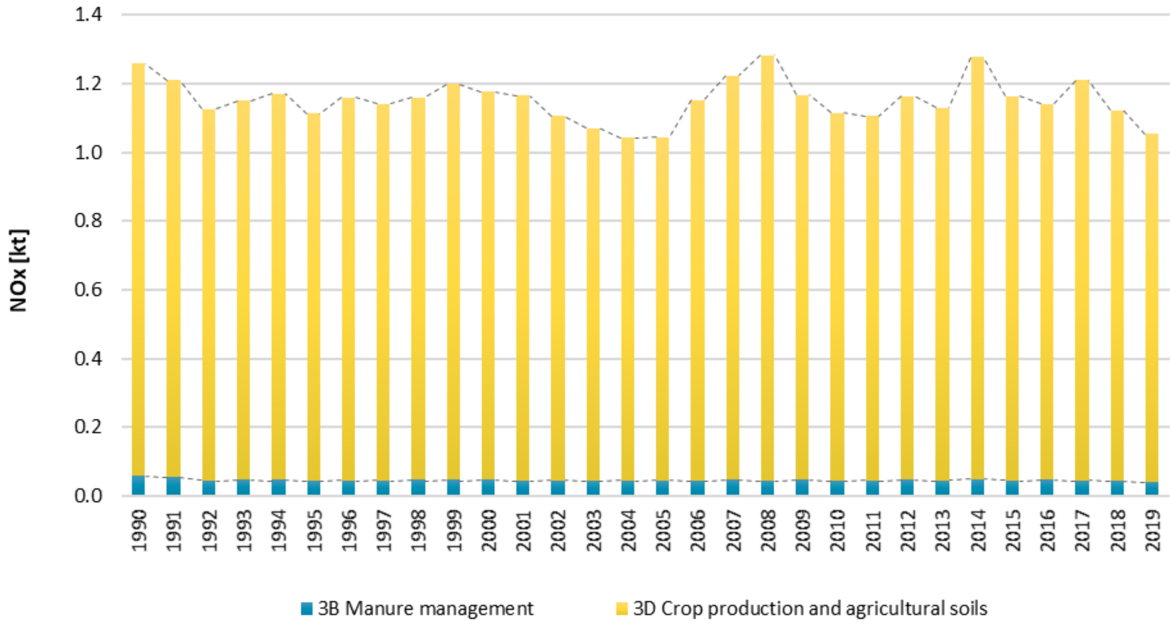
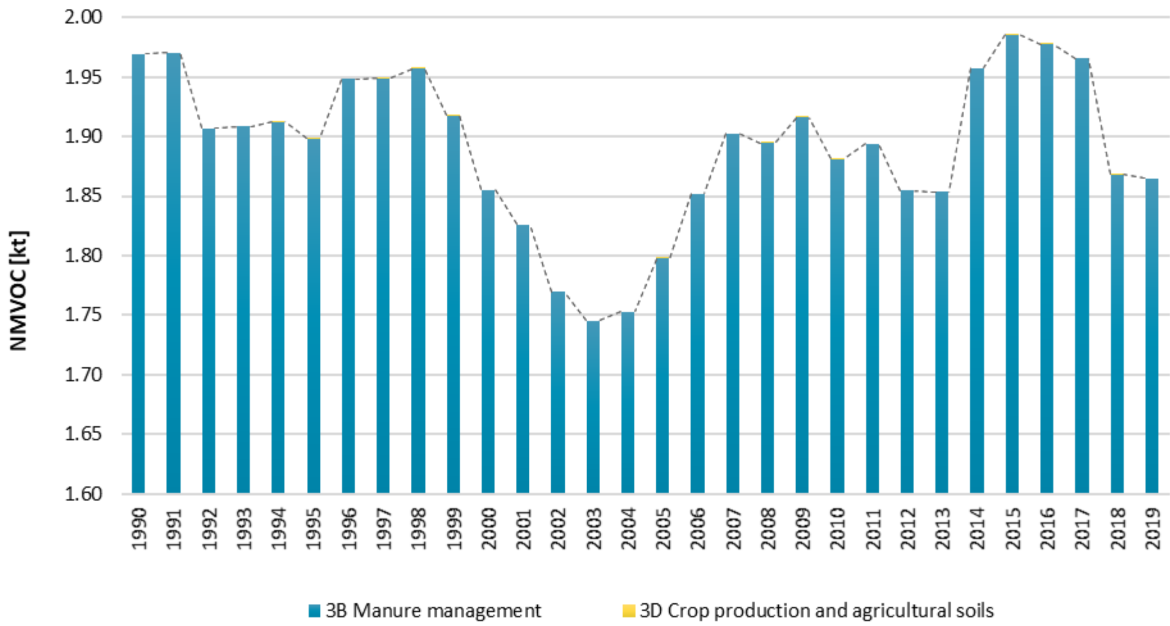
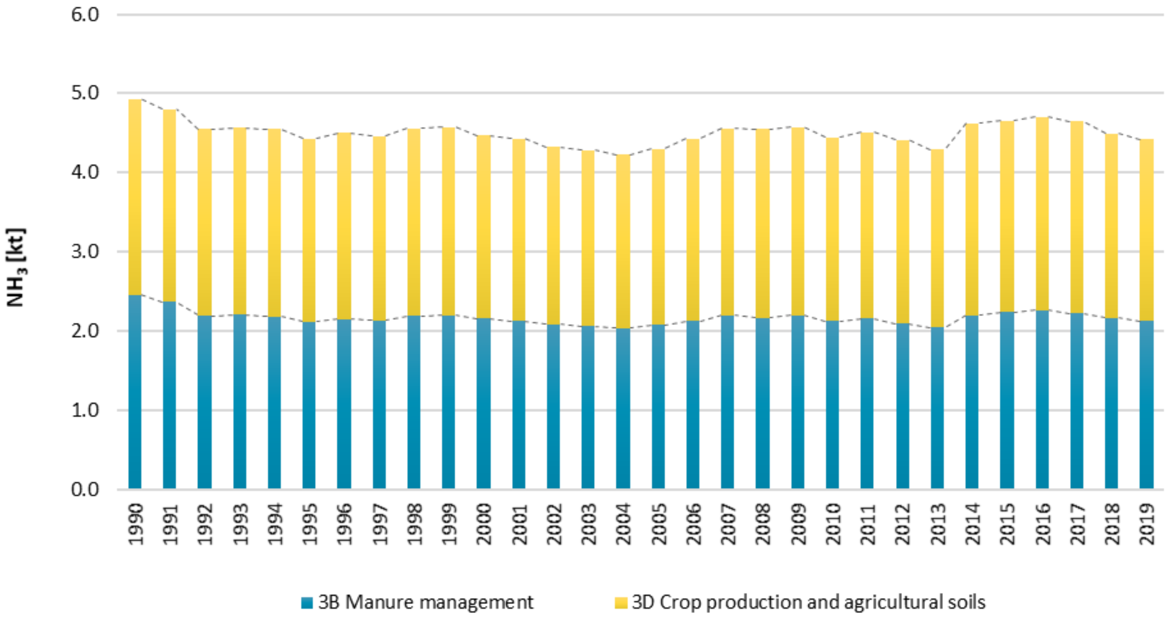
Zn [t]
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
2A Mineral industry
2B Chemical industry
2C Metal production
2D Solvent and product use
2G Other solvent and product use
2H Other industry production

Agriculture: NO_x, NMVOC, SO_2, NH_3, CO and PM



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NH3 [kt]
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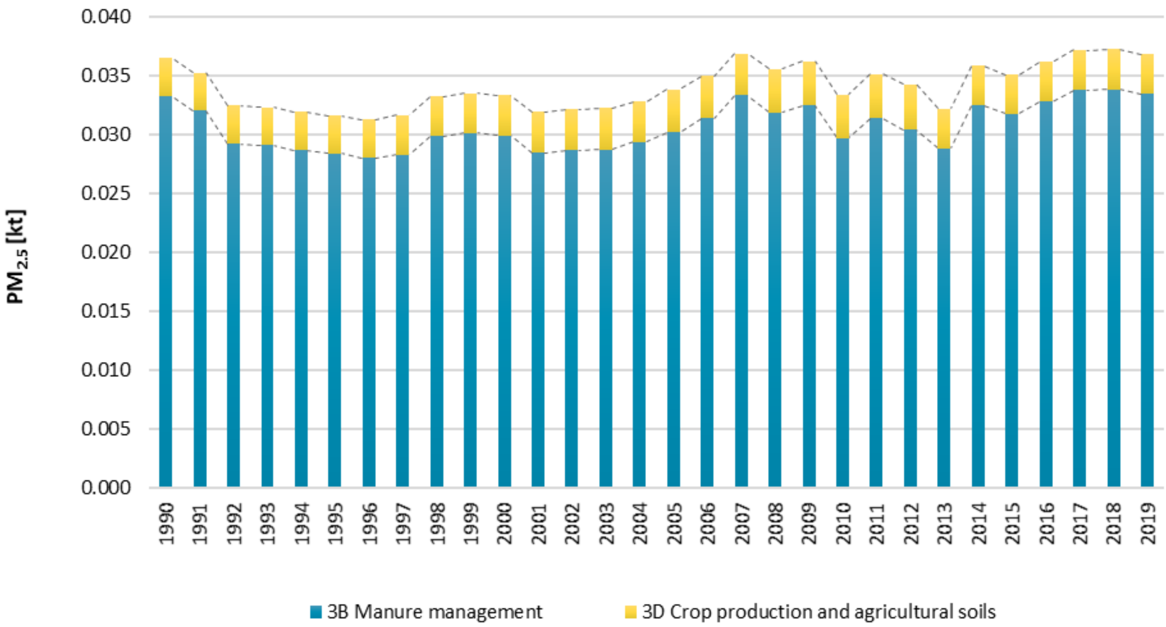
3B Manure management
3D Crop production and agricultural soils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PM2.5 [kt]
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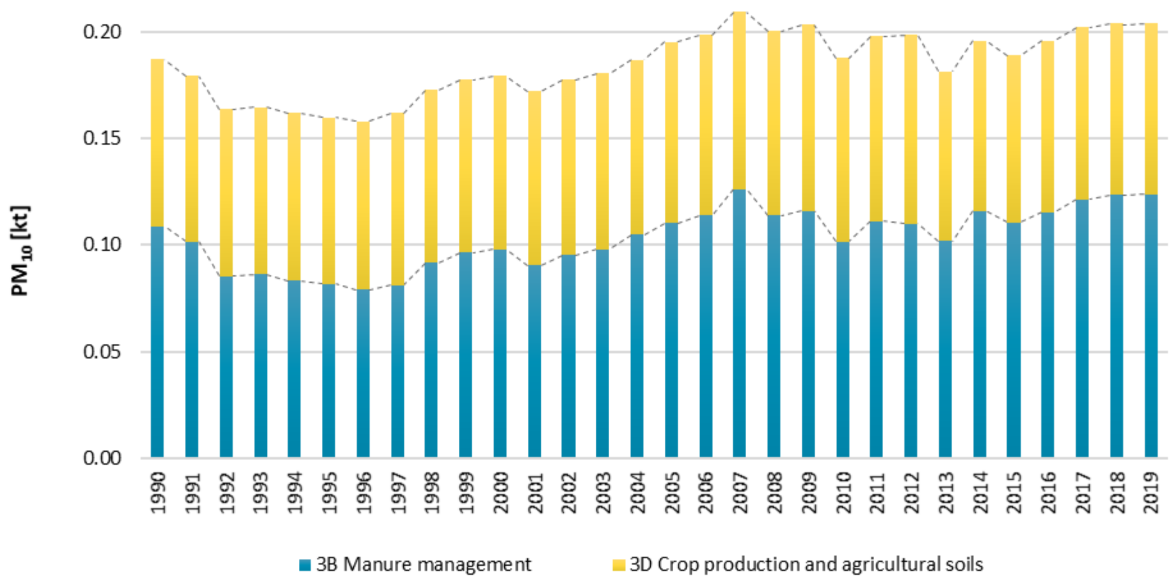
3B Manure management
3D Crop production and agricultural soils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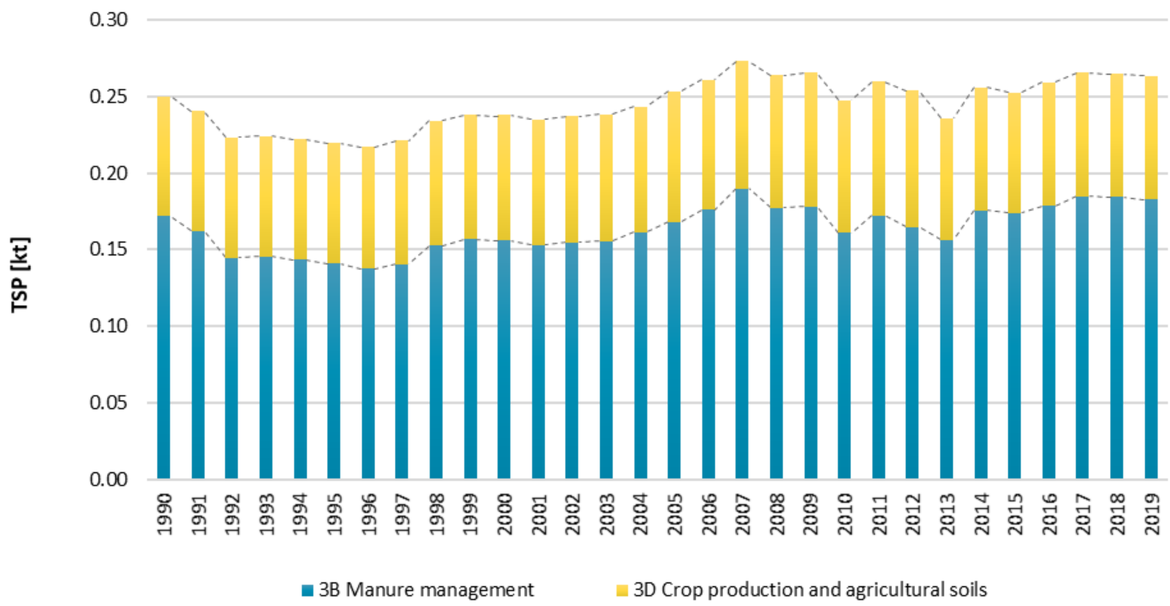
3B Manure management
3D Crop production and agricultural soils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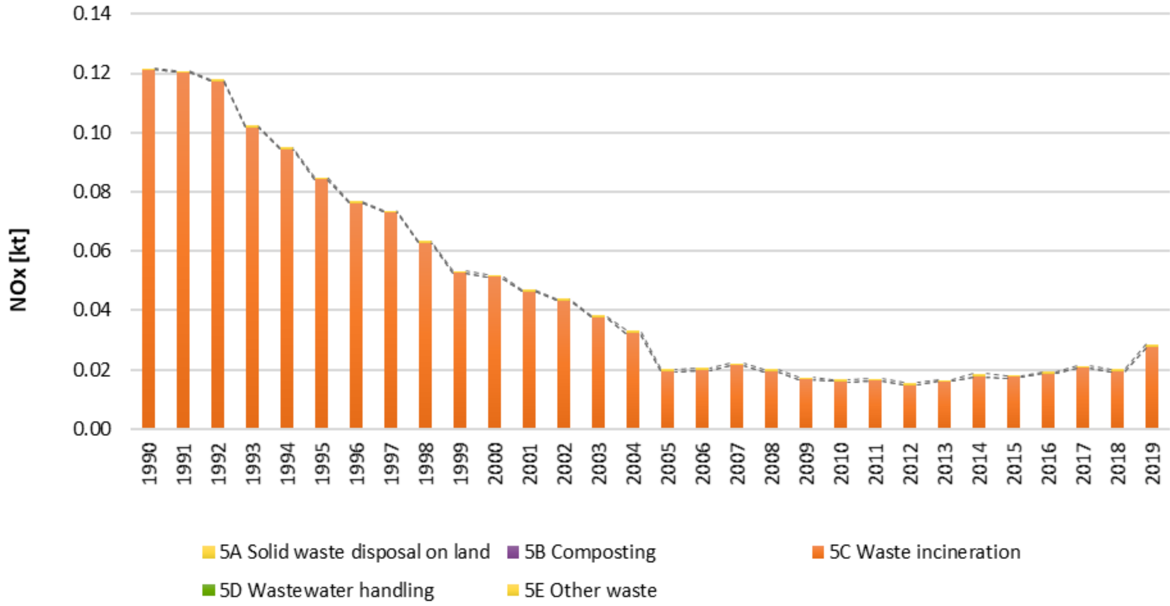
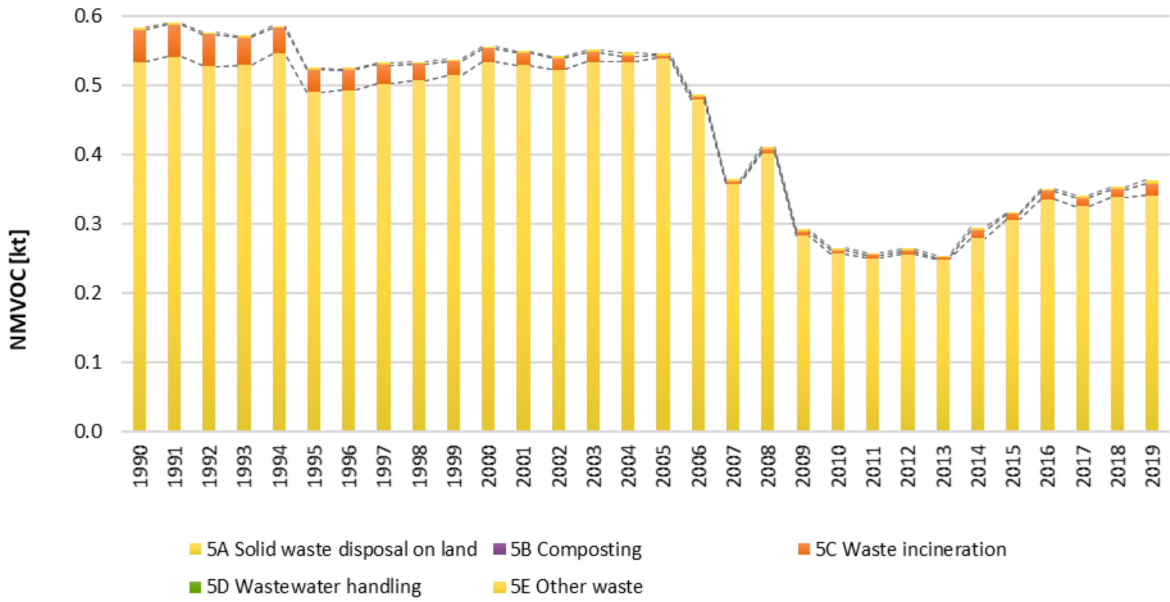
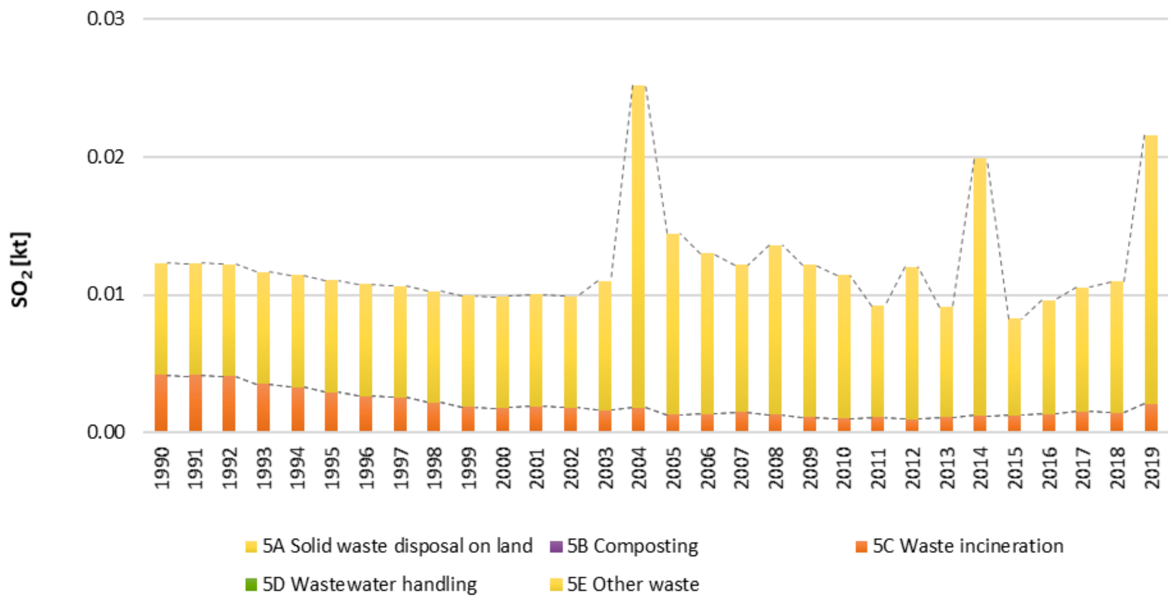
3B Manure management
3D Crop production and agricultural soils

Waste: NO_x, NMVOC, SO_2, NH_3, CO and PM



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SO2 [kt]
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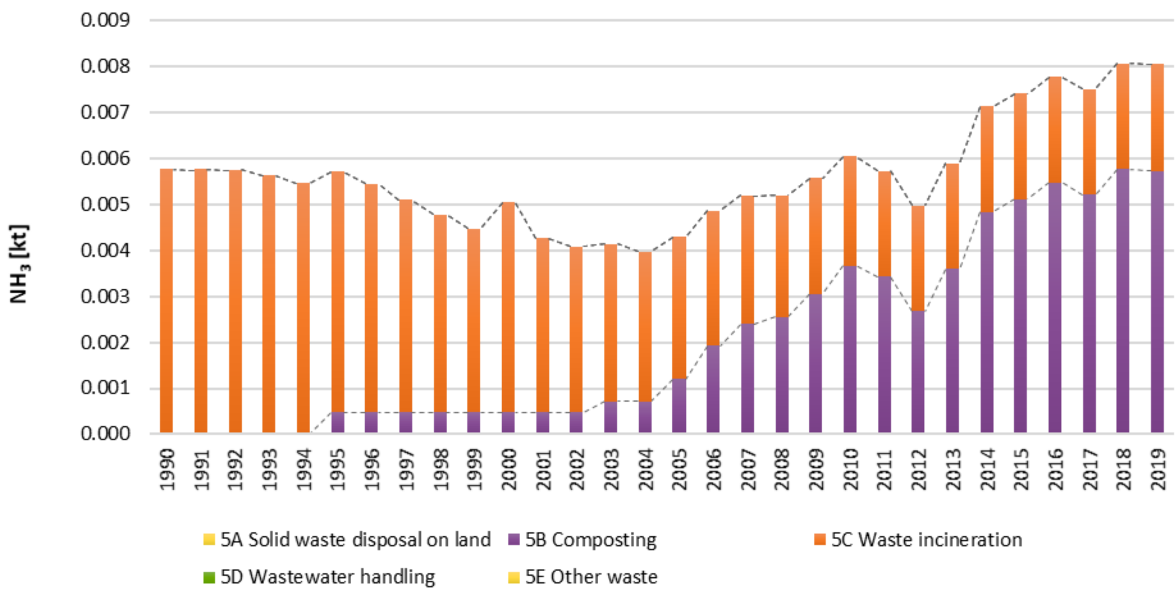
5A Solid waste disposal on land
5B Composting
5C Waste incineration
5D Wastewater handling
5E Other waste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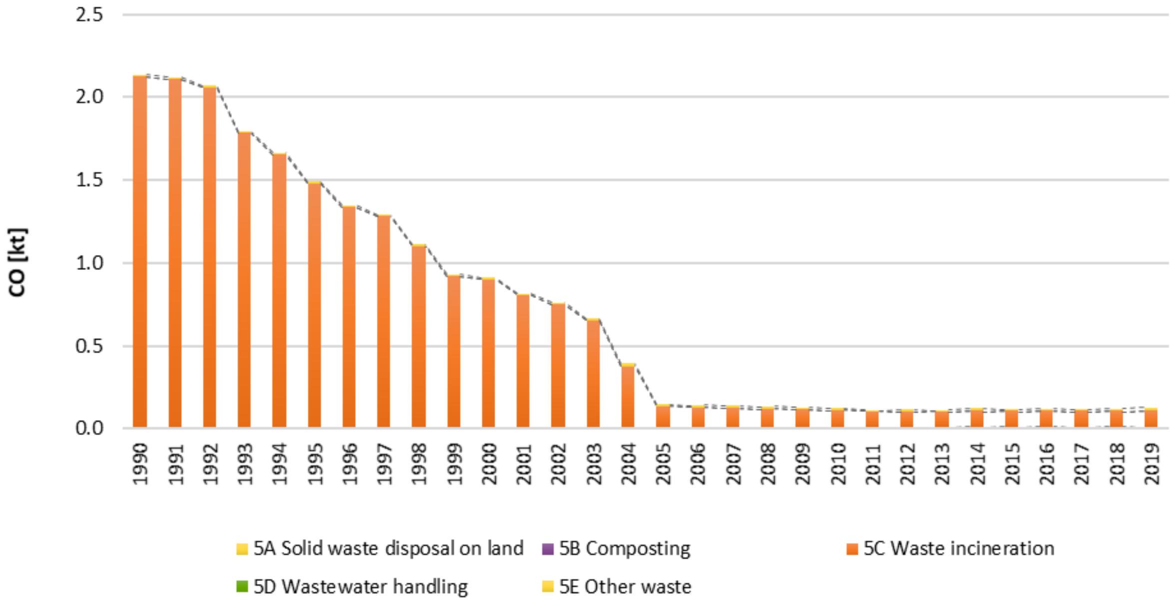
5C Waste incineration
5D Wastewater handling
5E Other waste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5A Solid waste disposal on land
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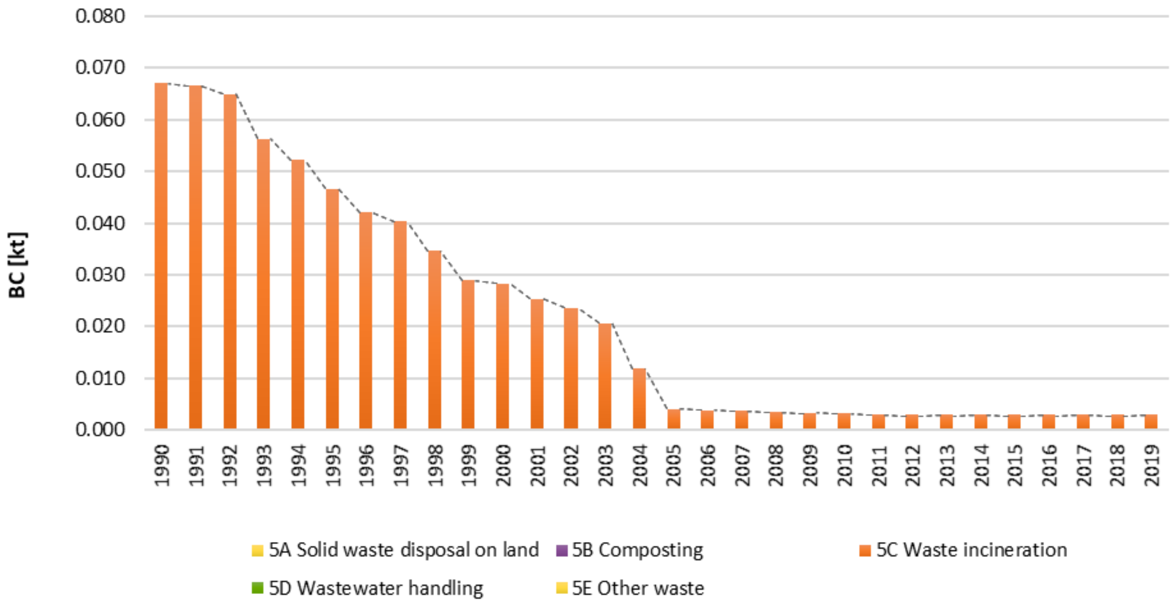
5D Wastewater handling
5E Other waste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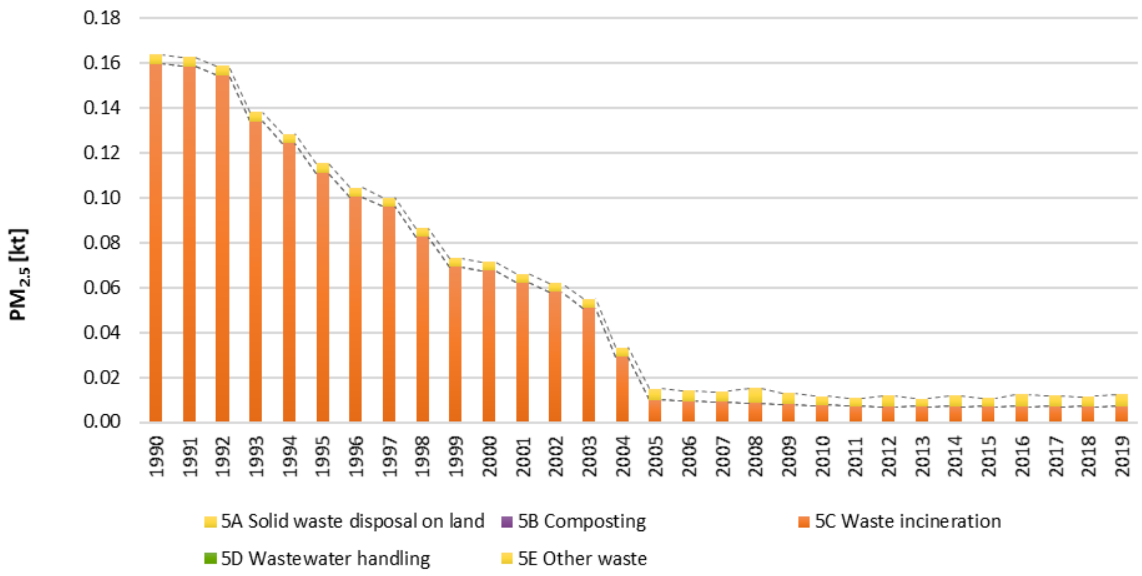
5C Waste incineration
5D Wastewater handling
5E Other waste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PM2.5 [kt]
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5C Waste incineration
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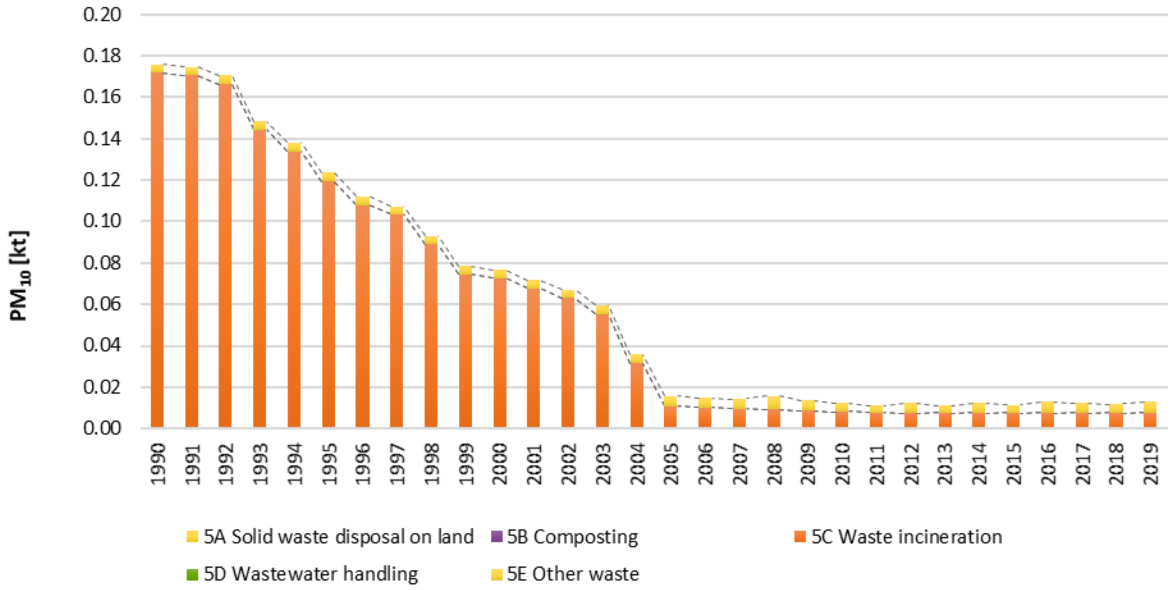
5E Other waste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PM10 [kt]
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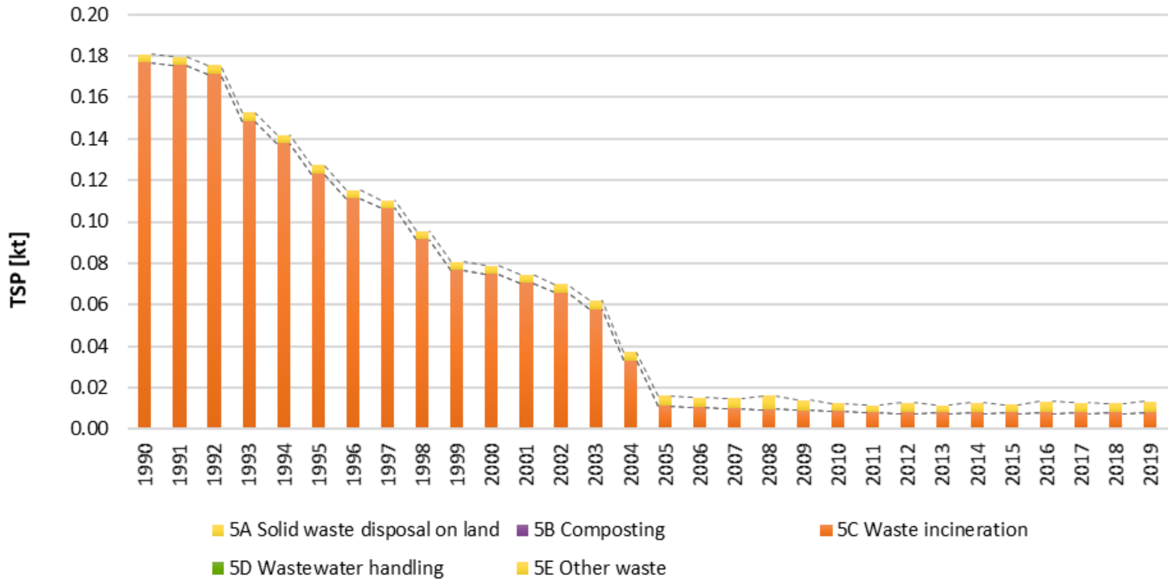
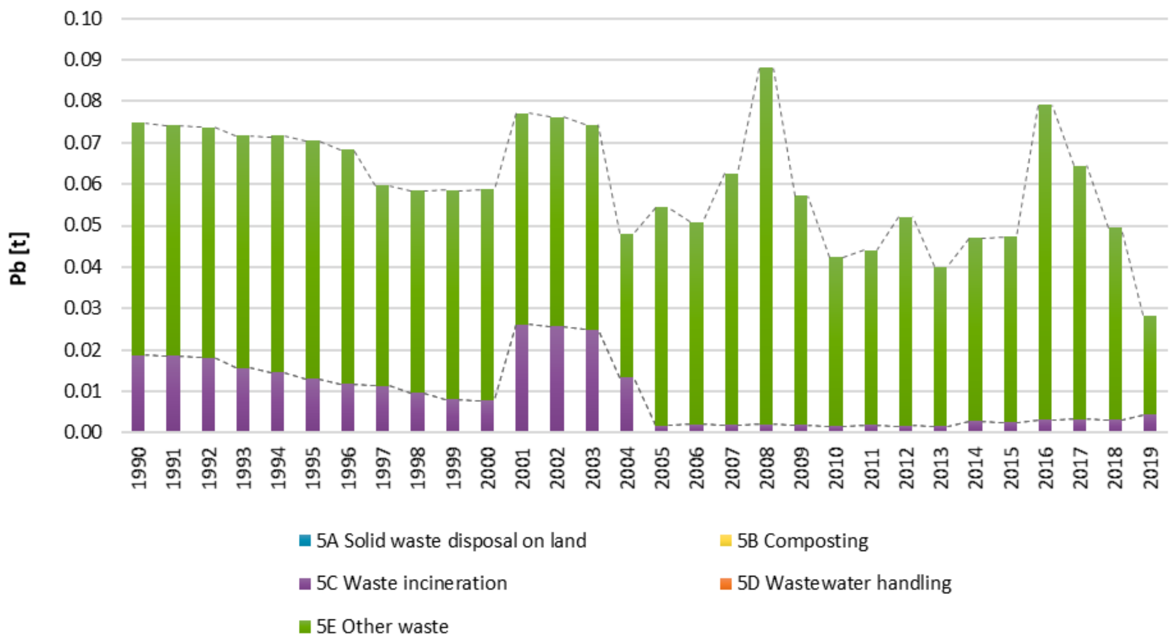
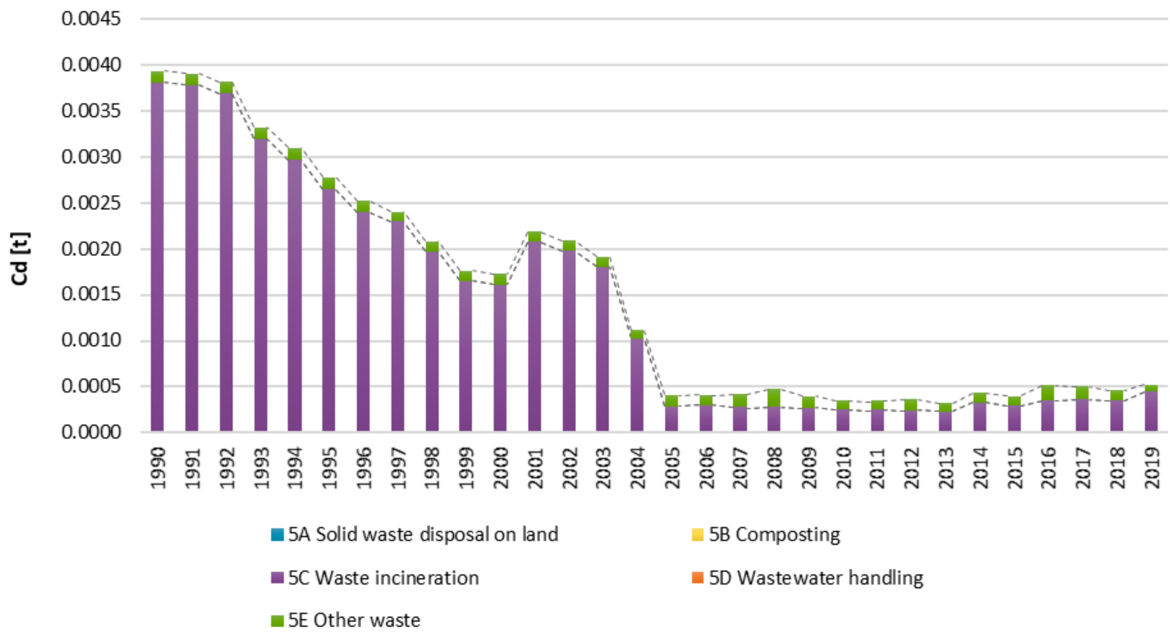


Waste sector: Heavy Metals

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5A Solid waste disposal on land
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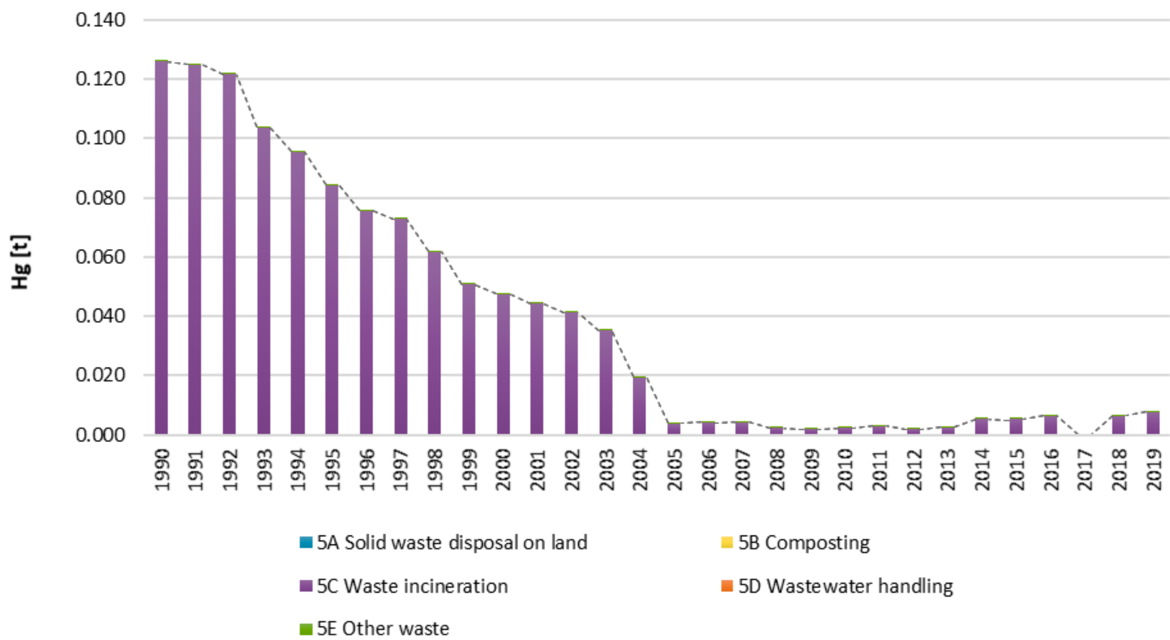
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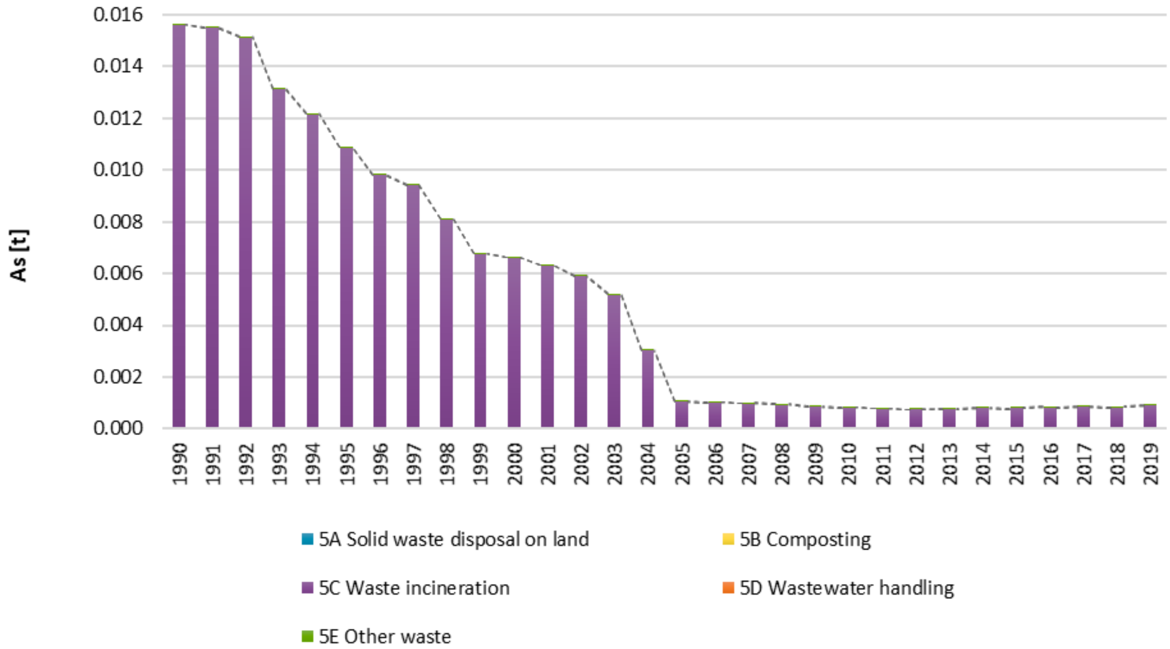
5E Other waste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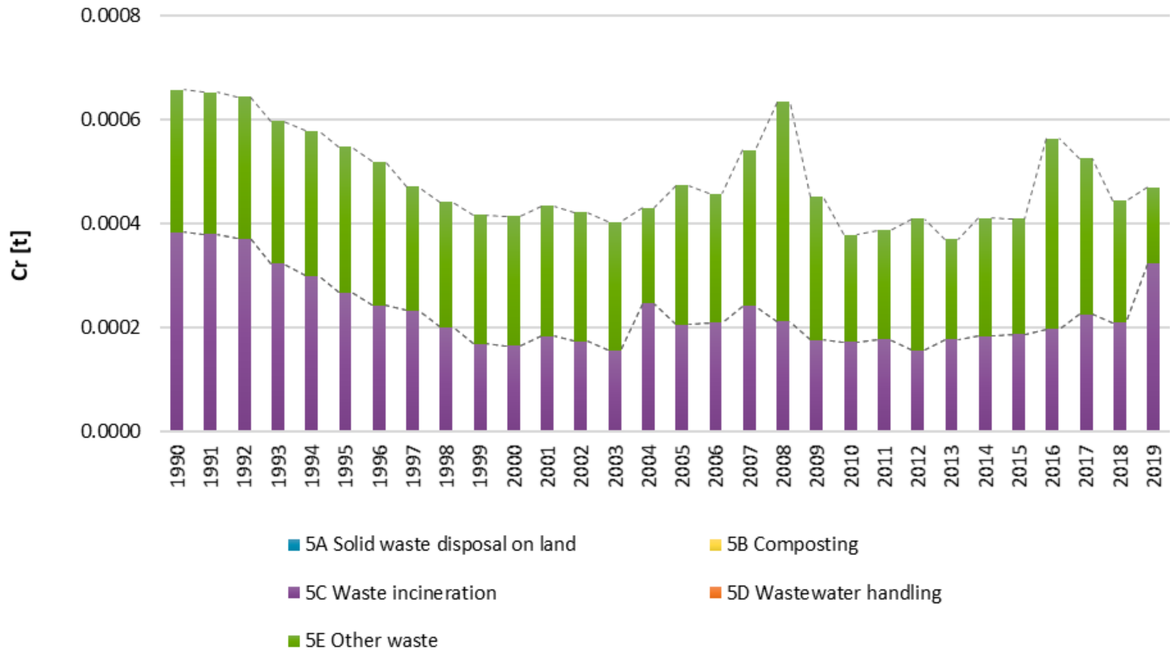
5B Composting
5C Waste incineration
5D Wastewater handling
5E Other waste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5D Wastewater handling
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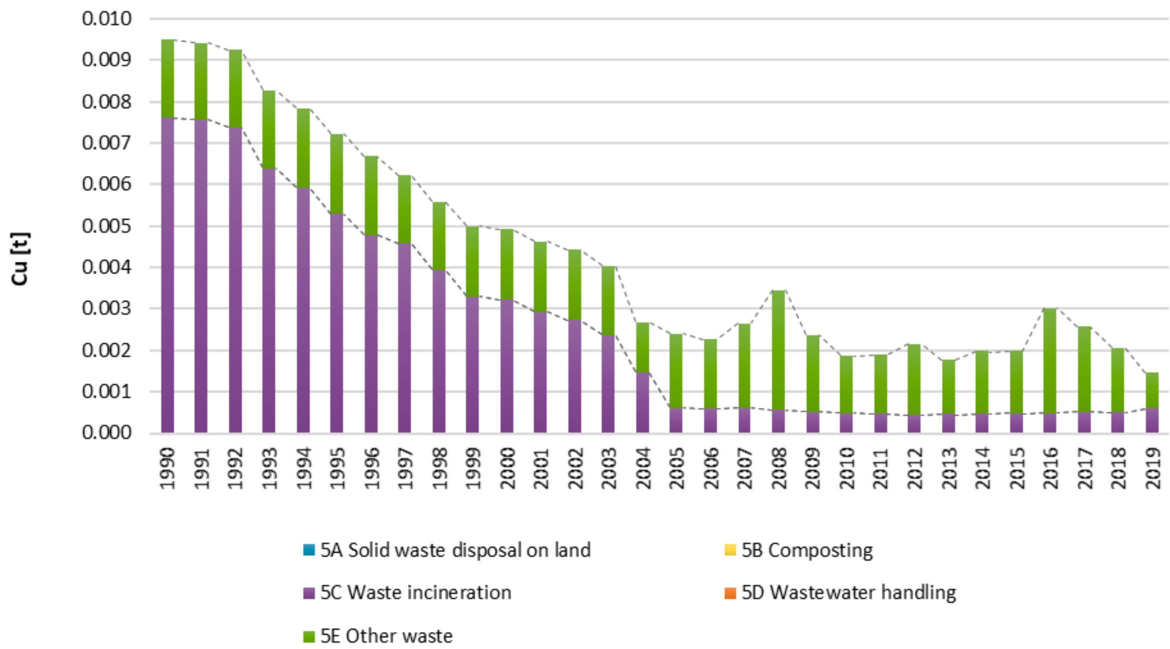

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0.004
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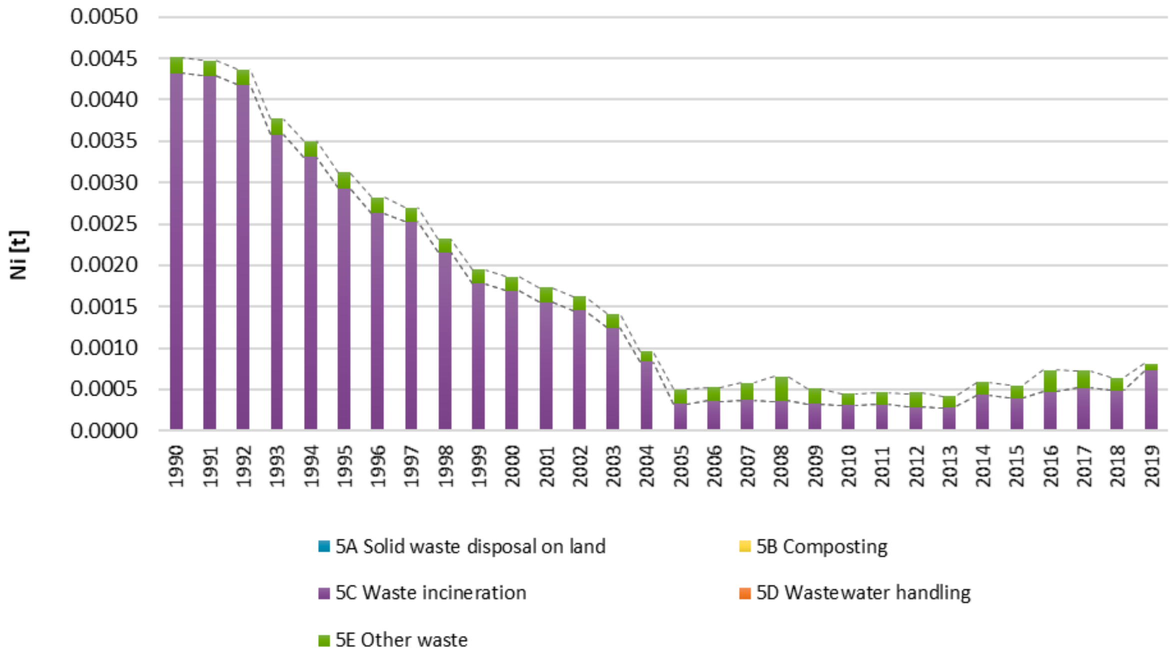
5B Composting
5C Waste incineration
5D Wastewater handling
5E Other waste



Ni [t]
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5B Composting
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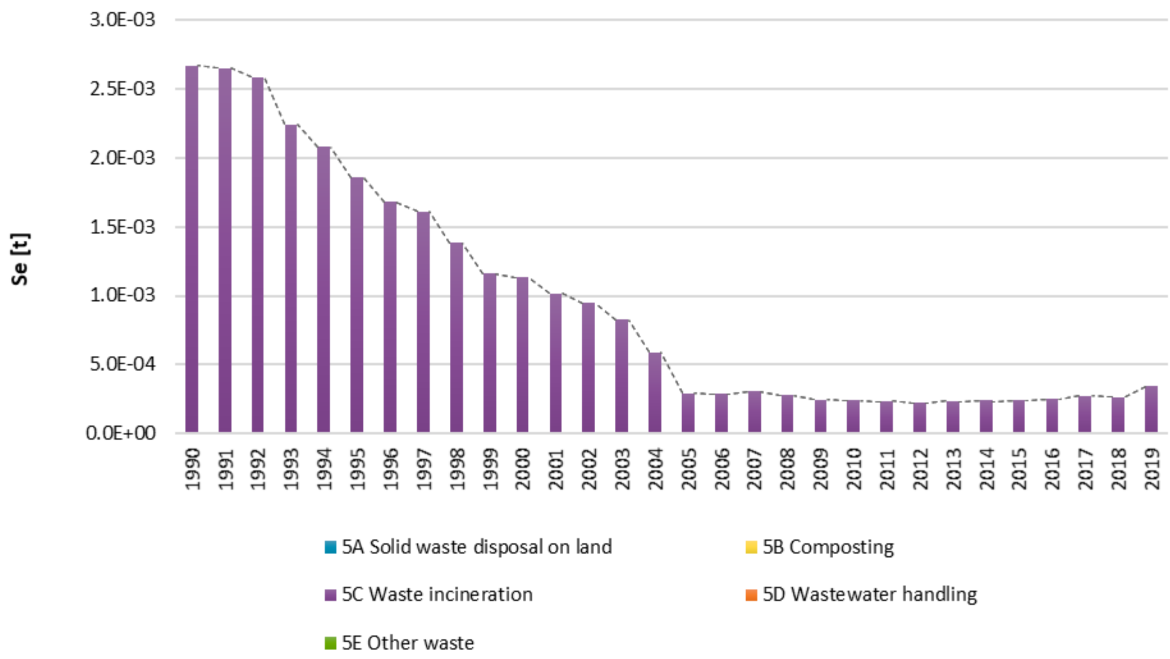
5D Wastewater handling
5E Other waste



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5.0E-04
0.0E+00
Se [t]
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
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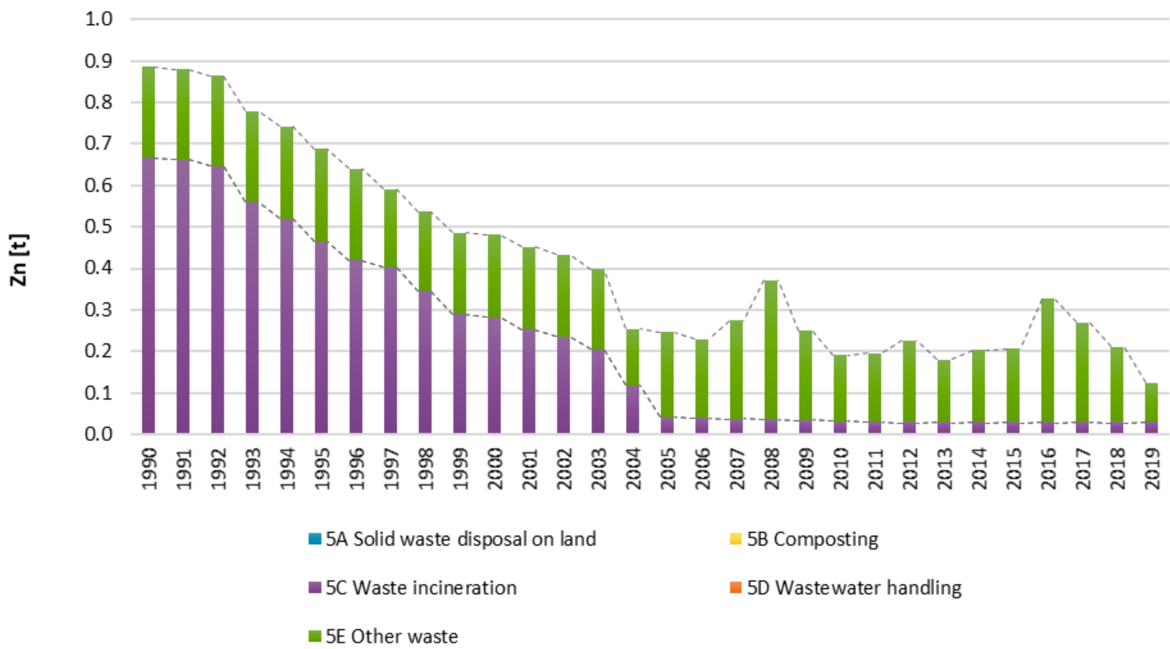
5B Composting
5C Waste incineration
5D Wastewater handling
5E Other waste



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Zn [t]
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5A Solid waste disposal on land
5B Composting
5C Waste incineration
5D Wastewater handling
5E Other waste