FINLAND's INFORMATIVE INVENTORY REPORT 2017

Air Pollutant Emissions 1980-2015

under the UNECE CLRTAP and the EU NECD

Part 2

Energy

Revised 28.04.2017 FINNISH ENVIRONMENT INSTITUTE

Centre for Sustainable Consumption and Production

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This part of the IIR was revised 28.04.2017

PART 2 ENERGY

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4 ENERGY (NFR 1)

Changes in chapter	
Update of text	January 2017 KS
Other (e.g. language, layout)	February 2017 KS
NOTE: *The time series for NFRs 1A1 and 1A2 have never been recalculated. Major improvements for the methods (emission factors) and methodological descriptions are pending.*	

4.1 Overview of the sector

The sources of stationary fuel combustion included under Chapter 4.2 Energy Industries and Manufacturing Industries and Construction are presented in Figure 4.1 and the air pollutants reported from these sources in Table 4.1.

Transport sector sources and emissions are presented under Chapter 4.3

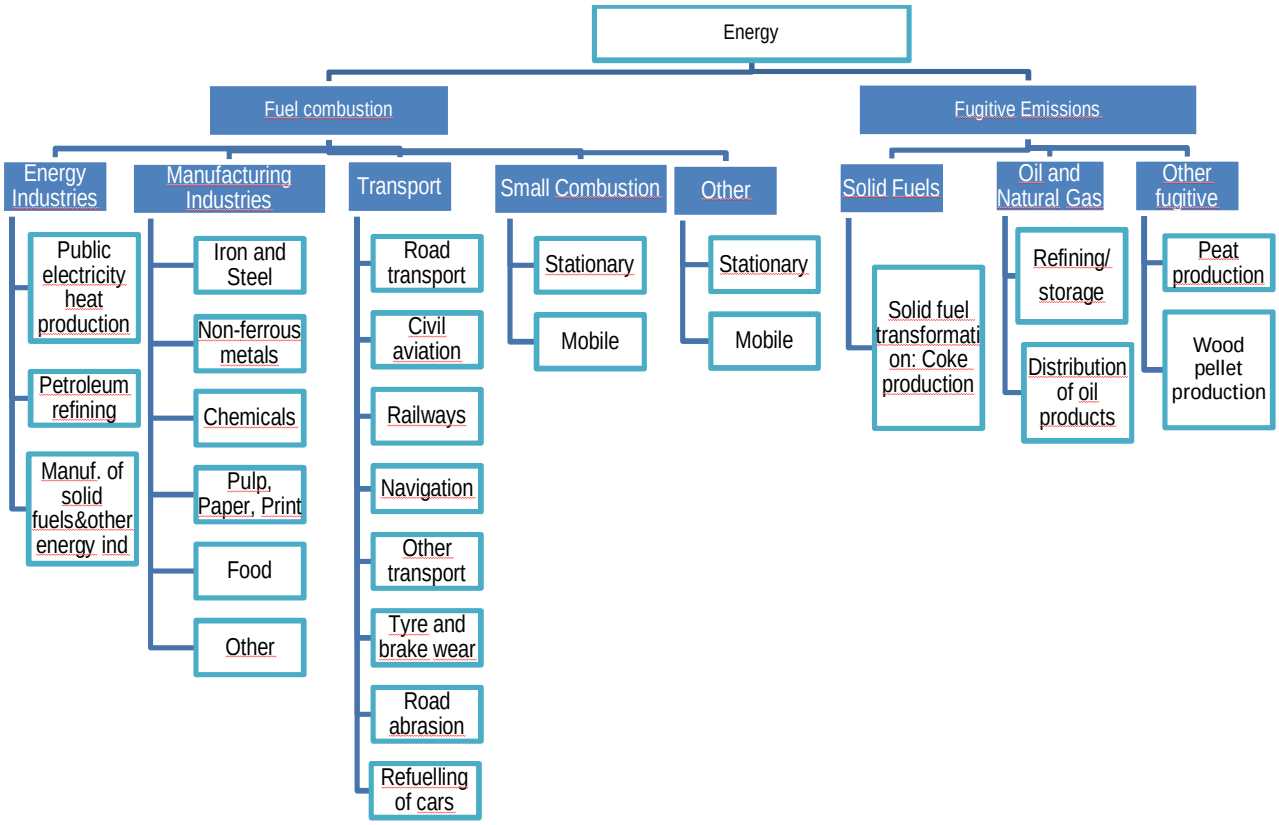


Figure 4.1. Emission sources included under the Energy Sector in the Finnish air pollutant inventory.

NFR 1.A.1 Energy industries and NFR 1.A.2 Manufacturing industries and Construction covers emissions from fuel combustion in point sources in the energy production and industrial processes sectors. Since the year 2011 inventory, all emissions from waste-incineration are reported under NFR 5.C. This will be revised throughout the whole time series when the recalculation has been finalized.

NFR 1.A.3 Transport covers emissions from road transport, civil aviation, railways, navigation and other transportation. In addition to fuel combustion, also emissions from tyre and brake wear road abrasion are calculated as well as emissions from refuelling of cars.

NFR 1.A.4 Other sector, NFR 1.A.5 Other and also partly NFR 1.A.2 Manufacturing Industries and Construction (Other – Stationary) cover all the remaining fuel combustion activities that are not covered by the categories 1.A.1–1.A.3.

NFR 1B, Fugitive emissions from fuels, covers emissions from peat production, oil refineries, storage and distribution of chemicals and oil. There is no exploration or production of oil and natural gas nor hard or brown coal mining in Finland.

Table 4.1. Emissions in 2014 reported under NFR 1A and 1B.

NFR14	Source	Pollutants reported
1A1	Energy industries	
	a Public electricity and heat production	NO_X, NMVOC, SO_X, NH_3, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB
	b Petroleum refining	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4
	c Manufacture of solid fuels and other energy industries	NA
1A2	Manufacturing industries and construction	
	a Iron and steel	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB
	b Non-ferrous metals	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB
	c Chemicals	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB
	d Pulp, Paper and Print	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB
	e Food processing, beverages and tobacco	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB
	fi Other - stationary	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB
	fii Other - mobile	NO_X, NMVOC, SO_X, NH_3, TSP, PM_{10}, $PM_{2.5}$, CO
1A3	Transport	
	a Aviation	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb
	bi-iv Road transport	NO_X, NMVOC, SO_X, NH_3, TSP, PM_{10}, $PM_{2.5}$, CO, PCDD/F, PAH-4, HCB, PCB
	bv Road transport - Gasoline evaporation	NMVOC
	bvi Road transport - Automobile tyre & brake wear	TSP, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn
	bvii Road transport - Automobile road abrasion	TSP, PM_{10}, $PM_{2.5}$
	c Railways	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, CO
	dii Navigation	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, CO, PCB
	e Pipeline compressors	NO_X, NMVOC, SO_X, CO, PCDD/F
1A4	Small combustion	
	ai Commercial and institutional - stationary	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB
	aii Commercial and institutional - mobile	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, CO
	bi Residential - stationary	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB
	bii Residential - mobile	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, CO
	ci Agriculture, Forestry, Fishing - Stationary	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB

NFR14	Source	Pollutants reported
	cii Agriculture, Forestry, Fishing - Off-road vehicles and other machinery	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, CO, Se
	ciii Agriculture, Forestry, Fishing - National fishing	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, CO, PCB
1A5	Other	
	a Stationary	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB
	b Military	NO_X, NMVOC, SO_X,TSP, PM_{10}, $PM_{2.5}$, CO
1B1	Fugitive emissions from solid fuels	
	a Coal mining and handling	NA
	b Solid fuel transformation: coke production	NMVOC, TSP, PM_{10}, $PM_{2.5}$,, PCDD/F, PAH-4, PCB
	c Other fugitive emissions from solid fuels: wood pellet	TSP, PM_{10}, $PM_{2.5}$
1B2	Oil and gas	
	aiv Oil - Refining / storage	, NMVOC, CO, PCB
	av Oil - Distribution of oil products	NOx, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO
	b Natural gas – distribution + transport	NA
	c Venting and flaring	NA – should be IE, emissions are reported in 1B2aiv
1B3	Other fugitive emissions	
	Peat production	TSP, PM_{10}, $PM_{2.5}$

4.1.1 Source category description

Changes in chapter	
Update of text	February 2017 KS
Other (e.g. language, layout)	February 2017 KS
NOTE:	

Similarly to other industrialised countries, the largest source of most air pollutants in Finland is the energy sector. Finland does not have domestic sources of fossil energy and imports substantial amounts of petroleum, natural gas, and other energy resources. The main domestic energy sources include wood fuels, peat and hydropower, which cover about 30% of energy demand.

Energy consumption has not increased in the 2000's due to decreased energy demand in the energy, which has been affected by improved energy efficiency and decreased volume of heavy industries. In the period of 2000-2010 the share of industry of the total energy use decreased from 52% to 45%[1].

National characteristics that are reflected in the emissions include (1) cold climate, (2) long distances, (3) energy-intensive industries, (4) increasing use of renewable energy and (5) strong annual variations in energy use.

[1] Finnish Environment Institute S YKE http://www.ymparisto.fi/fi-FI/Kartat_ja_tilastot/Ymparistoн_tilan_indikaattorit/Ilmastonmuutos_ja_energia/Energiankulutus_ei_enaa_kasva%2828547%29

(1) Cold climate

The annual mean temperature in the south of the country is around 5 ºC and 0 ºC in the north. The population-weighted average number of heating degree days for Finland is 5000, considerably more than in Sweden and Norway (4000). The Finnish climate is the coldest in the EU and, consequently, a large share of the energy (22 %) is used for the heating of buildings. The high demand for energy also forces the production and use of energy to be efficient. Finland is one of the world's leading countries in the production of combined heat and power (CHP), by which the same power plant produces both electricity for the local grid, and heat to warm buildings and run industrial processes. This district heating system includes a network of insulated pipes used to deliver heat, in the form of hot water or steam, from the point of generation to an end user and provide a means to transport heat efficiently. This makes good use of heat energy that would be wasted in facilities only generating electricity.

(2) Long distances

Finland is a highly motorized country, partly due to its long distances and sparse population. Consumption per kilometre has decreased but the amount of kilometres has increased being around 55 000 million kilometres per year.

(3) Energy-intensive industries

Almost half of all energy consumed is still used by industry where the heaviest users are pulp and paper industry, metal industry, oil refining and chemical industry. Much of the energy consumed by the manufacturing industries and construction is produced by themselves, e.g. black liquor, peel and branches are used by the forest industry itself in creating its own energy. The use of biofuels is increasing and the industries have also outsourced power plants from industry to the energy sector.

(4) Renewable energy

The share of renewable energy in total energy consumption grew to 35% in 2015. The share of wood fuels in Finland's total energy consumption continued to grow and was 25%. EU targets for renewable energy are calculated relative to total final energy consumption; calculated in this manner, the share of renewable energy was over 39 per cent in Finland in 2015 based on preliminary data. Final data will be released on Eurostat's website in February/March 2017. Finland's target for the share of renewable energy is 38% of final energy consumption in 2020, which was reached for the first time in 2014 (Energy supply and consumption, Statistics Finland). Also in the transport sector there is increased use of biofuels, for instance in the road traffic the share of biofuels was over 13% in 2015.

Wood fuels are the largest source of energy. Most firewood is by-product of other uses of wood. Peat is one of the main fuels after wood, hard coal and natural gas and it is a domestic energy source. The world's largest bio power plant with a capacity of 265 MW is situated in Pietarsaari in Finland.

Wood is also used directly for heating. In total around 6 million m^3 or 50 PJ of firewood are used annually for space heating.

(5) Annual variations

Energy sector emissions show strong annual variation in accordance with (1) the amount of energy used and (2) the proportion of imported electricity.

Fluctuations in the *amount of energy used* depend on the economic trend, the energy supply structure and climate conditions:

- In the 1990's, first the *economic depression* and later the recovery up to the early 2000's especially in the energy intensive export industries, have impacted the demand of energy. Between 2001 and 2006 the economy did not grow and the worldwide economic downturn that began in 2008 impacted energy consumption.

- The *availability of hydro power in the Nordic electricity market* influences significantly the electricity supply structure and hence the emissions. If the annual precipitation in the Nordic countries is lower than usual, hydro power becomes scarce and Finland's net imports of electricity decrease. During such years additional electricity is generated using coal and peat in condensing power production for its own needs and also to be sold on the Nordic electricity market. Finland's condensing power generation is reduced in years when electricity imports from the Nordic electricity market are increased due to a good water situation in the Nordic countries (Figure 2). Coal-fired condensing power production has varied between 4.8 TWh in 2015 and 17.9 TWh in 2003.
- In the integrated Nordic electricity market the annual rainfall and accordingly the availability of cheap hydropower, decreased the Finnish emissions in the early 1990's as well as in the turn of the millennium. In 2004 and 2005 there was good availability of hydro power in Nordic electricity markets and domestic condensing power production in Finland was replaced by imports of electricity. Especially in 2001-2003 and again in 2006 the shortage of hydro power in the Nordic market increased coal and peat-fuelled condensing power generation in Finland. In 2008 and 2009 the need for condensing power produced mainly with coal and peat decreased almost by 40 per cent from the year before and raised back to the level of 2007 in 2010. In 2011 condensing power generation decreased close to the level of the years 2008-2009 and in 2012 the decreasing continued to the lowest level in twenty years. Condensing power came back to 2008-2009 level in 2013. Electricity import was at quite high level with the exception of the years 2006 and 2010. Correspondingly, the condensing power generation was at low level in 2005, in 2008-09 and in 2011-2012. In 2012 the condensing power generation was at the lowest level after 1992 but came back to 2008-2009 level in 2013.

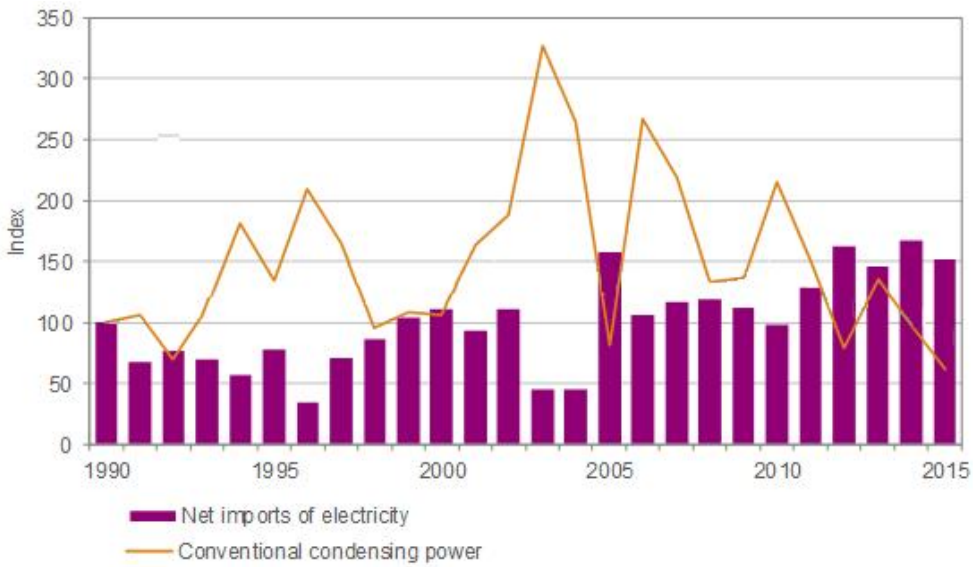


Figure 4.2. Net imports of electricity and conventional condensing power 1990-2015 (Finnish NIR 2017)

4.1.2 Energy use of waste

Changes in chapter	
Update of text	March 2016 KS
Other (e.g. language, layout)	February 2017 KS
NOTE:	

Energy use of waste is increasing significantly in Finland in the near future. In 2012 four new waste incineration plants were put into operation. There are six waste incineration plants in operation in Finland at the moment, two plants are under construction and one is under consideration. Waste incineration capacity will increase from the current 1 million t/a to about 1.8 million t/a by the end of 2018. Waste incineration is increasing because of the costs of other fuels are believed to rise and tightening regulations and increase in costs for landfilling.

Waste is also co-incinerated in Finland in boilers using typically peat and/or biomass as primary fuel. The annual amount of waste co-incinerated about 300,000 – 400,000 t/a. Different types of waste are used in incineration and co-incineration plants. Incineration plants use typically source separated municipal solid waste. In co-incineration plants, typically high quality industrial waste, solid recovered fuels and recovered wood are combusted (Finnish Energy, 2015)

All waste incineration/combustion plants are equipped with energy recovery, mostly combined heat and power production. Therefore no MSW incineration has been reported in the Waste sector.

In the air pollutant inventory, emissions from waste incineration are currently included under NFR 5C1 partly as the difference between data reported by the plants and emissions calculated in the energy model. The allocation of emissions will be revised when the time series of energy emissions has been finalized.

4.1.3 Overview of energy consumption

Changes in chapter	
Update of text	February 2017 KS
Change in methodology	none
Other (e.g. language, layout)	February 2017 KS
Notes	

4.1.3.1 Energy and electricity trends

Consumption of fuels in 1970-2015 is presented in Figures 4.3 and 4.4, information of electricity supply in Figure 4.5 and of electricity consumption by sector in Figure 4.6. Energy statistics is available online at http://pxweb2.stat.fi/sahkoiset_julkaisut/energia2013/html/engl0000.htm.

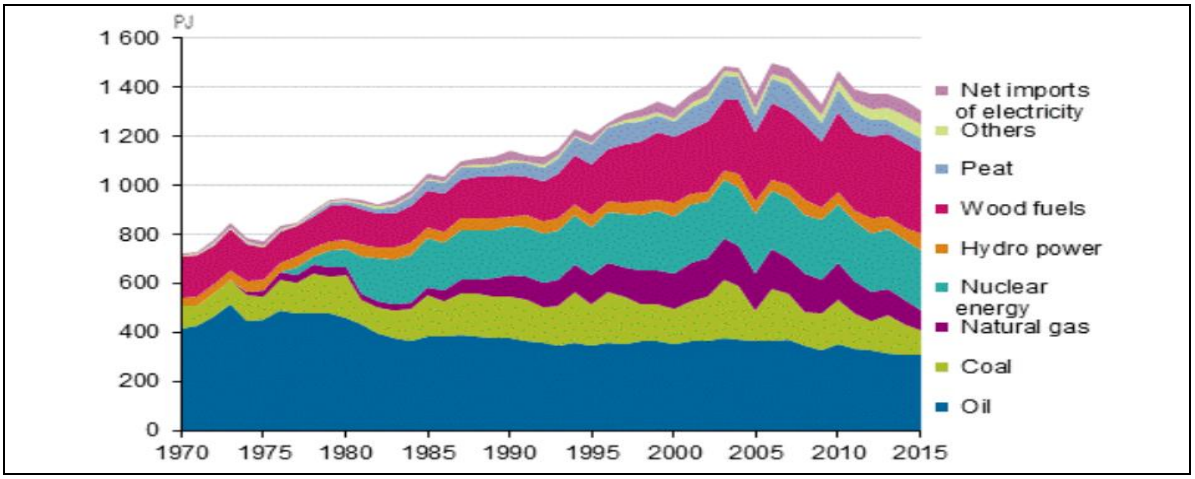


Figure 4.3. a) Energy sources 1990-2015; b) Consumption of fuel types 1970-2015

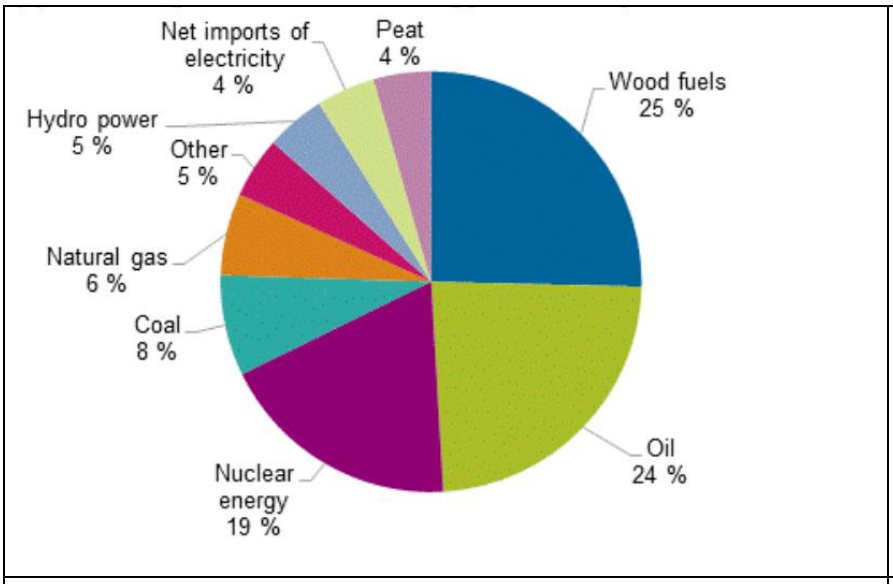


Figure 4.4. Total energy consumption by energy sources in 2015 (Yearbook of Energy Statistics 2016).

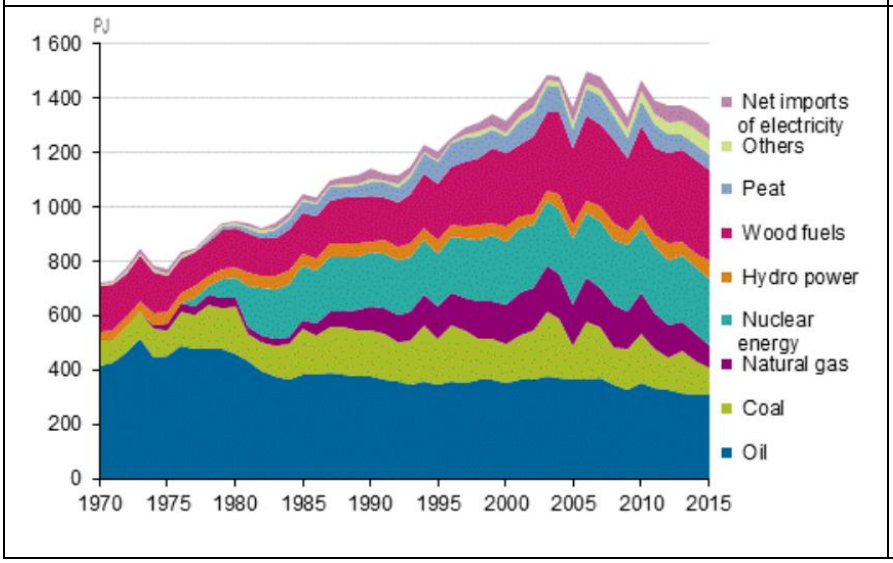


Figure 4.5. Electricity supply 1970-2015 (Yearbook of Energy Statistics 2016).

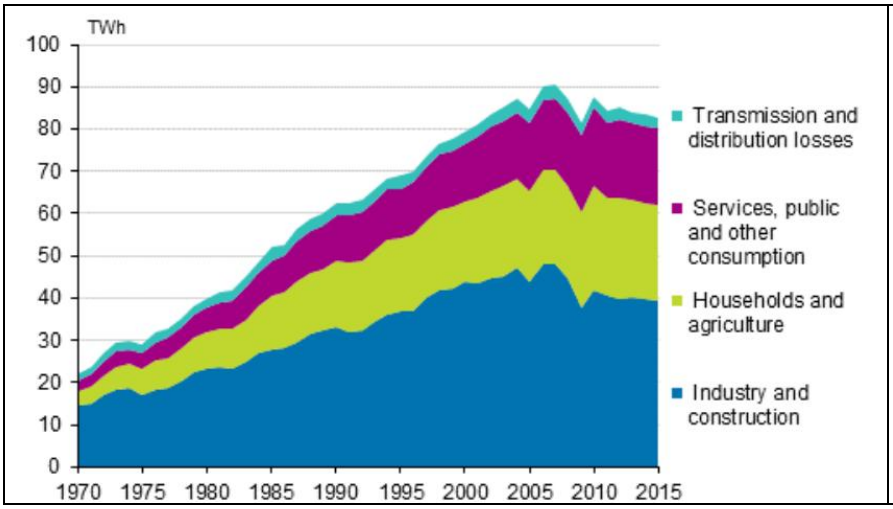


Figure 4.6. Electricity consumption by sector 1970-2015 (Yearbook of Energy Statistics 2015).

4.1.3.2 Energy production and consumption in 2015

Changes in chapter	
Update of text	February 2017 KS
Other (e.g. language, layout)	February 2017 KS
NOTE:	

Total consumption of energy

Total consumption of energy in Finland amounted to 1.30 million terajoules (TJ) in 2015, which was 3% less than in 2014. The use of renewable energy sources increased by 2% and that of fossil fuels decreased by 8%. Final energy consumption in transport remained at the same level and energy consumption in space heating decreased by 5%t from the year before. Final energy consumption in manufacturing industries contracted by 2%.

Trends of renewable energy and fossil fuels

The share of renewable energy in total energy consumption grew to 35% in 2015. The share of wood fuels in Finland's total energy consumption continued to grow and was 25%. EU targets for renewable energy are calculated relative to total final energy consumption. Early estimated in this manner, the share of renewable energy was over 39% in Finland in 2015 based on preliminary data. Final data will be released on Eurostat's website in February/March 2017. Finland's target for the share of renewable energy is 38% of final energy consumption in 2020, which was reached for the first time in 2014 (Energy supply and consumption, Statistics Finland).

The use of fossil fuels went down by 8% from the year before. Of fossil fuels, the use of natural gas fell by 14% and the use of peat by 5% from the year before. The consumption of coal (including hard coal, coke, and blast furnace and coke oven gas) decreased by 20% (Energy supply and consumption, Statistics Finland).

Electricity consumption and production

The consumption of electricity totalled 82.5 terawatt hours (TWh), which was 1% less than in the previous year. Of the total electricity consumption, 80% was covered by domestic production and 20% by net imports of electricity from the Nordic countries, Russia and Estonia. Net imports of electricity declined by 9% from the year before (Energy supply and consumption, Statistics Finland).

In 2015, the production of electricity in Finland amounted to 66.2 terawatt hours (TWh). The production went up by 1% from the year before. In turn, total electricity consumption went down by 1% and amounted to 82.5 TWh. Of total electricity consumption, 80% was covered by domestic production and 20% by net imports of electricity from the Nordic countries, Russia and Estonia. Electricity net imports declined 9% from the previous year. 32% of domestic electricity production was based on combined heat and power production.

Of all electricity production, 29.5 TWh were produced with renewable energy sources, which is the biggest amount ever. 45% of electricity production was covered with renewable energy sources, which is the largest share since the 1970s. Over one-half of the electricity produced with renewable energy sources was produced with hydro power, nearly one-tenth with wind power and almost all of the remainder with wood-based fuels. Hydro power was used for producing 16.6 TWh of electricity. More electricity than this has been produced with hydro power only in 2008 and 2012. 17% of electricity was produced with fossil fuels, 4% with peat and 34% with nuclear power (Production of electricity and heat, Statistics Finland).

District heating

The production of district heat totalled 35.0 TWh in 2015. The production went down from the year before. The use of renewable fuels in the production of district heat grew by 5% from the year before. Nearly one-half of district heat was produced with fossil fuels, the use of which fell by 14% from one year ago. Most of district heat was produced with wood fuels and hard coal.

The residential and commercial sectors have substituted direct oil heating with district heating and electricity after the 1990's.

Energy production and use in industry

Manufacturing industries and construction produce much of the energy they use by themselves. The trend in manufacturing industries is increased use of biofuels in the forest industry and outsourcing of power plants from industry to the energy sector.

The production of industrial heat was 51.8 TWh in 2015. The production went down slightly from the year before. Over 70% of heat produced for the needs of industry was based on renewable fuels. The biggest users of industrial heat is the forest industry, which uses its own fuels in production, like black liquor and other wood fuels. In the chemical and metal industries, part of the use of heat is considered as direct fuel use, and is thus not visible in the production figures on heat (Production of electricity and heat, Statistics Finland)

Detailed information on the properties of the different fuels is given in Annex 6[2].

An appendix presenting the shares of each fuel in the fuel combustion subsector will be added to the next submission.

[2] The default NCVs are practically constant over time except for some plant-specific fuels like refinery gases, BFG and certain waste-derived fuels. The operators should report to the VAHTI system both fuel quantities as well as energy contents of the fuels used. Thus in bottom-up data there are some variations in the NCVs. For instance, peat is one of the main fuels in Finland and it is is a domestic energy source. In stationary combustion it is the fourth largest fuel (after wood, hard coal and natural gas), representing typically over 6% of Total primary energy supply (TPES) and over 8% of combustible fuels. Due to local weather conditions in peat production and storage areas in 2012 and again in 2013, the quality of peat has been lower than usually. This can be seen from measured plant level data: in 2013 NCV of milled peat was 6% lower than the default.

Categories 1.A.1 Energy industries and 1.A.2 Manufacturing Industries and Construction

Changes in chapter	
Update of text	March 2017 KS and TF
Change in methodology	For 2015 emissions only
Other (e.g. language, layout)	February 2017 KS

4.1.4 Source category description

1A1a	**Public electricity and heat production**
1A1b	**Petroleum refining**
1A1c	**Manufacture of solid fuels and other energy industries**
1A2a	**Stationary combustion in manufacturing industries and construction: Iron and steel**
1A2b	**Stationary Combustion in manufacturing industries and construction: Non-ferrous metals**
1A2c	**Stationary combustion in manufacturing industries and construction: Chemicals**
1A2d	**Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print**
1A2e	**Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco**
1A2f/1A2gviii	**Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)**

4.1.5 Emission trends

Emission trends for NFRs 1A1 and 1A2 are presented in Figure 4.7.

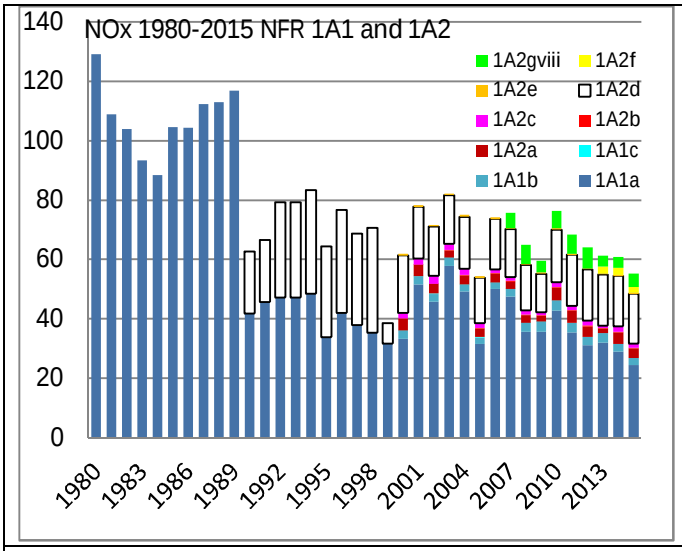
The trends presented in the figures do not fully represent the actual trends because the aggregation of emissions under the NFR codes is not consistent over the years (see the notes below).

For 1980-1999 emissions are reported more or less aggregated as it has not been possible to split data into NFR subcategories. This is due to the fact that emissions have not been recalculated and the data is available at the aggregation level used at the time of reporting each year and not possible to disaggregate back in the time series due to lack of resources for this work.

Since 2000 emissions are presented at more disaggregated level in the NFR tables, however, the same applies as for the earlier years: data has not been recalculated and it has therefore not been possible to disaggregate data into the changed NFR codes.

NOTE:

1. *The recalculation of time series has been under way for more than a decade, however, due to lack of sufficient resources, not yet finalized.*
2. *The inventory is based on both bottom-up and top-down data and reallocation of emissions is therefore quite laborious because data needs to be recalculated and processed at the level of individual processes and boilers. At the moment the data can be aggregated under the energy, industry, product use or waste sectors, depending on the year when the data was originally calculated since the early 1990's.*
3. *During 2017 it is planned to finalize the recalculation of fuel use from 1990 and to report the emissions based on that with the existing methodologies in the submission in 2018. In 2018 emission factors will be checked and possible recalculations will be carried out thereafter.*



	SOx
NMVOC	*NH3*

Figure 4.7. Air pollutant emission trends from NFRs 1A1 and *1A2 (to be completed for the 2018 resubmission)*

4.1.6 Methodological issues

Changes in chapter	
Update of text	March 2017 KS and TF
Change in methodology	For 2015 emissions only
Other (e.g. language, layout)	February 2017 KS

4.1.6.1 Overview of the calculation of emissions

Calculation of emissions in the energy sector is based on country specific methods using detailed information on the applied boiler technologies and abatement techniques, consumption of the different fuels in these boilers as well as boiler specific emission factors. The emission factors are either country or plant specific for all pollutants, except for most of the POP emission factors, which mainly are from international guidebooks. The calculation methods are consistent with the EMEP/EEA Emission Inventory Guidebook.

Note that the emission factors for NFRs 1A1 and 1A2 have not been updated for the last 10 years with certain exceptions (PCDD/F). Note also that the inventories have been carried out independently each year and no recalculations have been carried out. The recalculation of the time

series has been ongoing since 2014 and is scheduled to be finalized for fuel consumption data in 2017 and for emission factors in 2018-2019.

The inventory reporting tool IPTJ[3] currently includes emissions of SO_2, NO_2, CO, NMVOC, particles, heavy metals and POP compounds from fuel combustion for the years 2000-2015. In addition, CO_2, CH_4, N_2O, HCl and HF emission data is available for the energy sector in the IPTJ. Greenhouse gas emissions are used for comparison of emission levels with Statistics Finland, and for research purposes. Recalculation of emissions in the years 1990-1999 has been pending and under way for more than a decade.

The inventory is a combination of emission data reported by the plants according to their monitoring programmes under the environmental permits and default values for emissions calculated using fuel consumption data and emission data reported by the plants at individual boiler level

Both emission and fuel consumption data for installations falling under the scope of Environmental Protection Act are available in VAHTI[4] database.

The Emission Trading Registry data (ETS) on fuel consumption is used as complementary data in the inventory prior to 2015. In the 2015 inventory, it was the primary data source for the first time for fuel consumption for point sources

ETS data for 2015 was completed with fuel consumption data reported to the VAHTI database. During the preparation of the inventory default emission values at boiler level are calculated. These defaults are used in the inventory when no emission data reported by the plants is available. These default values are also used as verification of emission data reported by the plants are available, or when the data is assessed to be erroneous. The default values are also used as verification of emission data reported by the plants.

In the inventories for the years prior to 2015, plant level fuel consumption data from VAHTI is the primary data source for fuel consumption and in the preparation of the inventories it was compared and completed with data from the Emission Trading Registry.

Information compiled from VAHTI database and Emission Trading Registry is completed and cross-checked against fuel data from the energy statistics and comparisons are made with data in CRF tables prepared by Statistics Finland, at the aggregation level allowed for statistical confidentiality, and with data from the EU ETS registry.

VAHTI database includes detailed (boiler/process level) data, which allows calculation of emissions using technology-specific emission factors for non-CO_2 emissions. The information includes boiler/process techniques, abatement techniques, fuel properties and consumption. Pollutant specific emission data is available in VAHTI database depending on the specific reporting requirements given for each plant in their monitoring programmes. Reporting requirements are set mainly for SO_2, NO_x and TSP emissions, in some cases also NMVOCs, ammonia, heavy metals and POPs. The fuel consumption data reported to the Emission Trading Registry is generally not on the level of individual boilers/processes but on a more aggregated level. However, in the energy sectors' emission calculation model all the data are distributed to the detailed boiler/process level used in VAHTI database. The reported data are used as input for IPTJ.

Data used in the calculation of energy sector emissions at SYKE include:

[3] IPTJ, Air Pollutant Emissions Data System at SYKE
[4] VAHTI, database for supervising authorities at Centres for Economic Development, Transport and the Environment (ELY Centres)

1. Detailed bottom-up data for point sources covers approximately 2/3 of the total annual fuel combustion collected from Emission Trading Registry and VAHTI database (Table 4.2)

2. Aggregate transport and off-road vehicle data, which is originally calculated by the detailed calculation model LIPASTO (sectoral sub models LIISA, RAILI, MEERI and TYKO) at the VTT Technical Research Centre of Finland. These cover approximately 1/6 of the total fuel combustion.

3. Aggregate sectoral (sub-sectoral) data for other sources, such as small combustion, partly energy industries, residential and others, covers approximately the rest 1/6 of the total fuel combustion. This data is based on the national Energy Statistics, data in the CRF energy tables[12] by fuels, and on the energy balance difference. Currently, the energy balance difference is allocated under 1.A.2.g.viii. The allocation will be improved in the forthcoming inventories.

The number and distribution of Finnish energy plants in 2015 in VAHTI database is presented in Table 4.2. These point sources cover together two thirds of the total annual fuel combustion. The total number of installations in the VAHTI database is approximately one thousand. These installations include around 2 000 boilers or industrial processes.

Table 4.2. Number of boilers included in the year 2015 inventory in 2017

Category	Number of boilers in 1A1	Number of boilers in 1A2	Number of boilers in 5C1
Combustion plants > 300 MW (boilers)	20	5	
Combustion plants 50 - 300 MW (boilers)	88	54	
Combustion plants 20 - 50 MW (boilers)*	74	98	
Combustion plants < 20 MW (boilers)*	637	289	
Gas turbines	42		
Stationary engines	2	5	
Process ovens	5	155	
Waste incineration boilers**			6
Total	868	606	6

* information on combustion plants <50 MW is provided under Chapter x
** The NFR allocation of waste incineration boilers will be revised during the recalculation of the energy sector emissions

4.1.6.2 Fuel consumption

Changes in chapter	
Update of text	March 2017 KS and TF
Change in methodology	For 2015 emissions only
Other (e.g. language, layout)	February 2017 KS

VAHTI and Emission Trading Registry contain records for 91 fuel types. An overview of the consumption of different fuels in 1990-2015 in NFRs 1A1 and 1A2 is presented in Table 4.3.

Table 4.3. Fuel consumption in NFR 1A1 (a) and 1A2 (b) in 1990-2015 (PJ).

(a) Fuel combustion in NFR 1A1

		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Liquid fuels	Heavy fuel oil	16.0	21.0	17.1	16.7	17.8	16.5	13.7	16.0	17.4	12.2	11.1	6.9	7.4	8.1
	Light fuel oil	0.5	1.1	0.9	0.7	0.6	0.7	0.6	0.4	0.6	0.5	1.1	0.6	0.7	0.7
	Refinery gases	16.1	16.8	15.4	16.3	17.7	19.0	17.4	20.5	18.4	20.3	19.4	18.1	17.1	16.6
	Other liquid fuels	3.9	4.3	4.5	5.1	4.9	5.6	5.5	5.7	5.1	5.4	4.7	5.3	5.3	8.1
Solid fuels	Hard coal	99.2	105.9	88.0	73.2	159.3	137.2	89.4	111.1	139.3	98.8	79.9	110.8	83.8	59.6
	Other solid fuels	2.1	3.2	3.2	3.4	3.5	3.9	3.6	2.6	3.0	3.5	3.5	4.0	4.0	4.0
Gaseous fuels	Natural gas and other gaseous fuels	47.9	68.8	94.4	104.5	112.1	97.1	104.1	94.8	104.6	88.9	80.9	70.1	61.9	50.8
Biomass	Woodfuels	3.1	16.2	34.6	58.5	61.7	53.2	66.7	63.0	81.0	86.5	91.0	93.1	93.3	93.9
	Biogas	NO	0.1	0.1	1.0	0.8	1.0	1.1	0.9	0.4	0.3	0.3	0.3	0.3	0.4
	Other non-fossil fuels	NO	0.39	0.27	3.57	3.22	4.58	5.19	5.66	5.88	5.56	6.42	7.30	8.28	10.14
Peat	Peat	37.8	63.5	50.6	57.0	79.2	87.3	67.6	61.6	82.2	71.1	53.4	46.1	48.5	46.0
Other fuels	Mixed fuels and waste (fossil part)	0.01	0.43	1.43	1.53	1.01	1.38	1.73	2.35	2.22	2.09	3.06	4.14	5.19	5.85

Other liquid fuels includes e.g. petroleum coke, LPG, recycled waste oil and some other oil products.
Other solid fuels includes e.g. coke, coke oven gas and blast furnace gas.

(b) Fuel combustion in NFR 1A2

		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Liquid fuels	Heavy fuel oil	34.2	27.7	22.6	18.4	18.6	17.1	12.9	10.5	11.2	10.6	9.8	8.4	8.2	8.0
	Light fuel oil	17.6	17.1	19.3	19.3	19.4	20.2	20.3	19.0	19.0	18.8	18.5	18.7	17.9	18.0
	LPG	4.5	4.7	8.4	10.0	10.5	9.9	9.7	8.1	9.2	9.1	8.8	8.1	8.5	8.6
	Refinery gases	5.0	5.7	6.6	7.9	6.9	7.2	8.6	8.8	9.0	8.6	7.5	8.9	8.7	9.3
	Recycled waste oil	0.5	0.5	0.9	1.3	1.1	0.8	0.9	0.9	1.2	1.0	0.9	0.6	0.8	0.5
	Other liquid fuels	2.7	2.2	1.7	2.2	2.1	2.2	2.0	1.6	1.6	2.2	2.2	2.5	2.2	2.3
Solid fuels	Hard coal	28.4	16.4	10.3	7.3	5.3	4.9	5.4	4.1	5.4	4.4	3.9	3.4	3.3	2.4
	Coke	5.9	4.9	5.4	5.6	5.2	4.9	4.7	3.9	4.5	4.7	1.0	1.2	1.2	1.1
	Other solid fuels	9.0	11.9	15.2	14.7	15.4	12.8	13.3	9.4	12.5	12.3	11.4	11.5	12.5	11.1
Gaseous fuels	Natural gas and other gaseous fuels	39.9	43.1	39.8	36.4	38.8	42.5	39.8	32.2	35.9	33.8	27.0	29.9	27.0	24.6
Biomass	Woodfuels	42.1	43.9	51.2	39.0	41.6	38.7	38.6	34.4	35.1	35.3	38.1	41.5	41.6	41.0
	Black/sulphite liquor	87.4	111.1	139.8	129.4	156.0	154.1	141.8	110.2	135.7	135.1	135.8	140.7	141.9	142.1
	Biogas	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.8	1.2	1.4	1.4	1.7	1.7
	Other non-fossil fuels	1.3	1.5	2.1	2.2	2.7	2.4	2.7	3.7	3.9	3.6	3.9	4.7	4.8	4.1
Peat	Peat	14.1	14.9	11.4	12.2	14.7	15.6	14.6	11.1	13.0	12.5	10.7	9.4	10.6	9.9
Other fuels	Mixed fuels and waste (fossil part)	1.0	1.1	1.9	2.4	2.5	2.4	2.5	3.0	3.0	2.8	3.9	5.1	5.1	4.5

Other liquid fuels includes e.g. petroleum coke.
Other solid fuels includes e.g. coke oven gas and blast furnace gases.

4.1.7 Calculation proceses of emissions for combustion plants based on fuel use

Changes in chapter	
Update of text	April 2017 KS and TF
Change in methodology	For 2015 emissions only
Other (e.g. language, layout)	February 2017 KS

The process of calculating emissions from combustion plants is presented in Figure 4.8

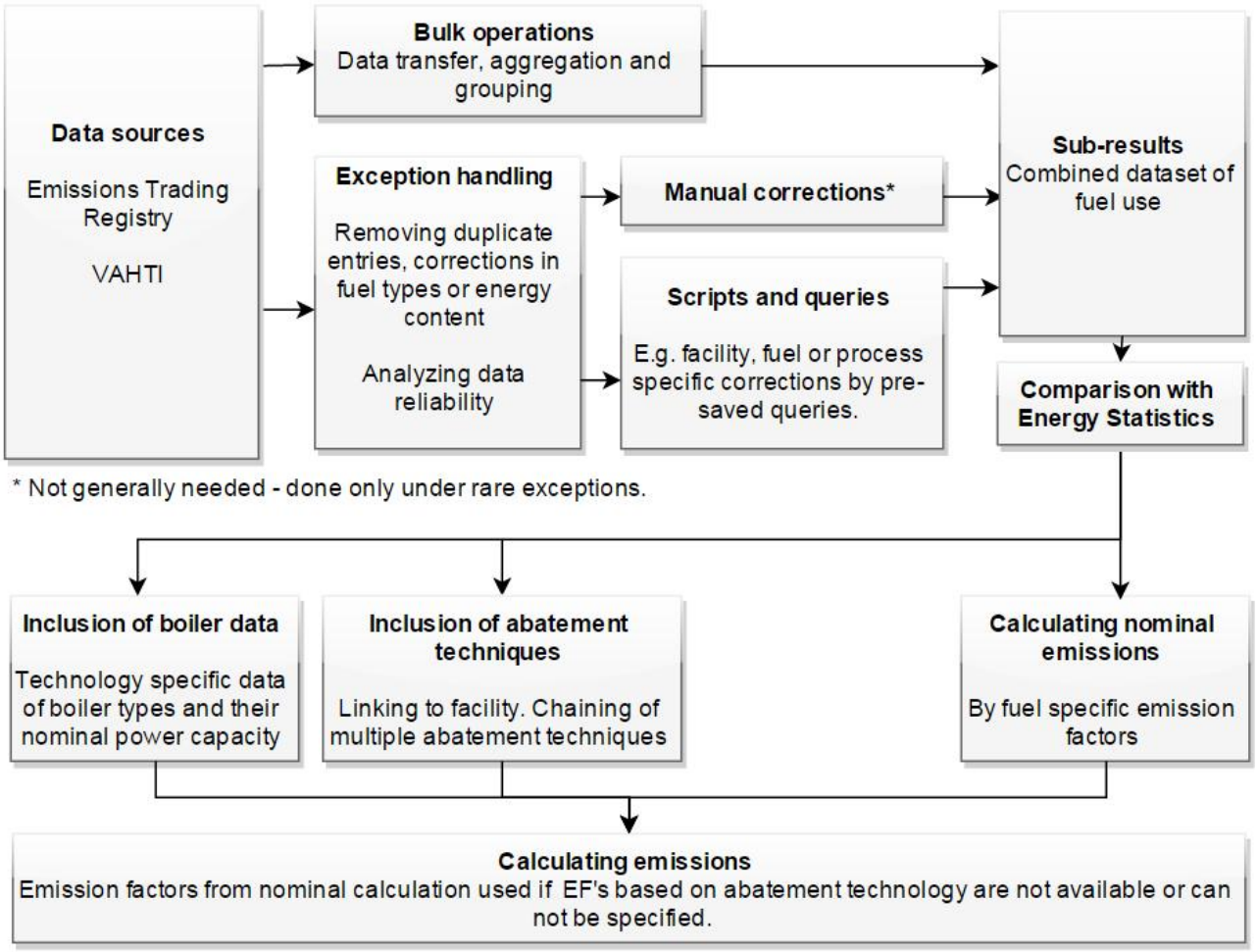


Figure 4.8 - The process of calculating emissions from combustion plants

Phase 1 – Compiling data of fuel use

The calculation based on fuel combustion is a multi-step process consisting of steps and assumptions to estimate the emissions in a greater detail in an energy calculation model for air pollutant emissions, which is separate from the inventory data compilation and reporting data system IPTJ.

The main data sources in the energy sector emissions inventory are VAHTI and Emissions Trading Registry out of which data are compiled into a single dataset. As mentioned in Chapter 4.1.6.1 above, the Emission Trading Registry was the primary data source for the first time for fuel

consumption for point sources in the 2015 inventory. The fuel data in the Emission Trading Registry is generally considered to be more reliable than VAHTI data due to the extensive verification measures that are performed to the reported data. The fuel consumption data reported to the Emission Trading Registry is generally on a more aggregated (plan) level compared to the boiler level data reported to the VAHTI system.

The energy calculation model was updated during the preparation of the 2015 inventory to allow the distribution of the plant level Emission Trading Registry fuel data to the boiler level used in the calculation model.

This data in the fuel dataset is then prepared by removing duplicate rows for accidental multiple entries and by identifying data in rows with large deviation or changes in comparison to the previous years, or errors in the volumetric allocation of the data. E.g. for LPG the volumetric errors precede from the reporting unit being changed from cubic metres to tons (of fuel). Erroneous rows are inspected separately by plant-specific database queries in the energy calculation model. In cases for large emission sources, the uncertain values are separately verified by inquiries to Regional Environmental Centres or in some cases, by contacting the plant separately.

The most common corrections made to the data before using it in the inventory are:

1. Correcting the energy content of the fuel
2. Reassigning reported fuel types (typically from main category of fuels to a specific fuel)
3. Relocating the point data of fuel use to the corresponding boilers
4. Correcting the value of fuel use where two or more boilers within a facility share the exact same value of fuel use
5. Distributing a sum value of plant specific fuel use to the corresponding boilers and removing the original sum value in order to prevent duplication

Corrections numbers 1 to 4 are carried out to correct inaccuracies in the data reported by plant operators. As an example, two or more boilers within a facility sharing the exact same fuel use is usually an indicator of a facility-level fuel use being duplicated to each unique boiler, thus correction number 4 is made after assessing the case in details. Correction number 5 is a detail-increasing operation and carried out when more accurate data of the facility configuration is available but not available in the data systems. This kind of information is usually based on expert knowledge of the plant.

In the case of plant specific data being available in both registers (VAHTI and Emissions Trading Registry), the entries with varying values for any relevant parameter are checked with specified queries which aim to select the values of greater reliability. A recurring error to be corrected is a unit conversion error in powers of ten. Lesser errors are revealed by comparing the calculatory heat of combustion based on the reported fuel data. The value from the data source possessing a more exact match to the calculatory value or a stronger correlation to other reported data is selected as the value for further calculations. In some cases, differing identification properties of the two data sources enable an aggregate value for a facility to be divided into its corresponding combustion units if a plant is known to possess multiple units. Table 4.3 presents the default heat of combustion, density and presumptive sulphur content for fuels.

To analyze fuel data reliability, a comparison is made to fuel data provided by Statistics Finland on CRF (Common Reporting Format) level. If notable differences occur, the sources of the differences are investigated and corrected upon need. The detail-increasing assumptions are based on expert knowledge of operational principles of a specific facility or a process and may take into account such variables as used fuel type and ratio, sulphur content, abatement technology or other boiler specific details. More information on the use of ETS data and inter-comparison with the Finnish greenhouse gas inventory is provided under Chapter 4.2.4.

As an example, the combined dataset for the year 2013 contained records for 2831 rows at the level of “points” (i.e. individual boilers/processes). For each row the dataset covers information for municipality, facility, combustion unit within a facility, sulphur contents and reported energy contents of fuels, calculated energy contents, selected energy contents, heat of combustion and other guiding details such as the data source or recordings for corrections when such are applied.

Table 4.3 The default heat of combustion, density and presumptive sulphur content for fuels

Fuel	Heat of combustion per tons		Heat of combustion per m^3		Density		Default S content
	Value	Unit	Value	Unit	Value	Unit	%
Heavy fuel oil (S<1%)	41.10	GJ/t	40.07	GJ/m3	0.98	t/m3	0.9
Light fuel oil (S=0.0915%)	42.80	GJ/t	36.17	GJ/m3	0.85	t/m3	0.0915
Diesel oil (S=0.001%)	42.80	GJ/t	35.95	GJ/m3	0.84	t/m3	0.001
industrial gasoline	44.30	GJ/t	31.01	GJ/m3	0.70	t/m3	0.005
Aviation fuel	43.30	GJ/t	34.42	GJ/m3	0.80	t/m3	0.04
Coal, bituminous (S=0.8%)	25.00	GJ/t	20.00	GJ/m3	0.80	t/m3	0.8
Coke (S=1.0%)	29.30	GJ/t	21.98	GJ/m3	0.75	t/m3	1
Milled peat	10.10	GJ/t	3.23	GJ/m3	0.32	t/m3	0.1
Sod peat	12.30	GJ/t	4.67	GJ/m3	0.38	t/m3	0.11
Natural gas	49.79	GJ/t	36.00	GJ/1000m3	0.72	kg/m3	0.0001
LPG	46.20	GJ/t	23.42	GJ/m3	0.51	t/m3	0.00002
Blast furnace gas	2.95	GJ/t	3.80	GJ/1000m3	1.29	kg/m3	0.000001
Coke oven gas	34.79	GJ/t	16.70	GJ/1000m3	0.48	kg/m3	0.05
Refinery gas	50.00	GJ/t	35.00	GJ/1000m3	0.70	kg/m3	0.01
Other fossil fuel	46.20	GJ/t	32.34	GJ/1000m3	0.70	kg/m3	0.004
Black liquor	11.50	GJ/t	16.56	GJ/m3	1.42	t/m3	5
Wood residue or chips	9.50	GJ/t	2.38	GJ/im3	0.25	t/im3*	0.008
Sawdust, cutter chips etc.	8.00	GJ/t	1.40	GJ/im3	0.18	t/im3*	0.0075
Board	7.50	GJ/t	2.48	GJ/im3	0.31	t/im3*	0.0165
Non specified industrial wood residues (other wood)	7.50	GJ/t	1.68	GJ/im3	0.21	t/im3*	0.012
Biogas from wastewater treatment	19.40	GJ/t	23.00	GJ/1000m3	1.16	kg/m3	0.01
Smelling gases	5.99	GJ/t	20.00	GJ/1000m3	3.34	kg/m3	15
Other biogas (other non-fossil gas)	19.83	GJ/t	20.00	GJ/1000m3	1.16	kg/m3	0.01
Recycled and waste oil	41.00	GJ/t	39.98	GJ/1000m3	0.98	kg/m3	0.9
Product gas (other gas)	11.68	GJ/t	13.30	GJ/1000m3	1.14	kg/m3	0.003
Wood residue or wood chips	10.00	GJ/t	3.25	GJ/im3	0.33	t/im3*	0.01
Motor gasoline (S=0.001%)	41.70	GJ/t	31.28	GJ/m3	0.75	t/m3	0.001
Other petrols	43.10	GJ/t	34.91	GJ/m3	0.81	t/m3	0.07
Convert gas	2.95	GJ/t	3.80	GJ/1000m3	1.29	kg/m3	0.000001
Wood pellets and brickets (refined wood fuels)	16.00	GJ/t	10.40	GJ/m3	0.62	t/m3	0.008
Landfill gas	11.94	GJ/t	17.00	GJ/1000m3	1.34	kg/m3	0.01
Hydrogen	120.00	GJ/t	10.80	GJ/1000m3	0.09	kg/m3	0.000001
HFO (normal, S>1%)	40.50	GJ/t	39.97	GJ/m3	0.99	t/m3	1.4
Special oils corresponding to HFO	40.20	GJ/t	39.97	GJ/m3	0.99	t/m3	2.7
Other medium heavy oils	42.70	GJ/t	35.01	GJ/m3	0.82	t/m3	0.12
Nafta	42.80	GJ/t	35.95	GJ/m3	0.84	t/m3	0.001
Aviation gasoline	43.70	GJ/t	31.03	GJ/m3	0.71	t/m3	0.002
Motor petrol	43.10	GJ/t	34.91	GJ/m3	0.81	t/m3	0.07
Kerosene	43.10	GJ/t	34.91	GJ/m3	0.81	t/m3	0.02

Town gas	14.66	GJ/t	16.90	GJ/1000m3	1.15	kg/m3	0.00001
Industrial biogas	27.32	GJ/t	20.00	GJ/1000m3	0.97	kg/m3	0.01
Refined recycled or waste oil	41.00	GJ/t	39.98	GJ/m3	0.98	t/m3	0.9
Oil products	42.12	GJ/t	35.28	GJ/m3	0.84	t/m3	0.21

Phase 2 – Calculating nominal emissions

The calculation of nominal emissions follows the equation:

$$E_{pollutant} = AR * EF_{fuel}$$

Where
E = Emissions of a pollutant
AR = Activity rate (e.g. energy value by fuel combustion)
EFfuel = Fuel specific emission factor

Energy value from fuel combustion to be used as the activity rate (AR) is derived by the following equation (point sources only):

AR= ΔHc * Fb

Where ΔHc = Heat of combustion [GJ/t]
Fb = Fuel consumption (boiler or facility) [t]

Nominal emissions are calculated for all points from fuel consumption with fuel specific emission factors. This gives an estimation of emissions without the effect of abatement techniques or technology specific details. The figure will be used as the default value of emissions per boiler. For boilers with applicable information of boiler and abatement technologies, the emission value is recalculated in phases 3-4 taking this information into account.

Phase 3 – Inclusion of boiler data

Boiler details are extracted from VAHTI and completed with expert knowledge of the plants. Technology specific emission factors are currently available for the following technologies with the listed classifications of capacities:

- grate 50-500 MW
- grate and combined 1-5 MW, 15-50 MW, 5-10 MW, 5-15 MW, 50 MW, 500 MW, 15-50 MW, 5-50 MW
- grate >500 MW,
- grate etc 1-15 MW, 1-50 MW, 15-150 MW, 50-150 MW, 50-300 MW, >300 MW
- grate combined and burner etc. 1-5 MW, 1-50 MW, 5-50 MW, 1 MW, >50 MW
- grate, combined >i 1 MW
- asphalt station
- BFB 15-50 MW, 5-15 MW, 5-50 MW, > 1 MW
- CFB 15-50 MW, 5-15 MW, 5-50 MW
- CFB > 1 MW
- diesel motor (working machines), all,< 50 MW, > 50 MW
- diesel power plant, all, < 50 MW, > 50 MW
- waste combustion boiler, all, 50-150 MW, 15-300 MW
- GT (and combined) < 5 MW, < 50 MW, < 500 MW, > 5 MW, > 50 MW, > 500 MW
- gasification 50-500 MW, 5-50 MW, > 50 MW, > 500 MW

- gasification, burner etc. 1-15 MW, 1-50 MW, 15-150 MW, 50-150 MW
- Boilers 0,2-1 MW, 10-15 MW, 1-15 MW, 1-5 MW,1-50 MW,150-500 MW,15-150 MW,15-50 MW, 50-150 MW, 50-300 MW, 50-500 MW, 5-10 MW, 5-15 MW, 5-50 MW, < 0,2 MW, < 1 MW
- Boilers and processes
- Boilers and processes
- residential buildings
- coking plant
- fluidized bed 50-500 MW, > 500 MW
- fluidized bed 1-15 MW, 1-50 MW, 15-150 MW, 50-150 MW
- fluidization, 150-200 MW, 200-300 MW, 300-400 MW, <150 MW
- fluidization and gasification 1-5 MW, 5-50 MW, > 50 MW, > 400 MW
- fluidization etc 1-5 MW,. 5-10 MW
- blast furnace
- recovery boiler
- other and unknown combustion
- other combustion 150-200 MW, 200-300 MW, 300-400 MW, < 150 MW, > 400 MW
- other ovens ym.
- pulverized fuel firing (corner) 50-500 MW
- pulverized fuel firing (corner) > 500 MW
- otto motor (working machines)
- otto motor power plant
- burner 15-50 MW, 50-300 MW, 50-500 MW, 5-15 MW, > 1 MW, > 300 MW, > 500 MW
- clinical waste incineration oven, all,1-50 MW
- pulverized fuel firing (wall) 50-500 MW, > 500 MW
- cement and lime
- sintering
- recovery boiler
- recovery boiler 50-150 MW, 50-300 MW, < 50 MW, > 150 MW, > 300 MW
- melting furnace
- unknown and other combustion
- furnaces.
- combined 50-500 MW, > 500 MW

Phase 4 – Inclusion of abatement techniques

VAHTI contains information of the following abatement techniques in use with combustion plants. For approximately a hundred boilers, the abatement technology is added retrospectively based on expert review. The efficiency of the abatement technique is used in determination of the emission factor for the boiler:

- abatement of air emissions
- scrubber
- ESP
- fiber filter
- cyclone
- multicyclone
- LOW-NOx burners
- feeding of upper air
- other staging of combustion air
- recycling of flue gases
- staging of fuel
- SCR
- SNCR
- wet method
- semi-dry method
- absorbent feed
- adsorber
- incineration
- condensor
- abatement of particles
- abatement of NOx emissions
- abatement of SOx emissions
- abatement of VOC emissions

The use of abatement techniques are not exclusive of each other. A facility can have multiple solutions in use. Therefore all points are checked for all techniques and further grouped into five categories based on their abatement capability. A corresponding emission factor is given for each combination of combustion technology, abatement capability classification and fuel. A compilation of these emission factors is annexed to this document as Attachment X .

Emission factors

Changes in chapter	
Update of text	March 2017 KS and TF
Change in methodology	For 2015 emissions only
Other (e.g. language, layout)	February 2017 KS

In general, the calculation of emissions follow the equation:

$E_{pollutant} = AR * EF_{technology,fuel}$ _(technology,fuel)

Where
E = Emissions of a pollutant
AR = Activity rate (e.g. energy value by fuel combustion)
$EF_{technology,\ fuel}$ = Technology and fuel specific emission factor

The technology specific emission factors are implied emission factors based on technological information in varying levels of detail. The emission factors are defined by boiler type, fuel, abatement technique or a configuration of multiple abatement techniques. Currently this creates a space of approximately 15 000 emission factors, with the possibility to reduce the actual amount to approximately 2500 EF's by listing only the existing combinations of abatement techniques and boiler details, and grouping the EF's accordingly. Updating the emission factors is problematic due to the cross-linking of data tables for boilers, abatement techniques and default emission factors. The list of implied emission factors are provided in Annex 2 of Part 2 of the IIR as well as the national general emission factors that are given as default factors to facilities reporting to E-PRTR when they do not use measured data (Annex 3 of Part 2 of the IIR).

4.1.8 Comparison of default values with reported data

The fuel consumption based calculatory emission values are compared to the facility-reported emission values from VAHTI. Calculatory and reported emission data is collected into a single table. If a point source does not contain reported VAHTI data for emissions, calculatory values are used. VAHTI emissions are distributed between fuels in the same ratio as with the calculatory values. The emissions are divided between process- and combustion-based emissions with the following hierarchical rule set:

1 Rows with reported VAHTI values are considered to result from combustion.
2 Rows with reported value being greater than the calculatory value, calculatory value is directed to result from combustion.
3 Rows with no calculatory value, reported values are directed to processes
4 Rows with reported value being greater than the calculatory value, the remainder of reported value minus calculatory value is directed to processes

The previous is done for all other reported compounds except particulate matter and black carbon which are calculated separately. Process based emissions of PM10 and PM2.5 are calculated based on the TSP values using the emission factors as presented in Table X.

4.1.9 Notes

Information on small and medium sized energy production units (1-MW) from a project in 2014 (this information is not yet fully incorporated into the inventory).

The number of medium sized 1-50 MW energy production units was 2349 in 2014 (ISPA, 2014), excluding energy production units in greenhouses and such 15-50 MW units which fall under IED (2010/75/EU) due to the common stack rule. Information is available from 262 municipalities covering 97.3% of population. For 10-20% of the energy production units, information is not available but these are included in the inventory through the national energy balance.

Fuel consumption information is available also for 373 energy production units of 1-5 MWs.

The shares of different sizes of energy production units of small and medium sized energy production units (1-50 MW) is presented in Figure 4.9 and the shares according to size and hours of operation in Table x.

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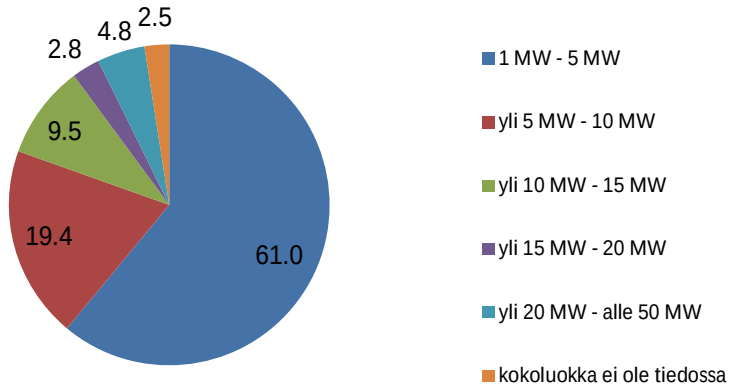


Figure 4.9. Number of small and medium sized energy production units by MWs

Table 4.4. Small and medium sized energy production units by sizes and operation hours

	1 MW - 5 MW		5 MW - 20 MW		20 MW - MW		size not known		Total	
hours of operation in 2014	Number	%	Number	%	Number	%	Number	%	Number	%
< 500	615	43	238	32	25	22	8	14	886	38
500 - 1500	252	18	228	31	34	30		0	514	22
1500 - 4000	168	12	109	15	16	14	1	2	294	13
> 4000	299	21	149	20	35	31	1	2	484	21
unknown	100	7	20	3	2	2	49	83	171	7
Total	1434	100	744	100	112	100	59	100	2349	100

In 2014 there were 197 energy production units of 1-5 MWs in greenhouses, out of which one third uses wood or other biomass and one third HFO, while the rest use LPG, peat or NG, two use HFO. There were also 6 energy production units in greenhouses of 5-10 MWs, half of which use NG and half coal.

Some notes related to boilers < 5 MW

Uncertainty of particle emissions from part of the small and medium sized boilers is affected by the fact that VAHTI does not include information on abatement techniques for all these boilers. Emissions from those heavy oil fired boilers over 1 MW, for which there is no information available

on the applied abatement technique, are assumed to be equipped with electrostatic filters. Correspondingly, solid fuel boilers over 5 MW are assumed to be equipped with cyclones. Other boilers with no information available on the applied abatement technique are calculated as unabated, which may overestimate these emissions.

Boilers under the capacity of 2 MW boiler are not included in the inventory database.

Note on Emission factors

Due to the wide use of bottom-up data in the inventory, it is not possible to present emission factors at a level that would enable reproduction of the energy sector inventory, as these emission factors are technology specific at many levels of detail, for approximately 250 categories of boilers and processes. Therefore the IIR annually provides the implied emission factors in Annex 2 as well as the national general emission factors that are given as default factors to facilities reporting to E-PRTR when they do not use measured data (Annex 3 Part 2 of the IIR).

4.1.10 Calculation of emissions

Changes in chapter	
Update of text	March 2017 KS, TF
Other (e.g. language, layout)	February 2017 KS
NOTE:	

SO_2 and NO_x emissions

SO_2 and NO_x emission data in the inventory are mainly reported by the plants and recorded in VAHTI. The emissions are allocated to fuel based emissions (NFR 1) by each fuel and to non-fuel-based (process) emissions (NFR 2). In cases where no emission data is available in VAHTI but fuel data is known (e.g. from the Emission Trading Register), calculated default data is used.

Particle emissions

Emission data on total suspended particles is mainly reported by the plants and recorded in VAHTI. The emissions are allocated to fuel based emissions (NFR 1) by each fuel and to non-fuel-based (process) emissions (NFR 2). In cases where no emission data is available in VAHTI but fuel data is known (e.g. from the Emissions Trading Register), default values are calculated with country specific methods using detailed technology based emission factors for each boiler or process type. The particle size distributions to PM_{10} and $PM_{2,5}$ are calculated with national factors (Karvosenoja, 2006).

Uncertainty of particle emissions from part of the small and medium sized boilers is affected by the fact that VAHTI does not include information on abatement techniques for all these boilers. Emissions from those heavy oil fired boilers over 1 MW, for which there is no information available on the applied abatement technique, are assumed to be equipped with electrostatic filters. Correspondingly, solid fuel boilers over 5 MW are assumed to be equipped with cyclones. Other boilers with no information available on the applied abatement technique are calculated as unabated, which may overestimate these emissions.

Black carbon

Average emission factors used in the preliminary inventory are presented in Table 4.4.

Table 4.4. Average emission factors in the Finnish BC inventory

Source	SNAP	EF	Unit	Reference
Boilers (solid)	010000-030000	3.3	% of PM2.5	GB13 ,EMEP/EEA
Boiler (liquid)	010000-030000	72	% of PM2.5	Aasestad, 2013
Stationary engines (gas)	010000-030000	2.5-7	% of PM2.5	GB13, EMEP/EEA Aasestad ,2013
Stationary engines (Liquid)	010000-030000	33.5-78	% of PM2.5	GB13, EMEP/EEA
Gas turbines (gas)	010000-030000	2.5	% of PM2.5	GB13, EMEP/EEA
Gas turbines 20-200 MW (liquid fuel)	010000-030000	33.5	% of PM2.5	GB13, EMEP/EEA
Grate furnace (liquid)	010000-030000	33.5, 81	% of PM2.5	Aasestad,2013 GB13 EMEP/EEA
Grate furnace (solid)	010000-030000	3.3	% of PM2.5	GB13, EMEP/EEA
Fluidized bed (LFO	010000-030000	33.5	% of PM2.5	GB13, EMEP/EEA
Other (liquid)	010000-030000	33.5	% of PM2.5	GB13, EMEP/EEA
Other (solid)	010000-030000	2.2, 5.6	% of PM2.5	GB13, EMEP/EEA
Other (gas)	010000-030000	2.5	% of PM2.5	GB13, EMEP/EEA
Coke oven	040201	0.05	% of PM2.5	GB13, EMEP/EEA
BOF	040206	0.36	% of PM2.5	GB13, EMEP/EEA
Electric furnace steel plant	040207	0.36	% of PM2.5	GB13, EMEP/EEA
Rolling mills	040208	0.36	% of PM2.5	GB13, EMEP/EEA
Sinter and pelletizing plant	040209	0.17	% of PM2.5	GB13, EMEP/EEA
Other (foundries)	040210	0.36	% of PM2.5	GB13, EMEP/EEA
Ferro alloys	040302	10	% of PM2.5	GB13, EMEP/EEA
Other (copper production)	040309a	0.1	% of PM2.5	GB13, EMEP/EEA
Sulphuric acid	040401	1.8	% of PM2.5	GB13, EMEP/EEA
NPK fertilizers	040407	1.8	% of PM2.5	GB13, EMEP/EEA
Titanium Oxide	040410	1.8	% of PM2.5	GB13, EMEP/EEA
Other (paper coatings)	040416	1.8	% of PM2.5	GB13, EMEP/EEA
Ethylene	040501	1.8	% of PM2.5	GB13, EMEP/EEA
Other (cleaning agents)	040527	1.8	% of PM2.5	GB13, EMEP/EEA
Paper pulp (kraft process)	040602	2.6	% of PM2.5	GB13, EMEP/EEA
Road paving with asphalt	040611	5.7	% of PM2.5	GB13, EMEP/EEA
Glass (decarbonizing)	040613	0.062	% of PM2.5	GB13, EMEP/EEA
Lime (decarbonizing)	040614	0.46	% of PM2.5	GB13, EMEP/EEA
Mineral wool enduction	060402	0.06	% of PM2.5	Aasestad, 2013
Fat, edible and non edible oil extraction	060404			
Other (tobacco)	060602	0.45	% of PM2.5	GB13, EMEP/EEA
Other (house fires)	060508	9	% of PM2.5	Aasestad, 2013
Tyre wear	070700	30	% of PM2.5	Aasestad, 2013
Brake wear	070700	1	% of TSP	Aasestad, 2013
Road surface wear	070700	0.83	% of TSP	Aasestad, 2013
Crematoria	090901	50	% of PM2.5	Aasestad, 2013
Field burning of agricultural waste	100300	13	% of PM2.5	Aasestad, 2013

NMVOC and CO emissions

NMVOC emission factors were revised in September 2006. During this study, the earlier low emission rates were confirmed. The revised NMVOC emission factors are constructed based on information from measurements of volatile organic compounds from the boilers (see Annexes 2 and 3). The emission calculation for CO and NMVOC is mainly based on emission factors and annual

fuel consumption data (available in VAHTI and in Emission Trading Registry). Only in few cases measured emissions values are available.

Heavy metal emissions

Heavy metal emissions are partly based on data reported by the plants and partly on data calculated in the energy calculation model. The emission factors are domestic (Melanen, 1999, Hupa, 1988, Pohjola, 1983).

Uncertainty of heavy metal emissions from part of the small and medium sized boilers is affected by the fact that VAHTI does not include information on abatement techniques for all these boilers. Emissions from those heavy oil fired boilers over 1 MW, for which there is no information available on the applied abatement technique, are assumed to be equipped with electrostatic filters. Correspondingly, solid fuel boilers over 5 MW are assumed to be equipped with cyclones. Other boilers with no information available on the applied abatement technique are calculated as unabated, which may overestimate these emissions. Measured heavy metal emissions from Vahti have not been checked as the other emission values.

PCDD/F emissions

PCDD/F emissions are calculated using fuel data and emission factors from the UNEP (UNEP, 1999) except for wood combustion for which the emission factors are taken from the USEPA database (USEPA, 1997) and peat, for which the emission factors are domestic (Ruuskanen, 2000).

PAH-4 emissions

PAH-4 emission factors for peat combustion are domestic (KTM, 1988). For the other fuels, emissions are calculated using emission factors from the EMEP/EEA Emission Inventory Guidebook (EEA, 2002), except for oil combustion, where the emission factors are taken from the UBA (UBA, 1998).

HCB emissions

HCB emissions are calculated using fuel data from wood and coal combustion and an international emission factor of 0.01 mg/t (Joas, A, 2006). The method is simplified, i.e. the calculation does not take fuel specific information nor detailed boiler and abatement technique information into consideration.

PCP emissions

PCP emissions from combustion of wood and bark are calculated with the emission factor 0.0219 µg/MJ according to the US EPA (AP-42). The calculation method is simplified and no detailed information on the applied boiler and abatement techniques is taken into consideration, neither does the emission factor depend on fuels used.

4.1.11 Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Uncertainty in fuel combustion (NFR 1.A) in total was ±1% in Finland in 2015.

Errors corrected to the inventory in data reported by the plants are presented in Annex 2.

The EU ETS started from 2005, the second period from 2008 and the third period from 2013. This has provided more reliable data on both activity data and properties of fuels. ETS was the primary data source for the fuel consumption in the 2015 inventory. These new data have been taken into account in the revised uncertainty estimation.

IPTJ includes currently emission data for the years 2000 – 2015 only. The recalculation of emissions in the earlier years will be carried out in the next years.

4.1.12 Source-specific QA/QC and verification

Quality checks

Normal statistical quality checks related to assessment of the magnitude and trends have been carried out. The data obtained from VAHTI and Emission Trading Registry is cross-checked against the summary data (by fuels and by CRF categories) reported to the UNFCCC as explained in Chapter 2.3.4.

Corrections made to 2015 VAHTI data are listed in Annex 4 of Part 2 of the IIR.

Use of ETS data

The ETS data on fuel consumption was previously used as complementary data in the inventory. In the 2015 inventory, it was the primary data source for the first time for fuel consumption for point sources. NCVs and fuel consumption data from the ETS plants are compared with the corresponding data in the air pollutant inventory. If there are significant differences, corrections are carried out to the inventory data. Generally, for the most common fuels, the differences in aggregated NCVs and EFs are less than +-1%. For different types of wood fuels the differences in NCVs can be somewhat larger (generally +-2-10%), due to difficulties of plant operators in disaggregating different types of wood residues to the fuel code system, but also due to variations in the moisture content of wood fuels. The difference in total amount of wood fuels in TJs was 0.6% in 2015.

Inter-comparison with greenhouse gas inventory data

The cross-checking with fuel and greenhouse gas emission data calculated by Statistics Finland is used as verification for the inventory. The calculation systems are separate but use mostly the same basic data sources for calculation of emissions from fuel combustion. These independent calculation systems are used as a verification tool for the energy sector inventories, and moreover, as source of additional corrections. Comparisons between the data in these two calculations systems are performed continuously during the inventory preparation. The annual calculation of air pollutant emissions at SYKE is performed a bit later than the GHG inventory at Statistics Finland and thus the source data set usually includes more updated data than one used in the preliminary EU GHG inventory at Statistics Finland. The thorough comparison between the air pollutant and GHG inventories in accordance with the EU Regulation 525/2013 is performed after 15 February and the differences are corrected to both inventories and reported according to both air pollutant and GHG reporting obligations.

4.1.13 Source-specific recalculations including changes made in response to the review process

None.

4.1.14 Source-specific planned improvements

The time series recalculation for fuel consumption data is scheduled to be finalized in 2017 and for emission factors in 2018-2019.

The availability and suitability of information from national district heating statistics to the inventory is studied in the next years when resources become available for the work.
The recalculation of time series has been under way for more than a decade. Due to lack of resources, the emissions of each inventory year have been estimated independently from the earlier years' estimates. Corrections to earlier years' data have only been made occasionally. Changes made over the years in the calculation of energy sector emissions have not been recalculated into the earlier years. The allocation of emissions under the different reporting codes has varied over the years depending on available information, data and reporting codes used in the time of reporting (SNAP, NFR 02, 04, 09, 14). Harmonization of the allocation of data has not been possible due to the use of plant level data in combination of calculated emissions in the energy and IPPU sectors before a revised calculation of the whole time series with the same methodology.

The allocation of the energy balance difference will be improved in the forthcoming inventories. Work has been carried out in 2016 to harmonize the splitting between energy and process based emissions (in cases where the emissions reported by the plants consist of both energy and process originated emissions together) by coding process level data into activity-pollutant relevant combinations.

During 2017 we hope to finalize the recalculation of fuel use in the time series 1990-2015. Revised estimates will be reported in the 2018 submission.

In 2018 it is planned to review the currently used emission factors.

Descriptions highlighting the domestic features of the industry will be improved in the future submissions. Forest industry is an example of the industries that produce a significant share of the energy they require.

Transport and Off-road mobile sources

Changes in chapter	
Update of text	February 2017 KS and TF
Other (e.g. language, layout)	February 2017 KS
Change in methodology	Yes
Notes	

4.1.15 Overview of the sector - Aviation, road transport, railroads and navigation

4.1.15.1 Source category description

Source categories and pollutants included in the transport sector inventory are presented in Table 4.5

Table 4.5. Emissions reported under the transport and off-road mobile sectors

NFR	Source	Description	Emissions
1A2gvii	Mobile Combustion in manufacturing industries and construction	Mobile machinery in manufacturing industries and construction. For details see Table in Section 4.3.2.3.	NO_X, NMVOC, SO_X, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, CO, Cd, Cr, Cu, Ni, Zn, PAH-4
1A3a	Aviation	Jet and turboprop powered aircraft (turbine engined fleet) and piston engined aircraft , domestic flights only	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO
1A3bi-iv	Road transport: passenger cars, light and heavy duty vehicles, mopeds, motorcycles and motorised quadricycles	Transportation on roads by vehicles with combustion engines: cars, vans, buses, coaches, lorries, articulated vehicles, motorcycles, mopeds and motorised quadricycles	NO_X, NMVOC, SO_X, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, PAH-4, HCB, PCB
1A3bv	Road transport: Gasoline evaporation	Gasoline evaporation from automobiles	NMVOC
1A3bvi	Automobile tyre and brake wear	PM and heavy metal emissions from automobile tyre and brake wear	TSP, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn
1A3bvii	Automobile road abrasion	PM emissions from road abrasion	TSP, PM_{10}, $PM_{2.5}$, BC
1A3c	Railways	Railway transport operated by diesel locomotives	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, BC, CO, Cd, Cr, Cu, Ni, Se, Zn, PAH-4
1A3dii	National Navigation (Shipping)	Sea-going ships (between domestic ports), icebreakers, working boats, cruisers, ferryboats and leisure boats.	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, HCB, PCB
1A4aii	Commercial and institutional (mobile)	Mobile machinery. For details see Table in Section 4.3.2.3.	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, BC, CO, Cd, Cr, Cu, Ni, Se, Zn, PAH-4
1A4bii	Residential: Household and gardening (mobile)	Mobile machinery. For details see Table in Section 4.3.2.3.	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, BC, CO, Cd, Cr, Cu, Ni, Se, Zn, PAH-4
1A4cii	Agriculture, forestry and fishing: Off-road vehicles and other machinery	Mobile machinery. For details see Table in Section 4.3.2.3.	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, BC, CO, Se, Cd, Cr, Cu, Ni, Se, Zn, PAH-4
1A4ciii	Agriculture, forestry and fishing: National fishing	Fishing boats	NO_X, NMVOC, SO_X, NH_3,TSP, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, HCB, PCB
1A5a/1A5b	Other Mobile (including military)	Military mobile sources are included in these categories together with some stationary sources	NO_X, NMVOC, SO_X,TSP, PM_{10}, $PM_{2.5}$, BC, CO

4.1.15.2 Calculation of emissions

Emissions for the road transport, navigation, railways and off-road machinery are calculated by the detailed LIPASTO calculation system (http://virtual.vtt.fi/virtual/lipasto/yksikkopaastot/henkiloliikennee/ilmaliikennee/maaritysperusteet_ilmae.htm) maintained and developed by the VTT Technical Research Centre of Finland. Emissions are calculated based on both fuels sold and fuels used as shown in Annex 5.

Ammonia, POP and heavy metal emissions as well as small particle emissions from road transport, road abrasion, tyre and brake wear, railways, navigation and off-road machinery are calculated at the Finnish Environment Institute.

Aviation emissions are calculated on the basis of Eurocontrol data and national statistics in a model maintained by Statistics Finland and shared with Finnish Environment Institute to include air pollutant emissions.

4.1.15.3 Trends and national characteristics

Emissions from the transport sector are affected by special national circumstances such as long distances, transport-intensive industries and travel to and from free-time residences. In addition, winter time conditions require use of studded tires, which also have an impact on road transport emissions.

The trends in transport sector emissions are decreasing though the energy consumption is increasing. In the off-road machinery sector, the emissions as well as the volume of off-road machinery have increased.

The graphs in Figure 4.9 illustrate the trends of sulphur dioxide, nitrogen dioxide, particulate matter, lead and hydrocarbon emissions from the road, railway, waterborne and air traffic sectors as well as energy consumption in 1980 – 2030.

Terms in the table: Ilmaliikenne (air traffic), vesiliikenne (waterborne traffic), raitioliikenne (railway traffic), tieliikenne (road traffic)

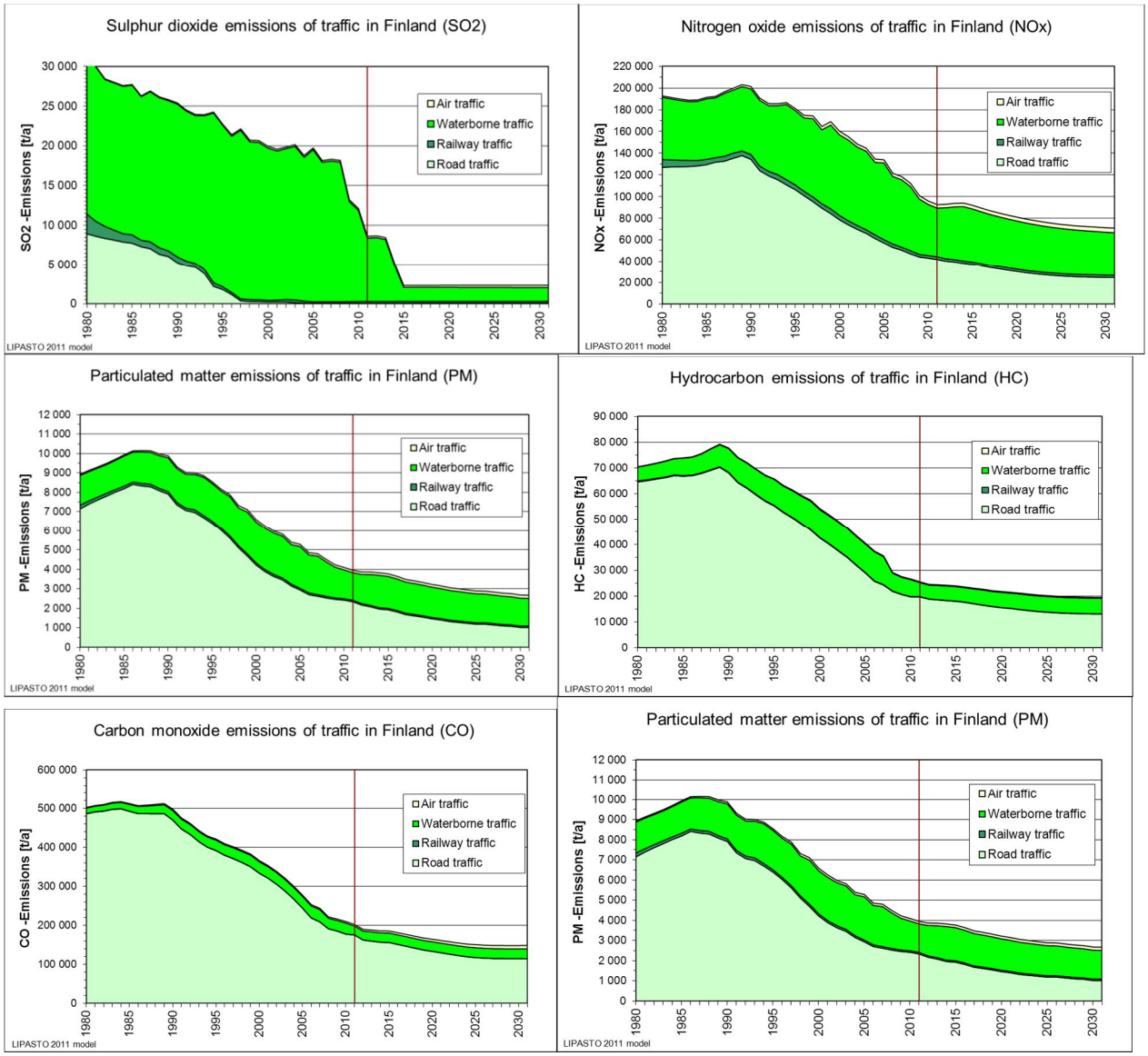
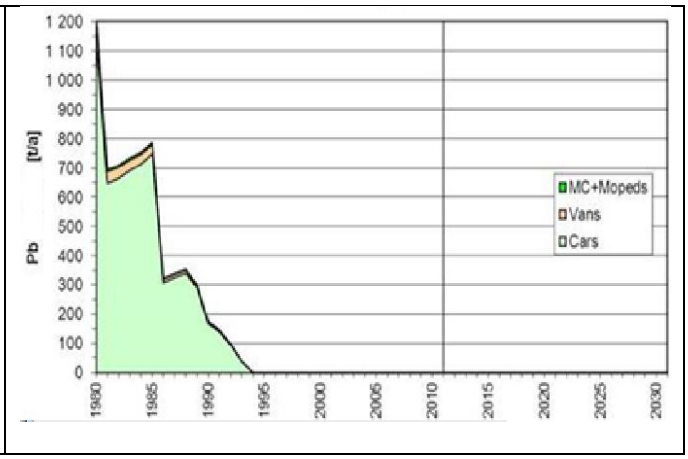


Figure 4.9a. Trends of emissions in the traffic sector. These six graphs plus the seventh in Figure 4.9b indicate the general trend of emissions in 1980 – 2030 in the transport sector but are based on a different allocation of emissions than in the report to the UNECE CLRTAP (e.g. include international traffic and electric trains). Source: LIPASTO calculation model website at http://lipasto.vtt.fi/indexe.htm. Note: HC = CH_4 + NMVOC.

Figure 4.9b. Lead emissions from lead in the fuel since 1980.



4.1.15.4 Fuel use

An overview of transport sector energy consumption is presented in Table 4.6.

Table 4.6 (a-c) Energy consumption in transport sector: (a) Energy consumption (PJ) in the transport sector in 1990-2015 and (b) The allocation of diesel oil, heating gasoil and non-road gasoil; numbers include bio-shares (PJ), and (c) Amount of bio-components of liquid fuels

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Civil aviation														
Aviation gasoline	0.11	0.08	0.08	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Jet kerosene	5.15	3.51	5.11	4.17	3.87	3.62	3.54	3.25	3.14	3.52	2.94	2.53	2.53	2.51
Road transportation														
Gasoline	80.7	76.7	71.3	75.0	74.3	74.2	66.4	64.1	62.7	59.3	56.9	57.9	55.8	55.5
Diesel oil	66.9	62.1	76.5	86.2	88.9	94.3	94.6	89.6	97.0	98.0	97.1	96.8	84.4	85.8
Natural gas	NO	NO	0.05	0.11	0.15	0.16	0.17	0.21	0.20	0.16	0.16	0.11	0.10	0.07
Liquid biofuels	NO	NO	NO	NO	0.03	0.08	2.95	5.43	5.76	8.16	8.04	9.27	20.68	20.71
Gaseous biofuels	NO	NO	NO	0.0001	0.0001	0.0002	0.0003	0.001	0.002	0.006	0.015	0.039	0.061	0.083
Railways														
Gasoil	2.58	2.61	2.17	1.73	1.76	1.48	1.57	1.25	1.30	1.34	1.29	1.26	1.15	0.93
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	0.012	0.021	0.025	0.009	NO	NO	NO
Navigation														
Residual oil	1.56	1.79	2.23	1.74	1.84	1.96	1.61	1.70	1.74	1.85	1.64	1.23	0.64	0.45
Gasoil	2.52	2.44	2.82	3.09	3.37	3.41	2.58	2.66	3.19	3.19	2.99	3.26	3.20	3.49
Gasoline	1.80	1.88	1.94	1.92	1.99	2.00	1.56	1.54	1.62	1.22	1.25	1.39	1.34	1.40
Diesel oil	NO	NO	NO	NO	NO	NO	0.41	0.47	0.52	0.46	0.52	0.51	0.36	0.35
Liquid biofuels	NO	NO	NO	NO	NO	NO	0.06	0.11	0.15	0.16	0.13	0.10	0.14	0.14
Other transportation														
Natural gas	0.04	0.45	0.65	0.75	0.71	0.49	0.35	0.39	0.53	0.29	0.31	0.24	0.23	0.07

PJ (including bio-shares)		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Road transportation	Diesel oil	66.9	62.1	76.5	86.2	88.9	94.3	95.1	92.0	99.6	102.5	101.4	103.3	102.3	103.8
Leisure boats		0.45	0.46	0.48	0.47	0.48	0.48	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.4
Domestic navigation	Non-road gasoil	4.45	4.11	4.24	4.20	4.57	4.56	4.15	4.25	4.77	4.76	4.53	4.86	4.71	4.90
Railway transport		2.58	2.61	2.17	1.73	1.76	1.48	1.57	1.26	1.32	1.37	1.30	1.26	1.15	0.93
Off-road vehicles and other machinery		29.39	28.33	30.36	30.82	30.80	31.48	31.78	30.13	30.28	30.09	30.37	30.07	29.40	29.18
Energy production, heating, industry	Light fuel oil (=heating gasoil)	68.89	63.17	59.26	53.30	50.56	48.71	41.75	39.83	44.34	37.38	40.24	35.53	34.33	33.09
Total gasoil + diesel oil		172.6	160.8	173.0	176.7	177.1	181.0	174.7	168.0	180.9	176.6	178.4	175.6	172.3	172.3

	Gasoline	Diesel oil	Non-road gasoil	Heating gasoil	Biogas	Avoided fossil CO_2, kt
2002	33	NO	NO	NO	0.0	2
2003	176	NO	NO	NO	0.1	13
2004	186	NO	NO	NO	0.1	14
2005	NO	NO	NO	NO	0.1	0
2006	34	NO	NO	NO	0.1	3
2007	71	5	NO	NO	0.2	6
2008	2 704	437	NO	NO	0.3	229
2009	3 209	2 460	415	546	1	486
2010	3 401	2 614	929	715	2	562
2011	3 881	4 583	655	665	6	718
2012	4 034	4 334	245	248	15	650
2013	2 977	6 563	NO	NO	39	702
2014	3 108	17 889	NO	NO	61	1547
2015	2 926	18 075	NO	NO	83	1548

4.1.16 Aviation

Changes in chapter	
Update of emission figures	January 2017 KS
Update of text	January 2017 KS
Other (e.g. language, layout)	January 2017 KS

1 A 3 a i (i) International aviation (LTO)
1 A 3 a ii (i) Civil aviation (Domestic, LTO)

4.1.16.1 Emission trend

The emission trend of NOx, NMVOC, SOx, CO and particle emissions is presented in Figure 4.10. Emissions from civil aviation include all domestic civil aviation: jet and turboprop powered aircraft (turbine-engined fleet in air transport) and piston engined aircraft (mostly general aviation)[5]. International LTO and Cruise emissions include all aircrafts in international aviation.

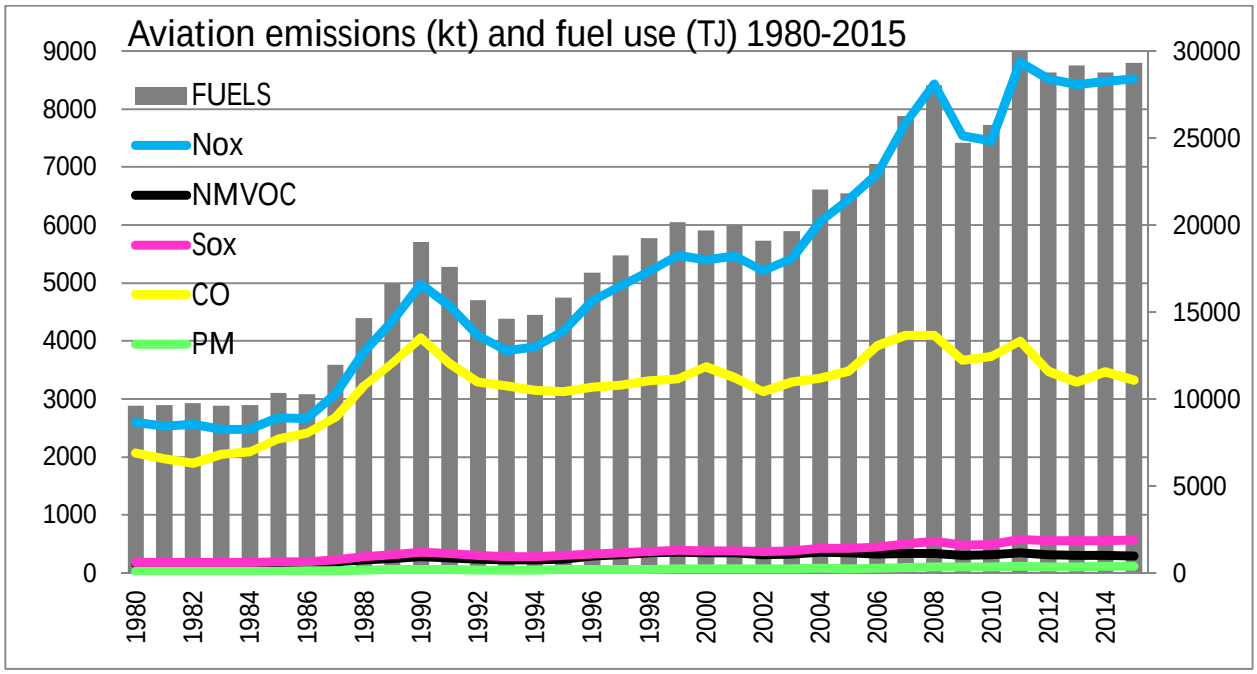


Figure 4.10. An overview of aviation emissions and fuel use 1980-2015.

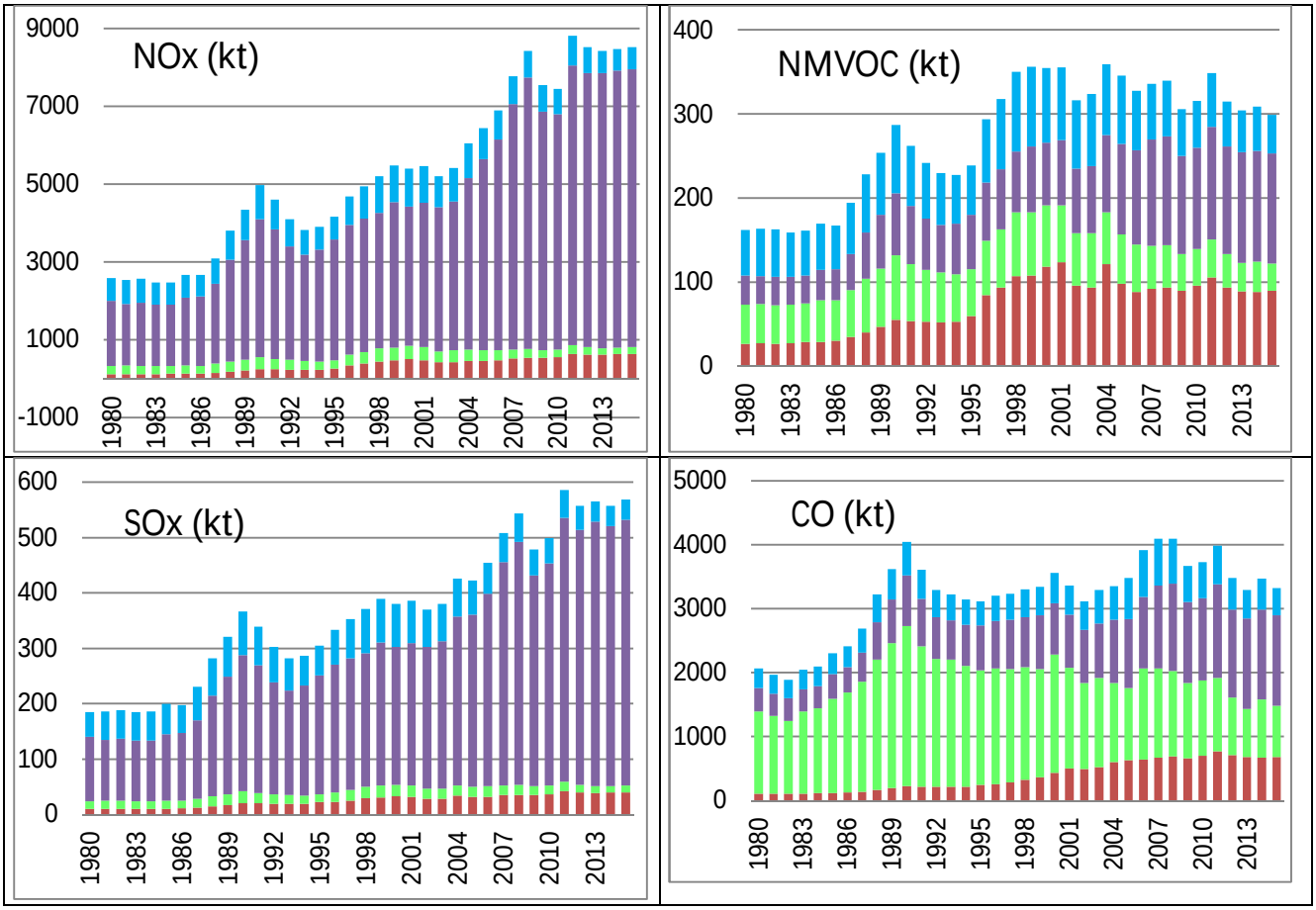
Variations of fuel consumption and emissions are caused by the variations in the number of flights, flight hours and fleet of aircraft. The economic recession in the early 1990"s decreased the number of flights. In late 1990"s there was increasing demand on domestic air transport and the number of commercial flights increased. During the 2000"s demand decreased again. At the same time airlines renewed their fleet, and more modern and environmentally-friendly aircrafts came into service. One

[5] Helicopters are not included in the calculations of civil aviation as a separate category due to the small number of flights and lack of emission factors. The fuel consumption of helicopters to be included under NFR1.A.5 (part of jet fuel consumption) will be checked to the next submission. These emissions were neither covered by the estimates of FINAVIA.

of the environmental investments include a high proportion of low-NOx engine[6] equipped aircrafts in the domestic fleet.

The balance between the use of turboprop-aircraft and over and under 100-seater jet aircraft has varied over the years according to market situation. These changes counterbalance each other, and therefore the emissions of domestic aviation have been fairly constant during the last few years excluding the year 2007 with a 9.4 % drop in number of flights. In 2008 the number of flights increased by 1% but the fuel consumption decreased by appr. 2% compared to year before. In 2009, the fuel consumption decreased further, by 7% compared to 2008 while the number of flights decreased less than 2%. In 2010 both the number of flights and the emissions decreased by more than 8% compared to the previous year. The fuel consumption increased by appr. 3% in 2011, but decreased radically, by more than 16%, in 2013. In 2014 the emissions were almost at the same level than in 2013, 50% below 1990 emissions. During the 2000's the overall trend has been decreasing, partly due to renewed fleet and partly due to ongoing recession started from 2008.

NFR category specific emission trends are presented in Figure 4.11.



[6] CFM56-5B engines equipped with CFM's advanced double annular combustor (DAC), which reduces oxides of nitrogen (NOx) emissions by 40 percent compared to engines equipped with single annular combustors (SAC).

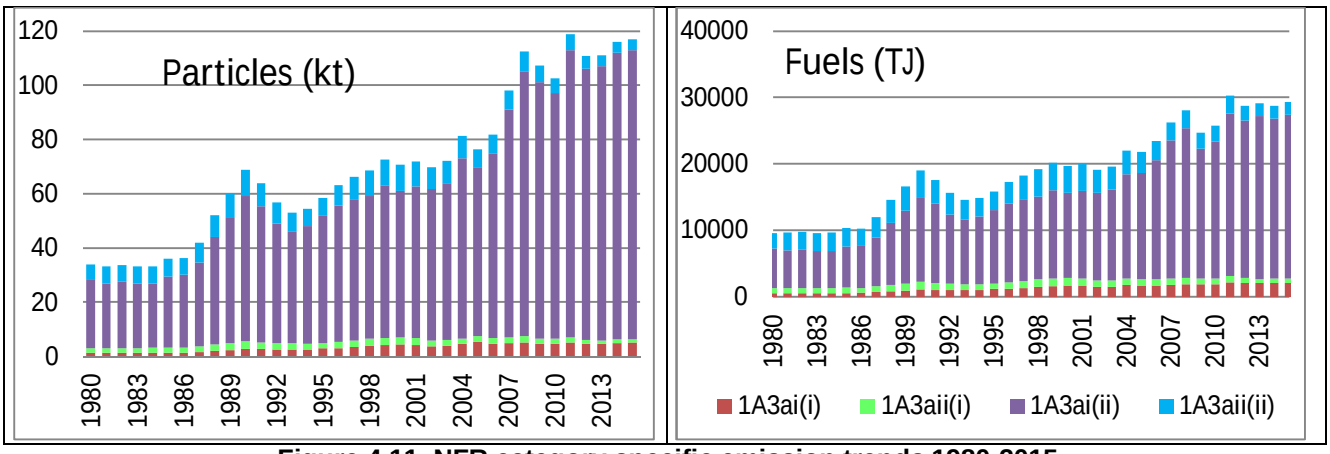


Figure 4.11. NFR category specific emission trends 1980-2015

Statistics on fuel consumption in aviation is presented in Table 4.8.

Table 4.8. Fuel consumption and number of flights/flight hours by fuel type in aviation 1990-2015

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Civil aviation, emissions, Mt CO_2 eq.	0.39	0.26	0.38	0.31	0.29	0.27	0.27	0.24	0.24	0.26	0.22	0.19	0.19	0.19
Aviation gasoline														
Fuel consumption, PJ	0.11	0.08	0.08	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Flight hours (general aviation)	-	-	-	52 662	59 230	57 676	55 215	51 218	51 104	48 511	37 238	30 279	39 097	33 964
Jet kerosene														
Fuel consumption, PJ	5.15	3.51	5.11	4.17	3.87	3.62	3.54	3.25	3.14	3.52	2.94	2.53	2.53	2.51
Number of flights (air transport)	-	-	-	66 518	68 285	61 696	62 385	60 747	56 222	61 086	51 073	45 703	44 117	42 485

number of flight and flight hours not available for 1990-2004.

4.1.16.2 Methodology specific questions

Previous method

Calculation of aviation emissions until the year 2009 was carried out by Finnish Civil Aviation Administration (Finavia). Activity data used in the calculation was from Finavia as well as the split between the national and international aviation emissions, which was based on the share of departure and arrival information of the total fight data (coefficients between 0.3 - 0.4). The calculations were based on traffic statistics, aircraft performance data and aircraft engine emission factors of each flight segment from the ICAO (International Civil Aviation Organisation) database. The description of the methodology was provided under the LIPASTO sub-model for aviation (ILMI, 2008).

In accordance with the Guidelines, international aviation fuel emissions were not included in national totals. In this system international aviation (LTO and Cruise) values included only the flight segments inside the Finnish Flight Information Region (almost similar to the Economic Region of Finland), not the whole flight or the overflights within Finland. LTO emissions included taxi in, take-off, approach and taxi out (approximately < 1000 m altitude). Cruise emissions included climb-out, cruise and descent (approximately > 1000 m altitude).

Since 2010 Finavia negotiated with EUROCONTROL on possibilities to move the calculation of aviation emissions from aviation to be carried out through a data system maintained by EUROCONTROL.

Due to changes to their earlier tasks, Finavia did not prepare the inventory for years after 2008. As the project by EUROCONTOL did not fully reach a level to produce emission data at an accuracy level that could be used in reporting of national aviation emissions, a modified calculation was continued for the period 2009-2014 at SYKE. This was based on shares of LTO and Cruise emissions in domestic and international aviation in CRF tables in the Finnish greenhouse gas inventory under UNFCCC.

New calculation model used in the 2017 submission

In this submission aviation emissions 1980-2015 have been calculated for the first time on a shared model by Statistics Finland (for the greenhouse gas reporting) and by Finnish Environment Institute (for air pollutants). The recalculation uses national fuel statistics for 1980-2015 and Eurocontrol fuel and emissions data by EU Member State for the period 2005-2015. The Eurocontrol data is calculated with a Tier 3 methodology applying the Advanced Emissions Model (AEM).

The Eurocontrol emission calculation system description is available at (http://forum.eionet.europa.eu/eionet-air-climate/library/aviation-fuel-and-emissions-data/2016).

The new calculation model is based on fuel shares for different aircraft types from the information received from EUROCONTROL. Finavia experts supported the adoption of the new model. A difference of 3-10% in the Eurocontrol jet fuel data and fuel data received from FINAVIA for 2005-2010 was identified and considered reasonable as the latest changes in the fleet had not been fully updated the earlier Finavia system. In the new model, EUROCONTROL jet fuel data is used starting from 2005.

For piston-engined aircraft using aviation gasoline fuel data is based on the earlier model and corrected with changes in flight hours because EUROCONTROL data cannot be used as its coverage is very low.

The results of the recalculation are presented in Figure 4.x above. An analysis of the recalculation and its impacts on emission levels will be presented in IIR 2018. The estimates by EUROCONTROL do not cover the following sources: non-scheduled flights, such as training, rescue and hobby flights, and neither reflects local taxi times at the airports.

4.1.16.3 Source-specific planned improvements

POP emissions and lead will be calculated and reported in the next submission 2018.

4.1.17 Road transport

Changes in chapter	
Update of emission figures	March 2017 JMP
Changes in methodology	Calculation model LIPASTO 2015 Aviation 2017 Ammonia 2015 PAH-4 2016
Update of text	January 2017 KS
Other (e.g. language, layout)	January 2017 KS

Road transport includes emissions from fuel combustion, road abrasion, tyre and brake wear and NMVOC emissions from gasoline evaporation.

1A3bi	**Road transport: Passenger cars**
1A3bii	**Road transport: Light duty vehicles**
1A3biii	**Road transport:, Heavy duty vehicles**
1A3biv	**Road transport: Mopeds & motorcycles**
1 A 3 b v	**Road transport: Gasoline evaporation**

4.1.17.1 Emission trend

The economic recession of the early 1990's explains why road traffic kilometrage did not increase as rapidly in Finland as in other countries. Since 1990 traffic volumes have increased although slower than in many other industrialised countries due to recession in the early 1990s. The market share of public transport in proportion to the total volume of passenger transport decreased steadily since 1990.

The worldwide economic downturn that began 2008 decreased the emissions of all transport modes. At the same time, the change in Finland to CO2 based taxation of cars has caused a transition from gasoline to diesel cars and lowered the specific fuel consumption of new cars, both gasoline and diesel. Kilometrage of lorries and articulated vehicles decreased almost 9% and emissions over 13% in a year. In 2010 emissions recovery from the economic downturn began slowly. Especially in heavy-duty transport the number of tonne-kilometres of goods transport increased 7%. The consumption of diesel and gasoline show an increase of about 1 PJ per year during the 1970's and 1980's. Then the consumption fell rapidly from 1990 onwards. Diesel consumption has returned to the pre-recession growth rate, but gasoline consumption has decreased, on average, by 1 PJ per year since the 1991 record-high level (Figure 4.8). Had the consumption of both fuels followed the pre-recession growth rate, without the decrease of the early 1990's, then the current level of consumption would give comparable percentage growth rates to those observed for other countries.

Fuel consumption per vehicle has stayed quite stable. Buses and coaches are the only vehicle type for which kilometrage and emissions have decreased in the whole time series.

Emission trends for NOx, SOx, NMVOC and NH3 are presented in Figure 4.13. All emissions are currently decreasing. The trends in emissions have continued downwards because of the prolonged

economic downturn. In the case of ammonia, vast majority of the emissions originate from passenger cars equipped with catalytic converters. The key driver in the ammonia emission level is the modernization of the car population since the emission levels decrease in the catalytic converters of more modern cars.

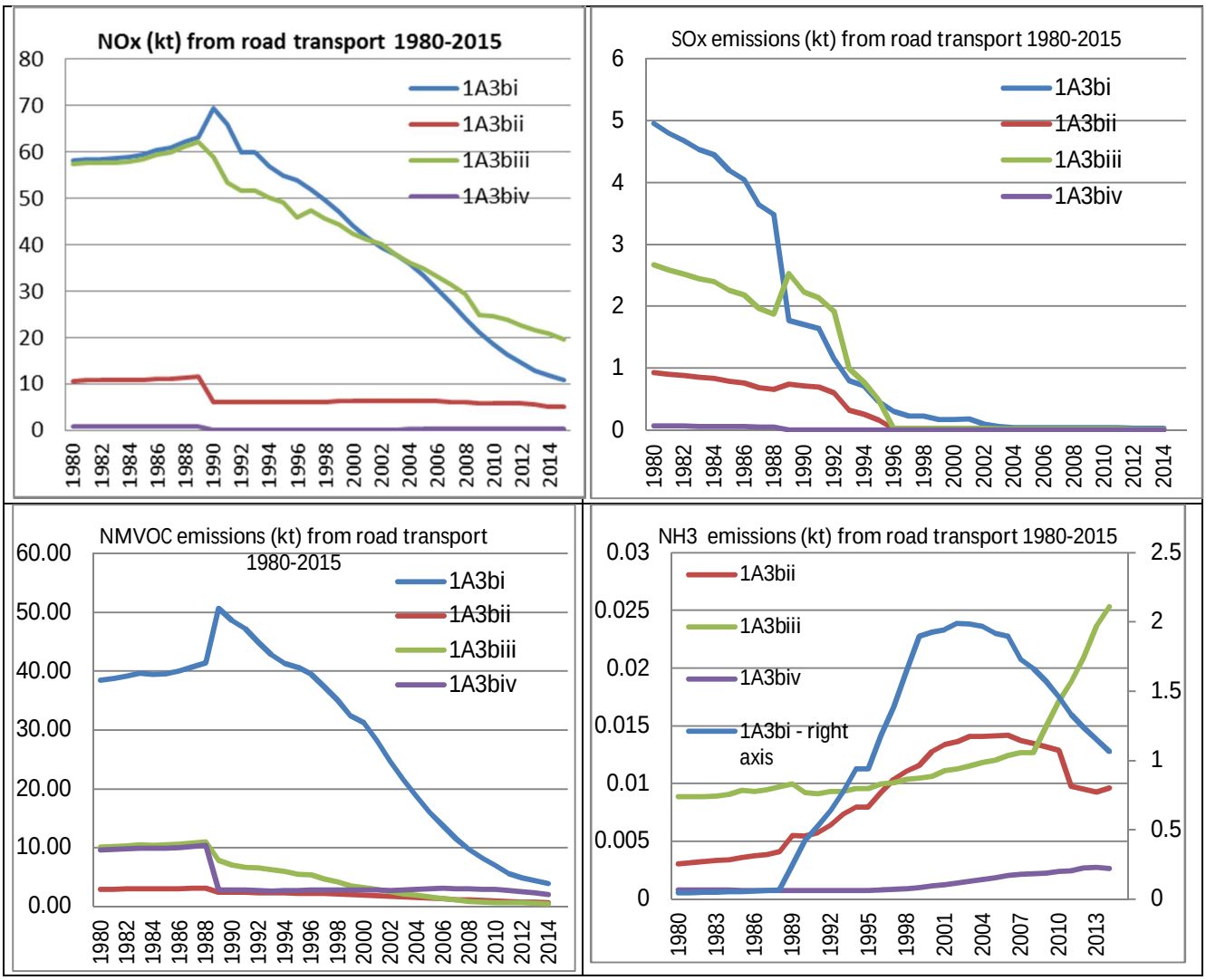


Figure 4.13. NOx, SOx, NMVOC and NH3 emissions from road transport 1980-2015

In the latest years there has been a growing share of biofuels in road transport. The intended purpose for the introduction of biofuels is to limit greenhouse gas emission as the annually driven kilometrage is growing. Passenger car use has been growing steadily and already accounts for some 88 per cent of the total passenger transport. The energy efficiency of new registered cars began to improve in the 1990s and can be seen in the greenhouse gas emission trend over the period 1990–2011 when vehicle-specific CO_2 emissions of new registered passenger cars fell almost 30 per cent (gasoline 28% and diesel 30%). In recent years the number of large diesel cars has been growing.

Fuel consumption and emission trends of particles, heavy metals and POP emissions are presented in Figure 4.14.

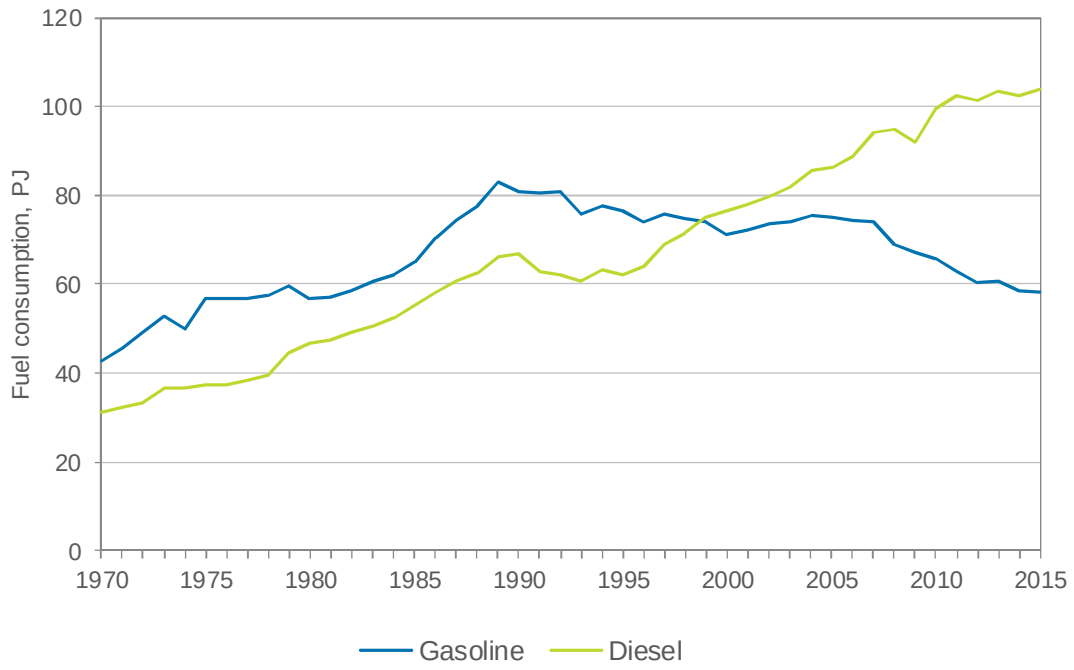


Figure 4.14 Consumption of diesel oil and gasoline (including bio-shares) in road transportation in the years 1970-2015 (Energy Statistics, Statistics Finland)

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4.1.17.2 Methodological issues

Emissions from transportation are calculated using the national model for transport emissions, LIPASTO (www.lipasto.vtt.fi). The LIISA sub-model of LIPASTO calculates road transport emissions of NO_x, SO_2, NMVOC, CO_2, CH_4, CO, Pb and TSP for the years 1980–2030. In the LIISA calculation model the emission factors have been adjusted to the Finnish car population. The results of LIISA are taken into the IPTJ system at Finnish Environment Institute.

The LIISA model has been totally renewed in 2013-2015 and the year 2013 is the first year calculated with the new model. Despite the renewal the calculation method is basically the same as in the old model. Recalculations made for the year 2012 show the following differences between the old and new LIISA models (Table 4.10). There are two main reasons that cause changes in the emission amounts; changes in kilometrage and changes in emission factors.

The new model also includes new vehicle technologies (FFV, gas, electric vehicles etc. as described in paragraph Methods) and for example urea additive AdBlue.

Recalculations have been made for the whole time series 1990–2012 to ensure the time series' consistency.

Table 4.10 Emission amount difference between old and new LIISA models (Finnish NIR 2014).

2012		CO	NOx	SO2	HC
difference in %	-50	12	-5	-40	

Calculation basis of emissions

Calculation of emissions is based on fuel consumption of road vehicles and the emission factors. The definition of consumption of fuel on the country level is based on fuel sales.

Fuels

Road traffic in Finland uses basically two different fuels, reformulated gasoline and diesel oil. Besides road traffic use, the gasoline sold in Finland is also used in working machines and leisure boats and hence the amount of gasoline used for other purposes than road traffic is deducted from the total sales of gasoline before the emission calculation. Diesel fuel sold in Finland is used almost exclusively by road traffic. Starting from year 2008 diesel has been used also as fuel in leisure boats. The amount of fuel imported in fuel tanks of vehicles from other countries is estimated to be small. The use of natural gas in road traffic in Finland is very small and is not included in the LIISA model. The emission factors are a sum of hot driving, idle and cold start-ups.

Kilometrage

The kilometrage [km/a] data for automobiles consist of two main categories: kilometrage on public roads (roads governed by the Finnish Road Administration (Finnra) and kilometrage on streets (governed by municipalities).

Automobile kilometrage on public roads consists of aggregated kilometres driven by five vehicle types (cars, vans, buses and coaches, lorries and articulated vehicles) on four road types (main roads in built-up areas, classified roads in built-up areas, main roads in rural areas and classified roads in rural areas) in six speed limit classes (50, 60, 70, 80, 100 and 120 km/h). These data allow detailed calculations to be performed on a smaller area than a country because the detailed data in the model are on the municipality level. For nation-wide calculations the kilometrage is summed up.

Street kilometrage is based on a total kilometrage (km/a) estimation made by the Finnish Transport Agency and crosschecked by the studies made at inspection stations. The estimated street kilometrage data are further divided into street types (main street, collector street, residential street, local plan road) based on information from traffic calculations in some cities.

Both public road and street mileage are divided according to the vehicle technology for every vehicle type: vehicles without catalytic converters, with catalytic converters, diesel, and gas (CNG).

Vehicle fleet model ALIISA

The source of the number, types and age of vehicles is the Finnish vehicle register (data obtained from Statistics Finland, the register is maintained by the Transport Safety Agency, TraFi).

The division of kilometrage by vehicle types and technologies is done by an ALIISA model, which is a vehicle fleet model and submodel to LIISA. The ALIISA model has 45 different vehicle types including gasoline, diesel, FFV (Flexible-fuel vehicle), ED95 (ethanol-diesel vehicle), gas, PHEV (plug-in hybrid electric vehicle), BEV (battery electric vehicle) and FCEV (fuel cell electric vehicle, hydrogen). Besides kilometrage, the ALIISA model comprises data on vehicle sales, fleet, fuel consumption, biofuels, energy and CO_2 emissions. All this forecasted to 2050. The ALIISA model ensures that all foreseeable technologies can be included in the emission calculations. Furthermore, kilometrage is divided according to vehicle age (model year).

Motorcycle and moped kilometrage is specified in a separate model using the number of motorcycles and mopeds and estimation of yearly kilometrage of each two-wheel types on two road types (roads and streets). Mopeds have only one engine type but kilometrage is further divided according to different emission standards (Euro 1 and Euro 2). Motorcycles have two main types of

engines, two-stroke and four-stroke. Kilometrage is divided into these main types and further to three engine volumes (under 250 ccm, 251-750 ccm and over 750 ccm) and according to emission standards (Euro 1 and Euro 2).

Road kilometrage by vehicle type is provided in Table 4.10

Table 4.10 Road traffic kilometrage [Million km/a] in LIISA (Finnish NIR 2017)

Year	Cars	Light duty trucks	Heavy duty trucks and	MC+Mopeds	Total
1990	35 757	3 593	3 440	467	43 257
1995	34 740	3 743	3 302	468	42 254
2000	38 698	4 266	3 606	607	47 177
2005	41 192	4 676	4 073	995	50 936
2006	41 259	4 779	4 156	1 107	51 302
2007	41 770	4 895	4 291	1 223	52 180
2008	41 102	4 945	4 372	1 299	51 718
2009	41 236	5 048	4 112	1 325	51 722
2010	40 990	5 136	4 338	1 384	51 849
2011	40 941	5 245	4 499	1 483	52 168
2012	40 359	5 298	4 516	1 518	51 691
2013	40 286	5 297	4 557	1 527	51 667
2014	40 720	5 105	4 694	1 529	52 047
2015	41 036	5 346	4 710	1 488	52 580

In the old version of LIISA ther was an inconsistency between kilometrage data and fuel sales. As the fuel sales data is quite accurate the kilometrage was revised as in Table 4.11. The original kilometrage by the Finnish Transport agency were reviesed based on a study by Statistics Finland (Statistics Finland 2010) where kilometrage were derived from odometer readings made in yearly inspections of vehicles.

Table 4.11 Revision percentage of kilometrage for the year 2012

Vehicle type	Change, %
Cars	-12
Vans	18
Buses/coaches	1.3
lorries	23
Total	-7.5

Fuels sold

Total fuel sales are from statistics compiled by the Finnish Petroleum and Biofuels Association. Fuel sales statistics are very accurate in Finland because national fuel sales correspond well with the fuel used in Finland. Gasoline used in road transport in Finland was 58.2 PJ and in leisure boats and working machines 4.9 PJ (8% of total sales) in 2015. Diesel fuel sales were 104.2 PJ of which use in leisure boats was 0.4 PJ (0.4% of total sales). Biodiesel and biogasoline are included in these figures.

The amount of gasoline used in other purposes than for road transportation is deducted from the total sales of gasoline. Gasoline used in working machines is calculated with the TYKO model (Chapter x). Gasoline and diesel used in leisure boats are calculated with the MEERI model (Chapter x).

The activity data for natural gas used in road transport are taken from Energy Statistics.

For modelling purposes, the data are broken down into different vehicle types and road types as explained above.

Bioshares of transport fuels

Activity data of blended biofuels for 2002 to 2007 are based on a separate survey made by Statistics Finland (Energy statistics team). The data includes the amount of blended biogasoline (ethanol), starting from 2002, as well as blended biodiesel, starting from 2007. The data of other biogenic compounds, like ETBE (ETBE = ethyl tert-butyl ether, a bioethanol based gasoline component), are not available for these years.

Due to the expiration of the periodic deduction of fuel tax, there was no consumption of bioethanol in 2005 (Ministry of Employment and the Economy, 2006), but in 2006 bioethanol re-entered the market.

Starting from 2008, the activity data of blended and pure biofuels are collected by Finnish Customs. These data include the following biofuels and bio-components:

- Bioethanol, NEXBTL-gasoline, bioshares of ETBE, TAEE[7] and THxEE[8]
- Biodiesel and synthetic biodiesel (mostly NEXBTL[9]-diesel)
- Biogasoil mixed in the non-road gasoil (mostly NEXBTL-diesel)

The consumption of biofuels is originally included in the total sales data of gasoline and diesel oil. Calculations in LIISA and other LIPASTO transport submodels are performed using total fuel consumption data, including biofuels. Shares of biofuels are calculated at Statistics Finland based on data received from Finnish Customs. It should be noted that due to calculation schedules preliminary data on bioshares is used in LIISA model and these values may slightly differ from the final figures which are used in the ILMARI system. For the GHG inventory, calculated fuel consumption data are split to fossil and biogenic parts using these bioshares. The emissions calculated in the LIISA moden are split to fossil and biogenic parts according to TJ shares.

In 2015 bioshares of gasoline and diesel oil were 4.6% and 17.3% respectively (calculated from TJ).

Biogenic emissions are from 2008 onwards allocated to the transport and machinery subcategories according to the consumption of these fuel types.

Biogas consumption in transport has been very small until 2009, but now the volume has started growing. Time series on biogas data starting from 2002 are now available in the Energy statistics. The share of biogas from total gas consumption in road transport was approximately 50% in 2015.

Emission factors and other parameters

The methods for calculating emissions from road transportation correspond to the EMEP Tier 3. All emission factors have been checked and harmonised to comply with the 2006 IPCC Guidelines and EMEP/EEA 2016.

[7] tertiary amyl ethyl ester
[8] tert-hexyl ethyl ether
[9] Production process for renewable diesel oil, commercialised by Neste Oil. A small amount of bio gasoline is by-produced in the process

Emission factors are determined for all the activity categories mentioned above. Country-specific net calorific values are shown in Table x.

For each automobile type, the cold driving emission and fuel consumption surplus is calculated according to the EMEP/EEA emission inventory guidebook 2016 (EMEP/EEA 2016).

For each automobile type, the amount of idle (min/d) is estimated. The number of cold start-ups per 1,000 vehicle kilometres is determined based on a separate research projects (Mäkelä 1993 and Mäkelä 1994).

The formula below has been used in calculation of emissions from automobiles in LIISA model:

$$E_{v,y} = \sum_{l=1}^{9}\sum_{m=1}^{20}\sum_{p=1}^{8}\sum_{r=1}^{6} s_{l,m,p,r,u,y}\left(b^{a}_{l,m,p,r,u,v,y} + b^{j}_{l,m,p,r,u,v,y} + b^{k}_{l,m,p,r,u,v,y}\right)$$

where

E	is total emissions
S	is kilometrage
ba	is the emission factor for hot driving
bj	is the emission factor for idle
bk	is the emission factor for cold start-ups
l	is type of vehicle
m	is model year of vehicle
p	is road type
r	is speed class
u	is fuel type
v	is compound
y	is calculation year

The more detailed description of the calculation methodology of the model is presented at the website referenced above.

Calculation of emissions not covered by LIISA

Particle emissions

Calculation of PM_{10} and $PM_{2,5}$ size fractions of particulate matter emissions from the results in the LIISA model has been carried out with national (Karvosenoja et al, 2002) or default factors (TNO, 2002) presented in Table 4.13.

Table 4.13 PM_{10} and $PM_{2.5}$ fraction factors for transport sector.

Sector	PM_{10} %	$PM_{2.5}$ %	Reference
Aviation	100	100	
Road transport	97.5	85.4	
Railways	97.5	85.4	TNO, 2002
Navigation	99	96.9	
Off-road machinery	96.5	89.3	

Black carbon emissions from road transport are calculated with the Tier 1 emission factors of the EMEP EEA Guidebook 2016.

NH_3 emissions

In the 2015 submission ammonia emissions from road transport were included for the first time. Emissions are calculated by EURO classes as descripted in Guidebook 2016 (EEA, 2016). In cases no emission factor is provided in Guidebook 2016 an expert estimate has been used. Emission factors are presented in Table 4.14 and activity data (driven kilometres) is presented in Table 4.15

Table 4.14 NH_3 emissions factors for road transport (EMEP EEA Guidebook 2016. Expert estimates are marked as "ex"

Vehicle type	EFs from EMEP EEA Guidebook 2016, unit mg/km						
	EURO 0	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6
Passenger cars, diesel	1	1	1	1	1	1.9	1.9
Passenger cars, without catalytic (gasoline)	2						
Passenger cars, with catalytic (gasoline)		92.2	104.3	34.2	34.1	12.3	12.3
Heavy duty with trailer, diesel	2.9	2.9	2.9	2.9	2.9	11	11
Heavy duty without trailer, diesel	2.9	2.9	2.9	2.9	2.9	11	11
Heavy duty without trailer, gas						33.8^{ex}	33.8^{ex}
Busses, diesel	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Busses, gas		33.8^{ex}	33.8^{ex}	33.8^{ex}	33.8^{ex}	33.8^{ex}	33.8^{ex}
Motocycles	1.9	1.9	1.9	1.9			
Mopeds	1	1	1	1			
Vans, diesel	1.2	1.2	1.2	1.2	1.2	1.9	1.9
Vans without catalytic	2.5						
Vans with catalytic		75.8	91	30.2	30.2	12.3	12.3
Vans (gas)						33.8^{ex}	33.8^{ex}
Passenger cars, (gas)					33.8	33.8	33.8
Motorised quadricycles			2.9^{ex}	2.9^{ex}			
Passenger cars (FFV)					33.9	33.9	33.9

POP emissions

The calculation of road transport POP emissions at the Finnish Environment Institute is based on emission factors and driven kilometres or consumed fuel (Table 4.12). The consumption of fuels as tonnes is converted into litres by dividing it with the density of petrol (0.75 kg/l) or diesel (0.845 kg/l).

POP emission factors are presented in Tables 4.16(a) and 4.16(b) and emissions from mobile combustion in Tables 4.17(a) and 4.17(b).

PAH-4

Finland currently reports only the sum of PAH-4 in the NFR tables because the reduction commitments are based on PAH-4. The sum of PAH-4 is calculated from the four indicator substances, i.e. benzo(a)pyrene, benzo(b)fluranthene, benzo(k) fluoranthene and indeno(1,2,3-cd)pyrene) have been calculated separately and are presented below. The EFs are from EMEP EEA Guidebook 2016.

PCDD/F

The PCDD/F emission factors are national (Ruuskanen, 2000).

HCB and PCB

HCB and PCB emission factors are from the study by BiPRO (BiPRO, 2006).

Heavy metal emissions

Heavy metal emissions apart from lead from road transport were included for the first time in the 2017 submission. The emissions are calculated with the Tier 3 emission factors of the EMEP EEA Guidebook 2016 for the following substances: As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn.

Lead emissions of lead added to the fuel are included in the LIISA model.

Table 4.16(a) Emission factors: PAH-4 indicator substances (benzo (a) pyrene, benzo (b) fluranthene, benzo (k) fluranthene and indeno (1,2,3-cd) pyrene) for the different vehicle types.

Vehicle type	benzo (a) pyrene (g/kg fuel)	benzo (b) fluoranthenee (g/kg fuel)	benzo (k) fluoranthene (g/kg fuel)	indeno (1,2,3-cd) pyrene (g/kg fuel)	Reference
Passenger cars					
- diesel	2.14e-05	2.24e-05	1.18e-05	2.12e-05	EMEP/GB16
- gasoline	5.50e-06	7.90e-06	3.90e-06	8.90e-06	
Heavy duty vehicles,					
- diesel	5.10e-06	3.08e-05	3.44e-05	7.90e-06	EMEP/GB16
Light duty vehicles, vans etc.	1.58e-05				
- diesel	4.20e-061				
- gasoline		1.66e-05	8.70e-06	1.58e-05	EMEP/GB16
Mopeds & motorcycles		6.10e-06	3.00e-06	6.90e-06	
- gasoline	8.40e-06				
		9.40e-06	6.80e-06	1.02e-05	
Heavy duty vehicles, lorries					EMEP/GB16

Table 4.16 (a) Emission factors: PCDD/F, HCB, PCB for the different vehicle types.

Sector	PCDD/F EF pg-I-TEQ/l (Ruuskanen, 2000)	PAH-4	HCB EF mg/t (BiPRO, 2006)	PCB EF mg/t (BiPRO, 2006)
Passenger cars - diesel - gasoline	100	see Table 4.17(b)	0.06	5
Heavy duty vehicles, - diesel	2 000		0.06	5
Light duty vehicles, vans etc. - diesel - gasoline Mopeds & motorcycles - gasoline	2 000		0.06	5
Heavy duty vehicles, lorries	2 000		0.06	5

Table 4.17(b) PCDD/F, HCB, PCB and PAH4 (as sum of Benzo (a) pyrene, Benzo (b) fluranthene, Benzo (k) fluranthene and Indeno (1,2,3-cd) pyrene) emissions 1990-2015 from mobile combustion in road transport

Year	PAH-4 (kg)	PCDD/F (g-I-TEQ)	HCB (kg)	PCB (kg)
1990	166	2.38	0.208	17.3
1991	158	2.22	0.202	16.8
1992	157	2.22	0.201	16.8
1993	152	2.17	0.192	16.0
1994	157	2.27	0.199	16.5
1995	155	2.24	0.196	16.3
1996	157	2.28	0.195	16.2
1997	166	2.42	0.204	17.0
1998	170	2.47	0.206	17.2
1999	175	2.54	0.209	17.4
2000	176	2.54	0.207	17.3
2001	179	2.57	0.211	17.6
2002	183	2.58	0.215	17.9
2003	187	2.61	0.219	18.2
2004	194	2.72	0.225	18.8
2005	195	2.68	0.226	18.8
2006	200	2.72	0.228	19.0
2007	209	2.83	0.235	19.6
2008	208	2.76	0.232	19.4
2009	202	2.53	0.225	18.8
2010	214	2.71	0.233	19.5
2011	218	2.72	0.235	19.6
2012	215	2.69	0.231	19.4
2013	217	2.95	0.230	19.2
2014	216	2.89	0.228	18.2
2015	216			

Table 4.17(c) Emissions of Benzo (a) pyrene, Benzo (b) fluranthene, Benzo (k) fluranthene and Indeno (1,2,3-cd) pyrene) from mobile combustion in road transport 1990-2015.

Year	benzo (a) pyrene (kg)	benzo (b) fluranthene (kg)	benzo (k) fluranthene (kg)	indeno (1,2,3-cd) (kg)
1990	26.4	56.8	47.5	35.4
1991	25.7	53.8	44.3	34.4
1992	25.4	53.5	44.0	34.2
1993	24.2	51.7	43.0	32.6
1994	25.0	53.8	44.9	33.6
1995	24.5	53.0	44.2	33.1
1996	24.5	53.7	45.3	33.0
1997	25.8	57.2	48.6	34.5
1998	26.4	58.5	49.7	35.2
1999	27.1	60.2	51.4	35.9
2000	27.4	60.6	51.8	36.0
2001	27.9	61.7	52.8	36.7
2002	28.5	63.1	54.0	37.4
2003	29.3	64.4	55.0	38.3
2004	30.5	66.8	57.1	39.7
2005	30.8	67.2	57.3	40.0
2006	31.6	68.7	58.6	40.8
2007	33.3	71.9	61.4	42.6
2008	33.5	71.4	60.8	42.5
2009	33.7	68.5	57.2	42.2
2010	35.2	73.1	61.7	43.9
2011	35.9	74.5	63.0	44.5

2012	35.9	73.3	61.7	44.2
2013	36.4	74.0	62	44.6
2014	36.3	73.6	61.7	44.5
2015	36.7	73.6	61.5	44.7

Table 4.12 Activity data for 1990-2015 in the LIISA sub-model.

	Driven kilometers (10^6 km/year)					Fuel consumption (t/year)				
Year	**PC**	**V**	**B**	**L**	**M**	**PC**	**V**	**B**	**L**	**M**
1990	35 757	3 593	660	2 780	467	2 138 470	320 819	173 647	816 880	12 974
1991	35 607	3 610	650	2 530	468	2 130 877	319 519	168 023	733 484	13 037
1992	35 530	3 667	640	2 500	470	2 119 034	325 663	166 761	729 043	13 106
1993	35 156	3 655	639	2 570	463	1 995 237	312 523	160 708	722 069	12 933
1994	34 980	3 626	633	2 582	456	2 043 741	323 865	166 818	762 309	12 760
1995	35 318	3 662	633	2 632	468	2 014 683	318 260	162 021	755 153	13 078
1996	35 595	3 685	635	2 669	478	1 968 274	321 504	164 050	774 497	13 344
1997	36 542	3 744	643	2 750	491	2 049 591	338 657	172 100	828 253	13 706
1998	37 522	3 865	606	2 795	515	2 045 917	351 414	164 935	856 069	14 396
1999	38 622	3 966	596	2 867	556	2 058 390	362 069	163 531	884 700	15 398
2000	39 257	4 033	596	2 807	607	2 025 930	367 868	163 821	880 140	16 728
2001	40 122	4 106	593	2 834	663	2 068 913	374 487	162 460	888 393	18 179
2002	41 100	4 153	598	2 905	733	2 130 860	378 861	161 961	892 246	19 860
2003	41 992	4 217	568	3 012	812	2 171 090	384 847	154 841	909 508	21 749
2004	42 945	4 280	590	3 077	898	2 223 932	398 837	162 715	948 820	23 800
2005	43 617	4 335	591	3 134	975	2 251 336	392 533	160 071	932 295	25 873
2006	44 009	4 371	589	3 189	1 003	2 262 374	396 576	159 674	950 312	28 389
2007	44 948	4 432	586	3 287	1 211	2 319 643	405 800	161 291	1 003 502	30 929
2008	44 672	4 416	597	3 292	1 311	2 311 528	395 313	161 599	973 050	33 099
2009	45 301	4 449	601	3 001	1 358	2 324 734	376 374	157 692	860 973	33 828
2010	45 608	4 466	604	3 141	1 437	2 357 740	391 758	161 178	944 011	35 405
2011	46 135	4 504	604	3 218	1 558	2 368 230	388 768	160 426	953 962	38 007
2012	45 968	4 484	608	3 177	1 653	2 329 741	387 330	162 041	938 561	39 943
2013	40 286	5 297	617	3 940	1 527	2 134 288	351 784	162 270	1 133 818	52 576
2014	40 729	5 105	620	4 074	1 529	2 140 616	332 978	157 799	1 124 087	53 089
2015	41 051	5 346	622	4 088	1 488	2 130 282	345 862	155 664	1 113 203	51 274

PC=Private cars, V=Vans, B=busses, L=lorries, M=Motorcycles

4.1.18 Gasoline evaporation

1 A 3 b v Road transport: Gasoline evaporation

Changes in chapter	
Update of emission figures	March 2017 JMP
Update of text	January 2017 ks
Change in methodology	none
Other (e.g. language, layout)	February 2017 KS

4.1.18.1 Emission trend

NMVOC emissions from gasoline evaporation in 1990-2015 are presented in Figure 4.15 and Table 4.17. The emissions have decreased strongly due to capture of gasoline fumes in petrol distribution network and during refuelling of cars, due to less evaporative emissions from cars and better storage of chemicals at the refineries.

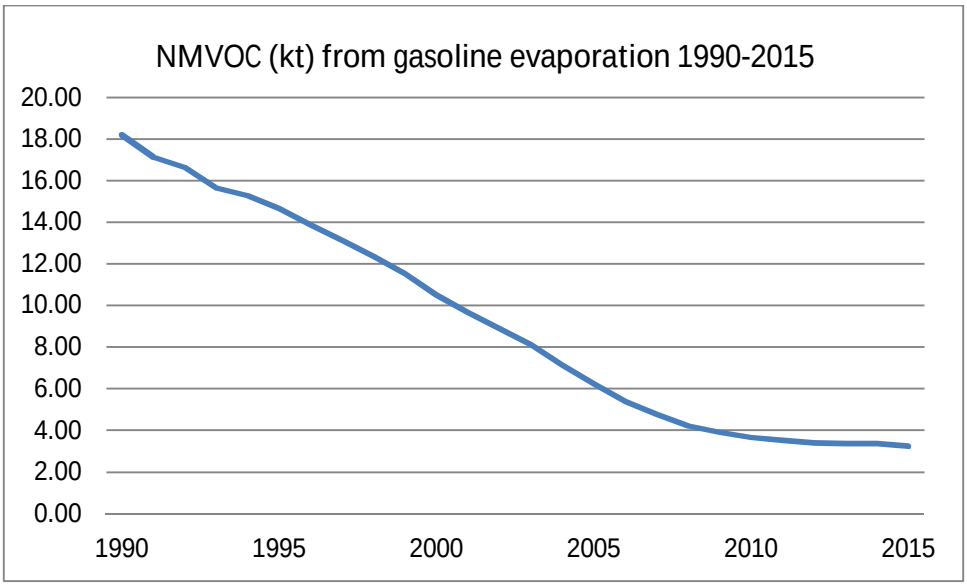

Figure 4.15. NMVOC emissions from gasoline evaporation 1980-2015

Table 4.17 NMVOC emissions 1990-2015 from vehicles.

Year	Gasoline evaporation (t)	Emissions for all road transport modes (t)
1990	18 199	63 862
1991	17 143	60 876
1992	16 646	59 183
1993	15 650	56 486
1994	15 286	53 974
1995	14 668	52 306
1996	13 880	51 093
1997	13 128	49 801
1998	12 382	47 141
1999	11 530	44 249

2000	10 523	40 765
2001	9 662	39 156
2002	8 898	35 813
2003	8 124	31 638
2004	7 162	28 130
2005	6 265	25 100
2006	5 401	22 036
2007	4 789	19 533
2008	4 222	16 806
2009	3 930	14 603
2010	3 685	12 865
2011	3 523	11 420
2012	3 393	9 816
2013	3 364	8 739
2014	3 373	7 887
2015	3 255	7 096

4.1.18.2 Methodological issues

NMVOC emissions from off-road machinery are calculated at the Finnish Environment Institute by subtracting the CH_4 emission values from the TOC values from VTT LIPASTO calculation system. NMVOC emissions from other transport modes are calculated at the renewed LIPASTO model.

Calculation of NMVOC emissions from gasoline evaporation from vehicles is based on annual expert estimation by VTT. NMVOC emissions from gasoline evaporation are difficult to measure resulting varying emission estimates.

LIPASTO calculation system uses emission factors of 0.6 g VOC/km for vehicles not equipped with a catalyst and 0.06 g VOC/km to vehicles equipped with catalysts. The annual kilometrage is presented in Table 4.8.

4.1.19 Tyre and brake wear

1 A 3 b vi Road transport: Automobile tyre and brake wear

Changes in chapter	
Update of emission figures	March 2017 JMP
Change of text	March 2017 KS
Other (e.g. language, layout)	January 2017 KS

4.1.19.1 Emission trends

Particle and heavy metal emission trends are presented in Figure 4.16.

TSP, PM10 and ÅM2.5 emissions have been estimated since 1980, heavy metals since 1990 and black carbon since 2000.

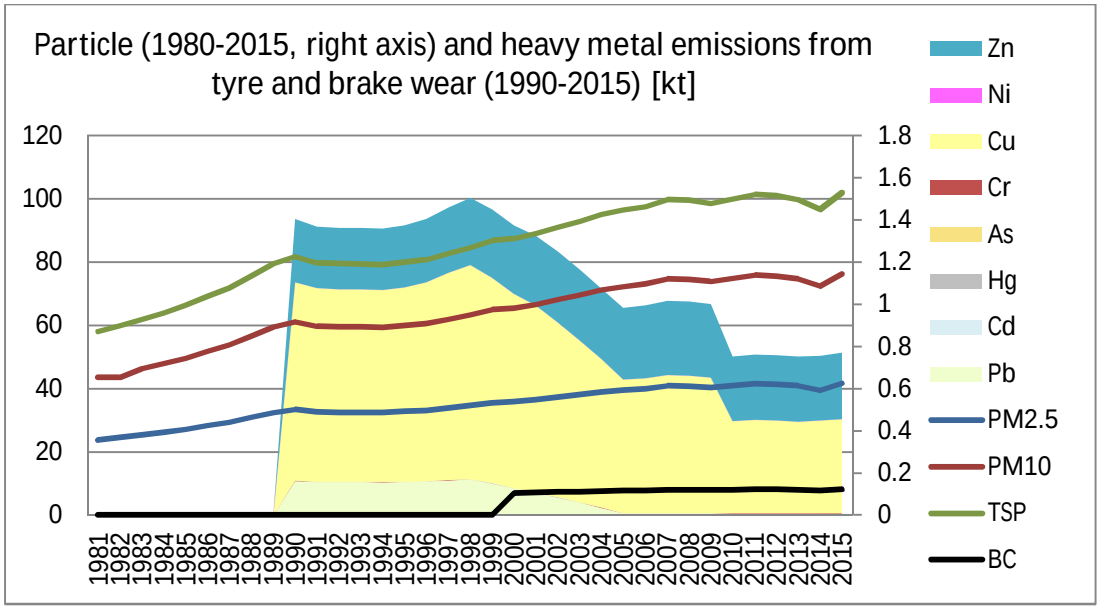

Figure 4.16 Particle and heavy metal emissions from tyre and brake wear

Particle emissions

Particle and black carbon emissions from tyre and brake wear have been calculated at the Finnish Environment Institute.

To the submission in 2009 the calculation method was changed for particles as a result of Nordic co-operation in developing methodologies that better correspond to the regional circumstances. Black carbon emissions were included in the inventory for first time in the 2014 submission.

Particle and black carbon emission factors for tyre and brake wear are presented in Table 4.18 and activity data as driven kilometres in Table 4.19.

Table 4.18 Particle (TSP, PM_{10}, $PM_{2,5}$) and black carbon (BC) emission factors for tyre and brake wear. ((1) Swedish IIR 2008, (2) Aasestad., K. (2013))

Source	Brake wear EF (g/km)			
	TSP (1)	PM_{10} (1)	$PM_{2,5}$ (1)	BC(2)
Passenger cars	0.0084	0.0082	0.0033	1% of TSP
Light duty vehicles	0.0131	0.0128	0.0051	1% of TSP
Heavy duty vehicles	0.0389	0.0381	0.0152	1% of TSP
Mopeds and Motorcycles	0.0022	0.0021	0.0009	1% of TSP
Source	Tyre wear EF (g/km)			
	TSP (1)	PM_{10}(1)	$PM_{2.5}$ (1)	BC (2)
Passenger cars	0.0128	0.0077	0.0054	30% of $PM_{2.5}$
Light duty vehicles	0.0203	0.0122	0.0085	30% of $PM_{2.5}$
Heavy duty vehicles	0.0610	0.0366	0.0256	30% of $PM_{2.5}$
Mopeds and Motorcycles	0.0064	0.0028	0.0019	30% of $PM_{2.5}$

Table 4.19 Tyre and brake wear particle emissions from Passenger cars 1990 - 2015 .

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1990	457.7	275.3	193.1	57.9	293.2	300.4	118.0	3.0
1991	455.8	274.2	192.3	57.7	292.0	299.1	117.5	3.0
1992	454.8	273.6	191.9	57.6	291.3	298.5	117.2	3.0
1993	450,0	270,7	189,8	57,0	288,3	295,3	116,0	3,0
1994	447.7	269.3	188.9	56.7	286.8	293.8	115.4	2.9
1995	452.1	271.9	190.7	57.2	289.6	296.7	116.5	3.0
1996	455,6	274,1	192,2	57,7	291,9	299,0	117,5	3,0
1997	467.7	281.4	197.3	59.2	299.6	307.0	120.6	3.1
1998	480.3	288.9	202.6	60.8	307.7	315.2	123.8	3.2
1999	494.4	297.4	208.6	62.6	316.7	324.4	127.5	3.2
2000	502,5	302,3	212,0	63,6	321,9	329,8	129,5	3,3
2001	513.6	308.9	216.7	65.0	329.0	337.0	132.4	3.4
2002	526.1	316.5	221.9	66.6	337.0	345.2	135.6	3.5
2003	537.5	323.3	226.8	68.0	344.3	352.7	138.6	3.5
2004	549,7	330,7	231,9	69,6	352,1	360,7	141,7	3,6
2005	558,3	335,9	235,5	70,7	357,7	366,4	143,9	3,7
2006	563,3	338,9	237,6	71,3	360,9	369,7	145,2	3,7
2007	575.3	346.1	242.7	72.8	368.6	377.6	148.3	3.8
2008	571.8	344.0	241.2	72.4	366.3	375.2	147.4	3.8
2009	579.9	348.8	244.6	73.4	371.5	380.5	149.5	3.8
2010	583,8	351,2	246,3	73,9	374,0	383,1	150,5	3,8
2011	590.5	355.2	249.1	74.7	378.3	387.5	152.2	3.9
2012	588.4	354.0	248.2	74.5	376.9	386.1	151.7	3.9
2013	515,7	310,2	217,5	65,3	330,3	338,4	132,9	3,4
2014	521.7	313.8	220.1	66.0	334.2	342.4	134.5	3.4
2015	525.3	316.0	221.6	66.5	336.5	344.7	135.4	3.4

Table 4.19 Tyre and brake wear particle emission from Light duty vehicles 1990 - 2015.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1990	72.9	43.8	30.5	9.2	47.1	46.0	18.3	0.5
1991	73,3	44,0	30,7	9,2	47,3	46,2	18,4	0,5
1992	74.4	44.7	31.2	9.4	48.0	46.9	18.7	0.5
1993	74.2	44.6	31.1	9.3	47.9	46.8	18.6	0.5
1994	73,6	44,2	30,8	9,2	47,5	46,4	18,5	0,5
1995	74.3	44.7	31.1	9.3	48.0	46.9	18.7	0.5
1996	74.8	45.0	31.3	9.4	48.3	47.2	18.8	0.5
1997	76,0	45,7	31,8	9,5	49,0	47,9	19,1	0,5
1998	78.5	47.2	32.9	9.9	50.6	49.5	19.7	0.5
1999	80.5	48.4	33.7	10.1	52.0	50.8	20.2	0.5
2000	81.9	49.2	34.3	10.3	52.8	51.6	20.6	0.5
2001	83,4	50,1	34,9	10,5	53,8	52,6	20,9	0,5
2002	84.3	50.7	35.3	10.6	54.4	53.2	21.2	0.5
2003	85.6	51.4	35.8	10.8	55.2	54.0	21.5	0.6
2004	86.9	52.2	36.4	10.9	56.1	54.8	21.8	0.6
2005	88,0	52,9	36,8	11,1	56,8	55,5	22,1	0,6
2006	88,7	53,3	37,2	11,1	57,3	55,9	22,3	0,6
2007	90.0	54.1	37.7	11.3	58.1	56.7	22.6	0.6
2008	89.6	53.9	37.5	11.3	57.8	56.5	22.5	0.6
2009	90.3	54.3	37.8	11.3	58.3	56.9	22.7	0.6
2010	90.7	54.5	38.0	11.4	58.5	57.2	22.8	0.6
2011	91,4	54,9	38,3	11,5	59,0	57,7	23,0	0,6
2012	91.0	54.7	38.1	11.4	58.7	57.4	22.9	0.6
2013	107.5	64.6	45.0	13.5	69.4	67.8	27.0	0.7
2014	103.5	62.2	43.3	13.0	66.8	65.2	26.0	0.7
2015	108.5	65.2	45.4	13.6	70.0	68.4	27.3	0.7

Table 4.19 Tyre and brake wear particle emission from Heavy duty vehicles 1990 - 2015 .

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1990	209.8	125.9	88.1	26.4	133.8	131.1	52.3	1.3
1991	194.0	116.4	81.4	24.4	123.7	121.2	48.3	1.2
1992	191.5	114.9	80.4	24.1	122.1	119.6	47.7	1.2
1993	195.8	117.5	82.2	24.7	124.9	122.3	48.8	1.2
1994	196.1	117.7	82.3	24.7	125.1	122.5	48.9	1.3
1995	199.2	119.5	83.6	25.1	127.0	124.4	49.6	1.3
1996	201.5	120.9	84.6	25.4	128.5	125.9	50.2	1.3
1997	207.0	124.2	86.9	26.1	132.0	129.3	51.6	1.3
1998	207.5	124.5	87.1	26.1	132.3	129.6	51.7	1.3
1999	211.2	126.7	88.7	26.6	134.7	131.9	52.6	1.3
2000	207.6	124.5	87.1	26.1	132.4	129.7	51.7	1.3
2001	209.0	125.4	87.7	26.3	133.3	130.6	52.1	1.3
2002	213.7	128.2	89.7	26.9	136.3	133.5	53.2	1.4
2003	218.4	131.0	91.6	27.5	139.3	136.4	54.4	1.4
2004	223.7	134.2	93.9	28.2	142.6	139.7	55.7	1.4
2005	227.2	136.3	95.4	28.6	144.9	141.9	56.6	1.4
2006	230.5	138.3	96.7	29.0	147.0	143.9	57.4	1.5
2007	236.3	141.8	99.1	29.7	150.7	147.6	58.9	1.5
2008	237.2	142.3	99.6	29.9	151.3	148.2	59.1	1.5
2009	219.7	131.8	92.2	27.7	140.1	137.2	54.8	1.4
2010	228.4	137.1	95.9	28.8	145.7	142.7	56.9	1.5
2011	233.1	139.9	97.8	29.4	148.7	145.6	58.1	1.5
2012	230.9	138.5	96.9	29.1	147.2	144.2	57.5	1.5
2013	278.0	166.8	116.7	35.0	177.3	173.6	69.3	1.8
2014	248.3	149.0	104.2	31.3	158.4	155.1	61.9	1.6
2015	287.3	172.4	120.6	36.2	183.2	179.5	71.6	1.8

Table 4.19 Tyre and brake wear particle emission from Mopeds and Motorcycles 1990 - 2015 .

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1990	2.1	1.3	0.9	0.3	1.0	1.0	0.4	0.0
1991	2.2	1.3	0.9	0.3	1.0	1.0	0.4	0.0
1992	2.2	1.3	0.9	0.3	1.0	1.0	0.4	0.0
1993	2.1	1.3	0.9	0.3	1.0	1.0	0.4	0.0
1994	2.1	1.3	0.9	0.3	1.0	1.0	0.4	0.0
1995	2.2	1.3	0.9	0.3	1.0	1.0	0.4	0.0
1996	2.2	1.3	0.9	0.3	1.1	1.0	0.4	0.0
1997	2.3	1.4	0.9	0.3	1.1	1.0	0.4	0.0
1998	2.4	1.4	1.0	0.3	1.1	1.1	0.5	0.0
1999	2.6	1.6	1.1	0.3	1.2	1.2	0.5	0.0
2000	2.8	1.7	1.2	0.3	1.3	1.3	0.5	0.0
2001	3.0	1.9	1.3	0.4	1.5	1.4	0.6	0.0
2002	3.4	2.1	1.4	0.4	1.6	1.5	0.7	0.0
2003	3.7	2.3	1.5	0.5	1.8	1.7	0.7	0.0
2004	4.1	2.5	1.7	0.5	2.0	1.9	0.8	0.0
2005	4.5	2.8	1.9	0.6	2.2	2.1	0.9	0.0
2006	5.1	3.1	2.1	0.6	2.4	2.3	1.0	0.0
2007	5.6	3.4	2.3	0.7	2.7	2.5	1.1	0.0
2008	6.0	3.7	2.5	0.7	2.9	2.8	1.2	0.0
2009	6.2	3.8	2.6	0.8	3.0	2.9	1.2	0.0
2010	6.6	4.0	2.7	0.8	3.2	3.0	1.3	0.0
2011	7.2	4.4	3.0	0.9	3.4	3.3	1.4	0.0
2012	7.6	4.6	3.1	0.9	3.6	3.5	1.5	0.0
2013	7.0	4.3	2.9	0.9	3.4	3.2	1.4	0.0
2014	6.6	4.0	2.7	0.8	3.2	3.0	1.3	0.0
2015	6.8	4.2	2.8	0.8	3.3	3.1	1.3	0.0

PAH-4

PAH-4 emissions from the use of rubber tyres are not estimated due to lack of suitable activity data. The preferred method to calculate these emissions would be the one presented in the Swedish IIR 2008.

Heavy metal emissions

Heavy metal emissions from road transport tyre and brake wear have been calculated since the submission in 2004. The time series 1990-2015 of heavy metal emissions from tyre and break wear is presented in Table 4.22.

Tyre wear

Metal emissions from tyre wear are part of particle emissions from tyres.

Lead, cadmium, chromium, copper, nickel and zinc emissions from tyre wear are calculated based on a method presented in the Sweden's IIR's 2008 and 2014. The emission factors are presented in Table 4.20 These emissions are calculated from TSP emissions presented above.

The calculation method for arsenic and mercury emissions from tyre wear is adopted from the Norwegian emission inventory (Norwegian IIR 2005). The emission factors are presented in Table 4.20 and the activity data as driven kilometres is presented in Table 4.21.

Table 4.20 Heavy metal emission factors for tyre wear (Swedish IIR 2008, according to to Hjortenkrans (2006)).

Vehicle category	Tyre wear emission factors							
	mg/kg of TSP emissons (Hjortenkrans 2008)						g/mill.km (Norwegian IIR 2005)	
	Pb	Cd	Cr	Cu	Ni	Zn	As	Hg
Passenger cars	9.4	1.1	1.7	8.6	3.2	9400	0.003	0.38
Light duty vehicles	9.4	1.1	1.7	8.6	3.2	9400	0.005	0.38
Heavy duty vehicles	9.5	0.86	1.3	7.4	2.9	12000	0.019	0.38
Mopeds& Motorcycles	9.4	1.1	1.7	8.6	3.2	9400	0.002	0.38

Brake wear

Lead, cadmium, copper and **zinc** emissions from **brake wear** are calculated based on the method presented in the Swedish IIR's 2008 and 2014. The detailed method is based on Westerlund (2001), where it is assumed that for passenger cars and vans new front linings weigh 0.15 kg, rear linings 0.11 kg and that all linings are used to 70% of their total length of life before being replaced. Front linings are replaced every 40 000 km (four linings) and rear linings every 60 000 km (four linings).

These assumptions lead to a brake lining consumption (in kilogrammes per year) of:

$$0.7 \times 4 \times \left(\frac{0.15}{40000} + \frac{0.11}{60000} \right) \times \frac{km(driven)}{\acute{y}ear} = \text{brake consumption (passenger cars)}$$

For heavy duty vehicles it is assumed that all brake linings are replaced every 100 000 kilometers. While the number of linings per wheel varies between make and model, it is here assumed that per wheel linings weigh 2.5 kg in the front and 3.5 kg in the rear. Total amount of linings consumed per year (in kilogrammes per year) in heavy duty vehicles equal to:

$$\left(\frac{2 \times 2.5}{100000} + \frac{2 \times 3.5}{100000} \right) \times \frac{km(driven)}{year} = \text{brake consumption (heavy duty vehicles)}$$

According measurements done in Sweden, buses use an average 0.00011 kg linings per kilometre. Yearly consumption of linings in buses can be calculated using mentioned factor and driven kilometres (Table 4.8) per year.

$$0.00011 \times \frac{km(driven)}{year} = \text{brake consumption (busses)}$$

In the study by Hjortenkrans et al. (2006) used in the Swedish method, measured metal contents in 2005 in both branded brake linings and those from independent suppliers are presented. A similar study was made in the late 1990s and the results show that there is a clear reduction of the Pb and Zn content in both branded linings and linings from independent suppliers. Also for copper the metal content in linings from independent suppliers from 2005 is much lower than in 1998. For branded linings the results is the contrary, the copper content in linings from 2005 is higher compared to linings from 1998. For the brake the following assumption is made; 40% of the traffic volume is related to new vehicles using branded linings and 60% to older vehicles using linings from independent suppliers. For Pb, Cu and Zn the emission factors are based on results presented by Westerlund (2001) for the years 1980–1998, and on results presented by Hjortenkrans (2006) for 2005 and onwards. The emission factors for 1999–2004 are interpolated. For Cd a constant emission factor is used for the whole time series.

No statistical data is available for Finland on break wear in different car types and ages, but in the inventory it is assumed that 30% of traffic volume is related to new vehicles (1-4 years old) using branded linings and 70% to older vehicles using linings from independent suppliers. These are slightly based on the statistics in Hjortenkrans et al. (2006) and in addition it is assumed that branded brake pads exist only in new cars. Emission factors used in the inventory for lead, cadmium, copper and zinc are presented in **Error! Reference source not found.**. In the 2017 submission it is assumed that during 1990-1995 15 % of car fleet can be considered to be new (1-4 years old), for years 1996-2000 assumption is 20 %, for years 2001- 2009 25 % and from year 2010 onwards 20 %.

Chromium emissions from brake wear are calculated according to the Norwegian method (Norwegian Emission Inventory, 2005). For the brake wear the division between new and old cars has been made based on information from the LIISA road transport emission calculation model: 0-4 years old cars are considered as new cars and cars older than 4 years as old cars. In the Norwegian inventory it is assumed that a new car will be four years old when the blocks = brakes are changed for the first time. The emission factor for brake wear in new passenger cars and vans is 0.36 g/mill.km, for old passenger cars and vans 0.35 g/mill.km and for heavy duty vehicles 14.82 g/mill.km.

Table 4.21 Heavy metal emission factors for brake wear, for all vehicle types (Swedish IIR 2014). Note chromium emissions are calculated from driven kilometers as explained above.

Vehicle age	Brake Wear, branded (ppm wt.)				Brake Wear, not-branded (ppm wt.)			
	Pb	Cd	Cu	Zn	Pb	Cd	Cu	Zn
1980-1998	13854	2.6	105070	20164	11381	0.445	61615	12447
1999	12090	2.6	108631	21855	9783	0.445	52835	11340
2000	10327	2.6	112193	23546	8185	0.445	44055	10233
2001	8563	2.6	115754	25237	6587	0.445	35275	9127
2002	6800	2.6	119316	26927	4989	0.445	26495	8020
2003	5037	2.6	122877	28618	3391	0.445	17715	6913
2004	3273	2.6	126439	30309	1793	0.445	8935	5807
2005-	1510	2.6	130000	32000	195	0.445	155	4700

Table 4.22 Heavy metal emissions (kg) 1990-2015 from road transport tyre and brake wear.

Note: the shares of old/new cars was changed from 2010 onwards for the submission of 2017 (can be seen in Cu, Pb and Zn emissions) and will be recalculated to the next submission.

Year	As	Cd	Cu	Cr	Pb	Hg	Ni	Zn
1990	0.192	2.85	62 777	66.0	10 834	16.4	2.31	20 060
1991	0.186	2.71	61 129	62.1	10 550	16.3	2.26	19 526
1992	0.186	2.69	60 861	61.5	10 503	16.3	2.26	19 445
1993	0.186	2.71	60 843	62.4	10 500	16.1	2.25	19 445
1994	0.185	2.71	60 649	62.4	10 467	16.1	2.24	19 383
1995	0.187	2.75	61 333	63.2	10 585	16.2	2.27	19 604
1996	0.189	2.82	62 866	63.9	10 735	16.4	2.29	19 955
1997	0.194	2.95	65 499	65.7	11 070	16.8	2.35	20 649
1998	0.198	3.03	67 719	66.2	11 329	17.2	2.40	21 216
1999	0.203	3.15	64 933	67.6	10 079	17.7	2.46	21 543
2000	0.204	3.20	61 425	67.0	8 590	18.0	2.48	21 600
2001	0.207	3.29	59 112	67.7	7 149	18.4	2.53	22 034
2002	0.212	3.37	55 286	69.2	5 636	18.8	2.58	22 262
2003	0.217	3.45	51 137	70.7	4 040	19.2	2.64	22 455
2004	0.222	3.25	46 917	72.3	2 383	19.7	2.59	22 244
2005	0.225	3.57	42 163	73.5	644	20.0	2.74	22 739
2006	0.228	3.62	42 597	74.5	650	20.2	2.77	22 980
2007	0.233	3.70	43 517	76.3	664	20.7	2.83	23 482
2008	0.233	3.70	43 403	76.4	663	20.6	2.82	23 424
2009	0.229	3.57	42 868	72.4	655	20.8	2.80	23 122
2010	0.233	3.65	29 087	75.0	518	21.0	2.84	20 453
2011	0.236	3.71	29 486	76.0	526	21.2	2.88	20 740
2012	0.236	3.69	29 331	75.3	523	21.2	2.87	20 633
2013	0.237	3.96	29 043	85.1	518	19.6	2.82	20 552
2014	0.240	3.76	29 456	87.1	525	19.8	2.74	20 372
2015	0.242	3.83	29.709	87.6	530	20.0	2.88	21 020

4.1.20 Road abrasion

1 A 3 b vii Road transport: Automobile road abrasion

Changes in chapter	
Update of emission figures	March 2017 JMP
Change in text	February 2017 KS
Other (e.g. language, layout)	February 2017 KS

4.1.20.1 Emission trend

The emissions are slightly increasing due to increased kilometrage of vehicles as seen in Figure4.17. The decrease in 2013 is due to decreased driven kilometres as presented in Table 4.10.

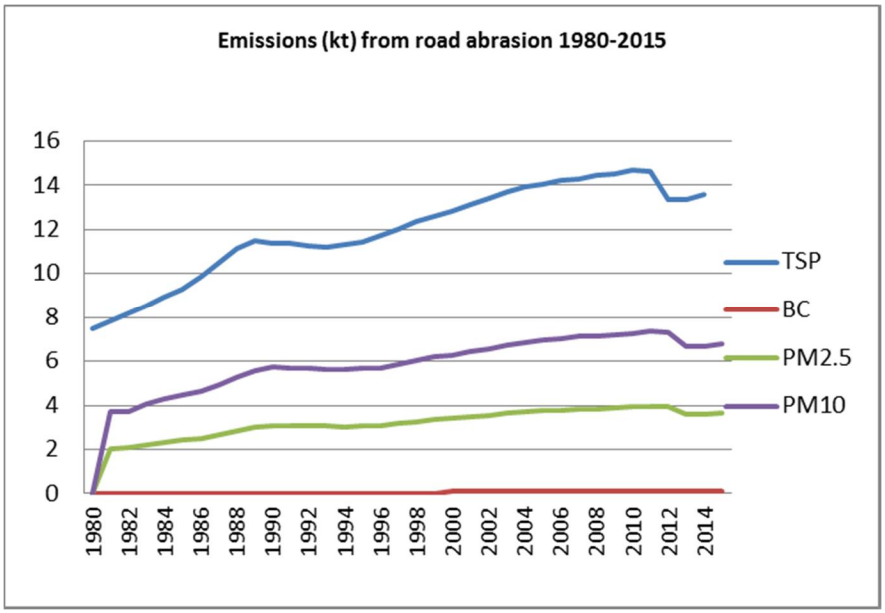

Figure 4.17. Emissions from road abrasion 1980-2015 (driven kilometres decreased in 2013)

4.1.20.2 Methodological issues

Particle and black carbon emissions

For the 2009 submission the calculation method was changed as a result of Nordic co-operation. The time series 1990-2015 of particle emissions from road abrasion is presented Table 4.24.

The emission factors for road abrasion presented in Table 4.23 are from the Swedish IIR 2008 and national expert estimation (SYKE 2014) to separate brake wear, tyres and road abrasion emissions. Activity data as driven kilometres has been taken from the LIISA submodel and presented in Table 4.8 above.

The following assumptions have been made for the calculation of particle emissions from the use of studded tyres:

- studded tyres are used only on passenger cars and light duty vehicles
- studded tyres are used during 4 and half months per year
- 80% of the passenger cars and light duty vehicles use studded tyres

$$\frac{4.5}{12} x 0.80 = 0.30 \Rightarrow 30\%$$

Based on these assumptions, the emission factors for Finnish conditions are slightly higher than in Sweden, due to e.g. a longer period for the use of studded tyres (4.5 months).

As presented in the Swedish IIR a correction factor of 50 x PM_{10} for the use of studded tyres has also been used to 30% of vehicle kilometres for passenger cars and light duty vehicles. In addition, the same particle size distribution as for road abrasion for non-studded tyres, has been used.

Black carbon emissions are calculated using emission factor 0.83 % of TSP emissions (Aasestad., K. 2013).

Table 4.23 Emission factors used for particle emissions from road abrasion (Swedish IIR 2008).

Vehicle category	Non studded tyres (road abrasion) EF (g/km)			Studded tyres (road abrasion) EF (g/km)		
	TSP	PM10	PM2.5	TSP	PM10	PM2.5
Passenger cars	0.018	0.009	0.005	0.900	0.450	0.243
Light duty vehicles	0.018	0.009	0.005	0.900	0.450	0.243
Heavy duty vehicles	0.099	0.049	0.027	-	-	-
Mopeds & Motorcycles	0.006	0.003	0.002	-	-	-

Table 4.24 Particle and black carbon emissions in 1990 - 2015 from road abrasion.

	Road abrasion emissions (t)			
	TSP	PM_{10}	$PM_{2,5}$	BC
1990	11 464	5 730	3 100	95.1
1991	11 400	5 699	3 083	94.6
1992	11 391	5 694	3 080	94.5
1993	11 289	5 643	3 053	93.7
1994	11 231	5 614	3 037	93.2
1995	11 342	5 669	3 067	94.1
1996	11 430	5 714	3 091	94.9
1997	11 724	5 860	3 170	97.3
1998	12 036	6 016	3 255	99.9
1999	12 382	6 189	3 348	102.8
2000	12 574	6 285	3 400	104.4
2001	12 842	6 419	3 473	106.6
2002	13 140	6 568	3 553	109.1
2003	13 390	6 693	3 621	111.4
2004	13 656	6 826	3 693	113.8
2005	13 926	6 961	3 766	115.6
2006	14 053	7 025	3 800	116.6
2007	14 224	7 110	3 847	118.1
2008	14 265	7 131	3 858	118.4
2009	14 424	7 210	3 900	119.7
2010	14 530	7 263	3 930	120.6
2011	14 698	7 347	3 975	122.0
2012	14 642	7 319	3 960	121.5

2013	13 342	6 669	3 609	110.7
2014	13 370	6 684	3 616	111.0
2015	13 583	6 789	3 673	112.7

4.1.20.3 Uncertainties

Uncertainties will be reported in the Annex of the IIR by 1st May.

4.1.20.4 QA/QC and verification

Road transport: During the revision of the LIPASTO model in 2014-2015 year 2012 emissions were calculated both with the old and new models to see the effect of the renovation of the model.

SOx, NOx, NMVOC and CO were compared to the data reported under the UNFCCC calculated at Statistics Finland.

4.1.20.5 Source specific planned improvements

None.

4.1.21 Railways, navigation, pipeline compressors

1 A 3 c Railways

Changes in chapter	
Update of emission figures	March 2017 JMP
Update of text	January 2017 KS
Other (e.g. language, layout)	January 2017 KS

4.1.21.1 Emission trend

As presented in Figure 4.18, emissions from railway transport are declining.

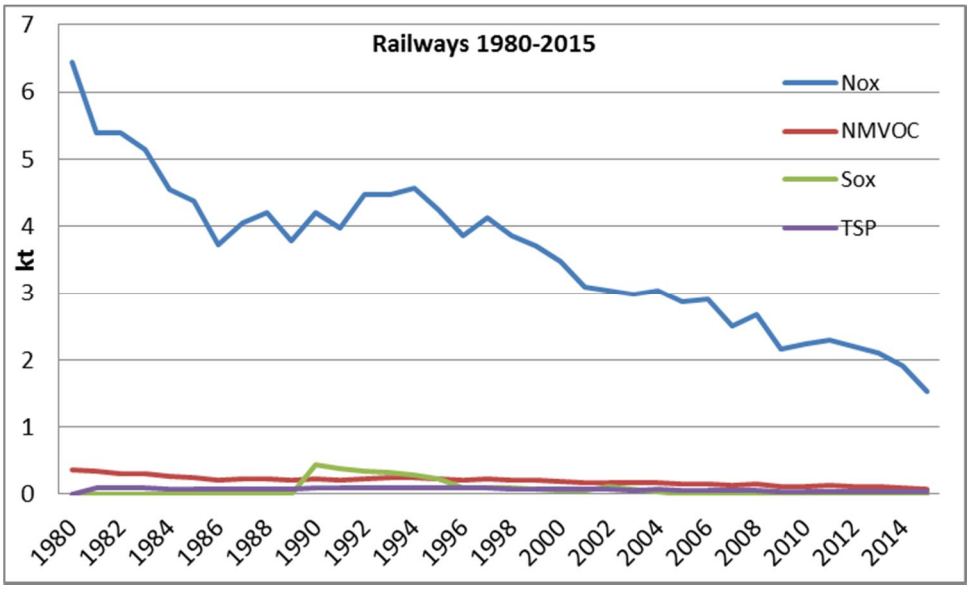

Figure 4.18. Emissions from railway transportation

Railway transport emissions are calculated with the RAILI sub-model of the LIPASTO calculation system (http://lipasto.vtt.fi/lipasto/index.htm) for 1980 – 2030.

In Finland railway transportation is a minor emission source in the transport sector and comprises railway transport operated by diesel locomotives. The railway lines are mainly electrified and transportation in minor railway lines operated by diesel locomotives has ceased. The recession and the rapid restructuring in Finland's forest industry significantly reduced freight carryings in 2008 and 2009. The recession still continued in 2014 and in 2015 there was a significant reduction in the transport volume compared to 2014.

In 2013 electric locomotives ran 86% of railway transportation, the number has increased by 2 percentage unit since 2008. Emissions from producing electricity used in electric trains are not included this category, but in category 1.A 1. According to the Transport and Communications Statistical Yearbook produced by Statistics Finland, in 2013 rail services accounted for over 28% of all freight carryings in Finland, which is considerably higher than the average for EU countries. In

2013 the volume of freight transport in Finland totaled 36.4 million tonnes, which is 3.0% more than in 2012 (Transport and Communications Statistical Yearbook for Finland, 2014).

4.1.21.2 Methodological issues

The RAILI model has been totally renewed and the year 2013 was the first year calculated with the new model. The calculation method is the same as in the old model. The emission factors have been harmonised to comply with the EMEP/EEA 2013 Guidebook and the calculation is carried out on Tier 3 level. The update of the model did not lead to differences in air pollutant emissions.

The RAILI model calculates SO_2, CO, NMVOC, NO_2 and PM emissions by multiplying the amount of fuel used (kg) with emission factors (g/kg fuel). The amount of fuel used is calculated separately for passenger transport, freight transport and locomotives without wagons and for rail yard operations. To include the mobilisation time of the fleet, preparation and finishing times and extra transfer of the fleet, the amount of fuel is multiplied by a factor. This factor is based on an earlier study (research done by VR, the Finnish railway operator) where the total energy use of these activities was calculated and then divided with the total amount of tonne kilometres resulting in a factor for the extra fuel consumption per tonne kilometre.

The amount of fuel used is calculated separately for passenger transport, freight transport and locomotives without wagons and for rail yard operations. To include the mobilisation time of the fleet, preparation and finishing times and extra transfer of the fleet, the amount of fuel is multiplied by a factor. This factor is based on an earlier study (research done by VR-Group Ltd, the Finnish railway operator) where the total energy use of these activities was calculated and then divided with the total amount of tonne kilometres resulting in a factor for the extra fuel consumption per tonne kilometre.

Activity data

Activity data consist of gross tonne kilometres for ten train weight classes on all rail sections (212 sections). Shunting locomotive use is expressed as time (h/a) in all rail yards. There are four separate diesel locomotive types in the model and ten train weight classes for both passenger and freight transport. For every locomotive type, specific energy consumption (litre/gross tonne km) has been determined. Shunting locomotive consumption is determined as litres per hour. Emission factors are expressed as grams per kg fuel used for each gas. Density for the diesel oil is 845 kg/m^3. Emissions from wagon heating and the use of aggregates (for electricity production) are calculated by multiplying gross tonne kilometres with emission factors for wagon heating and aggregates. Fuel consumption is presented in Table 4.18.

The gross tonne kilometre database and shunting locomotive statistics originate from VR Ltd, the only railway operator in Finland. The calculated amount of diesel fuel is crosschecked by the information of VR Ltd on the total fuel usage. All fuel used in railway transportation is nowadays gasoil for non-road use, which is technically the same product as sulphur free diesel oil.

In the calculation of emissions from railway transportation terajoules (TJs) have been used as activity data. Fuel oil consumption in railway transportation in Finland is presented in Table 4.8.

Emission factors

The emission factors are based on the latest version of the EMEP EEA Guidebook.

The formula below has been used in calculation of emissions from diesel trans in RAILI model:

$$E_{v,y} = \sum_{l=1}^{4}\sum_{m=1}^{10}\sum_{x=1}^{2} S_{l,m,y}\, b^{t}_{l,m} \quad V \quad e^{f}_{x,v} + S_{x,y}\, b^{z}\, e^{b}_{x} + S_{x,y}\, b^{a}\, e^{j}_{x} + \sum_{r=1}^{123} H_{l,r,x,y}\, b^{h}_{l,x} \quad e^{f}_{x,v}$$

where

E	is total emissions
S	is gross tonne kilometre
V	is a factor for extra fuel consumption of non-line (1 driving)
H	is shunting time
bt	is the specific fuel consumption per gross tonne kilometre
bh	is the specific fuel consumption per hour
bz	is the specific fuel consumption of heating per gross tonne kilometre
ba	is the specific fuel consumption of aggregate per gross tonne kilometre
ef	is the emission factor per fuel used
eb	is the emission factor per fuel used for wagon heating
ej	is the emission factor per fuel used for aggregates
l	is type of locomotive
m	is train weight class
x	is train type
r	is rail yard
y	is calculation year
v	is compound

(1 mobilisation time of the fleet, preparation and finishing times and extra transfer of the fleet*)*

Calculation of emissions not covered by RAILI

Emissions of small particles and black carbon, ammonia, heavy metals and PAH-4 from railways are calculated at SYKE. PM_{10} and $PM_{2,5}$ size fractions of particulate matter emissions are presented in table 4.13. Black carbon, ammonia and heavy metal (Cd, Cr, Cu, Ni, Se and Zn) emissions are calculated with the Tier 1 emission factors of the EMEP EEA Guidebook 2016. PAH-4 emissions are the sum of emissions of benzo(a)pyrene and benzo(b)fluoranthene, for which Tier 1 emission factors are given in EMEP EEA Guidebook 2016.

4.1.21.3 Uncertainties

Uncertainties will be reported in the Annex of the IIR by 1st May.

4.1.21.3.1 QA/QC and verification

The amount of gasoil calculated by VTT is crosschecked with the information of VR-Group on the total fuel usage. Statistics Finland crosschecks the fuel consumption data calculated within the RAILI model.

SOx, NOx, NMVOC and CO were compared to the data reported under the UNFCCC calculated at Statistics Finland.

4.1.21.4 Source specific planned improvements

None.

4.1.22 Navigation

1 A 3 d ii National navigation (Shipping)

Changes in chapter	
Update of emission figures	March 2016 JMP
Update of text	January 2017 KS
Other (e.g. language, layout)	January 2017 KS

4.1.22.1 Source category description

Domestic navigation includes sea-going ships, icebreakers, working boats, cruisers, ferryboats and leisure boats. Fishing boat emissions are included in the Agriculture, forestry and fisheries' sectors. Details on the inventory are presented in Chapter 4.3.2.

Domestic navigation is a minor emission source and the trends of all emissions are declining due to decreased activity.

4.1.22.2 Emission trends

Sulphur dioxide, nitrogen oxides, carbon monoxide, NMVOC and particle emissions from navigation are included in the inventory and presented in Figure 4.19.
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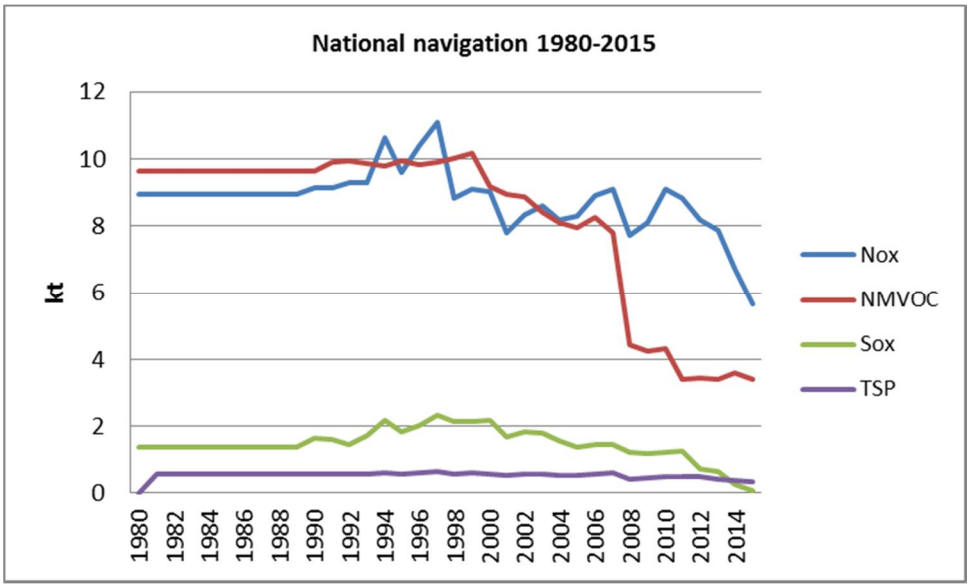


Figure 4.19. Emissions in 1980-2015 from National navigation

The amount of leisure boats increased strongly throughout the 1980s, as well as visits of ships in ports. The increase was folded by the recession in the beginning of the 1990. The amount of visits in ports have been fluctuating during the whole time series. In 2008, two contemporaneous changes concerning leisure boating took place: there was a significant increase in fuel price and a change in legislation stating that all diesel driven boats had to use higher taxed diesel fuel, which together led up to a clearly lower use of leisure boats.

Passenger ships show a stable trend, while cargo vessels have a downward trend due to the prolonged economic downturn.

Depending on the ice conditions at the Baltic Sea, the fuel consumption of icebreakers can vary substantially as can be seen in Table x.

4.1.22.3 Methodological issues

STEAM model

The Finnish Meteorological Institute has a world leading ship emission model STEAM, where the ship emission calculations are based on data from AIS (Automatic Identification System) on the entire Baltic Sea. The detailed results of this model have been used to estimate characteristics of ships, auxiliary engines, speeds and fuel types.

Fuel consumption

Data on total fuel consumption of icebreakers are obtained from Arctia Shipping Ltd.

Data on total fuel consumption of ferryboats and small ferries are acquired from road authorities Ferryboats are used to transport road vehicles across narrow water straits on the public road network and small ferries are used for transport connections between islands in the Finnish Archipelago. The amount of used fuels by ship type are described in Table x

Amount of used fuels (TJ) have been partly used as activity data to calculate emissions of domestic navigation.

Table 4.25 Fuel consumption (PJ) in national navigation by ship type 1990-2015

	Leisure boats	Passenger ships (domestic)	Cruisers	Cargo vessels	Working boats	Ferryboats	Icebreakers
1990	2.25	0.16	0.10	1.19	1.42	0.27	0.48
1995	2.35	0.12	0.10	1.39	1.27	0.31	0.58
2000	2.43	0.42	0.15	1.63	1.26	0.29	0.82
2005	2.40	0.47	0.12	1.24	1.26	0.28	0.98
2006	2.47	0.36	0.12	1.51	1.27	0.27	1.19
2007	2.48	0.39	0.12	1.68	1.27	0.27	1.16
2008	2.03	0.36	0.12	1.64	1.27	0.26	0.54
2009	2.10	0.36	0.12	1.52	1.27	0.26	0.86
2010	2.24	0.34	0.12	1.69	1.27	0.27	1.28
2011	1.78	0.45	0.12	1.89	1.27	0.26	1.11
2012	1.88	0.57	0.12	1.58	1.27	0.34	0.78
2013	2.00	0.64	0.12	1.29	1.27	0.31	0.85
2014	1.84	0.52	0.12	1.15	1.27	0.28	0.49
2015	1.89	0.52	0.08	1.21	1.27	0.30	0.55

National boat register

New legislation on the Finnish Boat Register entered into force in October 2007 and a thorough renovation of the national boat register was completed by the end of 2011. The coverage of the register was improved. by new groups of boats starting from 2008. As the register is a substantial source of the number and size of the leisure boats (actually the size of engines) this renovation has affected the results of the emission calculation of leisure boats. Over the years the number of boats in the register increased more than boats existed in reality because there was no sanction if the boat was not removed from the register after the boat (engine) was scrapped. In the renovation all boats that were not reregistered were removed from the register. This concerned boats (engines) over 20 horsepower. As a result the calculated emissions of leisure boats in 2011 were decreased compared to the emissions in 2010.

The number of bigger leisure boats is received from the Boat Register, the number of smaller boats is an estimation based on a thorough study made by VTT in 2004. The Boat Register data include information on the type of engine(s), engine power and age.

The database from the Finnish Transport Agency is analysed to produce power and speed classes for the ships. In addition, origin-destination matrices are produced using the data.

The number of working boats is obtained from different official organisations (e.g. customs, sea rescue).

The number of cruisers (sightseeing boats, etc.) comes from the Finnish Transport Agency.

Ferry traffic between Finland and Sweden

Ferry traffic between Finland and Sweden is frequent. Since 1999, all ferries have been put in at the ports of Åland (which is an archipelago between Sweden and Finland belonging to Finland) but only a very small portion of passengers on these ferries are actually travelling between the mainland and Åland (e.g. 0.7% of all passengers using the Helsinki to Sweden lines travel between Helsinki and Åland).

The method used to separate domestic ferry traffic from international traffic to Sweden is to define domestic ship kilometres according to the share of passengers travelling to the archipelago of Åland.

Channels outside ports

The activity data of ships driving in shipping channels outside ports (km/a) are calculated using the number of port visits and the distances between the ports (km). The total energy use (kWh) is calculated for every ship type using the data on engine power (kW), engine load (%) and speed (km/h). In the model there are 9 different ship types. Ships are further divided into different engine types (2-stroke and 4-stroke). These are further divided into different emission levels, at the moment from Tier 0 to Tier 2. Ships have 7 size categories. Emissions are calculated according to the fuels ships are using: Heavy fuel oil (HFO), HFO + scrubber, Marine diesel oil / Marine gas oil (MDO/MGO), Diesel and Gas (LNG).

Port visits

A detailed database on every ship visit in Finnish ports is run by the Finnish Maritime Administration. The database includes data on ship type, age, size (GRT), engine power, speed, load, port, previous port, destination, nationality, and trip type (domestic/international). Ferry traffic between Finland and Sweden is very frequent. Since 1999 all ferries have been put in at the ports of Åland (which is an island between Sweden and Finland belonging to Finland) but only a very small portion of passengers on these ferries are actually travelling between the mainland and Åland (e.g. between Helsinki and Åland 0.7% of all passengers using the Helsinki to Sweden lines). The method used to separate domestic ferry traffic from international traffic to Sweden is to define domestic ship kilometres according to the share of passengers travelling to the Island of Åland.

The database from the Finnish Maritime Administration is analysed to produce power and speed classes for the ships. In addition, origin-destination matrices are produced using the data.
The Finnish Maritime Administration's database is very accurate and detailed.

For calculating emissions in ports, the time (h) of manoeuvring and berthing is determined. Using engine power (kW), engine load (%) and time (h) taken for manoeuvring and berthing, the total energy use in the ports (kWh) is calculated for every ship type. The total emissions are obtained by multiplying the total energy use (kWh) of ships by the emission factors (g/kWh) of different engine types (2-stroke and 4-stroke and auxiliary engines) (g/kWh). Emission factors are at the year 1996 level but correction factors are used to update the factors to date.

MEERI sub-model of LIPASTO

Waterborne traffic emissions are calculated with the MEERI sub-model of the LIPASTO calculation system (http://lipasto.vtt.fi/lipasto/index.htm) for 1980 – 2030.

MEERI calculation system is based on port traffic service data. The system calculates emission amounts and energy consumption caused by waterborne traffic in shipping channels and in ports during base year 2006. Data is specified according to a type of ship (passenger ship, freight ship), its traffic service area (domestic traffic, international traffic), its origin (Finnish, international) and its tonnage (gross registered tons). In countrywide calculation it is possible to make an even more detailed choice of vessel type (e.g. passenger car ferry, tanker).

Emission data is calculated both on countrywide and on port level. The inventory does not include army ships and vessels. Emission estimates for the years 1980 - 1995 are on a more rough level

than years thereafter. The years 1996 - 2010 are calculated with detailed models and forecasts up to 2030.

In the model the amount of energy used (kWh) for each vessel type is multiplied by the corresponding emission factors (g/kWh). For icebreakers, ferryboats and lossit emissions are calculated at Tier 2 level by multiplying the amount of fuel used (kg/a) by emission factors (g/kg fuel)

Activity data for ships driving in shipping channels outside ports (km/a) are calculated using the number of port visits and the distances between the ports (km). The total energy use (kWh) is calculated for every ship type using the data on engine power (kW), engine load (%) and speed (km/h). There are nine different ship types in the model. Ships are further divided into different engine types (two-stroke and four-stroke) and emission levels, at the moment from Tier 0 to Tier 2. Ships have seven size categories.

Emissions are calculated based on the fuels ships are using: Heavy fuel oil (HFO), HFO + scrubber, Marine diesel oil / Marine gas oil (MDO/MGO), Diesel and Gas (LNG). The methods for calculating emissions from domestic navigation are on Tier 3 level.

Fuel consumption by ship type are presented in Table 4.25.

Emissions in ports

For calculating emissions in ports, the time (h) of manoeuvring and berthing is determined. Using engine power (kW), engine load (%) and time (h) taken for manoeuvring and berthing, the total energy use in ports (kWh) is calculated for every ship type. Total emissions are obtained by multiplying the total energy use (kWh) of ships by the emission factors (g/kWh) of different engine types (2-stroke and 4-stroke and auxiliary engines) (g/kWh).

The formula below has been used in calculation of emissions from all ships in the MEERI model except icebreakers:

$$E_{v,y} = \sum_{l=1}^{9}\sum_{m=1}^{7}\sum_{z=1}^{3}\sum_{p=1}^{7}\left(\begin{array}{l}\dfrac{S_{l,m,x,f,y}\ d_{x,l,m,f,y}\ p_{l,z,m}\ g_o}{f_{l,m}}\ e_{l,m,v,g,z} + S_{l,m,x,y}\ p_{l,z,m}\ g_o\ t\ e_{l,m,v,g,z} \\ +u\ p_{l,z,m}\ g_o\ e_{l,m,v,g,z}\end{array}\right)$$

where

E is total emissions
S is number of ships
d is distance travelled (from previous port visit)
e is the emission factor
l is type of ship
m is gross register ton class
x is port
o is operation area
z is engine type
p is engine power class
g is engine load
f is speed class
t is time used for manoeuvre and berthing
y is calculation year
v is compound

Icebreakers and ferries

Icebreaker and ferryboat emissions are calculated using total fuel consumption (from operator statistics, Icebreaker consumption from Arctia Shipping Oy and ferryboat consumption from Destia) and corresponding emission factors. Data on total fuel consumption of icebreakers are obtained from the Finnish Maritime Administration. Data on total fuel consumption of ferryboats are acquired from road authorities Ferryboats are used to transport road vehicles across narrow water straits on the public road network. The formula below has been used in calculation of emissions from icebreakers:

$$E_{v,y} = V_y \, e_v$$

where

E	is total emissions
V	is total fuel use of icebreakers
e	is emission factor
v	is compound
y	is calculation year

Leisure boats

The number of leisure boats increased strongly in the 1980's as well as the number of visits of ships in ports. The increase was folded by the recession in the beginning of the 1990's. The number of visits in ports have been fluctuating during whole time series. During 2008 two contemporaneous changes concerning leisure boating took place, namely a significant increase in fuel price and a change in legislation stating that all diesel driven boats had to use the higher taxed diesel fuel. All this led up to clearly low use of the leisure boats.

The methodology of leisure boat emission calculation was changed during the year 2011 and is based on the use of energy (kWh) and corresponding emission factors (g/kWh). Energy use is calculated by boat category (6), engine type (4), average engine power class (10) (kW), engine load (%) and average operation time per year (h/a). The total emissions are calculated by multiplying the total energy use (kWh) of engine types and corresponding emission factors (g/kWh).

The number of bigger leisure boats is received from the Finnish Boat Register, the number of smaller boats is an estimation based on a thorough study made by VTT in 2004. The Boat Register data include information on type of engine(s), engine power and age.

The MEERI model was modified to include a factor to handle annual changes in the leisure boat average operating hours. The results of the modification are included in 2008 data, but they did not affect the years prior to 2008.

The formula below has been used in calculation of emissions from leasure boats:

$$E_{v,y} = \sum_{l=1}^{6} \sum_{m=1}^{10} \sum_{x=1}^{4} S_{l,m,x,y} \, m_{l,x,} \, g_l \, t_l \, e_{v,x}$$

where

E	is total emissions
S	is number of boats
e	is the emission factor
l	is type of leisure boat

m is engine power class
z is engine type
t is average operating time
g is engine load
y is calculation year
v is compound

Working boats

The total emissions of working boats and cruisers are calculated by multiplying the total fuel use (kg/a) of boats by emission factors (g/kg fuel). Fuel consumption of these boats is calculated using the number of boats in different boat categories, engine power classes (kW) and average fuel consumption of a corresponding boat per year (kg/boat/a). The number of working boats is obtained from different official organisations (e.g. customs, sea rescue).

The formula below has been used in calculation of emissions from working boats:

$$E_{v,y} = \sum_{x=1}^{3} S_{x,y} \, V_{x,y} \, e_v$$

where

E is total emissions
S is number of working boats
V is total fuel use of a working boat
e is emission factor
x is type of working boat
v is compound
y is calculation year

The number of cruisers (sightseeing boats, etc.) comes from the Finnish Maritime Administration. The number of bigger leisure boats is received from the Finnish Boat Register, the number of smaller boats is an estimation based on a thorough study made by VTT in 2004. The Boat Register data include information on type of engine(s), engine power and age.

Passenger ships, cruisers

Passenger ships show stable trend while cargo vessels have downward trend due to the prolonged economic downturn. Depending on the ice conditions at the Baltic Sea the fuel consumption of icebreakers can vary substantially as can be seen in 0.

The number of cruisers (sightseeing boats, etc.) comes from the Finnish Transport Agency.

Calculation of emissions not covered by MEERI

Emissions of small particles and black carbon, ammonia, heavy metals, dioxins and furans and HCB from navigation are calculated at SYKE. PM_{10} and $PM_{2,5}$ size fractions of particulate matter emissions are presented in table 4.13. Black carbon, heavy metal (Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn), PCDD/F and HCB emissions are calculated with the Tier 1 emission factors of the EMEP EEA Guidebook 2016. Ammonia emissions are calculated with emission factors (4.7 mg/kg for gasoline fuels and 7.9 mg/kg for oil fuels) taken from COPERT III and suggested by VTT.

4.1.22.4 Uncertainties

Uncertainties will be reported in the Annex of the IIR by 1st May.

4.1.22.5 QA/QC and verification

Statistics Finland crosschecks the fuel consumption data calculated within the MEERI model.
.
SOx, NOx, NMVOC and CO were compared to the data reported under the UNFCCC calculated at Statistics Finland.

4.1.22.6 Source specific planned improvements

None.

4.1.23 International maritime navigation

1 A 3 d i (i) International maritime navigation

Changes in chapter	
Update of emission figures	February 2017 KS
Update of text	February 2017 KS
Other (e.g. language, layout)	February 2017 KS

4.1.23.1 Emission trends

Emission trends 1990-2015 from international maritime navigation are decreasing as presented in Figure 4.20.

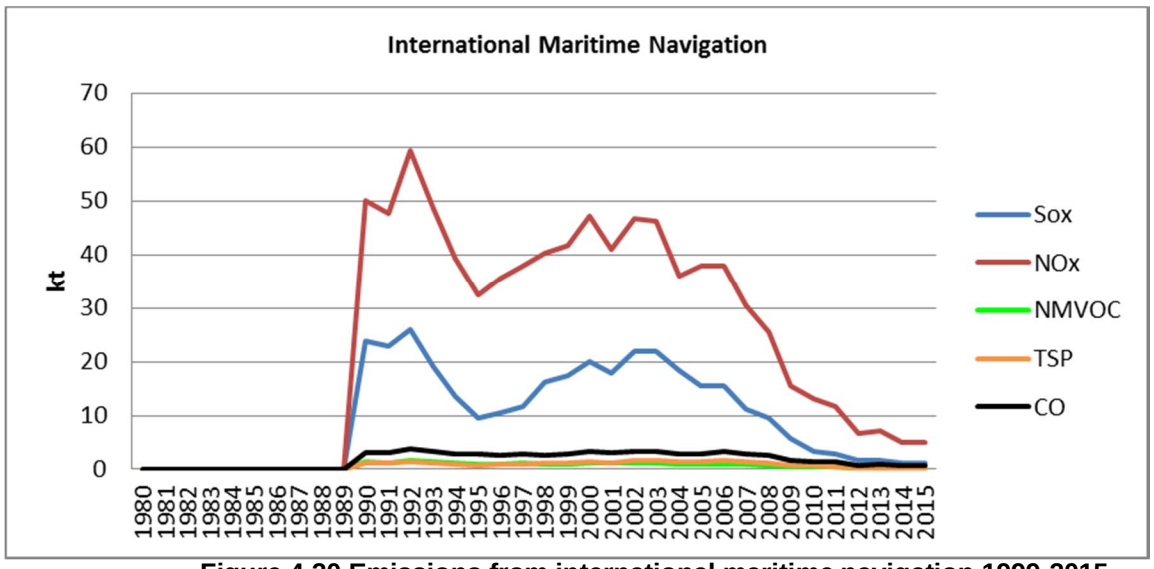


Figure 4.20 Emissions from international maritime navigation 1999-2015

4.1.23.2 Methodological issues

In accordance with the Guidelines, international marine bunker fuel emissions are not included in national totals.

The fuel use for international navigation is calculated according to the UNFCCC and UNECE reporting guidelines at Statistics Finland. In the NFR tables emissions from international maritime navigation are the same as reported in the Finnish greenhouse gas inventory under the UNFCCC (Figure x). The methodology for calculation of these emissions is explained in the Finnish NIR (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php)

4.1.23.3 Uncertainties

Uncertainties will be reported in the Annex of the IIR by 1st May.

4.1.23.4 QA/QC and verification

Statistics Finland crosschecks the fuel consumption data calculated within the MEERI model.
.
SOx, NOx, NMVOC and CO were compared to the data reported under the UNFCCC calculated at Statistics Finland.

4.1.23.5 Source specific planned improvements

Emissions for heavy metals and persistent organic pollutants will be added in the future. In addition, a future project lead by the Finnish Maritime Administration will provide more detailed information even in the EMEP grid.

1 A 3 d i (ii) International inland waterways

This source does not exist in Finland.

4.1.24 4.3.2.5 Pipeline compressors

1A3 e i Pipeline compressors

4.1.24.1 Emission trend

Emissions from pipeline compressors have been reallocated under NFR 1A3ei since the year 2009 and cover both emissions from gas turbines and fugitive emissions at the compressor stations. Presentation of the trend will be added when the time series is recalculated.

4.1.24.2 Methodological issues

Emissions from pipeline compressors are reported by the operators and the data is available in VAHTI.

4.1.24.3 Uncertainties

Uncertainties will be reported in the Annex of the IIR by 1st May.

4.1.24.4 QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out. The data obtained from VAHTI is cross-checked against the summary data (by fuels and by CRF categories) reported to the UNFCCC as explained in Chapter 2.3.4.

Corrections made to 2015 VAHTI data are listed in Annex 4 of Part 2 of the IIR.

At present, no verification has been carried out for the specific source-sector emissions.

4.1.24.5 Source specific planned improvements

Reallocation of emissions from the earlier years to NFR 1A3ei will be carried out when updating the inventory.

4.1.25 Off-road mobile sources

Changes in chapter	
Update of emission figures	March 2017
Update of text	January 2017 KS
Change in methodology	none
Other (e.g. language, layout)	January 2017 KS

1 A 2 g ii Mobile Combustion in manufacturing industries and construction
1 A 4 a ii Commercial / institutional: Mobile
1 A 4 b ii Residential: Household and gardening (mobile)
1 A 4 c ii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
1A 4 c iii Agriculture/Forestry/Fishing: National fishing
1 A 5 b Other, Mobile (including military, land based and recreational boats)

Off-road machinery is used out of road network, for instance such as tractors, forest machinery, road work machinery, snow mobiles, lawn movers and chain saws. The estimated emissions from

off-road machinery (machinery used in construction, agriculture and other applications) are included in the inventories and reported under the relevant emission sectors.

4.1.25.1 Emission trend

The emission reduction requirements have been tightened the last decade following the development of those for vehicles. Efficient reduction of emissions may increase fuel consumption. Particle, sulphur and nitrogen oxide emissions have come down, however, for instance CO emissions, which have come down during the latest years, are expected to grow along with the growth of the fleet/fuel consumption.

The emission trend of off-road vehicles and other machinery follows the overall trend of emissions; economic depression at the beginning of 90's decreased emissions. After that especially emissions from leisure time activities has increased (gasoline; ATV (all-terrain vehicle), snowmobiles) while emissions from business activities have decreased (gasoil/diesel).

Economic depression that started in 2008 has lowered the leisure time activity and hence the emissions in 2008. During 2009 the use of off-road vehicles and machinery was at lowest level in the total time series. In 2010 the market began to recover and the use of these vehicles and other machinery increased. Prolonged economic downturn has again turned the trend downwards. The greatest increase was in off-road vehicles and other machinery using gasoil/diesel. The use of biofuels started in 2008 and in 2010 the use was doubled.

Emission and fuel consumption trends are presented in Figure 4.21 and fuel consumption in NFR 1A4 and 1A5 in Table 4.20.

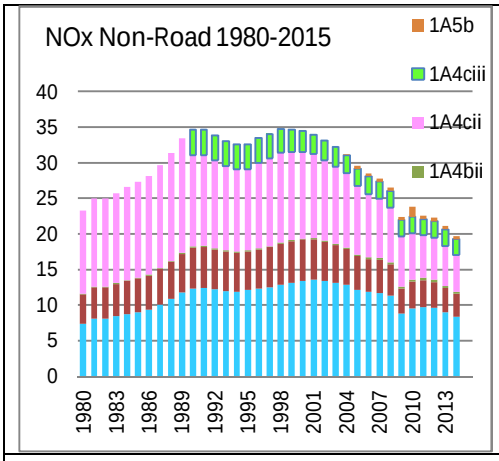


Figure 4.21 Emission trends and fuel consumption 1980-2015 *(to be completed to 2018 submission)*

Table 4.6. Fuel consumption 1990-2015 in NFR 1A4 and 1A5 (PJ) (Statistical Yearbook, 2011), includes both stationary and mobile.

The latest statistical yearbook can be found electronically at http://pxweb2.stat.fi/sahkoiset_julkaisut/vuosikirja2013/html/engl0005.htm

		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Liquid fuels	Heavy fuel oil	19.2	7.5	6.8	7.0	6.7	6.3	5.7	5.7	5.4	4.8	4.4	4.6	4.0	3.9
	Light fuel oil	82.6	75.4	71.3	65.7	63.0	60.9	54.2	51.2	55.0	48.4	52.1	47.9	46.1	42.8
	LPG	2.0	2.4	2.6	2.9	3.3	2.8	3.5	2.9	3.8	3.7	3.9	3.5	3.8	3.6
	Other liquid fuels	3.5	4.5	5.2	5.8	6.0	6.2	5.9	5.6	5.9	5.1	5.5	5.4	4.9	4.9
Solid fuels	Hard coal	0.52	0.29	0.21	0.13	0.12	0.12	0.12	0.14	0.15	0.15	0.12	0.10	0.10	0.10
Gaseous fuels	Natural gas and other gaseous fuels	3.0	5.3	7.0	7.4	7.6	7.2	6.3	6.9	7.5	6.9	6.7	6.6	6.4	7.1
Biomass	Woodfuels and other biofuels	45.3	45.1	45.8	54.5	56.3	56.7	61.5	65.9	74.1	63.3	68.7	63.9	63.2	59.6
Peat	Peat	1.4	1.1	1.3	1.6	1.6	1.8	1.9	2.1	2.6	2.1	2.3	2.4	1.7	1.6
Other	Mixed fuels and waste	0.003	0.001	0.001	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

4.1.25.2 Methodological issues

The calculation of off-road machinery is carried out at VTT Technical Research Centre by TYKO calculation model designed for the inventory of off-road machinery. The model estimates emissions and energy consumption of non-road machinery for five main categories: Drivable diesel, drivable gasoline, moveable diesel, moveable gasoline and handheld gasoline, totalling 51 different machine types. The main results of the TYKO model can be seen on the website: http://lipasto.vtt.fi/tyko/results.htm.

Unit emission figures for working machines on LIPASTO pages acknowledge the characteristics of the Finnish fleet, including age distribution and average power usage. Therefore the figures represent the average usage of each working machine type in Finland. Differences between old and new working machines may be significant. Information on emission standards and regulations in the European Union for road vehicles and working machines is available on DieselNet.

Values presented in Table 4.26 have been used for reformulated fuels while calculating the unit emissions.

Table 4.26 Properties of reformulated fuels used in calculation of unit emissions

Gasoline									
Specific	*weight*		0.75	kg/l	(density		750		kg/m³)
Heating		*value*			43				MJ/kg
Energy	1		kWh		=		3.6		MJ
Sulphur	*content*	*(S)*	0.0008	w-%	=	0.016		g/dm³	SO_2
Carbon dioxide (CO_2)	2350 g/(dm³ fuel) = 3133 g/(kg fuel)								
Diesel									
Specific	*weight*		0.845	kg/l	(density		845		kg/m³)
Heating		*value*			43				MJ/kg
Energy	1		kWh		=		3.6		MJ
Sulphur	*content*	*(S)*	0.0010	w-%	=	0.020		g/dm³	SO_2
Carbon dioxide (CO_2)	2660 g/(dm³ fuel) = 3148 g/(kg fuel)								

Emissions are calculated separately for gasoline, diesel and LPG machinery. The main method is to sum up the product of the machinery population, engine power, load factor, activity hours and

emission factors. Data on machine population are based on national estimations, machinery registrations, sales figures and knowledge on the life expectancy of machinery.

The Tier 3 calculation method is consistent with the EMEP/EEC Guidebook and is widely used, for example, in the U.S. EPA Nonroad model (1998) and CORINAIR Off-Road vehicle and Machines model (Andrias et al., 1994). Emissions in TYKO model are calculated with the formula below:

$$E_{v,t} = \sum_{l=1}^{44}\sum_{r=1}^{4} e_{l,r} \cdot g_{l,r} \sum_{t=1}^{40} k_{l,r,y} \sum_{m=1}^{40}\sum_{p=1}^{4}\sum_{u=1}^{3}\sum_{d=1}^{2} S_{l,m,p,r,u,d,t} \cdot a_{l,p,r,u,m,t,v,t} \quad (1)$$

where ,

Ev,y is total emissions v in year *y*
S is number of machines (population)
e is rated power
g is average load factor
k is activity (hours per year)
a is emission factor

indexes

l is type of machinery
m is model year of machine
p is type of engine
r is power class (average rated power)
u is fuel type
h is average lifetime
d is type of usage (professional/leisure)
y is age of machinery
v is compound
t is calculation year

$$S_t = S_{t-1}\ (1 - w_t) + C_t$$

St is machinery population in year *t*
wt is wastage of machinery in year *t*
Ct is sales of machinery in year *t*

Table 4.27 Breakdown of different machine types in TYKO model.

NFR subcategory	Type of machine
1A2gvii Other / mobile	Generator sets, gasoline
	Other moveable machines, gasoline
	Plate compactors
	Dumpers
	Rollers
	Excavators, skid steer
	Excavators, rubber tire
	Cranes
	Bulldozers
	Wheel loaders
	Telehandlers
	Tractors in industry

	Backhoe loaders
	Generator sets, diesel
	Compressors
	Other moveable machines, diesel
	Compactors, diesel
1A4aii Commercial/institutional	ATV, 2-stroke, professional
	ATV, 2-stroke, leisure
	ATV, 4-stroke, professional
	ATV, 4-stroke, leisure
	Snowmobiles, 2-stroke professional
	Snowmobiles, 2-stroke leisure
	Snowmobiles, 4-stroke professional
	Snowmobiles, 4-stroke leisure
	Other drivable, gasoline
	Forklift, gasoline
	Forklift, gas
	Chain saws, hobby
	Other handheld machines
	Forklifts, diesel
	Maintenance tractors
	Mini excavators, skid steer
	Skid steer loaders
	ATV, diesel
	Other drivable machines, diesel
	Other tractors
	Other lifts, diesel
	Graders
1A4bii Residential: Household and gardening	Riding mowers, gasoline
	Snow blowers
	Lawn movers, handheld
	Trimmers
	Lawn tractor, diesel
1A4cii Agriculture/Forestry/Fishing	Soil cultivator
	Combine harvesters
	Farm tractors
	Professional chain saws
	Clearing saws
	Forest harvesters
	Forwarders (forest tractors)

Calculation of emissions not covered by TYKO

Emissions of small particles and black carbon, ammonia, heavy metals, PAH-4 and NMVOC from off-road machinery are calculated at SYKE. PM_{10} and $PM_{2,5}$ size fractions of particulate matter

emissions are presented in table 4.13. Black carbon, ammonia and heavy metal (Cd, Cr, Cu, Ni, Se and Zn) emissions are calculated with the Tier 1 emission factors of the EMEP EEA Guidebook 2016. PAH-4 emissions are the sum of emissions of benzo(a)pyrene and benzo(b)fluoranthene, for which Tier 1 emission factors are given in EMEP EEA Guidebook 2016. NMVOC emissions are calculated by subtracting the CH_4 emission values from the TOC values from VTT LIPASTO calculation system.

4.1.25.3 Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

IPTJ includes currently emission data for the years 2000 – 2015 only. The recalculation of emissions in the earlier years will be carried out in the next years.

4.1.25.4 Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out. At present, no verification has been carried out for the specific source-sector emissions.

4.1.25.5 Source-specific recalculations including changes made in response to the review process

The updated time series 1990-2009 of heavy metal emissions from tyre and break wear as well as particle emissions from road abrasion and tyre and brake wear were reported in the 2011 submission.

Emissions from pipeline compressors have been reallocated under 1A3e since year 2009 emissions.

The revision of stock change data in the 2016 submission in the energy statistics affected to the residuals of fuels and statistical corrections.

4.1.25.6 Source-specific planned improvements

Emissions from the small scale inland cruising passenger transport are not included in the inventory at the moment as there is no data available for estimation of these emissions. The inventory includes, However, inland waterway ferries and leisure boats.

Reallocation of pipeline compressor emissions from the earlier years to NFR 1A3e will be carried out when updating the inventory.

Commercial/Institutional and Residential Plants, Household, Gardening, Agriculture/Forestry/Fishing and Other Stationary sources

Changes in chapter	
Update of emission figures	March 2017
Update of text	November 2016 KS
Change in methodology	2014-16 Small scale combustion
Other (e.g. language, layout)	February 2017 KS

1 A 4 a i Commercial / institutional: Stationary
1 A 4 c i Agriculture/Forestry/Fishing: Stationary
A 5 a Other stationary (including military)

4.4.1 Source category description – other fuels than wood

This chapter covers emissions from stationary combustion in commercial, institutional and residential sectors for NFR categories 1A4ai, 1A4ci and 1A5a. The description of combustion in residential buildings under NFR category 1A4bi is provided in Chapter 4.4.2.

NFR 1A4ai includes at the moment also emissions from point sources and part of such non-point source emissions that should correctly be allocated under NFR 1A1a. At the moment, emissions from some larger boilers that are connected to the district heating network are included in the inventory.

For other pollutants than BC and NH3 the time series has not been corrected.

A revision to the allocation in the time series will be possible to make only when the recalculation of the whole time series has been recalculated.

The emission inventory for mobile sources (1A2gviii, 1A4aii, 1A4bii, 1A4cii, 1A4ciii and 1A5b) is documented in Chapter 4.3. (Table 4.27a).

Table 4.28 Activities and emissions reported under NFR 1A4 and 1A5a.

NFR	Source	Emissions	Chapter
1A4ai	Commercial/ Institutional combustion - stationary	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB	4.4.11
1A4bi	Residential combustion - Stationary plants	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB	4.4.2
1A4ci	Combustion in Agriculture/Forestry/Fishing - Stationary	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB	4.4.11
1A5a	Other stationary combustion (including military)	NO_X, NMVOC, SO_X, NH_3, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB	4.4.11
1A2gviii, 1A4aii, 1A4bii, 1A4cii, 1A4ciii and 1A5b	Off-road, non-road, mobile sources (including military)	NOX, NMVOC, SOX, NH3, TSP, PM10, PM2.5, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB	4.4.6.4

Fuel combustion in these sectors in 1990-2014 by subcategory are presented in Figure 4.22 and in Table 4.10

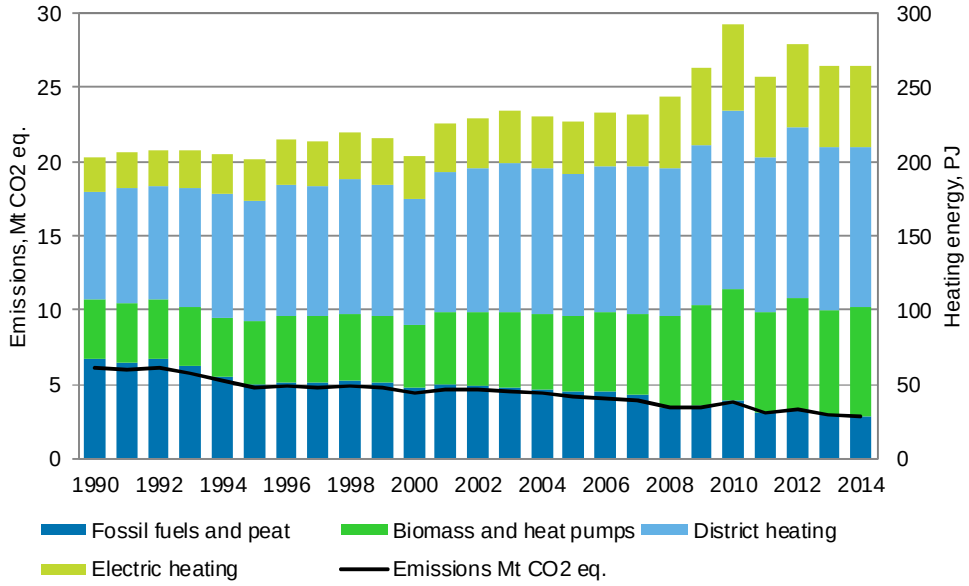


Figure 4.22. Energy consumption of heating in residential, commercial and public buildings and CO2 emissions of stationary combustion in CRF 1.A 4ai, 1.A 4bi and 1.A 4ci (Energy Statistics, Finnish NIR 2014)

The calculation of small scale combustion of wood has been revised (Chapter 4.3.6).

Methodological issues – other fuels than wood

The inventory is based on the difference in the consumption of fuels between the energy statistics and point sources, allocated to activities under this sector. The calculation methods are based on the EMEP/EEA Emission Inventory Guidebook.

$$E_{pollutant} = AR * EF_{fuel}$$

Where
E = Emissions of a pollutant
AR = Activity rate (e.g. energy value by fuel combustion)
EF_{fuel} = Fuel specific emission factor

Activity rate is derived from the following equation:

$AR = \Delta H_c * F_s$ where ΔH_c = Heat of combustion [GJ/t]
F_s = Fuel consumption (source specific) [t]

Fuel consumption F_s is obtained from the energy statistics (Statistics Finland 2016). Wood is the most common fuel (74% in 2012) followed by light fuel oil (24%) in residential buildings. Fuel consumption for NFRs 1A4 and 1A5 is presented in Table 4.33.

Table 4.33. Fuel combustion in NFR 1A4 and 1A5 1990-2014.

		1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Liquid fuels	Heavy fuel oil	19.3	7.6	6.9	7.3	7.1	6.7	6.0	6.0	5.8	5.1	4.8	4.7	4.3
	Light fuel oil	82.7	75.5	71.4	65.8	63.1	61.0	54.3	52.7	55.5	48.5	52.2	48.5	47.0
	LPG	2.0	2.4	2.6	2.9	3.3	2.8	3.5	2.9	3.8	3.7	3.9	3.5	3.8
	Other liquid fuels	3.5	4.5	5.2	5.6	5.8	6.0	5.8	5.6	5.9	5.1	5.6	5.5	5.0
Solid fuels	Hard coal	0.52	0.29	0.21	0.13	0.12	0.12	0.12	0.14	0.15	0.15	0.12	0.10	0.10
Gaseous fuels	Natural gas and other gaseous fuels	3.0	5.3	7.0	7.5	7.8	7.4	6.4	7.0	7.6	6.8	6.6	6.5	6.1
Biomass	Woodfuels and other biofuels	45.3	45.1	45.8	54.5	56.3	56.7	61.5	65.9	74.1	63.4	68.7	63.9	63.1
Peat	Peat	1.4	1.1	1.3	1.6	1.6	1.8	1.9	2.1	2.6	2.1	2.3	2.4	1.7
Other	Mixed fuels and waste	0.003	0.001	0.001	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO

At the moment, emissions from some larger boilers that are connected to the district heating network are included in these emissions. A revision to the allocation will be made to the next submission.

Procedure of calculation (other than small scale wood combustion)

Phase 1 - collection of activity data

The calculation of emissions in NFR categories 1A4ai, 1A4bi, 1A4ci and 1A5a is carried out by using the same methodology as with the NFR category 1A1 (energy industries). In contrast to the calculation of 1A1, fewer assumptions and corrections are applied as no detailed information is available for many small combustion units. Activity data is primarily obtained from the energy statistics and made compatible with the data submitted to the UNFCCC calculated at Statistics Finland. The emissions are calculated using national emission factors. The implied emission factors are provided in Annex 2.

The number of active boilers recorded into VAHTI included in the NFR 1A4 sector are presented in Table 4.26. Fuel consumption data obtained from the energy statistics is used when information on the fuel use at boiler level is not available.

Most of these are handled as non-point sources and the calculatory value is derived from reducing known point source emissions from the fuel-use-based statistics per source category. For non-point sources the activity data is currently available for the sources presented in Table X. To balance the equation of calculation of fuel use, the residue of total fuel consumption minus known point sources minus known non-point sources is allocated between unspecified energy production, district heating and industry.

Table 4.29 Source categories for non-point emissions

Type of facility	
Category	Source
Heating of residential buildings	Block houses
	Summer cottages
	Detached houses
	Row houses
Households	not heating, not off-road
Agriculture, forestry, fishing	not heating, not off-road
Agricultural buildings, heating	Agricultural buildings
Service buildings, heating	Service buildings, heating
Balance	Raw material energy use
	Balance, district heating
	Balance, other industry

The number of active boilers recorded into VAHTI included in the NFR 1A4 sector are presented in Table 4.26. Fuel consumption data obtained from the energy statistics is used when information on the fuel use at boiler level is not available.

The allocation of these point sources into NFR 1A4 needs to be revised, e.g. utilizing new information of district heating plants and allocating these under NFR 1A1. Also, part of the non-point source emissions, currently allocated under NFR 1A4, will then be removed under 1A1.

Table 4.30 The number of boilers active in 2015 (VAHTI, 2017).

Category	Number of boilers in 1A4ai	Number of boilers in 1A4bi	Number of boilers in 1A4ci	Number of boilers in 1A5a
Combustion plants > = 300 MW (boilers)	0	0	0	0
Combustion plants > = 50 and < 300 MW (boilers)	0	0	0	0
Combustion plants > = 20 and < 50 MW (boilers)	2	0	0	0
Combustion plants < 20 MW (boilers)	24	6	0	2
Gas turbines	0	0	0	0
Stationary engines	4	0	0	0
Process ovens	0	0	0	0
Other equipment	2	0	0	0
Total	32	3	0	2

Phase 2 - calculation of emissions

In general, the calculation of emissions follow the equation:

$$E_{pollutant} = AR * EF_{technology,fuel}$$

Where
E = Emissions of a pollutant
AR = Activity rate (e.g. energy value by fuel combustion)
$EF_{technology, fuel}$ = Technology and fuel specific emission factor

The technology specific emission factors are implied emission factors based on technology related information in varying levels of detail. The emission factors are defined by boiler type, fuel, and in some cases by abatement technique. In addition to the previous, for residential small combustion the emission factors are defined on a yearly basis.

Activity rates are derived by the following equations:

- Point sources $AR = \Delta H_c * F_b$

where ΔH_c = Heat of combustion [GJ/t]
F_b = Fuel consumption in a boiler [t]

- Non-point sources: $AR = \Delta H_c * F_t - F_p$,

where ΔH_c = Heat of combustion [GJ/t]
F_t =Fuel consumption (sector total) [t]
F_p =Fuel consumption (known point sources within sector) [t]

Emission factors (other than small scale wood combustion)

POP compounds

PAH-4 emissions are calculated using expert estimates based on information in the EMEP EEA Emission Inventory Guidebook (EEA, 2002). For oil combustion the emission factors are based on information from the UBA (UBA, 1998). For peat combustion the emission factors are domestic estimates (KTM, 1988).

The emission factors used for calculating POP emissions are presented in Table 4.31. PCP emission factor (0.0219 µg/MJ) is the same as for the public electricity and heat production and combustion in the manufacturing industries and may underestimate PCP emissions from 1A4 sector. Fuel consumption data obtained from the energy statistics is used as activity data.

Table 4.31 Emission factors for POP compounds in small combustion sources (other than wood combustion).

Fuel	PCDD/F mg I-Teq/TJ	PAH-4 g/TJ	PCB	PCP µg/MJ
	Reference			
	UNEP 1999* USEPA 1997** Ruuskanen 2000***	Expert estimation based on EEA, 2002* UBA, 1998 ** KTM, 1988 ***	EEA, 2005	US EPA (AP-42)
Coal	0.004*	0.012 *	4.5	
Heavy fuel oil	0.0004*	2.8 **	3.6	
Light fuel oil	0.0005*	2.8 **	3.6	
Peat	0.0175***	1 ***	0.9	
Natural gas	0.0005*	0 *		
HCB emission factors for NFR 1A4 subcategories for combustion of wood and coal				
1A4ai	0.01	Reference Joas A., 2006		
1A4bi	0.5			
1A4ci	0.5			

Heavy metal emissions

Heavy metal emissions from 1A4ci (agriculture and forestry) vary annually depending on the use of fuels.

Ammonia emissions

Ammonia emissions from NFRs 1A4ai, 1A4bi and 1A4ci are presented below under Chapter 4.4.8 Small combustion sources.

Particle emissions

Particle emissions (TSP, PM10, PM2.5, PM1 and BC) from NFRs 1A4ai, 1A4bi and 1A4ci are presented below under Chapter 4.4.8 Small combustion sources.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

IPTJ includes currently emission data for the years 2000 – 2015 only. The recalculation of emissions in the earlier years will be carried out in the next years.

Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

Recalculation of the time series is under way.

Source-specific planned improvements

Recalculation of the time series is under way.

4.4.2 Residential combustion of wood

1 A 4 b i Residential combustion of wood

Changes in chapter	
Update of emission figures	March 2017
Update of text	November 2017KS
Change in methodology	none
Other (e.g. language, layout)	November 2017 KS

This chapter covers emissions from small scale combustion of wood in households, agricultural, commercial and institutional spaces.

The division of national energy statistics on wood use cover residential and recreational buildings, single houses, row houses and block houses.

Table 4.32 Activities and emissions reported under NFR 1A4bi

SNAP codes – 020201, 020202a, 020202b, 020203, 020204 and 020205

NFR	Source	Emissions
1A4bi	Residential combustion - Stationary plants	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, PCDD/F, PAH-4, HCB, PCB

Revised inventory for Small scale combustion

Domestic appliances and practices

The inventory of small scale combustion of wood was revised in 2014-2016 to better reflect the domestic combustion technologies and practices. Also the allocation of wood fuels in the different NFR categories was checked. In the 2015 submission only BC and NH3 emissions were reported and in the submission 2016 all air pollutants.

Wood combustion is the primary heating method in approximately a quarter of residential detached and most of recreational buildings, and the secondary method in almost all residential and recreational buildings. There are approximately 2.2 million small scale wood burning devices and, in addition, 1.5 million sauna stoves in Finland (Tissari et al, 2008). Small scale combustion of wood has increased in the last decades to almost 60 PJ per year, and comprises about 35% of total primary heating energy in detached housing.

Many of the commonly used residential wood combustion appliances and specifically the burning habits in Finland differ from those used in Europe and even in the other Nordic countries, due to the characteristic principle of the devices to achieve high combustion rate with short operating time (Tissari et al, 2008). The combustion efficiency is higher and thus the cleanliness of burning better than in devices generally used in Europe. Also the placing of the combustion appliance and the chimney in the room space is central, thus giving maximum utilization of the heat radiation. In the latest decades the building regulations have further tightened and there are minimum values for the insulation structures and coefficients of heat transfer.

The largest share of wood is combusted in masonry ovens, log boilers and sauna stoves (Figure 4.11). Masonry heaters are energy efficient with high combustion rate, high heat storing capacity and low emissions, and are typically located centrally in the building to maximize the heat radiation. Log boilers and sauna stoves have lower energy efficiency and higher emissions.

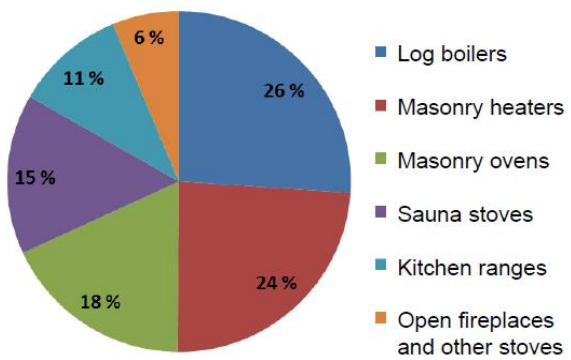


Figure 4.11. Residential wood use by combustion appliance type in Finland in 2010 (Paunu V. et al (2013)

Masonry heaters are typically massive (1000 - 6000 kg) heat storing structures with an upright rebox. The exhaust gas flows to an upper combustion chamber, then down through the ducts and

then to the chimney (Figure 4.12). The large mass efficiently stores heat and releases it slowly (average rate of 1-3 kW) in a period ranging from 10 hours to two days. Most new detached houses in Finland are equipped with a masonry heater (Tissari 2008, Paunu 2012). The low emission rate is based on hot and closed surfaces of the firebox that support the completeness of combustion, and the good secondary combustion due to the secondary combustion chamber. The air intake is restricted and the operation temperature high, while particles emissions are composed of the vapourized ash elements of wood (Tissari et al 2008).

Figure 4.12. Air flow in a masonry oven (Alakangas et al 2008)

The firebox in a *sauna stove* is small and there is no secondary combustion as the use purpose is different from appliances that are designed to heat residential spaces: the heating need in a sauna room is temporarily high and therefore the combustion rate is high. *Water boilers* are common in sauna buildings have similar construction and are used to heat water to be used directly from the boiler (Tissari 2008).

Wood log boilers in Finland are typically updraught boilers, not always equipped with a heat storage tank, have often low thermal output and high emissions, and are mainly used in rural areas as the main heating device.

Other typical heating appliances include

- *wood chip boilers*, with a capacity range of 100-200 kW, used to heat large agricultural buildings and school spaces
- *multifuel boilers*, where oil, wood and pellets can be combusted and
- *masonry cooking stoves* where then tructure includes both a wood burning oven and a masonry heater

The use of pellet burners or iron stoves is not common in Finland. (Tissari 2005).

Technology specific methodology for small scale combustion of wood

The new emission inventory for small scale wood combustion is based on the use of 13 wood combustion techniques in residential, recreational, agricultural and commercial/industrial buildings (see Chapter 4.4.8).

The technology specific method takes into account:

1 *Activity sector* where wood is combusted, i.e. (1) agriculture, (2) commercial/industry, (3) recreational and (4) residential sectors
2 *Amount of wood* (firewood, wood chips and pellets) combusted in different equipment used in these activity sectors:

1 iron stoves conventional (firewood)
2 iron stoves modern (firewood)
3 automatic fed boilers (wood chips)
4 automatic fed boilers (pellets)
5 manually fed boilers with accumulator (firewood)
6 manually fed boilers without accumulator (firewood)
7 manually fed boiler, modern (firewood)
8 open fireplace and other stove (firewood)
9 kitchen range (firewood)
10 masonry heaters, conventional (firewood)
11 masonry heaters, modern (firewood)
12 masonry ovens (firewood)
13 sauna stoves (firewood)

3 *Shares of normal and bad combustion conditions* in the different activity sectors and equipment are taken into account in the emission factors. The emission factors are calculated as the sum of the EF for normal combustion conditions (between 90% … 100% of total combustion time, defined for each equipment) and the EF for bad combustion conditions (between 0% … 10% of total combustion time defined for each equipment). The ratio bad combustion/normal combustion depends on the pollutant, being for instance for particulate matter between 1 … 3.3. For small particles, the emission factors are calculated as shares from the TSP emission factors (10%).

4 *The development of technology over time* reflecting also the share of bad combustion of total combustion time for the following three periods, i.e. (1) before year 2000, (2) years 2000-2010 and (3) years after 2010.

EFs in the old time series are presented in Table 4.34, new technology specific EFs in Table 4.34. The new technology specific emission factors for residential combustion of wood are presented in Table 4.35.

Table 4.34 Old emission factors for residential combustion of wood based fuels

EF unit	NMVOC	NOx	SOx	CO	TSP	PM10	PM2.5	As	Cd	Cr
[mg/MJ]	200*/600	100	20	2100	400	104*/384	20*/372	0.001	0.005	0.035
EF unit	Cu	Hg	Ni	Pb	V	Zn	PCP	PAH	PCDD/F	
[mg/MJ]	0.051	0.0005	0.03	0.045	0.1	0.7	0.0000219	0.250	0.021 [mg I-Teq/TJ]	

*The lower EF is used for 0.2-1 MW applicances

Reporting of the results using the new model

A country-specific methodology was developed in 2013-2014 to estimate emissions from small scale wood combustion. However, only the emissions for 2014 and 2015 for other pollutants than BC and NH3 are reported based on the new method, while the earlier years are waiting for the finalization of the pending recalculation of the energy emissions time series.

Ammonia emissions

NH3 emissions for small combustion sources were calculated for the first time in due to the adjustment application for ammonia (see Appendixes 3-4) submitted by Finland and accepted by the Expert Review Team for Adjustments. Activity data, emission factors and calculations are presented there.

The years before 2010 are not yet reported due to the pending recalculation of energy emissions time series as explained above. A complete time series for ammonia emissions from small combustion is, however, presented in Appendix 3B "Revised calculation for emissions from small combustion". The emissions are calculated based on fuel consumption data from the national Energy Statistics and using national emission factors with the methodology presented above.

Ammonia emissions 2010-2015 calculated with the technology specific new model are presented in Table 4.35.

Table 4.35 NH3 emissions for 2010-2015 for small combustion sources

NFR	2010	2011	2012	2013	2014	2015
1A4ai	0.0024	0.0021	0.0023	0.0022	0.0022	0.0020
1A4bi	0.9735	0.7928	0.8565	0.7852	0.7953	0.7508
1A4ci	0.0048	0.0041	0.0049	0.0055	0.0052	0.0047
Sum	0.9808	0.7989	9.8638	0.7929	0.8026	0.7574

Ammonia emission factors for small scale wood combustion presented in Table 4.36 are calculated as a share of carbon monoxide emissions for which extensive national measurements have been carried out for different combustion appliances and conditions (PUPO database http://www.uef.fi/en/fine/pupo). The specific emissions from different combustion appliances have in national measurements stayed at the level of 1.7-7.3 mg/MJ, which is just above the measurement threshold level. The ratio NH3:CO of 0.0073 is based on a literature value for wild fires in order not to underestimate emissions. The resulting emission factors match well the national measurement results for ammonia emissions in the different conditions

Table 4.36 Technology specific EFs for residential combustion of wood based fuels

MAIN POLLUTANTS	SO2	NOx	CO	NMVOCC	NH3	TSP	PM10	PM2.5	PM1	BC
	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ
Iron stoves conventional	5	80	3152.4	3984.45	23.01252	121.9356	117.0581	113.4001	109.742	27.313
Iron stoves modern	5	80	1491	81.53	10.8843	77.44556	74.34773	72.02437	69.701	17.381
Autom. Fed Wood Chips	5	80	142	3	1.0366	16.66667	16	15.5	15	0.5
Automatic Fed Pellets	5	80	113.6	3	0.82928	21.11111	20.26667	19.63333	19	0.6
Manually Fed, accumulator	5	80	213	49	1.5549	145.5556	139.7333	135.3667	131	24
Manually Fed without accumulator	5	80	1065	402	7.7745	752.2222	722.1333	699.5667	677	210
Manually Fed Modern	5	80	213	49	1.5549	17.77778	17.06667	16.53333	16	0.5
Open fire place, other stove	5	80	3834	405.02	27.9882	686.3278	658.8747	638.2848	617.695	35
Kitchen range	5	80	2130	92.05	15.549	56.47778	54.21867	52.52433	50.83	33.68
Masonry Heaters	5	80	1988	209.085	14.5124	148.3	142.368	137.919	133.47	47.177
Masonry Heaters Modern	5	80	1349	139.39	9.8477	52.72889	50.61973	49.03787	47.456	18.625
Masonry Ovens	5	80	1704	92.05	12.4392	51.56667	49.504	47.957	46.41	14.735
Sauna stoves	5	80	5680	907.35	41.464	505.5111	485.2907	470.1253	454.96	182.08
HEAVY METALS	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	V	Zn
	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ
Iron stoves conventional	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Iron stoves modern	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Autom. Fed Wood Chips	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Automatic Fed Pellets	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Manually Fed, accumulator	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Manually Fed without accumulator	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Manually Fed Modern	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Open fire place and other stove	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7

Kitchen range	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Masonry Heaters Conventional	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Masonry Heaters Modern	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Masonry Ovens	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7
Sauna stoves	0.001	0.003	0.035	0.006	0.005	0.03	0.01	0.005	0.001	0.7

POP COMPOUNDS	PCDD/F	PAH-4	HCB	PCB	PCP
	mg ITEQ/MJ	mg/MJ	mg/MJ	mg/MJ	mg/MJ
Iron stoves conventional	0.1	0.305	0.000005	0.00006	0.0000219
Iron stoves modern	0.1	0.1525	0.000005	0.00006	0.0000219
Autom. Fed Wood Chips	0.1	0.01	0.000005	0.00006	0.0000219
Automatic Fed Pellets	0.1	0.005	0.000005	0.00006	0.0000219
Manually Fed, accumulator	0.1	0.05	0.000005	0.00006	0.0000219
Manually Fed without accumulator	0.1	0.1	0.000005	0.00006	0.0000219
Manually Fed Modern	0.1	0.005	0.000005	0.00006	0.0000219
Open fire place and other stove	0.1	0.305	0.000005	0.00006	0.0000219
Kitchen range	0.1	0.121	0.000005	0.00006	0.0000219
Masonry Heaters	0.1	0.1525	0.000005	0.00006	0.0000219
Masonry Heaters Modern	0.1	0.121	0.000005	0.00006	0.0000219
Masonry Ovens	0.1	0.1525	0.000005	0.00006	0.0000219
Sauna stoves	0.1	0.305	0.000005	0.00006	0.0000219

Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out. The data obtained from VAHTI is cross-checked against the summary data (by fuels and by CRF categories) reported to the UNFCCC as explained in Chapter 2.3.4.

Corrections made to VAHTI data are listed in Annex 4 of Part 2 of the IIR.

At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

None.

Source-specific planned improvements

Reporting officially the inventory for other air pollutants than NH3 and BC from small combustion sources will be included when the energy sector time series recalculation has been finalized.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.
IPTJ includes currently emission data for the years 2000 – 2015 only. The recalculation of emissions in the earlier years 1990-1999 will be carried out in the next years.

4.5 Fugitive Emissions from Solid Fuels (NFR 1.B.1)

1 B 1 a Fugitive emission from solid fuels: Coal mining and handling

There is no hard or brown coal mining in Finland.

1 B 1 b Fugitive emission from solid fuels: Solid fuel transformation

Changes in chapter	
Update of emission figures	March 2017
Update of text	January 2017 KS
Change in methodology	2016
Other (e.g. language, layout)	February 2017 KS

Source category description

NMVOC, PCB, PCDD/F, PAH-4, particle and heavy metal emissions under the sector fugitive emissions from solid fuel (NFR 1B1) originate from coke production.

Emission trend

The contribution of emissions from coke production in 2014 to total emissions is presented in Table 4.34.

TABLE 4.34 Contribution of Fugitive emissions from solid fuels (NFR 1B1b) in 2014 to total emissions. (to be updated with 2015 emissions in the resubmission)

Pollutant	Emissions from Fugitive emissions from solid fuels in 2014	Total emissions in 2014	Unit	Share of total emissions %	% reported by the plants
As	0.012	2.42	Mg	0.5	100
Cd	<0.001	0.82	Mg	<0.1	100
Cr	0.006	20.3	Mg	<0.1	100
Cu	0.083	53.8	Mg	0.2	100
NH3	0.003	36.9	Gg	<0.1	0
Ni	0.016	16.5	Mg	<0.1	100
NMVOC	0.068	75.4	Gg	<0.1	0
Pb	0.028	14.5	Mg	0.2	100
PCBs	3.196	154.5	kg	2.1	0
PCDD/PCDF	0.204	13.2	g I-Teq	1.5	0
Zn	0.207	130.1	Mg	0.2	100
PAHs	0.471	9.7	Mg	4.8	0

Methodological issues

Heavy metal and TSP emissions are reported by the plants according to monitoring requirements in their environmental permits. Small particle fractions are calculated from this data using emission factors from TNO (2002).
The allocation varies annually depending on the share of fuels annually allocated here in the energy calculation model. Particle emissions in 2015 have included in NFR category 1A2a.

NH3, NMVOC, PCBs, PCDD/PCDF and PAH emissions are calculated using emission factors from EMEP EEA Guidebook 2016 (EEA, 2016).
.
Activity data for coke production is received from the Federation of Finnish Technology Industries. The production rates, calculated emissions and emission factors are presented in Table 4.37.

Table 4.37 EFs, activity data (annual production of coke) and emissions for coke production.

Pollutant	Emission Factor	Coke oven	Reference
NMVOC	0.077 kg/t		Guidebook , 2016 (EEA, 2016)
PM_{10}		50% of TSP	AEAT, 2000
$PM_{2.5}$		43% of TSP	AEAT, 2000
PCDD/F	0.23 µg I-TEQ/t		SEPA, 1996
benzo (a) pyrene	0.16 g/t		Guidebook 2016 (EEA, 2016)
benzo (b) fluranthene	0.2 g/t		Guidebook 2016 (EEA, 2016)
benzo (k) fluranthene	0.1 g/t		Guidebook 2016 (EEA, 2016)
indeno (1,2,3-cd) pyrene	0.07 g/t		Guidebook 2016 (EEA, 2016)
PCB	3.6 mg/t		BiPRO, 2006
NH_3	3.7 g/Mg coke		Guidebook2016(EEA, 2016)

Activity data and calculated emissionsfrom coke production									
Year	Activity data (t)	NMVOC (t)	PCDD/F g I-TEQ	benzo(a) pyrene (kg)	benzo(b) fluranthene (kg)	benzo(k) fluranthene (kg)	indeno(1,2,3-cd) pyrene (kg)	PCB (kg)	NH_3 (t)
1990	487 000	38	0.11	77.9	97.4	48.7	34.1	1.8	1.8
1991	471 000	36	0.11	75.4	94.2	47.1	33.0	1.7	1.7
1992	498 000	38	0.11	79.7	99.6	49.8	34.9	1.8	1.8
1993*	874 000	67	0.20	139.8	174.8	87.4	61.2	3.1	3.2
1994	922 000	71	0.21	147.5	184.4	92.2	64.5	3.3	3.4
1995	920 000	71	0.21	147.2	184.0	92.0	64.4	3.3	3.4
1996	910 000	70	0.21	145.6	182.0	91.0	63.7	3.3	3.4
1997	879 000	68	0.20	140.6	175.8	87.9	61.5	3.2	3.3
1998	912 000	70	0.21	145.9	182.4	91.2	63.8	3.3	3.4
1999	900 000	69	0.21	144.0	180.0	90.0	63.0	3.2	3.3
2000	910 000	70	0.21	145.6	182.0	91.0	63.7	3.3	3.4
2001	909 000	70	0.21	145.4	181.8	90.9	63.6	3.3	3.4
2002	912 000	70	0.21	145.9	182.4	91.2	63.8	3.3	3.4
2003	895 217	69	0.21	143.2	179.0	89.5	62.7	3.2	3.3
2004	903 723	70	0.21	144.6	180.7	90.4	63.3	3.3	3.3
2005	893 628	69	0.21	143.0	178.7	89.4	62.6	3.2	3.3
2006	869 937	67	0.20	139.2	174.0	87.0	60.9	3.1	3.2
2007	865 007	67	0.20	138.4	173.0	86.5	60.6	3.1	3.2
2008	860 428	66	0.20	137.7	172.1	86.0	60.2	3.1	3.2
2009	737 934	57	0.17	118.1	147.6	73.8	51.7	2.7	2.7
2010	826 800	64	0.19	132.3	165.4	82.7	57.9	3.0	3.1
2011	852 402	66	0.20	136.4	170.5	85.2	59.7	3.0	3.2
2012	880 551	68	0.20	140.9	176.1	88.1	61.6	3.2	3.3
2013	877 602	68	0.20	140.4	175.5	87.8	61.4	3.2	3.2
2014	887 784	68	0.20	142.0	177.6	88.8	62.1	3.2	3.3
2015	875 618	67	0.20	140.0	175.1	87.6	61.3	3.2	3.2
*At the end of 1992 a new coking battery was started in the Raahe plant									

Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out. The data obtained from VAHTI is cross-checked against the summary data (by fuels and by CRF categories) reported to the UNFCCC as explained in Chapter 2.3.4.

Corrections made to VAHTI data are listed in Annex 4 of Part 2 of the IIR.

At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

None.

Source-specific planned improvements

None.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

IPTJ includes currently emission data for the years 2000 – 2015 only. The recalculation of emissions in the earlier years 1990-1999 will be carried out in the next years.

1 B 1 c Other fugitive emissions from solid fuels

Changes in chapter	
Update of emission figures	March 2017
Update of text	March 2017 KS JMP
Change in methodology	2008, 2016
Other (e.g. language, layout)	February 2017 KS

Source category description

Emissions from peat production and production of wood pellets are reported under NFR 1B1c Other fugitive emissions from solid fuels.

Contribution of Other fugitive emissions from solid fuels (NFR 1B1c) in 2014 to total emissions is presented in Table 4.38.

Table 4.38 Contribution of Other fugitive emissions from solid fuels (NFR 1B1c) in 2014 to total emissions. (to be updated in the resubmission in May 2017)

Pollutant	Emissions from Fugitive emissions from solid fuels in 2014	Total emissions in 2014	Unit	Share of total emissions %	% reported by the plants
PM10	34.4	2.42	Gg	5.0	0
PM2.5	24.2	0.82	Gg	5.0	0
TSP	52.2	20.3	Gg	5.1	0

Wood pellets

Emissions from production of wood pellet have been included in the inventory since 2002. Between 2002-2005 the emissions have been reported under NFR 1A2f. In 2007 the allocation was under NFR 2G and since 2008 emissions have been reported under NFR 1B1c. Emissions from the production of wood pellets are available in VAHTI database based on reporting of industrial operators.

Peat production

One third of Finland's land area is marshland. The peat production area is currently approximately 60 000 ha out of which 44 000 ha will be exhausted by 2020 and 120 000 ha of new production areas will be needed in 2020-2050 (Figure 4.10). Finland is the leading peat producer in the world.

Figure 4.10 Peat production area, transport and loading of peat (Ympäristöhallinto, 2012)

Peat is produced either as milled or sod peat. Milled peat is used fuel. The production includes peat extraction from marshland (peatland) and further treatment to be used as fuel in heat and electricity production, as garden peat or to be used in compost. After the extraction, peat is dried on peat lands. The process steps of peat production are presented in Figure 4.13 a-b.

Peat harvesting is carried out using three different equipment:

(1) Haku method includes four phases: milling, turning, roughening, loading and stacking. The Haku method includes harvesting of several yields simultaneously utilizing dry weather and collecting 3-5 yields to harrowing/ridging.

(2) Suction wagon (Imu method): after milling and turning the suction wagon takes care of the rest.

(3) Mechanical collection wagon: after milling and turning the collection wagon takes care of the rest.

The Haku method was the most common in the earlier years, however, at the moment the Imu method using suction wagon has become the most common. The Imu method was earlier used for about 15 % of peat but now for around 10% of the harvested peat.

4.1.25.7 Emissions

Peat production generates water and air emissions (specifically particles and greenhouse gases) and has impact on nature values such as biota and scenery.

Peat is produced either as milled or sod peat. The sod peat production is not estimated to cause particle emissions. The milled peat production, which is the main production method, causes relatively high emissions of fugitive soil dust.

Dust emissions are affected by the rate of decomposition of peat as well as by weather and terrain conditions, and can be minimised by considering wind direction and speed during the work as well as by applying dust separators in the suction wagons. The annual production rates depend on the prevailing weather conditions: in a rainy summer the production rates are considerably lower than in a dry summer. Most of the working stages take place under dry conditions.

Sod peat

For sod peat production no dust emissions are anticipated. There are two harvesting periods at maximum during the year. In the sod peat method, peat is cut to 50 cm depth and moved as large peat carpets to dry. The sod pieces are turned twice during the drying period, then roughened and loaded for transportation. Sod peat is wet when lifted to dry and no dust is generated at this phase. The velocities used in the handling and turning phases are significantly slower than in the production of milled peat. While the working machines lift up peat dust during the operations, peat dust exits less in sod peat fields than in milled peat fields. The yield of sod peat is about 200 m3/ha. (A. Erkkilä, 2016)

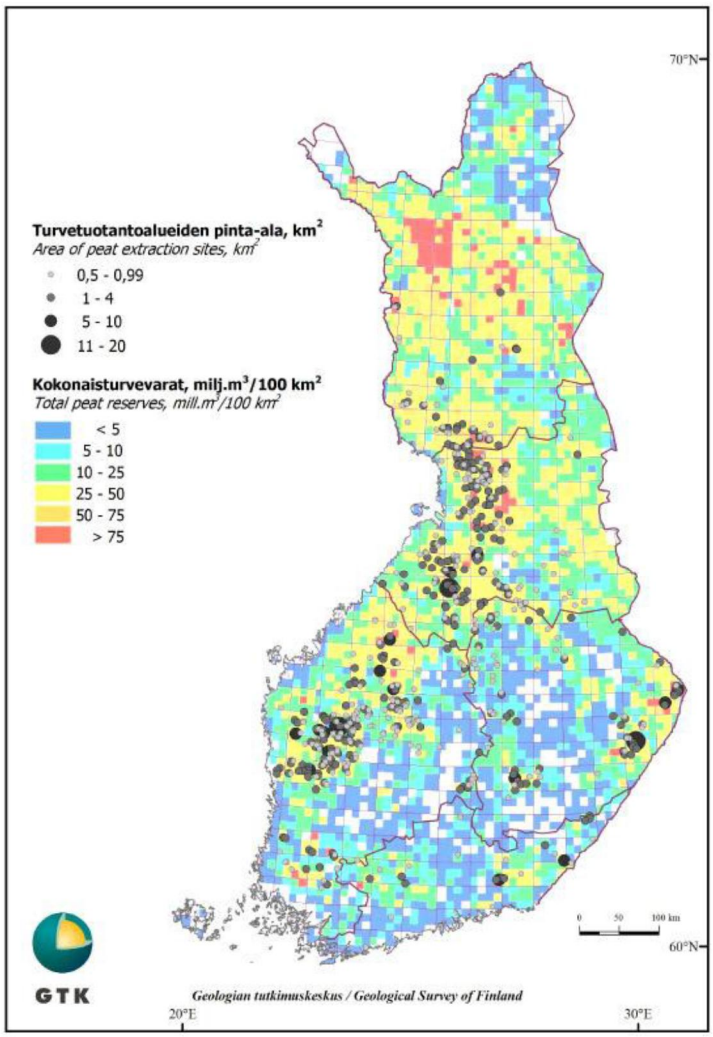
Milled peat

Milled peat is extracted by milling layers of 2-5 cm of the surface. The harvesting is carried out approximately 10 times annually. The yield of milled peat yield is around 40 m^3/ha. Milled peat production generates high dust emissions.

4.1.25.8 Methodological issues

In 1990-2000 45% of peat production was carried out using the “Haku” harvesting method, 15% using pneumatic harvesting and 40% using mechanical collector. From 2001 onwards 40 % of peat was collected using the “Haku” method, 10 % using pneumatic harvesting and 50 % using mechanical collector. These assumptions of used production methods are based on information from the experts in the industry (A., Erkkilä, VAPO Oy, 2015)

The emission factors are domestic and based on measurements carried out during summer 2007 (Table 4.39). Volumes of produced peat are obtained from Energy Statistics and are presented together with particle emissions in Table 4.40.



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Kokonaisturvevarat: GTK (Geological Survey of Finland).

Figure 4.23a Peat production areas in Finland

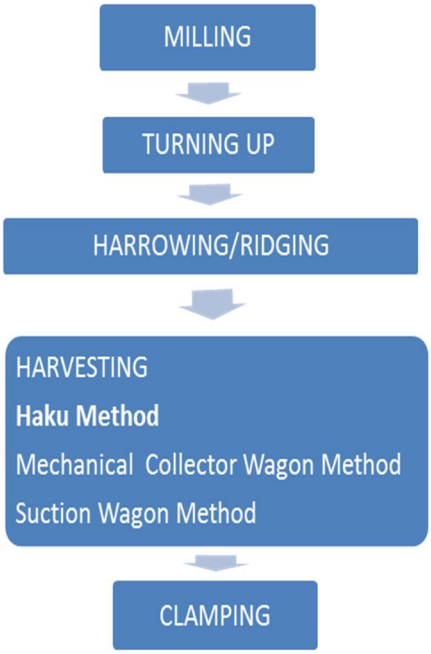

Figure 4.23b The process of peat harvesting and the three most common peat production processes

Table 4.39 TSP, PM_{10} and $PM_{2.5}$ emission factors for milled peat production.

Source	Emission factors per produced peat cubic metre (kg/m³)			Reference
	TSP	PM_{10}	$PM_{2.5}$	
Haku method*	0.1377	0.09	0.0632	Nuutinen et al., 2007
Pneumatic harvester	0.2142	0.14	0.0983	Nuutinen et al., 2007
Mechanical collector	0.1836	0.12	0.08427	Nuutinen et al., 2007

*The EF for Haku harvesting covers 2 harvests, therefore acitivity data for Haku harvests needs to be halved

Table 4.40 Particle emissions and activity data as volumes of produced peat in 1990-2015.

Year	Produced peat (1000m³)	TSP (t)	$PM_{2.5}$ (t)	PM_{10} (t)
1990	17 305	2363	1085	1545
1991	8 424	1150	528	752
1992	18 628	2544	1168	1663
1993	9 668	1320	606	863
1994	23 223	3171	1456	2073
1995	24 278	3315	1522	2167
1996	25 332	3459	1588	2261
1997	31 095	4246	1949	2775
1998	4 818	658	302	430
1999	25 046	3420	1570	2235
2000	12 261	1674	769	1094
2001	19 190	2701	1240	1766
2002	25 771	3628	1655	2371
2003	21 672	3051	1400	1994
2004	9 194	1294	594	846
2005	25 464	3584	1645	2343
2006	38 100	5363	2462	3505
2007	13 053	1837	843	1201
2008	13 950	1964	901	1284
2009	25 000	3519	1615	2300
2010	21 650	3048	1399	1992
2011	20 130	2834	1301	1852
2012	12 544	1766	801	1154
2013	20 567	2895	1329	1892
2014	18 855	2654	1218	1735
2015	10 125	1425	654	932

4.1.26 Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR..

4.1.27 Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out. The assumption of how the different peat handling methods are used were different for the years before 2000 and after 2000: the difference is

At present, no verification has been carried out for the specific source-sector emissions.

4.1.28 Source-specific recalculations including changes made in response to the review process

Change of method in 2016

The shares of different harvesting methods for milled peat production have been updated for whole time series in 2016 submission, because the earlier method was found defective and overestimated the emissions. The calculation was revised in 2016 as the earlier method assumed that Imu and Collection wagon methods were used annually and Haku method was used every two years.

4.1.29 Source-specific planned improvements

The method for estimating particle emissions from sod peat will be further studied as the production of sod peat differs much from the production of milled peat

4.6 Fugitive Emissions from oil and natural gas (NFR 1.B.2)

4.1.30 Exploration, production, transport (1B2ai)

There is no exploration or production of oil and natural gas in Finland.

Emissions from transport of natural gas in pipelines are included under NFR 1A3e.

4.1.31 Refining / storage (1B2aiv)

Changes in chapter	
Update of emission figures	March 2017JMP
Update of text	February 2917 KS
Change in methodology	none
Other (e.g. language, layout)	February 2917 KS

4.1.31.1 Source category description

The category covers oil refineries, venting and flaring emissions and storage of fossil fuels in all storages in the country. Emissions reported under this sector include NOx, SOx, particles and NMVOCs.

Table 4.41 Contribution of Refining/storage (NFR 1B2aiv) in 2014 to total emissions (to be completed with remaining emissions and 2015 data).

Pollutant	Emissions from Fugitive emissions from solid fuels in 2014	Total emissions in 2014	Unit	Share of total emissions %	% reported by the plants
NMVOC	3.03	75.4	Gg	4.0	100
PCBs	13.7	154.5	kg	8.9	0

4.1.31.2 Emission trend

The emission trends are presented in Figure 4.24.

NMVOC emissions are slightly decreasing.

-

PCB emissions show an increasing trend. However, the emissions are based on a simple calculation using an emission factor that is related to the production volumes, and thus does not necessarily represent the real world emissions.

SOx and TSP emissions are not fully represented in the figure because their allocation in the NFR categories has varied over the years and cannot at the moment presented as a full time series.

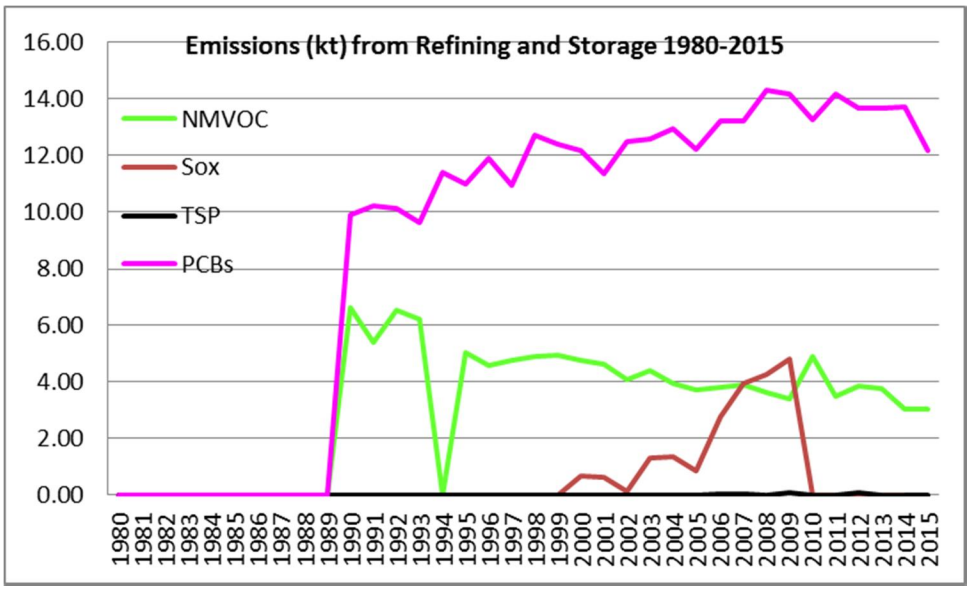

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Figure 4.24. Emissions from Refining and Storage 1980-2015.

4.1.31.3 Methodological issues

Petroleum industry reports their NMVOC, SOx, NOx and TSP emissions to the environmental authorities according to their monitoring programmes in the environmental permits since 1988.

Small particle emissions are calculated in the inventory using fraction factors (TNO 2002) from TSP emissions.

According to the BiPRO report (BiPRO 2006, 1994), petrol refineries are a source of PCB emissions. PCB emissions are estimated using the emission factor 1 mg/t (BiPRO 2006, 1994). Annual amounts of oil refined are taken from the Energy Statistics (Statistics Finland, 2015).

4.1.31.4 Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

4.1.31.5 Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out.

At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

None.

Source-specific planned improvements

Reallocation of venting and flaring emissions to 1B2c is planned to be carried out in the next inventory.

Emissions for 1988-1995 will be corrected using updated information from plants or national emission factors when the time-series will be recalculated.

4.2

4.7 Distribution of oil products (1B2av)

Changes in chapter	
Update of emission figures	March 2017 JMP
Update of text	February 2017 KS
Change in methodology	none
Other (e.g. language, layout)	February 2017 KS

Source category description

Emissions from service stations and storage tanks outside the refineries are included in this category.

Table 4.42 Contribution of Distribution of oli products (NFR 1B2av) in 2014 to the total emissions.

Pollutant	Emissions from Fugitive emissions from solid fuels in 2014	Total emissions in 2014	Unit	Share of total emissions %	% reported by the plants
NMVOC	3.003	75.4	Gg	4.0	7.4
NOx	<0.001	137.6	Gg	<0.1	100
PM10	<0.001	34.4	Gg	<0.1	0
PM2.5	<0.001	24.2	Gg	<0.1	0
TSP	<0.001	52.2	Gg	<0.1	100

NMVOC emissions have been mainly decreasing since 1988 when they were included in the inventory (Figure 4.25)

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NMVOC emissions are declining due to the following measures taken:

- capture of gasoline fumes in the petrol distribution network and refuelling of cars
- gradual renewal of the passenger car fleet
- better storage of chemicals at the refineries

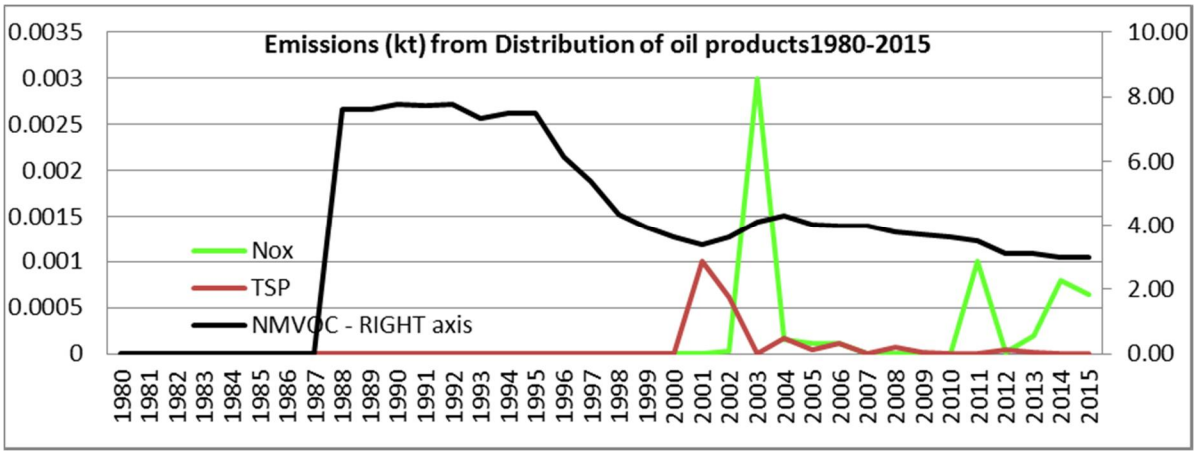

Figure 4.25 Emissions from distribution of oil products 1987-2015

Methodological issues

NMVOC

The emissions are calculated at SYKE based on a model developed in cooperation with the Finnish Oil and Gas Federation (Pohjolainen, 2008). The model has been used from 2005 onwards, emissions estimates 1990-2004 have been provided by Finnish Oil and Gas Federation by using the same model.

Sales of motor gasoline (m3) (table x) are used as activity data in revised model and are provided by the Finnish Oil and Gas Federation. In the model it is assumed that 90% of service stations had stage I equipment during 2007-2011 and that 10 % of service stations had stage II equipment's. The share of stage II equipment's in service stations is increasing due the new directive (2009/126/EY) implemented in January 2012. As an expert estimate of the model it was assumed that in 2012 onwards the share of stage II service stations is 30%.

In the model emissions are calculated for drop out and storage and for refuelling separately. It is also assumed that certain part (in percentage) of the filled up gasoline evaporates as NMVOC (see Table 4.43). The same assumptions are used for whole time series.

Table 4.43. Emission factors (as percentage) used in model

Type of station	no recovery	Stage 1 recovery	Stage 1+2 recovery
drop out+storage	0.16 %	0.03%	0.03%
refuelling	0.18%	0.18%	0.10%

Petroleum sales in Finland are presented in Table 4.44.

Table 4.44 The sales of petroleum in Finland 1990-2015 (Finnish Oil and Gas Federation)

year	sales of motor gasoline (m^3)	year	sales of motor gasoline (m^3)	year	sales of motor gasoline (m^3)
1990		2000	2 379 600	2010	2 236 908
1991		2001	2 412 400	2011	2 161 188
1992	2 574 133	2002	2 508 667	2012	2 092 130
1993	2 540 800	2003	2 469 067	2013	2 052 219
1994	2 558 400	2004	2 508 677	2014	1 978 831
1995	2 529 333	2005	2 501 333	2015	2 011 123
1996	2 455 867	2006	2 482 667		
1997	2 507 600	2007	2 481 366		
1998	2 477 067	2008	2 347 344		
1999	2 466 133	2009	2 285 349		

NOx and particles

Emissions are reported by the plants according to the monitoring requirements in the environmental permits. Particle emissions allocated to this activity may more correctly originate from fuel combustion but have been allocated here due to the functions of the IPTJ system which splits emissions between production and energy categories. In Table 4.x is presented contribution of emissions in 2014 to the total emissions.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR .

Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out.

At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

None.

Source-specific planned improvements

None.

4.8 Natural gas (1B2b)

Changes in chapter	
Update of emission figures	
Update of text	February 2917 KS
Change in methodology	none
Other (e.g. language, layout)	February 2917 KS

Source category description

NFR 1B2b covers activities related to transmission and distribution of natural gas. Emissions of air pollutants are not expected to occur from these operations.

There is no exploration or production of oil or natural gas in Finland.

Note that there are incorrect values of selene emissions in the NFR tables that have remained in the table due to a mistake. The reallocation of emissions will be carried out during the recalculation of the time series.

4.9 Venting and flaring (1B2c)

Changes in chapter	
Update of emission figures	
Update of text	February 2017 KS
Change in methodology	none
Other (e.g. language, layout)	February 2017 KS

Source category description

SOx, NOx, CO and NMVOC emissions from venting and flaring (NFR 1B2c) are currently reported under NFR 1B2aiv. Reallocation will be considered when the recalculated time series will be reported.

4.10 Other fugitive emissions from geothermal energy production, peat and other energy extraction not included in 1 B 2 (1B2d)

Changes in chapter	
Update of emission figures	
Update of text	March 2014 KS
Other (e.g. language, layout)	March 2014 KS

4.10.1. Source category description

There are no activities in Finland that would fall under this category.

Particle emissions from mining of milled peat that were earlier reported under NFR 1B2 were reallocated to NFR 1B3 in 2008.