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parašas

LITHUANIAN POLLUTANT EMISSION INVENTORY FOR PERIOD 1990-2018

2020 m. sausio 14 d. Sutarties Nr. 28TP-2016-98

Lithuanian Environmental Protection Agency

Legal Disclaimer

Abbreviations

BC – black carbon;
CEIP – Centre on Emission Inventories and Projections;
CPST – Centre for Physical Sciences and Technology in Lithuania;
CLRTAP – Convention on long Range Transboundary Air Pollutants (ECE/EB.AIR/97);
CORINAIR – The Core Inventory of Air Emissions in Europe;
DSGRL – Department of Statistics to the Government of the Republic of Lithuania;
DSI – dry sorbent injection;
EMEP/EEA – European Monitoring and Evaluation Program / European Environmental Agency;
EMEP/EEA 2013 or 2016 guidebook - The EMEP/EEA air pollutant emission inventory guidebook, where 2013 or 2016 is the year when guidebook was approved;
EMEP/CORINAIR - Atmospheric emission inventory guidebook, Cooperative Programme for Monitoring and Evaluation on the Long-Range Transmission of Air Pollutants in Europe, The Core Inventory of Air Emissions in Europe;
E-PRTR – European Pollutant Release and Transfer Register;
ESP – electrostatic precipitation;
FF – fabric filter;
FRD – Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania;
GHG – Green-house Gas;
HCB – hexachlorobenzene;
IIR – Informative Inventory Report;
IPCC GPG 2000 – IPCC Good Practice Guidance and Uncertainty management in national Greenhouse Gas Inventories (2000);
KCA – key category analysis;
LEPA – Environmental Protection Agency under the Ministry of Environmental Protection (Lithuanian Environmental Protection Agency);
MoE - Ministry of the Environmental Protection;
NEC – National Emission Ceilings (directive 2001/81/EC);
NFR – Nomenclature for Reporting;
NMVOC – non-methylated volatile organic compounds;
PAH – Polycyclic aromatic hydrocarbons;
PCB – polychlorinated biphenyl;
PCDD/PCDF – polychlorinated dibenzodioxins / polychlorinated dibenzofurans;
PM – particulate matter;
POP – persistent organic pollutants.
SNCR – selective non-catalytic reduction;
Tier 1 – A method using readily available statistical data on the intensity of processes (activity rates) and default emission factors. These emission factors assume a linear relation between the intensity of the process and the resulting emissions. The Tier 1 default emission factors also assume an average or typical

process description. This method is the simplest method, has the highest level of uncertainty and should not be used to estimate emissions from key categories;

Tier 2 – is similar to Tier 1 but uses more specific emission factors developed on the basis of knowledge of the types of processes and specific process conditions that apply in the country for which the inventory is being developed. Tier 2 methods are more complex, will reduce the level of uncertainty, and are considered adequate for estimating emissions for key categories;

TFEIP – Task Force on Emission Inventories and Projections;

TSP – total suspended particles;

UN – United Nations;

UNFCCC – United Nations Framework Convention on Climate Change;

UNECE – the United Nations Economic Commission for Europe.

The Lithuanian Environmental Protection Agency (EPA) was established on the 1st of January, 2003, by the Order of the Minister of the Environment of the Republic of Lithuania No. 466 which was released on the 30th of August, 2002. The LEPA performs functions of former Joint Research Centre, Water Resources Department of the Ministry of Environment and undertakes Chemical Substances Management previously managed by State Non-food Products Inspectorate under the Ministry of Economy.

Acknowledgments

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Executive Summary

The Republic of Lithuania, as a party of the United Nations Economic Commission for Europe (UNECE), under the Convention on Long-range Transboundary Air Pollution (CLRTAP, ECE/EB.AIR/97) is required to annually report pollutant emission data. In compliance with the CLRTAP and its protocols Lithuania submits statistics on the following pollutant emissions: SOx, NOx, NMVOC, NH3, BC, heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn), particulate matter (TSP, PM10, and PM2.5), and POPs (dioxins, furans, PAHs, and HCB).

The Centre for Physical Sciences and Technology (CPST) in Lithuania has a role of inventory preparation using Tier *1* approach (and Tier *3* for Road transport). The Air Division specialists from the Lithuanian Environment Protection Agency, Under Ministry of Environment (LEPA) perform the assessment on the transparency, quality and completeness of the inventories, improve inventory by recalculating emissions in higher Tier approaches. LEPA is responsible for the submission of the results to the Centre on Emission Inventories and Projections (CEIP) under the CLRTAP.

The current report includes information (background information, activity data, methodologies, QA/QC, recalculations and future projections and improvements) on emission inventory for the period 1990-2018. The commitments under the National Emission Ceilings (NEC) directive 2001/81/EC and reduction of the pollutant emissions are discussed in this report.

This report is Lithuanian's Annual Informative Inventory Report due March 15, 2020. The report contains information on Lithuanian's inventories for all years from the base years of the protocols to 2018. The inventory is submitted to the European Commission and EEA via EIONET CDR http://cdr.eionet.europa.eu/ annually. This report (IIR) is available for public and can be accessed via Lithuanian Environmental Protection Agency's website: http://oras.gamta.lt/cms/index?rubricId=872b11e2-6fbc-43ba-8c07-3fb37fb3e4cc and Convention on Long-range Transboundary Air Pollution webpage: http://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2020_submissions/

The report shows how Lithuania complies to and follows the Guidelines for Reporting Emission Data for inventory preparation, how attempts to ensure transparency, accuracy, consistency, comparability and completeness (TACCC) of the reporting. The submission of results was closely followed according to the template provided by the CLRTAP's Task Force on Emission Inventories and Protections (TFEIP) Secretariat.

Main differences from the last submission are:

1) Improved IIR by including more details on calculation methodologies, activity data uncertainties, removing excessive repetition of information on emission factors available on EMEP/EEA Guidebook 2013, 2016 and 2019;
2) Recalculation of large part of the inventory using the latest 2019 EMEP/EEA guidebook.
3) Evaluation of previously not estimated categories, e.g., NFR 3.D.f *Use of pesticides*, 3.F *Field burning of agricultural residues*, 5.C.2 *Open waste burning*, 5.E *Other waste* and other.
4) Improved methodologies and activity data in multiple categories, for instance, NFR 1A1a *Public electricity and heat production*, 2.D.3.a Domestic solvents, all NFR 5C1b categories (i.e., cremation, hazardous waste incineration, medical waste incineration and other) and other.

There is a necessity for inventory improvement in the future. One of the main priorities is to estimate KCA categories using Tier *2* or higher approach.

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1 INTRODUCTION

1.1 National Inventory Background

The Convention on Long-range Transboundary Air Pollution (CLRTAP) was signed in Geneva in 1979 by 34 Governments and the European Community. It was the first international document addressing problems of transboundary air pollution.

In January of 1994 the Republic of Lithuania ratified the 1979 Geneva Convention on Long-Range Transboundary Air Pollution and became a party to the Convention and its protocols. One of the obligations to the Convention on LRTAP is to submit an annual pollution emission inventory. According to the Reporting Instruction of Reporting Guidelines under the CLRTAP (ECE/EB.AIR.125) time series of emissions under nomenclature for reporting (NFR) and informative inventory reports (IIR) have to be submitted every year, including recalculated emissions for the period from 1990. Projection reports, gridded data and large point sources (LPS) information (Annex III - V) have to be reported every 4 years [1].

The Convention entered into force in 1983 and has been extended by eight protocols, which specify financing aspects of the cooperative monitoring and evaluation programme, address groups or individual pollutants' reduction and control issues, and other issues, such as eutrophication, acidification and ground level ozone formation. The following classes of pollutants are addressed in the inventory:

- Main pollutants (SOx, NOx, NMVOC, NH_3 and CO);
- Particulate matter (TSP, PM_{10}, $PM_{2.5}$ and BC);
- Heavy metals (Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn);
- Persistent organic pollutants (PCBs, Dioxins, Furans, PAHs and HCB).

The trend of national emissions of the main pollutants (except CO) and reduction commitments under revised Gothenburg Protocol for 2020-2029 are shown in Figure 1.

The 2019 Lithuanian IIR contains information on the national inventory for 2015 including descriptions of methodologies and NFR categories, input parameters, improvement, QA/QC, recalculations, analysis and interpretation of results, assessment for TACCC and other sections as formulated in ECE.EB.AIR.125 revised guidelines. Changed parameters are applied retrospectively for previous submissions and recalculated values are changed accordingly for annual submissions.

Emission estimates are mainly based on official publicly available Lithuanian Statistics Yearbooks: energy, production, agricultural, transport and other statistical data, which is available on the main website http://www.stat.gov.lt/en/. EMEP/EEA 2016, 2019 guidebook is often referred to when calculating category-specific emissions as almost no country specific data emission factors and methodologies are available.

In Figure 1 straight lines indicate emission reduction commitments for 2020 as set out in the Gothenburg protocol [1].

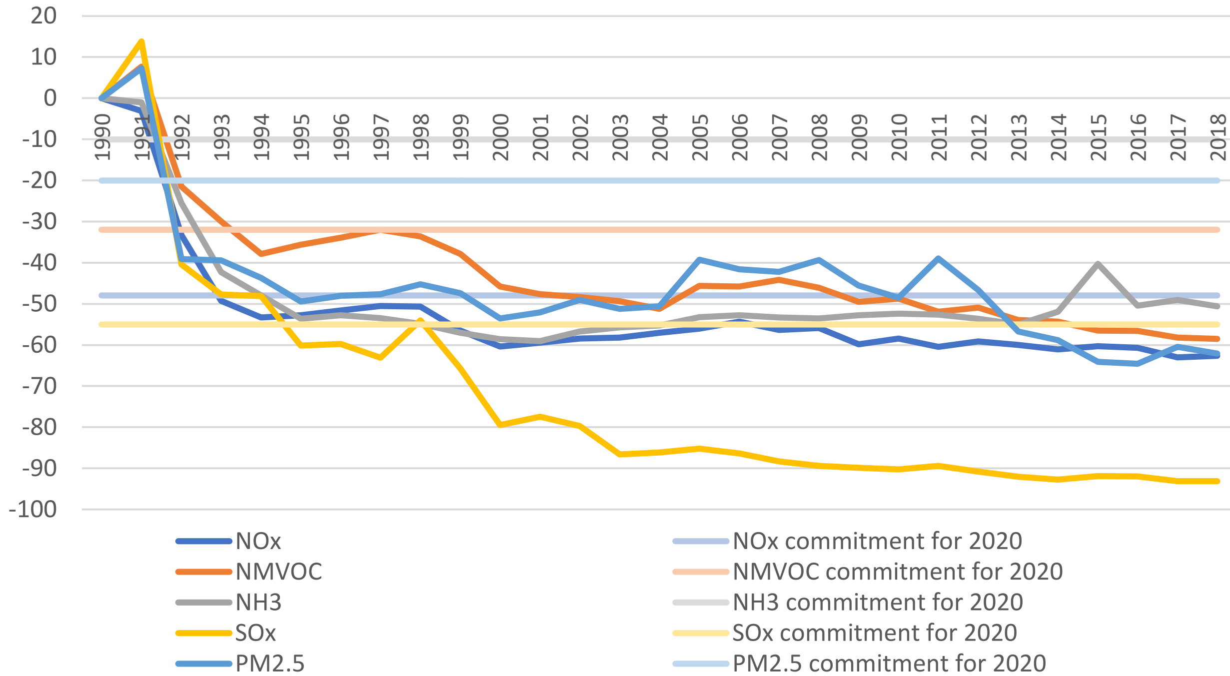

FIGURE 1 NATIONAL EMISSIONS OF 5 POLLUTANTS (DARKER SHADE CURVES) FOR PERIOD 1990-2018 AS A PERCENTAGE OF BASE YEAR 1990.

1.2 Country information

Lithuania is the southernmost of the three Baltic States – and the largest and most populous of them. Lithuania was the first occupied Soviet republic to break free from the Soviet Union and restore its sovereignty via the declaration of independence on 11 March 1990. Major cities include Vilnius with a population of 549,000, Kaunas with a population of 349,000 and Klaipeda with a population of 183,000. Siauliai and Panevezys are also important cities for commerce. The climate is midway between maritime and continental, with an average daytime temperature of -5° C in January and 20° C in July.

Lithuania

Year of EU entry: 2004

Capital city: Vilnius

Total area: 65 000 km^2

Population: 2.8 million

Currency: Euro (Eur)

The Lithuanian landscape is predominantly flat, with a few low hills in the western uplands and eastern highlands. The highest point is Aukštasis at 294 metres. Lithuania has 758 rivers, more than 2 800 lakes and 99 km of the Baltic Sea coastline, which are mostly devoted to recreation and nature preservation. Forests cover just over 30% of the country.

Some 84% of the population are ethnic Lithuanians. The two largest minorities are Poles, who account for just over 6.7% of the population, and Russians, who make up just over 6.3%. and 3.6% other (Belarusians, Ukrainians, Latvians, etc.). The Lithuanian language belongs to the family of Indo-European languages. Most of the population is Roman Catholic, but there are also Russian Orthodox, Evangelical Lutherans, Evangelical Reformers, Old Believers, Jews, Sunni Muslims and Karaites. The official state language is Lithuanian, which is the most archaic living Indo-European language and is closely related to Sanskrit. It is possible to compare Lithuanian and Sanskrit in such a way that even those who have not studied linguistics may observe the similarities. The 32-letter Lithuanian alphabet is Latin-based. English and Russian are widely spoken.

The capital, Vilnius, is a picturesque city on the banks of the rivers Neris and Vilnia, and the architecture within the old part of the city is some of Eastern Europe's finest. Vilnius University, founded in 1579, is a renaissance style complex with countless inner courtyards, forming a city within the city.

The Lithuanian president is elected directly for a five-year term and is active principally in foreign and security policy. The unicameral Lithuanian Parliament, the Seimas has 141 members.

1.3 Institutional Arrangements

The Lithuanian Environmental Protection Agency (LEPA) under the Ministry of Environment in 2011 was nominated to be responsible for the inventory communication by the Order No. D1-85. Air Division specialists in the LEPA have made a legal arrangement with Center of Physical Sciences to estimate inventory using Tier *1* approach. Such inventory report is delivered annually and is firstly estimated and compiled by experts of Center of Physical Sciences and Technology (CPST). Air Division specialist then recalculate, improve, check, archive and approve final inventory version. The LEPA has a legal responsibility for submission of the inventory under Convention on LRTAP.

For the years 1990-2018 primary estimation via Tier *1/2/3* EMEP/EEA 2016 and 2019 approach was performed by the experts of Center of Physical Sciences and analyzed, improved and communicated by the EPA (Environmental Quality Department under the Ministry of Environment before 2011) Air division specialists. No other institutional arrangements are made.

There is no clearly defined documentation and archiving system. Information needed to compile inventory reports is saved in the LEPA database and retrieved if needed.

Inventory improvements are prioritized based on the following factors:

1) Stages 1, 2 and 3 inventory reviews, which can be accessed on ceip.at website;
2) KCA categories, which are not estimated using Tier *2* approach yet;
3) Other experts' reviews and suggestions

1.4 Inventory Preparation Process

Inventory preparation is carried out with the help of experts of the Centre of Physical Sciences and Technology as described in 1.2. The activity data is mainly gathered from publicly available databases. The major and most accurate database is the National Statistical Yearbook managed by the Lithuanian Statistics Department. A few yearbooks are used to collect needed activity data. All activity data sources are available in Table 1.

The brief process of inventory preparation is shown in Figures 2-3.

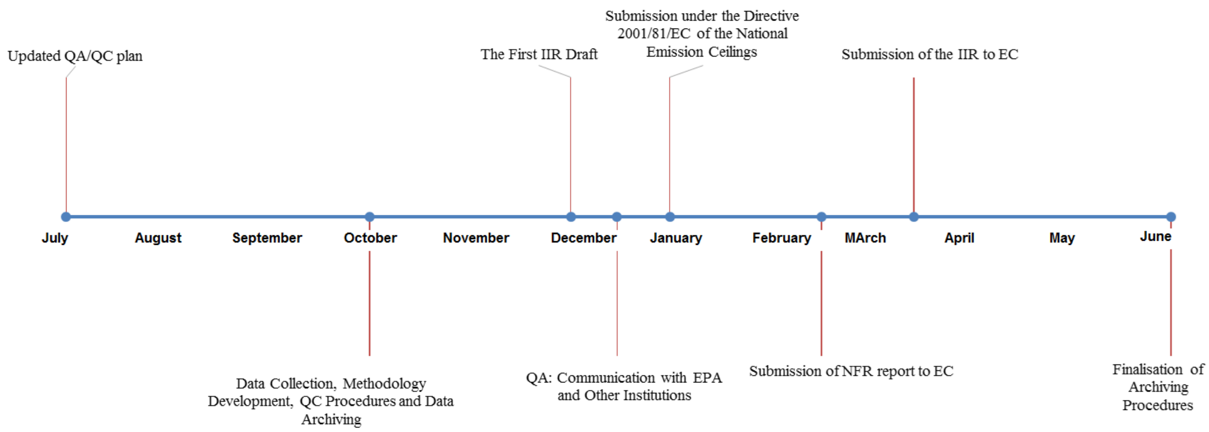

FIGURE 2 THE MILESTONES FOR PREPARATION AND SUBMISSION OF NATIONAL INVENTORY

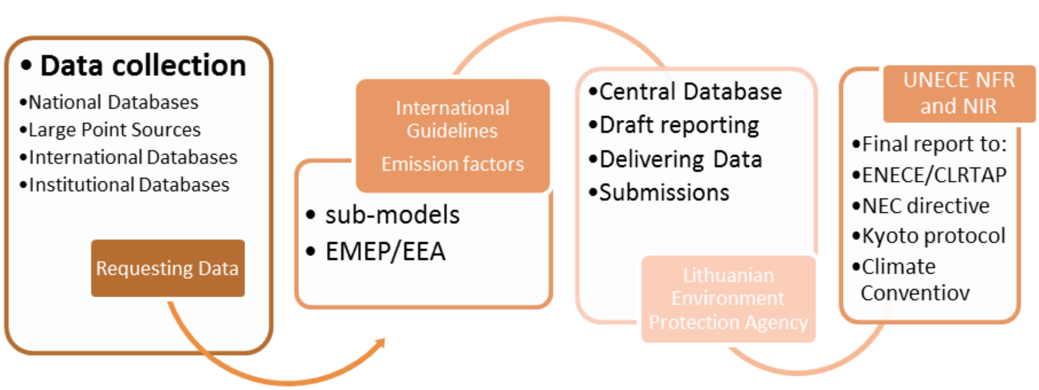

FIGURE 3 SCHEMATIC DIAGRAM OF THE PROCESS OF INVENTORY PREPARATION

Every year entire time series (period from 1990 to 2013 for 2020 inventory submission) are checked and revised, recalculations performed for changes made (error corrections, data improvement or methodology enhancement).

The milestones for preparation and submission of National Inventory under the Convention of LRTAP are shown in Figures 2-3.

Error! Reference source not found. illustrates the process of inventory preparation from the first step of collecting external data to the last step, where the reporting schemes are generated for the UNFCCC and EU (in the CRF format (Common Reporting Format)) and to the United Nations Economic Commission for Europe/Cooperative Programme for Monitoring and Evaluation of the Long range Transmission of Air Pollutants in Europe (UNECE/EMEP) (in the NFR format (Nomenclature For Reporting)). Data files and programme files used in the inventory preparation process are listed in Table 1.

1.5 Methods and Data Sources

Mainly national or international statistics have been used for the estimation of the 1990-2018 inventory. Also, for major part of the NFR categories 2016 EMEP/EEA methodology with provided emission factors was applied. All methodologies which were utilized are described for each NFR category. The most frequently used approach was Tier 2. Please see Table 1 for description of what activity data and from where it was gathered.

TABLE 1 SUMMARY OF THE MAIN SOURCES FROM WHICH ACTIVITY DATA

Energy (NFR 1)		
Energy Industries (NFR 1.A.1)	Fuel Consumption	National Statistical Yearbook (Lithuanian Statistics Department's Database) Companies Technology split (LT Study 2019)
Residential, public and Commercial Machinery (NFR 1.A.4)	Fuel Consumption	National Statistical Yearbook (Lithuanian Statistics Department's Database)
Oil and Gas Exploration, Transportation, Production (NFR 1.B.2)	Fuel Production	National Statistical Yearbook (Lithuanian Statistics Department's Database)
Industrial Processes (NFR 2)		
Mineral Products (NFR 2.A)	Production Information	National Statistical Yearbook (Lithuanian Statistics Department's Database)
		Source-specific Information from Production Plants
Solvent and Other Products Use (NFR 2.D)	Solvent Consumption	European Asphalt Pavement Association Yearbook
		National Statistical Yearbook (Lithuanian Statistics Department's Database)
		Green-house Gases Inventory Report 2018
		The Customs Database of the Republic of Lithuania
Agriculture (NFR 3)		
Manure Management (3.B)	Number of animals	National Statistical Yearbook (Lithuanian Statistics Department's Database)

Crop Production and Agricultural Soils (3.D)	Fertilizers usage, waste usage beneficial for agriculture, crop areas, pesticide usage	International Fertilizer Industry Association Database
		Food and Agriculture Organization of the UN, Statistics Division
		National Statistical Yearbook (Lithuanian Statistics Department's Database)
		Environmental Protection Agencies' Waste Registry Database
Field Burning of Agricultural Residues (3.F)	Area Burnt	Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania Database
Waste (NFR 5)		
Waste Treatments (NFR 5)	Amount of Waste	Green-house Gases Inventory Report 2018
		Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania Database
		National Statistical Yearbook (Lithuanian Statistics Department's Database)
		Environmental Protection Agencies' Waste Registry Database

1.6 Key Categories

Key categories are the smallest number of categories from which emissions sum contribute 80% of total national emissions. According to 2019 EMEP/EEA guidebook, a key category is pollutant emission category which has a significant influence on the country's inventory as it forms a considerable amount of the total emissions.

Key categories for certain pollutant were identified in terms of their contribution to the total emission of that specific pollutant. The key categories were not more disintegrated as it is expressed in the NFR. Methodological approach 1 was used to identify key categories. For more detailed methodological explanation, please see Appendix 1.

Level assessment was performed for 2005 and the latest year, 2018 (see Tables: Table 2, Table 3). This was done to show contribution of categories to the total emission of specific pollutant and how distribution has changed

Trend assessment was performed in order to find categories which trend changed significantly in any direction and that have had the most significant impact on the average trend. Declining trends could be associated with improved abatement measure in particular process or activity decrease in specific category, while increasing trend usually indicates increased activity/ production.

TABLE 2 CATEGORIES OBTAINED FROM LEVEL ASSESSMENT FOR THE YEAR 2005.

COMPONENT	KEY CATEGORIES (SORTED FROM HIGH TO LOW FROM LEFT TO RIGHT)											TOTAL (%)
SOX	1A1a (36.2%)	1A1b (29.6%)	1B2aiv (16.5%)									82.3
NOX	1A3biii (23.6%)	1A3bi (17.3%)	3Da1 (10.2%)	1A1a (8.5%)	3Da2a (6.7%)	1A3c (6.6%)	3Da3 (4.7%)	1A1b (4.5%)				82.1
NH3	3Da2a (33.7%)	3Da1 (20.4%)	3B3 (11.9%)	3Da3 (9.0%)	3B1a (8.3%)							83.3
NMVOC	1A4bi (21.3%)	1A3bi (13.8%)	3B1a (10.5%)	2H2 (8.5%)	2D3d (4.8%)	3B1b (4.7%)	1A3biii (3.6%)	5A (3.5%)	3De (3.4%)	1B2aiv (3.3%)	2B10a (2.7%)	80.1
CO	1A4bi (55.4%)	1A3bi (27.0%)										82.4
TSP	1A4bi (26.3%)	3Dc (23.3%)	2I (5.8%)	2A5a (5.8%)	3B4gi (4.3%)	2B10a (3.5%)	2A1 (3.4%)	1A3biii (3.3%)	3B3 (3.2%)	1A1a (2.8%)		81.8
PM10	3Dc (31.9%)	1A4bi (30.5%)	1A3biii (4.3%)	2A1 (4.1%)	2A5a (3.9%)	1A1a (3.6%)	1A3bi (2.3%)					80.6
PM2.5	1A4bi (41.9%)	2A5b (16.6%)	1A3biii (6.3%)	1A1a (4.8%)	2A1 (3.5%)	1A3bi (3.4%)	5E (3.0%)	1A3bii (2.1%)				81.6
PB	1A4bi (26.8%)	1A3bi (14.7%)	1A3biii (10.3%)	1A1a (9.8%)	1A3bvi (9.7%)	2A3 (6.3%)	1A4ai (5.8%)					83.5
HG	1A1a (59.7%)	1A2f (11.6%)	2K (9.7%)									81.0
CD	1A1a (56.7%)	1A4bi (13.1%)	2G (5.4%)	1A2gviii (5.0%)								80.2
DIOX	1A4bi (50.9%)	5C1biii (31.2%)										82.1
PAH	1A4bi (86.6%)											86.6
HCB	3Df (88.1%)											88.1

TABLE 3 CATEGORIES OBTAINED FROM LEVEL ASSESSMENT FOR THE YEAR 2018

COMPONENT	**KEY CATEGORIES (SORTED FROM HIGH TO LOW FROM LEFT TO RIGHT)**											**TOTAL (%)**
SOX	1B2aiv (47.1%)	1A1a (12.2%)	1A1b (9.4%)	1A2f (9.2%)	2B10a (7.6%)							85.4
NOX	1A3biii (32.0%)	3Da1 (17.8%)	1A3bi (7.2%)	3Da2a (6.5%)	1A3c (6.3%)	1A1a (5.7%)	3Da3 (4.7%)					80.1
NH3	3Da1 (34.6%)	3Da2a (28.9%)	3B1a (6.4%)	3B3 (6.0%)	3B1b (5.6%)							81.5
NMVOC	1A4bi (22.7%)	2H2 (11.2%)	3B1a (8.6%)	2D3a (6.6%)	3B1b (6.5%)	3B4h (5.5%)	1B2aiv (4.5%)	3De (4.3%)	2D3d (3.7%)	1A3bi (3.5%)	1A3biii (3.5%)	80.5
CO	1A4bi (60.5%)	1A3bi (16.7%)	1A1a (6.1%)									83.3
TSP	3Dc (27.7%)	1A4bi (19.4%)	2I (11.8%)	2A5a (8.0%)	3B4gi (4.1%)	1A3bi (3.5%)	2B10a (3.1%)	1A3biii (2.4%)	3B4gii (1.9%)			81.8
PM10	3Dc (40.3%)	1A4bi (23.5%)	2A5a (5.7%)	1A3bi (4.8%)	1A3biii (3.3%)	5E (2.6%)						80.2
PM2.5	1A4bi (42.2%)	1A3bi (9.3%)	2A5b (6.6%)	1A3biii (6.3%)	5E (5.1%)	5C2 (3.7%)	1A3bii (3.5%)	3Dc (3.1%)	1A1a (2.1%)			81.8
PB	1A4bi (34.3%)	1A3bvi (18.5%)	1A3bi (10.2%)	1A3biii (7.1%)	1A2f (6.5%)	1A1a (6.4%)						83.0
HG	1A2f (35.8%)	2K (20.3%)	1A4bi (17.6%)	1A4ai (7.6%)								81.3
CD	1A1a (30.7%)	1A4bi (23.2%)	2G (7.7%)	1A2f (5.0%)	1A1b (4.8%)	1A2gviii (4.6%)	2A3 (3.3%)	1A2c (3.1%)				82.3
DIOX	1A4bi (76.1%)	5E (15.4%)										91.5
PAH	1A4bi (93.0%)											93.0
HCB	1A1a (30.0%)	5C1biii (26.5%)	1A4bi (21.9%)	3Df (12.3%)								90.7

1.7 QA/QC and Verification Methods and General Uncertainty Evaluation

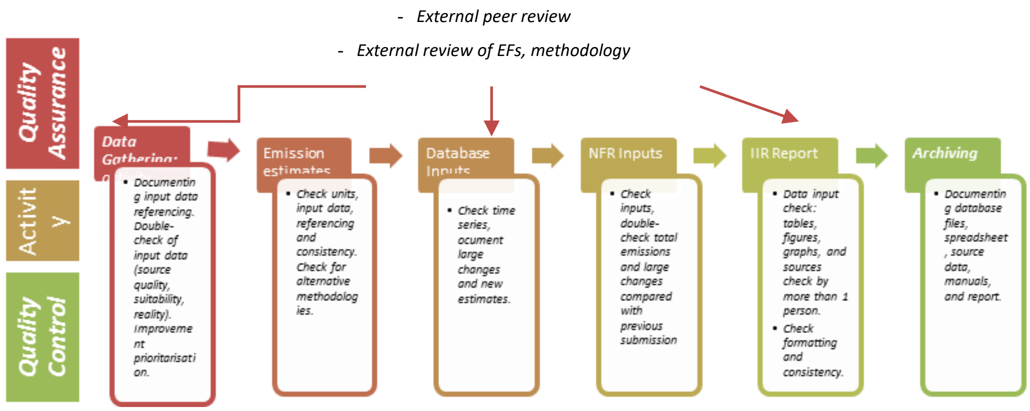

FIGURE 4 QUALITY ASSURANCE AND QUALITY CONTROL METHODS USED TO ENSURE QUALITY AND DATA CONSISTENCY OF THE INVENTORY.

Simple combination of uncertainties (see 2019 EMEP/EEA guidebook) was use to estimate uncertainties for all categories. The following general equation was applied for the most categories:

$$U_{Total} = \sqrt{U(activity\,data)^2 + U(emission\,factor)^2};$$

Where:

U_{Total} is overall uncertainty;

$U_{Activity\ data}$ is uncertainty from activity data;

$U_{Emission\ factor}$ is uncertainty from emission factor.

1.8 General Assessment of Completeness

The NFR Report is completed using following notation keys if numerical pollutant emission value is not provided:

- NO (not occurring) is used for processes that do not occur in the country;
- NE (not estimated) appears for emissions that do happen but are not estimated due to data unavailability or negligibility of emissions;
- NA (not applicable) is used for activities that do not emit specific pollutant;
- IE (included elsewhere) for pollutant emissions which are estimated but included in another category;
- C (confidential) appears for processes which are not reported as reporting at disaggregated level would lead to confidential information disclosure.

DDT, Aldrin, chlordane, chlordecone, dieldrin, endrin, HCB, HCH, heptachlor, mirex, pentachlorophenol (PCP) and toxaphene production, import and use are forbidden according to regulation (EC) No. 850/2004 of the European Parliament and of the Council [1].

TABLE 4 LIST OF SOURCES AND REASONS WHY CATEGORIES WERE NOT ESTIMATED.

Category Code	*Category Name*	*Pollutant*	*Reason(s) why not estimated (NE)*
3.D.a.4	Crop Residues Applied to Soils	All	No method available
3.D.b	Indirect Emissions from Managed Soils	All	No method available
3.D.e	Cultivated Crops	NH3	No method available
3.I	Agriculture Other: Ammonia-treated Straw	All	No activity data available
5.E, SNAP: 091003	Sludge Spreading	All	No activity data available

2 TRENDS IN EMISSIONS

2.1 Pollutant Emission Trends

The emissions trends of nitrogen oxides, carbon monoxide, non-methane volatile organic compounds and sulphur oxide (calculated as sulphur dioxide) emissions are presented in Figure 5 and Table 5.

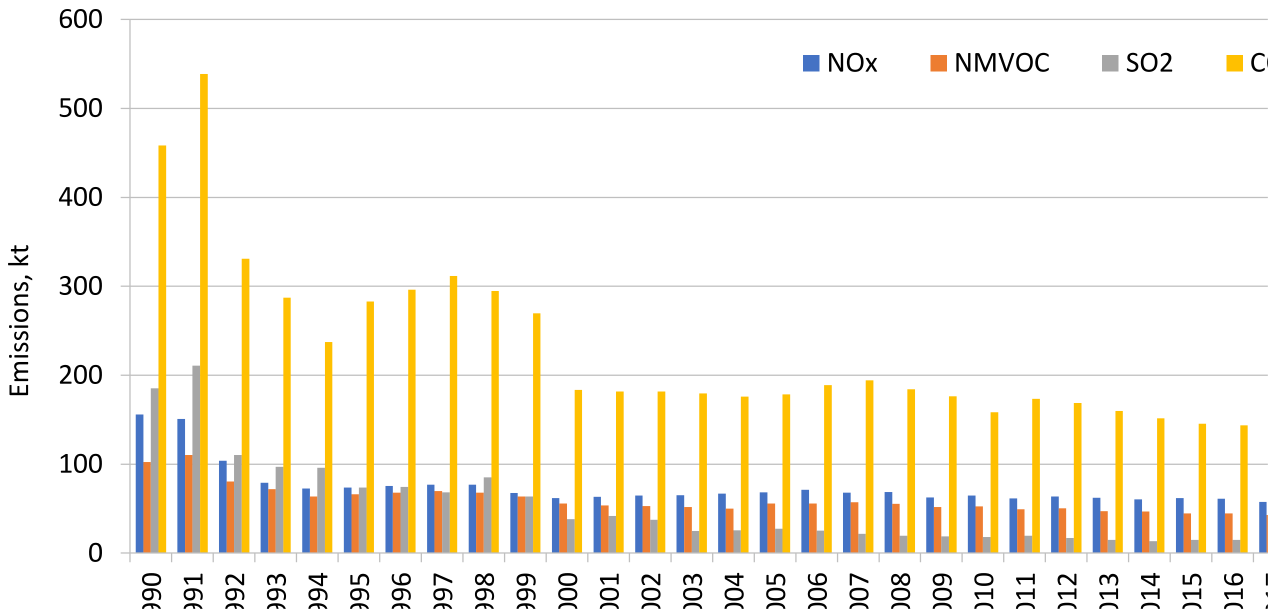

FIGURE 5 TRENDS IN EMISSIONS 1990-2018 (SOURCE: LRTAP AND NEC SUBMISSION 2020)

A rapid decrease of emissions followed the decline of the country economy in the 1990s. Since 2000, the GDP has been growing continuously. See Table 2, Table 3. Table 5 present results from the Level Assessment of the key source for 2005 and 2018. The sources that add up to at least 80% of the national total in 2005 and 2016 are defined as being a key source for each pollutant.

Lithuania has been reporting data regarding national total and sectoral emissions under The LRTAP convention since 2000 (Table 5).

TABLE 5 MAIN POLLUTANT EMISSIONS IN THE PERIOD 1990-2018, KT

	NOx	NMVOC	SO2	NH3	PM2.5
1990	155.72	102.54	185.14	77.28	15.19
1991	150.87	110.41	210.73	76.48	16.30
1992	103.87	80.51	110.24	57.52	9.26
1993	78.93	71.84	96.82	44.57	9.21
1994	72.63	63.72	96.03	40.19	8.56
1995	73.52	65.97	73.77	35.85	7.68
1996	75.33	67.79	74.44	36.48	7.90
1997	77.06	69.75	68.30	35.97	7.95
1998	76.83	68.05	85.06	34.89	8.32
1999	67.67	63.68	63.49	33.21	7.99

2000	61.75	55.62	37.96	32.02	7.05
2001	63.14	53.63	41.77	31.64	7.28
2002	64.73	52.95	37.52	33.44	7.74
2003	65.09	51.89	24.84	34.24	7.41
2004	66.95	50.01	25.58	34.56	7.50
2005	68.45	55.74	27.41	36.12	9.22
2006	71.06	55.55	25.20	36.51	8.87
2007	68.02	57.26	21.67	36.06	8.78
2008	68.74	55.23	19.57	35.91	9.22
2009	62.59	51.74	18.75	36.47	8.27
2010	64.73	52.53	18.07	36.79	7.82
2011	61.52	49.26	19.58	36.61	9.28
2012	63.67	50.31	17.06	35.81	8.10
2013	62.32	47.21	14.71	34.73	6.58
2014	60.55	46.85	13.41	37.16	6.26
2015	61.81	44.61	14.99	46.17	5.45
2016	61.25	44.56	14.94	38.30	5.39
2017	57.62	42.82	12.75	39.35	6.01
2018	58.13	42.55	12.75	38.16	5.76
Trend 2005-2018, % / Change 2018/2005, %	-15.08	-23.67	-53.47	5.65	-37.51
Trend 1990-2018, % / Change 2018/1990, %	-62.67	-58.50	-93.11	-50.62	-62.06
Reduction commitments 2020 vs 2005 (NECD)	**-48%**	**-32%**	**-55%**	**-10%**	**-20%**

2.2 Nitrogen Oxides (NOx)

Total (excluding agriculture) nitrogen oxides emissions have decreased 62% from 143.56 kt in 1990 to 57.23 kt in 2018 (Figure 6).

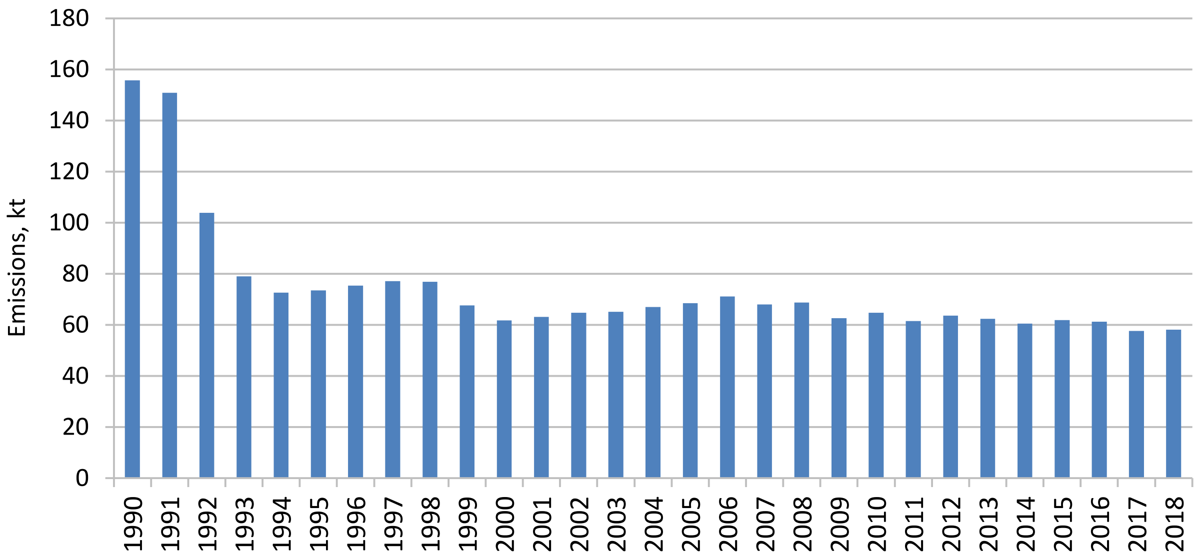

FIGURE 6 NATIONAL TOTAL EMISSION TREND FOR NOx, 1990 – 2018

Road Transport (1.A.3) is the principal source of NOx emissions, contributing ~41 % (and 23.71 kt) of the total in 2018 (Figure 7). The Public Electricity and Heat Production (1.A.1.a) sector accounts for a decreasing percentage of the national total. The contribution of the sector in 1990 to the national total was 11.2 % (17.4 kt), decreased to 5.7% (3.3 kt) in 2018 as a result of the decreases in fuel consumption due to the economic crisis impacting upon the sector (Figure 7). The 3.D.a.1 (17.7%) and Public electricity 1.A.1.a (5.7%) sectors are another main source of NOx emission, accounting for 23.4 % of emissions in 2018. The remainder of the NOx emissions arise from combustion sources in the 3.D.a.1 Inorganic N-fertilizers % of the total in 2018 (17.7 %).

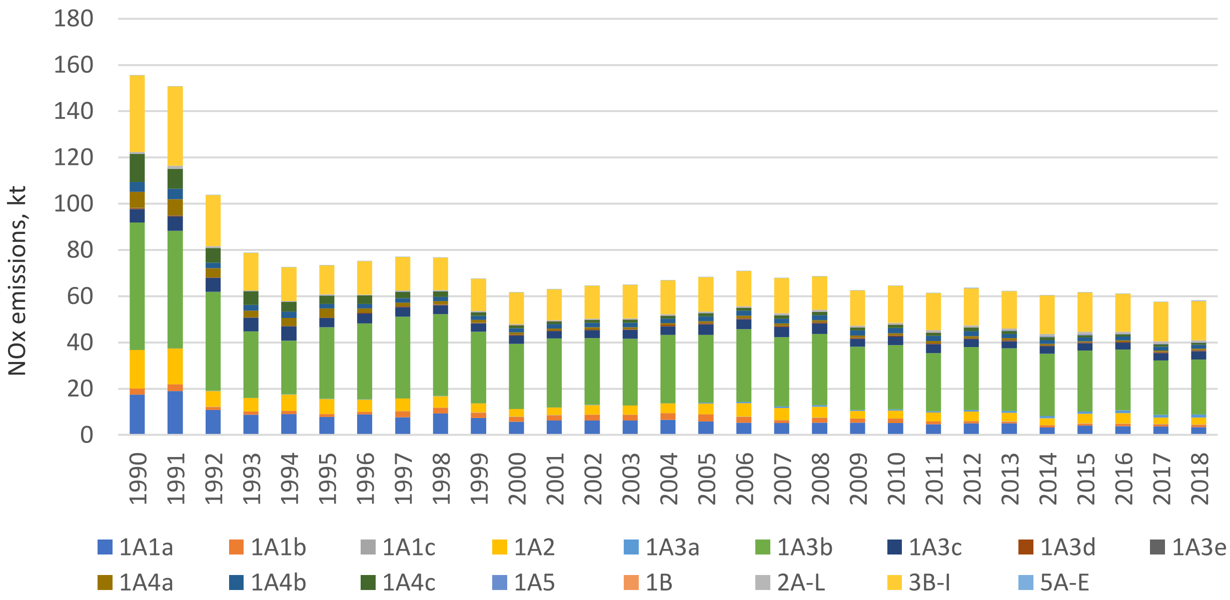

FIGURE 7 EMISSION TREND FOR NOX BY SECTORS, 1990 – 2018

The largest reduction of emissions has occurred in the road transport sector. These reductions have been achieved as a result of fitting three-way catalysts to petrol fueled vehicles. The reduction has been achieved also due to installation of low-NOx burners and denitrifying units in power plants and district heating plants.

2.3 Non-Methane Volatile Organic Compounds (NMVOC)

Total (excluding agriculture) non-methane volatile organic compound emissions have decreased by 58 %, from 102.5 kt in 1990 to 42.6 Gg in 2018 (Figure 8). The sources for the NMVOC emissions can be divided into main groups: solvents and incomplete combustion. The main contributor of NMVOC in the year 2018 is Industry and Solvents (2A-L, 3.B) – 55.6% and Residential: Stationary plants (1.A.4.b, 22.7 %), followed by Transport (1.A.3, 10.0 %).

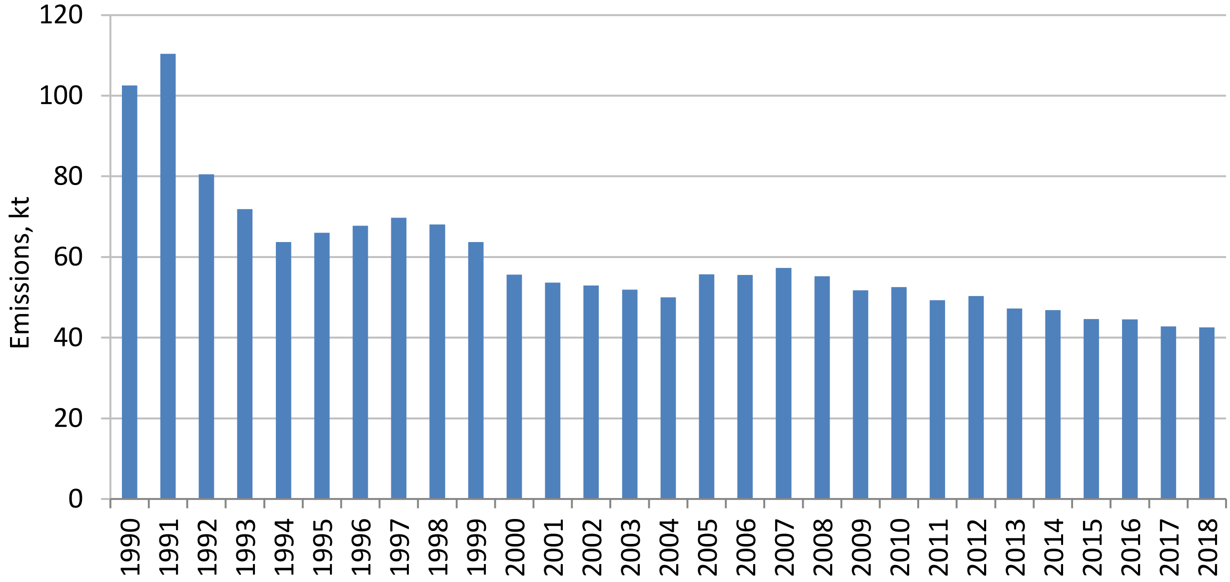

FIGURE 8 NATIONAL TOTAL EMISSION TREND FOR NMVOC, 1990-2018

The decline in emissions since 1990 has primarily been due to reductions achieved in the road transport sector due to the introduction of vehicle catalytic converters, driven by tighter vehicle emission standards. The reductions in NMVOC emissions have been enhanced by the switching from petrol to diesel cars.

The NMVOC emissions are determined mainly by Residential: Stationary plants and Road Transport. The combined solvents produced 25.9% of the 2018 total of NMVOC emissions in Lithuania having decreased between 1990 (17.8 kt) and 2018 (11.03 kt).

Technological controls for volatile organic compounds (VOCs) in motor vehicles have been more successful than in the case of NOx, and have contributed to a significant reduction in emissions from Road Transport (1.A.3.b), with the total transport sector's contribution having decreased by 60% between 1990 (24 %) and 2018 (10 %) (Figure 9).

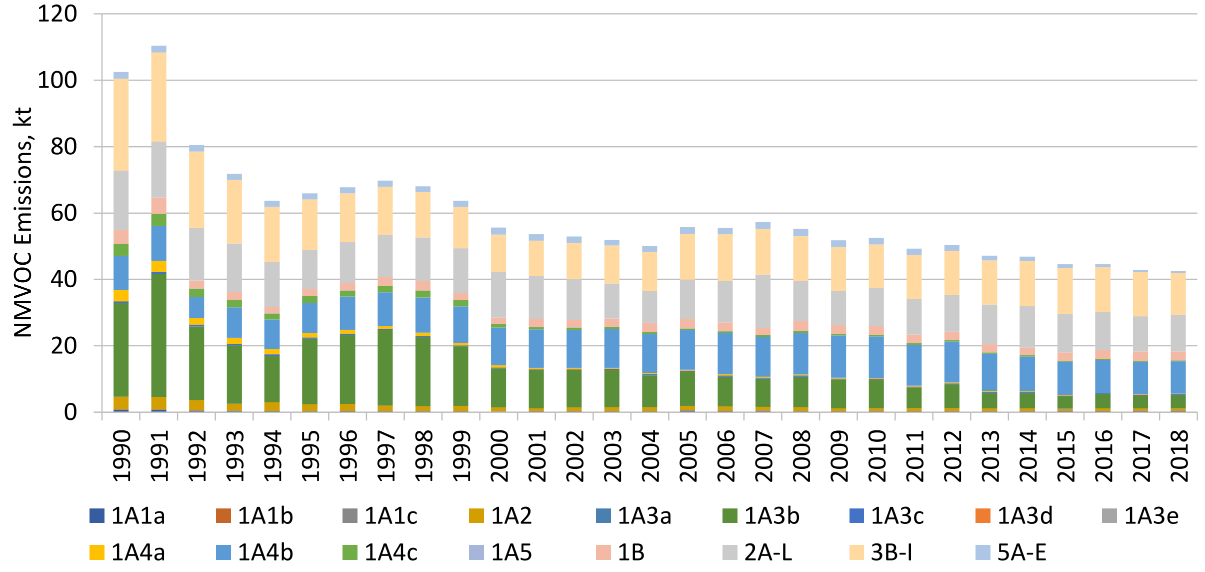

FIGURE 9 EMISSION TREND FOR NMVOC BY SECTORS, 1990-2018

Combustion sources in the Residential (1.A.4.b) sector is another important source, accounting for 22.7% of national total NMVOC emissions in 2018.

2.4 Sulphur Dioxide (SO_2)

The main part of the SO_2 emission originates from combustion of fossil fuels, mainly coal and oil in public power plants and district heating plants. Total sulphur dioxide emissions decreased by 93.1 %, from 185.1 kt in 1990 to 12.8 kt in 2018 (Figure 10). The Public electricity and heat production (1.A.1.a) and Fugitive emissions oil: Refining / storage (1.B.2.a.iv) sectors remain the principal source of SO_2 emissions, contributing 59.3% of the total in 2018.

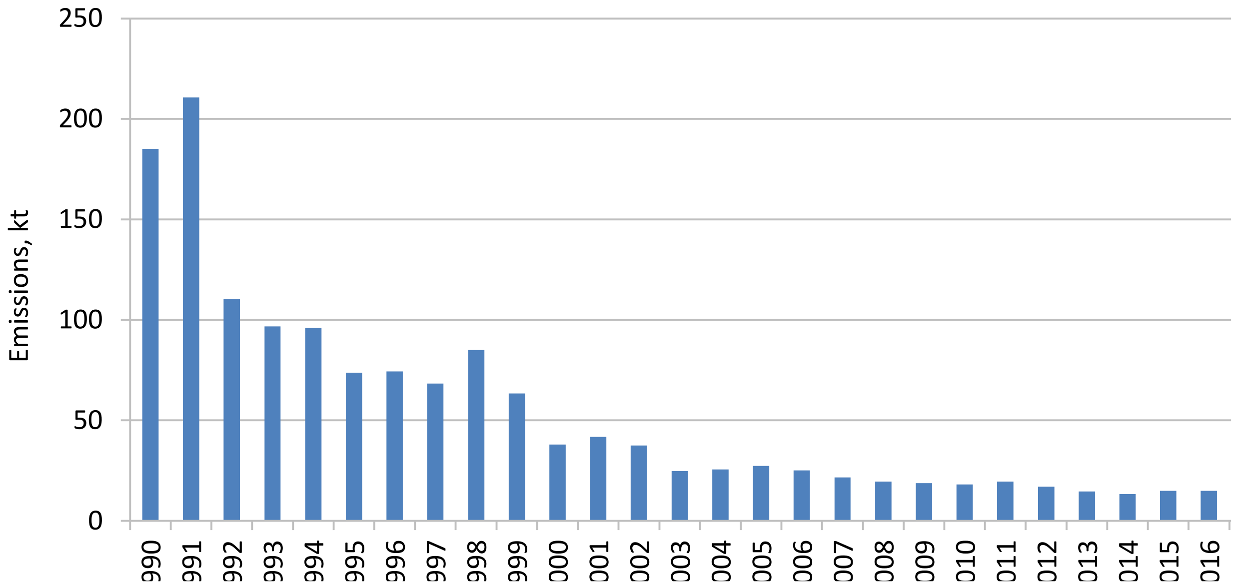

FIGURE 10 NATIONAL TOTAL EMISSION TREND FOR SO2, 1990-2018

Public Electricity and Heat Production (1.A.1.a) sector accounts for 12.2% of the total in 2018 and Stationary combustion in manufacturing industries and construction (1.A.2) sector largely account for the remainder of the emissions, with contribution of 11.0% in 2018. Chemical industry: Other (1.A.1.b) sector account for 9.4% of national total emissions of SO_2 in 2018 (Figure 11).

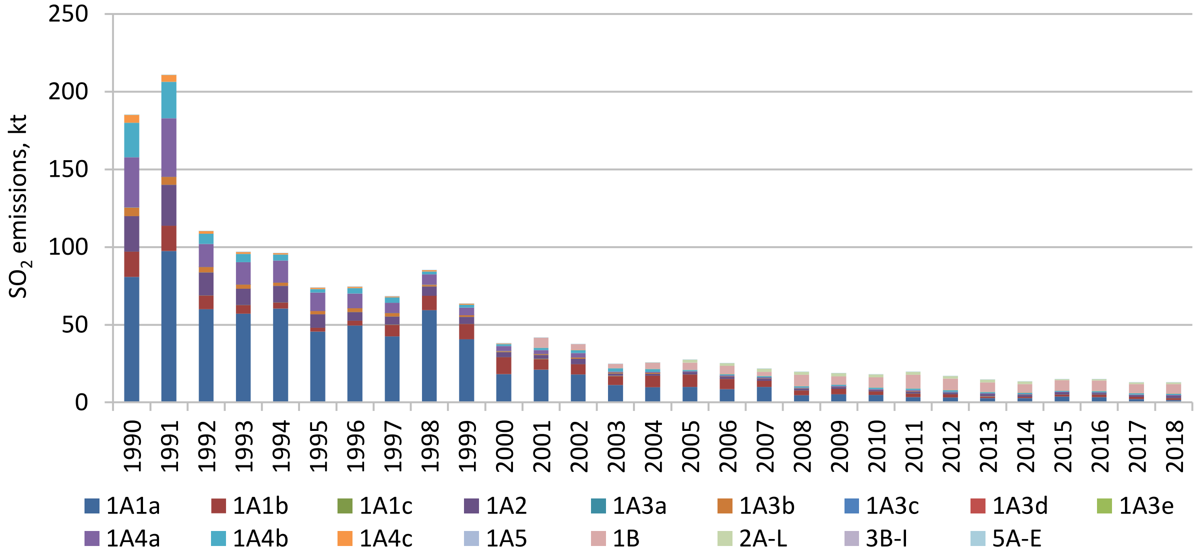

FIGURE 11 EMISSION TREND FOR SOX BY SECTORS, 1990-2018

The large reduction is largely due to installation of desulphurisation plant, use of fuels with lower content of sulphur in public power and district heating plants, introduction of liquid fuels with lower content of sulphur and substitution of high-sulphur solid and liquid fuels to low-sulphur fuels such as natural gas. Despite the large reduction of the SO_2 emissions, these plants make up about 71 % of the total emission.

2.5 Ammonia (NH_3)

Almost all atmospheric emissions of NH_3 result from agricultural activities (92.2%) and Residential: Stationary sector accounted for 2.3% of the total in 2018. Only a minor part originates from other combustion sectors. The total ammonia emission increased from 36.1 kt in 2005 to 38.2 kt in 2018. This is due to decreasing livestock population (Figure 12).

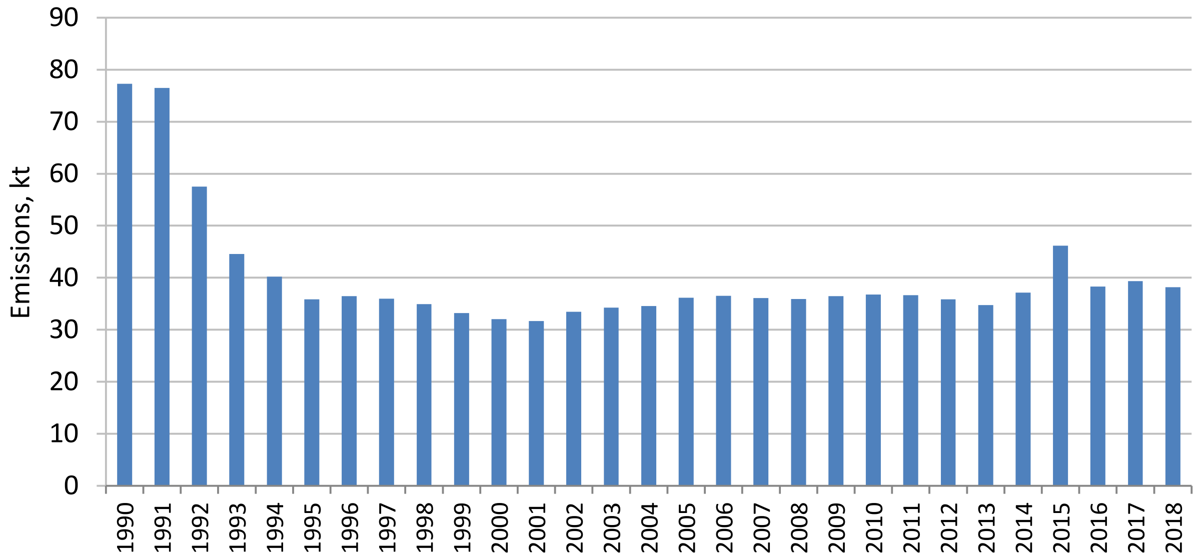

FIGURE 12 NATIONAL TOTAL EMISSION TREND FOR NH_3, 1990-2018

The major contributor to the total amount of NH3 emissions is agriculture sector (Figure 13). Throughout the 1990–2018 time series, the small contribution by Transport (1.A.3) sources has increased. Emissions from Sector 1.A.3.b have increased from 0.03 Gg in 1990 to 0.17 Gg in 2018.

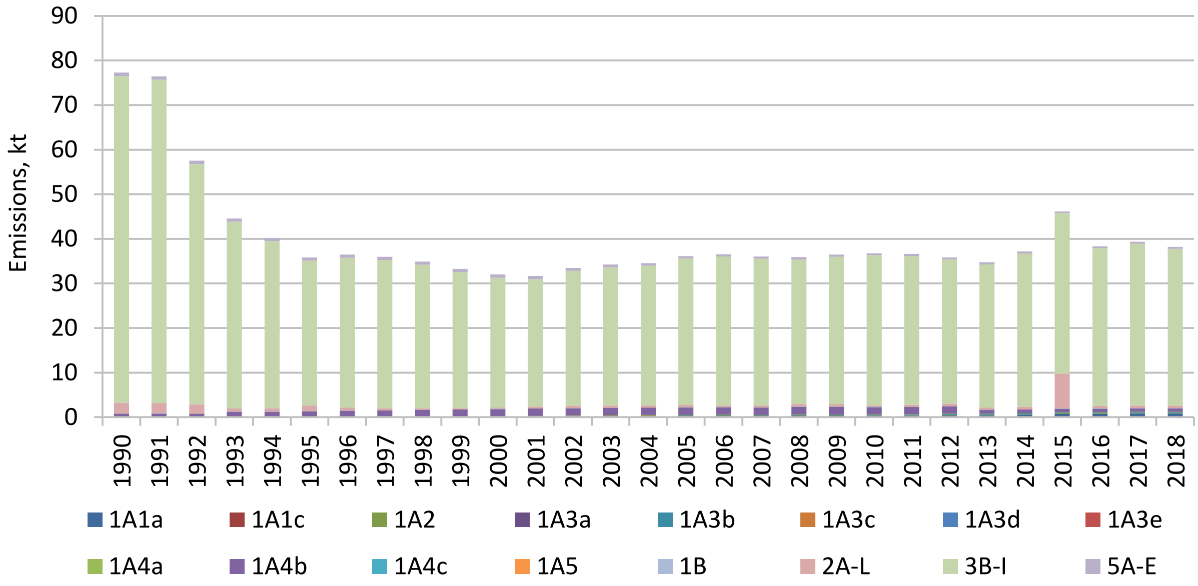

FIGURE 13 EMISSION TREND FOR NH3 BY SECTORS, 1990-2018

The emission ceilings of NECD were designed with the aim of attaining the European Community's interim environmental objectives set out in Article 5 of NECD by 2010. Meeting those objectives is expected to result in reduced acidification, health-and vegetation-related ground-level ozone exposure by 2010 compared with the 1990 situation.

2.6 PM2.5

PM2.5 emissions have decreased in 2005-2018 by 37.5%, and PM10 and TSP emissions have decreased by 18.0% and 12.7%. The largest part of PM emissions are produced in Energy sector (including Transport) – PM2.5 is 69.7%, with exception of PM10 – 38.9% and TSP emissions (31.6%) where emissions was produced in IPPU from total emissions in 2018 and 23.5% in Energy sector, it is connected with intensive combustion of wood, especially in Residential sector (NFR 1.A.4.b).

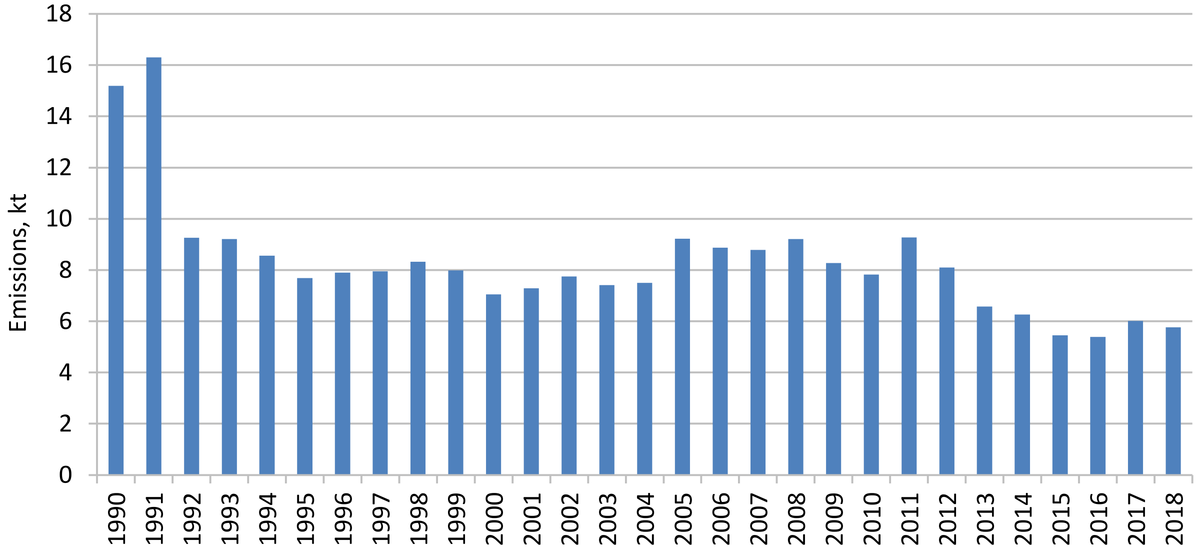

FIGURE 14 EMISSION TREND FOR $PM_{2.5}$, 1990-2018

PM emissions have increased in 2015-2018: $PM_{2.5}$ by 5.7%, PM_{10} by 1.4% and TSP by 10.6%. Increase in 2018 can be explained with increased activity in Road transport (NFR 1.A.3.b) (Figure 15).

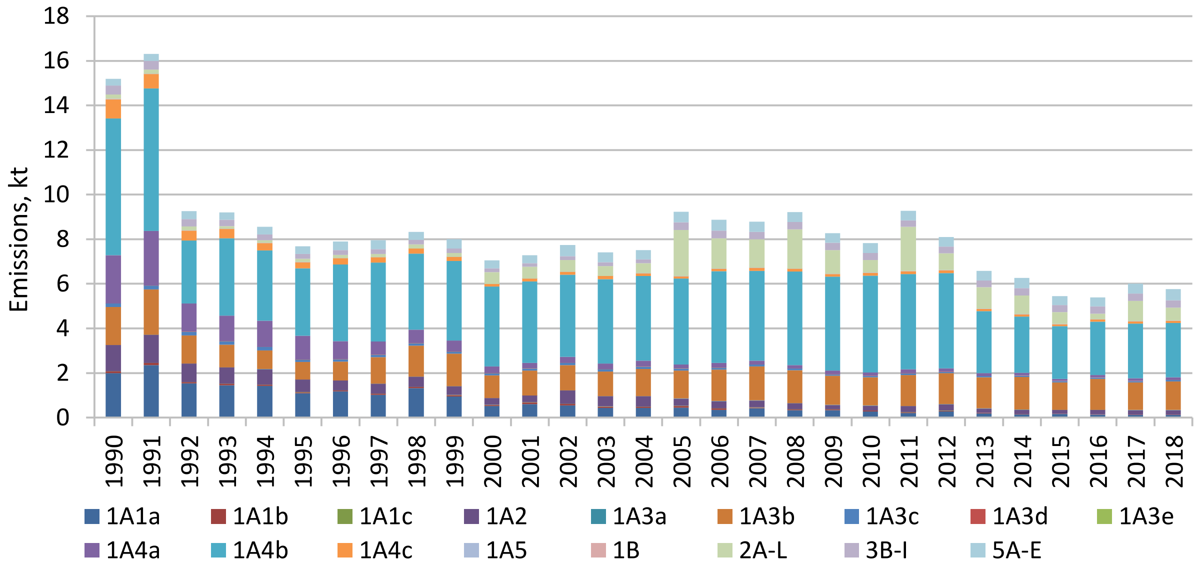

FIGURE 15 EMISSION TREND FOR $PM_{2.5}$ BY SECTORS, 1990-2018

3 ENERGY

3.1 Energy Sector overview

Energy Sector is the main source of the emissions accounting.

NFR 1.A.1.a Public electricity and heat production includes pollutants emission data from large point sources (LPS) reported by operators and from diffuse sources.

NFR 1.A.1.b Petroleum refining**.** Emissions are calculated on the basis of measurements or the combined method by producers (ORLEN Lietuva) (measurements plus calculations).

NFR 1.A.1.c The manufacture of solid fuels includes fuel data reported by statistics Lithuania.

Emissions from this source category have historically contributed significantly to the total anthropogenic emissions.

The Ignalina Nuclear Power Plant (NPP) played a key role in the Lithuanian energy sector producing up to 70-80% of the electricity until its closure by the end on 2009. It had installed capacity of 3000MW in two RB MK-1500 (large power channel reactor) reactors. The share of electricity produced in Ignalina NPP has been taken over mainly by the Lithuanian Thermal Power Plant and the largest combined heat and power plants at Vilnius and Kaunas. The closure of the Ignalina Nuclear Power Plant in Lithuania dramatically slashed the volume of electricity produced in the Baltic states. Finding new sources of energy to satisfy the needs of both businesses and the people of the region has become an overriding strategic priority.Thus, the projected energy demand after the decommissioning of Ignalina NPP has been met by using the existing generating capacities. The country is very dependent on electricity produced from fossil and gaseous fuels which are imported from the single source.

In February 2007, the three Baltic states (Lithuania, Latvia and Estonia) and Poland agreed to build a new nuclear plant at Ignalina, initially with 3200 MWe capacity (2 x 1600 MWe). Though located next to the Soviet-era Ignalina plant, the new one was to be called Visaginas after the nearby town of that name. The Visaginas Nuclear Energy (***Visagino Atominė Elektrinė***, VAE) company was established in August 2008 for the new units.

TABLE 6 PLANNED POWER REACTORS IN LITHUANIA

Reactor	*Type*	*Gross MWe*	*Construction start*	*Operation*
Visaginas 1	ABWR	1350	?	?

Visaginas is envisaged as the cornerstone of the new Baltic Energy Market Interconnector Plan linking to Poland, Finland and Sweden. A high-voltage (400 kV) 1000 MW interconnection, costing €250-300 million, to improve transmission capacity between Lithuania and Poland is to be built, with 500 MW by 2015 and another 500 MW by 2020http://world-nuclear.org/info/inf109.html. Much of the funding is from the European Union (EU). This follows inauguration of an interconnector between Estonia and Finland – Estlink-1, a 150 kV, 350 MW DC cable costing €110 million and also supported by EU funding. Estlink-2 will provide a further 650 MW in 2015. Another major transmission link under the Baltic Sea, the 700 MWe NordBalt project, is planned between Klaipeda in Lithuania and Nybro in Sweden. The €550 million project is expected to be completed by 2015http://world-nuclear.org/info/inf109.html - References. (The Baltic states and Belarus have good interconnection of grids from the Soviet era, but this did not extend to Poland, let alone to Germany. Kaliningrad gets all of its electricity from Russia, via the Lithuanian grid.)

Lithuania is also objecting on the same basis to Belarus plans to build a new nuclear power plant at Ostrovetsk, 23 km from the border and 55 km from Vilnius.

Fuel consumption in transport sector is dominated by diesel oil (56 %) and petrol (27 %). Passenger cars are mostly using petrol fuel and gas, whereas buses and heavy-duty vehicles run mainly on diesel fuel. The use of liquefied petroleum gas is strongly influenced by the fluctuation of fuel prices. In navigation diesel fuel and fuel oil are used.

District heating has an approximately 68% market share in the Lithuanian heat market, including delivery to industry. Approx. 58% of households are connected to the heating grid, the remaining percentage is due to the industrial and commercial sector. In total, 19,7 TWh heat was delivered to the grid system in 1997. Gas has a 55% share and oil 37% of input for district heat production. Lithuania is mostly a lowlands country, and as such does not have huge amounts of hydroelectric power potential. There are two major hydroelectric facilities on the Nemunas, both near the city of Kaunas; the larger of these is a pumped storage facility that eventually (after a second phase of construction) could have a capacity of as much as 1 600 MWe.

3.2 PUBLIC ELECTRICITY AND HEAT PRODUCTION (1.A.1.a)

Public electricity and heat production sector includes public CHP plants, autoproducer CHP plants, public heat plants, autoproducer heat plants and geothermal plants.

In the electricity sector the government owns the majority of production, transportation and distribution enterprises. The Law on Electricity of Lithuania, adopted on 7 February 2012, provides the legal framework for the development and enhancement of the competitiveness of the Lithuanian electricity market and ensures the activities of the power transmission system operator are separated from those of other power sector enterprises.

Lithuania faces some challenges in the district heating sector, which are related to the possibility of integrating renewable and local energy resources. A wider use of renewable energy can help energy supplies be diversified and the targets for sustainable development to be met.

In terms of the natural gas supply, Lithuania has to rely on two main wholesale companies, “Lietuvos Dujos” AB and “Dujotekana” UAB, which dominate the natural gas supply market. The natural gas retail market is 100% open in Lithuania but, due to the high concentration on the supply side, customers may not use the advantage of the open market. On the distribution side, it should be noted that approximately one third of the territory of Lithuania has not been gasified. Lithuania‘s natural gas transmission system is connected to Belarus’, Latvia’s and the Russian Federation’s gas systems. International connections with these countries are regulated on a contract basis. The technical capacities of the existing interconnection with Belarus are sufficient to meet customer needs. At present, Lithuania’s natural gas market is not integrated with those of other EU member states. In 2010 the Lithuanian Government made the decision to construct an LNG terminal in Klaipeda. The state enterprise Klaipedos Nafta was selected as the main terminal construction instrument. The projected potential capacity of the terminal is at its maximum 3 billion cubic metres (bcm)/a. The plan is that the plant will start its operations in 2014. The LNG terminal project is included in the Baltic Energy Market Interconnection Plan (BEMIP), which was approved by the European Commission and eight Baltic Sea states on 17 June 2009.
The production of electricity and heat from fossil fuels has traditionally been the most important source of key pollutants such as SO_2 and NO_X in most countries. 1.A.1.a sector remains one of the major

emission categories, even though the emissions of SO_2 and NO_X and other substances have decreased significantly over the 1990–2018 time series (Figure 5). The level of emissions in Sector 1.A.1.a depends heavily on the mix of fossil fuels used for electricity production. In 1990, coal, residual oil, diesel oil and natural gas were the principal fuels used. The use of coal and residual oil declined as biomass and natural gas became the preferred fuel during latter years, especially for new entrants in electricity production (Figure 16). After the collapse of the Soviet Union and the reestablishment of Independence in 1990, Lithuania substantially changed its core economic and institutional values. Lithuania has inherited the economy wherein energy consumption per unit of production was 3 times higher than in analogous West European industries.

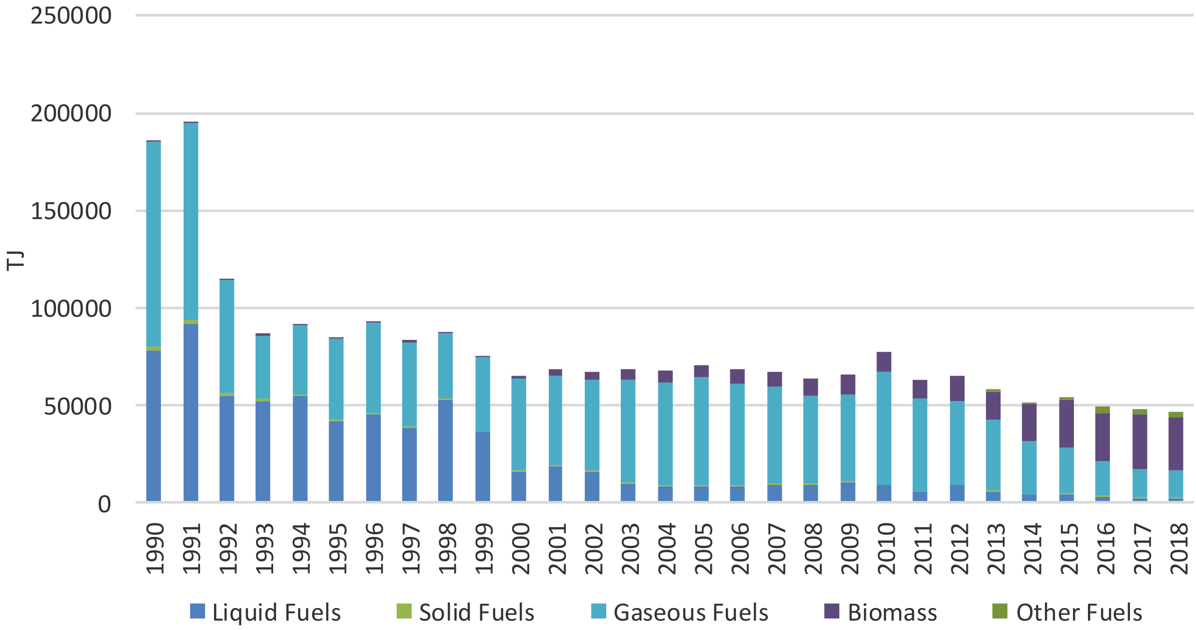

FIGURE 16 TENDENCIES OF FUEL CONSUMPTION IN 1.A.1.A

Natural gas is the main fuel used in the district heating sector. Since 2000 the share of renewable energy (biomass, wood, straw, chips, sawdust, wood pellets) increased significantly from 2% (2000) to 40.0% (2018) in Lithuanian district heating sector. Relevant share of residual fuel oil used for heat production in district heating systems was replaced by renewable energy sources mainly by biomass.

A very sharp increase in primary energy prices and loss of the former Eastern markets brought about a noticeable decline of national energy industry and energy exports. Energy demand and its production decreased almost by half.

After Lithuania had succeeded from the Soviet Union, the latter critically curtailed the supplies of energy and other resources. As a result, the economic output of Lithuania decreased by one third in 1992 and by one fourth in 1993.

TABLE 7 POLLUTANT EMISSIONS FROM THE 1.A.1.A IN THE PERIOD 1990-2018

	NOX	NMVOC	SOX	NH3	PM2.5	PM10	TSP	CO	SOX
1990	17,443	0,794	80,797	0,019	1,998	2,550	3,021	0,070	8,808
1991	19,002	0,806	97,527	0,036	2,347	3,019	3,553	0,076	8,770
1992	10,780	0,508	60,067	0,033	1,531	1,965	2,268	0,048	5,945
1993	8,753	0,425	57,139	0,033	1,447	1,861	2,140	0,044	4,822

1994	9,098	0,382	60,451	0,018	1,427	1,853	2,160	0,041	4,074
1995	7,847	0,326	45,667	0,021	1,093	1,420	1,643	0,031	3,560
1996	8,863	0,343	49,402	0,024	1,169	1,520	1,765	0,033	3,771
1997	7,600	0,304	42,418	0,030	1,026	1,334	1,531	0,029	3,459
1998	9,242	0,316	59,409	0,036	1,314	1,708	2,065	0,046	3,461
1999	7,398	0,275	40,619	0,023	0,953	1,234	1,457	0,031	3,227
2000	5,704	0,229	18,286	0,061	0,510	0,648	0,733	0,019	3,174
2001	6,322	0,256	21,054	0,106	0,606	0,764	0,862	0,025	3,664
2002	6,268	0,253	18,058	0,154	0,549	0,681	0,781	0,030	3,877
2003	6,266	0,263	11,218	0,187	0,432	0,517	0,586	0,031	4,289
2004	6,583	0,273	9,832	0,237	0,425	0,496	0,570	0,036	4,657
2005	5,794	0,464	9,930	0,233	0,446	0,496	0,540	0,208	4,865
2006	5,320	0,363	8,531	0,236	0,347	0,404	0,462	0,102	4,785
2007	5,164	0,423	10,065	0,204	0,414	0,478	0,547	0,141	5,008
2008	5,261	0,310	4,522	0,260	0,326	0,388	0,473	0,064	4,584
2009	5,245	0,275	5,295	0,283	0,329	0,404	0,510	0,020	4,731
2010	5,201	0,302	4,797	0,279	0,282	0,345	0,434	0,017	5,150
2011	4,641	0,261	3,421	0,257	0,198	0,238	0,293	0,012	4,540
2012	5,062	0,291	3,220	0,370	0,267	0,332	0,424	0,016	5,271
2013	4,979	0,312	2,772	0,427	0,186	0,229	0,286	0,011	5,659
2014	3,256	0,306	2,815	0,594	0,150	0,183	0,227	0,010	6,195
2015	4,093	0,353	3,704	0,780	0,157	0,191	0,241	0,012	7,470
2016	3,751	0,343	3,403	0,779	0,131	0,158	0,192	0,010	7,414
2017	3,610	0,395	2,086	0,887	0,124	0,148	0,176	0,010	8,599
2018	3,312	0,389	1,564	0,869	0,120	0,144	0,170	0,009	8,483
2005/2018, %	**-37,69**	**-14,88**	**-79,00**	**281,29**	**-72,25**	**-70,22**	**-67,41**	**-95,34**	**76,74**
2017/2018, %	**-8,26**	**-1,40**	**-24,99**	**-2,00**	**-2,84**	**-2,69**	**-3,46**	**-3,11**	**-1,35**

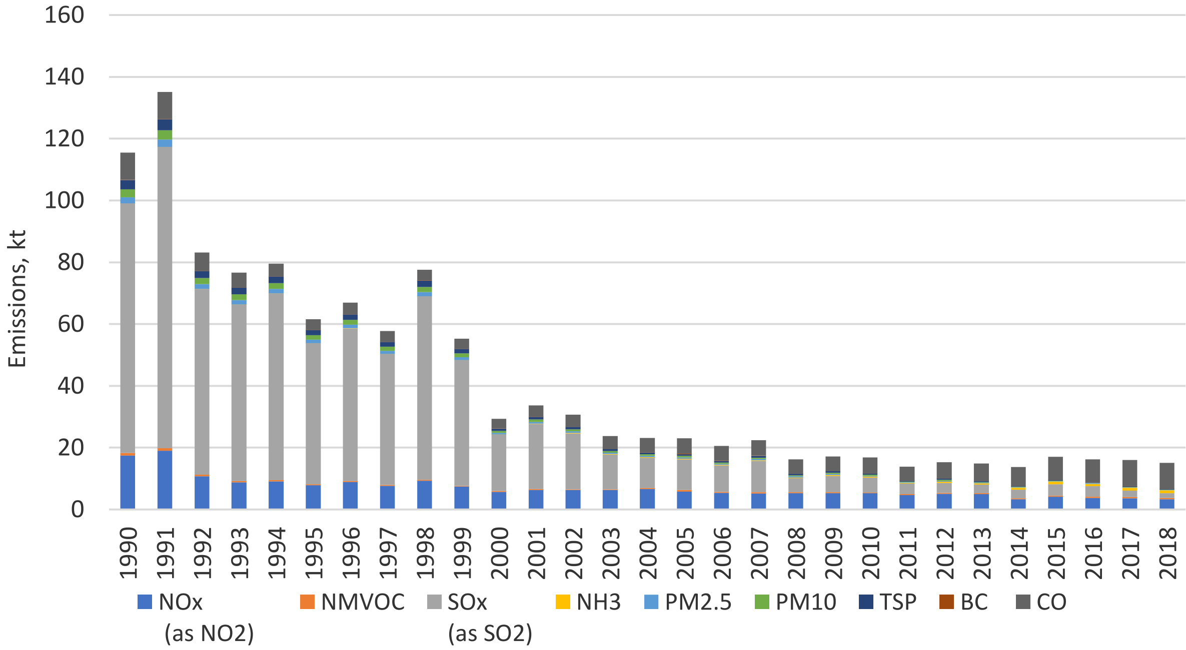

FIGURE 17 MAIN POLLUTANT EMISSIONS IN 1.A.1.A

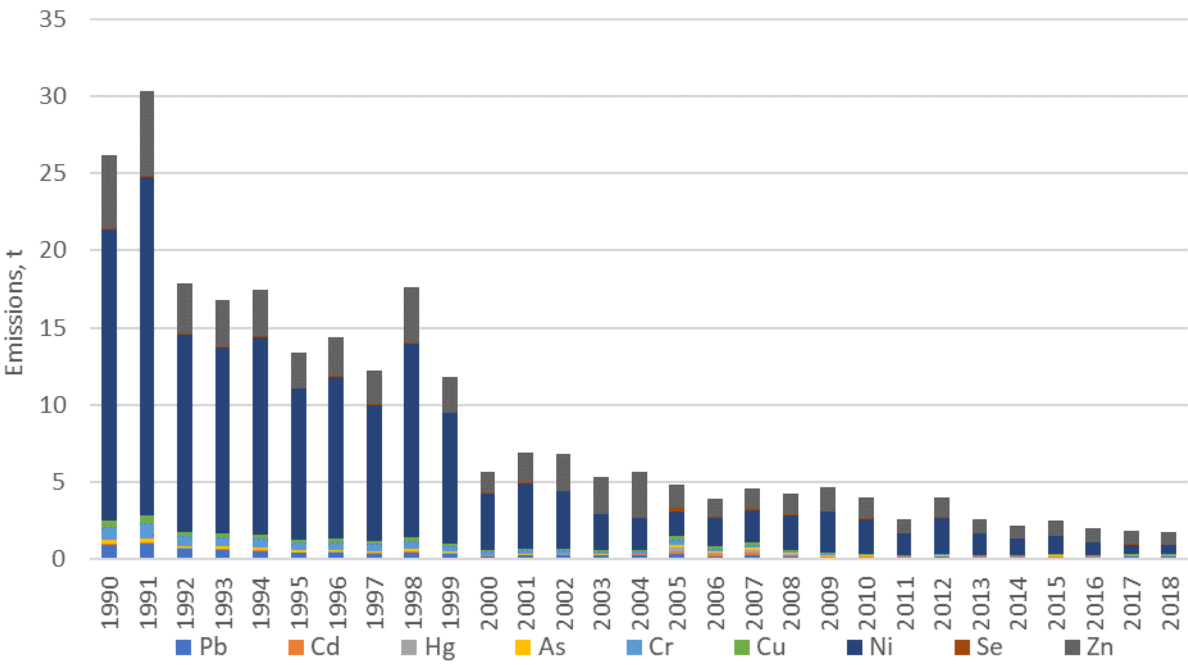

FIGURE 18 HEAVY METAL EMISSIONS IN 1.A.1.A

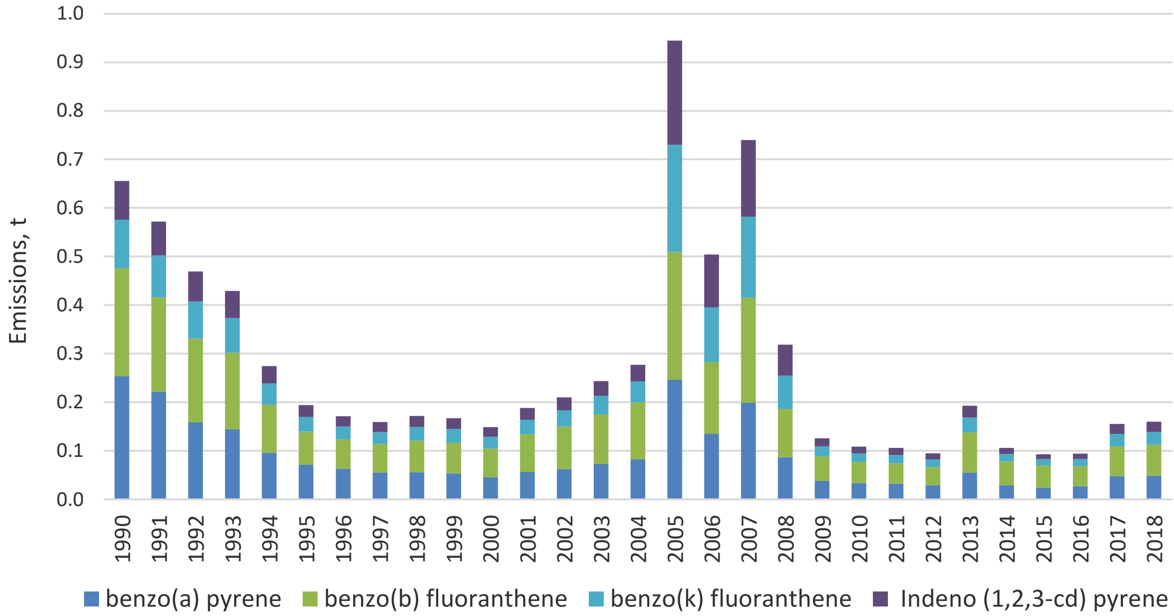

FIGURE 19 PAHS EMISSIONS IN 1.A.1.A

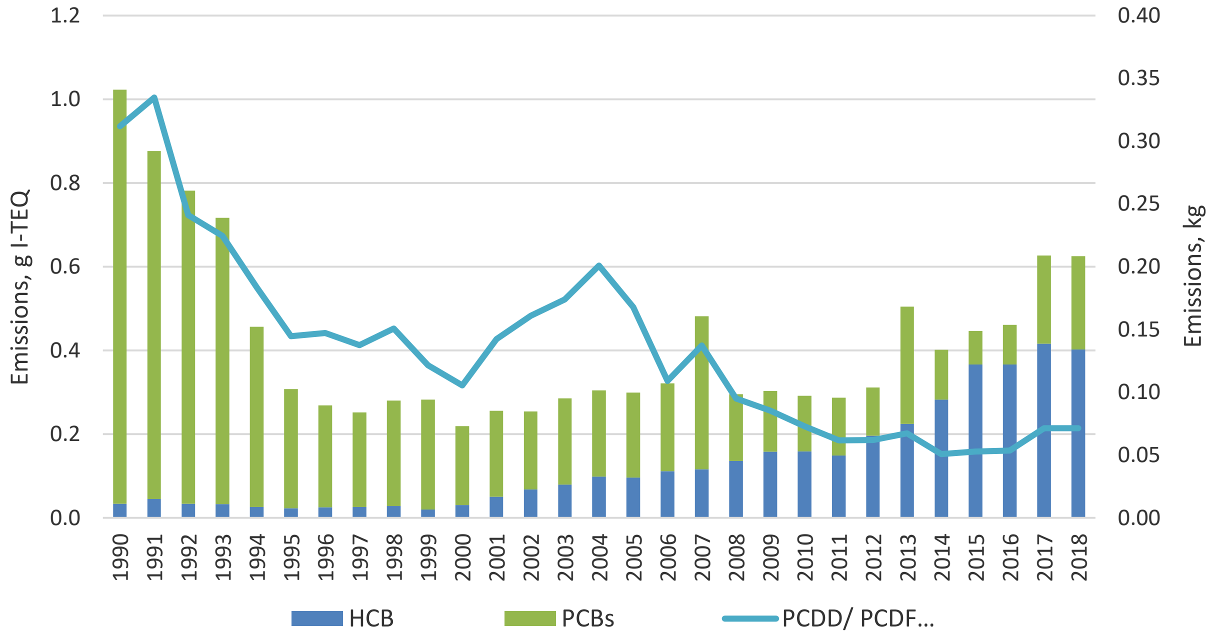

FIGURE 20 HCB, PCBS, PCDD EMISSIONS IN 1.A.1.A

3.2.1 Source category description

Data on direct emissions from large point sources was obtained from their annual emission questionnaires submitted to the EPA under Ministry of Environment. Emissions from area sources are estimated according to statistical fuel consumption data (Statistics Lithuania).

3.2.2 Methodological issues

A combination of Tier 3 (plant reports), Tier 2 (specific emission factors for gas turbines) and Tier 1 (default emission factor for the remaining fuels) was used. The main source of data for all energy industries in the Lithuania for the period 1990-2018 is Statistics Lithuania. Tier 1 with Tier 2 methods was used in 1.A.1.c and Tier 2 in 1.A.2.f, 1.A.1.b, 1.A.4.a, 1.A.4.b, 1.A.4.c, 1.B.2.a. The Tier 2 approach was applied with the activity data and the country-specific emission factors according to a country's fuel usage and installed combustion technologies.

3.2.3 Emission factors

Emission factors from Guidebook 2019 were applied: sector 1.A.1 Energy industries, chapter 3.4.2.2 Default Tier 1 emission factors (EF) (Table 49, Table 50, Table 52), chapter 4.4.2.2 Default emission factors (Table 53), chapter 3.3.2 Technology-specific emission factors (Table 73, Table 75, Table 76, Table 77, Table 78, Table 79, Table 81, Table 89); sector 5.C.1, chapter 3.2.2 Default emission factors (Table 110). The following nationwide abatement efficiency starting from the year 2000 was applied for calculating PM, Heavy metals, PAHs, Dioxins/Furans emissions:

Abatement efficiency												
		2000	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Fuel:	Coal, Peat											
Combustiom technology:	> 50 kWth to ≤ 1 MWth boilers											
Abatement efficiency, %:	0	14,5	58,0	58,0	58,0	58,0	72,5	72,5	72,5	72,5	72,5	72,5
Fuel:	Coal, Peat											
Combustiom technology:	>1 MWth to <=50 MWth boilers											
Abatement efficiency, %:	0	4,8	19,3	19,3	19,3	19,3	24,2	24,2	24,2	24,2	24,2	24,2
Fuel:	Wood											
Combustiom technology:	> 50 kWth to ≤ 1 MWth boilers											
Abatement efficiency, %:	0	13,6	54,4	54,4	54,4	54,4	68,0	68,0	68,0	68,0	68,0	68,0
Fuel:	Wood											
Combustiom technology:	>1 MWth to <=50 MWth boilers											
Abatement efficiency, %:	0	16,4	65,7	65,7	65,7	65,7	82,1	82,1	82,1	82,1	82,1	82,1

Abatement efficiency was estimated on the basis of National EF research, the ratio of national EF for PM2.5 to Guidebook 2019 EF for PM2.5 and national scale of usage of the abatement technologies.

3.2.4 Uncertainty

Uncertainty of activity data in Heat and Power Generation is ±2.0% taking into consideration recommendations provided by *the 2006 IPCC Guidelines*. According to *the 2006 IPCC Guidelines* (Volume 2, Chapter 1, page 1.19) biomass data are generally more uncertain than other data in national energy statistics, because a large fraction of the biomass may be part of the informal economy, and the trade in these types of fuels is frequently not registered in the national energy statistics and balances. That is a reason for higher uncertainty for biomass activity data than for other fuel types. The uncertainty rage for biomass is assigned ±5.0% taking into account implementation of solid biomass accounting rules for energy sector enterprises, biomass sellers and other legal entities (after revision in 2015) and following recommendations provided by *the 2006*

IPCC Guidelines. For emisssion factors from EMEP/EEA Guidebook 2019, uncertainty is indicated as the extreme points of the 95% confidence interval.

3.2.5 Implementation of NECD 2019 Review recommendations

Partially implemented.

3.3 PETROLEUM REFINING (1.A.1.B)

3.3.1 Source category description

Refineries require electrical and thermal energy in substantial quantities. Electrical and thermal energy is typically generated by combined heat and power (CHP) or cogeneration facilities at the refinery. Thermal energy can be provided directly (process furnaces on the production unit) or via steam produced within the production unit or from a utilities facility. The technologies for production of energy from combustion can be identical to those for 1.A.1.a. activities but in many instances the difference will be that the fuels utilized will be refinery gaseous and liquid fuels. Where non-refinery fuels are used in combustion processes the information provided in the 1.A.1.a activity can be applied. NOx, SOx and NMVOC emission data were taken from Refinery plant reports.

This chapter presents the entire consumption of fuels in oil industry. Main representative of this sector is only one company. Refineries process crude oil into a variety of hydrocarbon products such as gasoline, kerosene and etc. UAB ORLEN Lietuva[1] is the only petroleum refining company operating in the Baltic States. Oil refinery processes approximately 10 million tonnes of crude oil a year. The company is the most important supplier of petrol and diesel fuel in Lithuania, Latvia and Estonia.

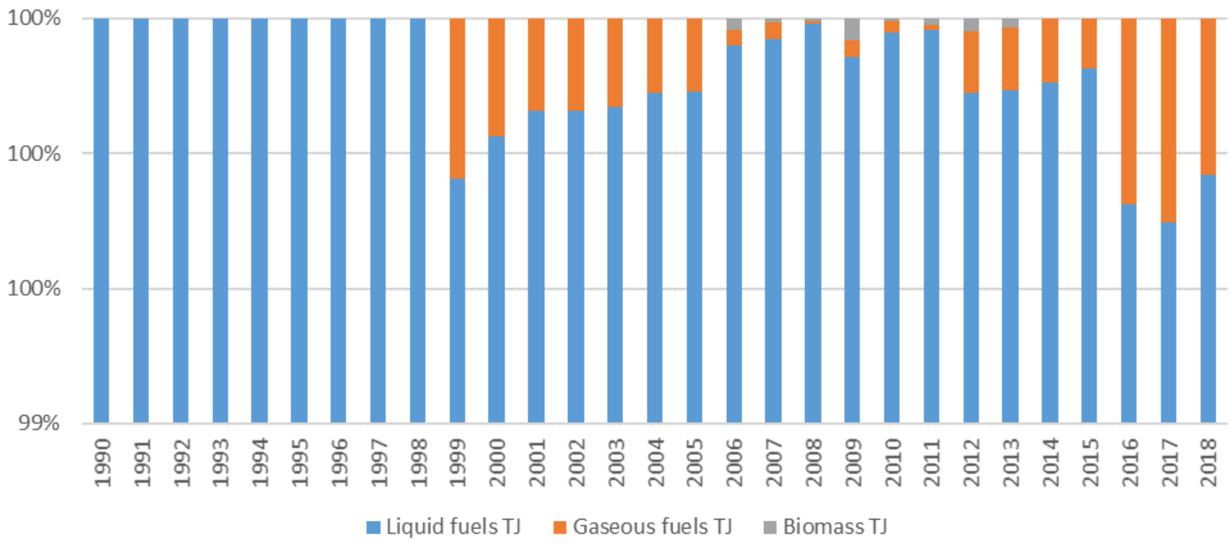

FIGURE 21 TENDENCIES OF FUEL CONSUMPTION 1A1B IN 1990-2018

Motor gasoline, jet kerosene, gas/diesel oil, residual fuel oil, LPG and non-liquefied petroleum gas used in Lithuania are produced by the oil refinery UAB ORLEN Lietuva. Imports of the fuels specified above comprise only a minor fraction of the fuels used in Lithuania (Figure 21). SOx emissions from coal,

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[1] http://www.orlenlietuva.lt

heavy fuel oil (mazut), peat combustion are based on national data on sulfur content in these types of fuel; SOx emissions from wood, natural gases combustion are based on EFs from GB2016. The SOx abatement device is installed in the biggest Lithuanian power plant Lietuvos elektrinė; SOx emission data from ORLEN petroleum refinery power plant are obtained from continous monitoring. About half of NOx emissions are based on plants reports. For gas turbines Tier2 EF for NOx from GB2019 was applied. There is only one wood boiler with capacity greater than 50 MW in Lithuania. NOx emissions from this boiler are based on plant report. Emissions from all other wood boilers were estimated on the basis of Tier 2 EF for wood boilers < 50 MW. While compiling PM2.5 emission, average abatement efficiency was estimated. There is much uncertainty in wood amounts (GHG plant reports provide amount in tonnes, Statistics Lithuania converts to 1000 of cubic meters) and wood calorific value in Lithuania.

3.3.2 Emission factors

Emissions factors for main pollutants, heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn) and POP's are taken from Emission Inventory Guidebook 2019. Energy industries. See Annex 1, Table 53.

TABLE 8 TIER 1 FUEL CLASSIFICATIONS

Tier 1 fuel classifications	Associated fuel types	Location
Natural gas	Natural gas	See 1.A.1.a Tier 1
Heavy fuel oil	Residual fuel oil. refinery feedstock. petroleum coke	See 1.A.1.a Tier 1
Other liquid fuels	(a) Gas oil, kerosene, naphtha, natural gas liquids, liquefied petroleum gas, Orimulsion, bitumen, shale oil (b) refinery gas	(a) See 1.A.1.a Tier 1 (b) Table 4-2

3.4 MANUFACTURE OF SOLID FUEL AND OTHER ENERGY INDUSTRIES (1.A.1.C)

3.4.1 Overview of the Sector

Emissions in this sector arise from fuel combustion in manufacturing of solid fuels and other energy industries. Emissions were calculated applying Tier 1. For calculation of emissions in category Manufacture of Solid Fuels and other Energy Industries (1.A.1.c) activity data had been obtained from the Lithuanian Statistics database (Figure 22).

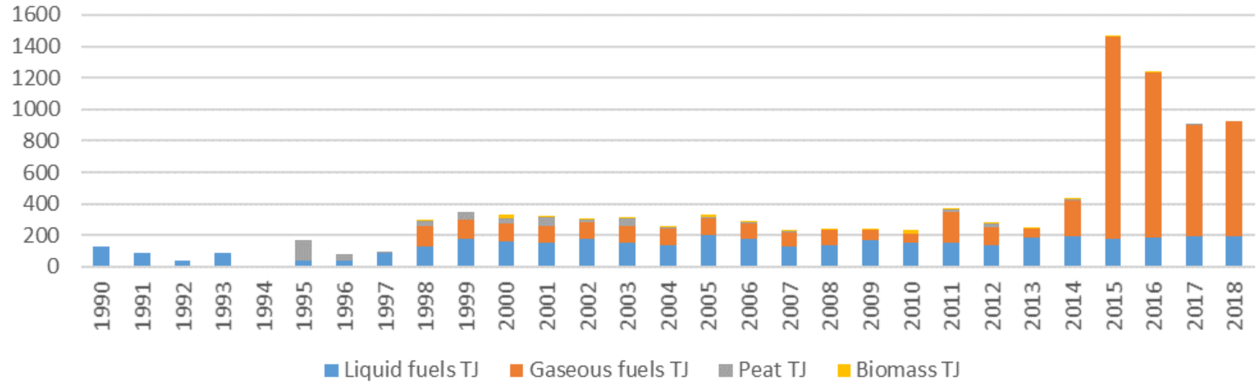


FIGURE 22 FUEL CONSUMPTION IN 1.A.1.C IN 1990-2018

Fuel consumption in Other Energy Industries increased significantly due to start of LNG terminal operation since January 2015. In 2015-2018, 710-1283 TJ of natural gas was combusted at LNG terminal for operational needs. The total fuel consumption in Other Energy Industries amounted 922 TJ in 2018. With reference to data of 2018, natural gas accounted 79%, liquid fuels – 21% and biomass – 0 % of structure.

Most of the heavy metals considered (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn) are normally released as compounds (e.g. oxides, chlorides) in association with particulates. Only Hg and Se are at least partly present in the vapor phase. Less volatile elements tend to condense onto the surface of smaller particles in the flue gas stream. Therefore, enrichment in the finest particle fractions is observed.

The content of heavy metals in coal is normally several orders of magnitude higher than in oil (except occasionally for Ni in heavy fuel oil) and in natural gas. For natural gas only emissions of mercury are relevant. During the combustion of coal, particles undergo complex changes, which lead to evaporation of volatile elements. The rate of volatility of heavy metal compounds depends on fuel characteristics (e.g. concentrations in coal, fraction of inorganic components, such as calcium) and on technology characteristics (e.g. type of boiler, operation mode).

3.4.2 Methodological issues and emission factors

EMEP/EEA Emission Inventory Guidebook 2019 was used as the main source of emission factors.

3.5 MANUFACTURING INDUSTRIES AND CONSTRUCTION (1.A.2)

Emissions from 1.A.2 sector are calculated using fuel consumption data from the Statistics Lithuania and some industrial manufactures prepared within Annual questionnaires. Natural gas is the main fuel used in chemical industry in Lithuania. During 1990-2012 periods it has contained 85-99% of total fuel used in industry. Emissions factors for heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn) and POP's taken from Guidebook 2016 were applied: chapter 1.A.4 Small Combustions. See Annex 1: Table 71, Table 72, Table 73, Table 74, Table 76, Table 80, Table 82, Table 83, Table 84, Table 85, Table 86, Table 87, Table 88, Table 89, Table 90, Table 91, Table 92.

GB TABLE NO	GB VERSION	GB CHAPTER	NFR SOURCE CATEGORY	TABLE TITLE
TABLE 3-7	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.7 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using hard and brown coal
TABLE 3-8	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.8 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using gaseous fuels
TABLE 3-9	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.9 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using liquid fuels
TABLE 3-10	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.10 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using solid biomass
TABLE 3-20	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.20 Tier 2 emission factors for small non-residential sources (> 50 kWth to ≤ 1 MWth) boilers burning coal fuels
TABLE 3-21	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.21 Tier 2 emission factors for non-residential sources, medium-size (> 1 MWth to ≤ 50 MWth) boilers burning coal fuels
TABLE 3-22	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.22 Tier 2 emission factors for non-residential sources, manual boilers burning coal fuels
TABLE 3-23	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.23 Tier 2 emission factors for non-residential sources, automatic boilers burning coal fuels
TABLE 3-24	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.24 Tier 2 emission factors for non-residential sources, medium-sized (> 50 kWth to ≤ 1 MWth) boilers liquid fuels
TABLE 3-25	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.25 Tier 2 emission factors for non-residential sources, medium sized (> 1 MWth to ≤ 50 MWth) boilers liquid fuels
TABLE 3-26	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.26 Tier 2 emission factors for non-residential sources, medium-sized (> 50 kWth to ≤ 1 MWth) boilers burning natural gas
TABLE 3-27	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.27 Tier 2 emission factors for non-residential sources, medium sized (> 1 MWth to ≤ 50 MWth) boilers burning natural gas
TABLE 3-28	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.28 Tier 2 emission factors for non-residential sources, gas turbines burning natural gas
TABLE 3-29	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.29 Tier 2 emission factors for non-residential sources, gas turbines burning gas oil
TABLE 3-30	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.30 Tier 2 emission factors for non-residential sources, reciprocating engines burning gas fuels
TABLE 3-31	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.31 Tier 2 emission factors for non-residential sources, reciprocating engines burning gas oil
TABLE 3-45	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.45 Tier 2 emission factors for non-residential sources, medium sized (>1 MWth to ≤ 50 MWth) boilers wood
TABLE 3-46	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.46 Tier 2 emission factors for non-residential sources, medium sized (>50KWth to ≤ 1 MWth) boilers wood (in the absence of information on manual/automatic feed)
TABLE 3-47	GB2016-July 2018	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.47 Tier 2 emission factors for non-residential sources, manual boilers burning wood
TABLE 3-48	GB2016-July 2017	1A4 Small combustion (stationary)	1.A.4.a.i	Table 3.48 Tier 2 emission factors for non-residential sources, automatic boilers burning wood

The following nationwide abatement efficiency starting from the year 2000 was applied for calculating PM, Heavy metals, PAHs, Dioxins/Furans emissions:

Abatement efficiency												
		2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018
Fuel:	Coal, Peat											
Combustiom technology:	> 50 kWth to ≤ 1 MWth boilers											
Abatement efficiency, %:	0	14,5	58,0	58,0	58,0	58,0	72,5	72,5	72,5	72,5	72,5	72,5
Fuel:	Coal, Peat											
Combustiom technology:	>1 MWth to <=50 MWth boilers											
Abatement efficiency, %:	0	4,8	19,3	19,3	19,3	19,3	24,2	24,2	24,2	24,2	24,2	24,2
Fuel:	Wood											
Combustiom technology:	> 50 kWth to ≤ 1 MWth boilers											
Abatement efficiency, %:	0	13,6	54,4	54,4	54,4	54,4	68,0	68,0	68,0	68,0	68,0	68,0
Fuel:	Wood											
Combustiom technology:	>1 MWth to <=50 MWth boilers											
Abatement efficiency, %:	0	16,4	65,7	65,7	65,7	65,7	82,1	82,1	82,1	82,1	82,1	82,1

Abatement efficiency was estimated on the basis of National EF research, the ratio of national EF for PM2.5 to Guidebook 2019 EF for PM2.5 and national scale of usage of the abatement technologies.

3.6 Non-Ferrous Metals (1.A.2.b)

There is non-ferrous metals industry in Lithuania. All emissions are reported as not occurring.

3.7 Chemicals (1.A.2.c)

The chemical industry is the second largest manufacturing industry in Lithuania. It produces a number of different products such as chemicals, plastics, solvents, petrochemical products, cosmetics etc. During the latter decade it has been noticed an intensive development of this industry (Figure 23).

Combustion in the chemicals sector ranges from conventional fuels in boiler plant and recovery of process by-products using thermal oxidizers to process-specific combustion activities (for example catalytic oxidation of ammonia during nitric acid manufacture). A gas turbine is installed in the largest chemical plant “Achema”. Tier 2 emission factors were applied for evaluating emissions from this gas turbine.

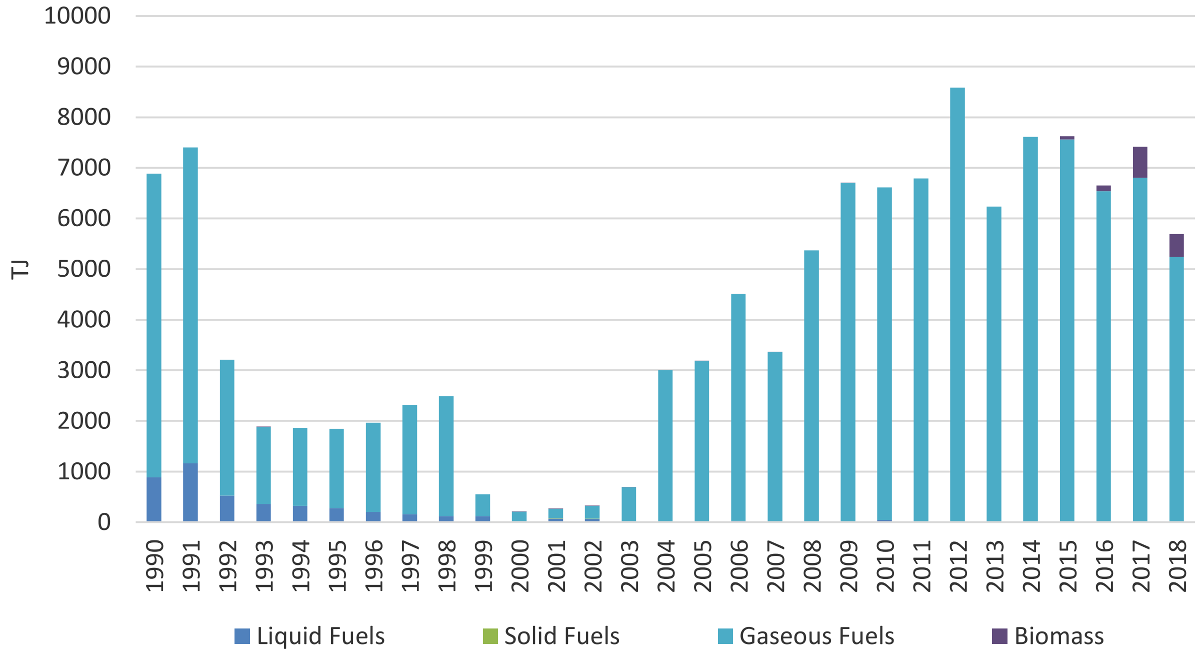


FIGURE 23 TENDENCIES OF FUEL CONSUMPTION IN SECTOR 1.A.2.C IN THE PERIOD 1990-2018

During 2008-2009, the growth rates of fuel consumption in Chemical industries went slow and 1.3% fuel consumption decrease has been noticed in 2009. Natural gas is the main fuel used in chemical industry in Lithuania. During 1990-2018 period, it has contained 71-99% of total fuel used in industry.

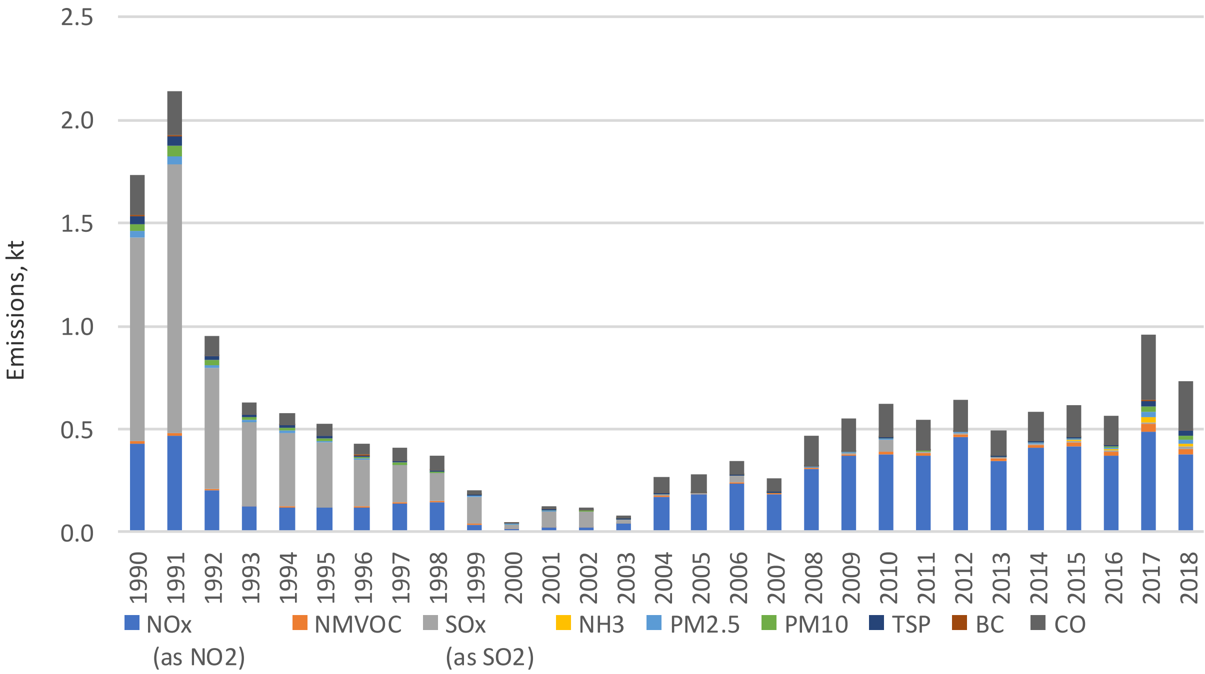


FIGURE 24 MAIN POLLUTANT EMISSIONS IN SECTOR 1.A.2.C IN THE PERIOD 1990-2018

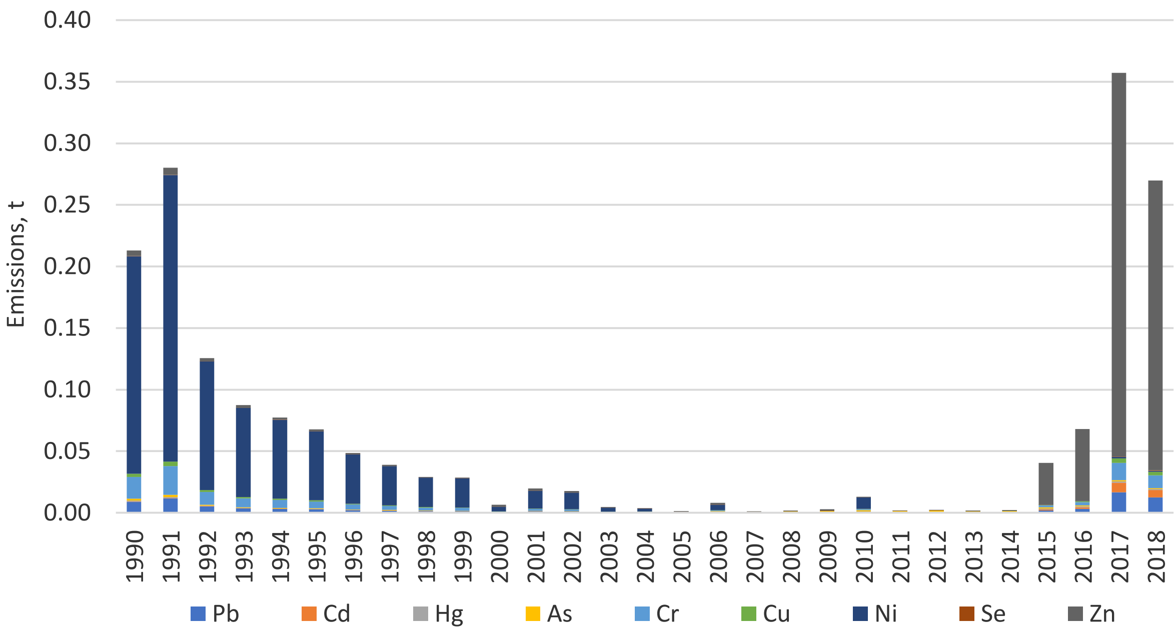


FIGURE 25 HEAVY METAL EMISSIONS IN SECTOR 1.A.2.C IN THE PERIOD 1990-2018

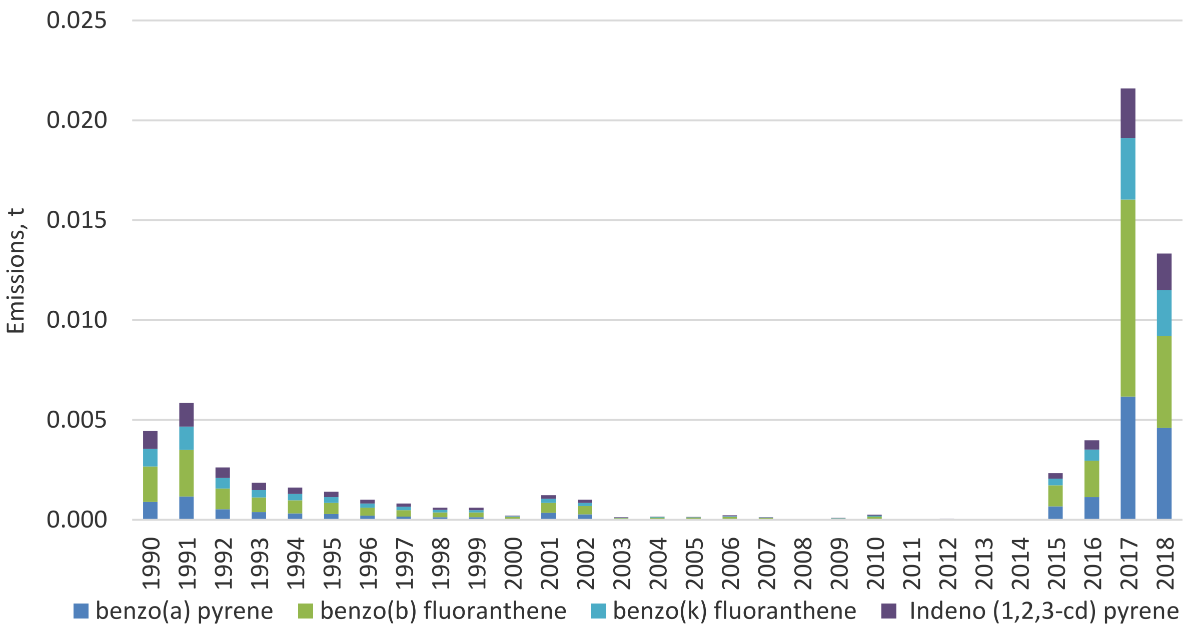


FIGURE 26 PAHS EMISSIONS IN SECTOR 1.A.2C IN THE PERIOD 1990-2018

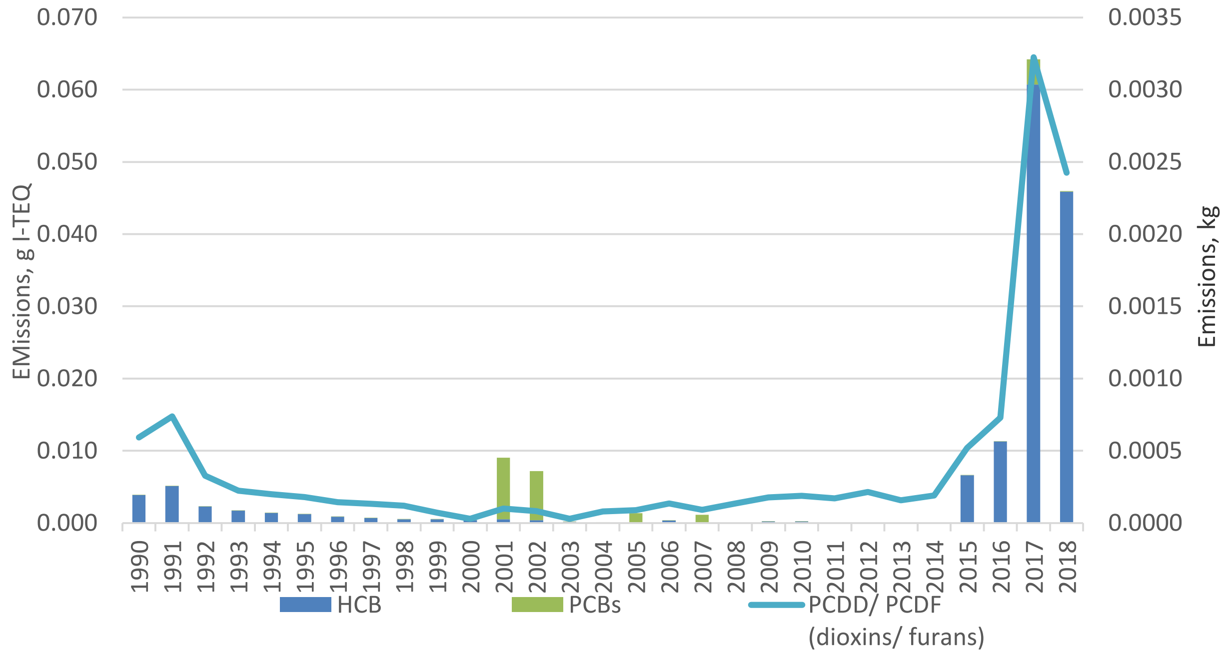


FIGURE 27 HCB, PCBS, PCDD EMISSIONS IN SECTOR 1.A.2.C IN THE PERIOD 1990-2018

During economic recession and "recovery" period (1990-2002) fuel consumption in Lithuania's chemical industry has had a tendency to decrease by 22.5% a year with a large decrease of natural gas consumption. Since 2003, when economy has started to grow at very fast rates, energy consumption in Chemical industries began to increase. In 2018, energy consumption in Chemical industries decreased by 23.2% (in comparison to 2017) and amounted 5.7 PJ. With reference to data of 2018, natural gas accounted 94% in the structure of total fuel consumption in Chemical industries, biomass - 8%.

3.8 Pulp, Paper and Print (1.A.2.d)

The production of pulp and paper requires considerable amounts of steam and power. Most pulp and paper mills produce their own steam in one or more industrial boilers or combined heat and power (CHP) units which burn fossil fuels and/or wood residues. Mills that pulp wood with a chemical process (Kraft, sulphite, soda, semi-chemical) normally combust their spent pulping liquor in a combustion unit. For example, a Kraft recovery furnace, to recover pulping chemicals for subsequent reuse. These units are also capable of providing process steam and power for mill operations. The pulp, paper and print industry is an important branch of manufacturing industry in Lithuania (Figure 28).

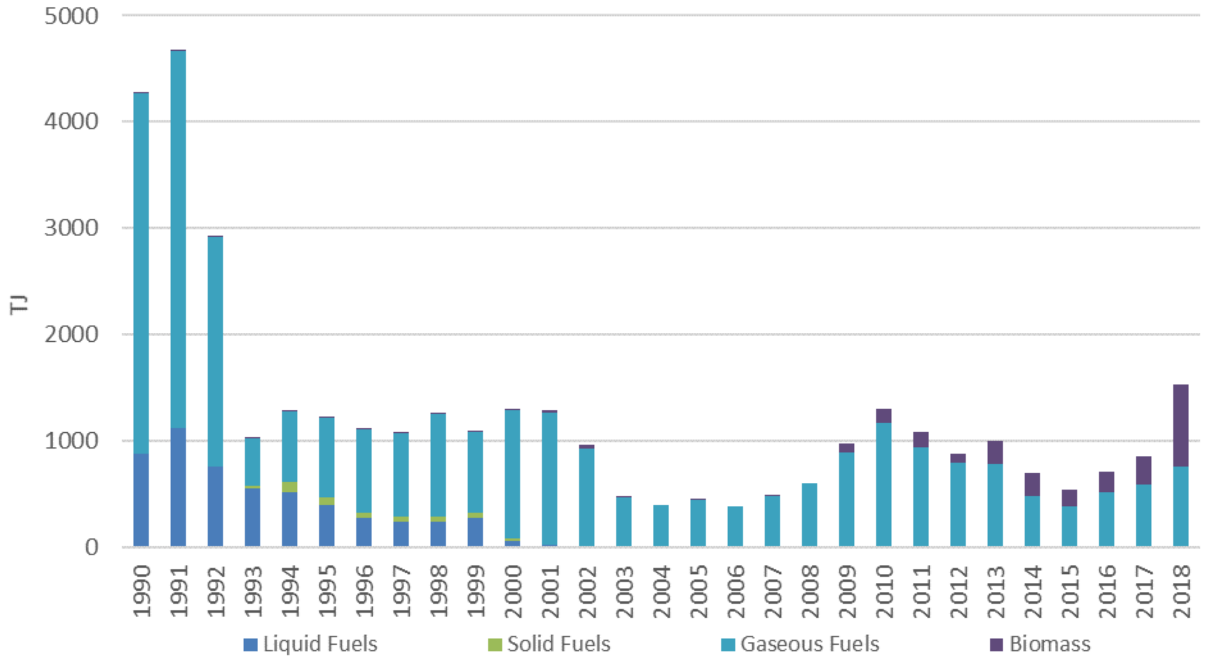


FIGURE 28 TENDENCIES OF FUEL CONSUMPTION IN PULP, PAPER AND PRINT INDUSTRIES DURING 1990-2018

The Pulp, Paper and Print industries has been growing by 10.1% during 2005-2008, and the growth rates have been by 4.6 percentage points higher than the average growth rate of manufacturing industry in Lithuania. However, in 2009 when economic crisis pick up the steam and the average value added created in Lithuanian manufacturing industry went down by 1.0%, the Pulp, Paper and Print industries has remained the sector with the lowest decline rate, which was 1.5% in 2009.

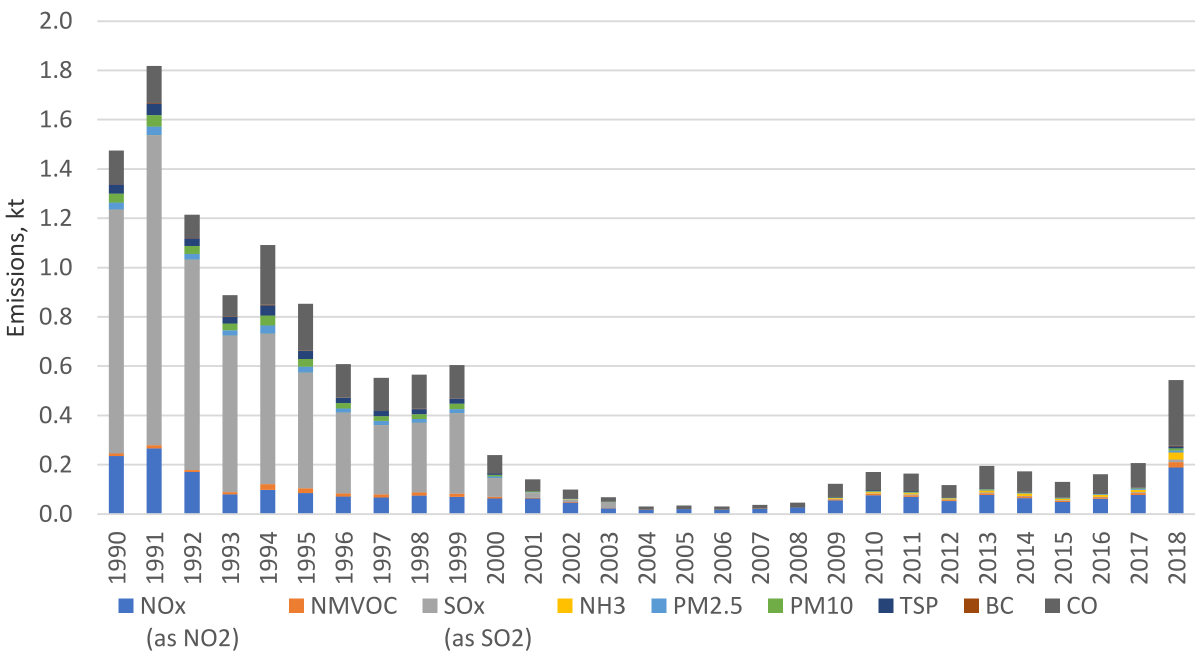


FIGURE 29 POLLUTANT EMISSIONS IN SECTOR 1.A.2.D IN THE PERIOD 1990-2018

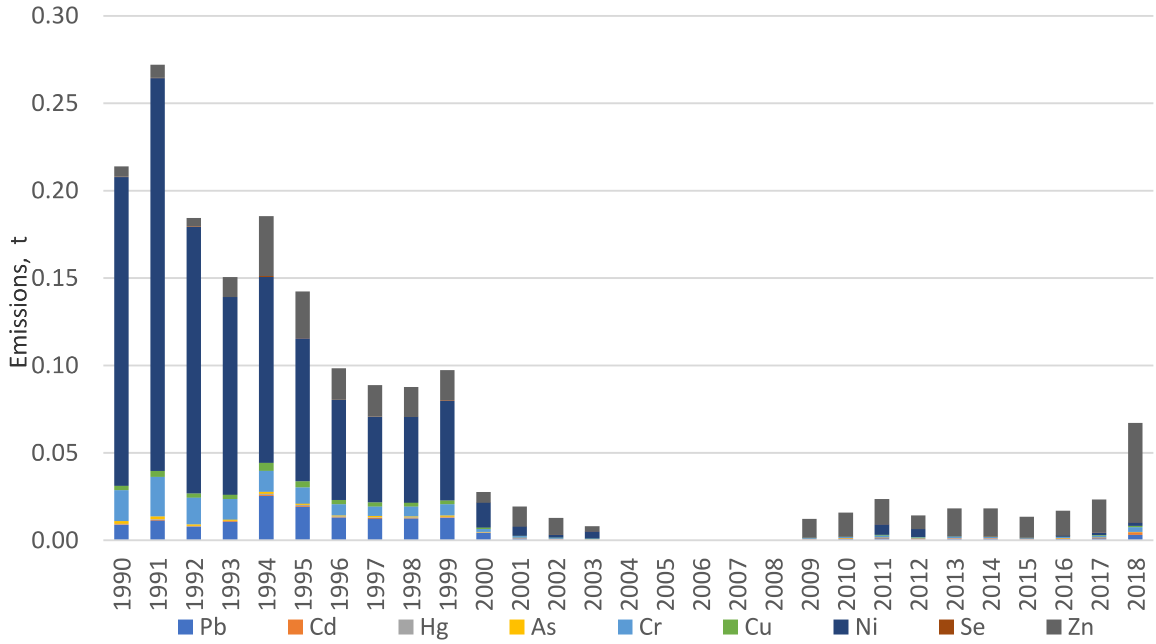


FIGURE 30 HEAVY METAL EMISSIONS IN SECTOR 1.A.2.D IN THE PERIOD 1990-2018

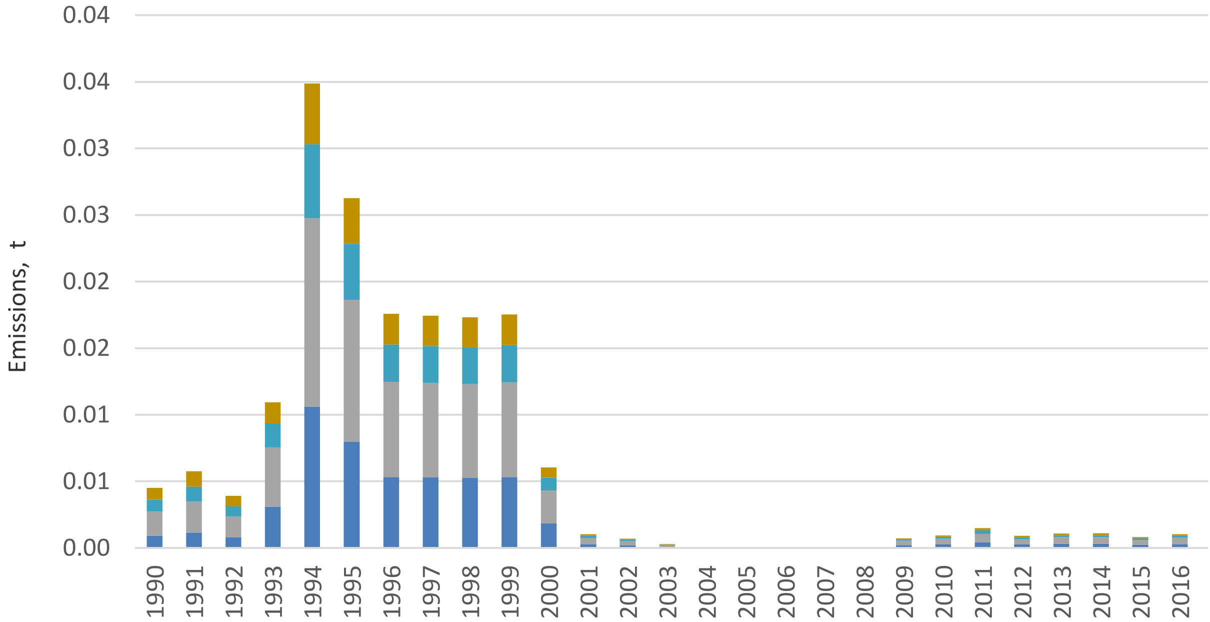


FIGURE 31 PAHS EMISSIONS IN SECTOR 1.A.2.D. IN THE PERIOD 1990-2018

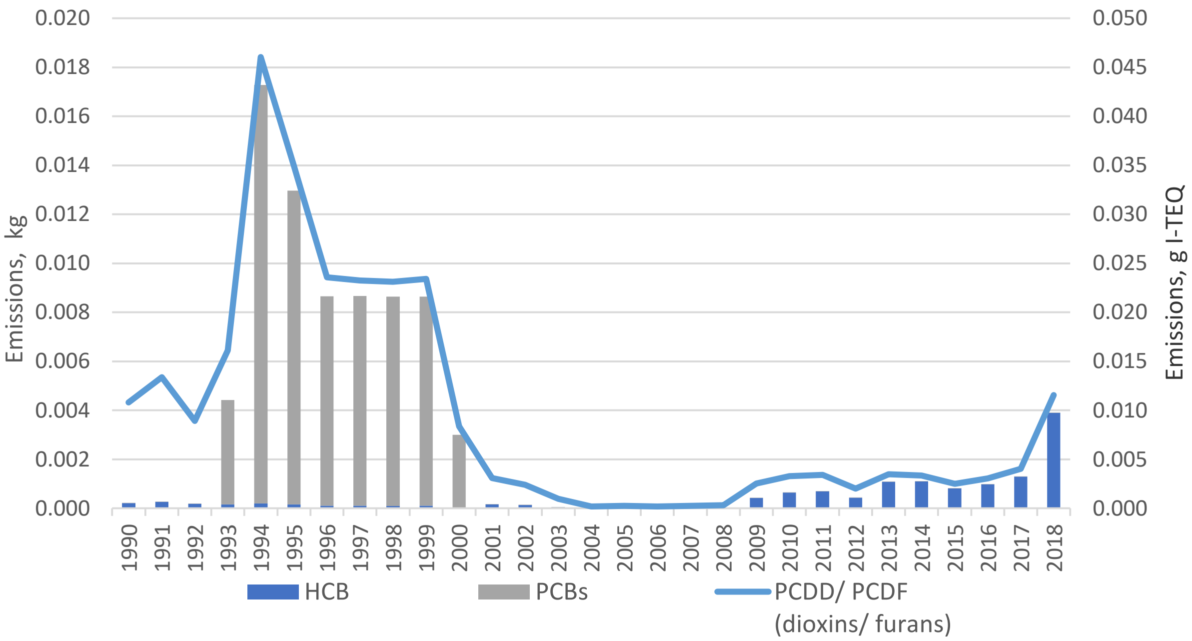


FIGURE 32 HCB, PCBS, PCDD EMISSIONS IN SECTOR 1.A.2.D IN THE PERIOD 1990-2018

Emission factors from Guidebook 2016 were applied: chapter 1.A.4 Small Combustions. See Annex 1: Table 60, Table 62, Table 63, Table 64, Table 65, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79, Table 80, Table 81, Table 82, Table 83, Table 84, Table 85, Table 86, Table 87, Table 88, Table 89, Table 90, Table 91, Table 92.

3.9 Food Processing. Beverages and Tobacco (1.A.2.e)

Food processing, beverages and tobacco industry has old traditions in Lithuania. Currently this branch of the manufacturing industry consists of the following important structural parts – production of meat and its products, preparation and processing of fish and its products, preparation, processing and preservation of fruits, berries and vegetables, production of dairy products, production of grains, production of strong and soft drinks as well tobacco. During economic crisis the decline rates have been the lowest (3.9% a year) (Figure 33).

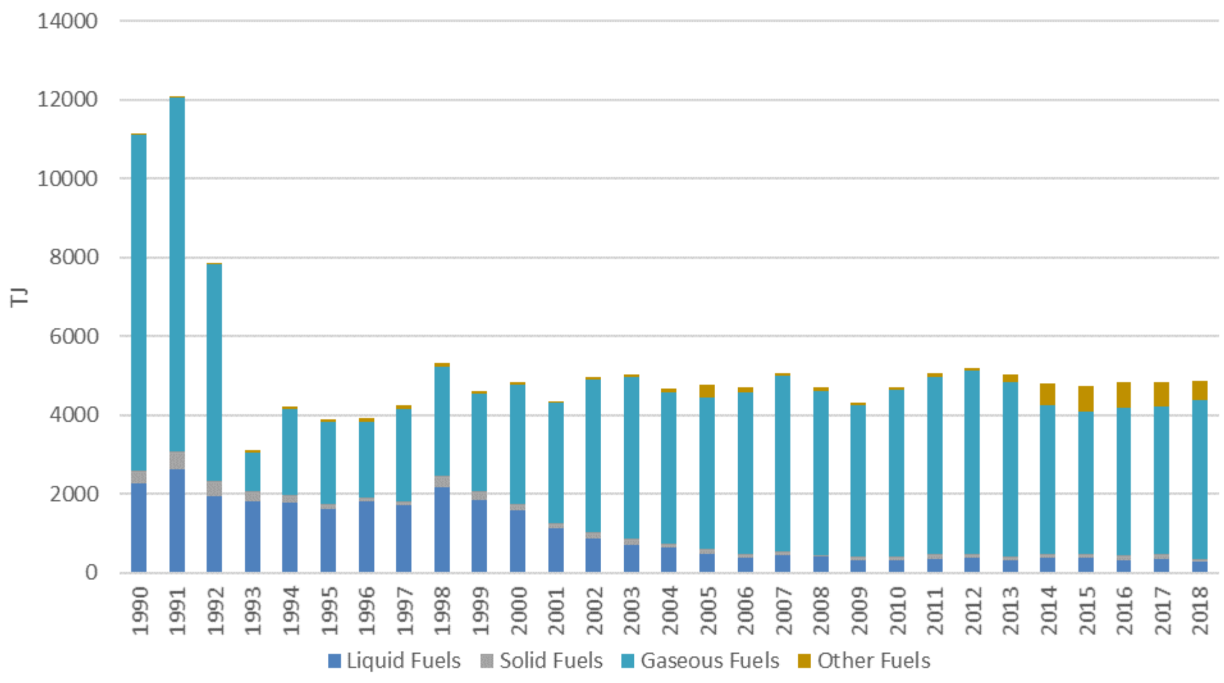


FIGURE 33 TENDENCIES OF FUEL CONSUMPTION IN SECTOR 1.A.2.E DURING 1990-2018

During the last decade food processing industry has passed a rapid restructuring process, when number of active economic entities in the main branches of food industry (except in fruit and berries industry) has noticeably decreased. However, the share of large companies has increased.

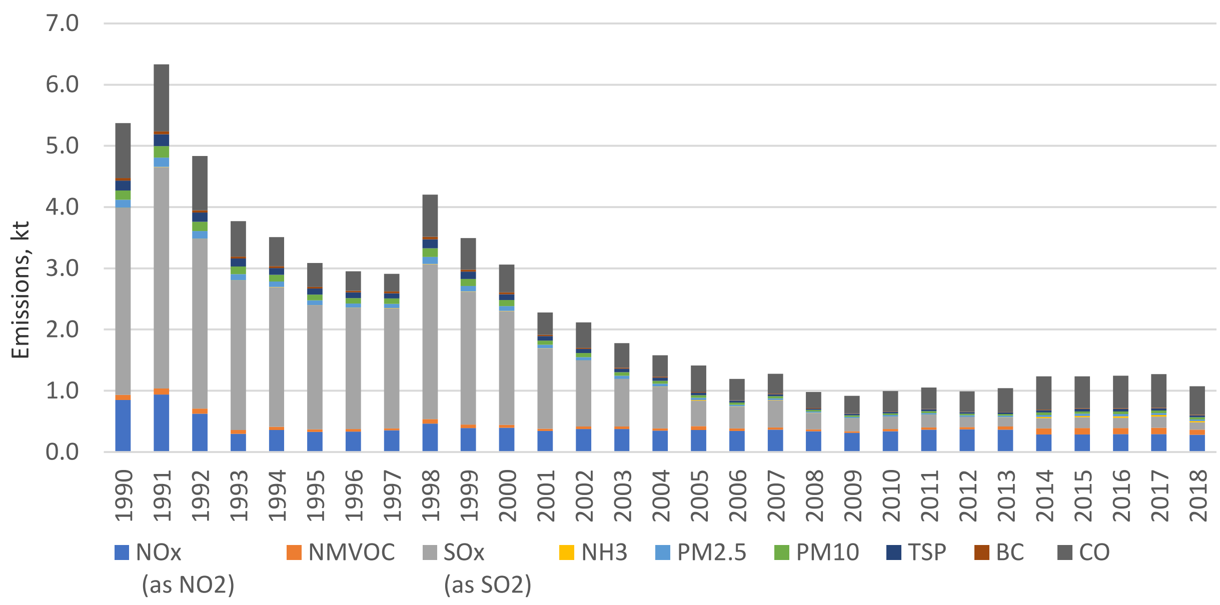


FIGURE 34 POLLUTANT EMISSIONS IN SECTOR 1.A.2.E IN THE PERIOD 1990-2018

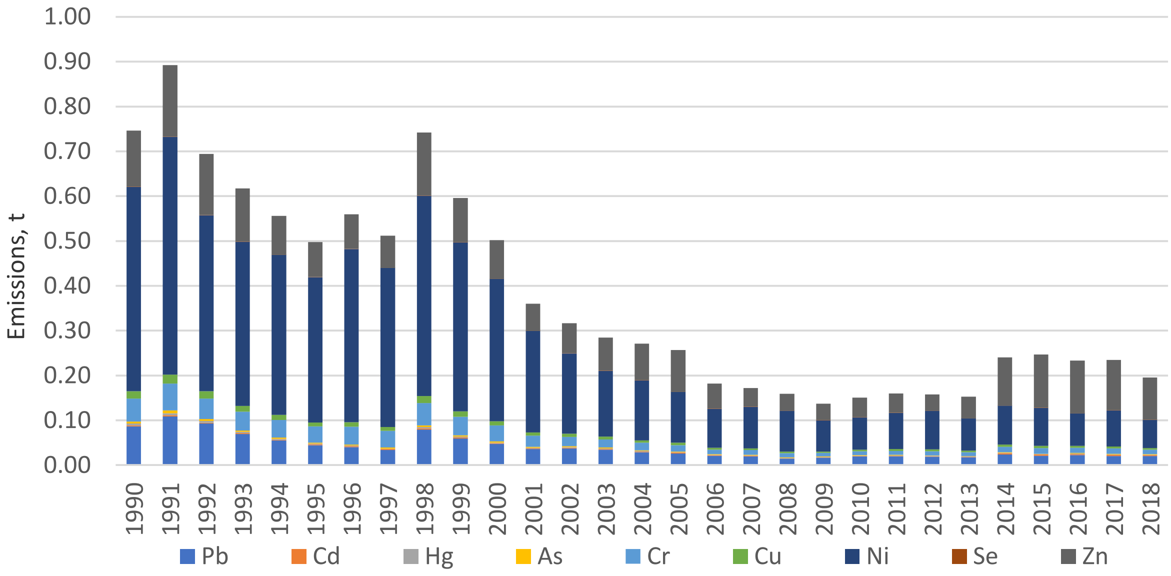


FIGURE 35 HEAVY METAL EMISSIONS IN SECTOR 1.A.2.E IN THE PERIOD 1990-2018

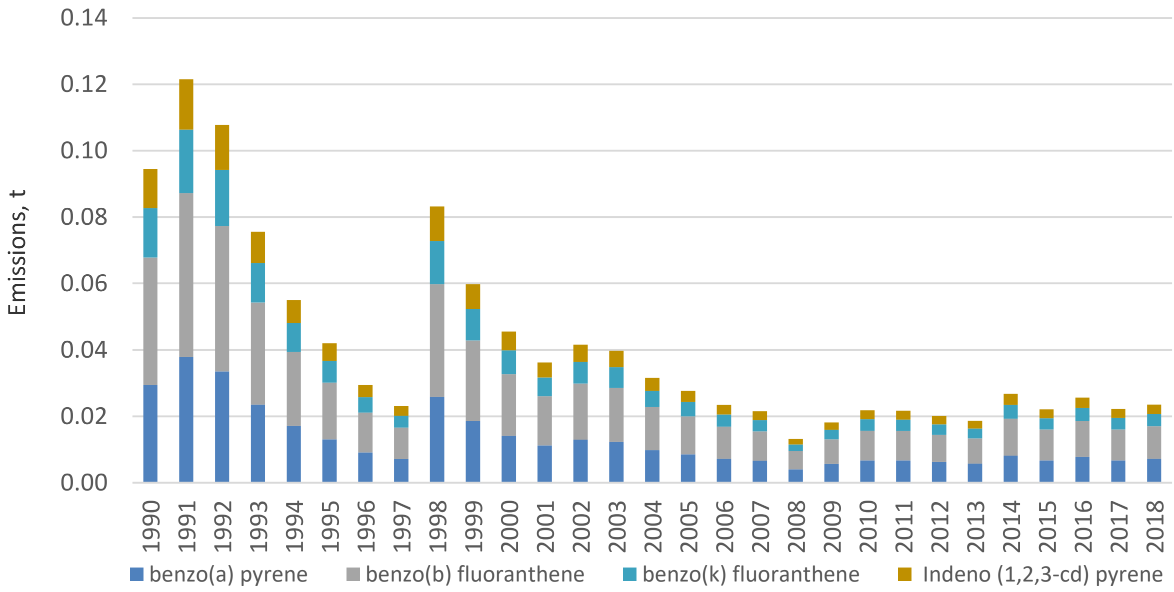


FIGURE 36 PAHS EMISSIONS IN SECTOR 1.A.2.E IN THE PERIOD 1990-2018

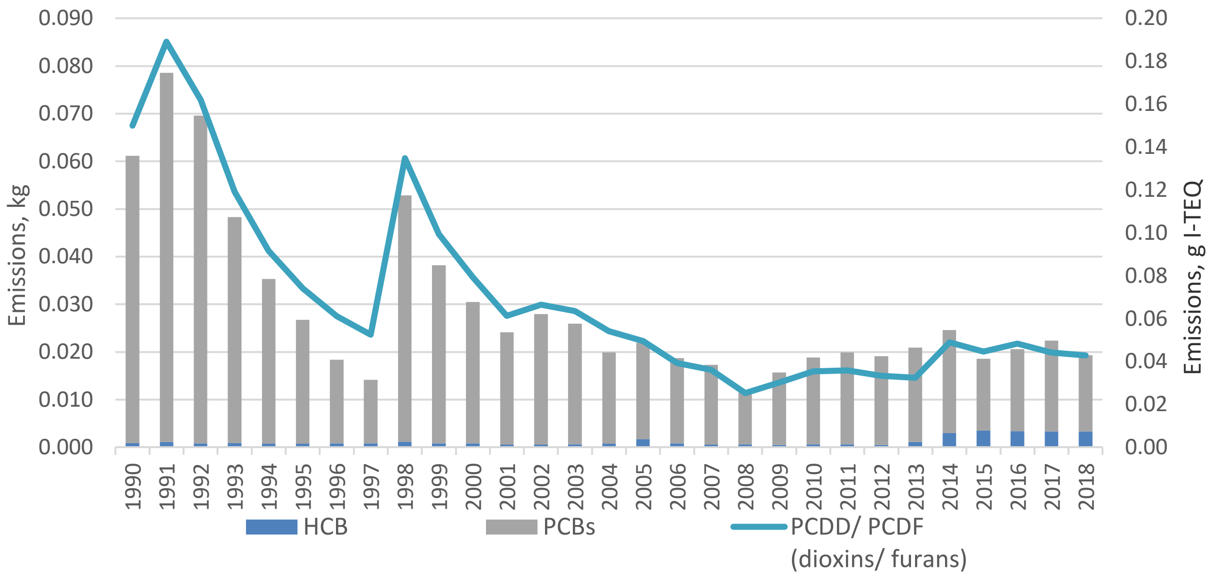


FIGURE 37 HCB, PCBS, PCDD EMISSIONS IN SECTOR 1.A.2.E IN THE PERIOD 1990-2018

Emission factors from Guidebook 2019 were applied: chapter 1.A.4 Small Combustions. See Annex 1: Table 71, Table 72, Table 75, Table 76, Table 77, Table 78, Table 88, Table 89.

3.10 Stationary combustion in manufacturing industries and construction (1.a.2.f)

3.10.1 Source category description

This chapter presents the consumption of fuels and emissions of air pollutants in five specific types of industry, all other are hidden under other industry where also fuel for construction industry is included. For this reason, in “NFR Code 1.A.2.f ” a high number of enterprises are included.

In 1.A.2.f sector the largest reductions have been noticed in liquid (residual fuel oil) consumption during the period 1990-2018 The share of residual fuel oil has decreased from 67% (1990) till 1% (2018). Although, volume of natural gas has been reducing. However, its share has remained rather stable during 1995-2012. During the period of rapid economic development coking coal has rapidly penetrated the market, i.e. the share has increased till 40% (2007). During 2008-2018 consumption of coking coal has been reducing, however the share on average – 35-40 % with 71 % in 2018. During 2005-2018 the share of natural gas fluctuates around 19 % in the structure of fuel consumption with share of 18 % in 2018.

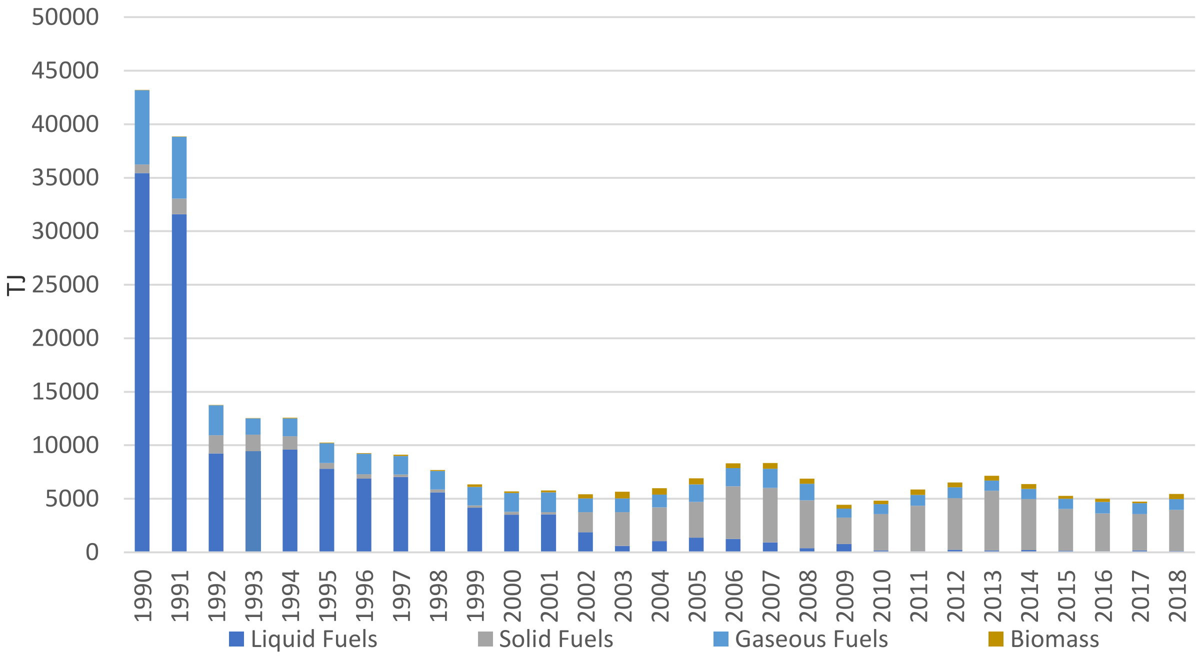


FIGURE 38 TENDENCIES OF FUEL CONSUMPTION IN SECTOR 1.A.2.F IN THE PERIOD 1990-2018

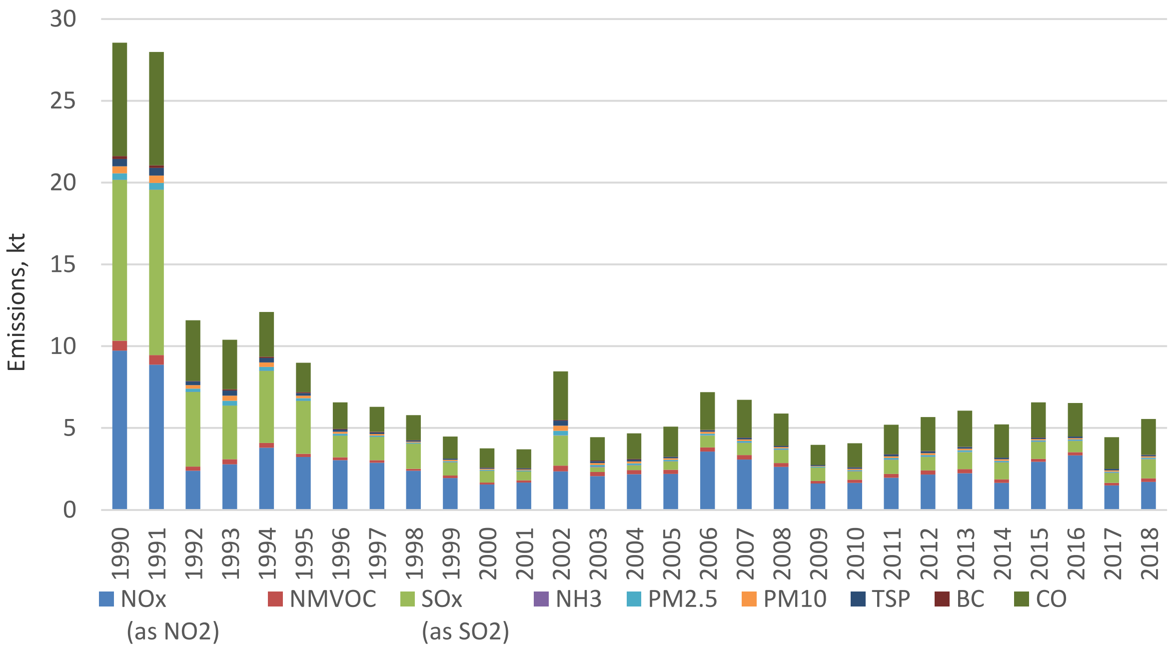


FIGURE 39 POLLUTANT EMISSIONS IN SECTOR 1.A.2.F IN THE PERIOD 1990-2018

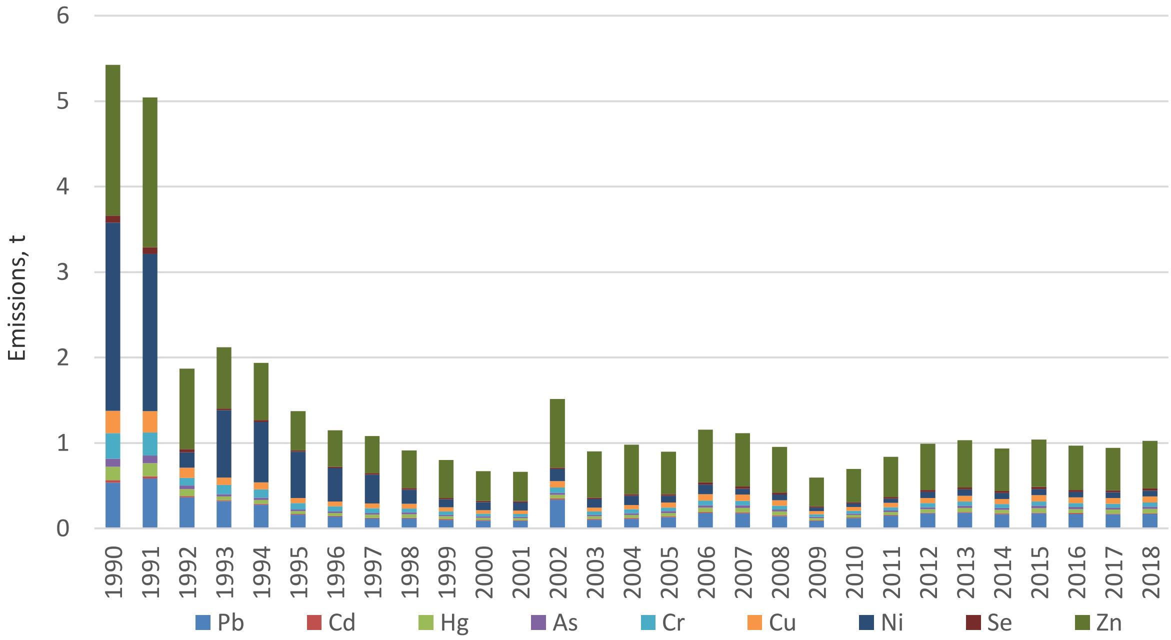


FIGURE 40 HEAVY METAL EMISSIONS IN SECTOR 1.A.2.F IN THE PERIOD 1990-2018

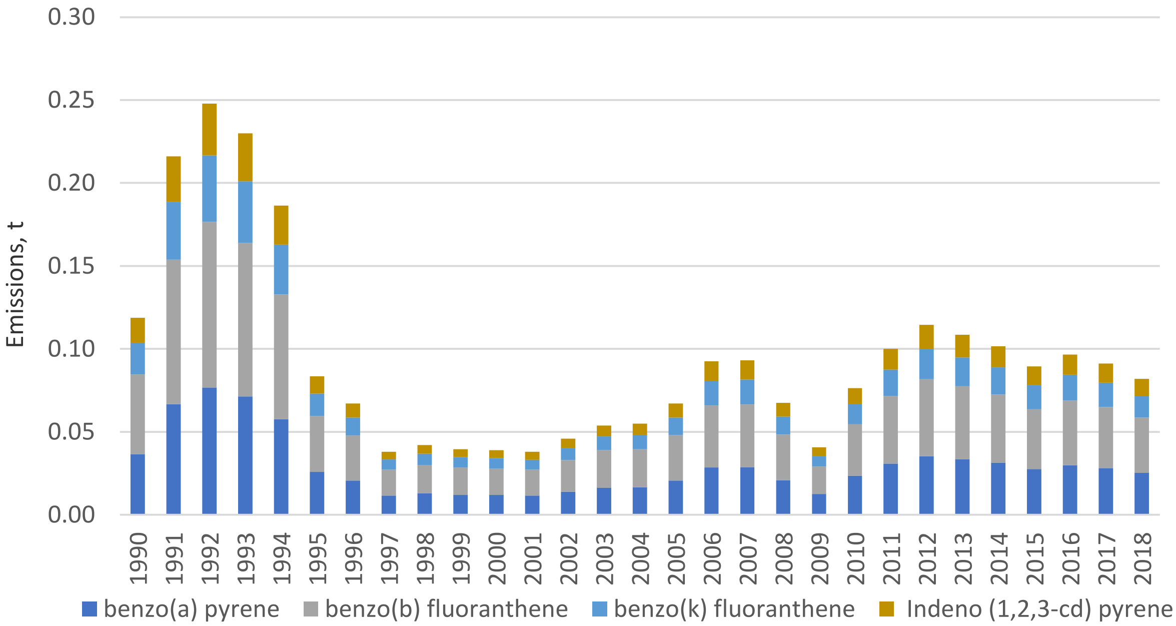


FIGURE 41 PAHS EMISSIONS IN SECTOR 1.A.2.F IN THE PERIOD 1990-2018

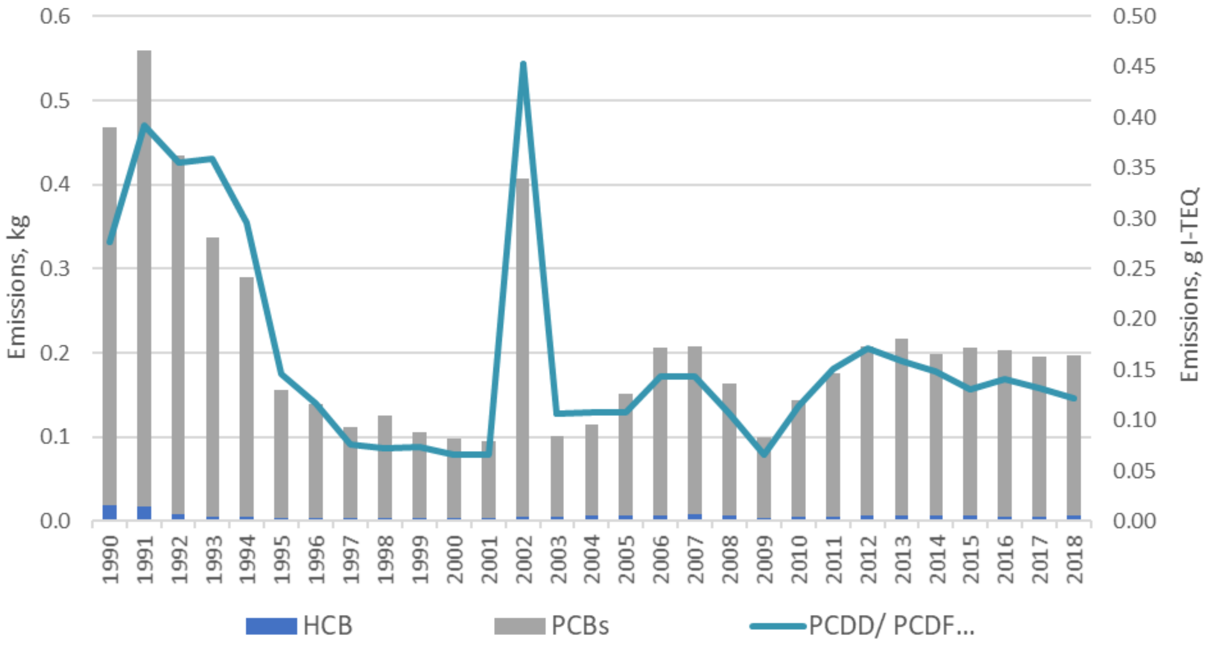


FIGURE 42 HCB, PCBS, PCDD EMISSIONS IN SECTOR 1.A.2.F IN THE PERIOD 1990-2018

3.10.2 Methodological issues

All the emission calculations are based on the Tier 1 method. Emissions from these transport sectors are calculated by multiplying the statistical fuel consumption by respective emission factors. Default emission factors for the main pollutants and heavy metals are taken from the EMEP/EEA emission guidebook 2016.

Emissions of SO_2 are dependent on fuel consumption and fuel type. SO_2 emissions are calculated by multiplying statistical fuel use by emission factors (Emission factors from Guidebook 2019 were applied: chapter 1.A.4 Small Combustions. See Annex 1: Table 60, Table 62, Table 63, Table 64, Table 65, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79, Table 80, Table 81, Table 82, Table 83, Table 84, Table 85, Table 86, Table 87, Table 88, Table 89, Table 90, Table 91, Table 92.

Table 9Table 7 and Table 10). SO_2 emissions are estimated according to the assumption that all sulphur in the fuel is completely transformed into SO_2. Equation (1) can be applied to the industrial. commercial. household/gardening and agricultural sectors. while equation (2) is solely for the national fishing sector:

$$E_{SO_2} = 2 \times k \times FC \quad (1)$$

$$E_{SO_2} = 2 \times S \times FC \quad (2)$$

where:

E_{SO2} – emissions of SO_2

k – weight related sulphur content in fuel (kg/kg fuel)

S – percentage sulphur content in fuel (%)

FC – fuel consumption

Pb emissions are estimated by assuming that 75% of the lead contained in gasoline is emitted into the air. Pb content in fuel are presented in Table 2-12.

Equation:

$$E_{Pb} = 0.75 \times k \times FC \quad (3)$$

Emission factors from Guidebook 2019 were applied: chapter 1.A.4 Small Combustions. See Annex 1: Table 60, Table 62, Table 63, Table 64, Table 65, Table 71, Table 72, Table 73, Table 74, Table 75, Table 76, Table 77, Table 78, Table 79, Table 80, Table 81, Table 82, Table 83, Table 84, Table 85, Table 86, Table 87, Table 88, Table 89, Table 90, Table 91, Table 92.

TABLE 9 PB EMISSION FACTORS FOR OTHER MOBILE SOURCES (KG/T)

Fuel	1990	2000	2001	2003	2004	2005	2006	2008	2009	2011-
Light fuel oil	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Diesel	0.5	0.5	0.05	0.035	0.03	0.005	0.004	0.004	0.001	0.1

TABLE 10 PB EMISSION FACTORS FOR OTHER MOBILE SOURCES.

NFR	Fuel	Unit	1990	2000	2004
1A2fii, 1A4aii, 1A4bii, 1A4cii, 1A4ciii	Gasoline	g/l	0.15	0.013	0.005
1A4ciii	Diesel/Light fuel oil	g/t	0.13	0.13	0.13

3.10.3 Source-specific planned improvements

No source-specific improvements have been planned.

3.11 Other (1.A.2.g.vii-viii)

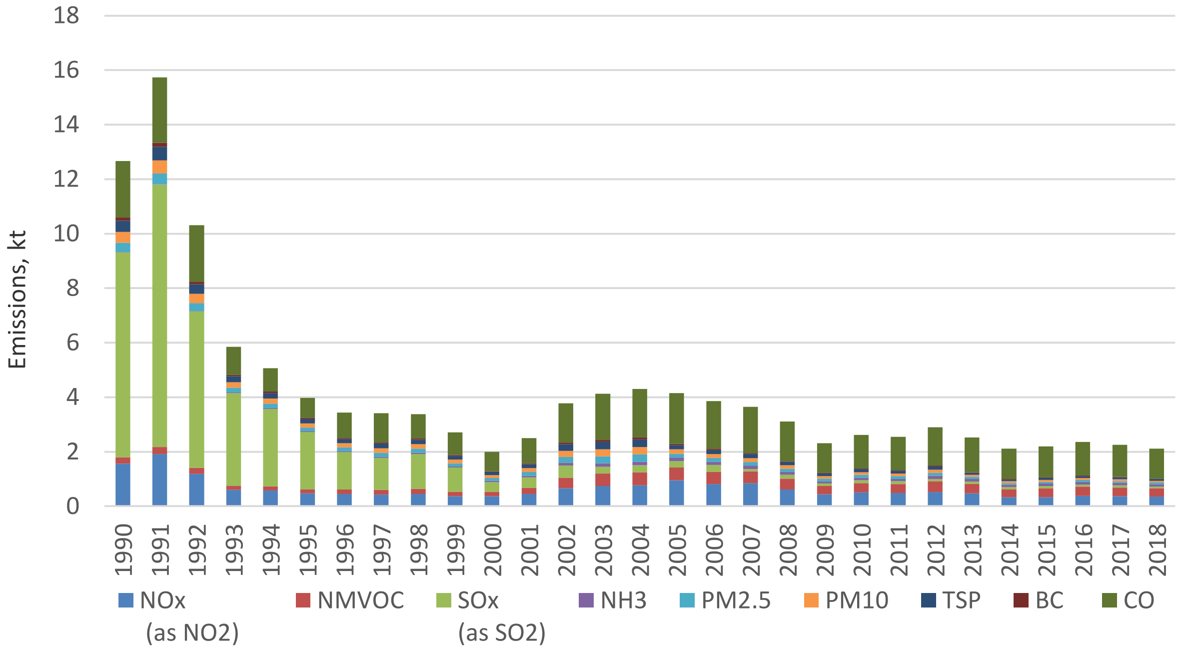


FIGURE 43 POLLUTANT EMISSIONS IN SECTOR 1.A.2.G.VII IN THE PERIOD 1990-2018

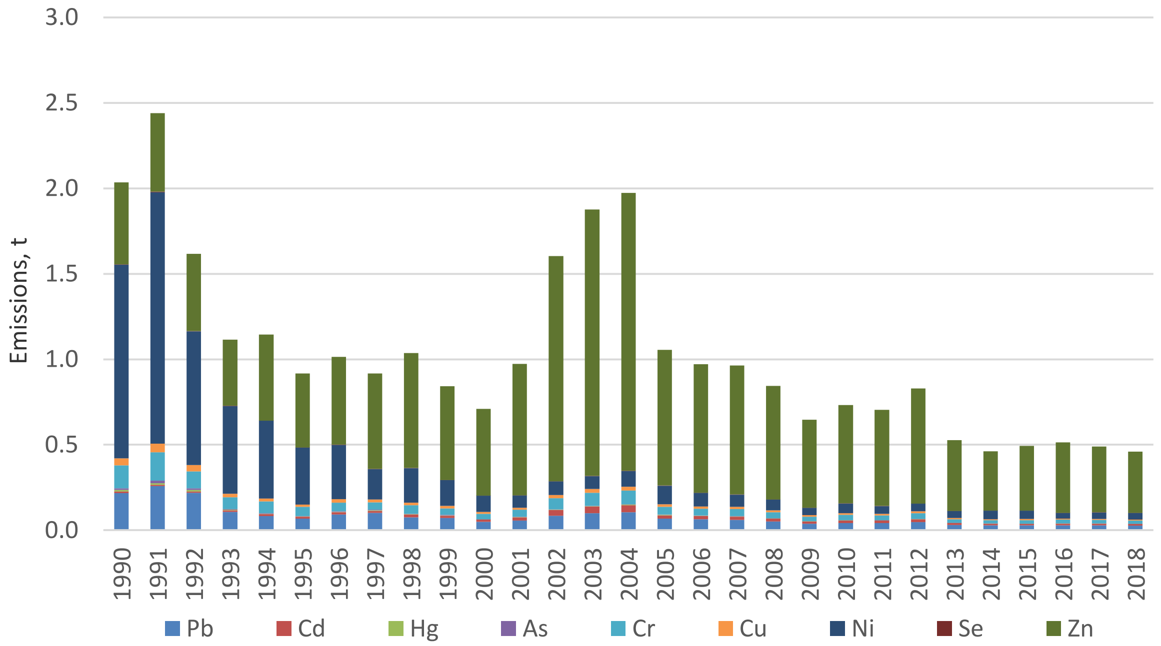


FIGURE 44 HEAVY METALS EMISSIONS IN SECTOR 1.A.2.G.VII IN THE PERIOD 1990-2018

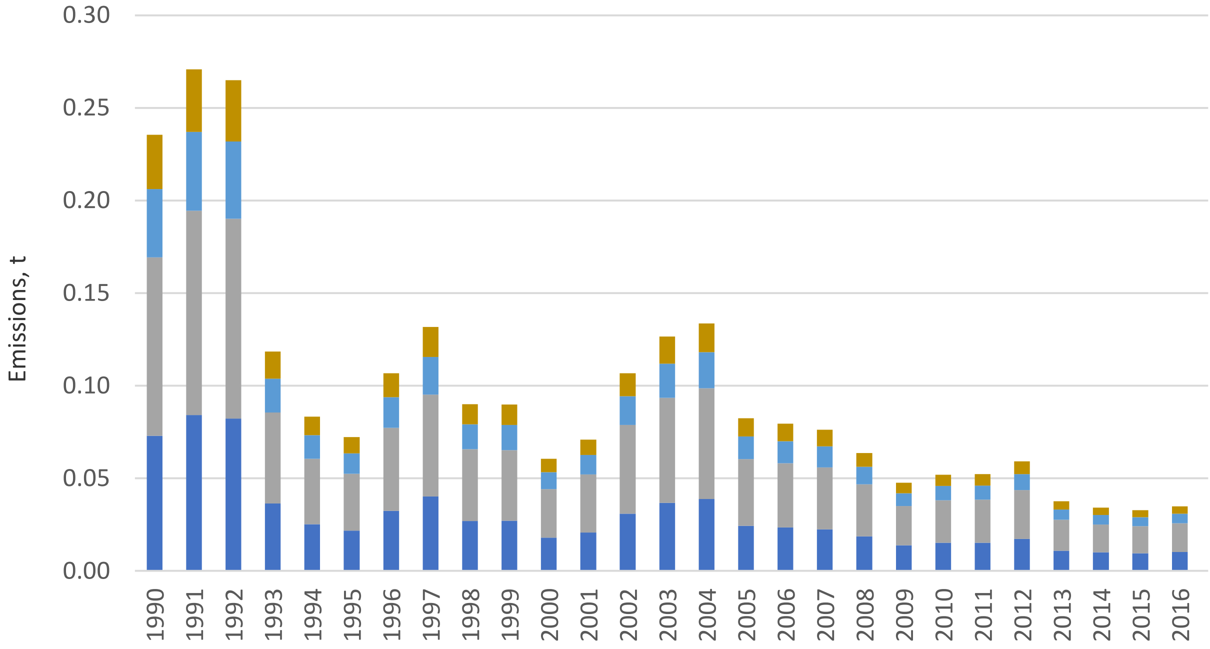


FIGURE 45 PAHS EMISSIONS IN SECTOR 1.A.2.G.VII IN THE PERIOD 1990-2018

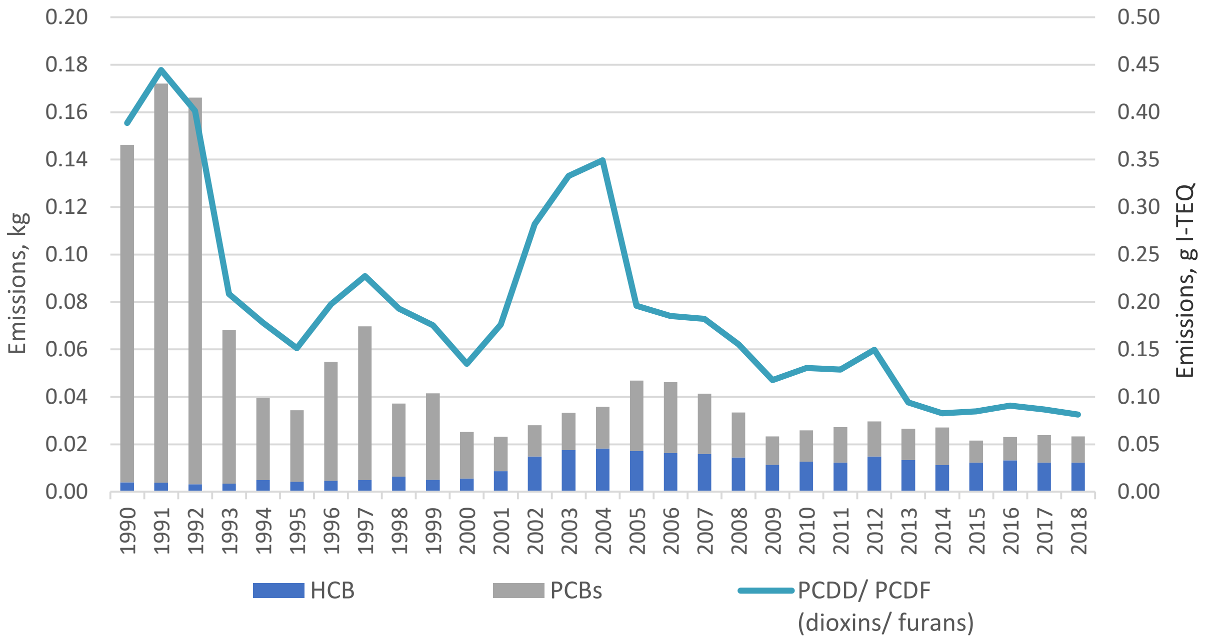


FIGURE 46 HCB, PCBS, PCDD EMISSIONS IN SECTOR 1.A.2.G.VIII IN THE PERIOD 1990-2018

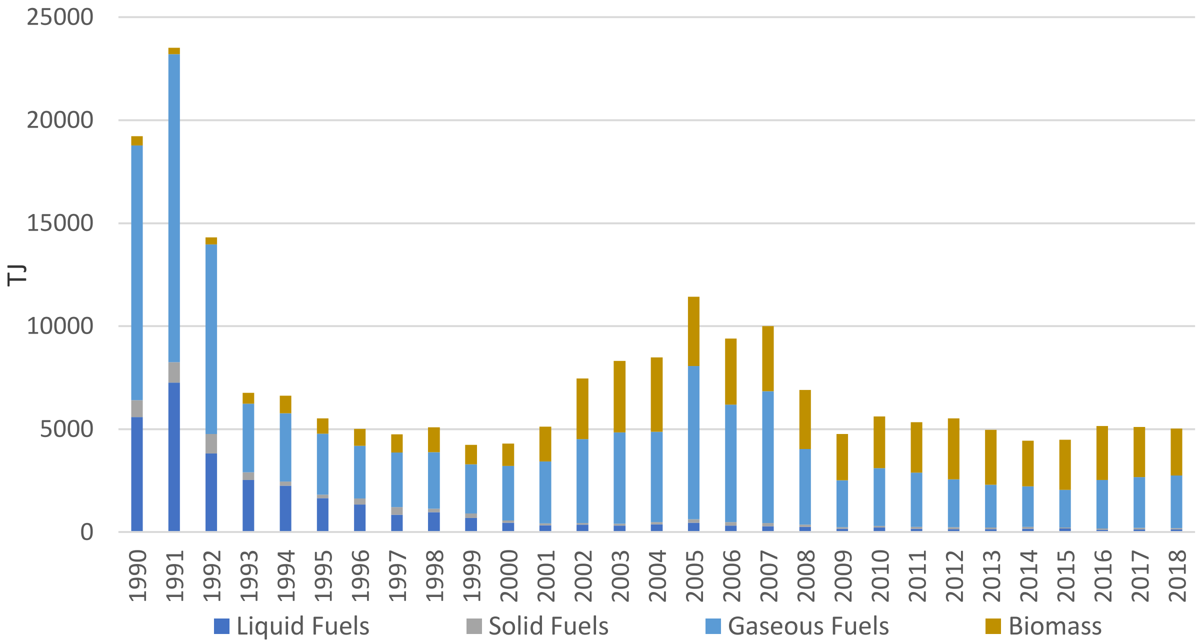


FIGURE 47 TENDENCIES OF FUEL CONSUMPTION IN SECTOR 1.A.2.G.VIII IN THE PERIOD 1990-2018

Emission factors from Guidebook 2019 were applied: chapter 1.A.4 Small Combustions. See Annex 1: Table 71, Table 72, Table 75, Table 76, Table 77, Table 78, Table 88, Table 89.

3.12 TRANSPORT (NFR 1.A.3)

Since 1990, the Government of Lithuania has adopted a number of important decisions on the reduction of transport pollution, i.e. national programmes like “Transport and the Protection of Environment”, “Measures for the Implementation of the National Transport Development Programme”, and other programmes aimed at reducing the negative impact of transport on the environment and on people’s health. Due to a difficult economic situation, the implementation of these programmes is slower than expected.

Please note that emissions from mobile sources are calculated based on **fuel sold** in Lithuania, thus national total emissions include, the main document, analyzing transport impact on the environment is the State Program “Transport and Environmental Protection”. It includes the activities to be followed:

1. On motor road transport:
   - national distribution of traffic flows.
   - perfection of means for selection and training of drivers.
   - trolley-bus network development in Vilnius and Kaunas.
   - optimization of fuel prices.
   - construction of new biotransport routes.

2. On railway transport:
   - electrification of Lithuanian railways.
   - pipeline transport development for oil products transportation.

3. On Sea transport:
   - power supply from the municipal power network to the ships in the port.

4. On the Entire Means of Transport:
   - the formation of the fleet of various means of transport,taking into account the existing ecological requirements. development and implementation of national ecological standards

Estimation of emissions in 1.A.3 *Transport* are carried out for each fuel in sub-categories listed below:

- *Civil and International Aviation* 1.A.3.a
- *Road Transportation* 1.A.3.b
- *Railways* 1.A.3.c
- *Navigation* 1.A.3.d
- *Other Transportation* 1.A.3.e

3.13 Civil aviation (NFR 1.A.3.a i-ii)

3.13.1 Overview of the Sector

This category includes activities related to air traffic within or in the surroundings of airports (landing and take-off cycles. LTO). International traffic includes all flights whose origin or final destination is a foreign airport. In Lithuania, there are four international airports (Figure 48):

- Vilnius International Airport
- Kaunas Airport

- Palanga International Airport
- Šiauliai International Airport

FIGURE 48 MAP OF AIRPORTS AND AERODROMES IN LITHUANIA

Lithuania reports its air pollutants emissions according to the requirements of the CLRTAP as well as greenhouse gas according to the requirements of the UNFCCC. The nomenclature for both reportings is (almost) the same (NFR), but there are differences concerning the system boundaries. Emissions from civil aviation are accounted for differently under the CLRTAP and the UNFCCC: Only emissions from domestic flights are accounted for in the GHG inventory, while emissions from international flights are reported as memo items. For the reporting under the CLRTAP, landing and takeoff (LTO) emissions of domestic and international flights are accounted for, while emissions of international and domestic cruise flights are reported under memo items only.

TABLE 11 ACCOUNTING RULES FOR EMISSIONS FROM 1A3A CIVIL AVIATION TRANSPORTATION FOR CLRTAP AND UNFCCC.

Differences between reporting under CLRTAP and UNFCCC concerning the accounting to the national total			**CLRTAP / NFR-Templates**			**UNFCCC/CRTables**	
			National total	National total for compliance	Memo item	National total	Bunker 1D
Aviation 1.A.3.a	Civil/Domestic aviation	Landing and Take-off (LTO)	Yes	Yes	No	Yes	No
		Cruise	No	No	Yes	Yes	No
	International	Landing and Take-off	Yes	No	No	No	Yes

	aviation	(LTO)					
		Cruise	No	No	Yes	No	Yes

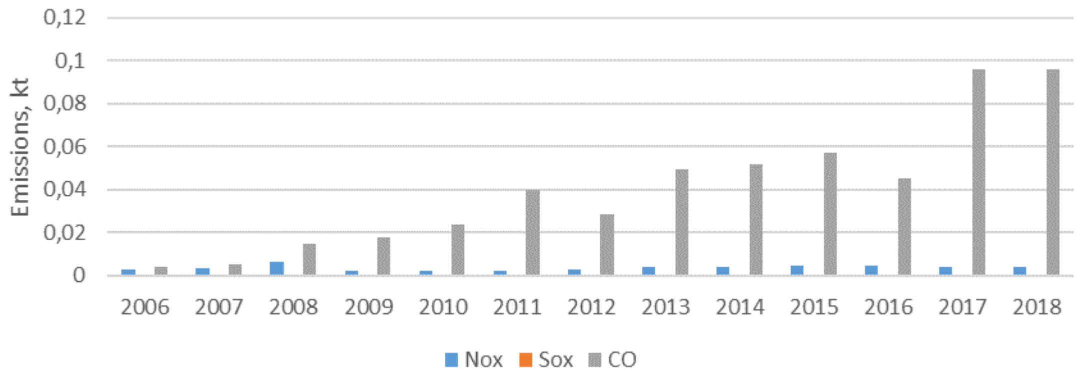


FIGURE 49 POLLUTANT EMISSIONS IN SECTOR 1.A.3.A.I

3.13.2 Methodological issues

For the years 1990-2018 data related to aviation gasoline and jet kerosene are those of the Statistics Lithuania database splited on international and domestic jet kerosene use, the amounts of domestic fuels use in years 1990 – 2004 were calculated based on extrapolation data on fuel share of jet kerosene used for international aviation in Lithuania. Aviation gasoline is more common as fuel for private aircraft, while the jet fuel used in aircraft, Airlines, military aircraft and other large aircraft. Net calorific values (NCVs) used to convert fuel consumption in natural units into energy units are provided in the Table 12. Emissions from 2006 were calculated using EUROCONTROL based on Tier 2.

TABLE 12 SPECIFIC NET CALORIFIC VALUES (CONVERSION FACTORS).

TYPE OF FUEL	TONNE	TONNE OF OIL EQUIVALENT (TOE)	TJ/TONNE
GASOLINE TYPE JET FUEL	1.0	1.070	0.04479
KEROSENE TYPE JET FUEL	1.0	1.031	0.04316

The aviation gasoline consumption and air pollutants emissions 1990-2005 were based on Tier *1* approach as this method should be used to estimate emissions from aircraft that use aviation gasoline which is only used in small aircraft and generally represents less than 1% of fuel consumption from aviation. The Tier *1* approach for aviation emissions uses the following general equation:

$$E_{Pollutant} = AR_{Fuel\ consumption} \times EF_{Pollutant}$$

where

$\boldsymbol{E_{pollutant}}$ is the annual emission of pollutant for each of the LTO and CCD phases of domestic and international flights;

$\boldsymbol{AR_{fuel\ consumption}}$ is the activity rate by fuel consumption for each of the flight phases and flight types;

$\boldsymbol{EF_{pollutant}}$ is the emission factor of pollutant for the corresponding flight phase and flight type.

Default emission factors for Civil aviation are taken from EMEP/EEA 2016 methodology and are presented in Table 13.

TABLE 13 EMISSION FACTORS USED IN THE CALCULATION OF EMISSIONS FROM CIVIL AVIATION (G/KG FUEL)

	NOx	CO	NMVOC	SO_2	PM
Aviation petrol	8.3	11.8	0.5	0.08	0.07

3.13.3 Uncertainties

Uncertainty in activity data 2005-2018 of fuel consumption is ±2%. For the 1990-2005 period uncertainty in activity data of fuel consumption is ±20%.

3.13.4 Source-specific QA/QC and verification

Assessment of trends have been performed.

3.13.5 Source-specific recalculations

Recalculations have been carried out 1990-2018 for domestic and international civil aviation due to corrected jet fuel consumption and EF.

3.13.6 Source-specific planned improvements

No improvements are planned for the next submission.

3.14 Road transport (1.A.3.b)

3.14.1 Overview of the Sector

Lithuania has a fairly well-developed road network provided with a dense road (1.291 km/km²) network (201). At the end of 2018, the length of roads amounted to 85.6 thousand kilometers; the length of E-roads amounted to 1,639 kilometers, of which motorways – 324 km (Statistics Lithuania, 2019).

Road transportation is the most important emission source in the Transport sector. This sector includes all types of vehicles on roads (passenger cars (PC), light duty vehicles (LD), heavy duty trucks and buses (HD), motorcycles and mopeds (2-wheels)) (Figure 50). The source category does not cover farm and forest tractors driving occasionally on the roads because they are included in other sectors as off-roads.

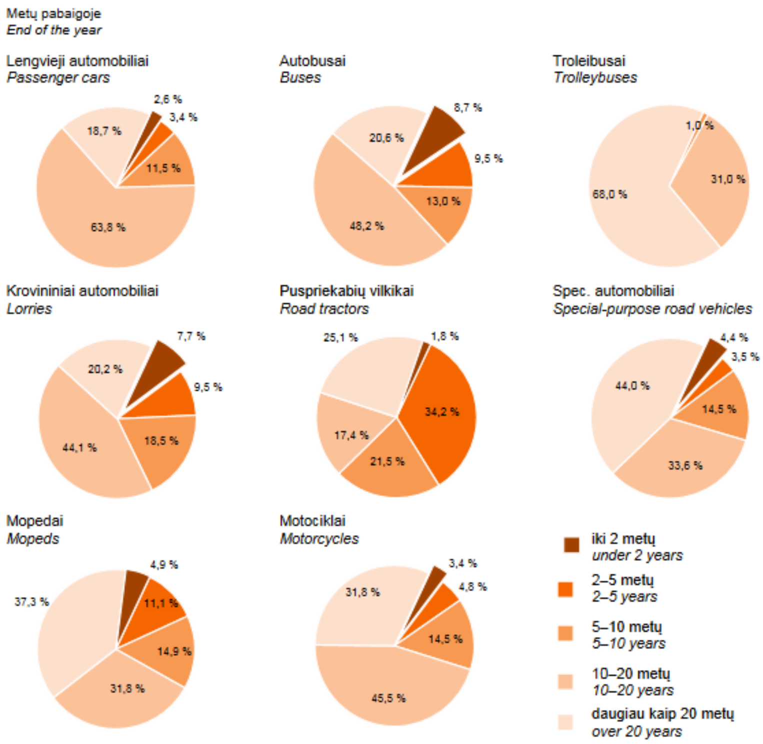


FIGURE 50 ROAD VEHICLES BY AGE, 2017

Activity data for mobile sources are based on official energy balance of the Lithuania prepared by the Statistics Lithuania (2020). The parameters necessary for distribution of sold fuels are transport mode, fuel type, weight of vehicle and equipment with more or less effective catalytic system. The appropriate distribution is necessary for assigning of the relevant emission factor. Sector 1A3b Road Transportation is split into five subsectors:

- 1.A.3.b i Passenger Cars
- A.3.b ii Light Duty Vehicles
- 1.A.3.b iii Heavy Duty Vehicles
- 1.A.3.b iv Mopeds & Motorcycles
- 1.A.3.b v Gasoline Evaporation
- 1.A.3.b vi Automobile tire and brake wear
- 1.A.3.b vii Automobile road abrasion

Calculations of emissions from road transport (NFR sector 1A3b) are based on:

- statistical fuel consumption data from Energy balance
- traffic intensity. estimated by Institute of Transport
- road transport fleet data, taken from Registry of Transport (State Enterprise “Regitra”). Emission factors and fuel consumption factors for NOX, NMVOC, CO, TSP and NH_3 emission estimations were calculated using COPERT V model. Road transport was differentiated into the passenger cars, light duty vehicles, heavy duty vehicles, buses and motorcycles categories.

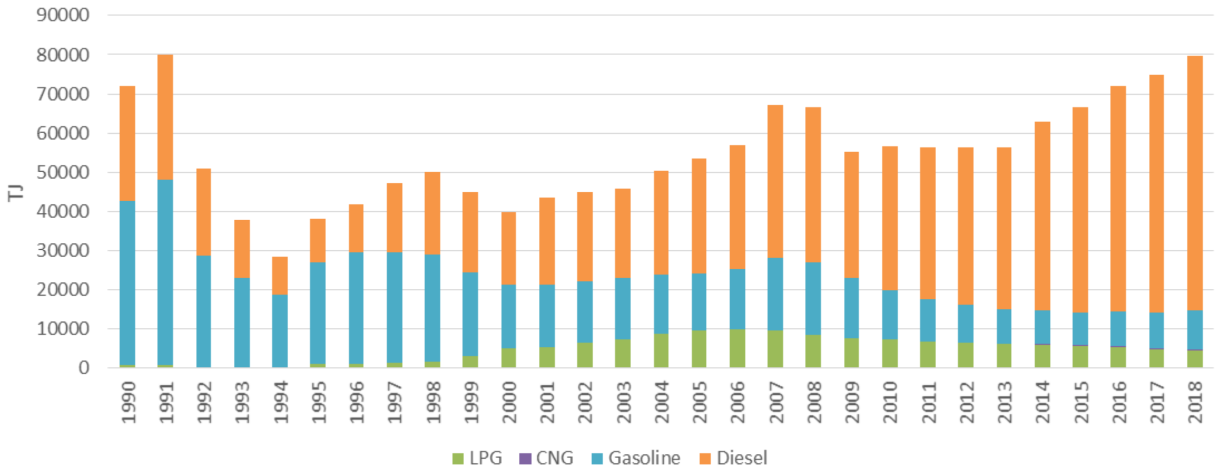
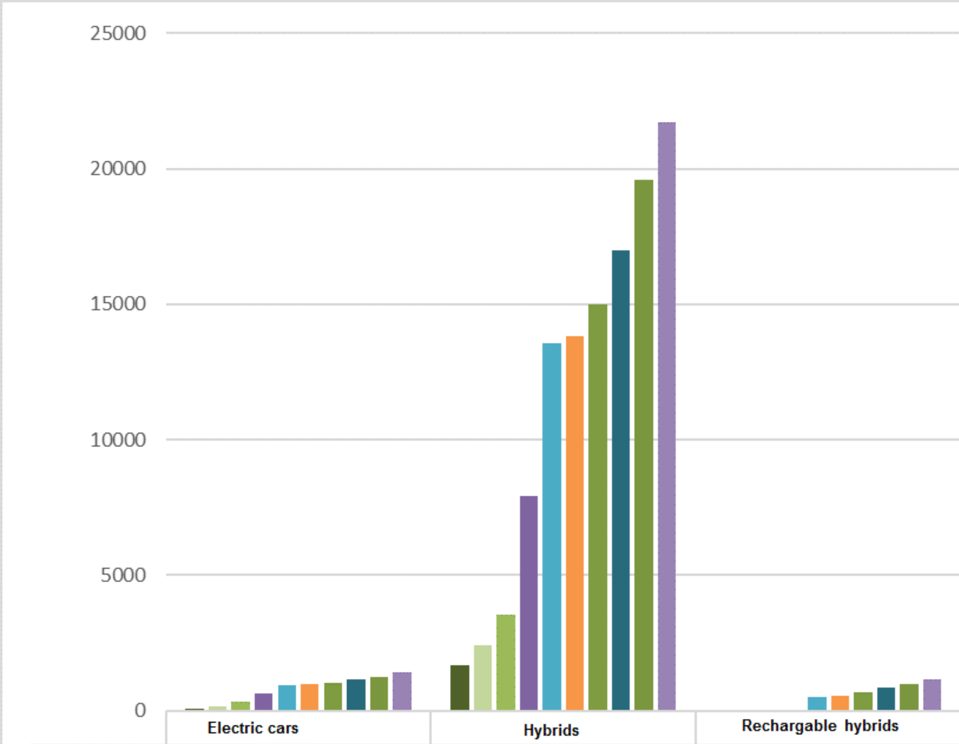


FIGURE 51 FUEL CONSUMPTION IN ROAD TRANSPORT IN 1990-2018, TJ

Diesel and petrol fuels are mainly used in transport sector with a slow and steady increase in electromobiles. According to “Regitra” there were 956 registered electromobiles in 2018.



	Electric cars	Hybrids	Rechargable hybrids
2014-12-31	63	1677	0
2015-12-31	159	2434	0
2016-11-14	337	3560	0
2017-12-01	620	7926	0
2018-12-01	956	13566	504
2019-01-01	983	13841	553
2019-04-01	1047	15010	685
2019-07-01	1149	16988	847
2019-10-01	1264	19608	997
2020-01-01	1434	21735	1172

FIGURE 52 SHARE OF ELECTROMOBILE

There is a marked switch from petrol engines to diesel. The number of petrol engines (all vehicles) and as a result petrol fuel consumption has dropped between 1990 and 2018, while the number of diesel engines increased significantly from ~116 to 790 thousand for the same period.

Passenger cars represent the most fuel-consuming vehicle category, followed by heavy-duty vehicles, light duty vehicles and 2-wheelers, in decreasing order.

Many factors had influence on changes of energy consumption: deep economic slump in 1991-1994, fast economic growth over the period 2000-2008, dramatic reduction of economic activities in all branches of the national economy, a significant increase of energy prices, an increase of energy efficiency and other reasons. During the period 2000-2008 the energy consumption was increasing by 3.8% per annum. During this period the average growth rate of GDP was 8.1% per annum (Statistics Lithuania, Statistical Yearbook of Lithuania, 2008). The impact of global economic recession was dramatic in Lithuania. The global economic crisis had an effect on Lithuanian GDP already in 2008, but GDP growth rate in 2008 was still positive (2.6%). In 2009, GDP decreased by 14.8%. Since 2010 Lithuania's GDP has grown slightly by 1.6% in 2010, 6.0% in 2011 and 3.8% in 2012. During 2013–2014, GDP growth rates slightly slowdown and accounted 3.5% per annum. In 2015, GDP growth rate reduced by two times (to 1.8%). Increased by 6.2% import volume of goods and services and by 0.4% reduced export volume were the key drivers of slacken rate of GDP growth. 1.A.3.biv is highly variable as vehicle registration is highly variable due to re-registration.

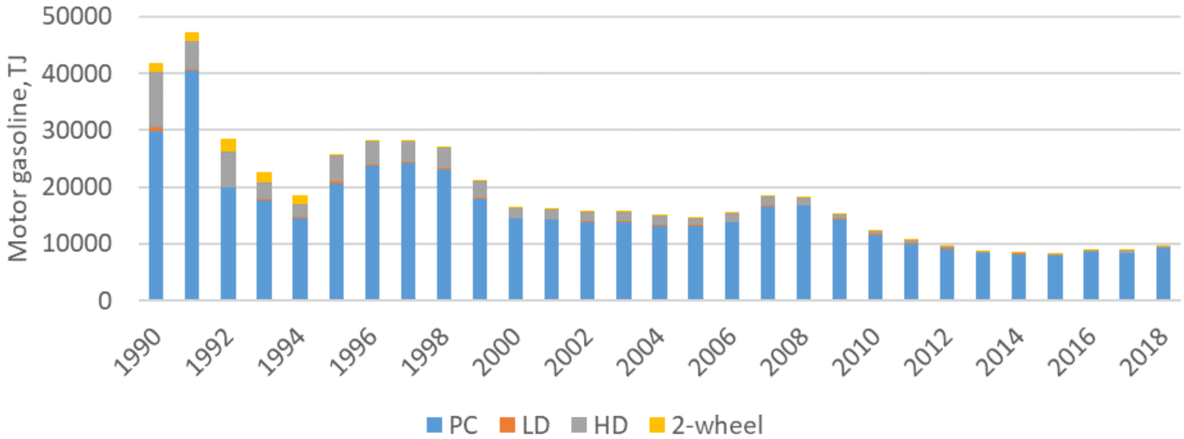


FIGURE 53 GASOLINE FUEL CONSUMPTION PER VEHICLE TYPE FOR ROAD TRANSPORT 1990-2018

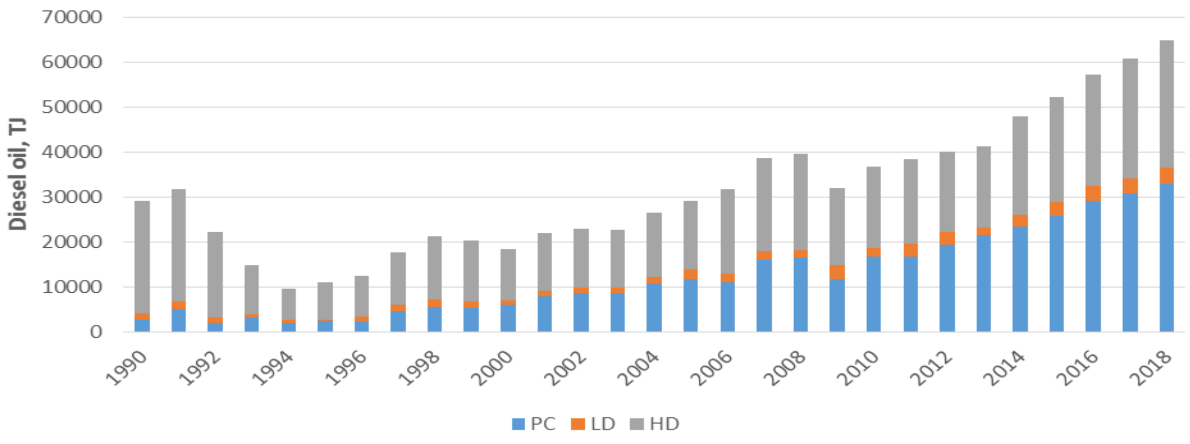


FIGURE 54 DIESEL OIL CONSUMPTION PER VEHICLE TYPE FOR ROAD TRANSPORT 1990-2018

In 2018, fuel consumption shares for diesel passenger cars, diesel heavy-duty vehicles, gasoline passenger cars, diesel light duty vehicles were 39 %, 36%, 12%, 4%, respectively.

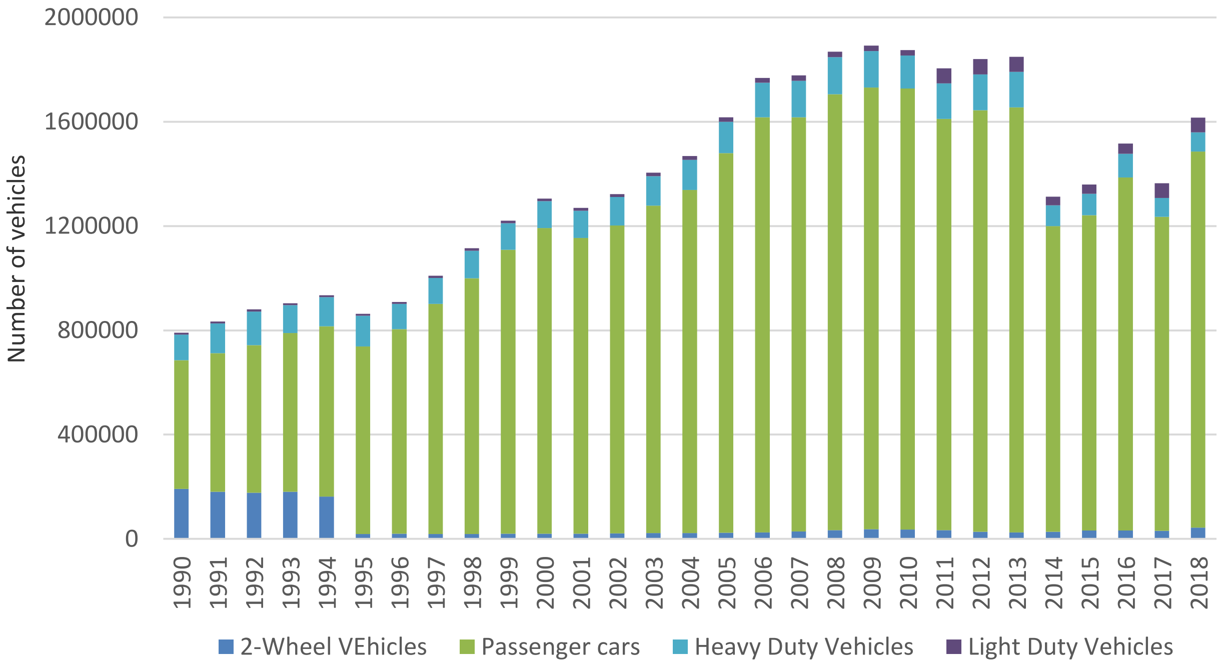


FIGURE 55 NUMBER OF VEHICLES IN LITHUANIA IN THE PERIOD 1990-2018

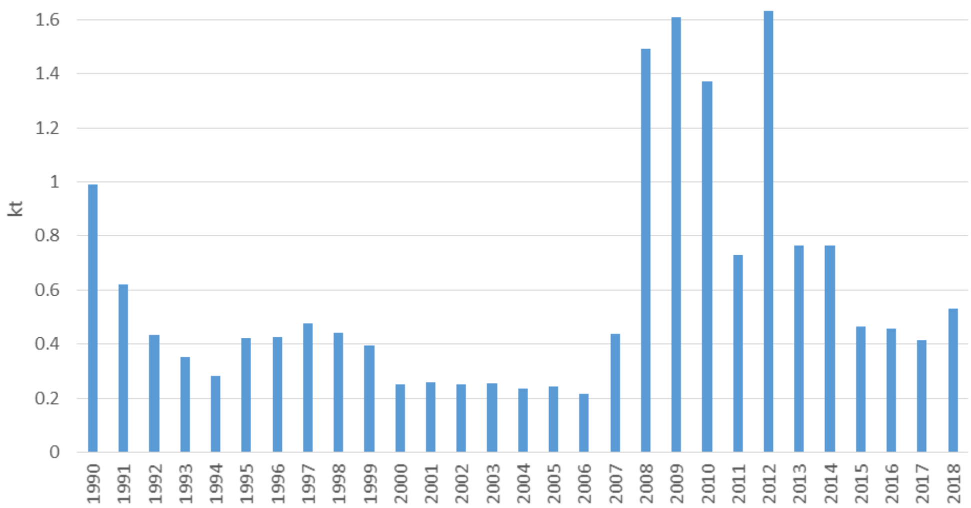


FIGURE 56 NMVOC EMISSIONS IN SECTOR 1.A.3.B.V

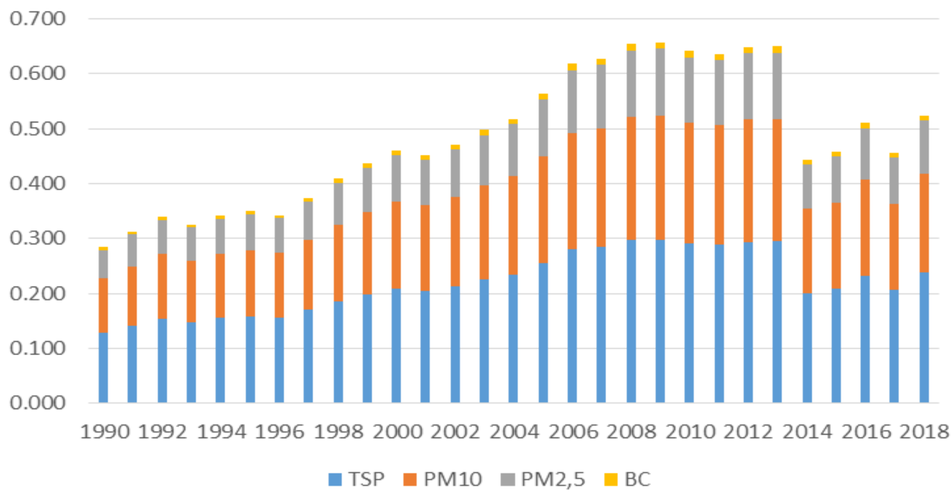


FIGURE 57 POLLUTANT EMISSIONS IN SECTOR 1.A.3.B.VI

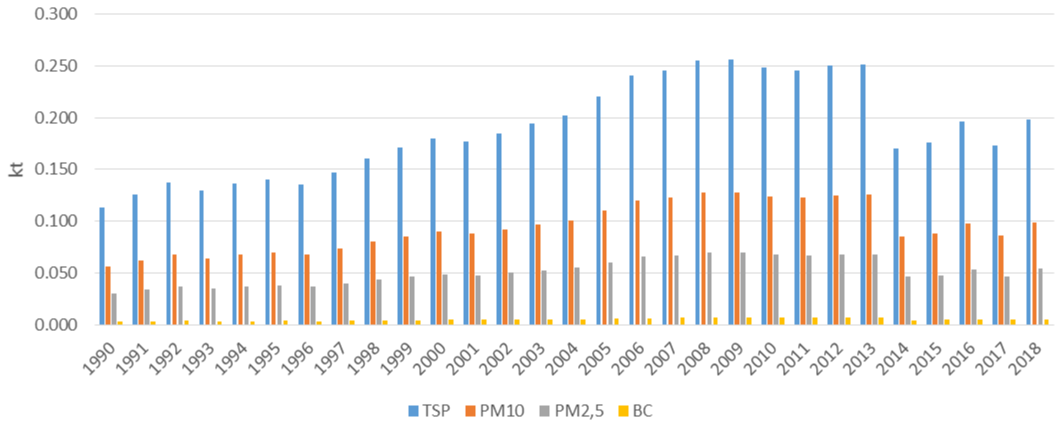


FIGURE 58 POLLUTANT EMISSIONS IN SECTOR 1.A.3.B.VII

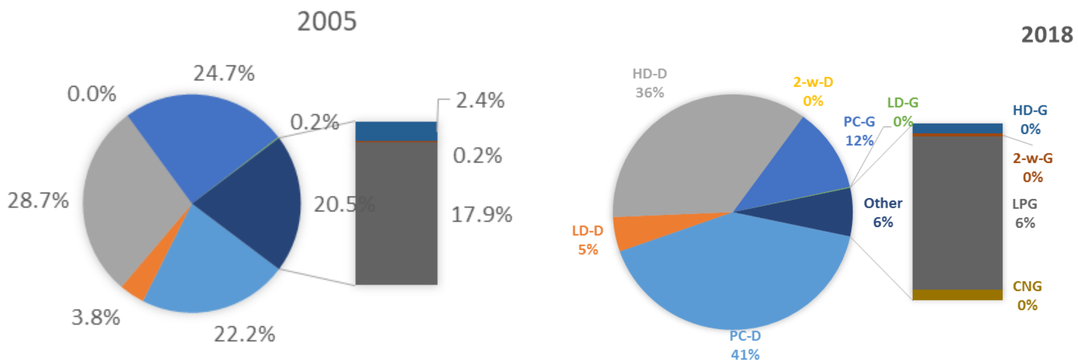


FIGURE 59 FUEL CONSUMPTION SHARE (TJ) PER VEHICLE TYPE AND FUEL TYPE FOR ROAD TRANSPORT IN 2005 AND 2018

3.14.2 Methodological issues

In the Tier *3* method emissions are calculated using a combination of firm technical data and activity data. The activity data of road transport was split and filled in for a range of parameters including:

- Fuel consumed, quality of each fuel type;
- Emission controls fitted to vehicle in the fleet;
- Operating characteristics (e.g. average speed per vehicle type and per road)
- Types of roads;
- Maintenance;
- Fleet age distribution;
- Distance driven (mean trip distance);
- Climate

The model calculates vehicle mileages, fuel consumption, exhaust gas emissions, evaporative emissions of the road traffic. The balances use the vehicle stock and functions of the km driven per vehicle and year to assess the total traffic volume of each vehicle category. The production year of vehicles in this category has been taken into account by introducing different classes. which either reflects legislative steps ('ECE', 'Euro') applicable to vehicles registered in each Member State. The technology mix in each particular year depends on the vehicle category and the activity dataset considered. Lubricant use in two-stroke engines amounts only to 0.72-1.44 TJ, consequently emissions do not exceed threshold of significance (10 kt), therefore emissions from lubricant use are considered as insignificant.

For the period between 1990 and 2006, it was necessary to estimate the figures with the aid of numerous assumptions. The total emissions were calculated by summing emissions from different sources, namely the thermally stabilized engine operation (hot) and the warming-up phase (cold start) (EEA 2000; MEET, 1999). For Tier *3* approaches cold start emissions were estimated:

$$E_{COLD;i,j} = \beta_{i,k} \times N_k \times M_k \times E_{HOT;i,k} \times (e_{COLD} / e_{HOT}\big|_{i,k} - 1) \quad (1)$$

Where:

$E_{COLD;i.k}$ - cold start emissions of pollutant i(for the reference year), produced by vehicle technology k,

$\beta_{i.k}$ - fraction of mileage driven with a cold engine or the catalyst operated below the light-off temperature for pollutant i and vehicle [veh] technology k,

N_k - number of vehicles of technology k in circulation,

M_k - total mileage per vehicle [km veh^{-1}] in vehicle technology k,

e_{COLD}/e_{HOT} - cold/hot emission quotient for pollutant i and vehicle of k technology,

$$E_{total} = E_{cold} + E_{hot} \quad (2)$$

where:

E_{TOTAL} - total emissions (g) of compound for the spatial and temporal resolution of the application.

E_{HOT} - emissions (g) during stabilized (hot) engine operation.

E_{COLD} - emissions (g) during transient thermal engine operation (cold start).

The *β*-parameter depends upon ambient temperature *ta* (for practical reasons the average monthly temperature was used). Since information on average trip length is not available for all vehicle classes. simplifications have been introduced for some vehicle categories. According to the available statistical data (André *et al*. 1998), a European value of 12.4 km has been established for the l_{trip} value and used in estimations in Lithuania.

Due to the fact that concentrations of some pollutants during the warming-up period are many times higher than during hot operation. In this respect, a distinction is made between urban. rural and highway driving modes. Cold-start emissions are attributed mainly to urban driving (and secondarily to rural driving). as it is expected that a limited number of trips start at highway conditions. Therefore, as far as driving conditions are concerned, total emissions were calculated by means of the equation:

$$E_{Total} = E_{Urban} + E_{Rural} + E_{Highway}. \quad (3)$$

where:

E_{URBAN}. E_{RURAL} and $E_{HIGHWAY}$ - the total emissions (g) of any pollutant for the respective driving situations.

Fuel was distributed to transport categories, types, ecology standards and driving modes according to data taken from State Enterprise Transport and Road Research Institute under the Ministry of Transport and Communications of the Republic of Lithuania.

Emissions was estimated from the fuel consumed (represented by fuel sold) and the distance travelled by the vehicles. The first approach (fuel sold) was applied.

Emission factor assumes full oxidation of the fuel. Emission equation for air pollutants for Tier *3* is:

$$Emission = \sum_{a,b,c,d}\left[Distance_{a,b,c,d} \cdot EF_{a,b,c,d}\right] + \sum_{a,b,c,d} C_{a,b,c,d} \ . \qquad (5)$$

where:

Emission - emission of air pollutants;

$EF_{a.b.c.d}$ - emission factor, kg/km;

$Distance_{a.b.c.d}$ - distance travelled during thermally stabilized engine operation phase, km;

$C_{a.b.c.d}$ - emission during (g) during transient thermal engine operation (cold start), kg;

b – vehicle type;

c – emission control technology;

d – driving situation (urban, rural, highway).

The annual mileage driven by the stock of vehicle per year is an important parameter in emission calculation as it affects both the total emissions calculated but also the relative contributions of the vehicle types considered. Calculations demand annual mileage per vehicle technology and the number of vehicles was supplied by the Lithuanian Road Administration and study funded by the European Commission – DG Environment and executed in collaboration with KTI, Renault, E3M-Lab/NTUA. Oekopol, and EnviCon. The source for these data is various European measurement programmes. Fuel consumption was calculated on the basis of appropriate assumptions for annual mileage of the different vehicle categories can be balanced with available fuel statistics (Ntziachristos et al. 2008). In general, the COPERT IV v.11 data are transformed into trip-speed dependent fuel consumption and emission factors for all vehicle categories and layers. The calculated fuel consumption in COPERT IV must equal the statistical fuel sale totals according to the UNFCCC and UNECE emissions reporting format. The statistical fuel sales for road transport are derived from the Statistics Lithuania.

For example, if a country has bulk fuel sold but does not have fuel use by vehicle type. they may allocate total fuel consumption across vehicle types based on the consumption patterns of their fleet (TRB's National Cooperative Highway Research Program (NCHRP) project report. Greenhouse Gas Emission Inventory Methodologies for State Transportation Departments). By applying a trial-and-error approach, it was possible to reach acceptable estimates of mileage. For each group, the emissions were estimated by combining vehicle type and annual mileage with hot emission factors, cold/hot ratios and evaporation factors.

Fuel was distributed to transport categories, types, ecology standards and driving modes according to mileage data taken from Institute of Transport and transport fleet data taken from Transport Registry.

Lubricant use in two-stroke engines amounts only to 0.72-1.44 TJ, consequently emissions do not exceed threshold of significance (10 kt), therefore emissions from lubricant use are considered as insignificant.

Lead (Pb) and other heavy metals emissions

Emissions of lead are estimated by assuming that 75 % of lead contained in the fuel is emitted into air. Then the equation is:

$$E_{Pb,j} = 0.75 \cdot k_{Pb,m} \cdot FC_{j,m} \qquad (2)$$

Where, $k_{Pb.m}$ – weight related lead content of gasoline (type m) in [kg/kg fuel]. The emission factor for lead is given in Table 14.

TABLE 14 EMISSION FACTOR FOR LEAD, G/L

Fuel	1990	2003	2006	2010
Leaded Gasoline	0.15	-	-	-
Unleaded Gasoline	0.013	0.005	0.003	0.0001

With regard to the emission of other heavy metal species, emission factors provided correspond both to fuel content and engine wear. Therefore, it is considered that the total quantity is emitted to the atmosphere (no losses in the engine). Heavy metal emissions depends on metal content in fuel. Therefore, emissions were calculated according to consumed fuel. LPG doesn't contain heavy metal; therefore, there are no heavy metals emissions from road transport using LPG.

TABLE 15 HEAVY METAL EMISSION FACTORS FOR ALL VEHICLE CATEGORIES IN [MG/KG FUEL]

Category	Cadmium	Copper	Chromium	Nickel	Selenium	Zinc
Road transport	0.01	1.7	0.05	0.07	0.01	1

Gasoline evaporation (1.A.3.b.v)

Gasoline evaporation emissions are estimated according to mileage of separate road transport categories consuming gasoline and number of vehicles consuming gasoline. Mileage of road transport categories was estimated according to statistical fuel consumption data and mileage data estimated by Institute of Transport.

TABLE 16 NMVOC EMISSION FACTORS FOR GASOLINE EVAPORATION

	NMVOC emission factors	Units
Passenger cars		
Diurnal and hot soak emissions in summer	3642.00	g/vehicle
Diurnal and hot soak emissions in winter	4807.00	g/vehicle
Running losses in summer	0.022	g/km
Running losses in winter	0.006	g/km
Light duty vehicle		
Diurnal and hot soak emissions in summer	3642.00	g/vehicle
Diurnal and hot soak emissions in winter	4807.00	g/vehicle
Running losses in summer	0.022	g/km

Running losses in winter	0.006	g/km
Motorcycles		
Diurnal and hot soak emissions in summer	1457.00	g/vehicle
Diurnal and hot soak emissions in winter	1923.00	g/vehicle
Running losses in summer	0.009	g/km
Running losses in winter	0.002	g/km

Tyre, brake wear and road abrasion emissions

Tyre, brake wear and road abrasion emissions are estimated according to mileage of separate road transport categories. Mileage of road transport categories was estimated according to statistical fuel consumption data, fuel consumption factors calculated by COPERT V and mileage data estimated by Institute of Transport. The resulting mileage data (Table 17) is used as activity rates for estimating tyre, brake wear and road abrasion emissions.

TABLE 17 ROAD TRANSPORT MILEAGE BY CATEGORIES. [KM]

Category	Mileage, km
Passenger cars	7 502 454 100
Light duty vehicle	1 566 991 000
Heavy duty vehicle	1 887 711 951
Buses	752 344 000
Motorcycles	5 632 879
Mopeds	10 176 919

TSP, PM_{10} and heavy metal emission factors for tyre, brake wear and road abrasion were taken from [18] literature and reported in Table 18. $PM_{2.5}$ and PM_{10} emission factors were taken from [7] reference and reported in Table 19-Table 20.

TABLE 18 TSP EMISSION FACTORS FOR TYRE. BRAKE WEAR AND ROAD ABRASION [18]

Transport category	Emission factor (g/km)		
	Tyre wear	Brake wear	Road abrasion
Motorcycles	0.0028	0.0037	0.0030
Passenger cars	0.0064	0.0073	0.0075
Light duty vehicles	0.0101	0.0115	0.0075
Heavy duty vehicles and buses	0.0270	0.0320	0.0380

TABLE 19 PM_{10} EMISSION FACTORS FOR TYRE, BRAKE WEAR AND ROAD ABRASION [18]

Transport category	Emission factor (g/km)		
	Tyre wear	Brake wear	Road abrasion
Motorcycles	0.0028	0.0020	0.0030
Passenger cars	0.0064	0.0033	0.0075
Light duty vehicles	0.0101	0.0052	0.0075
Heavy duty vehicles and buses	0.0270	0.0130	0.0380

TABLE 20 PM2.5 EMISSION FACTORS FOR TYRE, BRAKE WEAR AND ROAD ABRASION [7]

Transport category	Emission factor (g/km)		
	Tyre wear	Brake wear	Road abrasion
Motorcycles	0.0001	0.0003	0.0016
Passenger cars	0.0003	0.0022	0.0042
Light duty vehicles	0.0003	0.0022	0.0042
Heavy duty vehicles and buses	0.0020	0.0071	0.0209

TABLE 21 HEAVY METAL FRACTION OF TYRE, BRAKE WEAR AND ROAD ABRASION TSP EMISSION [18]

Heavy metal	Tyre wear [mg/kg TSP]	Brake wear [mg/kg TSP]	Road abrasion [mg/kg TSP]
As	0.8	10.0	0
Cd	2.6	13.2	1
Cr	12.4	669	40
Cu	174	51112	12
Ni	33.6	463	20
Pb	107	3126	15
Zn	7434	8676	35

3.14.3 Uncertainties and time-series consistency

Expert judgement suggests that the uncertainty of the activity data is approximately ±5%. The primary source of uncertainty is the activity data rather than emission factors.

3.14.4 Source-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.14.5 Source-specific recalculations

No source specific recalculations.

3.14.6 Source-specific planned improvements

No source-specific improvements.

3.15 Railways (NFR 1.A.3.c)

3.15.1 Overview of the Sector

In 2018, the operational length of railways amounted to 1,910.7 km. The length of electrified lines remained unchanged (152.4 km). Emissions from producing electricity used in electric trains are not included in this category, but in category 1.A.1. Lithuanian Railways (lithuanian: “Lietuvos Geležinkeliai”) is the national, state-owned railway company of Lithuania. Lithuanian’s trains operate frequent services across the whole of Lithuania. In 2018, goods transport by rail amounted to 56.7 million tonnes. National goods transport by rail amounted to 15.1 million tonnes.

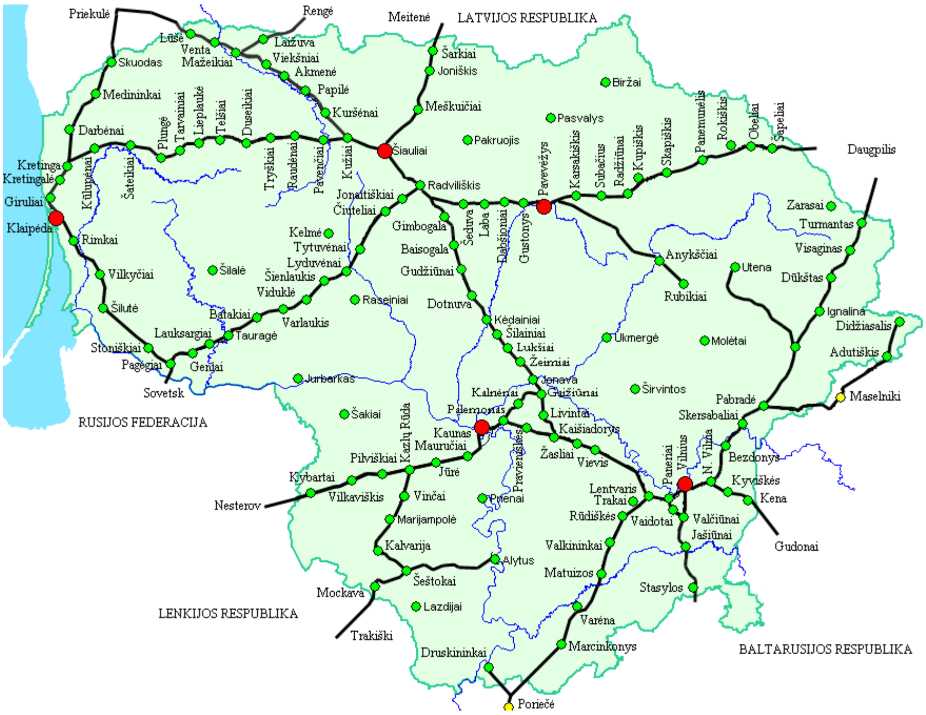


FIGURE 60 MAP OF LITHUANIAN RAILWAYS

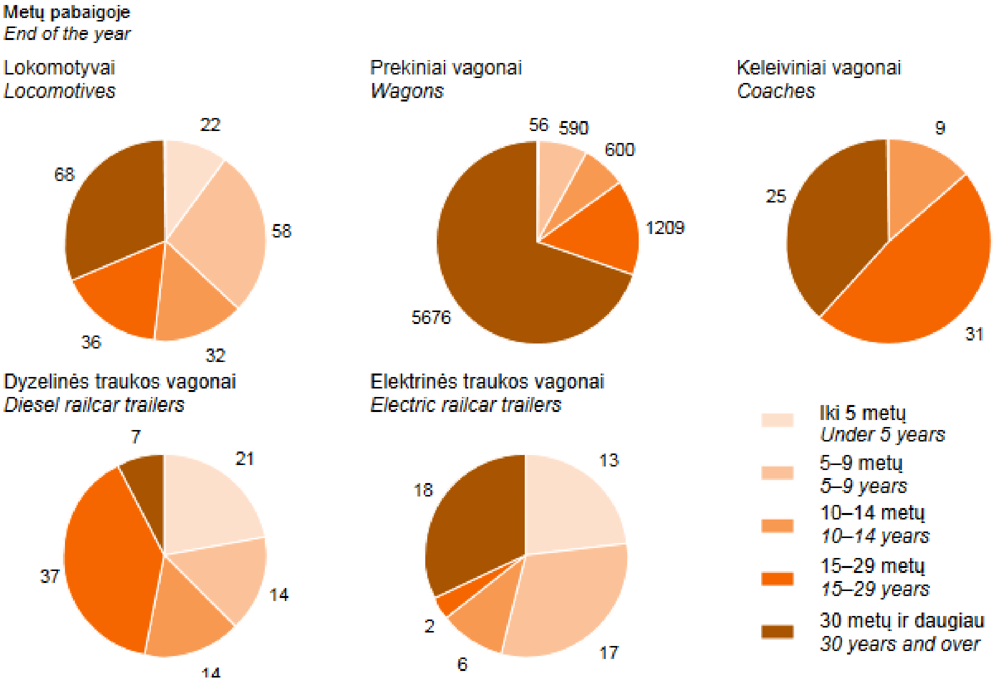


FIGURE 61 RAILWAY VEHICLES BY AGE, 2017

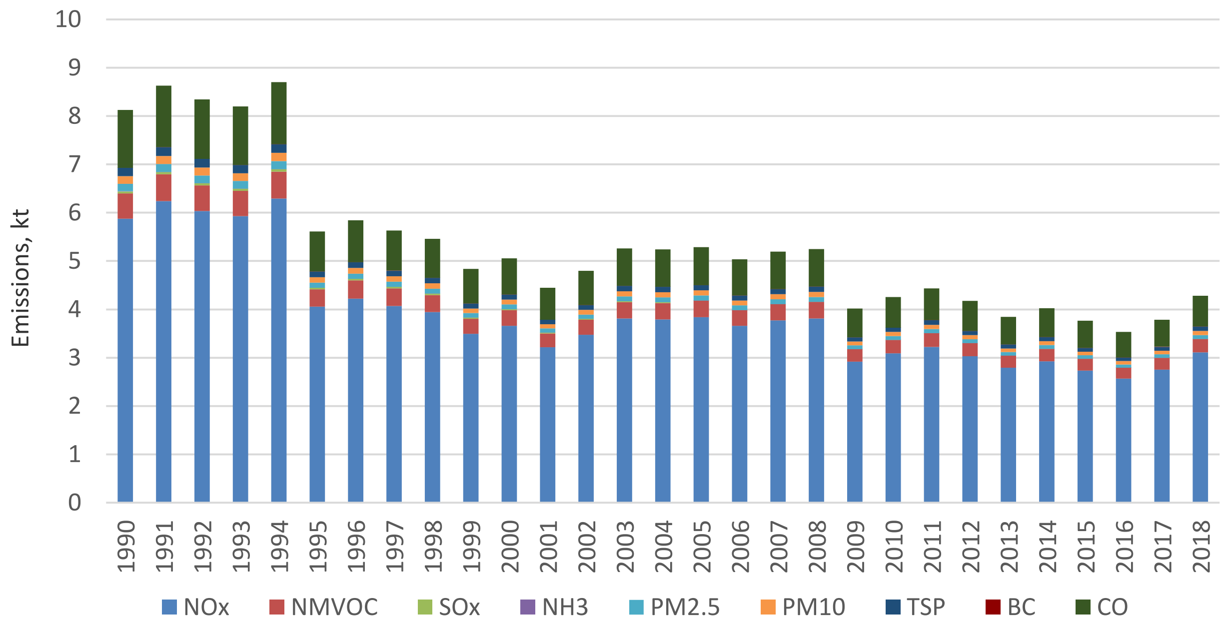


FIGURE 62 POLLUTANT EMISSIONS IN SECTOR 1.A.3.C

3.15.2 Methodological issues

The Tier 2 approach is based on apportioning the total fuel used by railways to that used by different generic locomotive technology types as the measure of activity. It assumes that the fuel can be apportion for example using statistics on the number of locomotives, categorized by type, and their average usage, e.g. from locomotive maintenance records (Figure 61).

For this approach the algorithm used is:

$$E_i = \sum_m \sum_j (FC_{j,m} \times EF_{i,j,m})$$

Where *Ei* - mass of emissions of pollutant *i* during inventory period; *FC* - fuel consumption; *EFi* - average emissions of pollutant *i* per unit of fuel used.

EFi,j,m - emission factor of pollutant *I* for each unit of fuel type *m* used by category *j* (kg/tonnes)

m – fuel type (diesel, gas oil)

j - locomotive category (shunting, rail car, line haul).

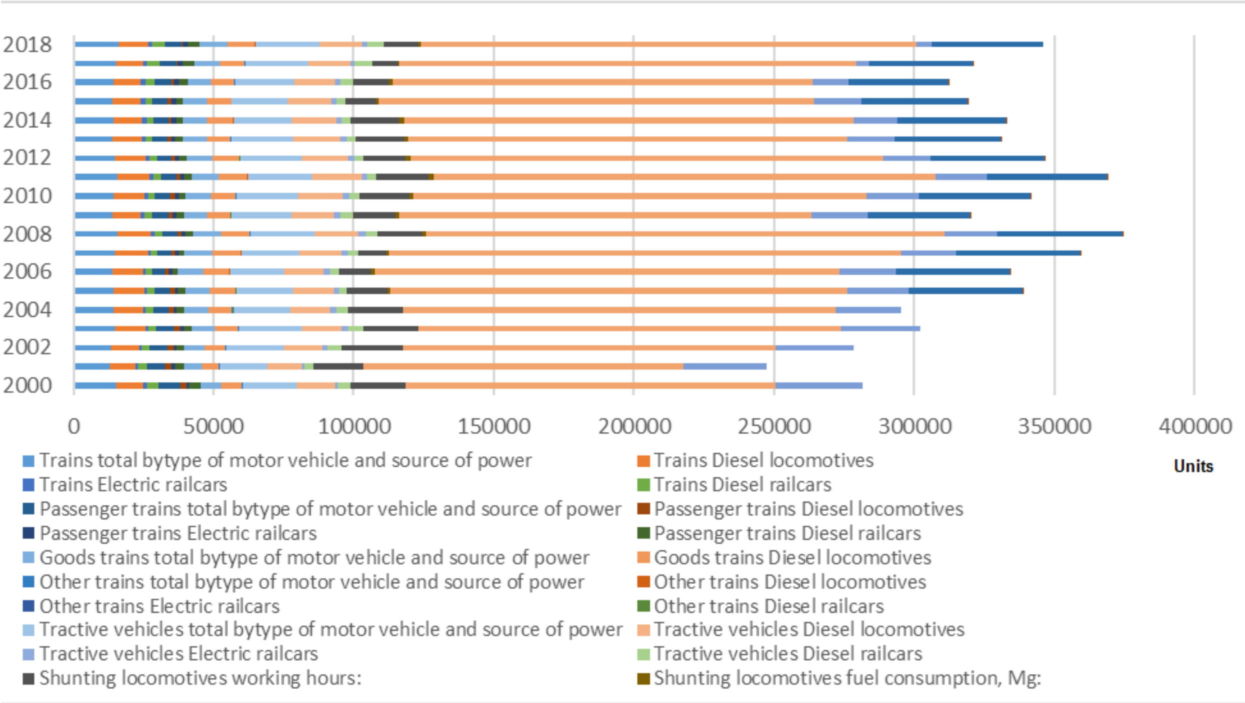


FIGURE 63 TRAINS TECHNOLOGY TYPES 2000-2018

Emissions were estimated using fuel statistics from Statistics Lithuania. Tier 2 emission factors were taken from 2016 EMEP/EEA Guidebook 1.A.3.c category (Table 54, Table 55, Table 56). While several EFs based on sulphur content in the fuel were used: for the 1990-2000 period 400 g Sulphur/Mg of fuel consumed, 2000-2005 – 300 g/Mg, 2005-2009 – 40 g/Mg and 8 g/Mg for every year from 2009. The following Guidebook-provided equation was used to estimate SOx emissions:

$$Emission_{SOx} = 2 \times Fuel\ consumed\ (Gg)_{Diesel} \times Sulphur\ content\ (Gg\ of\ S\ per\ Gg\ of\ diesel)$$

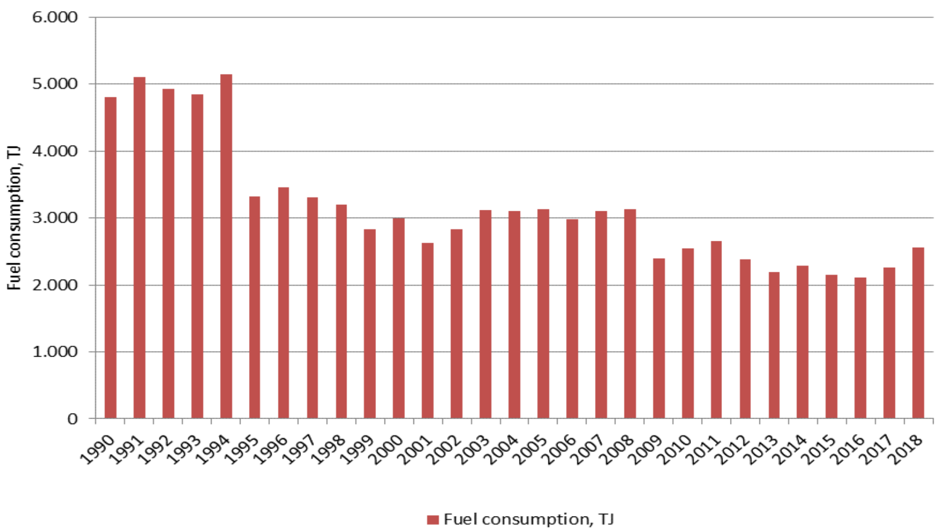


FIGURE 64 FUEL CONSUMPTION IN RAILWAY 1.A.3.C SECTOR

Fuel consumption in the railways transport decreased more than twice from 1990 to 2018. Similar change occurred in the amounts of emissions. 1990/2018 emissions dropped by 47.3%, while 2005/2018 emissions decreased by 18.9%. SOx emissions decreased by 99.0% and 83.8% from 1990 to 2018 and from 2005 to 2018, respectively.

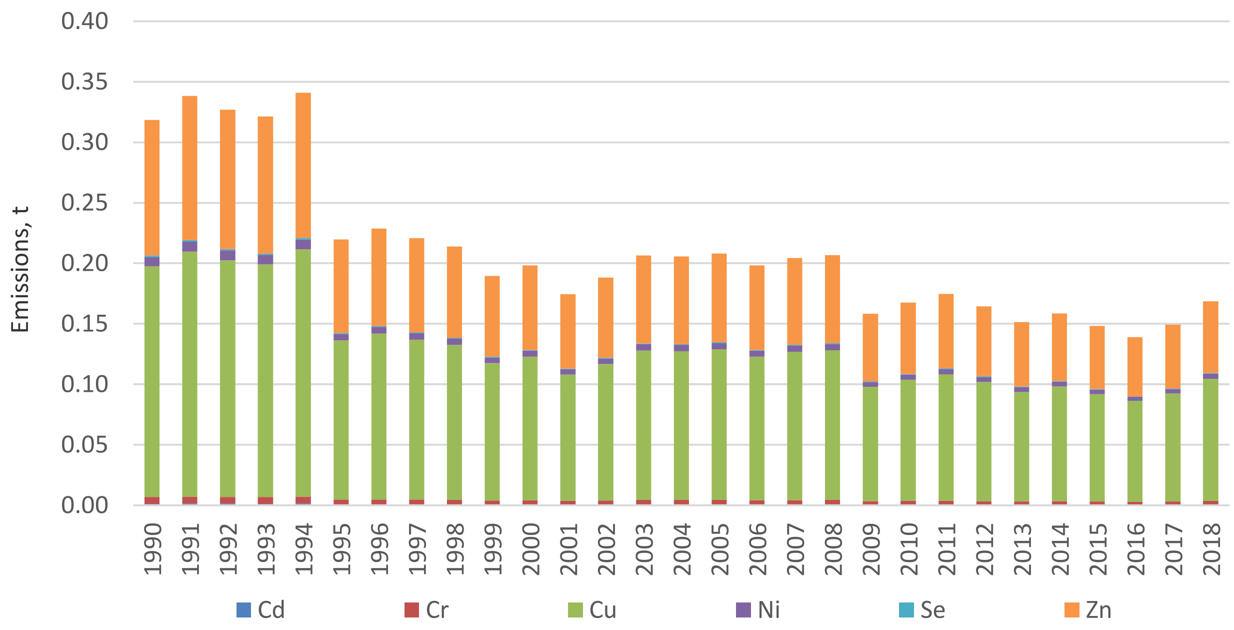


FIGURE 65 HEAVY METALS EMISSIONS IN SECTOR 1.A.3.C

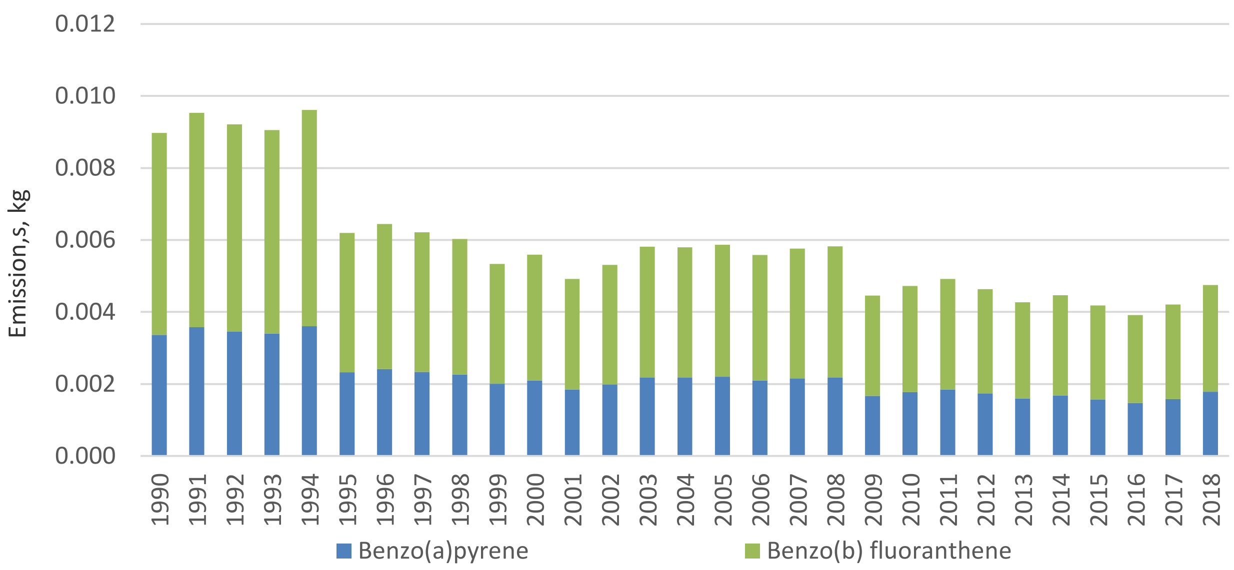


FIGURE 66 PAHS EMISSIONS IN SECTOR 1.A.3.C

B(k)f & Indeno (1.2.3-cd) pyrene and dioxins emission factor values are not available for railway emissions. It is therefore recommended to use values corresponding to old technology heavy duty vehicles from the Exhaust Emissions from Road Transport chapter (1.A.3.b.iii), BC fraction of PM (f-BC): 0.53.

3.15.3 Uncertainty analysis for the railway transport sector.

The uncertainty in activity data is 2%. The EF in Table above provide ranges indicating the uncertainties associated with diesel fuel. In the absence of specific information, the percentage relationship between the upper and lower limiting values and the central estimate may be used to derive default uncertainty ranges associated with emission factors for additives.

3.15.4 Source-specific planned improvements

No source-specific improvements.

3.16 National navigation (shipping) (NFR 1.A.3.d)

3.16.1 Overview of the Sector

Lithuania has ~900 km of inland waterways. Inland waterways are navigable rivers, canals, lakes, man-made water bodies, and part of the Curonian Lagoon belonging to the Republic of Lithuania. Length of inland waterways regularly used for transport in Lithuania equalled 493 km in 2018. In 2018, transport of goods by inland waterways amounted to 1.2 billion tonnes, the number of passengers carries – 2 million.

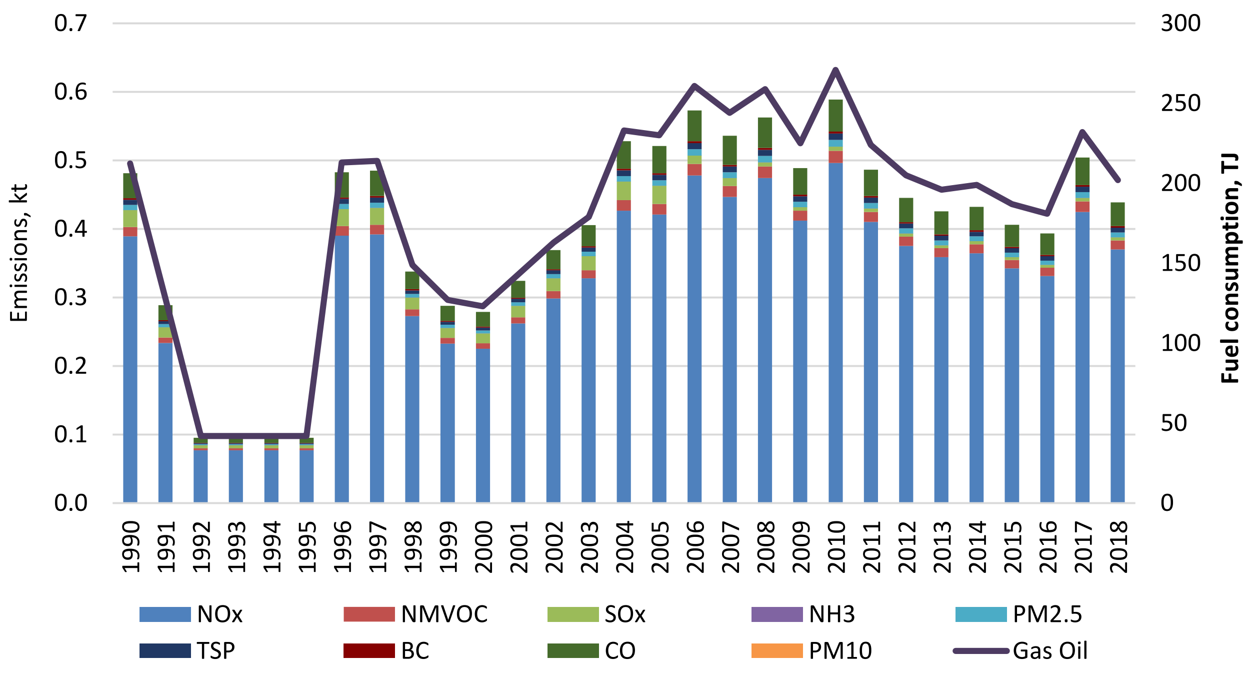


FIGURE 67 POLLUTANT EMISSIONS AND FUEL CONSUMPTION IN SECTOR 1.A.3.D.II

As seen in Figure 67 fuel consumption decreased by 12.2% between 2005 and 2018. This decrease is obviously due to the impact of the decreased fuel consumption in inland waterways.

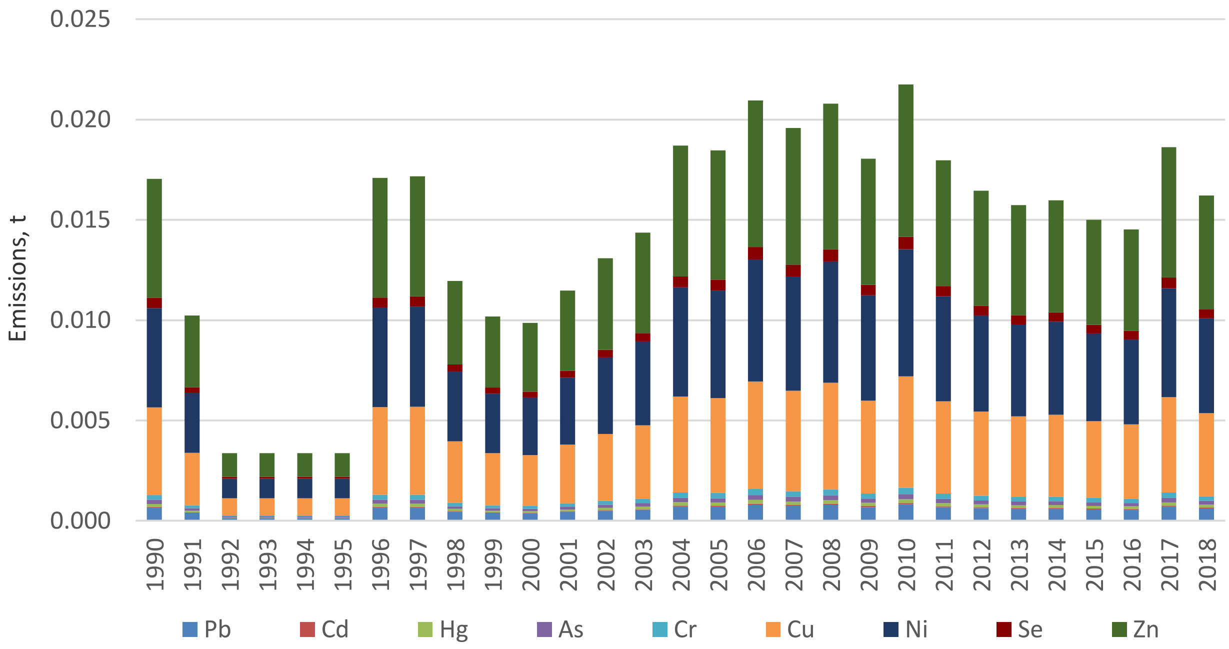


FIGURE 68 HEAVY METAL EMISSIONS IN SECTOR 1.A.3.D.II

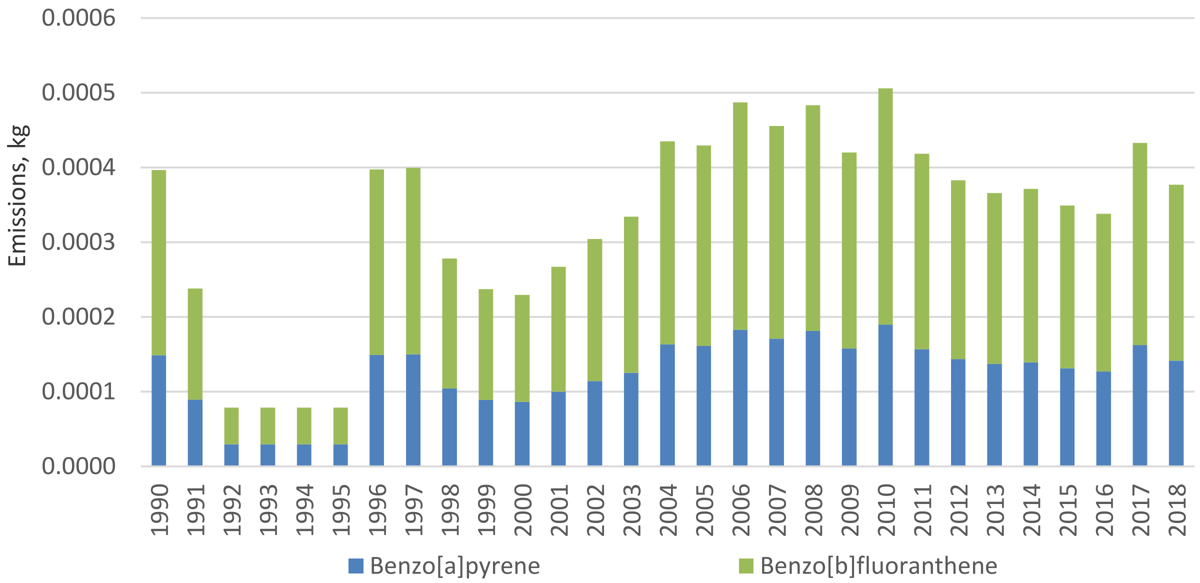


FIGURE 69 PAHS EMISSIONS IN SECTOR 1.A.3.D.II

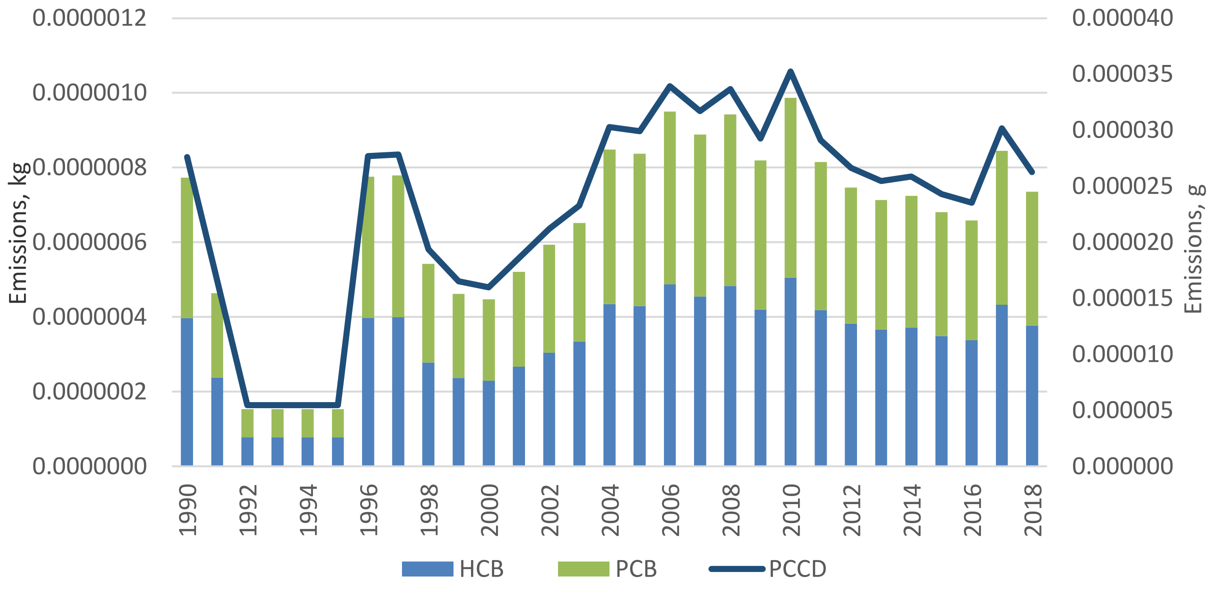


FIGURE 70 HCB, PCB AND PCDD EMISSIONS IN SECTOR 1.A.3.D.II

3.16.2 Methodological issues

Emissions were calculated according to EEA emission guidebook 2013 methodology Tier 1 approach. See Table 57, Table 58, Table 59.

A simple methodology for estimating emissions is based on total fuel consumption data. which have to be multiplied by appropriate emission factors. Therefore, the equation to be applied in this case is:

$$E_i = FC \times EF_i \qquad (2.9.3)$$

were E_i - mass of emissions of pollutant *i* during inventory period; *FC* - fuel consumption; EF_i - average emissions of pollutant *i* per unit of fuel used.

3.16.3 Uncertainty

Entec (2002) provides estimates of uncertainties for emission factors as indicated in the table below.

TABLE 22 ESTIMATED UNCERTAINTIES GIVEN AS PERCENTAGE RELATED TO THE EMISSION FACTOR PARAMETER

	At sea	Maneuvering	In port
NOx	±20%	±40%	±30%
SOx	±10%	±30%	±20%
NMVOC	±25%	±50%	±40%
PM	±25%	±50%	±40%
Fuel Consumption	±10%	±30%	±20%

This sector was not estimated. Inaccurate emissions were changed to not estimated.

3.17 Pipelines (NFR 1.A.3.e)

3.17.1 Overview of the Sector

In Lithuania, natural gas is transported via gas transmission and distribution systems. Statistics Lithuania started collecting data on consumption of natural gas used for gas transportation in pipeline compressor stations from 2001.

JSC "Lietuvos Dujos" is the operator of Lithuania's natural gas transmission system in charge of the safe operation, maintenance and development of the system. The transmission system is comprised of gas transmission pipelines, gas compressor stations, gas metering and distribution stations (Table 23).

TABLE 23 LITHUANIAN NATURAL GAS TRANSMISSION SYSTEM

Gas transmission pipelines	Gas distribution stations	Gas metering stations	Gas compressor stations
1.9 thous. km	65 stations	3 stations	2 stations

FIGURE 71 GAS DISTRIBUTION NETWORK IN LITHUANIA

Transport via pipelines includes transport of gases via pipelines.

3.17.2 Methodological issues

Statistics Lithuania has started collecting data on consumption of natural gas used for gas transportation in pipeline compressor stations from 2001. For the period prior to 2001 data on use of natural gas for transmission are not available.

The surrogate method to estimate unavailable data during 1990-2000 was used since the extrapolation approaches should not be done to long periods and inconsistent trend. To evaluate more accurate relationships the regression analysis was developed by relating emissions to more than one statistical parameter. The relationship between gas pipeline emissions and surrogate data was developed on the basis of underlying activity data during multiple years.

3.17.3 Uncertainties and time-series consistency

The uncertainty in activity data (fuel use) is 5%.

3.17.4 Source-specific QA/QC and verification

All quality procedures according to the Lithuanian QA/QC plan have been implemented during the work with this submission.

3.17.5 Source-specific recalculations

No recalculations.

3.18 NON-ROAD MOBILE SOURCES (1.A.4.aii-cii(iii), 1.A.5.b)

3.18.1 NR mobile source category description

This chapter covers several mobile sources. More specifically, the types of equipment covered in this chapter are included in the following NFR categories:

- Commercial and institutional mobile machinery (NFR 1.A.4.a.ii);
- Mobile combustion used in residential areas: household and gardening mobile machinery (NFR 1.A.4.b ii);
- Off-road vehicles and other machinery used in agriculture/forestry mobile machinery (excluding fishing) (NFR 1.A.4.c ii);
- Fishing (NFR 1.A.4.c iii)
- Mobile combustion in manufacturing industries and construction (NFR 1.A.2.g vii);
- Other mobile including military mobile machinery (NFR 1.A.5.b).

All these mobile sources are aggregated in one chapter because each of these sectors have minor importance into total emissions.

3.18.2 Methodological issues

This sector covers a mixture of equipment which is distributed across a wide range of sectors, typically land based, and is commonly referred to collectively as “Non-Road Mobile Machinery” (NRMM). Despite this diversity there is the common theme that all the equipment covered uses reciprocating engines, fueled with liquid hydrocarbon-based fuels. They comprise both diesel- (compression ignition), petrol- and LPG- (spark ignition) engine machinery. The diesel engines range from large diesel engines >200 kW (installed in cranes, graders/scrapers, bulldozers, etc.) to small diesel engines, around 5 kW, fitted to household and gardening equipment (e.g. lawn and garden tractors, leaf blowers, etc.).

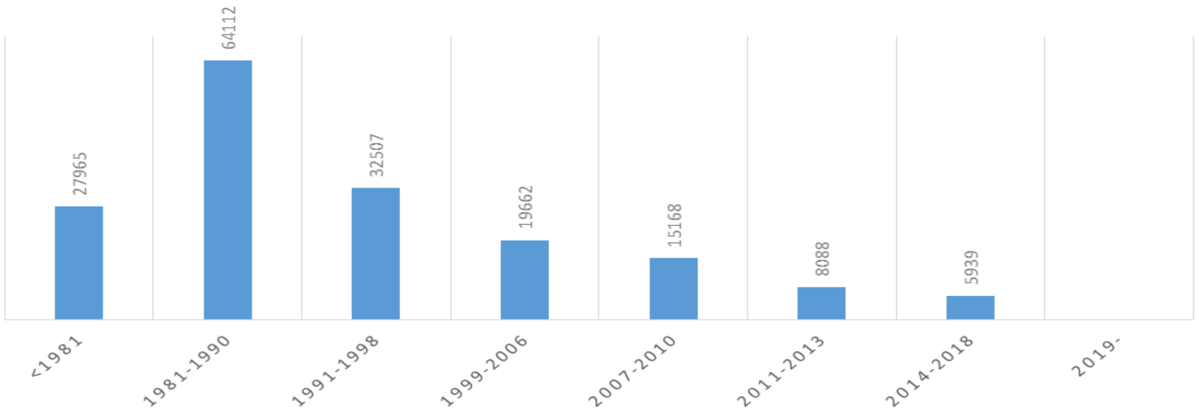
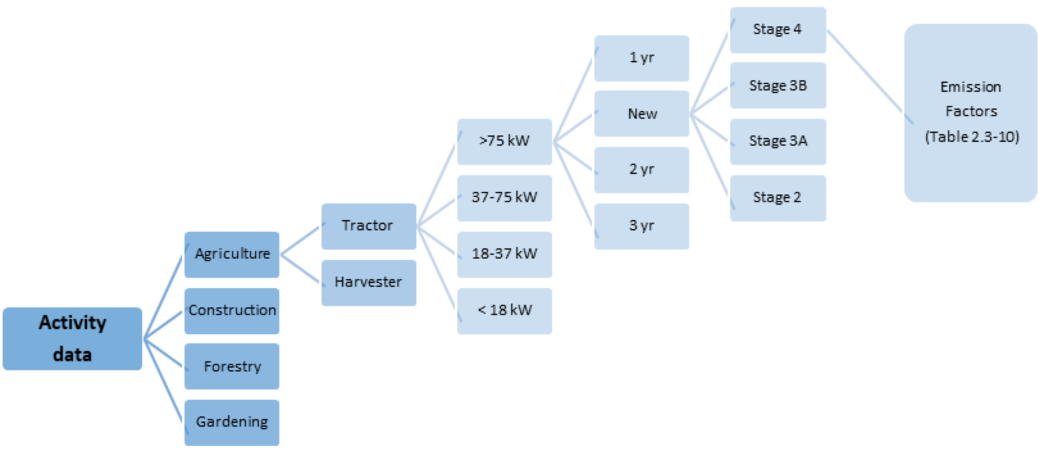


FIGURE 72 NUMBER OF OFF-ROAD VEHICLES IN 2016 (STATE ENTERPRISE AGRICULTURAL INFORMATION AND RURAL BUSINESS CENTER)

The vehicles were distributed by age and engine type.



EFs were applied provided for Tier 2 in Emission Guidebook (2019).

TABLE 24 TIER 2 EF FOR OFF-ROAD MACHINERY (DIESEL) 1.A.4.A II

Technology										
Pollutant	**Units**	**< 1981**	**1981-1990**	**1991-Stage I**	**Stage I**	**Stage II**	**Stage IIIA**	**Stage IIIB**	**Stage IV**	**Stage V**
BC	g/toes fuel	3414	2369	2001	800	825	758	78	78	56
CH_4	g/tons fuel	199	171	144	42	39	36	15	13	23
CO	g/tons fuel	20690	18890	16258	6639	7135	6826	6445	6019	7352
CO_2	*kg/tons fuel*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*
N_2O	g/tons fuel	121	128	135	137	136	136	137	137	136
NH_3	g/tons fuel	7	7	8	8	8	8	8	8	8
NMVOC	g/tons fuel	8077	6962	5851	1725	1587	1470	625	536	930
NOx	g/tons fuel	26552	33942	43552	31077	22101	15653	11933	1570	7663

PM_{10}	g/tons fuel	6207	4308	3642	1005	1034	950	98	98	116
$PM_{2.5}$	g/tons fuel	6207	4308	3642	1005	1034	950	98	98	116
TSP	g/tons fuel	6207	4308	3642	1005	1034	950	98	98	116

TABLE 25 TIER 2 EF FOR OFF-ROAD MACHINERY (DIESEL OIL) 1.A.C II

Technology										
Pollutant	**Units**	**< 1981**	**1981-1990**	**1991-Stage I**	**Stage I**	**Stage II**	**Stage IIIA**	**Stage IIIB**	**Stage IV**	**Stage V**
BC	g/tons fuel	3221	2221	1074	727	483	416	74	73	9
CH_4	g/tons fuel	191	158	110	38	29	29	29	13	13
CO	g/tons fuel	19804	17566	14147	6463	6104	6035	6087	6024	6077
CO_2	*kg/tons fuel*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*	*3160*
N_2O	g/tons fuel	122	129	137	138	138	139	139	139	139
NH_3	g/tons fuel	7	7	8	8	8	8	8	8	8
NMVOC	g/tons fuel	7760	6439	4493	1544	1181	1173	544	530	526
NOx	g/tons fuel	29901	37383	49002	30799	20612	12921	9318	1587	1861
PM_{10}	g/tons fuel	5861	5861	5861	5861	5861	5861	5861	5861	5861
$PM_{2.5}$	g/tons fuel	5861	5861	5861	5861	5861	5861	5861	5861	5861
TSP	g/tons fuel	5861	5861	5861	5861	5861	5861	5861	5861	5861

TABLE 26 TIER 2 EF FOR OFF-ROAD MACHINERY 1.A.4.A II, 1.A.4.B II, 1.A.4.C II (GASOLINE: TWO-STROKE)

Technology										
Pollutant	**Units**	**< 1981**	**1981-1990**	**1991-Stage I**	**Stage I**	**Stage II**	**Stage IIIA**	**Stage IIIB**	**Stage IV**	**Stage V**
BC	g/tons fuel	352	239	193	184	215	215	215	215	214
CH4	g/tons fuel	22483	19462	17284	16979	8517	8517	8517	8517	8539
CO	g/tons fuel	754523	699494	621083	620519	695237	695237	695237	695237	694870
CO2	*kg/tons fuel*	3197	3197	3197	3197	3197	3197	3197	3197	3197
N2O	g/tons fuel	12	16	16	18	20	20	20	20	20
NH3	g/tons fuel	2	3	3	4	4	4	4	4	4
NMVOC	g/tons fuel	298703	258562	229630	225579	113157	113157	113157	113157	111450
NOx	g/tons fuel	1050	1682	1852	3445	2495	2495	2495	2495	2490
PM10	g/tons fuel	7037	4786	3869	3683	4299	4299	4299	4299	4278
PM2.5	g/tons fuel	7037	4786	3869	3683	4299	4299	4299	4299	4278
TSP	g/tons fuel	7037	4786	3869	3683	4299	4299	4299	4299	4278

TABLE 27 TIER 2 EF FOR OFF-ROAD MACHINERY 1.A.4.A II, 1.A.4.B II, 1.A.4.C II (GASOLINE: FOUR-STROKE)

Technology										
Pollutant	**Units**	**< 1981**	**1981-1990**	**1991-Stage I**	**Stage I**	**Stage II**	**Stage IIIA**	**Stage IIIB**	**Stage IV**	**Stage V**
BC	g/tons fuel	7	7	8	8	8	8	8	8	8
CH4	g/tons fuel	710	910	672	650	568	568	568	568	468
CO	g/tons fuel	1214855	836966	768445	774457	804157	804157	804157	804157	778282
CO2	kg/tons fuel	3197	3197	3197	3197	3197	3197	3197	3197	3197
N2O	g/tons fuel	56	55	59	59	60	60	60	60	59
NH3	g/tons fuel	4	4	4	4	4	4	4	4	4
NMVOC	g/tons fuel	20182	25852	19082	18469	16126	16126	16126	16126	13293
NOx	g/tons fuel	2429	5743	7129	7088	6676	6676	6676	6676	5354
PM10	g/tons fuel	148	147	157	159	159	159	159	159	159
PM2.5	g/tons fuel	148	147	157	159	159	159	159	159	159
TSP	g/tons fuel	148	147	157	159	159	159	159	159	159

TABLE 28 TIER 2 HM AND POP EFS FOR OFF-ROAD MACHINERY 1.A.4.A II, 1.A.4.B II, 1.A.4.C II

		Diesel	Gasoline
Pollutant	**Units**	**Emission factor**	
Cadmium	mg/kg fuel	0.010	0.010
Copper	mg/ kg fuel	1.70	1.70
Chromium	mg/ kg fuel	0.050	0.050
Nickel	mg/ kg fuel	0.07	0.07
Selenium	mg/ kg fuel	0.01	0.01
Zinc	mg/ kg fuel	1.00	1.00
Benz(a)anthracene	µg/kg fuel	80	75
Benzo(b)fluoranthene	µg/kg fuel	50	40
Dibenzo(a,h)anthracene	µg/kg fuel	10	10
Benzo(a)pyrene	µg/kg fuel	30	40
Chrysene	µg/kg fuel	200	150
Fluoranthene	µg/kg fuel	450	450
Phenanthene	µg/kg fuel	2500	1200

BC: For agriculture, forestry, industry and gasoline/LPG machinery, the following BC fractions of PM (f-BC) are used: 0.57, 0.65, 0.62 and 0.05.

SO_2: The emissions of SO_2 are estimated by assuming that all Sulphur in the fuel is transformed completely into SO_2 using the formula:

$$E_{SO2} = 2\ \Sigma k_{S,l}\, b_{j,l}$$

where

$k_{S,l}$ = weight related Sulphur content of fuel of type [kg/kg],

$b_{j,l}$ = total annual consumption of fuel of type *l* in [kg] by source category *j*.

TABLE 29 SULPHUR CONTENT OF FUEL (BY WEIGHT)

NFR	Fuel	1990	2000	2001	2003	2004	2005	2006	2009	2010 -
1A2gvii 1A4aii 1A4bii 1A4ciii 1A4cii	Gasoline	0.10%	0.10%	0.05%	0.015%	0.013%	0.005%	0.002%	0.002%	0.002%
	Diesel	0.50%	0.50%	0.05%	0.035%	0.030%	0.005%	0.004%	0.002%	0.002%
	Light fuel oil	0.50%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.10%

TABLE 30 SULPHUR CONTENT AND SO_2 EFS USED IN OFF-ROAD SECTOR

	1990-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Diesel													0.2								0.1
Gasoline	0.015										0.02			0.01							0.0005

Notes:

Gasoline, diesel oil – EU legislation

Lead: Pb emissions are estimated according to the calculation that 75% of lead contained in gasoline is emitted into the air. Equation:

$$E_{Pb} = 0.75 \times k \times FC$$

where

E_{Pb} – Pb emissions;

k – weight-related lead content of gasoline (kg/kg);

FC – fuel consumption.

TABLE 31 LEAD CONTENT IN GASOLINE (G/L)

Fuel	Leaded gasoline	Unleaded gasoline
1990	0.15	0.013
2003	-	0.005
2006	-	0.003
2010	-	0.0001

Data need be used to split the total fuel consumption into engine technology layers for each following year starting from 2013 inventory year as Country specific data available only from 2013.

TABLE 32 AVERAGE YEAR SPECIFIC FUEL CONSUMPTION (%) PER ENGINE AGE AND INVENTORY YEAR FOR DIESEL-FUELED NON-ROAD MACHINERY IN 1.A.4.A.II AND 1.A.2.G II

	2013	2014	2015	2016	2017-2020
<1981	0	0	0	0	0
1981-1990	0	0	0	0	0
1991-Stage I	5	4	3	3	3
Stage I	0	0	0	0	0
Stage II	29	18	7	4	3
Stage IIIA	58	62	66	60	52
Stage IIIB	8	16	24	25	27
Stage IV	0	0	1	8	15
Stage V	0	0	0	0	0

TABLE 33 AVERAGE YEAR SPECIFIC FUEL CONSUMPTION (%) PER ENGINE AGE AND INVENTORY YEAR FOR DIESEL-FUELED NON-ROAD MACHINERY IN 1.A.4.C.II

	2013	2014	2015	2016	2017-2020
<1981	0	0	0	0	0
1981-1990	0	0	0	0	0
1991-Stage I	42	36	31	26	22
Stage I	9	10	10	10	9
Stage II	18	18	18	19	19
Stage IIIA	24	24	24	24	24
Stage IIIB	7	12	14	14	14
Stage IV	0	0	4	10	16
Stage V	0	0	0	0	0

TABLE 34 AVERAGE YEAR SPECIFIC FUEL CONSUMPTION (%) PER ENGINE AGE AND INVENTORY YEAR FOR DIESEL-FUELED NON-ROAD MACHINERY IN 1.A.2.G.VII

	2013	2014	2015	2016	2017-2020
<1981	0	0	0	0	0
1981-1990	0	0	0	0	0
1991-Stage I	5	4	3	3	3
Stage I	0	0	0	0	0
Stage II	29	18	7	4	3
Stage IIIA	58	62	66	60	52

Stage IIIB	8	16	24	25	27
Stage IV	0	0	1	8	15
Stage V	0	0	0	0	0

TABLE 35 AVERAGE YEAR SPECIFIC FUEL CONSUMPTION (%) PER ENGINE AGE AND INVENTORY YEAR FOR 2-STROKE MOTOR GASOLINE-FUELED NON-ROAD MACHINERY IN 1.A.4.A.II, 1.A.4.B.II AND 1.A.4.C.II

	2013	2014	2015	2016	2017-2020
1981-1990	0	0	0	0	0
1991-Stage I	10	0	0	0	0
Stage I	27	27	18	8	0
Stage II	63	73	82	92	100
Stage V	0	0	0	0	0

TABLE 36 AVERAGE YEAR SPECIFIC FUEL CONSUMPTION (%) PER ENGINE AGE AND INVENTORY YEAR FOR 4-STROKE MOTOR GASOLINE-FUELED NON-ROAD MACHINERY IN 1.A.4.A.II, 1.A.4.B.II AND 1.A.4.C.II

	2013	2014	2015	2016	2017-2020
1981-1990	0	0	0	0	0
1991-Stage I	25	17	8	0	0
Stage I	23	22	18	18	9
Stage II	52	61	74	82	91
Stage V	0	0	0	0	0

3.18.3 Emissions 1.A.4.a.ii

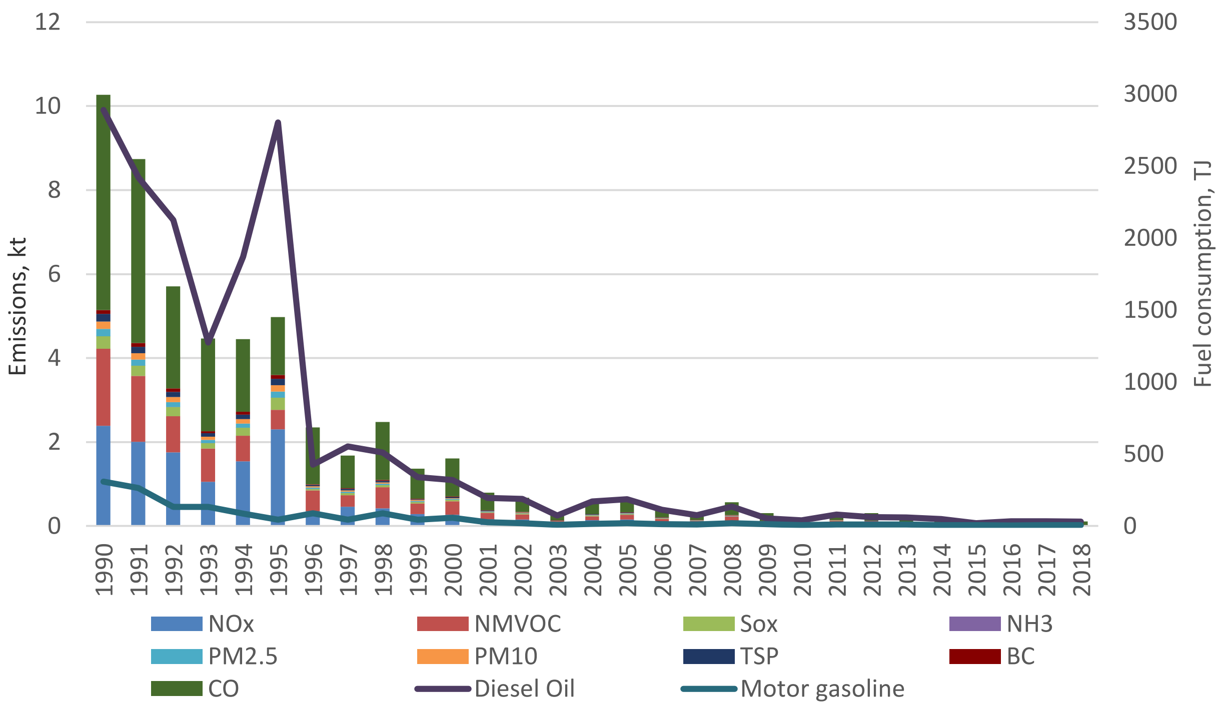


FIGURE 73 POLLUTANT EMISSIONS AND FUEL CONSUMPTION IN SECTOR 1.A.4.A.II

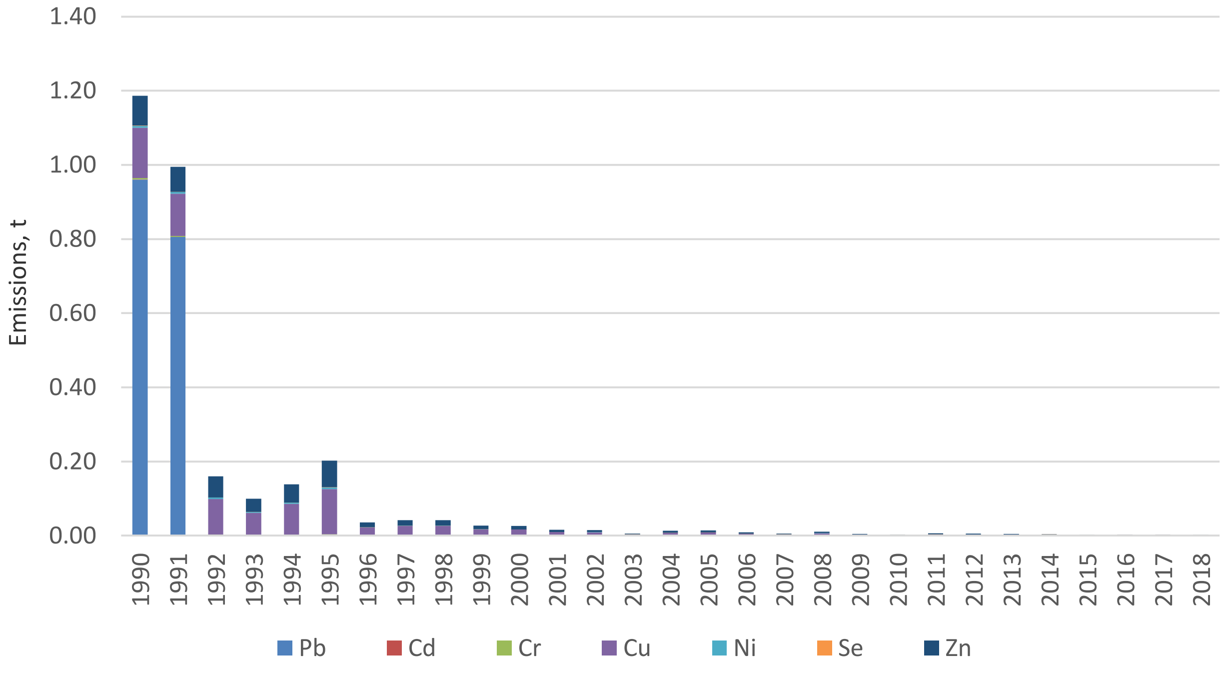


FIGURE 74 HEAVY METALS EMISSIONS IN SECTOR 1.A.4.A.II

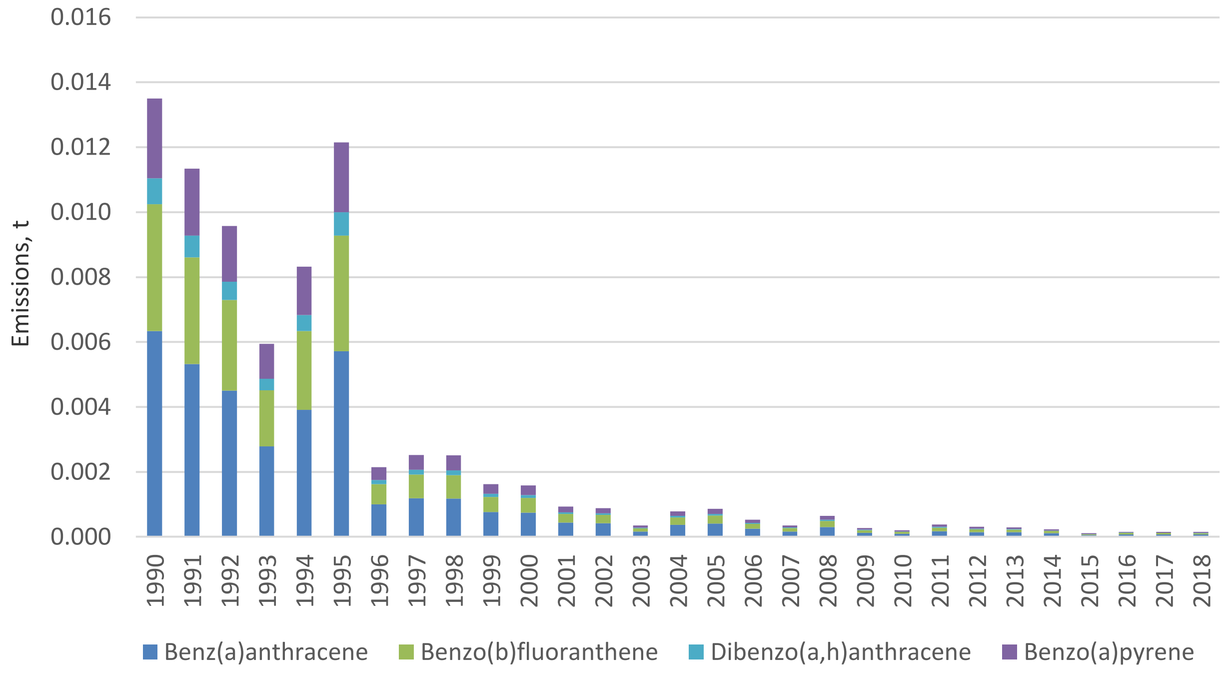


FIGURE 75 PAHS EMISSIONS IN SECTOR 1.A.4.A.II

3.18.4 Emissions 1.A.4.b.ii

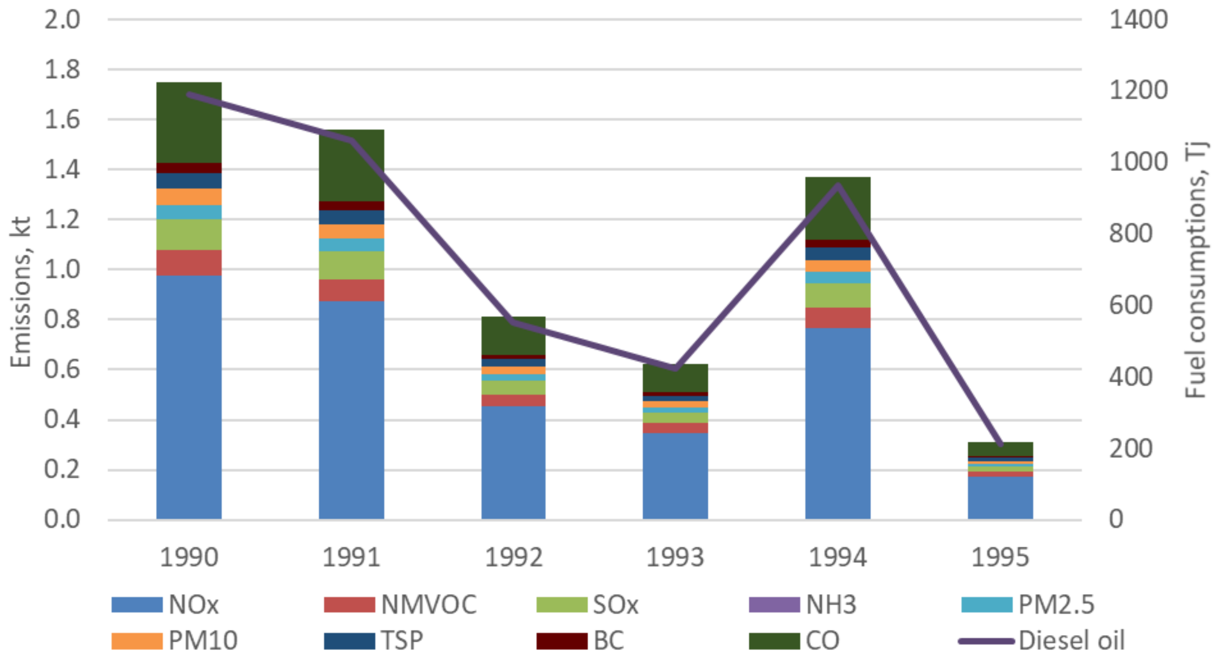


FIGURE 76 POLUTANT EMISSIONS IN SECTOR 1.A.4.B.II

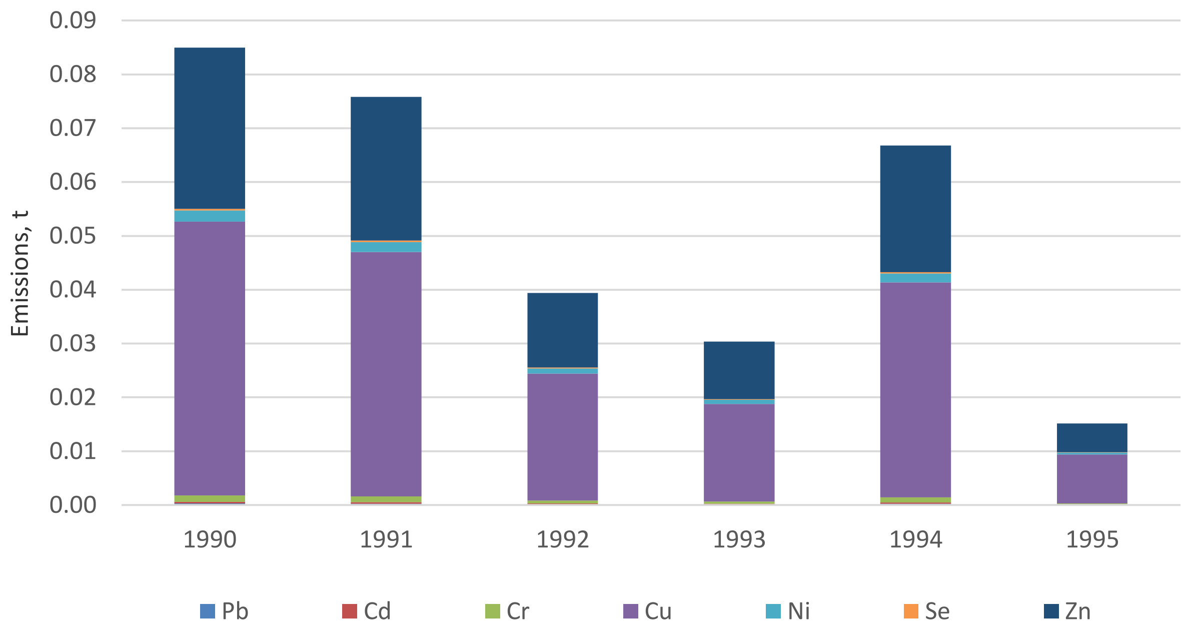


FIGURE 77 HEAVY METALS EMISSIONS IN SECTOR 1.A.4.B.II

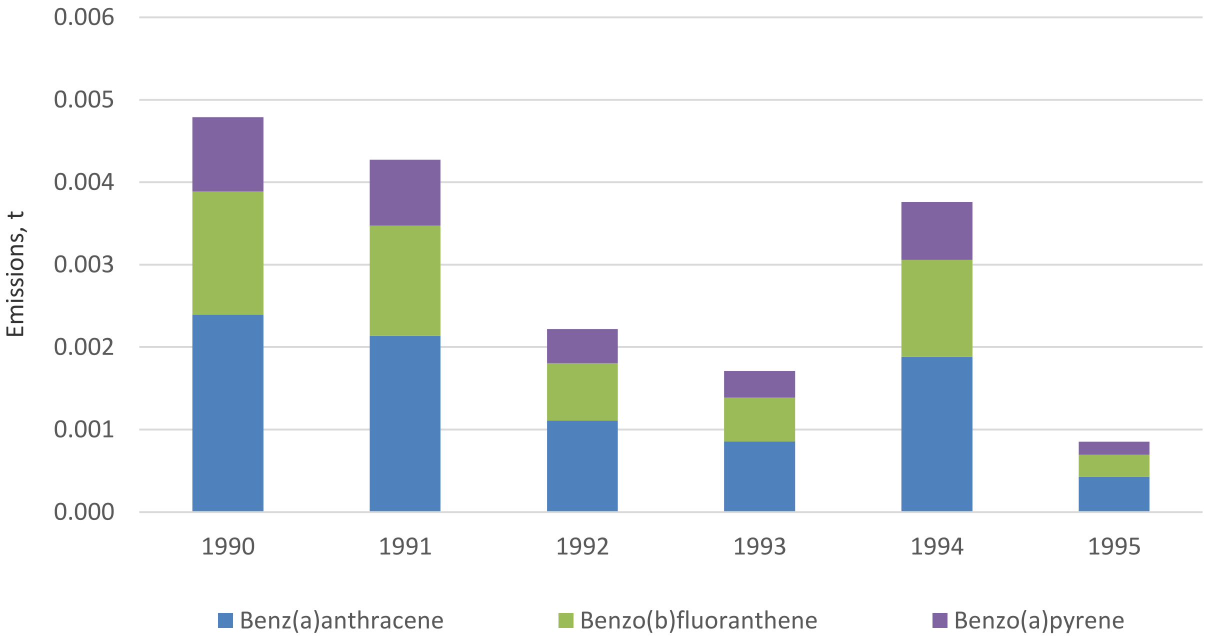


FIGURE 78 PAHS EMISSIONS IN SECTOR 1.A.4.B.II

3.18.5 Emissions 1.A.4.c.ii

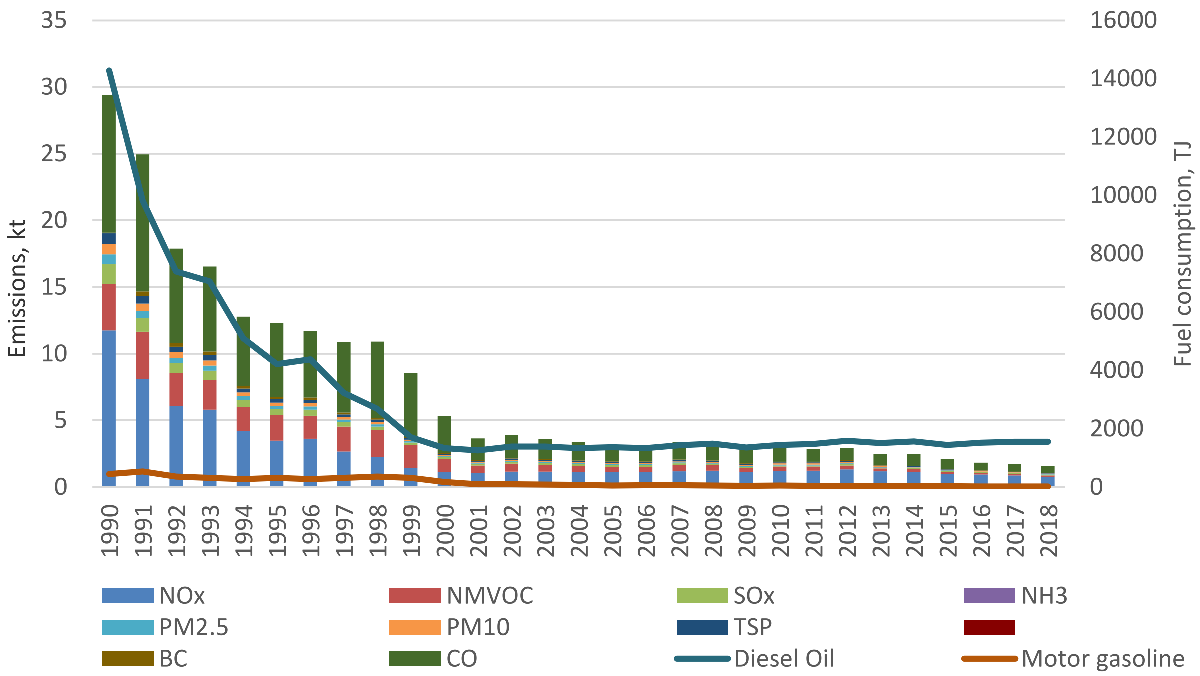


FIGURE 79 POLLUTANT EMISSIONS AND FUEL CONSUMPTION IN SECTOR 1.A.4.C.II

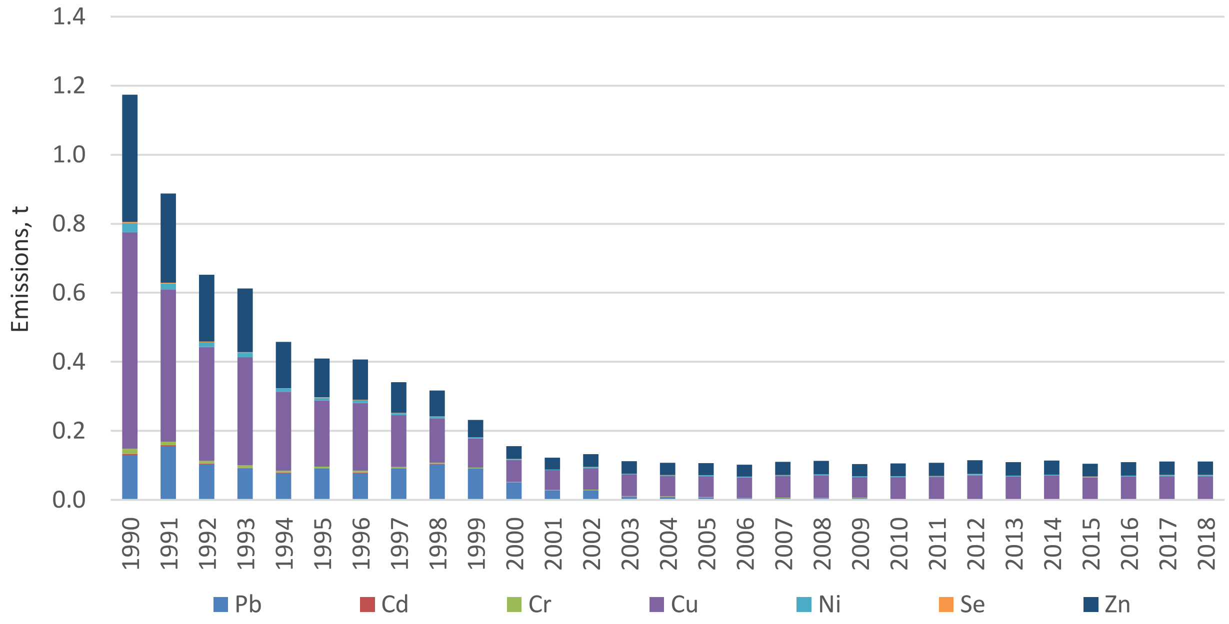


FIGURE 80 HEAVY METALS EMISSIONS IN SECTOR 1.A.4.C.II

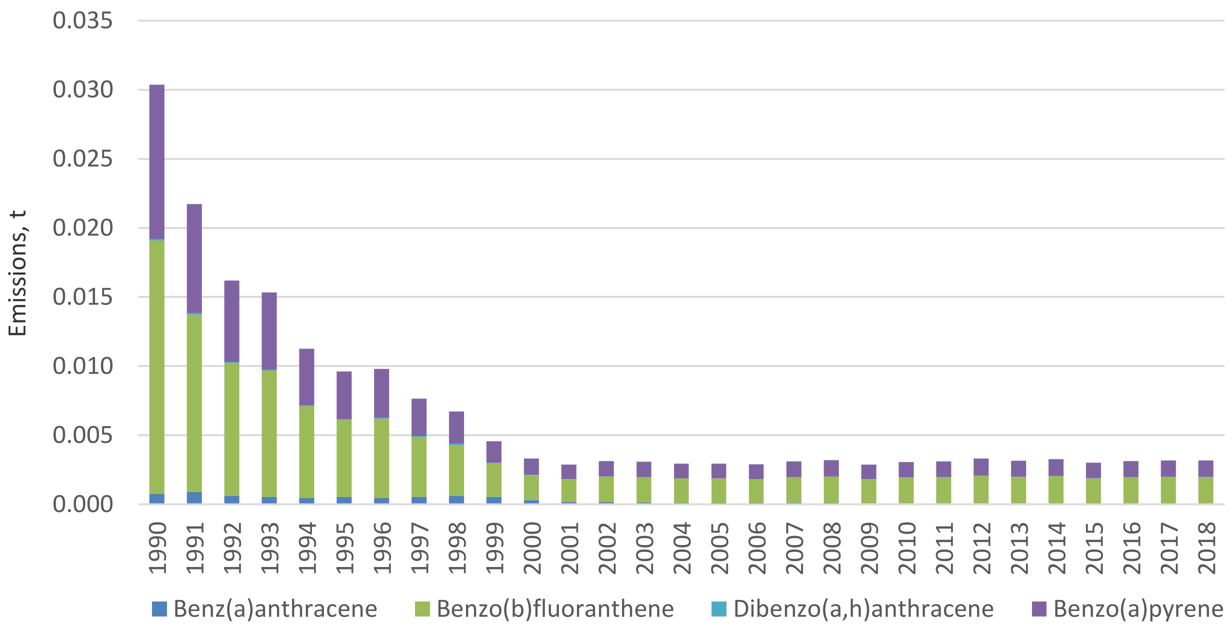


FIGURE 81 PAHS EMISSIONS IN SECTOR 1.A.4.C.II

3.18.6 Emissions 1.A.5.b

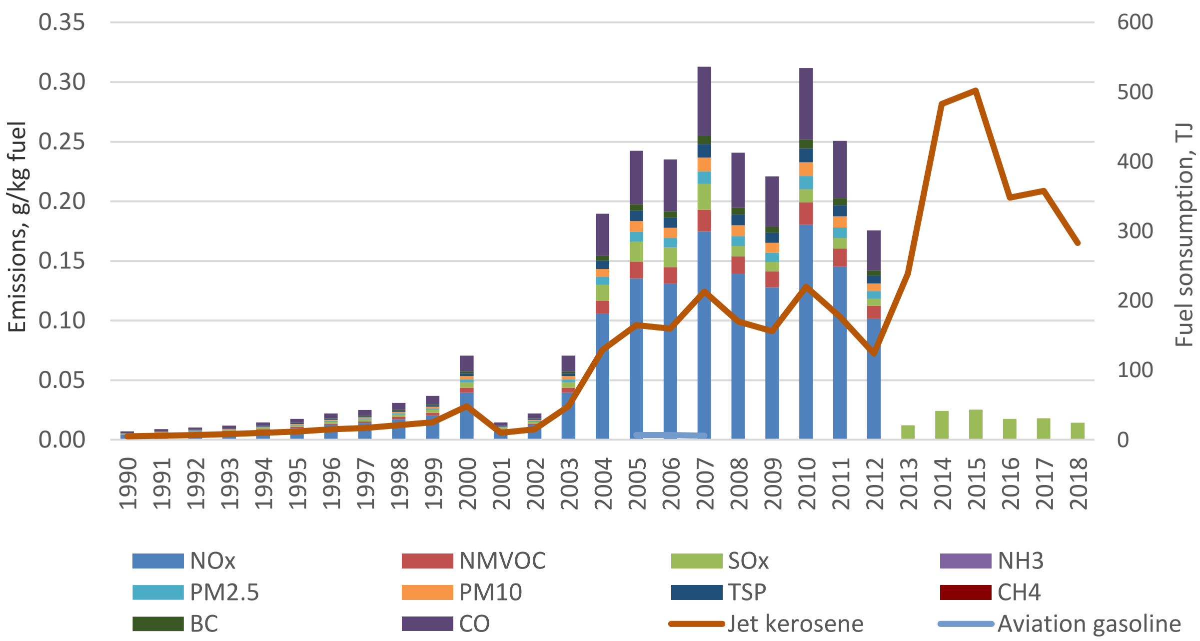


FIGURE 82 POLLUTANT EMISSIONS AND FUEL CONSUMPTION IN SECTOR 1.A.5.B

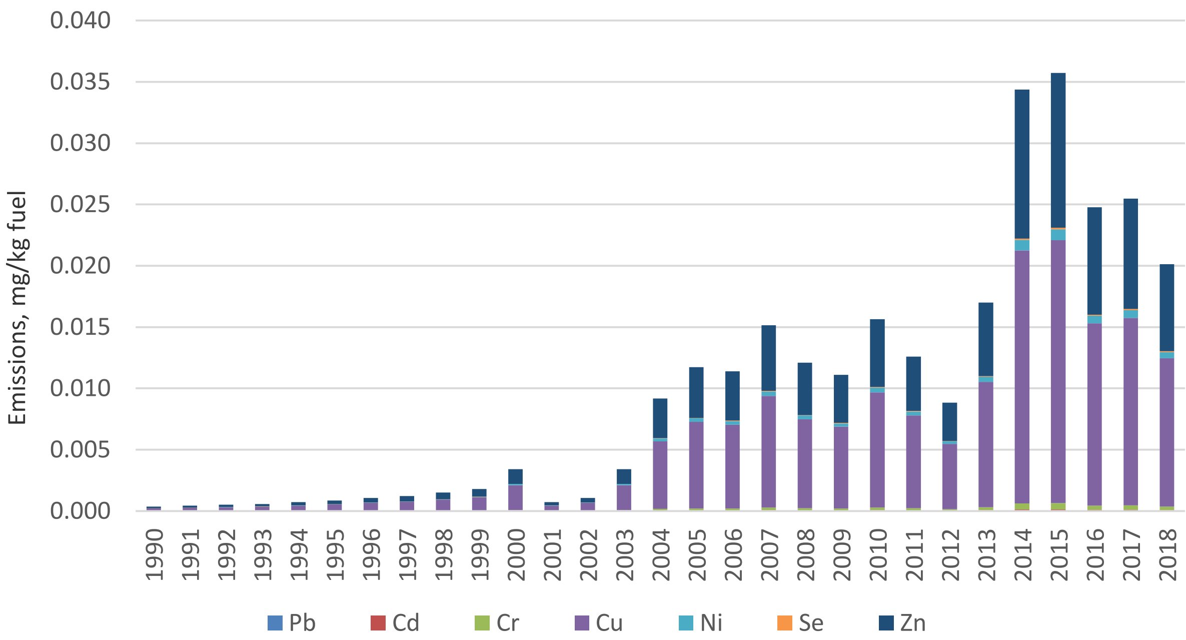


FIGURE 83 HEAVY METALS EMISSIONS IN SECTOR 1.A.5.B

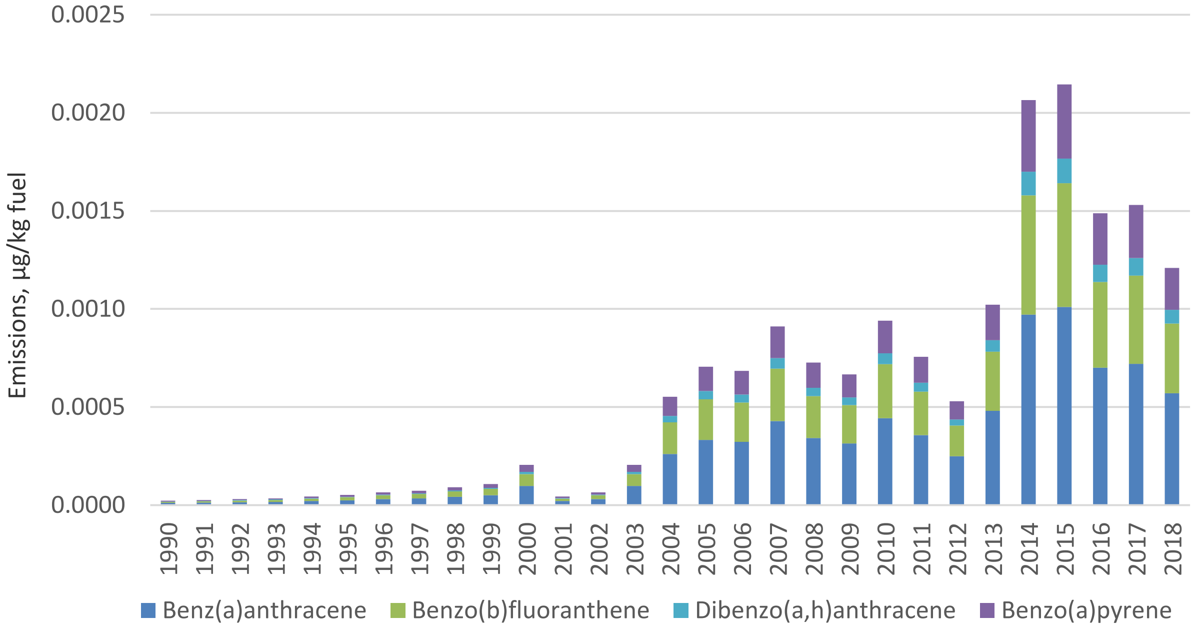


FIGURE 84 PAHS EMISSIONS IN SECTOR 1.A.5.B

3.19 Small Combustion (1.A.4.a.i-c.i) Other, Mobile (inc. military, land based and recreational boats) (1.A.5.a)

3.19.1 Source category description

The small combustion installations included in this chapter are mainly intended for heating and provision of hot water in residential and commercial/institutional sectors. Some of these installations are also used for cooking (primarily in the residential sector). In the agricultural sector the heat generated by the installations is used also for crops drying and for heating greenhouses.

Sectors covered in this chapter are:

- NFR Code 1A4ai — Commercial / institutional
- NFR Code 1A4bi — Residential
- NFR Code 1A2gvii — Mobile combustion in manufacturing industries and construction
- NFR Code 1A4ci — Agriculture/Forestry/Fishing

For calculation of emissions in category Commercial/ institutional sector (1.A.4.a). Residential (1.A.4.b) and Agriculture/Forestry/Fishing (1.A.4.c) activity data had been obtained from the Lithuanian Statistics database.

Commercial and institutional sector encompasses the following activities in Lithuania: wholesale and retail trade, maintenance of motor vehicle and motorbikes, repairing of household equipments, hotels and restaurants, financial intermediation, real estate management and rent, public management and defence, mandatory social security, education, health treatment and social work, other public, social and individual services, as well private households related activities.

The small combustion installations included in this chapter are mainly intended for heating and provision of hot water in residential and commercials/institutional sectors. Some of these installations are also used for cooking, primarily in the residential sector. Emissions from smaller combustion installations are significant due to their numbers, different type of combustion techniques employed and range of efficiencies and emissions.

Enterprises consuming fuel and energy belonging to the following economic activities: agricultural (with 10 and more employees), forestry and fishing.

Consumption in agriculture encompasses fuel and energy consumption by enterprises whose economic activity is related to agriculture, hunting and forestry.

Consumption in fishing encompasses fuels delivered to inland, coastal and deep-sea fishing vessels of all flags that are refuelled in the country (including international fishing) and fuel and energy used in the fishing industry.

The following nationwide abatement efficiency starting from the year 2000 was applied for calculating PM, Heavy metals, PAHs, Dioxins/Furans emissions (excluding 1A4bi):

Abatement efficiency												
		2000	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Fuel:	Coal, Peat											
Combustiom technology:	> 50 kWth to ≤ 1 MWth boilers											
Abatement efficiency, %:	0	14,5	58,0	58,0	58,0	58,0	72,5	72,5	72,5	72,5	72,5	72,5
Fuel:	Coal, Peat											
Combustiom technology:	>1 MWth to <=50 MWth boilers											
Abatement efficiency, %:	0	4,8	19,3	19,3	19,3	19,3	24,2	24,2	24,2	24,2	24,2	24,2
Fuel:	Wood											
Combustiom technology:	> 50 kWth to ≤ 1 MWth boilers											
Abatement efficiency, %:	0	13,6	54,4	54,4	54,4	54,4	68,0	68,0	68,0	68,0	68,0	68,0
Fuel:	Wood											
Combustiom technology:	>1 MWth to <=50 MWth boilers											
Abatement efficiency, %:	0	16,4	65,7	65,7	65,7	65,7	82,1	82,1	82,1	82,1	82,1	82,1

Abatement efficiency was estimated on the basis of National EF research, the ratio of national EF for PM2.5 to Guidebook 2019 EF for PM2.5 and national scale of usage of the abatement technologies.

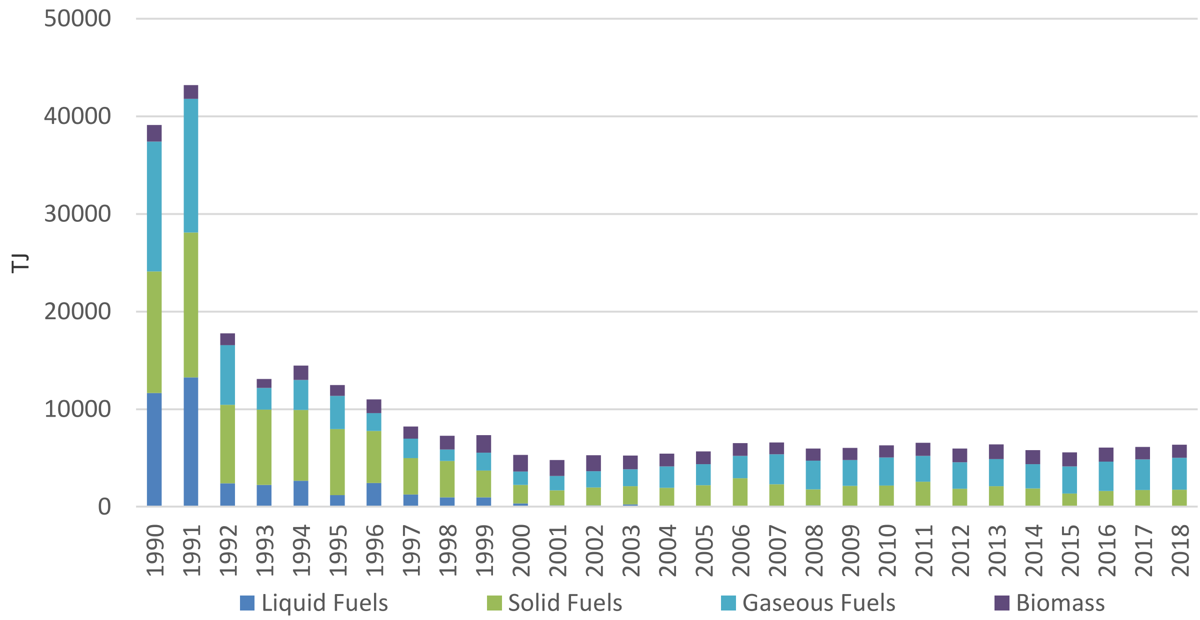


FIGURE 85 FUEL CONSUMPTION IN SECTOR 1.A.4.A.I SECTOR

After the drastically reduced fuel consumption volume in Commercial / institutional sector during 1990-2000, later (2001-2007) fuel consumption volume was increasing by 12.6% a year (Biomass 14%, liquid fuel and natural gas 27-28%).

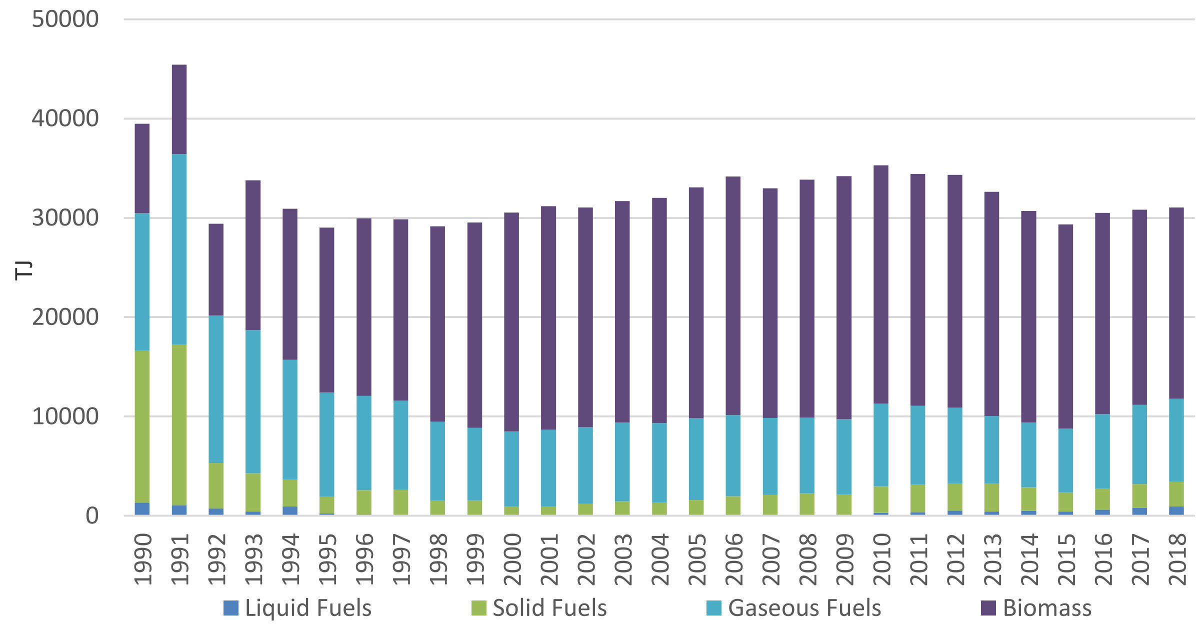


FIGURE 86 FUEL CONSUMPTION IN SECTOR 1.A.4.B IN THE PERIOD 1990-2018

3.19.2 Emissions 1.A.4.a.i

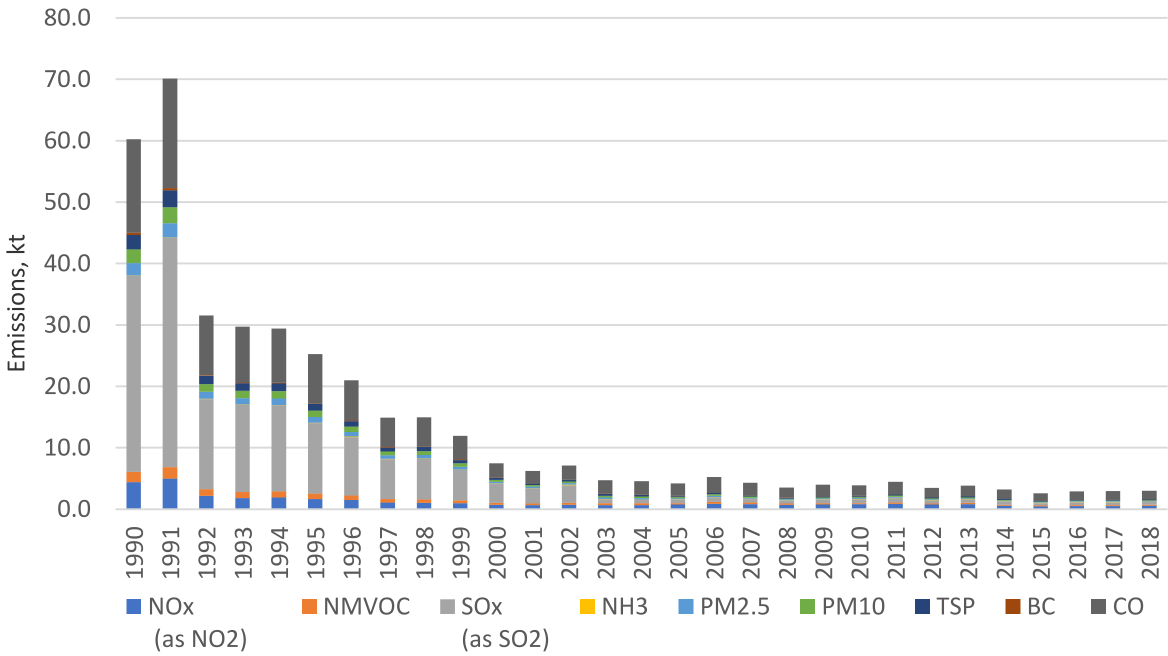


FIGURE 87 MAIN POLLUTANTS EMISSIONS IN SECTOR 1.A.4.A.I

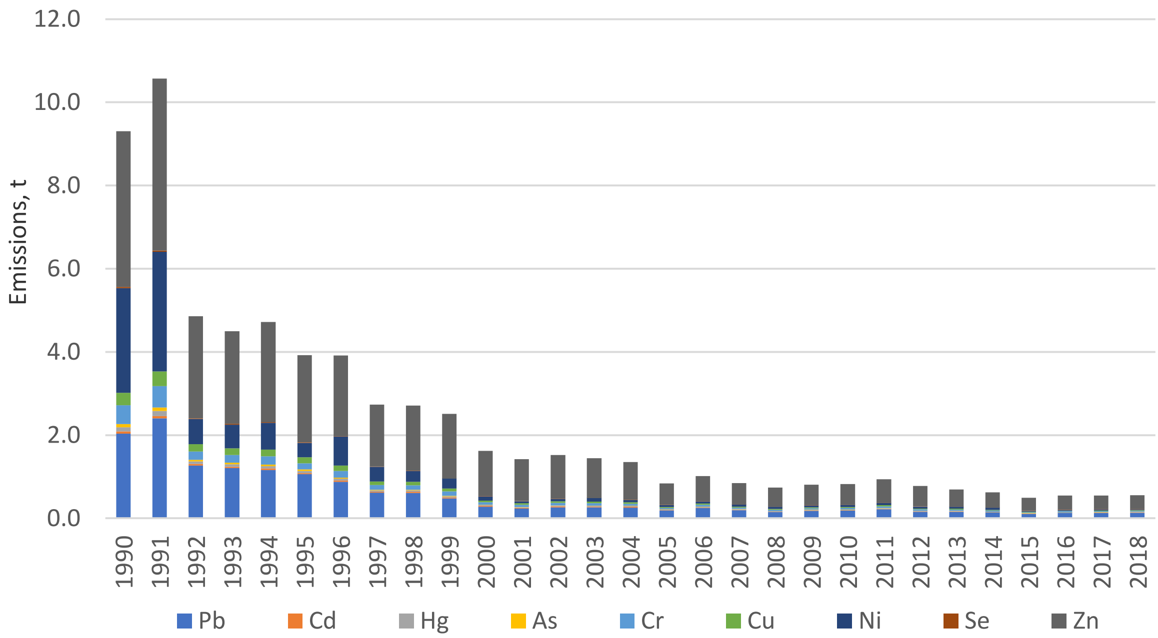


FIGURE 88 HEAVY METAL EMISSIONS IN SECTOR 1.A.4.A.I

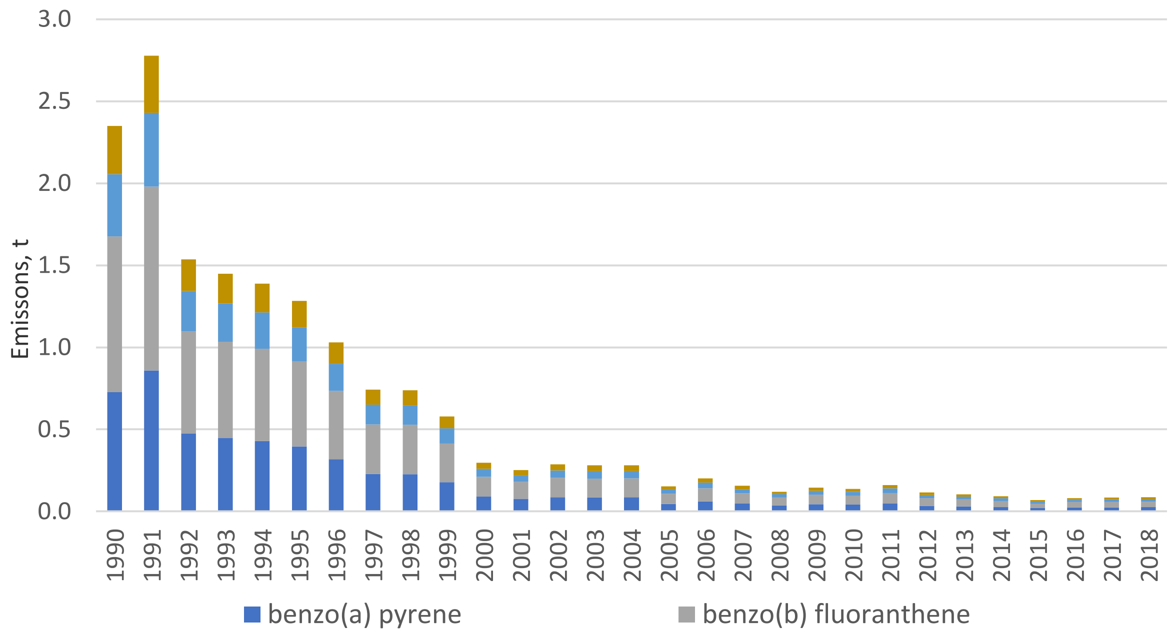


FIGURE 89 PAHS EMISSIONS IN SECTOR 1.A.4.A.I

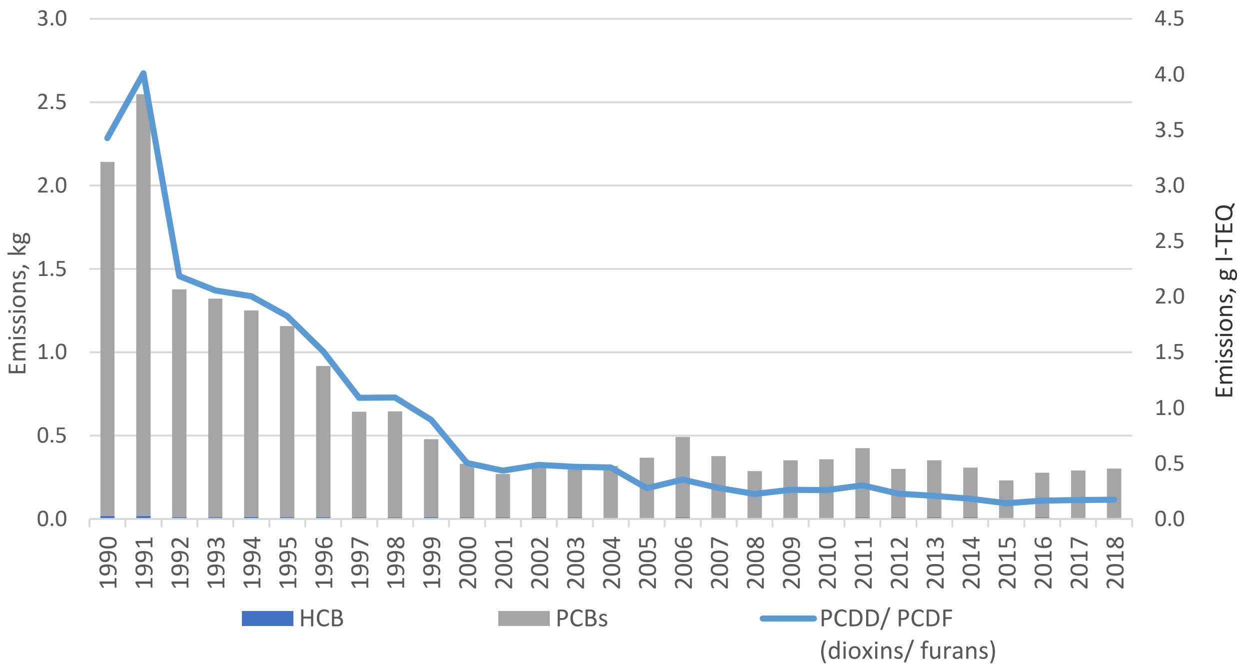


FIGURE 90 HCB, PCBS, PCDD EMISSIONS IN SECTOR 1.A.4.A.I

CO, PM2.5, NMVOC, PAH (polycyclic aromatic hydrocarbons) and dioxins/furans emissions from the category 1.A.4.bi contribute a large part to the total inventory.

3.19.3 Emissions 1.A.4.b.i

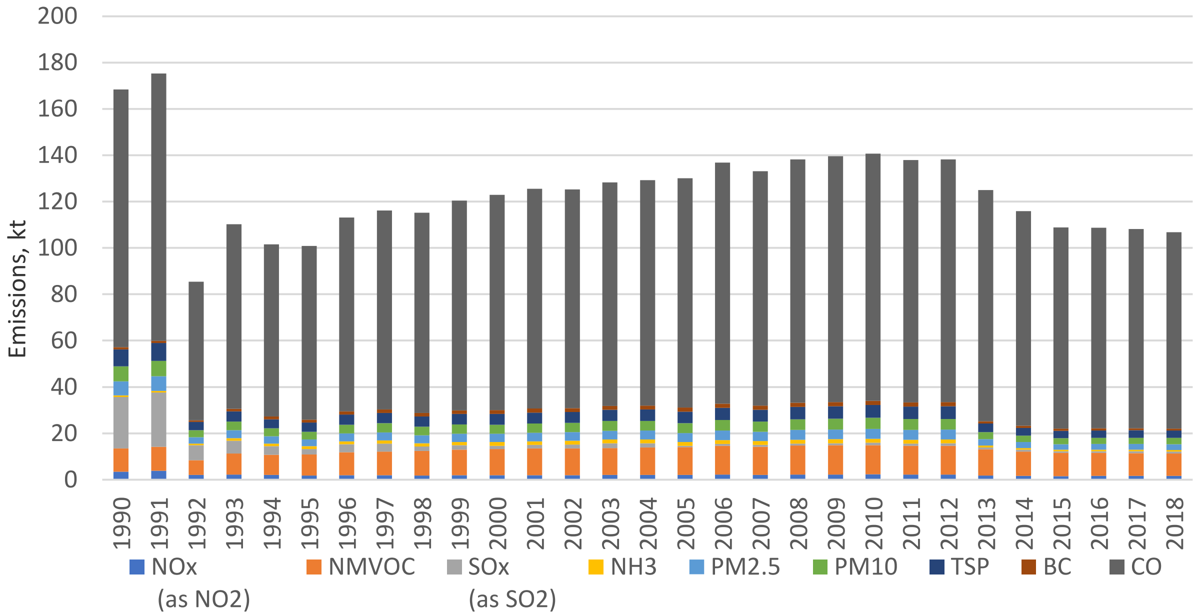


FIGURE 91 MAIN POLLUTANT EMISSIONS IN 1.A.4.B.I IN THE PERIOD 1990-2018

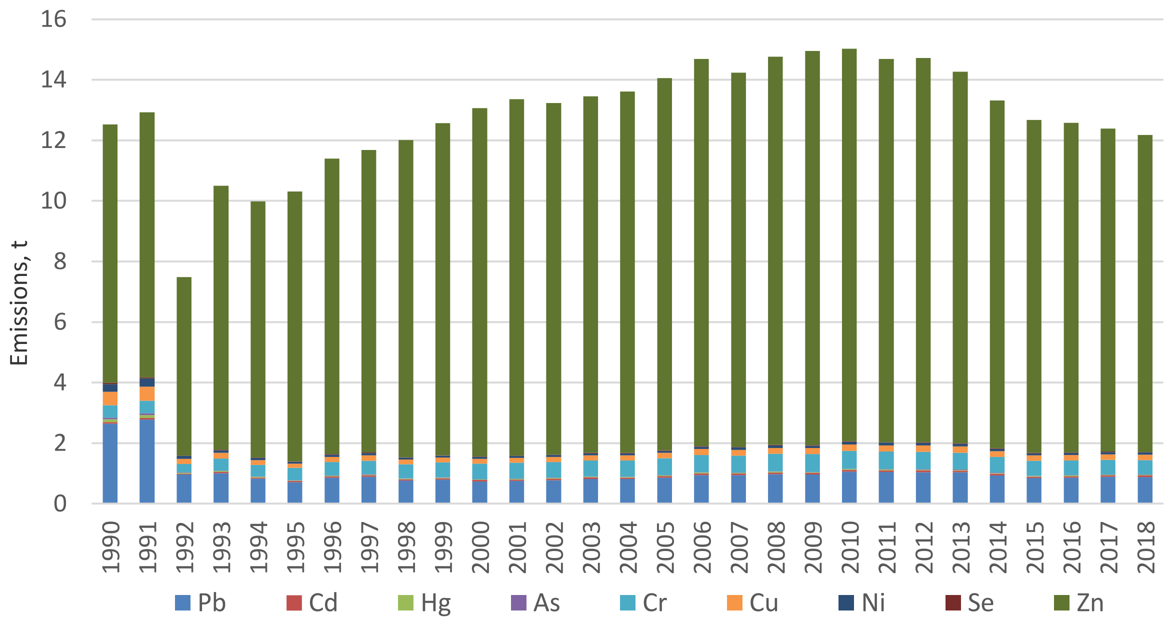


FIGURE 92 HEAVY METAL EMISSIONS IN 1.A.4.B.I IN THE PERIOD 1990-2018

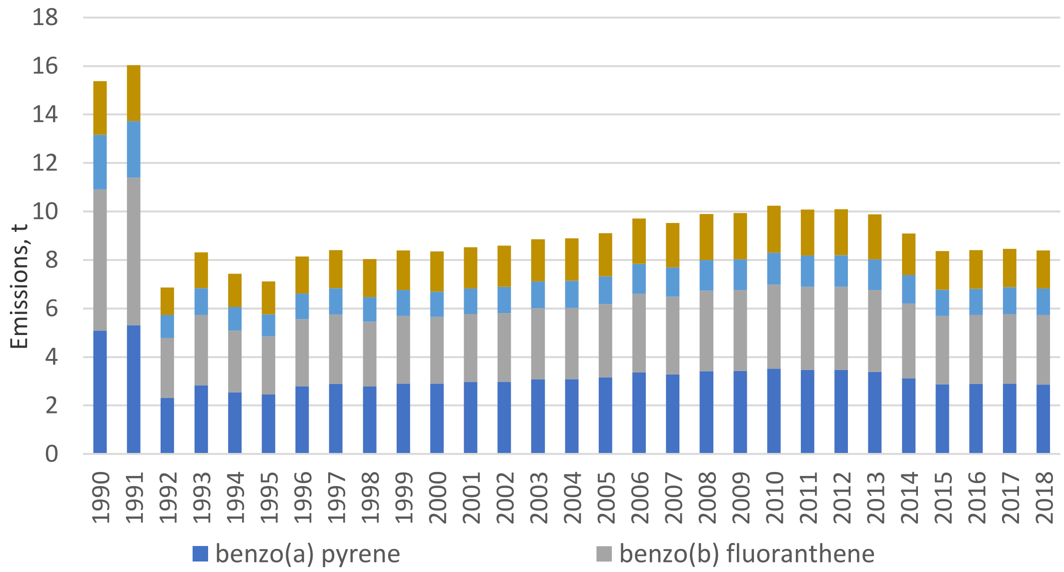


FIGURE 93 PAHS EMISSIONS IN 1.A.4.B.I IN THE PERIOD 1990-2018

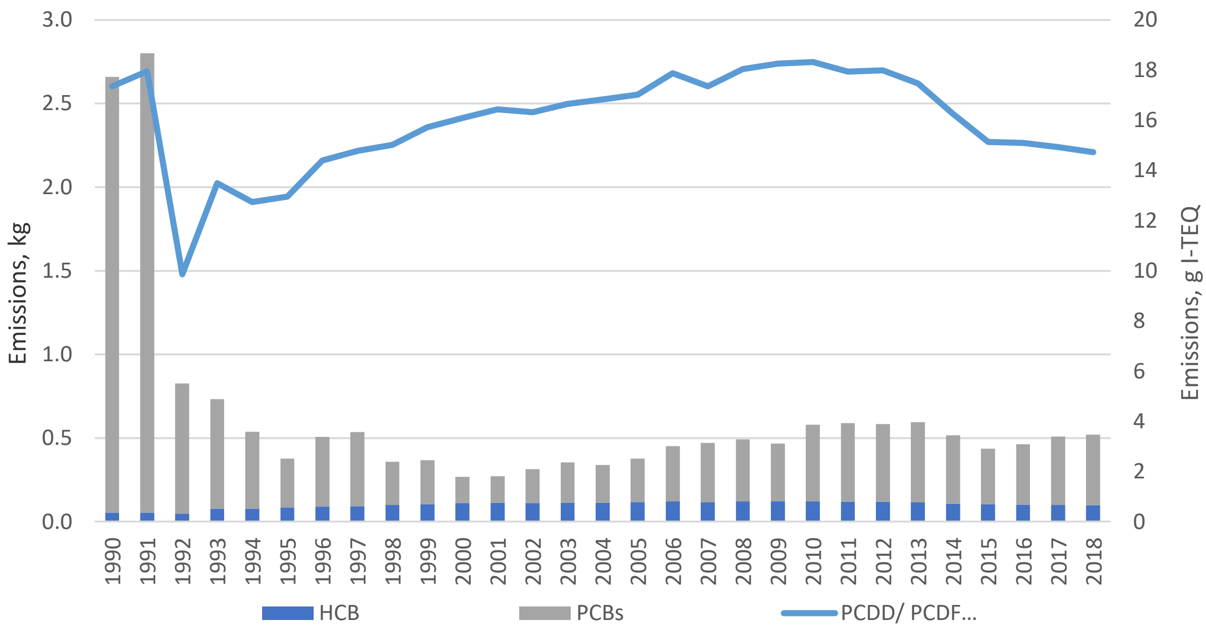


FIGURE 94 HCB, PCBS AND PCDD/F EMISSIONS IN 1.A.4.B.I IN THE PERIOD 1990-2018

3.19.4 Methodological issues

Residential: Stationary combustion (NFR 1.A.4.b.i)

For estimating emissions from wood combustion, estimates of fuel amount by combustion device type from GAINS model (IIASA) were applied. For fireplaces Tier 2 open fireplaces EFs (Table 3-14 from GB2019) were used, for heating stoves average of Tier 2 conventional stoves and Tier 2 energy efficient stoves EFs was applied, for manual single house boilers - Tier 2 conventional boilers EFs, for automatic single house boilers - average of Tier2 Advanced / ecolabelled stoves and boilers and Pellet stoves and boilers EFs. For LPG - Tier 2 Natural Gas EFs for Stoves, Fireplaces, Saunas and Outdoor Heaters. For all other fuels - Tier 1 from GB2016.

The source of emission factors was 2016 EMEP/ EEA guidebook, chapter "1.A.4 Small combustion". For emissions factors used for sector 1.A.4.a.i see: Table 71, Table 72, Table 75, Table 76, Table 77, Table 78, Table 89, Table 90. For emissions factors used for sector 1.A.4.b.i see: Table 61, Table 66, Table 67, Table 68, Table 69, Table 70, Table 83, Table 84, Table 85, Table 86, Table 87, Table 88. Emissions from wood were calculated using Tier 2 emission factors. Information on the combustion of wood in specific residential plants was taken from IIASA GAINS model.

TABLE 37 DISTRIBUTION OF FUELWOOD COMBUSTION DEVICES BY TYPE IN LITHUANIA'S RESIDENTIAL SECTOR

Type of technology	Average ratio of technology split, 2010	Average ratio of technology split, 2015
Fireplaces	0%	0%
Residential boilers (automatic feed)	1%	1%
Residential boilers (manual feed)	51%	55%; 11%*; 100%**
Stoves	48%	44%; 88%*; 0%**

Emissions from LPG were calculated using Tier 2 emission factors from Table 3-13 for Natural gas combustion in cooking. This was done on the basis of results of household survey performed by Statistics Lithuania (*more than 90 % of LPG is used food preparation*). Emissions from other fuels were estimated using Tier 1 emission factors. Activity data was gathered from the fuel balance compiled by the Statistics Lithuania.

3.19.5 Uncertainty

TABLE 38 UNCERTAINTIES OF EMISSIONS OF SOME AIR POLLUTANTS FROM FUEL COMBUSTION IN HOUSEHOLDS (NFR SECTOR 1.A.4.B.I)

Pollutant	95% confidence interval	
	Lower	Upper
NOx	-45%	70%
NMVOC	-80%	280%
Benz(a)pyrene	-70%	180%

3.19.6 Source-specific planned improvements

No source-specific improvements have been planned.

3.20 Other stationary (stationary combustion) (1.A.5.a).

Data on fuel consumption for military stationary combustion are not available. The statistical reports are based on information provided by the fuel suppliers therefore data on fuel used for military stationary combustion is included in Commercial/institutional category. Emissions are reported as “IE”. i.e. emissions from military stationary combustion (1.A.5.a) are included in Commercial/institutional category (1.A.4.a).

3.21 FUGITIVE EMISSIONS FROM FUELS (1.B)

3.21.1 Source category description

The extraction and first treatment of liquid fuels involves a number of activities, each of which represents a potential source of NMVOC emissions. The oil supply chain comprises:

- Exploration and production;
- Transport by pipeline, rail or ship;
- Refining of petroleum products;
- Storage and distribution of products by pipeline, rail, road tanker or ship;
- Retailing to final consumers.

Sectors covered in this chapter are:

• NFR Code 1B1a, 1B1b, 1B1c - Fugitive emissions from solid fuels: Coal mining and handling. There are no mining activities in Lithuania and hence no fugitive emissions from coal mines occur. All emissions are reported as not occurring/not applicable.

• NFR Code 1B2a iv - Refining / storage

• NFR Code 1B2av - Distribution of oil products

ORLEN Lietuva owns and operates a system of pipelines, which includes two pump stations near Birzai and another near Joniskis, crude oil pipelines to the Mazeikiai Refinery and Butinge Terminal, a crude oil pipeline leading to Ventspils, and a products pipeline supplying diesel fuel to Ventspils.

Construction of pipelines in Lithuania started in 1966, with crude oil starting to flow through the pipelines in 1968. In 1992, the company Naftotiekis was established for the operation of Lithuanian pipelines, which later, in 1998, was incorporated into Mazeikiu Nafta in 1998.

Currently the Company own and operated about 500 km of the crude oil and petroleum

3.22 Coal mining and handling (1.B.1.a)

3.22.1 Source category description

In Lithuania, companies using coal as fuel or companies selling coal, have two kinds of coal – washed and unwashed. Washed charcoal has less dust than unwashed coal, so storage of washed carbon, unlike the storage of non-washed carbon, is attributed to controlled coal storage. On the other hand, companies storing unwashed coal are classified as uncontrolled carbon storage companies. An assessment of coal-controlled and uncontrolled storage is carried out when there is no available specific information on the measures used by companies to reduce air pollution. No specific data on the trade (storage) of unwashed carbon in Lithuania has been found, it is only mentioned that such coal is traded in Lithuania. The main suppliers of coal to Lithuania are Russia and Ukraine. It has been reported that washed coal is better than unwashed, as it burns completely, and there are no rock residues left in the boiler, which can be up to 25% in unwashed coal. Washed charcoal not only emits more heat, but also burns better, and rarely needs to be cleaned.

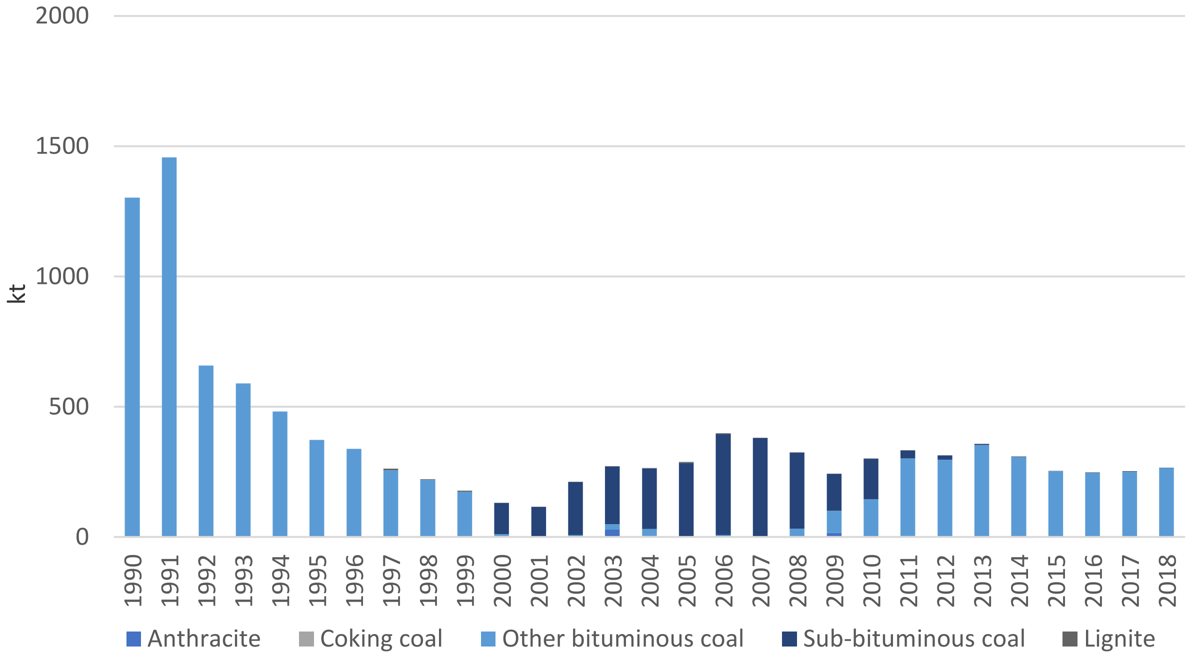


FIGURE 95 TRENDS IN AMOUNT OF STORED COAL IN THE PERIOD 1990-2018

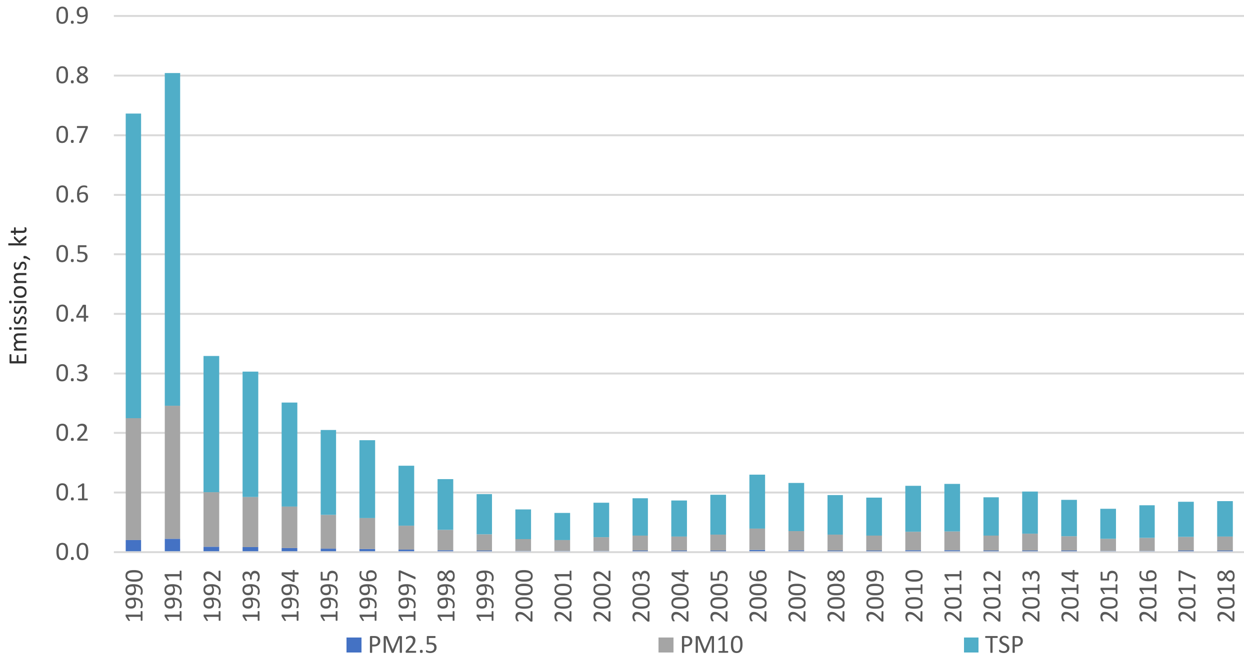


FIGURE 96 POLLUTANT EMISSIONS IN SECTOR 1.B.1.A IN THE PERIOD 1990-2018

The source of emission factors was 2019 EMEP/ EEA guidebook, chapter "1.A.4 Small combustion". For emissions factors used for sector 1.B.1.a. see: Table 93, Table 94.

3.23 Exploration, Production and Transport of Oil (1.B.2.a.i)

3.23.1 Source category description

Based on activity data requirements and availability 1990-onwards, fugitive emissions from sub-sector 1.B.2.a.i Extraction, 1st treatment and loading of liquid (SNAP 050200) were calculated with Tier 2 EMEP/EEA technology-specific approach by multiplying processes (**Exploration** (drilling, testing, servicing), **Production** (fugitive, venting, flaring) and **Transport** specific AD stratified according to the different processes with the corresponding IPCC2006 EFs.

TABLE 39 TIER 2 EFS FOR SOURCE CATEGORY 1.B.2.A.I EXPLORATION PRODUCTION, TRANSPORT, ONSHORE FACILITIES BY IPCC2006

Code					
Pollutant NMVOC		**Value**	**Unit**	**Abatement technologies**	**Data providers**
Exploration	Drilling Testing Servicing	8.7E-07 1.2E-05 1.7E-05	kt per 10^3 m^3 total oil production	No abatement technologies are identified in this source category.	1990 – onwards, Activity data for fugitive emissions from oil can be obtained from database of the Lithuanian Statistics: (see http://www.stat.gov.lt).
Production	Fugitives Venting Fluring	1.8E-06 4.3E-04 2.1E-05	kt per 10^3 m^3 total oil production	No abatement technologies are identified in this source category.	1990 – onwards, Activity data for fugitive emissions from oil can be obtained from database of the Lithuanian Statistics: (see http://www.stat.gov.lt).
Transport	Pipelines	5.4E-05	kt per 10^3 m^3 total oil production	No abatement technologies are identified in this source category.	1990 – onwards, Activity data for fugitive emissions from oil can be obtained from database of the Lithuanian Statistics: (see http://www.stat.gov.lt).

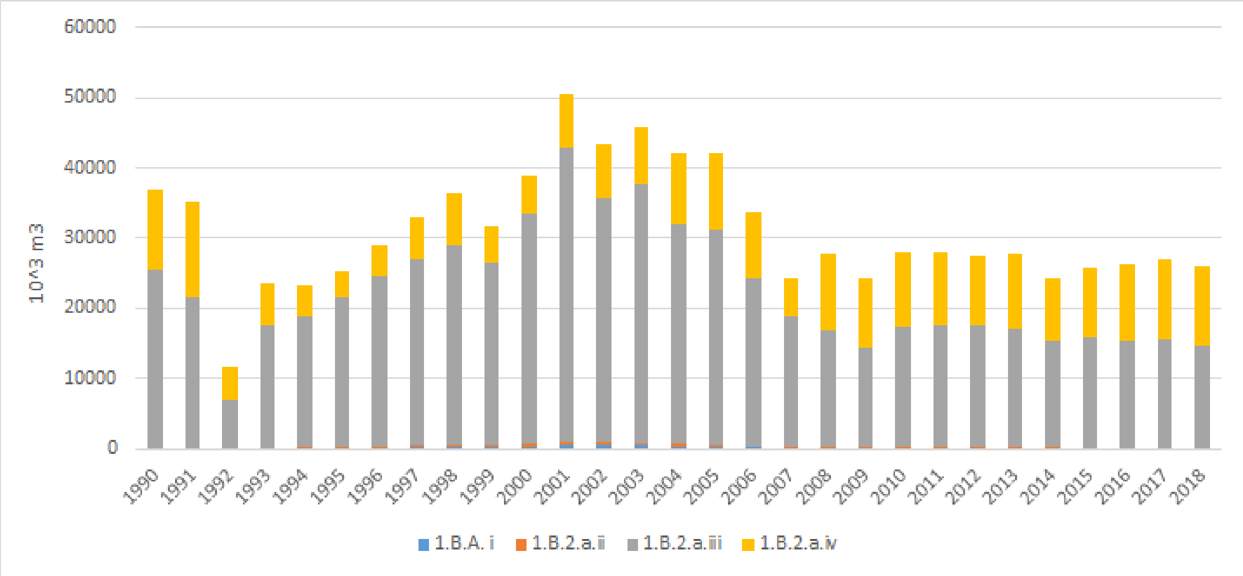


FIGURE 97 GAS EXPLORATION, PRODUCTION, TRANSPORT 1990-2018

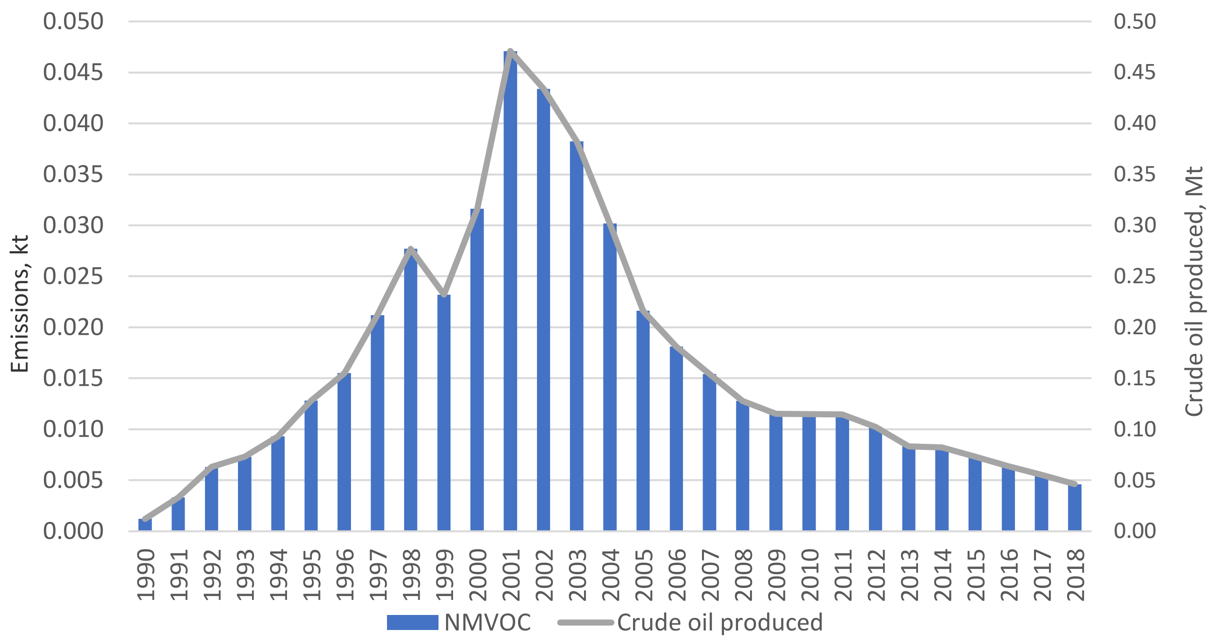


FIGURE 98 NMVOC EMISSIONS AND CRUDE OIL PRODUCTION IN THE PERIOD 1990-2018

Default EF value is provided in Table 98.

3.24 Fugitive Emissions from Oil Refining (1.B.2.a.iv)

Due to the fact that there is only one crude oil refining company in Lithuania (AB ORLEN Lietuva). calculation of NMVOC emissions for this category have been based on company's "Air Pollution Annual Report", which is available on AIVIKS database [1]. In the company's report VOC emissions are included. The NMVOC numbers have been obtained assuming that 10% of VOC is methane, while 90% - NMVOC

[2]. Other substances (i.e. methanol, benzene, toluene, xylene, etc.) which were reported separately. have been included into the total NMVOC emission.

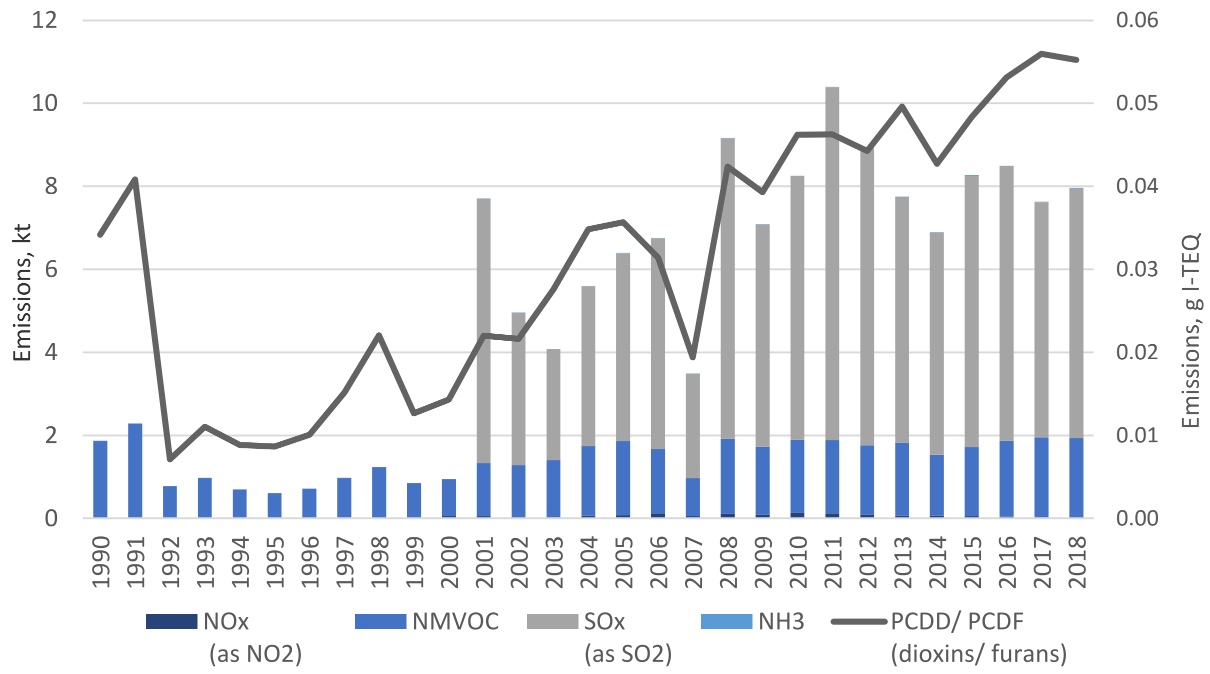


FIGURE 99 POLLUTANT EMISSIONS IN SECTOR 1.B.2.A.IV IN THE PERIOD 1990-2018

3.24.1 Emission factors

The source of emission factors was 2019 EMEP/ EEA guidebook. chapter "1.B.2.a.iv Fugitive emissions oil: refining / storage", paragraphs *3.2 Tier 1 default approach (1.B.2.a.iv)(Tier 1 EFs)* and *3.3 Tier 2 technology-specific approach (1.B.2.a.iv) (Tier 2 EFs).* Emissions of NMVOC, NH3, PCDD/F were calculated using Tier 1 emission factors (Table 95) and emissions of Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene were calculated using Tier 2 emission factors (Table 96). Other pollutant emissions are not estimated.

3.25 Fugitive Emissions from Distribution of Oil Products (1.B.2.a.v)

3.25.1 Source category description

In Lithuania, oil terminals and service stations must have permits with overload >100 m^3 per year.

Two complementary directives aim jointly to reduce NMVOC emissions from the storage and distribution of petrol:

- Directive 94/63/EC concerning emissions of NMVOCs from the storage of petrol and distribution from terminals to service stations (the VOC-I Directive), which covers refineries and the delivery of petrol to service stations;
- Directive 2009/126/EC concerning petrol vapor recovery during refueling of motor vehicles at service stations (the VOC - II Directive).

Since 1 January 2004 requirements entered into force in major installations: terminals with an annual gasoline turnover of more than 50 000 tons per year, and in terminals where gasoline is transported to railway tanks, tank-vehicles and/or vessels with an annual petroleum turnover of more than 150 thous. tons per year, as well as petrol stations with a petrol turnover of 1000 m^3 per year, as well as in petrol stations in cities.

3.25.2 Methodological issues

The calculation of the NMVOC time series for fugitive emissions from gasoline distribution, 1990-2015, can be based on methods given by CONCAWE, including annual national gasoline consumption and assumptions on the share of gasoline evaporated at different stages of the handling procedure, as well as effects of applied abatement technology at gasoline stations.

Algorithms are provided for the following sources:

- Storage tanks;
- Automobile refueling.

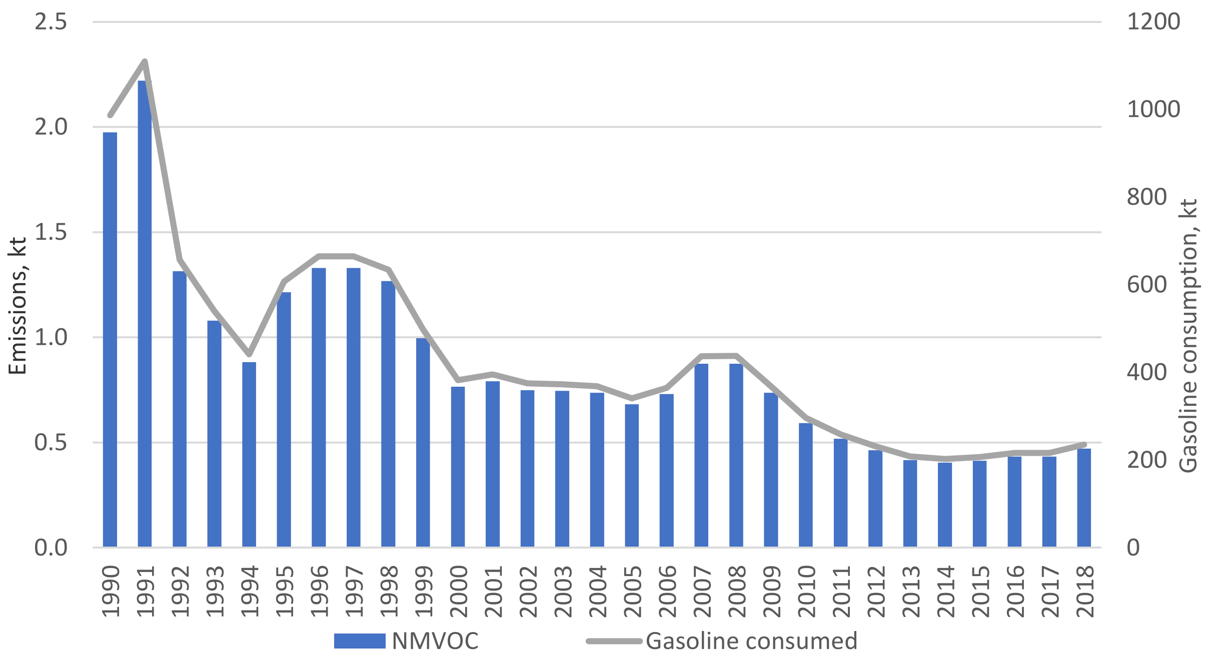


FIGURE 100 NMVOC EMISSIONS AND GASOLINE CONSUMPTIONS IN THE PERIOD 1990-2018

Gasoline vapor emissions at service stations can be controlled using “vapor balancing” techniques:

Storage tank filling: When the storage tank is filled the vapors normally vented to atmosphere can be fed back into the tanker cargo tank (compartment) from which the gasoline is being off-loaded. This technique is called “Stage 1B” vapor balancing.

Default Tier 1 EF value for NMVOC emissions was used, see Table 97.

3.26 Fugitive emissions from natural gas (1.B.2.b)

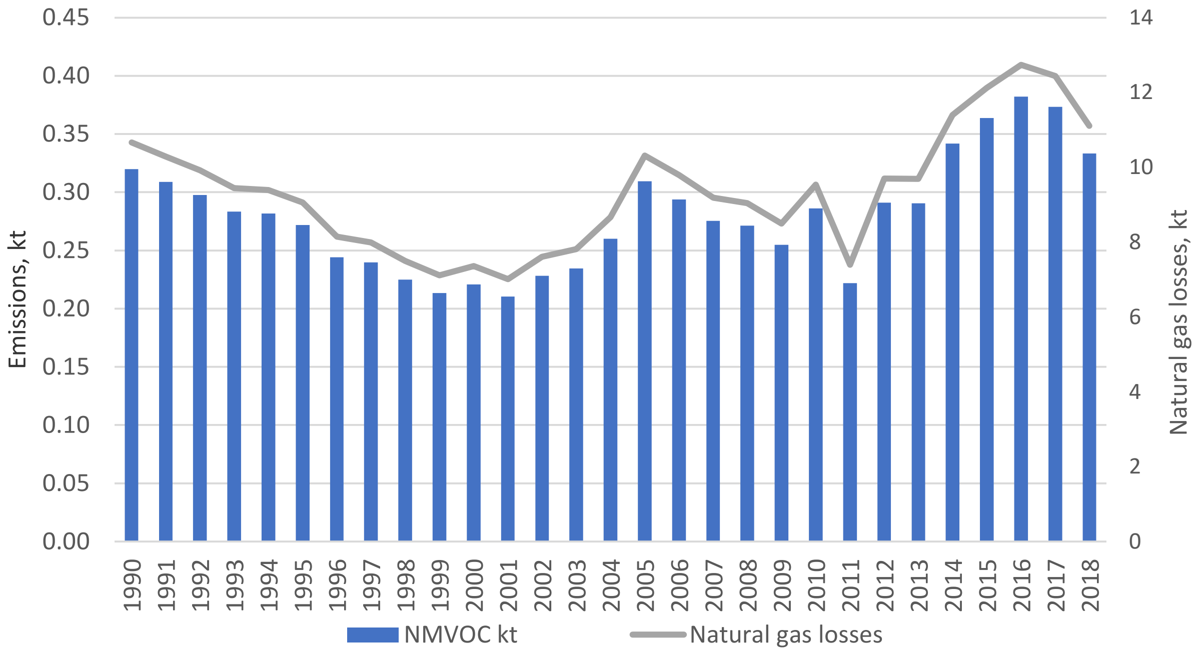


FIGURE 101 NMVOC EMISSIONS AND NATURAL GAS LOSSES IN THE PERIOD 1990-2018

The average proportion of NMVOC in natural gas supplied in Lithuania, according to a study published on the Internet, is 1,4% of mass. NMVOC include ethane, propane, butane, pentane, hexane.

3.27 Fugitive Emissions from Venting and Flaring (1.B.2.c)

Emissions from venting and flaring are included into 1B2ai, 1B2aiv and 1B2b categories.

3.28 Fugitive Emissions from Energy Production (1.B.2.d)

Emissions not occurred.

References:

[1] ORLEN Lietuva “Annual Air Pollution Report”, available on http://aplinka.lt, last accessed on 07/06/2017;

[2] Hjerrild & Rasmussen. 2014: Fugitive VOC from refineries, taken from Danish Inventory Report.

4 INDUSTRIAL PROCESSES AND PRODUCT USE

4.1 Source category description

The economic structure of Lithuania has gone through noticeable changes. During the period of 1992–1994, the share of industry in the GDP dropped from 35.5 % to 20.4 %, while the share of trade in the GDP structure grew from 4.5 to 23.5 %. Since 1992, economic recession resulted in the reduction of energy consumption, but the latter was slower than the decline in GDP. Therefore, energy demand of the national economy during this period was growing in relative terms. It is evident that the production output varied between different industries. As the most serious decline was observed in the production of electronic equipment, machinery, metalworking, the likelihood of reaching the former levels of production is quite low for these sectors. Since 1991. Lithuania's export to the western countries has increased from 5.1 % to 54.6 % of total exports. It should be noted that the share of imports from these countries into Lithuania has also increased from 9.8 % to 67.1 % of the total imports. The main trading partners of Lithuania are Russia, Germany, Belarus, Latvia, Ukraine, the Netherlands, Poland, and Great Britain.

This chapter covers emissions from industrial processes (NFR sectors 2A. 2B. 2D). The food industry in Lithuania is dominated by meat production, diary and fish products. The fishing industry is concentrated in Klaipėda, and in 1993 this industry was the largest in the food sector. High prices of the primary food products have contributed to the decline of food industry.

Dominating industry in Lithuania is manufacturing. Manufacturing constituted 87% of the total industrial production (except construction) in 2011. Four most important sectors within Manufacturing cumulatively produced 78% of production:

- Manufacture of refined petroleum products (~30%);
- Manufacture of food products and beverages (~20%);
- Manufacture of wood products and furniture (~10%);
- Manufacture of chemicals and chemical products (~10%).

4.2 MINERAL PRODUCTS (2.A)

Emissions from lime production, organic chemicals (i.e. polyethylene, polyvinylchloride, polypropylene, polystyrene) production and food and beverages (i.e. bear, wine, spirit, bread, cake, meat, fat, animal feed) production were estimated according to statistical production of commodities. Emissions from cement, sulphur from petroleum, sulphur acid, nitric acid, ammonia, ammonium nitrate, urea, phosphate fertilizer and formaldehyde production were reported according to submissions of large point sources.

4.3 Cement production (2.A.1)

4.3.1 Source category description

Cement is produced in a single company - AB Akmenės Cementas, which is situated in the North Western part of Lithuania. The factory was constructed in soviet times (1947-1974), cement produced in the factory was exported to other Republics of USSR, Hungary, Cuba and Yugoslavia. The total nominal capacity of the plant is about 5 million tonnes cement per year. The data on clinker production and composition were provided by the AB Akmenės Cementas. Activity data is collected on company level.

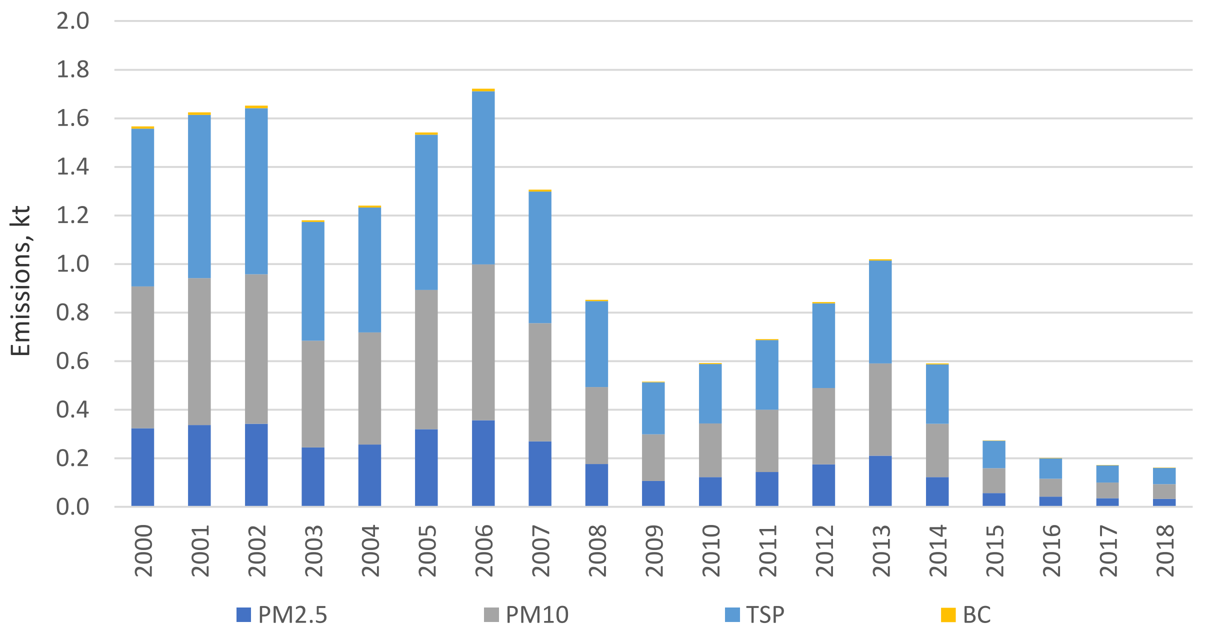


FIGURE 102 POLLUTANT EMISSIONS IN SECTOR 2.A.1 IN THE PERIOD 2000-2018

4.3.2 Methodology

The Tier 1 approach for process emissions from cement uses the general equation

$$E_{Pollutant} = AR_{Production} \times EF_{Pollutant}$$

where:

- $E_{pollutant}$ is the emission of a pollutant (kg)
- $AR_{production}$ is the annual production of cement (in Mg)
- $EF_{pollutant}$ is the emission factor of the relevant pollutant (in kg pollutant / Mg cement produced)

This equation is applied at the national level, using annual national total cement production data.

TABLE 40 EMISSION FACTORS FOR SECTOR 2.A.1

Pollutant	Value	Units	95% confidence level		Reference
			Lower	Upper	
TSP	260	g/Mg clinker	130	520	European Commission (2010)
PM10	234	g/Mg clinker	117	468	European Commission (2010)
PM2.5	130	g/Mg clinker	65	260	European Commission (2010)
BC	3	% of PM2.5	1.5	6	US EPA (2011. file no.: 91127)

Emissions of metal compounds from cement kilns can be grouped into three general classes: volatile metals. e.g. Hg; semi-volatile metals, including Cd, Pb, Se, and Zn; and refractory or non-volatile metals, including Cr, As, Ni, Mg, and Cu. Although partitioning of these metal groups is affected by kiln operating procedures, the refractory metals tend to concentrate in the clinker, while volatile metals tend to be emitted through the primary exhaust stack, and semi-volatiles are partitioned between clinker and the primary exhaust.

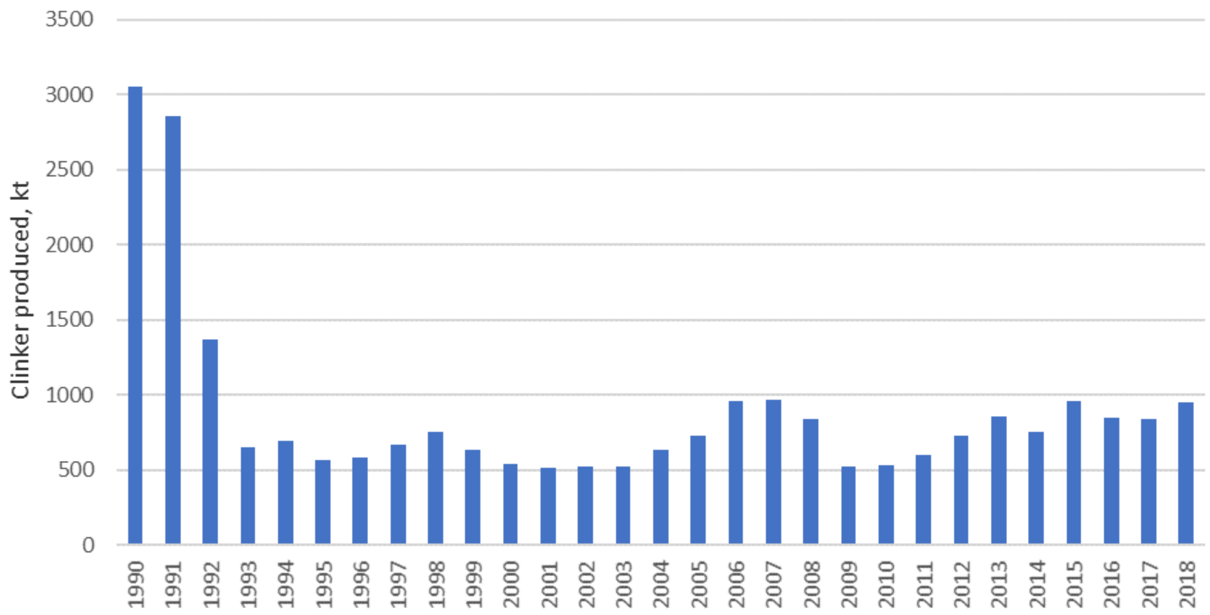


FIGURE 103 CLINKER PRODUCTION IN 1990-2018

2.A.1 emissions data are based on data from facilities (Tier 3 method) from 2006.

4.3.3 Uncertainty

Activity data uncertainty is assumed to be 2%. Data on clinker production provided by the single production company is considered reliable;

4.4 Lime production (2.A.2)

4.4.1 Source category description

Emissions from lime production were estimated using emission factors proposed by EEA/EMEP Emission guidebook 2013. Data on lime (both hydrated ($Ca(OH)_2$) and anhydrous (CaO)) production for years after 2004 is available on the Lithuanian Statistics database, while production information of lime for years before 2005 was provided by Lithuania Statistics. There is no information available on the amounts of anhydrous lime manufactured before 2002, thus it was assumed that none had been produced. Lime is also produced and then used in sugar industry, necessary for sugar purification. Sugar companies were inquired to provide information on the amounts of lime manufactured as this sub-category is not covered in Lithuania Statistics database.

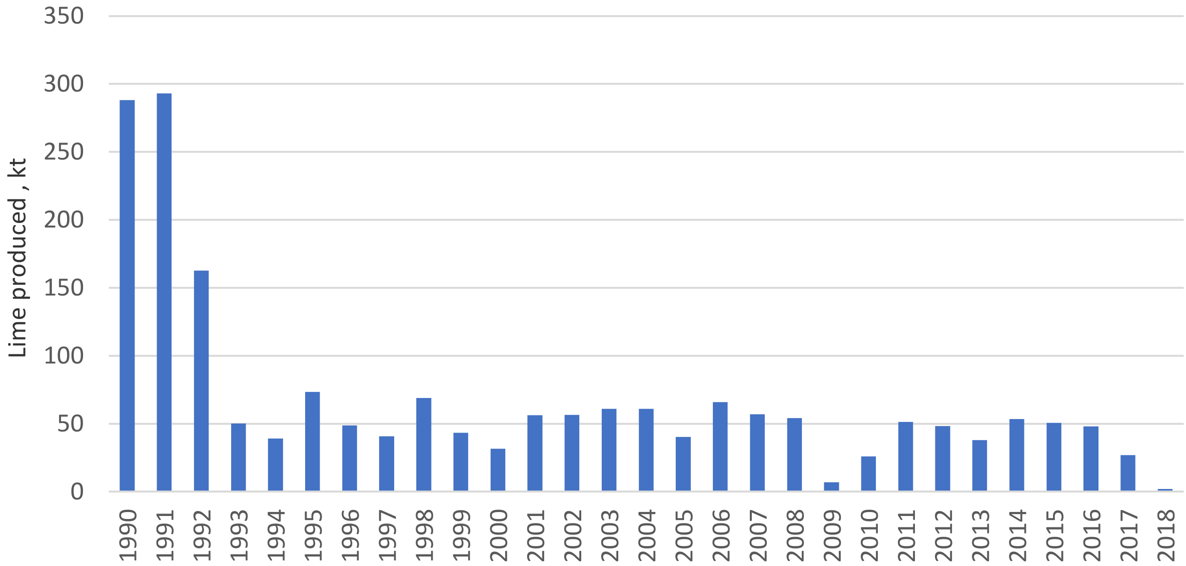


FIGURE 104 LIME PRODUCTION IN THE PERIOD 1990-2018

Lime production decreased by 99 % from 1990 to 2018 while increased by 95 % from 2005 to 2018.

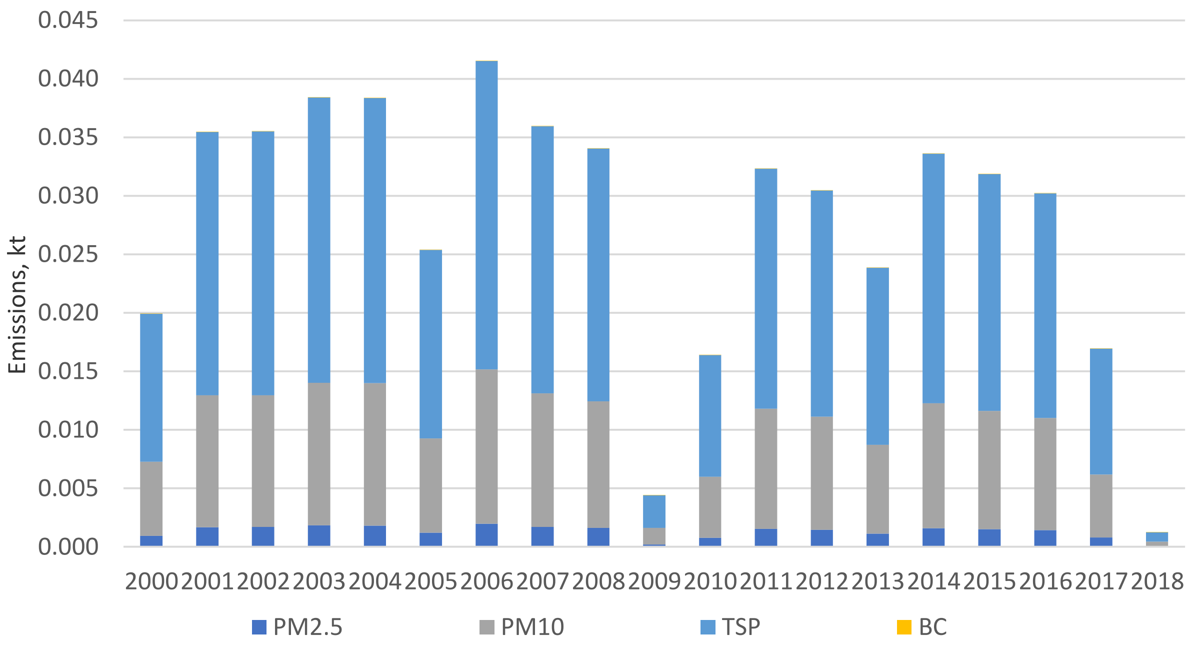


FIGURE 105 POLLUTANT EMISSIONS IN SECTOR 2.A.2 IN THE PERIOD 2000-2018

4.4.2 Methodology

The Tier 1 approach for process emissions from cement uses the general equation

$$E_{Pollutant} = AR_{production} \times EF_{pollutant}$$

where:

- $E_{pollutant}$ is the emission of a pollutant (kg)
- $AR_{production}$ is the annual production of lime (in Mg)
- $EF_{pollutant}$ is the emission factor of the relevant pollutant (in kg pollutant / Mg lime produced)

TABLE 41 EF FROM INDUSTRIAL PROCESS

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	9 000	g/Mg lime	3 000	22 000	European Commission (2001)
PM10	3 500	g/Mg lime	1 000	9 000	Visschedijk et. (2004) applied on TSP
PM2.5	700	g/Mg lime	300	2 000	Visschedijk et. (2004) applied on TSP
BC	0.46	% of PM2.5	0.23	0.92	Chow et al. (2011)

4.5 Glass production (2.A.3)

Total glass production quantities are shown in the figure below.

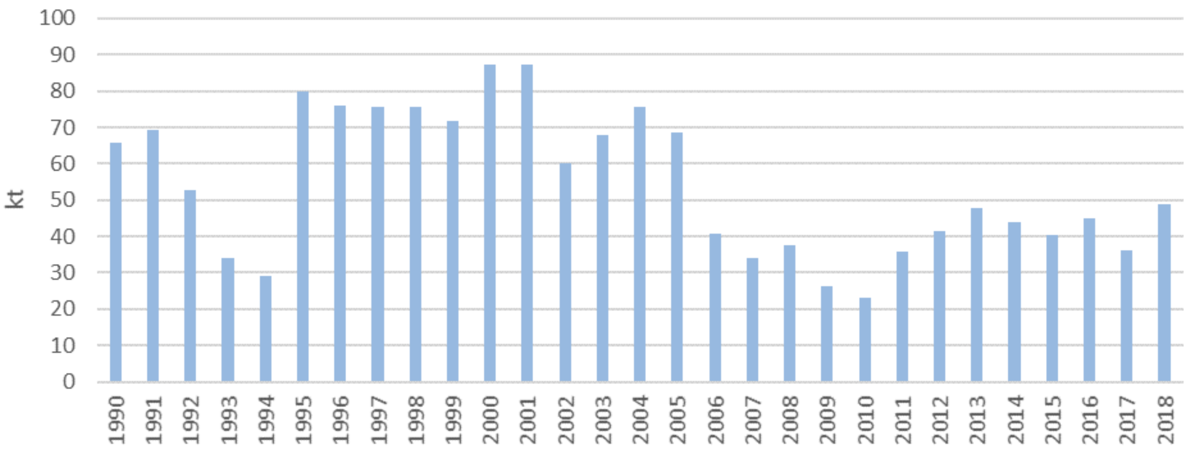


FIGURE 106 GLASS PRODUCTION FOR THE 1990-2018 PERIOD, KT

4.5.1 Methodology

Emission factors from 2019 EMEP/EEA guidebook were used to estimate emissions from this category.

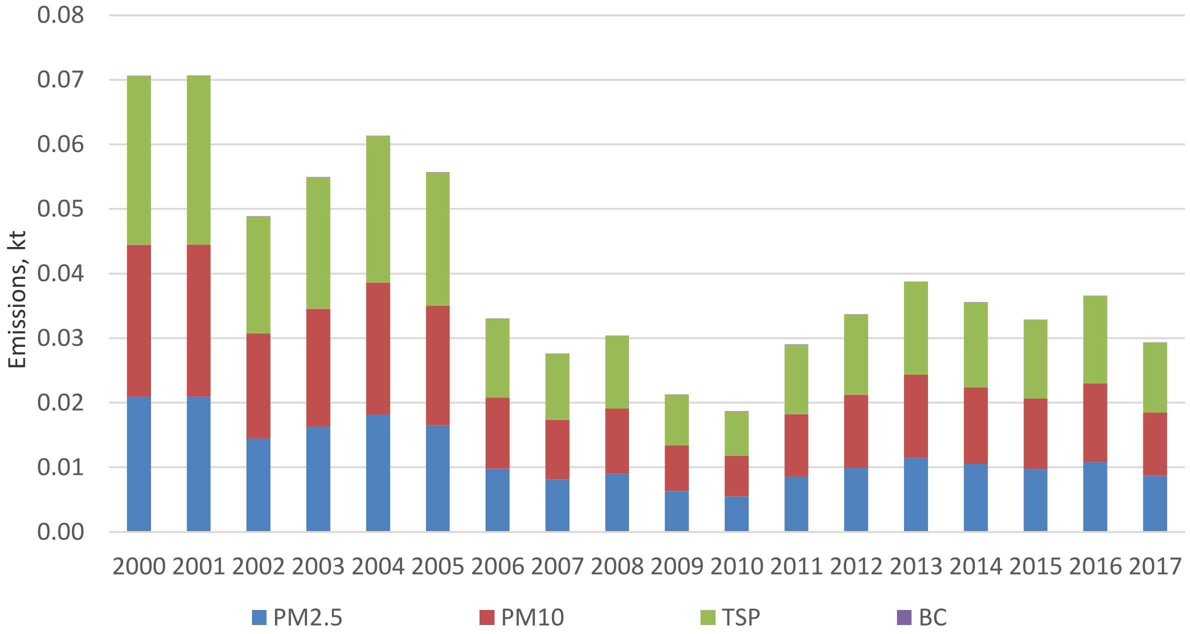


FIGURE 107 ESTIMATED POLLUTANT EMISSIONS (GG) FROM GLASS PRODUCTION

From the Figure 107 it is seen that 1990/2018 emissions decreased by 26 %, while 2005/2018 also emissions dropped by 28 %. Pollutants emissions from this category contribute only a small part to the total inventory.

4.6 Quarrying and Mining of Minerals Other than Coal (2.A.5.a);

4.6.1 Overview of the Sector

Based on EMEP/EEA Guidebook (2019), emissions from this sector are insignificant, as their contribution to total national emissions is less than 1% of any pollutant. Although emissions from the sector are significant at local level, emissions at national level are relatively low and only relevant for relatively particulate fractions. In the course of quarrying, digging and handling excavated minerals (e.g. sifting, shredding) and transferring them, solid particles are emitted to the atmosphere. According to the EMEP/EEA Guidebook (2019) Particulate Control, this process also includes watering and process coverings. In Lithuania, when treating quarries or excavated minerals, equipment is not covered by hoods or similar materials because of the security measures and easier visual inspection of the production.

Activity data for this category was gathered from Lithuania Statistics database. Information of the following commodities was obtained:

- Silica sand;
- Construction sand;
- Gravel pebbles, shingle and silica;
- Crushed dolomite;
- Crushed granite;
- Extraction of peat.

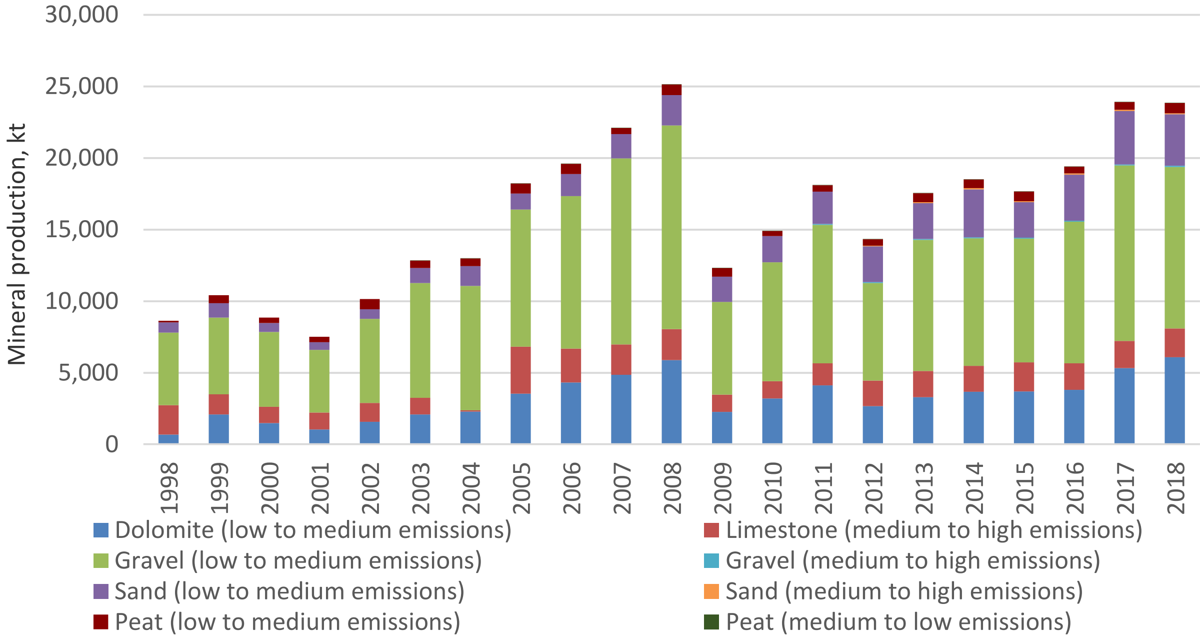


FIGURE 108 MINERAL PRODUCTION IN THE PERIOD 1998-2018

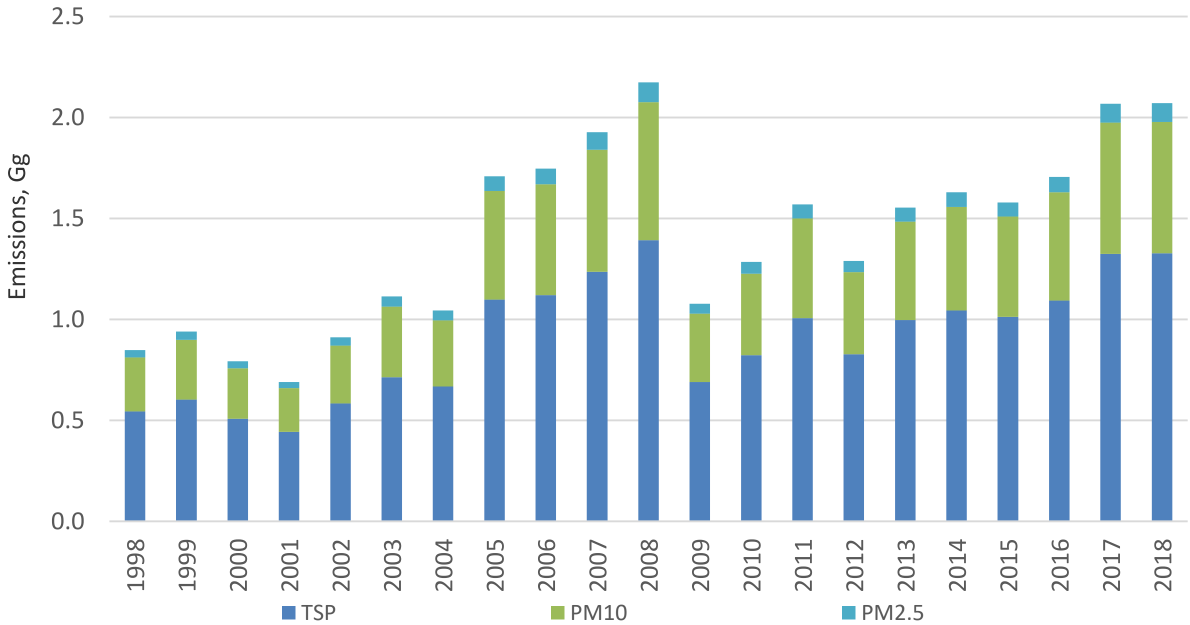


FIGURE 109 TSP, PM10, PM2.5 EMISSIONS IN THE PERIOD 1998-2018

4.6.2 Methodology

Tier 2 approach was applied using emission factors from 2019 EMEP/EEA Guidebook, see Table 101.

4.7 Construction and Demolition (2.A.5.b)

4.7.1 Overview of the Section

Data on the construction of residential and non-residential buildings is available on Lithuanian Statistics database. Area of buildings which were demolished is not available and it can be omitted due to relatively negligible pollution compared with that from construction activities. The majority of the construction activity takes place in urban and other densely populated areas. In Lithuania, most of the construction also takes place in the largest expanding cities: Vilnius, Kaunas and other. According to the EMEP/EEA Guidebook (2019), the average soil dust during construction damaged area can be found between the natural undamaged soil dust and sand dust, as sand is the most commonly used in construction. The amount of sand dust in silt content is about 12%. Based on the EMEP/EEA Guidebook (2016), soil dust contains 0.002-0.078 mm (or 0.063 mm according to ISO definition) of particles, therefore amounts of all surface dust are summed up appropriately. The total average soil silt in Lithuania is obtained by calculating the arithmetic mean of 10 surface soil samples.

FIGURE 110 AREA AFFECTED BY CONSTRUCTION ACTIVITIES, THOUSAND M².

Area affected by construction of residential buildings increased by 87% from 2005 to 2018, non-residential - decreased by 87%, roads - decreased by 77%.

4.7.2 Methodology

The equation (1) from 2019 EMEP/EEA Guidebook chapter "2.A.5.b Construction and demolition" was used to estimate EF values.

TABLE 42 VALUES OF PARAMETERS IN THE EQUATION (1)

	d	1-CE	24/PE	s/9%	EF PM2.5
Detached single/two family	0,50	1,00	0,2000	2	0,0086
Apartment buildings	0,75	1,00	0,2000	2	0,0300
Non residential construction	0,83	0,50	0,2000	2	0,1000
Road construction	1,00	0,50	0,2000	2	0,2300

4.7.3 Time Series

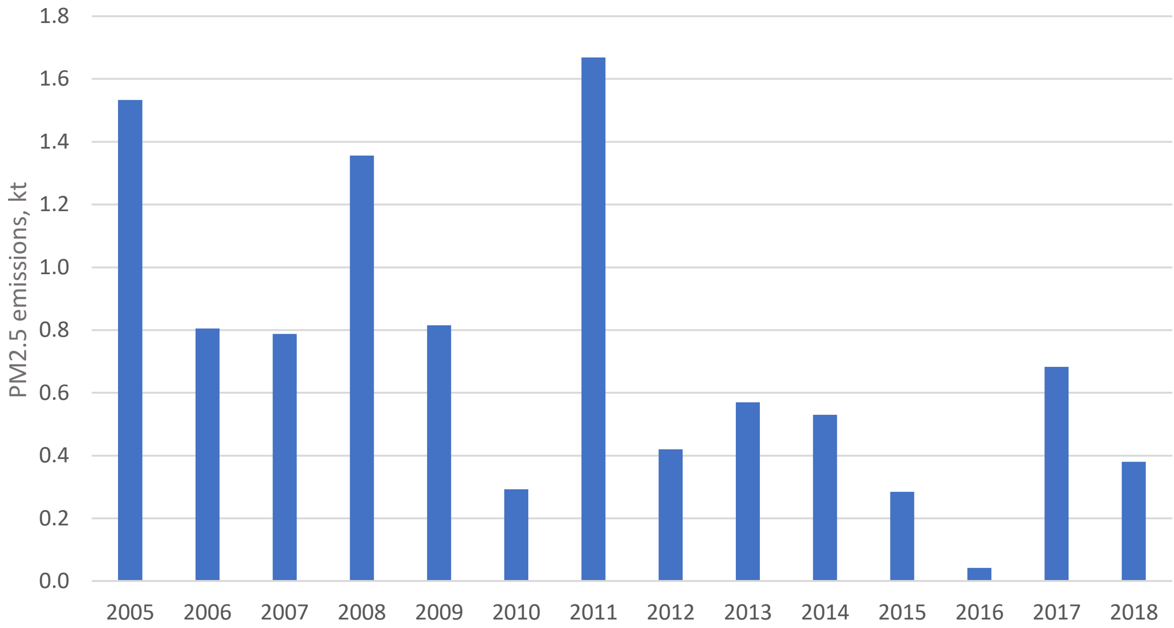


FIGURE 111 ESTIMATED POLLUTANT EMISSIONS (KT).

$PM_{2.5}$ emissions decreased by 75% from 2005 to 2018. The main contributor to 2A5b source of emissions is the construction of roads.

4.8 Storage, handling and transport of mineral products (2.A.5.c)

4.8.1 Source category description

The largest Lithuanian manufacturer of ceramic products are in production since 1923. There is no publicly available information on the storage of the products, the quantities produced, or the means used to reduce air pollution. In Lithuania, the distribution of mineral products (ceramics, glass wool, silicate bricks) takes place indoors, usually dust extraction systems, air purification devices, which significantly (up to 99%) reduce emissions to the atmosphere from the room. However, in the absence of emission factors in the EMEP/EEA Guidebook (2019) and in the absence of national emission factors, emissions are not calculated for controlled mineral processing.

4.9 Other mineral products (2.A.6)

No emissions were calculated

4.10 CHEMICAL INDUSTRY (2.B)

4.11 Ammonia production (2.B.1)

4.11.1 Source category description

AB Achema is a single ammonia production company in Lithuania. In the production plant ammonia is produced at 22.0-24.0 MPa pressure from hydrogen and nitrogen, which are generated at 800-1000 °C temperatures by conversion of natural gas. The converted gas is cleaned from impurities (CO, CO_2, H_2O vapour, etc.).

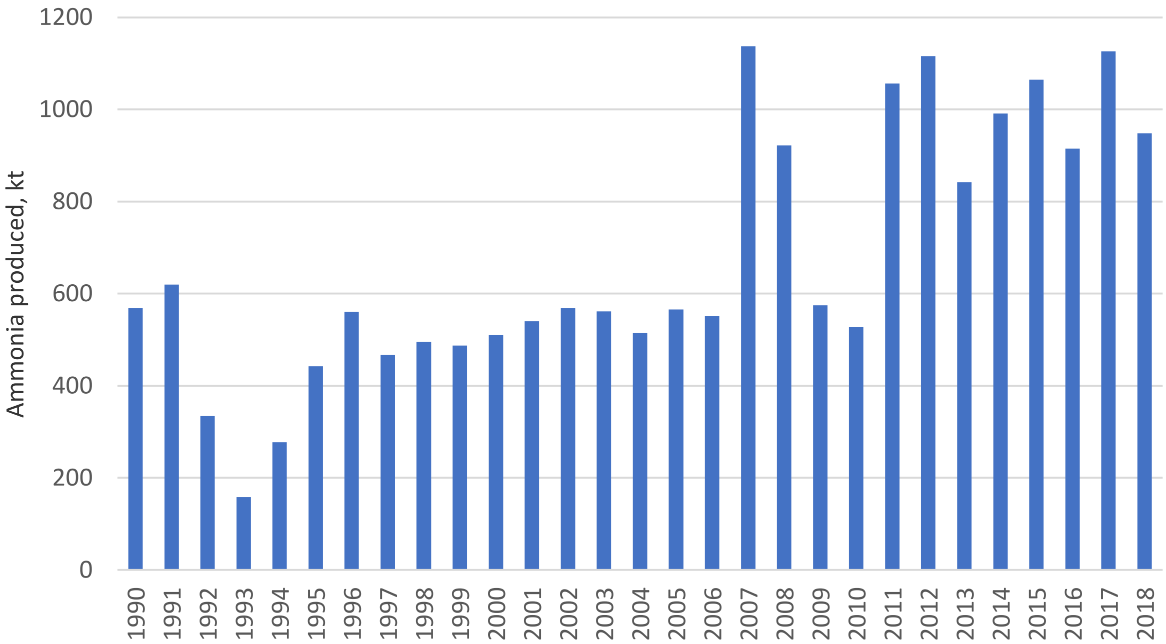


FIGURE 112 AMMONIA PRODUCTION QUANTITIES (GG) FROM 1990 TO 2018

4.11.2 Methodology

NOx, CO, NH_3 emissions for 2005-2018 period were collected from CLRTAP reports provided by the company, while previous years' emissions were included elsewhere (under NFR 2B10a category) as emissions were not separated by different processes. Abatement is applied for NOx, NMVOC emissions are not reported by the producer.

4.11.3 Time Series

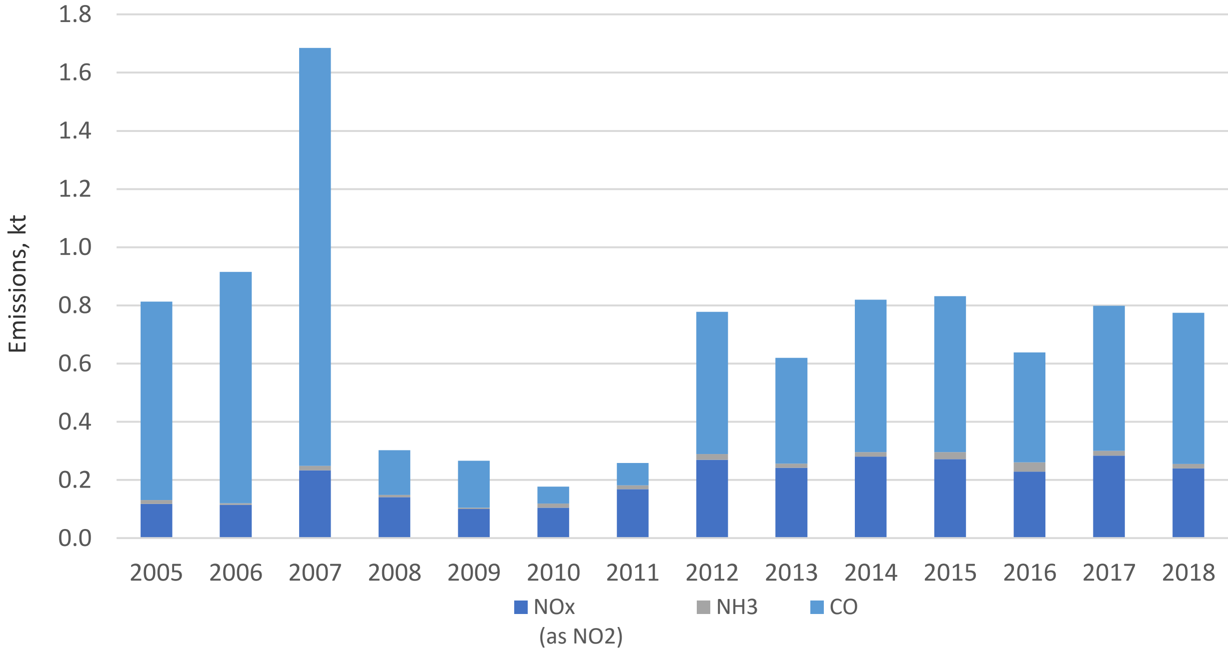


FIGURE 113 NO_x, NH_3 AND CO EMISSIONS FROM AMMONIA PRODUCTION IN THE PERIOD 2005-2018

4.12 Nitric acid production (2.B.2)

Nitric acid is produced by AB Achema which is the single nitric acid producer in Lithuania. According to information provided by AB Achema, the nitric acid is produced in UKL-7 units and GP unit by absorbing NO_2 with water. NO_2 is produced by air oxidation of NO with oxygen. Nitric oxide (NO) produced by air oxidation of ammonia with oxygen on Pt mesh catalyst. UKL-7 units are working by single pressure (high pressure) scheme. Gaseous emissions after absorption are cleaned from NO_X in a reactor. Grande Paroisse (GP) unit uses a dual-pressure scheme (medium/high). Gaseous emissions from GP are cleaned from NO_X in the reactor using a De NO_X technology.

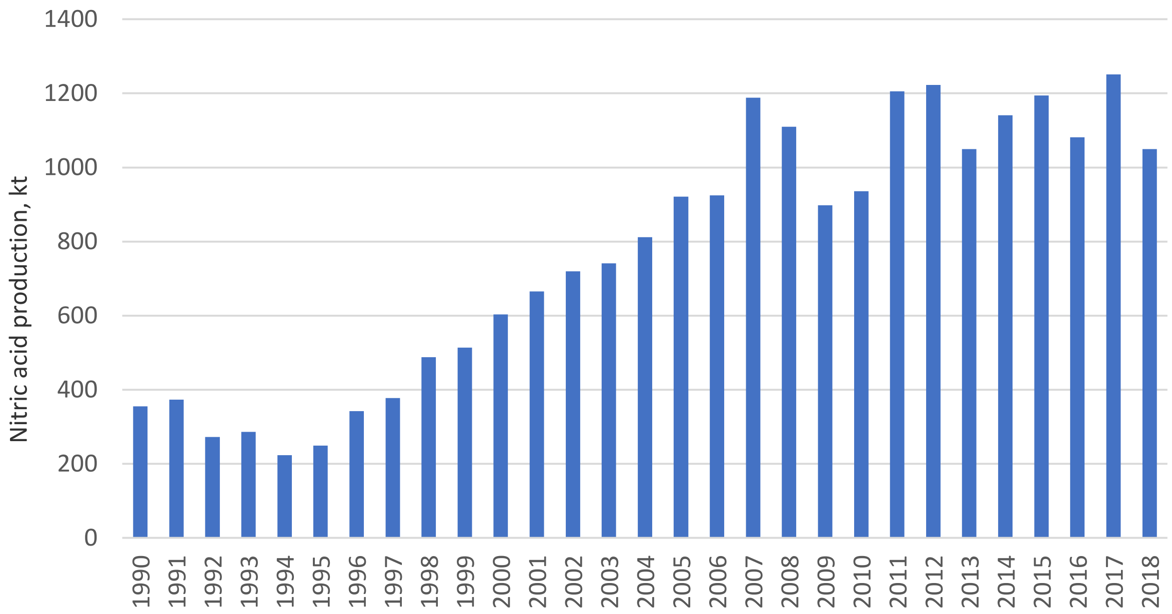


FIGURE 114 TRENDS IN NITRIC ACID PRODUCTION IN THE PERIOD 1990-2018

4.12.1 Methodology

2006-2018 CO, NOx and NH_3 emissions were taken from CLRTAP reports submitted by AB Achema. 1990-2005 emissions were included under 2B10a category *Other chemical industry* as no information on the emissions from nitric acid production was available.

4.12.2 Time Series

2006/2015 NOx emissions increased by 47.6%, while CO emissions dropped by 92.1%.

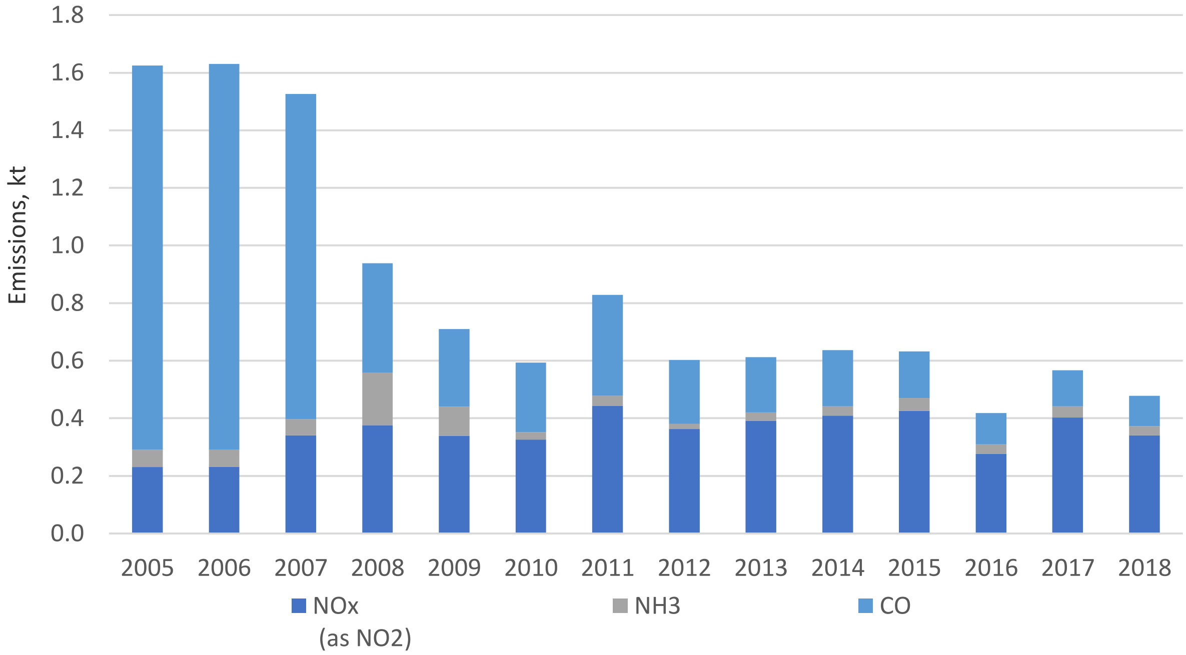


FIGURE 115 NOX, NH_3 AND CO EMISSIONS FROM NITRIC ACID PRODUCTION.

4.13 Chemical industry: other (NFR 2.B.10.a)

4.13.1 Overview of the Sector

This category includes emissions from the production of other chemical species in two major companies. Processes which fall under this category are:

- Sulfuric acid production, *SNAP 040401*;
- Ammonium nitrate production, *SNAP 040405*;
- Urea production, *SNAP 040408*;
- Phosphate fertilizers production, *SNAP 040414*;
- Other chemical species production, including production of CAN, *SNAP 040416*;
- Acetate yarn production

4.13.2 Methodology

2006-2018 emissions from the processes mentioned above were taken from AB Achema and AB Lifosa CLRTAP reports. For years 1990-2006 no details on the emissions according to different production sources were available. Thus, all production-related emissions were reported under NFR 2.B.10.a category. NFR 2.B.1 and 2.B.2 categories were labelled as 'IE' for the 1990-2006 period.

4.13.3 Time Series

1990/2018 emissions show down trend, which is mainly due to the fact that emissions from NFR 2.B.1 and 2.B.2 categories are included under this category for 1990-2006 years. Please see figure in the beginning of the sector for overall pollutants emissions trends for the 1990-2018 period.

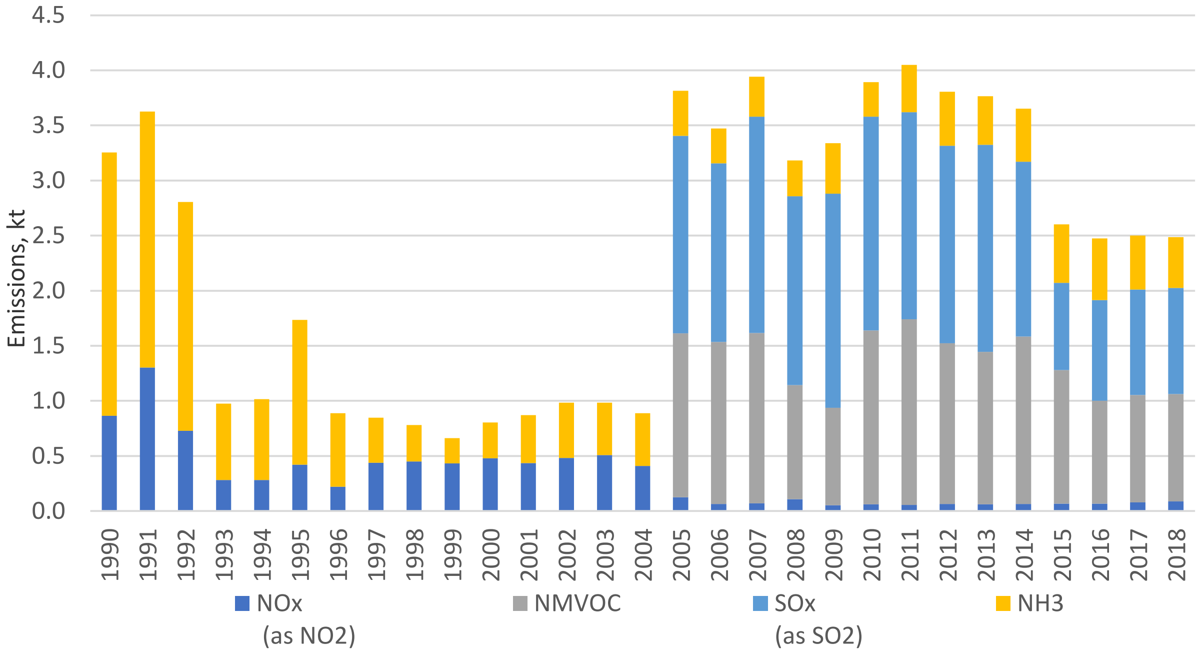


FIGURE 116 POLLUTANT EMISSIONS IN SECTOR 2.B.10.A IN THE PERIOD 1990-2018

NMVOC and SOx emissions were not estimated for the period 1990-2004.

4.14 METAL PRODUCTION (2.C)

4.15 Iron and Steel Production (NFR 2.C.1)

4.15.1 Overview of the Sector

Three companies were producing cast iron before 2009. After the closure of one factory the other two have been operating in the sector. One of the facilities has been producing cast iron in the blast furnace, while the other has been manufacturing cast iron in the induction furnace since 2011.

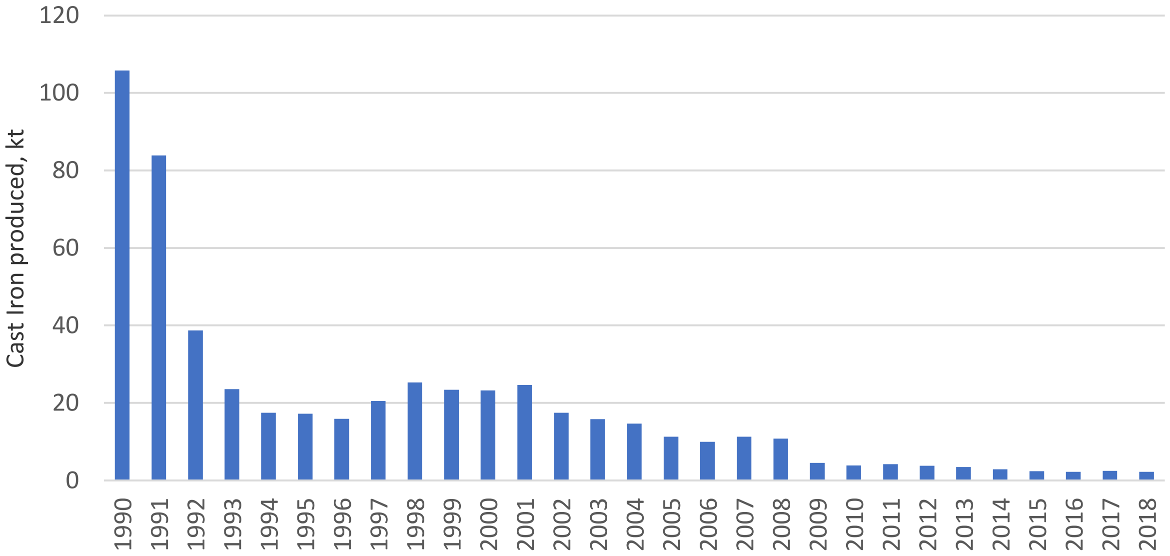


FIGURE 117 CAST IRON PRODUCTION IN THE PERIOD 1990 - 2018.

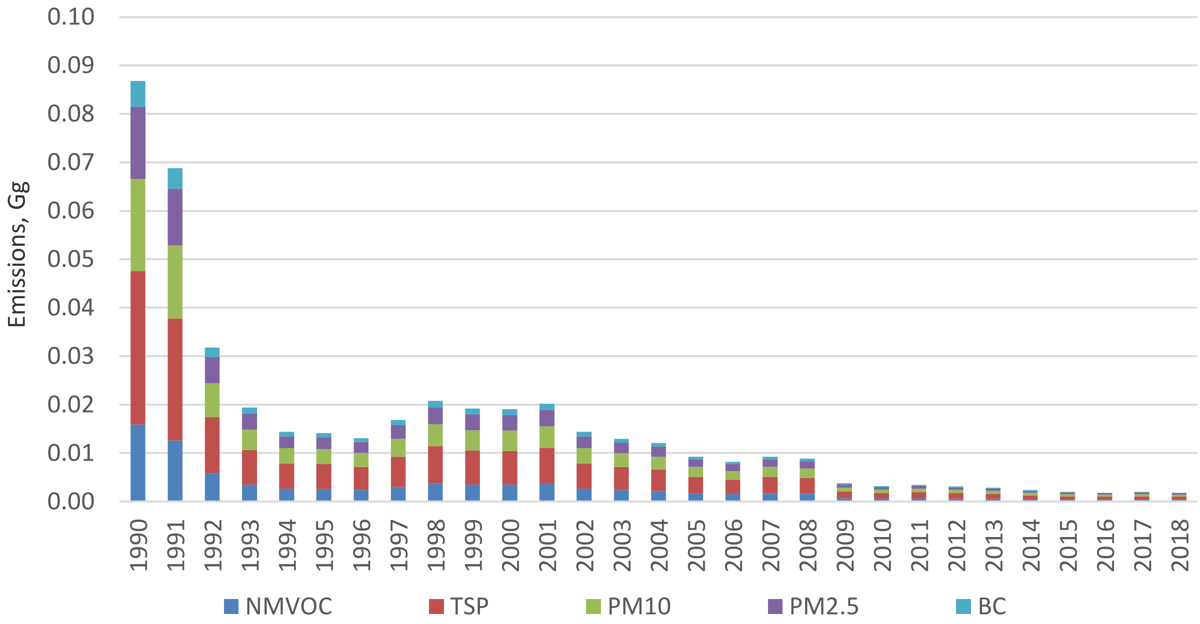


FIGURE 118 POLLUTANT EMISSIONS IN SECTOR 2.C.1 IN THE PERIOD 1990-2018

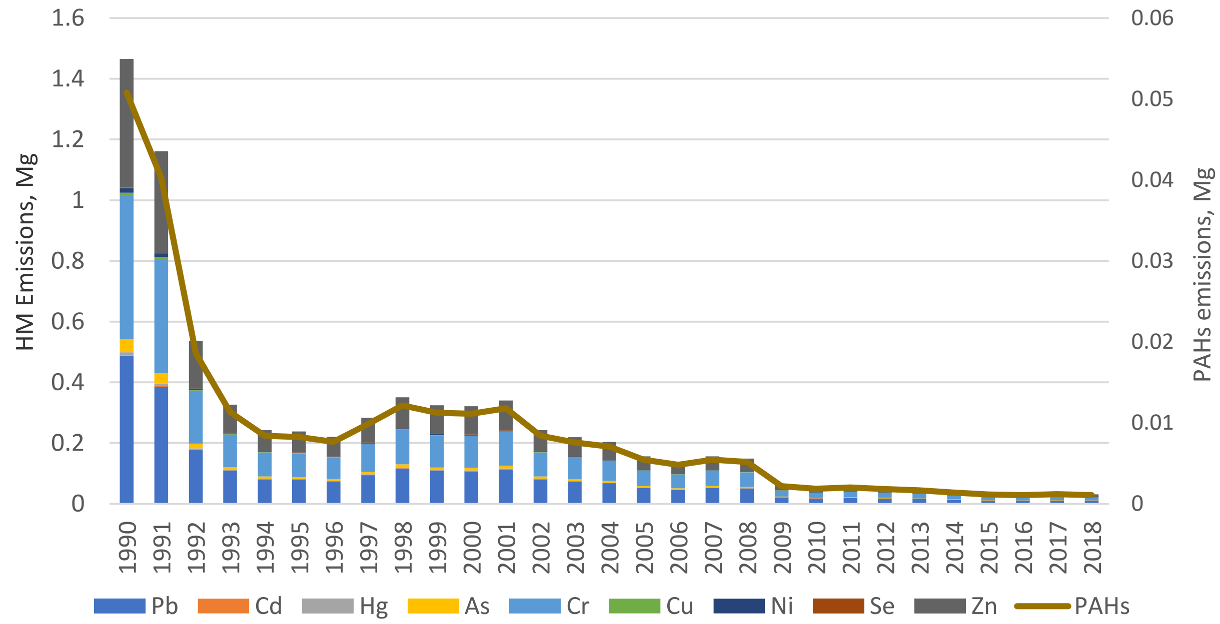


FIGURE 119 HEAVY METAL AND PAHS EMISSIONS IN SECTOR 2.C.1. IN THE PERIOD 1990-2018

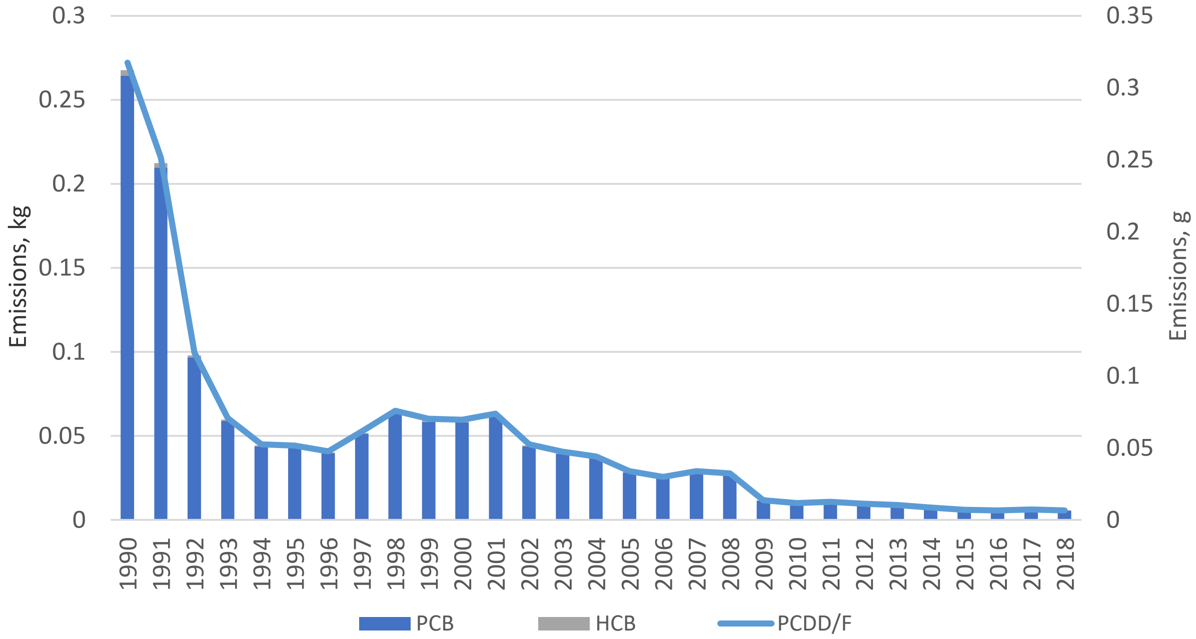


FIGURE 120 PCB, HCB AND PCDD/F EMISSIONS IN SECTOR 2.C.1 IN THE PERIOD 1990-2018

4.15.2 Methodology

The 2016 EMEP/ EEA guidebook Tier 1 emission factors were used to estimate pollutants emissions from the category (Table 103). Activity data was gathered from Statistics Lithuania. Three types of commodities produced were included into the estimation of emissions:

- Grey iron castings for machinery and mechanical appliances excluding for piston engines (PRODCOM 2451135000);
- Grey iron castings for locomotives/rolling stock/parts, use other than in land vehicles. bearing housings, plain shaft, bearings, piston engines, gearing, pulleys, clutches, machinery (PRODCOM 2451139000);
- Parts for other utilization (malleable iron casting) (PRODCOM 2451119000).

4.16 STORAGE, HANDLING AND TRANSPORT OF METAL PRODUCTS (2.C.7.D)

In this sector, only the storage and processing of iron ore is examined at Tier 2 level. In Lithuania, iron ore is not extracted, it is only transported through Lithuania to other countries for a short period of time. Therefore, iron ore processing is not going on in Lithuania and emissions should not be counted, it can be labeled as NO - not occurring.

4.17 OTHER SOLVENT AND PRODUCT USE (2.D.3)

4.17.1 Overview of the Sector

NMVOC emission from industrial and non-industrial paint application. metal degreasing. application of glues and adhesives, dry cleaning, use of domestic solvent were estimated (NFR sector 2).

NMVOCs are used in a large number of products sold for use by the public. These can be divided into a number of categories:	Products for the maintenance or improvement of personal appearance, health or hygiene.
Cosmetics and toiletries	
Household products	Products used to maintain or improve the appearance of household durables.
Construction/DIY	Products used to improve the appearance or the structure of buildings such as adhesives and paint remover. This sector would also normally include coatings. However, these fall outside the scope of this section (see B) and will be omitted.
Car care products	Products used for improving the appearance of vehicles to maintain vehicles or winter products such as antifreeze.

Coating applications and Domestic solvent use including fungicides covered major Lithuania's NMVOC emissions in 2018. The largest share is for Coating applications – 41% (Figure 121).

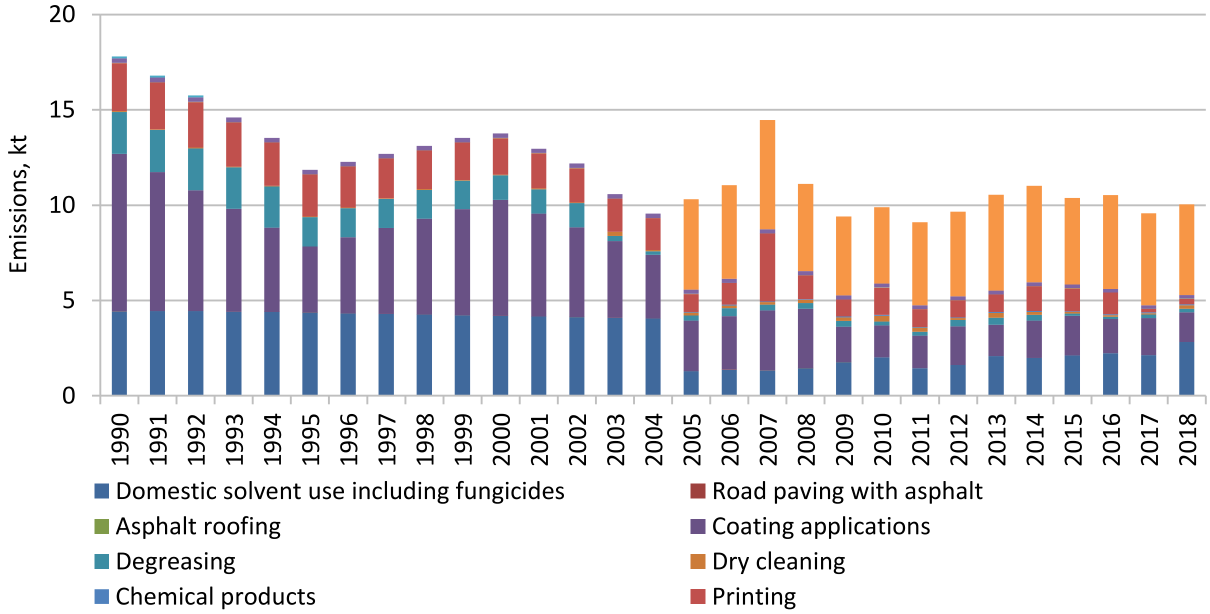


FIGURE 121 NMVOC EMISSIONS 1990-2018 BY SECTORS

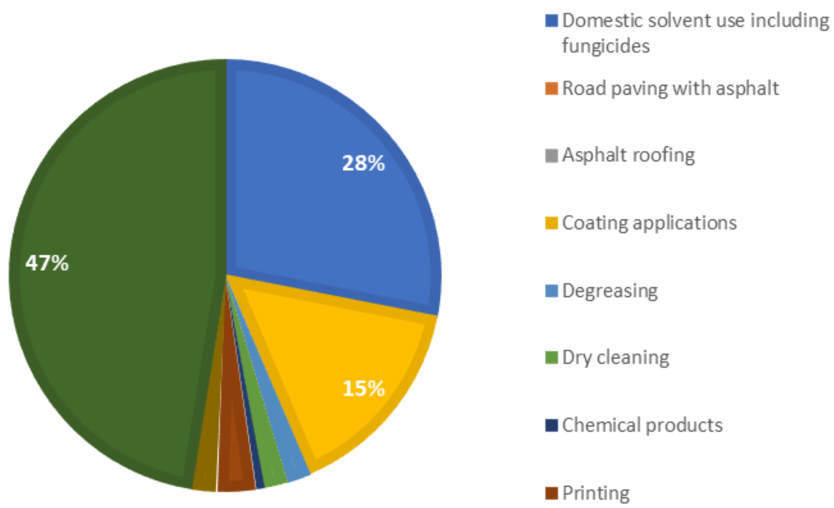


FIGURE 122 DISTRIBUTION OF NMVOC EMISSIONS IN OTHER SOLVENT AND PRODUCT USE SECTOR FOR 2018.

Emission from solvent and other product use were estimated according to number of population and NMVOC emission factor in [g/inhabitant] units during 1990-2018 given in Statistics Lithuania (2018).

Derived and used in estimation NMVOC emission factors are listed in Figure 121 and Figure 122. Emissions from Coating application were calculated for 2005-2018 Tier 2 method using activity data of production.

4.18 Domestic solvent use including fungicides (2.D.3.a)

NMVOCs are used in a large number of products sold for use by the public. These can be divided into a number of categories.

	Category	Title
NFR:	2.D.3.a	Domestic solvent use including fungicides
SNAP:	060408	Domestic solvent use (other than paint application)
	060411	Domestic use of pharmaceutical products

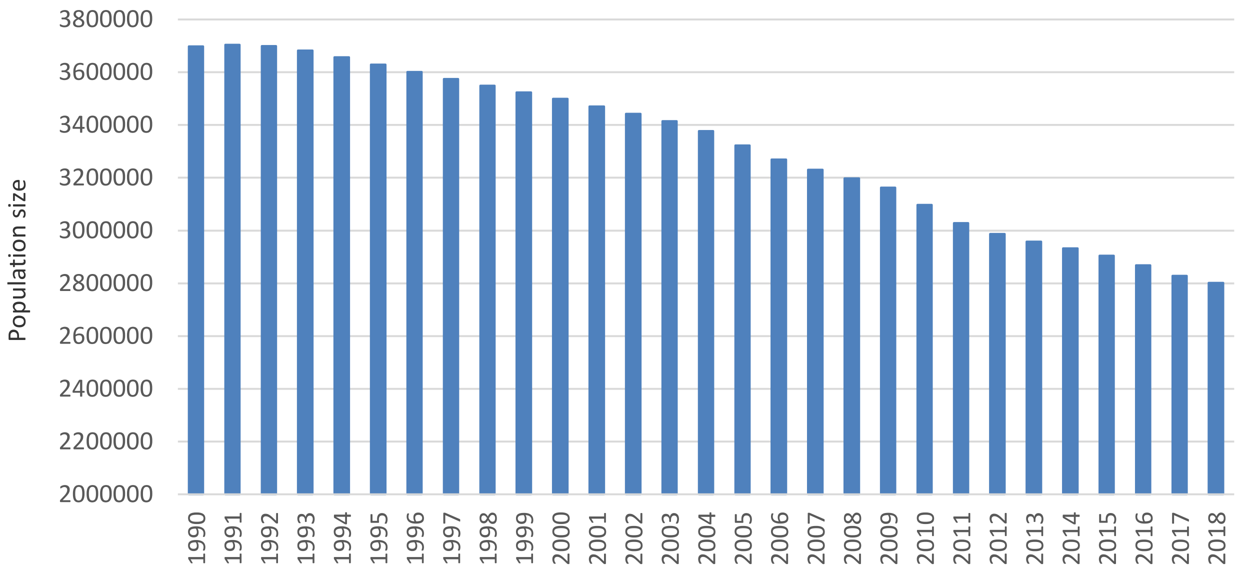


FIGURE 123 POPULATION SIZE IN LITHUANIA IN THE PERIOD 1990-2018, [INHABITANTS]

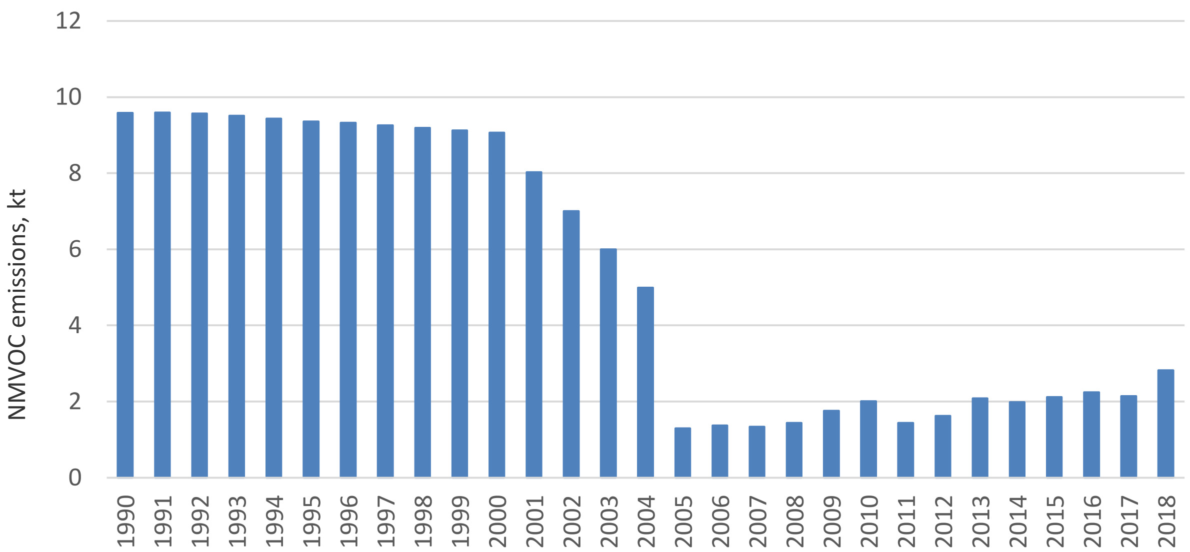


FIGURE 124 NMVOC EMISSIONS IN SECTOR 2.D.3.A IN THE PERIOD 1990-2018

In 2013, a new version of Guidebook EF was developed, which emphasizes the utilization of country-specific data and assesses the comparability between countries, which improved completeness and transparency as well as uncertainty estimates. That means that country specific studies is welcome. Not possible to implement Tier 2 (except based on per capita) without study and external expert. EF values for Tier 2 approach were developed based on Estonia practice, where EFs are 1990 – 2000 - 2.59 kg/cap; 2001 – 2.312 kg/cap; 2002 – 2.034 kg/cap; 2003 – 1.756 kg/cap; 2004 – 1.478 kg/cap; 2005-2014 1.2 kg/cap; 2015 – 2019 1.09 kg/cap (based on Latvia Tier 2).

4.19 Road paving with asphalt (2.D.3.b)

Asphalt is commonly referred to as bitumen, asphalt cement, asphalt concrete or road oil. This sector covers emissions from asphalt paving operations as well as subsequent releases from the paved surfaces. Asphalt roads are a compacted mixture of aggregate and an asphalt binder.

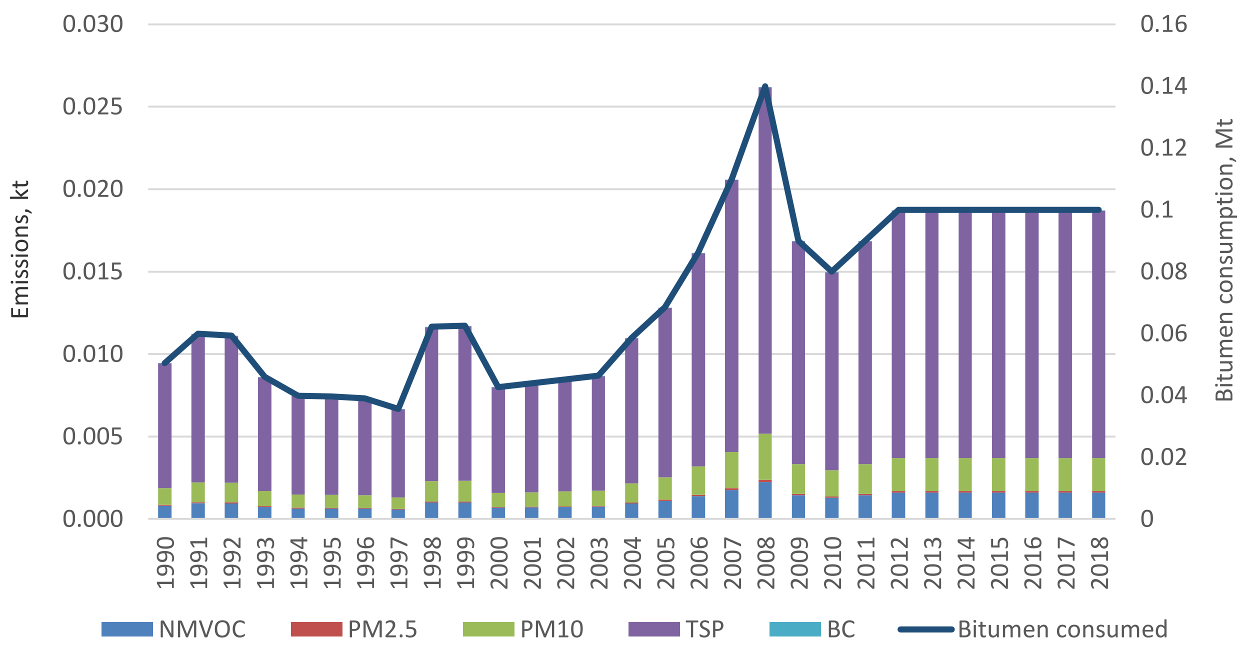


FIGURE 125 POLLUTANT EMISSIONS AND BITUMENT CONSUMPTION IN SECTOR 2.D.3.B

According to GHG emissions inventory NMVOC emissions from road paving with asphalt are calculated based on annual consumption of bitumen. NMVOC emission was calculated using default emission factor 0.016 kg/tonne of asphalt (EMEP/EEA. 2.D.3.b Road paving with asphalt), Table 104.

4.20 Asphalt roofing (2.D.3.c)

There is only one manufacturer in Lithuania producing asphalt roofing materials: flexible roofing tiles of different modifications, thickness and bitumen flexible roofing tiles of different geometric shapes for pitched roofs as well as membrane roofing for flat roofs. Activity data on production of roofing materials was provided by the producer for the period 2001-2018.

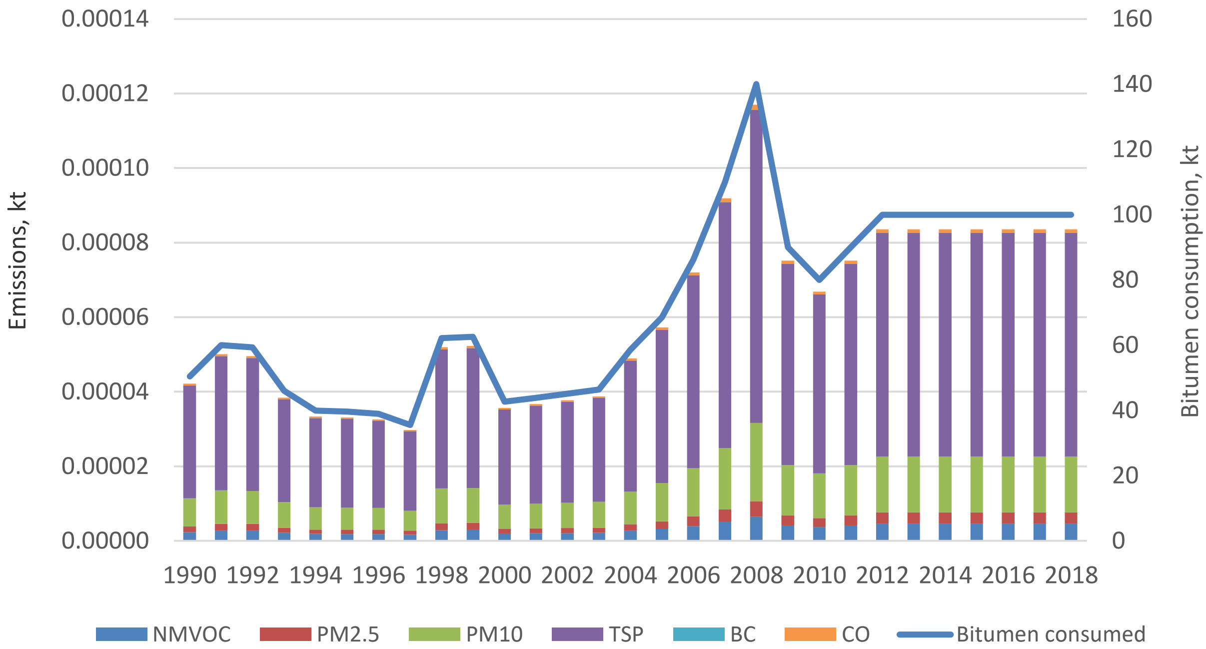


FIGURE 126 POLLUTANT EMISSIONS IN SECTOR 2.D.3.C

Emissions were calculated using Tier 2 approach, emission factors were taken from 2019 EMEP/EEA guidebook, chapter 2.D.3.b Road paving with asphalt. See Table 105.

4.21 Coating applications (2.D.3.d)

Mostly 2.D.3.d Coating applications includes activities in:

- Decorative coating application.
- Industrial coating application.
- Other coating application.

In current NMVOC calculations (2005-onwards) the selection of paints is implemented based on Statistics Lithuania activity data.

Based on EMEP/EEA Guidebook 2016 information and paints sold amount obtained it was concluded that activity data allocation by SNAP categories is needed with different EF implementation. Some paint is used by point sources (private companies) and most of the remaining paint is used for decorative coating application (SNAP 060103, 060104).

Selection of most important coating application activity data:

1990 – 2004 emissions are based on IIASA calculations.

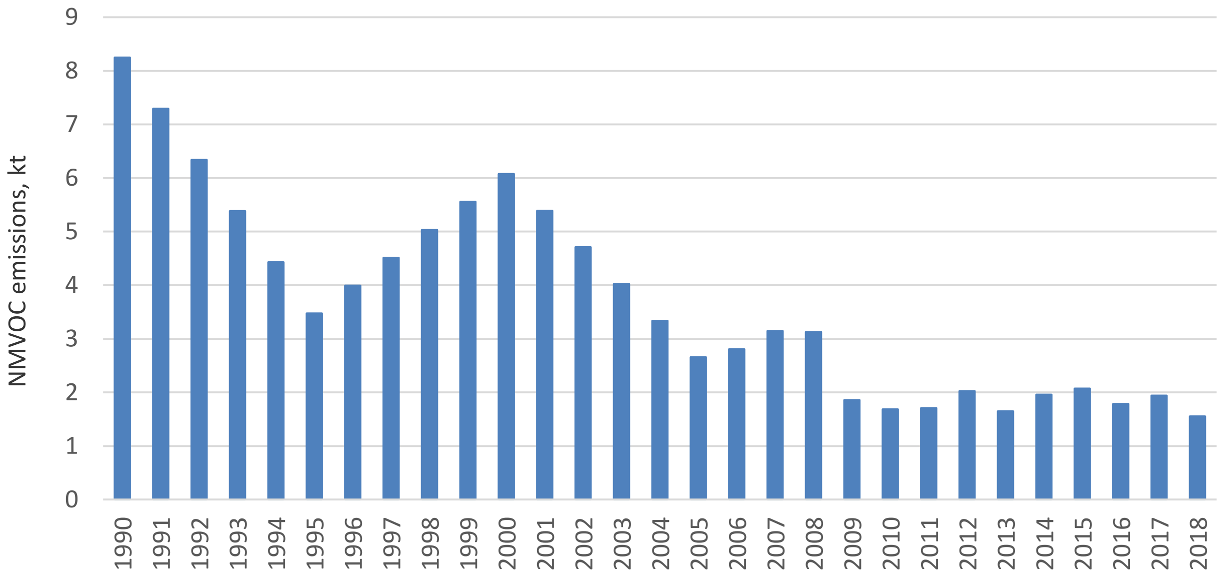


FIGURE 127 NMVOC EMISSIONS IN SECTOR 2.D.3.D

This sector covers the use of paints by industry and by the commercial and domestic sectors. Most paints contain organic solvent which must be removed by evaporation after the paint has been applied to a surface in order for the paint to dry. The proportion of organic solvent in paints can vary considerably. Traditional solvent-borne paints contain approximately 50 % organic solvents and 50 % solids. Number of factors affect the mass of NMVOC emitted per unit of coated product. These include solvent content of coatings, volume solids content of coating, paint usage, transfer efficiency.

In current NMVOC calculations (2005-onwards) the selection of paints is implemented based on Statistics Lithuania activity data.

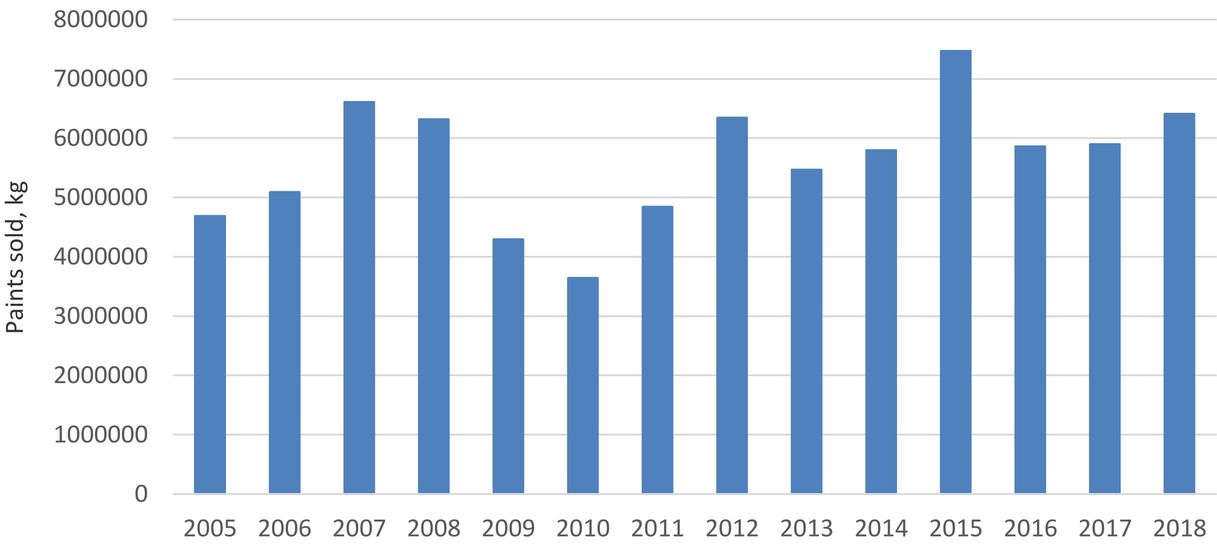


FIGURE 128 PAINTS SOLD IN LITHUANIA 2005-2018 (STATISTICS LITHUANIA, 2018)

Based on EMEP/EEA Guidebook 2016 information and paints sold amount obtained it was concluded that activity data allocation by SNAP categories is needed with different EF implementation. Some paint is used by point sources (private companies) and most of the remaining paint is used for decorative coating application (SNAP 060103. 060104). For earlier NMVOC emission estimation (1990-2000) EMEP/EEA Guidebook 2009 and CORINAIR (2000) EF aggregated by main categories can be applied.

4.22 Degreasing (2.D.3.e)

Degreasing within the industry is a minor source of NMVOC. The major users of solvent degreasing are the metal-working industries. Solvent degreasing is also used in industries as printing and production of chemicals, plastics, rubber, textiles, glass, paper and electric power.

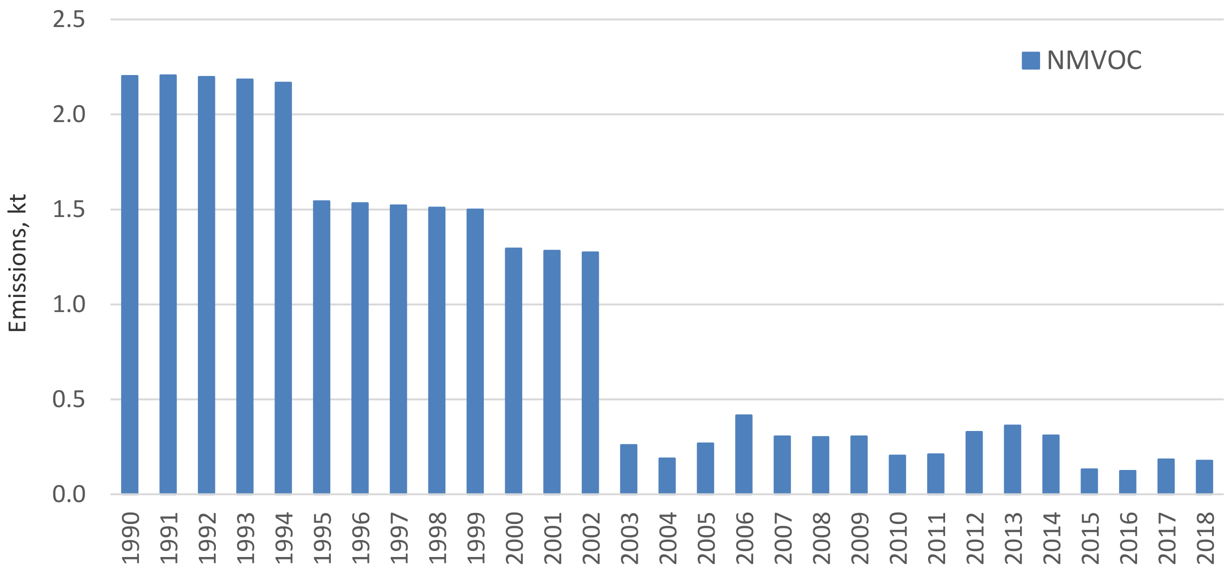


FIGURE 129 NMVOC EMISSIONS IN SECTOR 2.D.3.E

During LRTAP in-depth review of national emission inventories in 2018 Solvent Use sector experts Ardi Link and Kristina Saarinen (personal communication) provided organic solvents list needed to incorporate to NMVOC emissions evaluation:

- methylene chloride (MC)
- tetrachloroethylene (PER)*
- trichloroethylene (TRI)[2]
- xylenes (XYL).

* As **PER** is also used for dry cleaning, this **is not included** as a degreaser.

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[2] The use of 1,1,1,-trichloroethane (TCA) has been banned since the Montreal Protocol and replaced by trichloroethylene (TRI).

So far NMVOC emissions were calculated and reported based on Tier 1 method using data on per capita emission. By the year 2018 this method was considered obsolete because essential assumptions about EFs were out of date. For calculations the algorithm need to be revised and a new become available data source using Lithuanian solvent user consumer's reports and Statistics Lithuania data on Production of Commodities 2002-2018.

As no facility level data available on Vapour cleaning and Cold cleaning operations, so the NMVOC EF for the activity without the application of an abatement technology is 0.72 t/t. For the different abatement technologies (closed system) the degree of implementation, the technical efficiency and the applicability are provided by EGTEI (2005) and De Roo et al. 2009 – 89 %. The following equation can be applied (D'Haene et al. 2002):

$$E_{i,j} = \sum_{i=1}^{n}(A_{i,j} * EF_{I,J} * \gamma_{i,j,t} * (1 - \eta_{i,j,t} * \alpha_{i,j,t}))$$

Where:

$E_{i.j}$ - NMVOC emission for activity i and year j

$A_{i.j}$ - total activity figure for activitiy i (t solvent/year)

t - abatement technology

$EF_{i.j}$ - NMVOC EF of activity i without application of an abatement technology (hypothetical)

$\Upsilon_{i.j.t}$ - degree of implementation of the abatement technology for the activity (-)

$\eta_{i.j.t}$ - technical efficiency of the abatement technology t (-)

$\alpha_{i.j.t}$ - applicability of the technology t = the part of the emission on which the technology can be applied

It is very difficult to get a reliable picture of the penetration of the different techniques. Assuming a stationary situation for practical reasons is practicing, based on statement that the open-top tanks, however, have been phased out in the European Union due to the Solvents Emissions Directive 1999/13/EC (only small facilities, using not more than 1 or 2 tonnes of solvent per year (depending on the risk profile of the solvent) are still allowed to use open top tanks) and closed tanks offer much better opportunities for recycling of solvents. The distribution of technologies based on expert judgement is provided (Table 43).

TABLE 43 EXPERT JUDGEMENT-BASED ABATEMENT EFFICIENCY FACTORS AND THE DISTRIBUTION BETWEEN ABATEMENT TECHNOLOGIES

	Abatement efficiency		**Distribution abatement technology**	
	Semi open-top degreaser and good housekeeping	Sealed chamber system using chlorinated solvents	Semi open-top degreaser and good housekeeping	Sealed chamber system using chlorinated solvents
1990	25%	95%	100	0
1995	25%	95%	80	20
2000	25%	95%	60	40
2005	25%	95%	40	60
2010	25%	95%	20	80
2015	25%	95%	10	90
2020	25%	95%	0	100

The emissions for 1990-2002 have been calculated with per capita activity data (0.7 kg/cap).

4.23 Dry cleaning (2.D.3.f)

Dry Cleaning refers to any process to remove contamination from furs, leather, down leathers, textiles or other objects made of fibers, by using organic solvents. Emissions arise from evaporative losses of solvent, primarily from the final drying of the clothes, known as deodorization. Emissions may also arise from the disposal of wastes from the process.

Please note that for EU Member States, the European Solvent Directive 1999/13/EC has led to a phase-out of the open-circuit machine, because their emissions exceed the limits.

In the European Union, the dry-cleaning sector is essentially made up of small units, using one to two machines of 10/12 kg capacity.

Chlorinated organic solvent tetrachloroethylene is not produced in Lithuania, all used amount are imported.

The most widespread solvent used in dry cleaning, accounting for about 90% of total consumption, is **tetrachloroethene** (also called tetrachloroethylene or perchloroethylene (PER)). The most significant pollutants from dry cleaning are NMVOCs, including chlorinated solvents. Heavy metals and POPs emissions are unlikely to be significant. The sales figures of tetrachloroethylene use in 2.D.3.f in EPA database are obtained each year from operator’s report, NMVOC emissions are provided in Figure 130.

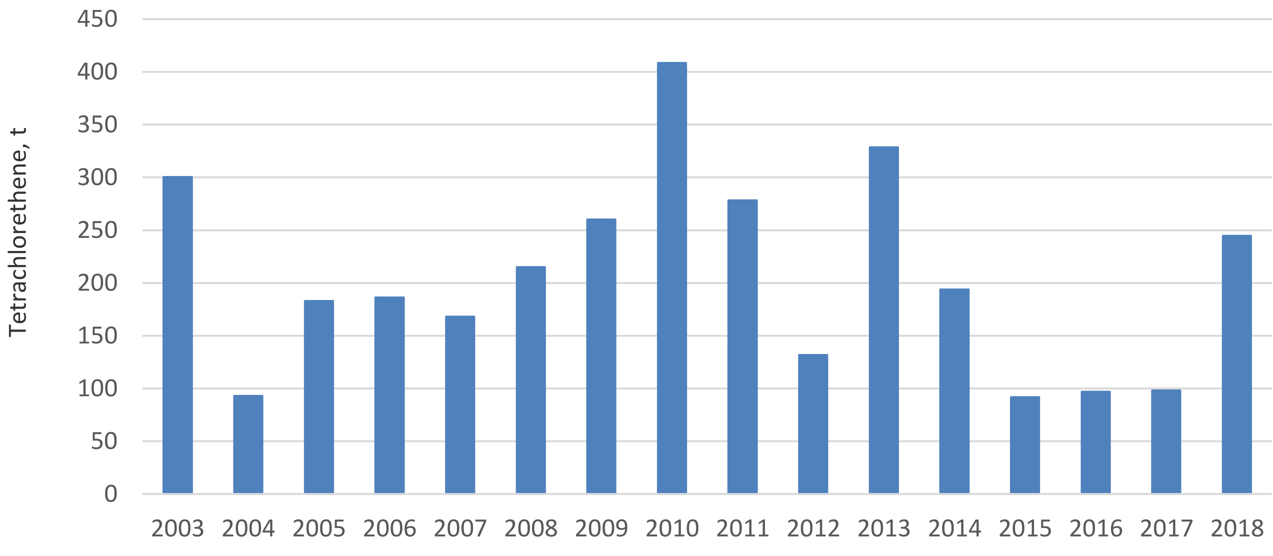


FIGURE 130 TETRACHLORETHENE CONSUMPTION IN SECTOR 2.D.3.F

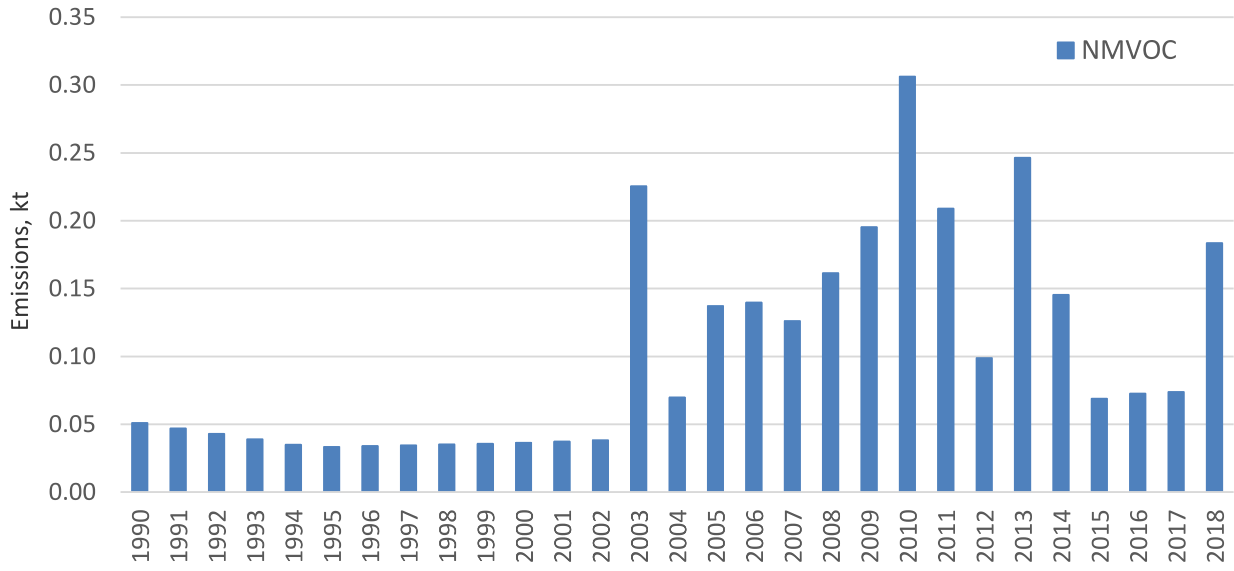


FIGURE 131 NMVOC EMISSIONS IN SECTOR 2.D.3.F

As by Tier 2 methodology provided in EMEP/EEA Emission inventory guidebook (2019) EF can be evaluated by g/kg textile treated. Such method activity data input need to be evaluated by study in Lithuania. Alternative but less precise method can be transferred from Estonia practice. i.e. EF = 400 g/kg solvent use.

The emissions of NMVOC from solvents and other product use are calculated using a simplified version of the detailed methodology GB2019. It represents a mass balance per PER amount. Where emissions are calculated by multiplying relevant activity data with an EF, according to the equation:

$$Consumption = Production + Import + Export$$

$$Emission = Consumption \times EF_{(\mathrm{fraction\ emitted. control\ strategies\ applied})}$$

Information regarding emissions when using Best Available Techniques is available from the BREF documents for the Surface Treatment of Metals and the Surface Treatment using Organic Solvents. 1990 – 2003 NMVOC emissions were calculated by IIASA.

4.24 Chemical products (2.D.3.g)

These activities cover the emissions from the use of chemical products for 2005-2008.

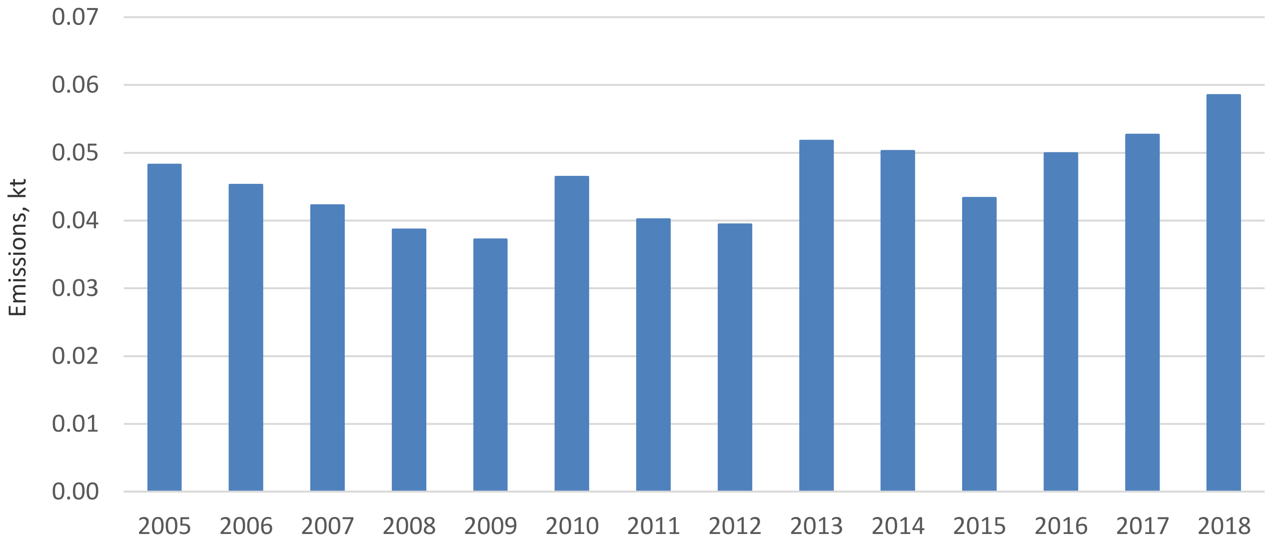


FIGURE 132 NMVOC EMISSIONS IN SECTOR 2.D.3.G

This includes many activities, however, many of these activities are considered insignificant. meaning that emissions from these activities contribute less than 1 % to the national total emissions for every pollutant. In order to avoid double counting Asphalt blowing is included in sector 2.D.3.c.

4.25 Printing (2.D.3.h)

2005-2018 emissions from *Printing* category were estimated based on the production and trade amounts of black and other than black printing paint. Emissions for the period 1990-2005 were obtained by extrapolating paint consumption figures for the 2005-2018 period. There is a decreasing trend observed for the period 2005-2018. Please see figure below.

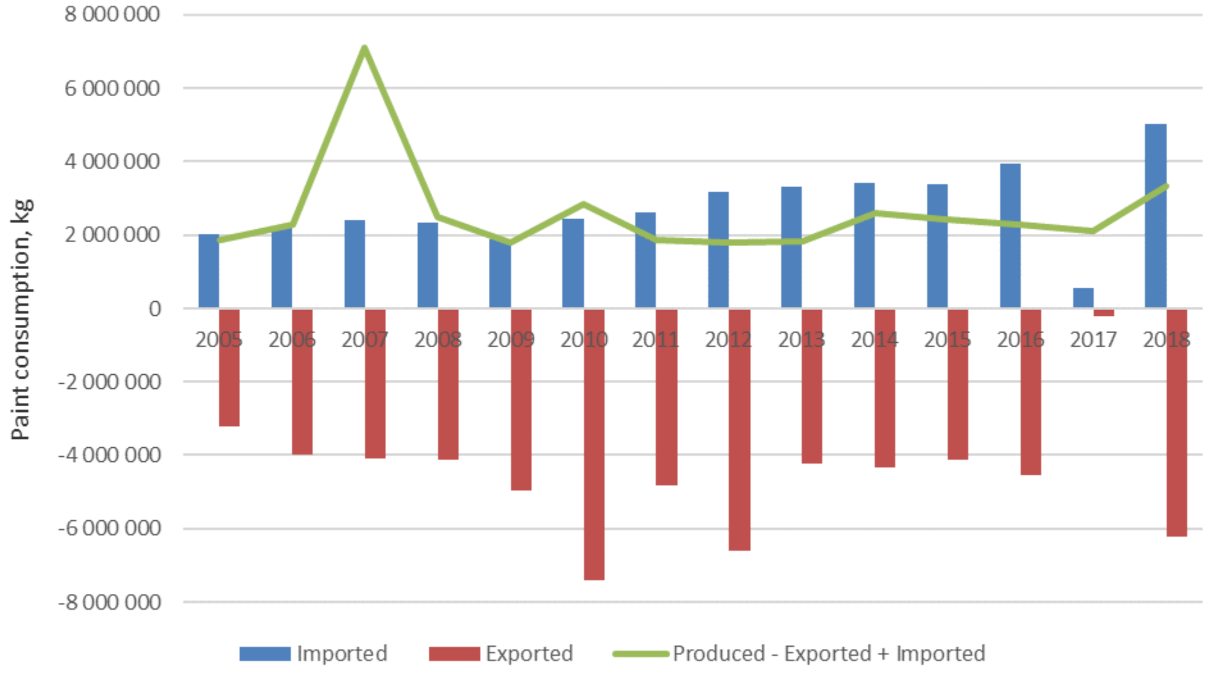


FIGURE 133 ESTIMATED PAINT CONSUMPTION FOR 2005-2018.

Raw data on production, import and export for years 2005 – 2018 was obtained from the Lithuania Statistics database. From this data set $AR_{Consumption}$ was estimated:

$$AR_{Consumption} = Production - Export + Import.$$

Tier 1 EF equal to 500 grams of NMVOC per kilogram of paint from 2016 EMEP/ EEA guidebook was applied.

The activity data was used in the following equation to estimate NMVOC emissions for years 2005 – 2018:

$$E_{NMVOC} = AR_{Production} \times \cdot EF_{Average} \times Conversion\ factor$$

The 1990 – 2005 emission were estimated using extrapolation of obtained 2005-2018 data points. The equation used is shown in the figure above.

Figure below shows NMVOC emissions from the *Printing* category. Estimated 2005-2018 NMVOC emissions form a declining trend, which was the basis for the 1990-2018 emissions estimation. On the other hand, the 2005/2018 emissions increased by 12%.

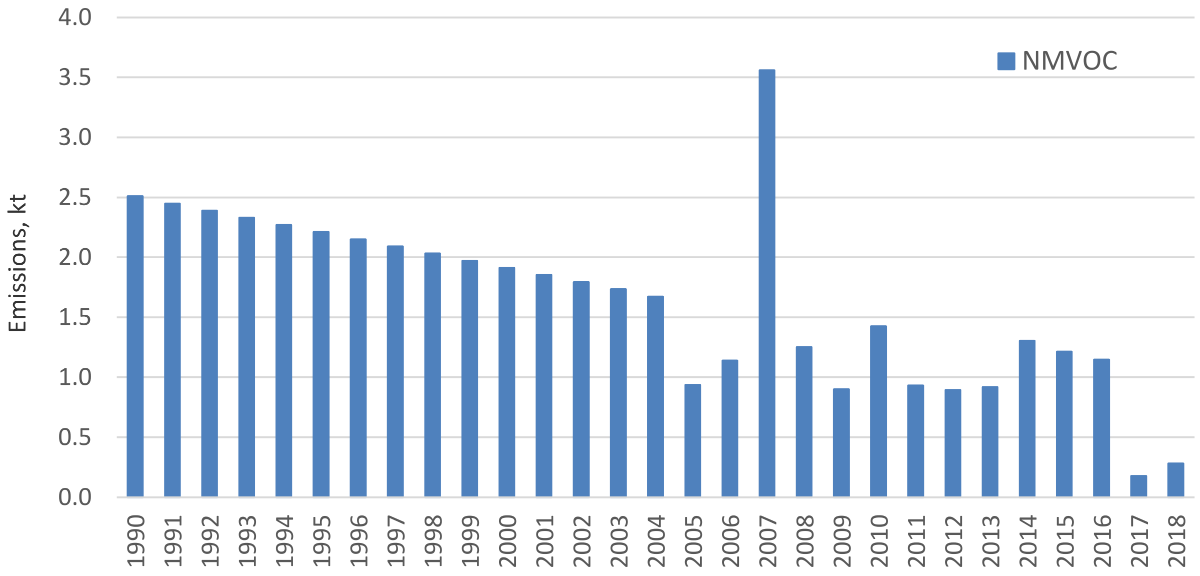


FIGURE 134 NMVOC EMISSIONS IN SECTOR 2.D.3.H

4.26 Other solvent and product use (2.D.3.i. 2.G)

NFR 2G Other Product Use category has been estimated and included into the inventory for the first time. Emissions from *Use of fireworks (SNAP 060601), Tobacco combustion (SNAP 060602)* and *Use of shoes (SNAP 060603)*. This category is a minor contributor to the national inventory. Please see figures below for activity data for different categories.

Firework use (t) trend in Lithuania for 1990-2018. Information obtained from Statistics Lithuania and Comext Eurostat.

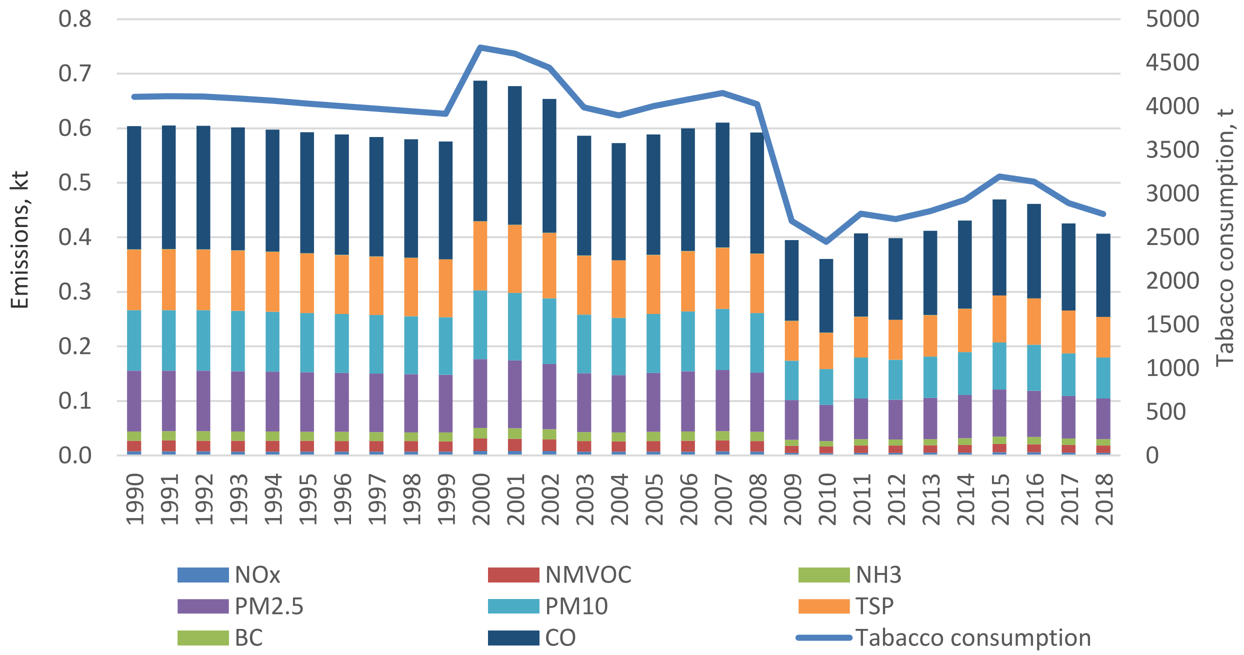


FIGURE 135 POLLUTANT EMISSIONS AND TOBACCO CONSUMPTION IN LITHUANIA, 1990-2018

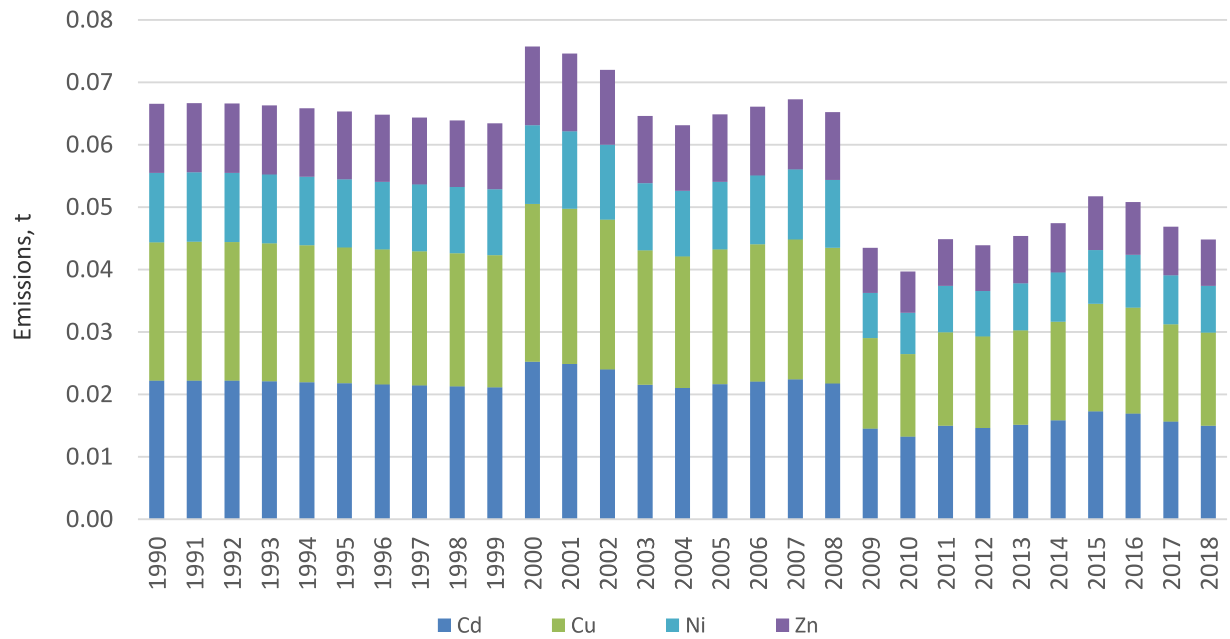


FIGURE 136 HEAVY METALS EMISSIONS FROM TOBACCO USE IN LITHUANIA, 1990-2018

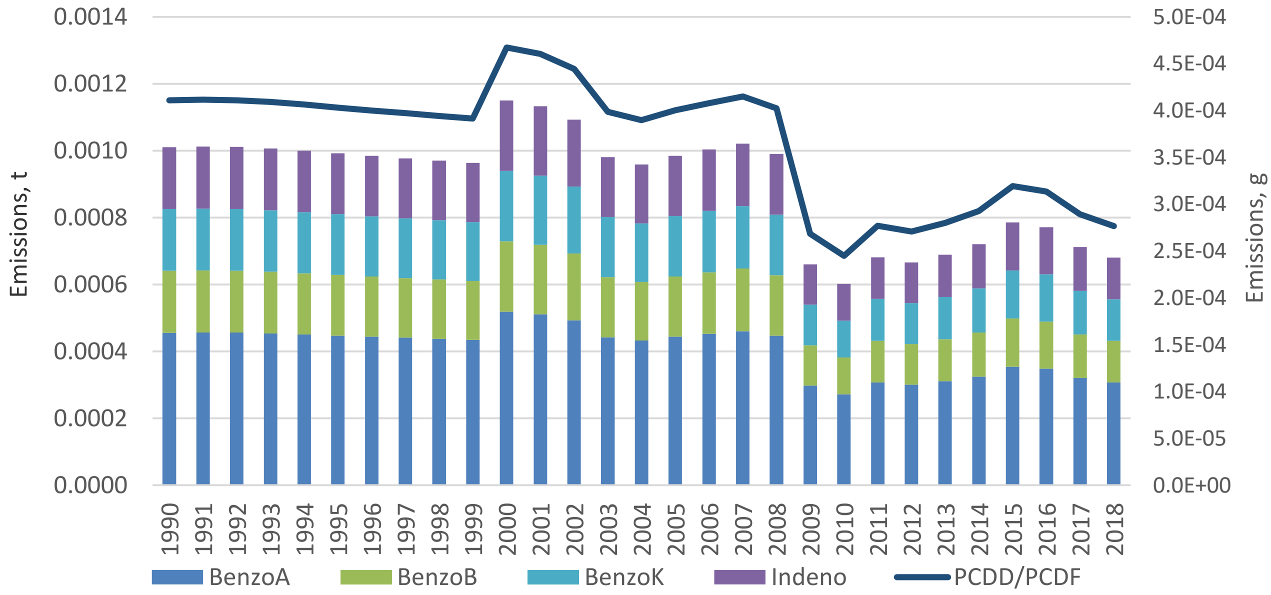


FIGURE 137 PAHS EMISSIONS FROM TABACCO USE IN LITHUANIA, 1990-2018

Information on cigarette consumption (cigarettes per inhabitant per year) from 2000 to 2018 is available from Statistics Lithuania database. Averaged 2000 – 2018 (i.e. 1112.07 cigarettes/ inhabitant/ year) value was used to estimate tobacco consumption for years before 2000. For estimated tobacco consumption for 1990-2018. Emissions from tobacco consumption were estimated using emission factors from 2019 EMEP/EEA guidebook, see (Table 106).

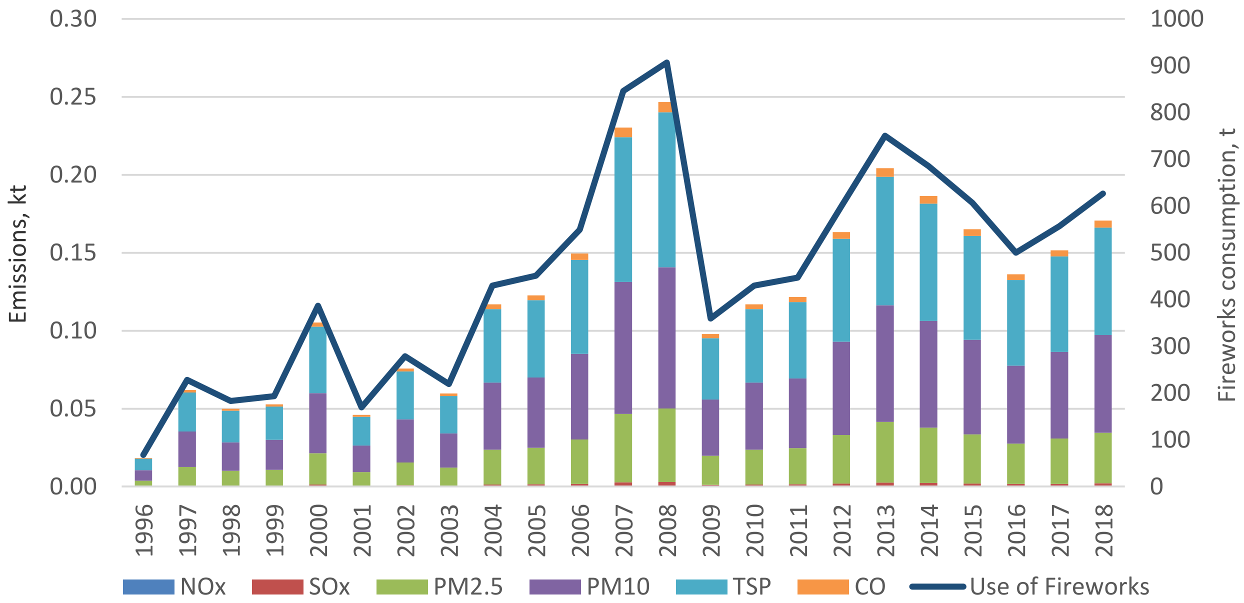


FIGURE 138 FIREWORK USE AND POLLUTANT EMISSIONS, 1996-2018

Statistical data on *Use of fireworks (SNAP 060601)* was based on import and export of fireworks (*CN 36041000*) and signal flares, fog signals and other firework related (*CN 36049000*) goods. In order to obtain consumption in the country, exported quantity was subtracted from imported amount. Statistics for 1999 – 2015 were gathered from EUROSTAT reference database for external trade COMEXT. Information was compared with 1996 – 2018 data obtained from Statistics Lithuania. Statistical data for 1999 – 2018 years was found to be identical.

No information on 1990 – 1995 was available. Thus, emissions were not estimated for that period. Please see Figure 138 for firework consumption trend in Lithuania for 1996 – 2019. Emissions from firework use were estimated using Tier 2 approach emission factors from 2019 EMEP/EEA guidebook, see Table 107.

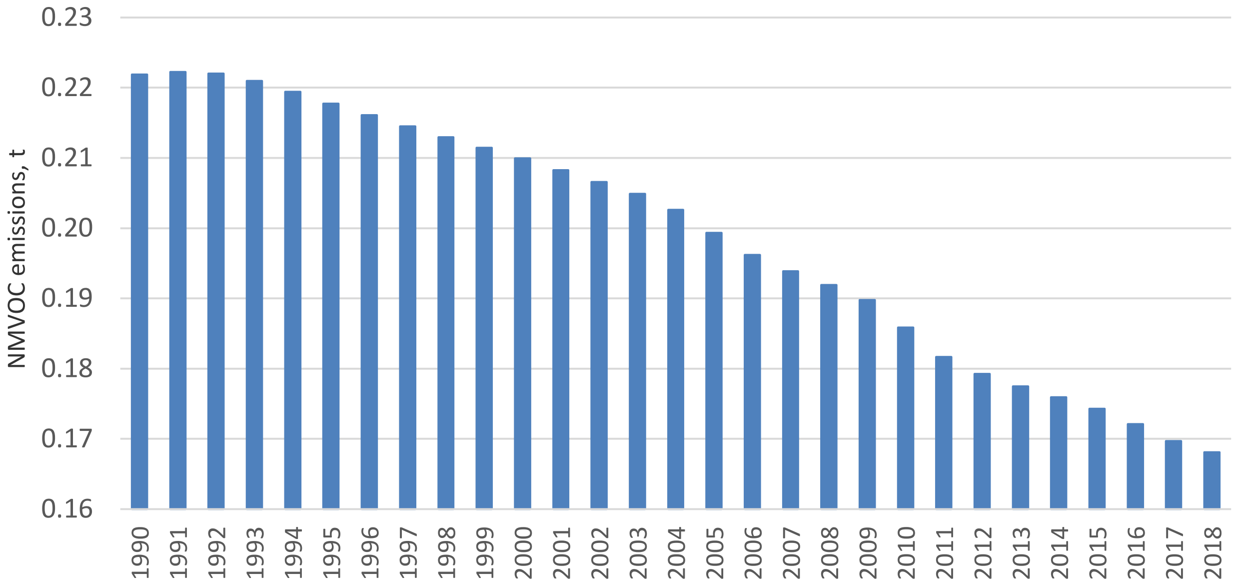


FIGURE 139 NMVOC EMISSIONS FROM USE OF SHOES

Use of shoes (SNAP 060603) category was estimated based on assumption that one inhabitant uses one pair of shoes per year. 2019 EMEP/EEA Guidebook emission factors were applied.

Emissions from the use of fireworks (*SNAP 060601*) increased by 829.5% from 1996 to 2018. while increased by 39.0% from 2005 to 2018.

Emissions from tobacco smoking decreased by 32.6% from 1990 to 2018 and by 30.9% from 2005 to 2018.

Emissions from use of shoes dropped by 24.3% and by 15.7% from 1990 to 2018 and from 2005 to 2018, respectively.

4.27 OTHER INDUSTRIAL PROCESSES (NFR 2.H – 2.K);

4.28 Pulp and paper industry (NFR 2.H.1)

There is no pulp industry in Lithuania. However, there are couple paper-producing companies in Lithuania.

2016 EMEP/EEA Guidebook Tier 1 emission factors were used to estimate emissions from this category. 1990-1993 estimates were calculated and included to the inventory.

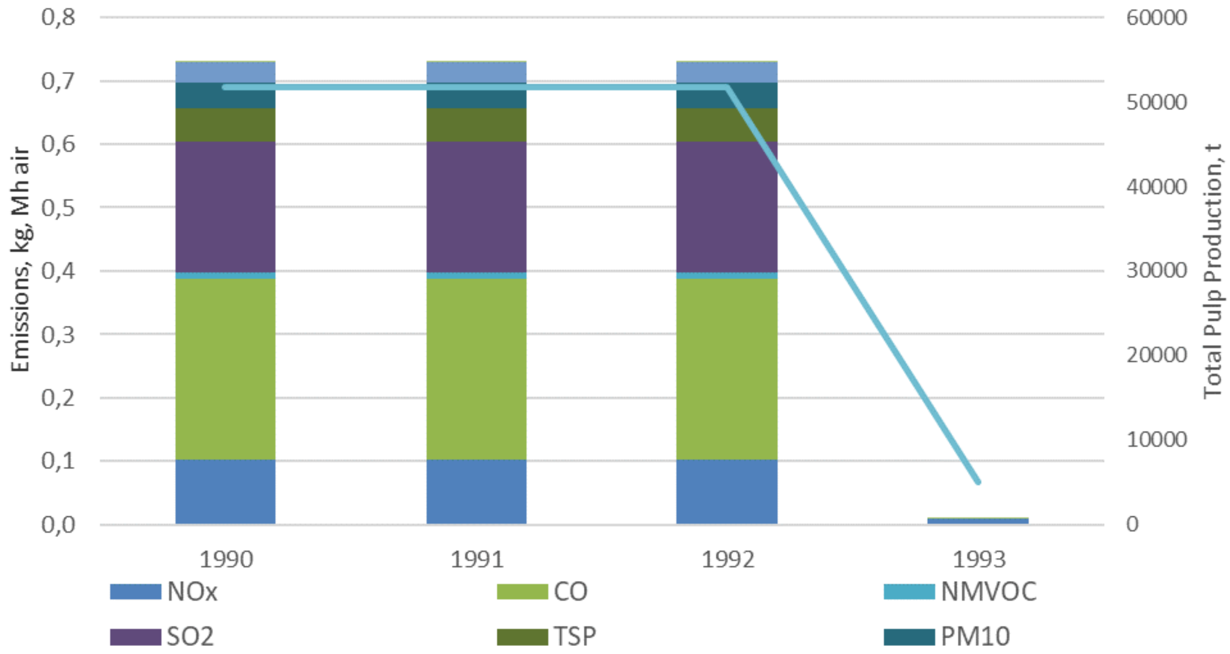


FIGURE 140 POLLUTANT EMISSIONS AND PULP PRODUCTION (T) IN THE PERIOD 1990-1993

4.29 Food and Beverages Industry (NFR 2.H.2)

Information on the production and processes described under this category was gathered from Statistics Lithuania. Please see Figure 141 for changes in production quantities from 2005 to 2018. Food and beverages production has increased in 32.1% in 2018 since 2005.

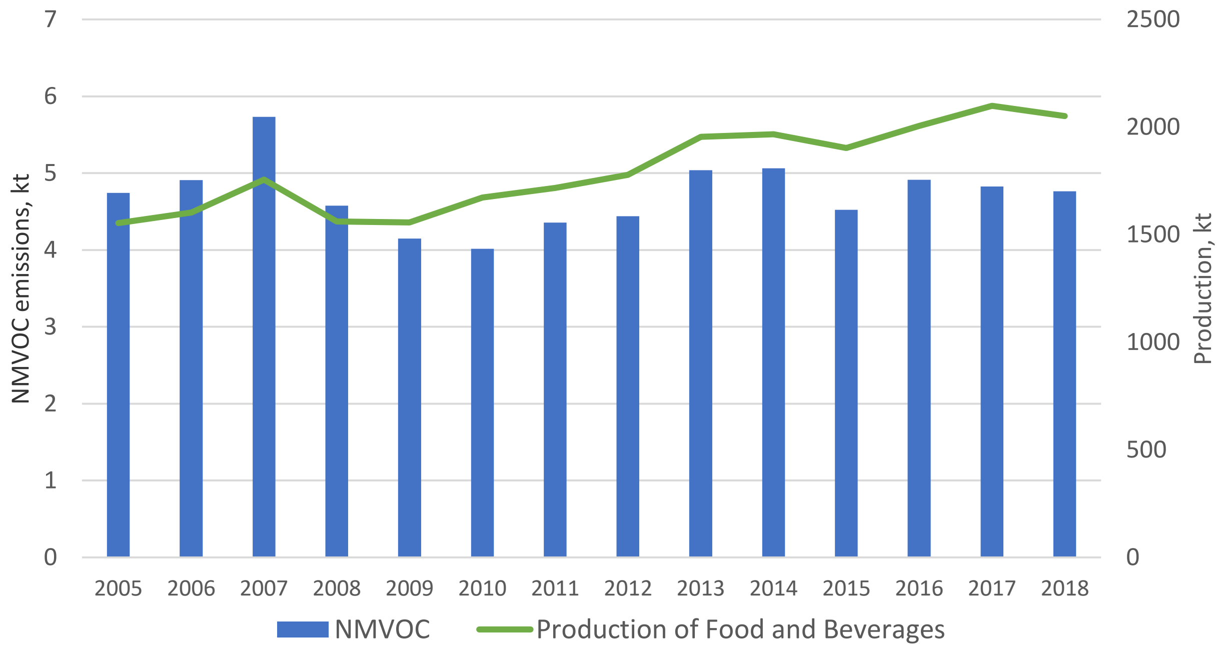


FIGURE 141 TRENDS IN NMVOC EMISSIONS AND PRODUCTION OF FOOD AND BEVERAGES, 2005 - 2018

Figure 141 shows NMVOC emissions from the food and beverages industry. 2005/2018 emissions increased by 0.5%.

Emission factors from Guidebook 2019 were applied: chapter "2.H.2 Food and beverages industry", see Table 108.

Activity data on the production of the following goods was collected from Statistics Lithuania in (numbers in brackets are PGPK 2013 (Products. Manufactured Goods and Services Classification System) codes):

- Sugar (1062139000, 1081123000, 1081129000, 1081130000);
- Bread (1071110000, 1071110010, 1071110080);
- Beer (1105100000, 1105101000);
- Spirits and whisky (1101105000, 1101104000, 1101106300, 101107000, 1101102000, 1101108000, 1101103000);
- Wine (1102119000, 1102121500, 1102122000, 1103100010);
- Coffee (1083115000, 1083117000);
- Animal feed (1091101000, 1091103300, 1091103500, 1091103700, 1091103900, 1092103000, 1092106000);
- Meat, fish curing/ frying (1013118000, 1013120000, 1013130000, 1020248000, 1020248500, 1020242000, 1020242500, 1020245000, 1020245500);
- Margarine and butter (1051303000, 1051305000, 1082120000, 1089194060, 1042103000);
- Biscuits, cakes and other (1072113000, 1072115000, 1072123000, 1072125300, 1072125500, 1072125700, 1072125900, 1072194000, 1072199000, 1071120000).

4.30 Wood processing (NFR 2I)

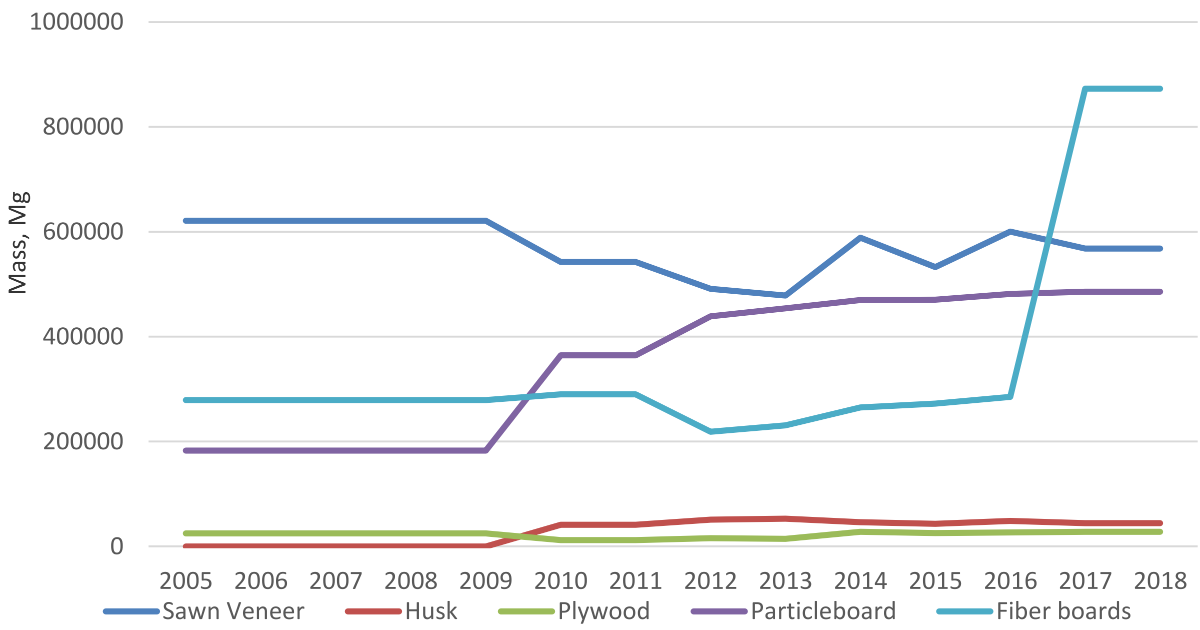


FIGURE 142 TRENDS IN INDUSTRIAL PRODUCTION INCLUDING PRODUCTION, CONSUMPTION, STORAGE, TRANSPORTATION OR HANDLING OF BULK PRODUCTS IN THE PERIOD 2005 – 2018

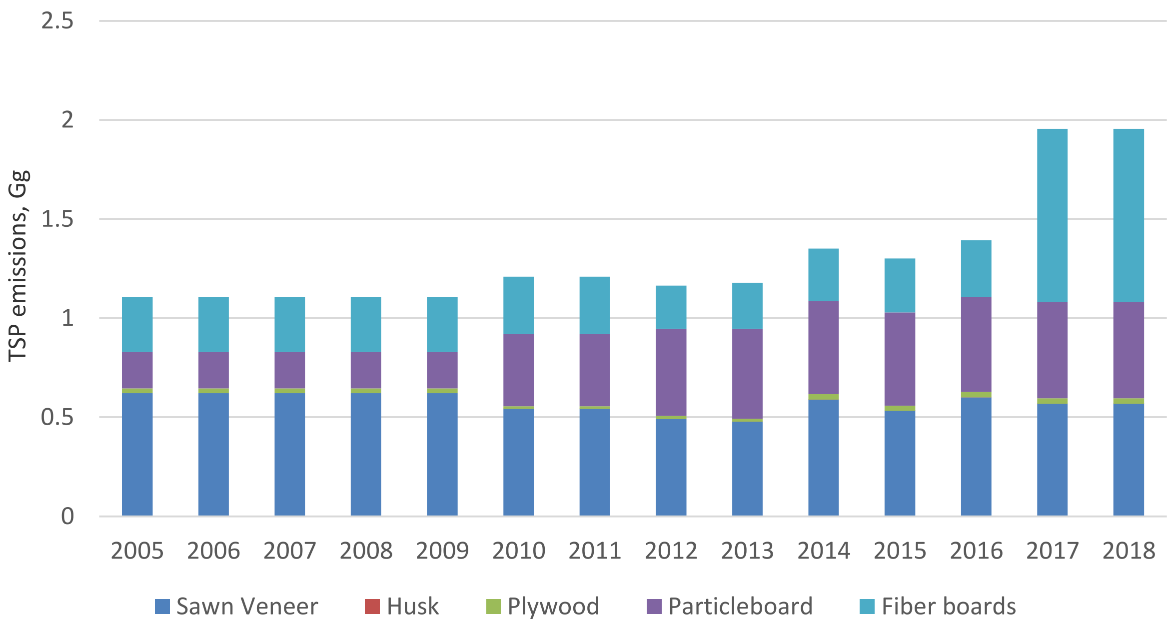


FIGURE 143 TSP EMISSIONS IN SECTOR 2.L IN THE PERIOD 2005-2018

TSP emissions were estimated using emission factor taken from GB2016 equal to 1 kg/Mg of product.

4.31 Production of POPs (NFR 2.J)

Not estimated.

4.32 Consumption of POPs and heavy metals (e.g. electrical and scientific equipment) (NFR 2.K)

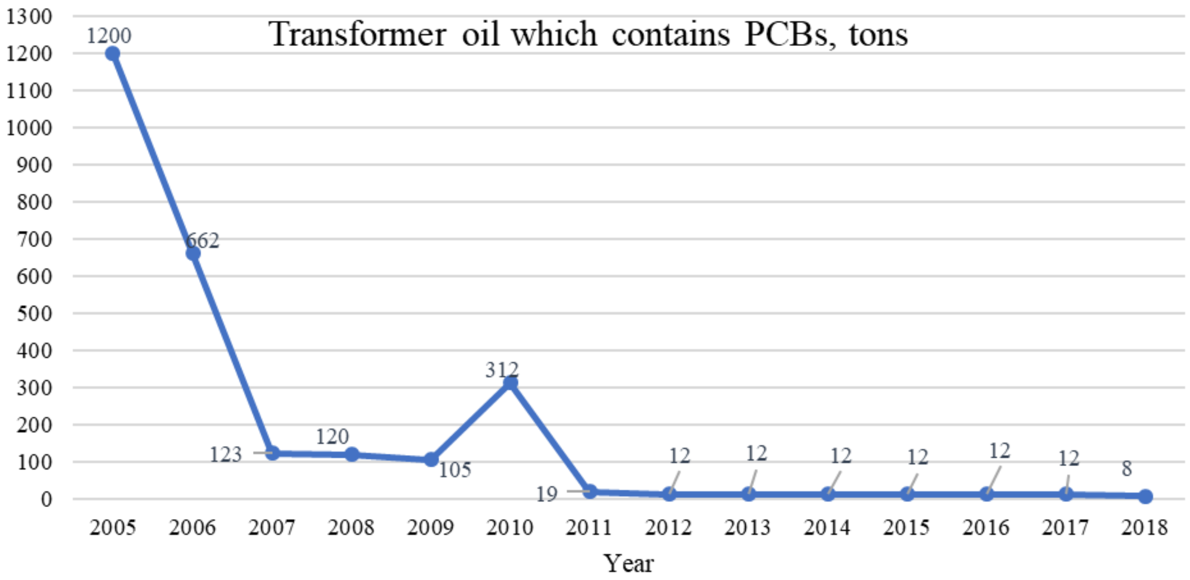
In most cases, emissions from this sector are considered to be insignificant as they account for less than 1% of total national emissions. However, for some POPs, the use of electrical equipment may be an important source of emissions. According to the EMEP/EEA Guidebook (Berdowski et al. (1997) estimates that 94% of all PCB emissions are generated by electrical equipment. In Lithuania, PCB emissions from electrical equipment constitute the biggest part of all PCB emissions.

In year 2018, only one company in Lithuania still uses this equipment. As there is no information on the amount of PCB in the liquid, the same assumption is made as in the previous emission assessment, that PCB is equal to 0.05% of the liquid mass (Lithuania IIR 2018).

According to the requirements of the Rules on PCB/PCT Management, adopted on 26 September 2003 by Order No 473 of the Minister of Environment (as amended in 2004), holders of equipment containing PCBs shall compile inventory of equipment where PCB content exceeds 5 dm^3 and equipment containing PCBs from 0.05% to 0.005% by fluid weight. The Rules on PCB/PCT Management are aimed at implementing the PCB Directive – Council Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT). The updated inventory reports are submitted to the Regional Environmental Protection Departments annually.

NUMBER OF TRANSFORMERS WITH OIL CONTAINING PCBS, UNITS

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
2562	2330	2118	875	61	8	8	8	8	8	8	5



According to the Rules on PCB/PCT Management. PCB-containing equipment was to be decontaminated and/or disposed by the end of 2010 at the latest. The major part of the equipment inventoried before the end of 2010 in Lithuania has been disposed by this deadline. It should be noted that not all companies holding PCB–containing equipment managed to comply with this deadline. The Regional Environmental Departments are observing such companies concerning their situation, actions and plans for disposal/decontamination of PCB equipment no longer permitted. However, transformers the fluids in which contain between 0.05% and 0.005% of PCBs by weight are to be either decontaminated or disposed of at the end of their useful lives.

Data on electrical equipment containing liquids with PCBs was provided by the specialists of waste licensing division in Lithuanian EPA. No information on the amount of liquid containing PCBs was available for year 2006. Thus, average of 2005 and 2007 was taken.

Mercury emissions were estimated using Tier 1 approach and population in Lithuania.

5 AGRICULTURE

5.1 Source category description

This chapter covers emissions from manure management, direct soil emissions and application of mineral fertilizer (NFR sectors 3B, 3Da1 and 3Da2b). Emissions from manure management were estimated according to statistical livestock and poultry number. Direct emissions from soil were estimated according to statistical data on N-fertilizers produced and sold in Lithuania. Agriculture has always been a very important sector of Lithuania's economy, and like other economic sectors, it has undergone sudden changes and reforms since the country achieved independence. These changes include land privatization and the introduction of market-based prices, which influenced a significant drop in agricultural production.

5.2 Manure Management (NFR 3.B)

5.2.1 Overview of the Category

Livestock, poultry and other animal population sizes significantly dropped with the re-establishment of private ownership after the Soviet Union had collapsed. Change in animal population caused a significant decrease in pollutant emissions from agriculture sector. Cattle and swine population size has remarkably decreased, which was the reason for significant change in emissions as cattle and poultry subcategories' emission factors are the largest (cattle 1990/2018 population decrease by 68.9%, swine population by 71.8%). On the other hand, 2005/2018 population changes were not that remarkable, with the largest 77% decrease in horses and swine (46%) population size.

TABLE 44 NUMBER OF LIVESTOCK IN THE PERIOD 1990-2018

Livestock	Dairy cattle	Non-dairy cattle	Sheep	Horses	Goats
	thous heads	thous heads	thous heads	thous heads	thous heads
1990	844.850	1540.995	72.165	78.853	4.550
1991	836.950	1450.921	68.179	81.242	5.750
1992	784.850	1192.385	65.323	81.154	7.550
1993	707.952	864.411	57.530	80.530	9.600
1994	646.488	657.269	50.569	79.747	11.400
1995	600.460	545.370	43.013	77.857	13.500
1996	587.967	509.585	35.993	79.453	15.750
1997	586.352	500.967	31.055	81.552	17.700
1998	560.257	463.547	23.678	78.245	21.100
1999	516.010	433.271	17.610	74.812	24.200
2000	466.339	388.799	15.052	71.645	23.850
2001	440.055	339.198	14.159	66.457	23.350
2002	442.524	351.737	15.409	62.582	22.850
2003	445.688	377.670	18.145	62.122	24.600
2004	441.011	387.494	23.231	63.608	27.050
2005	425.219	394.995	30.554	63.117	24.450
2006	407.734	431.985	39.146	61.728	21.400
2007	401.729	432.150	47.528	58.379	20.250
2008	399.601	402.902	54.028	55.164	18.150
2009	384.680	402.197	59.481	51.701	15.659

2010	367.214	406.368	66.044	46.828	15.383
2011	354.663	413.191	70.766	40.519	15.503
2012	340.291	415.821	85.165	32.913	14.278
2013	323.359	412.269	108.509	25.821	13.715
2014	314.863	423.544	130.027	20.186	13.412
2015	307.267	433.873	154.456	17.757	13.259
2016	293.120	430.411	172.887	16.823	13.468
2017	279.281	419.595	178.867	15.643	13.864
2018	264.481	414.095	178.462	13.948	14.314

5.2.2 Methodology

Methodology for estimation of NH_3, NMVOC, NO_X, PM_{10}, $PM_{2.5}$ and TSP emissions was taken from 2019 EMEP/EEA Guidebook. Detailed information on the method applied, emission factors and activity data is given in Table 45.

TABLE 45 EMISSION FACTORS AND METHODS USED FOR EACH POLLUTANT.

NFR code	Animal category	Method applied	Emission factor	Activity data
3B1a, 3B1b	Dairy and other cattle	**T1** (NMVOC, PM_{10}, $PM_{2.5}$, TSP) **T2** (NH_3, NOx)	**DV** (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$, TSP)	LTST
3B2, 3B4d, 3B4e	Sheep, goats, horses	**T1** (NMVOC, PM_{10}, $PM_{2.5}$, TSP) **T2** (NH_3, NOx)	**DV** (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$, TSP)	LTST
3B3	Swine (fattening pigs and sows)	**T1** (NMVOC, PM_{10}, $PM_{2.5}$, TSP) **T2** (NH_3, NOx)	**DV** (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$, TSP)	LTST. LGHGNIR
3B4gi, 3B4gii, 3B4giii,	Laying hens, other chickens, turkeys, ducks, geese, fur bearing animals	**T1** (NMVOC, PM_{10}, $PM_{2.5}$, TSP) **T2** (NH_3, NOx)	**DV** (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$, TSP)	LTST. LGHGNIR
3B4giv, 3B4h	Other poultry	**T1** (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$, TSP)	**DV** (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$, TSP)	LTST. LGHGNIR

LGHGNIR – Lithuania's Green House Gas National Inventory Report 2018. LTSTD – Lithuania Statistics. DV – default value taken from 2016 EMEP/EEA Inventory Guidebook.

When Tier 1 approach was used to calculate pollutant emissions, the following equation was applied:

Equation 5.1:

$$E_{Pollutant} = AAP_{Animal\ category} \times EF_{Pollutant\ Animal\ category} \times Unit\ Conversion\ factor$$

where $AAP_{Animal\ Category}$ is annual average population of animal category (animals per annum);

and $EF_{Pollutant\ Animal\ Category}$ represents emission factors for different animal categories (kg of pollutant per AAP per year).

AAP values for year N were estimated as average of animal numbers on the 1st of January of year N and year N+1.

Tier 2 method was implemented using EEA Manure Management N-flow tool.

For NO and NH_3 emission calculations information on the manure type and percentage amount of manure per management system was used, modifying equation 5.1 to:

Equation 5.2

$$E_{Pollutant} = AAP_{Animal\ category} \times EF_{Pollutant\ Animal\ category} \times$$
$$\%\ Manure\ of\ specific\ type\ per\ total\ manure \times Unit\ Conversion\ Factor$$

NMVOC emissions were calculated based on the animal diet, i.e. percentage of silage in animal feed [3]. The correlation of silage feeding and grazing/ confinement periods were taken into account [4] to estimate percentage of silage in animals' diet. For 3B2, 3B4d and 3B4e identical amount of silage feed was assumed as for the cattle categories.

5.2.3 Emissions

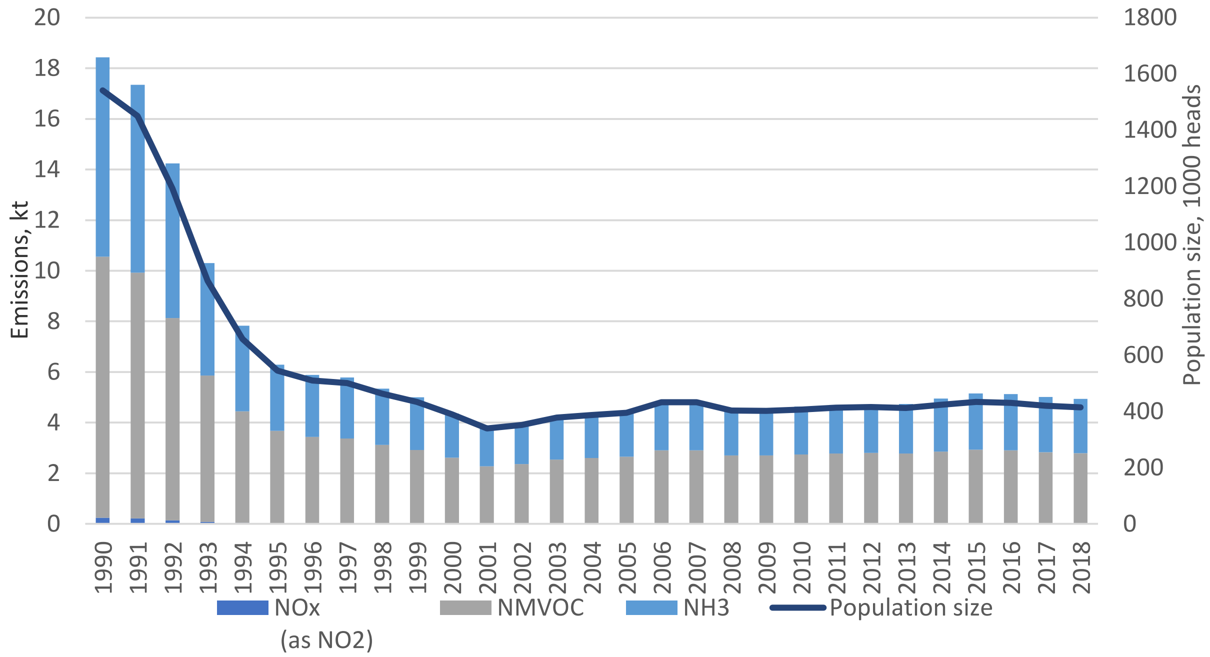


FIGURE 144 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.1.B IN THE PERIOD 1990-2018

The reduction of 1990/2018 emissions in sector 3.B.1.a is remarkable. The ammonia emissions dropped from 2.989 kt in 2005 to 2.453 kt in 2018. The steady decrease in NH_3 emissions can be correlated with the decline in animal numbers and improved manure management system in the recent years.

Total pollutant reduction commitments for Lithuania for year 2020 under the NEC directive 2001/81/EC (2020 – 2005 emissions change) are -48% for NOx, -32% for NMVOC and -10% for NH_3.

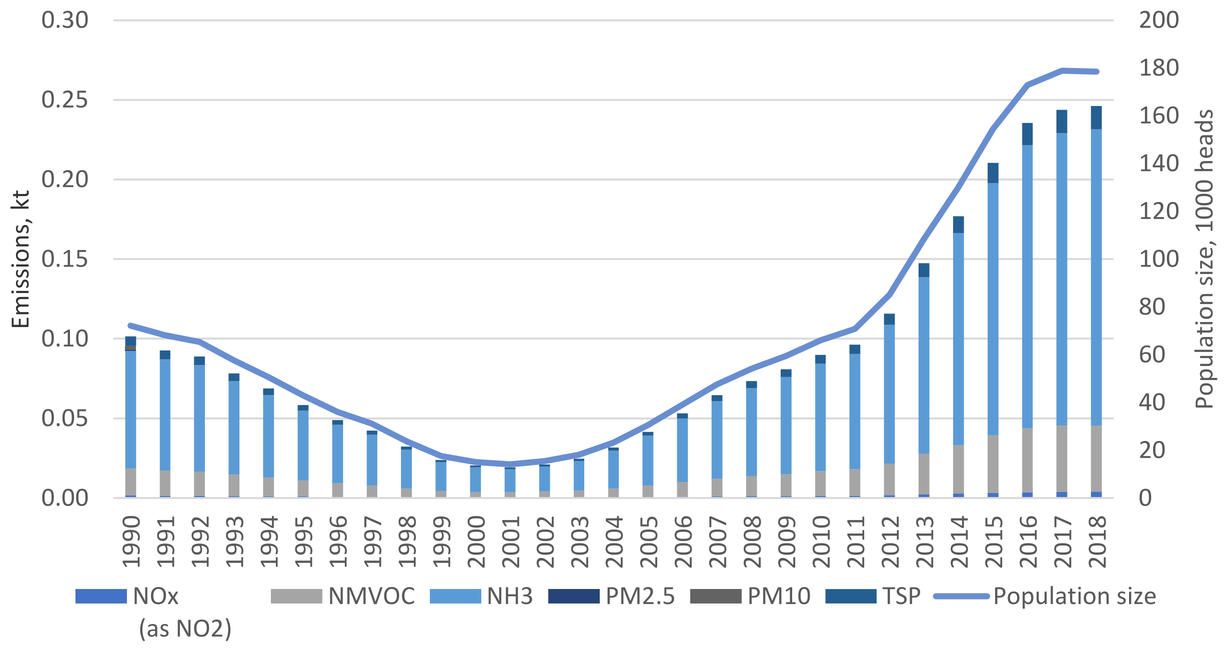


FIGURE 145 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.2 IN THE PERIOD 1990-2018

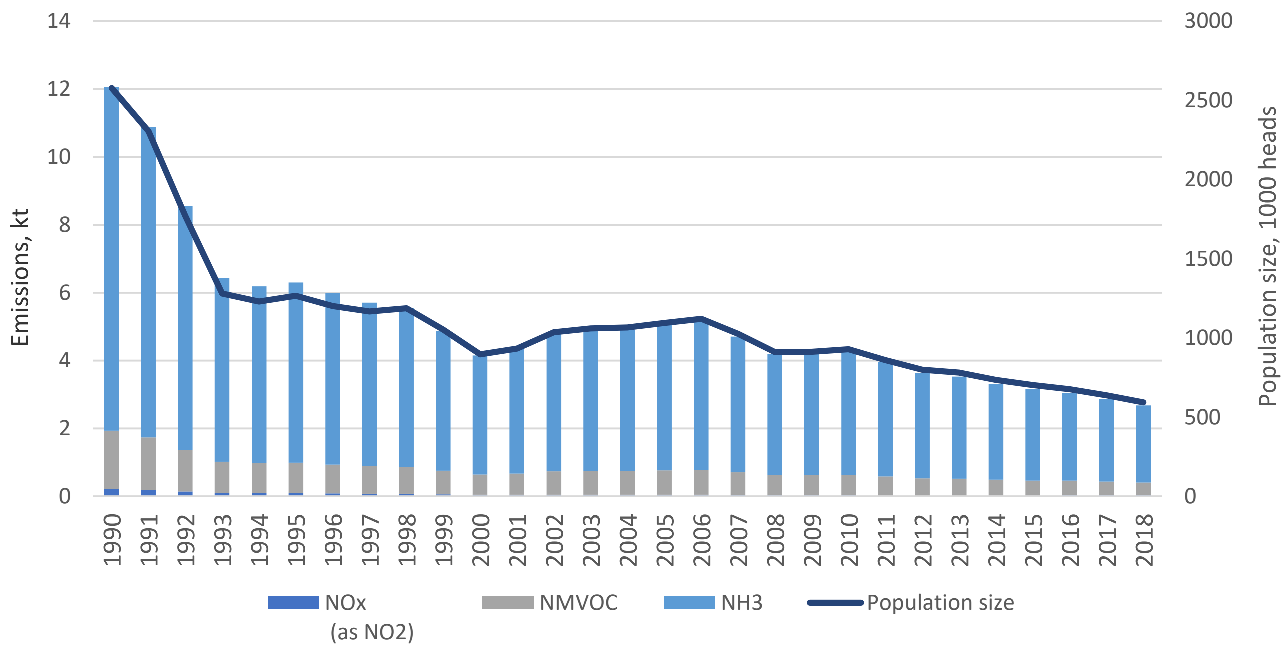


FIGURE 146 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.3 IN THE PERIOD 1990-2018

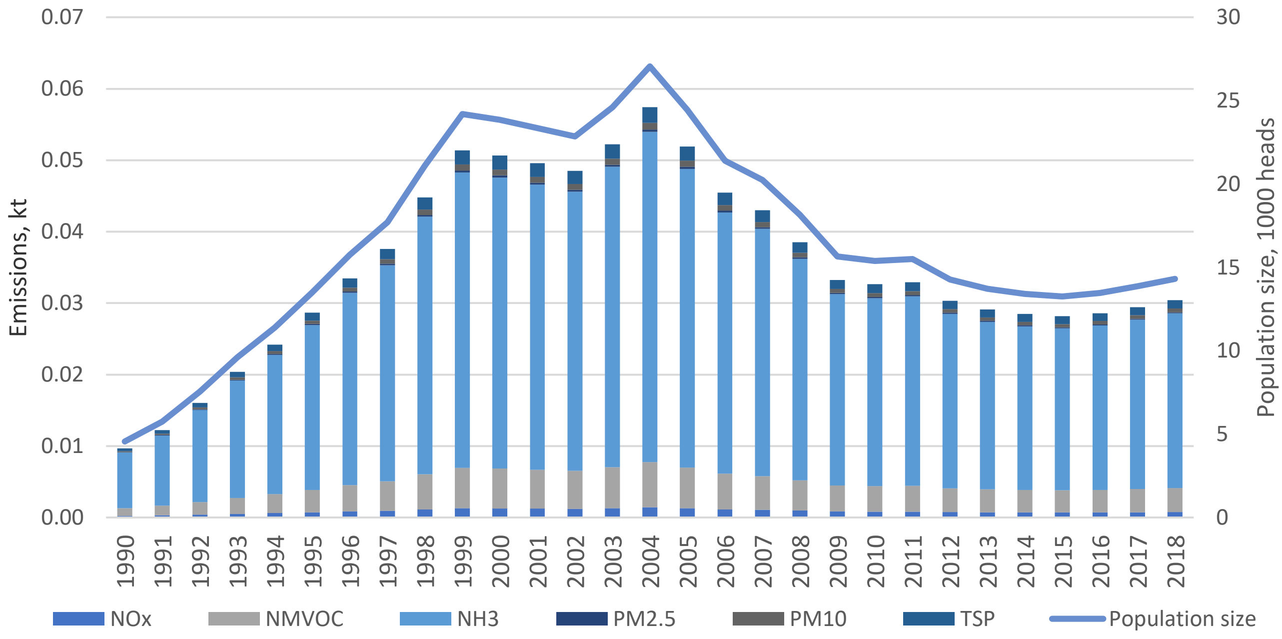


FIGURE 147 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.4.D IN THE PERIOD 1990-2018

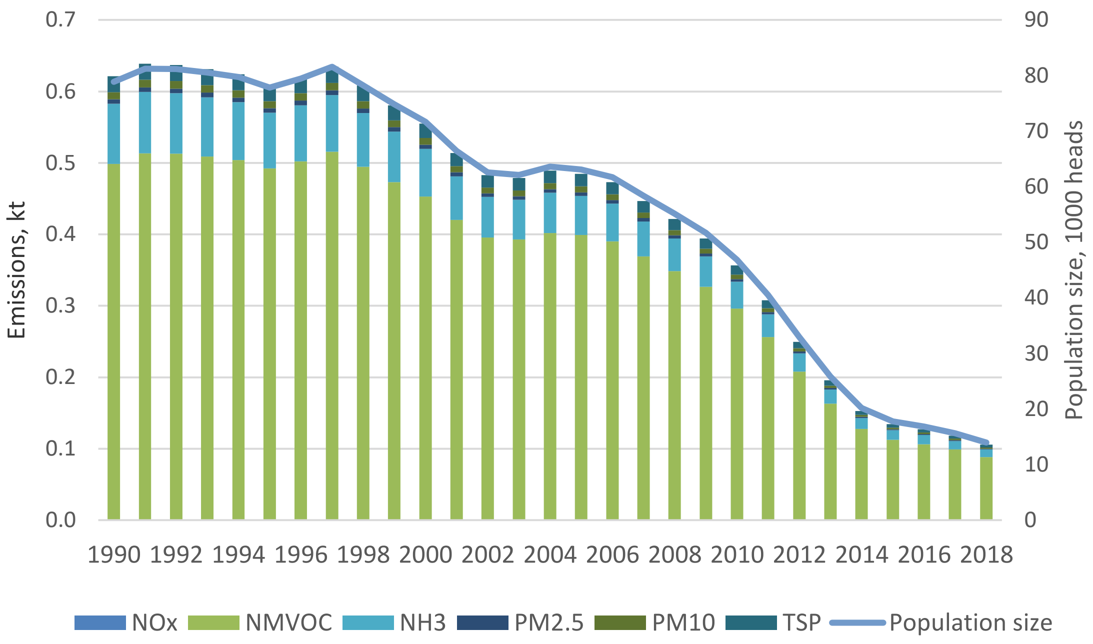


FIGURE 148 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.4.E IN THE PERIOD 1990-2018

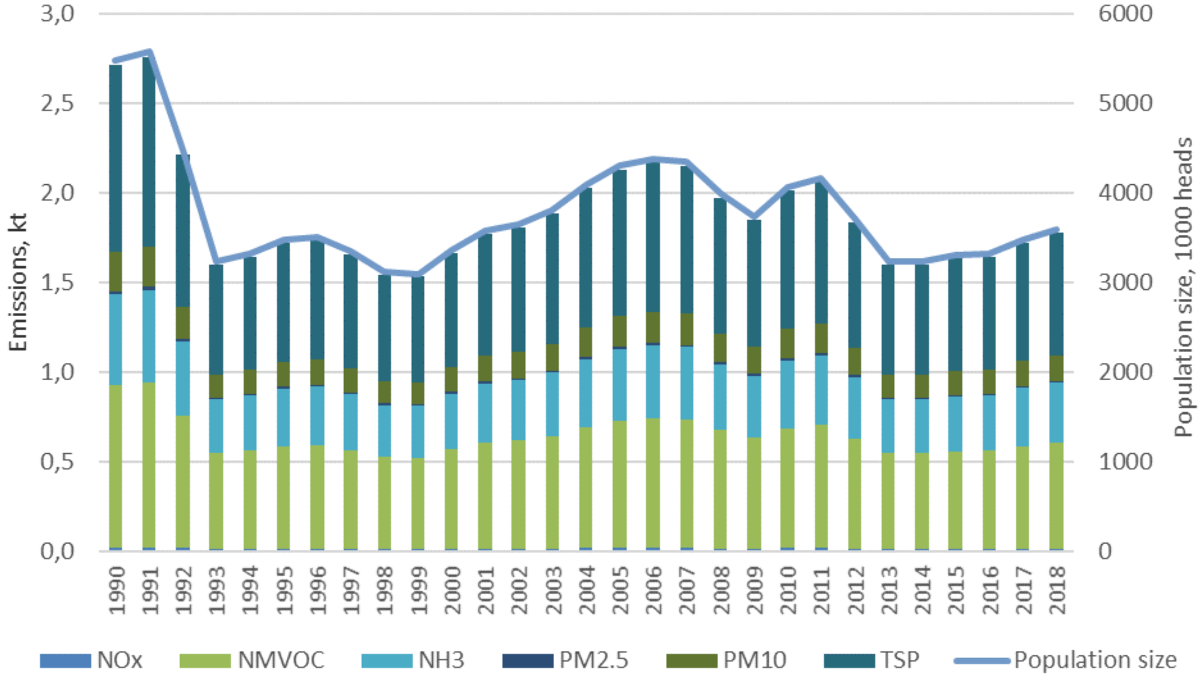


FIGURE 149 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.4.G.I IN THE PERIOD 1990-2018

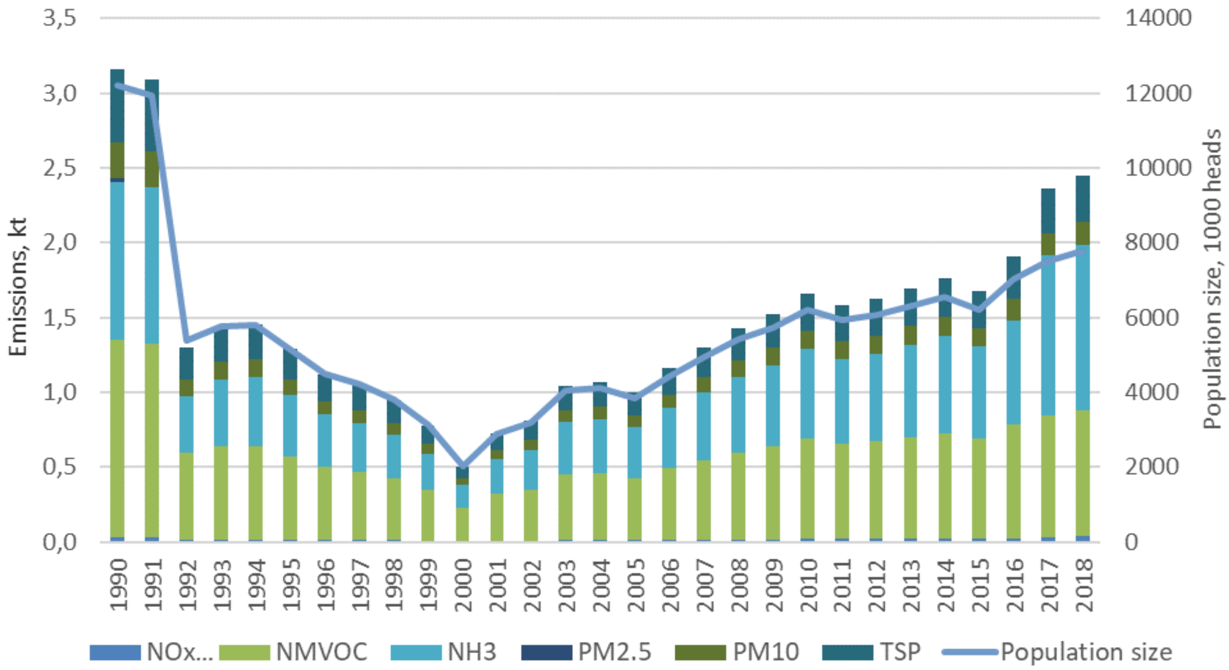


FIGURE 150 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.4.G.II IN THE PERIOD 1990-2018

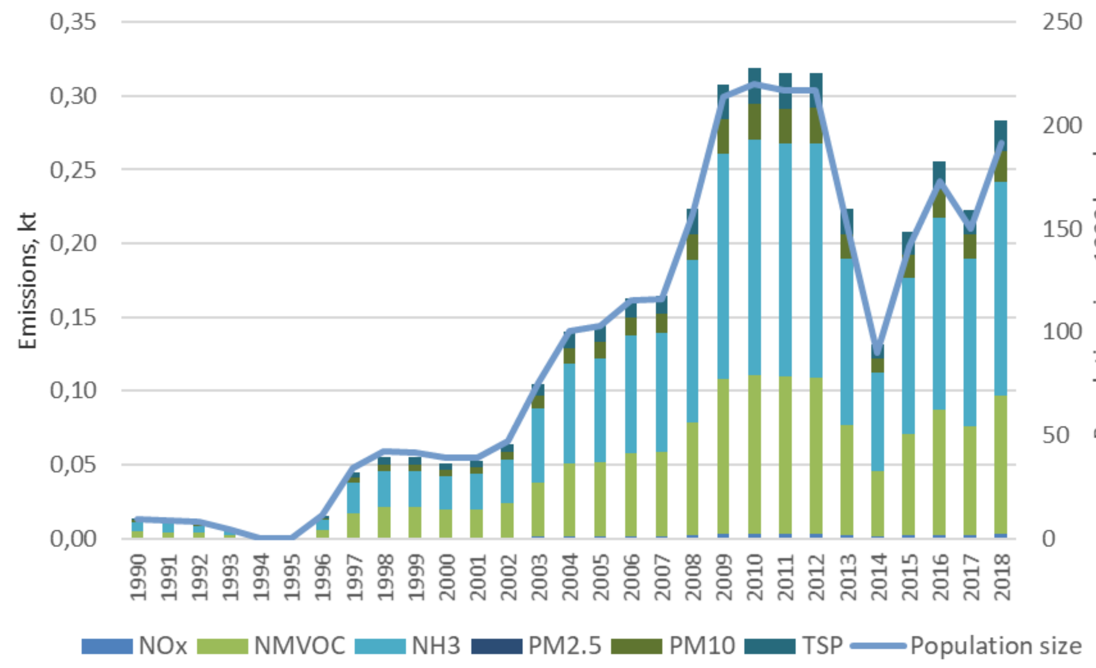


FIGURE 151 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.4.G.III IN THE PERIOD 1990-2018

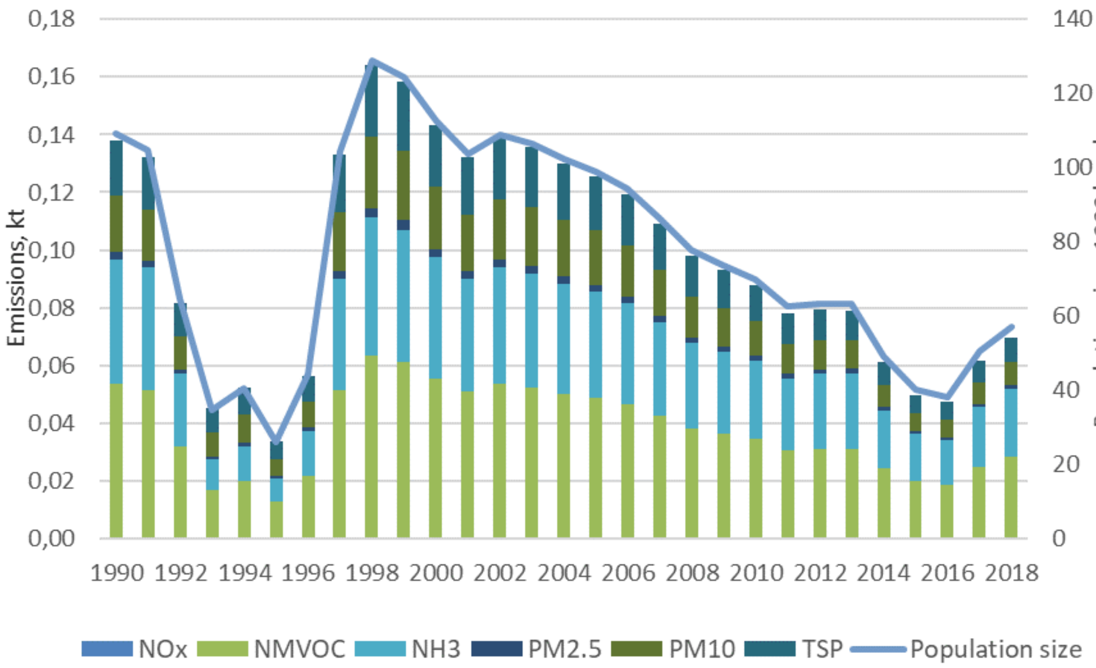


FIGURE 152 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.4.G.IV IN THE PERIOD 1990-2018

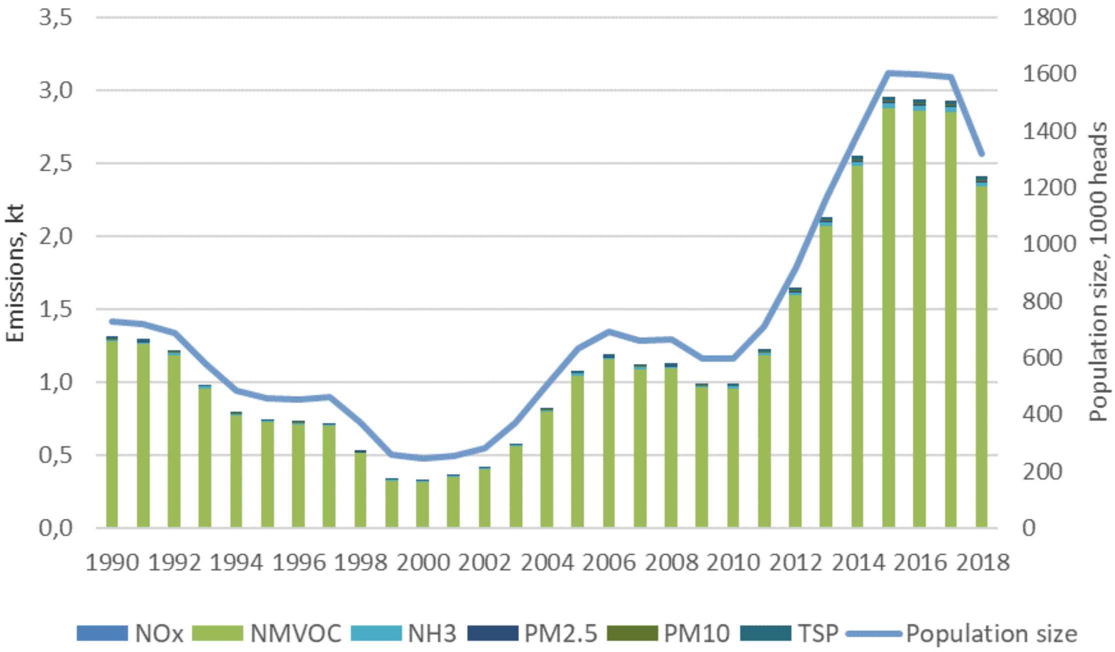


FIGURE 153 TRENDS IN POLLUTANT EMISSIONS AND POPULATION SIZE IN CATEGORY 3.B.4.H IN THE PERIOD 1990-2018

5.3 Crop Production and Agricultural Soils (3.D)

5.4 Application of Inorganic N-fertilizers (3.D.a.1)

5.4.1 Overview of the Category

Inorganic-N fertilizers is one of the major NOx and NH_3 contributors. Thus, higher Tier methodology is necessary for better estimation of emissions arising from processes described under this category. As it is seen from figure below the consumption of N-fertilizers has been increasing steadily for over the past 20 years.

Consumption data was gathered from international database IFA.

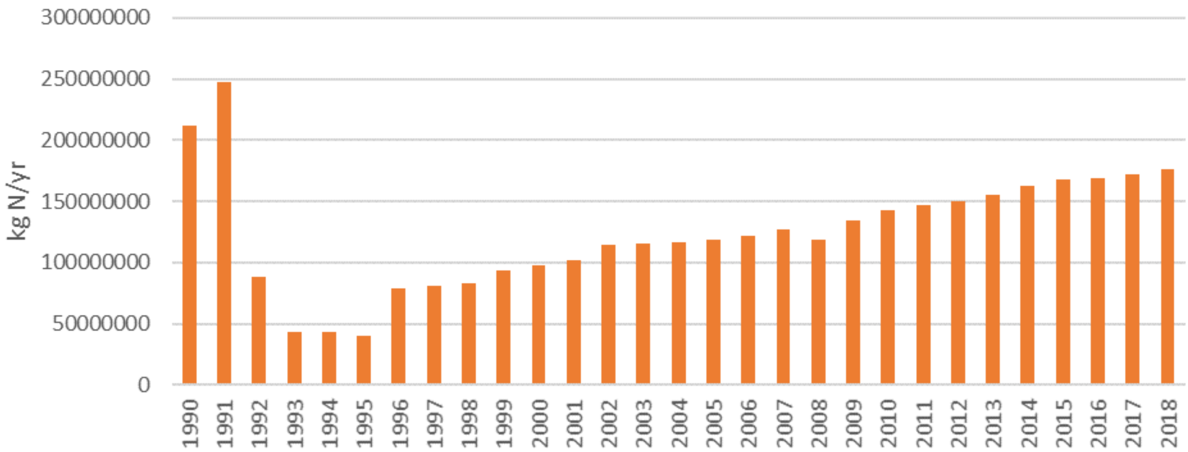


FIGURE 154 CONSUMPTION STATISTICS OF INORGANIC N-FERTILIZERS (GG) PROVIDED BY IFA.

AMOUNT OF N-FERTILIZERS BY TYPE USED IN LITHUANIA, N 1000 T

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Urea	20,1	12,0	20,1	12,3	23,1	10,0	9,0	9,0	10,0	26,1	11,4	11,7	8,9	9,1
Ammonium sulphate	11,7	13,0	12,6	12,5	16,8	10,0	9,0	10,0	8,0	12,6	35,8	35,0	45,1	46,2
Ammonium nitrate	47,2	52,4	51,0	50,5	54,5	60,0	62,0	63,0	61,0	56,9	56,1	58,4	51,3	52,5
Calc. amm. nitrate	7,4	8,2	8,0	7,9	4,9	5,0	5,0	3,0	5,0	6,0	5,8	6,6	6,2	6,3
Nitrogen solutions	14,0	15,6	15,1	15,0	5,4	20,2	20,0	20,0	20,0	16,8	30,9	31,5	33,5	34,3
Ammonium phosphate	13,2	14,6	14,2	14,1	3,9	5,0	10,0	5,0	5,0	4,0	3,4	2,9	3,1	3,2
Other NP	2,8	3,1	3,0	3,0	9,7	10,0	10,0	15,0	15,0	18,2	5,4	5,3	3,1	3,2
N P K compound	2,8	3,1	3,0	3,0	16,2	23,0	22,0	25,0	31,0	22,7	19,0	18,1	20,8	21,3
All	119,0	122,0	127,0	118,3	134,5	143,2	147,0	150,0	155,0	163,3	167,8	169,5	172,0	176,1

5.4.2 Methodology

Methodology for estimation of pollutant emissions was taken from 2019 EMEP/EEA guidebook. NO Tier 1 emission factors were used to estimate NOx emissions. The following equation was used:

Equation 5.3:

$$E_{Pollutant} = AR_{Consumption} \times EF_{Pollutant} \times Unit\ Conversion\ factor \times Other\ CF$$

Where *Other CF* is only applicable for conversion of NO to NO_2. The factor is equal to 44/30.

NH3 emissions were estimated by Tier 2 approach using emission factors from Table 3.2 (chapter 3.D Crop production and agricultural soils, page 15. Value of parameter “Climate” was chosen as “Cool”, The average of EF values for normal pH and high pH were taken.

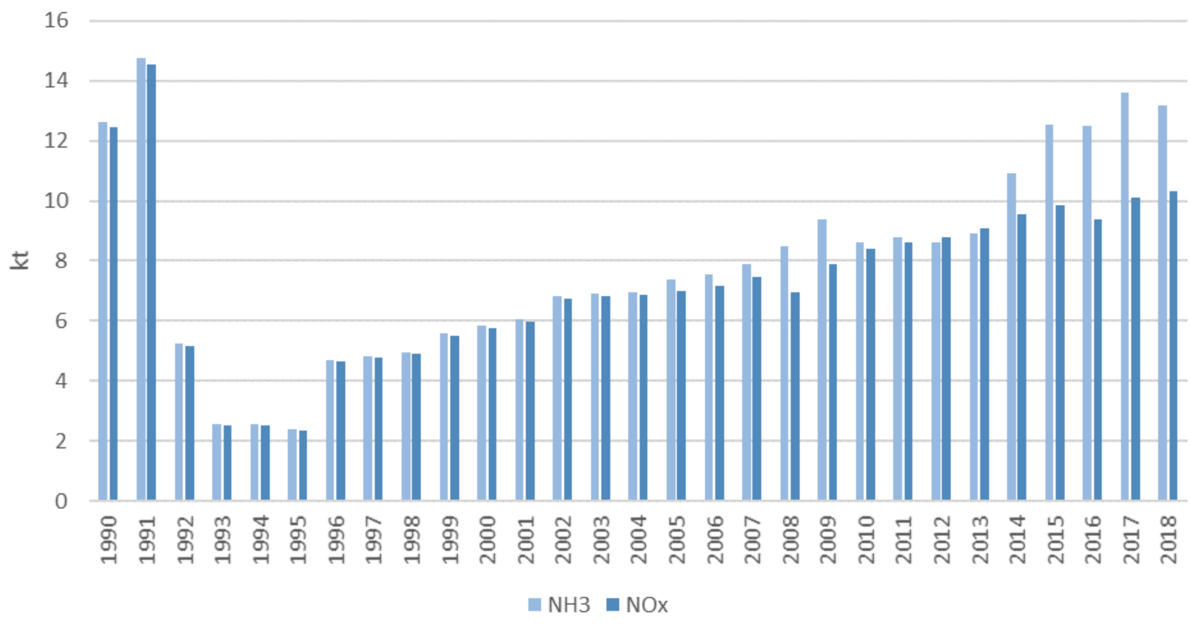


FIGURE 155 NH_3 AND NOX EMISSIONS FOR THE PERIOD 1990-2018

5.5 Waste application to Soils (3.D.a.2)

Lithuania's Environmental Protection Agency gathers information on the waste collection [7]: destruction, reuse, and management. This is done according to minister's statute no. 217 "Waste Management Rules" [8]. Data from this register, available on the www.gamta.lt website under R10 category (reuse of waste in agriculture beneficial for agriculture), was taken and used for the pollutant emission calculations for the 3.D.a.2 section.

5.6 Animal Manure Application to Soils (3.D.a.2.a)

5.6.1 Overview of the Category

With the approval of the latest 2019 EMEP/ EEA guidebook, NH_3 emission factors from for this sector were included. It can be mentioned that Lithuanian EPA collects information on the amount of manure and dung, and used straw applied on the soil beneficial for the soil. However, additional data is needed, such as dry mass amount in the mixture or separate substances, nitrogen amount in the dry matter and other details.

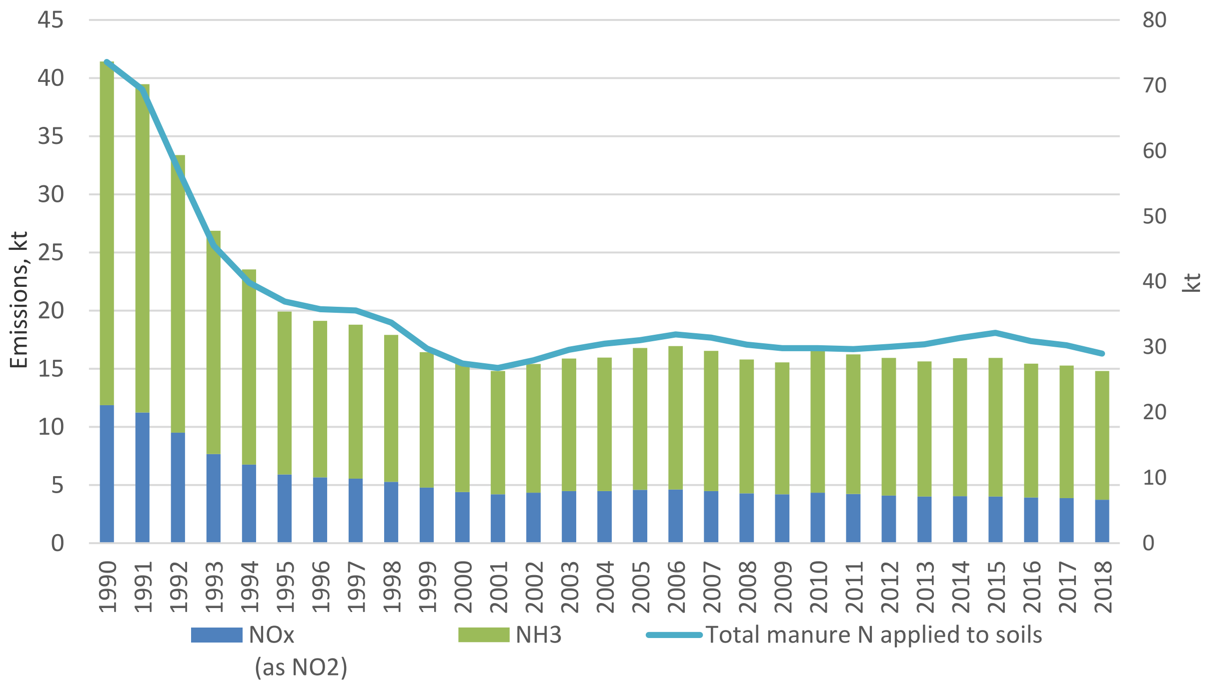


FIGURE 156 TRENDS IN POLLUTANT EMISSIONS AND TOTAL MANURE N APPLIED TO SOILS IN CATEGORY 3.D.A.2.A IN THE PERIOD 1990-2018

5.6.2 Methodology

Methodology for estimation of NH_3 emissions was taken from 2019 EMEP/EEA Guidebook. The following methodology was used to estimate NH_3 release to the atmosphere:

Equation 5.4:

$$E_{NH_3} = AAP_{Animal\ category} \times EF_{Pollutant\ Animal\ category} \times \%\ of\ Manure_{Manure\ category} \times Unit\ COnversion\ Factor$$

where AAP is annual average population of animal category (animals per annum) and EF represents emission factors for different animal categories (kg of NH_3 per AAP per year).

5.6.3 Time Series

The ammonia emissions 1990/2018 and 2005/2018 trends showed similar declines as for 3B category. 1990/2018 pollutant release to the atmosphere decreased by 37.5%, while 2005/ 2018 emissions increased by 32.6%. The total number of livestock, poultry and other animals does not closely correlate with the emission trend (Figure 157). Although total animal population decreased by 47.4% from 1990, emissions dropped by 65.9%. This can be explained in terms of different emission factors for different animal groups and different animal group numbers development over time.

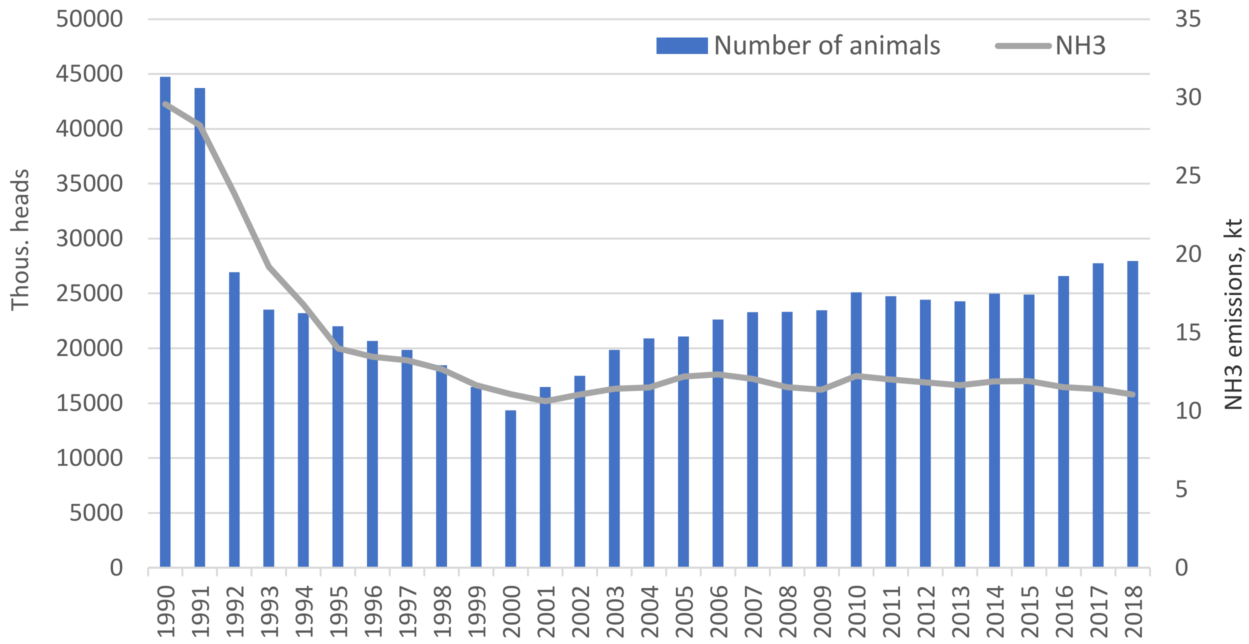


FIGURE 157 NUMBERS OF ANIMALS AND CORRESPONDING AMMONIA EMISSIONS FROM ANIMAL MANURE APPLICATION TO SOILS.

5.7 Sewage Sludge Applied to Soils (3.D.a.2.b)

5.7.1 Overview of the Category

Sewage sludge in Lithuania is used as soil amendment. Amounts of nitrogen sludge applied to soils were obtained from Lithuanian Environmental Protection Agency (EPA). Information for 1990, 2000-2003 and 2015 years was not available. Thus, data was filled by assuming identical value as on 1991, by interpolation or by extrapolation. Respectively, 2015 value was found by applying linear equation $y = 3140.748 \cdot x + 6734355$, where x = 2015 (R^2 = 0.01).

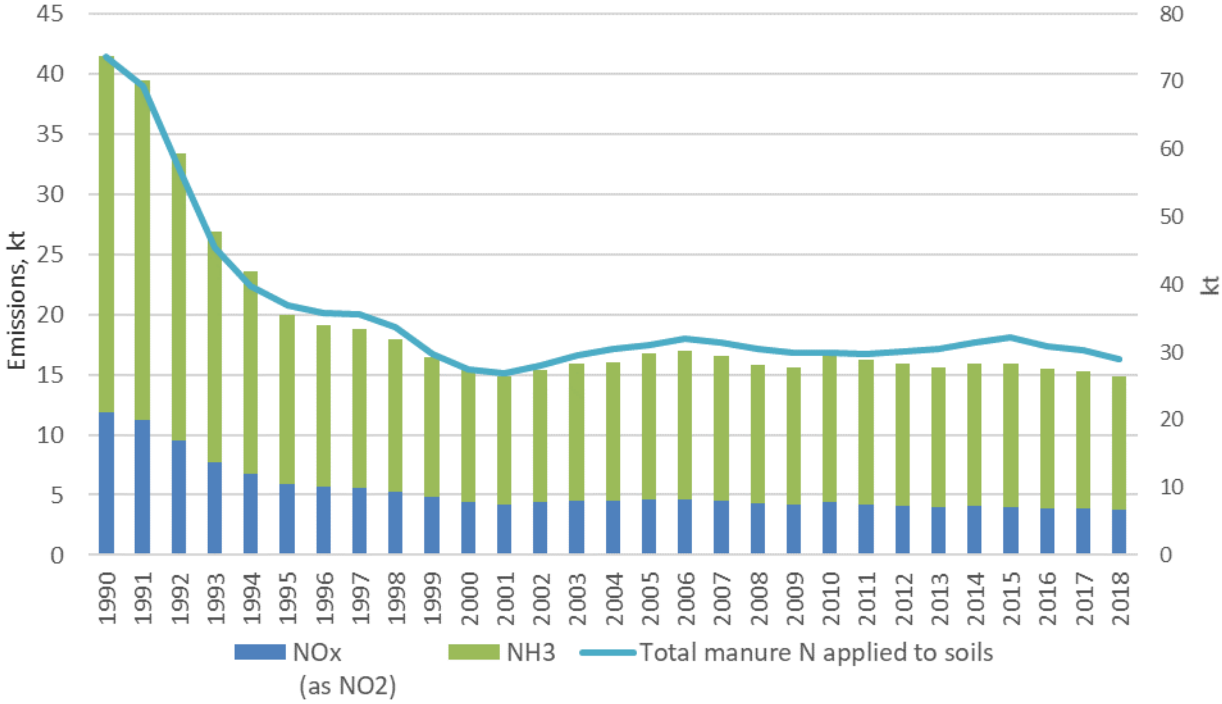


FIGURE 158 TRENDS IN POLLUTANT EMISSIONS AND USE OF SEWAGE SLUDGE IN SECTOR 3.D.A.2.B

5.7.2 Methodology

Amount of nitrogen was multiplied with 2019 EMEP/EEA Guidebook's emission factor. In order to obtain NO_2 emissions 0.04 kg NO_2 / (kg N in sewage sludge) emission factor was used, while for NH_3 – 0.13 kg NH_3 x (kg N in sewage sludge)$^{-1}$. The following equation was applied:

Equation 5.5:

$$E_{Pollutant} = Total\ Sewage\ Sludge\ Applied \times Dry\ Matter\ Content \times Total\ Nitrogen\ Content \times Emission\ Factor \times Unit\ Conversion\ Factor \times Conversion\ Factor\ to\ Specific\ Pollutant$$

5.8 Other Organic Fertilizer Application (3.D.a.2.c)

5.8.1 Overview of the Category

Using financial resources from 2004-2006 EU ISPA/Cohesion funds Lithuania financed of about 50 green waste composting sites (GWCS), which started operating from 2010. Regional waste management centers (RWMC) provided data on quantities of compost and corresponding dry matter (DM) and nitrogen content. Average DM content in compost was equal to 0.0063 kg/kg, while average nitrogen content in DM – 54 %.

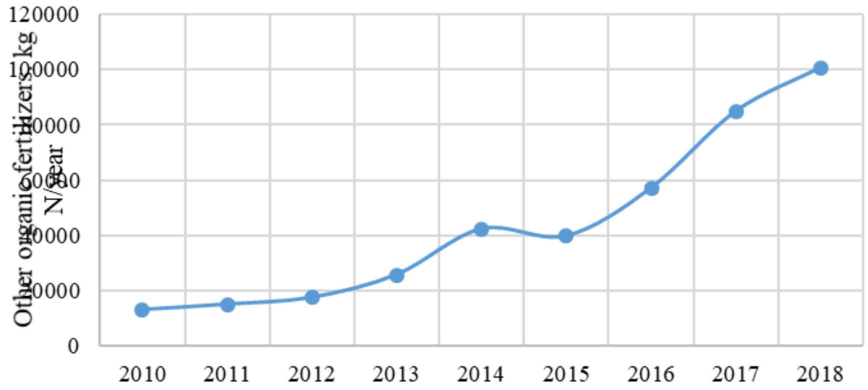


FIGURE 159 AMOUNT IN KILOGRAMS OF NITROGEN IN OTHER ORGANIC FERTILIZERS.

5.8.2 Methodology

Amount of nitrogen in compost was used with 2016 EMEP/EEA Guidebook emission factors. NO emissions were estimated using emission factor equal to 0.04 kg NO x (kg waste-N applied)$^{-1}$. while NH_3 emissions were calculated using emission factor of 0.08 kg NH_3 x (kg waste-N applied)$^{-1}$. General equation is shown below:

Equation 5.6:

$$E_{Pollutant} = Total\ Organic\ Fertilizer\ Applied \times Dry\ Matter\ Content \times Total\ Nitrogen\ Content \times Emission\ Factor \times Unit\ Conversion\ Factor \times Conversion\ Factor\ to\ Specific\ Pollutant$$

Emissions prior 2010 were labelled as not occurring.

5.8.3 Time Series

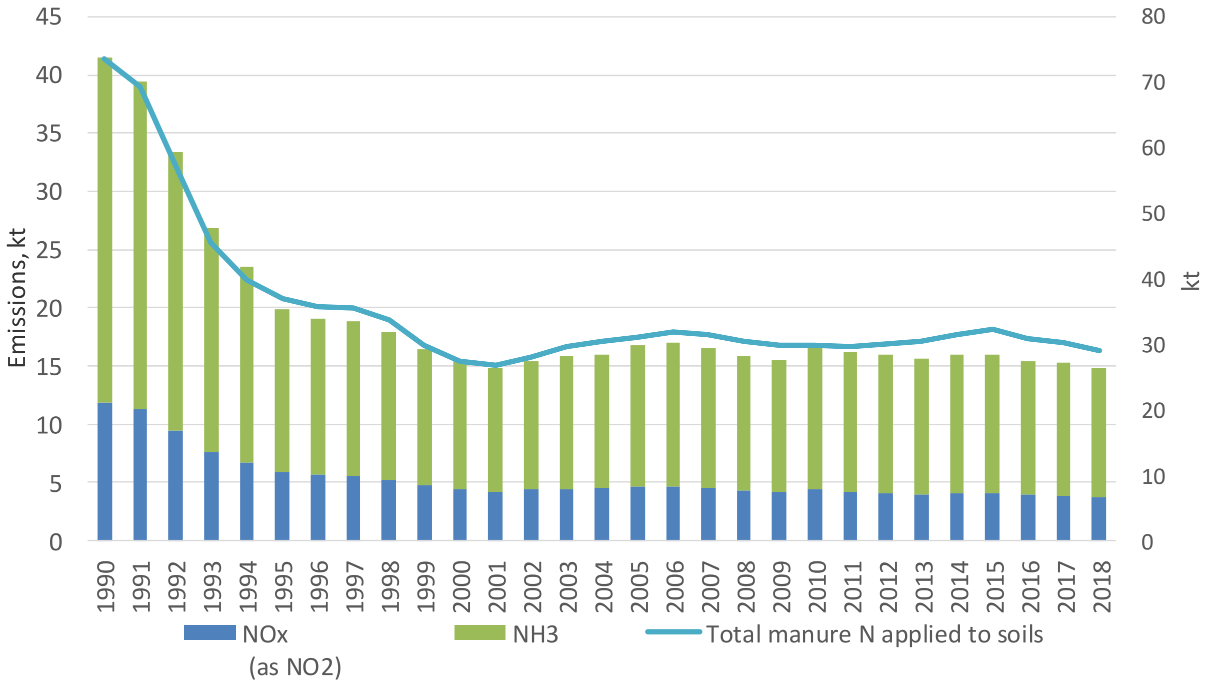


FIGURE 160 TRENDS IN EMISSIONS AND USE OF COMPOST IN SECTOR 3.D.A.2.C

5.9 Urine and Dung Deposited by Grazing Livestock (3.D.a.3)

5.9.1 Overview of the Category

This category was estimated using EEA Manure Management N-flow tool.

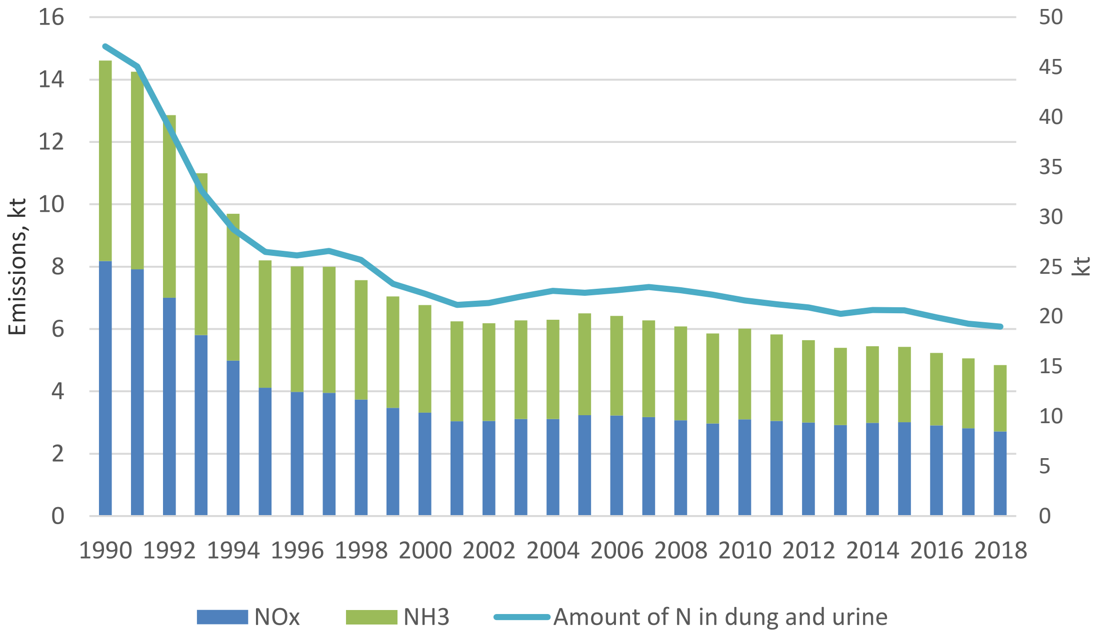


FIGURE 161 TRENDS IN POLLUTANT EMISSIONS AND AMOUNT OF N IN DUNG AND URINE IN CATEGORY 3.D.A.3 IN THE PERIOD 1990-2018

$$E_{NH_3} = AAP_{Animal\ category} \times EF_{Pollutant\ Animal\ category} \times \%\ of\ Manure_{Manure\ type} \times Unit\ Conversion\ Factor$$

5.9.2 Time Series

Figure 161 shows how ammonia emissions developed over time. In the last decade emissions were constantly dropping, which can be attributed to the decrease in cattle, outdoor swine and horse populations. There is no impact for this kind of emissions from the poultry and indoor swine.

5.10 Crop Residues Applied to Soils (3.D.a.4)

Not estimated.

5.11 Indirect Emissions from Managed Soils (3.D.b)

Not estimated.

5.12 Farm-level agricultural operations including storage, handling and transport of agricultural products (3.D.c)

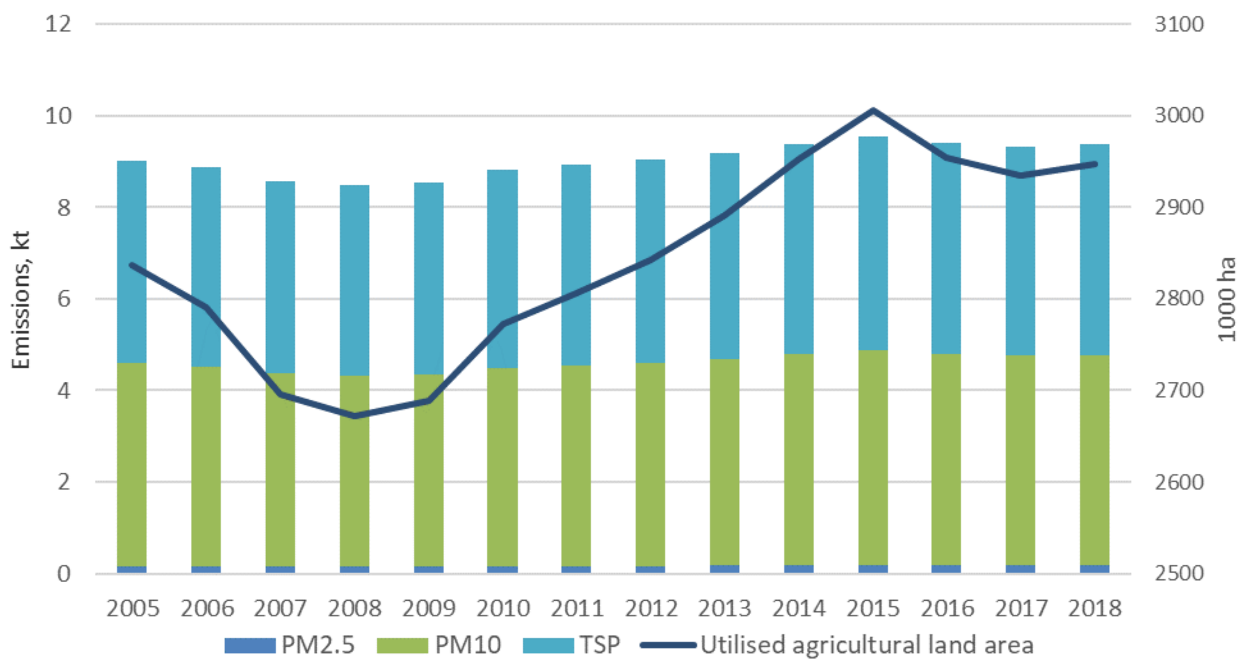


FIGURE 162 TRENDS IN EMISSIONS AND UTILISED AGRICULTURAL LAND AREA IN SECTOR 3.D.C

5.13 Off-farm storage, handling and transport of bulk agricultural products (3.D.d)

Not estimated.

5.14 Cultivated Crops (3.D.e)

NMVOC emissions were estimated by Tier 1 method with EF 0.86 kg/ha.

5.15 Agriculture Other Including Use of Pesticides (3.D.f. 3.I)

5.15.1 Overview of the Section

This category addresses emission sources that are not included in other Agriculture sections. Emissions may arise from application of pesticides (NFR 3.D.f) and other (NFR 3.I), such as treatment of straw with ammonia. Agriculture is the main sector from which the biggest pollution from pesticide use originate.

5.16 Use of Pesticides (3.D.f)

5.16.1 Overview of the Category

Use of pesticides (i.e. insecticides, fungicides, plant growth regulators, rodenticides, herbicides and other) for plant protection increases human health and environmental hazards. The 2001 Stockholm Convention on Persistent Organic Pollutants (POPs) and Protocol to the Convention on LRTAP banned production and consumption of 11 specific POPs. Also, multiple Directives concerning maximum levels of pesticide residues in and on fruits and vegetables (Directive 76/895/EEC), cereal products (86/362/EEC), food of animal origin (86/363/EEC), plant origin products (90/642/EEC), placing of plant products on the market (91/414/EEC) and biocidal products on the market (98/8/EEC), framework for Community action for sustainable pesticide use (Directive 2009/128/EC), maximum levels of pesticides on and in animal food and feed (EC regulation No. 396/2005), and other.

According to the latest study the mostly consumed pesticides in 2014 were herbicides (43%), 29% - fungicides, 26% - plant growth regulators and 2% - insecticides. [3] The major herbicides used were glyphosate (20.6%), MCPA (16.8%) and 57 other active ingredients. In fungicides category – 57 active ingredients (major: tebuconazole - 25.6%), insecticides – 18 active substances (major: thiacloprid with 45.5% of total insecticides used) and only 5 active substances in plant growth regulators with major substance being chlormequat (84.3%).

90-95% of sugar beetroot, sweetcorn, rapes and cereal all species were processed with pesticides, while other species' smaller percentage of harvest was treated with pesticides: potatoes (62%), vegetables (26%), and fruit and berries (23%). On average 1.08 kg of active ingredient was used for one hectare processed, with the most for berries and fruit (3.09 kg/ha) and the least for sweetcorn (0.38 kg/ha).

[1] http://chm.pops.int/default.aspx
[2] http://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/ece.eb.air.104.e.pdf
[3] https://osp.stat.gov.lt/informaciniai-pranesimai?articleId=3975263

Information on the amounts of different pesticide used (i.e. insecticides, fungicides, herbicides, etc.) for the 1992-2014 period can be gathered from the Statistics Division of the Food and Agriculture Organization of UN (short form FAOSTAT) [11].

No national data on total or plant-specific pesticide consumption is available. In 2014 conducted study showed that estimates taken from EUROSTAT and FAOSTAT are much larger.

Emissions from the use of pesticides reporting with the Convention on LRTAP is limited to HCB emissions as other pesticides are not included into the NFR form.

5.16.2 Methodology

Pesticides which contain minor amounts of HCB as impurity were addressed. Only two chemicals, chlorothalonil and clopyralid, were identified which are included into the 1185/2009 regulation and may contain small amounts of HCB. 2014 HCB emission was determined using emission factors given by Yang (2006) [3.2]. EFs for HCB from chlorothalonil and clopyralid are equal to 10 g/ Mg and 2.5 g/ Mg of pesticide, respectively. Pesticides quantities were obtained from the statistical study which are equal to 5190.07 kg of chlorothalonil and 1359.65 kg clopyralid.

No annual statistics are collected on the pesticide consumption. HCB emission from the use of pesticides in 1990 was calculated based on reported HCB emissions by other countries. The average ratio of HCB emitted per agricultural land (kg of HCB per 1000 ha) was applied for agricultural area (3389 thousand ha) in Lithuania in 1992 (no data on agricultural land in 1990 is available at FAOSTAT database) and reported for 1990 on assumption that HCB emissions from this sub-sector were similar for years 1990 and 1992.

TABLE 46 AGRICULTURAL LAND (1000 HA). REPORTED HCB EMISSIONS FROM NFR 3.D.F AND RATIO BY COUNTRY. AGRICULTURAL LAND DATA WAS GATHERED FROM FAOSTAT DATABASE.

Country	Agricultural Land, 1000 ha (1990)	Reported HCB emissions from NFR 3.D.f (1990)	Ratio, kg/1000 ha
Denmark	2788	18.280	6.56E-03
Finland	2393	1.207	5.04E-04
Italy	16840	23.486	1.39E-03
Germany	18032	21.830	1.21E-03
United Kingdom	18203	116.326	6.39E-03
		Average	3.21E-03

5.16.3 Time Series

Obtained HCB emissions for 1990 and 2015 are equal to 10.88 kg and 5.530 x 10^{-2} kg. respectively. The emission decreased by 99.49%. Similar changes in HCB emissions were reported in Denmark's (-99.83%). Finland's (-98.18%) and Italy's (-98.34%) NFRs.

5.17 Agriculture Other (3.I)

This section includes use of ammonia-treated straw and other pollution sources, but those emissions have not been estimated.

5.18 Field Burning of Agricultural Residues (3.F)

5.18.1 Overview of the Category

Field burning of agricultural residues such as stubble, is forbidden by the order no. 269 on Environmental Protection Requirements for Burning Plants or Plants' Residues.

Emissions in the sector were reported as not occurring.

5.19 References

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[2] I. Konstantinavičiūtė. S. Byčenkienė. E. Kairienė. T. Smilgius. R. Juška. I. Žiukelytė. R. Lenkaitis. V. Kazanavičiūtė. S. Jezukevičius. J. Aleinikovienė. T. Juraitė. L. Čeičytė. J. Merkelienė. R. Tijūnaitė. E. Kairienė. T. Aukštinaitis. „Lithuania's National Inventory Report 2018 (Green House Gas Emissions)". excel datasheet: Enteric page. also NIR: p. 362;

[3] R. Juška. V. Juškienė. R. Juodka. R. Leikus. R. Matulaitis. V. Ribikauskas. „Lietuvos Mėšlo tvarkymo sistemose susidarančių metano ir azoto suboksido kiekio tyrimai ir įvertinimas". p. 16;

[4] I. Konstantinavičiūtė. S. Byčenkienė. E. Kairienė. T. Smilgius. R. Juška. I. Žiukelytė. R. Lenkaitis. V. Kazanavičiūtė. S. Jezukevičius. J. Aleinikovienė. T. Juraitė. L. Čeičytė. J. Merkelienė. R. Tijūnaitė. E. Kairienė. T. Aukštinaitis. „Lithuania's National Inventory Report 2016 (Green House Gas Emissions)". excel datasheet: Enteric page. also NIR: p. 362.

[5] Lietuvos Respublikos žemės ūkio ministro įsakymas Nr. 3D-254: Lietuvos kaimo plėtros 2014-2020 metų programos priemonės „Agarinė aplinkosauga ir klimatas" įgyventinimo taisyklės. punktas 21.6;

[6] Database of inorganic fertilizer activity (consumption. import. export. production). available on http://ifadata.fertilizer.org/ucSearch.aspx. last accessed on 30/05/2016;

[7] Register of created. gathered and reused waste. available on http://atliekos.gamta.lt/cms/index?rubricId=01f545a1-ebed-4f2d-b05a-2b1bf5e7494b. last visited on 01/06/2016;

[8] Statute no. 217 on waste management rules. available on https://www.e-tar.lt/portal/lt/legalAct/TAR.38E37AB6E8E6/zIxClWuoUS. last accessed on 01/06/2016;

[9] P. F. Pratt and J. Z. Catellanos. Journal of California Agriculture. July-August. 1981. page 24.

[10] A. Slapikaite. Kauno Nuoteku Valyklos Pirminiu Sesdintuvu Efektyvumo Tyrimai. 2009. p. 12. http://vddb.laba.lt/fedora/get/LT-eLABa-0001:E.02~2009~D_20090603_094528-72199/DS.005.0.01.ETD

[11] Pesticides use Database. Food and Agriculture Organization of the United Nations. available at http://faostat.fao.org/site/424/DesktopDefault.aspx?PageID=424#ancor. last accessed on 01/06/2016;

[xxxx. 23 psl] Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania. available on http://www.vpgt.lt/go.php/lit/English. last visited on 20/06/2016;

[12] Gyvulių skaičiaus ir gyvulininkystės produktų gamybos statistinio tyrimo metodika. 2012. also available on http://osp.stat.gov.lt/documents/10180/550594/Gyvuliu_sk_metodika_2012.pdf. last accessed on 07/2016.

6 WASTE

6.1 Overview of the Sector

The waste section constitutes of the following categories:

- Solid Waste Disposal on Land: Both Managed and Unmanaged (NFR 5.A);
- Biological Treatment of Waste (NFR 5.B):
    - Biological Treatment of Waste: Compost Production (NFR 5.B.1);
    - Biological Treatment of Waste: Anaerobic Digestion (NFR 5.B.2);
- Waste Incineration (5.C)
    - Municipal Waste Incineration (NFR 5.C.1.a);
    - Other Waste Incineration of (NFR 5.C.1.b):
        - Ind. Wastes Incl. Hazardous and Sewage Sludge (NFR 5.C.1.b.i-ii);
        - Clinical Waste (NFR 5.C.1.b.iii);
        - Cremation (NFR 5.C.1.b.v);
    - Open Waste Burning (NFR 5.C.2);
- Wastewater Handling (NFR 5.D):
    - Wastewater Treatment in Industry and Domestically (NFR 5.D.i-ii);
    - Wastewater Treatment in Residential Sector: Latrines (NFR 5.D.iii);
- Other Waste, Incl. House, Industrial and Car Burns (NFR 5.E).

Emissions from the processes included under the *Waste* sector contribute a relatively small part to the total inventory. There are not many facilities which fall under this category. Emissions emerging from some of the facilities, e.g. UAB Toksika and UAB Fortum Klaipeda, which incinerate waste with energy recovery are reported under the 1A1a category.

For this submission emissions from *NFR 5B2 Biological treatment of waste – Anaerobic digestion at biogas facilities*, *5.C.2 Open burning of waste, 5D3 Other wastewater handling – latrines,* and *5E Other waste* categories were estimated, while other categories were recalculated.

The main information on the waste production, management and reuse is available on Lithuanian Environmental Protection Agency‘s website, waste register [1]. Demographic information was taken from Lithuania‘s Statistics Department (LTSTD) [2]. Data on the part of population using latrines was collected from 2016 GHG NIR [3]. Also, figures on waste production, management and reuse has been double-checked with GHG NIR. Statistics of car, house, industrial and other fires were gathered from Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania [4].

6.1.1 Methodology

Pollutant emissions from the waste production, management, and reuse were estimated using the 2019 EMEP/EEA Air Pollutant Emission Inventory Guidebook, the 2006 IPCC Guidelines and the 2000 IPCC Good Practice Guidance. Statistical data reported in IIR/NFR (Informative Inventory Report) are consistent with the information in the GHG (Green-House Gas) NIR/CRF (National Inventory Report) where applicable.

6.2 Solid Waste Disposal on Land: Managed and Unmanaged (5.A)

6.2.1 Overview of the Section

This category addresses emissions from waste disposal on land. Relatively small amounts of pollutants, mainly NMVOC which emissions decreased by about 52.3% from 2005 to 2018, are emitted from this category. Such reduction of NMVOC emissions is a major improvement and is associated with the waste treatment and recovery using other, more environmentally friendly methods, such as recycling. TSP and PM levels were estimated as well.

6.2.2 Waste reporting

Waste is managed according to waste disposal and recovery operations stated by the national law no. 217 [5]. Please refer to the table below for more information on the operations. Waste statistics are collected and stored according to European waste list adopted by the European Commission [111]. [111] http://eur-lex.europa.eu/legal-content/GA/TXT/?uri=CELEX:32000D0532 Statistics are collected and archived by the Lithuanian Environmental Protection Agency.

TABLE 47 AVERAGE COMPOSITION OF MSW IN LITHUANIA

Ingredient	Amount
Plastic	9%
Paper and cardboard	14%
Glass	9%
Metal	3%
Textile	4%
Biodegradable (kitchen) waste	42%
Composite packaging	2%
Construction and demolition waste	4%
Hazardous waste	2%
Leather. rubber	1%
Wood	2%
Sand. sweepings	4%
Other	4%

TABLE 48 WASTE DISPOSAL AND RECOVERY OPERATIONS.

Waste disposal operations	
D1	Deposit into or on to land (e.g. landfill, etc.)
D2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
D3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
D4	Surface engineered landfill (e.g. placement of liquid or sludgy discards into pits, pond or lagoons, etc.)
D5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment
D6	Release into a water body except seas/ oceans
D7	Release to seas/ oceans including sea-bed insertion
D8	Biological treatment not specified elsewhere in this Annex which results in final compounds or

	mixtures which are discarded by means of any of the operations numbered D 1to 12
D9	Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to 12 (e.g. evaporation, drying, calcination, etc.)
D10	Incineration on land
D11	Incineration at sea
D12	Permanent storage (e.g. emplacement of containers in a mine, etc.)
D13	Blending or mixing prior to submission to any of the operations numbered D 1to 12
D14	Repackaging prior to submission to any of the operations numbered D 1 to 13
D15	Storage pending any of the operations numbered D1 to D14 (excluding temporary storage, pending collection, on the site where the waste is produced)
Waste recovery operations	
R1	Use principally as a fuel or other means to generate energy
R2	Solvent reclamation/ regeneration
R3	Recycling/ reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)
R4	Recycling/ reclamation of metals and metal compounds
R5	Recycling/ reclamation of other inorganic materials
R6	Regeneration of acids or bases
R7	Recovery of compounds used for pollution abatement
R8	Recovery of components from catalysts
R10	Land treatment resulting in benefit to agriculture or ecological improvement
R11	Use of waste for submission to any of the operations numbered R 1 to 10
R12	Exchange of waste for submission to any of the operations numbered R 1 to 11
R13	Storage of waste pending any of the operations numbered R 1 to 12 (excluding temporary storage, pending collection, on the site where the waste is produced)

6.2.3 Methodology

Tier 1 approach with default pollutant emission factors was used for both managed and unmanaged solid waste disposal. Information on the waste disposal from 1991 to 2014 was taken from the 2016 GHG report and compared with data gathered from Lithuanian EPA database. It was assumed that identical amount of waste was disposed on 1990 as on 1991 and on 2015 as on 2014 as no information was available at the time. From 2004 data classified under D1 (*Deposition into or on to land (e.g. landfill. etc.)*) and D5 (*Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment. etc.)*) was considered.

Equation 6.1: $E_{Pollutant} = AR_{Waste} \times EF_{Pollutant} \times Conversion\ Factor$

where $E_{Pollutant}$ is emission of specific pollutant in Gg;
AR_{Waste} is activity data (waste disposed) in kg mega grams;
$EF_{Pollutant}$ is the emission factor for specific pollutant;
Conversion Factor is number which converts units to Gg.

6.2.4 Time Series

There is a declining trend in amounts of waste disposal on land. Wastes are not disposed in unmanaged and semi-aerobically managed ways. The landfill waste amounts dropped from 1233.8 Gg in 2005 to 346.2 Gg in 2018. This change can be attributed to the improved landfills compliance with the EU landfill directive 1999/31/EC.

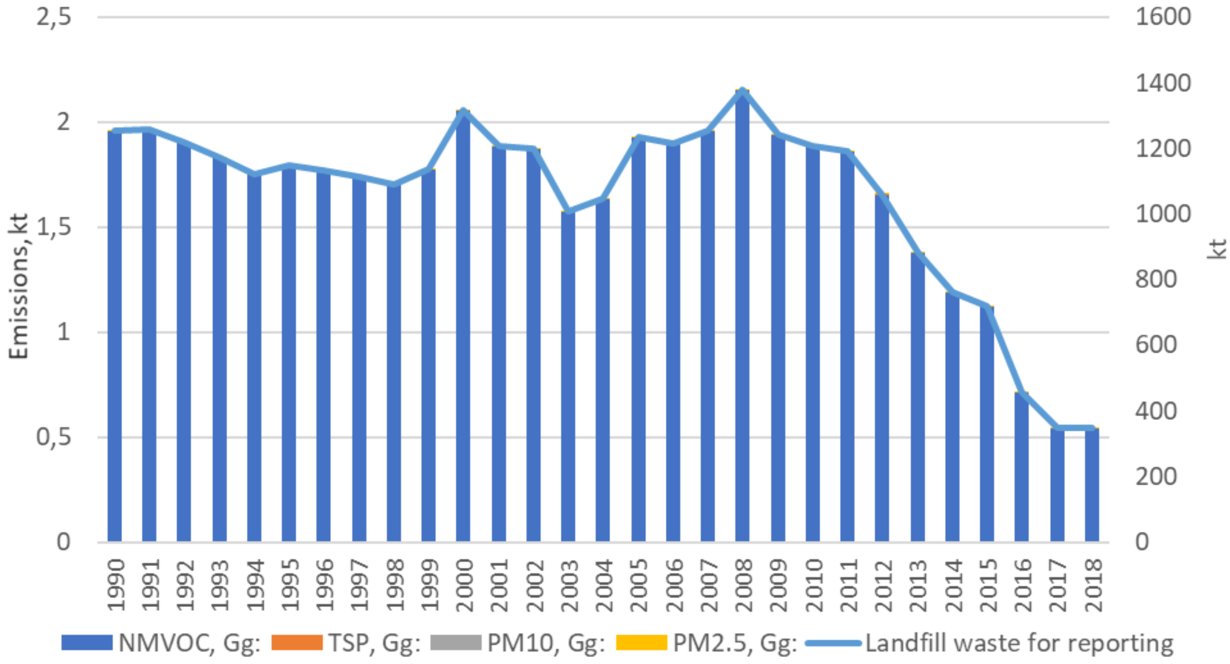

FIGURE 163 TRENDS IN EMISSIONS AND AMOUNT OF LANDFILL WASTE FOR REPORTING, 1990-2018

6.3 Biological Treatment of Waste (5.B)

6.3.1 Overview of the Sector

This section addresses emissions from biological treatment of waste by composting and anaerobic digestion with biogas production. The ammonia emissions from these categories are relatively small, although NH_3 emissions for the period from 2005 to 2018 have increased 30 times (to 0.095 kt in 2018).

6.4 Compost Production (5.B.1)

6.4.1 Overview of the section

According to 2016 technical manual, emissions from any pollutant in this sector are not considered significant at national level. In Lithuania, even before 2010-2011, composting activities were almost non-existent, emissions were very small and did not have a significant impact on the overall emissions of the state.

In general, in the period 1990-2018, composting of organic waste in Lithuania became more active only after the establishment of Regional Waste Management Centers (RATCs) in 2011. And in 2015, after completion of the construction of Mechanical Biological Treatment (MBA) equipment, composting intensified. From 1 January 2019 with the introduction of individual food waste collection, food waste management - composting will become even more intensive and more dependent on the population than the MBA or Regional Waste Management Centers. Since 2017, organic waste is no longer dumped on landfill, further actions of better sorting, collection and composting of organic waste in Lithuania will help to maintain these results.

When assessing emissions from open composting in Lithuania, no air pollution abatement measures are applied and emissions cannot be reduced, but air pollution is reduced by biofilters according to the activity of MBA equipment, according to 2016. Technical guide - 90%.

The waste reporting regulations have changed several times since the independence of Lithuania:

- Recording of waste disposal and recovery started in 1991. From 1991 to 1999 composted waste was included under *R15* category – composting. Value of waste composted in 1990 was chosen to be identical as in 1991;
- From 2000 to 2004 composting was reported under *3.2* category – biological treatment of non-hazardous waste;
- With entry to the EU in 2008 waste framework directive (2008/98/EC) was adopted and composting has been recorded under *R3* category – recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes).

6.4.2 Methodology

Data on the compost production was gathered from 2016 GHG report. Tier 1 emission factor from 2016 EMEP/EEA guidebook was used to estimate ammonia emissions from 1990 to 2018. Taking into account that in 2018 The GHG report does not consistently present the amounts of organic waste consumed throughout the year, some of which were obtained by extrapolation. There are no real data for the periods from 1990 to 2003, so the same expert assessment as in the GHG report should be followed that composted quantities are in the same trend as in 2004-2011. The gradual growth of composted waste is calculated over this period by the exponential trend formula:

$$Y=e^{0.114X-226.63},$$

where: Y – amount of composted waste;

X – years of composting.

The extrapolation of this equation until 1990 was used to estimate the amount of composted waste in the 1990-2004 period. In the absence of more detailed data, such estimation of composted quantities should remain in the calculation of emissions later.

6.4.3 Time Series

Please see figure below for NH_3 emissions for the period 1990.-2018 The 2005/2018 emissions increased almost 30 times. However. this category is only a minor contributor to the total inventory.

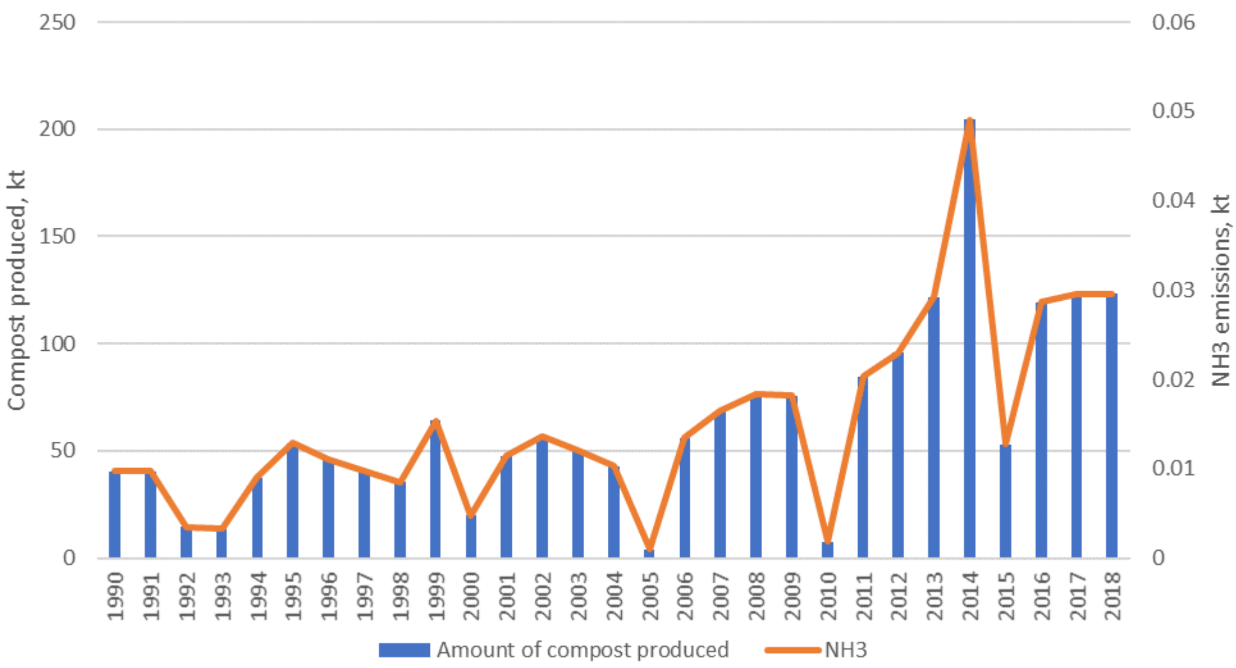

FIGURE 164 TRENDS IN AMOUNT OF COMPOST PRODUCED AND NH_3 EMISSIONS IN SECTOR 5.B.1, 1990-2018

6.5 Anaerobic Digestion (5.B.2)

Biofuel, including biogas, production has become very popular in Lithuania. There is a financial support from the national budget provided to biofuel (rapeseed-based) producers according to order no. 3D-417 issued by the minister of the Ministry of Agriculture of the Republic of Lithuania [7].

The biogas production involves anaerobic digestion of waste (biomass) with release of methane as major component gas, which after purification and removal of pollutants (e.g. Sulphur) can be burnt to release energy. Biogas plants, which only collect gas and/or burn it for energy, are included under 1.A.1.a category. Most of these plants (currently 9 are operating) are built in existing or closed landfills (examples of operating plants in Lithuania include landfills in Vilnius (Kazokiskes), Klaipeda (Kalote and Dumpiu), Kaunas (Lapiu) and other).

Biogas production from anaerobic digestion started in 2002. Currently there are 12 biogas generating facilities in agricultural sector [8] which do not exploit all the production potential. However, in the recent Lithuanian country-side development 2014 – 2020 programme support for biogas production from agricultural and other wastes is foreseen [9]. This programme focusses on the improvement of establishment conditions of biogas plants in the largest animal-breeding facilities. There were 7 biogas generating facilities in Idavang pig farms (manure and silage based), Kurana (plant waste based), Vilniaus Degtine (spirits production waste), Rokiskio suris (milk and cheese waste) and Agaras (carcass based).

There are also few water treatment facilities which produce biogas from sewage sludge treatment. Gas generated form anaerobic treatment of biogenic material is then cleaned and combusted or sold/transferred to other facilities. Major companies in Lithuania are: Kauno vandenys, Aukstaitijos Vandenys and Utenos Vandenys [10].

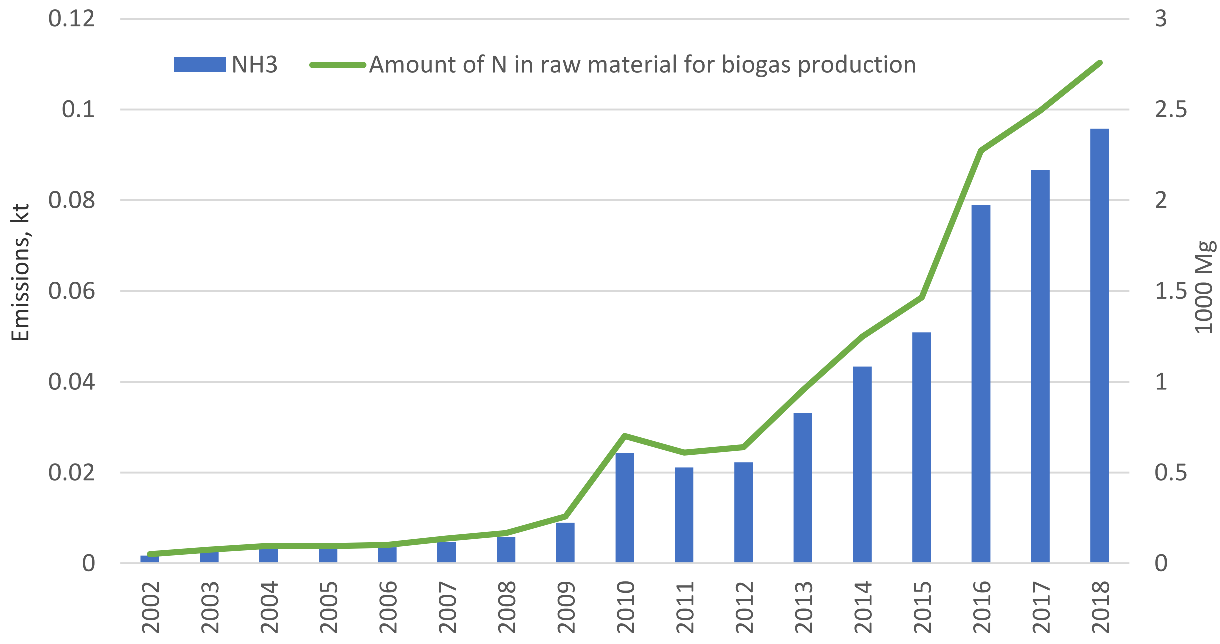

FIGURE 165 NH_3 EMISSIONS FROM ANAEROBIC DIGESTION AT BIOGAS FACILITIES AND AMOUNT OF N IN RAW MATERIAL FOR BIOGAS PRODUCTION

Figure 165 shows emission from the 5.B.2 *Anaerobic digestion* category and and amount of N in raw material for biogas production from 2002 to 2018. Biogas production amounts during 1990 – 2002 were estimated to be 0 by the Statistics Lithuania. The biogas production from 2002 to 2018 increased by almost 55 times resulting in according ammonia emissions increase.

6.5.1 Methodology

Information on the biogas production from treatment of agricultural (i.e. food, manure, slurry, other household and crop) wastes and sewage sludge wastes (such as floatation sludge) can be accessed at the Statistics Lithuania on the fuel balance datasheet. However, no other details (e.g. dry matter in the sludge, nitrogen content and other) are available thus increasing uncertainty and reducing quality of the results.

Volumes of biogas produced were gathered from the Statistics Lithuania. In order to estimate emissions from the biogas production according to the methodology provided in the 2019 EMEP/ EEA guidebook, the biogas volume was converted to approximate amount of biogenic material.

Firstly, the gas volume was converted to the mass of dry matter. For biogas produced from agricultural wastes conversion factors of pig slurry, cattle slurry, maize and grass wastes, and household wastes were averaged. Averaged value equaled to 0.444 m^3 of biogas/ kg of DM. For sewage sludge averaged conversion factor equaled to 0.635 m^3/ kg of DM and equal to conversion factor of floatation sludge.

It was assumed that DM content in the biogenic material is 9% on average which depends on biogas production mechanism. Obtained values were assumed to be equal to the amount of biogenic material and liquid digestate used in the biogas production.

Activity data with 2019 EMEP/ EEA guidebook Tier 2 emission factors for storage (before digestion) biogenic material and liquid digestate storage (after digestion) were used. The sum of the mentioned Tier 2 emission factors was applied in the following equation:

$$E_{Biogas\,NH_3} = EF_{Default\,NH_3} \times AD_{Total\,Biogas\,Production} \times Conversion\ Factor$$

Where E_{Biogas_NH3} is ammonia emissions from biogas production (Gg);
$EF_{Default\_NH3}$ is the sum of the two emission factors from the 2016 EMEP/EEA guidebook;
$AD_{Total\ Biogas\ Production}$ is converted activity data from National Statistics;
Conversion Factor is the number to convert units to Gg per year.

6.6 Waste Incineration (5.C)

6.6.1 Overview of the Sector

Emissions from waste incineration in Lithuania contribute only a small amount of the total pollutant emissions. With no municipal waste incineration, amounts of industrial waste and clinical waste incinerated have decreased resulting in smaller pollutant emissions. Emissions from *NFR 5.C.1.b.i* – ii categories decreased by about 18.3% from 2005 to 2015. Emissions from cremation (*NFR 5.C.1.b.v*) are small as well.

6.7 Municipal Waste Incineration (NFR 5.C.1.A)

6.7.1 Overview of the Sector

Emissions from municipal waste incineration were recalculated. In 1990 only 2.5 tons of waste were burnt without energy recovery. It was assumed that minimal abatement technologies were used at that time.

In 2015 UAB Fortum Klaipeda was the major company incinerating municipal/ industrial waste (non-hazardous municipal and non-hazardous industrial) with energy recovery, thus emissions from UAB Fortum Klaipeda are reported under 1.A.1.a category and 5.C.1.A is labelled as NO. The company started operating in 2013 and has been incinerating 140 – 300 thousand tons of waste and biomass every year. Sophisticated technologies are installed in the company to minimize air pollution from the process:

- Natural gas is used during incineration initiation and termination;
- First chamber incineration temperature is 850 – 1100°C;
- Waste separation, size reduction and mixing;
- Semi-dry smoke technology equipment with CaO and active carbon reagents. fabric filter and SNKR – selective non catalytic reduction;
- And other.

In 2014 facility incinerated 22.8 Gg of non-hazardous industrial waste and 119.7 Gg of non-hazardous municipal waste: cardboard and paper waste, organic waste, flammable waste, mechanically processed waste, textile waste and other.

From 2015 UAB Toksika started incinerating hazardous waste with energy recovery. Therefore, part of the emissions from the facility will be reported under the *NFR 1A1a* category.

6.7.2 Methodology

Activity data and information on the UAB Fortum Klaipeda were obtained from Lithuanian Environmental Protection Agency database

There has not been any waste incinerations in Lithuania since 2000, thus this category is labelled as NO in the NFR for years after 1999. Until year 2000 default emission factors incorporated into eq. 6.1 were used to determine pollutants' emissions. Data was collected from Lithuania's EPA waste management database.

Default Tier 1 EF values are presented in Table 110.

6.8 Industrial Waste Incineration (NFR 5.C.1.B.i)

6.8.1 Overview of the Sector

In 2015 UAB Toksika and UAB Fortum Klaipeda incinerated industrial waste. However, no emissions are reported under this category as UAB Fortum Klaipeda burns non-hazardous waste with energy recovery, while UAB Toksika incinerates hazardous and medical waste. No information on how much industrial waste was burnt in 1990 was available. Industrial waste incinerated before 2000 was reported as included elsewhere as there was no separation at the time between incinerated municipal and industrial waste. Therefore, emissions from all industrial and municipal waste incinerated are reported under NFR 5C1A category.

6.8.2 Methodology

See 5.C.1.B.iii for details.

6.8.3 Time Series

See details under 5.C.1.B.iii.

6.9 Hazardous Waste Incineration (NFR 5.C.1.B.ii)

6.9.1 Overview of the Sector

Hazardous waste has been incinerated throughout all Lithuania's Independence since 1990 with the largest amount (5.66 kt) incinerated in 2015. Only one company UAB Toksika incinerates hazardous waste in Lithuania. Major hazardous wastes that were incinerated in UAB Toksika in 2015 were:

- Absorbent, filter material, wiping clothes, protective clothing all of which are contaminated with hazardous chemicals (28.8% of the total);
- Contaminated wood, sawdust, and other wood by-products (24.9% of the total).

Please see next section *Clinical Waste Incineration (NFR 5.C.1.B.iii)* for more details.

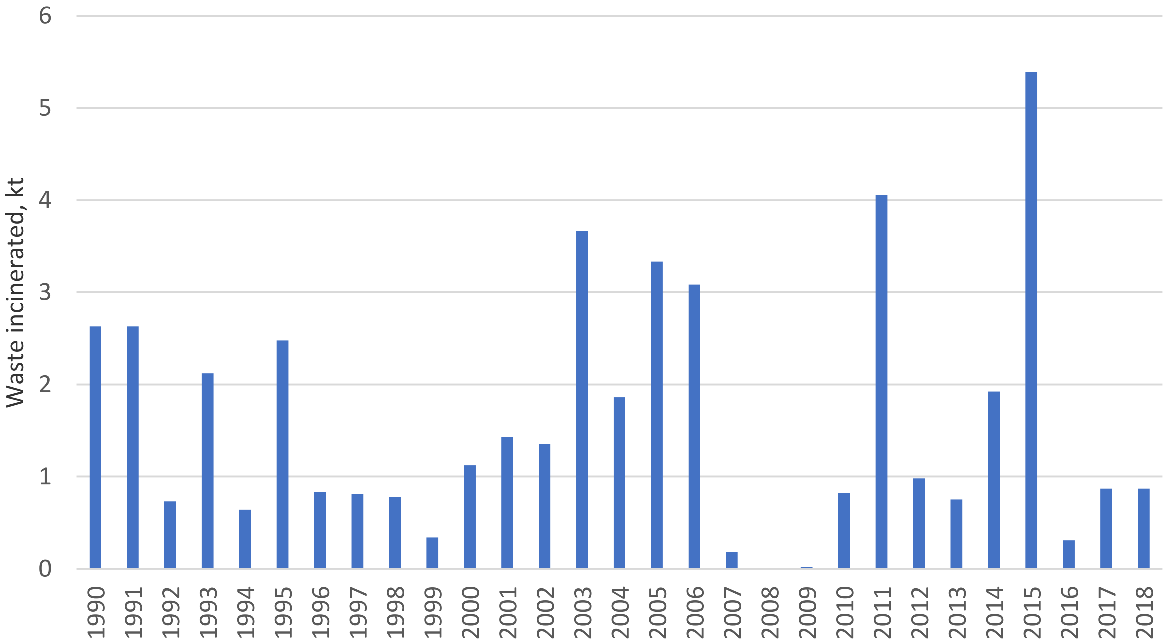

FIGURE 166 AMOUNT OF HAZARDOUS WASTE INCINERATED 1990-2018

6.9.2 Methodology

Activity data for 1990-2018 was obtained from Lithuanian EPA. For the period before 2013, when UAB Toksika started incinerating hazardous waste, emissions from this category were estimated using Tier 1 emission factors from the 2019 EMEP/EEA guidebook, see Table 109. For the activity data gathered from UAB Toksika upper values of Tier 1 emission factors were used.

6.9.3 Time Series

Emissions from this source are relatively small when taking into account whole inventory. In 2015 emissions from this category contributed less than 1% of the total emissions. Comparing 2005 with 2018, emissions decreased by almost 74%.

6.10 Clinical Waste Incineration (NFR 5.C.1.B.iii)

6.10.1 Overview of the Sector

UAB Toksika is one of the major broad-spectrum waste burning facilities in Lithuania at the moment, incinerating up to 3 kilotons of waste per year. Waste that is burnt includes industrial and medical wastes. It is described under this category as the incinerator used for waste combustion is adapted for medical waste incineration (rotary kiln incinerator with sophisticated abatement technologies).

The following abatement is used to minimize emissions from incineration:

- Smoke from incineration is treated using semi-dry scrubbers (consisting of absorption part with NaOH solution injection and second – with $NaHCO_3$ and activated carbon injection system), fabric filter (FF), wet smoke-cleaning system/ scrubber (spray tower), selective non-catalytic reduction (SNCR) system and catalytic (TiO_2 + WO_3 + V_2O_5);
- Temperature in the secondary incineration camera is maintained at 850 - 1100°C;
- Constant pollutant monitoring;
- And other.

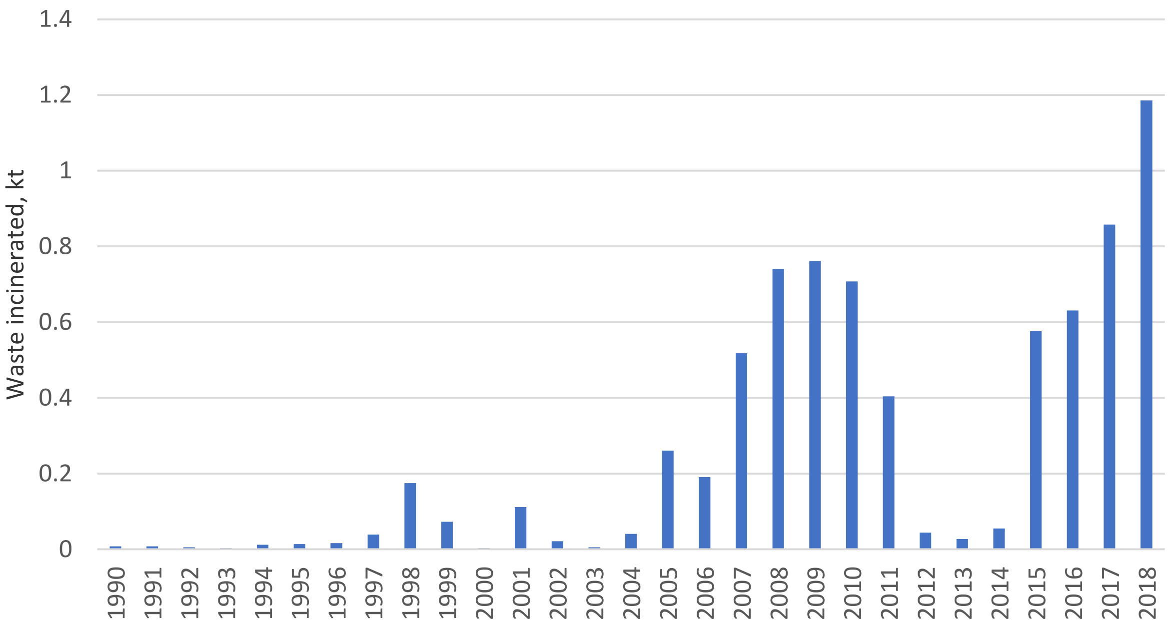

FIGURE 167 AMOUNT OF CLINICAL WASTE INCINERATED FROM 1990 TO 2018.

6.10.2 Methodology

Activity data was gathered from Lithuanian Environmental Protection Agency's database. No detailed information on the facilities which incinerated clinical waste in 1990 is available, thus it was assumed that no abatement technologies were used resulting in application of Tier 1 emission factors for year 1990. In 2015 medical waste was burnt in UAB Toksika which technical specifications are available in Impact on the Environment Report (IER). Inventorization Report (IR) and Integrated

Pollutant Prevention and Control (IPPC) permit. Sophisticated abatement technologies are used in the facility, thus emission factors for controlled incineration in rotary kiln with SD/ CI/ FF abatement from USA EPA 1993 guidelines were used to estimate emission for 2014 and 2015.

Emissions before 2014 were estimated using 1993 USA EPA guidelines for controlled incineration with uncontrolled emissions.

Emissions from this category contribute a minor amount to the total inventory. 354.5% increase is observed in pollutants emissions from 2005 to 2018.

6.11 Sewage Sludge Incineration (NFR 5.C.1.B.iv)

6.11.1 Overview of the Sector

Sewage sludge from wastewater treatment was incinerated in early 1990s (1990 – 1994) and only quantities incinerated are available. There are no currently operating sewage sludge incineration facilities in Lithuania. Although small amounts of sewage sludge have been incinerated since Toksika opening in 2013, the facility incinerates small quantities of contaminated sewage sludge, thus it is not separated under this category but included in *Hazardous waste incineration* (NFR 5.C.1.b.iii).

6.11.2 Methodology

Activity data was obtained from Lithuanian Environmental Protection Agency.

In 1990 12.45 t of sewage sludge was incinerated. Tier 2 emission factors from 2019 EMEP/ EEA guidebook were used to estimate emissions for 1990-1994. After 1995 sewage sludge was not incinerated, thus emissions were reported as not occurring.

6.12 Cremation (5.C.1.b.v)

6.12.1 Overview of the Section

There is only one cremation company in Lithuania AB K2 LT. The facility's construction was finished in the late 2011 after Lithuanian government passed a law on cremation service in 2007. There are sophisticated incineration and pollution prevention technologies installed in the facility, i.e.:

- Electromechanic loading mechanism with hermetical loading cell doors, which prevent coffin incineration in the cremation cell and smoke in gas incineration cell below minimal temperature (650°C and 850°C, respectively);
- The gas incineration cell (at 850 - 900°C) is used to burn smoke emitted in the coffin incineration cell;
- Smoke cleaning system consists of cyclone, chemicals' addition to neutralize pollutants, reactor with spherical rotator for effective chemical additives use in circulation process and fabric filter. Gas cleaning system is mainly used to reduce particulate matter and dioxin/furan emissions. Sorbalit® 30% (activated carbon) is used in the process among other chemicals.
- And other.

Natural gas is used for body combustion in the facility.

6.12.2 Methodology

JSC K2 LT provides information in the Inventorization reports on the estimation of several pollutants from the facility and how/from what sources those pollutants are emitted. However, only 6 pollutants' emissions were predicted (NOx. NMVOC. SOx. TSP. CO. and Hg). It is also noted that no PCDD/PCDF emissions were detected.

Guidebook-provided. default Tier 1 emission factors with facility-level projected abatement efficiency (85 %) were used in equation 6.1.

6.13 Open Burning of Waste (NFR 5.C.2)

6.13.1 Overview of the Sector

Order no. 269 on Environmental Protection Requirements for Burning Plants or Plants' Residues forbids to incinerate more than 5m^3 of agricultural wastes and any incineration of municipal or industrial wastes. Open small-scale waste burning includes burning of crop residues, wood, plastics and other general wastes. These activities statistics are not available on national and institutional databases.

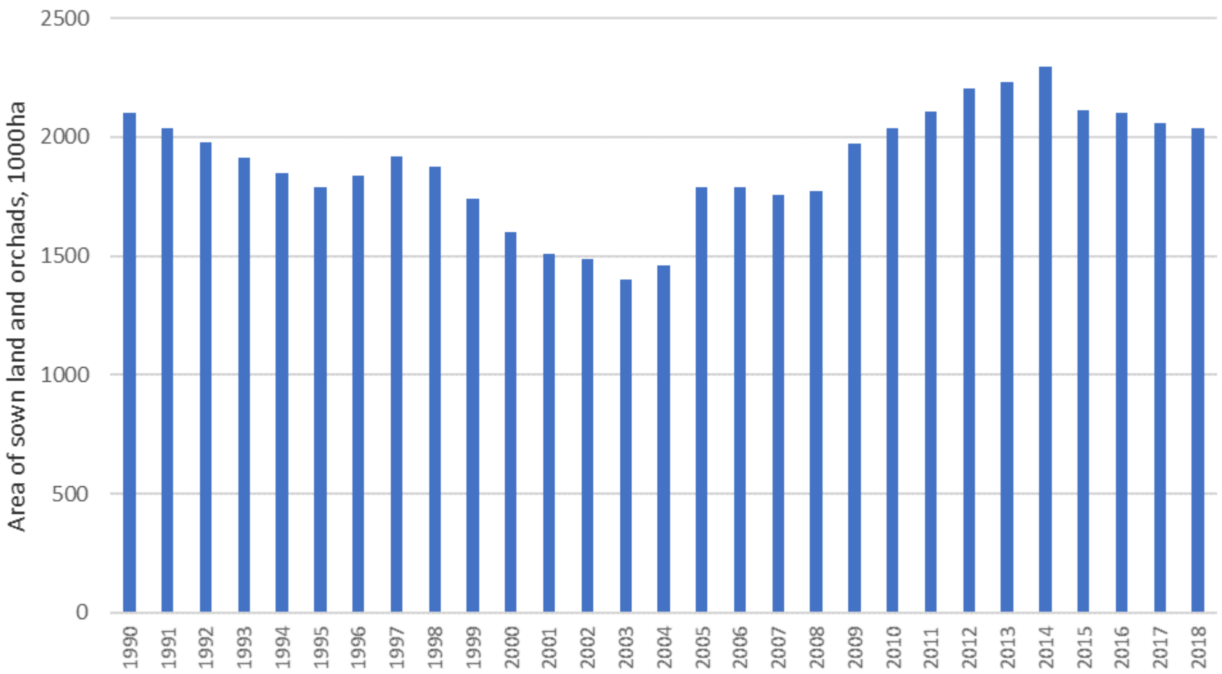

FIGURE 168 AREA OF SOWN LAND AND ORCHADS, 1990-2018

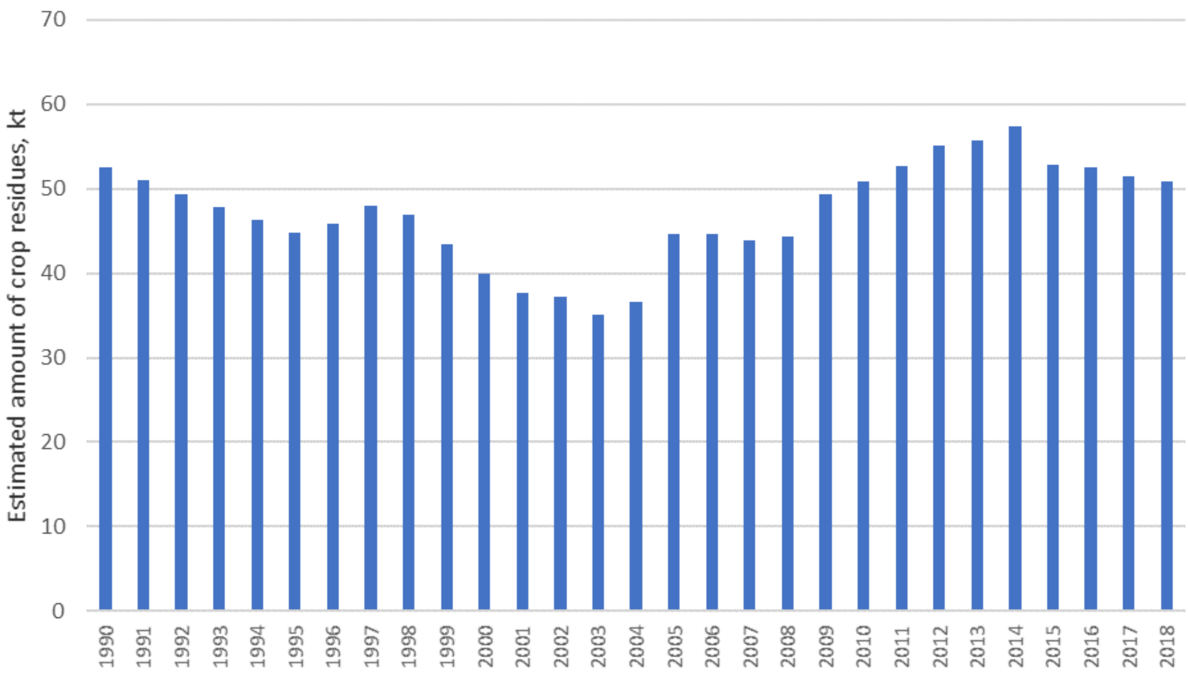

FIGURE 169 ESTIMATED AMOUNT OF CROP RESIDUES, 1990-2018

6.13.2 Methodology

Only emissions from burning of crop residues were estimated on the basis of the propostion that "the average amount of waste burned for arable farmland is estimated to be 25 kg/hectare" (EMEP/EEA guidebook 2019, chapter 5C2).

Statistics of arable farmland was taken from online database of Statistics Lithuania. Emission factors were taken from "Table 3-1 Tier 1 emission factors for source category 5.C.2 Small-scale waste burning" in GB2019.

6.13.3 Time Series

All pollutants release to the atmosphere decreased from 1990 to 2018 due to declining population in Lithuania.

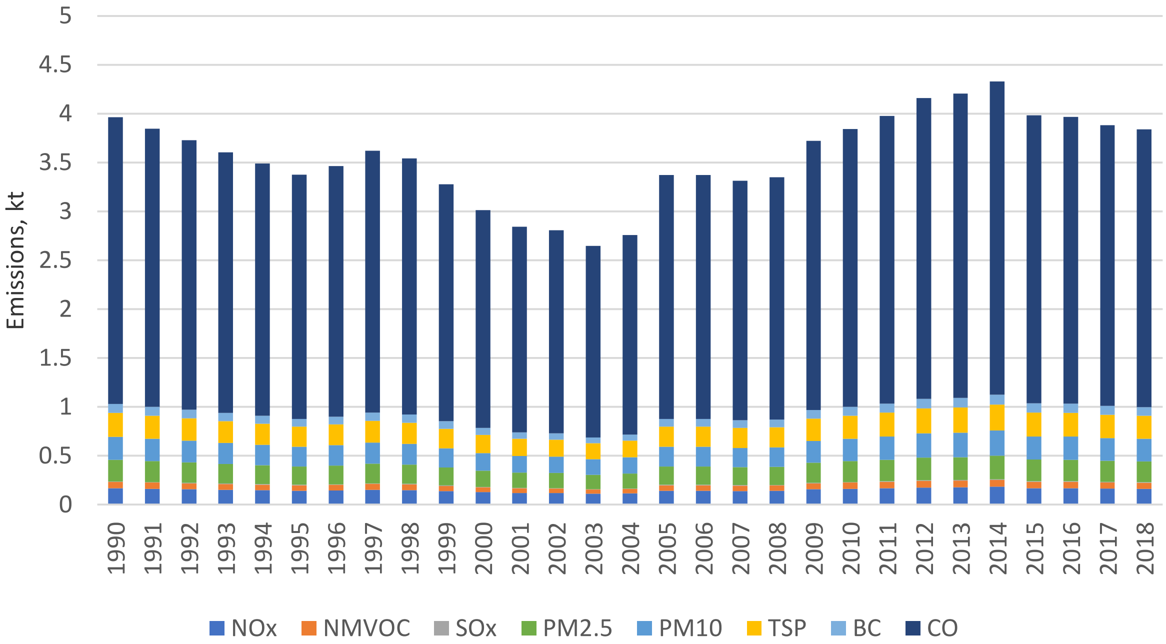

FIGURE 170 POLLUTANT EMISSIONS IN SECTOR 5.C.2, 1990-2018

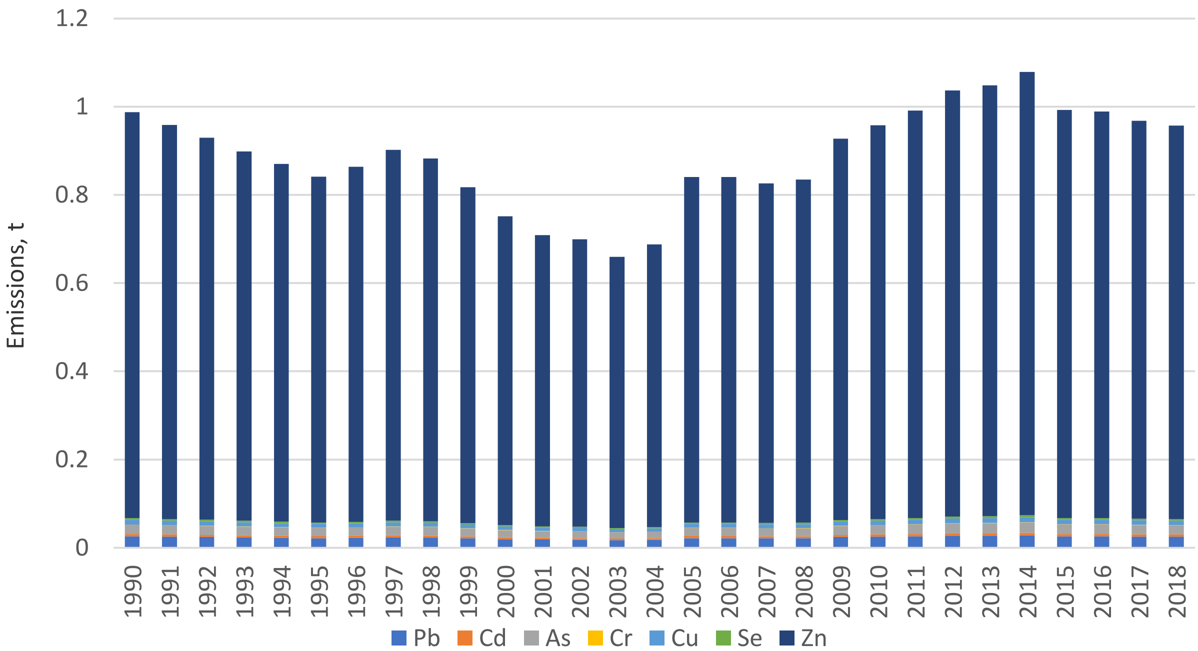

FIGURE 171 HEAVY METAL EMISSIONS IN SECTOR 5.C.2, 1990-2018

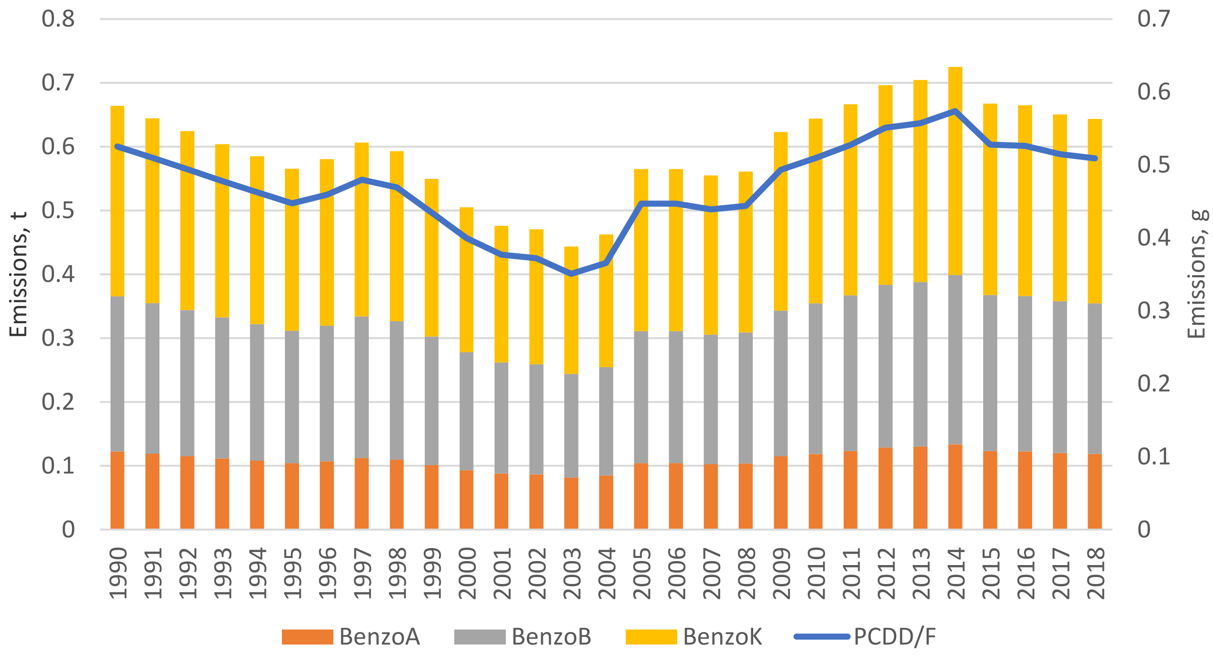

FIGURE 172 PAHS AND PCDD/F EMISSIONS IN SECTOR 5.C.2, 1990-2018

6.14 Wastewater Handling (5.D)

6.14.1 Overview of the Sector

The Council Directive 91/271/EEC which addresses urban waste water treatment was adopted on May 1991 by European Union [14]. According to the Directive all agglomerations having more than 2000 inhabitant equivalents (organic biologically degradable load) must use secondary, biological or equivalent, waste water treatment technology, while those with more than 10 thousand inhabitant equivalents must reduce nitrogen and phosphorus levels as well using tertiary treatment technology. In order to accomplish Directive's requirements 46 waste water treatment mechanisms were reconstructed or built until 2013 [15]. The major treated waste water reception sites are rivers and lakes, minor – Baltic Sea (only by Palanga agglomeration).

6.15 Wastewater Treatment in Industry and Domestically (5.D.1 and 5.D.2)

6.15.1 Overview of the Sector

Information on the waste water treatment for 1990 – 2018 was provided by Lithuanian EPA [16], Water Condition Assessment division specialists. Information was checked with data provided by Statistics Department for period 2002 – 2013. Figure 173 shows that less than 10% of all waste water that is released is cleaned. This is because most of the waste water does not need cleaning, but is still recorded. Not cleaned but still released waste water amounts have decreased significantly from 1990 (by 81.5% from 1990 to 2018).

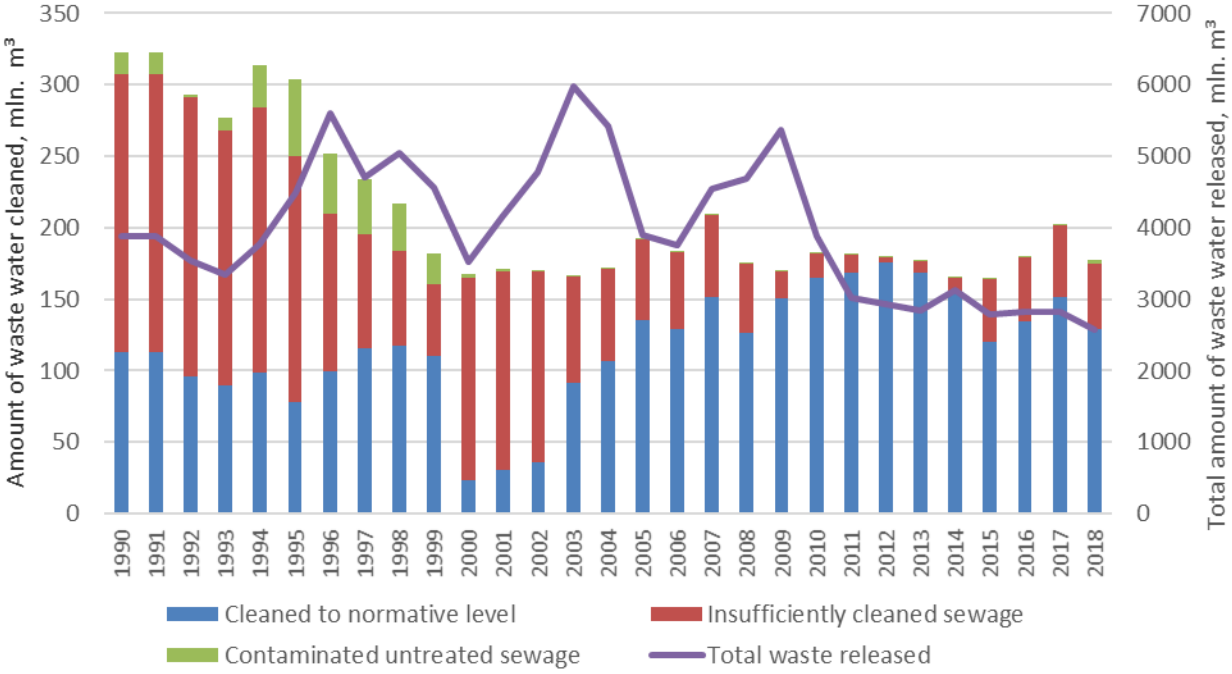

FIGURE 173 AMOUNT (MILLION M³) OF WASTE WATER COLLECTED AND CLEANED TO OR BELOW NORMATIVE LEVEL

6.15.2 Methodology

This category covers emissions from wastewater treatment and transportation. while disposal of sewage is reported under 5A category.

2019 EMEP/ EEA guidebook was used to estimate emissions from this sector. Information of wastewater treatment and discharge for 2002 – 2016 is publicly available on LT EPA (the remaining data for 1991 – 2002 is available on special request). Data gathering is regulated by order no. 408 by Minister of Environment of the Republic of Lithuania introduced on 20/12/1999 and amended twice, last time on 03/01/2013.

Statistics reported by EPA are distributed into two categories according to wastewater's type: a) surface wastewater and b) industrial and domestic wastewater. Surface wastewater is not treated biologically, only using primary treatment or no treatment. Only industrial and domestic wastewater were taken into calculation: treated to required normative values and treated but not to the normative value. The calculation approach is shown in eq. 6.1.

Please note that emissions from wastewater which was released domestically or from industry treatment were not separated into two categories. 5D2 category was labelled as 'IE'.

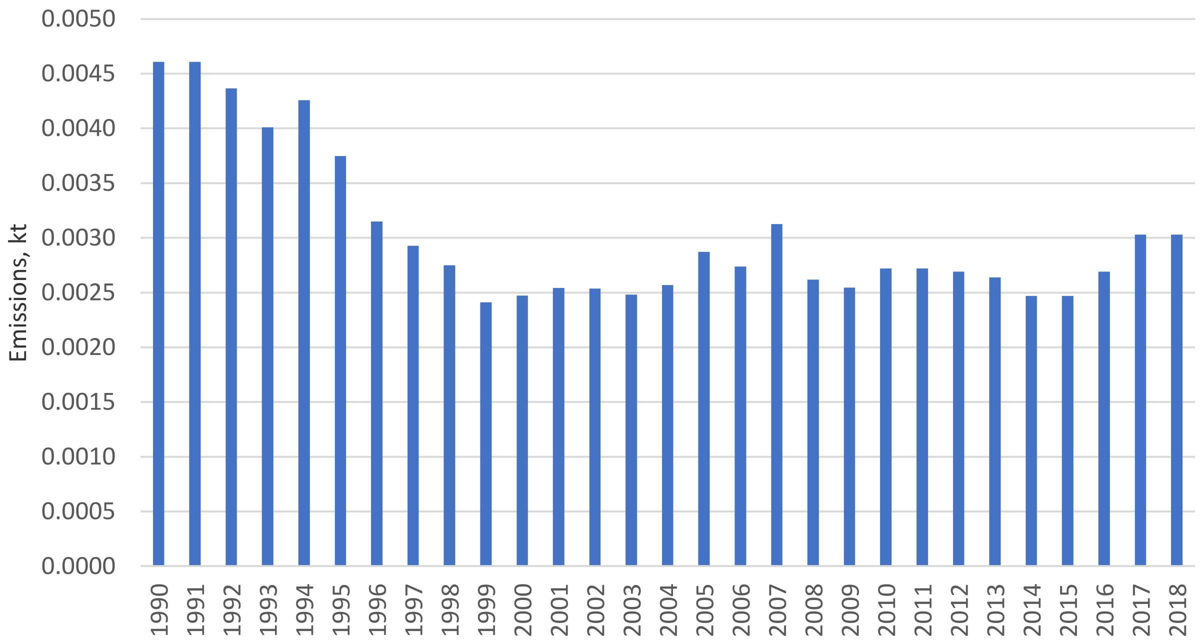

FIGURE 174 NMVOC EMISSIONS IN SECTOR 5.D.1, 1990-2018

As shown in the figure above NMVOC emissions from waste water treatment decreased by 34.2% from 1990 to 2018. It must be noted that untreated waste water released to the surface waters quantities dropped by 81.5% since 1990 (in 2018 it makes 0.107% of all waste water), while volume of waste water which was treated, but not to the normative values and then released to the surface waters makes 1.784% of all waste water, it decreased by 76.4% in comparison to 1990. Less waste water is produced, thus less is needed to be treated. In comparison to 1990, in 2018 there is 33.6% decrease in waste water amount.

6.16 Wastewater Treatment in Residential Sector: Latrines (5.D.3)

6.16.1 Overview of the Sector

Information on the number of households and part of population connected to the sewerage is provided by Lithuanian water suppliers association [17], which members provide clean water and treat waste water nationwide. The rest of population is assumed to be using septic tanks or latrines. Information on population part using latrines was gathered from Lithuania Statistics. Lithuania Statistics has conducted surveys on this topic since 2005.

Much larger part of rural inhabitants is utilizing latrines (about 20-30% of rural population is connected to the sewerage), while percentage is smaller for city population, which 90-96% is connected to centralized sewerage [18].

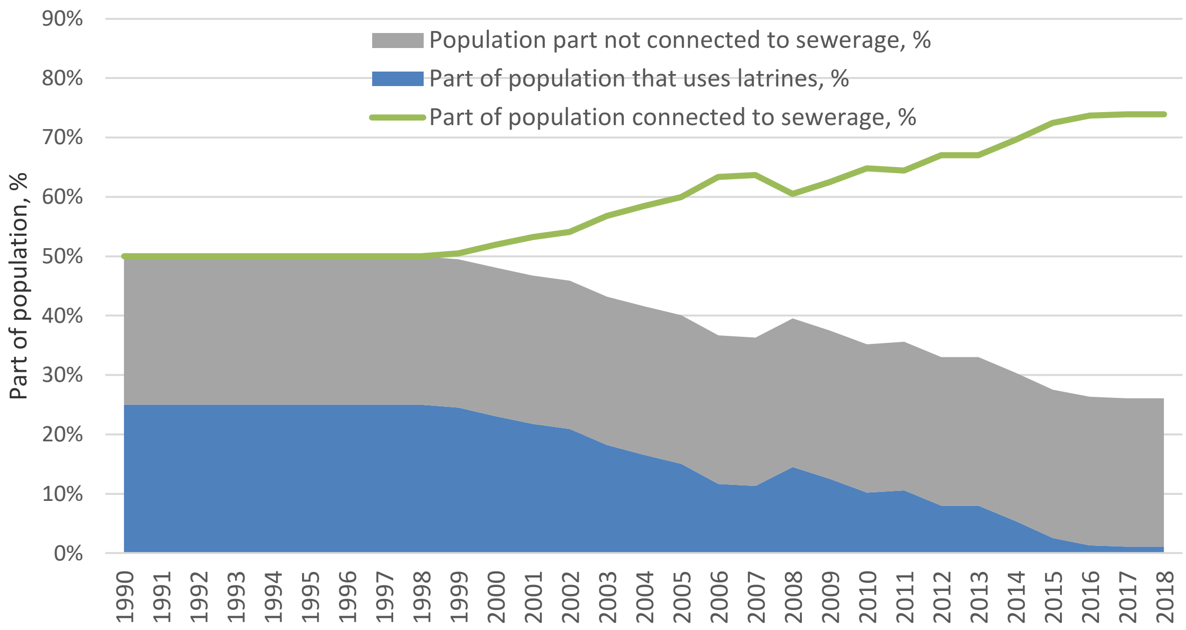

FIGURE 175 PART OF POPULATION (%) THAT IS CONNECTED OR NOT CONNECTED TO THE SEWERAGE AND PERCENTAGE OF POPULATION THAT IS USING LATRINES.

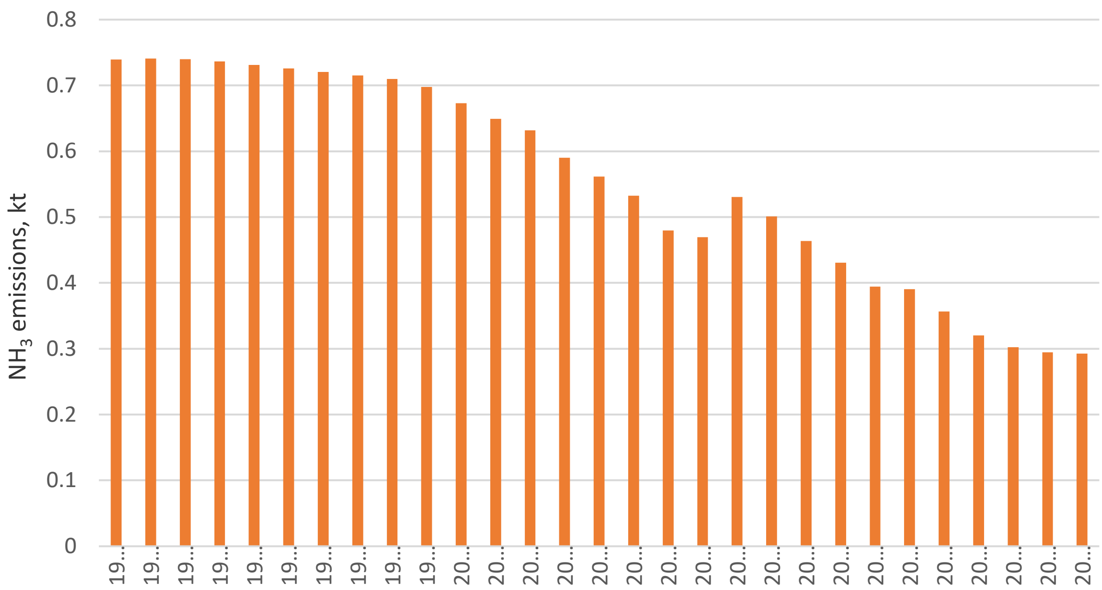

FIGURE 176 NH_3 EMISSIONS IN SECTOR 5.D.3, 1990-2018

6.16.2 Methodology

Calculation of emissions from this section was based on the population part which is using latrines. The percentage of population utilizing latrines during 2005 – 2018 and population size from 1990 to 2018 were gathered from Lithuania Statistics.

Statistics on the population part using latrines for the 1990 – 2004 period was calculated using 11 data points (2005 – 2016 statistics). Correlation line was drawn with resulting correlation factor $R^2 = 0.948$ (please see Appendix). Default Tier 2 emission factor from 2019 EMEP/ EEA guidebook was used in eq. 6.1 to determine ammonia emissions.

Emissions from this section are steadily decreasing as larger part of population connect to the sewerages or install septic tanks. In the future emissions from this category ought to reach smaller values closer to zero.

6.17 Other Waste, Including House. Industrial and Car Fires (5E)

6.17.1 Overview of the Sector

Database on car and building fires statistics was established in 2004 by the Fire and Rescue Department under the Ministry of the Interior of the Republic of Lithuania (FRD). The detailed information is publicly available on institution's website [4]. Values before 2005 were estimated using averages of building fires per total registered fires. Please see figure below.

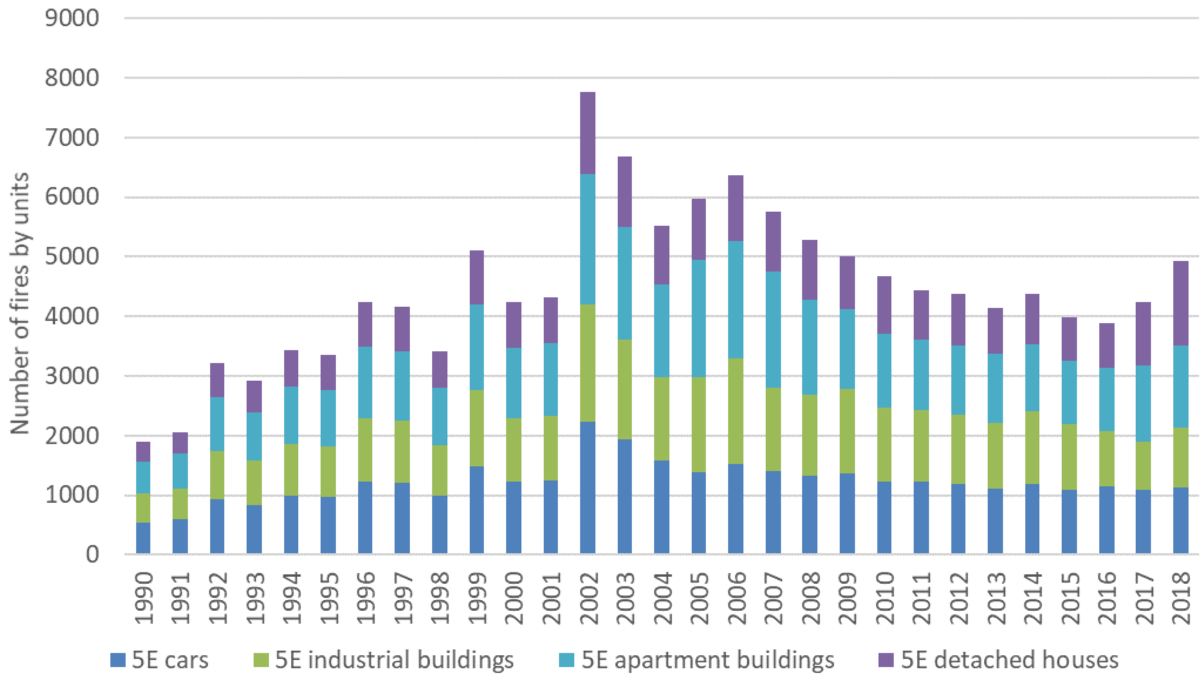

FIGURE 177. TOTAL NUMBER FIRES BY CATEGORY FOR THE PERIOD 1990-2018.

Registered fire rate increased by about 159% from 1990 to 2018. The major categories contributing to the total number of fires are detached houses and apartment buildings fires, while the least occurring - car fires.

6.17.2 Methodology

Statistics from 2005 to 2018 on the numbers of fires of cars, houses and industrial buildings were obtained from Fire and Rescue Department under the Ministry of the Interior of the Republic of

Lithuania. The total number of registered fires per year were gathered from National Statistics Yearbooks and compared with data from FRD.

Ratios between the number of specific fires (e.g. flat, car and etc.) per year and total number of fires on that year were averaged. Total number of fires for the 1990 – 2005 period was used with obtained averaged ratios in order to estimate numbers of specific fires on specific years before 2005. See Figure 177 for results.

Default Tier 2 emission factors from 2019 EMEP/ EEA guidebook with numbers of specific fires per year were used to estimate pollution from this category. See Annex1: Table 111, Table 112, Table 113, Table 114.

6.17.3 Time Series and Key Categories

There is a direct relationship between emissions and number of fires. Both pollution (comparing 1990 and 2018 emissions in kt) from this category and number of fires increased by a factor of 2.40 from 1990 to 2018, while pollutants release to the atmosphere increased by 4.95% from 2005 to 2018. Please see figure below.

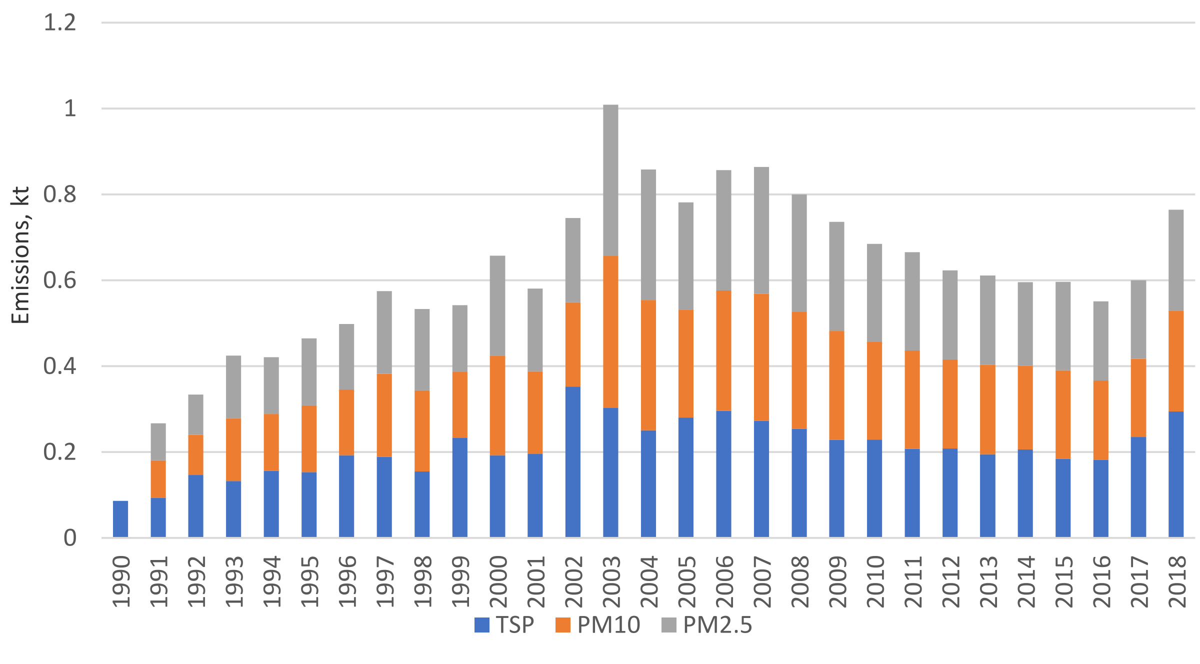

FIGURE 178 POLLUTANT EMISSIONS IN SECTOR 5.E, 1990-2018

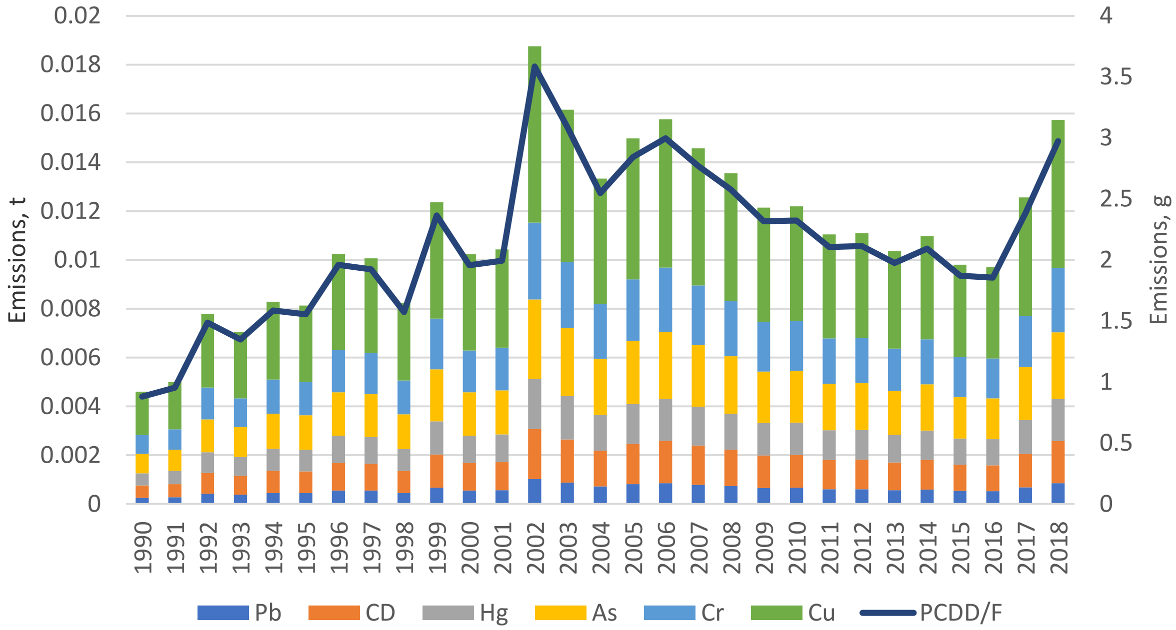

FIGURE 179 EMISSIONS OF HEAVY METALS AND PCDD/F IN SECTOR 5.E, 1990-2018

7 REFERENCES

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ANNEX 1

1.A.1.a

TABLE 49 TIER 1 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.1.A USING BIOMASS (GB 2019 TABLE 3-7)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.1.a**	**Public electricity and heat production**			
Fuel	**Biomass**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	81	g/GJ	40	160	Nielsen et al., 2010
CO	90	g/GJ	45	180	Nielsen et al., 2010
NMVOC	7.31	g/GJ	2.44	21.9	US EPA (2003), chapter 1.6
SOx	10.8	g/GJ	6.45	15.1	US EPA (2003), chapter 1.6
TSP	172	g/GJ	86	344	US EPA (2003), chapter 1.6
PM10	155	g/GJ	77	310	US EPA (2003), chapter 1.6
PM2.5	133	g/GJ	66	266	US EPA (2003), chapter 1.6
BC	3.3	% of PM2.5	1.6	6.6	See Note
Pb	20.6	mg/GJ	12.4	28.9	US EPA (2003), chapter 1.6
Cd	1.76	mg/GJ	1.06	2.47	US EPA (2003), chapter 1.6
Hg	1.51	mg/GJ	0.903	2.11	US EPA (2003), chapter 1.6
As	9.46	mg/GJ	5.68	13.2	US EPA (2003), chapter 1.6
Cr	9.03	mg/GJ	5.42	12.6	US EPA (2003), chapter 1.6
Cu	21.1	mg/GJ	12.6	29.5	US EPA (2003), chapter 1.6
Ni	14.2	mg/GJ	8.51	19.9	US EPA (2003), chapter 1.6
Se	1.2	mg/GJ	0.722	1.69	US EPA (2003), chapter 1.6
Zn	181	mg/GJ	108	253	US EPA (2003), chapter 1.6
PCB	3.5	µg/GJ	0.35	35	US EPA (2003), chapter 1.6
PCDD/F	50	ng I-TEQ/GJ	25	75	UNEP (2005) (for clean wood)
Benzo(a)pyrene	1.12	mg/GJ	0.671	1.57	US EPA (2003), chapter 1.6
Benzo(b)fluoranthene	0.043	mg/GJ	0.0215	0.0645	US EPA (2003), chapter 1.6
Benzo(k)fluoranthene	0.0155	mg/GJ	0.00774	0.0232	US EPA (2003), chapter 1.6
Indeno(1,2,3-cd)pyrene	0.0374	mg/GJ	0.0187	0.0561	US EPA (2003), chapter 1.6
HCB	5	µg/GJ	0.5	50	Bailey, 2001

Note: For conversion of the US EPA data units have been converted using 1055.0559 J/BTU and 453.59237 g/lb. The BC emission factor is an average of the data in Dayton & Bursey (2001) and the Speciate database (US EPA, 2011).

TABLE 50 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.1.A, DRY BOTTOM BOILERS USING RESIDUAL OIL (GB TABLE 3-11)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.A.1.a**	**Public electricity and heat production**
Fuel	**Residual Oil**	

SNAP (if applicable)	010101 010102	Public power - Combustion plants >= 300 MW (boilers) Public power - Combustion plants >= 50 and < 300 MW (boilers)			
Technologies/Practices	Dry Bottom Boilers				
Not applicable					
Not estimated	NH_3, PCBs, Benzo(a)pyrene, HCB				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	142	g/GJ	70	300	US EPA (2010), chapter 1.3
CO	15.1	g/GJ	9.06	21.1	US EPA (2010), chapter 1.3
NMVOC	2.3	g/GJ	1.4	3.2	US EPA (2010), chapter 1.3
SOx	495	g/GJ	146	1700	See Note
TSP	35.4	g/GJ	2	200	US EPA (2010), chapter 1.3
PM10	25.2	g/GJ	1.5	150	US EPA (2010), chapter 1.3
PM2.5	19.3	g/GJ	0.9	90	US EPA (2010), chapter 1.3
BC	5.6	% of PM2.5	0.22	8.69	See Note
Pb	4.56	mg/GJ	2.28	9.11	US EPA (2010), chapter 1.3
Cd	1.2	mg/GJ	0.6	2.4	US EPA (2010), chapter 1.3
Hg	0.341	mg/GJ	0.17	0.682	US EPA (2010), chapter 1.3
As	3.98	mg/GJ	1.99	7.97	US EPA (2010), chapter 1.3
Cr	2.55	mg/GJ	1.27	5.1	US EPA (2010), chapter 1.3
Cu	5.31	mg/GJ	2.66	10.6	US EPA (2010), chapter 1.3
Ni	255	mg/GJ	127	510	US EPA (2010), chapter 1.3
Se	2.06	mg/GJ	1.03	4.12	US EPA (2010), chapter 1.3
Zn	87.8	mg/GJ	43.9	176	US EPA (2010), chapter 1.3
PCDD/F	2.5	ng I-TEQ/GJ	1.25	3.75	UNEP (2005); Heavy fuel fired power boilers
Benzon(b)fluoranthene	4.5	µg/GJ	1.5	13.5	US EPA (2010), chapter 1.3
Benzon(k)fluoranthene	4.5	µg/GJ	1.5	13.5	US EPA (2010), chapter 1.3
Indeno(1,2,3-cd)pyrene	6.92	µg/GJ	3.46	13.8	US EPA (2010), chapter 1.3

TABLE 51 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.1.A, DRY BOTTOM BOILERS USING NATURAL GAS (GB TABLE 3-12)

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.1.a	Public electricity and heat production			
Fuel	Natural Gas				
SNAP (if applicable)	010101 010102	Public power - Combustion plants >= 300 MW (boilers) Public power - Combustion plants >= 50 and < 300 MW (boilers)			
Technologies/Practices	Dry Bottom Boilers				
Not estimated	NH_3, PCBs, HCB				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	89	g/GJ	15	185	US EPA (1998), chapter 1.4
CO	39	g/GJ	20	60	US EPA (1998), chapter 1.4
NMVOC	2.6	g/GJ	0.65	10.4	US EPA (1998), chapter 1.4
SOx	0.281	g/GJ	0.169	0.393	US EPA (1998), chapter 1.4
TSP	0.89	g/GJ	0.445	1.34	US EPA (1998), chapter 1.4
PM10	0.89	g/GJ	0.445	1.34	US EPA (1998), chapter 1.4

PM2.5	0.89	g/GJ	0.445	1.34	US EPA (1998), chapter 1.4
BC	2.5	% of PM2.5	1	6.3	See Note
Pb	0.0015	mg/GJ	0.0005	0.0045	Nielsen et al., 2012
Cd	0.00025	mg/GJ	0.00008	0.00075	Nielsen et al., 2012
Hg	0.1	mg/GJ	0.01	1	Nielsen et al., 2010
As	0.12	mg/GJ	0.04	0.36	Nielsen et al., 2012
Cr	0.00076	mg/GJ	0.00025	0.00228	Nielsen et al., 2012
Cu	0.000076	mg/GJ	0.000025	0.000228	Nielsen et al., 2012
Ni	0.00051	mg/GJ	0.00017	0.00153	Nielsen et al., 2012
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA (1998), chapter 1.4
Zn	0.0015	mg/GJ	0.0005	0.0045	Nielsen et al., 2012
PCDD/F	0.5	ng I-TEQ/GJ	0.25	0.75	UNEP (2005)
Benzo(a)pyrene	0.56	µg/GJ	0.19	0.56	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Benzo(b)fluoranthene	0.84	µg/GJ	0.28	0.84	
Benzo(k)fluoranthene	0.84	µg/GJ	0.28	0.84	
Indeno(1,2,3-cd)pyrene	0.84	µg/GJ	0.28	0.84	

Note: The BC emission factor is the average of the data available in England et al. (2004), Wien et al. (2004) and the Speciate database (US EPA, 2011).

TABLE 52 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.1.A, GAS TURBINES USING GASEOUS FUELS (GB TABLE 3-17)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.1.a**	**Public electricity and heat production**			
Fuel	**Gaseous Fuels**				
SNAP (if applicable)	**010104**	**Public power - Gas turbines**			
Technologies/Practices	**Gas Turbines**				
Not estimated	**NH_3, PCB, PCDD/F, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	48	g/GJ	28	68	Nielsen et al., 2010
CO	4.8	g/GJ	1	70	Nielsen et al., 2010
NMVOC	1.6	g/GJ	0.5	7.6	Nielsen et al., 2010
SOx	0.281	g/GJ	0.169	0.393	See note
TSP	0.2	g/GJ	0.05	0.8	BUWAL, 2001
PM10	0.2	g/GJ	0.05	0.8	BUWAL, 2001
PM2.5	0.2	g/GJ	0.05	0.8	Assumed equal to PM2.5
BC	2.5	% of PM2.5	1	6.3	See Note
Pb	0.0015	mg/GJ	0.0005	0.0045	Nielsen et al., 2012
Cd	0.00025	mg/GJ	0.00008	0.00075	Nielsen et al., 2012
Hg	0.1	mg/GJ	0.01	1	Nielsen et al., 2010
As	0.12	mg/GJ	0.04	0.36	Nielsen et al., 2012
Cr	0.00076	mg/GJ	0.00025	0.00228	Nielsen et al., 2012
Cu	0.000076	mg/GJ	0.000025	0.000228	Nielsen et al., 2012
Ni	0.00051	mg/GJ	0.00017	0.00153	Nielsen et al., 2012
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA (1998), chapter 1.4
Zn	0.0015	mg/GJ	0.0005	0.0045	Nielsen et al., 2012
Benzo(a)pyrene	0.56	µg/GJ	0.19	0.56	US EPA (1998), chapter 1.4 ("Less than" value based on method detection

					limits)
Benzo(b)fluoranthene	1.58	µg/GJ	0.5	4.7	API, 1998
Benzo(k)fluoranthene	1.11	µg/GJ	0.4	3.3	API, 1998
Indeno(1,2,3-cd)pyrene	8.36	µg/GJ	2.8	25.1	API, 1998

TABLE 53 TIER 1 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.1.B. REFINERY GAS (GB2019 TABLE 4-2)

Tier 1 default emission factors					
	Code	**Name**			
NFR Source Category	**1.A.1.b**	**Petroleum refining**			
Fuel	**Refinery Gas**				
Not applicable					
Not estimated	**NH_3, PCDD/F, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	**63**	**g/GJ**	**31.5**	**84.4**	**US EPA (1998), chapter 1.4**
CO	12.1	g/GJ	7.3	17	Concawe (2015)
NMVOC	2.58	g/GJ	1.29	5.15	US EPA (1998), chapter 1.4
SOx	0.281	g/GJ	0.169	0.393	US EPA (1998), chapter 1.4
TSP	0.89	g/GJ	0.297	2.67	US EPA (1998), chapter 1.4
PM10	0.89	g/GJ	0.297	2.67	US EPA (1998), chapter 1.4
PM2.5	0.89	g/GJ	0.297	2.67	US EPA (1998), chapter 1.4
BC	18.4	% of PM2.5	5.2	36.3	US EPA, 2011
Pb	1.79	mg/GJ	0.895	3.58	API (1998, 2002)
Cd	0.712	mg/GJ	0.356	1.42	API (1998, 2002)
Hg	0.086	mg/GJ	0.043	0.172	API (1998, 2002)
As	0.343	mg/GJ	0.172	0.686	API (1998, 2002)
Cr	2.75	mg/GJ	1.37	5.48	API (1998, 2002)
Cu	2.22	mg/GJ	1.11	4.44	API (1998, 2002)
Ni	3.6	mg/GJ	1.8	7.2	API (1998, 2002)
Se	0.42	mg/GJ	0.21	0.84	API (1998, 2002)
Zn	25.5	mg/GJ	12.8	51	API (1998, 2002)
Benzo(a)pyrene	0.669	µg/GJ	0.223	2.01	API (1998, 2002)
Benzo(b)fluoranthene	1.14	µg/GJ	0.379	3.41	API (1998, 2002)
Benzo(k)fluoranthene	0.631	µg/GJ	0.21	1.89	API (1998, 2002)
Indeno(1,2,3-cd)pyrene	0.631	µg/GJ	0.21	1.89	API (1998, 2002)

TABLE 54 TIER 2 EMISSION FACTORS FOR LINE-HAUL LOCOMOTIVES (GB2019 TABLE 3.2)

Tier 2 default emission factors					
	Code	**Name**			
NFR Source Category	**1.A.3.c**	**Railways**			
Fuel	**Gas Oil/Diesel**				
SNAP (if applicable)	**080203**	**Locomotives**			
Technologies	**Line-haul locomotives**				
Not applicable	**Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, PCB, HCB**				
Not estimated	**SOx, Pb, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	63	kg/tonne	29	93	Halder et al. (2005)
CO	18	kg/tonne	5	21	See Note 1
NMVOC	4.8	kg/tonne	2	9	See Note 1
NH3	10	g/tonne	0	0	See Note 3
TSP	1.8	kg/tonne	0.32	6	See Note 2
PM10	1.2	kg/tonne	0.45	3	Halder et al. (2005)
PM2.5	1.1	kg/tonne	0.42	3	See Note 2
N2O	24	g/tonne	0	0	See Note 3
CH4	182	g/tonne	77	350	See Note 1
CO2	3140	kg/tonne	3120	3160	Derived from carbon balance

TABLE 55 TIER 2 EMISSION FACTORS FOR SHUNTING LOCOMOTIVES (GB2019 TABLE 3.3)

Tier 2 default emission factors					
	Code	**Name**			
NFR Source Category	**1.A.3.c**	**Railways**			
Fuel	**Gas Oil/Diesel**				
SNAP (if applicable)	**080201**	**Shunting Locomotives**			
Technologies	**Shunting locomotives**				
Not applicable	**HCH, PCB, HCB**				
Not estimated	**SOx, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	54.4	kg/tonne	27	85	Halder et al. (2005)
CO	10.8	kg/tonne	2	18	See Note 1
NMVOC	4.6	kg/tonne	1	8	See Note 1
NH3	10	g/tonne	0	0	See Note 3
TSP	3.1	kg/tonne	0.75	5	See Note 2
PM10	2.1	kg/tonne	0.53	4	Halder et al. (2005)
PM2.5	2	kg/tonne	0.5	4	See Note 2
N2O	24	g/tonne	0	0	See Note 3
CH4	176	g/tonne	41	297	See Note 1
CO2	3190	kg/tonne	726	5340	Derived from carbon balance

TABLE 56 TIER 2 EMISSION FACTORS FOR RAILCARS (GB2019 TABLE 3.4)

Tier 2 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.c	Railways			
Fuel	Gas Oil/Diesel				
SNAP (if applicable)	080202	Rail Cars			
Technologies	Rail Cars s				
Not applicable	HCH, PCB, HCB				
Not estimated	SOx, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	39.9	kg/tonne	22	78	Halder et al. (2005)
CO	10.8	kg/tonne	6	20	See Note 1
NMVOC	4.7	kg/tonne	2	8	See Note 1
NH3	10	g/tonne	0	0	See Note 3
TSP	1.5	kg/tonne	0.24	9	See Note 2
PM10	1.1	kg/tonne	0.28	4	Halder et al. (2005)
PM2.5	1	kg/tonne	0.26	3	See Note 2
N2O	24	g/tonne	0	0	See Note 3
CH4	179	g/tonne	93	321	See Note 1
CO2	3140	kg/tonne	3120	3160	Derived from carbon balance

Notes:

1. Derived Tier 2 EF scaled by the range of engine powers, and specific fuel consumptions, as reported in Halder et al. 2005.
2. PM10 EFs taken from Halder et al. 2005. PM2.5 was considered 95 % of PM10 and PM10 was considered 95 % of TSP.
3. Taken from conventional heavy-duty trucks included in the Exhaust Emissions from Road Transport Chapter (1.A.3.b.iii)
4. POPs, heavy metals and SO2: use Tier 1 methods and emission factors
5. BC fraction of PM (f-BC): 0.65.

TABLE 57 TIER 1 EMISSION FACTORS FOR SHIPS USING BUNKER FUEL OIL (GB2019 TABLE 3-1)

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.d	Navigation			
Fuel	Bunker Fuel Oil				
Not estimated	SOx. Pb. Hg. As. PCDD/F. B(k)F. I(1.2.3.-cd)pyrene				
Not applicable	DDT. PCB. HCB				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	79.3	kg/tonne	0	0	Entec (2007). See also note (2)
CO	7.4	kg/tonne	0	0	Lloyd's Register (1995)
NMVOC	2.7	kg/tonne	0	0	Entec (2007). See also note (2)
SOx	20	kg/tonne	0	0	Note value of 20 should read
TSP	6.2	kg/tonne	0	0	Entec (2007)
PM10	6.2	kg/tonne	0	0	Entec (2007)

PM2.5	5.6	kg/tonne	0	0	Entec (2007)
Pb	0.18	g/tonne	0	0	average value
Cd	0.02	g/tonne	0	0	average value
Hg	0.02	g/tonne	0	0	average value
As	0.68	g/tonne	0	0	average value
Cr	0.72	g/tonne	0	0	average value
Cu	1.25	g/tonne	0	0	average value
Ni	32	g/tonne	0	0	average value
Se	0.21	g/tonne	0	0	average value
Zn	1.2	g/tonne	0	0	average value
PCB	0.57	mg/tonne	0	0	Cooper (2005)
HCB	0.14	kg/tonne	0	0	Cooper (2005)

TABLE 58 TIER 1 EMISSION FACTORS FOR SHIPS USING MARINE DIESEL OIL/MARINE GAS OIL (GB2019 TABLE 3-2)

Tier 1 default emission factors					
	Code	**Name**			
NFR Source Category	**1.A.3.d**	**Navigation**			
Fuel	**Marine diesel oil/marine gas oil**				
Not estimated	**NH3, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1.2.3-cd)pyrene, Total 4 PAHs**				
Not applicable	**Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex.**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	78.5	kg/tonne	0	0	Entec (2007). See also note [2]
CO	7.4	kg/tonne	0	0	Lloyd’s Register (1995)
NMVOC	2.8	kg/tonne	0	0	Entec (2007). See also note [2]
SOx	20	kg/tonne	0	0	Note value of 20 should read
TSP	1.5	kg/tonne	0	0	Entec (2007)
PM10	1.5	kg/tonne	0	0	Entec (2007)
PM2.5	1.5	kg/tonne	0	0	Entec (2007)
Pb	0.13	g/tonne	0	0	average value
Cd	0.01	g/tonne	0	0	average value
Hg	0.03	g/tonne	0	0	average value
As	0.04	g/tonne	0	0	average value
Cr	0.05	g/tonne	0	0	average value
Cu	0.88	g/tonne	0	0	average value
Ni	1	g/tonne	0	0	average value
Se	0.1	g/tonne	0	0	average value
Zn	1.2	g/tonne	0	0	average value
PCB	0.038	mg/tonne	0	0	Cooper (2005)
HCB	0.08	mg/tonne	0	0	Cooper (2005)

Notes

[1] S = percentage sulphur content in fuel; pre-2000 fuels: 0.5 % wt. [source: Lloyd’s Register. 1995]. For European Union as specified in the Directive 2005/33/EC: a. 0.2 % wt. from 1 July 2000 and 0.1 % wt. from 1 January 2008 for marine diesel oil/marine gas oil used by seagoing ships (except if used by ships crossing a frontier between a third country and a Member State);

b. 0.1% wt. from 1 January 2010 for inland waterway vessels and ships at berth in Community ports.

[2] Emission factors for NOx and NMVOC are the 2000 values in cruise for medium speed engines (see Tier 2).

[3] Reference: ‘average value’ is between Lloyd’s Register (1995) and Cooper and Gustafsson (2004)

[4] BC fraction of PM (f-BC) = 0.31. Source: for further information see Appendix A.

TABLE 59 TIER 1 EMISSION FACTORS FOR SHIPS USING GASOLINE (GB2019 TABLE 3-3)

Tier 1 default emission factors					
	Code	**Name**			
NFR Source Category	**1.A.3.d**	**Navigation**			
Fuel	**Marine diesel oil/marine gas oil**				
Not estimated	**NH3. Benzo(a)pyrene. Benzo(b)fluoranthene. Benzo(k)fluoranthene. Indeno(1.2.3-cd)pyrene. Total 4 PAHs**				
Not applicable	**Aldrin. Chlordane. Chlordecone. Dieldrin. Endrin. Heptachlor. Heptabromo-biphenyl. Mirex.**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	9.4	kg/tonne	0	0	Winther & Nielsen (2006)
CO	573.9	kg/tonne	0	0	Winther & Nielsen (2006)
NMVOC	181.5	kg/tonne	0	0	Winther & Nielsen (2006)
SOx	20	kg/tonne	0	0	Winther & Nielsen (2006)
TSP	9.5	kg/tonne	0	0	Winther & Nielsen (2006)
PM10	9.5	kg/tonne	0	0	Winther & Nielsen (2006)
PM2.5	9.5	kg/tonne	0	0	Winther & Nielsen (2006)

Notes: The table contains averaged figures between 2-stroke and 4-stroke engines. assuming a share of 75% 2-stroke and 25% 4-stroke ones. If more detailed data are available, the Tier 2 method should be used. BC fraction of PM (f-BC) = 0.05

1.A.4.

TABLE 60 TIER 1 EMISSION FACTORS FOR NFR SOURCE CATEGORY 1.A.4.B, USING HARD COAL AND BROWN COAL (GB2019 TABLE 3.3)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Hard Coal and Brown Coal**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	110	g/GJ	36	200	GB (2006) chapter B216
CO	4600	g/GJ	3000	7000	GB (2006) chapter B216
NMVOC	484	g/GJ	250	840	GB (2006) chapter B216
SOx	900	g/GJ	300	1000	GB (2006) chapter B216
NH3	0.3	g/GJ	0.1	7	GB (2006) chapter B216
TSP	444	g/GJ	80	600	GB (2006) chapter B216
PM10	404	g/GJ	76	480	GB (2006) chapter B216
PM2.5	398	g/GJ	72	480	GB (2006) chapter B216
BC	6.4	% of PM2.5	2	26	Zhang et al., 2012
Pb	130	mg/GJ	100	200	GB (2006) chapter B216
Cd	1.5	mg/GJ	0.5	3	GB (2006) chapter B216
Hg	5.1	mg/GJ	3	6	GB (2006) chapter B216
As	2.5	mg/GJ	1.5	5	GB (2006) chapter B216
Cr	11.2	mg/GJ	10	15	GB (2006) chapter B216

Cu	22.3	mg/GJ	20	30	GB (2006) chapter B216
Ni	12.7	mg/GJ	10	20	GB (2006) chapter B216
Se	120	mg/GJ	60	240	GB (2006) chapter B216
Zn	220	mg/GJ	120	300	GB (2006) chapter B216
PCB	170	μg/GJ	85	260	Kakareka et al. (2004)
PCDD/F	800	ng I-TEQ/GJ	300	1200	GB (2006) chapter B216
Benzo(a)pyrene	230	mg/GJ	60	300	GB (2006) chapter B216
Benzo(b)fluoranthene	330	mg/GJ	102	480	GB (2006) chapter B216
Benzo(k)fluoranthene	130	mg/GJ	60	180	GB (2006) chapter B216
Indeno(1,2,3-cd)pyrene	110	mg/GJ	48	144	GB (2006) chapter B216
HCB	0.62	μg/GJ	0.31	1.2	GB (2006) chapter B216

TABLE 61 TIER 1 EMISSION FACTORS FOR NFR SOURCE CATEGORY 1.A.4.B. USING GASEOUS FUELS (GB2019 TABLE 3.4)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Gaseous fuels**				
Not applicable	**PCB, HCB**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	51	g/GJ	31	71	*
CO	26	g/GJ	18	42	*
NMVOC	1.9	g/GJ	1.1	2.6	*
SOx	0.3	g/GJ	0.2	0.4	*
TSP	1.2	g/GJ	0.7	1.7	*
PM10	1.2	g/GJ	0.7	1.7	*
PM2.5	1.2	g/GJ	0.7	1.7	*
BC	5.4	% of PM2.5	2.7	11	*
Pb	0.0015	mg/GJ	0.0008	0.003	*
Cd	0.00025	mg/GJ	0.0001	0.0005	*
Hg	0.1	mg/GJ	0.0013	0.68	*
As	0.12	mg/GJ	0.06	0.24	*
Cr	0.00076	mg/GJ	0.0004	0.0015	*
Cu	0.000076	mg/GJ	0.00004	0.00015	*
Ni	0.00051	mg/GJ	0.0003	0.0010	*
Se	0.011	mg/GJ	0.004	0.011	*
Zn	0.0015	mg/GJ	0.0008	0.003	*
PCDD/F	1.5	ng I-TEQ/GJ	0.8	2.3	*
Benzo(a)pyrene	0.56	μg/GJ	0.19	0.56	*
Benzo(b)fluoranthene	0.84	μg/GJ	0.28	0.84	*
Benzo(k)fluoranthene	0.84	μg/GJ	0.28	0.84	*
Indeno(1,2,3-cd)pyrene	0.84	μg/GJ	0.28	0.84	*

* average of Tier 2 EFs for residential gaseous fuel combustion for all technologies

TABLE 62 TIER 1 EMISSION FACTORS FOR NFR SOURCE CATEGORY 1.A.4.A/C, 1.A.5.A, USING HARD AND BROWN COAL (GB2019 TABLE 3.7)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Hard Coal and Brown Coal**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	173	g/GJ	150	200	GB (2006) chapter B216
CO	931	g/GJ	150	2000	GB (2006) chapter B216
NMVOC	88.8	g/GJ	10	300	GB (2006) chapter B216
SOx	840	g/GJ	450	1000	GB (2006) chapter B216
TSP	124	g/GJ	70	250	GB (2006) chapter B216
PM10	117	g/GJ	60	240	GB (2006) chapter B216
PM2.5	108	g/GJ	60	220	GB (2006) chapter B216
BC	6.4	% of PM2.5	2	26	See Note
Pb	134	mg/GJ	50	300	GB (2006) chapter B216
Cd	1.8	mg/GJ	0.2	5	GB (2006) chapter B216
Hg	7.9	mg/GJ	5	10	GB (2006) chapter B216
As	4	mg/GJ	0.2	8	GB (2006) chapter B216
Cr	13.5	mg/GJ	0.5	20	GB (2006) chapter B216
Cu	17.5	mg/GJ	5	50	GB (2006) chapter B216
Ni	13	mg/GJ	0.5	30	GB (2006) chapter B216
Se	1.8	mg/GJ	0.2	3	GB (2006) chapter B216
Zn	200	mg/GJ	50	500	GB (2006) chapter B216
PCB	170	µg/GJ	85	260	Kakareka et al. (2004)
PCDD/F	203	ng I-TEQ/GJ	40	500	GB (2006) chapter B216
Benzo(a)pyrene	45.5	mg/GJ	10	150	GB (2006) chapter B216
Benzo(b)fluoranthene	58.9	mg/GJ	10	180	GB (2006) chapter B216
Benzo(k)fluoranthene	23.7	mg/GJ	8	100	GB (2006) chapter B216
Indeno(1,2,3-cd)pyrene	18.5	mg/GJ	5	80	GB (2006) chapter B216
HCB	0.62	µg/GJ	0.31	1.2	GB (2006) chapter B216

Note: 900 g/GJ of sulphur dioxide corresponds to 1.2 % S of coal fuel of lower heating value on a dry basis 24 GJ/t and average sulphur retention in ash as value of 0.1.

TABLE 63 TIER 1 EMISSION FACTORS FOR NFR SOURCE CATEGORY 1.A.4.A/C, 1.A.5.A, USING GASEOUS FUELS (GB2019 TABLE 3.8)

Tier 1 emission factors		
	Code	**Name**
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**
Fuel	**Gaseous Fuels**	
Not applicable	**PCB, HCB**	

Not estimated	NH₃				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	74	g/GJ	46	103	*
CO	29	g/GJ	21	48	*
NMVOC	23	g/GJ	14	33	*
SOx	0.67	g/GJ	0.40	0.94	*
TSP	0.78	g/GJ	0.47	1.09	*
PM10	0.78	g/GJ	0.47	1.09	*
PM2.5	0.78	g/GJ	0.47	1.09	*
BC	4.0	% of PM2.5	2.1	7	*
Pb	0.011	mg/GJ	0.006	0.022	*
Cd	0.0009	mg/GJ	0.0003	0.0011	*
Hg	0.1	mg/GJ	0.007	0.54	*
As	0.10	mg/GJ	0.05	0.19	*
Cr	0.013	mg/GJ	0.007	0.026	*
Cu	0.0026	mg/GJ	0.0013	0.0051	*
Ni	0.013	mg/GJ	0.006	0.026	*
Se	0.058	mg/GJ	0.015	0.058	*
Zn	0.73	mg/GJ	0.36	1.5	*
PCDD/F	0.52	ng I-TEQ/GJ	0.25	1.3	*
Benzo(a)pyrene	0.72	ug/GJ	0.20	1.9	*
Benzo(b)fluoranthene	2.9	ug/GJ	0.7	12	*
Benzo(k)fluoranthene	1.1	ug/GJ	0.3	2.8	*
Indeno(1,2,3-cd)pyrene	1.08	ug/GJ	0.30	2.9	*

* average of Tier 2 EFs for commercial/institutional gaseous fuel combustion for all technologies

TABLE 64 TIER 1 EMISSION FACTORS FOR NFR SOURCE CATEGORY 1.A.4.A/C, 1.A.5.A, USING LIQUID FUELS (GB2019 TABLE 3.9)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Liquid Fuels**				
Not estimated	**NH₃**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	306	g/GJ	50	1319	*
CO	93	g/GJ	2	200	*
NMVOC	20	g/GJ	0.018	70	*
SOx	94	g/GJ	28	140	*
TSP	21	g/GJ	6	42	*
PM10	21	g/GJ	0.75	80	*
PM2.5	18	g/GJ	0.75	60	*
BC	56	% of PM2.5	20	100	*
Pb	8	mg/GJ	0.006	40	*
Cd	0.15	mg/GJ	0.00025	0.6	*

Hg	0.1	mg/GJ	0.025	0.22	*
As	0.5	mg/GJ	0.0005	2	*
Cr	10	mg/GJ	0.1	40	*
Cu	3	mg/GJ	0.065	20	*
Ni	125	mg/GJ	0.0025	600	*
Se	0.1	mg/GJ	0.0005	0.44	*
Zn	18	mg/GJ	0.21	116	*
PCDD/F	6	*ng I-TEQ/GJ*	0.2	20	*
Benzo(a)pyrene	1.9	µg/GJ	0.19	1.9	Nielsen et al. (2010)
Benzo(b)fluoranthene	15	µg/GJ	1.5	15	Nielsen et al. (2010)
Benzo(k)fluoranthene	1.7	µg/GJ	0.17	1.7	Nielsen et al. (2010)
Indeno(1,2,3-cd)pyrene	1.5	µg/GJ	0.15	1.5	Nielsen et al. (2010)
HCB	0.22	µg/GJ	0.022	1.5	Nielsen et al. (2010)
PCB	0.13	ng/GJ	0.013	0.22	Nielsen et al. (2010)

* average of Tier 2 EFs for commercial/institutional liquid fuel combustion for all technologies (gas oil and fuel oil), where the TSP EF has been set to the PM10 EF to ensure consistency in PM emission factors

TABLE 65 TIER 1 EMISSION FACTORS FOR NFR SOURCE CATEGORY 1.A.4.A/C, 1.A.5.A, USING SOLID BIOMASS [6)]

(GB2019 TABLE 3.10)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Solid Biomass**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	91	g/GJ	20	120	Lundgren et al. (2004) [1)]
CO	570	g/GJ	50	4000	EN 303 class 5 boilers, 150-300 kW
NMVOC	300	g/GJ	5	500	Naturvårdsverket, Sweden
SOX	11	g/GJ	8	40	US EPA (1996b)
NH3	37	g/GJ	18	74	Roe et al. (2004) [2)]
TSP	170	g/GJ	95	320	Denier van der Gon (2015) applied on Naturvårdsverket, Sweden
PM10	163	g/GJ	91	305	Denier van der Gon (2015) applied on Naturvårdsverket, Sweden [3)]
PM2.5	160	g/GJ	90	299	Denier van der Gon (2015) applied on Naturvårdsverket, Sweden [3)]
BC	28	% of PM2.5	11	39	Goncalves et al. (2010), Fernandes et al. (2011), Schmidl et al. (2011) [4) 5)]
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008),

					Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCBs	0.06	µg/GJ	0.006	0.6	Hedman et al. (2006)
PCDD/F	100	ng I-TEQ/GJ	30	500	Hedman et al. (2006)
Benzo(a)pyrene	10	mg/GJ	5	20	Boman et al. (2011); Johansson et al. (2004)
Benzo(b)fluoranthene	16	mg/GJ	8	32	
Benzo(k)fluoranthene	5	mg/GJ	2	10	
Indeno(1,2,3-cd)pyrene	4	mg/GJ	2	8	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

1. Larger combustion chamber, 350 kW

2. Assumed equal to low emitting wood stoves

3. PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011),Pettersson et al. (2011) and the TNO CEPMEIP database. Emission factors have been recalculated torepresent total particles (including condensable component) by assuming condensables represent 12% of the total PM mass for PM2.5 (average of automatic and medium sized boilers from Denier van der Gon etal., 2015).

4. The value of 28% BC is only valid for total particles. Since the condensable component is not expected to include any BC, in case a filterable only approach is used an EF of 28% * 160 = 45 g/GJ can be assumed for BC.

5. Assumed equal to advanced/ecolabelled residential boilers

6. If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated tog/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

TABLE 66 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, FIREPLACES BURNING NATURAL GAS (GB2019 TABLE 3.13)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.A.4.b.i**	**Residential plants**
Fuel	**Natural gas**	
SNAP (if applicable)	**020205**	**Residential - Other equipment (stoves, fireplaces, cooking,...)**
Technologies/Practices	**Stoves, Fireplaces, Saunas and Outdoor Heaters**	

Not applicable	PCB, HCB				
Not estimated	NH3				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	60	g/GJ	36	84	DGC (2009)
CO	30	g/GJ	18	42	DGC (2009)
NMVOC	2.0	g/GJ	1.2	2.8	Zhang et al. (2000)
SOx	0.3	g/GJ	0.18	0.42	DGC (2009)
TSP	2.2	g/GJ	1.3	3.1	Zhang et al. (2000)
PM10	2.2	g/GJ	1.3	3.1	*
PM2.5	2.2	g/GJ	1.3	3.1	*
BC	5.4	% of PM2.5	2.7	11	Hildemann et al. (1991), Muhlbaier (1981) **
Pb	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
Cd	0.00025	mg/GJ	0.00013	0.00050	Nielsen et al. (2013)
Hg	0.1	mg/GJ	0.0013	0.68	Nielsen et al. (2010)
As	0.12	mg/GJ	0.060	0.24	Nielsen et al. (2013)
Cr	0.00076	mg/GJ	0.00038	0.0015	Nielsen et al. (2013)
Cu	0.000076	mg/GJ	0.000038	0.00015	Nielsen et al. (2013)
Ni	0.00051	mg/GJ	0.00026	0.0010	Nielsen et al. (2013)
Se	0.011	mg/GJ	0.0038	0.011	US EPA (1998)
Zn	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
PCDD/F	1.5	ng I-TEQ/GJ	0.80	2.3	UNEP (2005)
Benzo(a)pyrene	0.56	ug/GJ	0.19	0.56	US EPA (1998)
Benzo(b)fluoranthene	0.84	ug/GJ	0.28	0.84	US EPA (1998)
Benzo(k)fluoranthene	0.84	ug/GJ	0.28	0.84	US EPA (1998)
Indeno(1,2,3-cd)pyrene	0.84	ug/GJ	0.28	0.84	US EPA (1998)

* assumption: EF(TSP) = EF(PM10) = EF(PM2.5). The TSP, PM10 and PM2.5 emission factors represent filterable PM

** average of EFs from the listed references

TABLE 67 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, STOVES BURNING SOLID FUEL (EXCEPT BIOMASS) (GB2019 TABLE 3.14)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Solid Fuel (not biomass)**				
SNAP (if applicable)	**020205**	**Residential - Other equipment (stoves, fireplaces, cooking,...)**			
Technologies/Practices	**Stoves**				
Not applicable					
Not estimated	NH3				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	100	g/GJ	60	150	GB (2006) chapter B216
CO	5000	g/GJ	3000	7000	GB (2006) chapter B216
NMVOC	600	g/GJ	360	840	GB (2006) chapter B216
SOx	900	g/GJ	540	1000	GB (2006) chapter B216
TSP	500	g/GJ	240	600	GB (2006) chapter B216

PM10	450	g/GJ	228	480	GB (2006) chapter B216
PM2.5	450	g/GJ	216	480	GB (2006) chapter B216
BC	6.4	% of PM2.5	2	26	Zhang et al., 2012
Pb	100	mg/GJ	60	240	GB (2006) chapter B216
Cd	1	mg/GJ	0.6	3.6	GB (2006) chapter B216
Hg	5	mg/GJ	3	7.2	GB (2006) chapter B216
As	1.5	mg/GJ	0.9	6	GB (2006) chapter B216
Cr	10	mg/GJ	6	18	GB (2006) chapter B216
Cu	20	mg/GJ	12	36	GB (2006) chapter B216
Ni	10	mg/GJ	6	24	GB (2006) chapter B216
Se	2	mg/GJ	1.2	2.4	GB (2006) chapter B216
Zn	200	mg/GJ	120	360	GB (2006) chapter B216
PCB	170	µg/GJ	85	260	Kakareka et al. (2004)
PCDD/F	1000	ng I-TEQ/GJ	300	1200	GB (2006) chapter B216
Benzo(a)pyrene	250	mg/GJ	150	324	GB (2006) chapter B216
Benzo(b)fluoranthene	400	mg/GJ	150	480	GB (2006) chapter B216
Benzo(k)fluoranthene	150	mg/GJ	60	180	GB (2006) chapter B216
Indeno(1,2,3-cd)pyrene	120	mg/GJ	54	144	GB (2006) chapter B216
HCB	0.62	µg/GJ	0.31	1.2	GB (2006) chapter B216

The TSP, PM10 and PM2.5 emission factors have been reviewed and it is unclear whether they represent filterable PM or total PM (filterable and condensable) emissions

TABLE 68 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, BOILERS BURNING SOLID FUEL (EXCEPT BIOMASS) (GB2019 TABLE 3.15)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Solid Fuel (not biomass)**				
Technologies/Practices	**Small (single household scale, capacity <=50 kWth) boilers**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	158	g/GJ	80	300	US EPA, 1998
CO	4787	g/GJ	3000	7000	US EPA, 1998
NMVOC	174	g/GJ	87	260	US EPA, 1998
SOx	900	g/GJ	540	1000	GB (2006) chapter B216
TSP	261	g/GJ	130	400	US EPA, 1998
PM10	225	g/GJ	113	338	Tivari et al., 2012
PM2.5	201	g/GJ	100	300	Tivari et al., 2012
BC	6.4	% of PM2.5	2	26	Zhang et al., 2012
Pb	200	mg/GJ	60	240	GB (2006) chapter B216
Cd	3	mg/GJ	0.6	3.6	GB (2006) chapter B216
Hg	6	mg/GJ	3	7.2	GB (2006) chapter B216
As	5	mg/GJ	0.9	6	GB (2006) chapter B216
Cr	15	mg/GJ	6	18	GB (2006) chapter B216
Cu	30	mg/GJ	12	36	GB (2006) chapter B216
Ni	20	mg/GJ	6	24	GB (2006) chapter B216
Se	2	mg/GJ	1.2	2.4	GB (2006) chapter B216
Zn	300	mg/GJ	120	360	GB (2006) chapter B216
PCB	170	µg/GJ	85	260	Kakareka et al. (2004)

PCDD/F	500	ng I-TEQ/GJ	300	1200	GB (2006) chapter B216
Benzo(a)pyrene	270	mg/GJ	150	324	GB (2006) chapter B216
Benzo(b)fluoranthene	250	mg/GJ	150	480	GB (2006) chapter B216
Benzo(k)fluoranthene	100	mg/GJ	60	180	GB (2006) chapter B216
Indeno(1,2,3-cd)pyrene	90	mg/GJ	54	144	GB (2006) chapter B216
HCB	0.62	µg/GJ	0.31	1.2	GB (2006) chapter B216

TABLE 69 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, BOILERS BURNING NATURAL GAS (GB2019 TABLE 3.16)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Natural gas**				
Technologies/Practices	**Small (single household scale, capacity <=50 kWth) boilers**				
Not applicable	**PCB, HCB**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	42	g/GJ	25	59	DGC (2009)
CO	22	g/GJ	18	42	DGC (2009)
NMVOC	1.8	g/GJ	1.1	2.5	Italian Ministry for the Environment (2005)
SOx	0.30	g/GJ	0.18	0.42	DGC (2009)
TSP	0.20	g/GJ	0.12	0.28	BUWAL (2001)
PM10	0.20	g/GJ	0.12	0.28	BUWAL (2001)
PM2.5	0.20	g/GJ	0.12	0.28	*
BC	5.4	% of PM2.5	2.7	11	Hildemann et al. (1991), Muhlbaier (1981) **
Pb	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
Cd	0.00025	mg/GJ	0.00013	0.00050	Nielsen et al. (2013)
Hg	0.1	mg/GJ	0.0013	0.68	Nielsen et al. (2010)
As	0.12	mg/GJ	0.060	0.24	Nielsen et al. (2013)
Cr	0.00076	mg/GJ	0.00038	0.0015	Nielsen et al. (2013)
Cu	0.000076	mg/GJ	0.000038	0.00015	Nielsen et al. (2013)
Ni	0.00051	mg/GJ	0.00026	0.0010	Nielsen et al. (2013)
Se	0.011	mg/GJ	0.0038	0.011	US EPA (1998)
Zn	0.0015	mg/GJ	0.0008	0.003	Nielsen et al. (2013)
PCDD/F	1.5	ng I-TEQ/GJ	0.80	2.3	UNEP (2005)
Benzo(a)pyrene	0.56	ug/GJ	0.19	0.56	US EPA (1998)
Benzo(b)fluoranthene	0.84	ug/GJ	0.28	0.84	US EPA (1998)
Benzo(k)fluoranthene	0.84	ug/GJ	0.28	0.84	US EPA (1998)
Indeno(1,2,3-cd)pyrene	0.84	ug/GJ	0.28	0.84	US EPA (1998)

* assumption: EF(PM10) = EF(PM2.5). The TSP, PM10 and PM2.5 emission factors have been reviewed and it is unclear whether they represent filterable PM or total PM (filterable and condensable) emissions

** average of EFs from the listed references

TABLE 70 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, BOILERS BURNING LIQUID FUELS (GB2019 TABLE 3.18)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Gas oil**				
Technologies/Practices	**Small (single household scale, capacity <=50 kWth) boilers**				
Not applicable	**PCB, HCB**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	69	g/GJ	41	97	Italian Ministry for the Environment (2005)
CO	3.7	g/GJ	2	5	Italian Ministry for the Environment (2005)
NMVOC	0.17	g/GJ	0.06	0.51	Italian Ministry for the Environment (2005)
SOX	79	g/GJ	47	111	Italian Ministry for the Environment (2005)
TSP	1.5	g/GJ	1	2	Italian Ministry for the Environment (2005)
PM10	1.5	g/GJ	1	2	*
PM2.5	1.5	g/GJ	1	2	*
BC	3.9	% of PM2.5	2	8	US EPA (2011)
Pb	0.012	mg/GJ	0.006	0.024	Pulles et al. (2012)
Cd	0.001	mg/GJ	0.0003	0.001	Pulles et al. (2012)
Hg	0.12	mg/GJ	0.03	0.12	Pulles et al. (2012)
As	0.002	mg/GJ	0.0005	0.002	Pulles et al. (2012)
Cr	0.2	mg/GJ	0.1	0.4	Pulles et al. (2012)
Cu	0.13	mg/GJ	0.065	0.26	Pulles et al. (2012)
Ni	0.005	mg/GJ	0.0025	0.01	Pulles et al. (2012)
Se	0.002	mg/GJ	0.0005	0.002	Pulles et al. (2012)
Zn	0.42	mg/GJ	0.21	0.84	Pulles et al. (2012)
PCDD/F	1.8	ng I-TEQ/GJ	0.4	9	Pfeiffer et al. (2000)
Benzo(a)pyrene	80	ug/GJ	16	120	Berdowski et al. (1995)
Benzo(b)fluoranthene	40	ug/GJ	8	60	Berdowski et al. (1995)
Benzo(k)fluoranthene	70	ug/GJ	14	105	Berdowski et al. (1995)
Indeno(1,2,3-cd)pyrene	160	ug/GJ	32	240	Berdowski et al. (1995)

* assumption: EF(TSP) = EF(PM10) = EF(PM2.5). The TSP, PM10 and PM2.5 emission factors represent filterable PM emissions

TABLE 71 TIER 2 EMISSION FACTORS FOR SMALL NON-RESIDENTIAL SOURCES (> 50 KWTH TO ≤ 1 MWTH) BOILERS BURNING COAL FUELS (GB2019 TABLE 3.20)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**

Fuel	Coal Fuels				
Technologies/Practices	Medium size (>50 kWth to <=1 MWth) boilers				
Not applicable					
Not estimated	NH_3				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOX	160	g/GJ	150	200	GB (2006) chapter B216
CO	2000	g/GJ	200	3000	GB (2006) chapter B216
NMVOC	200	g/GJ	20	300	GB (2006) chapter B216
SOx	900	g/GJ	450	1000	GB (2006) chapter B216
TSP	200	g/GJ	80	250	GB (2006) chapter B216
PM10	190	g/GJ	76	240	GB (2006) chapter B216
PM2.5	170	g/GJ	72	220	GB (2006) chapter B216
BC	6.4	% of $PM_{2.5}$	2	26	Zhang et al., 2012
Pb	200	mg/GJ	80	300	GB (2006) chapter B216
Cd	3	mg/GJ	1	5	GB (2006) chapter B216
Hg	7	mg/GJ	5	9	GB (2006) chapter B216
As	5	mg/GJ	0.5	8	GB (2006) chapter B216
Cr	15	mg/GJ	1	20	GB (2006) chapter B216
Cu	30	mg/GJ	8	50	GB (2006) chapter B216
Ni	20	mg/GJ	2	30	GB (2006) chapter B216
Se	2	mg/GJ	0.5	3	GB (2006) chapter B216
Zn	300	mg/GJ	100	500	GB (2006) chapter B216
PCB	170	µg/GJ	85	260	Kakareka et al. (2004)
PCDD/F	400	ng I-TEQ/GJ	40	500	GB (2006) chapter B216
Benzo(a)pyrene	100	mg/GJ	13	150	GB (2006) chapter B216
Benzo(b)fluoranthene	130	mg/GJ	17	180	GB (2006) chapter B216
Benzo(k)fluoranthene	50	mg/GJ	8	100	GB (2006) chapter B216
Indeno(1,2,3-cd)pyrene	40	mg/GJ	6	80	GB (2006) chapter B216
HCB	0.62	µg/GJ	0.31	1.2	GB (2006) chapter B216

TABLE 72 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MEDIUM-SIZE (> 1 MWTH TO ≤ 50 MWTH) BOILERS BURNING COAL FUELS (GB2019 TABLE 3.21)

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i 1.A.5.a	Commercial / institutional: stationary Agriculture / forestry / fishing: Stationary Other, stationary (including military)			
Fuel	Coal Fuels				
Technologies/Practices	Medium size (>1 MWth to <=50 MWth) boilers				
Not applicable					
Not estimated	NH_3				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
OX	180	g/GJ	150	200	GB (2006) chapter B216
CO	200	g/GJ	150	3000	GB (2006) chapter B216
NMVOC	20	g/GJ	10	300	GB (2006) chapter B216
SOx	900	g/GJ	450	1000	GB (2006) chapter B216
TSP	80	g/GJ	70	250	GB (2006) chapter B216
PM10	76	g/GJ	60	240	GB (2006) chapter B216
PM2.5	72	g/GJ	60	220	GB (2006) chapter B216

BC	6.4	% of $PM_{2.5}$	2	26	Zhang et al., 2012
Pb	100	mg/GJ	80	200	GB (2006) chapter B216
Cd	1	mg/GJ	0.5	3	GB (2006) chapter B216
Hg	9	mg/GJ	5	10	GB (2006) chapter B216
As	4	mg/GJ	0.5	5	GB (2006) chapter B216
Cr	15	mg/GJ	1	20	GB (2006) chapter B216
Cu	10	mg/GJ	8	30	GB (2006) chapter B216
Ni	10	mg/GJ	2	20	GB (2006) chapter B216
Se	2	mg/GJ	0.5	3	GB (2006) chapter B216
Zn	150	mg/GJ	100	300	GB (2006) chapter B216
PCB	170	µg/GJ	85	260	Kakareka et al. (2004)
PCDD/F	100	ng I-TEQ/GJ	40	500	GB (2006) chapter B216
Benzo(a)pyrene	13	mg/GJ	10	150	GB (2006) chapter B216
Benzo(b)fluoranthene	17	mg/GJ	10	180	GB (2006) chapter B216
Benzo(k)fluoranthene	9	mg/GJ	8	100	GB (2006) chapter B216
Indeno(1,2,3-cd)pyrene	6	mg/GJ	5	80	GB (2006) chapter B216
HCB	0.62	µg/GJ	0.31	1.2	GB (2006) chapter B216

Table 73 Tier 2 emission factors for non-residential sources, manual boilers burning coal fuels (GB2019 Table 3.22)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Coal Fuels**				
Technologies/Practices	**Advanced coal combustion techniques <1MWth - Manual Boiler**				
Not applicable					
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	200	g/GJ	150	300	GB (2006) chapter B216
CO	1500	g/GJ	200	3000	GB (2006) chapter B216
NMVOC	100	g/GJ	20	300	GB (2006) chapter B216
SOx	450	g/GJ	300	900	GB (2006) chapter B216
TSP	150	g/GJ	80	250	GB (2006) chapter B216
PM10	140	g/GJ	76	240	GB (2006) chapter B216
PM2.5	130	g/GJ	72	220	GB (2006) chapter B216
BC	6.4	% of PM2.5	2	26	Zhang et al., 2012
Pb	150	mg/GJ	80	200	GB (2006) chapter B216
Cd	2	mg/GJ	1	3	GB (2006) chapter B216
Hg	6	mg/GJ	5	9	GB (2006) chapter B216
As	4	mg/GJ	0.5	5	GB (2006) chapter B216
Cr	10	mg/GJ	1	15	GB (2006) chapter B216
Cu	15	mg/GJ	8	30	GB (2006) chapter B216
Ni	15	mg/GJ	2	20	GB (2006) chapter B216
Se	2	mg/GJ	0.5	3	GB (2006) chapter B216
Zn	200	mg/GJ	100	300	GB (2006) chapter B216
PCB	170	µg/GJ	85	260	Kakareka et al. (2004)
PCDD/F	200	ng I-TEQ/GJ	40	500	GB (2006) chapter B216

Benzo(a)pyrene	90	mg/GJ	13	150	GB (2006) chapter B216
Benzo(b)fluoranthene	110	mg/GJ	17	180	GB (2006) chapter B216
Benzo(k)fluoranthene	50	mg/GJ	8	100	GB (2006) chapter B216
Indeno(1,2,3-cd)pyrene	40	mg/GJ	6	80	GB (2006) chapter B216
HCB	0.62	µg/GJ	0.31	1.2	GB (2006) chapter B216

TABLE 74 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, AUTOMATIC BOILERS BURNING COAL FUELS (GB2019 TABLE 3.23)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Coal Fuels**				
Technologies/Practices	**Advanced coal combustion techniques <1MWth - Automatic Boiler**				
Not applicable					
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	165	g/GJ	100	250	US EPA, 1998
CO	350	g/GJ	175	700	Thistlethwaite, 2001
NMVOC	23	g/GJ	10	100	US EPA, 1998
SOx	450	g/GJ	400	1000	GB (2006) chapter B216
TSP	82	g/GJ	41	164	Thistlethwaite, 2001
PM10	78	g/GJ	39	156	Struschka et al., 2008
PM2.5	70	g/GJ	35	140	Struschka et al., 2008
BC	6.4	% of PM2.5	2	26	Zhang et al., 2012
Pb	167	mg/GJ	83	335	Thistlethwaite, 2001
Cd	1	mg/GJ	0.5	1.5	Thistlethwaite, 2001
Hg	16	mg/GJ	8	32	Thistlethwaite, 2001
As	46	mg/GJ	4.6	92	Thistlethwaite, 2001
Cr	6	mg/GJ	2	18	Thistlethwaite, 2001
Cu	192	mg/GJ	19.2	400	Thistlethwaite, 2001
Ni	37	mg/GJ	3.7	74	Thistlethwaite, 2001
Se	17	mg/GJ	1.7	34	Thistlethwaite, 2001
Zn	201	mg/GJ	50	500	Thistlethwaite, 2001
PCB	170	µg/GJ	85	260	Kakareka et al. (2004)
PCDD/F	40	ng I-TEQ/GJ	20	500	GB (2006) chapter B216
Benzo(a)pyrene	0.079	mg/GJ	0.008	0.8	Thistlethwaite, 2001
Benzo(b)fluoranthene	1.244	mg/GJ	0.12	12.4	Thistlethwaite, 2001
Benzo(k)fluoranthene	0.845	mg/GJ	0.08	8.5	Thistlethwaite, 2001
Indeno(1,2,3-cd)pyrene	0.617	mg/GJ	0.06	6.2	Thistlethwaite, 2001
HCB	0.62	µg/GJ	0.31	1.2	GB (2006) chapter B216

TABLE 75 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MEDIUM-SIZED (> 50 KWTH TO ≤ 1 MWTH) BOILERS LIQUID FUELS (GB2019 TABLE 3.24)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Stationary** **Other, stationary (including military)**			
Fuel	**Fuel oil (Residual fuel oil)**				
SNAP (if applicable)	**20100** **20300**	**Commercial and institutional plants** **Plants in agriculture, forestry and aquaculture**			
Technologies/Practices	**Fuel oil (Distillate fuel oil) combustion in boilers ≤ 1MW**				
Not applicable	**Se**				
Not estimated	**NH_3, TSP, BC, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, PCB, HCB, PCDD/F**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	100	g/GJ	50	150	GB (2006) chapter B216
CO	40	g/GJ	24	40	GB (2006) chapter B216
NMVOC	15	g/GJ	9	15	GB (2006) chapter B216
SOx	140	g/GJ	84	140	GB (2006) chapter B216
PM10	3	g/GJ	0.75	6	GB (2006) chapter B216
PM2.5	3	g/GJ	0.75	6	GB (2006) chapter B216
Pb	20	mg/GJ	5	40	GB (2006) chapter B216
Cd	0.3	mg/GJ	0.075	0.6	GB (2006) chapter B216
Hg	0.1	mg/GJ	0.025	0.2	GB (2006) chapter B216
As	1	mg/GJ	0.25	2	GB (2006) chapter B216
Cr	20	mg/GJ	5	40	GB (2006) chapter B216
Cu	10	mg/GJ	2.5	20	GB (2006) chapter B216
Ni	300	mg/GJ	75	600	GB (2006) chapter B216
Zn	10	mg/GJ	2.5	20	GB (2006) chapter B216
PCDD/F	10	I-TEQng/GJ	2.5	20	GB (2006) chapter B216
Benzo(a)pyrene	8	mg/GJ	2	16	GB (2006) chapter B216
Benzo(b)fluoranthene	9	mg/GJ	2.25	18	GB (2006) chapter B216
Benzo(k)fluoranthene	6	mg/GJ	1.5	12	GB (2006) chapter B216
Indeno (1,2,3-cd)pyrene	3	mg/GJ	0.75	6	GB (2006) chapter B216

TABLE 76 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MEDIUM SIZED (> 1 MWTH TO ≤ 50 MWTH) BOILERS LIQUID FUELS (GB2019 TABLE 3.25)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Stationary** **Other, stationary (including military)**
Fuel	**Fuel oil (Residual fuel oil)**	
SNAP (if applicable)	**20100** **20300**	**Commercial and institutional plants** **Plants in agriculture, forestry and aquaculture**

Technologies/Practices	Fuel oil (Residual oil) combustion in boilers > 1MW				
Not applicable					
Not estimated	NH_3, TSP, BC, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	100	g/GJ	50	150	GB (2006) chapter B216
CO	40	g/GJ	20	80	GB (2006) chapter B216
NMVOC	5	g/GJ	2	15	GB (2006) chapter B216
SOx	140	g/GJ	84	140	GB (2006) chapter B216
PM10	40	g/GJ	10	80	GB (2006) chapter B216
PM2.5	30	g/GJ	7.5	60	GB (2006) chapter B216
Pb	10	mg/GJ	2.5	20	GB (2006) chapter B216
Cd	0.3	mg/GJ	0.075	0.6	GB (2006) chapter B216
Hg	0.1	mg/GJ	0.025	0.2	GB (2006) chapter B216
As	1	mg/GJ	0.25	2	GB (2006) chapter B216
Cr	20	mg/GJ	5	40	GB (2006) chapter B216
Cu	3	mg/GJ	0.75	6	GB (2006) chapter B216
Ni	200	mg/GJ	50	400	GB (2006) chapter B216
Zn	5	mg/GJ	1.25	10	GB (2006) chapter B216
PCDD/F	10	I-TEQ ng/GJ	2.5	20	GB (2006) chapter B216
Benzo(a)pyrene	1	mg/GJ	0.5	2	GB (2006) chapter B216
Benzo(b)fluoranthene	2	mg/GJ	1	4	GB (2006) chapter B216
Benzo(k)fluoranthene	1	mg/GJ	0.5	2	GB (2006) chapter B216
Indeno (1,2,3-cd)pyrene	1	mg/GJ	0.5	2	GB (2006) chapter B216

TABLE 77 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MEDIUM-SIZED (> 50 KWTH TO ≤ 1 MWTH) BOILERS BURNING NATURAL GAS (GB2019 TABLE 3.26)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Natural Gas**				
Technologies/Practices	**Medium size (>50 kWth to <=1 MWth) boilers**				
Not applicable	**PCB, HCB**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	73	g/GJ	44	103	Italian Ministry for the Environment (2005)
CO	24	g/GJ	18	42	Italian Ministry for the Environment (2005)
NMVOC	0.36	g/GJ	0.2	0.5	UBA (2008)
SOx	1.4	g/GJ	0.83	1.95	Italian Ministry for the Environment (2005)
TSP	0.45	g/GJ	0.27	0.63	Italian Ministry for the Environment (2005)

PM10	0.45	g/GJ	0.27	0.63	assumption: EF(TSP) = EF(PM10) = EF(PM2.5).
PM2.5	0.45	g/GJ	0.27	0.63	assumption: EF(TSP) = EF(PM10) = EF(PM2.5).
BC	5.4	% of PM2.5	2.7	11	average of EFs from Hildemann et al. (1991), Muhlbaier (1981)
Pb	0.0015	mg/GJ	0.00075	0.003	Nielsen et al. (2013)
Cd	0.00025	mg/GJ	0.00013	0.0005	Nielsen et al. (2013)
Hg	0.1	mg/GJ	0.0013	0.68	Nielsen et al. (2010)
As	0.12	mg/GJ	0.060	0.24	Nielsen et al. (2013)
Cr	0.00076	mg/GJ	0.00038	0.0015	Nielsen et al. (2013)
Cu	0.000076	mg/GJ	0.000038	0.00015	Nielsen et al. (2013)
Ni	0.00051	mg/GJ	0.00026	0.001	Nielsen et al. (2013)
Se	0.011	mg/GJ	0.0037	0.011	US EPA (1998)
Zn	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
PCDD/F	0.5	ng I-TEQ/GJ	0.3	0.8	UNEP (2005)
Benzo(a)pyrene	0.56	µg/GJ	0.19	0.56	US EPA (1998)
Benzo(b)fluoranthene	0.84	µg/GJ	0.28	0.84	US EPA (1998)
Benzo(k)fluoranthene	0.84	µg/GJ	0.28	0.84	US EPA (1998)
Indeno(1,2,3-cd)pyrene	0.84	µg/GJ	0.28	0.84	US EPA (1998)

TABLE 78 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MEDIUM SIZED (> 1 MWTH TO ≤ 50 MWTH) BOILERS BURNING NATURAL GAS (GB2019 TABLE 3.27)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Natural Gas**				
Technologies/Practices	**Medium size (>1 MWth to <=50 MWth) boilers**				
Not applicable	**PCB, HCB**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	40	g/GJ	30	55	DGC (2009)
CO	30	g/GJ	15	30	DGC (2009)
NMVOC	2	g/GJ	1.2	2.8	DGC (2009)
SOx	0.3	g/GJ	0.2	0.4	DGC (2009)
TSP	0.45	g/GJ	0.27	0.63	Italian Ministry for the Environment (2005)
PM10	0.45	g/GJ	0.27	0.63	assumption: EF(TSP) = EF(PM10) = EF(PM2.5).
PM2.5	0.45	g/GJ	0.27	0.63	assumption: EF(TSP) = EF(PM10) = EF(PM2.5).
BC	5.4	% of PM2.5	2.7	11	Hildemann et al. (1991), Muhlbaier (1981) **
Pb	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
Cd	0.00025	mg/GJ	0.00013	0.00050	Nielsen et al. (2013)

Hg	0.1	mg/GJ	0.0013	0.68	Nielsen et al. (2010)
As	0.12	mg/GJ	0.060	0.24	Nielsen et al. (2013)
Cr	0.00076	mg/GJ	0.00038	0.0015	Nielsen et al. (2013)
Cu	0.000076	mg/GJ	0.000038	0.00015	Nielsen et al. (2013)
Ni	0.00051	mg/GJ	0.00026	0.0010	Nielsen et al. (2013)
Se	0.011	mg/GJ	0.0037	0.011	US EPA (1998)
Zn	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
PCDD/F	0.5	ng I-TEQ/GJ	0.3	0.8	UNEP (2005)
Benzo(a)pyrene	0.56	µg/GJ	0.19	0.56	US EPA (1998)
Benzo(b)fluoranthene	0.84	µg/GJ	0.28	0.84	US EPA (1998)
Benzo(k)fluoranthene	0.84	µg/GJ	0.28	0.84	US EPA (1998)
Indeno(1,2,3-cd)pyrene	0.84	µg/GJ	0.28	0.84	US EPA (1998)

TABLE 79 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, GAS TURBINES BURNING NATURAL GAS (GB2019 TABLE 3.28)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Natural Gas**				
SNAP (if applicable)	**020104** **020203** **020302**	**Comm./instit. - Stationary gas turbines** **Residential - Gas turbines** **Agri./forest/aqua. - Stationary gas turbines**			
Technologies/Practices	**Gas Turbines**				
Not applicable	**PCB, HCB**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	48	g/GJ	29	67	Nielsen et al. (2010)
CO	4.8	g/GJ	1.8	42	Nielsen et al. (2010)
NMVOC	1.6	g/GJ	1.0	2.2	Nielsen et al. (2010)
SOx	0.5	g/GJ	0.30	0.70	BUWAL (2001)
TSP	0.2	g/GJ	0.12	0.28	BUWAL (2001)
PM10	0.2	g/GJ	0.12	0.28	BUWAL (2001)
PM2.5	0.2	g/GJ	0.12	0.28	assumption: EF(PM10) = EF(PM2.5).
BC	2.5	% of PM2.5	1.5	3.5	England et al. (2004), Wien et al. (2004) and US EPA (2011)
Pb	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
Cd	0.00025	mg/GJ	0.00013	0.00050	Nielsen et al. (2013)
Hg	0.1	mg/GJ	0.0013	0.68	Nielsen et al. (2010)
As	0.12	mg/GJ	0.060	0.24	Nielsen et al. (2013)
Cr	0.00076	mg/GJ	0.00038	0.0015	Nielsen et al. (2013)
Cu	0.000076	mg/GJ	0.000038	0.00015	Nielsen et al. (2013)
Ni	0.00051	mg/GJ	0.00026	0.0010	Nielsen et al. (2013)
Se	0.011	mg/GJ	0.0038	0.011	US EPA (1998)
Zn	0.0015	mg/GJ	0.00075	0.0030	Nielsen et al. (2013)
PCDD/F	0.5	ng I-TEQ/GJ	0.3	0.8	UNEP (2005)
Benzo(a)pyrene	0.56	µg/GJ	0.19	0.56	US EPA (1998)
Benzo(b)fluoranthene	0.84	µg/GJ	0.28	0.84	US EPA (1998)
Benzo(k)fluoranthene	0.84	µg/GJ	0.28	0.84	US EPA (1998)
Indeno(1,2,3-cd)pyrene	0.84	µg/GJ	0.28	0.84	US EPA (1998)

TABLE 80 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, GAS TURBINES BURNING GAS OIL (GB2019 TABLE 3.29)

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i 1.A.5.a	Commercial / institutional: stationary Agriculture / forestry / fishing: Stationary Other, stationary (including military)			
Fuel	Gas Oil				
SNAP (if applicable)	020104 020203 020303	Comm./instit. - Stationary gas turbines Residential - Gas turbines Agri./forest/aqua. - Stationary gas turbines			
Technologies/Practices	Gas Turbines				
Not applicable	PCB, HCB				
Not estimated	NH3, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOX	83	g/GJ	50	116	Nielsen et al. (2010)
CO	2.6	g/GJ	2	4	Nielsen et al. (2010)
NMVOC	0.18	g/GJ	0.018	1.8	US EPA (2000)
SOx	46	g/GJ	28	65	*
TSP	9.5	g/GJ	6	13	Nielsen et al. (2010)
PM10	9.5	g/GJ	6	13	**
PM2.5	9.5	g/GJ	6	13	**
BC	33.5	% of PM2.5	20.1	46.9	Hildemann et al. (1991) and Bond et al. (2006)
Pb	0.012	mg/GJ	0.006	0.024	Pulles et al. (2012)
Cd	0.001	mg/GJ	0.00025	0.001	Pulles et al. (2012)
Hg	0.12	mg/GJ	0.03	0.12	Pulles et al. (2012)
As	0.002	mg/GJ	0.0005	0.002	Pulles et al. (2012)
Cr	0.2	mg/GJ	0.1	0.4	Pulles et al. (2012)
Cu	0.13	mg/GJ	0.065	0.26	Pulles et al. (2012)
Ni	0.005	mg/GJ	0.0025	0.01	Pulles et al. (2012)
Se	0.002	mg/GJ	0.0005	0.002	Pulles et al. (2012)
Zn	0.42	mg/GJ	0.21	0.84	Pulles et al. (2012)
PCDD/F	1.8	ng I-TEQ/GJ	0.4	9	Pfeiffer et al. (2000)

* estimate based on 0.1 % S and LHV = 43.33 TJ/1000 tonnes

** assumption: EF(TSP) = EF(PM10) = EF(PM2.5). The TSP, PM10 and PM2.5 emission factors have been reviewed and it is unclear whether they represent filterable PM or total PM (filterable and condensable) emissions

TABLE 81 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, RECIPROCATING ENGINES BURNING GAS FUELS (GB2019 TABLE 3.30)

Tier 2 emission factors		
	Code	Name
NFR Source Category	1.A.4.a.i	Commercial / institutional: stationary

	1.A.4.c.i **1.A.5.a**	**Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**			
Fuel	**Natural Gas**				
SNAP (if applicable)	**020105** **020204** **020304**	**Comm./instit. - Stationary engines** **Residential - Stationary engines** **Agri./forest/aqua. - Stationary engines**			
Technologies/Practices	**Stationary reciprocating engines**				
Not applicable	**PCB, HCB**				
Not estimated	**NH_3**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	135	g/GJ	81	189	Nielsen et al. (2010)
CO	56	g/GJ	34	78	Nielsen et al. (2010)
NMVOC	89	g/GJ	53	125	Nielsen et al. (2010)
SOx	0.5	g/GJ	0.05	1	BUWAL (2001)
TSP	2	g/GJ	1	3	BUWAL (2001)
PM10	2	g/GJ	1	3	BUWAL (2001)
PM2.5	2	g/GJ	1	3	assumption: EF(PM10) = EF(PM2.5).
BC	2.5	% of PM2.5	1.5	3.5	England et al. (2004), Wien et al. (2004) and US EPA (2011)
Pb	0.04	mg/GJ	0.02	0.08	Nielsen et al. (2010)
Cd	0.003	mg/GJ	0.00075	0.003	Nielsen et al. (2010)
Hg	0.1	mg/GJ	0.025	0.1	Nielsen et al. (2010)
As	0.05	mg/GJ	0.0125	0.05	Nielsen et al. (2010)
Cr	0.05	mg/GJ	0.025	0.1	Nielsen et al. (2010)
Cu	0.01	mg/GJ	0.005	0.02	Nielsen et al. (2010)
Ni	0.05	mg/GJ	0.025	0.1	Nielsen et al. (2010)
Se	0.2	mg/GJ	0.05	0.2	Nielsen et al. (2010)
Zn	2.9	mg/GJ	1.5	5.8	Nielsen et al. (2010)
PCDD/F	0.57	ng I-TEQ/GJ	0.11	2.9	Nielsen et al. (2010)
Benzo(a)pyrene	1.2	µg/GJ	0.24	6	Nielsen et al. (2010)
Benzo(b)fluoranthene	9	µg/GJ	1.8	45	Nielsen et al. (2010)
Benzo(k)fluoranthene	1.7	µg/GJ	0.34	8.5	Nielsen et al. (2010)
Indeno(1,2,3-cd)pyrene	1.8	µg/GJ	0.36	9	Nielsen et al. (2010)

TABLE 82 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, RECIPROCATING ENGINES BURNING GAS OIL (GB2019 TABLE 3.31)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary** **Other, stationary (including military)**
Fuel	**Gas Oil**	
SNAP (if applicable)	**020105** **020204** **020304**	**Comm./instit. - Stationary engines** **Residential - Stationary engines** **Agri./forest/aqua. - Stationary engines**

Technologies/Practices	Reciprocating Engines				
Not estimated	NH_3				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	942	g/GJ	565	1319	Nielsen et al. (2010)
CO	130	g/GJ	78	182	Nielsen et al. (2010)
NMVOC	50	g/GJ	30	70	BUWAL (2001)
SOx	48	g/GJ	29	67	BUWAL (2001)
TSP	30	g/GJ	18	42	BUWAL (2001)
PM10	30	g/GJ	18	42	BUWAL (2001)
PM2.5	30	g/GJ	18	42	assumption: EF(PM_{10}) = EF($PM_{2.5}$).
BC	78	% of $PM_{2.5}$	47	100	Hernandez et al. (2004)
Pb	0.15	mg/GJ	0.075	0.3	Nielsen et al. (2010)
Cd	0.01	mg/GJ	0.005	0.02	Nielsen et al. (2010)
Hg	0.11	mg/GJ	0.055	0.22	Nielsen et al. (2010)
As	0.06	mg/GJ	0.03	0.12	Nielsen et al. (2010)
Cr	0.2	mg/GJ	0.1	0.4	Nielsen et al. (2010)
Cu	0.3	mg/GJ	0.15	0.6	Nielsen et al. (2010)
Ni	0.01	mg/GJ	0.005	0.02	Nielsen et al. (2010)
Se	0.22	mg/GJ	0.11	0.44	Nielsen et al. (2010)
Zn	58	mg/GJ	29	116	Nielsen et al. (2010)
PCB	0.13	ng/GJ	0.013	0.13	Nielsen et al. (2010)
PCDD/F	0.99	ng I-TEQ/GJ	0.20	5.0	Nielsen et al. (2010)
Benzo(a)pyrene	1.9	µg/GJ	0.19	1.9	Nielsen et al. (2010)
Benzo(b)fluoranthene	15	µg/GJ	1.5	15	Nielsen et al. (2010)
Benzo(k)fluoranthene	1.7	µg/GJ	0.17	1.7	Nielsen et al. (2010)
Indeno(1,2,3-cd)pyrene	1.5	µg/GJ	0.15	1.5	Nielsen et al. (2010)
HCB	0.22	µg/GJ	0.022	0.22	Nielsen et al. (2010)

TABLE 83 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, OPEN FIREPLACES BURNING WOOD [4)]

(GB2019 TABLE 3.39)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Wood**				
SNAP (if applicable)	**020205**	**Residential - Other equipment (stoves, fireplaces, cooking,...)**			
Technologies/Practices	**Open fireplaces**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	50	g/GJ	30	150	Pettersson et al. (2011) [1)]
CO	4000	g/GJ	1000	10000	Goncalves et al. (2012)
NMVOC	600	g/GJ	20	3000	Pettersson et al. (2011) and McDonald et al. (2000)
SOX	11	g/GJ	8	40	US EPA (1996/1)
NH3	74	g/GJ	37	148	Roe et al. (2004)
TSP (total particles)	880	g/GJ	440	1760	Alves et al. (2011) [2)]
PM10 (total particles)	840	g/GJ	420	1680	Alves et al. (2011) [2)]
PM2.5 (total particles)	820	g/GJ	410	1640	Alves et al. (2011) [2)]
BC (based on total particles)	7	% of PM2.5	2	18	Alves et al. (2011), Goncalves et al. (2011),

					Fernandes et al. (2011), Bølling et al. (2009), Fine et al. (2002), Kupiainen & Klimont (2004)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCBs	0.06	µg/GJ	0.006	0.6	Hedman et al. (2006) 3)
PCDD/F	800	ng I-TEQ/GJ	20	5000	Glasius et al. (2005); Hedman et al. (2006); Hübner et al. (2005)1)
Benzo(a)pyrene	121	mg/GJ	12	1210	Goncalves et al. (2012); Tissari et al. (2007); Hedberg et al. (2002); Pettersson et al. (2011); Glasius et al. (2005); Paulrud et al. (2006); Johansson et al. (2003); Lamberg et al. (2011)
Benzo(b)fluoranthene	111	mg/GJ	11	1110	
Benzo(k)fluoranthene	42	mg/GJ	4	420	
Indeno(1,2,3-cd)pyrene	71	mg/GJ	7	710	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

1) Assumed equal to conventional stoves

2) PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

3) Assumed equal to conventional boilers.

4) If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated to g/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

TABLE 84 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, CONVENTIONAL STOVES BURNING WOOD AND SIMILAR WOOD WASTE 3) (GB2019 TABLE 3.40)

Tier 2 emission factors

	Code	Name			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Wood and similar wood waste**				
SNAP (if applicable)	**020205**	**Residential - Other equipment (stoves, fireplaces, cooking,...)**			
Technologies/Practices	**Conventional stoves**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	50	g/GJ	30	150	Pettersson et al. (2011)
CO	4000	g/GJ	1000	10000	Pettersson et al. (2011) and Goncalves et al. (2012)
NMVOC	600	g/GJ	20	3000	Pettersson et al. (2011)
SOX	11	g/GJ	8	40	US EPA (1996/2)
NH3	70	g/GJ	35	140	Roe et al. (2004)
TSP (total particles)	800	g/GJ	400	1600	Alves et al. (2011) and Glasius et al. (2005) [1)]
PM10 (total particles)	760	g/GJ	380	1520	Alves et al. (2011) and Glasius et al. (2005) 1)
PM2.5 (total particles)	740	g/GJ	370	1480	Alves et al. (2011) and Glasius et al. (2005) [1)]
BC (based on total particles)	10	% of PM2.5	2	20	Alves et al. (2011), Goncalves et al. (2011), Fernandes et al. (2011), Bølling et al. (2009), US EPA SPECIATE (2002), Rau (1989)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCBs	0.06	µg/GJ	0.006	0.6	Hedman et al. (2006) [2)]
PCDD/F	800	ng I-TEQ/GJ	20	5000	Glasius et al. (2005); Hedman et al. (2006); Hübner et al. (2005)
Benzo(a)pyrene	121	mg/GJ	12	1210	Goncalves et al. (2012);

Benzo(b)fluoranthene	111	mg/GJ	11	1110	Tissari et al. (2007); Hedberg et al. (2002); Pettersson et al. (2011); Glasius et al. (2005); Paulrud et al. (2006); Johansson et al. (2003); Lamberg et al. (2011)
Benzo(k)fluoranthene	42	mg/GJ	4	420	
Indeno(1,2,3-cd)pyrene	71	mg/GJ	7	710	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

[1)] PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

[2)] Assumed equal to conventional boilers.

[3)] If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated to g/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

TABLE 85 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, HIGH-EFFICIENCY STOVES BURNING WOOD [6)] (GB2019 TABLE 3.41)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Wood**				
SNAP (if applicable)	**020205**	**Residential - Other equipment (stoves, fireplaces, cooking,...)**			
Technologies/Practices	**High-efficiency stoves**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	80	g/GJ	30	150	Pettersson et al. (2011) [1)]
CO	4000	g/GJ	500	10000	Johansson et al. (2003) [2)]
NMVOC	350	g/GJ	100	2000	Johansson et al. (2004) [2)]
SOX	11	g/GJ	8	40	US EPA (1996b)
NH3	37	g/GJ	18	74	Roe et al. (2004) [3)]
TSP (total particles)	400	g/GJ	200	800	Glasius et al. (2005) [4) 5)]
PM10 (total particles)	380	g/GJ	290	760	Glasius et al. (2005) [4) 5)]
PM2.5 (total particles)	370	g/GJ	285	740	Glasius et al. (2005) [4) 5)]
BC (based on total particles)	16	% of PM2.5	5	30	Kupiainen & Klimont (2007) [2)]
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008),

					Lamberg et al. (2011)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCB	0.03	µg/GJ	0.003	0.3	Hedman et al. (2006)
PCDD/F	250	ng I-TEQ/GJ	20	2600	Hedman et al. (2006)
Benzo(a)pyrene	121	mg/GJ	12	1210	Goncalves et al. (2012); Tissari et al. (2007); Hedberg et al. (2002); Pettersson et al. (2011); Glasius et al. (2005); Paulrud et al. (2006); Johansson et al. (2003); Lamberg et al. (2011)
Benzo(b)fluoranthene	111	mg/GJ	11	1110	
Benzo(k)fluoranthene	42	mg/GJ	4	420	
Indeno(1,2,3-cd)pyrene	71	mg/GJ	7	710	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

1) Assumed equal to conventional stoves.

2) Assumed equal to conventional boilers.

3) Assumed low emitting.

4) Wood stoves < 3 years old.

5) PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

6) If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated to g/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

7) Emission factors for solid particles are calculated from the total particulate EFs by assuming the PM2.5 solid particle EF is equal to those for conventional stoves (i.e. the emission reduction by using high-efficiency stoves is fully achieved in the condensable fraction). BC, PM10 and TSP are calculated by assuming the condensable fraction only contains particles <2.5µm and does not contain any BC.

TABLE 86 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, ADVANCED / ECOLABELLED STOVES AND BOILERS BURNING WOOD 3) (GB2019 TABLE 3.42)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Wood**				
SNAP (if applicable)	**020205**	**Residential - Other equipment (stoves, fireplaces, cooking,...)**			
Technologies/Practices	**Advanced / ecolabelled stoves and boilers**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	95	g/GJ	50	150	Pettersson et al. (2011)

CO	2000	g/GJ	500	5000	Johansson et al. (2003)
NMVOC	250	g/GJ	20	500	EMEP/EEA (2009)
SOX	11	g/GJ	8	40	US EPA (1996/2)
NH3	37	g/GJ	18	74	Roe et al. (2004) 1)
TSP (total particles)	100	g/GJ	20	250	Johansson et al.(2003); Goncalves et al. (2010); Schmidl et al. (2011) 2)
PM10 (total particles)	95	g/GJ	19	238	Johansson et al.(2003); Goncalves et al. (2010); Schmidl et al. (2011) 2)
PM2.5 (total particles)	93	g/GJ	19	233	Johansson et al.(2003); Goncalves et al. (2010); Schmidl et al. (2011) 2)
BC (based on total particles)	28	% of PM2.5	11	39	Goncalves et al. (2010), Fernandes et al. (2011), Schmidl et al. (2011)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCB	0.007	µg/GJ	0.0007	0.07	Hedman et al. (2006)
PCDD/F	100	ng I-TEQ/GJ	30	500	Hedman et al. (2006)
PM10 (total particles)	95	g/GJ	19	238	Johansson et al.(2003); Goncalves et al. (2010); Schmidl et al. (2011) 2)
Benzo(a)pyrene	10	mg/GJ	5	20	Boman et al. (2011); Johansson et al. (2004)
Benzo(b)fluoranthene	16	mg/GJ	8	32	
Benzo(k)fluoranthene	5	mg/GJ	2	10	
Indeno(1,2,3-cd)pyrene	4	mg/GJ	2	8	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

1) Assumed low emitting.

2) PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

[3)] If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated to g/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

TABLE 87 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.A.4.B.I, CONVENTIONAL BOILERS < 50 KW BURNING WOOD AND SIMILAR WOOD WASTE [6)] (GB2019 TABLE 3.43)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Wood and similar wood waste**				
SNAP (if applicable)	**020202**	**Residential plants, combustion plants < 50 MW (boilers)**			
Technologies/Practices	**Conventional boilers < 50 kWth**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	80	g/GJ	30	150	Pettersson et al. (2011)
CO	4000	g/GJ	500	10000	Johansson et al. (2003) 1)
NMVOC	350	g/GJ	100	2000	Johansson et al. (2004) 2)
SOX	11	g/GJ	8	40	US EPA (2003)
NH3	74	g/GJ	37	148	Roe et al. (2004)
TSP (total particles)	500	g/GJ	250	1000	Winther (2008) 3) and Johansson et al. (2003) 4)
PM10 (total particles)	480	g/GJ	240	960	Winther (2008) 3) and Johansson et al. (2003) 4)
PM2.5 (total particles)	470	g/GJ	235	940	Winther (2008) 3) and Johansson et al. (2003) 4)
BC (based on total particles)	16	% of PM2.5	5	30	Kupiainen & Klimont (2007) 5)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008),

					Lamberg et al. (2011)
PCBs	0.06	µg/GJ	0.006	0.6	Hedman et al. (2006)
PCDD/F	550	I-Teq ng/GJ	20	2600	Hedman et al. (2006); Hübner et al. (2005)
Benzo(a)pyrene	121	mg/GJ	12	1210	Goncalves et al. (2012); Tissari et al. (2007); Hedberg et al. (2002); Pettersson et al. (2011); Glasius et al. (2005); Paulrud et al. 2006); Johansson et al. (2003); Lamberg et al. (2011)
Benzo(b)fluoranthene	111	mg/GJ	11	1110	
Benzo(k)fluoranthene	42	mg/GJ	4	420	
Indeno(1,2,3-cd)pyrene	71	mg/GJ	7	710	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

Table 88 Tier 2 emission factors for source category 1.A.4.b.i, pellet stoves and boilers burning wood pellets [1)] (GB2019 Table 3.44)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.b.i**	**Residential plants**			
Fuel	**Wood**				
SNAP (if applicable)	**020202**	**Residential plants, combustion plants < 50 MW (boilers)**			
Technologies/Practices	**Pellet stoves and boilers**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	80	g/GJ	50	200	Pettersson et al. (2011)
CO	300	g/GJ	10	2500	Schmidl et al. (2011) and Johansson et al. (2004)
NMVOC	10	g/GJ	1	30	Johansson et al. (2004) and Boman et al. (2011)
SOX	11	g/GJ	8	40	US EPA (1996/2)
NH3	12	g/GJ	6	24	Roe et al. (2004)
TSP (total particles)	62	g/GJ	31	124	Denier van der Gon et al. (2015)
PM10 (total particles)	60	g/GJ	30	120	Denier van der Gon et al. (2015)
PM2.5 (total particles)	60	g/GJ	30	120	Denier van der Gon et al. (2015)
BC (based on total particles)	15	% of PM2.5	6	39	Schmidl et al. (2011)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)

Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCB	0.01	µg/GJ	0.001	0.1	Hedman et al. (2006)
PCDD/F	100	ng I-TEQ/GJ	30	500	Hedman et al. (2006)
Benzo(a)pyrene	10	mg/GJ	5	20	Boman et al. (2011); Johansson et al. (2004)
Benzo(b)fluoranthene	16	mg/GJ	8	32	
Benzo(k)fluoranthene	5	mg/GJ	2	10	
Indeno(1,2,3-cd)pyrene	4	mg/GJ	2	8	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

TABLE 89 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MEDIUM SIZED (>1 MWTH TO ≤ 50 MWTH) BOILERS WOOD (GB2019 TABLE 3.45)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Stationary** **Other, stationary (including military)**			
Fuel	**Wood**				
SNAP (if applicable)	**20100** **20300**	**Commercial and institutional plants** **Plants in agriculture, forestry and aquaculture**			
Technologies/Practices	**Wood combustion >1MW – Boilers**				
Not applicable	**HCH**				
Not estimated					
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	210	g/GJ	50	300	US EPA (2003)
CO	300	g/GJ	50	4000	German test standard for 500 kW-1MW boilers; Danish legislation (Luftvejledningen)
NMVOC	12	g/GJ	5	300	Johansson et al. (2004) [1)]
SOx	11	g/GJ	8	40	US EPA (2003)
NH_3	37	g/GJ	18	74	Roe et al. (2004) [2)]
TSP (total particles)	40	g/GJ	20	80	Denier van der Gon et al. (2015) applied on Johansson et al. (2004) 3) 5)
PM10 (total particles)	38	g/GJ	19	76	
PM2.5 (total particles)	37	g/GJ	18	74	
BC (based on total particles)	15	% of PM2.5	6	39	Schmidl et al. (2011) [4)]
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002),

					Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCB	0.007	μg/GJ	0.0007	0.07	Hedman et al. (2006)
PCDD/F	100	ng I-TEQ/GJ	30	500	Hedman et al. (2006)
Benzo(a)pyrene	10	mg/GJ	5	20	Boman et al. (2011); Johansson et al. (2004)
Benzo(b)fluoranthene	16	mg/GJ	8	32	
Benzo(k)fluoranthene	5	mg/GJ	2	10	
1,2,3-cd)pyrene	4	mg/GJ	2	8	
HCB	5	μg/GJ	0.1	30	Syc et al. (2011)

1) Assumed equal to low emitting wood stoves

2) PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

3) Assumed equal to advanced/ecolabelled residential boilers

4) If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated to g/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

5) Emission factors for total particles are calculated by taking the ratio between PM2.5 for total particles and for solid particles only based on Denier van der Gon et al. (2015) for medium-sized automatic boilers. BC, PM10 and TSP are calculated by assuming the condensable fraction only contains particles <2.5μm and does not contain any BC.

TABLE 90 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MEDIUM SIZED (>50 KWTH TO ≤ 1 MWTH) BOILERS WOOD (IN THE ABSENCE OF INFORMATION ON MANUAL/AUTOMATIC FEED) (GB2019 TABLE 3.46)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Stationary** **Other, stationary (including military)**
Fuel	**Wood**	

SNAP (if applicable)	20100 20300	Commercial and institutional plants Plants in agriculture, forestry and aquaculture			
Technologies/Practices	**Wood combustion <1MW – Boilers**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	91	g/GJ	20	120	Lundgren et al. (2004) 1)
CO	435	g/GJ	50	4000	EN 303 class 5 boilers, 150-300 Kw, German test standard for 500 kW-1MW boilers
NMVOC	156	g/GJ	5	400	Aggregate of EMEP Table 3.47 and Table 3.48
SOX	11	g/GJ	8	40	US EPA (2003)
NH3	37	g/GJ	18	74	Roe et al. (2004) 2)
TSP (total particles)	105	g/GJ	41.5	166	Average of EMEP Table 3.47 and Table 3.48
PM10 (total particles)	100.5	g/GJ	39.5	158	
PM2.5 (total particles)	98.5	g/GJ	38.5	154	
BC (based on total particles)	26	% of PM2.5	8.5	39	Average of Table 3.47 and Table 3.48
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCB	0.007	μg/GJ	0.0007	0.07	Hedman et al. (2006)
PCDD/F	100	ng I-TEQ/GJ	30	500	Hedman et al. (2006)
Benzo(a)pyrene	10	mg/GJ	5	20	Boman et al. (2011); Johansson et al. (2004)
Benzo(b)fluoranthene	16	mg/GJ	8	32	
Benzo(k)fluoranthene	5	mg/GJ	2	10	
1,2,3-cd)pyrene	4	mg/GJ	2	8	
HCB	5	μg/GJ	0.1	30	Syc et al. (2011)

1) Assumed equal to low emitting wood stoves

2) PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

3) Assumed equal to advanced/ecolabelled residential boilers

[4)] Emission factors for total particles are calculated by taking the ratio between PM2.5 for total particles and for solid particles only based on Denier van der Gon et al. (2015) for medium-sized manual boilers (there is very little difference between automatic and medium sized boilers concerning the solid and condensable fractions in total PM according to this paper). BC, PM10 and TSP are calculated by assuming the condensable fraction only contains particles <2.5µm, and does not contain any BC.

TABLE 91 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, MANUAL BOILERS BURNING WOOD [4)]

(GB2019 TABLE 3.47)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Stationary** **Other, stationary (including military)**			
Fuel	**Wood**				
SNAP (if applicable)	**20100** **20300**	**Commercial and institutional plants** **Plants in agriculture, forestry and aquaculture**			
Technologies/Practices	**Wood combustion <1MW – Manual Boilers**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	91	g/GJ	20	120	Lundgren et al. (2004) 1)
CO	570	g/GJ	50	4000	EN 303 class 5 boilers, 150-300 Kw
NMVOC	300	g/GJ	5	500	Naturvårdsverket, Sweden
SOX	11	g/GJ	8	40	US EPA (2003)
NH3	37	g/GJ	18	74	Roe et al. (2004) 1)
TSP (total particles)	170	g/GJ	85	340	Denier van der Gon et al. (2015) applied on Naturvårdsverket, Sweden 5)
PM10 (total particles)	163	g/GJ	81	326	Denier van der Gon et al. (2015) applied on Naturvårdsverket, Sweden 2) 5)
PM2.5 (total particles)	160	g/GJ	80	320	Denier van der Gon et al. (2015) applied on Naturvårdsverket, Sweden 2) 5)
BC (based on total particles)	28	% of PM2.5	11	39	Goncalves et al. (2010), Fernandes et al. (2011), Schmidl et al. (2011) 3) 5)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)

Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCB	0.06	µg/GJ	0.006	0.6	Hedman et al. (2006)
PCDD/F	100	ng I-TEQ/GJ	30	500	Hedman et al. (2006)
Benzo(a)pyrene	10	mg/GJ	5	20	Boman et al. (2011); Johansson et al. (2004)
Benzo(b)fluoranthene	16	mg/GJ	8	32	
Benzo(k)fluoranthene	5	mg/GJ	2	10	
1,2,3-cd)pyrene	4	mg/GJ	2	8	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

1) Assumed equal to low emitting wood stoves

2) PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

3) Assumed equal to advanced/ecolabelled residential boilers

4) If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated to g/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

5) Emission factors for total particles are calculated by taking the ratio between PM2.5 for total particles and for solid particles only based on Denier van der Gon et al. (2015) for medium-sized manual boilers. BC, PM10 and TSP are calculated by assuming the condensable fraction only contains particles <2.5µm and does not contain any BC.

TABLE 92 TIER 2 EMISSION FACTORS FOR NON-RESIDENTIAL SOURCES, AUTOMATIC BOILERS BURNING WOOD [5)]

(GB2019 TABLE 3.48)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.A.4.a.i** **1.A.4.c.i** **1.A.5.a**	**Commercial / institutional: stationary** **Stationary** **Other, stationary (including military)**			
Fuel	**Wood**				
SNAP (if applicable)	**20100** **20300**	**Commercial and institutional plants** **Plants in agriculture, forestry and aquaculture**			
Technologies/Practices	**Wood combustion <1MW - Automatic Boilers**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOX	91	g/GJ	20	120	Lundgren et al. (2004) [1)]
CO	300	g/GJ	50	4000	German test standard for 500 kW-1MW boilers;Danish legislation (Luftvejledningen)
NMVOC	12	g/GJ	5	300	Johansson et al. (2004) [1)]
SOX	11	g/GJ	8	40	US EPA (2003)
NH3	37	g/GJ	18	74	Roe et al. (2004) [2)]
TSP (total particles)	40	g/GJ	20	80	Denier van der Gon et al. (2015) applied on Johansson et al. (2004) [6)]
PM10 (total particles)	38	g/GJ	19	76	Denier van der Gon et al. (2015) applied on Johansson et al. (2004) [3) 6)] Denier van der Gon et al.
PM2.5 (total particles)	37	g/GJ	18	74	
BC (based on total particles)	15	% of PM2.5	6	39	

					(2015) applied on Johansson et al. (2004) 3) 6) Schmidl et al. (2011) 4)
Pb	27	mg/GJ	0.5	118	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Cd	13	mg/GJ	0.5	87	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Hg	0.56	mg/GJ	0.2	1	Struschka et al. (2008)
As	0.19	mg/GJ	0.05	12	Struschka et al. (2008)
Cr	23	mg/GJ	1	100	Hedberg et al. (2002), Struschka et al. (2008)
Cu	6	mg/GJ	4	89	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
Ni	2	mg/GJ	0.5	16	Hedberg et al. (2002), Struschka et al. (2008), Lamberg et al. (2011)
Se	0.5	mg/GJ	0.25	1.1	Hedberg et al. (2002)
Zn	512	mg/GJ	80	1300	Hedberg et al. (2002), Tissari et al. (2007), Struschka et al. (2008), Lamberg et al. (2011)
PCB	0.007	µg/GJ	0.0007	0.07	Hedman et al. (2006)
PCDD/F	100	ng I-TEQ/GJ	30	500	Hedman et al. (2006)
Benzo(a)pyrene	10	mg/GJ	5	20	Boman et al. (2011); Johansson et al. (2004)
Benzo(b)fluoranthene	16	mg/GJ	8	32	
Benzo(k)fluoranthene	5	mg/GJ	2	10	
1,2,3-cd)pyrene	4	mg/GJ	2	8	
HCB	5	µg/GJ	0.1	30	Syc et al. (2011)

1) Data for modern boilers

2) Assumed equal to low emitting wood stoves

3) PM10 estimated as 95 % of TSP, PM2.5 estimated as 93 % of TSP. The PM fractions refer to Boman et al. (2011), Pettersson et al. (2011) and the TNO CEPMEIP database.

4) Assumed equal to residential pellet boilers

5) If the reference states the emission factor in g/kg dry wood the emission factors have been recalculated to g/GJ based on NCV stated in each reference. If NCV is not stated in a reference, the following values have been assumed: 18 MJ/kg for wood logs and 19 MJ/kg for wood pellets.

6) Emission factors for total particles are calculated by taking the ratio between PM2.5 for total particles and for solid particles only based on Denier van der Gon et al. (2015) for medium-sized automatic boilers. BC, PM10 and TSP are calculated by assuming the condensable fraction only contains particles <2.5µm, and does not contain any BC.

1.B.1.a

TABLE 93 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.B.1.A COAL MINING AND HANDLING, STORAGE OF COAL, UNCONTROLLED (GB2019 TABLE 3-4)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.B.1.a**	**Coal mining and handling**

Fuel	**NA**				
Technologies/Practices	**Storage of coal**				
Abatement technologies	**Uncontrolled**				
Not applicable	**NOx, CO, SOx, NH_3, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH**				
Not estimated	**NMVOC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, BC**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	10.25	Mg/ha/year	1.025	102.5	Visschedijk et al. (2004) applied in Peutz (2006)
PM10	4.1	Mg/ha/year	0.41	41	Peutz (2006), US EPA (2006)
PM2.5	0.41	Mg/ha/year	0.041	4.1	Visschedijk et al. (2004) applied in Peutz (2006)

TABLE 94 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.B.1.A COAL MINING AND HANDLING, STORAGE OF COAL, CONTROLLED (GB2019 TABLE 3-5)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.B.1.a**	**Coal mining and handling**			
Fuel	**NA**				
Technologies/Practices	**Storage of coal**				
Abatement technologies	**Controlled**				
Not applicable	**NOx, CO, SOx, NH_3, BC, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, HCH**				
Not estimated	**NMVOC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	1.025	Mg/ha/year	0.1025	10.25	Visschedijk et al. (2004) applied in Peutz (2006)
PM10	0.41	Mg/ha/year	0.041	4.1	Peutz (2006), Vrins (1999)
PM2.5	0.041	Mg/ha/year	0.0041	0.41	Visschedijk et al. (2004) applied in Peutz (2006)

1.B.2.a.

TABLE 95 TIER 1 EMISSION FACTORS FOR SOURCE CATEGORY 1.B.2.A.IV REFINING, STORAGE (GB2019 TABLE 3-1)

Tier 1 emission factors		
	Code	**Name**
NFR Source Category	**1.B.2.a.iv**	**Fugitive emissions oil: Refining / storage**
Fuel	**NA**	
Not applicable	**BC, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene,**	

	Indeno(1,2,3-cd)pyrene, HCB, PCB				
Not estimated					
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	0.24	kg/Mg crude oil input	0.08	0.72	1)
CO	0.09	kg/Mg crude oil input	0.03	0.26	1)
NMVOC	**0.20**	kg/Mg crude oil input	0.07	0.61	1)
SOx	0.62	kg/Mg crude oil input	0.21	1.9	1)
NH_3	**0.0011**	kg/Mg crude oil input	0.0004	0.0034	1)
TSP	0.016	kg/Mg crude oil input	0.005	0.048	2)
PM10	0.0099	kg/Mg crude oil input	0.003	0.030	1)
PM2.5	0.0043	kg/Mg crude oil input	0.001	0.013	2)
Pb	0.0051	g/MG crude oil input	0.002	0.015	1)
Cd	0.0051	g/MG crude oil input	0.002	0.015	1)
Hg	0.0051	g/MG crude oil input	0.002	0.015	1)
As	0.0051	g/MG crude oil input	0.002	0.015	1)
Cr	0.0051	g/MG crude oil input	0.002	0.015	1)
Cu	0.0051	g/MG crude oil input	0.002	0.015	1)
Ni	0.0051	g/MG crude oil input	0.002	0.015	1)
Se	0.0051	g/MG crude oil input	0.002	0.015	1)
Zn	0.0051	g/MG crude oil input	0.002	0.015	1)
PCDD/F	**0.0057**	µg/Mg crude oil input	0.002	0.017	1)

TABLE 96 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 1.B.2.A.IV REFINING, STORAGE, FLUID CATALYTIC CRACKING - CO BOILER (NOT INSTALLED) (GB2019 TABLE 3-2)

Tier 2 emission factors		
	Code	**Name**
NFR Source Category	**1.B.2.a.iv**	**Fugitive emissions oil: Refining / storage**
Fuel	**NA**	
SNAP (if applicable)	**040102**	**Fluid catalytic cracking - CO boiler**
Technologies/Practices	**Catalytic Cracking unit regenerators Partial burn without CO boiler**	

Abatement technologies	Cyclone systems installed internally within the regenerator				
Not applicable	**HCB, PCB**				
Not estimated	**PCDD/F**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	0.2	kg/m3 fresh feed	0.12	0.29	CONCAWE (2017)
CO	39	kg/m3 fresh feed	24	55	CONCAWE (2017)
NMVOC	0.63	kg/m3 fresh feed	0.38	0.88	CONCAWE (2017)
SOx	1.4	kg/m3 fresh feed	0.85	2	CONCAWE (2017)
NH3	0.16	kg/m3 fresh feed	0.093	0.22	CONCAWE (2017)
TSP	0.7	kg/m3 fresh feed	0.05	2	Environment Australia, 1999
PM10	0.55	kg/m3 fresh feed	0.18	1.6	CONCAWE (2017)
PM2.5	0.24	kg/m3 fresh feed	0.08	0.5	1)
BC(a)	0.13	% of PM2.5	0.05	0.2	2)
Pb	0.32	g/m3 fresh feed	0.11	0.96	CONCAWE (2017)
Cd	0.063	g/m3 fresh feed	0.021	0.19	CONCAWE (2017)
Hg	0.07	g/m3 fresh feed	0.023	0.21	CONCAWE (2017)
As	0.014	g/m3 fresh feed	0.0046	0.042	CONCAWE (2017)
Cr	0.33	g/Mg coke burned	0.1	1	Bertrand & Siegell, 2002; CONCAWE (2017) (b)
Cu	0.14	g/m3 fresh feed	0.046	0.42	CONCAWE (2017)
Ni	0.61	g/m3 fresh feed	0.2	1.8	CONCAWE (2017)
Se	0.014	g/m3 fresh feed	0.005	0.042	CONCAWE (2017)
Zn	0.12	g/m3 fresh feed	0.039	0.35	CONCAWE (2017)
Benzo(a)pyrene	**0.71**	mg/Mg coke burned	0.4	1.4	CONCAWE (2017)
Benzo(b)fluoranthene	**1.2**	mg/Mg coke burned	0.6	2.4	CONCAWE (2017)
Benzo(k)fluoranthene	**0.82**	mg/Mg coke burned	0.4	1.6	CONCAWE (2017)
Indeno(1,2,3-cd)pyrene	**0.62**	mg/Mg coke burned	0.3	1.2	CONCAWE (2017)

TABLE 97 TIER 1 EMISSION FACTOR FOR SOURCE CATEGORY 1.B.2.A.V DISTRIBUTION OF OIL PRODUCTS (GB2019 TABLE 3-1)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**1.B.1.a.v**	**Distribution of oil products**			
Fuel	**NA**				
Not applicable	**NOx, CO, NH_3, PM2.5, PM10, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Not estimated	**SOx, PCDD/F**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	2	Kg/Mg gasoline handled	0.2	2	Richards et al. (1990)

TABLE 98 TIER 2 EMISSIONS FOR SOURCE CATEGORY 1.B.2.A.I EXPLORATION PRODUCTION TRANSPORT, ONSHORE FACILITIES (GB2019 TABLE 3-3)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**1.B.2.a.i**	**Exploration production, transport**			
Fuel	**NA**				
SNAP (if applicable)	**050201**	**Land-based activities**			
Technologies/Practices	**Facilities producing oil only**				
Not applicable	**NOx, CO, NH_3, TSP, PM2.5, PM10, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Not estimated	**SOx, PCDD/F**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.1	Kg/Mg oil	0.045	0.2	CORINAIR (1990)

2.A

TABLE 99 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 2.A.2 LIME PRODUCTION (GB2019 TABLE 3.3)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**2.A.2**	**Lime production**			
Fuel	**NA**				
SNAP (if applicable)	**040614**	**Lime (decarbonizing)**			
Technologies/Practices	**Typical emissions from some types of lime kiln**				
Abatement technologies	**Controlled**				
Not applicable	**NH_3, As, Cr, Cu, Ni, Se, Zn, HCH, PCBs, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Not estimated	**NOx, CO, NMVOC, SOx,Pb, Cd, Hg**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	400	g/Mg mineral	100	1000	European Commission (2001)
PM10	200	g/Mg mineral	60	400	Visschedijk et al. (2004)
PM2.5	30	g/Mg mineral	10	80	Visschedijk et al. (2004)
BC	0.46	% of PM2.5	0.23	0.92	Chow et al. (2011)

TABLE 100 TIER 1 EMISSION FACTORS FOR SOURCE CATEGORY 2.A.3 GLASS PRODUCTION (GB2019 TABLE 3.1)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**2.A.3**	**Glass production**			
Fuel	**NA**				
Not applicable	**HCH, PCBs**				
Not estimated	**NOx, NMVOC, SOx, NH3, CO, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	300	g/Mg glass	100	600	Average between flat and container glass
PM10	270	g/Mg glass	90	540	Visschedijk et al (2004) applied on TSP
PM2.5	240	g/Mg glass	80	480	Visschedijk et al (2004) applied on TSP
BC	0.062	% of PM2.5	0.031	0.12	US EPA (2011, file no.: 91143)
Pb	1.7	g/Mg glass	0.1	15	Average between flat and container glass
Cd	0.13	g/Mg glass	0.01	0.28	Average between flat and container glass
Hg	0.003	g/Mg glass	0.0003	0.039	Average between flat and

					container glass
As	0.19	g/Mg glass	0.01	1.1	Average between flat and container glass
Cr	0.23	g/Mg glass	0.01	2.3	Average between flat and container glass
Cu	0.007	g/Mg glass	0.001	0.011	Average between flat and container glass
Ni	0.49	g/Mg glass	0.02	1	Average between flat and container glass
Se	0.8	g/Mg glass	0.02	8.9	Average between flat and container glass
Zn	0.37	g/Mg glass	0.13	0.56	Average between flat and container glass

Note: the emission of lead is mainly determined by the amount of recycled glass used (Beerkens, 2008).

TABLE 101 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 2.A.5.A QUARRYING AND MINING OF MINERALS OTHER THAN COAL, LOW TO MEDIUM EMISSION LEVEL

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**2.A.5.a**	**Quarrying and mining of minerals other than coal**			
Fuel	**NA**				
Technologies/Practices	**Low to medium emission level**				
Not applicable	**NOx, CO, NMVOC, SOx, NH_3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, HCH, PCBs, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	51	g/Mg mineral	25	100	Visschedijk et al. (2004)
PM10	25	g/Mg mineral	13	50	Visschedijk et al. (2004)
PM2.5	2.5	g/Mg mineral	1.9	7.6	Visschedijk et al. (2004)

TABLE 102 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 2.A.5.A QUARRYING AND MINING OF MINERALS OTHER THAN COAL, MEDIUM TO HIGH EMISSION LEVEL (GB2019 TABLE 3-1)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**2.A.5.a**	**Quarrying and mining of minerals other than coal**			
Fuel	**NA**				
Technologies/Practices	**Medium high to high emission level**				
Not applicable	**NOx, CO, NMVOC, SOx, NH3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, HCH, PCBs, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	102	g/Mg mineral	50	200	Visschedijk et al. (2004)

PM10	50	g/Mg mineral	25	100	Visschedijk et al. (2004)
PM2.5	5.0	g/Mg mineral	2.5	10	Visschedijk et al. (2004)

2.C.1.

TABLE 103 TIER 1 EMISSION FACTORS FOR SOURCE CATEGORY 2.C.1 IRON AND STEEL PRODUCTION (GB2019 TABLE 3.1)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**2.C.1**	**Iron and steel production**			
Fuel	**NA**				
Not estimated	**NOx, CO, SOx, NH3, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	150	g/Mg steel	55	440	European Commission (2001)
TSP	300	g/Mg steel	90	1 300	European Commission (2001)
PM10	180	g/Mg steel	60	700	Visschedijk et al. (2004) applied on TSP
PM2.5	140	g/Mg steel	40	500	Visschedijk et al. (2004) applied on TSP
BC	0.36	% of PM2.5	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	4.6	g/Mg steel	0.5	46	European Commission (2001), Theloke et al. (2008)
Cd	0.02	g/Mg steel	0.003	0.1	European Commission (2001), Theloke et al. (2008)
Hg	0.1	g/Mg steel	0.02	0.5	European Commission (2001), Theloke et al. (2008)
As	0.4	g/Mg steel	0.08	2	Theloke et al. (2008)
Cr	4.5	g/Mg steel	0.5	45	European Commission (2001), Theloke et al. (2008)
Cu	0.07	g/Mg steel	0.01	0.3	European Commission (2001), Theloke et al. (2008)
Ni	0.14	g/Mg steel	0.1	1.1	European Commission (2001), Theloke et al. (2008)
Se	0.02	g/Mg steel	0.002	0.2	Guidebook (2006)
Zn	4	g/Mg steel	0.4	43	European Commission (2001), Guidebook (2006)
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	3.0	µg I-TEQ/Mg steel	0.04	6.0	European Commission (2012)
Total 4 PAHs	0.48	g/Mg steel	0.009	0.97	European Commission (2012)
HCB	0.03	mg/Mg steel	0.003	0.3	Guidebook (2006)

Note: These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001.

2.D.3

TABLE 104 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 2.D.3.B ROAD PAVING WITH ASPHALT, BATCH MIX HOT MIX ASPHALT PLANT (GB2019 TABLE 3.2)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**2.D.3.b**	**Road paving with asphalt**			
Fuel	**NA**				
SNAP (if applicable)	**040611**	**Road paving with asphalt**			
Abatement technologies	**Uncontrolled**				
Not applicable	**NH3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCBs**				
Not estimated	**NOx, CO, SO2, BC, PCDD/F, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	16	g/Mg asphalt	3	100	US EPA (2004)
TSP	15 000	g/Mg asphalt	10	100 000	US EPA (2004)
PM10	2 000	g/Mg asphalt	4	10 000	US EPA (2004)
PM2.5	100	g/Mg asphalt	4	1 000	US EPA (2004)
BC	5.7	% of PM2.5	2.8	11	US EPA (2011, file No.: 91159)

TABLE 105 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 2.D.3.C, ASPHALT ROOFING, DIP SATURATOR (GB2019 TABLE3.2)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**2.D.3.c**	**Asphalt roofing**			
Fuel	**NA**				
SNAP (if applicable)	**040610**	**Roof covering with asphalt materials**			
Technologies/ Practices	**Dip saturator, drying-in drums section, wet looper and coater**				
Abatement technologies	**Uncontrolled**				
Not applicable	**SOx, NH3, As, Cr, Cu, Ni, Se, Zn, HCH, PCBs,**				
Not estimated	**NOx, Pb, Cd, Hg, PCDD/F, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
CO	9.5	g/Mg shingle	3	30	US EPA (1995)
NMVOC	46	g/Mg shingle	15	150	US EPA (1995)
TSP	600	g/Mg shingle	200	1 800	US EPA (1995)
PM10	150	g/Mg shingle	50	450	US EPA (1995)/US EPA (2004)

PM2.5	30	g/Mg shingle	10	90	US EPA (1995)/US EPA (2004)
BC	0.013	% of PM2.5	0.006	0.026	US EPA (2011 file no.: 91148)

TABLE 106 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 2.D.3.I, 2.G OTHER SOLVENT AND PRODUCT USE, TOBACCO COMBUSTION (GB2019 TABLE 3-15)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**2.D.3.i, 2.g**	**Other solvent and product use**			
SNAP (if applicable)	**060602**	**Tobacco combustion**			
Not estimated	**SO2, Pb, Hg, As, Cr, Se, As, PCBs, HCB, HCH**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	1.80	kg/Mg tobacco	1.7	1.9	Martin et al., 1997
CO	55.1	kg/Mg tobacco	53	57	Martin et al., 1997
TSP	600	g/Mg shingle	200	1 800	US EPA (1995)
PM10	150	g/Mg shingle	50	450	US EPA (1995)/US EPA (2004)
PM2.5	30	g/Mg shingle	10	90	US EPA (1995)/US EPA (2004)
NMVOC	4.84	kg/Mg tobacco	2.4	9.7	Sandmo, 2011
NH3	4.15	kg/Mg tobacco	3.9	4.4	Martin et al., 1997
TSP	27.0	mg/cigarette	25	30	Schauer et al., 1998. PM2.5
PM10	27.0	mg/cigarette	25	30	Schauer et al., 1998. PM2.5
PM2.5	27.0	mg/cigarette	25	30	Schauer et al., 1998. PM2.5
BC (2)	0.45	% of PM1.8	0.30	0.67	Schauer et al., 1998. It is assumed that EC equals BC for tobacco smoking
Cd	5.4	µg/cigarette	1.4	22	Schauer et al., 1998. EFs are calculated from 0.01 % and 0.02 % of PM1.8
Ni	2.7	µg/cigarette	0.7	11	
Zn	2.7	µg/cigarette	0.7	11	
Cu	5.4	µg/cigarette	2.4	12	
PCDD/F	0.1	µg I-TEQ/Mg tobacco	0.05	0.2	UNEP toolkit, 2005
Benzo(a)pyrene	0.111	g/Mg tobacco	0.06	0.22	*
Benzo(b)fluoranthene	0.045	g/Mg tobacco	0.023	0.09	*
Benzo(k)fluoranthene	0.045	g/Mg tobacco	0.023	0.09	*
Indeno(1,2,3-cd)pyrene	0.045	g/Mg tobacco	0.023	0.09	*

* - Data on sidestream and mainstream smoke are calculated from Daher et al. (2010) tables 1 and 2

TABLE 107 TIER 2 EMISSION FACTOR FOR SOURCE CATEGORY 2.D.3.I, 2.G OTHER SOLVENT AND PRODUCT USE, OTHER, USE OF FIREWORKS (GB2019 TABLE 3-14)

Tier 2 emission factors

	Code	Name			
NFR Source Category	**2.D.3.i, 2.g**	**Other solvent and product use**			
SNAP (if applicable)	**060601**	**Other, Use of Fireworks**			
Not estimated	**NH3, Se, Zn, HCH, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
SO_2	3020	g/t product	1500	4500	N=2 (NNWB, 2008; Swiss IIR, 2012)
CO	7150	g/t product	6800	7500	N=2 (NNWB, 2008; Swiss IIR, 2012)
NOx	260	g/t product	130	520	N=1 (Swiss IIR, 2012)
TSP	109,830	g/t product	50,000	170,000	N=2 (Klimont et al., 2002; Swiss IIR, 2012)
PM10	99,920	g/t product	40,000	160,000	N=2 (Klimont et al., 2002; Swiss IIR, 2012)
PM2.5	51,940	g/t product	10,000	90,000	N=2 (Klimont et al., 2002; Swiss IIR, 2012)
As	1.33	g/t product	0.1	13	N=1 (Passant et al., 2003)
Cd	1.48	g/t product	0.1	14	N=2 (Passant et al., 2003; Swiss IIR, 2012)
Cr	15.6	g/t product	0.1	150	N=1 (Passant et al., 2003)
Cu	444	g/t product	100	2000	N=1 (Passant et al., 2003)
Hg	0.057	g/t product	0.005	0.5	N=2 (Fyrv. Miljö, 1999, Swiss IIR, 2012)
Ni	30	g/t product	0.6	150	N=1 (Fyrv. Miljö, 1999)
Pb	784	g/t product	200	3000	N=2 (Passant et al., 2003; Swiss IIR, 2012)
Zn	260	g/t product	26	2000	N=1 (Fyrv. Miljö, 1999)

2H2

TABLE 108 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 2.H.2 FOOD AND BEVERAGES INDUSTRY, ANIMAL RENDERING (GB2019 TABLES 3-2 – 3-28)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**2.H.2**	**Food and beverages industry**			
Pollutant	**NMVOC**				
Technologies/ Practices	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
Bread, typical (Europe)	4.5	kg/Mg bread	0.45	45	EMEP/EEA (2006)
Bread, typical (North America)	8	kg/Mg bread	0.8	80	EMEP/EEA (2006)
Sponge-dough bread	8	kg/Mg bread	2.7	24	Henderson (1977)
White Bread	4.5	kg/Mg bread	1.5	14	Bouscaren (1992)
White bread shortened process	2	kg/Mg bread	0.7	6	Bouscaren (1992)
Wholemeal bread	3	kg/Mg bread	1	9	Bouscaren (1992)
Light Rye bread	3	kg/Mg bread	1	9	Bouscaren (1992)
Cakes, biscuits and breakfast cereals	1	kg/Mg product	0.1	10	EMEP/EEA (2006)
Meat, fish and poultry	0.3	kg/Mg product	0.03	3	EMEP/EEA (2006)
Sugar	10	kg/Mg sugar	1	100	EMEP/EEA (2006)
Margarine and solid cooking fats	10	kg/Mg product	1	100	EMEP/EEA (2006)
Animal feed	1	kg/Mg feed	0.1	10	EMEP/EEA (2006)
Coffee roasting	0.55	kg/Mg beans	0.18	1.7	Rentz et al. (1991)
Wine (unspecified colour)	0.08	kg/hl wine	0.008	0.8	EMEP/EEA (2006)
Red wine	0.08	kg/hl wine	0.03	0.24	EMEP/EEA (2006)
White wine	0.035	kg/hl wine	0.012	0.11	EMEP/EEA (2006)
Beer (including de-alcoholized)	0.035	kg/hl beer	0.012	0.11	EMEP/EEA (2006)
Spirits unspecified sort	15	kg/hl alcohol	1.5	150	EMEP/EEA (2006)

5.C.1

TABLE 109 TIER 1 EMISSION FACTORS FOR SOURCE CATEGORY 5.C.1.B.I, 5.C.1.B.II, 5.C.1.B.IV INDUSTRIAL WASTE INCINERATION INCLUDING HAZARDOUS WASTE AND SEWAGE SLUDGE (GB2019 TABLE 3-1)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**5.C.1.b.i 5.C.1.b.ii 5.C.1.b.iv**	**Industrial waste incineration including hazardous waste and sewage sludge**			
Not applicable	**PCB**				
Not estimated	**NH3, Cr, Cu, Zn, Se, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	0.87	kg/Mg waste	0.087	8.7	European Commission (2006)
CO	0.07	kg/Mg waste	0.007	0.7	European Commission (2006)
NMVOC	7.4	kg/Mg waste	0.74	74	Passant (1993)
SO_2	0.047	kg/Mg waste	0.0047	0.47	European Commission (2006)
TSP	0.01	kg/Mg waste	0.001	2.3	European Commission (2006)
PM10	0.007	kg/Mg waste	0.0007	0.15	US EPA (1996) applied on TSP
PM2.5	0.004	kg/Mg waste	0.0004	0.1	US EPA (1996) applied on TSP
BC1	3.5	% of PM2.5	1.8	7	Olmez et al. (1988)
Pb	1.3	g/Mg waste	0.48	1.9	Theloke et al. (2008)
Cd	0.1	g/Mg waste	0.048	0.15	Theloke et al. (2008)
Hg	0.056	g/Mg waste	0.04	0.08	European Commission (2006)
As	0.016	g/Mg waste	0.01	0.019	Theloke et al. (2008)
Ni	0.14	g/Mg waste	0.048	0.19	Theloke et al. (2008)
PCDD/F	350	µg I-TEQ/Mg waste	0.5	35000	UNEP (2005)
Total 4 PAHs	0.02	g/Mg waste	0.007	0.06	Wild (1995)
HCB	0.002	g/Mg waste	0.0002	0.02	Berdowski et al. (1997)

TABLE 110 TIER 1 EMISSION FACTORS FOR SOURCE CATEGORY 5.C.1.A MUNICIPAL WASTE INCINERATION (GB2019 TABLE 3-1)

Tier 1 emission factors					
	Code	**Name**			
NFR Source Category	**5.C.1.a**	**Municipal waste incineration**			
Fuel	**NA**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	1071	g/Mg	749	1532	Nielsen et al. (2010)
CO	41	g/Mg	7	253	Nielsen et al. (2010)

NMVOC	5.9	g/Mg	2.7	12.9	Nielsen et al. (2010)
SO2	87	g/Mg	16	466	Nielsen et al. (2010)
NH3	3.0	g/Mg	0.5	18.3	Nielsen et al. (2010)
TSP	3.0	g/Mg	1.1	8.3	Nielsen et al. (2010)
PM10	3.0	g/Mg	1.1	8.3	CEPMEIP
PM2.5	3.0	g/Mg	1.1	8.3	CEPMEIP
BC1	3.5	% of PM2.5	1.8	7	Olmez et al. (1988)
Pb	58.0	mg/Mg	12.0	280.3	Nielsen et al. (2010)
Cd	4.6	mg/Mg	1.1	19.3	Nielsen et al. (2010)
Hg	18.8	mg/Mg	7.3	48.3	Nielsen et al. (2010)
As	6.2	mg/Mg	1.3	29.6	Nielsen et al. (2010)
Cr	16.4	mg/Mg	3.0	88.7	Nielsen et al. (2010)
Cu	13.7	mg/Mg	3.9	47.3	Nielsen et al. (2010)
Ni	21.6	mg/Mg	4.2	111.6	Nielsen et al. (2010)
Se	11.7	mg/Mg	2.2	62.0	Nielsen et al. (2010)
Zn	24.5	mg/Mg	2.7	219.6	Nielsen et al. (2010)
PCBs	3.4	ng/Mg	1.2	9.2	Nielsen et al. (2010)
PCDD/F	52.5	ng/Mg	16.6	166.3	Nielsen et al. (2010)
Benzo(a)pyrene	8.4	µg/Mg	2.8	33.6	Nielsen et al. (2010)
Benzo(b)fluoranthene	17.9	µg/Mg	6.0	71.4	Nielsen et al. (2010)
Benzo(k)fluoranthene	9.5	µg/Mg	3.2	37.8	Nielsen et al. (2010)
Indeno(1,2,3-cd)pyrene	11.6	µg/Mg	3.9	46.2	Nielsen et al. (2010)
HCB	45.2	µg/Mg	8.0	254.1	Nielsen et al. (2010)

TABLE 111 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 5.E OTHER WASTE, CAR FIRE (GB2019 TABLE 3-2)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**5.E**	**Other waste**			
Fuel	**NA**				
Technologies/ Practices	**Car fire**				
Not applicable	**HCH**				
Not estimated	**SO2, NOx, NMVOC, CO, NH3, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, Benzo(a)pyrene, Benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, PCBs**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	2.3	kg/fire	1	5	Aasestad (2007)
PM10	2.3	kg/fire	1	5	Aasestad (2007)
PM2.5	2.3	kg/fire	1	5	Aasestad (2007)
PCDD/F	0.048	mg/fire	0.02	0.1	Hansen (2007)

TABLE 112 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 5.E OTHER WASTE, DETACHED HOUSE FIRE (GB2019 TABLE 3-3)

Tier 2 emission factors

	Code	Name			
NFR Source Category	**5.E**	**Other waste**			
Fuel	**NA**				
Technologies/ Practices	**Detached house fire**				
Not applicable	**NH3, HCH**				
Not estimated	**NOx, CO, NMVOC, SO2, BC, NI, Se, Zn, PCBs, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	143.82	kg/fire	71.9	287.6	Aasestad (2007)
PM10	143.82	kg/fire	71.9	287.6	Aasestad (2007)
PM2.5	143.82	kg/fire	71.9	287.6	Aasestad (2007)
Pb	0.42	g/fire	0.2	0.8	Aasestad (2007)
Cd	0.85	g/fire	0.4	1.7	Aasestad (2007)
Hg	0.85	g/fire	0.4	1.7	Aasestad (2007)
As	1.35	g/fire	0.7	2.7	Aasestad (2007)
Cr	1.29	g/fire	0.6	2.6	Aasestad (2007)
Cu	2.99	g/fire	1.5	6.0	Aasestad (2007)
PCDD/F	1.44	mg/fire	0.7	2.9	Aasestad (2007)

TABLE 113 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 5.E OTHER WASTE, APARTMENT BUILDING FIRE (GB2019 TABLE 3-5)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**5.E**	**Other waste**			
Fuel	**NA**				
Technologies/ Practices	**Apartment building fire**				
Not applicable	**NH3, HCH**				
Not estimated	**NOx, CO, NMVOC, SO2, BC, NI, Se, Zn, PCBs, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	43.78	kg/fire	21.9	87.6	Aasestad (2007)
PM10	43.78	kg/fire	21.9	87.6	Aasestad (2007)
PM2.5	43.78	kg/fire	21.9	87.6	Aasestad (2007)
Pb	0.13	g/fire	0.1	0.3	Aasestad (2007)
Cd	0.26	g/fire	0.1	0.5	Aasestad (2007)
Hg	0.26	g/fire	0.1	0.5	Aasestad (2007)
As	0.41	g/fire	0.2	0.8	Aasestad (2007)
Cr	0.39	g/fire	0.2	0.8	Aasestad (2007)
Cu	0.91	g/fire	0.5	1.8	Aasestad (2007)
PCDD/F	0.44	mg/fire	0.2	0.9	Aasestad (2007)

TABLE 114 TIER 2 EMISSION FACTORS FOR SOURCE CATEGORY 5.E OTHER WASTE, INDUSTRIAL BUILDING FIRE GB2019 TABLE 3-6)

Tier 2 emission factors					
	Code	**Name**			
NFR Source Category	**5.E**	**Other waste**			
Fuel	**NA**				
Technologies/ Practices	**Industrial building fire**				
Not applicable	**NH3, HCH**				
Not estimated	**NOx, CO, NMVOC, SO2, BC, Ni Se, Zn, PCBs, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB**				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	27.23	kg/fire	13.6	54.5	Aasestad (2007)
PM10	27.23	kg/fire	13.6	54.5	Aasestad (2007)
PM2.5	27.23	kg/fire	13.6	54.5	Aasestad (2007)
Pb	0.08	g/fire	0.04	0.2	Aasestad (2007)
Cd	0.16	g/fire	0.1	0.3	Aasestad (2007)
Hg	0.16	g/fire	0.1	0.3	Aasestad (2007)
As	0.25	g/fire	0.1	0.5	Aasestad (2007)
Cr	0.24	g/fire	0.1	0.5	Aasestad (2007)
Cu	0.57	g/fire	0.3	1.1	Aasestad (2007)
PCDD/F	0.27	mg/fire	0.1	0.5	Aasestad (2007)