FINLAND's INFORMATIVE INVENTORY REPORT 2019

under the UNECE CLRTAP and the EU NECD

Air Pollutant Emissions 1980-2017

Part 3 – Transport

MARCH 2019

FINNISH ENVIRONMENT INSTITUTE
Centre for Sustainable Consumption and Production
Environmental Management in Industry – Air Emissions Team

Finland’s IIR
Part 3
Transport

Cover page photo for Part 3 Transport: Riku Lumiaho (2015) Lossi (Ferry boat)

PART 3 TRANSPORT AND OFF-ROAD MOBILE SOURCES (NFR 1A3)

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3.1 OVERVIEW OF THE SECTOR

The Transport Sector inventory covers emissions from civil aviation, road transport, railways, navigation and off-road mobile sources, tyre and brake wear, road abrasion and refuelling of cars. Pipeline compressors are also included. The source categories and pollutants included in the transport sector are presented in Tables 3.1

Table 3.1 Emissions reported under the transport sector

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, Se, 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, Pb, Cd, As, Cr, Cu, Ni, Se, 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, Se, Zn, PCDD/F, HCB, PCB
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

National characteristics

Emissions from the transport sector are affected by specific national circumstances such as

(1) winter time conditions, which require use of studded tyres
(2) long distances and transport-intensive industries
(3) travel to and from free-time residences

NOTE: Fuel based emissions from road transport, navigation, railroads and non-road vehicles and machinery are calculated in the national model for transport LIPASTO. The EFs have been changed to this submission to those in the Guidebook. The unit emissions page of LIPASTO does not show EFs used in the inventory but are used in different purposes than the emissions inventory.

Emission trends

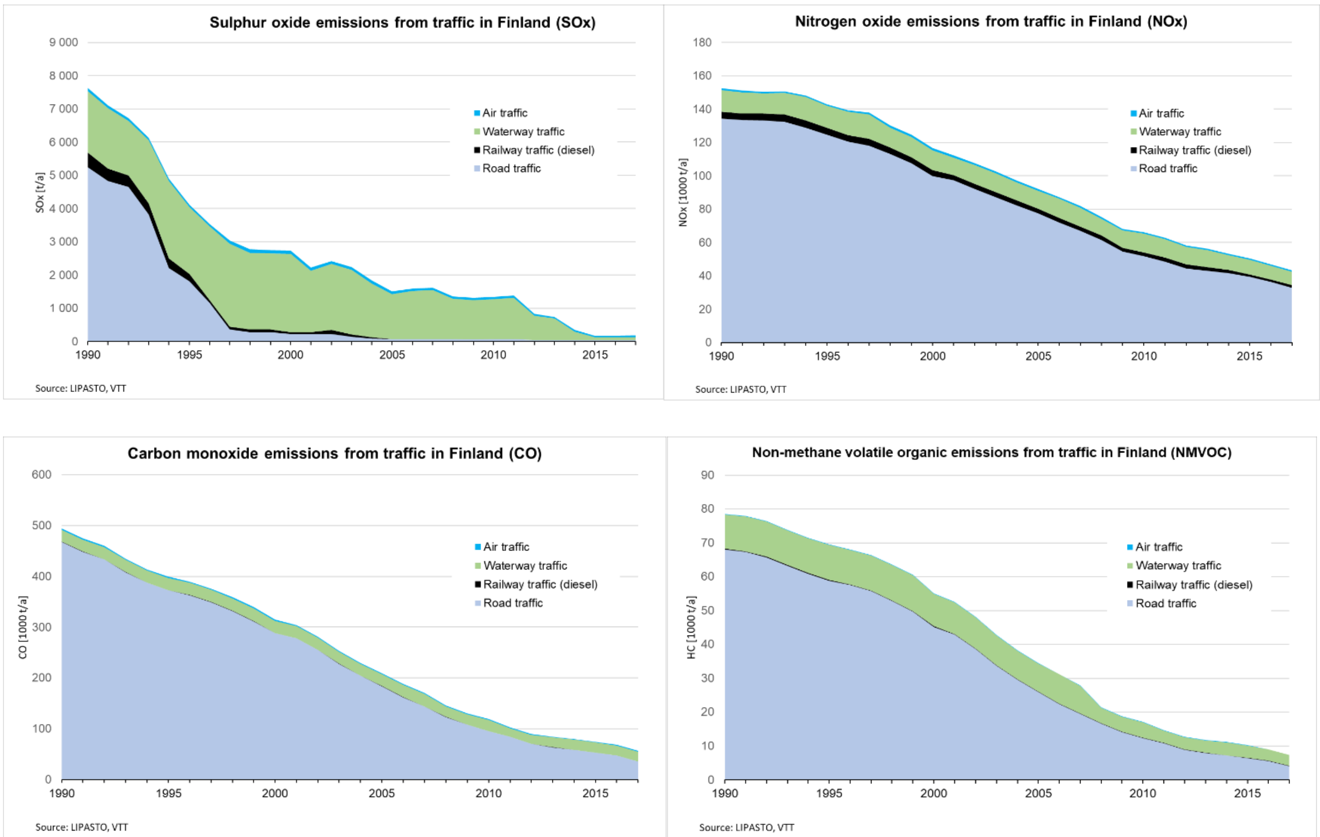
Transport sector emission trends in 1990-2017 by pollutants and the main transport modes from the national transport sector calculation system LIPASTO are presented in Figure 3.1(a). Transport sector emission trends by pollutants in 1980-2017 as reported under the UNECE CLRTAP are presented in Figure 3.1(b).

Emissions from the transport sector have been decreasing although fuel consumption is increasing, except for off-road machinery, which is growing for the volume of the machinery. Emissions of sulphur oxides and lead have decreased due to the reduced contents in fuels and implementation of catalysts and filters have removed nitrogen oxide and particle emissions and reduced carbon monoxide.

For gasoline passenger cars emission regulations were introduced in Finland in the beginning of 1991 although cars equipped with catalysts were already sold earlier. The Euro 5 standard introduced in September 2009 requires implementation of catalysts. Catalysts and filters in road transport include

- Diesel Oxidation Catalytic converter *(DOC)* reduces the share of CO and HC in exhaust gases.
- Particle filters, especially in diesel cars
- Motor management systems can be adjusted to low particle and NOx levels
- NOx catalyst in diesel cars
- Selective catalytic reduction *(SCR)* for reduced NOx emissions (AdBlue)

Based on the EU sulphur directive, since the beginning of 2015 ships in the Baltic Sea and North Sea have used fuels including maximum 0.1% Sulphur, or as an alternative, they need to install scrubbers to reduce 90% of Sulphur emissions. In the Baltic Sea area the highest allowed sulphur content before 2015 was 1%.



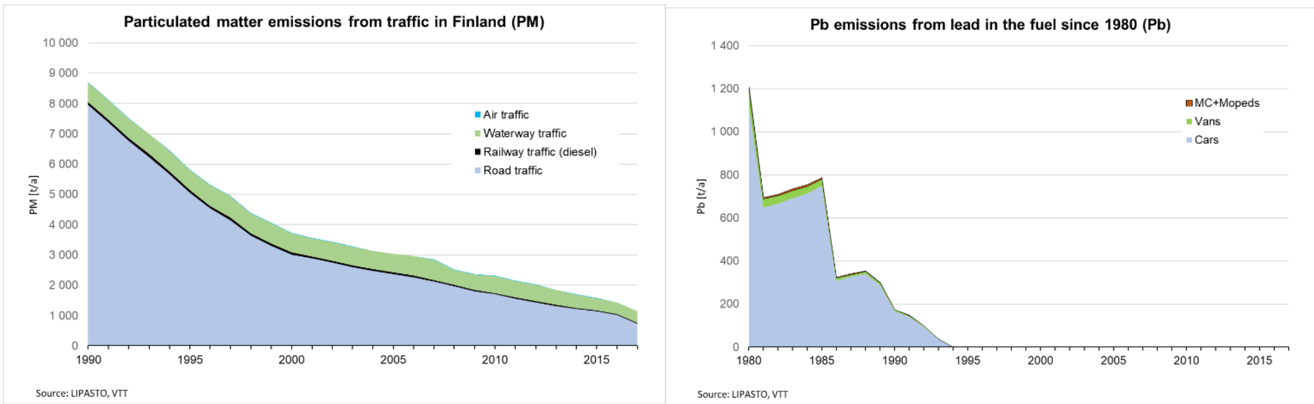


Figure 3.1 (a). Emission trends in Transport 1980/90-2030 in the LIPASTO system. International traffic and electric trains are included in LIPASTO, contrary to the reporting requirement under the UNECE CLRTAP.

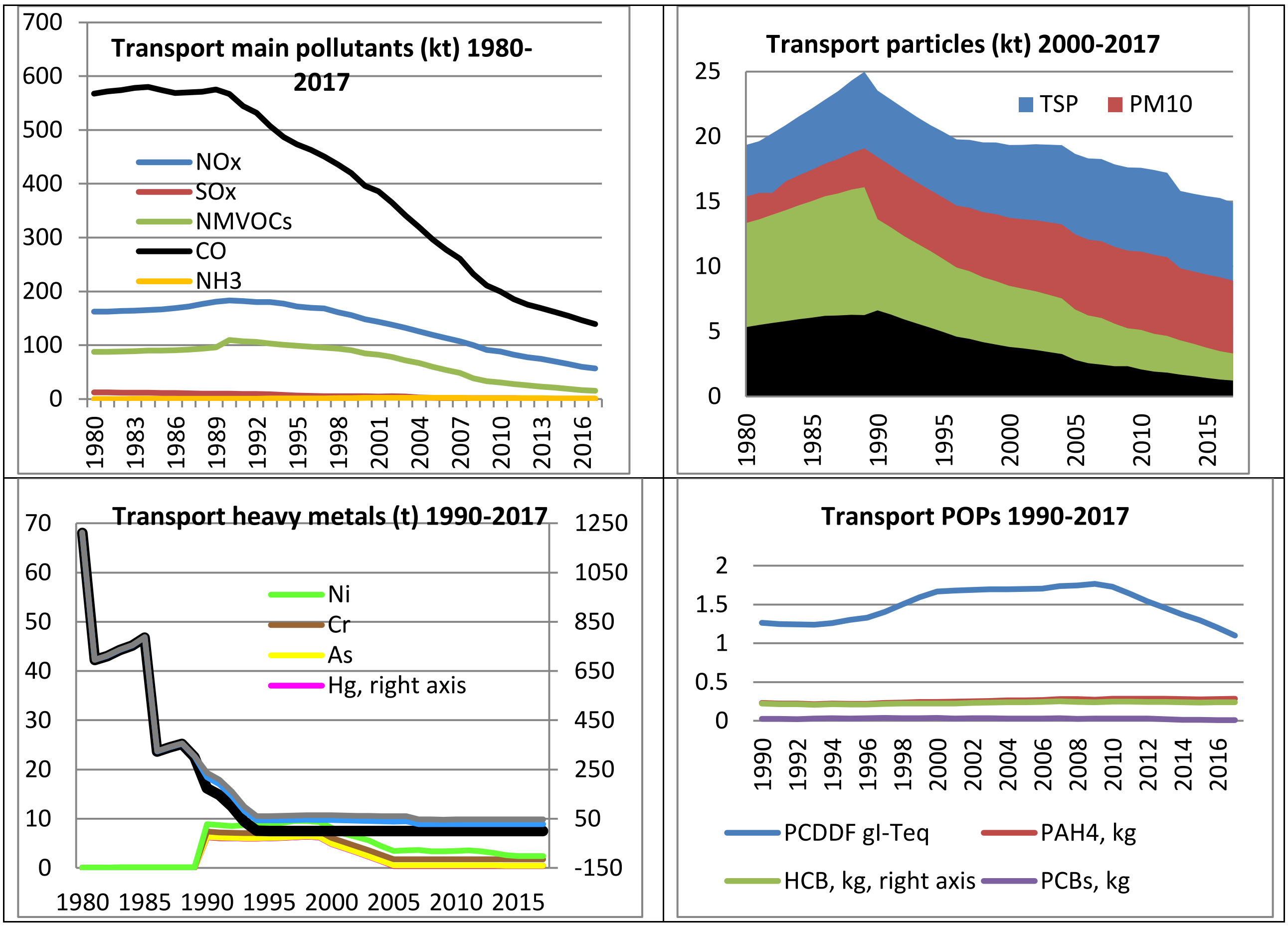


Figure 3.2 (b) Transport sector emissions 1980-2017 as reported under the UNECE CLRTAP

Note that there is discontinuity in the emissions between 1980's and 1990's: the emissions in the 1980's have not yet been recalculated/are not yet estimated for all subcategories.

Fuel use and Use of lubricants

Fuel consumption

In the 1990's the growth of emissions from road transport was slow in Finland compared to many other Annex I countries, mainly due to the effect that the economic recession in the early 1990s had on transport. Also, the worldwide economic downturn that began in 2008 decreased the kilometrage of all transport modes.

In 2016 the use of diesel oil in road transport increased by 7% as did the bio-share in fuels.

An overview of transport sector energy consumption 1990-2017 is presented in Table 3.2 (a).

There have been some changes in legislation and fuel tax decisions concerning the use of diesel oil and gasoil over time. A new fuel product, non-road gasoil, was introduced during 2005. Non-road gasoil is technically the same fuel as diesel oil, but has lower taxes and includes a Euromarker to allow monitoring of illegal use. Recently, the situation has changed again. Almost all gasoil is presently sold under the title "sulphur free gasoil", which is in practise the same product as non-road-gasoil. In this report, we use the terminology "non-road-gasoil" to describe the use of gasoil in diesel engines in off-road vehicles and other machinery and domestic navigation (wherever it is allowed to use lower taxed gasoil instead of higher taxed diesel oil). In leisure boats, the use of diesel oil (instead of gasoil) was made obligatory from the beginning of 2008. Table 3.3 (b) shows the changes in the allocation of diesel oil, non-road gasoil and heating gasoil used in different subsectors of the inventory.

Bio-shares of transport fuels (Finland's NIR 2018)

Increasing amounts of biogenic additives or biofuels are mixed in road transport fuels. Use of blended bio-gasoline (ethanol) started from 2002 and of blended biodiesel from 2007. Due to the expiration of the periodic deduction of fuel tax, there was no consumption of bioethanol in 2005, but in 2006 bioethanol re-entered the market. Data of other biogenic compounds, like ETBE (ETBE = ethyl tert-butyl ether, a bioethanol based gasoline component), are not available for 2002 to 2007. Data on blended and pure biofuels from 2008 include:

- Bioethanol, BTL-gasoline, bio-shares of ETBE, TAEE9 and THxEE10
- Biodiesel and synthetic renewable diesel (mostly BTL-diesel)
- Bio-gasoil mixed in the non-road gasoil (mostly BTL-diesel)

The time series on biogas data starting from 2002 are available in the Energy statistics. The shares of biofuels are based on data from Finnish Customs and Tax administration. From 2013 the bio-share of gasoil decreased to 0.1-0.2%. Because the share is so low, Statistics Finland decided to allocate this bio-share into road transport instead of non-road use. In 2016 the bio-shares of gasoline and diesel oil were 4.8% and 4.1% respectively (calculated from TJ). The share of biogas in total gas consumption in road transport was 44%.

Energy consumption in the Transport sector is presented in Table 3.4(a), the allocation of fuels in transport sectors in Table 3.4(b), the amounts of bio-components in liquid fuels in Table 3.4(c) and the mixing requirements and effective bio-shares in liquid and gaseous fuels Table 3.4(d).

The bio-shares of fuels have been included in the NFR table of the 2019 submission.

Table 3.3 (a) Energy consumption (PJ) in the transport sector in 1990-2016 (Finland's NIR 2018)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Civil aviation												
Aviation gasoline	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,00	0,01	0,004	0,002	0,002
Jet kerosene	2,2	1,9	2,8	2,6	2,7	3,0	2,7	2,6	2,6	2,6	2,7	2,9
Road transportation												
Gasoline	80,5	76,4	71,0	74,4	66,3	64,1	62,3	60,9	59,8	59,2	58,8	57,9
Diesel oil	67,4	62,6	76,5	86,2	99,5	102,4	101,3	103,2	102,0	101,0	104,5	106,6
Natural gas	NO	NO	0,05	0,1	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Liquid biofuels	NO	NO	NO	NO	6,0	8,5	8,4	9,5	21,0	21,0	7,6	16,6
Gaseous biofuels	NO	NO	NO	0,0001	0,002	0,006	0,02	0,04	0,1	0,1	0,1	0,1
Railways												
Gasoil	2,6	2,6	2,2	1,7	1,3	1,4	1,3	1,3	1,1	0,9	0,9	0,9
Navigation												
Heavy fuel oil	1,6	1,8	2,2	1,7	1,7	1,9	1,6	1,2	0,6	0,4	0,4	0,4
Gasoil	4,9	4,6	4,7	4,7	4,8	4,8	4,5	4,9	4,7	4,9	4,6	4,8
Gasoline	1,8	1,9	1,9	1,9	1,7	1,3	1,3	1,5	1,4	1,5	1,4	1,4
Diesel oil	NO	NO	NO	NO	0,5	0,5	0,5	0,5	0,4	0,4	0,4	0,4

Table 3.3 (b) The allocation of diesel oil, heating gasoil and non-road gasoil; numbers include bio-shares (PJ)

PJ (including bio-shares)		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Road transportation	Diesel oil	66.9	62.1	76.5	86.2	95.1	92.0	99.6	102.5	101.4	102.4	101.1	101.7	105.1	106.6
Leisure boats		0.45	0.46	0.48	0.47	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
Domestic navigation	Non-road gasoil	4.45	4.11	4.24	4.20	4.15	4.25	4.77	4.76	4.53	4.86	4.71	4.94	4.63	4.79
Railway transport		2.58	2.61	2.17	1.73	1.57	1.26	1.32	1.37	1.35	1.26	1.15	0.93	0.87	0.87
Off-road vehicles and other machinery		29.39	28.33	30.36	30.72	32.81	31.52	31.54	30.04	31.81	31.21	30.56	29.48	28.25	29.86
Energy production, heating, industry	Light fuel oil (=heating gasoil)	68.89	63.17	59.26	53.40	40.72	39.95	44.08	36.94	39.26	34.81	34.09	31.63	34.09	32.91
Total gasoil + diesel oil		172.6	160.8	173.0	176.7	174.7	169.5	181.9	176.1	178.9	175.1	172.1	169.1	173.3	175.5

Table 3.3 (c) Amount of bio-components of liquid fuels

	Gasoline	Diesel oil	Non-road gasoil	Heating gasoil	Biogas	Avoided fossil CO_2, kt
2002	33	NO	NO	NO	0.01	2
2003	176	NO	NO	NO	0.07	13
2004	186	NO	NO	NO	0.07	14
2005	NO	NO	NO	NO	0.07	0.004
2006	34	NO	NO	NO	0.11	3
2007	71	5	NO	NO	0.22	6
2008	2 704	437	NO	NO	0.29	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	IE	IE	39	698
2014	3 108	17 889	IE	IE	61	1 542
2015	2 926	18 094	IE	IE	82	1 545
2016	3 008	4 578	IE	IE	77	556
2017	3 586	12 972	IE	IE	109	1 217

The classification of fuels and their properties is presented at Statistics Finland's website http://tilastokeskus.fi/tup/khkinv/khkaasut_polttoaineluokitus.html (see the English language tables).

Table 3.5 (d) Mixing requirements and effective bioshares in liquid and gaseous fuels (Finland's NIR)

Year	**Mixing requirement as % of heating value specific, includes double counting)**	**Effective bio-shares (%) of the fuels used in(not fuel the model. No double counting**
2007	0%	0.0 %
2008	2%	1.8 %
2009	4%	3.8 %
2010	4%	3.8 %
2011	6%	4.7 %
2012	6%	4.7 %
2013	6%	5.7 %
2014	6%	13.0 %
2015	8%	12.6 %
2016	10%	4.3 %
2017	12%	12.2 %
2018	15%	12.7 %
2019	18%	13.2 %
2020	20%	13.5 %

Use of lubricants

Emissions from (2-stroke) lubricants in fuels are included in the emission factors. However, the activity data, i.e. the use of 2-stroke and 4-stroke lubricants, are allocated under NFR 1A2gviii to avoid possible contradictions to the energy balance (in the Finnish ghg inventory under CRF 2D1).

Finland does not have data on the sales of 2-stroke oil separately from the use of 4-stroke oil and other lubricants. To be able to allocate these emissions to Energy Sector, a split to four subsectors (road transport, residential non-road machinery, commercial non-road machinery and leisure boats) would be needed, and a full time series is not available. The allocation does not result in over- or underestimation and the emissions are negligible. The uncertainties exceed the level of the activity volume and the volume of emissions by orders of magnitude. Lubricant use has been checked to be consistent in the

Finnish ghg and air pollutant inventories. Collecting the sales statistics for lubricants to enable the calculation has been discussed with Statistics Finland, which has noted the request.

3.4 Aviation

Changes in chapter	
Update of text	February 2019 KS, KG

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

Source category description

The contribution of the category to total emissions is presented in Tables 3.6 a and b.

Table 3.6 (a) Contribution of NFR 1A3ai(i) in 2017 to total emissions

Pollutant	Emissions in 2017		Unit	Share of total emissions %
NOx (as NO2)	0.736		Gg	0.6
NMVOC	0.102		Gg	0.1
SOx (as SO2)	0.045		Gg	0.1
PM2.5	0.005		Gg	<0.1
PM10	0.005		Gg	<0.1
TSP	0.005		Gg	<0.1
BC	0.003		Gg	<0.1
CO	0.741		Gg	0.2

Table 3.6 (b) Contribution of NFR 1A3aii(i) in 2017 to total emissions

Pollutant	Emissions in 2017		Unit	Share of total emissions %
NOx (as NO2)	0.180		Gg	0.1
NMVOC	0.029		Gg	<0.1
SOx (as SO2)	0.012		Gg	<0.1
PM2.5	0.001		Gg	<0.1
PM10	0.001		Gg	<0.1
TSP	0.001		Gg	<0.1
BC	<0.001		Gg	<0.1
CO	0.296		Gg	<0.1
Pb	0.027		Mg	0.2

Emission trend

Variations in fuel consumption and emissions are caused by variations in the number of flights, flight hours as well as changes in the fleet of aircraft. The economic recession in the early 1990's decreased the number of flights. In the late 1990's, the demand on domestic air transport and the number of commercial flights increased. During the 2000's, the overall emission trends have been decreasing, partly due to renewed fleet and the years after 2008 due to the recession that started in 2008.

After the flight numbers have started to increase, there is clear increase in NOx emissions although the domestic carrier has several low-NOx –engine equipped aircrafts.

The emission trends of NOx, NMVOC, SOx, CO, NH3, Pb and particles from aviation are presented in Figure 3.3.

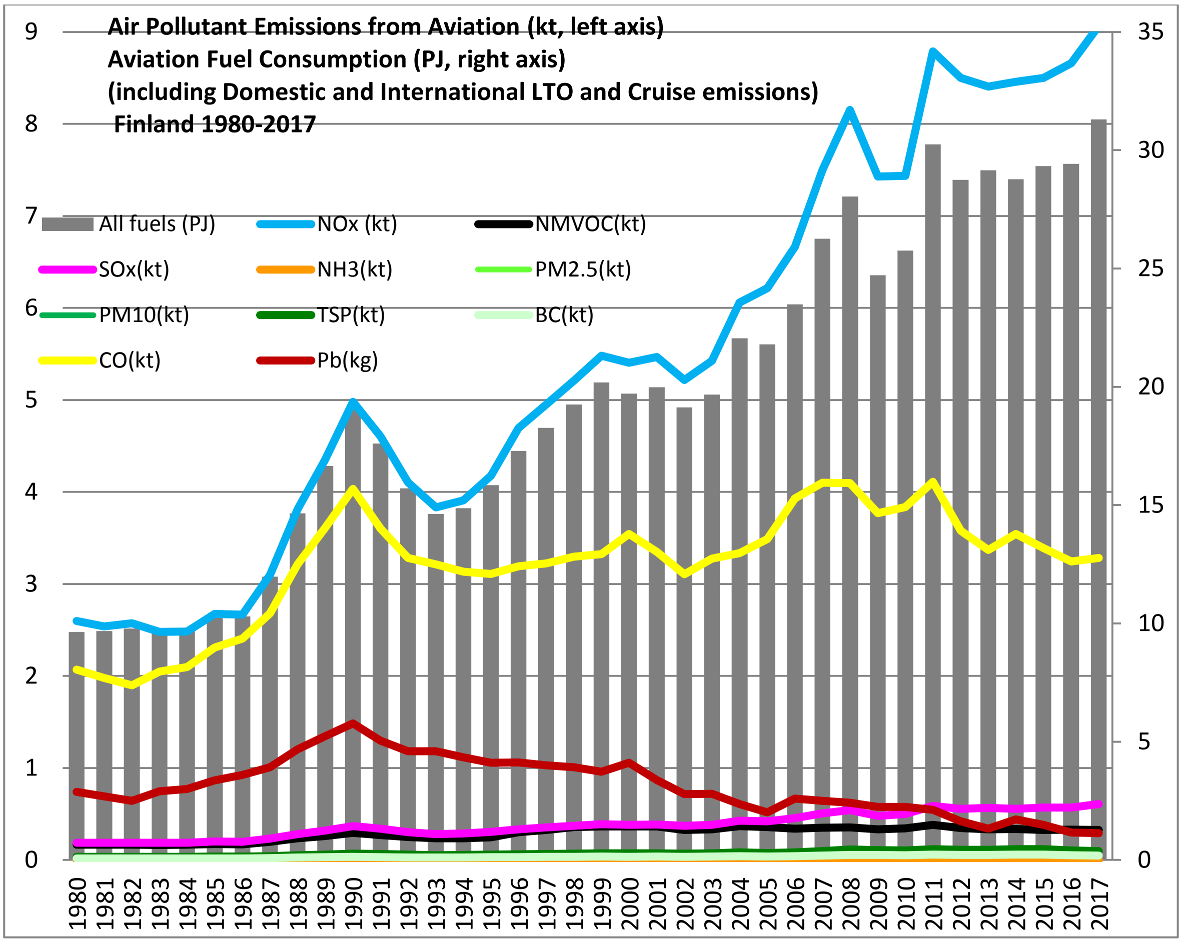


Figure 3.3. An overview of aviation emissions and fuel use 1980-2017.

Domestic aviation

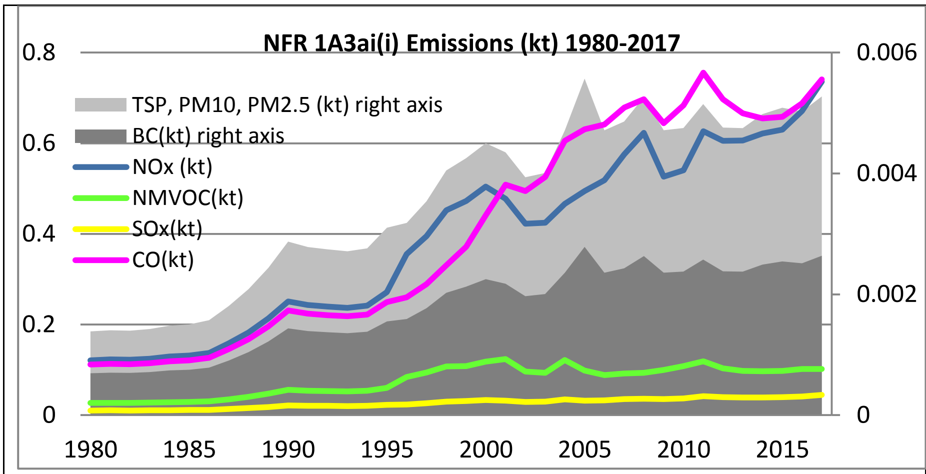
Emissions from civil aviation include all domestic civil aviation: jet and turboprop powered aircraft (turbine-engined fleet in air transport) and piston engined aircraft (mostly general aviation). Helicopters are not included in the calculations of civil aviation as a separate category due to the small 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 following next submissions after identifying the related data. These emissions were neither covered by the earlier estimates of FINAVIA.

International aviation

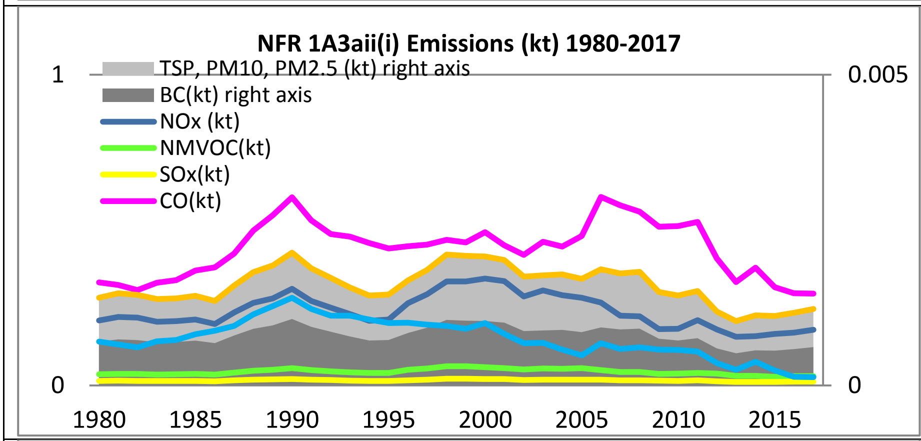
International LTO and Cruise emissions include all aircrafts in international aviation.

International aviation volumes to and from Finland have been in constant increase since the late 1980's, while there have been some periods of decrease in the early 1990's and in the beginning of the 2000's.

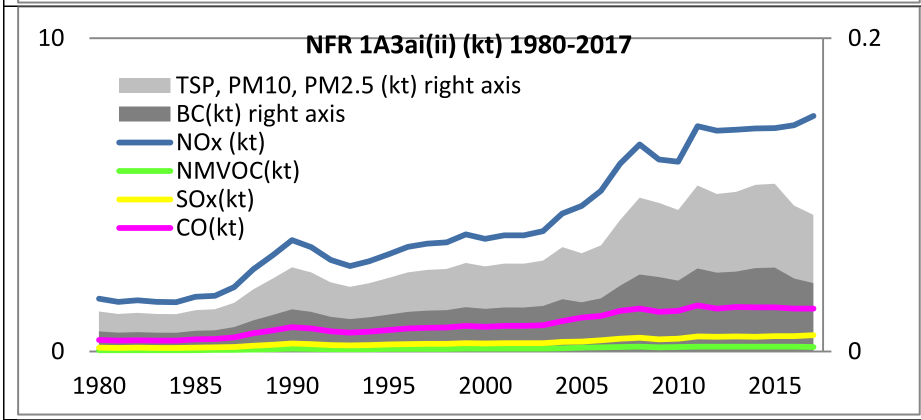
The emission trends of NOx, NMVOC, SOx, CO, NH3, Pb and particles are presented by NFR category in Figures 3.4 a-d.



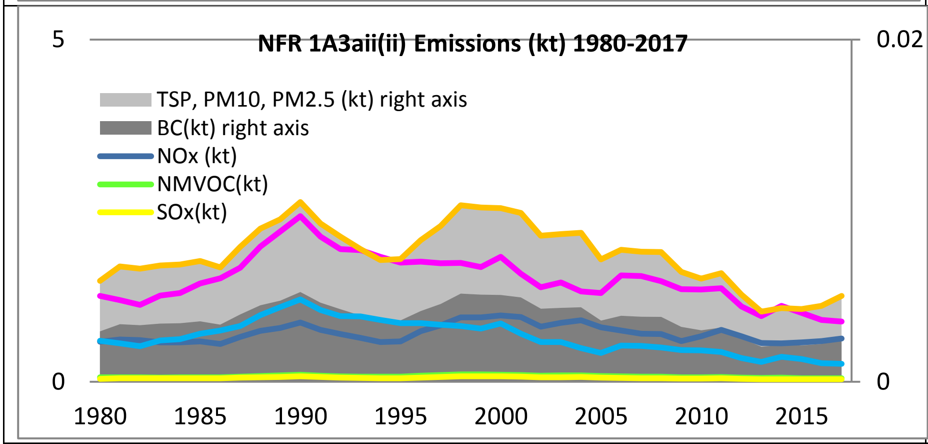
a)
1A3ai(i) (International LTO) 1980-2017



b)
1A3aii(i) (Domestic LTO) 1980-2017



c)
1A3ai(ii) (International Cruise) 1980-2017



d)
1A3aii(ii) (Domestic Cruise) 1980-2017

Figure 3.4. NFR category specific emission trends 1980-2017

Methodological issues

Previous method

Calculation of aviation emissions until the year 2009 was carried out by the 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).

Finavia did not prepare the inventory for years after 2010 for 2008 but started discussion with EUROCONTROL on possibilities to move the calculation of aviation emissions to be carried out through a data system maintained by EUROCONTROL. As the project by EUROCONTOL did not fully reach 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 from the CRF tables in the Finnish greenhouse gas inventory under the UNFCCC.

The revised method since the 2017 submission

Aviation emissions since the 2017 submission have been calculated with a national Aviation emissions calculation model on the basis of EUROCONTROL data and national statistics on fuel use. The model is maintained by Statistics Finland and shared with Finnish Environment Institute to include air pollutant emissions. Finavia experts supported the adoption of the new model.

The recalculation uses national fuel statistics for 1980-2016 and EUROCONTROL fuel and emissions data by EU Member State for the period 2005-2016. The estimates by EUROCONTROL do not cover the following sources: non-scheduled flights, such as training, rescue and hobby flights, and it neither reflects local taxi times at the airports.

For the 2018 submission, the EUROCONTROL fuel use data was corrected with information in national statistics for domestic aviation as presented in Table 3.8.

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).

Emissions from domestic aviation 1980-2004 and partly until 2008 have been calculated in the calculation model maintained for those years by Finavia. The new national Aviation emissions calculation model is based on fuel shares for different aircraft types from the EUROCONTROL data since 2005. Slight differences (3-10%) between the Eurocontrol jet fuel data and fuel data received from FINAVIA for 2005-2010 have been identified and considered reasonable as the latest changes in the fleet had not been fully updated in the earlier Finavia system.

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 for these aircraft.

Statistics Finland has corrected the data provided in the EUROCONTROL model to match with the national fuel statistics as explained in the Finnish NIR.

Description of the calculation model maintained by Finavia for 1980-2008 and the current calculation method is presented in the Finnish NIR (p. 98).

Emission factors

EMEP/EEA Emission Inventory Guidebook 2016 emission factors are used in the calculation of NOx, NMVOC, NH3, SOx, CO and particle emissions (TSP, PM10, PM2.5 and BC).

Lead emissions

For the calculation of lead emissions from avgas volumes presented in Table 3.9, the domestic emission factor of 0.013443936 t/TJ was used. The EF is based on the known mix of avgas qualities, including low leaded, used in the country.

Table 3.9 Fuel use in Aviation 1980-2017

Year			1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Domestic fuels	Jet fuel	TJ (43.3)	3 042	3450	3405	3411	3430	3517	3287	3904	4408	4656
	Jet fuel	kt	70.2	79.7	78.6	78.8	79.2	81.2	75.9	90.2	101.8	107.3
	Avgas	TJ (43.7)	55.2	51..6	47.9	55.5	57.4	64.4	68.8	75.0	89.6	100.1
	Avgas	kt	1.3	1.2	1.1	1.3	1.3	1.5	1.6	1.7	2.0	2.3
Intl Fue ls	Jet fuel	TJ (43.3)	6 538	6 173	6 335	6 173	6 173	6 782	6 944	8 000	10 153	11 899
	Jet fuel	kt	151	142.6	146.3	142.6	142.6	156.6	160.4	184.8	234.5	274.8
Year			**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Domestic fuels	Jet fuel	TJ (43.3)	5 154	4548	4172	3773	3452	3508	4096	4556	5213	5167
	Jet fuel	kt	119	105	96	67	80	61	95	105	120	119
	Avgas	TJ (43.7)	110	96	88	88	83	79	79	76	75	71
	Avgas	kt	2.5	2.2	2.0	2.0	1.9	1.8	1.8	1.7	1.7	1.6
Intl Fuels	Jet fuel	TJ (43.3)	13 767	12 955	11 452	10 762	11 330	12 254	13 118	13 629	13 964	14 946
	Jet fuel	kt	317.9	299.2	264.5	248.5	261.7	283	303	314.8	322.5	345.2
Year			**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Intl Fuels	Jet fuel	kt	5109	5020	4361	4410	4491	4140	3848	3597	3520	3227
	Jet fuel	kt	118	116	101	103	96	89	83	81	75	72
	Avgas	TJ (43.7)	78	64	53	53	45	39	50	48	46	43
	Avgas	kt	1.8	1.5	1.2	1.2	1.0	0.9	1.1	1.1	1.1	1.0
Intl fuels	Jet fuel	TJ (43.3)	14 526	14 890	14 721	15 212	17 517	17 625	19 598	22 618	24 482	21 449
	Jet fuel	kt	335.5	343.9	340	351.3	404.5	407.1	452.6	522.3	565.4	495.4
Year			**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**		
Intl Fuels	Jet fuel	TJ (43.7)	3129	3486	2916	2502	2511	2481	2528	2631		
	Jet fuel	kt	72	81	67	58	58	57	58	61		
	Avgas	TJ (43.7)	43	41	31	25	33	28	22	22		
	Avgas	kt	1.0	0.9	0.7	0.6	0.8	0.7	0.5	0.5		
Intl fuels	Jet fuel	TJ (43.3)	22 589	26 730	25 800	26 629	26 240	26 818	26 880	28653		
	Jet fuel	kt	521.7	617.3	595.8	615	606	619.4	620.8	661.7		

Uncertainties

Uncertainties are presented in Annex 7 of the IIR.

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.

Recalculations and source-specific improvements

2018
Ammonia and lead emissions as well as all particle sizes and BC were included for the whole time series.

Source-specific planned improvements

The possibility to add additional heavy metal and POP emissions will be studied for the next submission in 2019.

3.5 Road transport

Changes in chapter	
Update of text	March 2019 KS, TF, KM, KG, JMP, NIR2018

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**

The national model for Transport sector emissions – LIPASTO

Emissions from the road transport, navigation, railways and off-road machinery are calculated in the detailed LIPASTO calculation system, which is maintained and developed by VTT Technical Research Centre of Finland http://lipasto.vtt.fi/en/inventaarioe.htm

Currently, the LIPASTO system covers all other emission compounds but not ammonia, POP compounds, heavy metals and small particle fractions (PM2.5 and PM10). These are calculated at separately the Finnish Environment Institute SYKE using the activity data available in the LIPASTO system.

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

All emission factors have been updated to the 2019 submission to those presented in Guidebook 2016.

Source category description

The contribution of the category to total emissions is presented in Table 3.10

Table 3.10 Contribution of NFR 1A3bi in 2017 to total emissions

Pollutant	Emissions in 2017		Unit	Share of total emissions %
NOx (as NO2)	13.585		Gg	10.5
NMVOC	2.040		Gg	2.3
SOx (as SO2)	0.027		Gg	<0.1
NH3	0.878		Gg	2.8
PM2.5	0.321		Gg	1.8
PM10	0.321		Gg	1.1
TSP	0.321		Gg	0.7
BC	0.167		Gg	4.1
CO	28.890		Gg	8.0
Pb	0.002		Mg	<0.1
Cd	<0.001		Mg	<0.1
Hg	0.016		Mg	2.7
As	<0.001		Mg	<0.1

Cr	0.015		Mg	<0.1
Cu	0.010		Mg	<0.1
Ni	0.003		Mg	<0.1
Se	<0.001		Mg	<0.1
Zn	0.057		Mg	<0.1
PCDD/ PCDF	0.701		g I-Teq	5.2
PAHs	0.095		Mg	0.9
HCB	0.126		kg	0.4
PCB	<0.001		kg	<0.1

Emission trends

The consumption of diesel and gasoline increased by about 1 PJ per year during the 1970's and 1980's. Then the consumption fell rapidly from 1990 onwards due to recession. Diesel consumption 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. 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. The economic recession of the early 1990's explains why road traffic kilometrage (mileage) 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 until 1997.

From 2008 onwards, the emissions have decreased due to many simultaneous different factors, both societal and legislative.
- A new prolonged economic depression decreased kilometrage
- The fuel consumption of cars has decreased due to EU CO2 limits set to the car manufacturers
- A national car tax reform based on CO2 emissions caused a dramatic transition from gasoline to diesel cars and decreased CO2 emissions in 2009.
- Biofuels have lowered the CO2 emissions but there are strong yearly fluctuations in the bio-shares of diesel oil. While gasoline has a technical limit for the maximum ethanol blend diesel has no technical limit. This fact is used for the bio-share obligations i.e. to increase the bio-share in diesel oil when needed. The fuel suppliers are allowed high yearly fluctuations in the bio component mix as long as the long-term trend fulfils the legislative targets.

Fuel consumption per vehicle has stayed 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 3.5. 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.

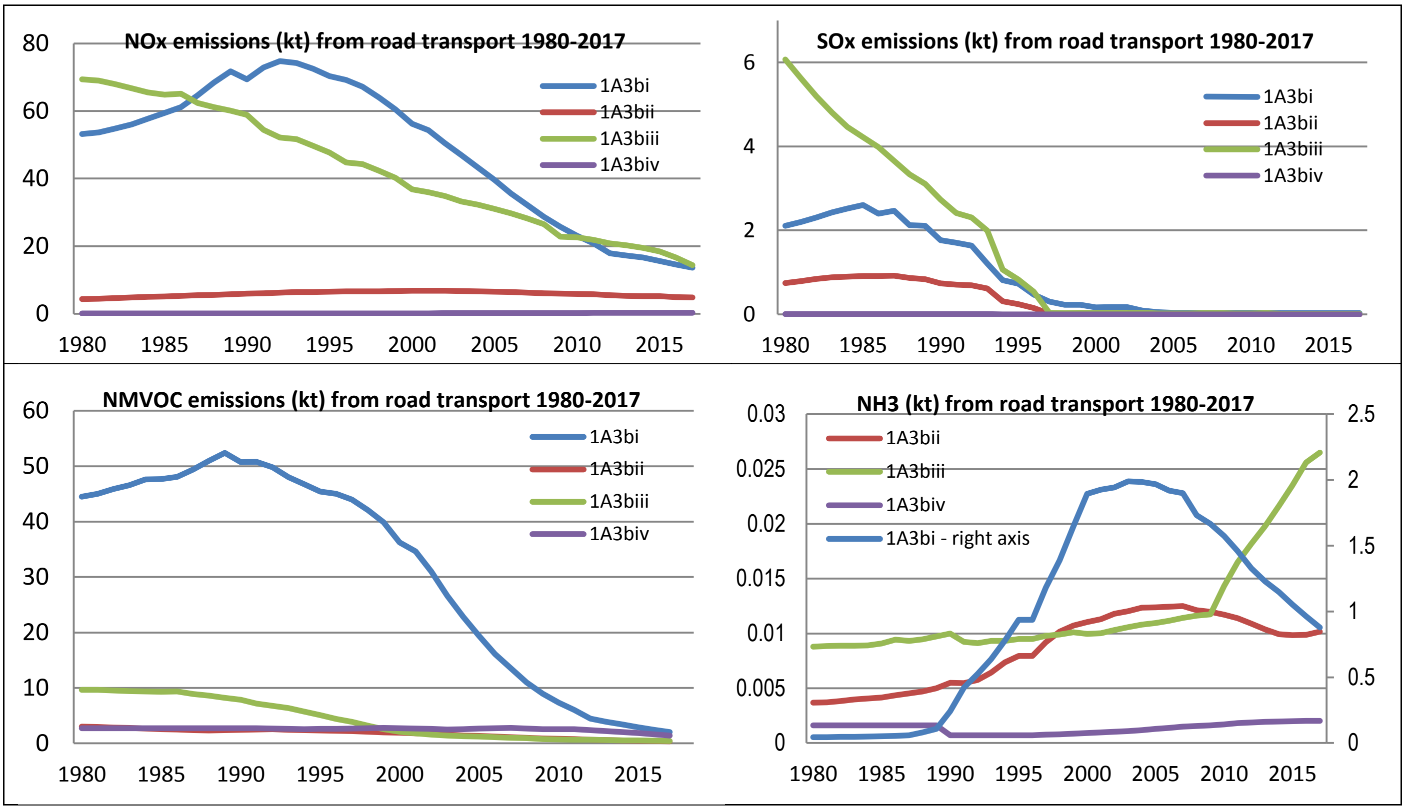


Figure 3.5. NOx, SOx, NMVOC and NH3 emissions from road transport 1980-2017

The economic recession in the early 1990's slowed down the increase of fuel use, which, however, grew per 2 PJ per year during 1970-1980's. 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. The energy efficiency of new registered cars began to improve in the 1990s. Since 1995 the consumption of diesel has grown while the consumption of gasoline has decrease by 1 PJ per year since the 1990's.

Fuel consumption is presented in Figure 3.6 and the road kilometrage in Table 3.12. The results of the recalculated fuel use by vehicle category are presented in Figure 3.7 and in details on the website of LIPASTO http://lipasto.vtt.fi/en/aliisa/aliisa_results.htm .

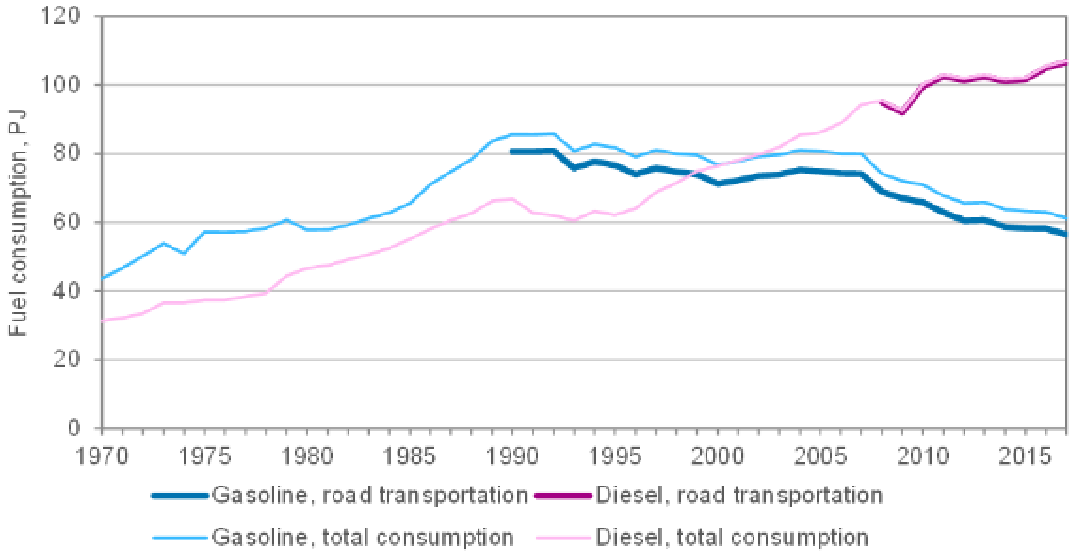


Figure 3.6 Consumption of diesel oil and gasoline (including bio-shares) in road transportation in the years 1970-2017 (Energy Statistics, Statistics Finland, NIR 2019)

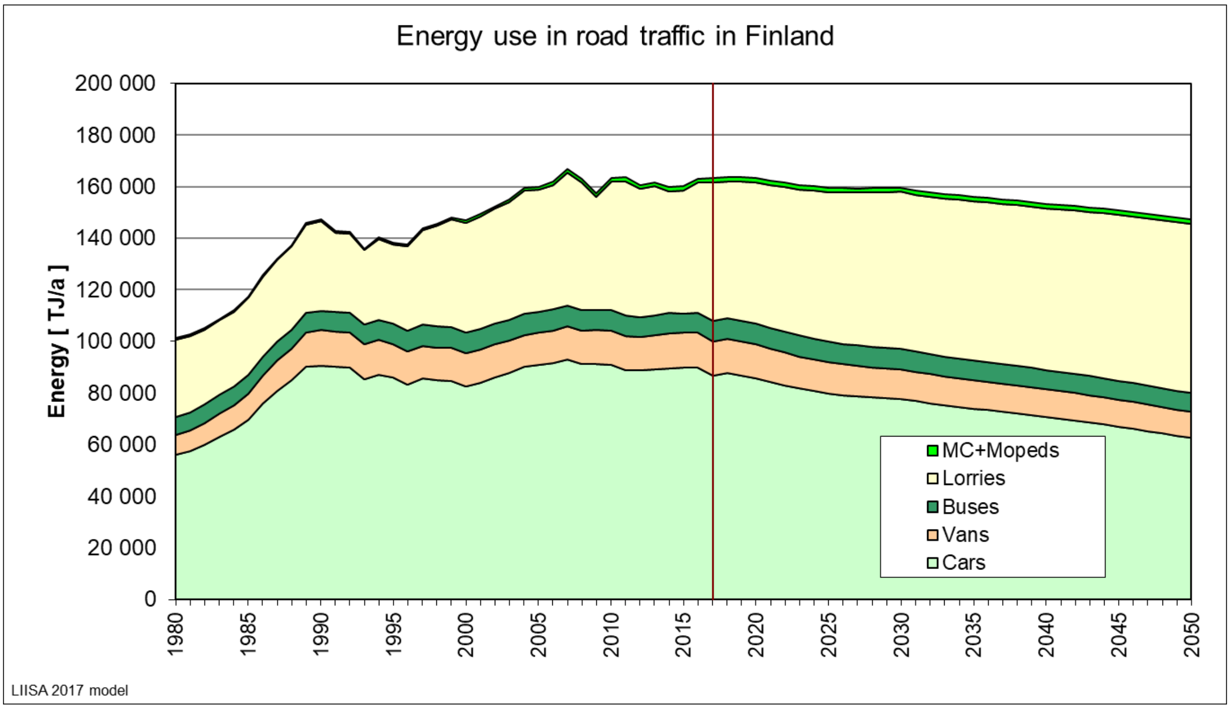


Figure 3.7 The results of the recalculated fuel use by vehicle category (LIPASTO, VTT)

Methodological issues

Change of text	
March 2019	KS, KG, KF, TF

LIISA submodel of the LIPASTO calculation system

Emissions from transportation are calculated using the national calculation system for transport emissions, LIPASTO (www.lipasto.vtt.fi). The LIISA sub-model of LIPASTO calculates fuel based emissions from road transport: NO_x, SO_2, NMVOC, CO_2, CH_4, CO, Pb and TSP for the years 1980–2050. Non-fuel based Pb emissions are calculated at SYKE.

In the 2019 version of the LIISA calculation model the emission factors are from EMEP EEA Guidebook 2016 and have not been adjusted to the Finnish car population as in the earlier LIISA model. The full description of the LIISA model is available online http://www.lipasto.vtt.fi/liisa/liisa_menetelma.pdf , currently only in Finnish. The LIISA model also includes new vehicle technologies (FFV, gas, electric vehicles etc. as described in paragraph Methods) and for example urea additive AdBlue.

The emission calculation is based on annual kilometrage (km/a) per vehicle type. The emission factors are classified according to the emission standards (Euro0-Euro6 classes) and include degradation of vehicles. Also cold start of vehicles is taken into account. The calculation follows the 2006 IPCC Guidelines for National Green House Gas Inventories and the EMEP/EEA Emission Inventory Guidebook 2016.

Basis of calculation

In the LIISA model, CO_2 and SO_2 emissions are calculated from fuel consumption of road vehicles and emission factors. The definition of consumption of fuel on the country level is based on fuel sales. All other emissions are calculated from the driven kilometrages and corresponding emission factors.

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 emission factors are a sum of hot driving, idle and cold start-ups.

Kilometrage (mileage)

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 Infrastructure 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). Road traffic kilometrage in Finland is presented in Table 3.12

Table 3.12 Road traffic kilometrage in Finland (million km/a) (LIISA submodel and NIR 2018)

Year	Cars	Light duty trucks	Heavy duty trucks and buses	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	40 284	5 297	4 557	1 527	51 665
2014	40 720	5 105	4 694	1 529	52 047
2015	41 030	5 346	4 710	1 488	52 575
2016	41 196	5 367	4 828	1 413	52 804

Vehicle fleet model ALIISA and the kilometrage

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 Finnish Transport Communications Agency, Traficom).

The division of kilometrage by vehicle types and technologies is done by an ALIISA model, which is a vehicle fleet model and sub-model 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 3.13

Table 3.13 Road kilometrage 1990-2017 (million km/a) from LIISA (Finland's NIR 2019)

Year	Cars	Light duty trucks	Heavy duty trucks and buses	MC+Mopeds	Total
1990	35 757	3 593	3 440	448	43 237
1995	34 740	3 743	3 272	447	42 203
2000	38 699	4 266	3 412	556	46 934
2005	41 195	4 676	3 732	781	50 385
2008	41 102	4 945	3 941	964	50 952
2009	41 236	5 048	3 697	989	50 970
2010	40 991	5 136	3 835	1 045	51 007
2011	40 682	5 145	3 906	1 131	50 864
2012	40 030	5 133	3 910	1 171	50 244
2013	40 455	5 189	3 954	1 194	50 792
2014	41 064	5 306	3 974	1 205	51 549
2015	40 603	5 488	4 028	1 220	51 339
2016	40 682	5 511	4 130	1 226	51 549
2017	40 528	5 608	4 001	1 225	51 362

In 2015 the Finnish Transport Infrastructure Agency started a project aiming at producing better (more detailed and improved accuracy) annual kilometrage data by combining new data on odometer readings available from the Periodic Technical Inspection Centres (nowadays covering the whole vehicle fleet yearly inspected) with the data from the automatic road volume measurement points on public roads. Based on the project results a new calculation system of yearly road transportation kilometrage in Finland was introduced and applied in 2017, also to the LIISA model. In addition, in 2017 the motorcycle and moped kilometrage calculation method has been improved by VTT. Due to these improvements in the kilometrage calculation a new recalculation for the period 1991 to 2016 was made.

Table 3.14. The percentage change of kilometrage due to recalculation (Finland's NIR 2019)

Change [%]	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Passenger cars	0.0	0.0	0.0	0.0	0.0	-0.6	-0.8	0.4	0.8	-1.0	-1.2
Vans	0.0	0.0	0.0	0.0	0.0	-1.9	-3.1	-2.0	3.9	2.7	2.7
Buses	0.0	0.0	0.3	0.1	0.1	-0.1	-1.1	-0.3	0.1	0.3	1.5
Lorries	0.0	-1.1	-6.5	-9.8	-13.5	-15.2	-15.4	-15.3	-17.7	-16.7	-16.8
Motorcycles	0.0	-4.5	-8.3	-21.5	-24.5	-23.7	-22.9	-21.8	-21.2	-18.0	-13.2
Total	0.0	-0.1	-0.5	-1.1	-1.6	-2.5	-2.8	-1.7	-1.0	-2.3	-2.4

Fuels sold

Total fuel sales are from statistics compiled by the Finnish Petroleum and Biofuels Association completed with data from Tax administration. 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 58.3 PJ and in leisure boats and working machines 4.7 PJ (8% of total sales) in 2016. Diesel fuel sales were 111.3 PJ of which use in leisure boats was 0.4 PJ (0.4% of total sales). Bio-diesel and bio-gasoline 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 from the Energy Statistics.

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

Information on fuel properties can be found on Statistics Finland's website http://tilastokeskus.fi/tup/khkinv/khkaasut_polttoaineluokitus.html .

Degradation of vehicles

The national road transport calculation method LIISA takes into account the degradation of vehicles. Degradation has impact on CO, HC and NOx emissions of cars and light duty vehicles as stated in the Guidebook.

In the Guidebook degradation factors are based on vehicle kilometrage. As in the LIISA model the calculation of emission is based on the total kilometrage of each vehicle type and the vehicle age, the degradation factors published in the Guidebook cannot be used as such in the LIISA model. Instead, the kilometrage based factors in the Guidebook have been used to define age-based factors for the LIISA model. In each calculation year the factors are defined for the different Euro-classes. The correlation between the vehicle age and the kilometrage in the Finnish fleet has been calculated using the ALIISA vehicle model. The correction factors for the Euro-classes for the year 2016 are expressed in Table 3.15

Table 3.15. Correction factors for degradation in the LIISA model. (LIPASTO)

Compound and vehicle type	Emission factors for degradation in LIISA model, gasoline vehicles						
	Euro 0	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
CO cars	1.84	1.84	1.84	1.15	1.15	1.09	1.00
CO vans	1.84	1.84	1.84	1.15	1.15	1.09	1.00
HC cars	1.88	1.88	1.88	1.00	1.00	1.00	1.00
HC vans	1.88	1.88	1.88	1.00	1.00	1.00	1.00

NOx cars	2.02	2.02	2.02	1.22	1.22	1.13	1.00
NOx vans	2.02	2.02	2.02	1.22	1.22	1.13	1.00

Emission factors and other parameters

The methods for calculating emissions from road transportation correspond to the EMEP Tier 3. The work to check and harmonize emission factors to comply with the 2006 IPCC Guidelines and EMEP/EEA 2016 is finalized and results are included in 2017 calculation. Recalculations have been made for the period 1991-2016.

Emission factors are determined for all the activity categories mentioned above.

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

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

$$E^c = \sum_{r=1}^{6}\sum_{v=1}^{6}\sum_{l=1}^{5}\sum_{x=1}^{6}\sum_{f=1}^{6}\sum_{y=1}^{7}\left(M_{r,v,l,x,f,y}\left(e^{c,h}_{r,v,l,x,f,y}+e^{c,s}_{r,v,l,x,f,y}\right)\right)$$

where

E^c	total emissions of compound c
c	compound
r	road type (6 types)
v	speed limit class (6 classes)
l	type of vehicle (5 types)
x	type of driving power (6 types)
f	fuel type (6 types)
y	emission standard level (Euro) (7 classes)
M	kilometrage (given by road type, speed limit class and main type of vehicle, and divided to vehicle subclasses using a car fleet model called ALIISA)
$e^{c,h}$	emission factor for hot driving
$e^{c,s}$	emission factor for cold start-ups

The more detailed description of the calculation methodology of the model is presented at the website referenced above (currently only available on the Finnish webpages).

Calculation of emissions not covered by LIISA

Emissions not covered by the LIISA sub-model of the LIPASTO calculation system are calculated at Finnish Environment Institute SYKE using activity data from the LIISA and emission factors from the EMEP/EEA Guidebook.

Particle emissions

TSP emissions are based on the results of the LIISA road transport model, where the emission factors are expert estimates combining national measurement results to the methods in the 2016 Guidebook. In most cases the emission factors are those presented in the Guidebook. To the 2018 submission,

Calculation of PM_{10} and $PM_{2,5}$ size fractions of TSP emissions from the results in the LIISA model was revised to the 2018 submission to use the fraction factors of the 2016 EMEP/EEA Emission Inventory

Guidebook, i.e. the rations between all particle fractions is 1:1. The impact of the revision was below the threshold of the 2% for a technical correction in the NECD review.

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

NH_3 emissions

Ammonia emissions from road transport were included in the inventory for the first time in the 2015 submission. The emissions are calculated by EURO classes as described 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 3.16 and activity data (driven kilometres) in Table 3.17.

Table 3.16 NH_3 emissions factors for road transport (EMEP EEA Guidebook 2016. Estimates made by VTT LIPASTO experts 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	34.2	12.3	12.3
Heavy duty with trailer, diesel*	2.9	2.9	2.9	2.9	2.9	11	9
Heavy duty without trailer, diesel	2.9	2.9	2.9	2.9	2.9	11	9
Heavy duty without trailer, gas						33.8[ex]	33.8[ex]
Busses, diesel*	2.9	2.9	2.9	2.9	2.9	11	9
Busses, gas		88[ex]	100.7[ex]	33.8[ex]	33.8[ex]	33.8[ex]	33.8[ex]
Motocycles	1.9	1.9	1.9	1.9	1.9		
Mopeds	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)		88[ex]	100.7[ex]	33.8[ex]	33.8	33.8	33.8
Motorised quadricycles		1	1				
Passenger cars (FFV)					33.9	33.9	33.9

**Note – In the NECD 2017 review, the TERT noted that there is inconsistency in the NH3 EFs for diesel vehicles presented in Table 3-21, Table 3-23 and Table 3-100 (in particular, different factors are suggested for Euro VI heavy duty vehicles) of the 2016 EMEP/EEA Guidebook and recommended to check potential amendments of these EFs in the near future.*

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 3.17). 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).

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 emissions from road transport are calculated with the emission factors provided in the Tables 3.75 and 3.76 of the EMEP EEA Guidebook 2016. Emission factors are given separately for PCDD and PCDF.

HCB

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

PCB

PCB emissions from road transport are calculated with the emission factors provided in the Tables 3.75 and 3.76 of the EMEP EEA Guidebook 2016.

Heavy metal emissions

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 and have thus been reported in all earlier submissions.

Table 3.18 Activity data for 1990-2017 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	448	2 121 152	320 819	173 647	816 880	14 225
1991	35 607	3 610	650	2 530	448	2 111 137	315 979	177 097	726 885	14 344
1992	35 366	3 670	640	2 500	449	2 100 221	319 822	178 514	720 801	14 460
1993	34 556	3 667	639	2 571	442	1 996 588	314 274	182 400	675 823	14 306
1994	34 406	3 672	633	2 583	435	2 037 385	314 582	184 048	737 263	14 157
1995	34 740	3 743	633	2 639	447	2 008 346	307 250	184 893	724 734	14 512
1996	34 863	3 817	635	2 671	457	1 945 618	304 322	188 264	769 385	14 827
1997	35 655	3 865	612	2 759	469	2 000 829	299 237	191 967	859 573	15 300
1998	36 580	4 009	606	2 801	492	1 984 811	297 696	192 840	919 844	16 153
1999	37 730	4 180	597	2 868	527	1 980 139	300 102	191 750	978 613	17 446
2000	38 699	4 266	598	2 814	556	1 932 179	298 538	189 261	1 001 041	18 641
2001	39 207	4 361	596	2 841	585	1 964 373	297 317	190 956	1 026 173	19 726
2002	39 653	4 452	602	2 914	619	2 015 906	295 912	194 116	1 041 516	20 952
2003	40 315	4 514	573	3 021	663	2 053 074	293 140	185 230	1 072 408	22 321
2004	40 663	4 591	595	3 078	717	2 105 923	292 376	191 014	1 125 112	23 936
2005	41 195	4 676	596	3 136	781	2 127 510	294 466	189 635	1 107 045	25 959
2006	41 262	4 779	596	3 195	848	2 142 867	298 166	188 101	1 134 923	28 014
2007	41 771	4 895	593	3 290	924	2 181 718	302 511	184 974	1 213 675	30 429
2008	41 102	4 945	605	3 336	964	2 156 534	302 580	186 381	1 163 569	32 509
2009	41 236	5 048	609	3 088	989	2 176 379	307 187	186 127	1 026 120	33 133
2010	40 991	5 136	612	3 223	1 045	2 169 931	310 781	185 021	1 168 364	34 884
2011	40 682	5 145	611	3 295	1 131	2 137 427	309 818	183 024	1 218 343	37 786
2012	40 030	5 133	609	3 301	1 171	2 131 035	305 957	180 617	1 162 413	38 887
2013	40 455	5 189	615	3 339	1 194	2 130 849	307 914	180 396	1 170 726	39 658
2014	41 064	5 306	620	3 354	1 205	2 139 090	314 712	182 338	1 101 121	40 152
2015	40 603	5 488	624	3 405	1 220	2 106 997	314 960	175 274	1 102 756	40 217
2016	40 682	5 511	637	3 494	1 226	2 106 167	313 402	181 763	1 172 147	40 402
2017	40 528	5 608	631	3 370	1 225	2 094 850	320 955	184 142	1 200 030	40 793

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

Uncertainties

Uncertainties are presented in Annex 7 of the IIR. The results of the uncertainty analysis are used to improve the accuracy of the inventory.

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.

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.

A more detailed description of the QA/QC steps will be added to the 2020 submission with reference to the CLRTAP 2018 S3 review.

Source specific recalculations

2015-2016

- Revision of the calculation model LIPASTO, major changes into the estimation of kilometrages driven

2015

- Aviation emissions previously calculated by Finavia, were estimated at SYKE based on approximations from different data sources
- Ammonia emissions from transport were included in the inventory

2016

- PAH emission factors were revised according to the GB

2017

- The emissions were updated according to the results of the revised LIPASTO models.
- Aviation emissions calculated according to the Eurocontrol data in cooperation with Statistics Finland (ghg and ap inventories)
- Heavy metal emissions were included for the first time.

2018

- Calculation of PM_{10} and $PM_{2,5}$ size fractions of TSP emissions from the results in the LIISA model was revised according to the method of the 2016 EMEP/EEA Emission Inventory Guidebook, i.e. the rations between all particle fractions is 1:1. The impact of the revision was below the threshold of the 2% for a technical correction in the NECD review.
- The time series 1980-1989 was updated according to the new version of the LIISA model
- PCDD/F and PCB emission factors were revised according to the 2016 EMEP/EEA Emission Inventory Guidebook.

2019

- Details of the recalculations carried out in 2018 and 2019 to the 2017 submission are presented in Annex 9 to be submitted by 1 May 2019.
- NFR 1A3bv - Method to calculate NMVOC emissions from gasoline evaporation according to the Tier 2 methodology of the EMEP/EEA Emission Inventory Guidebook 2016 was carried out.

Source specific planned improvements

Not scheduled

- Inclusion of aviation heavy metal and POP emissions according to the EUROCONTROL calculation will be studied

3.6 Gasoline evaporation

1 A 3 b v	Road transport: Gasoline evaporation

Changes in chapter	
`February 2019	TF

Emission trend

NMVOC emissions from gasoline evaporation in 1990-2017 are presented in Figure 3.8 and Table 3.19. 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.

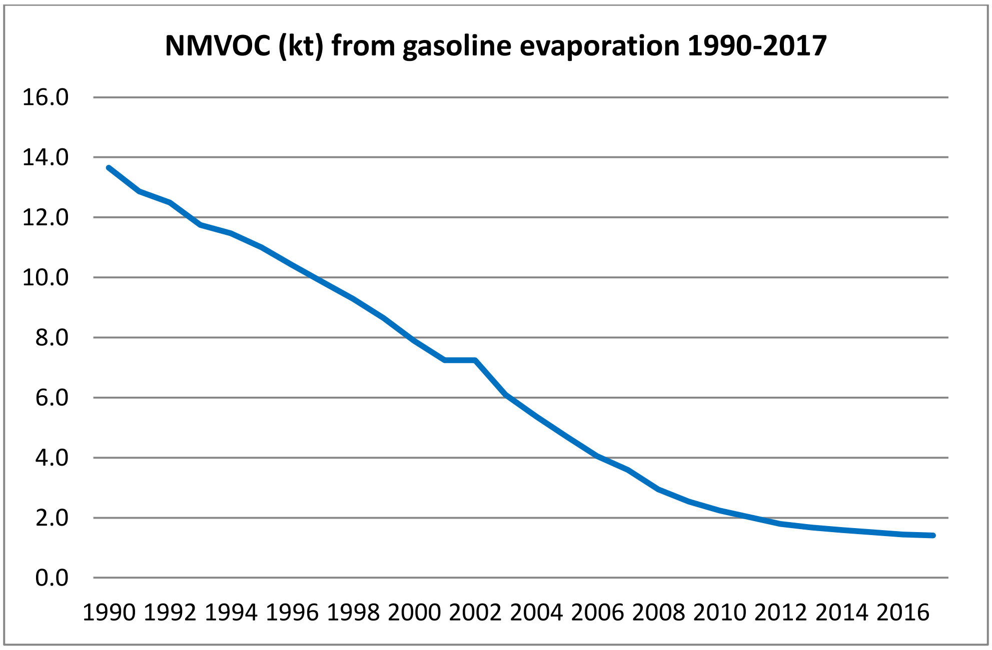


Figure 3.8. NMVOC emissions from gasoline evaporation 1980-2017

Table 3.19 NMVOC emissions 1990-2017 from vehicles.

Year	Gasoline evaporation (t)	Year	Gasoline evaporation (t)
1990	13655	2010	2243
1991	12863	2011	2016
1992	12490	2012	1791
1993	11743	2013	1673
1994	11470	2014	1596
1995	11006	2015	1520
1996	10415	2016	1443
1997	9850	2017	1410
1998	9291		
1999	8651		
2000	7896		
2001	7250		
2002	7250		
2003	6096		
2004	5374		
2005	4701		
2006	4053		
2007	3593		
2008	2944		
2009	2539		

Methodological issues

NMVOC emissions of gasoline evaporation from petrol fuelled vehicles are estimated with the Tier 2 methodology of the 2016 EMEP/EEA Guidebook. The methodology was implemented in the 2019 submission following the recommendation of the TERT in the 2017 NECD review. According to the methodology, three different mechanisms related to evaporative emissions are considered:

- diurnal losses,
- running losses,
- hot-soak losses

Diurnal losses occur due to daily temperature variations. The increase of ambient temperature causes the thermal expansion of the fuel and vapour in the fuel tank. As a result, some of the increased volume of fuel vapour is vented to the atmosphere. Running losses result from the vapour generation in the fuel tank when the vehicle is in motion. Hot-soak emissions are evaporative emissions from the fuel delivery system when a hot engine is turned off and the vehicle is no longer in motion.

NMVOC emissions from gasoline evaporation are calculated with equations (2)-(4) of the Guidebook (chapter 3.3.1, p. 10 of section 1.A.3.b.v Gasoline evaporation). The annual gasoline vehicle fleet (number of passenger cars, vans, motorcycles and mopeds) was available for the calculation from 2007. In the case of passenger cars and vans, the data was available according to the Euro classification but not according to the size class. Due to this, a conservative assumption to use emission factors of size class 1.4-2.0 l for the whole fleet was made. The number motorcycles and mopeds were available according to the Euro classification and size class. In addition, motorcycles were further divided into 2-stroke and 4-stroke engines. Emission factors needed in the calculation were taken from tables 3-5 (passenger cars and vans) and 3-6 (motorcycles and mopeds) of the Guidebook. The emission factors are given for typical temperature ranges in winter and summer, and for typical fuels which are produced with seasonally different vapour pressures. Based on this, and taking into account the Finnish climate conditions, the following assumptions were made when choosing the emission factors:

- emission factors from the temperature range summer 10 to 25 °C were applied for June, July, August and September (altogether 122 days of the year),
- emission factors from the temperature range winter 0 to 15 °C were applied for April, May, October and November (altogether 122 days of the year),
- emission factors from the temperature range winter -5 to -10 °C were applied for January, February, March and December (altogether 121 days of the year)

The assumptions from the fuel tank sizes and carbon canisters size were based on information in table 3-13 of the Guidebook. It was assumed that all conventional passenger cars and vans are uncontrolled, Euro 1 and 2 vehicles have small canisters and Euro 3 to 6 vehicles have medium canisters. No information on the carbon canisters on motorcycles or mopeds were given in the Guidebook. In the absence of any national information either, it was assumed that no motorcycles or mopeds are equipped with carbon canisters in Finland.

The average number of trips per day in different vehicle categories was calculated by means of equation (5) of the Guidebook and the average trip length. The average trip length of passenger cars was available from the latest national passenger traffic survey conducted by Finnish Transport Infrastructure Agency in 2018. The average trip length of 18 km from the survey was used in the calculation. In the case of vans, motorcycles and mopeds, no national estimate for average trip length was available. Therefore, the average European trip length of 12,4 km available in the road transport exhaust emission chapter of the Guidebook (chapter 3.4.1, p. 48) was applied for them. No specific national information on the fraction of gasoline powered vehicles equipped with carburettor and/or fuel return systems was available. Therefore, the default assumption from the Guidebook was used. According to the Guidebook, in Europe, the fraction of passenger cars and vans equipped with a carburettor is approximately 99 % for pre-Euro 1 vehicles (i.e. only 1 % equipped with fuel injection) and 0 % for post-Euro 1 vehicles. For motorcycles, the fraction is 100 % for conventional and Euro 1 vehicles, 20 % for Euro 2 and 0 % for Euro 3. In the absence of specific national data, the fraction of trips finished with hot engine also needed in the calculation, was assumed to be 100%.

Since the number of annual vehicle fleet is available for the calculation from 2007, the emissions for earlier years need to be estimated by other means. The trend in the emissions calculated with the Tier 2 approach of the Guidebook and the old approach used prior to 2019 submission is identical for the years 2007 to 2016. Therefore, the emissions for 1990 to 2006 are estimated by assuming the same emission trend prior to 2007 as in the old approach.

Uncertainties

Uncertainties are presented in Annex 7.

QA/QC and verification

Normal statistical QA/QC procedures are carried out.

Source specific recalculations

The whole time series of NMVOC emissions from gasoline evaporation for 1990 to 2016 was recalculated following the revision of the emission estimation methodology. The Tier 2 approach of the 2016 EMEP/EEA Guidebook was implemented in the 2019 submission. The recalculated emissions are lower compared to the previous emission estimates. The emission estimates calculated with the Tier 2 approach are considered more accurate compared to the old estimates calculated with much more simplified approach. Comparison of NMVOC emissions reported in the 2018 and 2019 submission is presented in Table 3.20 and Figure 3.9.

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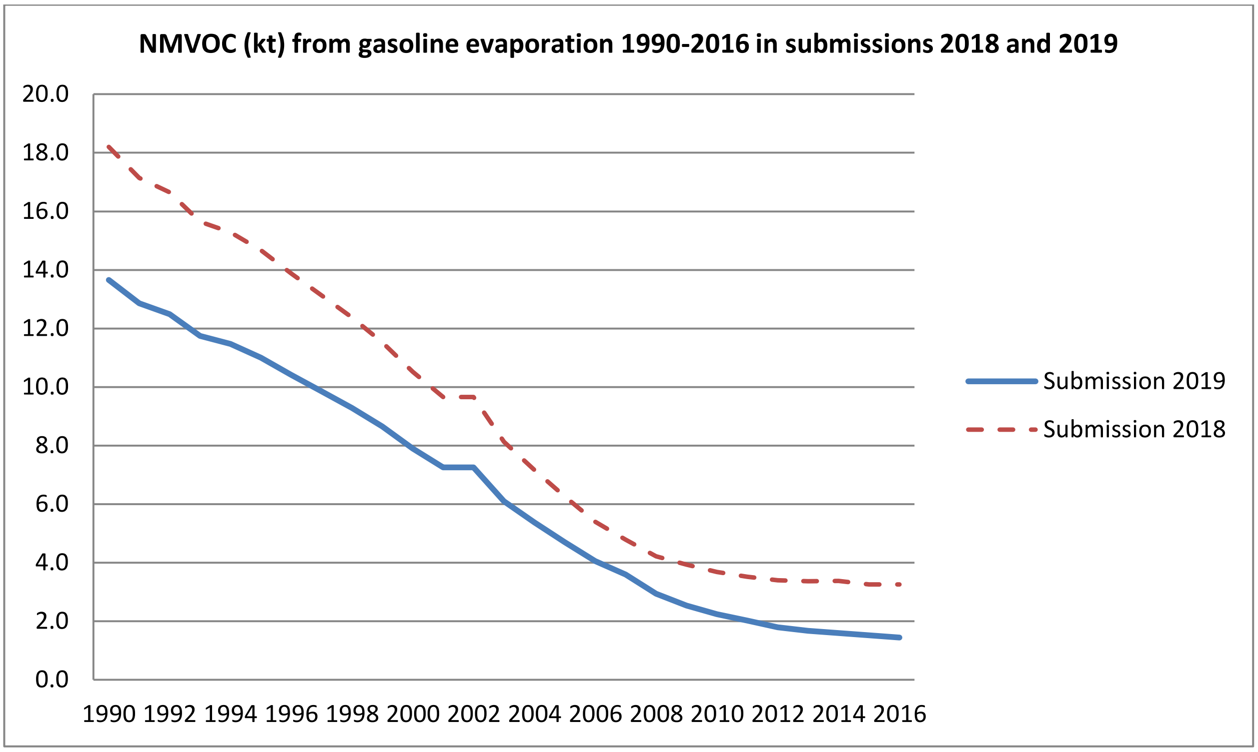
Year	Gasoline evaporation (t), submission 2018	Gasoline evaporation (t), submission 2019
1990	18 199	13 655
1991	17 143	12 863
1992	16 646	12 490
1993	15 650	11 743
1994	15 286	11 470
1995	14 668	11 006
1996	13 880	10 415
1997	13 128	9 850
1998	12 382	9 291
1999	11 530	8 651
2000	10 523	7 896
2001	9 662	7 250

2002	8 898	7 250
2003	8 124	6 096
2004	7 162	5 374
2005	6 265	4 701
2006	5 401	4 053
2007	4 789	3 593
2008	4 222	2 944
2009	3 930	2 539
2010	3 685	2 243
2011	3 523	2 016
2012	3 393	1 791
2013	3 364	1 673
2014	3 373	1 596
2015	3 255	1 520
2016	3 255	1 443



Source specific planned improvements

None.

3.7 Tyre and brake wear

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

Changes in chapter	
March 2019	JMP, KS

Emission trends

In the inventory, TSP, PM_{10} and $PM_{2.5}$ emissions are included since the year 1980, heavy metals since 1990 and black carbon since 2000. The explanations for the trends will be included in the 2019 submission.

In 2019 submission the calculation method has been changed as a result of the co-operation between Nordic countries (NAEGG co-operation). The used calculation methods are based on the Tier 2 method of Guidebook 2016.

Particle and heavy metal emission trends are presented in Figure 3.9. and in Tables 3.20 (a-e).

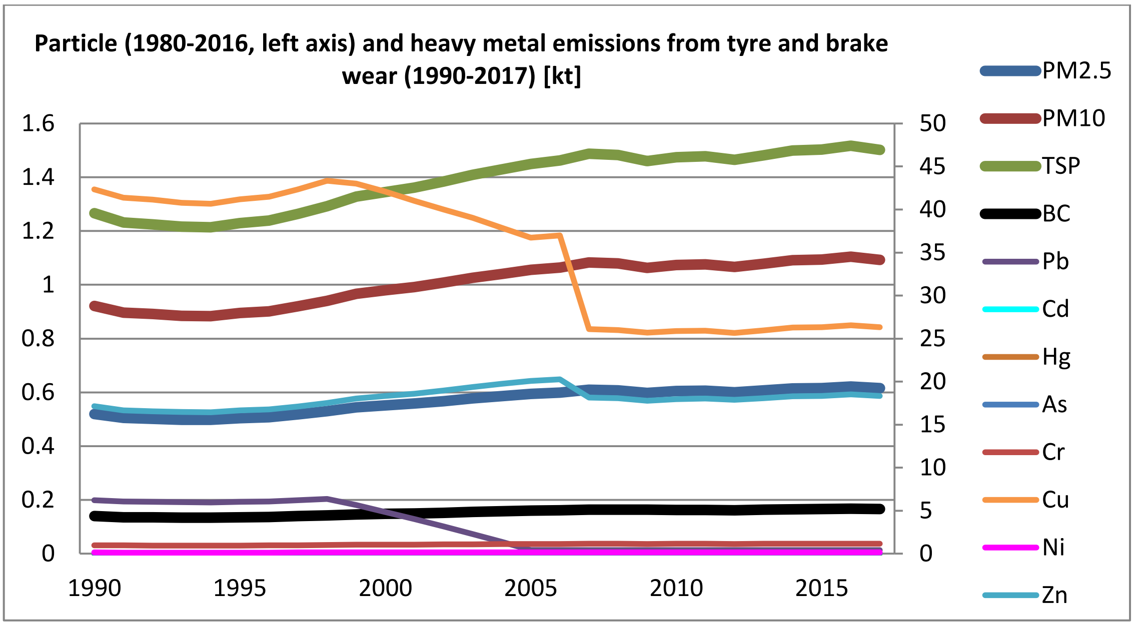


Figure 3.10 Particle and heavy metal emissions from tyre and brake wear

Table 3.21(a) Heavy metal emissions (kg) 1990-2017 from road transport tyre and brake wear.

Year	Pb (kg)	Cd (kg)	As (kg)	Cr (kg)	Cu (kg)	Ni (kg)	Zn (kg)	Se (kg)
1990	6208	1.4	31.9	982	42326	141	17150	8.5
1991	6070	1.4	31.1	961	41385	138	16672	8.3
1992	6034	1.4	30.9	955	41144	137	16564	8.3
1993	5978	1.4	30.7	946	40763	136	16462	8.2
1994	5965	1.4	30.6	944	40672	136	16432	8.2
1995	6042	1.4	31.0	956	41193	138	16650	8.3
1996	6084	1.4	31.2	963	41482	139	16772	8.3
1997	6211	1.4	31.9	983	42350	141	17121	8.5
1998	6356	1.5	32.6	1006	43335	145	17497	8.7
1999	5662	1.5	33.5	1035	43024	149	18045	8.9

Year	Pb (kg)	Cd (kg)	As (kg)	Cr (kg)	Cu (kg)	Ni (kg)	Zn (kg)	Se (kg)
2000	4855	1.5	34.0	1050	42072	151	18321	9.1
2001	4014	1.6	34.5	1064	40996	153	18608	9.2
2002	3159	1.6	35.0	1080	39992	156	18973	9.3
2003	2266	1.6	35.6	1100	39044	158	19388	9.5
2004	1367	1.6	36.1	1115	37870	160	19727	9.6
2005	427	1.7	36.6	1131	36715	163	20087	9.8
2006	431	1.7	36.9	1140	37005	164	20260	9.9
2007	418	1.7	37.6	1160	26111	167	18133	10.0
2008	416	1.7	37.4	1154	25987	166	18086	10.0
2009	411	1.7	37.0	1141	25691	164	17775	9.9
2010	414	1.7	37.3	1150	25895	166	17972	9.9
2011	415	1.7	37.3	1151	25917	166	18021	9.9
2012	411	1.7	36.9	1140	25669	164	17869	9.9
2013	415	1.7	37.4	1152	25950	166	18065	10.0
2014	421	1.7	37.8	1168	26295	168	18288	10.1
2015	421	1.7	37.9	1169	26321	168	18332	10.1
2016	425	1.7	38.2	1179	26542	170	18521	10.2
2017	421	1.7	37.9	1169	26319	168	18316	10.1

Table 3.21(b) Tyre and brake wear particle emissions from Passenger cars 1990 - 2017.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2,5}$	BC	TSP	PM_{10}	$PM_{2,5}$	BC
1990	465	279	195	71	268	263	105	7.0
1991	463	278	194	71	267	262	104	7.0
1992	460	276	193	70	265	260	103	6.9
1993	449	270	189	69	259	254	101	6.8
1994	447	268	188	68	258	253	101	6.7
1995	452	271	190	69	261	255	102	6.8
1996	453	272	190	69	261	256	102	6.8
1997	464	278	195	71	267	262	104	7.0
1998	476	285	200	73	274	269	107	7.2
1999	490	294	206	75	283	277	110	7.4
2000	503	302	211	77	290	284	113	7.6
2001	510	306	214	78	294	288	115	7.7
2002	515	309	217	79	297	291	116	7.8
2003	524	314	220	80	302	296	118	7.9
2004	529	317	222	81	305	299	119	8.0
2005	536	321	225	82	309	303	120	8.1
2006	536	322	225	82	309	303	121	8.1
2007	543	326	228	83	313	307	122	8.2
2008	534	321	224	82	308	302	120	8.0
2009	536	322	225	82	309	303	121	8.1
2010	533	320	224	82	307	301	120	8.0
2011	529	317	222	81	305	299	119	8.0
2012	520	312	219	80	300	294	117	7.8
2013	526	316	221	80	303	297	118	7.9
2014	534	320	224	82	308	302	120	8.0
2015	528	317	222	81	305	298	119	7.9
2016	529	317	222	81	305	299	119	8.0
2017	527	316	221	81	304	298	119	7.9

Table 3.21(c) Tyre and brake wear particle emission from Light duty vehicles 1990 - 2017.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1990	72	43	30	11	42	41	16	1.1
1991	72	43	30	11	42	41	16	1.1
1992	73	44	31	11	43	42	17	1.1
1993	73	44	31	11	43	42	17	1.1
1994	73	44	31	11	43	42	17	1.1
1995	75	45	31	11	44	43	17	1.1
1996	76	46	32	12	45	44	17	1.2
1997	77	46	32	12	45	44	18	1.2

1998	80	48	34	12	47	46	18	1.2
1999	84	50	35	13	49	48	19	1.3
2000	85	51	36	13	50	49	19	1.3
2001	87	52	37	13	51	50	20	1.3
2002	89	53	37	14	52	51	20	1.4
2003	90	54	38	14	53	52	21	1.4
2004	92	55	39	14	54	53	21	1.4
2005	94	56	39	14	55	54	21	1.4
2006	96	57	40	15	56	55	22	1.5
2007	98	59	41	15	57	56	22	1.5
2008	99	59	42	15	58	57	23	1.5
2009	101	61	42	15	59	58	23	1.5
2010	103	62	43	16	60	59	23	1.6
2011	103	62	43	16	60	59	23	1.6
2012	103	62	43	16	60	59	23	1.6
2013	104	62	44	16	61	59	24	1.6
2014	106	64	45	16	62	61	24	1.6
2015	110	66	46	17	64	63	25	1.7
2016	110	66	46	17	64	63	25	1.7
2017	112	67	47	17	66	64	26	1.7

Table 3.21(d) Tyre and brake wear particle emission from Heavy duty vehicles 1990 – 2017.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1990	303	182	127	46	113	110	44	2.9
1991	280	168	118	43	104	102	41	2.7
1992	276	166	116	42	103	101	40	2.7
1993	283	170	119	43	105	103	41	2.7
1994	283	170	119	43	105	103	41	2.7
1995	288	173	121	44	107	105	42	2.8
1996	291	175	122	45	108	106	42	2.8
1997	297	178	125	45	110	108	43	2.9
1998	300	180	126	46	112	109	44	2.9
1999	305	183	128	47	113	111	44	3.0
2000	300	180	126	46	112	110	44	2.9
2001	302	181	127	46	113	110	44	2.9
2002	309	186	130	47	115	113	45	3.0
2003	316	190	133	48	118	115	46	3.1
2004	323	194	136	49	120	118	47	3.1
2005	328	197	138	50	122	120	48	3.2
2006	334	200	140	51	124	122	48	3.2
2007	342	205	144	52	127	125	50	3.3
2008	347	208	146	53	129	126	50	3.4
2009	325	195	137	50	121	119	47	3.2
2010	337	202	142	52	126	123	49	3.3
2011	344	206	144	53	128	125	50	3.3
2012	344	206	145	53	128	125	50	3.3
2013	348	209	146	53	129	127	50	3.4
2014	350	210	147	54	130	128	51	3.4
2015	354	213	149	54	132	129	51	3.4
2016	363	218	153	56	135	133	53	3.5
2017	352	211	148	54	131	128	51	3.4

Table 3.21(e)Tyre and brake wear particle emission from Mopeds and Motorcycles 1990 - 2017.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1990	2.1	1.2	0.9	0.31	1.7	1.6	0.6	0.04
1991	2.1	1.2	0.9	0.32	1.7	1.6	0.6	0.04
1992	2.1	1.2	0.9	0.32	1.7	1.6	0.6	0.04
1993	2.0	1.2	0.9	0.31	1.6	1.6	0.6	0.04
1994	2.0	1.2	0.8	0.31	1.6	1.6	0.6	0.04
1995	2.1	1.2	0.9	0.31	1.7	1.6	0.6	0.04
1996	2.1	1.3	0.9	0.32	1.7	1.7	0.7	0.04
1997	2.2	1.3	0.9	0.33	1.7	1.7	0.7	0.05
1998	2.3	1.4	1.0	0.35	1.8	1.8	0.7	0.05
1999	2.4	1.5	1.0	0.37	1.9	1.9	0.8	0.05
2000	2.6	1.5	1.1	0.39	2.1	2.0	0.8	0.05

2001	2.7	1.6	1.1	0.41	2.2	2.1	0.8	0.06
2002	2.8	1.7	1.2	0.44	2.3	2.2	0.9	0.06
2003	3.0	1.8	1.3	0.47	2.5	2.4	1.0	0.06
2004	3.3	2.0	1.4	0.50	2.7	2.6	1.0	0.07
2005	3.6	2.2	1.5	0.55	2.9	2.8	1.1	0.08
2006	3.9	2.3	1.6	0.60	3.1	3.1	1.2	0.08
2007	4.3	2.6	1.8	0.65	3.4	3.4	1.3	0.09
2008	4.4	2.7	1.9	0.68	3.6	3.5	1.4	0.09
2009	4.5	2.7	1.9	0.70	3.7	3.6	1.4	0.10
2010	4.8	2.9	2.0	0.74	3.9	3.8	1.5	0.10
2011	5.2	3.1	2.2	0.80	4.2	4.1	1.6	0.11
2012	5.4	3.2	2.3	0.82	4.3	4.2	1.7	0.11
2013	5.5	3.3	2.3	0.84	4.4	4.3	1.7	0.12
2014	5.5	3.3	2.3	0.85	4.5	4.4	1.7	0.12
2015	5.6	3.4	2.4	0.86	4.5	4.4	1.8	0.12
2016	5.6	3.4	2.4	0.86	4.5	4.4	1.8	0.12
2017	5.6	3.4	2.4	0.86	4.5	4.4	1.8	0.12

Methodological issues

Particle emissions

In 2019 submission the calculation method has been changed as a result of the Nordic project on POP and heavy metal emissions (2016-2018), funded by the Nordic Council of Ministers.

<u>Tyre wear</u>

TSP emissions from tyre wear are estimated according to the Tier 2 method of Guidebook 2016 (Table 3-4). In order to calculate the emission factor for heavy-duty vehicles (equation 3 and 4 in the Guidebook) it is assumed that on average, heavy-duty vehicles in Finland have five axes and that the average load factor for heavy-duty vehicles is 0.5. These assumptions are based on expert judgements.

For determination of the speed correction factor (Equation 5 of Guidebook 2016), it is assumed that the average speed of the different vehicle types is as listed in Table 2.28a.

Table 3.22. Average speed per vehicle type and corresponding speed correction factor, tyre wear.

Vehicle type	Average speed (km/h)	Speed correction factor
Two-wheelers	80	1
Passenger cars	60	1.2
Light-duty vehicles	60	1.2
Heavy-duty vehicles	50	1.3

PM_{10} and $PM_{2.5}$ emission factors are calculated according to Table 3-5 in Guidebook 2016, and BC emissions are calculated as 0.153 * TSP emissions, also according to the Guidebook.

Table 3.22. PM emission factors for tyre wear (mg/vkm)

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Mopeds and Motorcycles
TSP	13	20	88	4.6
PM10	7.7	12	53	2.8
PM2.5	5.4	8.5	37	1.9

Particle and black carbon emission factors for tyre and brake wear are presented in Table 3.23 and b and activity data as driven kilometres in Table 3.18.

Brake wear

TSP emissions from brake wear are estimated using emission factors according to Table 3-6 of Guidebook 2016. In order to calculate the emissions from heavy-duty vehicles with equations 6 and 7 in the Guidebook a load factor of 0.5 is assumed.

For determination of the speed correction factor (Equation 8 in Guidebook 2016), it is assumed that the average speed of the different vehicle types is as listed in Table 2.28c.

Table 3.23. Average speed per vehicle type and corresponding speed correction factor, brake wear.

Vehicle type	Average speed (km/h)	Speed correction factor
Two-wheelers	80	0.59
Passenger cars	60	1.13
Light-duty vehicles	60	1.13
Heavy-duty vehicles	50	1.4

PM_{10} and $PM_{2.5}$ emission factors are calculated according to Tables 3-7 in the Guidebook. Black carbon emissions are calculated as 0.0261 * TSP emissions, also according to the Guidebook values. The used emission factors are presented in Table 2.28d.

Table 3.24 The used emission factors for particles in tyre wear (Guidebook 2016)

Pollutant	Passenger cars	Light duty vehicles	Heavy duty vehicles	Mopeds and Motorcycles
TSP	7.5	12	33	3.7
PM10	7.4	11	32	3.6
PM2.5	2.9	4.6	13	1.4

Tyre wear

Heavy metal emissions

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn) are calculated as a fraction of TSP according to the metal content of tyres from a Swedish study from 2006 (Hjortenkrans et al. 2006). Several other studies on metal content from tyres are available, however the Hjortenkrans study is assumed to be most relevant for the Nordic conditions. In this study, the metal contents of tyres are measured for retreaded tyres and non-retreaded tyres. For the purposesof the emission inventory, retread tyres are assumed to be used for heavy-duty vehicles and buses and non-retread tyres are assumed to be used for all other vehicle types.

Emission estimates of arsenic are based on the metal fractions given in Guidebook 2016 since arsenic is not included in the Hjortenkrans study. The content of mercury is based on a Norwegian study (Braekken 1993).

PAH emissions

The EF of benzo-a-pyrene from Guidebook 2016 Table 3-10 is used in the inventory. No other PAHs species are estimated. The used emission factors are presented in Table 2.29.

Table 3.25. HM and PAH emission factors for tyre wear (mg/kg)

Pollutant	Fraction of TSP (mg/kg) , Passenger cars, LDV, two-wheelers	Fraction of TSP (mg/kg), HDV
As	3.8	3.8
Pb	9.4	9.5
Hg	-	-
Cd	1.1	0.86
Cr	1.7	1.3
Cu	8.6	7.4
Ni	3.2	2.9
Zn	9400	12000
Benzo(a)pyrene	3.9	3.9

Brake wear

Heavy metal emissions

Heavy metals (Cd, Cu, Pb and Zn) are calculated as a fraction of TSP emissions according to the metal content of brakes available from the Swedish study Hjortenkrans et al. 2006. Hjortenkrans distinguishes between front and rear brakes as well as branded brakes and brakes from independent suppliers. In order to make an average emission factor it is assumed that 58 % of brake lining wear comes from rear brakes and 42 % from front brakes, which is in line with the assumptions made in Westerlund (2001)[1]. In addition, it is assumed that 40 % of vehicle kilometers (vkm) are travelled by new cars (assumed to be newer than four years) that use branded brake lining and 60 % by older cars using brake lining from independent brands, based on by the same study (Westerlund 2001)[2]

Where metal fractions are missing in Hjortenkrans 2006, values from Guidebook 2016 are used. This is the case for arsenic, chromium and nickel.

Corresponding information on the content of lead, copper and zinc in brakes from a 1998 study (Westerlund 1998) is provided in Hjortenkrans 2006. These values are applied in the inventory from 1990 to1998 in the same way as the Hjortenkrans values in Table 6. For the years 1999-2004, the metal contents are interpolated, and from 2005 onwards, the values from Hjortenkrans 2006 are applied.

PAH emissions

EFs for B(a)P, B(a)F, B(k)F from Guidebook are used.

The emission factors are presented in Table 3.26.

Table 3.26. Heavy metal and PAH emission factors for break wear (mg/kg).

Pollutant	Fraction of TSP (mg/kg), All vehicle types
As	67.5
Pb	815
Cd	1.39
Cr	2311
Cu	52089
Ni	327
Zn	15900
Benzo(a)pyrene	0.74
Benzo(b)fluoranthene	0.42
Benzo(k)fluoranthene	0.62

Table 3.27. Cu, Pb and Zn as fractions of TSP for the time series 1990 onwards.

Year	Cu	Pb	Zn
1990-1998	99686	14604	19911
1999	96173	12640	20047
2000	92661	10676	20184
2001	89148	8712	20320
2002	85635	6748	20456
2003	82123	4784	20593
2004	78610	2820	20729
2005-	75097	856	20865

[1] Assumptions in Westerlund (2001) are based on personal communication with Roland Hedlund, BBA Friction Sweden AB, in 1998.
[2] Assumptions in Westerlund (2001) are based on personal communication with Lars Burman, Slb Analys, The Stockholm Environment and Health Protection Administration, in 1998.

Uncertainties

Uncertainties are presented in Annex 7.

QA/QC and verification

Normal statistical QA/QC procedures have been carried out,

Source specific recalculations

2004

- Heavy metal emissions from road transport tyre and brake wear have been included in the inventory since the submission in 2004.

2009

- To the submission in 2009 the calculation method for particles was changed as a result from the Nordic co-operation in developing methodologies that better correspond to the regional circumstances. The method is based on Hjortenkrans 2006 and 2008 publications and information in the Swedish IIR.

2014

- Black carbon emissions were included in the inventory for first time in the 2014 submission.

2018

- Mercury emissions were corrected for the whole time series due to the incorrect unit used in the earlier calculations.
- The shares of old/new cars were updated for the whole time series for Cu, Pb and Zn emissions.

2019

- The calculation methods changed to follow the Guidebook 2016 methodology
- PAH emissions included in the calculation method
- Emission factors from Guidebook 2016 have been adopted to the LIPASTO calculation sub-models

Source specific planned improvements

- Inclusion of other PAH-4 species than B(a)P when information is available.

3.8 Road abrasion

1 A 3 b vii Road transport: Automobile road abrasion

Changes in chapter	
March 2019	JMP, KS

Emission trend

The emissions are slightly increasing due to increased kilometrage of vehicles as seen in Figure 3.11. The emissions decreased in 2013 due to decrease in driven kilometres as can be seen in Table 3.27.

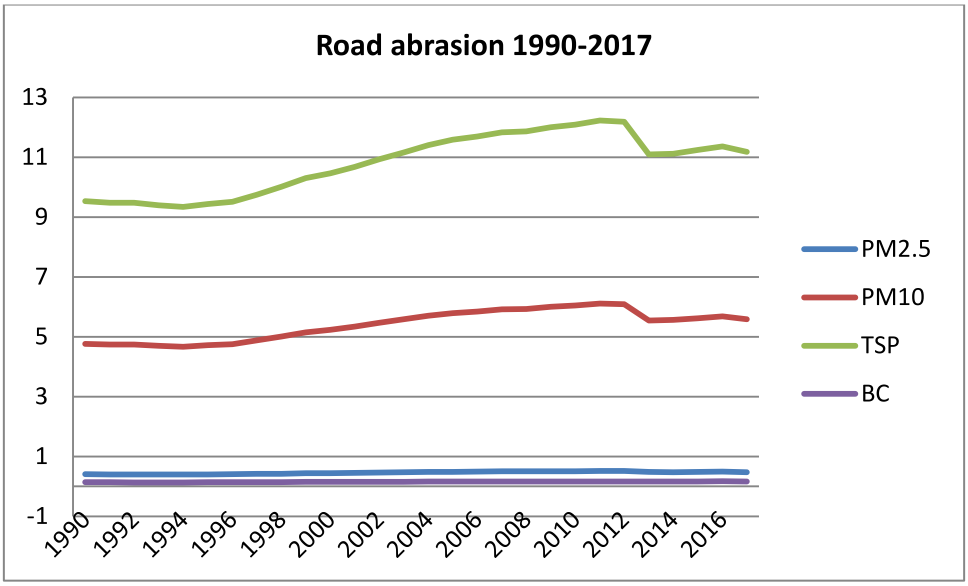


Figure 3.11. Emissions from road abrasion 1990-2017.

Methodological issues

Particle emissions

Activity data

Activity data as driven kilometres has been taken from the LIISA sub-model and is presented in Table 3.12 and 3.13.

Emission factors

Non-studded tyres
- TSP emission factors for road abrasion presented in Table 2.32 are from the Guidebook 2016 Table 3-8 and the fraction factors for PM_{10} and $PM_{2.5}$ from TSP are calculated according the Guidebook 2016 Table 3-9.

Studded tyres
- Emission factors for studded tyres based on Swedish IIR 2008. The emission factors are adopted for Finnish conditions and are thus slightly higher than for Sweden, due to e.g. a longer period for use of studded tyres. The following assumptions have been made for the calculation of particle emissions from the use of studded tyres:
    - studded tyres are used only in passenger cars and light duty vehicles
    - studded tyres are used during 4.5 months per year in Finland

- 80% of the passenger cars and light duty vehicles use studded tyres

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

Applying the method presented in the Swedish IIR 30% of vehicle kilometres of passenger cars and light duty vehicles are driven with studded tyres, and 70% with non-studded tyres. For the studded tyres a correction factor of 50 x PM_{10} is used.

The same particle size fraction factors are used for both studded and non-studded tyres.

Black carbon

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

Table 3.28 Emission factors used for particle emissions from road abrasion

Vehicle category	Non studded tyres (road abrasion) EF (g/km) Guidebook 2016			Studded tyres (road abrasion) EF (g/km) Swedish IIR 2008		
	TSP	PM10	PM2.5	TSP	PM10	PM2.5
Passenger cars	0.015	0.0075	0.0041	0.75	0.375	0.01875
Light duty vehicles	0.015	0.0075	0.0042	0.75	0.375	0.01875
Heavy duty vehicles	0.076	0.038	0.021	-	-	-
Mopeds & Motorcycles	0.006	0.003	0.0016	-	-	-

Table 3.29 Particle and black carbon emissions in 1990 - 2017 from road abrasion.

	Road abrasion emissions (t)			
	TSP	PM_{10}	$PM_{2,5}$	BC
1990	9531	4766	404	79.1
1991	9480	4740	398	78.7
1992	9434	4717	395	78.3
1993	9248	4624	390	76.8
1994	9214	4607	389	76.5
1995	9314	4657	393	77.3
1996	9363	4681	396	77.7
1997	9566	4783	404	79.4
1998	9821	4910	414	81.5
1999	10136	5068	427	84.1
2000	10381	5190	434	86.2
2001	10525	5262	440	87.4
2002	10658	5329	446	88.5
2003	10834	5417	454	89.9
2004	10941	5470	459	90.8
2005	11091	5546	466	92.1
2006	11136	5568	469	92.4
2007	11291	5645	476	93.7
2008	11149	5575	472	92.5
2009	11187	5593	469	92.9
2010	11161	5580	471	92.6
2011	11096	5548	470	92.1
2012	10940	5470	464	90.8
2013	11057	5528	469	91.8
2014	11229	5615	476	93.2
2015	11168	5584	475	92.7
2016	11200	5600	478	93.0
2017	11176	5588	474	92.8

Uncertainties

Uncertainties are presented in Annex 7.

QA/QC and verification

Normal statistical QA/QC procedures have been carried out.

Source specific recalculations

2009

- The calculation method was changed as a result of Nordic co-operation.

2018

- The particle emission factors for road abrasion were revised based on the recommendation from the 2017 NECD Technical Review. Earlier all emission factors were from Swedens' IIR, in the 2018 submission Guidebook 2016 emission factors were adopted.

2019

- The kilometrage was checked according to the LIPASTO calculation model and the activity data for 1992 changed slightly while the other years were not impacted.

Source specific planned improvements

None.

3. 9 Railways

1 A 3 c Railways

Changes in chapter	
March 2019	KS

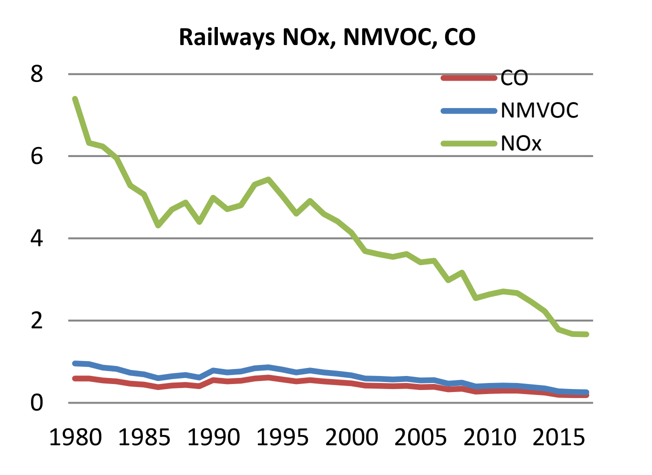
Source category description

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.

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).

Emission trend

Most railway lines are nowadays 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.



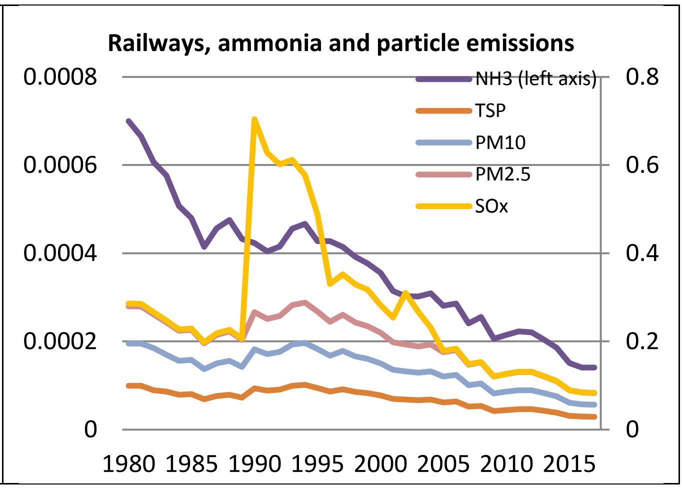


Figure 3.12. Emissions from railway transportation

Note that the peak in SO2 emissions between the 1980's and the 1990's is due to lack of recalculation of the 1980's and will be dealt with in the future submissions.

Methodological issues

Railway transport emissions are calculated with the RAILI sub-model of the LIPASTO calculation system (http://lipasto.vtt.fi/lipasto/index.htm) for 1980 – 2050.

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 2016 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, CH_4, 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 (107 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 834 kg/m3. 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 3.30.

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 3.30.

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 trains in RAILI model:

$$E^c = \sum_{x=1}^{2}\left(\left(\sum_{l=1}^{4}\sum_{w=1}^{10} d_{x,l,w} f_{x,l,w}^{d}\right) g_x e_x^{c,f} + d_x\left(f_x^h e^{c,h} + f_x^a e^{c,a}\right) + \left(\sum_{r=1}^{N}\sum_{l=1}^{4} t_{x,l,r} f_{x,l}^{t}\right) e_x^{c,f} + \left(\sum_{l=1}^{4} k_l f_l^k\right) e_x^{c,f}\right)$$

where

E^c	total emissions of compound c
c	compound
x	train type: person/freight train
l	type of locomotive (4 types)
w	train weight class (10 classes)
d	gross tonne kilometre
g	a factor for extra fuel consumption of non-line driving *
r	rail yard
N	number of rail yards
t	shunting time
k	locomotive kilometre

f^d	specific fuel consumption per gross tonne kilometre
f^t	specific fuel consumption per hour
f^h	specific fuel consumption of heating per gross tonne kilometre
f^a	specific fuel consumption of aggregate per gross tonne kilometre
f^k	pecific fuel consumption per locomotive kilometre
$e^{c,f}$	emission factor of compound c per fuel used
$e^{c,h}$	emission factor of compound c per fuel used for wagon heating
$e^{c,a}$	emission factor of compound c per fuel used for aggregates
*	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, 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.

Uncertainties

Uncertainties are presented in Annex 7.

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.

Source specific improvements and recalculations

None

Source specific planned improvements

None.

3.10 Navigation

1 A 3 d ii National navigation (Shipping)

Changes in chapter	
March 2019	KS, KM

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 2.x

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

Emission trends

Emission trends from navigation are included in the inventory and presented in Figure 3.13

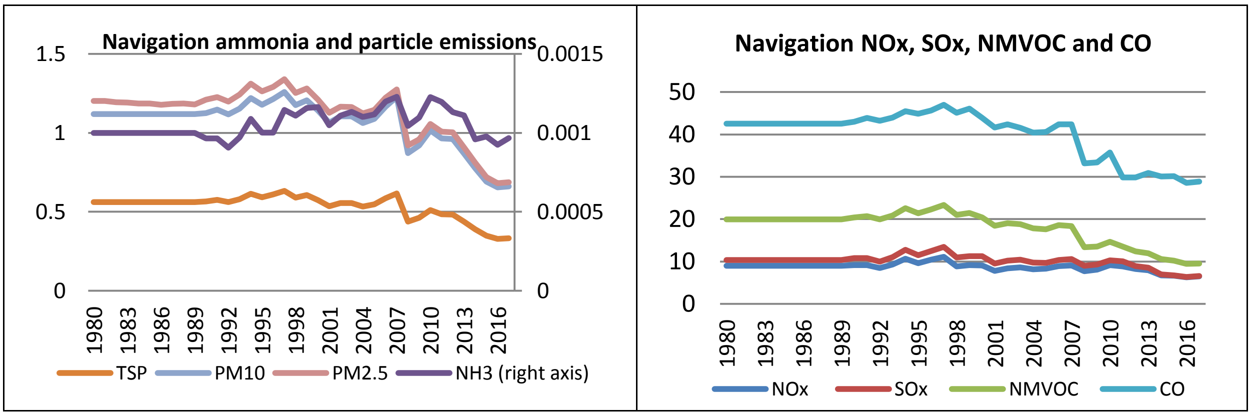


Figure 3.13. Emissions in 1980-2016 from National navigation

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 number of visits in ports has 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.

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. Emission from ferry boats show a stable increasing trend for the whole time series, while for cargo vessels the upward trend since 1990 changed to a downward trend in 2012 due to the prolonged economic downturn.

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 3.30

Methodological issues

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 – 2050, where the methods depend on the vessel category.

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). There are nine different ship types in the model. Ships are further divided into different engine types (two-stroke and four-stroke). These are further divided into different 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) and Diesel.

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 detailed and accurate database from the Finnish Transport Infrastructure Agency is analysed to produce power and speed classes for the ships. The Boat Register is the best available source for boats. In addition, origin-destination matrices are produced using the data.

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

$$E^c = \sum_{x=1}^{2}\sum_{l=1}^{9}\sum_{w=1}^{7}\left(\frac{\sum_{i=1}^{N_{l,w}} d_{l,w,i}}{v_{l,w}^a} g_{l,x}^d p_{l,w,x}^a \sum_{y=1}^{10}\sum_{f=1}^{5}\left(r_{x,y} s_{x,f} e_{x,l,w,y,f}^{c,d}\right) + N_{l,w}\left(t_{l,w}^m g_{l,x}^m p_{l,w,x}^a \sum_{y=1}^{10}\sum_{f=1}^{5}\left(r_{x,y} s_{x,f} e_{x,l,w,y,f}^{c,m}\right) + t_{l,w}^b g_{l,x}^b p_{l,w,x}^a \sum_{y=1}^{10}\sum_{f=1}^{5}\left(r_{x,y} s_{x,f} e_{x,l,w,y,f}^{c,b}\right)\right)\right)$$

where

E^c	total emissions of compound c
c	compound
x	engine function type (2 types): main engine / auxiliary engine
l	type of ship (9 types)
w	gross register ton (GRT) class (7 classes)
N	number of trips / port visits
d	distance of an individual trip
v^a	average design speed
p^a	average nominal engine power
g^d	engine load factor during driving
g^m	engine load factor during manoeuvre
g^b	engine load factor during berthing
y	engine type by two/four-stroke engine and emission standard level (Tier) (10 combined types)
r	share of engines by engine type
f	fuel type of engine (5 types)
s	share of engines by fuel type

t^m	time used for manoeuvre
t^b	time used for berthing
$e^{c,d}$	emission factor of compound c for driving
$e^{c,m}$	emission factor of compound c for manoeuvre
$e^{c,b}$	emission factor of compound c for berthing

Data on total fuel consumption of ferryboats and small ferries are acquired from road authorities.

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.

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

$$E^c = \sum_{f=1}^{N^f} S_f e_f^c$$

where

E^c	total emissions of compound c
c	compound
f	fuel type
N^f	number of fuel types
S	total fuel use by fuel type
e^c	emission factor for compound c

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

Leisure boats

Leisure boat emission estimations are based on the use of energy (kWh) and corresponding emission factors (g/kWh). Energy use is calculated by boat category (six), engine type (four), average engine power class (10) (kW), engine load (%) and average operation time per year (h/a). Total emissions are calculated by multiplying total energy use (kWh) of engine types with corresponding emission factors (g/kWh).

Formula for leisure boats:

$$E^c = \sum_{l=1}^{6} \sum_{y=1}^{3} \sum_{r=1}^{10} N_{l,y,r} p_r \, g_{l,y,r} t_l e_y^c$$

Where

E^c	total emissions of compound c
c	compound
l	type of leisure boat (6 types)
y	engine type & fuel: gasoline two/four-stroke engine and diesel engine (3 combined types)
r	engine power class (10 classes)
N	number of boats
p	nominal engine power (class centre)
g	engine load factor
t	activity (hours in use per year)
e^c	emission factor for compound c

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.

Working boats and cruisers

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

$$E^c = \sum_{l=1}^{3} N_l s_l e^c$$

where

E^c	total emissions of compound c
c	compound
l	type of working boat (3 types)
N	number of working boats
s	average fuel use of a working boat per year
e^c	emission factor for compound c

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 Infrastructure Agency.

Emission factors

Meeri uses emission factors from the EMEP/EEA Emission Inventory Guidebook 2016.

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.

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

For the MEERI model, a detailed database on every ship visit in Finnish ports is obtained from the Finnish Transport Infrastructure Agency. The database includes data on ship type, age, size (GT = gross tonnage), engine power, speed, engine 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 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. 0.2% of all passengers using the Helsinki to Sweden lines travel between Helsinki and Åland in 2015). 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.

Fuel consumption

Amount of used fuels (TJ) per ship type (Table 3.31) have been partly used as activity data to calculate emissions of domestic navigation. In 2016 bio-shares of gasoline and diesel oil were 4.8% and 4.1% respectively (calculated from TJ).

Table 3.31 Amount of fuels used in domestic navigation by ship type 1990-2017 (PJ) (MEERI, NIR 2019)

	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
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	1.92	0.52	0.09	1.22	1.28	0.31	0.56
2016	1.84	0.54	0.08	1.17	1.27	0.28	0.40
2017	1.83	0.53	0.08	1.24	1.27	0.28	0.57

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 calculated using national distribution factors, 0,99 for PM10 and 0,969 for PM2.5 (Karvosenoja, 2006). 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.

Uncertainties

Uncertainties are presented in Annex 7.

QA/QC and verification

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

Recalculations

None.

Source specific planned improvements

None.

3.11 Off-road mobile sources

Changes in chapter	
March 2019	KS, KM

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)

Source category description

This chapter covers emissions from mobile combustion in commercial, institutional and residential sectors for NFR categories 1A4aii, 1A4ci, 1A4ciii and 1A5b (Table 3.32).

Table 3.32 Mobile sources reported under NFR 1A2, 1A44 and 1A5a.

NFR	Source	Emissions
1A2gvii	Manufacturing industry – off-road vehicles and machinery	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
1A4aii	Commercial/ Institutional combustion - mobile	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
1A4bii	Household and gardening (mobile)	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
1A4cii	Agriculture/Forestry/Fishing – Stationary- off-road vehicles and other machinery	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
1A4ciii	National Fishing	
1A5b	Other mobile (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

The Finnish Off-Road machinery model covers machinery types presented in Table 3.33 below.

Table 3.33 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)

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 3.14 and fuel consumption in in Table 3.35.

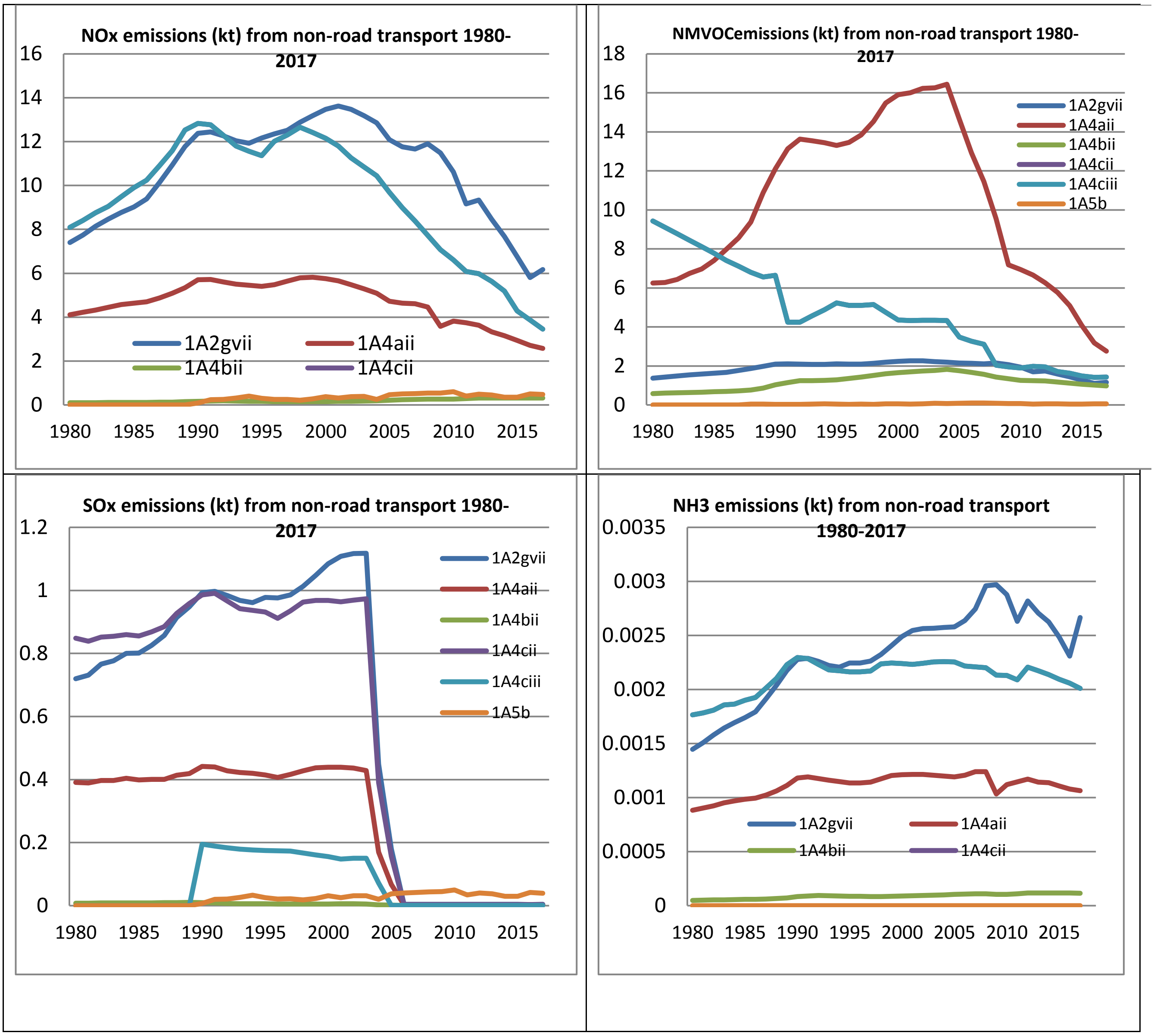


Figure 3.14 Emission trends 1980-2017

Fuel combustion

Table 3.35 Fuel consumption in non-road transport 1990-2017

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Non-road												
Diesel oil	29,4	28,3	30,4	30,7	31,5	30,0	31,8	31,2	30,6	29,5	28,2	29,9
Gasoline	3,1	3,2	3,6	3,8	3,4	3,6	3,7	3,7	3,7	3,5	3,4	3,3
Liquid gas	0,3	0,3	0,2	0,3	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Liquid biofuels	NO	NO	NO	NO	0,9	0,7	0,2	NO	NO	NO	NO	NO

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.

The breakdown of different machine types in TYKO model is presented in Table 3.36 and the properties of fuels used in working machines in Table 3,37.

Table 3.36 Fuel properties of working machines (TYKO model 4.3.2019)

Gasoline	
Specific weight	0.75 kg/l (density 750 kg/m^3)
Heating value	43 MJ/kg
Energy	1 kWh = 3.6 MJ
Sulphur content (S)	0.0008 w-% = 0.016 g/dm^3 SO_2
Carbon dioxide (CO_2)	2350 g/(dm^3 fuel) = 3133 g/(kg fuel)
Diesel	
Specific weight	0.845 kg/l (density 845 kg/m^3)
Heating value	43 MJ/kg
Energy	1 kWh = 3.6 MJ
Sulphur content (S)	0.0010 w-% = 0.020 g/dm^3 SO_2
Carbon dioxide (CO_2)	2660 g/(dm^3 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:

$$E^c = \sum_{l=1}^{N^l} g_l \sum_{r=1}^{4} p_{l,r} \sum_{x=1}^{3} \sum_{f=1}^{3} \sum_{s=1}^{6} \left(\sum_{u=1}^{3} \sum_{a=1}^{40} N^m_{l,r,x,f,s,u,a} t_{l,r,x,f,s,u,a} \right) e^c_{l,r,x,f,s}$$

where ,

E^c	total emissions of compound c
c	compound
l	type of machinery
N^l	number of machinery types (presently 50)
g	engine load factor by machinery type
r	engine power class (4 classes)
p	nominal engine power (class centre)
x	engine type (presently 3: two/four-stroke gasoline and diesel engines)

f	fuel type (3 types)
s	emission standard level (Stage) by model year of machinery (6 classes)
u	type of usage (3 types: professional/leisure/both)
a	age of machine (max 40)
N^m	number of machines by detail (machinery fleet in the calculation year by age)
t	activity (hours in use per year)
e^c	emission factor for compound c

Formula for detailed machinery fleet calculations:

$$N_y^m = N_{y-1}^m\left(1 - w_y^m\right) + S_y^m$$

where

$N^m{}_y$	machinery fleet by type (detailed) in the year y
$w^m{}_y$	scrapping factor of machinery in the year y
$S^m{}_y$	new sales of machinery in the year y

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 not included in the TYKO model but calculated at Finnish Environment Institute SYKE using activity data from the TYKO model and emission factors from the EMEP/EEA Emission Inventory Guidebook 2016.

PM_{10} and $PM_{2,5}$ size fractions of particulate matter emissions are calculated from TSP emissions in the TYKO model using fraction factors (TSP=PM10=PM2.5) from Guidebook 2016.

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.

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

2018

- PM10 and PM2.5 size fractions of particulate matter emissions were revised to correspond to the EMEP EEA Guidebook 2016. Therefore, the PM10 and PM2.5 emissions were recalculated for the whole time series 1980-2015.

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.

3.12 Other Mobile

No activities fall under this category

3.13 International maritime navigation

1 A 3 d i (i) International maritime navigation

Changes in chapter	
	February 2019 KS

Emission trends

Emission trends 1990-2016 from international maritime navigation are fluctuating annually depending on where fuel is purchased in the world destinations. The trend is presented in Figure 3.15.

In the biggest vessels there are already Sulphur removal systems and removal of particles and Sulphur is becoming mandatory in the next few years. The abatement systems will also remove heavy metal emissions.

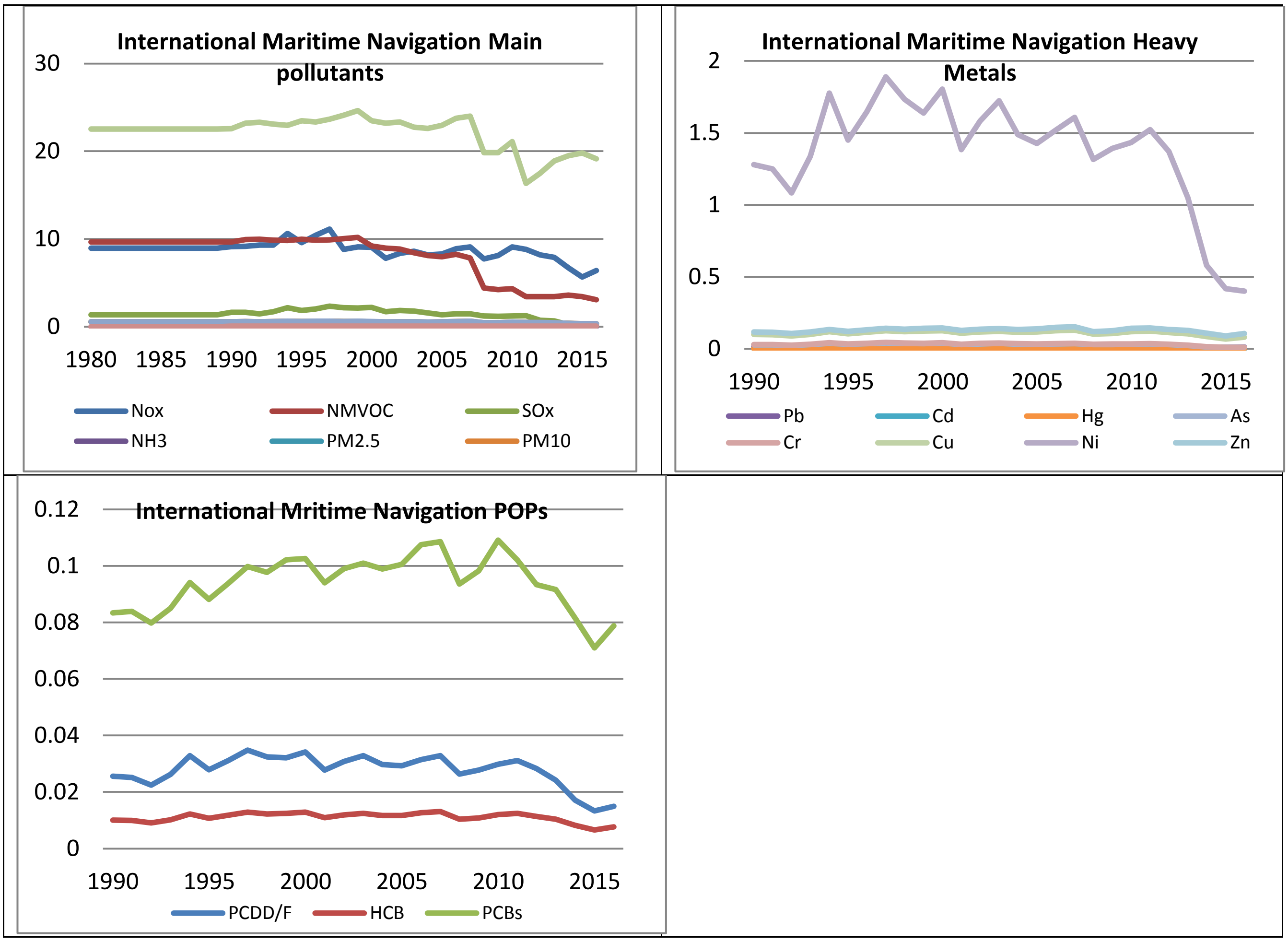


Figure 3.15 Emissions from international maritime navigation 1999-2017

Methodological issues

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

The international bunkers cover international aviation and navigation according to the IPCC Guidelines. The fuel use for international navigation is calculated according to the UNFCCC and UNECE reporting guidelines at Statistics Finland. The fluctuating fuel use includes fuel sales to ships and aircrafts traveling abroad, and is impacted by the fuel prices, especially the ferries between Finland and Sweden can refuel in one or the other country depending on fuel prices. The Finnish currency was devalued in the early 1990s, which affected fuel prices strongly. This effect has disappeared due to Finland's EU membership and the common currency. Since the beginning of the 2000s refuelling in Finland diminished to a very low level until 2015. In 2015 the marine bunker sales increased and was approximately at the same level also in 2016.

Regarding trips to Sweden via Åland, these are treated as international, because the number of passengers (or cargo) leaving or entering the ships in Åland is very low. A small share of Åland transport has been allocated to domestic navigation. The fuel volumes of the Åland correction (gasoil and residual fuel oil) are subtracted from bunkers and added to total domestic fuel consumption.

In the NFR tables emissions from international maritime navigation are the same as reported in the Finnish greenhouse gas inventory. The methodology for calculation of these emissions is explained in the Finnish NIR.

Uncertainties

No uncertainty analysis has been carried out for these emissions.

QA/QC and verification

Statistics Finland crosschecks the fuel consumption data calculated within the MEERI model and against the data reported to the IEA Oil Questionnaire.

Recalculations and improvements due to review recommendations

None.

Source specific planned improvements

Not scheduled

- Emissions for heavy metals and persistent organic pollutants will be added based on the results of a Nordic project (NMR HMs and POPs).
- In addition, a future project lead by the Finnish Maritime Administration will provide more detailed information even in the EMEP grid.

3.14 International Inland waterways

1 A 3 d i (ii) International inland waterways

This source does not exist in Finland.

3.15 Pipeline compressors

Changes in chapter	
February 2019	KS, JMP

1A3 e i Pipeline compressors

Emission trend

Emissions from pipeline compressors were reallocated under NFR 1A3ei in 2009 and cover both emissions from gas turbines and fugitive emissions at the compressor stations.

The emission trend presented in Figure 3.16 follows loosely the total consumption of natural gas: until 2003 the consumption increased and the transmission grid expanded, but then started to decrease as the running time of the compressors decreased.

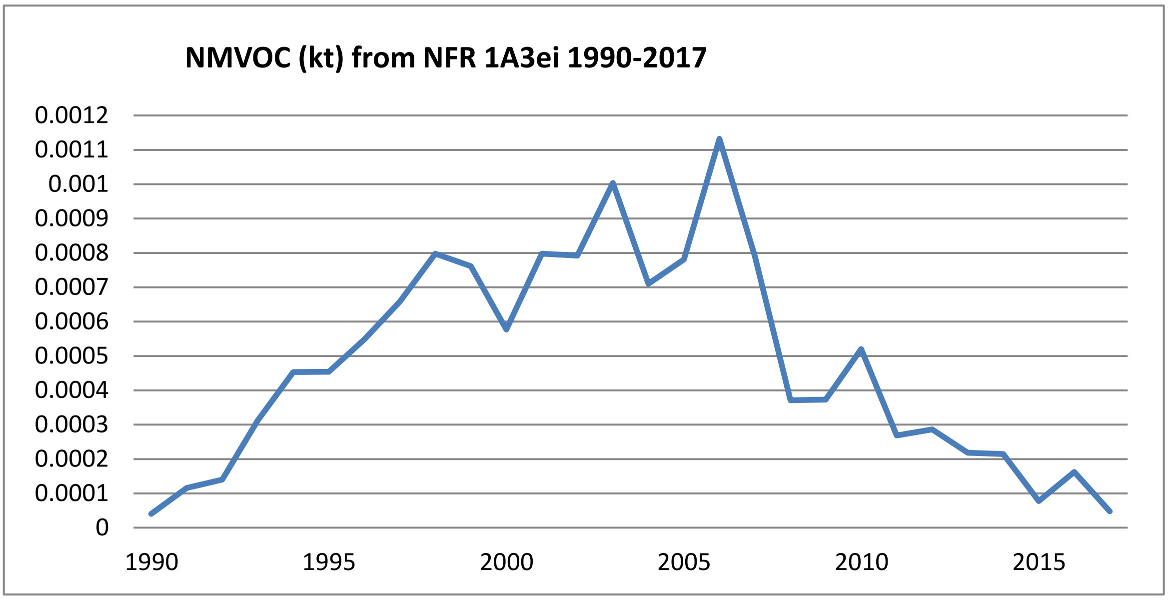


Figure 3.16 NMVOC emissions from pipeline compressors 1980-2017

Methodological issues

Emissions from pipeline compressor stations are reported by the operators and the data are available in YLVA.

Uncertainties

Uncertainties are presented in Annex 7.

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.

Recalculations and improvements due to review recommendations

2009
Emissions from pipeline compressors were included

2018
NMVOC emissions from leaks in pipelines (reported under NFR 1B2b) were included in the inventory based on the recommendation from the 2017 NECD Technical Review.

Source specific planned improvements

Allocation of emissions to this NFR from the beginning of the 1980's will be studied out in the coming years.

3.16 Fugitive Emissions from oil and natural gas (NFR 1.B.2) – Distribution of oil products (1B2av)

Changes in chapter	
February 2019	JMP KS

Source category description

Emissions from service stations and storage tanks outside the refineries are included in this category. The contribution to total emissions and shares reported by operators are presented in Table 3.37.

Table 3.37 Contribution of Distribution of oil products (NFR 1B2av) in 2016 to the total emissions.

Pollutant	Emissions from Fugitive emissions from solid fuels in 2016	Total emissions in 2016	Unit	Share of total emissions %	% reported by the operators
NMVOC		2.915	Gg	3.3	7.2
PM2.5		<0.001	Gg	<0.1	0
PM10		<0.001	Gg	<0.1	0
TSP		<0.001	Gg	<0.1	100
NMVOC		2.915	Gg	3.3	7.2

NMVOC emissions have been mainly decreasing since 1988 when they were included in the inventory (Figure 3.17)

.
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

Emission trend graphs and explanations for trends will be added to the next submission

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 tasks of which has been taken over by Statistics Finland. 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. The operation of Finnish Oil and Gas Federation ceased in 2018 and is currently managed by Statistics Finland.

Sales of motor gasoline (m3) (Table 3.38) 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 3.38). The same assumptions are used for whole time series.

Table 3.38. Emission factors

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%

Table 3.39 The sales of petroleum in Finland 1992-2017 (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	2016	1 957 126
1997	2 507 600	2007	2 481 366	2017	1 919 126
1998	2 477 067	2008	2 347 344		
1999	2 466 133	2009	2 285 349		

NOx and particles

Emissions are reported by the operators according to the monitoring requirements in the environmental permits.

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