LITHUANIAN POLLUTANT EMISSION INVENTORY FOR PERIOD 1990-2019

2020 m. sausio 14 d. Sutarties Nr. 28T-2020-8

Lithuanian Environmental Protection Agency

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

Authors of the report greatly appreciate input of the following individuals and institutions:

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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 1990-2019. 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 2019. 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 **Klaida! Nerastas nuorodos šaltinis.**.

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. Country specific data emission factors and methodologies are available for small combustion.

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 1990-2019 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 Figure 1 and Figure 2.

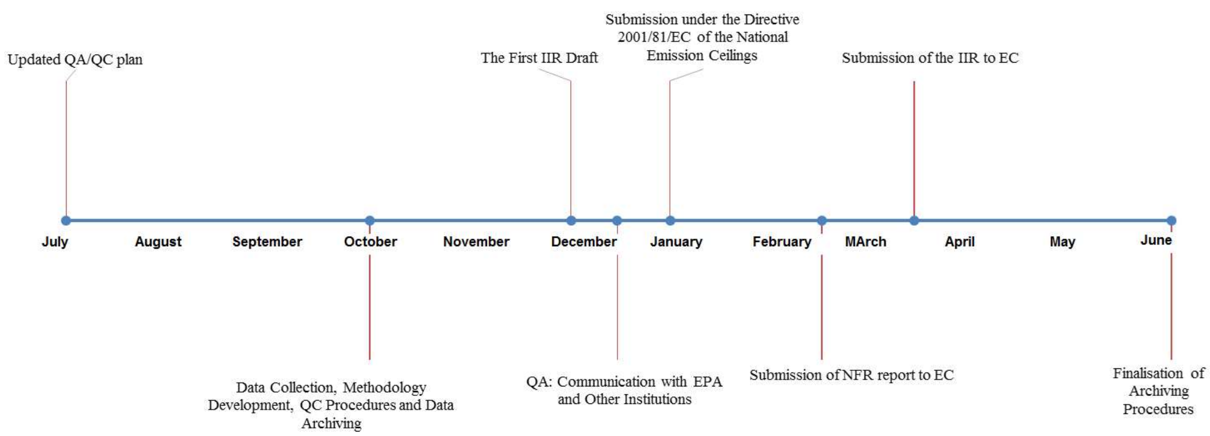


FIGURE 1 THE MILESTONES FOR PREPARATION AND SUBMISSION OF NATIONAL INVENTORY

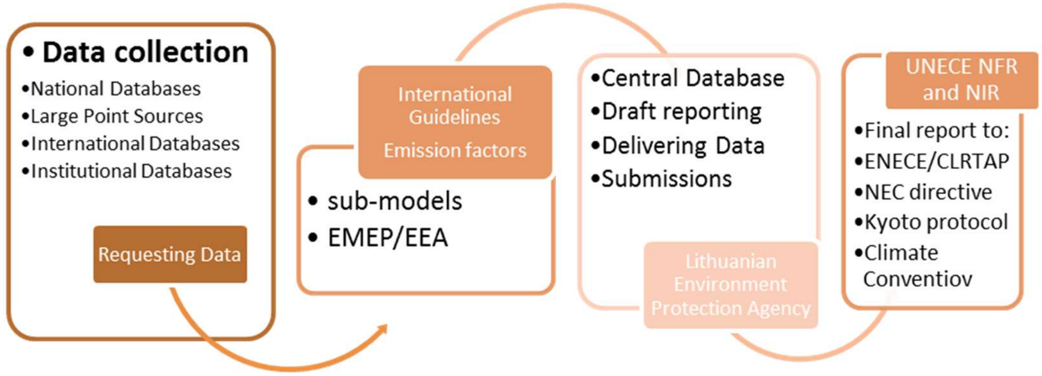


FIGURE 2 SCHEMATIC DIAGRAM OF THE PROCESS OF INVENTORY PREPARATION

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 Figure 1 and Figure 2.

Figure 2 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 1990-2019 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 the table below 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	Fuel Consumption	National Statistical Yearbook (Lithuanian Statistics Department's Database)

Machinery (NFR 1.A.4)		
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 QA/QC and Verification Methods and General Uncertainty Evaluation

- *External peer review*
- *External review of EFs, methodology*

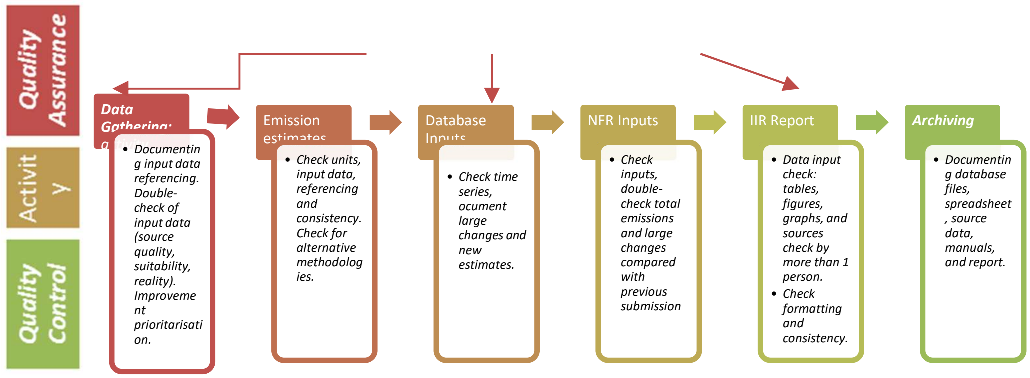


FIGURE 3 QUALITY ASSURANCE AND QUALITY CONTROL METHODS USED TO ENSURE QUALITY AND DATA CONSISTENCY OF THE INVENTORY.

Simple combination of uncertainties (see 2019 EMEP/EEA guidebook) was used 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.

1.7 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 2 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 ENERGY

Energy Sector overview

Energy Sector is the main source of the emissions accounting.

NFR 1.A.1.a Public electricity and heat production: NOx emissions in public power plants subsector were estimated on the basis of information on progress in Large combustion plants directive implementation (reducing NOx concentrations) and continuous concentration monitoring reports. This information is available from the websites of the operators. The emissions of refinery power plant were moved to 1A1b from 2005. For details on fuel consumption and emissions in this sector please refer the attached Excel file “Annexe for LT NIIR 1990-2019” sheet “1A1a”.

NFR 1.A.1.b Petroleum refining**.** Emissions are calculated on the basis of measurements or the combined method by producers) (measurements plus calculations). This sector includes all emissions from refinery power plant from 2005. For details on emissions in this sector please refer the attached Excel file “Annexe for LT NIIR 1990-2019” sheet “1A1b”.

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

Emissions from 1A1 sources 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 3 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.

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

Overview of the Sector

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 54-Table 57, Table 59, Table 63, Table 65-Table 75.

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 (the values for 2019 are the same as for 2018)

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.

For details on fuel consumption and emissions in these sectors please refer the attached Excel file “Annexe for LT NIIR 1990-2019” sheet “1A2 stationary”.

2.1.1 Mobile combustion (1.A.2.g.vii)

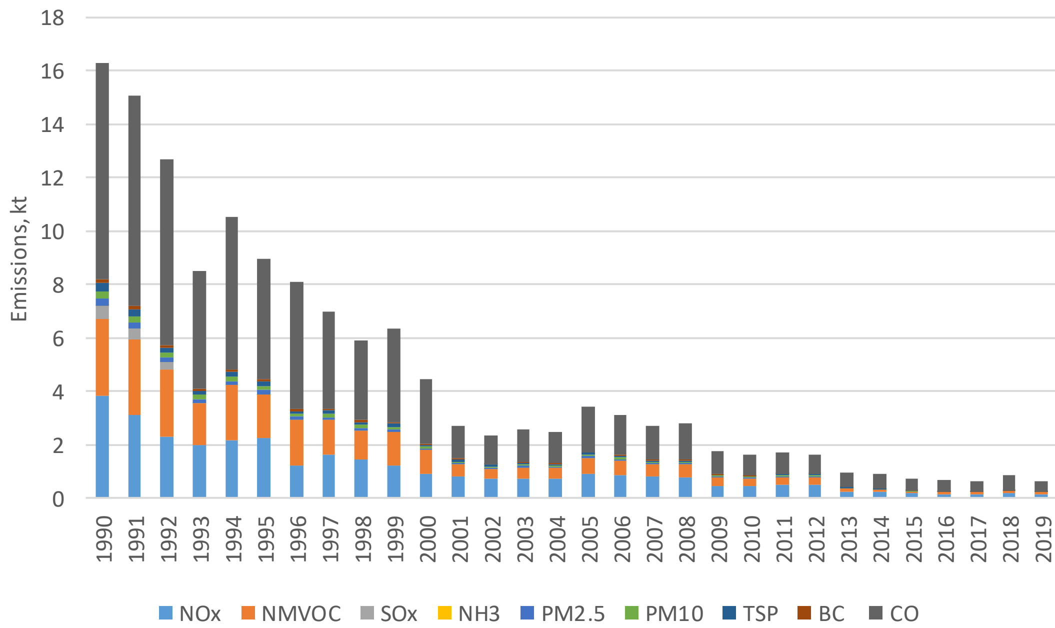


FIGURE 4 POLLUTANT EMISSIONS IN SECTOR 1.A.2.G.VII

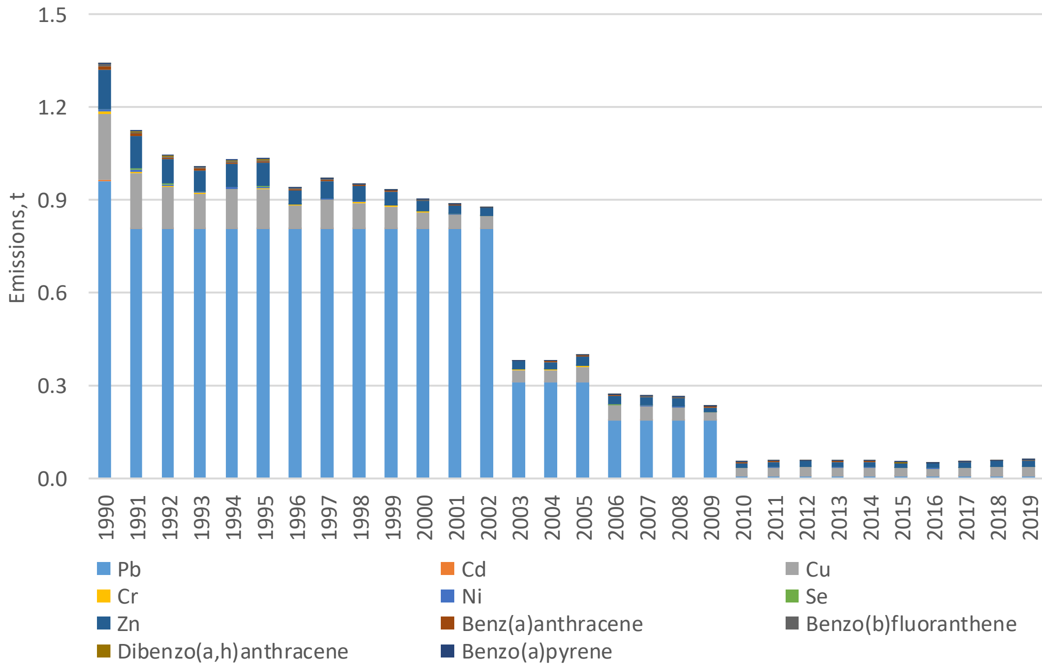


FIGURE 5 HEAVY METAL AND PAHS EMISSIONS IN SECTOR 1.A.2.G.VII

Emission factors from Guidebook 2019 were applied: chapter 1.A.4 Small Combustions. See Annex 1: Table 54-Table 55, Table 58-Table 61, Table 71-Table 72.

2.2 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

Projected fuel consumption data are provided in the attached Excel file “Annexe for LT NIIR 1990-2019” sheet “Transport”. Source of these data is Lithuanian National Climate and Energy Action Plan.

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

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

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 6):

- Vilnius International Airport
- Kaunas Airport
- Palanga International Airport
- Šiauliai International Airport

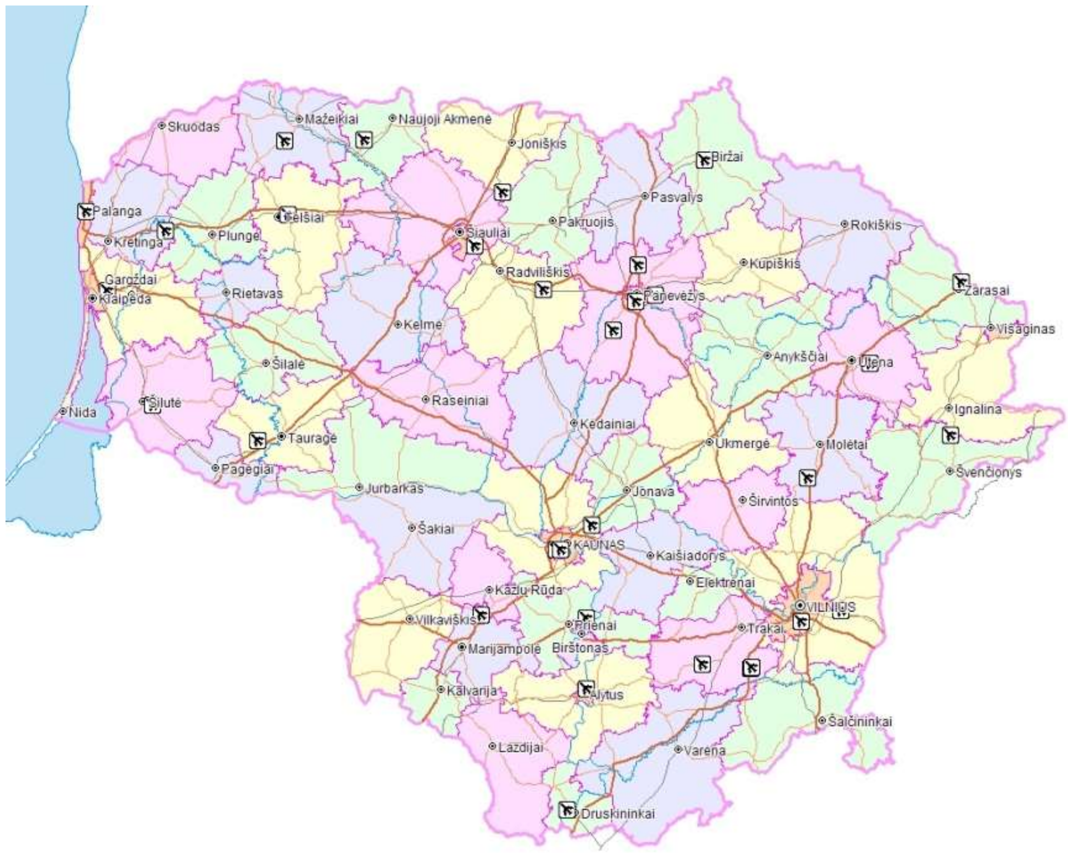


FIGURE 6 MAP OF AIRPORTS AND AERODROMES IN LITHUANIA

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 4 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 aviation	Landing and Take-off (LTO)	Yes	No	No	No	Yes
		Cruise	No	No	Yes	No	Yes

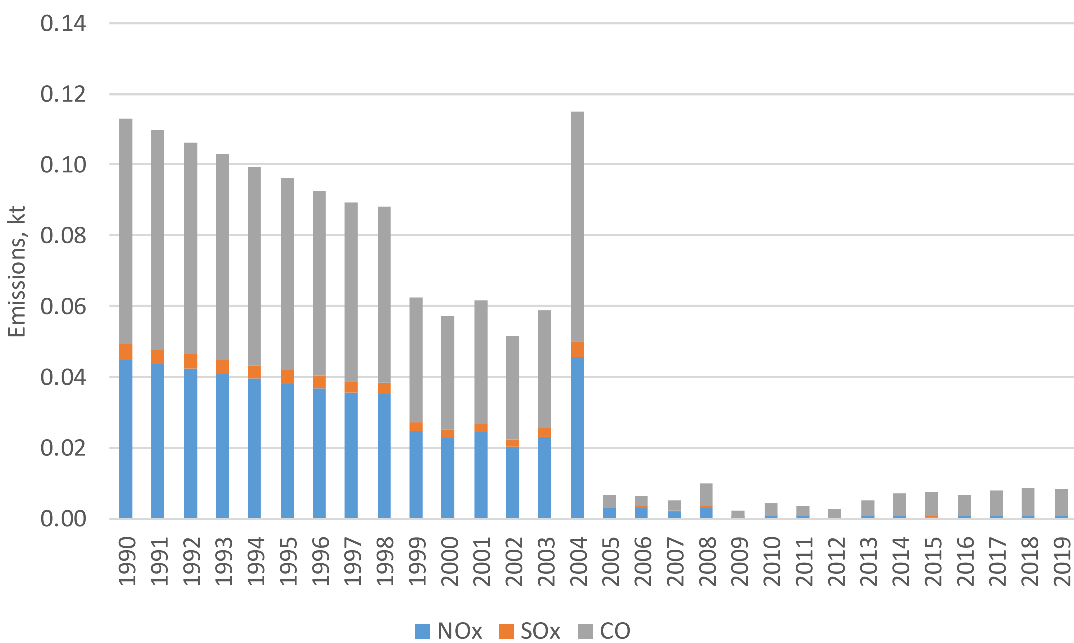


FIGURE 7 POLLUTANT EMISSIONS IN SECTOR 1.A.3.A.I

Methodological issues

For the years 1990-2019 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 5. Emissions from 2006 were calculated using EUROCONTROL based on Tier 2.

TABLE 5 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

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

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

$EF_{pollutant}$ 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 6.

TABLE 6 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

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%.

Source-specific QA/QC and verification

Assessment of trends have been performed.

Source-specific planned improvements

Use of EUROCONTROL data is planned for the next submissions.

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

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 2019, the length of roads amounted to 85.6 thousand kilometers; the length of E-roads amounted to 1,639 kilometers, of which motorways – 309 km (Statistics Lithuania, 2021).

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 8). 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.

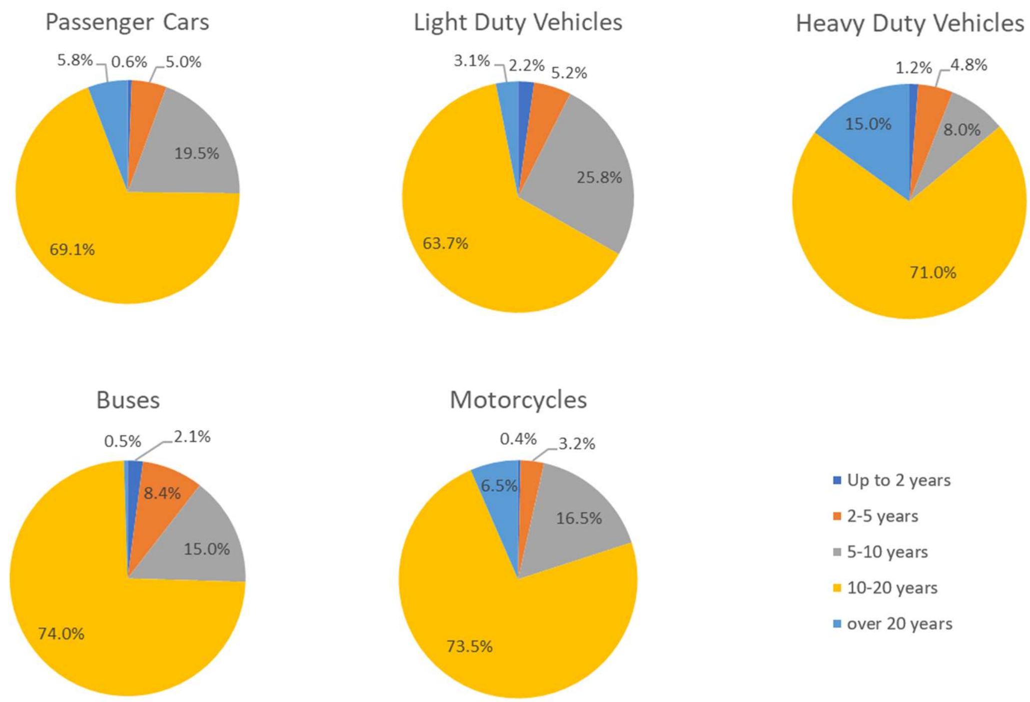


FIGURE 8 ROAD VEHICLES BY AGE, 2019

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.

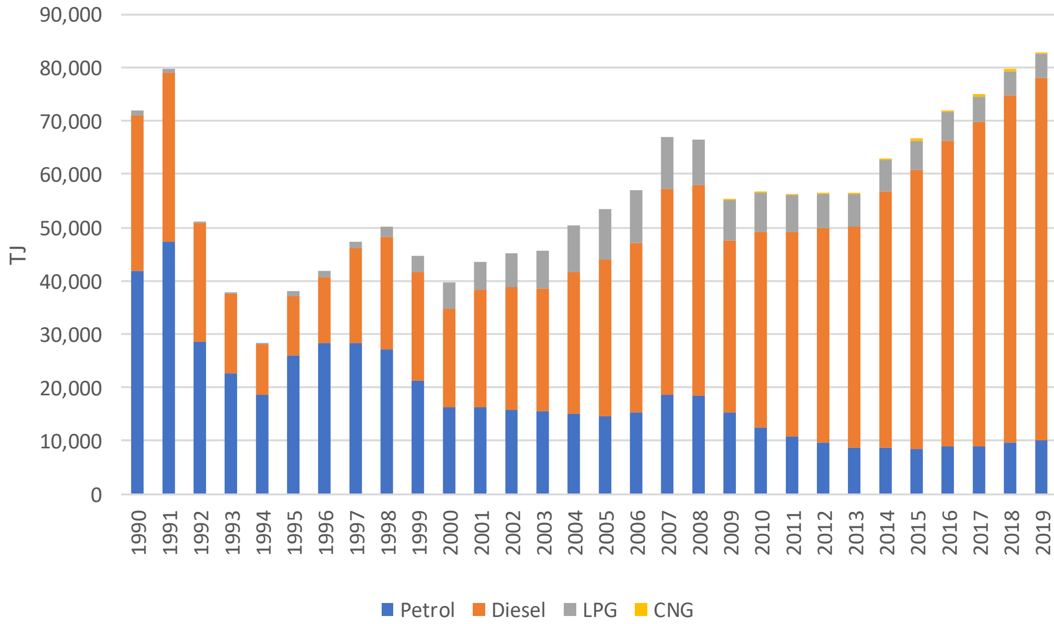


FIGURE 9 FUEL CONSUMPTION IN ROAD TRANSPORT IN 1990-2019, TJ

Diesel and petrol fuels are mainly used in transport sector with a slow and steady increase in electromobiles. According to “Regitra” there were 2496 registered electro cars in 2019.

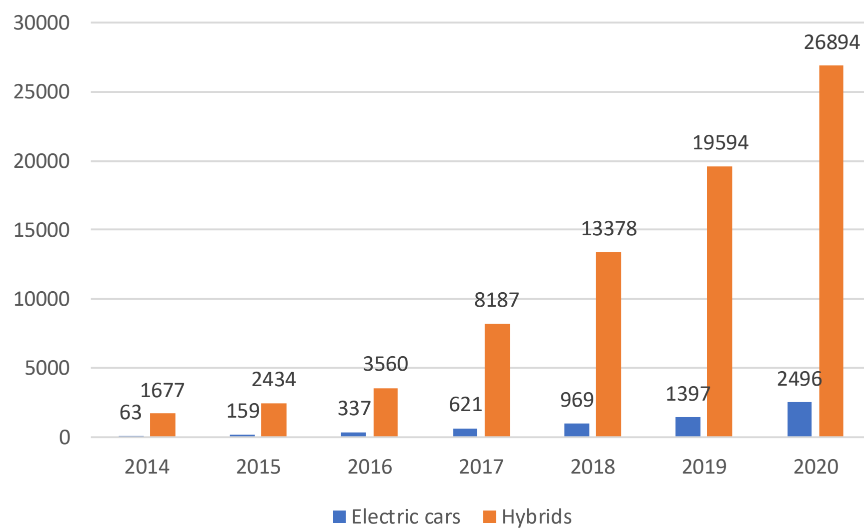


FIGURE 10 SHARE OF ELECTROMOBILE

There is a marked switch from petrol engines to diesel. The number of petrol engines (all vehicles) has decreased and as a result petrol fuel consumption has dropped between 1990 and 2019, while the number of diesel engines increased significantly from ~14 to 1027 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, are 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.b.iv is highly variable as vehicle registration is highly variable due to re-registration.

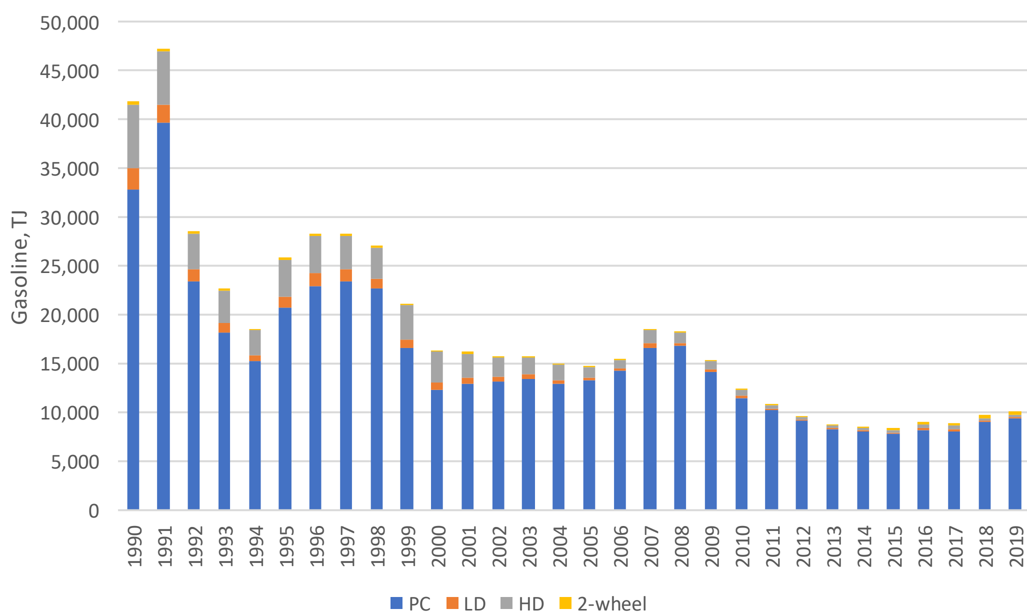


FIGURE 11 GASOLINE FUEL CONSUMPTION PER VEHICLE TYPE FOR ROAD TRANSPORT 1990-2019

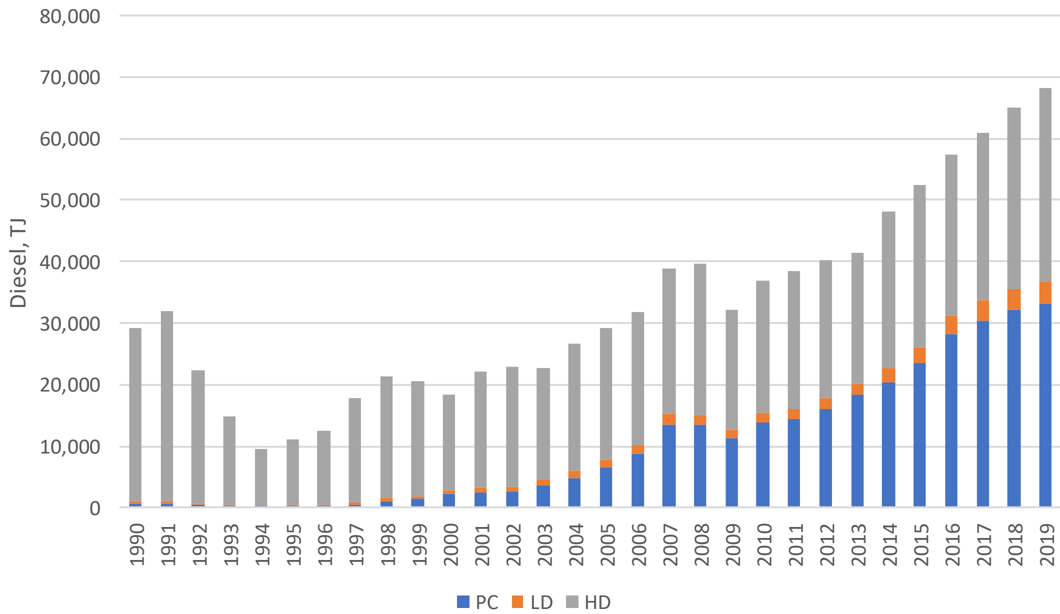


FIGURE 12 DIESEL OIL CONSUMPTION PER VEHICLE TYPE FOR ROAD TRANSPORT 1990-2019

In 2019, fuel consumption shares for diesel passenger cars, diesel heavy-duty vehicles, gasoline passenger cars, diesel light duty vehicles were 43 %, 40%, 12%, 5%, respectively.

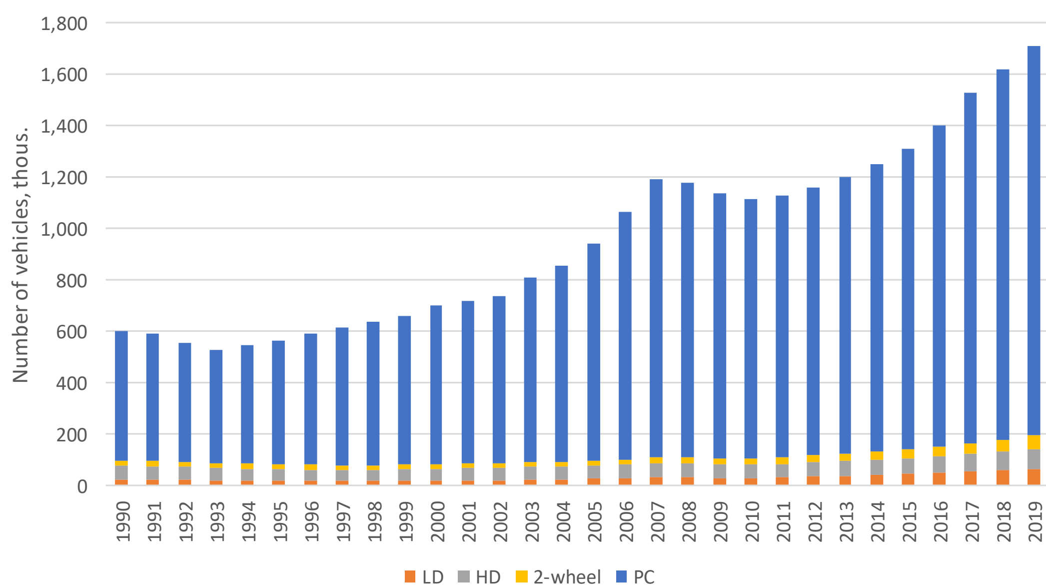


FIGURE 13 NUMBER OF VEHICLES IN LITHUANIA, 1990-2019

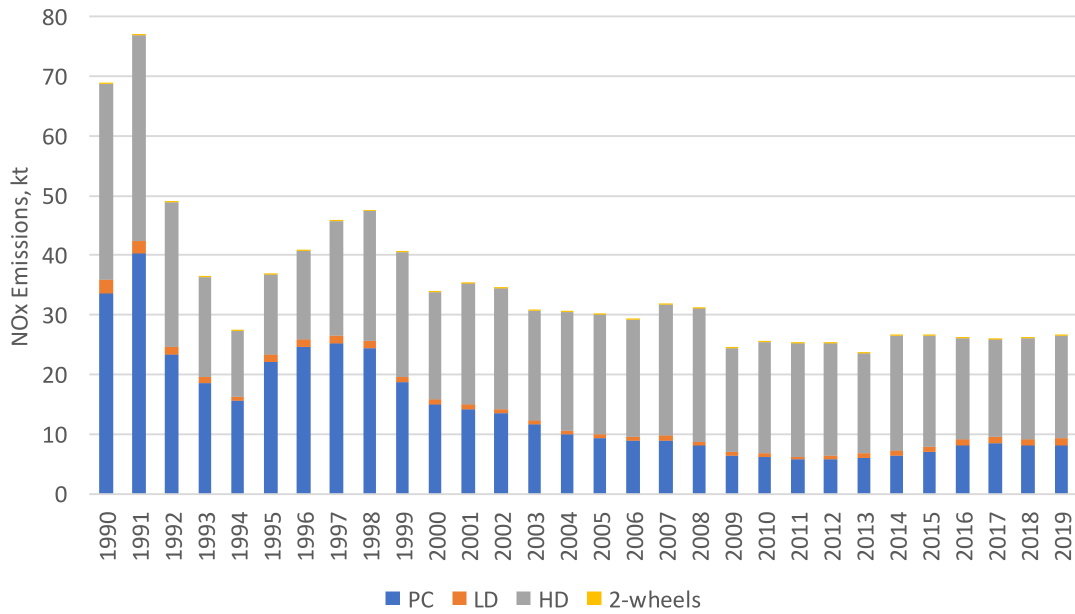


FIGURE 14 DEVELOPMENT OF NOX EMISSIONS IN ROAD TRANSPORT SECTOR 1990-2019

Development of NOx emissions in Road transport sector is presented in Figure 14. Passenger cars NOx emissions contribution to Road transport has decreased by 76 % since 1990. During the whole period 1990-2019 HD vehicles contribute the biggest part to NOx emissions in Road transport sector.

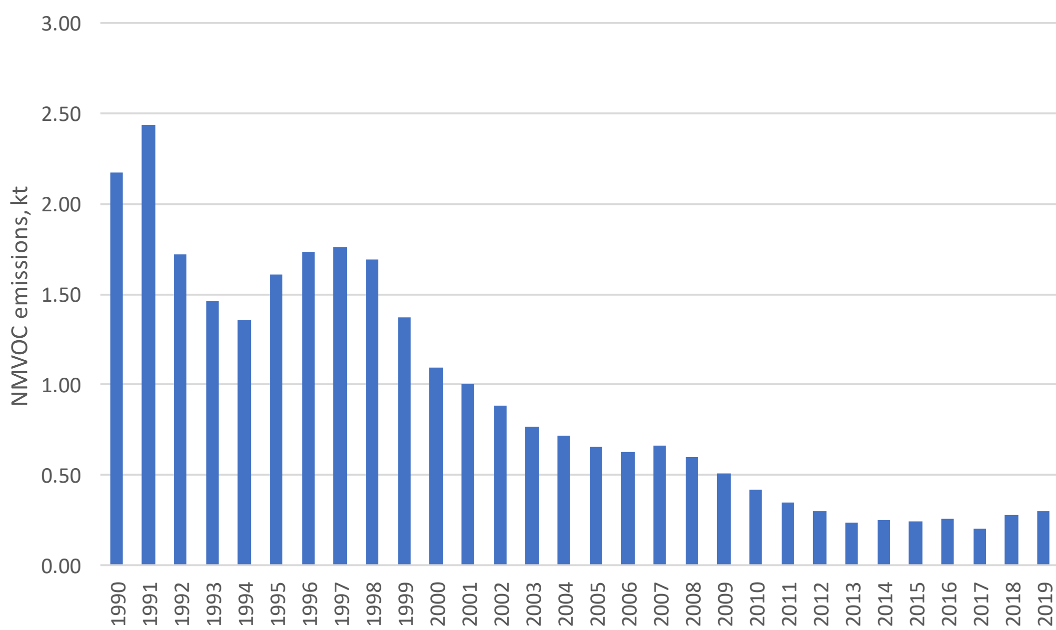


FIGURE 15 NMVOC EMISSIONS IN SECTOR 1.A.3.B.V

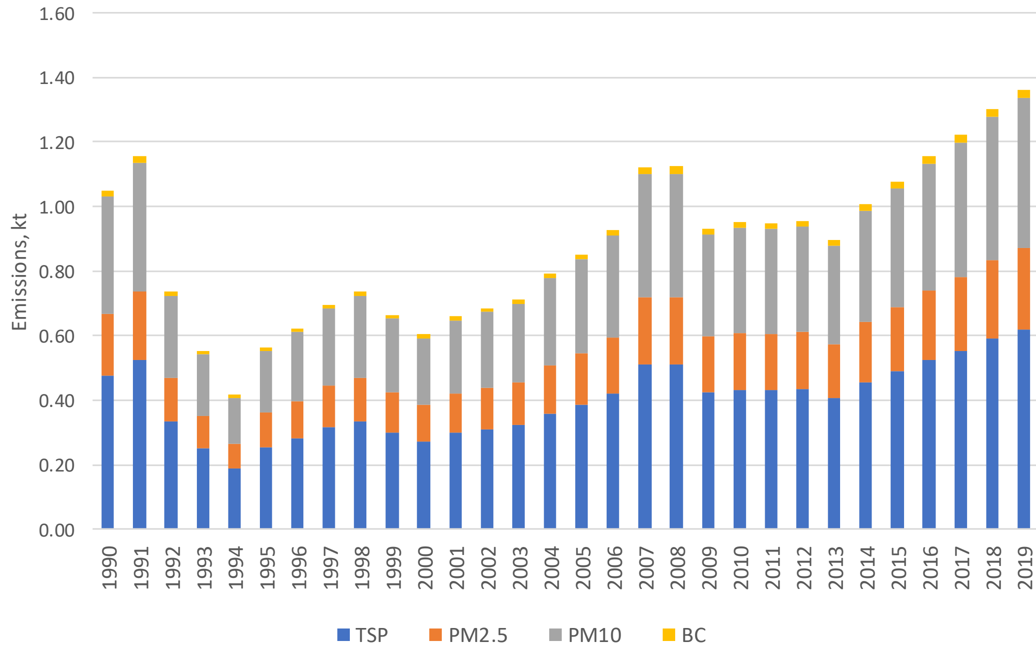


FIGURE 16 POLLUTANT EMISSIONS IN SECTOR 1.A.3.B.VI

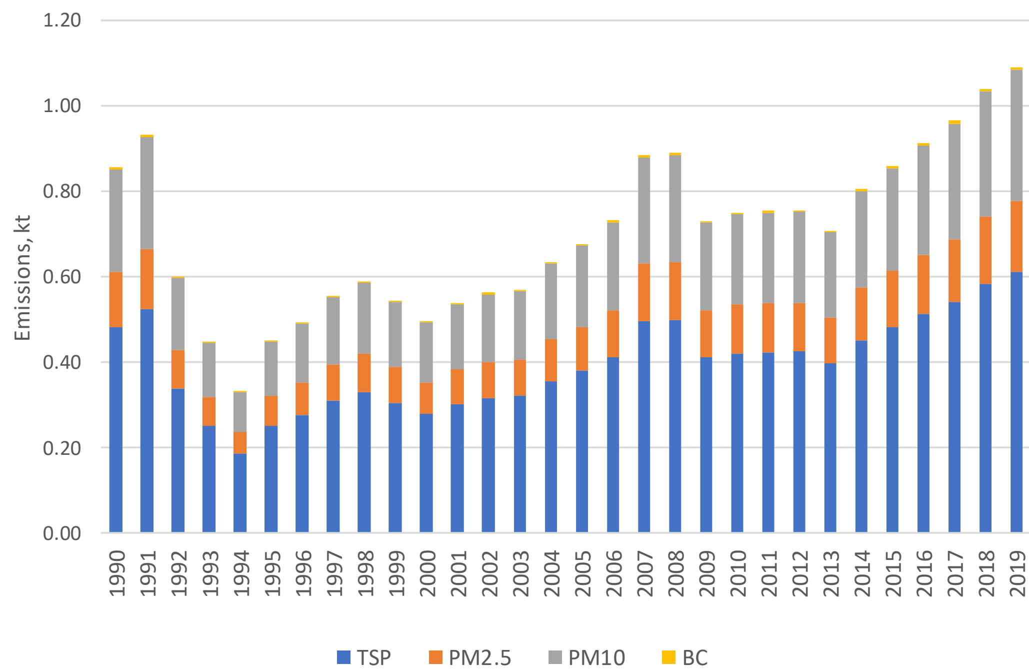


FIGURE 17 POLLUTANT EMISSIONS IN SECTOR 1.A.3.B.VII

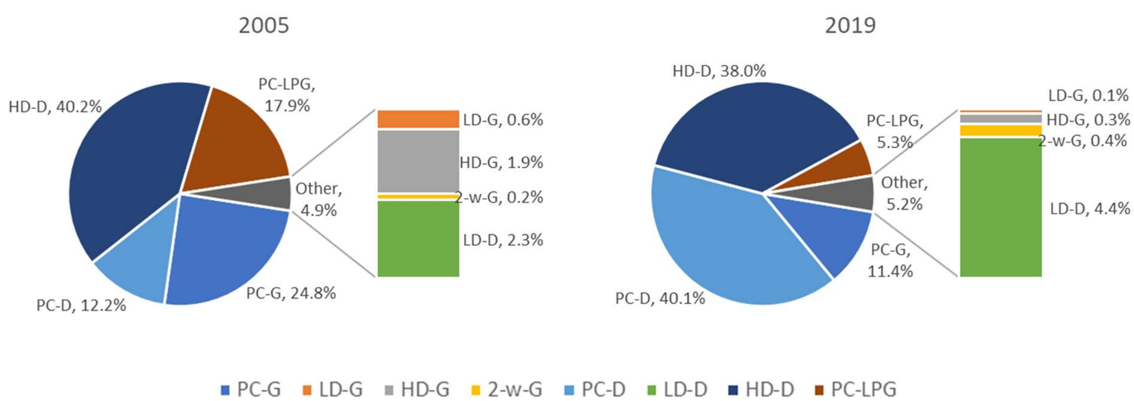


FIGURE 18 FUEL CONSUMPTION SHARE PER VEHICLE TYPE AND FUEL TYPE FOR ROAD TRANSPORT IN 2005 AND 2019

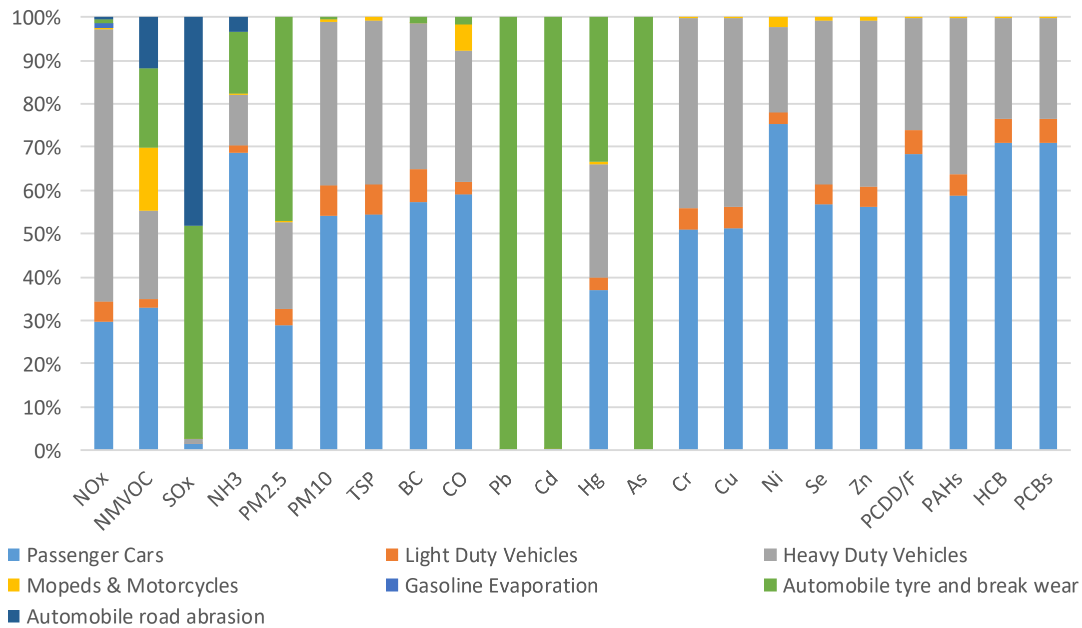


FIGURE 19 DISTRIBUTION OF EMISSIONS IN TRANSPORT SECTOR BY SUBSECTORS IN 2019, %

Passenger cars takes up the biggest part of Transport sector emissions for most of the pollutants followed by Heavy Duty vehicles (Figure 19). Automobile tyre and break wear contributes the biggest part (99.7 %) of Pb, Cd and As emissions.

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:

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

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.

<u>Lead (Pb) and other heavy metals emissions</u>

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

$$E_{Pb,j}^{CALC} = 0.75 \cdot k_{Pb,m} \cdot FC_{jm}^{CALC} \ . \quad (2)$$

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 7.

TABLE 7 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 8 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 9 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 10) is used as activity rates for estimating tyre, brake wear and road abrasion emissions.

TABLE 10 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 11. $PM_{2.5}$ and PM_{10} emission factors were taken from [7] reference and reported in Table 12-Table 13.

TABLE 11 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 12 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 13 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 14 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

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.

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.

Source-specific recalculations

No source specific recalculations.

Source-specific planned improvements

No source-specific improvements.

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

Overview of the Sector

In 2019, 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 2019, goods transport by rail amounted to 55.2 million tonnes. National goods transport by rail amounted to 15.7 million tonnes.

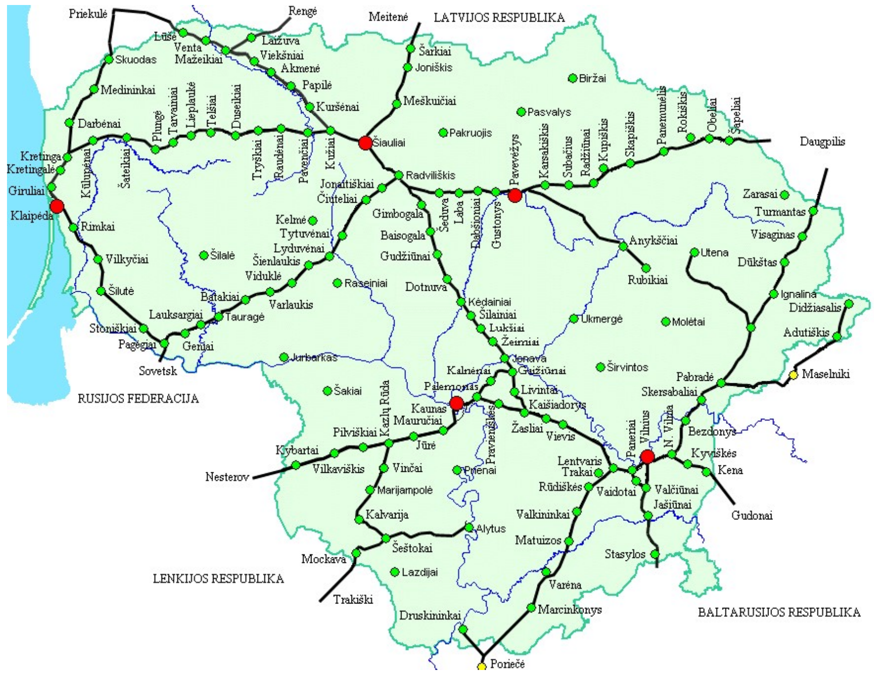


FIGURE 20 MAP OF LITHUANIAN RAILWAYS

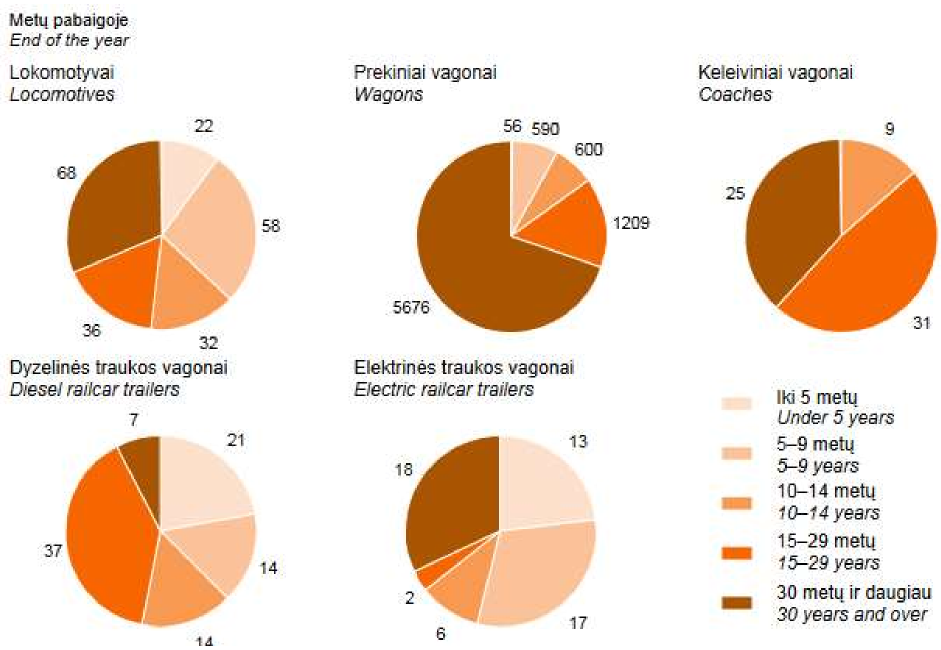


FIGURE 21 RAILWAY VEHICLES BY AGE, 2017

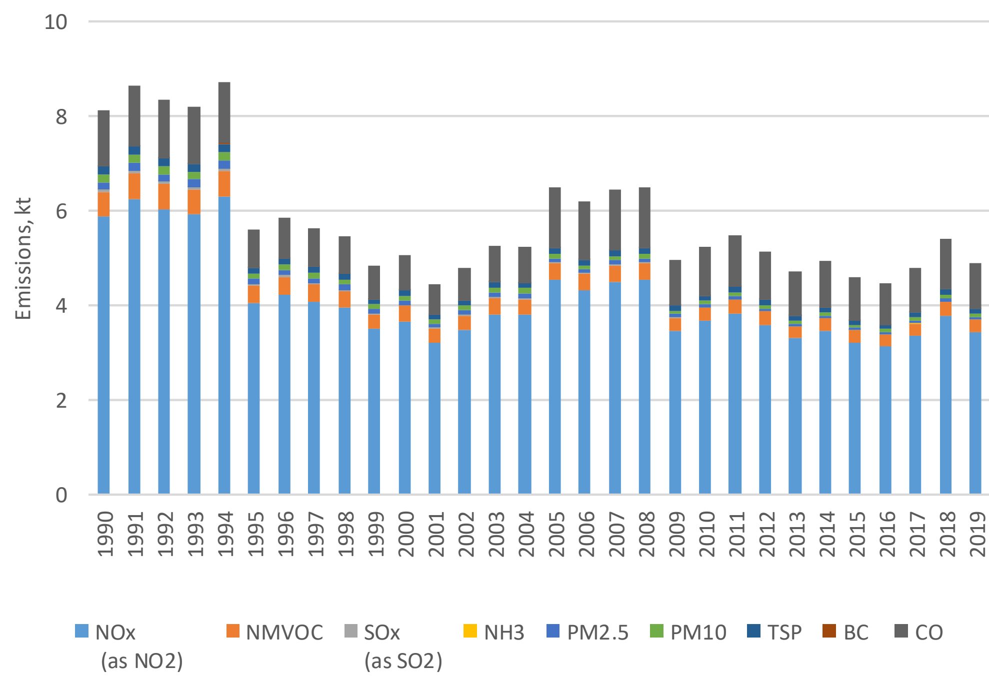


FIGURE 22 POLLUTANT EMISSIONS IN SECTOR 1.A.3.C

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 21).

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).

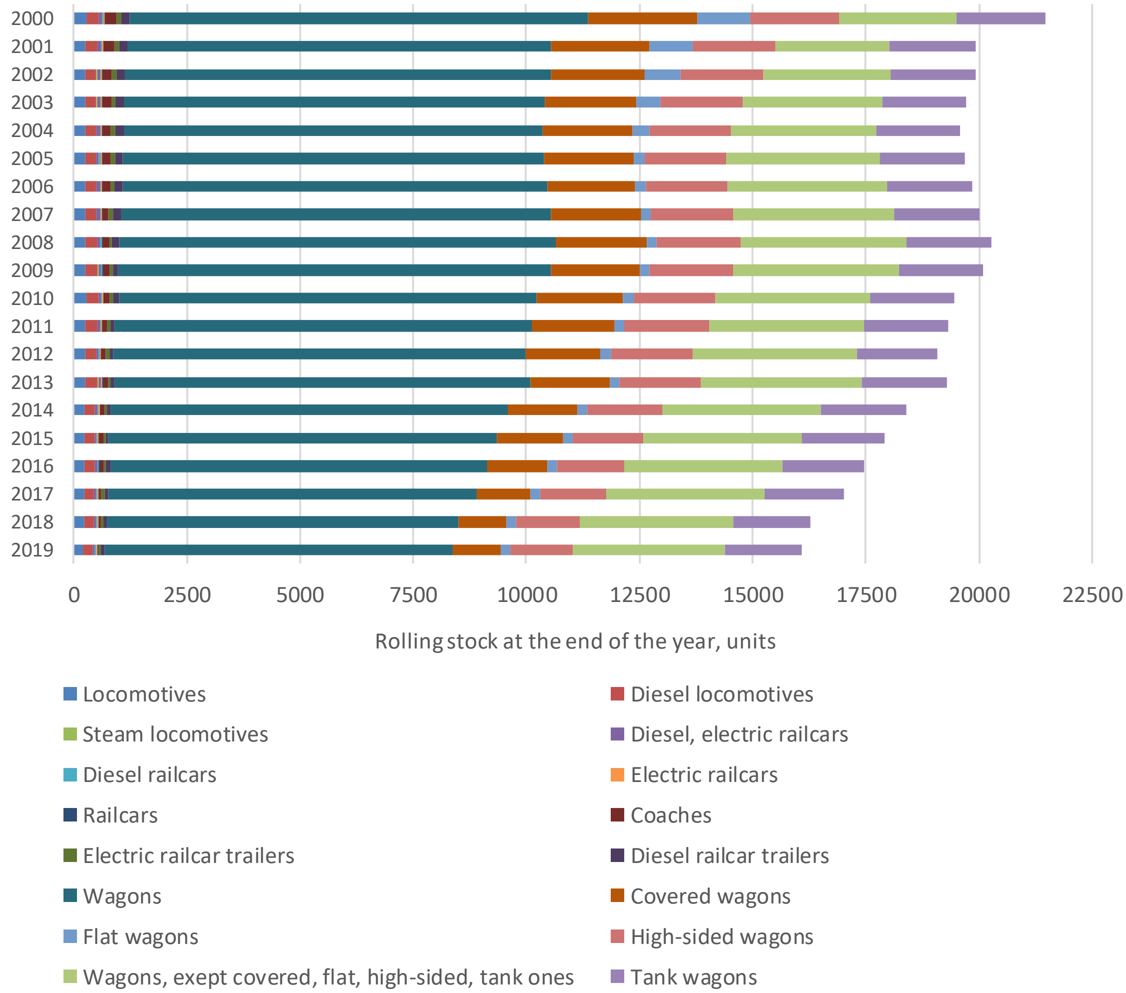


FIGURE 23 TRAINS TECHNOLOGY TYPES 2000-2019

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 37, Table 38, Table 39). 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:

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

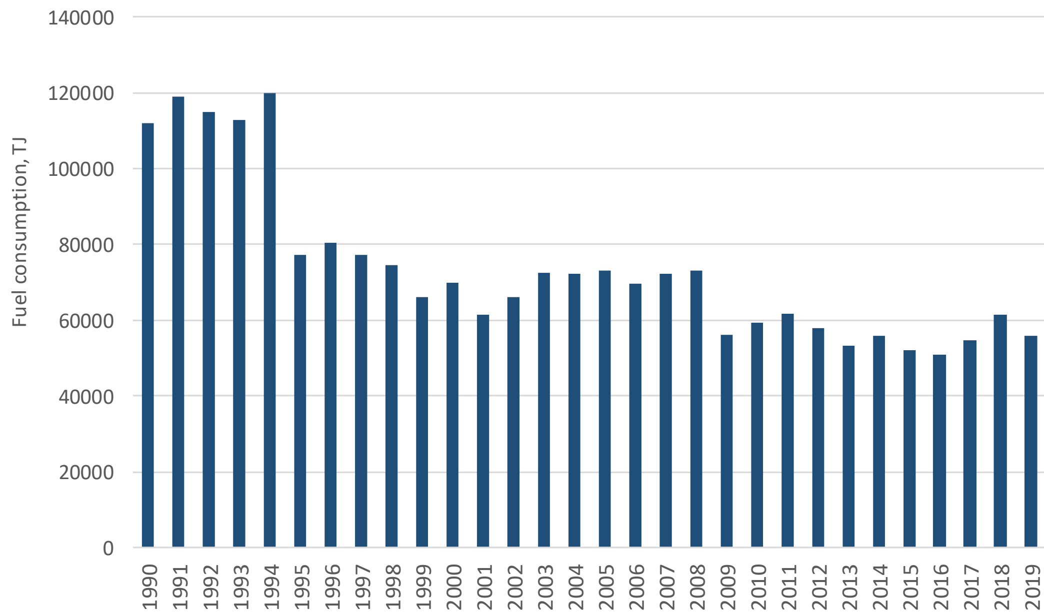


FIGURE 24 FUEL CONSUMPTION IN RAILWAY 1.A.3.C SECTOR

Fuel consumption in the railways transport decreased 50% from 1990 to 2019. Similar change occurred in the amounts of emissions. 1990/2019 emissions dropped by 40.2%, while 2005/2019 emissions decreased by 24.4%. SOx emissions decreased by 99.0% and 97.9% from 1990 to 2019 and from 2005 to 2019, respectively.

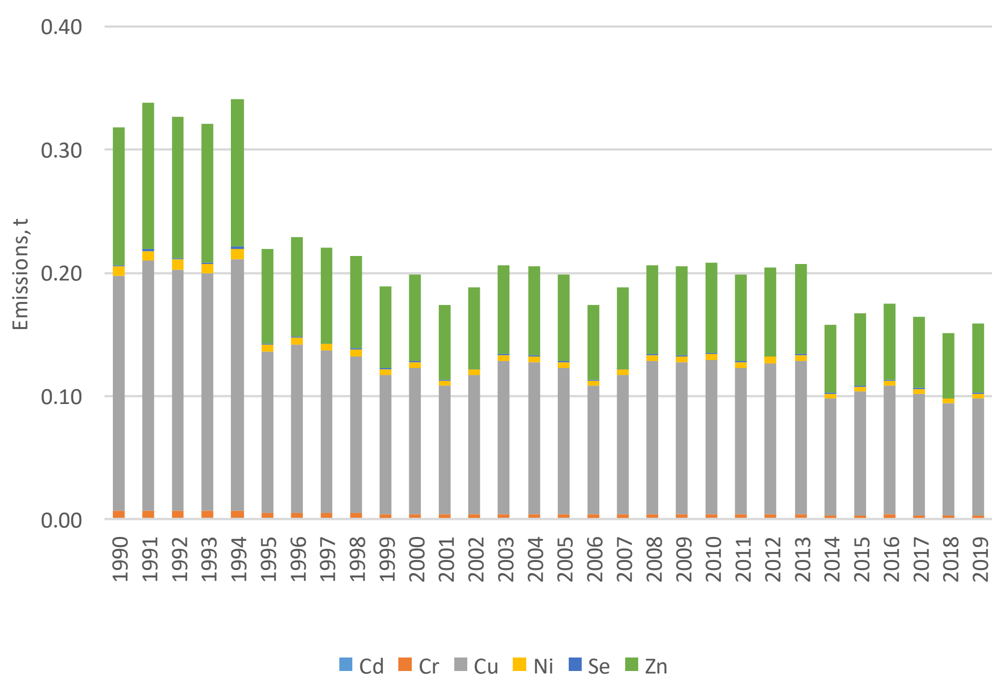


FIGURE 25 HEAVY METALS EMISSIONS IN SECTOR 1.A.3.C

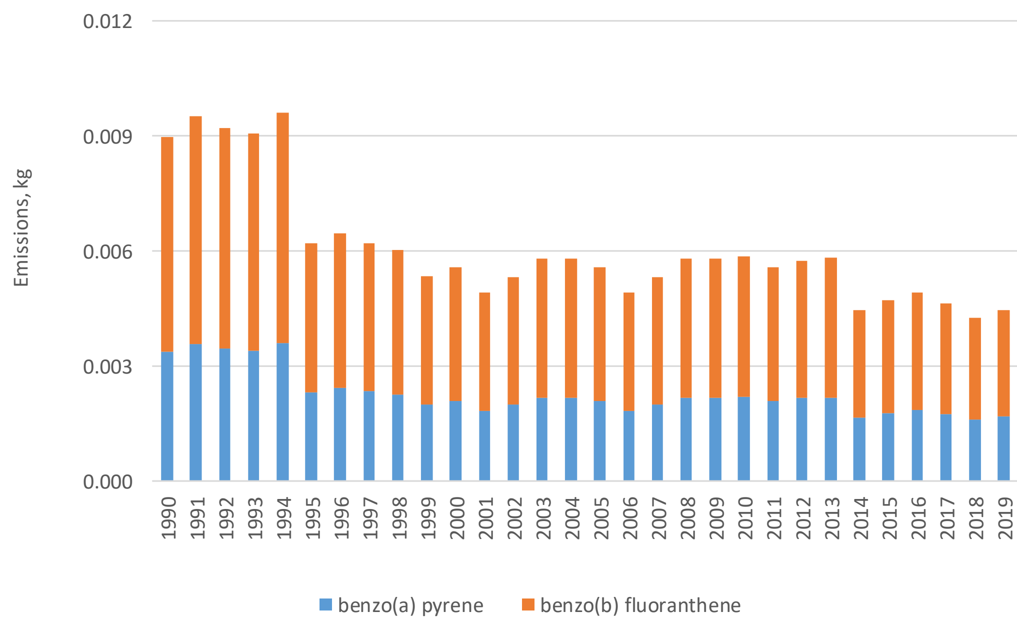


FIGURE 26 PAHS EMISSIONS IN SECTOR 1.A.3.C

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.

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.

Source-specific planned improvements

No source-specific improvements.

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

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 435 km in 2019. In 2019, transport of goods by inland waterways amounted to 1.2 million tonnes, the number of passengers carries – 2.1 million.

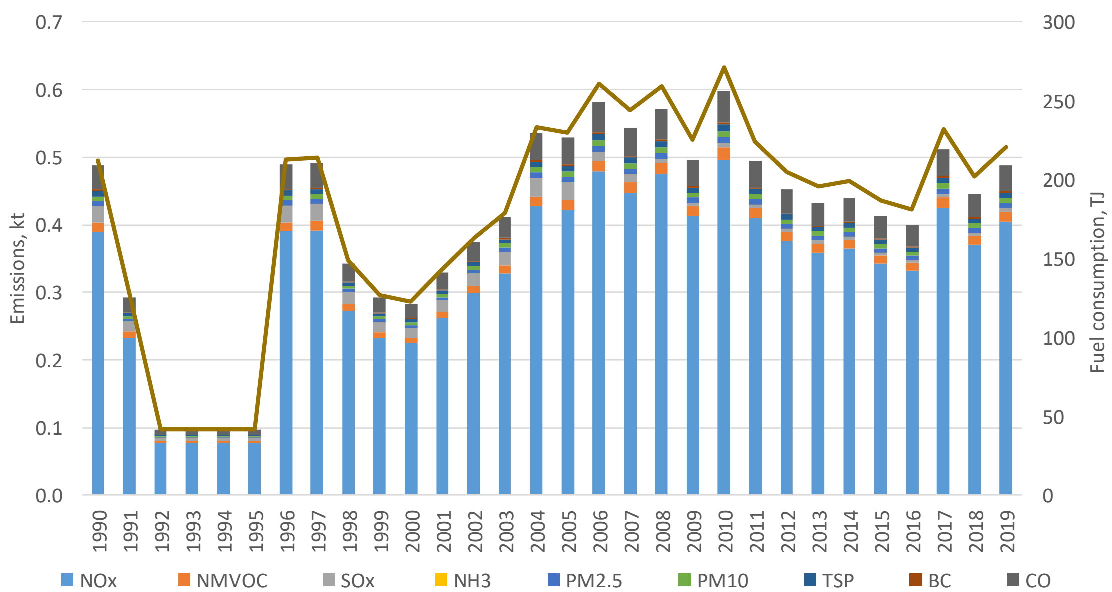


FIGURE 27 POLLUTANT EMISSIONS AND FUEL CONSUMPTION IN SECTOR 1.A.3.D.II

As seen in Figure 27 fuel consumption decreased by 3.9 % between 2005 and 2019. This decrease is obviously due to the impact of the decreased fuel consumption in inland waterways.

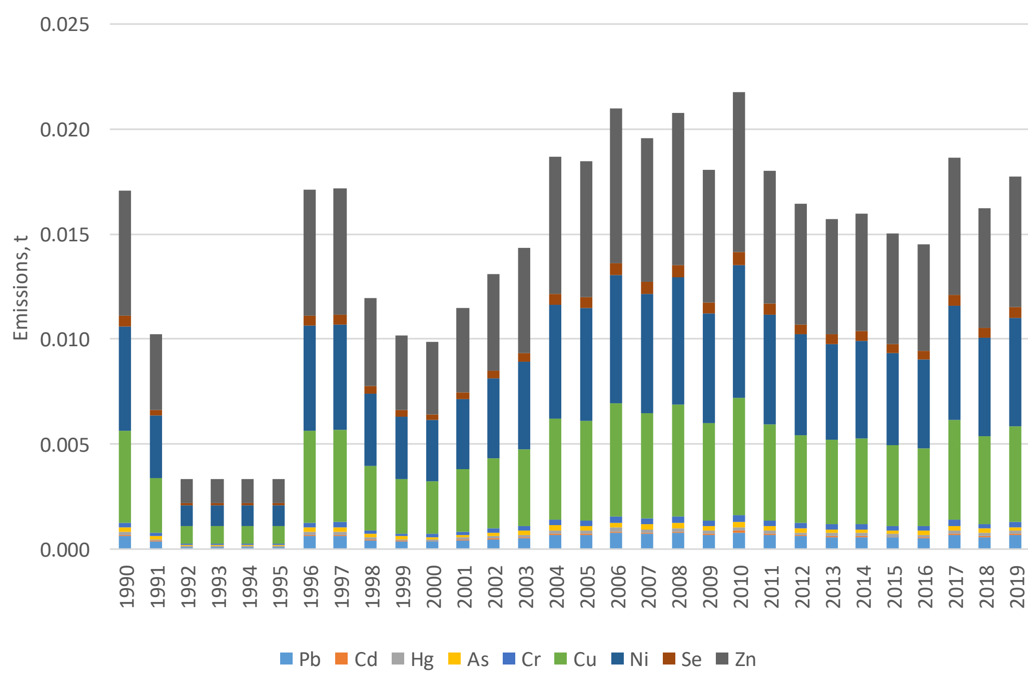


FIGURE 28 HEAVY METAL EMISSIONS IN SECTOR 1.A.3.D.II

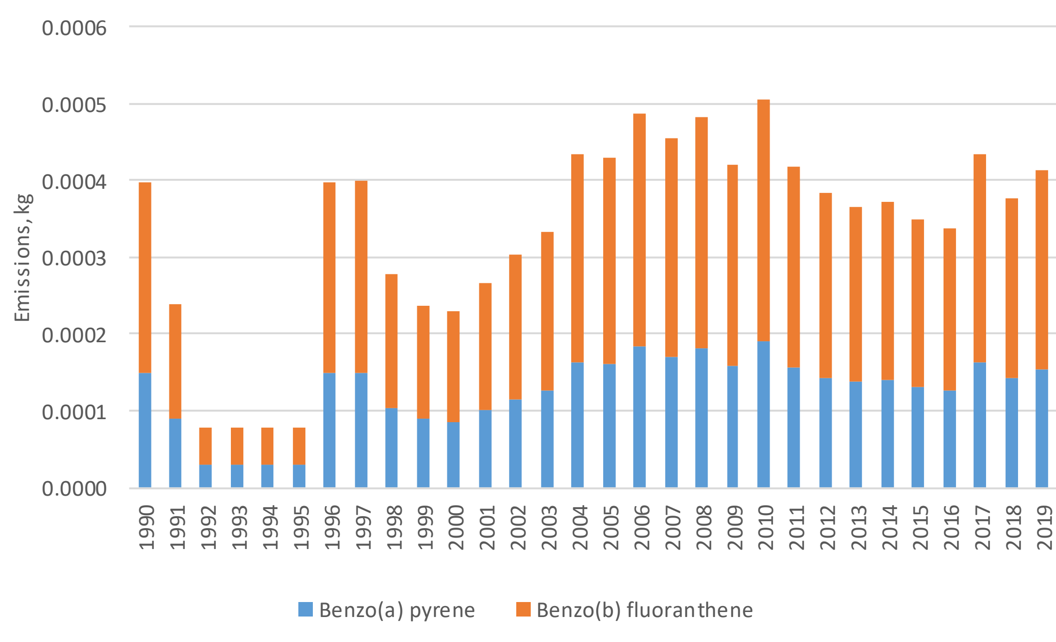


FIGURE 29 PAHS EMISSIONS IN SECTOR 1.A.3.D.II

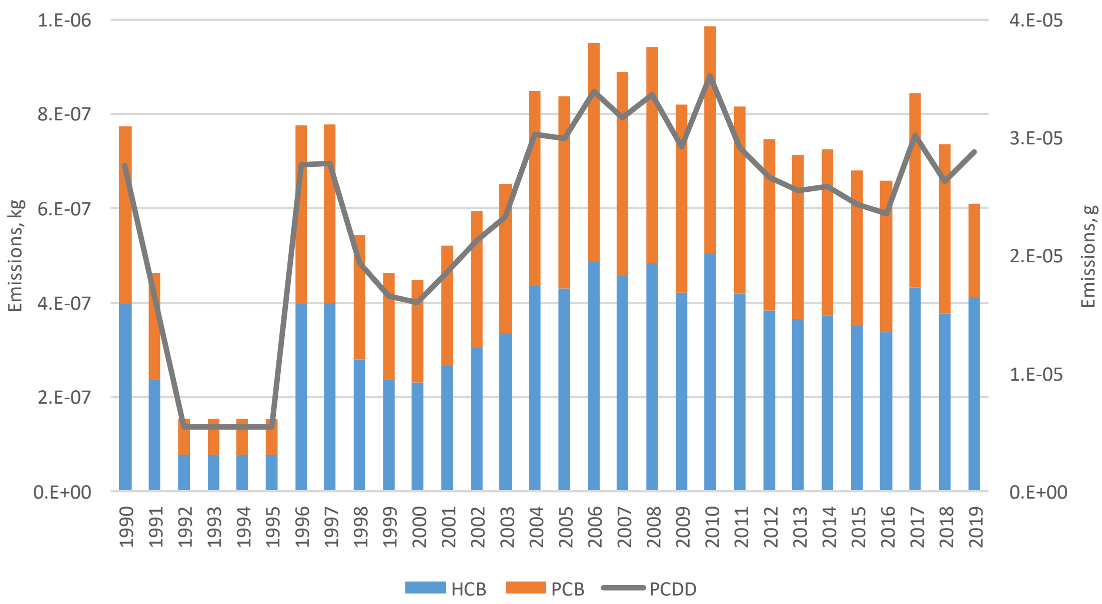


FIGURE 30 HCB, PCB AND PCDD EMISSIONS IN SECTOR 1.A.3.D.II

Methodological issues

Emissions were calculated according to EEA emission guidebook 2013 methodology Tier 1 approach. See Table 40-Table 42.

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:

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

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.

Uncertainty

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

TABLE 15 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.

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

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 16).

TABLE 16 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

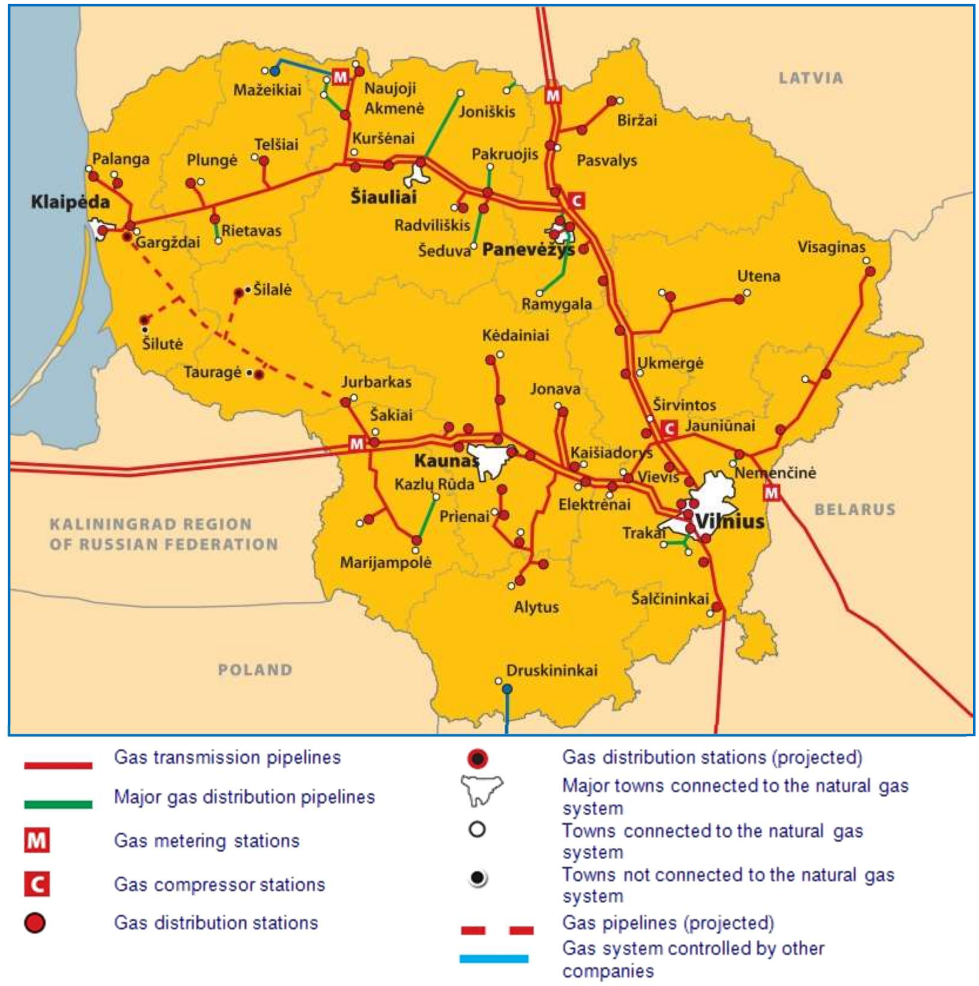


FIGURE 31 GAS DISTRIBUTION NETWORK IN LITHUANIA

Transport via pipelines includes transport of gases via pipelines.

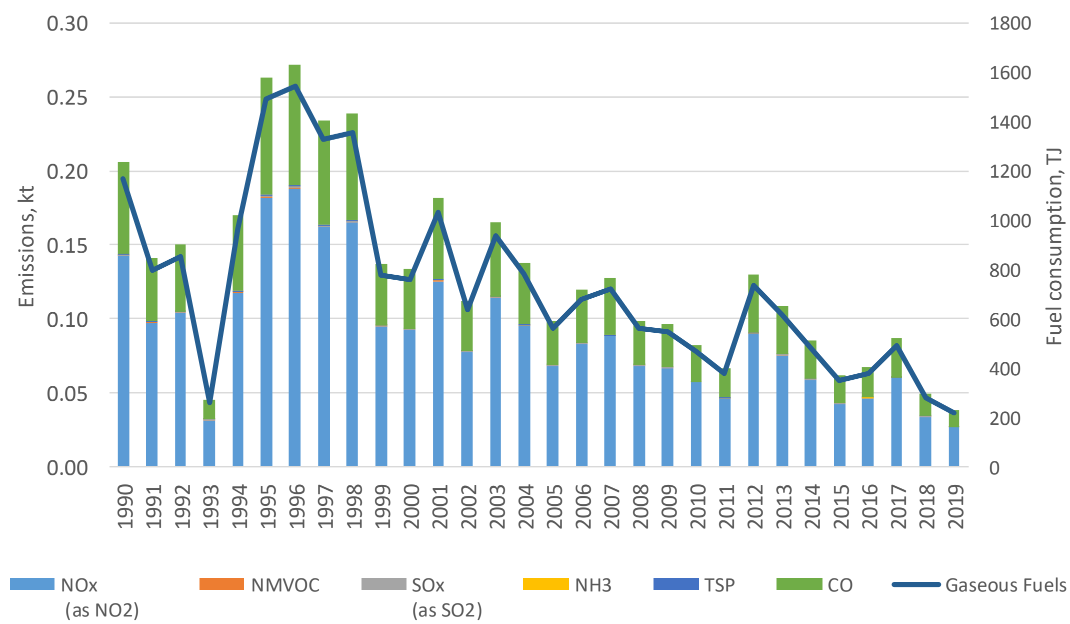


FIGURE 32 POLLUTANT EMISSIONS AND FUEL CONSUMPTION IN SECTOR 1.A.3.E.I

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.

Uncertainties and time-series consistency

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

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.

Source-specific recalculations

No recalculations.

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

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.

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.).

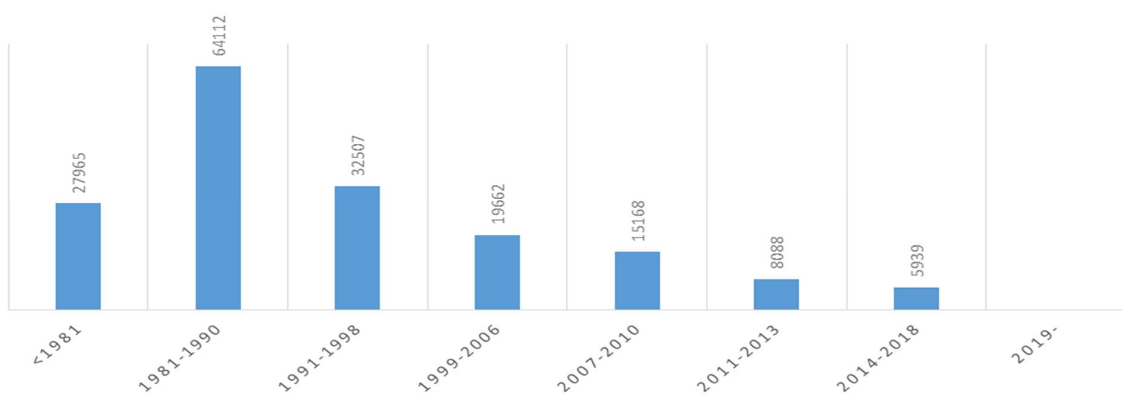
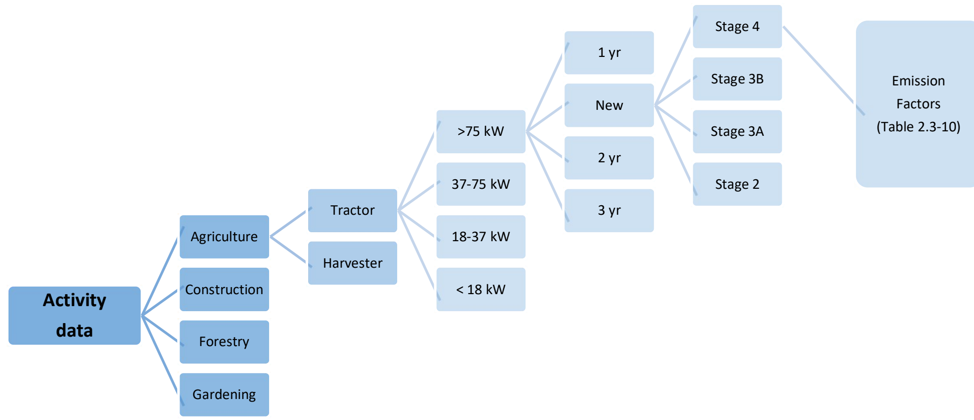


FIGURE 33 NUMBER OF OFF-ROAD VEHICLES IN 2016 (STATE ENTERPRISE AGRICULTURAL INFORMATION AND RURAL BUSINESS CENTER)

The vehicles were distributed by age and engine type.



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

Table 17 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 18 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 19 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
CH_4	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
CO_2	kg/tons fuel	3197	3197	3197	3197	3197	3197	3197	3197	3197
N_2O	g/tons fuel	12	16	16	18	20	20	20	20	20
NH_3	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 20 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
CH_4	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
CO_2	kg/tons fuel	3197	3197	3197	3197	3197	3197	3197	3197	3197
N_2O	g/tons fuel	56	55	59	59	60	60	60	60	59
NH_3	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 21 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 22 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 23 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 24 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 25 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 26 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 27 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 28 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 29 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

2.3.1 Emissions 1.A.4.a.ii

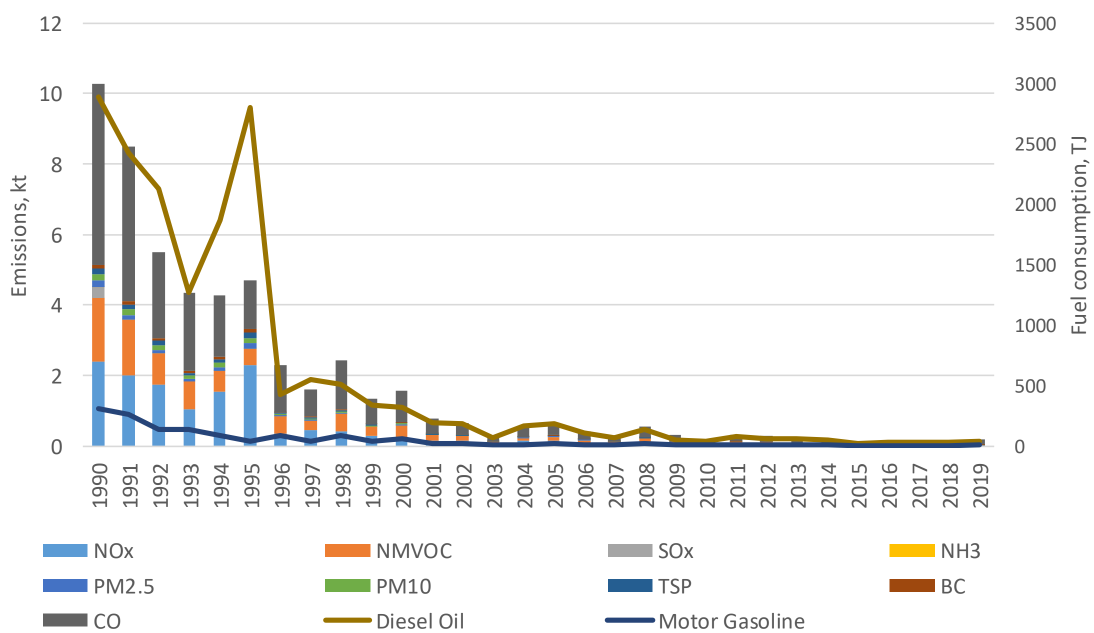


Figure 34 Pollutant emissions and fuel consumption in sector 1.A.4.a.ii

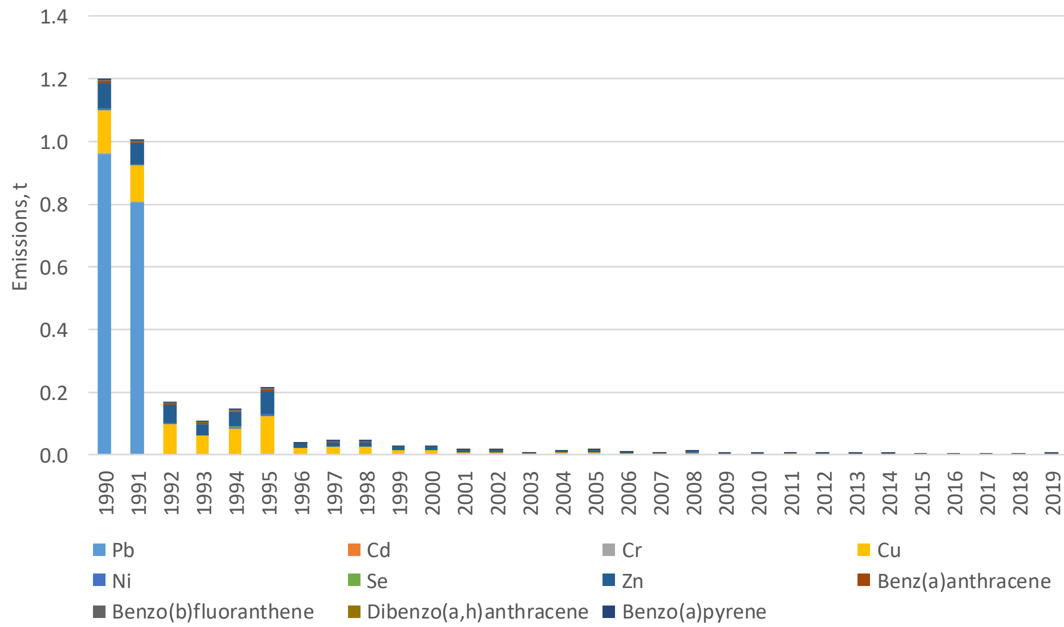


FIGURE 35 HEAVY METAL AND PAHS EMISSIONS IN SECTOR 1.A.4.A.II

2.3.2 Emissions 1.A.4.b.ii

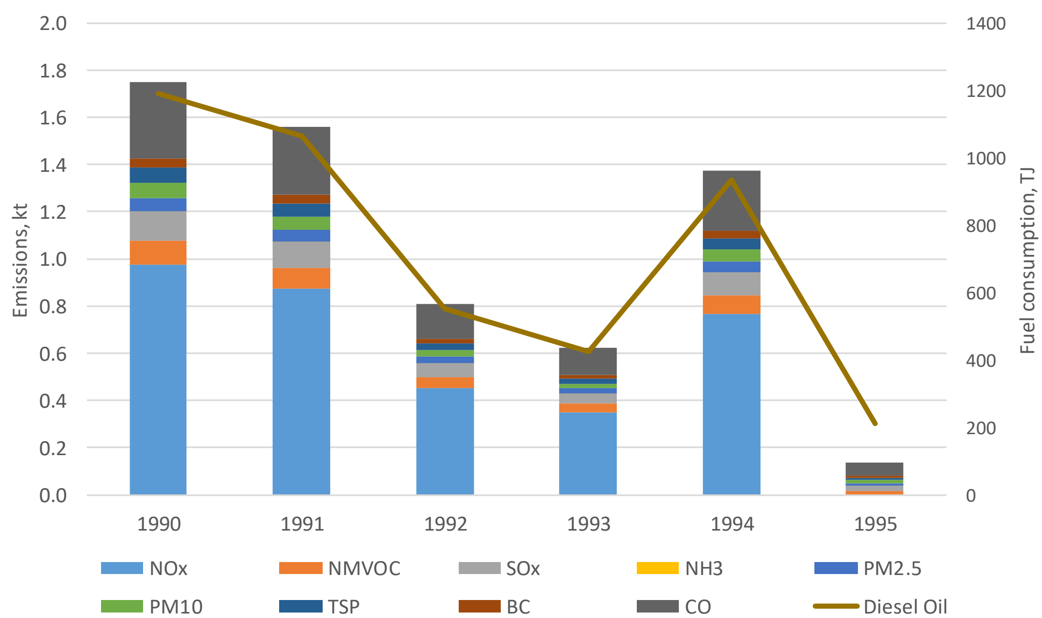


FIGURE 36 POLUTANT EMISSIONS IN SECTOR 1.A.4.B.II

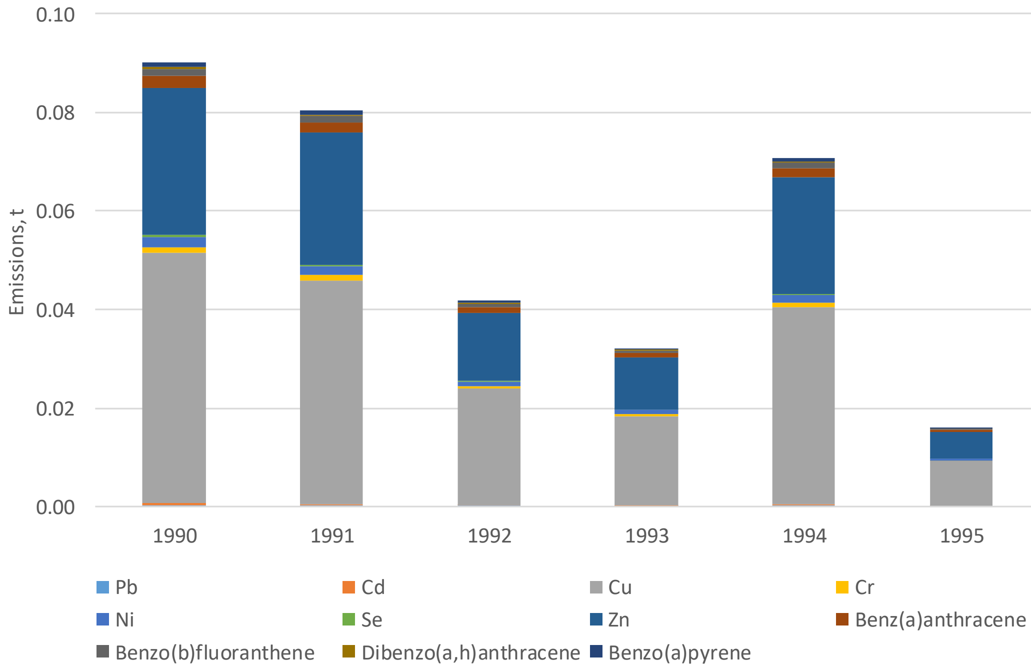


Figure 37 Heavy metal and PAHs emissions in sector 1.A.4.b.ii

2.3.3 Emissions 1.A.4.c.ii

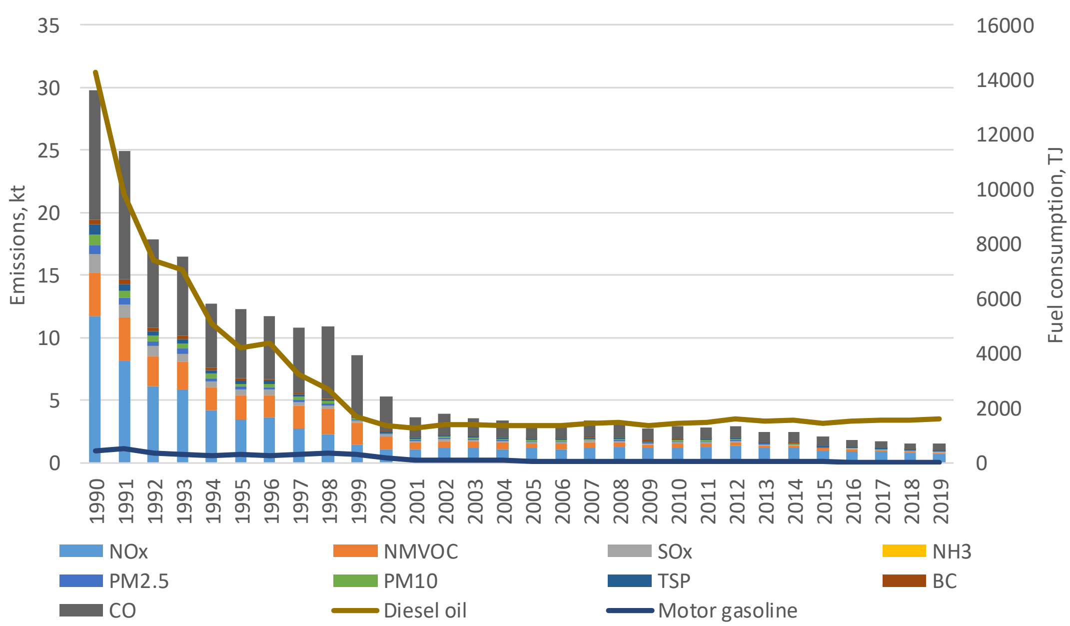


Figure 38 Pollutant emissions and fuel consumption in sector 1.A.4.c.ii

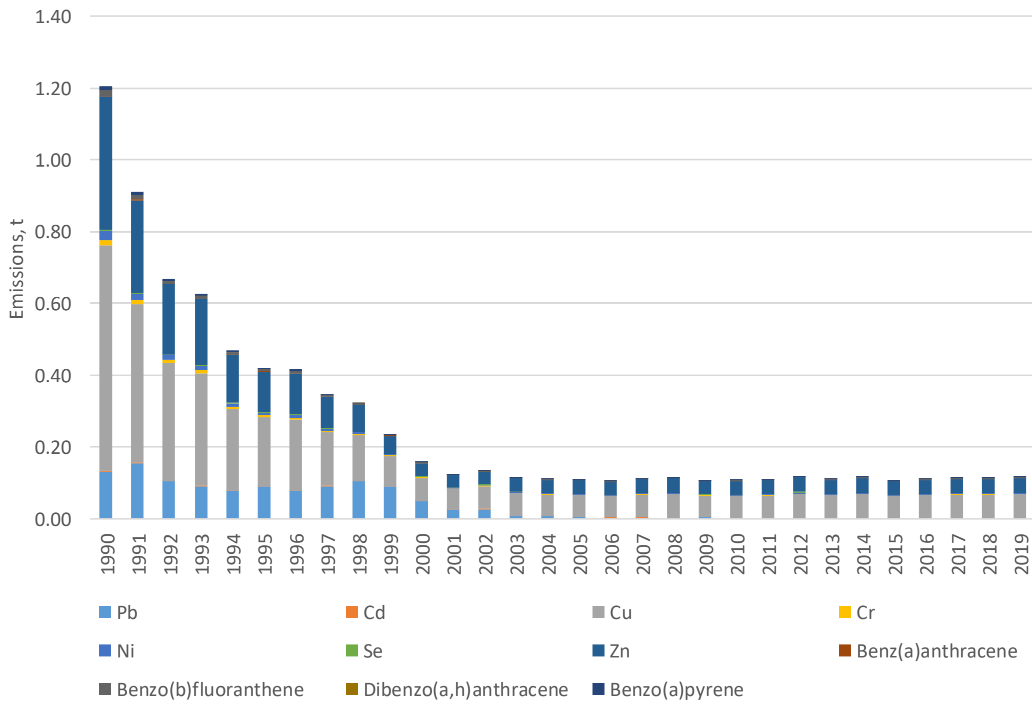


FIGURE 39 HEAVY METAL AND PAHS EMISSIONS IN SECTOR 1.A.4.C.II

2.3.4 Emissions 1.A.4.c.iii

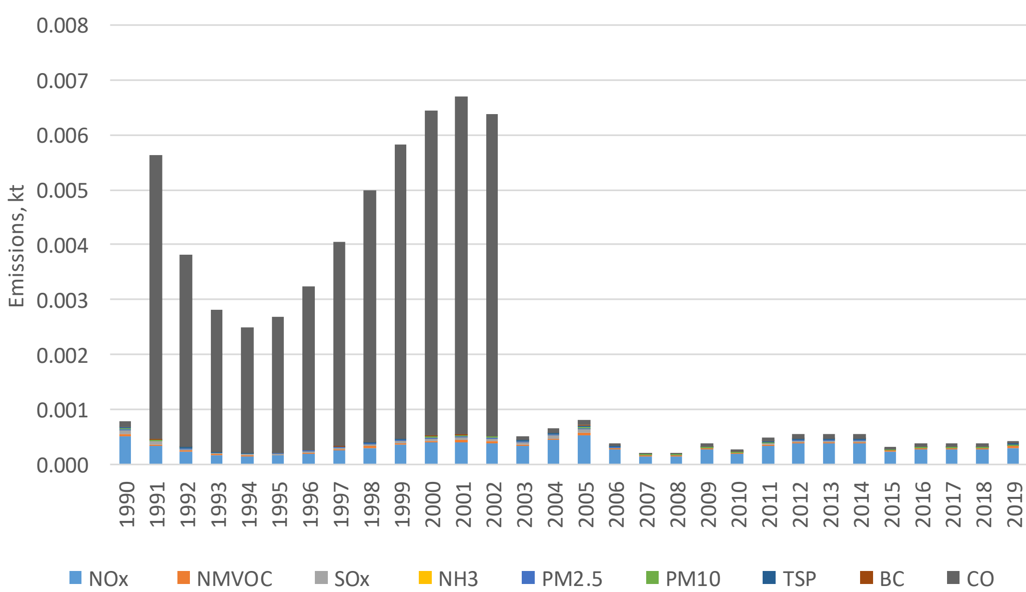


FIGURE 40 POLLUTANT EMISSIONS IN SECTOR 1.A.4.C.III

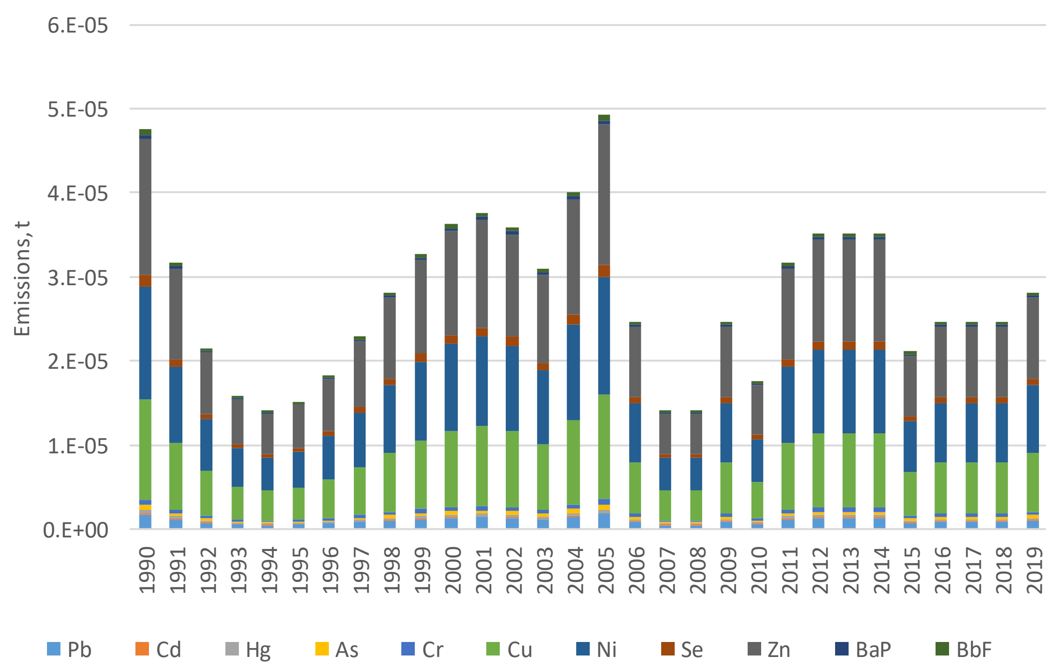


FIGURE 41 HEAVY METAL AND PAHS EMISSIONS IN SECTOR 1.A.4.C.III

2.3.5 Emissions 1.A.5.b

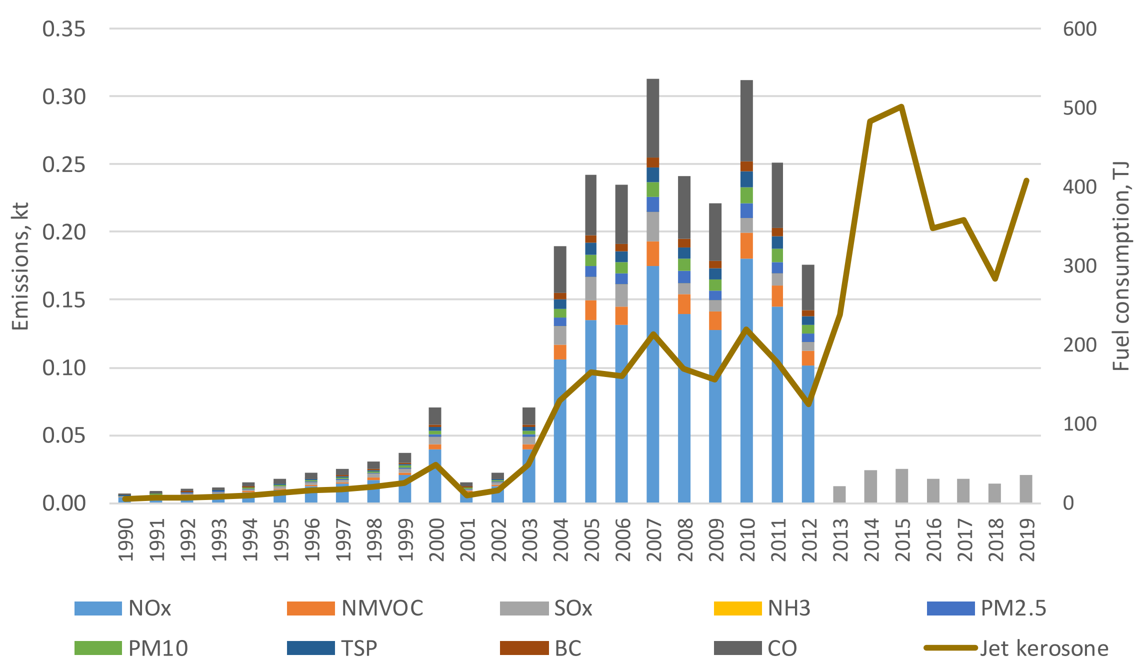


FIGURE 42 POLLUTANT EMISSIONS AND FUEL CONSUMPTION IN SECTOR 1.A.5.B

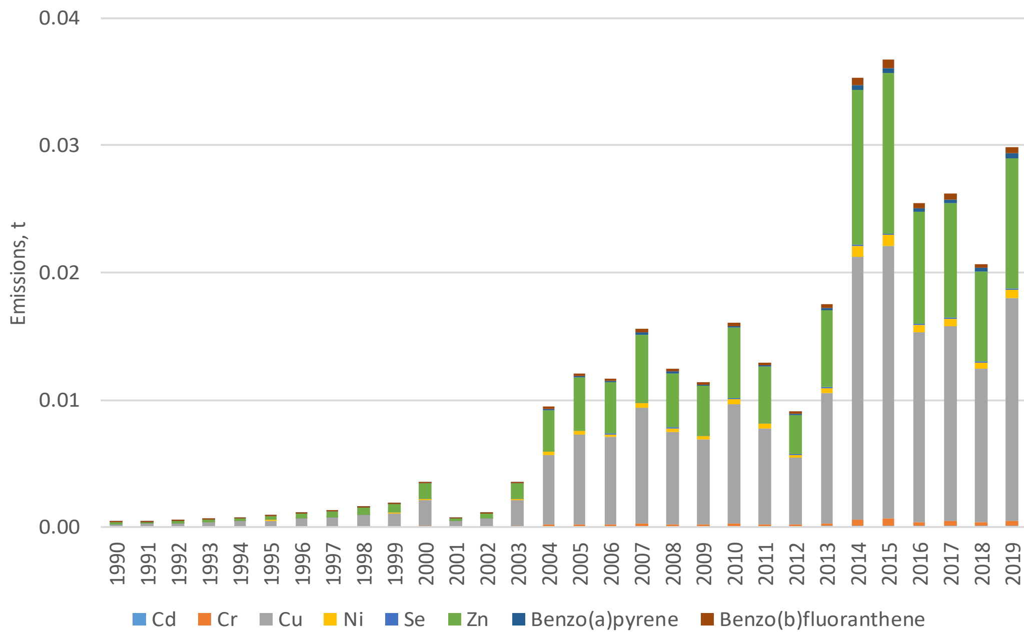


FIGURE 43 HEAVY METALS AND PAHS EMISSIONS IN SECTOR 1.A.5.B

2.4 FUGITIVE EMISSIONS FROM FUELS (1.B)

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

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

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 30 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).

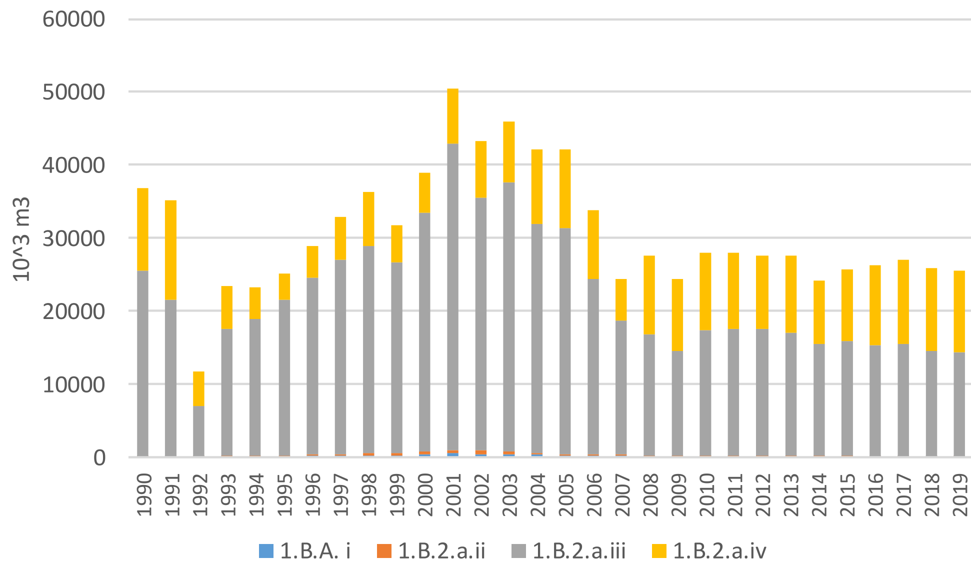


FIGURE 44 GAS EXPLORATION, PRODUCTION, TRANSPORT 1990-2019

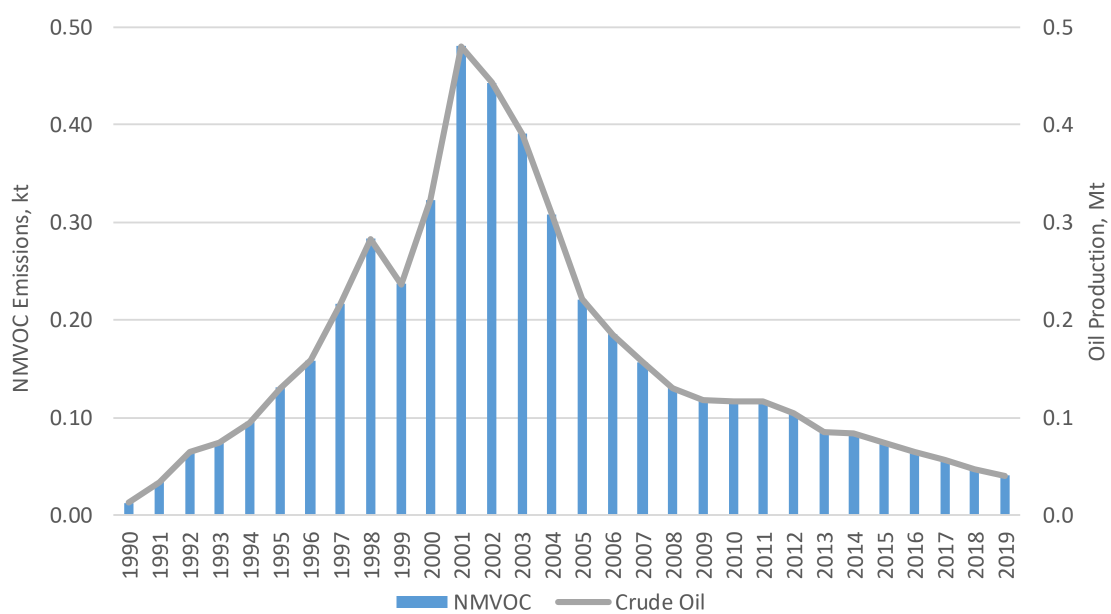


FIGURE 45 NMVOC EMISSIONS IN THE PERIOD 1990-2019

Default EF value is provided in Table 81.

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

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.

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.

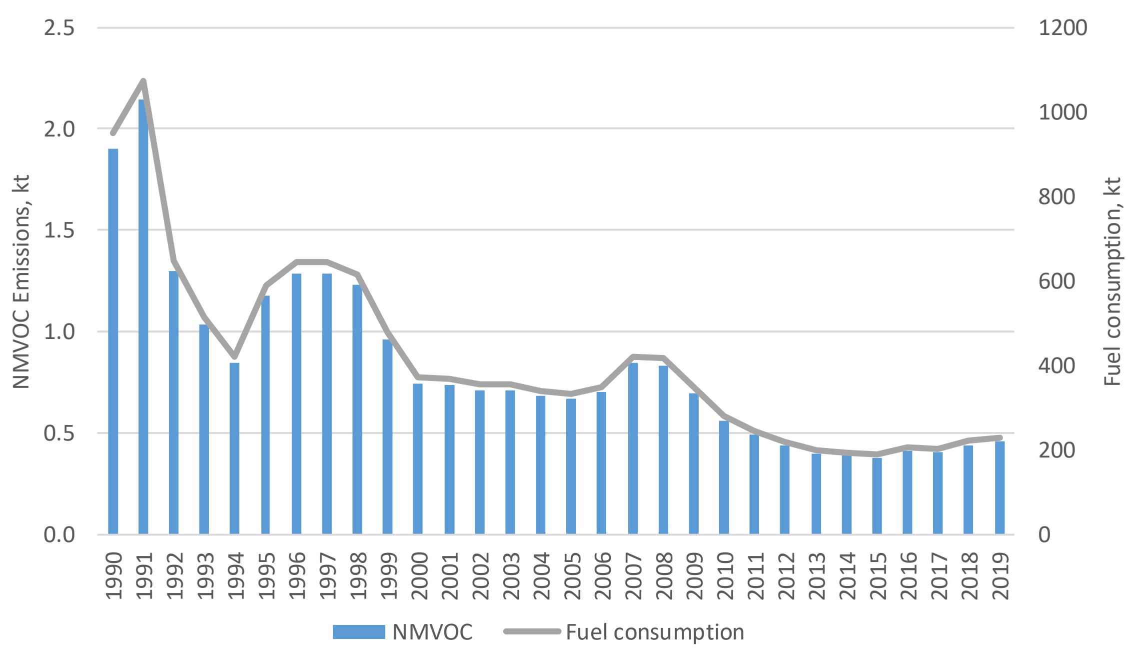


FIGURE 46 NMVOC EMISSIONS AND FUEL CONSUMPTION IN THE PERIOD 1990-2019

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 80.

2.4.3. 1B2a iv - Refining / storage

This industrial process is one of the bigests sources of SO2 and NMVOC. Data on emissions for SO2 were taken from the refinery plant reports. Emissions of NMVOC were estimated on the basis of the refinery plant reports and Lithuanian GHG inventory data (for subtraction amount of methane). For details on emissions in this sector please refer the attached Excel file “Annexe for LT NIIR 1990-2019” sheet “1B2aiv”.

3 INDUSTRIAL PROCESSES AND PRODUCT USE

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%).

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

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 2019 (55 %). The second largest share is for Coating applications – 39% (Figure 48).

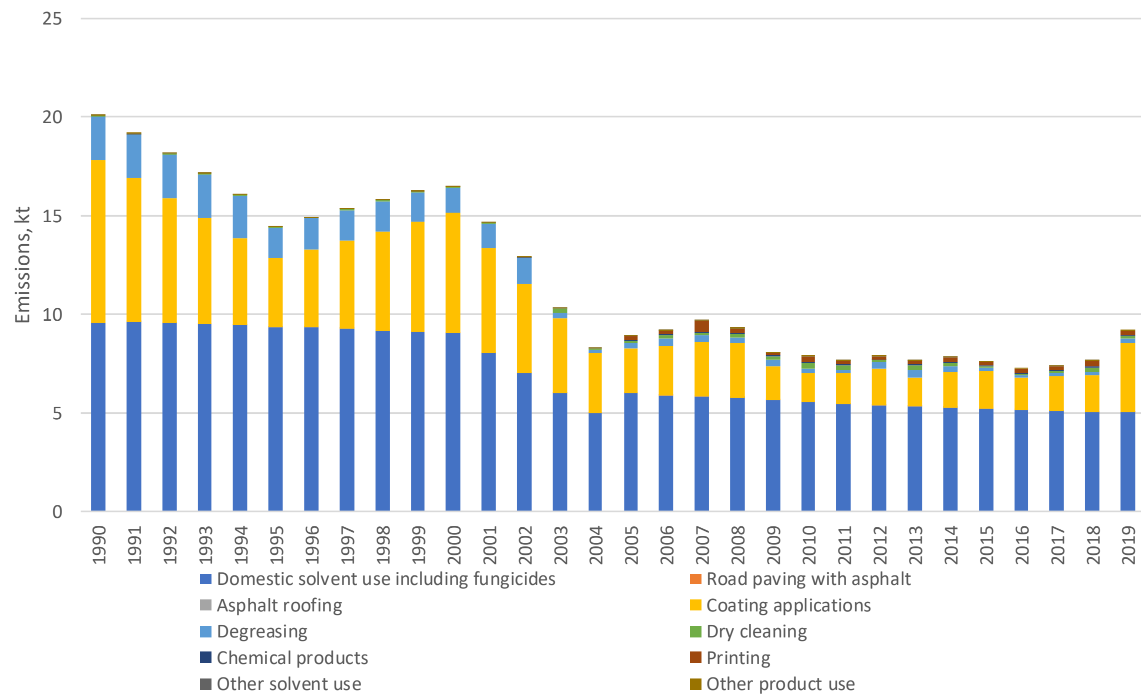


FIGURE 47 NMVOC EMISSIONS 1990-2019 BY SECTORS

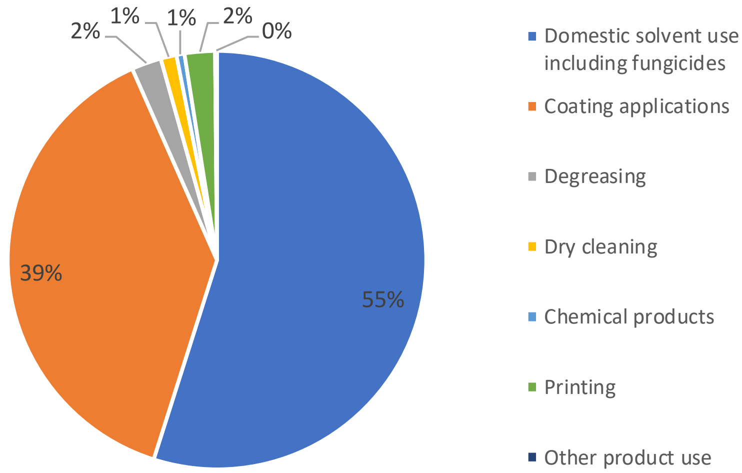


FIGURE 48 DISTRIBUTION OF NMVOC EMISSIONS IN OTHER SOLVENT AND PRODUCT USE SECTOR FOR 2019.

Emission from solvent and other product use were estimated according to number of population and NMVOC emission factor in [g/inhabitant] units during 1990-2019 given in Statistics Lithuania (2019).

Derived and used in estimation NMVOC emission factors are listed in Figure 47 and Figure 48. Emissions from Coating application were calculated for 2005-2019 Tier 2 method using activity data of production.

3.1.1 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

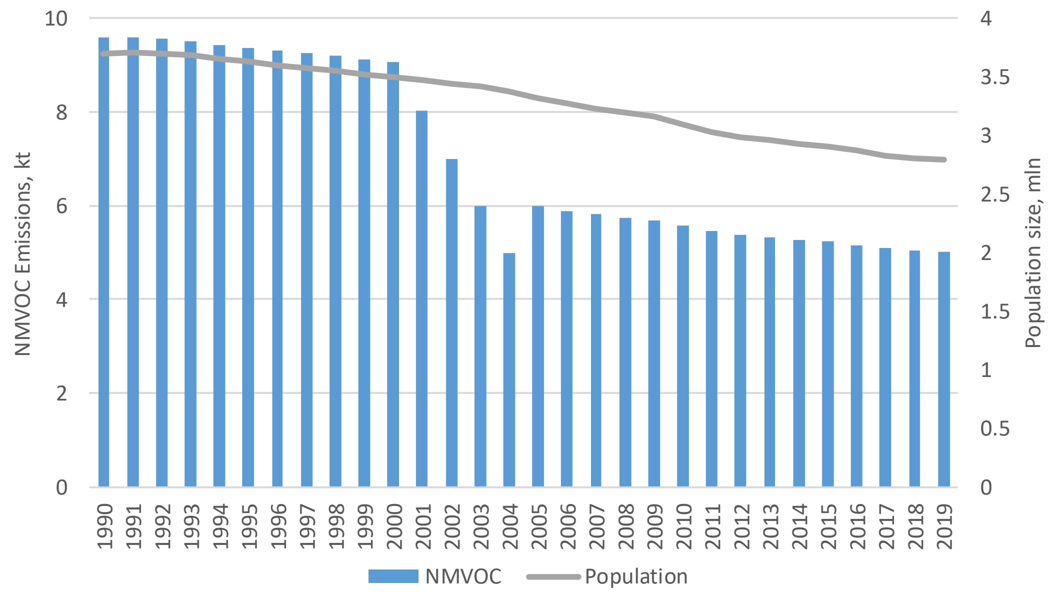


FIGURE 49 NMVOC EMISSIONS AND POPULATION SIZE IN LITHUANIA IN SECTOR 2.D.3.A

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).

3.1.2 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.

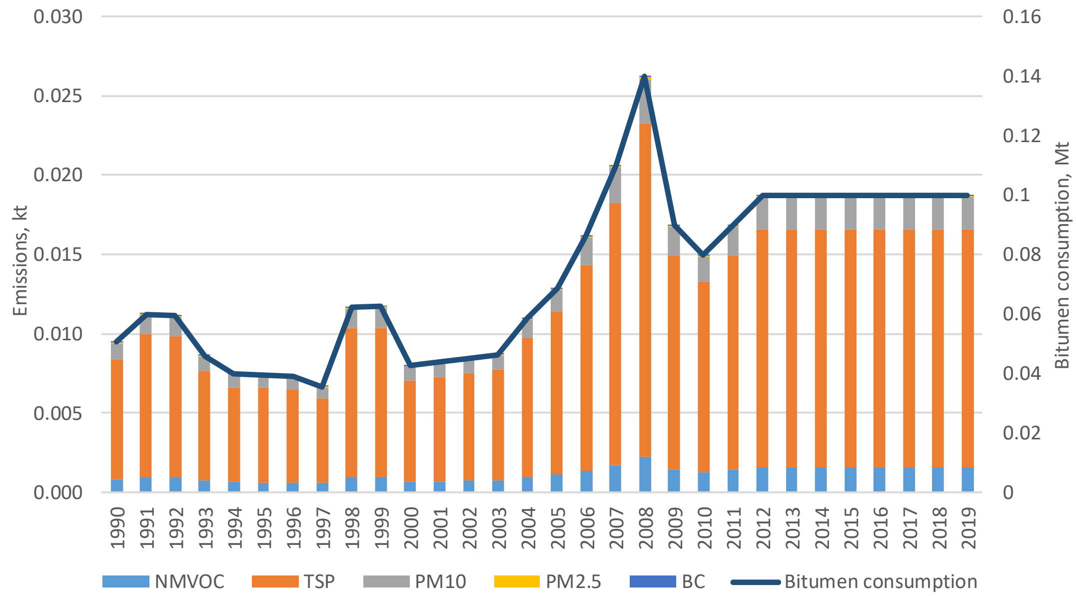


FIGURE 50 POLLUTANT EMISSIONS AND BITUMENT CONSUMPTION IN SECTOR 2.D.3.B

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 87.

3.1.3 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 2001-2019.

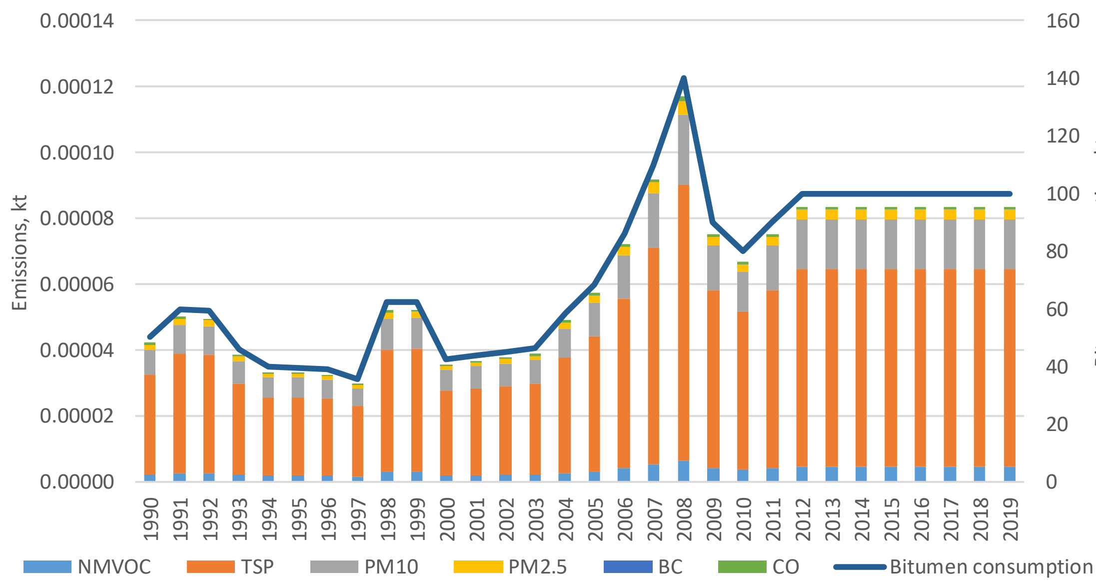


FIGURE 51 POLLUTANT EMISSIONS IN SECTOR 2.D.3.C

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 88.

3.1.4 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.

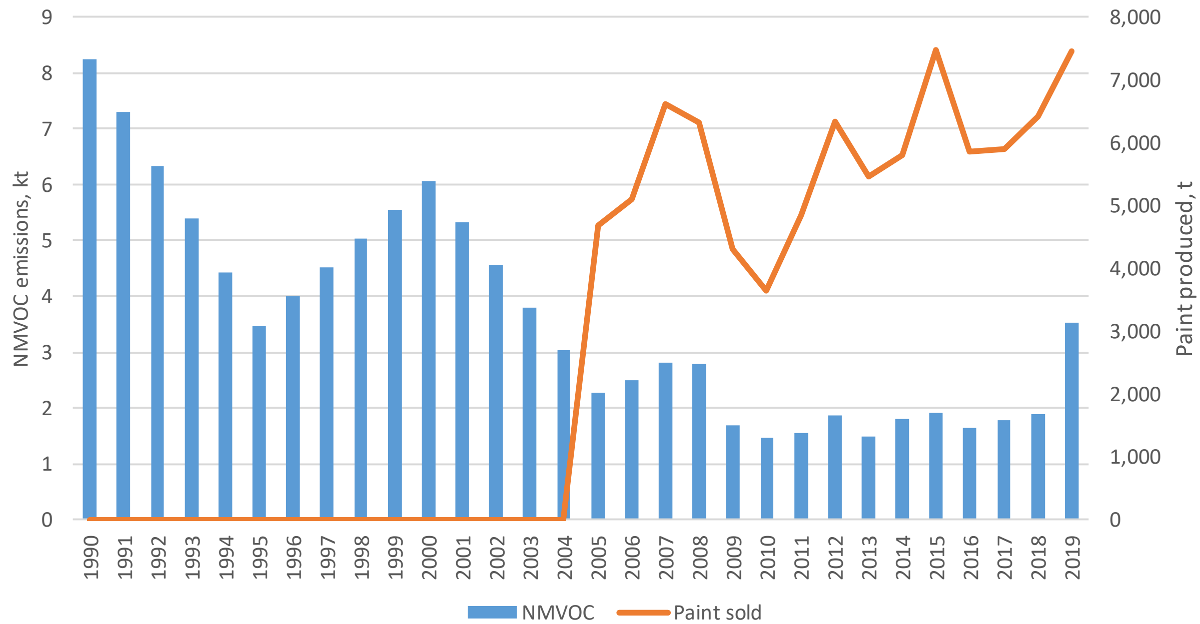


FIGURE 52 NMVOC EMISSIONS AND PAINTS PRODUCED (T) IN LITHUANIA IN SECTOR 2.D.3.D

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.

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.

3.1.5 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.

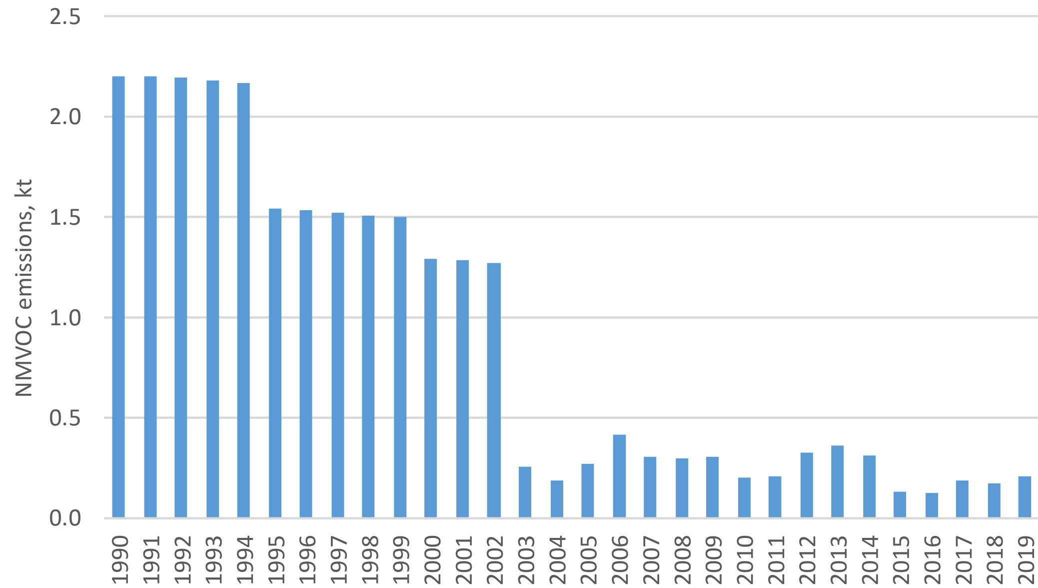


FIGURE 53 NMVOC EMISSIONS IN SECTOR 2.D.3.E

During LRTAP in-depth review of national emission inventories in 2019 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)[1]
- xylenes (XYL).

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

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):

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

---

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

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 in the table below.

TABLE 31 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).

3.1.6 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 54.

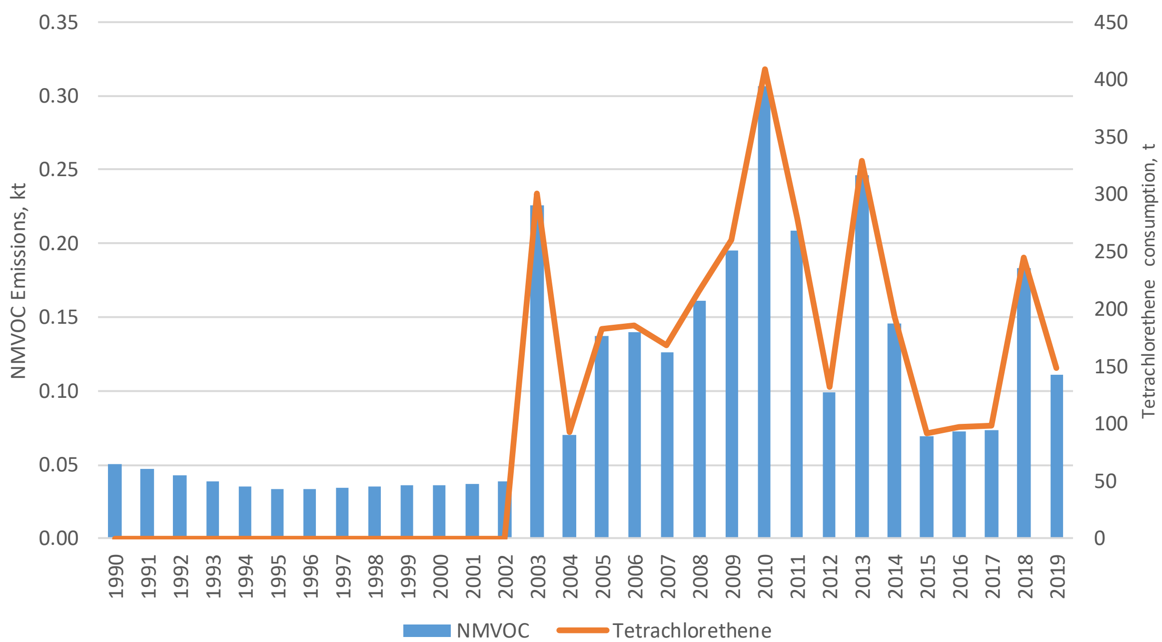


FIGURE 54 NMVOC EMISSIONS AND TETRACHLORETHENE CONSUMPTION IN SECTOR 2.D.3.F

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:

$$Consumption = Production + Import + Export$$
$$Emission = Consumption \times EF_{(\text{fraction emitted.control strategies applied})}$$

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.

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

These activities cover the emissions from the use of chemical products for 2005-2019.

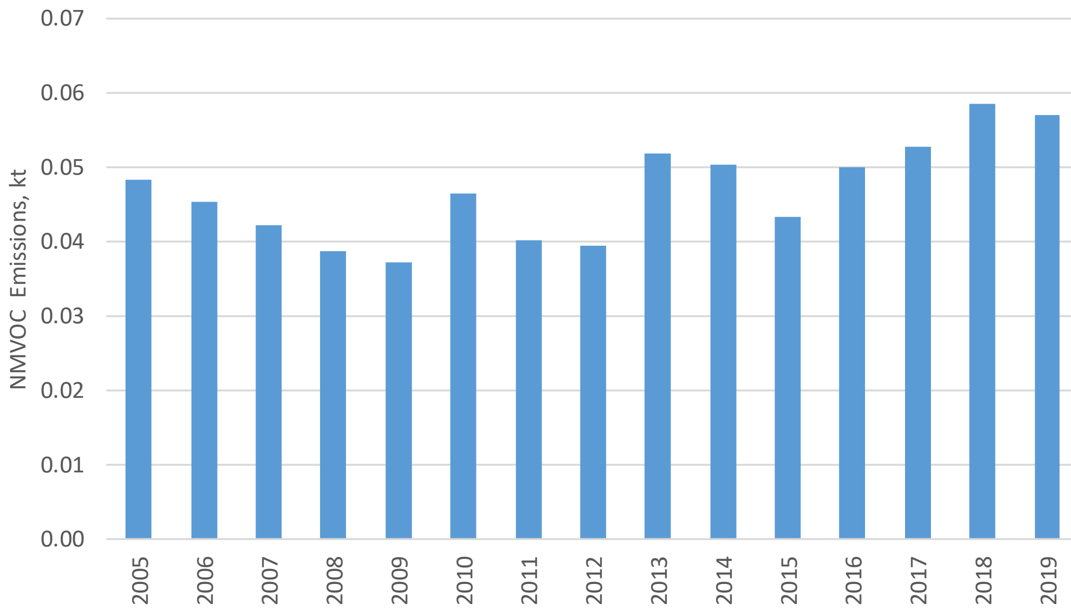


FIGURE 55 NMVOC EMISSIONS IN SECTOR 2.D.3.G

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.

3.1.8 Printing (2.D.3.h)

2005-2019 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 2005-2019 period. There is a decreasing trend observed for the period 2005-2019. Please see figure below.

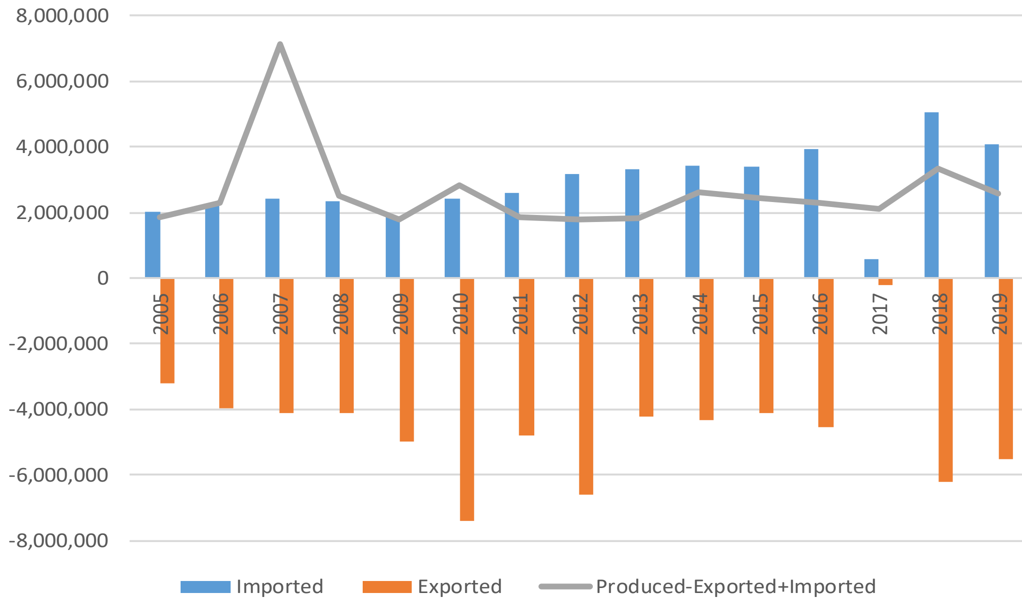


FIGURE 56 ESTIMATED PAINT CONSUMPTION FOR 2005-2019

Raw data on production, import and export for years 2005 – 2019 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 – 2019:

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

The 1990 – 2005 emission were estimated using extrapolation of obtained 2005-2019 data points. The equation used is shown in the figure above.

Figure below shows NMVOC emissions from the *Printing* category. Estimated 2005-2019 NMVOC emissions form a declining trend, which was the basis for the 1990-2019 emissions estimation. On the other hand, the 2005/2019 emissions increased by 12%.

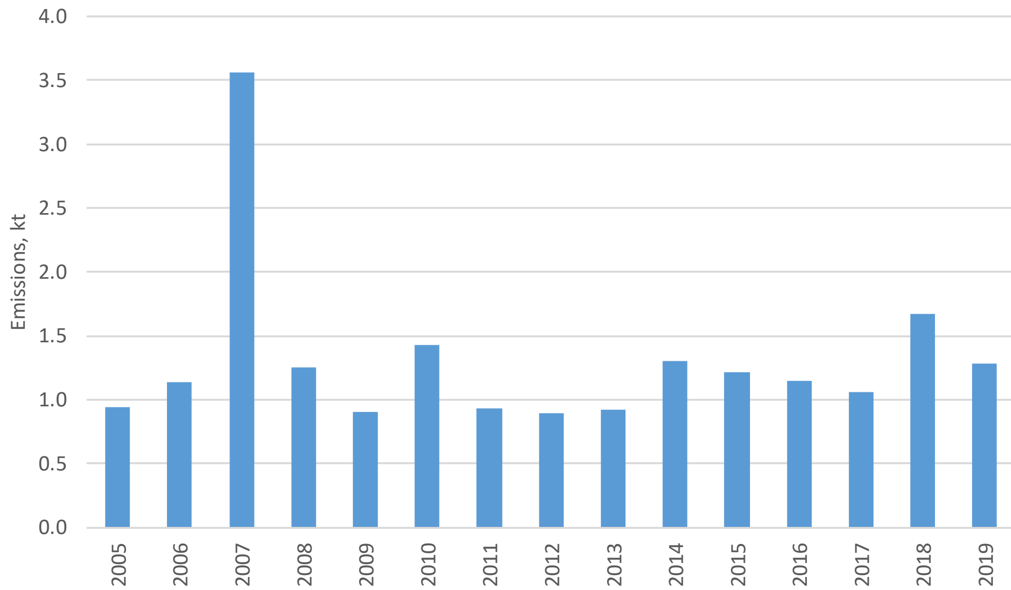


FIGURE 57 NMVOC EMISSIONS IN SECTOR 2.D.3.H

3.1.9 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)*. 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 1990-2019. Information obtained from Statistics Lithuania and Comext Eurostat.

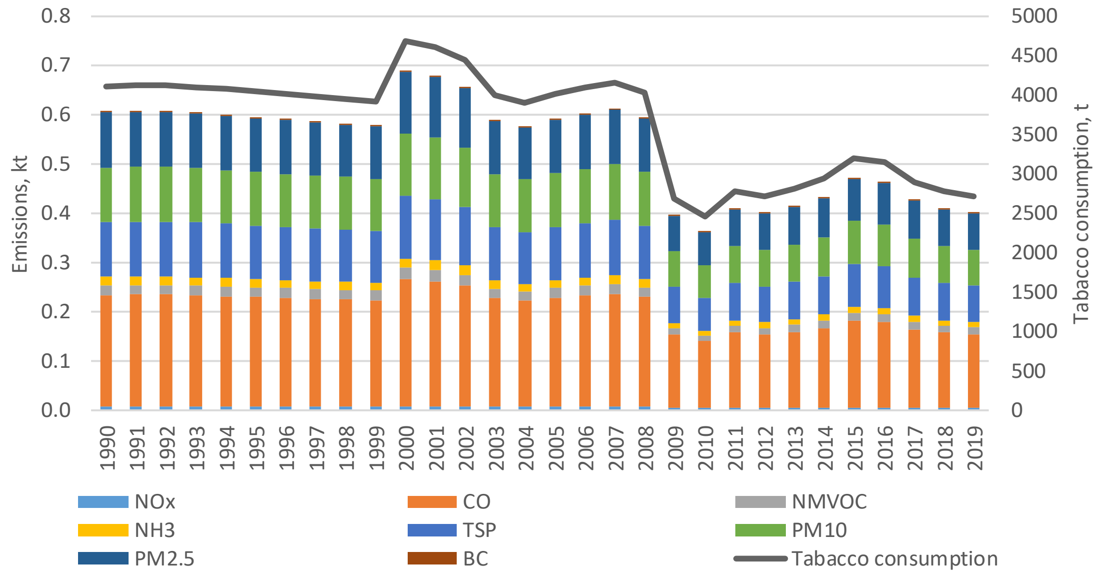


FIGURE 58 POLLUTANT EMISSIONS AND TOBACCO CONSUMPTION IN LITHUANIA, 1990-2019

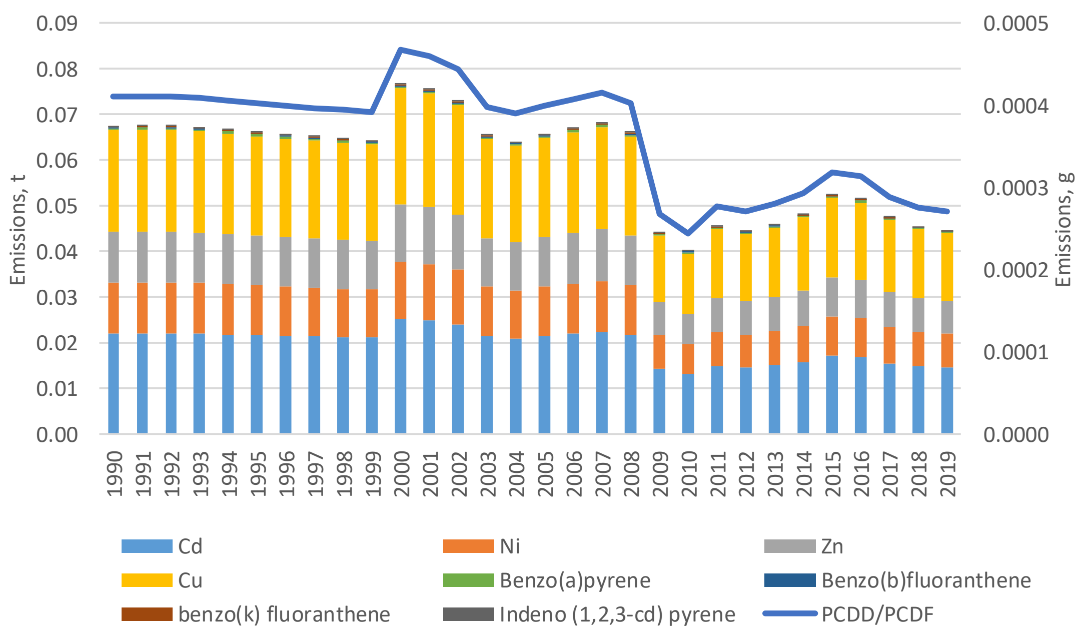


FIGURE 59 HEAVY METALS AND PAHS EMISSIONS FROM TOBACCO USE IN LITHUANIA, 1990-2019

Information on cigarette consumption (cigarettes per inhabitant per year) from 2000 to 2019 is available from Statistics Lithuania database. Averaged 2000 – 2019 (i.e. 1092.9 cigarettes/ inhabitant/ year) value was used to estimate tobacco consumption for years before 2000. For estimated tobacco consumption for 1990-2019. Emissions from tobacco consumption were estimated using emission factors from 2019 EMEP/EEA guidebook, see (Table 89).

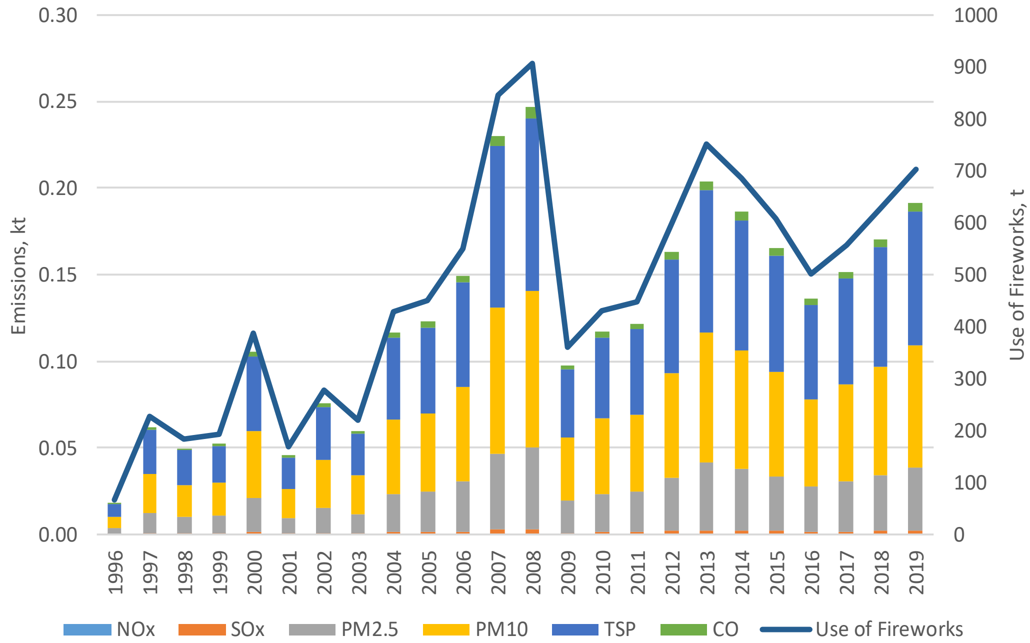


FIGURE 60 FIREWORK USE AND POLLUTANT EMISSIONS, 1996-2019

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 – 2019 data obtained from Statistics Lithuania. Statistical data for 1999 – 2019 years was found to be identical.

No information on 1990 – 1995 was available. Thus, emissions were not estimated for that period. Please see Figure 60 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 90.

Emissions from the use of fireworks (*SNAP 060601*) increased by 937.5% from 1996 to 2019. while increased by 55.7% from 2005 to 2019.

Emissions from tobacco smoking decreased by 33.9% from 1990 to 2019 and by 31.9% from 2005 to 2019.

4. 1A4 Small stationary combustion

The emissions in this group of sectors were estimated using fuel activity data provided by Statistics Lithuania, emission factors from EMEP/EEA Emission inventory guidebook 2019 chapter “1A4 Small combustion. For wood combustion in 1A4bi in fireplaces, manual boilers and automatic boilers national NOx emission factors from 2014 were applied. Data about distribution of wood, coal and peat by types of combustion devices were taken from IIASA GAINS model. For more details please refer the attached Excel file “Annexe for LT NIIR 1990-2019” sheets “1A4bi”, “1A4ai”, “1A4ci”.

5. 2A group of sectors – processing of minerals

The main pollutants in this groups are PM. In 2A1, 2A2 sectors the up-to-date abatement technologies are installed. The measures for reducing PM emissions in 2A5a quarrying and mining of minerals other than coal are also applied. The PM emissions in 2A5b Construction and demolition are highly uncertain due to the problems in the data on length of the streets and roads of Statistics Lithuania (for some years difference between length in previous year is negative).

Planned improvements. Lithuanian EPA plans to inquiry the municipalities regarding length of the new constructed streets and roads. The construction of the new roads, streets, railways, bicycle tracks is the large scale process in Lithuania.

6. 2B – chemical industry

All data on the emissions in this group of sectors are taken from the reports of the chemical plants.

7. 2H2 - Food and beverages industry

This is a significant source of NMVOC generating about 4-5 kt of this pollutant annualy and contributing to the national total (excluding agriculture) 9-13 per cent.

8. 3B – Manure management, 3Da1 - Inorganic N-fertilizers

NH3, NOx emissions from 3B1a Diary cattle 1990-2019 and 3B1b Non-dairy cattle 1990-2019 and 3B3 swine 2005-2019 were estimated using EEA Manure management N – flow tool. Data on manure management systems were taken from Lithuanian GHG inventory.

NH3, NOx emissions from all other categories were estimated using Tier 1 methodology.

NMVOC emissions from 3B1a Diary cattle 1990-2019 and 3B1b Non-dairy cattle 1990-2019 were estimated using Tier 2 methodology. NMVOC emissions from all other categories were estimated using Tier 1 methodology.

PM emissions from all categories were estimated using Tier 1 methodology.

Livestock numbers (historical and projected) are provided in the attached Excel file “Annexe for LT NIIR 1990-2019” sheet “Agriculture”.Emissions from 3Da1 were estimated by Tier 2 methodology: pH of soils is less 7, amounts of fertilizers were taken from www.ifastat.org. Amounts (historical and projected) of fertilizers are provided in the attached Excel file “Annexe for LT NIIR 1990-2019” sheet “Agriculture”.

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1.A.1.a

TABLE 32 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 33 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 34 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 35 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 36 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)

1.A.3

TABLE 37 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 38 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 39 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 SO_2: use Tier 1 methods and emission factors
5. BC fraction of PM (f-BC): 0.65.

TABLE 40 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 41 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 42 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 43 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 44 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 45 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 46 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	NH_3				
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 47 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	**NH_3**				
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 48 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 49 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	NH_3				
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 50 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	NH_3				
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 51 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 52 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 53 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 54 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 55 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 56 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 57 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 58 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 59 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 60 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 61 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 62 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 63 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 64 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** **1.A.4.c.i**	**Commercial / institutional: stationary** **Agriculture / forestry / fishing: Stationary**

	1.A.5.a	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 65 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 66 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 67 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); Tissari et al. (2007); Hedberg et al. (2002);
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	Pettersson et al. (2011); Glasius et al. (2005); Paulrud et al. (2006); Johansson et al. (2003); Lamberg et al. (2011)
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 68 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 69 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 70 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 71 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 72 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 73 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 74 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 75 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
PM2.5 (total particles)	37	g/GJ	18	74	
BC (based on total particles)	15	% of PM2.5	6	39	

					al. (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 76 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 77 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 78 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 79 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 80 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 81 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 82 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 83 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 84 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 85 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 86 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 87 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 88 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 89 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 90 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 91 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 92 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 93 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 94 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 95 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 96 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 97 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)