UMHVERFISSTOFNUN

ANNUAL ICELANDIC INFORMATIVE INVENTORY REPORT TO UNECE

Emissions of POP‘s and Other
Air Pollutants in Iceland 1990-2014

2016

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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.

According to Article 8 of the Convention, Parties shall exchange information on emissions of pollutants. To comply with this requirement, Iceland has prepared an Informative Inventory Report (IIR) for the year 2014. 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 1990-2014. This report emphasizes on emissions of Persistent Organic Pollutants as Iceland has only ratified the Protocol on Persistent Organic Pollutants (POPs). Emissions of the indirect greenhouse gases (NO_x, CO and NMVOC) and SO_2 are provided in the NFR tables for information purposes, as they are calculated to comply with the reporting requirements of the United Nations Framework Convention on Climate Change (UNFCCC). Emission estimates for ammonia (NH_3), particulate matter (PM) and black carbon (BC) are provided for a few 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 Holuhraun eruption in 2014 are provided. Emissions of heavy metals have not been estimated.

The IIR is written by the Environment Agency of Iceland (EAI).

Environment Agency of Iceland, Reykjavík, 15. February 2016.

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Executive Summary

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. To comply with this requirement, Iceland has prepared an Informative Inventory Report (IIR) for the year 2016. 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 – 2014. This report emphasizes on anthropogenic emissions of Persistent Organic Pollutants (Dioxin, PAH4 and HCB), 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 for information purposes, as they are calculated to comply with the reporting requirements of the UNFCCC. For this submission emission estimates for ammonia (NH_3), particulate matter (PM) and black carbon (BC) are provided for a few emission sources. A short description of the trends and the calculation method for those 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 Holuhraun eruption in 2014 are provided. Emissions of heavy metals have not been estimated.

Responsible institute

The Environment Agency of Iceland (EAI), an agency under the direction of 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 EAI participates in meetings under the United Nations Economic Commission for Europe (UNECE) Task Force on Emission Inventories and Projections (TFEIP) and the related expert panels, where parties to the convention prepare the guidelines and methodologies on inventories.

Trends in POPs emissions

From 1990 to 2014 dioxin emissions decreased by 88% (Figure ES. 1). The largest contributor of dioxin emissions in Iceland is waste incineration, followed by commercial fishing.

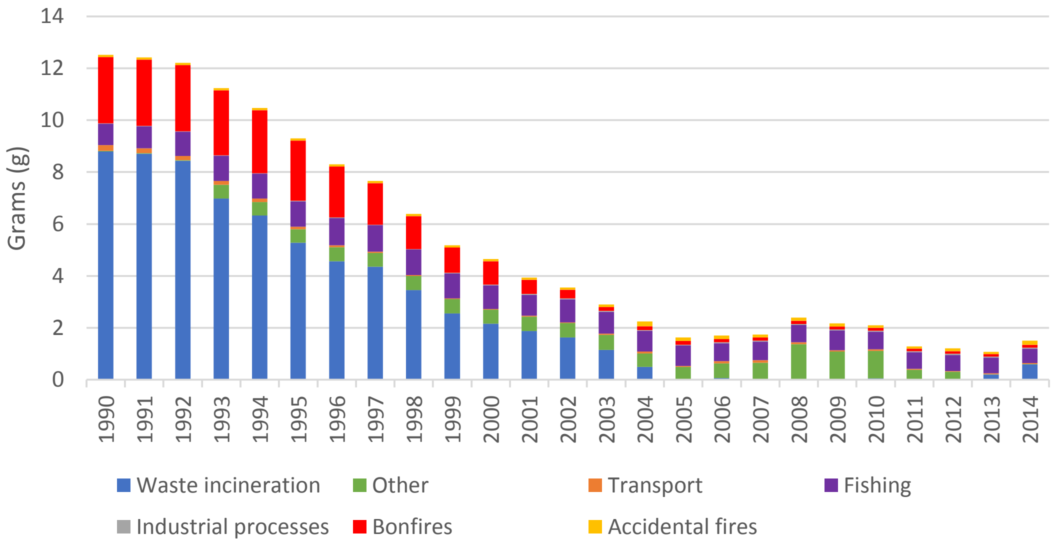

Figure ES. 1 Trends in dioxin emissions by source, 1990-2014.

PAH4 emissions from 1990 to 2014 increased by 70% (Figure ES. 2).The largest contributor of PAH4 emissions in Iceland are industrial processes, road transport and accidental fires.

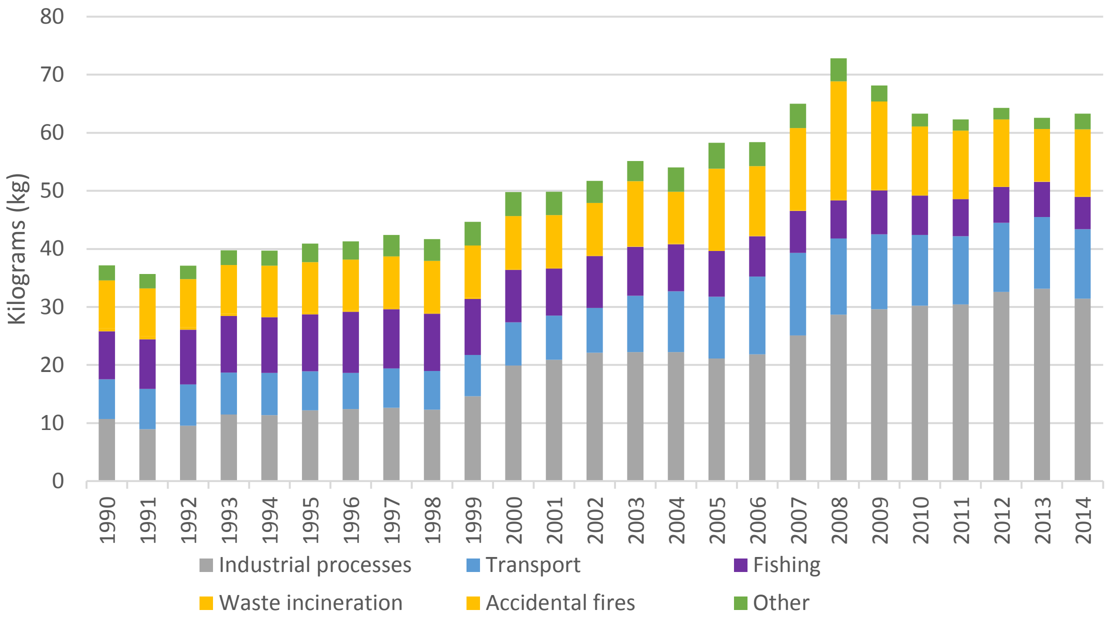

Figure ES. 2 Trends in PAH4 emissions by source, 1990-2014.

The hexachlorobenzen (HCB) emissions from 1990 to 2014 decreased by 61% (Figure ES. 3). The largest contributor of HCB emissions in Iceland is waste incineration with and without energy recovery, followed by industrial processes. Emissions from waste incineration with energy recovery are reported under the Energy sector. Interpretations of the HCB trend analysis should be done with care as emissions have only been estimated for a few sources.

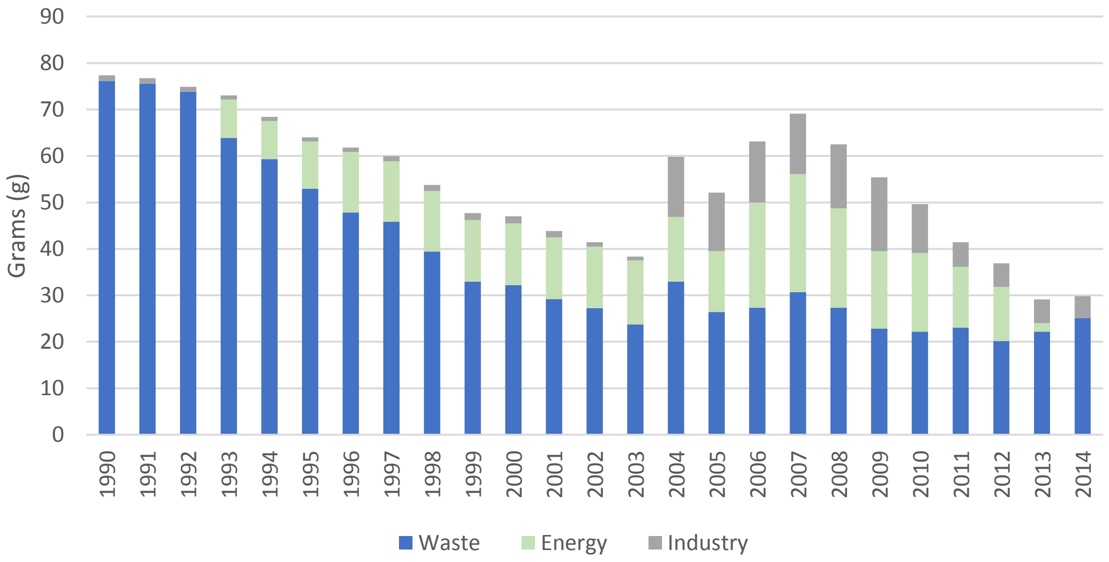

Figure ES. 3 Trends in HCB emissions by source, 1990-2014.

1 Introduction

1.1 Background Information

The 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP) was signed by Iceland on 13th of 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) has been signed and ratified by Iceland. The POP-Protocol was ratified by Iceland in May 2003 and entered into force in October 2003.

The present report together with the associated NFR (Nomenclature for Reporting) tables is Iceland's contribution to the 2016 reporting under the Convention. As Iceland has only ratified the POP-Protocol, the report emphasizes anthropogenic emissions of POPs and covers anthropogenic emissions of dioxin, PAH4 and HCB in the period 1990-2014, as well as gridded data for dioxin, PAH4 and HCB for the years 1990, 1995, 2000, 2005 and 2010. A description of the trends and calculation methods is given. Anthropogenic emissions of the indirect greenhouse gases (NO_x, CO, NMVOC) and SO_2 are provided in the NFR tables for information purposes, as they are calculated to comply with the reporting requirements of the UNFCCC. Emission estimates for ammonia (NH_3) and particulate matter (PM) are provided for a few emission sources. A short description of the trends and the calculation methods for those 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 Holuhraun eruption in 2014 are provided. Emissions of heavy metals have not been estimated. Black carbon was estimated for the first time in the 2015 submission in the sectors where $PM_{2.5}$ is estimated. This year black carbon estimations were added for mobile combustion in manufacturing industries and construction (1A2), transport (1A3), fishing (1A4), road paving with asphalt (2D3b) and municipal waste incineration (5C1a).

1.2 Institutional Arrangements for Inventory Preparation

The Environment Agency of Iceland (EAI), an agency under the auspices of the Ministry for the Environment and Natural Resources, has overall responsibility for the annual preparation and submission of the national inventory to the UNECE-LRTAP Convention. EAI compiles and maintains the emission inventory and reports to the Convention. Figure 1.1 illustrates the flow of information and allocation of responsibilities. The methodologies and data sources used for different sectors are described in Chapter 1.3.

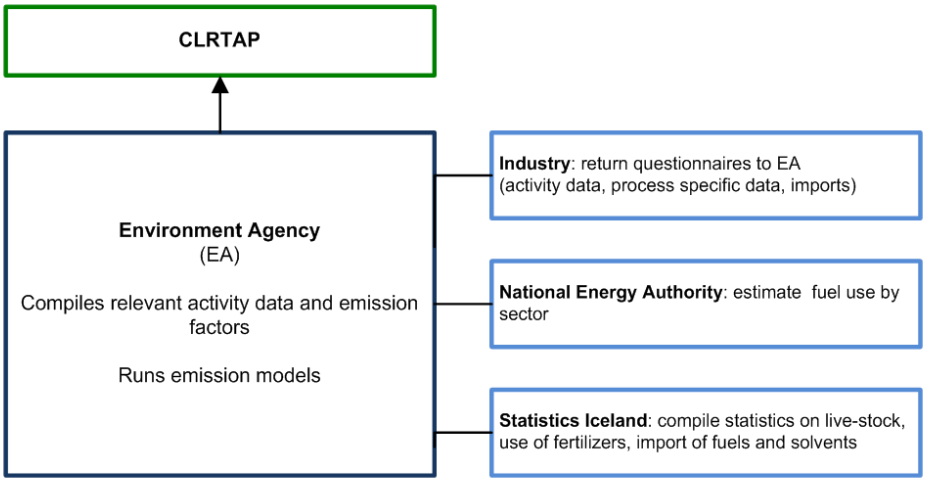

Figure 1.1 Information flow and distribution of responsibilities in the Icelandic emissions inventory system for reporting to the CLRTAP.

1.3 Methodologies & Data Sources

The EAI collects the bulk of data necessary to run the general emission model, i.e. activity data and emission factors. Activity data is collected from various institutions and companies, as well as by EAI directly. The National Energy Authority (NEA) collects annual information on fuel sales from the oil companies. This information was until 2008 provided on a voluntary basis. From 2008 and onwards, Act no. 48/2007 amending Act no. 87/2003 about the National Energy Authority, enables the NEA to obtain sales statistics from the oil companies. Statistics Iceland, which is the center for official statistics in Iceland, provides information on population, GDP, production of various products, imports of solvents and other products, import of fertilizers and import and export of fuels. The EAI collects various additional data through the annual emission reports reported under the European Emissions Trading System (EU ETS), European Pollutant Release and Transfer Register (E-PRTR), Green Accounting reports from industry submitted under Regulation no. 851/2002 and directly from operators. EAI also estimates activity data with regard to waste. Emission factors are mainly taken from the *Emission Inventory Guidebook* (EEA, 2013), the *Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases* (UNEP, 2005), *Annual Danish Informative Inventory Report to UNECE* (NERI, 2011), *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*[1] (Statistics Norway, 2002) and *Utslipp til luft av noen miljögifter i Norge - Dokumentajon av metode og resultater*[2] (Statistics Norway, 2001). 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 1 aluminium plant and the ferrosilicon plant. The results from these measurements have been used for waste incineration plants since the 2012 submission. Results from the measurements at industrial sites have been used since the 2013 submission.

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[1] Utslipp til luft av dioksiner i Norge: Air emissions of dioxins in Norway – Documentation of methods and results

[2] 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

The general emission model is based on the equation:

Emission (E) = Activity level (A) · Emission Factor (EF)

The standard equation for estimating PAH emission factor (example for B[b]F) is:

Emission factor (B[b]F) = Emission Factor (B[a]P) · Profile ratio B[b]F/ B[a]P

1.4 Key Source Categories

A key source category is a category that is prioritized within the national inventory system because its estimate has a significant influence on the total inventory of pollutants in terms of the absolute level of emissions, the trend in emissions, or both.

Table 1.1 Key source analysis for reported POPs in 2014.

Component	Key categories (Sorted from high to low from left to right)					Total (%)
DIOX	*Waste incineration (NFR 5C1a),* (46.7%)	*Fishing (NFR 1A4ciii),* (37.1%)				83.8
PAH4	*Aluminium production (NFR 2C3),* (25.1%)	*Ferroalloy production (NFR 2C2),* (24.5%)	*Accidental fires (NFR 5E),* (18.2%)	*Road transport: Passenger cars (NFR 1A3bi),* (10.8%)	*Fishing (NFR 1A4ciii),* (8.8%)	87.4
HCB	*Waste incineration (NFR 5C1a),* (84.2%)					84.2

1.5 Quality Assurance & Quality Control

The objective of QA/QC activities in national emissions inventories is to improve transparency, consistency, comparability, completeness, accuracy, confidence and timeliness. A QA/QC plan for the annual inventory of Iceland has been prepared. The document describes the quality assurance and quality control program. It includes the quality objectives and an inventory quality assurance and a quality control plan. It also describes the responsibilities and the time schedule for the performance of QA/QC procedures. The QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Source category specific QC measures have been developed for several key source categories. A quality manual for the Icelandic air emission inventory has been prepared. It is available the EAI's website (ust.is/library/Skrar/Atvinnulif/Loftslagsbreytingar/Iceland_QAQC_plan.pdf).

To further facilitate the QA/QC procedures all calculation sheets include a brief description of the method used. They are also provided with colour codes for major activity data entries and emissions results to allow immediate visible recognition of outliers.

1.6 Uncertainty Evaluation

An estimate of the quantitative uncertainty of the Icelandic POP emission inventory has not yet been prepared.

1.7 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. However, by following international guidelines on emissions reporting, there are some sources, which are deliberately not included in the national totals:

- Natural sources are not included in the national totals although estimates of some sources are made.
- Estimates of emissions from international navigation and aviation are made, and reported as memo items (excluded from national totals). For aviation this is not fully in line with the reporting guidelines for CLRTAP, as cruise emissions from domestic and international aviation should be excluded from national totals, but emissions from landing and take-off from both domestic and international aviation should be included in national total. In the Icelandic inventory all emissions from domestic aviation are included in national totals but all emissions from international aviation are excluded (in line with the reporting guidelines under the UNFCCC).

An assessment of the completeness of the emission inventory should address the issues of spatial, temporal and sectoral coverage along with all underlying source categories and activities.

In terms of spatial coverage, the emissions reported under the CLRTAP cover all activities within Iceland's jurisdiction. This report provides information on emissions of HCB, PAH4 and dioxins within the EMEP-Grid for the years 1990, 1995, 2000, 2005 and 2010.

In the case of temporal coverage, NFR table 1 is reported for the whole time series from 1990 to 2014, for dioxins and PAH4. Emissions of HCB have been estimated for few sources for the whole time series, but PCB emissions are not estimated. Further emissions of NO_x, CO, NMVOC and SO_2 are provided in the NFR table 1 for the whole time series as well as emissions of NH_3 and particulate matter that have been estimated for a few sources. Black carbon emission estimations for 2013 and 2014 were added for mobile combustion in manufacturing industries and construction (1A2), transport (1A3), fishing (1A4). Emissions from black carbon from road paving with asphalt (2D3b) and municipal waste incineration (5C1a) were estimated for the whole time series.

With regard to sectoral coverage there are sources which are not estimated. The activities/gases are not included in the present submission due to lack of data, and/or that additional work was impossible due to time constraints in the preparation of the emission inventory.

The main sources not estimated for PAH4 are:

- 1A3b v: Road transport, gasoline evaporation
- 1A3b vi: Automobile tire and break wear
- 1A3b vii: Automobile road abrasion
- 1A3d i: International maritime navigation
- 1A4b: Residential

The main sources not estimated for HCB are:

- 1A2: Manufacturing industry and construction
- 1A3: Transport
- 1A4b: Residential
- 1A4c iii: Fishing
- 2D3: Solvent and other product use
- 2K: Consumption of POPs and heavy metals (HM)

1.8 Structure of the report

The report is divided into 8 chapters. Chapter 1 provides general information on the institutional arrangements for inventory preparation, inventory preparation process, methodologies and data sources used, key source categories and quality assurance and quality contol. Chapter 2 provides information on trends in emissions and Chapters 3 to 7 provide information on activity data and methodologies used for emission calculations by sector. Chapter 8 contains information on spatially distributed emissions within the EMEP-grid.

1.9 Planned improvements

Improvement of methodologies to estimate emissions from transportation with the use of COPERT as well as use of aviation data from Eurocontrol. Black carbon emissions from few sources are only estimated for 2013 and 2014, it is planned to expand the estimations further. At the moment PM emission are only estimated for a few sources in the industrial processes sector, there are ambitions to estimate more sources.

There are plans to review digestible energy content for both cattle and sheep in order to reflect changes that have occured in animal nutrition since 1990. Gross energy intake and average animal weight for cattle and sheep will also be reviewed and updated if necessary. This might have changed since data was last updated in view of changes in feed and breeding.

Emmisions of POP´s from agriculture are low, the subject will be inspected for potential miscalculation/error before next submission.

Revise emission factors for POPs pollutants in accidental fires.

Key source analysis and missing annexes will be added in the next submission.

2 Trends in Emissions

2.1 Emission Profile in Iceland

The emissions profile for Iceland is unusual in some respects. Firstly, 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 (70% in 2014) and geothermal power (30% in 2014). Furthermore geothermal energy sources are used for space heating (in over 90% of all homes). It should be noted, though, that significant amounts of Sulphur as hydrogen supplied (H_2S) are emitted from geothermal power plants. Secondly, over 90% of the fuel used in the energy sector is used by mobile sources (transport, mobile machinery and fishing vessels). Thirdly, 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 75% of the electricity produced in Iceland in 2014 was used in the metal production industry. The production capacity has increased considerably since 1990. In 1990, 87,839 tonnes of aluminium were produced in one aluminium plant and 62,792 tonnes of ferrosilicon in one ferrosilicon plant. In 1998 a second aluminium plant was established and a third in 2007. In 1999 a third furnace was added to the ferrosilicon plant. In 2014, 839,449 tonnes of aluminium were produced at three aluminium plants and 107,785 tonnes of ferrosilicon at the ferrosilicon plant.

The emissions profile in Iceland is further influenced by the fact that Iceland was severely hit by an economic crisis late year 2008, when its three largest banks collapsed. The blow was particularly hard owing to the large size of the banking sector in relation to the overall economy as it had grown to be ten times the annual GDP. The crisis resulted in a serious contraction of the economy, a depreciation of the Icelandic króna (ISK), and a drastic increase in external debt. This has led to contraction in private consumption, higher fuel prices and contraction of the construction sector.

2.2 Emission Trends for Persistent Organic Pollutants (POPs)

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 an 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, PCBs). 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.

The total amount of dioxins, PAH4 and HCB in Iceland in 1990 and 2014 is presented in Table 2.1 Emissions of POPs in Iceland 1990 and 2014.Table 2.1. PAH4 emissions have increased by 71% from 1990 to 2014, whereas dioxin emissions have decreased by 88% and HCB emissions by 61% during the same period.

Table 2.1 Emissions of POPs in Iceland 1990 and 2014.

Year	Dioxin [g I-TEQ]	PAH4 [t]	HCB [kg]
1990	12.5	0.04	0.08
2014	1.50	0.06	0.03
Trend 1990-2014	**-88%**	**71%**	**-61%**

The trends in total POPs emissions relative to 1990 emissions is shown in Figure 2.1. Here, the upwards trend in emissions of PAH4 seems to be persistent. HCB and Dioxin emissions have, overall, been decreasing since their 1990 levels.

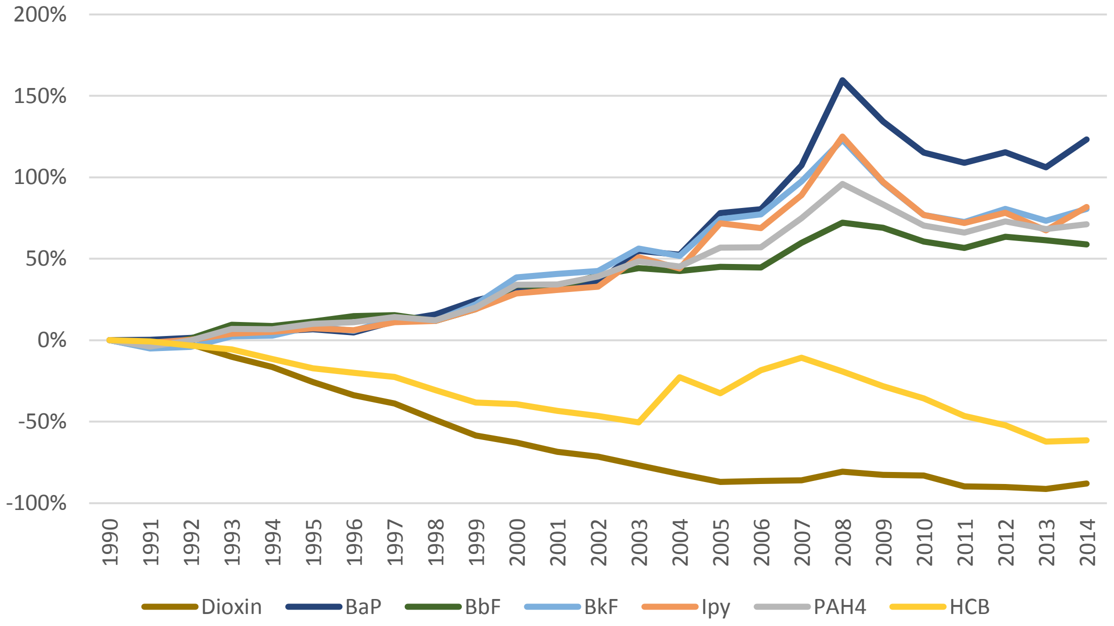

Figure 2.1 Trends in total POPs emissions 1990-2014 (% of 1990 emissions).

2.2.1 Trends in dioxin emissions

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 as a result of 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 are able to 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.

In 1990, the total emissions of dioxins in Iceland were 12.6 g I-TEQ. In 2014 total emissions were 1.5 g I-TEQ. This implies a decrease of 88% over the time period. Figure 2.2 shows the dioxin emissions by source from 1990 to 2014.

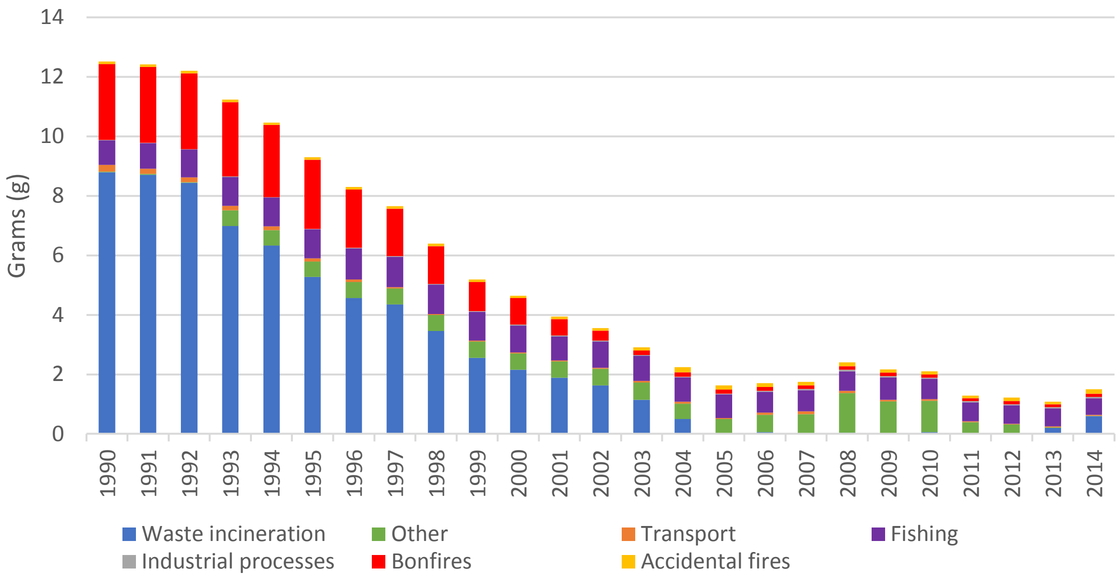

Figure 2.2 Dioxin emissions 1990-2014 by source.

Figure 2.3 shows that the main source of dioxin emissions in 2014 were waste incineration (40%) and commercial fishing (37%) which falls under the sub-category Other sectors (1A4). Other important sources are bonfires (7%) and accidental fires (10%). It is worth mentioning that transport and industrial processes are only responsible for 3% each of the total dioxin emissions.

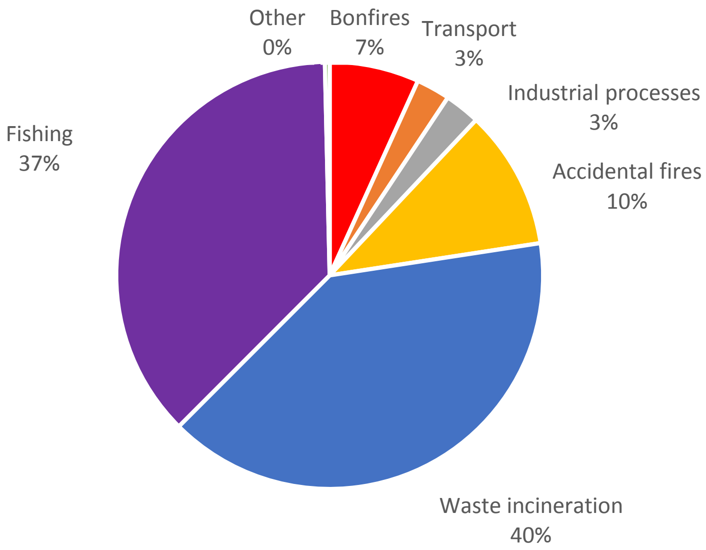

Figure 2.3 Dioxin emission shares 2014 by source.

Practices of waste disposal treatment have undergone a radical change in Iceland since 1990. This is the main reason for the decline in dioxin emissions by 88% from 1990 to 2014. Open pit burning that used to be the most common means of waste disposal outside the capital area, has gradually decreased since 1990. At the same time the total amount of waste being incinerated has decreased while increasing levels were incinerated with energy recovery (reported under 1A1a and 1A4). In the last years those incineration plants have been closed down one by one. At the end of 2014 only one incineration plant was operating in Iceland. The incineration plant is called Kalka and it does not recover energy. Open pit burning is practically non-existent today, the last site was closed by the end of 2010. 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.

Dioxin emissions from electricity generation and space heating are very low because they are generated from renewable energy sources. Emissions in this sector are dominated by emissions from waste incineration with energy recovery, which are reported under 1A1a and 1A4.

Dioxin emissions from road transport decreased by 91% between 1990 to 2014 despite the 97% growth in the number of vehicles and 49% increase in fuel consumption. This is due to the phase-out of leaded fuel.

Emissions have decreased since 1990 from the fishing sector as well as from the other transport sector due to less fuel consumption in these sectors. For commercial fishing this decline amounted to 33%. Emissions from commercial fishing are high compared to the fuel consumption. The emission factors for burning fuel at sea are much higher than when burning fuel on land, due to the presence of salt (and therefore chlorine) in the air going to the engines. In 1990, emissions from commercial fishing were 7% of the national total. In 2014, emissions from commercial fishing amounted to 37% as emissions from most other sources have decreased drastically since 1990.

Dioxin emissions from industrial processes sector have increased by 155% during the period due to increased activity in the non-ferrous metals production sector. Aluminum production has increased from 87,839 tonnes in 1990 to 839,449 tonnes in 2014, with the main increase after 2005. Production of ferrosilicon has increased from 62,792 tonnes to 107,785 tonnes in the same period. Iceland had one cement plant but it ceased operation in 2011.

A peak in emissions from accidental fires can be seen 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.

2.2.2 Trends in polycyclic aromatic hydrocarbons (PAHs) emissions

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 are able to 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)pyren, benzo(b)fluoranthen, benzo(k)fluoranthen and indeno(1,2,3-cd)pyren are used as PAH indicators for the purposes of emission inventories, as specified in the POP - Protocol.

In 1990, the total emissions of PAH4 in Iceland were 37.2 kg. In 2014 total emissions were 63.6 kg. This implies an increase of 71% over the time period. Figure 2.4 shows the emissions by source from 1990 to 2014.

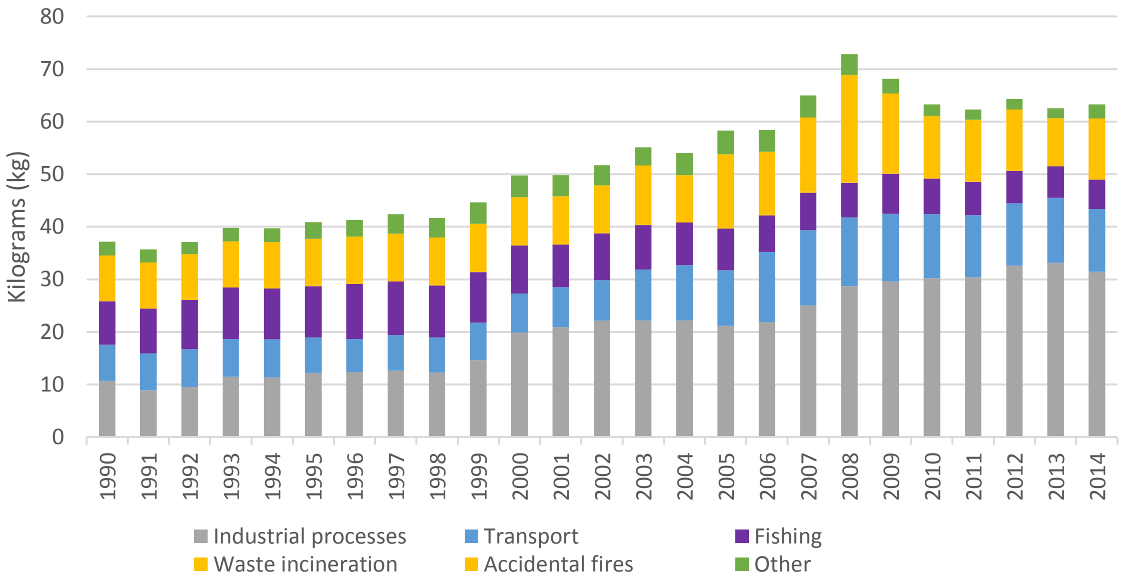

Figure 2.4 PAH4 emissions 1990-2014 by source.

The main reasons for the growth in PAH4 emissions from 1990 to 2014 are increased emissions from industrial processes, due to increased production capacity in the non-ferrous metals production sector.

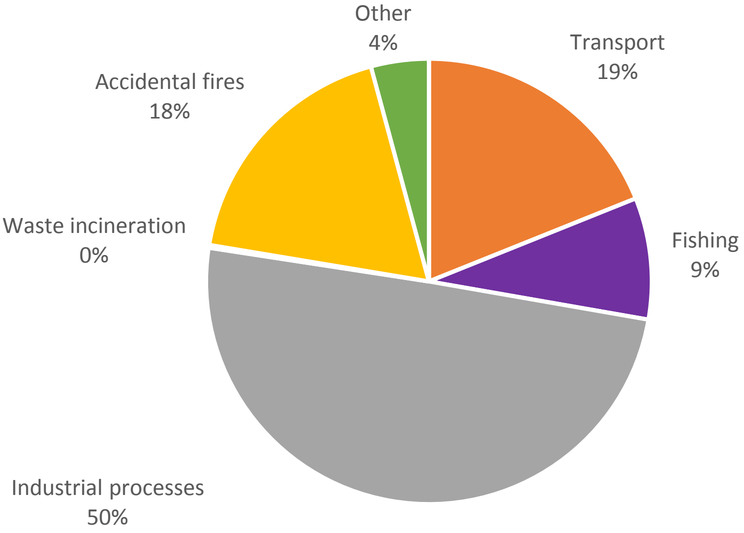

Figure 2.5 PAH4 emission shares 2014 by source.

As mentioned above, the production capacity in the metal production sector has increased substantially in recent years. Aluminium production has increased from 87,839 tonnes in 1990 to

839,449 tonnes in 2014 and from ferrosilicon production has increased from 62,792 tonnes in 1990 to 107,785 tonnes in 2014. 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.

By the mid 1990's economic growth gained momentum in Iceland. Iceland experienced until 2007 one of the highest growth rates of GDP among OECD countries. Late year 2008, Iceland was severely hit by an economic crisis and three of Iceland's largest banks collapsed. The crisis resulted in serious contraction of the economy, followed by increased unemployment and a depreciation of the Icelandic króna. The increase in GDP from 1990 to 2007 resulted in higher emissions from most sources, in particular from road transport and the construction sector. The crisis led to collapse of the construction sector in the autumn 2008. PAH4 Emissions from the manufacturing industries & construction sector were 33% lower in 2014 than in 2007. Emissions from the cement plant were 69% lower in 2011 than in 2007 and the plant ceased operation in late 2011.

Road transport is an important source of PAH4 emissions in Iceland. Since 1990 the vehicle fleet in Iceland has increased by 97%. Furthermore the trend until 2007 was towards larger passenger cars which consume more fuel. In recent years the share of diesel cars has also increased substantially. This led to increased emissions from road transportation. Emissions from road transport in 2007 were 122% higher than in 1990. In 2008 fuel prices rose significantly leading to lower emissions from road transport sector compared to the year before. PAH4 emissions from road transport in 2014 were 13% below the 2007 level, but 92% above the 1990 emissions.

Accidental fires are an important source of PAH4 emissions in Iceland. Emissions from accidental fires were 43% higher in 2014 than in 1990 but the reason is an enormous fire which broke out in an industrial laundry service. A peak in emissions from accidental fires can be seen in 2008 when unusually many vehicle fires were registered. Many of these fires are believed not to be accidental but rather man-made ignition. Many of the vehicles that caught (or were set on) fire this year had been financed with loans, that were in arrears. The depreciation of the Icelandic króna in 2008 resulted in the huge inflation of car loans, as they were mostly in foreign currency.

PAH4 Emissions from commercial fishing rose from 1990 to 1996 because a substantial portion of the fishing fleet was operating in distant fishing grounds, consuming more fuel. From 1996 the emissions decreased again reaching 1990 levels in 2004. In 2014, the emissions were 33% below 1990 levels. Annual changes in emissions reflect the inherent nature of the fishing industry.

PAH4 Emissions from the waste incineration have decreased by 72% from 1990 to 2014, partly because primitive incineration plants and open pit burning were closed down.

2.2.3 Trends in hexachlorobenzene (HCB) emissions

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. On the whole, processes resulting in dioxin formation also result in HCB emissions. HCB is considered to be probable human cancerogen. 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. In 1990, the total estimated emissions of HCB in Iceland were 77.4 g. In 2014 total emissions were 29.8 g. This implies a decrease of 61.4% over the time period. Figure 2.6 represents the trend in HCB emissions by source from 1990 to 2014.

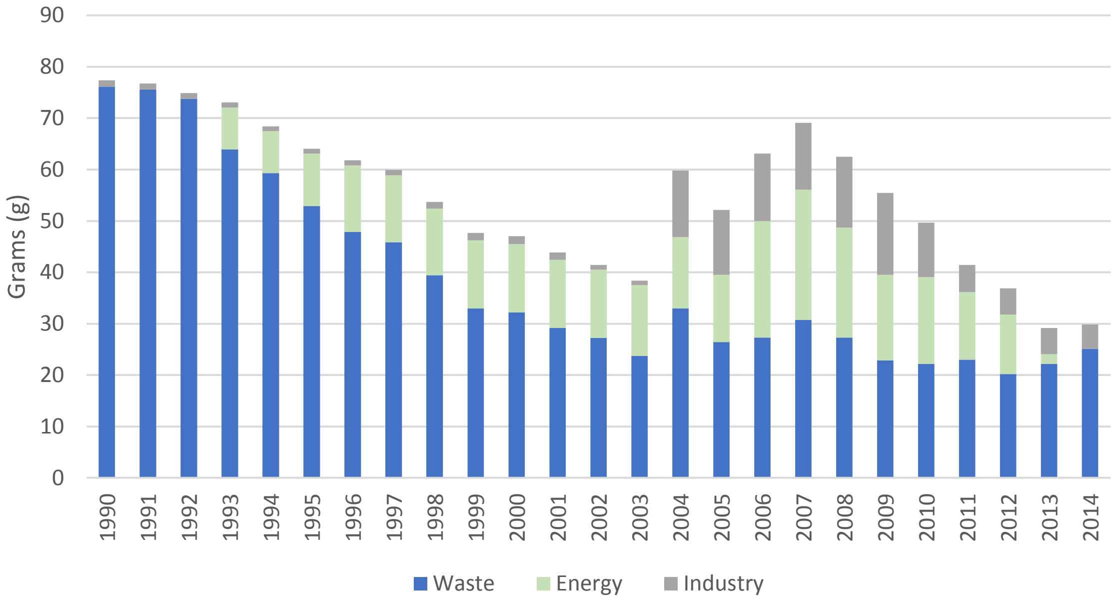

Figure 2.6 HCB emissions 1990 – 2014 by source.

The main sources of estimated HCB emissions are waste incineration with and without energy recovery and industrial processes (secondary aluminum production and cement production). A sudden increase in HCB emissions from industrial processes is seen in 2004 when a secondary aluminum production plant was established. The production at the plant went down by 54% from 2010 to 2014. As shown in Figure 2.7 waste was responsible for 84% of the estimated HCB emissions in Iceland in 2014. The reduction of HCB emissions in the energy sector is explained by a shut-down of four waste incineration plants with energy recovery on the period 2012-2014.

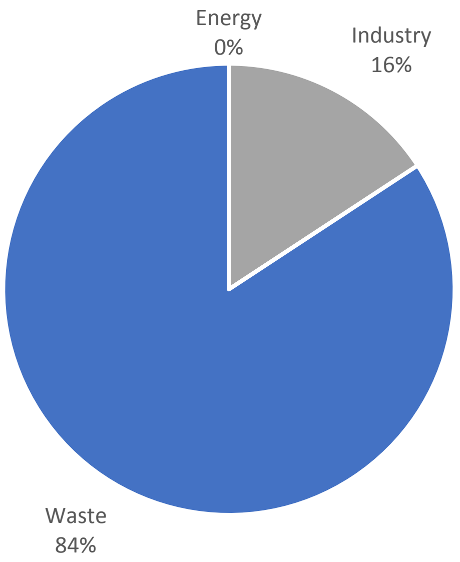

Figure 2.7 HCB emission shares 2014 by source.

2.2.4 Trends in Persistent Organic Pollutants (POPs) by Main Source Sectors

POPs emissions trends in the energy sector are shown in Figure 2.8 as a percentage of the 1990 levels. Figure 2.9 shows the trends in the contribution of POPs emissions from the sector from 1990 - 2014. In 2014 the energy sector contributed to 40% and 32% of total dioxin and PAH4 emissions, respectively. The contribution of the energy sector to the total PAH4 emissions has decreased since 1990 even though the emissions have increased over the same period of time.

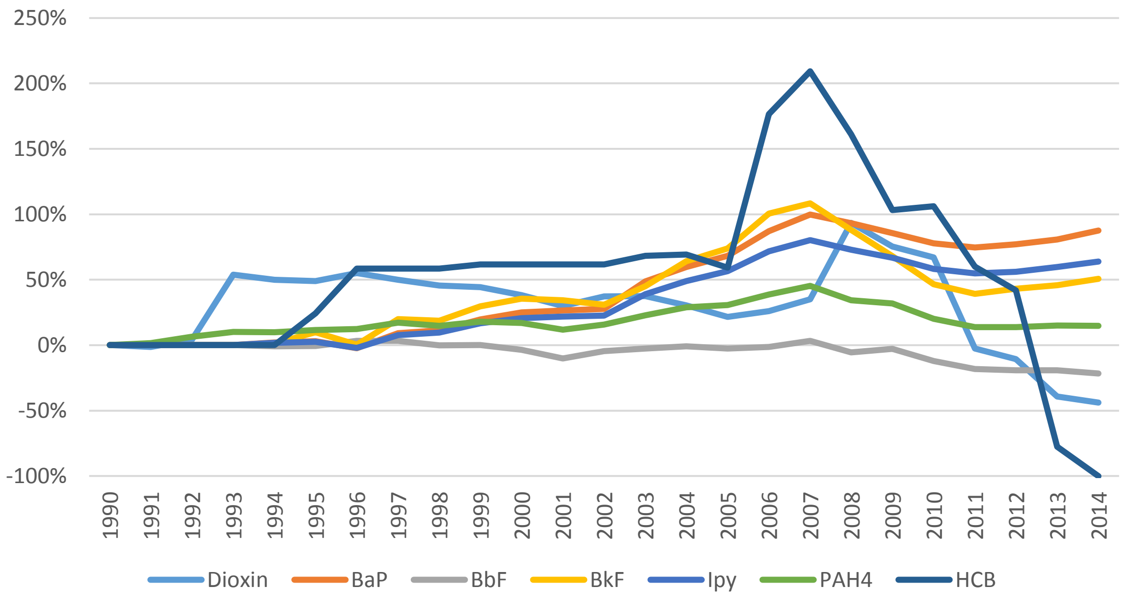

Figure 2.8 Trends in POPs emissions from the energy sector 1990-2014 (% of 1990 levels).

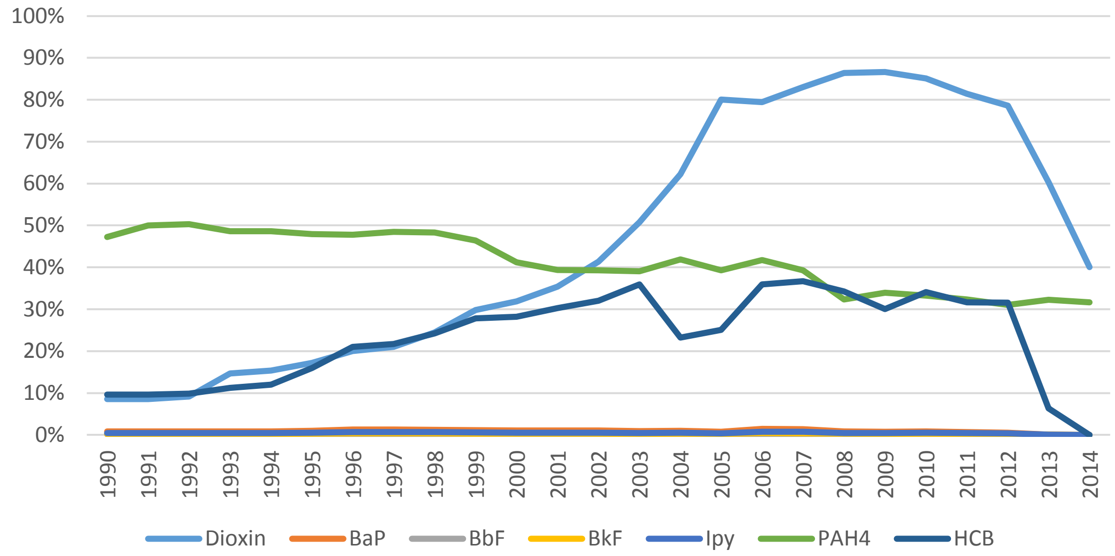

Figure 2.9 Trends in the contribution of POPs emissions from the energy sector (% of total pollutant emissions).

POPs emissions trends in the industrial sector are shown in Figure 2.10 as a percentage of the 1990 levels. Figure 2.11Figure 2.9 shows the trends in the contribution of POPs emissions from the sector from 1990-2014. In 2014 the industrial sector contributed 49% of total PAH4 emissions, 16% of total HCB emissions and 3% of total dioxin emissions. The industrial sector has not reduced its emissions of any POPs air pollutant since 1990. The contribution of the sector in the total PAH4 emissions has been steadily increasing from 30% in 1990 to around 50% in 2014. The large increase in HCB emissions from 2004-2009 leads to a contribution of the industrial sector of around 20% over that period.

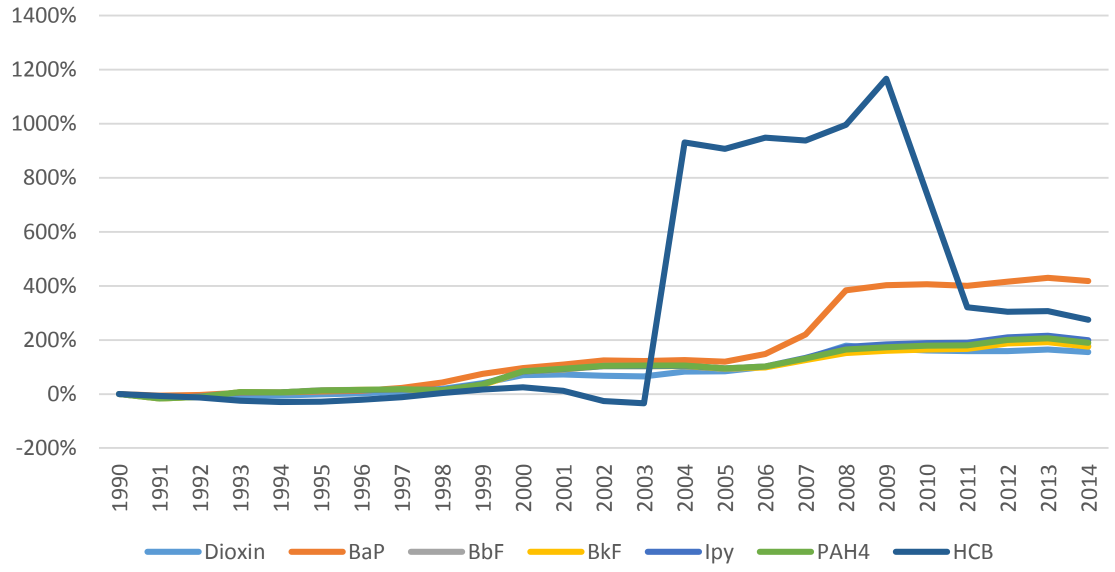

Figure 2.10 Trends in POPs emissions from the industrial sector 1990-2014 (% of 1990 levels).

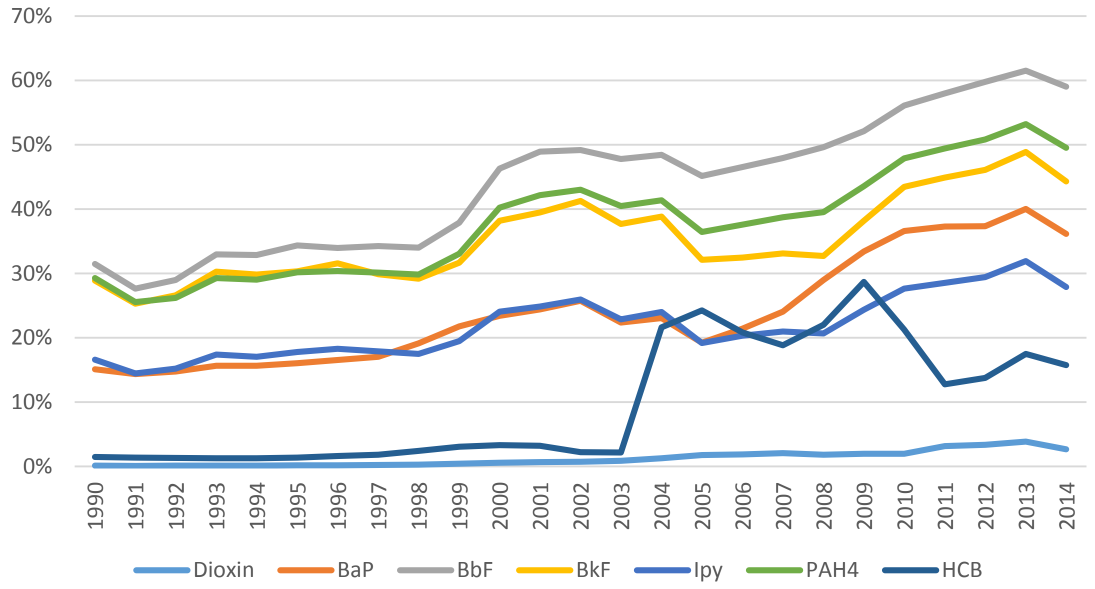

Figure 2.11 Trends in the contribution of POPs emissions from the industrial sector (% of total pollutant emissions).

POPs emissions trends in the waste sector are shown in Figure 2.12 as a percentage of the 1990 levels. Figure 2.13Figure 2.9 shows the trends in the contribution of POPs emissions from the sector from 1990-2014. In 2014 the waste sector contributed to 84% of total HCB emissions, 57% of total dioxin emission and 19% of total PAH4 emissions. The sector has decreased its HCB considerably since 1990 or by 67% but is still the dominant sector in the contribution to the total HCB emissions. PAH4 emissions have not decreased since 1990 and the contribution has remained relatively stable at around 20%.

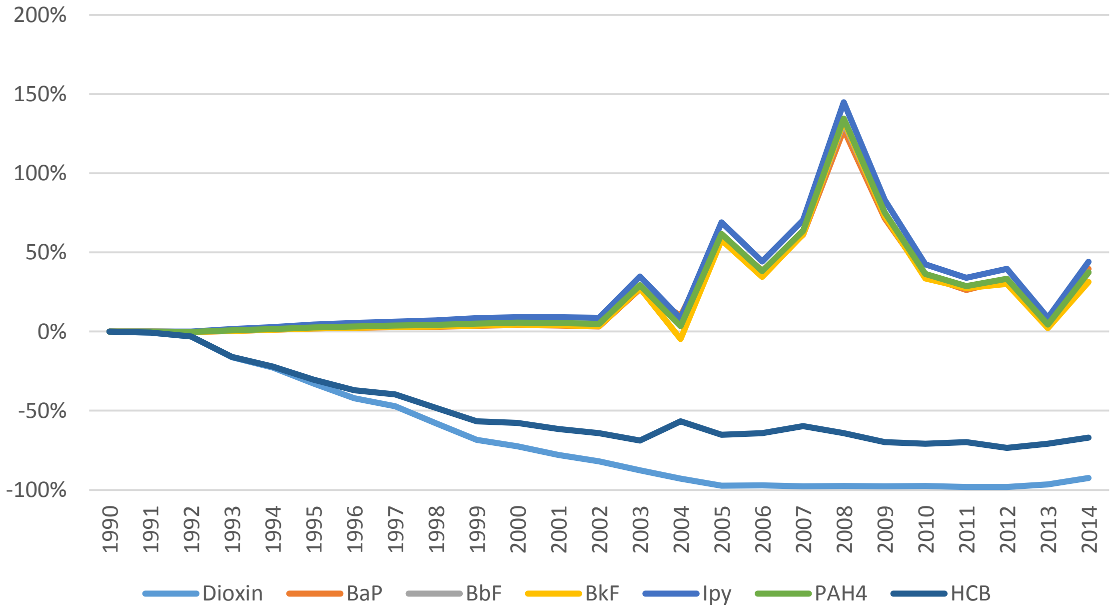

Figure 2.12 Trends in POPs emissions from the waste sector 1990-2014 (% of 1990 levels).

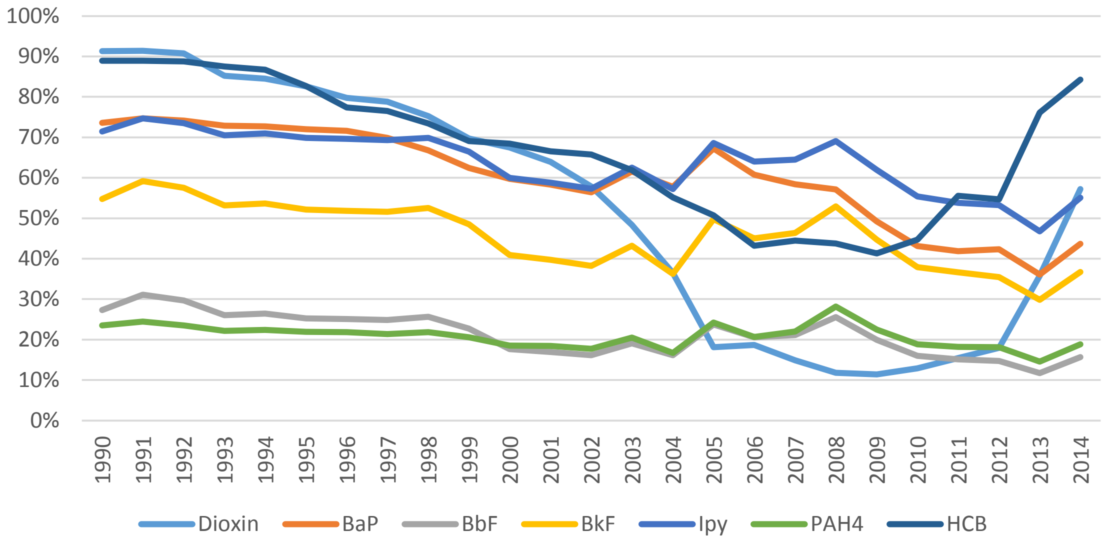

Figure 2.13 Trends in the contribution of POPs emissions from the waste sector (% of total pollutant emissions).

The emissions of POPs pollutants are not applicable for the agricultural sector.

2.3 Emission Trends for SO_X, NO_X, NH_3, NMVOC, CO, Particulate Matter and BC

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 has only ratified the POP protocol of the CLRTAP. Reporting of other pollutants than POPs is therefore not obligatory. Emissions of NO_x, CO, NMVOC and SO_2 are provided in the NFR tables for information purposes, as they are calculated to comply with the reporting requirements of the UNFCCC. For this submission emission estimates for ammonia and particulate matter are provided for a few emission sources. A short description of the trends of those pollutants is given in the following section.

The total amount of SO_2, NO_X, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$ and TSP emissions in Iceland in 1990 and 2014 is presented in Table 2.2. The most increase in emissions from 1990 to 2014 are emissions of SO_2 which have increased by 210% during that time period. Black carbon is excluded because the majority of the emission estimates are only available for the years 2013 and 2014 at the moment.

Table 2.2 Emissions of SO_2, NO_x, NH_3, NMVOC, CO and PM.

	SO_X [kt] SO_2	**NO_X [kt] NO_2**	**NH_3 [kt]**	**NMVOC [kt]**	**CO [kt]**	**PM_{10} [kt]**	**$PM_{2.5}$ [kt]**	**TSP [kt]**
1990	20.89	27.72	5.78	13.93	57.27	0.59	0.37	0.70
2014	64.84	20.00	5.59	6.71	114.67	0.78	0.28	0.98
Trend 1990-2014	**210%**	**-28%**	**-3%**	**-52%**	**100%**	**32%**	**-25%**	**41%**

The emission trends of the total NO_x, NMVOC, SO_2, NH_3, CO, $PM_{2.5}$, PM_{10} and TSP emissions relative to 1990 levels is shown in Figure 2.14. The emissions of SO_2 (H_2S emissions as SO_2 for emissions from geothermal plants) has increased significantly since 1990 levels or by around 200%. CO emissions have increased by around 100% since 1990. The most significant decrease in emissions are NMVOC emissions which have decreased by 52% since 1990 levels.

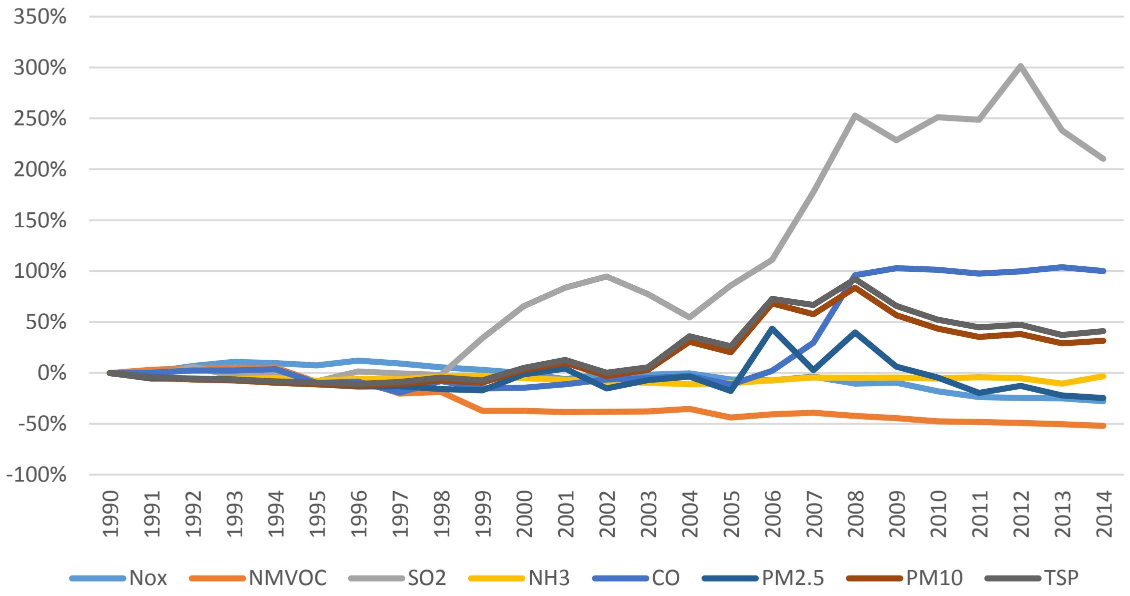

Figure 2.14 Trends in NO_x, NMVOC, SO_2, NH_3, CO, $PM_{2.5}$, PM_{10} and TSP emissions 1990-2014 (% of 1990 emissions).

2.3.1 Trends in Sulphur oxides (SO_x) emissions

Geothermal energy exploitation is by far 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 by 294% since 1990 due to increased activity in this field, as electricity production at geothermal power plants has increased 15-fold since 1990. The expansion of the metal production sector has been accommodated with parallel investments in increased power capacity, especially after 2005. Other significant sources of SO_2 in Iceland are industrial processes and manufacturing industry and construction (see Figure 2.15). 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. In 1990, 87,839 tonnes of aluminium were produced at one plant and 62,792 tonnes of ferroalloys at one plant. In 2014 839,449 tonnes of aluminium were produced at three plants and 107,785 tonnes of ferroalloys were produced at one plant. This led to increased emissions of SO_2 (401% increase of SO_2 emissions from ferroalloys and aluminium production compared to 1990 levels). The fishmeal industry is the main contributor to SO_2 emissions from fuel combustion in the sector Manufacturing Industries and Construction. Emissions from the fishmeal industry increased from 1990 to 1997 but have declined since as fuel has been replaced with electricity and production has decreased; the emissions were 99% below the 1990 level in 2014.

Sulphur emissions from the commercial fishing fleet depend upon the use of residual fuel oil. When fuel prices go up, the use of residual fuel oil rises and the use of gas oil drops. This leads to higher Sulphur emissions as the Sulphur content of residual fuel oil is significantly higher than in gas oil. The rising fuel prices since 2008 have led to higher Sulphur emissions from the fishing fleet in recent years. Emissions from the fishing fleet in 2014 were 6% below the 1990 emissions and fuel consumption was 33% less.

In 2014 total Sulphur emissions in Iceland, calculated as SO_2, were 210% above the 1990 level, but 140% above the 1990 level when excluding emissions from geothermal power plants (Figure 2.15).

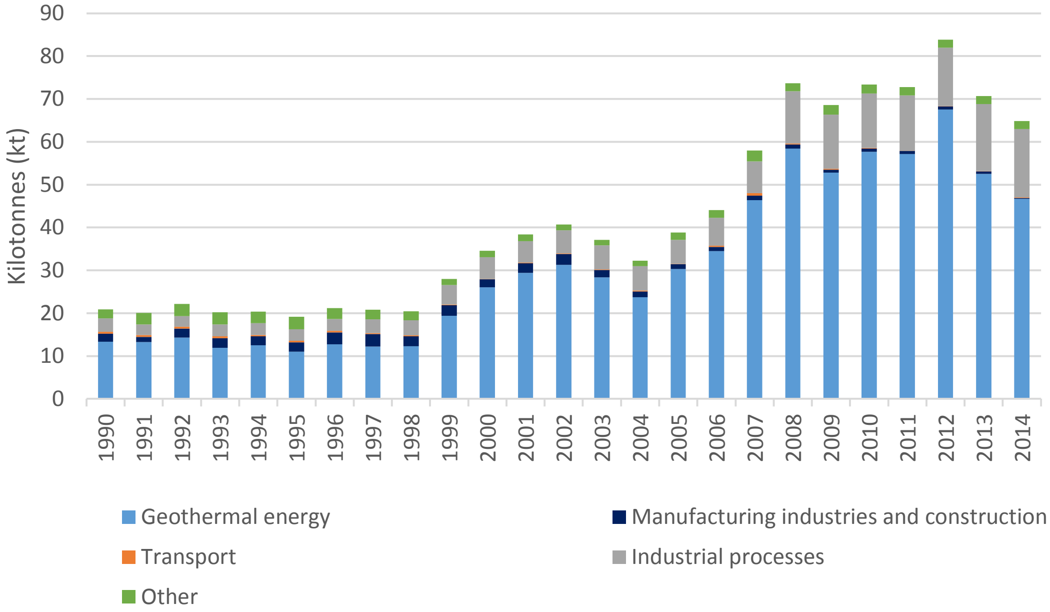

Figure 2.15 SO_2 emissions 1990-2014 by source.

In 2010 the volcano Eyjafjallajökull started erupting. The eruption lasted from 14th of April until 23rd of May. During that time 127 Gg of SO_2 were emitted or 71% more than total man made emissions in Iceland in 2010.

In 2011 the volcano Grímsvötn started erupting. The eruption lasted from 21st until 28th of May. During that time 1000 Gg of SO_2 were emitted or 12 times more than total man made emissions in 2011.

Big eruption started in Holuhraun on August 29th 2014 and ended on February 27th 2015. It was the biggest eruption in Iceland since the Laki eruption 1783. Total SO_2 emission from this eruption was estimated 12,006 kt. Devided on calender years 10,880 kt of SO_2 was 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 August 29th 2014 to December 31st 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. As these emissions from volcanos are natural they are not included in national totals.

2.3.2 Trends in nitrogen oxides (NO_X) emissions

The main sources of nitrogen oxides (NO_x) in Iceland are commercial fishing, transport, and the manufacturing industry and construction (see Figure 2.16). The NO_x 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 2014 were 33% below the 1990 level. Annual changes are inherent to the nature of fisheries. Emissions from transport are dominated by road transport. These emissions have decreased rapidly (by 20%) after the use of catalytic converters in all new vehicles became obligatory in 1995, despite the fact that fuel consumption has increased by 50%. The rise in emissions from the manufacturing industries and construction until 2007 are dominated by increased activity in the construction sector during the period. In 2014 emissions from manufacturing industry and construction (1A2) were 22% lower than in 1990. This is due to the collapse of the construction sector (including less emission from the cement plant) and to less fuel consumption at fishmeal plants as fuel has been replaced with electricity and production has decreased. Total NO_x emissions, like the emissions from fishing, increased until 1996 and decreased thereafter until 2001. Emission rose again between 2001 and 2004 and then decreased again.

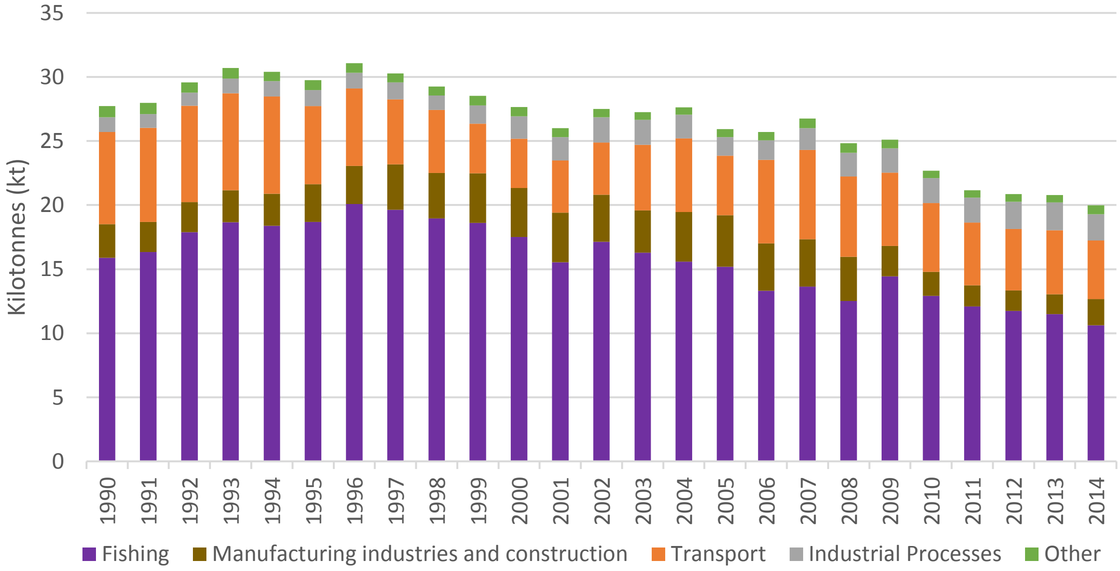

Figure 2.16 NO_X emissions 1990-2014 by source.

2.3.3 Trends in ammonia (NH_3) emissions

Ammonia emissions (NH_3) have only been estimated for the agriculture sector (NFR 3B). Manure management, manure deposition of grazing animals on pastures, and fertilizer application are the main sources. Emissions have been fluctuating between around 5 and 6 Gg NH_3 since 1990. Emissions decreased by 11% between 1990 and 2004 but have been increasing again since then. Therefore the overall trend between 1990 and 2014 is a 3% decrease. The main driver behind the general trend and its oscillations is the trend in livestock population. Sheep and cattle are the main ammonia emissions causing categories constituting more than 80% of total NH_3 emissions. NH_3 emissions from fertilizer application plays only a minor role as can be seen in Figure 2.17.

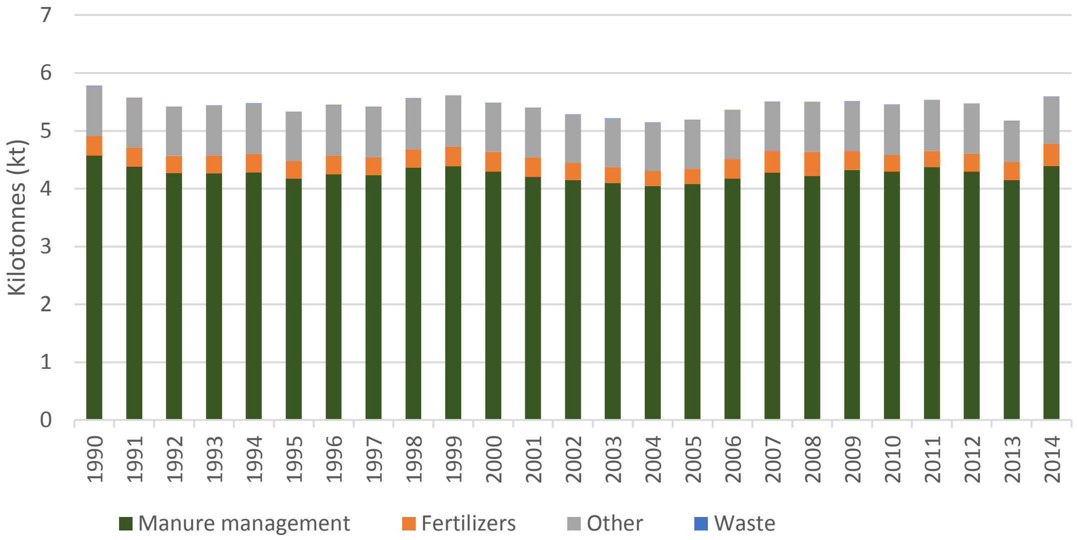

Figure 2.17 NH3 emissions 1990-2014 by source.

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

The main sources of non-methane volatile organic compounds (NMVOC) are transport and solvent use (categories 1A3 and 2D), as can be seen in Figure 2.18. Emissions from transport are dominated by road transport. These emissions decreased rapidly after the use of catalytic converters in all new vehicles became obligatory in 1995. Emissions from solvent use have been around 1 Gg and show a downward trend in recent years. Other emissions include emissions from industrial processes, where food and drink production is the most prominent contributor. The total emissions showed a downward trend from 1994 to 2014. The emissions in 2014 were 51% below the 1990 level.

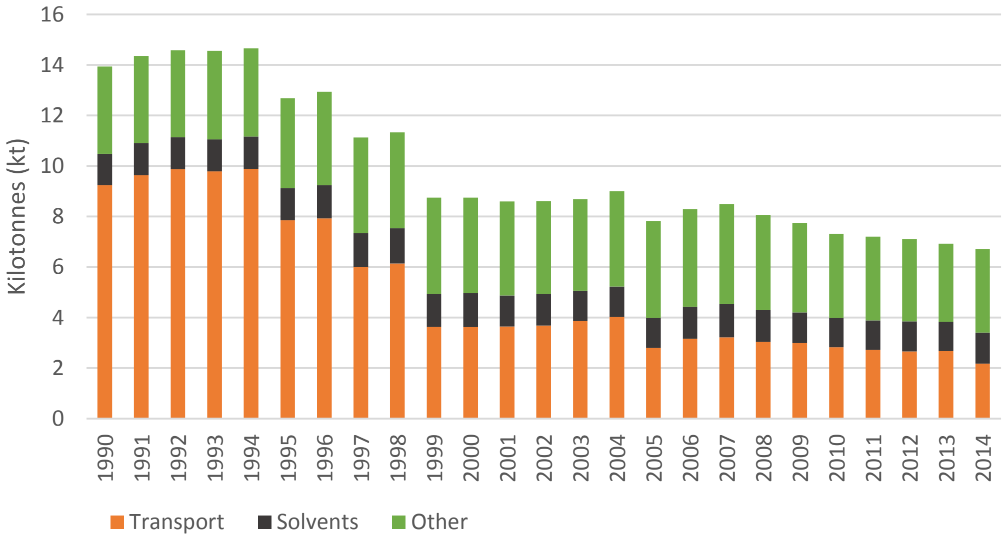

Figure 2.18 NMVOC emissions 1990-2014 by source.

2.3.5 Trends in carbon monoxid (CO) emissions

Industrial Processes is the most prominent contributor to CO emissions in Iceland, as can be seen in Figure 2.19, being responsible for over 88% of total CO emissions. It is worth mentioning that emissions from road transport have decreased rapidly after the use of catalytic converters in all new vehicles became obligatory in 1995. The emissions in 2014 were 101% above the 1990 level.

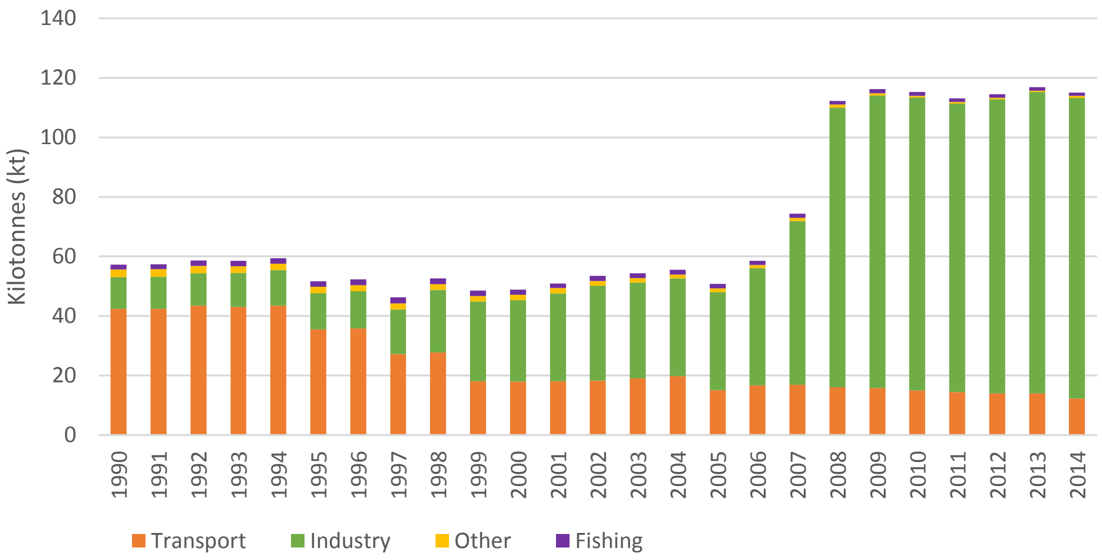

Figure 2.19 CO emissions 1990-2014 by source.

2.3.6 Trends in particulate matter (PM) and BC emissions

Emissions of particulate matter (TSP, PM_{10}, $PM_{2.5}$) have only been estimated for aluminium production, ferroalloys production, cement production, the agriculture sector and from tobacco smoking. The trend in emissions of PM_{10} and $PM_{2.5}$ can be seen in Figure 2.20 and 2.21. As emissions have only been estimated for few sources the trend should be interpreted with care.

Black carbon emissions are estimated for energy (1A), industrial processes (2A-G) and waste (5) sectors. Black carbon from transport (1A3) and national fishing (1A4ciii) were estimated for the first time in this year's submission. Emissions were only estimated for 2013 and 2014. Emission factors were taken from *Emissions of Black carbon and organic carbon in Norway 1990-2011* (Aasestad, 2013). The transport fleet has advanced over the years and based on expert judgement the EF's were suitable for the years 2013 and 2014, therefore emissions estimates only date back to 2013. Emissions from transport include emissions from passenger cars, light duty vehicles, heavy duty vehicles and buses, automobile tyre and brake wear, domestic aviation and national navigation. Emissions were calculated from fuel use multiplied with emission factors for appropriate source.

Black carbon from municipal waste incineration (5C1a) was also estimated for the first time this year, unlike the transport and fishing sector the waste sector was estimated for the years 1990-2014. The trend is downward, where 2014 emissions are 93% below the 1990 and the reason is decrease in open burning of waste.

The total estimated black carbon emissions in 2014 were approximately 313 tonnes and over 80% of it is from two key sources. The national fishing sector is responsible for 46% of the total emissions in

2014 and 36% stem from mobile combustion in manufacturing industries and construction, as can be seen in Figure 2.22.

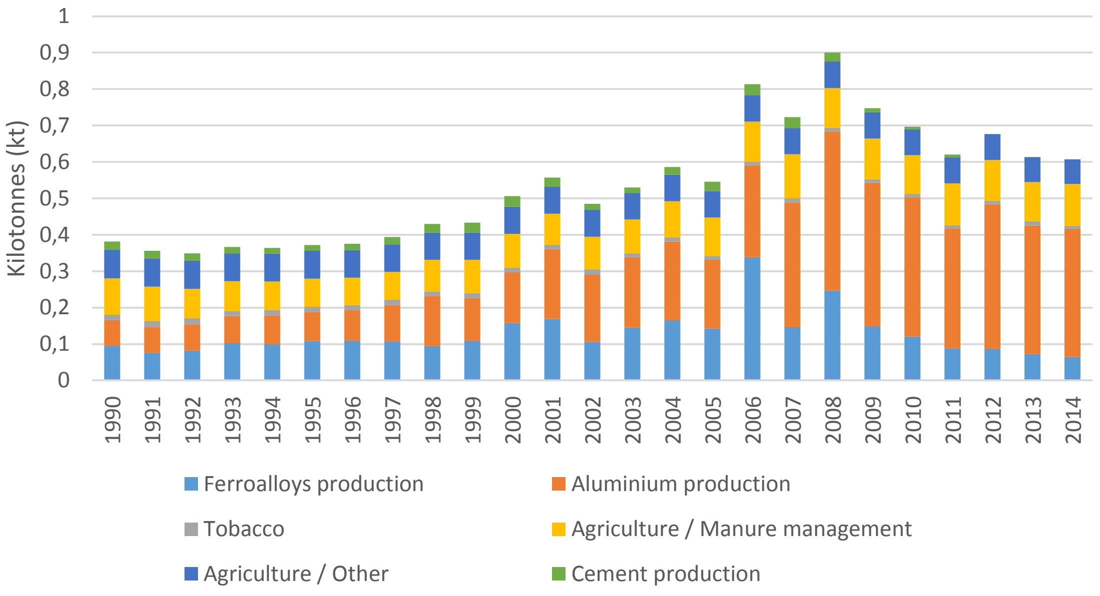

Figure 2.20 PM$_{10}$ emissions 1990-2014 by source.

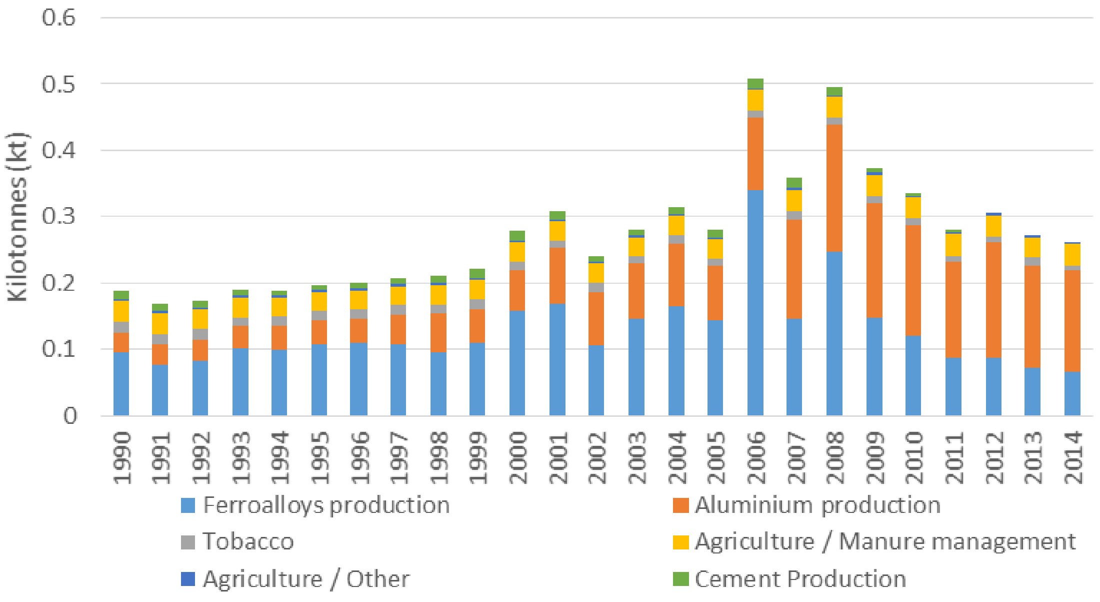

Figure 2.21 PM$_{2.5}$ emissions 1990-2014 by source.

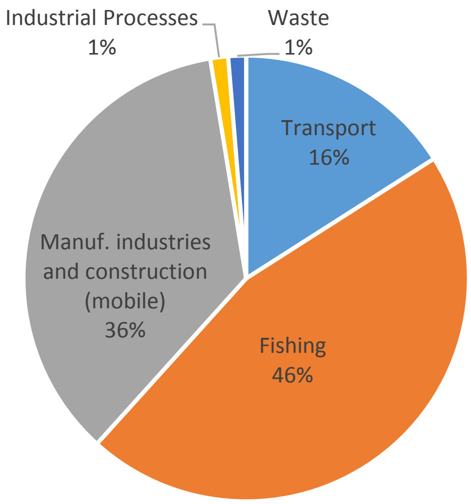

Figure 2.22 Black Carbon emission shares 2014 by source.

Emissions from the metal production sector overweigh the estimated emissions of particulates in Iceland. As stated above, the production capacity in the metal production sector has increased substantially. Aluminium production has increased from 87,839 tonnes in 1990 to 839,449 tonnes in 2014 and from ferrosilicon production has increased from 62,792 tonnes in 1990 to 107,785 tonnes in 2014.

Agricultural emissions stem from practices associated with the cultivation of grass and barley fields as well as livestock manure management. Total PM emissions from agriculture were 0.14 Gg in 2014 and 45% of the emissions were originated from aluminium production.

In 2010 the volcano Eyjafjallajökull erupted. The eruption lasted from 14th of April until 23rd of May. During that time around 6,000 Gg of PM_{10} were emitted or around 10,000 times more than total estimated man made emissions in 2010.

In 2011 the volcano Grímsvötn erupted. The eruption lasted from 21st until 28th of 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 EAI 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 Gg PM_{10} and 13,000 Gg of $PM_{2.5}$. As these emissions from volcanos are natural they are not included in national totals.

Big eruption started in Holuhraun on August 29th 2014 and ended on February 27th 2015. Unlike the eruptions in Eyjafjallajökull and Grímsvötn, which where phreatic eruptions, the eruption in Holuhraun was effusive eruption i.e. the lava steadily flows out of the volcano without explosive activity. So production of ash was negligible and emission of PM_{10} and $PM_{2.5}$ was not estimated.

2.3.7 Trends in SO_2, NO_x, NH_3, NMVOC, CO and PM by Main Source Sectors

Figure 2.23 shows trends in the emissions of non-POPs pollutants in the energy sector as a percentage of the 1990 levels. Figure 2.24 shows the trends in the contribution of non-POPs emissions from the sector from 1990-2014. The energy sector contribution to the total non-POPs pollutants emissions in 2014 is 87% for NO_x, 41% for NMVOC, 75% for SO_2 and 12% for CO. The contribution of other non-POPs pollutant emissions to the total emissions is zero (not applicable or not estimated). Emissions of SO_2 in are 176% higher in 2014 than in 1990. The contribution of the energy sector in the total SO_2 emissions has, however, remained relatively stable at around 80% since 1990 due to a similar increase in the emissions in the industrial sector over the same period of time (see Figure 2.25). Emissions of NO_x, NMVOC and CO have been steadily decreasing in the energy sector since 1990 as well contribution of this sector to the total emissions of these pollutants.

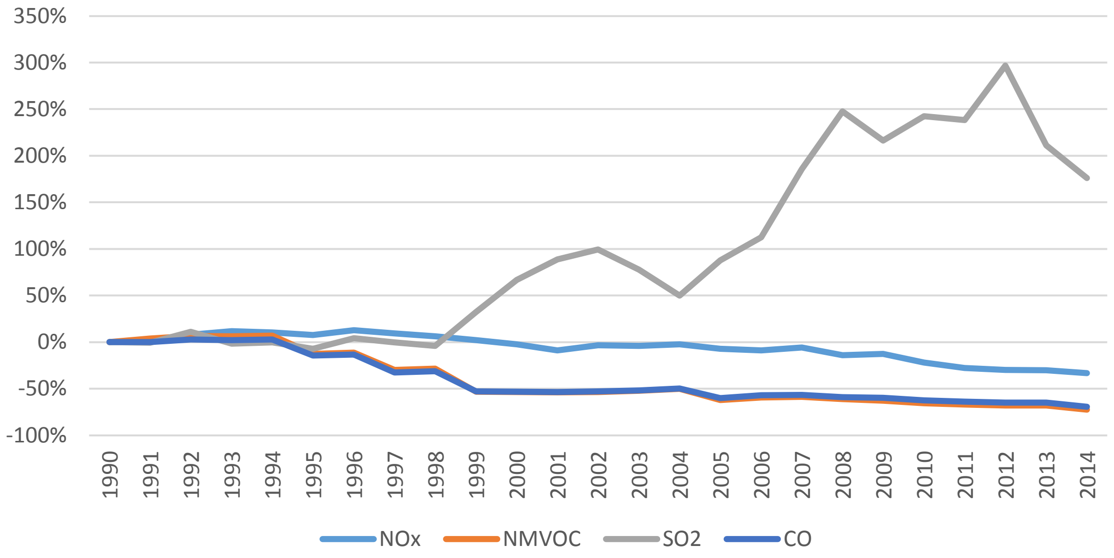

Figure 2.23 Trends in NO_X, NMVOC, SO_2 and CO emissions from the energy sector 1990-2014 (% of 1990 levels).

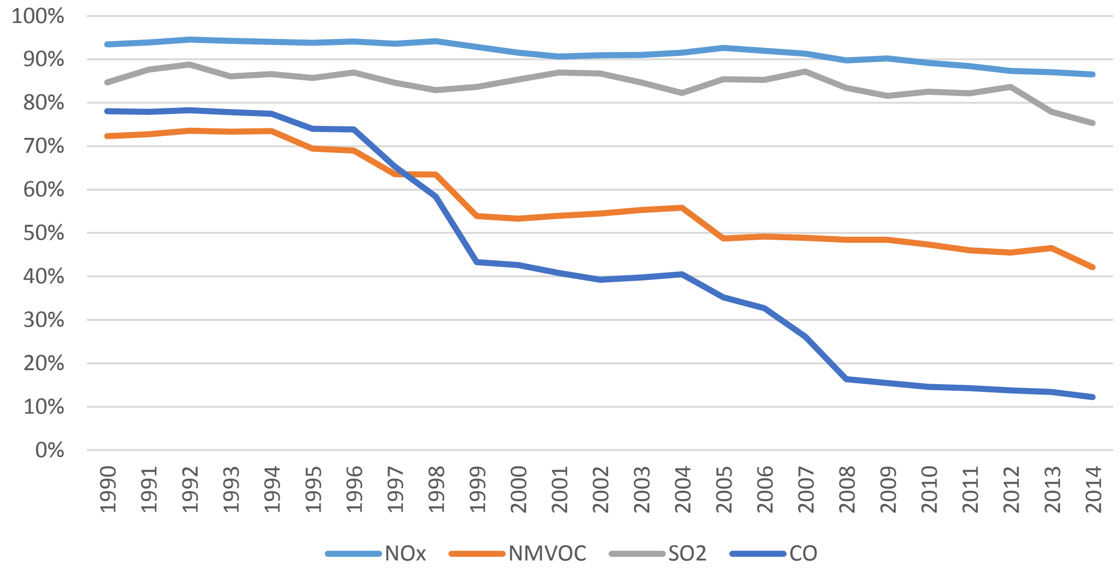

Figure 2.24 Trends in the contribution of NO_X, NMVOC, SO_2 and CO emissions from the energy sector (% of total pollutant emissions).

Figure 2.25 shows trends in the emissions of non-POPs pollutants in the industrial sector as a percentage of the 1990 levels. Figure 2.26 shows the trends in the contribution of non-POPs emissions from the sector from 1990-2014. The industrial sector contributions to the total non-POPs pollutants emissions in 2014 are 10% for NO_x, 28% for NMVOC, 25% for SO_2, 88% for CO, 81% for $PM_{2.5}$, 55% for PM_{10} and 53% for TSP. The contribution of other non-POPs pollutant emissions to the total emissions is zero (not applicable or not estimated). The large increase in CO emissions from the industrial sector has made this sector the dominant contributor of CO emissions in Iceland. Emissions of all the reported non-POPS emissions has increased in the industrial sector since 1990. Contributions of the industrial sector to the total emissions has also increased over that same period.

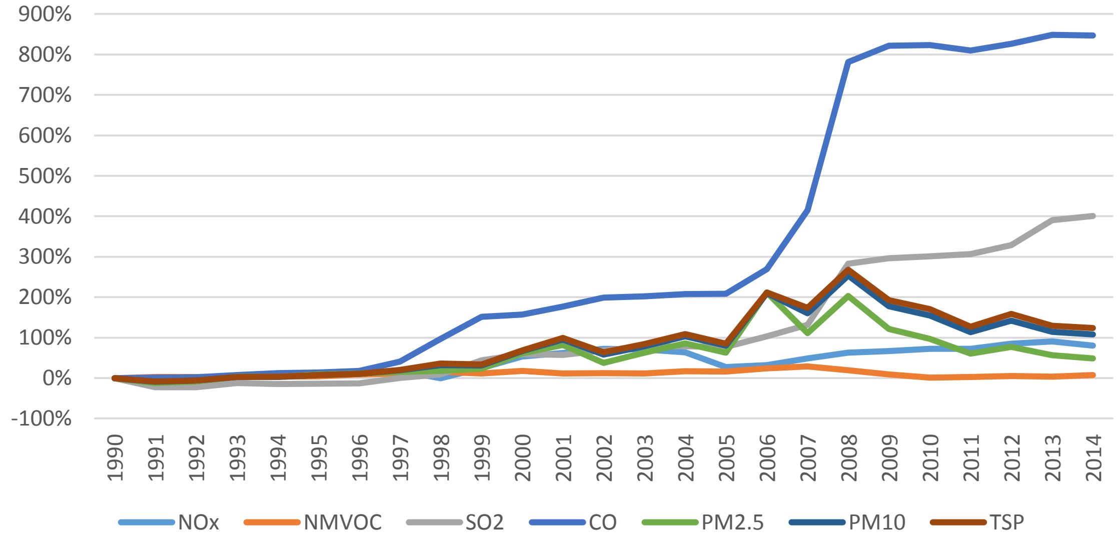

Figure 2.25 Trends in NO_x, NMVOC, SO_2, NH_3, CO, $PM_{2.5}$, PM_{10} and TSP emissions from the industrial sector 1990-2014 (% of 1990 levels).

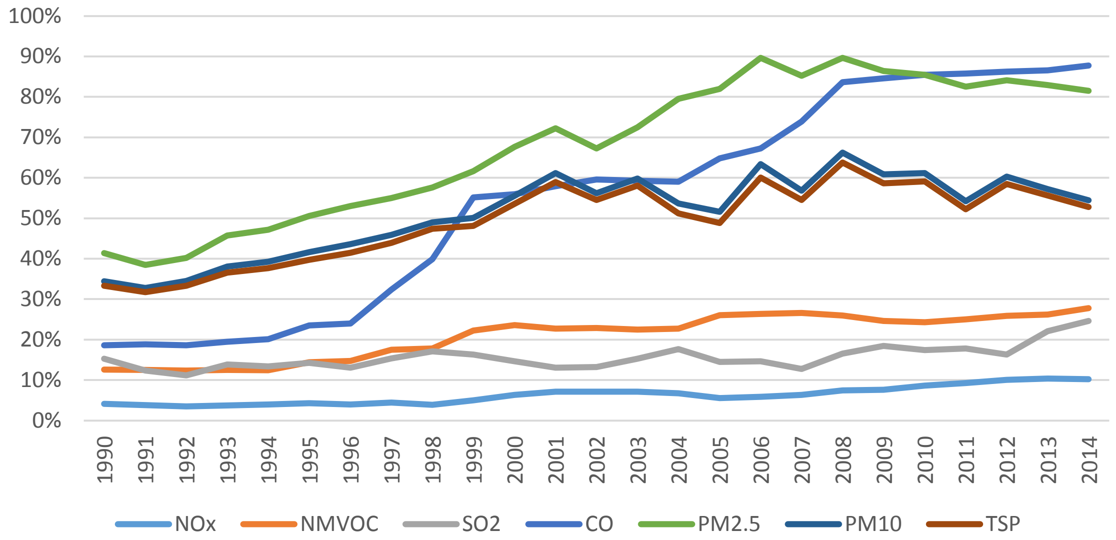

Figure 2.26 Trends in the contribution of NO_X, NMVOC, SO_2, CO and PM emissions from the industrial sector (% of total pollutant emissions).

Figure 2.27 shows trends in the emissions of non-POPs pollutants in the agricultural sector as a percentage of the 1990 levels. Figure 2.28 shows the trends in the contribution of non-POPs emissions from the sector from 1990-2014. The agricultural sector contribution to the total non-POPs pollutants emissions in 2014 is 3% for NOX, 28% for NMVOC, 100% for NH3, 13% for PM2.5, 23% for PM10 and 24% for TSP. The contribution of other non-POPs pollutant emissions to the total emissions is zero (not applicable or not estimated). No significant decrease in emissions have been in this sector since 1990. NO_X emissions have been fluctuating around the 1990 levels with a relatively high amplitude but still remains a negligible contributor to the total NOX emissions throughout the period.

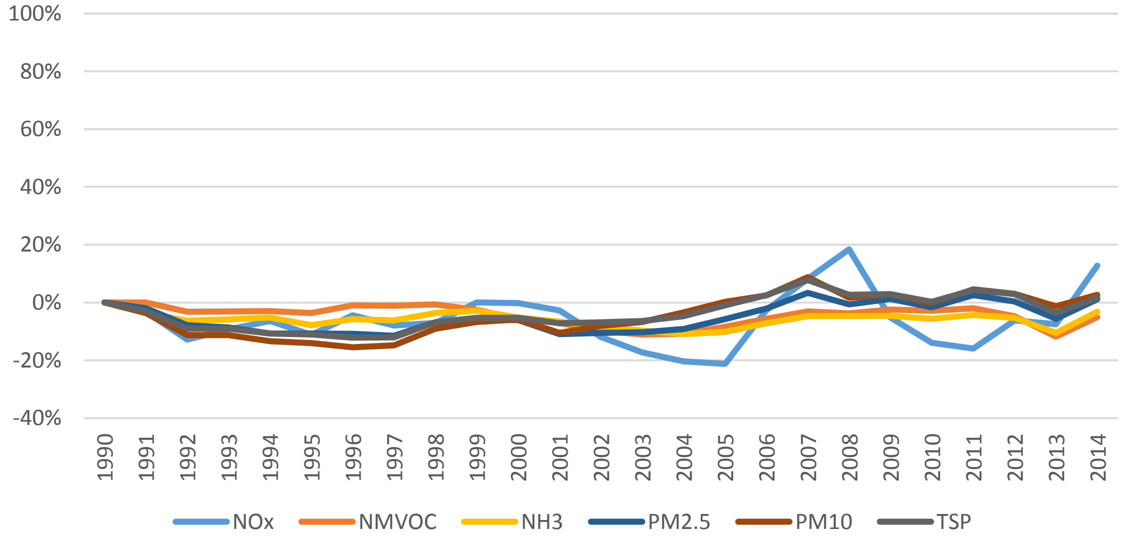

Figure 2.27 Trends in NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10} and TSP emissions from the agricultural sector 1990-2014 (% of 1990 levels).

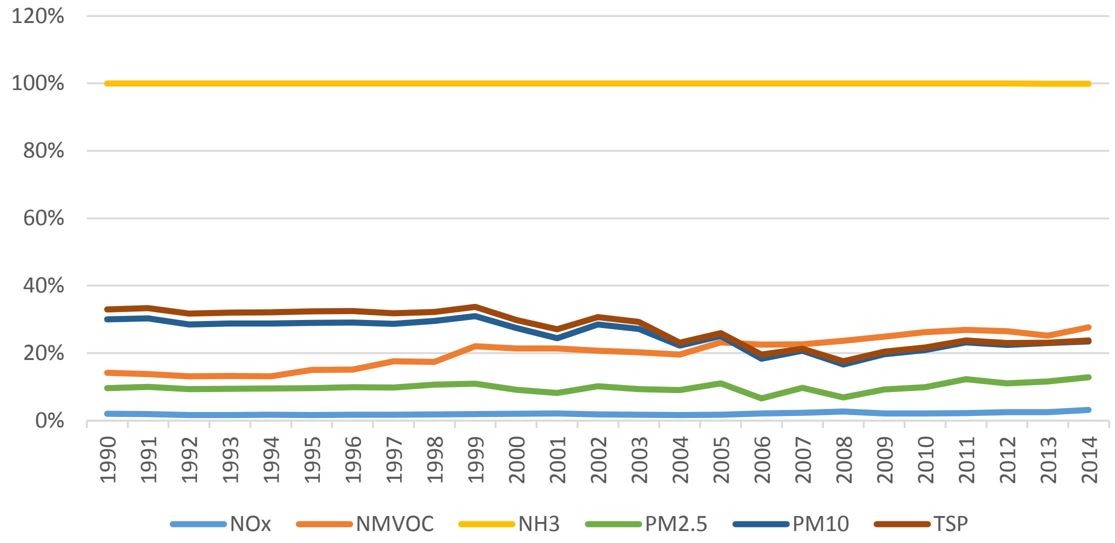

Figure 2.28 Trends in the contribution of NO_X, NMVOC, NH_3 and PM emissions from the agricultural sector (% of total pollutant emissions).

Figure 2.29 shows trends in the emissions of non-POPs pollutants in the waste sector as a percentage of the 1990 levels. Figure 2.30 shows the trends in the contribution of non-POPs emissions from the sector from 1990-2014. The waste sector contribution to the total non-POPs pollutants emissions in 2014 is 3% for NMVOC, 6% for $PM_{2.5}$, 22% for PM_{10} and 23% for TSP. NO_X, SO_2 and NH_3 emissions from the waste sector contribute to less than 1% of the total emissions for each pollutant. The contribution of other non-POPs pollutant emissions to the total emissions is zero (not applicable or not estimated). The dramatic increase in NH_3 emissions does not affect the contribution of the sector to the total emissions due to the dominating emission share of the agricultural sector. The contribution of the waste sector to the total PM emissions has decreased significantly since 1990.

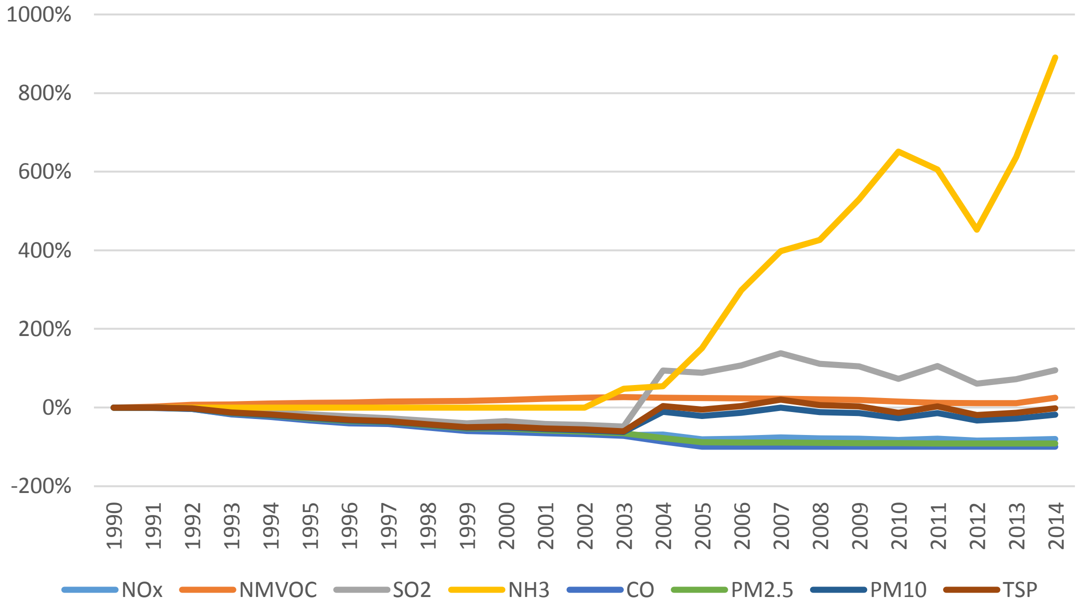

Figure 2.29 Trends in NO_X, NMVOC, SO_2, NH_3, CO, $PM_{2.5}$, PM_{10} and TSP emissions from the waste sector 1990-2014 (% of 1990 levels).

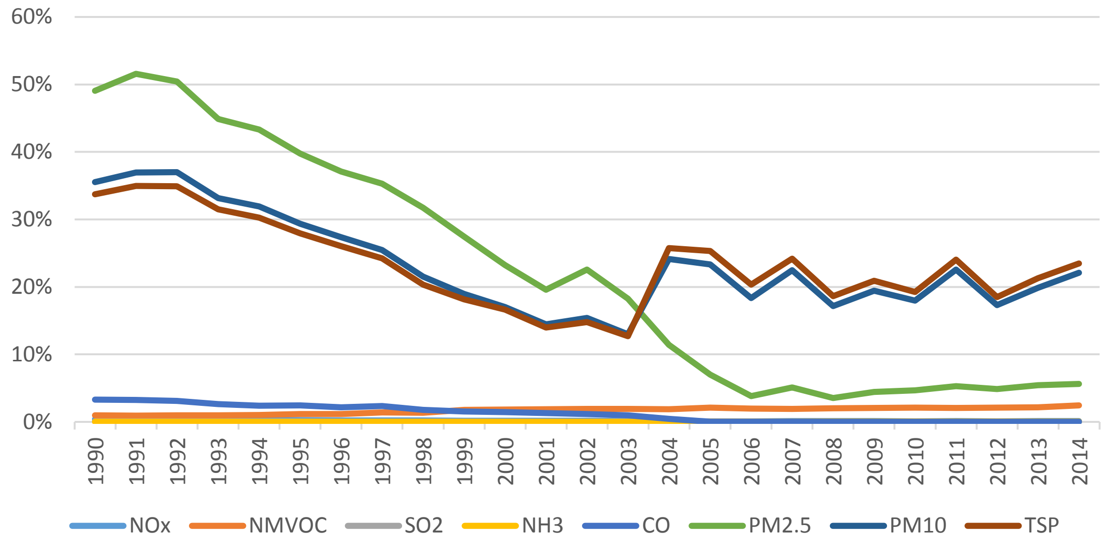

Figure 2.30 Trends in the contribution of NO_X, NMVOC, SO_2, NH_3, CO and PM emissions from the waste sector (% of total pollutant emissions).

3 Energy (NFR sector 1)

3.1 Overview

The energy sector is divided into four main chapters: Energy industries (1A1), Manufacturing industries & construction (1A2), Transport (1A3) and Other sectors (1A4).
Summary tables for the emissions from the energy sector are shown below in Table 3.1 and Table 3.2.

Table 3.1 NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, BC and CO emissions from the energy sector, 2014.

		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**	0.03	0.00	0.01	NR	NR	NR	NR	NE	0.01
1A2	**Manufacturin Industries and Construction**	2.04	0.29	0.24	NR	NR	NR	NR	0.11	0.65
1A3	**Transport**	4.59	2.18	0.12	NR	NR	NR	NR	0.05	12.00
1A4	**Other Sectors**	10.66	0.31	1.79	NR	NR	NR	NR	0.14	1.07
1B2	**Fugetive Emissions from Distribution of oil production and energy production**	NO/NE/NA	0.0063	46.71	NA	NA	NA	NA	NA	NA
Energy, Total		**17.33**	**2.78**	**48.87**	**0.00**	**0.00**	**0.00**	**NR**	**0.31**	**14.04**

Table 3.2 Dioxin, PAH and HCB emissions from the energy sector, 2014.

		Dioxin [g I-TEQ]	**B(a)P [t]**	**B(b)f [t]**	**B(k)f [t]**	**IPY [t]**	**PAH4 [t]**	**HCB [kg]**
1A1	Energy Industries	0.00003	NO	NO	NO	NO	NO	NO
1A2	Manufacturing Industries and Construction	0.00446	0.00016	0.00089	0.00131	0.00022	0.00258	NA
1A3	Transport	0.03844	0.00225	0.00407	0.00279	0.00282	0.01189	NE
1A4	Other Sectors	0.55932	NO	0.00558	NO	NA	0.00558	NO
1B2	Fugitive Emissions from Distribution of oil production and energy production	NO	NA	NA	NA	NA	NA	NA
Energy, Total		**0.6023**	**0.0024**	**0.0106**	**0.0041**	**0.0030**	**0.0201**	**NO/NA/NE**

3.2 Introduction

The energy sector in Iceland is unique in many ways. Iceland ranks 1st among Organisation for Economic Co-operation and Development (OECD) countries in the per capita consumption of primary energy. The per capita primary energy consumption in 2014 was around 796 GJ. However, the proportion of domestic renewable energy in the total energy budget is about 85%, which is a much higher share than in most other countries. The cold climate and sparse population calls 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 used approximately 75% of the total electricity produced in Iceland in 2014. Iceland relies heavily on its geothermal energy sources for space heating (over 90% of all homes) and electricity production (30% of the electricity) and on hydropower for electricity production (70% of the electricity). Thus, emissions in the energy sector originate predominantly from mobile sources: road transport, fishing and equipment in the construction sector, as well as waste incineration with energy recovery.

3.3 Methodology

Emissions from fuel combustion are estimated at the sectoral level. 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. The division of fuel sales by sector does not reflect the IPCC (International Panel on Climate Change)/NFR sectors perfectly so the EAI has made adjustments to the data where needed to better reflect the IPCC/NFR categories. Tables explaining this adjustment are given in Annex I. The first table in Annex I is named “Fuel sales (gas oil and residual fuel oil) by sectors 1A1a, 1A2 (stationary) and 1A4 (stationary) – as provided by the National Energy Authority”. This table contains the original values. The adjustment is done in the following way for gasoil:

- First fuel consumption needed for the known electricity production with fuels is calculated (1A1a – electricity production), assuming 34% efficiency of the diesel engines. The values calculated are compared with the fuel sales for the category 10X60 Energy industries (nomenclature from the NEA).
- In years where there is less fuel sale to energy industries, according to the sales statistics (1,423 tonnes in 2014)as would be needed for the electricity production (603 tonnes in 2014), the fuel needed to compensate is taken from the category 10X90 Other; and if that is not sufficient from the category 10X40 House heating and swimming pools.
- In years where there is surplus, the extra fuel is added to the category 10X40 House heating and swimming pools. In 2014 there was a surplus in the energy industries category, so 820 tonnes were added to the category 10X40 House heating and swimming pools. So now the category 10X40 has 3929 tonnes in 2014 (3,109+820).
- NEA has estimated that the fuel use by swimming pools (1A4a), but it should be noted that the majority of swimming pools in Iceland have geothermal water. The estimated fuel use values are given in the lower table of Annex I. It is 300 tonnes in 2014. These values are subtracted from the adjusted 10X40 category, leaving 1684 tonnes in the category in 2014 (3,929-300). The rest is then 1A4c – Residential.
- For years where there is still fuel in the category 10X90 Other (214 tonnes were left in that category in 2014), this is added to the 10X5X Industry (originally with 4,357 tonnes in 2014). This is the fuel use in 1A2 – Industry (4,357+214=4,571 tonnes in 2014).

Explanation for the adjustment for residual fuel oil is given in Annex I. The adjustment applies for the sectors 1A1a Energy Industries, 1A2 Manufacturing Industry and Construction (stationary combustion) and 1A4 Small Combustion and Other Mobile Combustion. Emissions from waste incineration with energy recovery are reported under energy industries and commercial but a description of the method is under the waste section. Fuel combustion activities are divided into two main categories; stationary and mobile combustion. Stationary combustion includes Energy Industries, Manufacturing Industries and a part of the Other sectors (Residential and Commercial/Institutional sector). Mobile combustion includes Civil Aviation, Road Transport, Navigation, Fishing (part of the Other sectors), Mobile Combustion in Construction (part of Manufacturing Industries and Construction sector) and International Bunkers.

The QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardised procedures for emission calculations, estimating uncertainties, archiving information and reporting, as further elaborated in the QA/QC manual. No source specific QA/QC procedures have been developed yet for the Energy sector.

- This chapter on Energy (NFR sector 1) is divided into the following chapters:
- Energy Industries (NFR 1A1)
- Manufacturing Industries and Construction (NFR 1A2)
- Transport (NFR 1A3)
- Other Sectors (NFR 1A4)
- Fugitive Emissions (NFR 1B2)

3.4 Energy Industries (NFR 1A1)

Energy Industries include emissions from electricity and heat production. Iceland has extensively utilised 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. Activity data on fuel use for the energy industries are based on data provided by the NEA and adjusted by EAI, see Annex I. Activity data on waste is collected by EAI directly from the plants.

3.4.1 Electricity & heat (1A1a)

Electricity was produced from hydropower, geothermal energy and fuel combustion in 2014 (Table 3.3), with hydropower as the main source of electricity (NEA, 2014). Electricity was produced with fuel combustion at two locations that are located far from the distribution system (two sparsely populated islands, Grimsey and Flatey). Some public electricity facilities have emergency backup fuel combustion power plants which they can use 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	2012	2013	2014
Hydropower	4,159	4,678	6,352	7,015	12,592	12,337	12,863	12,873
Geothermal	283	288	1,323	1,658	4,465	5,210	5,245	5,238
Fuel combustion	6	8	5	8	2	2.8	2.8	2.4
Total (GWh)	**4,448**	**4,974**	**7,680**	**8,681**	**17,059**	**17,550**	**18,111**	**18,114**

Activity data (the amount of gasoil used) for electricity production with fuel combustion is calculated from the information on electricity production (GWh), based on the energy content of the gasoil (43 TJ/kt) assuming 34% efficiency.

Geothermal energy was the main source of heat production in 2014. 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 burn waste to produce heat and are connected to the local distribution system. Emissions from these waste incineration plants are reported under Energy Industries. A description of the method to estimate emissions from waste incineration plants is given in Chapter 6.

3.4.1.1 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 and 2011. The use of residual fuel oil 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 (unfavorable 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	2012	2013	2014
Gas/Diesel oil (electricity)	1.40	2.12	1.12	1.97	0.43	0.71	0.69	0.60
Residual fuel oil (heat)	2.99	3.08	0.07	0.20	0.00	0.14	0.13	0.19
Solid waste (heat)	NO	4.65	6.05	5.95	8.11	5.63	0.92	0.00

3.4.1.2 Emission factors

Emission factors for dioxin are taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005). They are 0.5 µg I-TEQ/TJ (0.022 µg I-TEQ/t fuel) for gas/diesel oil and 2.5 µg I-TEQ/TJ (0.1 µg I-TEQ/t fuel) for residual fuel oil. PAH4 and HCB emissions are not estimated from this source. Emissions of SO_2 are calculated from the S-content of the fuels. Emission factors for NOx and CO are taken from Table 1-15 of the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual. NMVOC emission factor is taken from Table 1.11 in the Reference Manual.

3.5 Manufacturing Industries & Construction (NFR 1A2)

3.5.1 Manufacturing industries, stationary combustion (1A2a-g)

3.5.1.1 Activity Data

Information on the total amount of fuel used by the manufacturing industries was obtained from the NEA and adjusted by EAI (see Annex I). The total fuel consumption per fuel type can be seen in Table 3.5. The sales statistics for the manufacturing industry (as adjusted by EAI) are given for the sector as a total. There is thus a given total, which the usage in the different subcategories must sum up to. The sales statistics do not specify the fuel consumption by the different industrial sources. This division is made by the EAI on basis of the reported fuel use by all major industrial plants that fall under law no. 70/2012 on Climate Change (metal production, cement) and from green accounts submitted by the industry in accordance with regulation no. 851/2002 for industry not falling under law no. 70/2012. Fuel consumption in the fishmeal industry from 1990 to 2002 was estimated from production statistics, but the numbers for 2003 to 2014 are based on data provided by the industry (application for free allowances under the EU Emissions Trading System (EU ETS) for the years 2005 to 2010, information from the Icelandic Association of Fishmeal Manufacturers for 2003, 2004 and 2011 and 2012). The difference between the given total for the sector and the sum of the fuel use of the reporting industrial facilities are categorized as 1A2f other non-specified industry. Emissions are calculated by multiplying energy use with a pollutant specific emission factor. 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 1A2fi. 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	2012	2013	2014
Gas/Diesel oil	5.07	1.13	10.25	22.19	9.39	5.41	7.57	4.57
Residual fuel oil	55.93	56.22	46.21	25.01	16.55	17.84	13.79	1.61
LPG	0.48	0.39	0.86	0.93	1.05	1.83	1.27	1.19
Electrodes (residue)	0.80	0.29	1.50	0.00	0.40	0.00	0.00	0.00
Steam coal	18.60	8.65	13.26	9.91	3.65	0.00	0.00	0.00
Petroleum coke	0.00	0.00	0.00	8.13	0.00	0.00	0.00	0.00
Waste oil	0.00	4.99	6.04	1.82	1.36	1.25	2.13	0.85

3.5.1.2 Emission factors

Emission factors for dioxin for liquid fuel used in stationary combustion in manufacturing industry are taken from the “Utslipp til luft av dioksiner i Norge” (Statistics Norway, 2002). PAH4 emission factors for coal used in stationary combustion (used in the cement industry) as well as the profile ratio are taken from the chapter An approach to estimation of PAH emission in the Emission Inventory Guidebook (EEA 2007). The BaP emission factor for industrial coal combustion for large plants is taken from Appendix 3 of the chapter and the profile ratio is found in section 7. PAH 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 Emission Inventory Guidebook (EEA 2013). 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/t fuel]	B(a)P [mg/GJ]	B(b)F [mg/GJ]	B(k)F [mg/GJ]	IPy [mg/GJ]
Gas/Diesel Oil	0.1	1.9	15	1.7	1.5
Residual fuel oil	0.1	1.9	15	1.7	1.5
LPG	0.06	0.72	2.9	1.1	1.08
Electrodes residues	IE[1]	0.14	PR: 0.05	PR: 0.01	PR:0.8
Steam coal	IE[1]	0.14	PR: 0.05	PR: 0.01	PR:0.8
Petroleum coke	IE[1]	1.9	15	1.7	1.5
Waste oil	4	1.9	15	1.7	1.5

[1] Coal, electrodrodes 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_2 emissions are calculated from the S-content of the fuels. Source specific emission factors for NOx and CO are taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Emission factors for NMVOC are taken from EMEP guidebook 2013 (EEA, 2013). Sulphur emissions from use of petroleum coke occur in the cement industry. Further waste oil has mainly been used in the cement industry. Emission estimates for SO_2 for the cement industry are based on measurements.

3.5.2 Manufacturing industries, mobile combustion (1A2gvii)

3.5.2.1 Activity data

Activity data for mobile combustion in the construction sector is provided by the NEA. Oil, which is reported to fall under vehicle usage, is in some instances actually used for machinery and vice versa as it happens that machinery refuels at a tank station, (thereby reported as road transport), as well as fuel that is sold to contractors, to be used on machinery, is used for road transport (but reported under construction). This is, however, very minimal and the deviation is believed to level out. Emissions are calculated by multiplying energy use with a pollutant specific emission factor. 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	2012	2013	2014
Gas/Diesel oil	37.98	46.74	61.89	67.78	32.23	29.07	27.65	40.46

3.5.2.2 Emission factors

Emission factors for dioxin from mobile sources are taken from “Utslipp til luft av dioxiner i Norge” (Statistics Norway, 2002). They are 0.1 µg/t fuel. PAH emissions are not estimated from this source. SO2 emissions are calculated from the S-content of the fuels. Emission factors for NOx, CO and NMVOC are taken the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual (IPCC, 1996) and the EMEP guidebook 2013 (EEA, 2013). Emission factors for BC are taken from Emissions of Black Carbon and Organic Carbon in Norway 1990-2011 (Aasestad, 2013).

3.6 Transport (NFR 1A3)

3.6.1 Civil aviation (1A3a)

Emissions are calculated by multiplying energy use with a pollutant specific emission factor. Emissions from civil aviation are estimated as totals, so landings and take-offs for civil aviation are included in civil aviation – cruise. Landing and take-offs in international aviation are included in international aviation – cruise, and not included in national totals.

3.6.1.1 Activity data

Total use of jet kerosene and gasoline is based on the NEA's annual sales statistics for fossil fuels. Activity data for fuel combustion are given in Table 3.8.

Table 3.8 Fuel use (kt), domestic aviation.

	1990	1995	2000	2005	2010	2012	2013	2014
Jet Kerosene	8.409	8.253	7.728	7.39	6.066	6.133	5.735	12.3
Aviation gasoline	1.681	1.131	1.102	0.872	0.648	0.492	0.494	0.5

3.6.1.2 Emission factors

Emission factors for dioxin are 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 are not estimated. SO_2 emissions are calculated from the S-content of the fuels. Emission factors for NOx, CO and NMVOC are taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual (IPCC, 1996). Emission factors for BC are taken from Emissions of Black Carbon and Organic Carbon in Norway 1990-2011 (Aasestad, 2013). The emission factors are presented in Table 3.9.

Table 3.9 Emission factors for dioxin, NOx, CO, NMVOC and BC, aviation.

	Dioxin [µg I-TEQ/t fuel]	NOx [kg/TJ]	CO [kg/TJ]	NMVOC [kg/TJ]	BC g/kg fuel
Jet Kerosene	**0.06**	**250**	**100**	**50**	**0.0045**
Aviation gasoline	**2.2**	**250**	**100**	**50**	**0.0045**

3.6.1.3 Planned improvements

Planned improvements involve moving emission estimates from aviation to the Tier 2 methodology by next submission and deviate between cruise and landing/take-off emissions as well as using data from Eurocontrol.

3.6.2 Road vehicles (1A3b)

Emissions from Road Traffic are estimated by multiplying the fuel use by type of fuel and vehicle, and fuel and vehicle pollutant specific emission factors.

3.6.2.1 Activity data

Total use of diesel oil and gasoline are based on the NEA's annual sales statistics for fossil fuels (Table 3.10).

Table 3.10 Fuel use (kt), road transport.

	1990	1995	2000	2005	2010	2012	2013	2014
Gasoline	127.81	135.60	142.60	156.73	148.21	136.84	134.94	132.05
Diesel oil	36.57	36.86	47.46	83.48	106.43	110.54	117.05	112.75

NEA estimated on how the fuel consumption is divided between different vehicles groups, i.e. passenger cars, light duty vehicles, and heavy duty vehicles are used for the period 1990 to 2005. From 2006 to 2014 EAI estimated how the fuel consumption is divided between the different vehicles groups, using information on the number of vehicles in each group and the driven mileage in each group from the Icelandic Transport Authority (ICETRA), using average fuel consumption based on the 1996 IPCC Guidelines Regarding Average Fuel Consumption Per Group. The data for 2006 to 2014 contains information on motorcycles. The ICETRA has been working with the EAI to provide data that would enable the use of a computer program to calculate emissions from road transport (COPERT). This work was not finished in time for this submission, but will hopefully be included in next submission. Therefore are the time series is not fully consistent as two different methodologies are used. For the years 1990 to 2005 emissions from motorcycles are included in emissions from other vehicles.

The EAI has estimated the amount of passenger cars by emission control technology. The proportion of passenger cars with three-way catalysts has steadily increased since 1995 when they became mandatory in all new cars. The assumptions are shown in Figure 3.1. Although three-way catalysts have been mandatory for a long time now, it is assumed that the proportion of cars with three-way catalyst stagnates at 86%, as the catalysts usually lose their function after about 10 years.

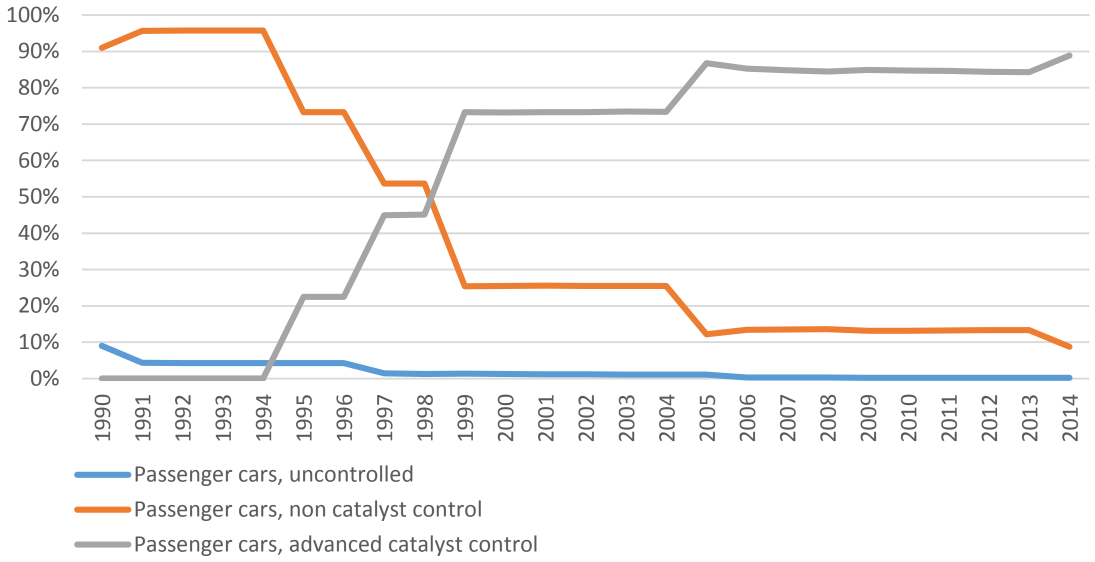

Figure 3.1 Passenger cars by emission control technology.

3.6.2.2 Emission factors

Emission factors for dioxin are taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005). They are presented in Table 3.11. Emission factors for PAH are taken from the chapter “An approach to estimation of PAH emission” in the Emission Inventory Guidebook (EEA, 2007). Emission factors for PAH4 are presented in Table 3.12.

Table 3.11 Emission factors for dioxin, road vehicles.

	Dioxin [µg I-TEQ/t fuel]
Gasoline, leaded	2.2
Gasoline, unleaded, no catalyst	0.1
Gasoline, unleaded, with catalyst	0
Gas/ Diesel oil	0.1

Table 3.12 Emission factors for PAH4, road vehicles.

	B(a)P [mg/GJ]	Fuel cons. [l/100 km]	B(a)P µg/kg fuel	Ratio to B(a)P B(b)F	B(k)F	IPy
Passenger cars - gasoline, conventional	1.1	8.5	17.14	1.2	0.9	1
Passenger cars - gasoline, catalyst	0.4	8.5	6.23	0.9	1.2	1.4
Light duty vehicles - gasoline	1.1	13.6	10.71	1.2	0.9	1
Pass.cars diesel - direct ing.	0.7	7	11.79	0.9	1	1.1
Pass.cars diesel - indirect inj.	2.8	7	47.14	0.9	0.8	0.9
Light duty vehicles - direct inj.	0.7	10.9	7.57	0.9	1	1.1
Light duty vehicles - indirect inj.	2.8	10.9	30.29	0.9	0.8	0.9
HDV (diesel)	1	29.9	3.94	5.6	8.2	1.4
Other use, gas/diesel oil, (*HDV)	1	29.9	3.94	5.6	8.2	1.4

SO_2 emissions are calculated from the S-content of the fuels. Emission factors for other pollutants depend upon vehicle type and emission control. They are taken from the revised 1996 IPCC Guidelines (IPCC, 1996). Emission factors for BC are taken from Emissions of Black Carbon and Organic Carbon in Norway 1990-2011 (Aasestad, 2013) and the BC emissions are only estimated for the years 2013 and 2014. The reason is rapid evolvement of the car fleet the past years and therefore more accurate data and emissions factors are needed in order to get a realistic emissions trend. Emission factors are presented in Table 3.13.

Table 3.13 Emission factors for NOx, CO, NMVOC and BC for European vehicles.

	NOx [g/kg fuel]	CO [g/kg fuel]	NMVOC [g/kg fuel]	BC [g/kg fuel]
Passenger cars - gasoline, uncontrolled	27	550	63	NE
Passenger cars - gasoline, non-catalyst control	37	300	72	NE
Passenger cars - gasoline - three way catalyst	8.2	45.9	7.1	NE
Light duty vehicles - gasoline	29	360	59	NE
Heavy duty vehicles - gasoline	40	346	32	NE
Motorcycles - gasoline	2.7	730	530	NE
Passenger cars - diesel	11	12	3	0.325
Light duty vehicle - diesel	16	18	4.6	0.644
Heavy duty vehicles - diesel	42	36	8	0.202

3.6.2.3 Planned improvements

Planned improvements involve getting more comprehensive data from the ICETRA for estimating emissions from road transport with the COPERT model as well as estimate BC for 1990-2012.

3.6.3 National navigation (1A3dii)

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

3.6.3.1 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 3.14.

Table 3.14 Fuel use (kt), national navigation.

	1990	1995	2000	2005	2010	2012	2013	2014
Gas/Diesel oil	11.75	7.04	3.43	6.20	8.46	4.14	3.73	4.29
Residual fuel oil	7.17	4.76	0.54	0.88	2.61	0.18	1.24	2.14

3.6.3.2 Emission factors

Emission factors for dioxin and PAH (only B(b)F) are taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). SO_2 emissions are calculated from the S-content of the fuels. Emission factors for NOx, CO and NMVOC are taken from Table 1.48 in the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for ocean-going ships. Emission factors for BC are taken from Emissions of Black Carbon and Organic Carbon in Norway 1990-2011 (Aasestad, 2013) and the BC emissions are only estimated for the years 2013 and 2014. Emission factors are presented in Table 3.15.

Table 3.15 Emission factors for dioxin, B(b)f, NO_x, CO, NMVOC and BC navigation.

	Dioxin [µg I-TEQ/t fuel]	B(b)F [g B(bF)/t fuel]	NOx [kg/TJ]	CO [kg/TJ]	NMVOC [kg/TJ]	BC g/kg fuel
Gas/Diesel Oil, on ocean	4	0.04	1800	180	52	0.6
Residual fuel oil, on ocean	4	0.04	1800	180	52	2.193

3.7 Other Sectors (NFR 1A4)

3.7.1 Commercial, institutional & residential fuel combustion (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.

3.7.1.1 Activity data

Activity data for fuel use is provided by the NEA, which collects data on fuel sales by sector. EAI adjusts the data provided by the NEA as further explained in Annex I. Activity data for waste incineration are collected by the EAI directly. Activity data for fuel combustion and waste incineration in the Commercial/Institutional sector are given in Table 3.16.

Table 3.16 Fuel use (kt), commercial/institutional sector.

	1990	1995	2000	2005	2010	2012	2013	2014
Gas/Diesel oil	1.80	1.60	1.60	1.00	0.30	0.30	0.30	0.30
Waste oil	3.27	-	-	-	-	-	-	-
LPG	0.29	0.31	0.46	0.50	0.17	0.47	0.51	0.34
Solid waste	0.00	0.45	0.58	0.58	0.35	0.18	-	-

Activity data for fuel combustion in the Residential sector is given in Table 3.17. The table displays that the use of kerosene increased substantially from 2005 to 2010. Kerosene is used in summerhouses but also, to some extent, in the Commercial sector for heating of commercial buildings. The usage has been very low over the years and therefore the kerosene utilisation has all been allocated to the Residential sector. The increase in usage in the years 2008 to 2011 is believed to be attributed to rapidly rising fuel prices in the Transport sector. This has motivated some diesel car owners to use kerosene on their cars as the kerosene does not have CO_2 tax, despite the fact that it is not good for the engine. Since 2012 the CO_2 tax covers also kerosene and the use decreased rapidly again.

Table 3.17 Fuel use (kt), residential sector.

	1990	1995	2000	2005	2010	2012	2013	2014
Gas/Diesel oil	8.73	6.36	6.03	3.24	1.92	1.69	1.68	3.63
LPG	0.42	0.45	0.72	0.93	1.42	0.59	0.68	0.77
Kerosene	0.51	0.15	0.15	0.17	1.22	0.12	0.09	0.76

3.7.1.2 Emission factors

Emission factors (EFs) for dioxin from stationary combustion are taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). They are 0.1 µg/t fuel for gas oil and kerosene, 0.06 µg/t fuel for LPG (Liquified Petroleum Gas) and 4 µg/t for waste oil. Emissions of SO_2 are calculated from the S-content of the fuels. Emission factors for other pollutants are taken from the revised 1996 IPCC Guidelines (IPCC, 1996) and the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2013). Default EFs from Tables 1.7 to 1.11 in the Reference Manual were used in cases where EFs were not available. 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.

3.7.2 Agriculture, forestry & fishing (1A4c)

Emissions from fuel use in agriculture and forestry are included elsewhere, mainly within the construction (1A2fii) and Residential sectors (1A4bi); 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.

3.7.2.1 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. Activity data for fuel combustion in the Fishing sector are given in Table 3.18.

Table 3.18 Fuel use (kt), fishing sector.

	1990	1995	2000	2005	2010	2012	2013	2014
Gas/Diesel oil	174.90	191.13	211.11	171.68	128.16	116.23	112.75	102.24
Residual fuel oil	32.42	53.44	16.01	26.30	41.41	37.68	38.15	37.38

3.7.2.2 Emission factors

Emission factors for dioxin and PAH (only B(b)F) are taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). They are presented in Table 3.15. SO_2 emissions are calculated from the S-content of the fuels. Emission factors for other pollutants are taken from Table 1.48 in the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual for ocean-going ships (IPCC, 1996) and the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2013). Emission factors for BC are taken from Emissions of Black Carbon and Organic Carbon in Norway

1990-2011 (Aasestad, 2013) and the BC emissions are only estimated for the years 2013 and 2014. Emission factors are also presented in Table 3.15.

3.7.3 International bunker fuels

Emissions from international aviation and marine bunker fuels are excluded from national totals in line with the reporting guidelines under the UNFCCC. Emissions are calculated by multiplying energy use with pollutant specific emission factors.

Activity data is provided by the NEA, which collects data on fuel sales by sector. This data distinguish 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. Emission factors for aviation bunkers are the same as described for domestic aviation.

The retail supplier divides fuel use between international navigation (including foreign fishing vessels) and national navigation based on identification numbers which differ between Icelandic and foreign companies. The emission factors for marine bunkers are the same as described for national navigation.

3.7.3.1 Planned improvements

A better methodology for the fuel split between international and domestic aviation will be developed in the near future as Iceland takes part in the EU ETS for aviation from 2012 onward and better data will become available. Emissions estimates for aviation will hopefully be moved to Tier 2 methodology by next submissions with the use of data from Eurocontrol.

3.8 Fugitive Emissions (NFR 1B2)

3.8.1 Distribution of oil products (1B2av)

NMVOC emissions from distribution of oil products are estimated by multiplying the total imported fuel with an emission factor. The emission factor is taken from the EMEP/EEA air pollutant emission inventory guidebook – 2009 (EEA, 2009) and is 9 kg/Mg. Data on total import of fuels are taken from Statistics Iceland.

3.8.2 Geothermal energy (1B2d)

Iceland relies heavily on geothermal energy for space heating (90%) and to a significant extent for electricity production (30% of the total electricity production in 2014). Geothermal energy is generally considered to have 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.

3.8.2.1 Activity data

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.

Table 3.19 shows the electricity production with geothermal energy and the total Sulphur emissions (calculated as SO_2).

Table 3.19 Electricity production and emissions from geothermal energy in Iceland.

	1990	1995	2000	2005	2010	2012	2013	2014
Electricity production (GWh)	282.91	288.18	1322.95	1658.00	4465.00	5209.54	5244.70	5238.41
Sulphur emissions (as SO_2, Gg)	13.33	11.01	26.02	30.31	58.19	67.51	52.53	46.71

4 Industrial Processes (NFR sector 2)

4.1 Overview

Most of the pollution in the industrial processes sector can be traced back to one industry, the metal production industry. However the main NMVOC pollution is from solvents and product use. Summary tables for the emissions from the industrial processes sector are shown below in Table 4.1 and Table 4.2.

Table 4.1 NOx, NMVOC, SOx, NH$_3$, PM, BC and CO emissions from the industrial processes, 2014.

		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	NE	NE	0.0008	NR	NR	NR	NR	NR	0.0218
2B	Chemical Industry	NE	NE	NO	NO	NO	NO	NO	NO	NO
2C	Metal Production	2.05	0.09935	15.948	NR	0.2188	0.4166	0.5079	0.00401	0.1746
2D, 2G	Other solvent & Product use	0.0005	1.49694	NA	NR	0.0078	0.0081	0.0935	0.00003	NA
2H2	Food and Beverages Industry	NA	0.2910	NA	NR	NE	NE	NE	NA	NA
Industrial Processes, Total		**2.0511**	**1.8873**	**15.949**	**-**	**0.2265**	**0.4243**	**0.5172**	**0.00405**	**0.1964**

Table 4.2 Dioxin, PAH and HCB emissions from the industrial processes, 2014.

		Dioxin [g I-TEQ]	**B(a)P [t]**	**B(b)f [t]**	**B(k)f [t]**	**IPY [t]**	**PAH4 [t]**	**HCB [kg]**
2A	Mineral Industry	0.00004	NE	NE	NE	NE	NE	0.0047
2B	Chemical Industry	NO	NO	NO	NO	NO	NO	NO
2C	Metal Production	0.04036	0.00241	0.01102	0.00603	0.00222	0.03143	0.00470
2D, 2G	Other solvent and Product use	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000	NE
2H2	Food and Beverages Industry	NA	NA	NE	NE	NE	NE	NA
Industrial Processes, Total		**0.04043**	**0.00241**	**0.01102**	**0.00603**	**0.00222**	**0.03143**	**0.00470**

4.2 Introduction

The industrial process sector plays a big part in emissions of dioxins, HCB and PAH4 as well as other pollutants; PAH4 from metal production in particular. Due to the expansion of energy intensive industry, emissions have increased rapidly since 1996. The main category within the industrial process sector is metal production. The location of operating industrial facilities in 2014 including the cement plant which closed down in 2011 is shown in Figure 4.1.

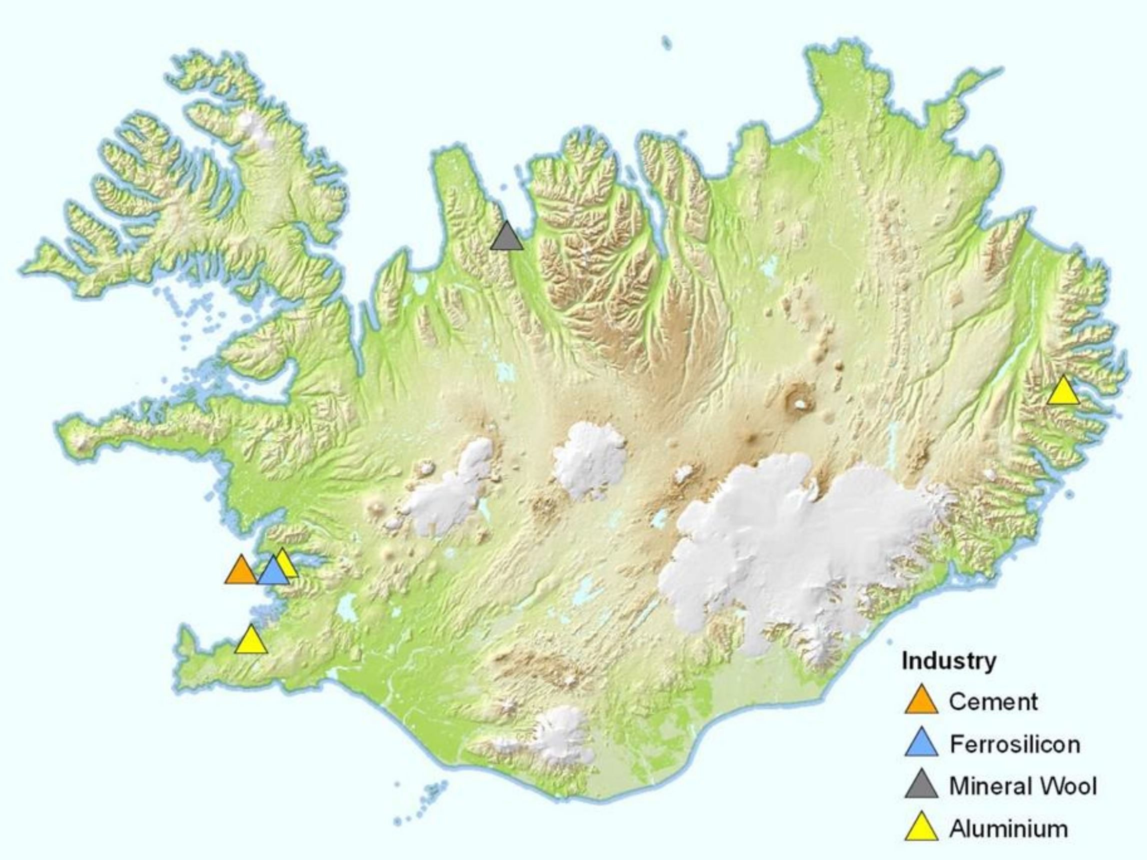

Figure 4.1 Location of industrial facilities in 2014, including a non-operating cement production plant.

4.3 Methodology

Methodology is based on EMEP air pollutant emission inventory guidebook (EMEP, 2013). Emissions are calculated by multiplying energy use by source with pollutant specific emissions factors. Emissions factors are taken from Emissions Inventory Guidebook (EEA, 2007, EEA, 2013), the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005), Utslipp til luft av dioxiner I Norge (Statistics Norway, 2002), The 2006 IPCC Guidelines for Greenhouse Gas Inventories (IPCC, 2006) as well as based on measurements at plants. Activity data is collected from data reported under the EU ETS, Statistics Iceland, Green Accounting or directly from the operators. This chapter on Industrial Processes (NFR sector 2) is divided into the following chapters:

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

4.4 Mineral Industry (NFR 2A)

4.4.1 Cement production (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.

4.4.1.1 Activity data

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

4.4.1.2 Emission factors

Emission factor for dioxin is taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005). 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 2013 Emission Inventory Guidebook (EEA, 2013) Emission estimates for SO_2 are based on measurements. Emissions of PAH, NOx, CO and NMVOC originate mainly from combustion and are reported under 1A2fi.

4.4.2 Mineral wool production (2A6)

There is one Mineral Wool Production Plant in operation in Iceland.

4.4.2.1 Activity data

Activity data for the mineral wool plant is based on data submitted to the EAI under the EU ETS and in Green Accounting.

4.4.2.2 Emission factors

Emissions of dioxins are calculated from the amount 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 estimated. Emissions of SO_2 are based on S-content of the elctrodes used. Emissions of CO are based on measurements. NOx and NMVOC emissions originate from combustion and are reported under sector 1A2gviii.

4.5 Chemical Industry (NFR 2B)

4.5.1 Other (2B10a)

The only chemical industry that has existed in Iceland is the production of silicium and fertilizer. The fertilizer production plant was closed down in 2001 and the silicium production plant was closed down in 2004. This industry is not considered to be a source of dioxins or PAHs.

At the silicium production plant, silicium 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. Emissions also occurred from the use of soda ash in the production process and those emissions are reported here.

When the fertilizer production plant was operational it reported its emissions of NO_x and N_2O to the EAI.

4.6 Metal Production (NFR 2C)

4.6.1 Ferroalloys production (2C2)

Ferrosilicon (FeSi, 75% Si) is produced at one plant in Iceland. The raw material is quartz (SiO_2). The quartz is reduced to Si and CO using reducing agents. The waste gas CO and some SiO burns to form CO_2 and silica dust. In the production raw ore, carbon material and slag forming materials are mixed and heated to high temperatures for reduction and smelting. Ready-to-use iron pellets for the production are imported so no additional emissions occur from the iron part of the FeSi production. The carbon materials used are coal, coke and wood. Electric (submerged) arc furnaces with Soederberg electrodes are used. The furnaces are semi-covered. Emissions originate from the use of coal and coke as reducing agent, as well as from consumption of electrodes. 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).

4.6.1.1 Activity data

The consumption of reducing agents and electrodes are collected by the EAI directly from the single operating ferroalloys production plant. Further information on total production is given. Activity data for raw materials, products and the resulting emissions are given in Table 4.3.

Table 4.3 Raw materials (kt), production (kt) at the ferrosilicon plant.

	1990	1995	2000	2005	2010	2012	2013	2014
Electrodes	3.83	3.88	6.00	6.00	4.79	5.09	5.07	4.34
Coking coal	45.12	52.38	88.00	86.87	96.10	105.09	111.02	102.97
Coke oven coke	24.92	30.14	35.80	42.59	30.26	35.37	33.66	29.46
Char coal	-	-	-	2.075	-	-	-	-
Waste wood	16.65	7.73	16.20	15.55	11.29	23.35	26.37	25.68
Limestone	-	-	0.47	1.62	0.50	2.42	2.26	2.13
Production (FeSi)	62.79	71.41	108.40	110.96	102.21	118.36	119.61	107.79
Coarse Microsilica	0.86	0.97	1.35	1.58	1.11	1.25	1.37	1.37
Fine Microsilica	13.16	14.97	21.35	24.26	17.01	20.86	23.71	21.03

4.6.1.2 *Emission factors*

In 2011 emissions of dioxin and PAH4 (each component was measured) 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. The emission factors are presented in Table 4.4.

Emission factor for CO is 1.62 kg/t FeSi is taken from table 2.16 and emission factors for NOx and NMVOC are taken from table 1.9 and 1.11 of the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference manual (IPCC, 1996). Sulphur emissions are calculated from S-content of the reducing agents. Emission factors are presented in Table 4.4.

Emissions of particulates 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 9.9 in “Reference document on Best Available Techniques in the Non Ferrous Metals Industries” (European Commission, 2001). 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.

Table 4.4 Emission factors for dioxin, PAH4, NOx and NMVOC from ferroalloys production.

	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]	NOx [kg/TJ]	NMVOC [kg/TJ]
FeSi	0.114	2.79	102.22	29.68	9.39	-	-
Coal	-	-	-	-	-	300	20
Coke	-	-	-	-	-	300	20
Charcoal	-	-	-	-	-	300	20
Waste wood	-	-	-	-	-	100	50
Electrodes	-	-	-	-	-	300	20

4.6.2 Primary aluminium production (2C3)

In 2014 aluminium was produced at 3 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, NOx, CO, particulate matter and SO_2. Emissions originate from the consumption of electrodes during the electrolysis process.

4.6.2.1 *Activity data*

The EAI collects annual process specific data from the three operating aluminium through EU ETS and Green Accounting reports. The total production of the three aluminium plants is given in Table 4.5.

Table 4.5 Aluminium production (t).

	1990	1995	2000	2005	2010	2012	2013	2014
Production	87,839	100,198	226,362	272,488	818,859	821,021	840,975	839,449

4.6.2.2 Emission factors

In 2011 emissions of dioxin were measured at the aluminium plants. At one plant PAH4 was also measured. The same plant also measured PAH4 in 2002. For PAH4 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 in Table 4.6.

NOx is calculated by using the emission factor of 1 kg/t aluminium that is based on the Emission Inventory Guidebook (EEA, 2013). CO calculations are based on the emission factor of 120 kg/t of Aluminium wich is also from the Inventory Guidebook. Particulate matter was calculated from information on particulates per tonne of produced aluminium that the aluminium plants report in their green accounts submitted in accordance with regulation nr. 851/2002. Emissions of SO_2 are estimated from S-content of alumina and electrodes.

Table 4.6 Emission factors, dioxin, PAH4, NOx and CO from 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	CO [kg/t Al]	NOx [kg/t Al]
Al	0.0329	0.0189	13%	61%	18%	8%	120	1

4.6.3 Secondary aluminium production (2C3)

In 2004 a secondary aluminium production plant was established in Iceland. The plant recycles scrap aluminium from the two primary aluminium plants in southwest of Iceland. The scrap metal is melted in batches in a rotary kiln. Emissions of dioxin and HCB are estimated. Activity data is taken from Green Accounting (Table 4.7). The dioxin emission factor comes from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005). 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 HCB emission factor (5 g/Mg) is taken from the Emission Inventory Guidebook (EEA, 2013). Measurements of dioxin at the plant in 2012, showed that the EF of 0.5 µg/t represents the plant well. In 2011 and 2012 this secondary aluminium plant only recycled scrap aluminium from one of the aluminium plants in the southwest of Iceland, but late 2012 another secondary aluminium plant was established to recycle scrap metal from the other plant.

Table 4.7 Secondary aluminium production (t).

	2005	2010	2012	2013	2014
Production	2,251	2,036	973	1,015	1,021

4.7 Other Solvent & Product Use (NFR 2D, 2G)

This chapter describes mainly non-methane volatile organic compounds (NMVOC) emissions from solvents. 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 only stem from road paving with asphalt (2D3b) and other use of products, sector 2G, namely from preservation of wood and use of tobacco. 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.

4.7.1 Road paving with asphalt (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. Information on the amount of asphalt produced comes from Statistics Iceland. The emission factors for NMVOC and BC are taken from Table 3.1, from Chapter 2.D.3.b in the EMEP/EEA emission inventory guidebook (EEA, 2013). Emissions factors for TSP are based on measurements from an asphalt production plant. PM2.5 and PM10 emission factors are then calculated by using the same ratio to TSP as given in Table 3.1 from chapter 2.D.3.b in GB13. 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.

4.7.2 Coating applications (2D3d)

Mainly the emissions in this category stem from paint applications. The EMEP guidebook (EEA, 2013) 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, 2013). The Tier 1 emission factor 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. It is assumed that all paint imported and produced domestically is applied domestically during the same year. Therefore 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.

4.7.3 Degreasing & dry cleaning (2D3e & f)

The EMEP guidebook provides a Tier 1 emission factor for degreasing based on amounts of cleaning products used. There is data on the amount of cleaning products imported provided by Statistics Iceland. Of the chemicals listed by the EMEP 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). In order to estimate emissions from degreasing more correctly without underestimating them, 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. The amount of imported solvents for degreasing was multiplied with the NMVOC Tier 1 emission factor for degreasing: 460 g/kg cleaning product.

Emissions from dry cleaning were calculated using the Tier 2 emission factor for open-circuit machines provided by the EMEP guidebook. Activity data for calculation of NMVOC emissions is the amount of textile treated annually, which is assumed to be 0.3 kg/head (EMEP guidebook default) and calculated using demographic data. The NMVOC emission factor for open-circuit machines is 177g/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 guidebook reduction default value of 0.89. NMVOC emissions from dry cleaning were calculated thus:

$$E_{NMVOC}(t) = \text{population}(t) \bullet 0.3 \bullet (177/1000) \bullet (1-0.89)$$

Where:

$E_{NMVOC}(t)$ = emissions of NMVOC in year t, kg
Population (t) = population in year t
0.3 = amount of textiles treated inhabitant/year, kg
177 = g NMVOC emissions/kg textile treated
0.89 = abatement efficiency of closed circuit PER machines

4.7.4 Chemical products (2D3g)

The only activity identified for the subcategory chemical products, manufacture and processing is manufacture of paints. NMVOC emissions from asphalt blowing, included in the EMEP guidebook under chemical products, are covered in the industry sector (not occurring in Iceland). NMVOC emissions from the manufacture of paints were calculated using the EMEP guidebook Tier 2 emission factor of 11 g/kg product. The activity data consists of the amount of paint produced domestically as discussed above in chapter 4.7.2 Coating Applications.

4.7.5 Printing (2D3h)

NMVOC emissions for printing were calculated using the EMEP guidebook Tier 1 emission factor of 500g/kg ink used. Import data on ink was received from Statistics Iceland.

4.7.6 Other solvent & product use (2D3i & 2G)

Other domestic use of solvents

NMVOC emissions from other domestic use were calculated using the EMEP guidebook emission factor of 1 kg/inhabitant/year.

4.7.6.1 Wood preservation

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). Activity data consists of annual import of creosotes and the assumption that all imported creosote is applied during the year of import. Emission factors for PAH are taken from chapter 2.D.3.i, 2.G of the Emission Inventory Guidebook (EEA, 2013). 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 guidebook Tier 2 emission factors for creosote preservative type (105 g/kg creosote) and organic solvent borne preservative (945 g/kg preservative). Import data on both wood preservatives was received from Statistics Iceland (Statistics Iceland, 2014).

4.7.6.2 Use of tobacco (smoking)

Tobacco smoking is a minor source of dioxins, PAH and other pollutants. Activity data consists of all smoking tobacco imported and is provided by Statistics Iceland (Statistics Iceland, 2014). Emissions factors are taken from Table 3-14 in chapter 2.D.3.i, 2.G in the Emission Inventory Guidebook (EEA, 2013). They are presented in Table 4.8.

Table 4.8 Emission factors for tobacco smoking.

	Dioxin [ng I-TEQ/T]	**NOx [kg/t]**	**CO [kg/t]**	**NMVOC [kg/t]**	**B(a)P [g/t]**	**B(b)F [g/t]**	**B(k)F [g/t]**	**IPy [g/t]**
Tobacco	100	1.8	55.1	4.84	0.111	0.045	0.045	0.045

4.8 Food & Beverages Industry (NFR 2H2)

Other production in Iceland is the Food and Drink Industry. NMVOC emissions from this sector were estimated for the first time in 2012 submission. Production statistics were obtained by Statistics Iceland for beer, fish, meat and poultry for the whole time series(Figure 4.3). Statistics for coffee roasting and animal feed were available for the years 2005 to 2014. Production statistics were extrapolated for the years 1990 to 2004. Further production of bread, cakes and biscuits was estimated from consumption figures. Emission factor for NMVOC were taken from Tables 2-24 and 2-25 in the 1996 IPCC Guidelines (IPCC, 1996).

NMVOC emissions from the food and beverage industry. In 2014 NMVOC emissions were estimated at 0.46 kt and that is a 13 % increase from the 1990 levels. Production of food and beverages has however, for the same period, increased by 27%, see Figure 4.3. The reasons for this are lower production of bread and animal feed, i.e. the decrease in emissions from the production of bread and animal feed from 1990-2014 are higher than the increased emissions from beer and meat production for the same period.

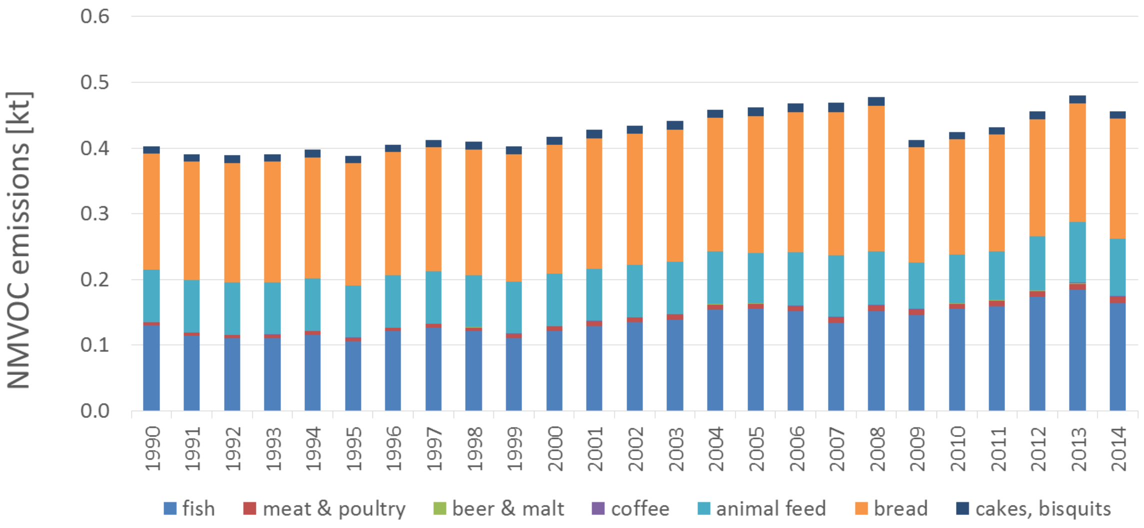

Figure 4.2 NMVOC emissions from food and beverage production 1990-2014

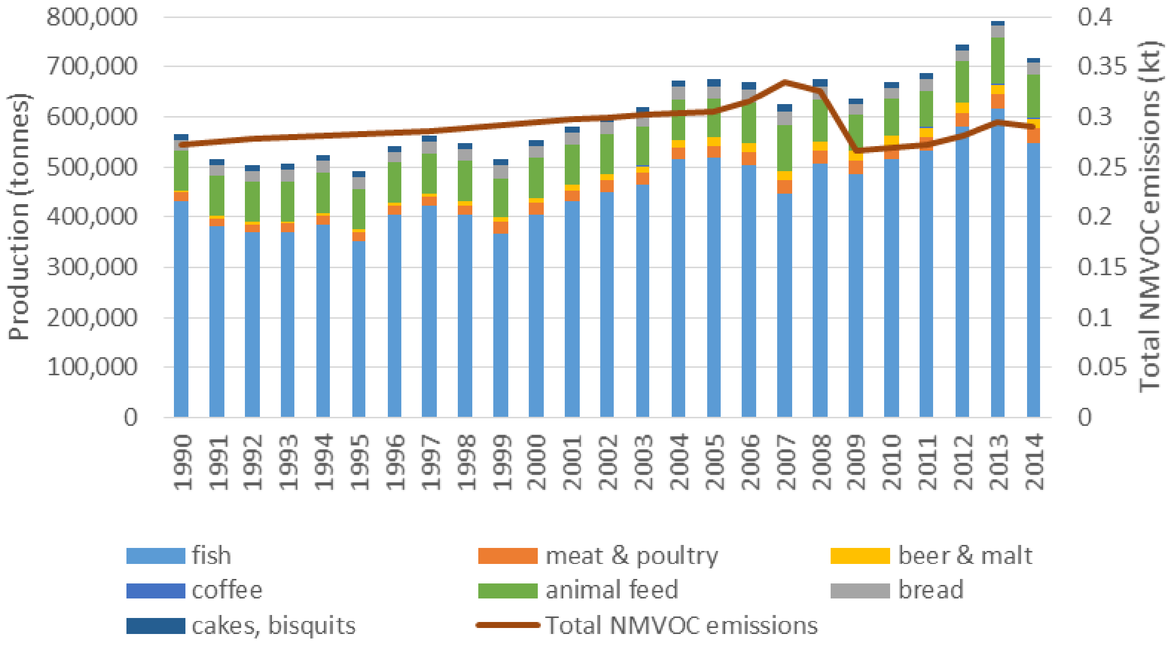

Figure 4.3 Food and drink production 1990-2014.

5 Agriculture (NFR sector 3)

5.1 Overview

The main pollution from the agriculture sector is ammonia (NH_3) where the dominating source is manure management. It is worth mentioning that dioxin, PAH and HCB emissions are not applicable. Summary tables for the emissions from the sector are shown below in Table 5.1.

Table 5.1 NO_x, NMVOC, SO_x, NH_3, PM, BC and CO emissions from the agriculture sector, 2014.

		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**	0.053	1.877	NA	4.393	0.033	0.115	0.165	NA	NA
3D	**Crop Production and agricultural soils**	0.573	8.56E-08	NA	1.195	0.003	0.068	0.068	NA	NA
3Df, 3I	**Agriculture other including use of pesticides**	NE	NE	NA	NE	NE	NE	NE	NE	NA
Agriculture, Total		**0.626**	**1.877**	**0**	**5.588**	**0.036**	**0.183**	**0.233**	**0**	**0**

5.2 Introduction

Icelanders are 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 are all of an 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.

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

5.3 Methodology

This chapter on Agriculture (NFR sector 3) is divided into the following chapters:

- Manure management (NFR 3B)
- Crop production and agricultural soils (NFR 3D)
- Agriculture other Including use of pesticides (NFR 3D and 3I)

Methodology is based on chapter 3.B and 3.D of the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2013) and all equations as well as the majority of emission factors and other parameters stem from the guidebook chapter. For brevity the guidebook will be referred to as the EMEP GB. Equations and parameters will not be listed in this chapter. Instead it is referred to the respective places in 3.B and 3.D of the EMEP GB.

Ammonia, nitric oxide, TSP, PM_{10} and $PM_{2.5}$ emissions are estimated with Tier 2 methods. In absence of higher tiers for 3.D, NO and NMVOC emissions are estimated with Tier 1 e.g. horses in solid storage. Tier 2 for ammonia and nitric oxide (NOx) uses a mass flow approach which is based on 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. The set of equations provided by the EMEP GB was applied to more disaggregated livestock categories than the NFR methodology demands (e.g. mature ewes, rams, animals for replacement, and lambs instead of just sheep). The resulting emissions were then aggregated to the respective NFR categories. NH_3 emissions from grazing animals are part of this process and therefore calculated in this context but reported under agricultural soils (3.D). In reporting total NH_3 emissions from crop production and agricultural soils emissions from grazing animals are added to those from fertilizer application. Activity data, emission factors and other parameters used in these calculations will be discussed in the following chapters. 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.

5.4 Manure Management (NFR 3B)

5.4.1 Activity data

All emission estimates in 3.B depend on annual average populations (AAP) of livestock categories. Data on livestock population comes from a census conducted by the Icelandic Food and Veterinary Authority (IFVA). Since this data 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. When calculating the AAP of livestock categories the amount of livestock with a lifespan of less than one year is weighted with its respective lifespan, e.g. a 6 month lifespan equals a factor of 0.5. The inclusion of young animals leads to livestock populations being considerable higher for some categories than the ones published by the IFVA (http://mast.is/default.aspx?pageid=647aa097-b558-452c-99de-8994d03bf7c7) or the complete methodology of calculating the AAP please refer to Iceland´s National Inventory Report on Greenhouse Gas Emissions (EAI, 2015).

Table 5.2 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 dairy cattle and sheep population and an increase in swine and poultry population.

Table 5.2 Annual average population of livestock according to NFR categorization in Iceland for 1990, 1995, 2000, 2005, 2010, 2012, 2013 and 2014.

	1990	1995	2000	2005	2010	2012	2013	2014
3B1a Dairy cattle	32,249	30,428	27,066	24,538	25,711	24,761	24,210	26,159
3B1b Non-dairy cattle	42,654	42,771	45,069	41,441	48,070	46,752	44,556	48,285
3B2 Sheep	861,815	719,530	729,290	711,327	748,002	744,065	735,859	759,470
3B3 Swine	29,645	31,130	32,267	38,438	40,515	43,978	30,581	36,210
3B4a Buffalo	NO	NO	NO	NO	NO	NO	NO	NO
3B4d Goats	504	511	608	641	1,065	1,252	1,301	1,441
3B4e Horses	73,867	80,246	75,630	76,629	78,849	75,948	56,896	66,483
3B4f Mules and asses	NO	NO	NO	NO	NO	NO	NO	NO
3B4gi Laying hens	214,975	164,402	193,097	166,119	174,519	200,169	202,116	219,163
3B4gii Broilers	454,305	188,812	338,756	595,171	537,933	572,090	576,864	596,358
3B4giii Turkeys	0	3,044	10,908	8,120	10,496	11,037	11,662	12,038
3B4giv Other poultry	5,277	5,270	2,498	1,716	1,346	991	1,490	1,432
3B4h Other (fur animals)	49,592	37,893	41,431	36,948	37,627	40,439	64,764	51,788

5.4.2 Emission factors & associated parameters

NH_3 and NO Tier 2 emissions depend on the total amounts of N and 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 by EMEP. The nitrogen excretion (NEX) rate per livestock category is calculated using default values from p. 10.58 of vol. 4-2 of the 2006 IPCC guidelines (IPCC, 2006) that take animal weight and therefore the smaller size of Icelandic breeds into account. The NEX for dairy cattle is country specific (Ketilsdóttir and Sveinsson, 2010). 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 (EA, 2013). 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 hay 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 EMEP default data of hay used per day adjusted for the time periods animals stay inside. The above mentioned parameters are summarized in Table 5.3. 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 absence of default values for sheep slurry, EMEP BG default values for cattle were used instead.

Table 5.3. Parameters used in calculation of NH_3 and NO emissions of manure management.

Livestock sector (NFR)	Mean NEX [kg head-1 yr-1]	Prop. TAN(of N)	Fraction slurry	Fraction solid	Housing period [days]	Straw [kg/yr]	NMVOC [kg head-1 yr-1]
3B1a Dairy cattle	89.7 (72-95)[1]	0.6	1	0	270		
3B1b Non-dairy cattle	39.9 (15-60)[2]	0.6	1	0	29		
3B2 Sheep	14.3 (6-29)[3]	0.5	0.3	0.7	200	133	0.53
3B3 Swine -fattening pigs	7.6	0.7	1	0	365		
3B3 Swine -Sows	23	0.7	1	0	365		
3B4d Goats	20.3	0.5	0	0	201	134	0.54
3B4e Horses	28 (6-36)[4]	0.6	0	0	51	140	0.58
3B4gi Laying hens	1.4	0.7	0	1	365		
3B4gii Broilers	0.8	0.7	0	1	365		
3B4giii Turkeys	1.4	0.7	0	1	365		
3B4giv Other poultry	1.2	0.7	0	1	365		
3B4h Other (fur animals)	5.8 (5-12)[5]	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 (foxes, minks, and rabbits).

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 5.3 above). The majority of laying hens in Iceland is kept in cages.

5.4.3 Emissions

NH_3 emissions exclude emissions from manure deposited on fields by grazing animals, which are reported under agricultural soils. Total ammonia (NH_3) emissions have been decreasing gently during the last two decades, from 4.57 Gg in 1990 to 4.39 Gg in 2014. This decrease is mainly due to a decrease of the sheep population. Sheep account for almost 44% of total NH3 emissions and cattle for approximately 38%. Around 1/3 of emissions occur during livestock housing, 1/4 during manure storage and 2/5 after spreading of manure. The described trends and fractions can be seen in Figure 5.1.

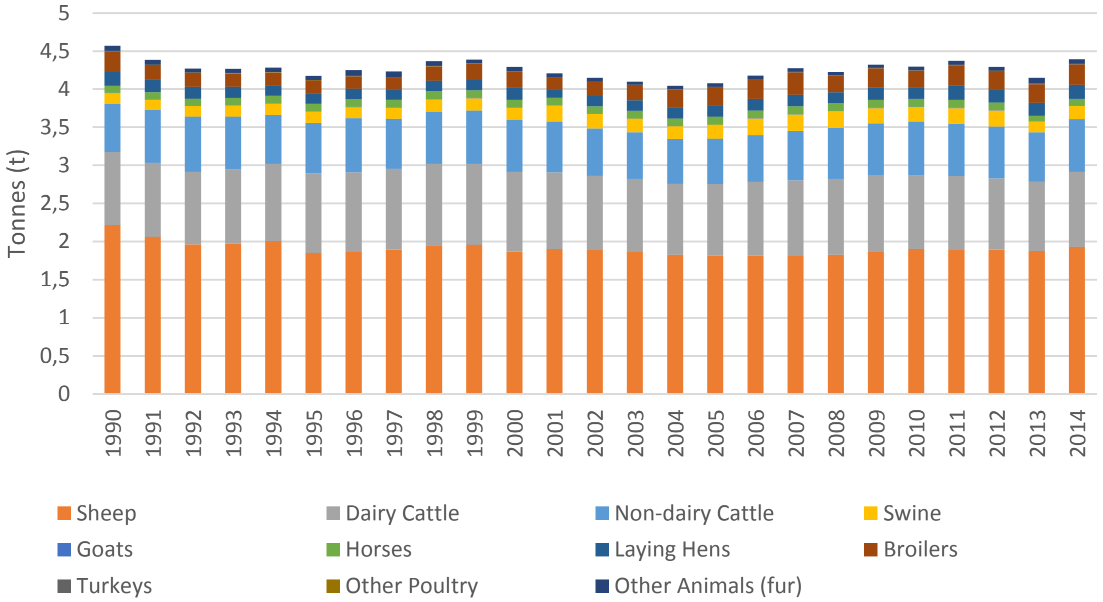

Figure 5.1 Ammonia (NH_3) emissions from animal husbandry and manure management in tonnes.

Nitric oxide emissions, in contrast to ammonia emissions, occur only during storage. They have been decreasing from 58 tonnes in 1990 to 53 tonnes in 2014, or by roughly 9%. This decrease is mainly due to the decrease in sheep population already mentioned above. NO emissions from sheep constitute roughly 2/3 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 and horses. Cattle and swine emissions constitute negligible amounts due to the fact that their manure is stored as slurry.

NMVOC emissions were not included in previous calculations. NMVOC emissons in 1990 were 1.98Gg for manure management, have decreased by 5% since then and are now 1.88 Gg. The largest source of NMVOC emissions is from sheep 49% and 28% from horses 28%.

PM_{10} emissions increased between from 100 tonnes in 1990 to 115 tonnes in 2014 (13%). Emissions were highest in 2007 when they amounted to 121 tonnes. Both the general increasing trend since 1990 and the decrease since 2007 are almost exclusively due to oscillations 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, which emitted on average around 30% of total PM_{10} emissions between 1990 and 2011) are laying hens, dairy cattle, cattle, and sheep (each around 10 -20%).

Total $PM_{2.5}$ emissions oscillated between 28 and 33 tonnes (highest in 2007) from 1990 to 2014 and showed no clear trend. Emissions from cattle constituted more than 70% of total emissions, emissions from swine and broilers each amount to 10% of total emissions.

TSP emissions for agriculture are calculated for the first time in this submission. The emissions have been slightly increasing from 0.151 Gg in 1990 to 0.165 Gg in 2014 the increase is mostly due to poultry and swine.

5.5 Crop Production & Agricultural Soils (NFR 3D)

5.5.1 Activity data

Activity data for NH_3, NO and NMVOC emissions consists of the amount of fertilizer nitrogen applied to agricultural soils. 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 (http://mast.is/matvaelastofnun/utgafa/skyrslur/#arsskyrslur). There exists no exact data regarding 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.

Activity data for particulate matter emissions consists of the areas of crops cultivated. The total amount of cropland is recorded in the Icelandic geographic land use database (IGLUD), which is maintained by the Agricultural University of Iceland. Data regarding the area of barley fields comes from the Farmers Association of Iceland (http://bondi.lbhi.is/lisalib/getfile.aspx?itemid=2211 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).

5.5.2 Emission factors

NH_3 mission factors were taken from Table 3-2 in the EMEP guidebook (p.14). 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 January 1st have reached 400 °C. According to this definition the mean spring temperature in Iceland is about 9 °C.

NO and NMVOC emission factors were taken from Table 3-1 of the EMEP GB 2013 (p.11) and were 0.026 and 5.96E-09 kg/kg (EEA, 2009) fertilizer applied, respectively.

PM_{10} and $PM_{2.5}$ emission factors for barley and grass were taken from Tables 3-3 and 3-5 of the EMEP GB, respectively (p. 14-15).

Emissions

Total NH_3 emissions oscillated between 1.1 and 1.3 kilotonnes between 1990 and 2014. In 2014 67% of emissions originate from manure deposited by livestock during grazing and 33% originate from N fertilizer applied to agricultural soils. Total emissions do not show any discernible trend: while the size of (and thus emissions from) the sheep population is decreasing, is the horse population increasing. N fertilizer application was highest in 2008 but a weakening of the Icelandic currency has made the import of fertilizer more expensive and thusly lead to diminishing application.

The emission development of NO and NMVOC are linearly dependent from the application of fertilizer and therefore show the same development with a peak in 2008 at 0.61 kilotonnes and a 47% decline since then. In 2014 NO emissions amounted to 0.57 kilotonnes and is increasing again after 2008 (20% since 2013). NMVOC emissions from crop production and agricultural soils were 86 grams.

PM_{10} emissions decreased due to the decrease in total cropland from 78 tonnes in 1990 to 68 tonnes in 2014. It is estimated that $PM_{2.5}$ emissions have dropped from 3.21 tonnes in 1990 to 3.02 tonnes in 2014. The drop in $PM_{2.5}$ is a little less due to strong increase in the barley cultivation.

5.6 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 3.D.f of the EMEP GB not banned until 2009 is lindane. 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 3.D of the EMEP GB (p. 5) was applied to these values resulting in HCH emissions of 1, 8,1, and 0.5 kg for the years 1990-1992. Table 5.4 gives an overview of the use of pesticides in Iceland.

Table 5.4 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

The waste sector consist mainly of emissions from solid waste disposal on land (5A), waste incineration (5C) and other waste (5E). Summary tables for the emissions from the waste sector are shown below in Table 6.1 and Table 6.2.

Table 6.1 NOx, NMVOC, SOx, NH_3, PM, BC and CO emissions from the waste sector, 2014.

		NOx [kt] NO_2	**NMVOC [kt]**	**SO_X [kt] SO2**	**NH_3 [kt]**	**$PM_{2.5}$ [kt]**	**PM_{10} [kt]**	**TSP [kt]**	**BC [kt]**	**CO [kt]**
5A	Solid Waste Disposal on Land	NA	0.17	NE	NA	NE	NE	NE	NE	NE
5B1	Composting	NE	NE	NE	0.0048	NE	NE	NE	NE	NE
5C	Waste Incineration	0.023	0.00025	0.021	3.8E-5	0.016	0.17	0.23	0.004	0.0088
5D	Wastewater Handling	NE	NE	NE	NE	NE	NE	NE	NE	NE
5E	Other Waste	NE	NE	NE	NE	NE	NE	NE	NE	NE
Waste, Total		**0.023**	**0.17**	**0.021**	**0.0049**	**0.016**	**0.17**	**0.23**	**0.004**	**0.0088**

Table 6.2 Dioxin, PAH and HCB emissions from the waste sector, 2014.

		Dioxin [g I-TEQ]	**B(a)P [t]**	**B(b)f [t]**	**B(k)f [t]**	**IPY [t]**	**PAH4 [t]**	**HCB [kg]**
5A	Solid Waste Disposal on Land	NA	NA	NA	NA	NA	NA	NA
5B1	Composting	NA	NA	NA	NA	NA	NA	NA
5C	Waste Incineration	0.70	0.000053	0.000035	0.000039	4.0E-09	0.00013	0.025
5D	Wastewater Handling	NE	NE	NE	NE	NE	NE	NE
5E	Other Waste	0.16	0.0018	0.0037	0.0034	0.0027	0.012	NE
Waste, Total		**0.86**	**0.0018**	**0.0037**	**0.0034**	**0.0027**	**0.012**	**0.025**

6.2 Introduction

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 was set into operation and most of the waste of the capital´s population 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. At the end of 2014 there was only one incineration plant in use, located in the southwest part of Iceland, Reykjanes. 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 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 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 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 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. 293 tonnes of clinical waste were incinerated in 2014.

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 can be seen in Figure 6.1 which show different waste management practices in 1990 and 2010. This has resulted in larger SWDS and enabled the shutdown of a number of small sites. In 2014, more than 80% of all landfilled waste was 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. At the end of 2014 there was only one incineration plant open, located in the southwest part of Iceland.

In 2014, about 38% of all waste generated was landfilled, 54% recycled or recovered, 3% incinerated, and 5% composted.

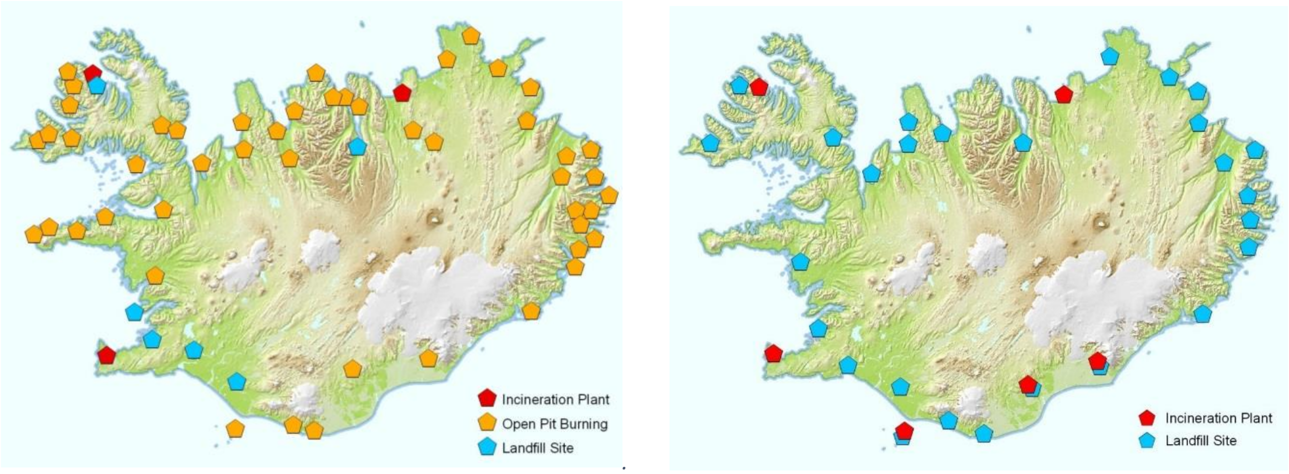

Figure 6.1 Waste management practices in 1990 (left) and in 2010 (right).

6.3 Methodology

The methodology is based on EMEP air pollutant emission inventory guidebook (EMEP, 2013). Emissions are calculated by multiplying relevant activity data by source with pollutant specific emissions factors. Emissions factors are taken from Emissions Inventory Guidebook (EEA, 2013), 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), as well as based on measurements at incineration plants. This chapter on Waste (NFR sector 5) is divided into the following chapters:

- Solid Waste Disposal on Land (NFR 5A)
- Composting (NFR 5B1)
- Waste Incineration (NFR 5C)
- Wastewater Handling (NFR 5D)
- Other Waste (NFR 5E)

6.4 Solid Waste Disposal on Land (NFR 5A)

Major emissions from waste disposal at landfill sites are emissions of greenhouse gases. It is assumed that emissions of small quantities of NMVOC, CO, NH_3 and NO_x occur at landfill sites. PM emissions are emitted from waste handling as well, but no emission factors are available. For the 2013 submission emissions of NMVOC were estimated for the first time.

6.4.1 Activity data

Information on the amounts of waste landfilled as well as its composition can be found in Iceland´s National Inventory Report on greenhouse gas emissions. In the greenhouse gas inventory a first order decay model is used to estimate methane emissions from landfills. By setting the methane correction factor to one for all SWDS and by assuming a methane content of 50% volume the model can be used to estimate the amount of landfill gas emitted which is needed to estimate NMVOC emissions.

6.4.2 Emission factors

NMVOC emissions are calculated using the Tier 1 emission factor supplied by the EMEP guidebook (EEA, 2013) of 5.65 g/m^3 (1.56 kg/Mg) landfill gas.

6.5 Composting (NFR 5B1)

Compost production in Iceland started in 1995 and has increased annually since then. In 2013 more than 20,000 tonnes of waste were composted. NH_3 emissions from waste composting were calculated by multiplication of waste amounts with a default emission factor of 0.24 kg/Mg organic waste (EEA, 2013).

6.6 Waste Incineration (NFR 5C)

This chapter deals with incineration, open burning of waste, bonfires and cremation. Incineration of waste is subdivided into incineration with energy recovery (reported under 1A1a and 1A4) and incineration without energy recovery.

6.6.1 Activity data

Activity data on waste in Iceland has proven to be insufficient in the past. There is little information about actual amounts of generated waste as well as on its composition and characteristics, before 1990. Activity data on incinerated waste from major incineration plants have been collected by the EAI since 2000. Historic data as well as data on open pit burning not reported to EA, was estimated with the assumptions that 500 kg of wastes have been incinerated per inhabitant in the communities where waste is known to have been incinerated (both in primitive incineration plants as well as open pit burning) in 1990, 1995 and 2000 and interpolated in the years between. These communities were mapped by EAI in the respective years. The data after the year 2000 is considered rather reliable, but pre-2000 data very unreliable.

In 1993 incineration plants were opened on the Vestmannaeyjar archipelago and in Svínafell. These two plants as well as three more, which were opened in 1995 (Ísafjörður), 1999 (Skaftárhreppur), and 2006 (Húsavík) recover the energy of the incineration and use it for either public heat production (Vestmannaeyjar, Ísafjörður, Húsavík) or commercial/institutional heat production (Svínafell, swimming pool; Skaftárhreppur, swimming pool, school building). Svínafell and Ísafjörður stopped operation in late 2010, Skaftárhreppur and Vestmannaeyjar in 2012 and Húsavík in 2013. The incineration plant Kalka (established in 2005) produces energy and electricity for its own requirements and therefore rates as auto producer. Thus it is categorized as incineration plant without energy recovery as is Tálknafjörður, a small incinerator which operated from only from 2001 to 2004. Emissions from waste incineration with energy recovery are reported in sector 1A1a (public electricity and heat production) and 1A4a (commercial). Amounts of waste incinerated are presented in Table 6.3.

Table 6.3 Waste incineration from 1990 to 2014, (ktonnes).

	1990	1995	2000	2005	2010	2012	2013	2014
Incineration with energy recovery (1A1a)	-	4.7	6.1	6.0	8.1	5.6	NO	NO
Incineration with energy recovery (1A4a)	-	0.5	0.6	0.5	0.3	0.2	NO	NO
Incineration plants (5C1a)	-	-	-	10.9	9.3	8.4	9.4	10.9
Open burning of waste (5C1a)	33.8	22.6	12.7	0.1	0.1	NO	NO	NO
Bonfires (5C1a)	4.3	3.9	3.4	2.3	1.8	1.7	1.7	1.7

6.6.2 Emission factors

Emission factors for dioxin from waste incineration are based on measurements at the plants, except for Kalka which reports its emissions. Several point measurements exist in the period 2007 to 2012. Average emission from these measurements at similar incineration plants (Hoval technique) at Ísafjörður, Skaftárhreppur and Vestmannaeyjar was close to 50 µg/t. As all these incineration plants are operated as batch, an emission factor for those plants was chosen to be 100 µg/t. The incineration plant at Ísafjörður was closed down in 2010, after a period of malfunctioning. No dioxin measurements took place at the plant for the last three years of operation. Other pollutants were measured at the plant, indicating that there were significantly more emissions from all pollutants for the last three years of operation. For those years, the emission factor of 300 µg/t for uncontrolled domestic waste burning, was taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP, 2005). This factor is also used for the incineration plant at Svínafell (also Hoval technique), based on measurements at the plant. For the incineration plant at Húsavík an emission factor of 10 µg/t was chosen, based on measurements. Emission factors for other substances than dioxin are taken from table 3.2 in chapter 5.C.1.a of the Emission Inventory Guidebook (EEA, 2013). They do not differentiate between different incinerations techniques and are applied to the total waste amount incinerated. The emission factors are presented in Table 6.4 and Table 6.5.

Table 6.4 Emission factors for dioxin, PAH and HCB from waste incineration

	Dioxin [µg I-TEQ/t]	B(a)P [mg/t]	B(b)F [mg/t]	B(k)F [mg/t]	HCB [g/t]
Open pit burning	300	2.33	4.63	5.68	0.002
Hoval technique*	100	4.2	3.2	3.1	0.002
Húsavík	10	4.2	3.2	3.1	0.002
Kalka	Reported	4.2	3.2	3.1	0.002

* The incineration plant at Svínafell is classified as open pit burning.

Table 6.5 Emission factors for NOx, CO, NMVOC, SO_2, NH_3, $PM_{2.5}$, PM_{10}, TSP and BC from waste incineration.

	NOx [kg/t]	CO [kg/t]	NMVOC [kg/t]	SO_2 [kg/t]	NH_3 [g/t]	$PM_{2.5}$ [kg/t]	PM_{10} [kg/t]	TSP [kg/t]	BC [% of PM2.5]
Open pit burning	3.18	55.83	1.23	0.11	NE	4.19	4.51	4.64	42
Hoval technique*	1.8	0.7	0.02	1.7	3	9.2	13.7	18.3	3.5
Húsavík	1.8	0.7	0.02	1.7	3	9.2	13.7	18.3	3.5
Kalka	1.8	0.7	0.02	1.7	3	9.2	13.7	18.3	3.5

* The incineration plant at Svínafell is classified as open pit burning.

6.6.3 Open pit burning

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 characterised 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. As can be seen from Table 6.3 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 factor influence the dioxin formation. It can therefore be hard to come up with a reasonable emission factors. In addition to that the activity data is quite uncertain as well, as no official statistics are available. Historic data on open pit burning was estimated with the assumptions that 500 kg of wastes 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 EAI in the respective years. The date is known at the EA, at which sites, where open pit burning has been performed have been closed down 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.

Emission factor for dioxin for open pit burning are 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 PAH4, HCB, are taken from table 3.2 in chapter 5.C.1.a of the Emission Inventory Guidebook (EEA, 2013). Emission factors for other pollutants are taken from table 3.1 in chapter 5.C.2. of the Emission Inventory Guidebook (EEA,2013).

6.6.4 Bonfires

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.

Activity data is not easily obtained. In 2011 the EAI along with the municipality of Reykjavík decided to weigh all the material of a single bonfire. Then the piled material was photographed and height, width and length measured. The weight was then correlated to the more readily measureable 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 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.

Emission factor are also difficult to estimate. From 2003 onwards an emission factor of 60 µg/t is used. This factor is taken from table 54 of the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005) and is given for open burning of wood. For 1990 to 1995 an emission factor of 600 µg per tonne burnt material was used. 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. Further some businesses used the opportunity to get rid of all kind of wastes. Therefore it was considered suitable to double the emission factor used for open pit burning. The emission factor was then interpolated from 600 µg to 60 µg per tonne burned material from 1996 to 2003. The emission factors for other pollutants than dioxin are the same as for waste incineration, as presented in Table 6.4 and Table 6.5 above.

6.6.5 Cremation

Cremation is performed at a single facility, located in Reykjavík. Human bodies are incinerated along with the coffin. The heat at the combustion chamber reaches high temperatures. Emissions of dioxins and PAH (emission factor is only given for BaP) are estimated. Activity data was collected from the single facility. Emission factors are 0.027 µg/body for dioxin and 13.2 µg/body for BaP. They are taken from the Emission Inventory Guidebook (EEA, 2013).

6.7 Wastewater Handling (NFR 5D)

According to the EMEP guidebook (EEA, 2013) wastewater will be an insignificant source for air pollutants. However, in urban areas, NMVOC emissions from waste water 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 are not estimated from wastewater handling.

6.8 Other Waste (NFR 5E)

This section deals with emissions from compost production and accidental vehicle and building fires. Emissions from landfill fires have not been estimated.

6.8.1 Vehicle & building fires (5E)

Activity data for vehicle and building fires were obtained for the years 2003 to 2012 from the Capital District Fire and Rescue Service (CDFRS). Data for 2013 was unavailable and is therefore estimated using the historic data from 2003 to 2012. Building fires are classified by duration of response into small, medium and large fires. The data is presented in Table 6.6. 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 6.7, 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 6.6 and Table 6.7 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 (see Figure 6.2). The house had a thick layer of asphalt roll roofing with an estimated weight of around 80 tonnes.

Figure 6.2 Major fire broke out in an industrial laundry service in Reykjavik in July 2014. Photo: Gulli Helga ©

Table 6.6 Vehicle and building fires, capital area.

Year	Vehicle fires	<60 min	Building fires 60-120 min	>120 min	Total scaled building fires
2003	36	161	21	4	23
2004	25	153	24	5	25
2005	43	141	24	11	30
2006	34	130	24	9	28
2007	44	142	20	7	24
2008	64	150	25	9	30
2009	46	114	16	12	26
2010	34	118	17	9	24
2011	35	121	10	5	16
2012	36	99	24	9	26
2013	26	85	18	5	18
2014	35	99	20	12	27

Table 6.7 Vehicle and building fires, Iceland.

Year	Vehicle fires	<60 min	Building fires 60-120 min	>120 min	Total scaled building fires
2003	54	242	32	6	34
2004	38	230	36	8	38
2005	65	212	36	17	46
2006	51	195	36	14	42
2007	66	213	30	11	37
2008	96	225	38	14	44
2009	69	171	24	18	39
2010	51	177	26	14	36
2011	53	182	15	8	25
2012	54	149	36	14	39
2013	39	128	27	8	28
2014	53	149	30	18	40

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. 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.

Emissions from vehicle fires are calculated by multiplying the number of vehicle fires with selected emission factors. Emission factors are not available for different vehicle types, whereas it is assumed that all the different vehicle types leads to similar emissions. 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. The burned mass is then multiplied with emission factors for dioxin and PAH4. They are taken from the Annual Danish Informative Inventory Report to the UNECE (National Environmental Research Institute, 2011) and are 0.0428 mg dioxin per fire, 14.7 g BaP per tonne, 32.3 g BbF and BkF per tonne and 23.3 g IPy per tonne.

Emission factors for building fires are also taken from the Annual Danish Informative Inventory Report to the UNECE (National Environmental Research Institute, 2011). 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. The emission factors for undetached and industrial buildings are given in Table 6.8.

Table 6.8 Emission factors, building fires.

	Dioxin [mg/fire]	**B(a)P** [g/fire]	**B(b)F** [g/fire]	**B(k)F** [g/fire]	**IPy** [g/fire]
Undetached buildings	2.8	6.36	10.1	3.60	6.90
Industrial buildings	4.2	18.0	28.5	10.1	19.5

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

For the major industrial fire in 2014, the estimated weight of the asphalt roll roofing burned down (80 tons) was assumed to be a large part of the emissions from this particular fire. 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. PAH4 emissions were calculated by using emission factors from 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. The fire is depicted in Figure 6.2.

6.9 Planned improvements

For future submissions, the elimination of “not-estimated” sources of POPs and other Pollutants is given a high priority along with a better estimation of emissions of POPs and other pollutants from building and vehicle fires. More detailed data for building fires is seen to be important as uncertainties are high and of potential significance especially in years of large industrial fires. Review of emission factors for open pit burning is needed but is given a low priority as open pit burning is non-existing as of today.

A different definition of hazardous wastes led to a large increased waste amounts landfilled. The main reason is the inclusion of hazardous waste from heavy industry which was not included before.

Planned improvements is to gather data on this hazardous waste from 1990 and to include it in the calculations.

7 Natural Sources (NFR 11)

7.1 Volcanoes (NFR 11A)

In this chapter emission from volcanos is counted. Last three eruptions in Iceland are counted her. These eruptions are; Eyjafjalljökull eruption April-May 2010, Grímsvötn eruption in May 2011 and Holuhraun eruption September 2014-February 2015. As emissions from these eruptions are natural they are only reported in this chapter but not included in national totals.

7.1.1 Eyjafjallajökull eruption 2010

In 2010 the volcano Eyjafjallajökull erupted. The eruption lasted from 14th of April until 23rd of May. 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 (https://wiki.met.no/emep/emep_volcano_plume) and amounted to 127 kt of SO_2, around 6000 kt of PM_{10} and around 1700 Gg of $PM_{2.5}$. These 6000 kt of PM_{10} was around 10 000 times more than total estimated man made PM_{10} emissions in Iceland in 2010.

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

7.1.2 Grímsvötn eruption 2011

In 2011 the volcano Grímsvötn erupted. The eruption lasted from 21st of May until 28th of 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. 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 EAI 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 $PM_{2.5}$. These emissions are not included in national totals. Figure 7.2, a NASA MODIS satellite image acquired at 05:15 UTC on May 22, 2011 shows the plume from Grímsvötn casting shadow to the west. (Photo NASA/GSFC/Jeff Schmaltz/MODIS Land Rapid Response Team).

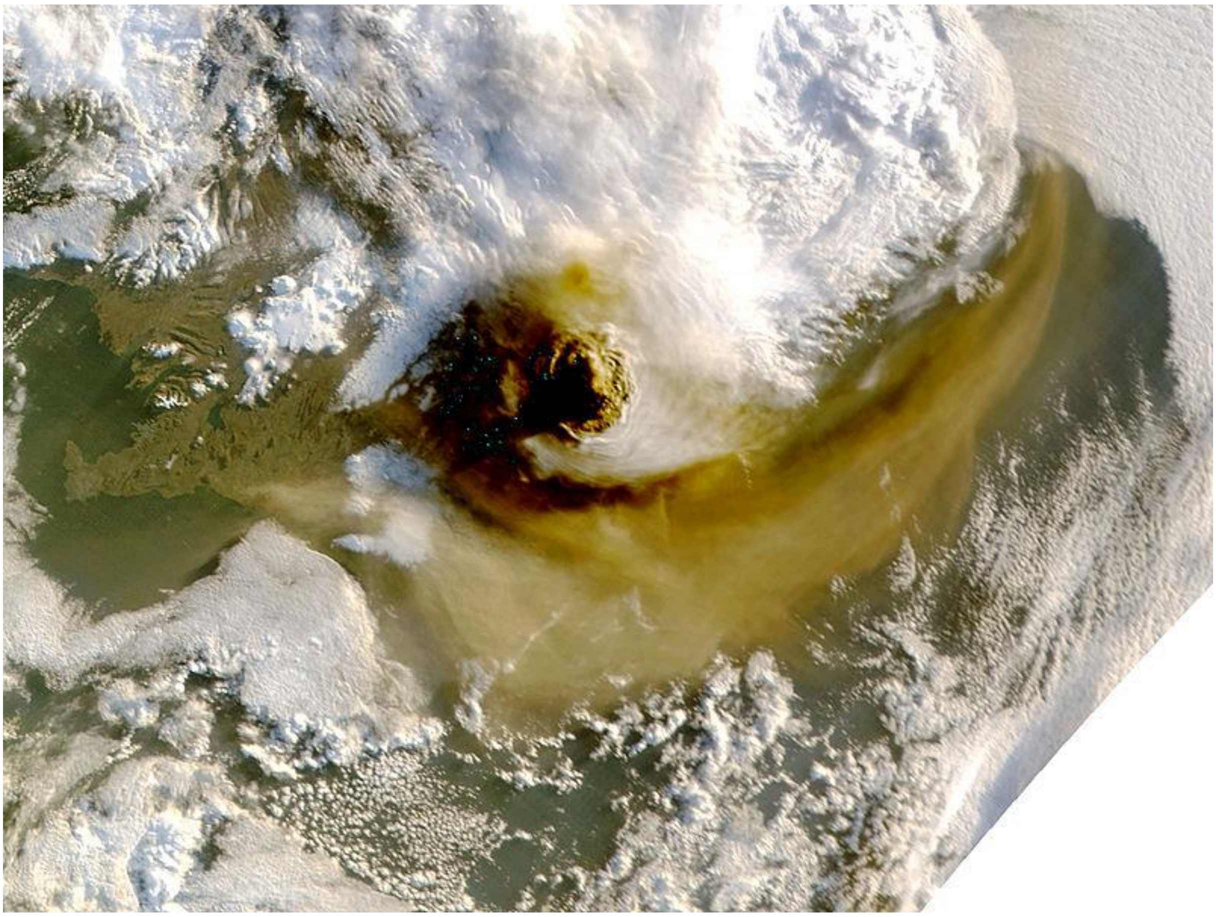

Figure 7.2 Grímsvötn eruption in May 2011.

7.1.3 Holuhraun eruption 2014 - 2015

The eruption in Holuhraun began on August 29th 2014 and ended on February 27th 2015. It was the biggest eruption in Iceland since the Laki eruption 1783.

Emission estimates in the Holuhraun eruption was done by the volcanic hazard team at the Icelandic Met Office. According to information from Sara Barsotti and Melissa Anne Pfeffer the estimates was 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 analyzed 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. Devided on calender years 10,880 kt of SO_2 was 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 August 29th 2014 to December 31st 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.

Negligible emission of ash was from this eruption and it was not estimated. Further information about SO_2 emissions from the eruption are in Table 7.1 below. As these emissions are natural they are not included in national totals.

Table 7.1 Eruption emission parameters.

	Average monthly emission rates [kg/s]	**SO_2 per month [kt]**
August 2014	280	1000
September 2014	1400	5000
October 2014	1400	5000
November 2014	2500	9000
December 2014	560	2000
January 2015	2000	7000
February 2015	84	300

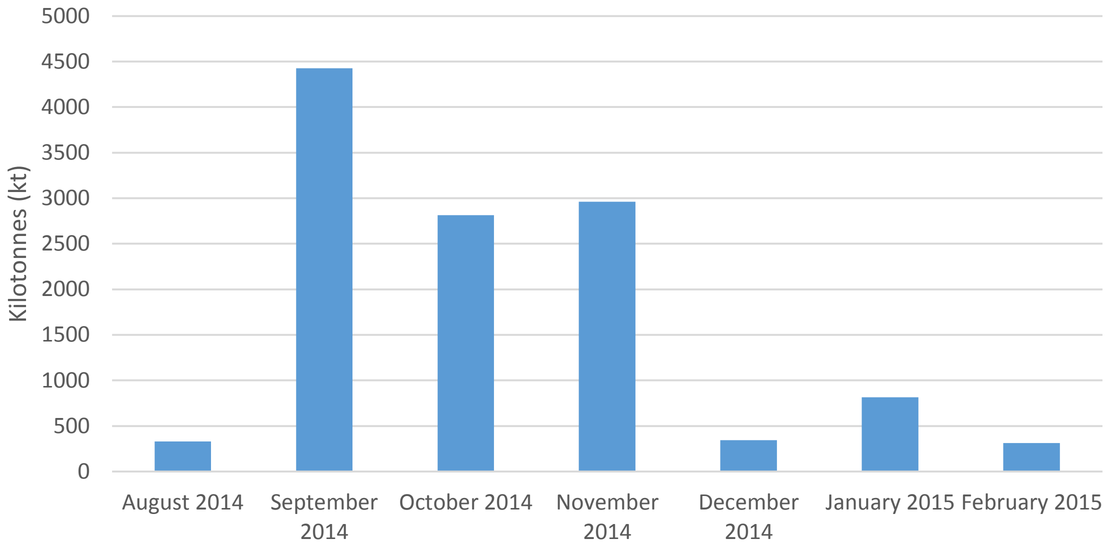

Figure 7.3 Monthly emission from Holuhraun during the eruption.

The eruption caused widespread SO_2 pollution all over Iceland and indeed also in other countries in Europe. During the eruption there was a lot of action going on in the various institutions to disseminate information to the public. The Icelandic Met Office used 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 xx 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. Gas pollution has been extensive across all of Iceland. The NE part of the country has suffered the highest impact from the eruption. The model suggests that an area 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 have frequently been exposed to high ground-level concentrations of SO_2 for up to 15 days.

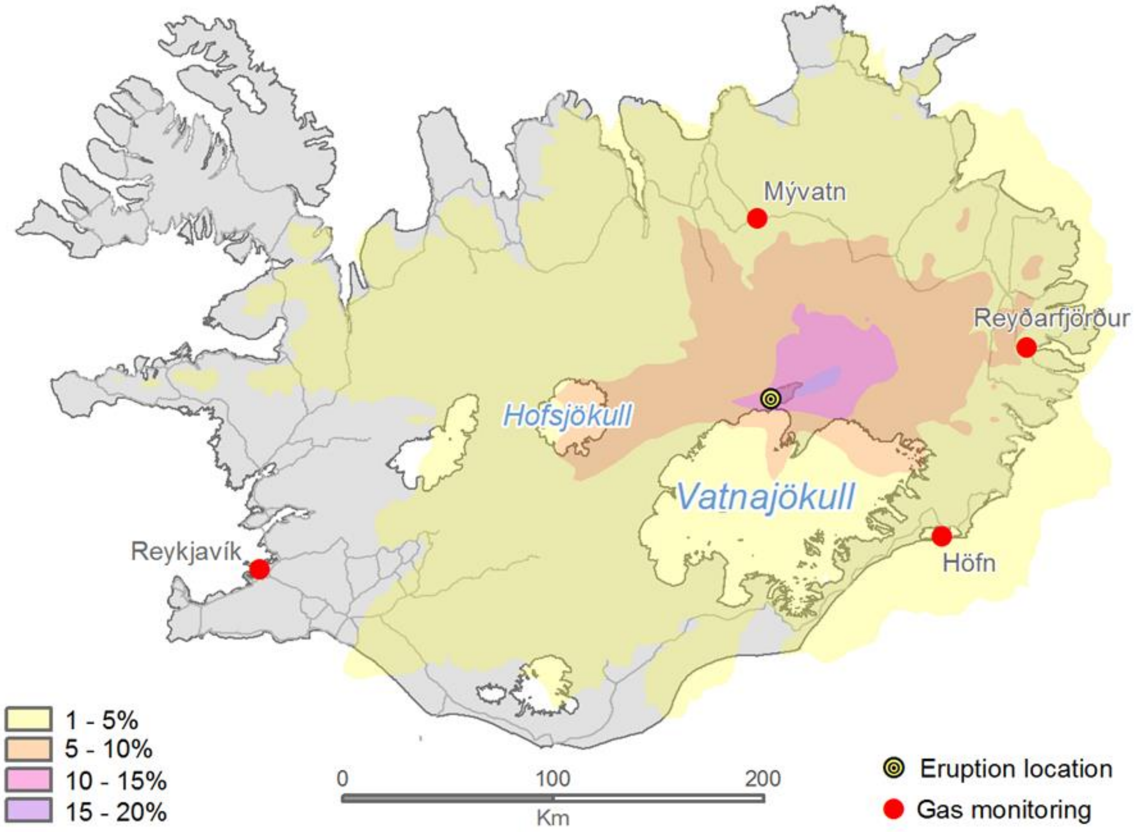

Figure 7.4 SO_2 dispersion during the eruption (Map Bogi Brynjar Björnsson at Icelandic Met Office. (Gíslason, 2015)).

SO_2 dispersion during the eruption modelled by CALPUFF presented as frequency of hourly concentrations higher than the 350 µg/m^3 health limit. The monitoring stations mentioned in the text and in Figure 7.4 are also shown.

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 of the Environmental Agency of Iceland (EAI) http://airquality.is. 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 fluoresence 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/m^3 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 hand held sensors the highest being 21,000 µg/m^3 in Höfn. 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/m^3 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 (for 17 consecutive hours and a total of 86 hours), 1.4 % in Reyðarfjörður (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 February 18. Gas emissions from Holuhraun increased ground-level SO_2 concentrations in Europe in September 2014 when the eruption intensity was high.

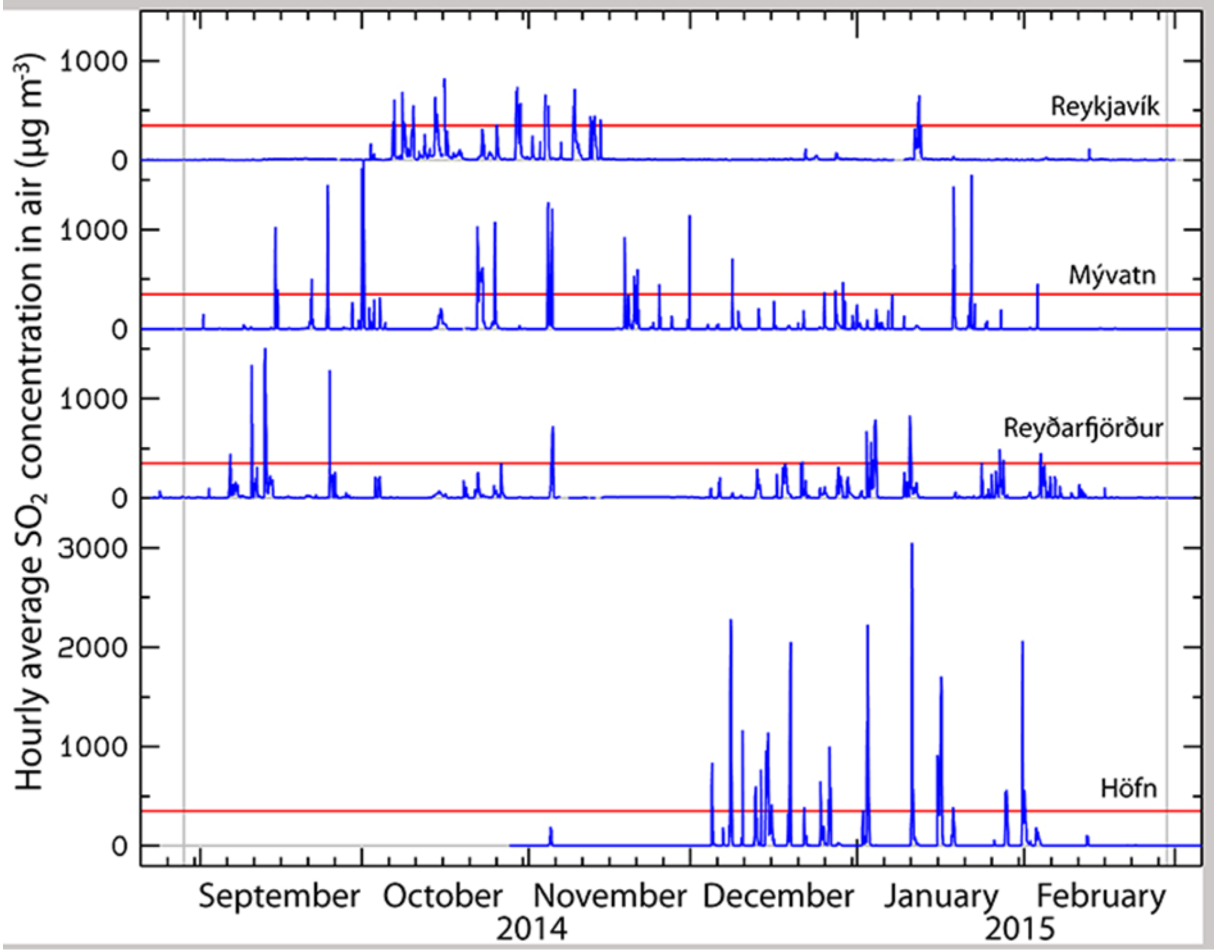

Figure 7.5 SO_2 concentration in air (Graph Þórður Arason at Icelandic Met Office (Gíslason, 2015))

The SO_2 concentration in air at four of the permanent gas monitoring stations presented in Figure 7.5. The 350 μg/m³ 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.

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 Table zz, 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 22 September the ground-level concentrations were highest in Austria at 235 μg/m³. 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/m³. On this day unusually high concentrations were measured at most of the 30 monitoring stations in Austria. (Gíslason, 2015).

Table 7.2 Highest one hour SO_2 peak by country (Gíslason, 2015)

Counry	Station name	Latitude	Longitude	Height above sea level	Date	Distance from the eruption	Highest one hour SO2 peak
Ireland	Ennis	52.84	-9	16 m	06.09.2014	1407 km	498 µg/m3
Ireland	Portlaoise	53.04	-7.29	98 m	06.09.2014	1420 km	343 µg/m3
Netherlands	Philippine	51.29	3.75	5 m	22.09.2014	1905 km	82 µg/m3
Belgium	Ghent region	51.15	3.81	12 m	22.09.2014	1931 km	87 µg/m3
Britain	Wicken Fen	52.3	0.29	3 m	22.09.2014	1701 km	96 µg/m3
Austria	Masenber	47.35	15.89	1210 m	22.09.2014	2754 km	235 µg/m3

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

8 Spatially Distributed Emissions on Grid

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.

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.

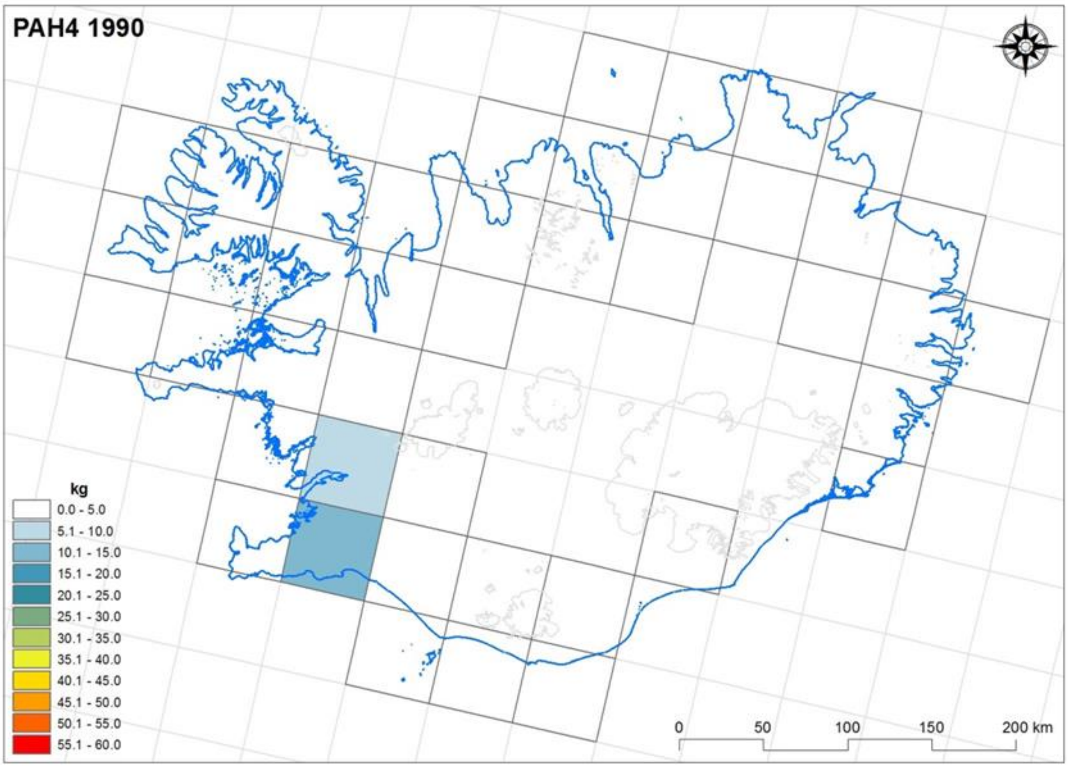

Figure 8.1 Emissions of PAH4 within the EMEP-Grid in 1990.

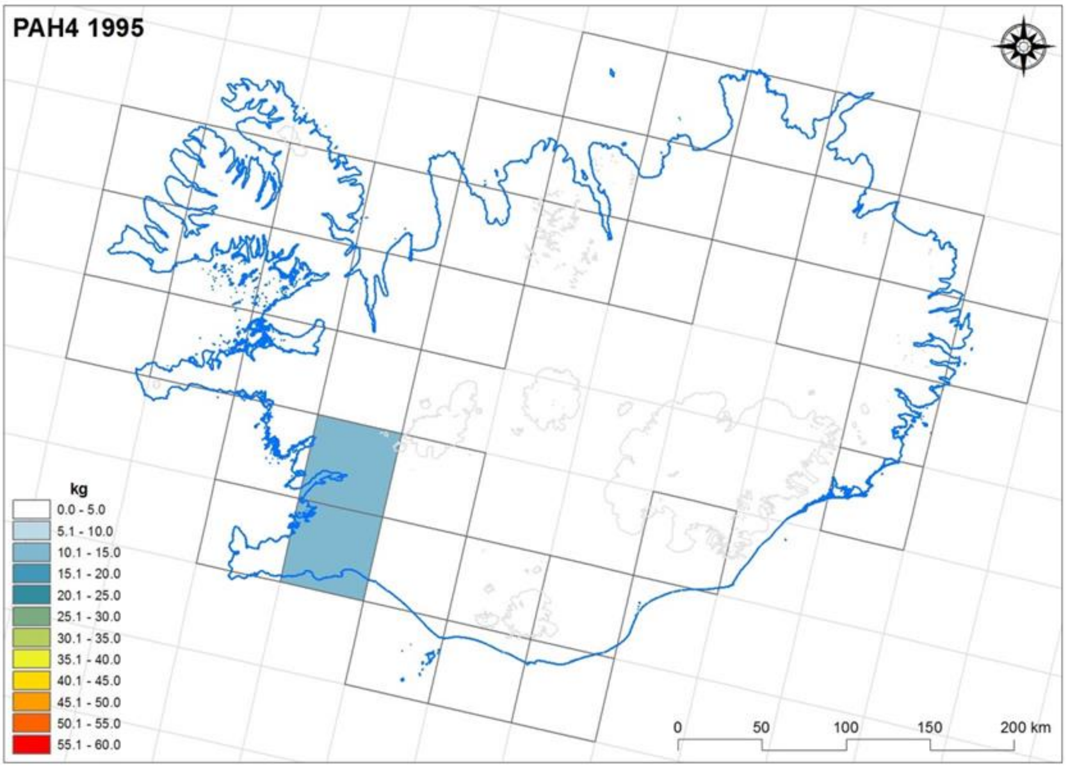

Figure 8.2 Emissions of PAH4 within the EMEP-Grid in 1995.

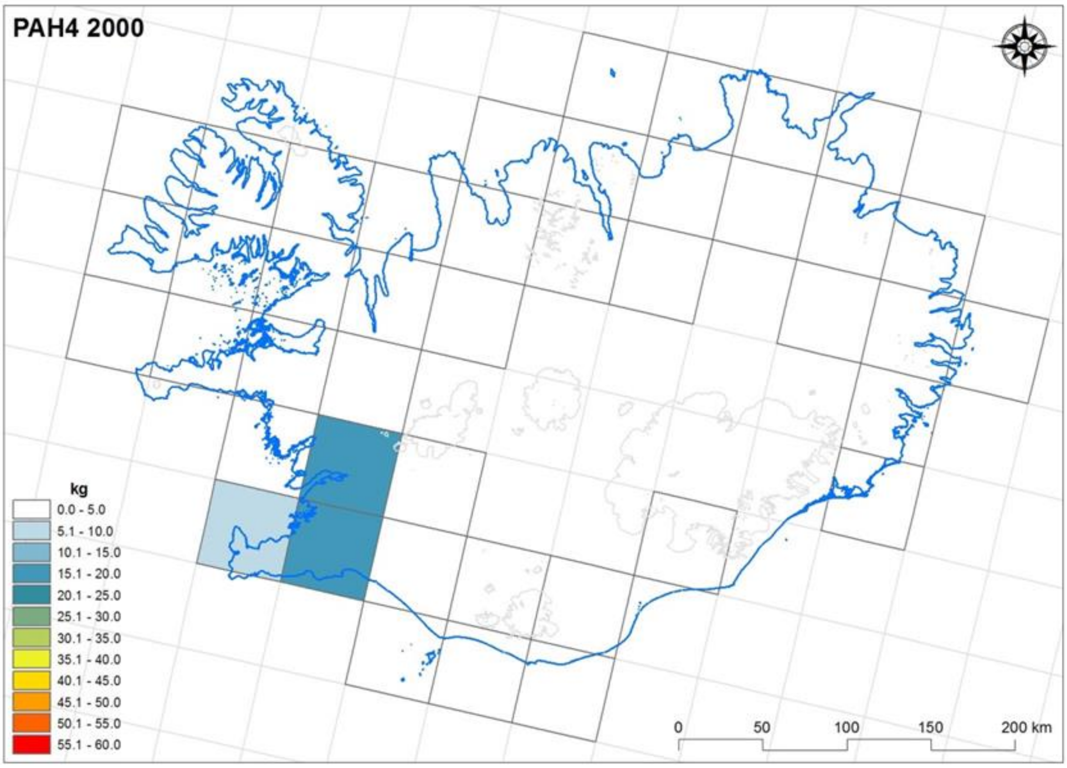

Figure 8.3 Emissions of PAH4 within the EMEP-Grid in 2000.

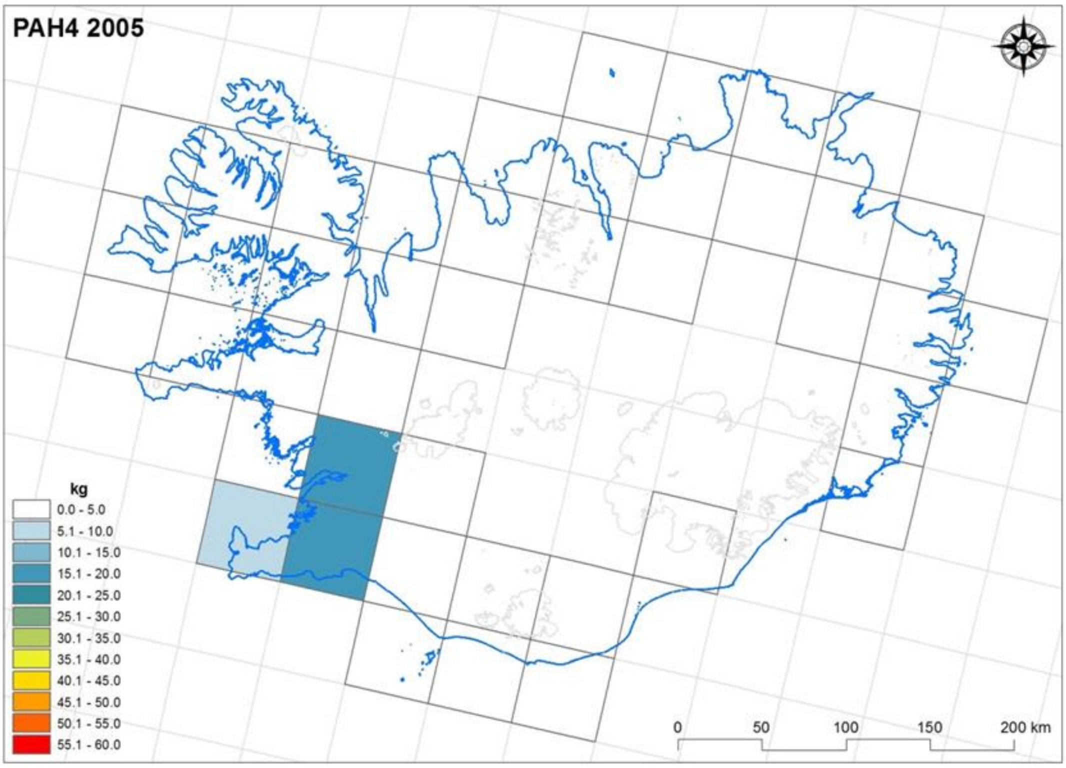

Figure 8.4 emissions of PAH4 within the EMEP-Grid in 2005.

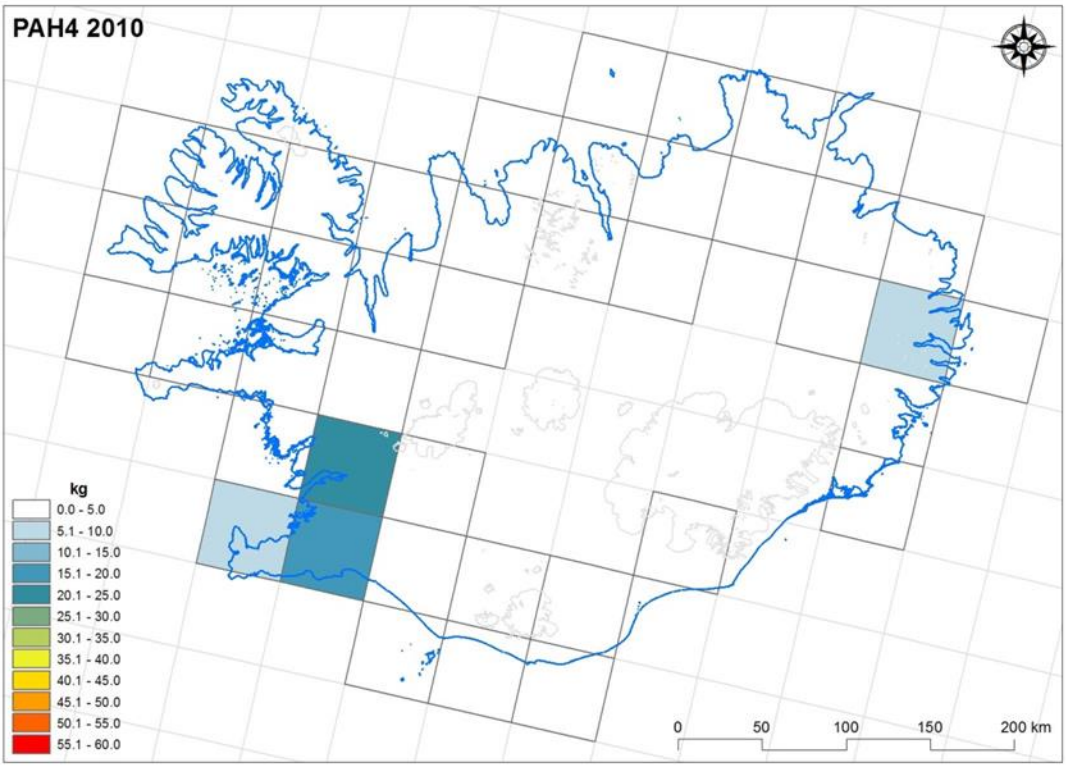

Figure 8.5 Emissions of PAH4 within the EMEP-Grid in 2010.

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.

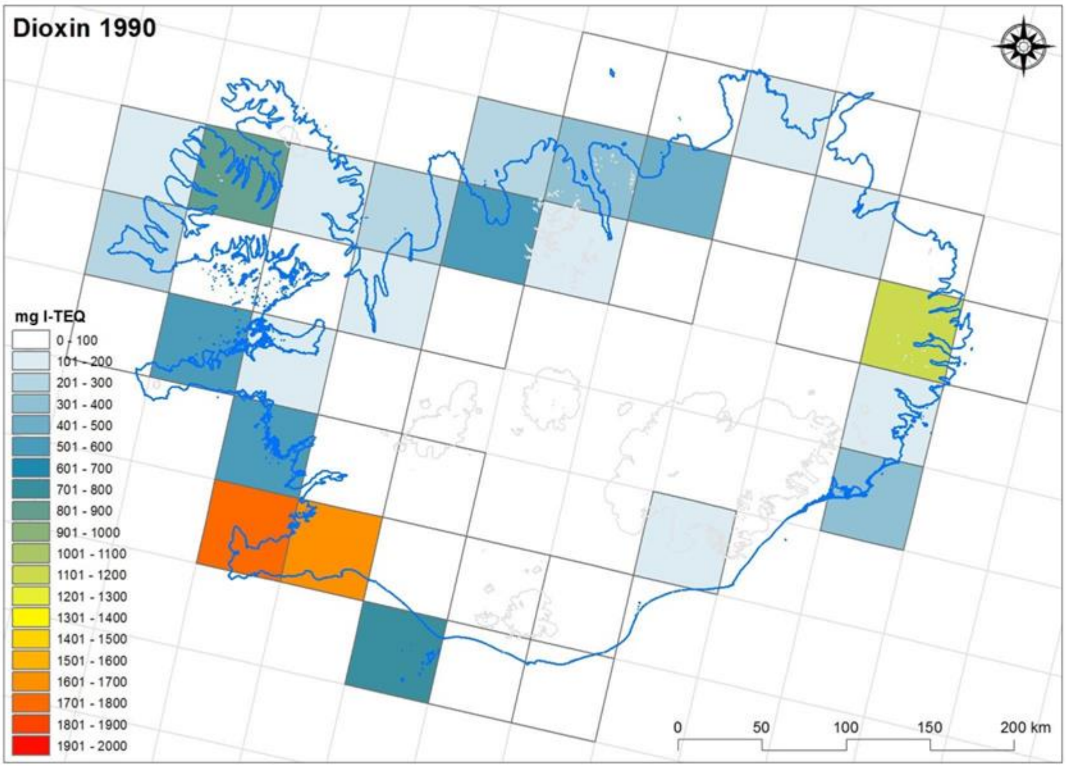

Figure 8.6 Dioxin emissions within the EMEP-Grid in 1990.

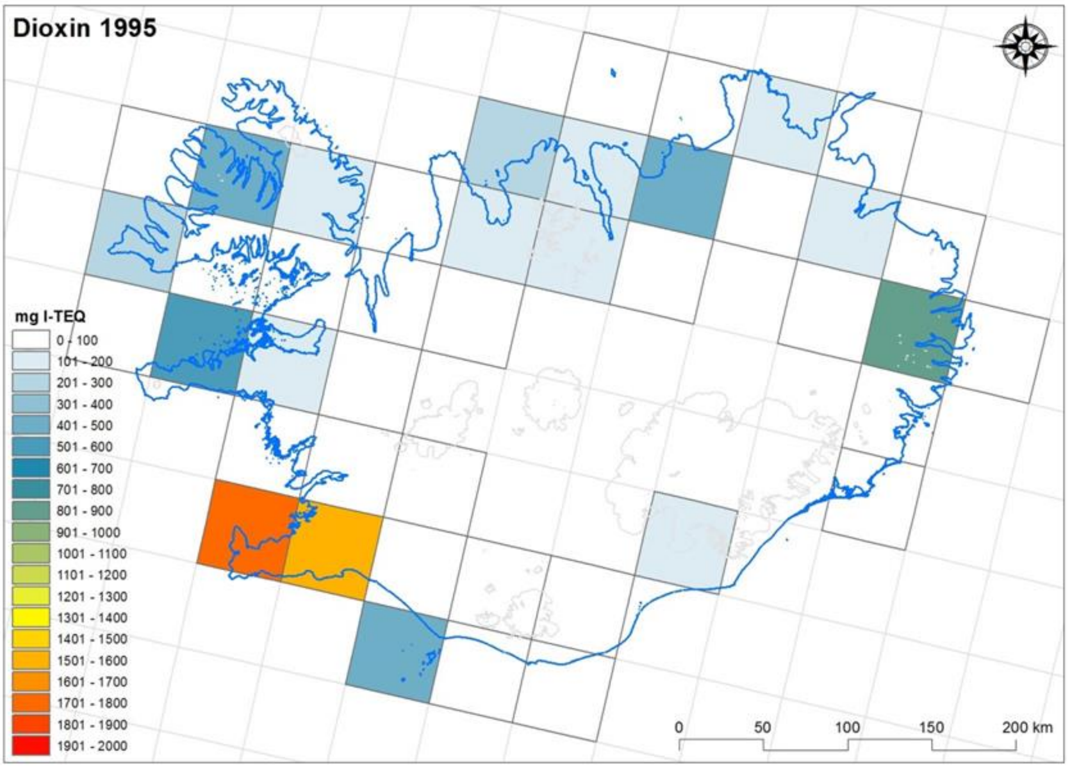

Figure 8.7 Dioxin emissions within the EMEP-Grid in 1995.

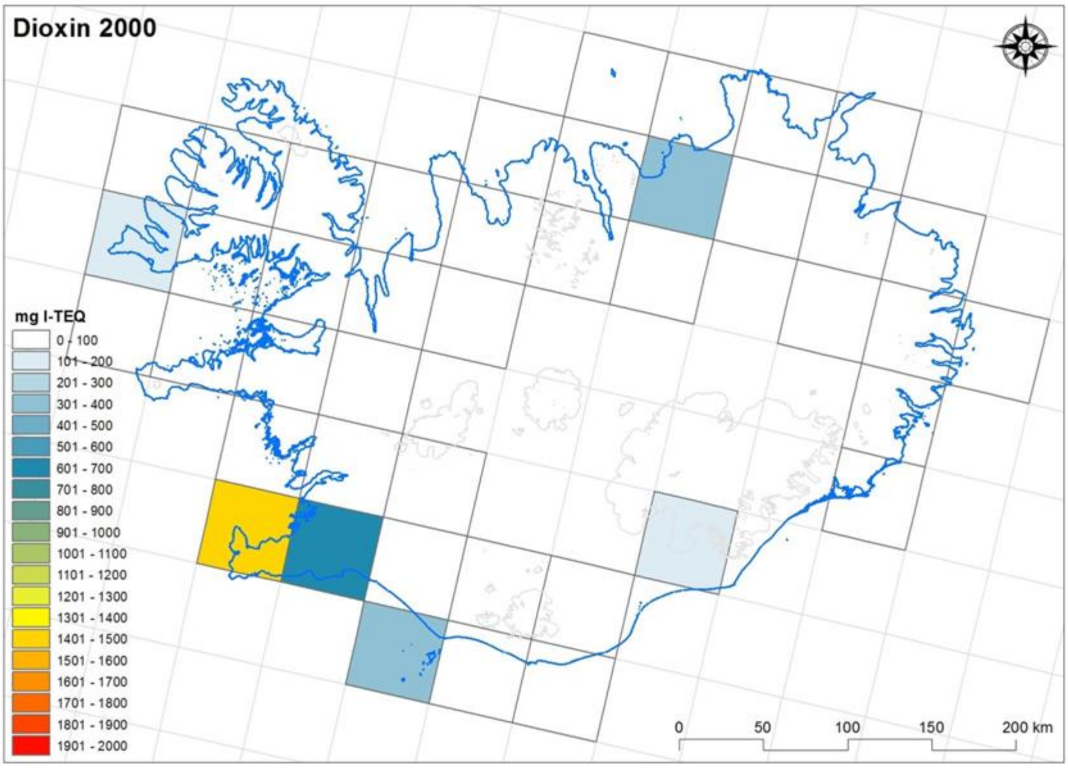

Figure 8.8 Dioxin emissions within the EMEP-Grid in 2000.

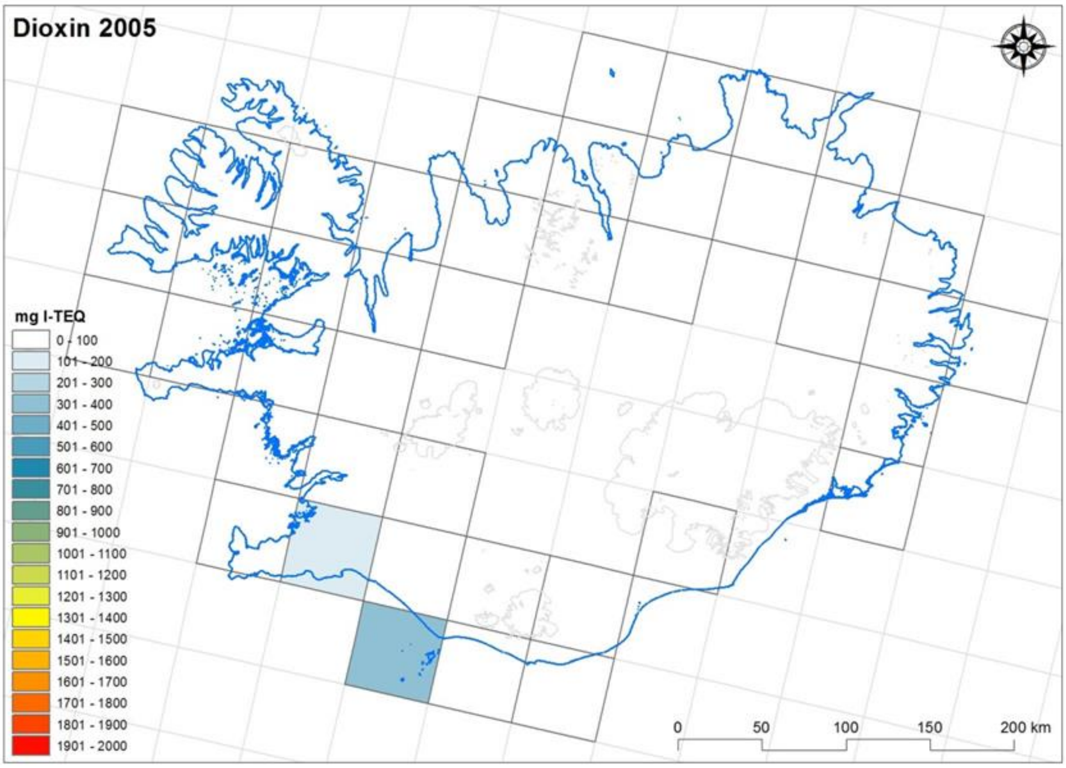

Figure 8.9 Dioxin emissions within the EMEP-Grid in 2005.

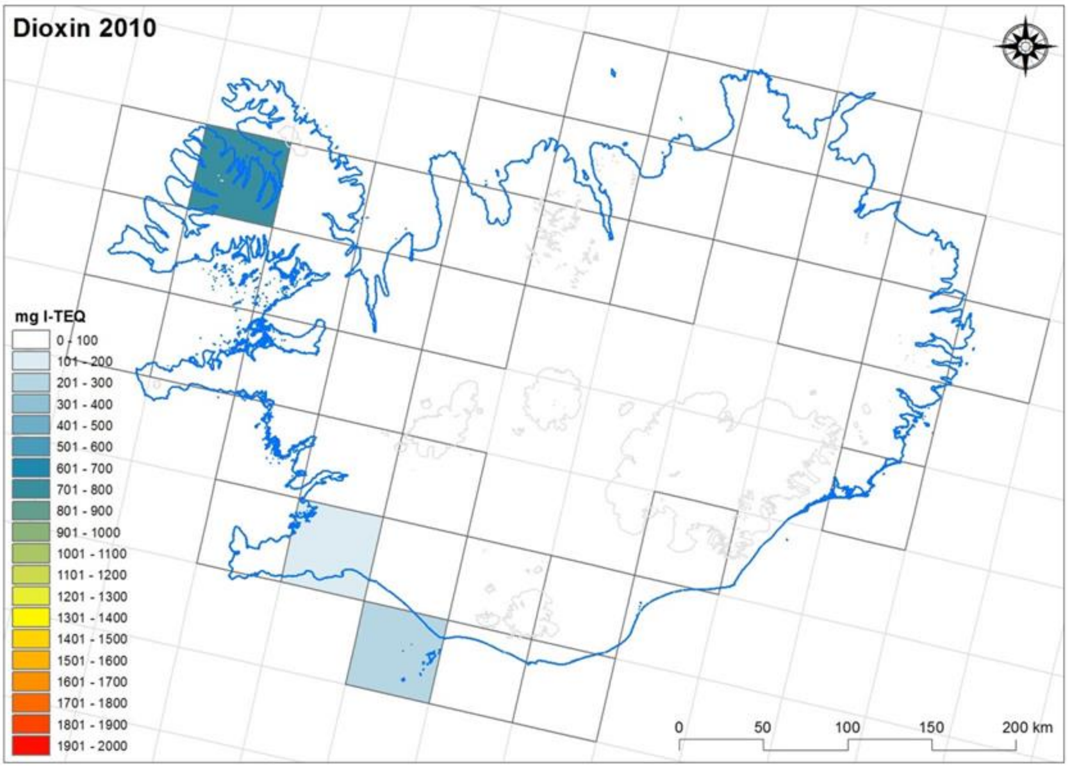

Figure 8.10 Dioxin emissions within the EMEP-Grid in 2010.

9 References

Aasestad, K. (2013). *Emissions of Black carbon and organic carbon in Norway 1990-2011.* Statistics Norway.

Baldvinsson, Í. Þ. (2011). *Gaslosun jarðvarmavirkjana á Íslandi.* National Energy Authority.

EAI. (2015). *National Inventory Report 2015. Emissions of greenhouse gases in Iceland from 1990 to 2013.* Reykjavík: EAI. Retrieved from http://ust.is/library/Skrar/Einstaklingar/Loftgaedi/2015_12_08_NIR_submitted%20Version%206.pdf

EEA. (2007). *EMEP/CORINAIR Emission Inventory Guidebook 2007.* European Environment Agency.

EEA. (2009). *EMEP/EEA air pollutant emission inventory guidebook - 2009.* European Environment Agency.

EEA. (2013). *EMEP/EEA air pollutant emission inventory guidebook - 2013.* European Environment Agency.

European Commission. (2001). *Integrated Polltion Prevention and Control (IPCC). Reference Document on Best Available Techniques in the Non Ferrous Metals Industries.*

Gíslason, S. S. (2015). *Environmental pressure from the 2014–15 eruption of Bárðarbunga volcano, Iceland.* Geochem. Persp. Let. 1, 84-93.

IPCC. (1996). *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: The Reference Manueal (Volume 3).* Intergovernmental Panel on Climate Change.

IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Intergovernmental Panel on Climate Change. Retrieved from 2006 IPCC Guidelines for National Greenhouse Gas Inventories: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol3.html

NEA. (2014). *Natinal Energy Authority, Hydro, Electricity*.

NERI. (2011). *Annual Danish Infomative Inventory Report to UNECE - Emission Inventories from the base year of the protocolst to year 2009.* Aarhus University - Denmark: National Environmental Research Institute. Retrieved from http://www.neri.dk

Schmidt, A. W. (2015). *Long range transport and air quality impacts of SO2 emissions from Holuhraun (Bárdarbunga, Iceland).* . Geophysical Research Abstracts 17, EGU 2015–14866–1.

Statistics Norway. (2001). *Utslipp til luft av noen miljogifter i Norge - Dokumentasjon av metode og resultater.* Oslo: Statistics Norway. Retrieved from https://www.ssb.no/a/publikasjoner/pdf/rapp_200117/rapp_200117.pdf

Statistics Norway. (2002). *Utslipp til luft av dioksiner i Norge - Dokumentasjon av metoder og tesultater.* Oslo-Kongsvinger: Statistic Norway. Retrieved from https://www.ssb.no/a/publikasjoner/pdf/rapp_200207/rapp_200207.pdf

UNEP. (2005). *Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases.* Geneva, Switzerland: United Nations Environment Programme.

Annex 1 Explanation of EAI‘s Adjustment of Data on Fuel Sales by Sector

Fuel sales (gas oil and residual fuel oil) by sectors 1A1a, 1A2 (stationary) and 1A4 (stationary) – as provided by the National Energy Authority.

No.	**Category**	**1990** **Tonnes**	**1995** **Tonnes**	**2000** **Tonnes**	**2005** **Tonnes**	**2006** **Tonnes**	**2007** **Tonnes**	**2008** **Tonnes**	**2009** **Tonnes**	**2010** **Tonnes**	**2011** **Tonnes**	**2012** **Tonnes**	**2013** **Tonnes**	**2014** **Tonnes**
Gas/Diesel Oil														
10X40	**house heating and swimming pools**	**10,623**	**8,535**	**7,625**	**4,240**	**2,417**	**2,420**	**1,546**	**1,626**	**1,637**	**1,595**	**1,745**	**1,585**	**3,109**
10X5X	**industry**	**5,072**	**1,129**	**10,253**	**22,177**	**23,751**	**14,852**	**8,553**	**9,849**	**9,391**	**4,919**	**5,412**	**7,575**	**4,571**
10X60	**energy industries**	**1,300**	**1,091**	**1,065**	**21**	**1,349**	**1,109**	**1,436**	**760**	**1,012**	**683**	**955**	**1,090**	**1,423**
10X90	**other**	**0**	**458**	**1,386**	**8,928**	**8,296**	**2,033**	**1,336**	**1,499**	**2,728**	**1,136**	**260**	**768**	**214**
Residual Fuel Oil														
10840	**house heating and swimming pools**	**2,989**	**3,079**	**122**	**195**	**76**	**86**	**63**	**78**	**0**	**0**	**0**	**0**	**191**
1085X	**industry**	**55,934**	**56,224**	**46,213**	**25,005**	**23,635**	**22,839**	**20,475**	**17,646**	**16,546**	**17,294**	**17,839**	**13,789**	**3,806**
10860	**energy industries**	**0**	**0**	**0**	**0**	**5**	**4,498**	**0**	**0**	**0**	**0**	**135**	**125**	**0**
10890	**other**	**39**	**52**	**67**	**0**	**0**	**45**	**913**	**0**	**1,629**	**780**	**0**	**0**	**0**

ADJUSTMENTS

For gas oil:

First fuel consumption needed for the known electricity production with fuels is calculated (**1A1a** – electricity production), assuming 34% efficiency, the values calculated are compared with the fuel sales for the category 10X60 Energy industries.

- In years where there is less fuel sale to energy industries as would be needed for the electricity production, the fuel needed is taken from the category 10X90 Other and when that is not sufficient from the category 10X40 House heating and swimming pools.
- In years where there is surplus the extra fuel is added to the category 10X40 House heating and swimming pools.

NEA has estimated the fuel use by swimming pools (**1A4a**). These values are subtracted from the adjusted 10X40 category. The rest of the category is then **1A4c** – Residential.

For years when there is still fuel in the category 10X90 Other, this is added to the 10X5X Industry. This is the fuel use in **1A2** – Industry.

	1990	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Swimming pools	1800	1600	1600	1000	300	300	300	300	300	300	300	300	300

For Residual Fuel Oil:

The sectors 10840 and 10860 are added together. This is the fuel use by **1A1a** - public heat plants, In year 1997 four tonnes are subtracted from this category as the category 10890 has minus four tonnes, leaving category 10890 with 0 in 1997. The categories 1085X Industry and 10890 Other are added together, this is the fuel use in **1A2** – industry