FINLAND's INFORMATIVE INVENTORY REPORT 2024

under the UNECE CLRTAP and the EU NECD

Air Pollutant Emissions 1980-2022

Part 3 – Transport

MARCH 2024

FINNISH ENVIRONMENT INSTITUTE

Climate solutions unit, Air pollution group

VTT Technical Research Centre Finland

Finland’s IIR

Part 3

Transport

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

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

3.1 Overview of the sector
3.2 Emission trends
3.3 Fuel use and use of lubricants
3.4 Aviation
3.5 Road transport
3.6 Gasoline evaporation
3.7 Tyre and brake wear
3.8 Road abrasion
3.9 Railways,
3.10 Navigation
3.11 Off-road mobile sources
3.12 Other Mobile
3.13 International maritime navigation
3.14 International inland waterways
3.15 Pipeline compressors
3.16 Distribution of oil products

Sub-chapters included under each NFR subcategory:

Source category description
Emission trend
Methodological issues
Uncertainty and time series' consistency
Source-specific QA/QC and verification
Source-specific recalculations including changes in response to the review
Source-specific planned improvements

3.1 Overview of the sector

Changes in chapter	
February 2024	KM, KS, TF

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 Table 3.1a.

Table 3.1a 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, PAH-4
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
1A5a	Other Stationary (including military)	Military mobile sources are included in this category together with some stationary sources	NO_X, NMVOC, SO_X, TSP, PM_{10}, $PM_{2.5}$, BC, CO, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, Se, PCDD/F, PAH-4

Key categories and the tier level of methods used to estimate emissions are presented in Table 3.1b

Table 3.1b Key categories and tier level of methods for the Transport sector inventory.

NFR	Fuel	NH_3	Tier	NO_x	Tier	SO_x	Tier	NMVOC	Tier	CO	Tier
1A2gvii	Liquid			L1	3						
1A3bi	Diesel oil			L1, T1	3						
1A3bi	Gasoline	T1	3	L1, T1	3			T1	3	L1, T1	3
1A3bii	Diesel oil			L1, T1	3						
1A3biii	Diesel oil			L1, T1	3	T1	3	T1	3		
1A3bv								L1, T1	2		
1A3c	Liquid			L1	3						
1A3dii	Liquid							L1	3	L1	3
1A4aii	Liquid							T1	3	T1	3
1A4bii	Liquid							L1	3	L1, T1	3
1A4cii	Liquid			L1, T1	3						
1A4ciii	Liquid			L1	3						
1B2av								L1	3		
NFR	Fuel	$PM_{2.5}$	Tier	PM_{10}	Tier	TSP	Tier	BC	Tier		
1A2gvii	Liquid	L1	3					L1, T1	1		
1A3bi	Diesel oil	T1	3	T1	3	T1	3	T1	1		
1A3biii	Diesel oil	T1	3	T1	3	T1	3	T1	1		
1A3bvi		L1, T1	2	L1, T1	2	L1, T1	2	L1, T1	2		
1A3bvii		L1, T1	2	L1, T1	2	L1, T1	2				
1A3dii	Liquid	L1	3								
1A4cii	Liquid	T1	3	T1	3	T1	3	T1	3		
NFR	Fuel	Pb	Tier	Cd	Tier	Hg	Tier	As	Tier	Cr	Tier
1A3bi	Gasoline	T1	3								
1A3bvi										L1, T1	2
NFR	Fuel	Cu	Tier	Ni	Tier	Se	Tier	Zn	Tier		
1A3bvi		L1, T1	2	T1	2			L1, T1	2		
NFR	Fuel	PCDD/F	Tier	PAHs	Tier	HCB	Tier	PCB	Tier		

National characteristics

Emissions from the transport sector in Finland 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

NOTE1: Fuel based emissions from road transport, navigation, railroads and non-road vehicles and machinery are calculated in the national model for transport LIPASTO using Guidebook 2019 emission factors. The unit emissions page on LIPASTO website (http://www.lipasto.vtt.fi/en/index.htm) does not show EFs used in the inventory but are used in different purposes than the emissions inventory.

NOTE2: In the 2024 submissions under the CLRTAP and NECD, all methodologies and emission factors used in the emission estimation in the transport sector are from the 2019 version of the EMEP/EEA Emissions Inventory Guidebook. The possible changes in the transport sector methodologies and emission factors introduced in the 2023 version of the Guidebook will be studied during the preparation of the emission inventory for the year 2023. Following this, the possible recalculations of emissions will be included in the 2025 submissions.

3.2 Emission trends

Changes in chapter	
February 2024	AL, KM, KS, TF

Transport sector emission trends in 1990-2022 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 1980-2022 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)

Since the beginning of 2015, based on the EU Sulphur Directive (2016/802), 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%.

The significant reduction in most emissions of air and waterway traffic for the year 2020 is due to COVID-19. CO and NMVOC emissions in waterway traffic are increased because leisure boat traffic dominates the emission shares for these emissions and leisure boating did not suffer from COVID restrictions in Finland.

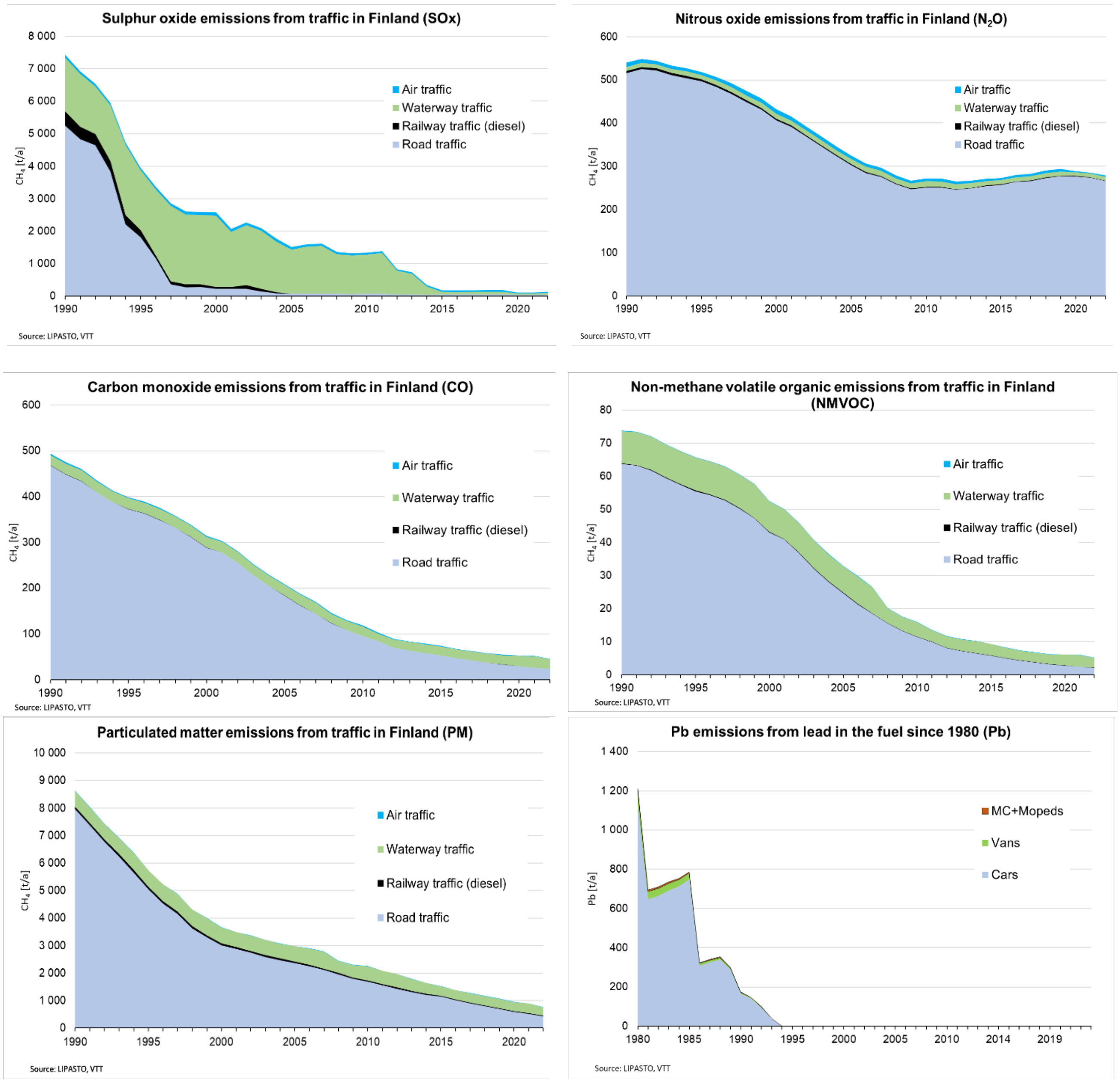


Figure 3.1 (a). Emission trends from fuel combustion in Transport 1980/90-2022 in the LIPASTO system.

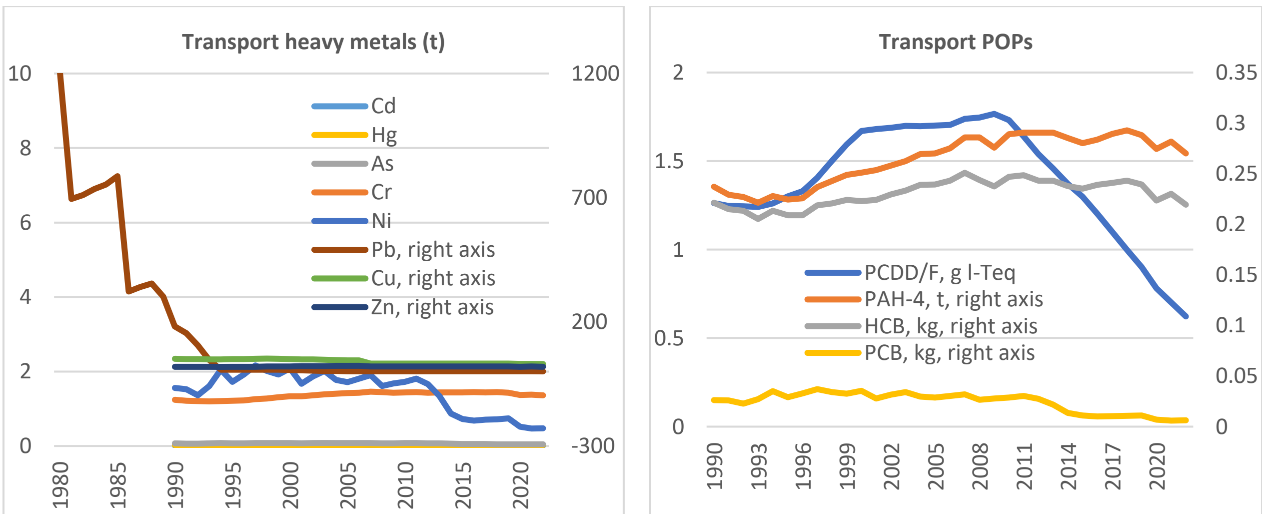


Figure 3.1 (b) Heavy metal and POP emissions from the transport sector 1990-2022 (Pb for 1980-2022).

3.3 Fuel use and Use of lubricants

Changes in chapter	
February 2024	AL, KM, KS, TF

Fuel consumption

In the 1990s the growth of emissions from road transport was slow in Finland compared to many other Annex I countries, mainly due to 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.

An overview of transport sector energy consumption 1990-2022 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.

Bio-shares of transport fuels (Statistics Finland 2024)

Increasing amounts of biogenic additives or biofuels are mixed in road transport and some other 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 to 2015 was collected by Finnish Customs. Data from 2016 to 2020 was collected by Tax Administration and data from 2021 by Energy authority. These data include the following biofuels and bio-components:

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

The time series on biogas data starting from 2002 are available in the Energy statistics. The consumption of biofuels is originally included in the total sales data of gasoline, diesel oil and gasoil which was prior to 2018 received from Petroleum and Biofuels Association both for the LIPASTO system and for the ILMARI system by Statistic Finland. Since the operation of Petroleum and Biofuels Association ended in 2018, Statistics Finland has been responsible for this oil statistics data collection. The shares of biofuels are in the ILMARI system based on data received from Finnish Customs, Tax administration and/or Energy authority. From 2013 until 2020 the bio-share of gasoil decreased to 0.1-0.2%. Because the share was so low, Statistics Finland decided to allocate this bio-share into road transport instead of non-road use. In 2022 bioshares of gasoline and diesel oil were 9.8% and 17.8% respectively (calculated from TJ). The share of biogas (incl. LBG) in transport and non-road machinery gas consumption was 88% in 2022. The bioshare of gasoil was 3.9% in 2022.

Energy consumption in the transport sector is presented in Table 3.2(a) and the amounts of bio-components in transport fuels in Table 3.2(b).

The bio-shares of fuels were included for the first time in the NFR tables in the 2019 submission. The bio-share data is presented in the NFR tables from 2008. The bio-components have been calculated for road transport in the VTT LIPASTO system. For other transport, the bio-components have been calculated at in the IPTJ system at Syke based on bio-share data from Statistics Finland.

Table 3.2 (a) Fuel consumption (PJ) in the transport sector in 1990-2022 (IPTJ, Statistics Finland and VTT Technical Research Centre Finland 2024).

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
Civil aviation													
Aviation gasoline	0.11	0.08	0.08	0.04	0.04	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.02
Jet kerosene	5.15	3.51	5.11	4.09	3.07	2.42	2.46	2.61	2.89	2.83	1.17	1.05	1.83
Road transportation													
Gasoline	80.1	76.1	70.7	74.0	61.4	55.6	55.2	53.2	52.4	51.2	47.3	47.6	44.1
Diesel oil	67.1	62.3	76.2	85.8	96.5	83.8	100.7	93.9	96.8	92.5	88.0	81.3	81.7
Natural gas	NO	NO	0.00	0.11	0.20	0.16	0.17	0.10	0.15	0.24	0.44	0.47	0.57
Liquid biofuels	NO	NO	NO	NO	5.34	20.6	7.29	16.2	15.2	17.8	16.4	27.7	22.4
Gaseous biofuels	NO	NO	NO	NO	NO	NO	NO	0.12	0.15	0.24	0.44	0.47	0.57
Railways													
Gasoil	2.58	2.61	2.17	1.73	1.30	0.93	0.87	0.91	0.98	0.95	0.87	0.97	0.80
Liquid biofuels	NO	NO	NO	NO	0.02	NO	NO	NO	NO	NO	NO	0.03	0.03
Navigation and national fishing													
Residual oil	1.56	1.79	2.23	1.74	1.74	0.45	0.41	0.43	0.44	0.47	0.24	0.17	0.17
Gasoil	4.89	4.57	4.72	4.67	4.73	4.94	4.64	4.80	4.83	4.98	3.84	3.88	4.10
Gasoline	1.80	1.88	1.94	1.92	1.63	1.42	1.37	1.35	1.36	1.36	1.57	1.72	1.40
Diesel oil	NO	NO	NO	NO	0.52	0.35	0.39	0.35	0.35	0.34	0.38	0.35	0.30
Liquid biofuels	NO	NO	NO	NO	0.13	0.14	0.09	0.13	0.13	0.15	0.18	0.34	0.30
Off-road working machinery													
Motor gasoline	3.11	3.20	3.60	3.84	3.30	3.37	3.24	3.06	2.96	2.85	2.75	2.63	2.51
Gasoil	29.4	28.3	30.4	30.7	31.1	29.5	28.2	29.9	30.0	29.8	29.9	29.0	28.3
Liquid gas	0.31	0.26	0.21	0.25	0.19	0.17	0.16	0.16	0.15	0.16	0.16	0.17	0.17
Liquid biofuels	NO	NO	NO	NO	0.63	0.16	0.16	0.19	0.20	0.20	0.22	1.25	1.42
Other transportation													
Natural gas	0.04	0.45	0.58	0.76	0.50	0.07	0.16	0.05	0.12	0.12	0.02	0.12	0.02

Table 3.2 (b) Amount of bio-components of transport fuels (TJ) (IPTJ and Technical Research Centre Finland 2024).

	Gasoline	Diesel oil	Gasoil	Natural gas
2008	2 649	475	NO	NO
2009	3 184	2 484	302	NO
2010	2 985	2 591	539	NO
2011	3 797	4 541	626	NO
2012	3 974	4 296	245	NO
2013	2 854	6 820	IE	NO
2014	3 030	18 005	IE	NO
2015	2 901	18 036	IE	NO
2016	3 004	4 538	IE	NO
2017	3 585	12 937	IE	116
2018	3 741	11 775	IE	154
2019	3 918	14 184	IE	241
2020	4 148	12 619	IE	436
2021	5 002	23 206	1 103	469
2022	5 205	17 698	1 265	568

IE = included in diesel oil

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).

Use of lubricants

Emissions from (2-stroke and 4-stroke) lubricants in fuels are included in the emission factors. The estimates of amounts of 2-stroke lubricants (Table 3.3 (a)) have been calculated for road transport, commercial, residential and agriculture non-road machinery and leisure boats from the gasoline consumption figures available from the LIPASTO system. The amounts have been calculated by assuming maximum 2.5% oil mix in gasoline. The estimates of amounts of 4-stroke lubricants (Table 3.3 (b)) for road transport have been calculated by utilizing the mean CO_2 emission factors from combustion of lubricant oil presented in table 3-13 in the road transport chapter of the EMEP/EEA emission inventory guidebook 2019.

Table 3.3 (a). Amount of lubricant consumption in 2-stroke engines (IPTJ, Statistics Finland 2024).

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
2-stroke engine lubricant consumption, kt													
Road transport	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Commercial non-road machinery	0.5	0.6	0.8	0.8	0.6	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2
Residential non-road machinery	0.5	0.6	0.7	0.7	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4
Agriculture non-road machinery	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.2
Leisure boats	0.6	0.6	0.7	0.7	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4

Table 3.3 (b). Amount of lubricant consumption in 4-stroke engines (IPTJ, Statistics Finland 2024).

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
4-stroke engine lubricant consumption, kt													
Road transport, passenger cars	6.1	5.7	5.5	6.1	6.2	6.0	6.0	5.9	5.9	5.8	5.4	5.3	4.9
Road transport, light duty vehicles	0.7	0.6	0.6	0.6	0.6	0.7	0.6	0.7	0.7	0.7	0.6	0.6	0.6
Road transport, heavy duty vehicles	0.8	0.7	1.0	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.1	1.2	1.2
Road transport, L-category vehicles	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.1	0.1	0.1	0.1	0.1

3.4 Aviation

Changes in chapter	
February 2024	AL, KM, KS, TF

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 3.4 (a) and (b).

Table 3.4 (a) Contribution of NFR 1A3ai(i) in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	0.557	Gg	0.6
NMVOC	0.059	Gg	<0.1
SOx (as SO_2)	0.035	Gg	0.2
$PM_{2.5}$	0.004	Gg	<0.1
PM_{10}	0.004	Gg	<0.1
TSP	0.004	Gg	<0.1
BC	0.002	Gg	<0.1
CO	0.568	Gg	0.2

Table 3.4 (b) Contribution of NFR 1A3aii(i) in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	0.124	Gg	0.1
NMVOC	0.017	Gg	<0.1
SOx (as SO_2)	0.009	Gg	<0.1
$PM_{2.5}$	0.001	Gg	<0.1
PM_{10}	0.001	Gg	<0.1
TSP	0.001	Gg	<0.1
BC	<0.001	Gg	<0.1
CO	0.259	Gg	<0.1
Pb	0.045	Mg	0.4

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 1990s decreased the number of flights. In the late 1990s, the demand on domestic air transport and the number of commercial flights increased. During the 2000s, 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. The significant reduction in all emissions for the year 2020 is due to COVID-19.

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

The emission trends of NO_x, NMVOC, SO_x, CO, NH_3, Pb and particles from aviation are presented in Figure 3.2.

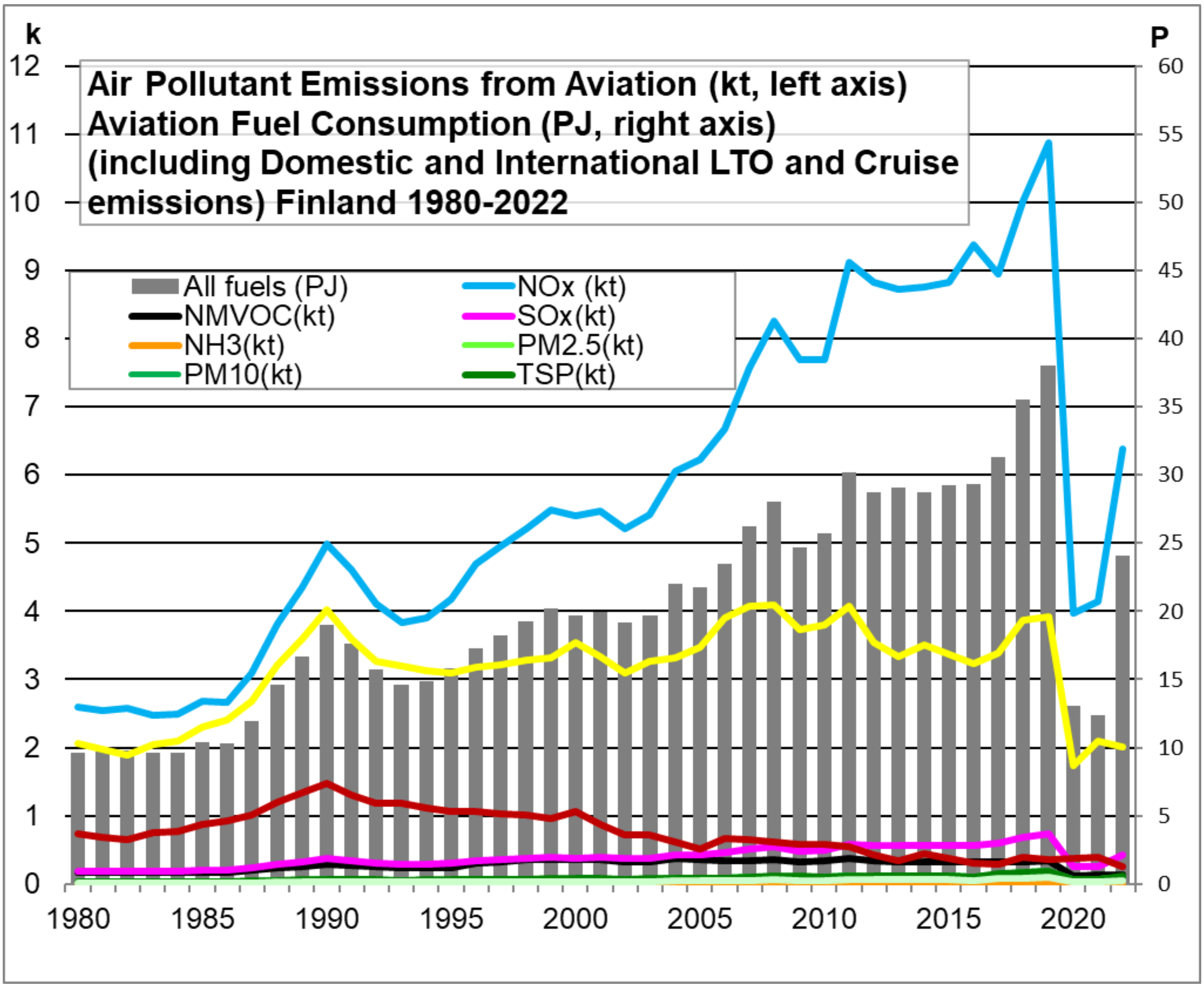


Figure 3.2. An overview of aviation emissions and fuel use 1980-2022.

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. However, the fuel consumption of helicopters is included under NFR 1.A.5 (part of jet fuel consumption). 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 1980s, while there have been some periods of decrease in the early 1990s and in the beginning of the 2000s.

The emission trends of NO_x, NMVOC, SO_x, CO, NH_3, Pb and particles are presented by NFR category in Figures 3.3 a-d.

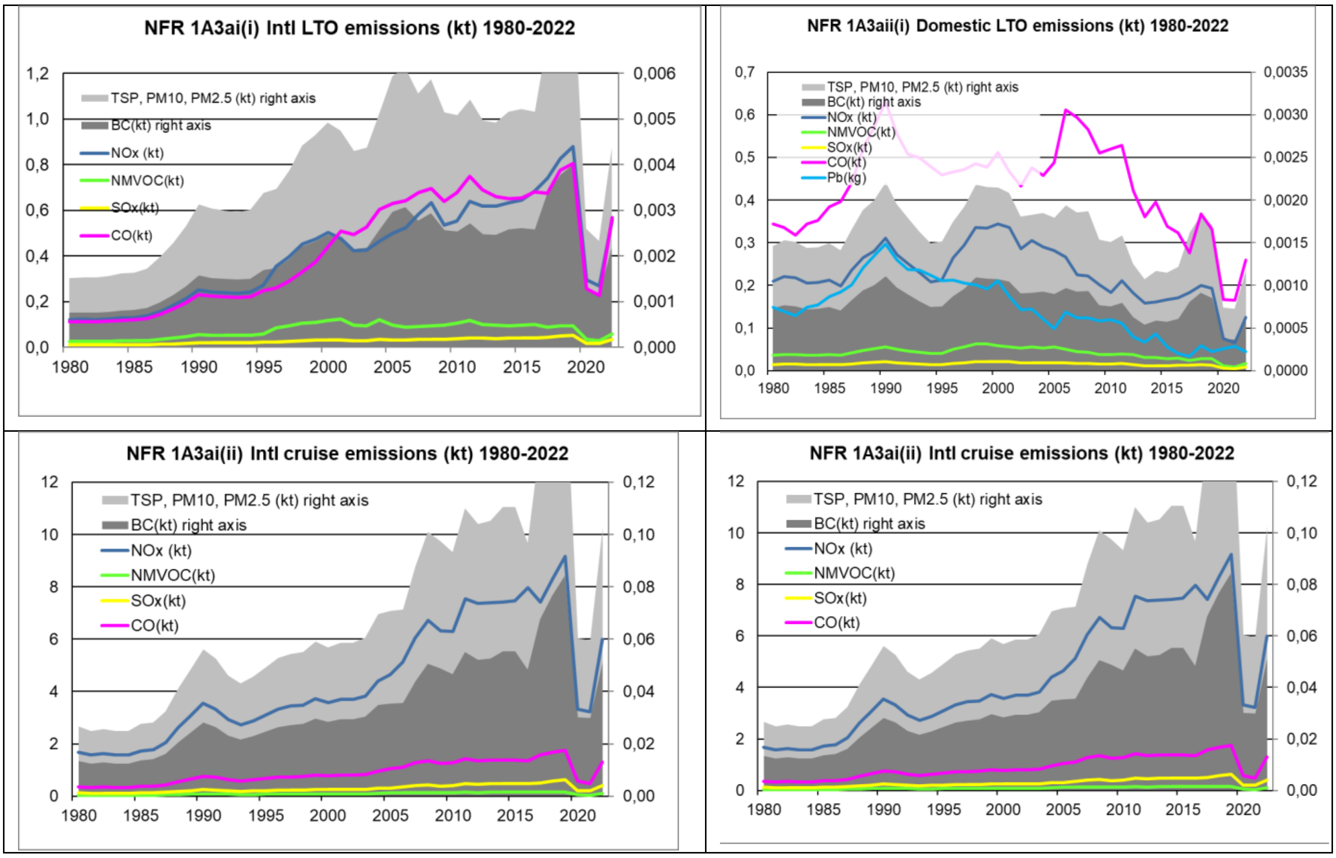


Figure 3.3 a-d: NFR category specific emission trends in aviation 1980-2022

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 VTT/Finnish Environment Institute to include air pollutant emissions. Finavia experts supported the adoption of the new model.

The calculation uses national fuel statistics for 1980-2022 and EUROCONTROL fuel and emissions data by EU Member State for the period 2005-2022. 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 2019 submission, the EUROCONTROL fuel use data was corrected with information in national statistics for domestic aviation as presented in Table 3.5.

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 (https://www.eurocontrol.int/publication/eurocontrol-method-estimating-aviation-fuel-burnt-and-emissions).

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 NID.

Description of the calculation model maintained by Finavia for 1980-2008 and the current calculation method is presented in the Finnish NID (chapter 3.2.5.3, pp. 111-113).

Emission factors

EMEP/EEA Emission Inventory Guidebook 2019 emission factors are used in the calculation of NO_x, NMVOC, NH_3, SO_x, CO and particle emissions (TSP, PM_{10}, $PM_{2.5}$ and BC).

Lead emissions

For the calculation of lead emissions from avgas volumes presented in Table 3.5, 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 3.5 Fuel use in Aviation 1980-2022.

Year	Domestic fuels								International Fuels			
	Jet fuel		Jet fuel		Avgas		Avgas		Jet fuel		Jet fuel	
	LTO		Cruise		LTO		Cruise		LTO		Cruise	
	TJ (43.3)	kt	TJ (43.3)	kt	TJ (43.3)	kt	TJ (43.3)	kt	TJ (43.3)	kt	TJ (43.3)	kt
1980	730	16.9	2 312	53.4	11.0	0.25	44.1	1.0	527	12.2	6 011	138.8
1985	739	17.1	2 779	64.2	12.9	0.29	51.5	1.2	571	13.2	6 211	143.4
1990	1 082	25.0	4 072	94.0	22.1	0.51	88.3	2.0	1 093	25.2	12 674	292.7
1995	737	17.0	2 772	64.0	15.7	0.36	63.0	1.4	1 181	27.3	11 073	255.7
2000	1 073	24.8	4 036	93.2	15.7	0.36	62.8	1.4	1 713	39.6	12 813	295.9
2005	951	22.0	3 144	72.6	7.3	0.17	31.2	0.7	1 656	38.2	15 970	368.8
2006	934	21.6	2 882	66.6	10.2	0.23	39.5	0.9	1 676	38.7	17 922	413.9
2007	875	20.2	2 705	62.5	9.2	0.21	38.6	0.9	1 822	42.1	20 795	480.3
2008	868	20.1	2 614	60.4	9.2	0.21	37.1	0.8	1 872	43.2	22 610	522.2
2009	780	18.0	2 404	55.5	8.7	0.20	34.2	0.8	1 849	42.7	19 600	452.7
2010	758	17.5	2 309	53.3	8.9	0.20	34.0	0.8	1 919	44.3	20 670	477.4
2011	838	19.3	2 589	59.8	8.2	0.19	32.4	0.7	2 182	50.4	24 548	566.9
2012	689	15.9	2 163	49.9	5.9	0.13	25.3	0.6	2 061	47.6	23 739	548.2
2013	602	13.9	1 834	42.4	4.9	0.11	20.4	0.5	2 025	46.8	24 604	568.2
2014	604	14.0	1 847	42.7	6.4	0.15	26.4	0.6	2 047	47.3	24 193	558.7
2015	605	14.0	1 812	41.8	4.2	0.10	24.3	0.6	2 054	47.4	24 764	571.9
2016	616	14.2	1 846	42.6	3.0	0.07	19.1	0.4	2 136	49.3	24 744	571.4
2017	639	14.7	1 971	45.5	2.5	0.06	19.2	0.4	2 314	53.4	26 339	608.3
2018	704	16.3	2 184	50.4	4.3	0.10	25.0	0.6	2 592	59.9	30 035	693.6
2019	685	15.8	2 143	49.5	3.3	0.08	22.7	0.5	2 720	62.8	32 446	749.3
2020	260	6.0	910	21.0	3.8	0.09	23.6	0.5	896	20.7	10 978	253.5
2021	239	5.5	814	18.8	4.2	0.10	26.3	0.6	814	18.8	10 444	241.2
2022	456	10.5	1 369	31.6	3.3	0.08	18.9	0.4	1 786	41.3	20 475	472.9

Uncertainties

Uncertainties are presented in Annex 6 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.

2021

- All emissions for the whole time series were recalculated due to update of fuel data in the EUROCONTROL data

2023

- All emissions for 2017 to 2020 were recalculated due to updates in the EUROCONTROL calculation system. These updates resulted also in the recalculation of NMVOC emissions in domestic aviation for the years until 2004.

- Particle emissions in international aviation were recalculated for 2005 following the recommendation in 2022 NECD inventory review. As a result of the corrections made to the 2005 calculation, the emissions for the earlier years were also corrected and recalculated.

Source-specific planned improvements

- The possibility to add additional heavy metal and POP emissions will be studied for future years.

3.5 Road transport

Changes in chapter	
February 2024	AL, KS, TF, KM, KG, JMP

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

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 2020 submission to those presented in Guidebook 2019.

Source category description

The contribution of the category to total emissions is presented in Tables 3.6 (a)-(d).

Table 3.6 (a) Contribution of NFR 1A3bi in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	8.785	Gg	8.8
NMVOC	0.955	Gg	1.3
SOx (as SO_2)	0.022	Gg	<0.1
NH_3	0.564	Gg	1.8
$PM_{2.5}$	0.174	Gg	1.3
PM_{10}	0.174	Gg	0.6
TSP	0.174	Gg	0.4
BC	0.084	Gg	2.7
CO	17.615	Gg	5.7
Pb	0.002	Mg	<0.1
Cd	<0.001	Mg	<0.1
Hg	0.013	Mg	2.6
As	<0.001	Mg	<0.1
Cr	0.012	Mg	<0.1

Cu	0.009	Mg	<0.1
Ni	0.003	Mg	<0.1
Se	<0.001	Mg	<0.1
Zn	0.048	Mg	<0.1
PCDD/ PCDF	0.409	g I-Teq	4.3
PAH-4	0.076	Mg	0.4
HCB	0.105	kg	0.4
PCB	<0.001	kg	<0.1

Table 3.6 (b) Contribution of NFR 1A3bii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	3.507	Gg	3.5
NMVOC	0.192	Gg	0.3
SOx (as SO_2)	0.003	Gg	<0.1
NH_3	0.011	Gg	<0.1
$PM_{2.5}$	0.147	Gg	1.1
PM_{10}	0.147	Gg	0.5
TSP	0.147	Gg	0.4
BC	0.081	Gg	2.6
CO	1.242	Gg	0.4
Pb	<0.001	Mg	<0.1
Cd	<0.001	Mg	<0.1
Hg	0.002	Mg	0.3
As	<0.001	Mg	<0.1
Cr	0.002	Mg	<0.1
Cu	0.002	Mg	<0.1
Ni	<0.001	Mg	<0.1
Se	<0.001	Mg	<0.1
Zn	0.005	Mg	<0.1
PCDD/ PCDF	0.134	g I-Teq	1.4
PAH-4	0.016	Mg	<0.1
HCB	0.017	kg	<0.1
PCB	<0.001	kg	<0.1

Table 3.6 (c) Contribution of NFR 1A3biii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	6.926	Gg	7.0
NMVOC	0.202	Gg	0.3
SOx (as SO_2)	0.015	Gg	<0.1
NH_3	0.031	Gg	<0.1
$PM_{2.5}$	0.099	Gg	0.7
PM_{10}	0.099	Gg	0.4
TSP	0.099	Gg	0.2
BC	0.053	Gg	1.7
CO	1.875	Gg	0.6
Pb	<0.001	Mg	<0.1
Cd	<0.001	Mg	<0.1
Hg	0.008	Mg	1.5
As	<0.001	Mg	<0.1
Cr	0.012	Mg	<0.1
Cu	0.008	Mg	<0.1
Ni	<0.001	Mg	<0.1
Se	<0.001	Mg	<0.1
Zn	0.026	Mg	<0.1
PCDD/ PCDF	0.051	g I-Teq	0.5
PAH-4	0.112	Mg	0.6
HCB	0.087	kg	0.3
PCB	<0.001	kg	<0.1

Table 3.6 (d) Contribution of NFR 1A3biv in 2022 to total emissions.

Pollutant	Emissions in 2021	Unit	Share of total emissions %
NOx (as NO_2)	0.158	Gg	0.2
NMVOC	0.801	Gg	1.1

SOx (as SO_2)	<0.001	Gg	<0.1
NH_3	0.002	Gg	<0.1
$PM_{2.5}$	0.015	Gg	0.1
PM_{10}	0.015	Gg	<0.1
TSP	0.015	Gg	<0.1
BC	0.004	Gg	0.1
CO	2.853	Gg	0.9
Pb	<0.001	Mg	<0.1
Cd	<0.001	Mg	<0.1
Hg	<0.001	Mg	<0.1
As	<0.001	Mg	<0.1
Cr	<0.001	Mg	<0.1
Cu	<0.001	Mg	<0.1
Ni	<0.001	Mg	<0.1
Se	<0.001	Mg	<0.1
Zn	0.001	Mg	<0.1
PCDD/ PCDF	0.015	g I-Teq	0.2
PAH-4	0.001	Mg	<0.1
HCB	0.002	kg	<0.1
PCB	<0.001	kg	<0.1

Emission trends

The consumption of diesel and gasoline increased by about 1 PJ per year during the 1970s and 1980s. 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 1990s, then the current level of consumption would give comparable percentage growth rates to those observed for other countries. The economic recession of the early 1990s 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. The significant reduction in all emissions for the year 2020 is due to COVID-19.

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 CO_2 limits set to the car manufacturers
- A national car tax reform based on CO_2 emissions caused a dramatic transition from gasoline to diesel cars and decreased CO_2 emissions in 2009.
- Biofuels have lowered the CO_2 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 for HVO fuels. 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.

Passenger car fuel consumption per vehicle has lowered steadily since 2008. For heavy vehicles, fuel consumption has stayed rather stable.

Emission trends for NO_x, SO_x, NMVOC and NH_3 are presented in Figure 3.4. All emissions except ammonia are currently decreasing. The trends in emissions have continued downwards because of the prolonged economic downturn and due to the still tightening emission standards (e.g. use of SCR technology in diesel vehicles significantly reduces NO_x emissions).

In the case of ammonia, vast majority of the emissions originate from gasoline passenger cars equipped with catalytic converters. Ammonia was formed extensively in Euro 1 and Euro 2 cars, which led to a sharp increase in ammonia emissions from passenger cars in the 1990s. Successive Euro classes have seen significant reductions in emissions resulting in lower passenger car emissions. The rapid increase in ammonia emissions from heavy duty vehicles from 2010 onwards is due to the urea additive used in SCR diesel technology, which has become the main technology since Euro 5. The increase in ammonia emissions from light duty vehicles (almost all diesel vehicles) from 2010 is due to the same deployment of SCR technology as in heavy duty vehicles.

The economic recession in the early 1990s slowed down the increase of fuel use, which, however, grew per 2 PJ per year during 1970-1980s. 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 1990s.

Fuel consumption is presented in Figure 3.5 and the road kilometrage in Table 3.9. The results of the recalculated energy use by vehicle category are presented in Figure 3.6 and in details on the website of LIPASTO http://lipasto.vtt.fi/en/aliisa/aliisa_results.htm.

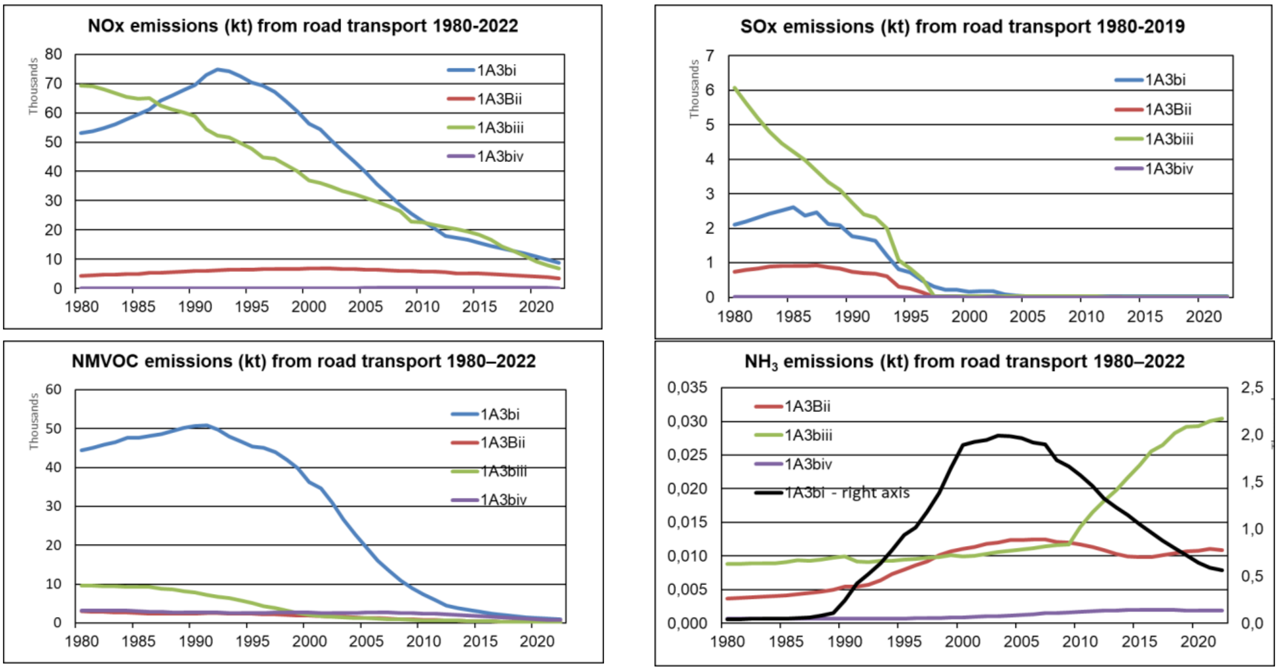


Figure 3.4. NO_x, SO_x, NMVOC and NH_3 emissions from road transport 1980-2022.

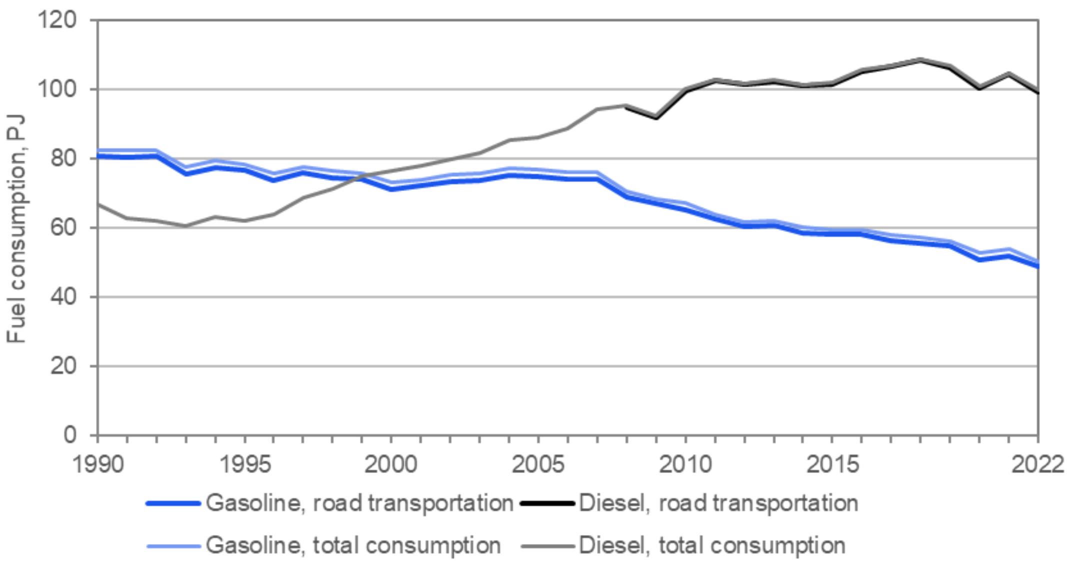


Figure 3.5. Consumption of diesel oil and gasoline (including bioshares) in road transportation in 1970 to 2022 (Energy Statistics, Statistics Finland, NID 2024).

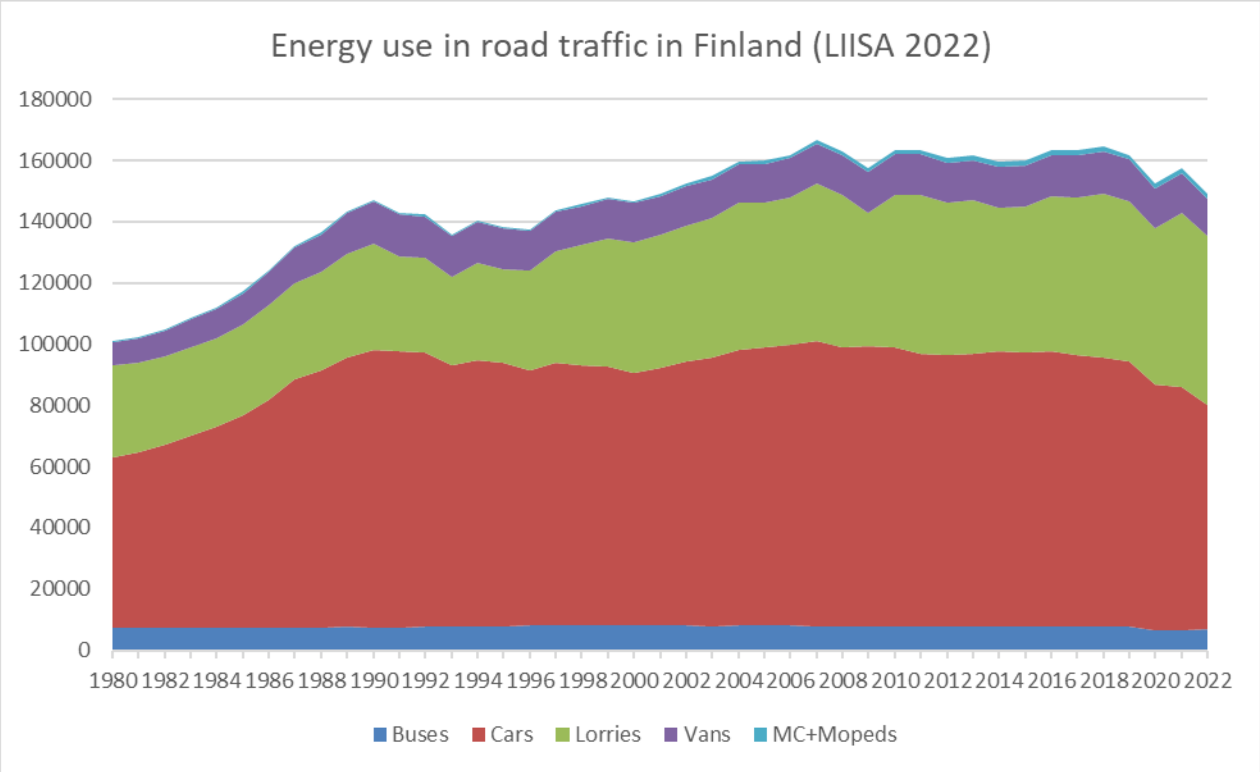


Figure 3.6. Energy use by vehicle category (LIPASTO, VTT 2024).

Methodological issues

Changes in chapter	
February 2024	AL, KS, TF, KM, KG

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, TSP, $PM_{2.5}$, PM_{10}, BC, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/ PCDF, PAHs, HCB and PCB for the years 1980–2050.

In the latest version of the LIISA calculation model the emission factors are from EMEP EEA Guidebook 2019. 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 Methodological Issues) and for example urea additive AdBlue.

Basis of calculation

The emission calculation is based on annual kilometrage (km/a) per vehicle type (NO_x, SO_2, NMVOC, CO_2, CH_4, CO, TSP, $PM_{2.5}$, PM_{10}, BC, PCDD/ PCDF and PCB). 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 Greenhouse Gas Inventories and the EMEP/EEA Emission Inventory Guidebook 2019.

CO_2 and SO_2 as well as Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PAHs and HCB 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.

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. 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 amounts of fuels (gasoline and diesel) used for other purposes than road transport is deducted from the total sales of fuels before the emission calculation. Fuels used for other purposes than road traffic are calculated by separate models. 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 Transport Infrastructure Agency 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. An essential part of defining the total annual kilometrage is the annual analysis of the odometer readings available from the Periodic Technical Inspection Centres and done by Statistics Finland.

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, FFV, diesel, gas (CNG), PHEV(BE), PHEV(DI), BEV and Hydrogen. Road traffic kilometrage in Finland is presented in Table 3.9.

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 0 to Euro 5). 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 0 to Euro 5). Also, L6e class (diesel, moped car, quadricycle) is included in this category.

Fuels sold

Total fuel sales are from statistics compiled by the Finnish Petroleum and Biofuels Association until summer 2020 and Statistics Finland from autumn 2020 on. These data are compared to and supplemented with the data received 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 49.0 PJ and in leisure boats and working machines 4.3 PJ (8.1% of total sales) in 2022. Diesel fuel used in road transport was 99.4 PJ and in leisure boats 0.4 PJ (0.4% of total sales). Biodiesel 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. Gasoline and diesel used in leisure boats are calculated with the MEERI model.

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 NO_x 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 2020 are expressed in Table 3.7.

Table 3.7. 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	1.15	1.11
CO vans	1.84	1.84	1.84	1.15	1.15	1.15	1.11
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	1.22	1.16
NOx vans	2.02	2.02	2.02	1.22	1.22	1.22	1.16

Emission factors and other parameters

The methods for calculating emissions from road transportation correspond to the EMEP Tier 3.

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 2019 (EMEP/EEA 2019).

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

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

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).

Particle emissions

Particle emissions cover TSP, PM_{10} and $PM_{2.5}$. According to the EMEP/EEA Emission Inventory Guidebook 2019 the fraction factors, i.e. the rations between all particle fractions is 1:1. Black carbon emissions from road transport are calculated with the Tier 1 emission factors of the EMEP EEA Guidebook 2019.

Black carbon emissions from road transport are calculated with the Tier 1 emission factors of the EMEP EEA Guidebook 2019.

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 2019 (EEA, 2019). In cases no emission factor is provided in Guidebook 2019, an expert estimate has been used. Emission factors are presented in Table 3.8 and activity data (driven kilometres) in Table 3.9.

Table 3.8. NH_3 emissions factors for road transport (EMEP/EEA Guidebook 2019. Estimates made by VTT LIPASTO experts are marked as "ex").

Vehicle type	**EFs from EMEP EEA Guidebook 2019, 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							33.8ex
	33.8ex						
Busses, diesel	2.9	2.9	2.9	2.9	2.9	11	9
Busses, gas		88ex	100.7ex	33.8ex	33.8ex	33.8ex	33.8ex
Motocycles	1.9	1.9	1.9	1.9	1.9	1.9	
Mopeds	1	1	1	1	1	1	
Vans, diesel	1.2	1.2	1.2	1.2	1.2	1.9	1.9
Vans without catalytic	2.5						
Vans with catalytic		75.8	91	30.2	30.2	12.3	12.3
Vans (gas)						33.8ex	33.8ex
Passenger cars, (gas)		88ex	100.7ex	33.8ex	33.8	33.8	33.8
Motorised quadricycles		1	1	1	1	1	
Passenger cars (FFV)					33.9	33.9	33.9

POP emissions

The calculation of road transport POP emissions is based on emission factors and driven kilometres or consumed fuel (Table 3.9). of fuels as tonnes is converted into litres by dividing it with the density of petrol (0.744 kg/l for the year 2019) or diesel (0.804 kg/l for the year 2019, depending on the bioshare).

PAH-4
The road transport emission factors for the four indicator substances, i.e. benzo(a)pyrene, benzo(b)fluoranthene, benzo(k) fluoranthene and indeno(1,2,3-cd)pyrene are from EMEP EEA Guidebook 2019. The sum of PAH-4 is calculated from the four indicator substances.

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 2019. 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 2019.

Heavy metal emissions

The emissions are calculated with the Tier 3 emission factors of the EMEP EEA Guidebook 2019 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 3.9 Activity data for 1980-2022 in the LIISA sub-model.

Year	Driven kilometers (10^6 km/year)					Fuel consumption (t/year)				
	Passenger cars	Light duty trucks	Buses	Heavy duty trucks	MC+Mopeds	Passenger cars	Light duty trucks	Buses	Heavy duty trucks	MC+Mopeds
1980	22 620	2 024	640	2 390	480	1 309 687	175 937	167 979	701 332	14 043
1985	27 748	2 709	670	2 460	480	1 629 157	233 514	170 380	698 507	14 436
1990	35 757	3 593	660	2 780	448	2 121 152	320 819	173 647	816 880	14 020
1995	34 740	3 743	633	2 639	447	2 008 346	307 250	184 893	724 734	14 303
2000	38 699	4 266	598	2 814	556	1 932 179	298 538	189 261	1 001 041	18 373
2005	41 195	4 676	596	3 136	781	2 127 510	294 466	189 635	1 107 045	25 566
2006	41 262	4 779	596	3 195	848	2 142 867	298 166	188 101	1 134 923	27 584
2007	41 771	4 895	593	3 290	924	2 181 718	302 511	184 974	1 213 675	29 945
2008	41 102	4 945	605	3 336	964	2 156 534	302 580	186 381	1 163 569	32 348
2009	41 236	5 048	609	3 088	989	2 176 379	307 187	186 127	1 026 120	32 896
2010	40 991	5 136	612	3 223	1 045	2 169 931	310 781	185 021	1 168 364	34 543
2011	40 682	5 145	611	3 295	1 131	2 137 427	309 818	183 024	1 218 343	37 481
2012	40 030	5 133	609	3 301	1 171	2 131 035	305 957	180 617	1 162 413	38 707
2013	40 455	5 189	615	3 339	1 194	2 130 849	307 914	180 396	1 170 726	38 946
2014	41 064	5 306	620	3 354	1 205	2 139 090	314 712	182 338	1 101 121	39 449
2015	40 603	5 488	622	3 404	1 220	2 106 966	314 951	175 269	1 102 725	39 923
2016	40 682	5 511	636	3 493	1 226	2 106 779	313 512	181 827	1 172 566	40 087
2017	40 528	5 608	630	3 369	1 225	2 094 971	321 003	184 170	1 200 214	40 459
2018	40 537	5 686	613	3 409	1 194	2 084 391	320 313	181 714	1 250 611	39 566
2019	40 446	5 720	598	3 337	1 154	2 053 766	316 709	177 484	1 223 063	38 411

2020	38 622	5 655	517	3 251	1 125	1 903 842	301 766	154 199	1 193 602	37 564
2021	37 876	5 758	447	3 279	1 115	1 893 640	308 979	147 175	1 317 420	37 258
2022	36 822	5 560	487	3 163	1 092	1 747 290	287 015	160 954	1 281 240	36 650

NOTE: The figures presented in the table do dot include electric or hydrogen vehicles.

Uncertainties
Uncertainties are presented in Annex 6 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.

Concerning GHG emissions and CO, HC, NO_x, PM and SO_x, the QA/QC plan for the road transport sector includes thorough QA/QC measures based on 2006 IPCC Guidelines. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made, if necessary. A bilateral quality meeting is held annually between the GHG inventory unit (Statistics Finland) and the sectoral expert (VTT). These GHG quality measures are also suitable for other compounds than mentioned above.

For each compound, the LIISA model has a consistent time series for the years 1980-2050. Forecasts allow the identification of abnormal emission trends to detect potential errors.

Source specific recalculations

2014-2015
- 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. SO_x, NO_x, NMVOC and CO were compared to the data reported under the UNFCCC calculated at Statistics Finland.

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.

2020

- Impact of speed was included in the calculation of TSP emissions which resulted in higher emissions, i.e. an increase of about 13% to all particle species (see Tables 3.11 c,d,e,f) and to heavy metal emissions as these are fractions of TSP.
- Abrasion emissions include some small changes to all years due to adoption of latest kilometrage values in the LIISA model, the impact being 0-16%.
- Selene from tyre wear was included in the calculation for the first time.
- A summary of recalculations under NFR 1A3b to the 2020 submission (Table 3.10):

Table 3.10. A summary of recalculations under NFR 1A3b to the 2020 submission.

NFR	Pollutant	Year	Effect on emissions	Justification
1A3bi	All reported pollutants	1987-1989	Only a minor increasing or decreasing effect on emissions	Update of kilometrage data on passenger cars with catalytic converter
1A3bi	SOx and heavy metals	1986-1989	Only a minor increasing or decreasing effect on emissions	Update of sulphur content of the fuel
1A3biii	All reported pollutants	2015-2017	Only a minor increasing on emissions	Update of kilometrage data on EURO3-6 busses and some trucks
1A3biv	All reported pollutants	1980-1989		Correction of incorrect emissions in the NFR tables and update of fuel use data in the emission calculation
1A3biv	SOx and heavy metals	1990-2017	Only a minor increasing or decreasing effect on emissions	Update of sulphur content of the fuel
1A3biv	NMVOC	1999-2017	Only a minor increasing effect on emissions	Correction of CH4 emissions in the calculation for motorcycles
1A3biv	Particles	2003-2017	Slight increase of emissions	Correction of errors in the calculation of emissions for motorcycles
1A3biv	PAH	1990-2017	Only a minor decreasing effect on emissions in the 1990's and slight increase of emissions after that	Correction of errors in the calculation

2021

- Recalculation of 1A3biv. The definition of emission factors for vehicle category L6e-B, light quadri-mobile (moped cars) has long been a problem for the lack of proper data. Now the Guidebook 2019 includes emission factors for micro-cars, intended for this vehicle category. The entire time series has been recalculated using these coefficients.
- Checking and revision of fuel properties (density, NCV, bio share) has slightly changed results for the years 2013-2018.

2022

- As a reference to the 2021 NECD inventory review question FI-1A3biv-2021-0001, the recalculation of heavy metal, small particle and POP emissions from 2003 onwards for category 1A3biv was finalized and the revised estimates were included in the 2022 submission.

Source specific planned improvements

None.

3.6 Gasoline evaporation

1 A 3 b v Road transport: Gasoline evaporation

Changes in chapter	
February 2024	AL, TF, KM

Source category description

The contribution of the category to total emissions is presented below.

Table 3.11. Contribution of NFR 1A3bv in 2022 to total emissions.

Pollutant	Emissions in 2021	Unit	Share of total emissions %
NMVOC	1.205	Gg	1.6

Emission trend

NMVOC emissions from gasoline evaporation in 1990-2022 are presented in Figure 3.7 and Table 3.12. 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.

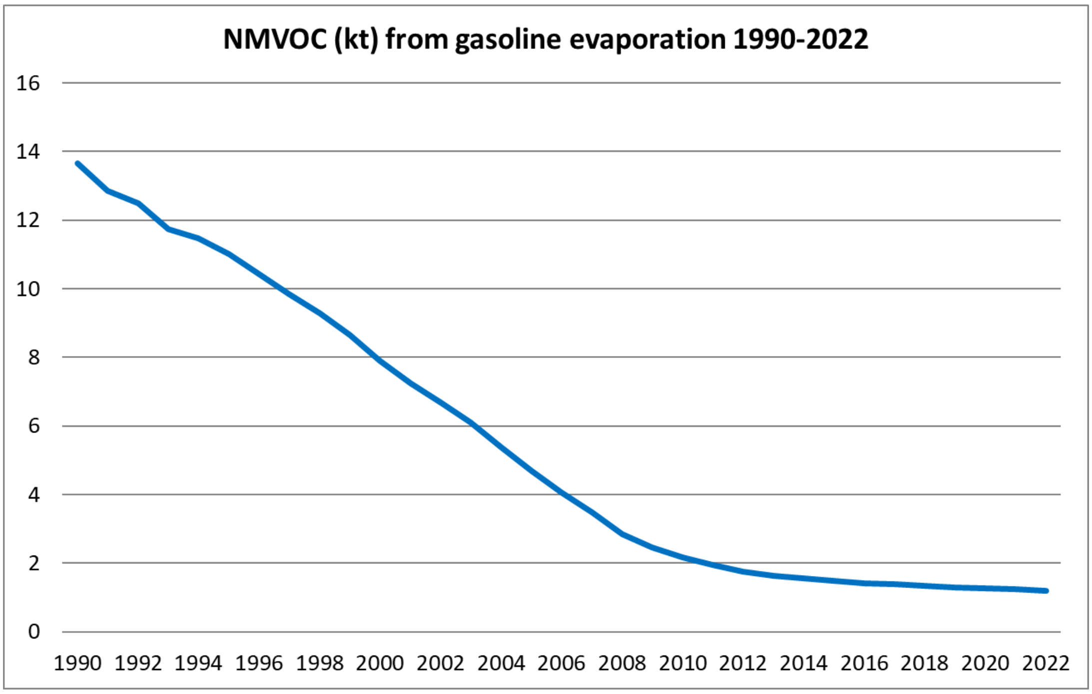


Figure 3.7. NMVOC emissions from gasoline evaporation 1990-2022.

Table 3.12 NMVOC evaporative emissions 1990-2021 from vehicles.

Year	Gasoline evaporation (t/a)	Year	Gasoline evaporation (t/a)
1990	13 655	2007	3 487
1991	12 863	2008	2 859
1992	12 490	2009	2 462
1993	11 743	2010	2 175
1994	11 470	2011	1 957
1995	11 006	2012	1 748
1996	10 415	2013	1 639
1997	9 850	2014	1 567
1998	9 291	2015	1 497
1999	8 651	2016	1 425

2000	7 896	2017	1 396
2001	7 250	2018	1 349
2002	6 689	2019	1 306
2003	6 096	2020	1 272
2004	5 374	2021	1 236
2005	4 701	2022	1 205
2006	4053		

Methodological issues

NMVOC emissions of gasoline evaporation from petrol fuelled vehicles are estimated with the Tier 2 methodology of the 2019 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 2007onwards. 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 onwards, 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 6.

QA/QC and verification

Normal statistical QA/QC procedures are carried out.

Source specific recalculations

2019

- The whole time series of NMVOC emissions from gasoline evaporation for 1990 to 2016 was recalculated due to inclusion of a T2 method. None.

2020

- NMVOC emissions in 2002, 2007-2017 were recalculated. All EURO 1 vehicles corrected to be equipped with fuel injection system in the calculation (previously only 1% was assumed to be equipped with fuel injection). Only a minor decreasing impact on emissions.

Source specific planned improvements

None.

3.7 Tyre and brake wear

1A3bvi Road transport: Automobile tyre and brake wear

Changes in chapter	
February 2024	AL, KM, KS, TF

Source category description

The contribution of the category to total emissions is presented below.

Table 3.13. Contribution of NFR 1A3bvi in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
$PM_{2.5}$	0.607	Gg	4.5
PM_{10}	1.102	Gg	4.1
TSP	1.485	Gg	3.5

BC	0.157	Gg	5
Pb	0.461	Mg	3.7
Cd	0.002	Mg	0.2
As	0.041	Mg	2.1
Cr	1.284	Mg	8.6
Cu	28.906	Mg	75.3
Ni	0.184	Mg	1.9
Se	0.03	Mg	7.1
Zn	18.403	Mg	14

Emission trends

In the inventory, TSP, PM_{10}, $PM_{2.5}$ and BC emissions are included since the year 1980 and heavy metals since 1990.

In 2021 submission the calculation method is according to the results of the co-operation between Nordic countries (NAEGG co-operation). The used calculation methods are based on the Tier 2 method of Guidebook 2019.

Because in both tyre and brake wear particulate and BC emissions are determined as fixed factors by the kilometres driven, their trend is consistent with the trend of kilometres driven described above. The trend is upwards, with the exception of the recession of the 1990s and 2008 onwards.

Heavy metals are defined relative to TSP. Therefore, their trend also depends on the kilometres driven. An exception to this is Cu, Pb and Zn in brake wear, for which the method has time series for emission factors. This can also be seen in the figure and tables as decreasing emissions.

Particle and heavy metal emission trends are presented in Figure 3.8. and in Tables 3.14 (a-f) and kilometres driven in Table 3.9.

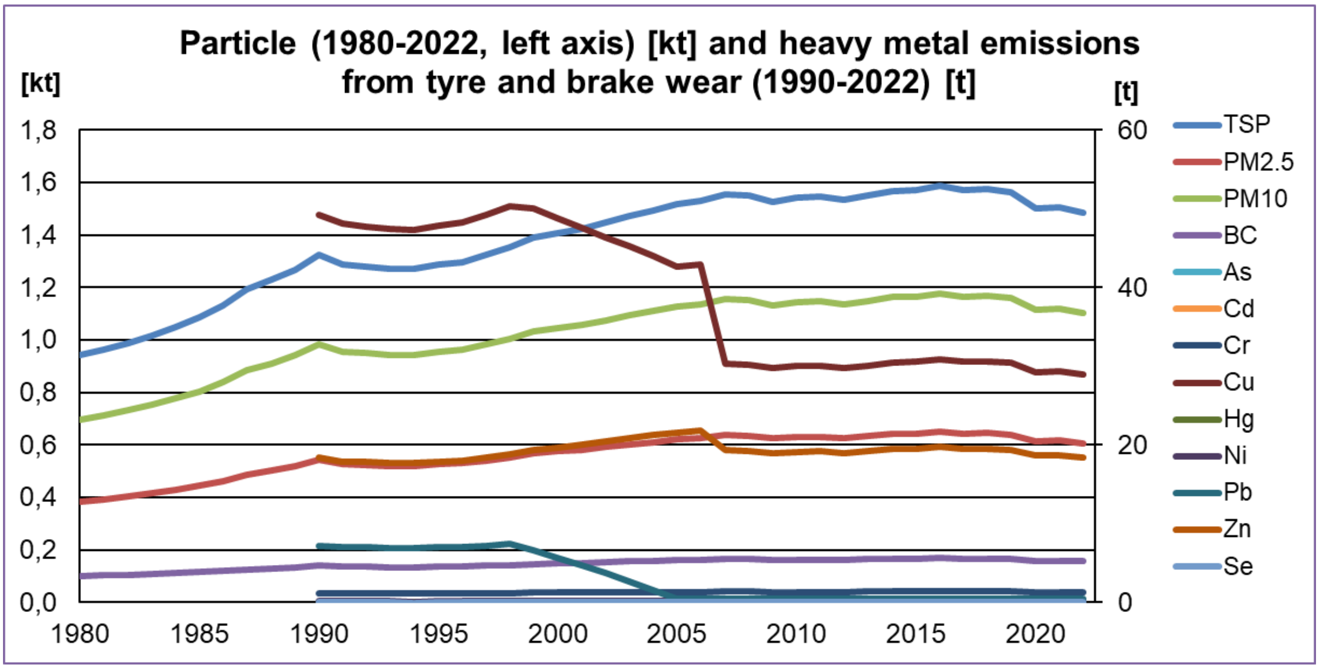


Figure 3.8. Particle and heavy metal emissions from tyre and brake wear.

Table 3.14 (a). Heavy metal emissions (kg) 1990–2022 from road transport tyre wear.

Year	Pb [kg]	Cd [kg]	As [kg]	Cr [kg]	Cu [kg]	Ni [kg]	Zn [kg]	Se [kg]
1990	7.8	0.84	3.2	1.3	6.8	2.6	8 586	16.6
1991	7.6	0.82	3.1	1.3	6.6	2.5	8 301	16.1
1992	7.6	0.82	3.0	1.3	6.6	2.5	8 242	16.0

1993	7.5	0.81	3.0	1.2	6.5	2.5	8 217	15.9
1994	7.5	0.81	3.0	1.2	6.5	2.5	8 205	15.9
1995	7.6	0.82	3.1	1.3	6.6	2.5	8 318	16.1
1996	7.7	0.82	3.1	1.3	6.6	2.5	8 381	16.2
1997	7.8	0.84	3.2	1.3	6.8	2.6	8 555	16.6
1998	8.0	0.86	3.2	1.3	6.9	2.6	8 732	16.9
1999	8.2	0.89	3.3	1.4	7.1	2.7	8 964	17.4
2000	8.3	0.90	3.3	1.4	7.2	2.7	9 044	17.6
2001	8.4	0.91	3.4	1.4	7.3	2.8	9 150	17.8
2002	8.5	0.92	3.4	1.4	7.4	2.8	9 305	18.1
2003	8.7	0.94	3.5	1.4	7.6	2.9	9 480	18.4
2004	8.8	0.95	3.6	1.5	7.7	2.9	9 621	18.7
2005	9.0	0.97	3.6	1.5	7.8	2.9	9 765	19.0
2006	9.0	0.97	3.6	1.5	7.8	3.0	9 857	19.2
2007	9.2	0.99	3.7	1.5	8.0	3.0	10 039	19.5
2008	9.2	0.99	3.7	1.5	8.0	3.0	10 031	19.4
2009	9.0	0.97	3.6	1.5	7.8	3.0	9 813	19.1
2010	9.1	0.98	3.7	1.5	7.9	3.0	9 946	19.3
2011	9.1	0.98	3.7	1.5	7.9	3.0	9 989	19.4
2012	9.1	0.98	3.7	1.5	7.9	3.0	9 914	19.2
2013	9.2	0.99	3.7	1.5	7.9	3.0	10 023	19.4
2014	9.3	1.00	3.7	1.5	8.0	3.0	10 139	19.7
2015	9.3	1.00	3.7	1.5	8.1	3.0	10 173	19.7
2016	9.4	1.01	3.8	1.5	8.1	3.1	10 294	19.9
2017	9.3	1.00	3.7	1.5	8.1	3.0	10 159	19.7
2018	9.3	1.00	3.8	1.5	8.1	3.1	10 197	19.8
2019	9.2	1.00	3.7	1.5	8.0	3.0	10 101	19.6
2020	8.9	0.96	3.6	1.5	7.7	2.9	9 693	18.8
2021	8.9	0.96	3.6	1.5	7.7	2.9	9 716	18.9
2022	8.8	0.95	3.5	1.5	7.6	2.9	9 582	18.6

Table 3.14 (b). Heavy metal emissions (kg) 1990–2022 from road transport brake wear.

Year	Pb [kg]	Cd [kg]	As [kg]	Cr [kg]	Cu [kg]	Ni [kg]	Zn [kg]	Se [kg]
1990	7 212	0.69	33.3	1 141	49 231	161	9 833	9.9
1991	7 040	0.67	32.5	1 114	48 055	158	9 598	9.6
1992	6 998	0.67	32.3	1 107	47 766	157	9 541	9.6
1993	6 939	0.66	32.1	1 098	47 366	155	9 461	9.5
1994	6 925	0.66	32.0	1 096	47 268	155	9 441	9.5
1995	7 014	0.67	32.4	1 110	47 878	157	9 563	9.6
1996	7 064	0.67	32.6	1 118	48 217	158	9 631	9.7
1997	7 211	0.69	33.3	1 141	49 224	161	9 832	9.9
1998	7 376	0.70	34.1	1 167	50 348	165	10 056	10.1
1999	6 567	0.72	35.1	1 201	49 965	170	10 415	10.4
2000	5 624	0.73	35.6	1 217	48 813	172	10 633	10.5
2001	4 647	0.74	36.0	1 233	47 554	174	10 839	10.7
2002	3 656	0.75	36.6	1 252	46 394	177	11 082	10.8
2003	2 639	0.77	37.2	1 275	45 294	180	11 358	11.0
2004	1 576	0.78	37.7	1 292	43 935	183	11 586	11.2
2005	485	0.79	38.3	1 311	42 588	185	11 833	11.3
2006	489	0.79	38.6	1 321	42 925	187	11 926	11.4
2007	474	0.81	39.2	1 344	30 285	190	9 244	11.6
2008	472	0.80	39.1	1 338	30 154	189	9 205	11.6
2009	466	0.79	38.6	1 320	29 762	187	9 085	11.4
2010	470	0.80	38.9	1 332	30 017	188	9 163	11.5
2011	470	0.80	38.9	1 333	30 050	189	9 173	11.5
2012	466	0.79	38.6	1 321	29 766	187	9 086	11.4
2013	471	0.80	39.0	1 335	30 091	189	9 185	11.6
2014	477	0.81	39.5	1 352	30 484	191	9 305	11.7
2015	478	0.81	39.5	1 354	30 519	192	9 316	11.7
2016	482	0.82	39.9	1 366	30 792	193	9 399	11.8
2017	477	0.81	39.5	1 354	30 512	192	9 314	11.7
2018	479	0.82	39.7	1 358	30 615	192	9 345	11.8
2019	476	0.81	39.4	1 349	30 407	191	9 282	11.7
2020	457	0.78	37.8	1 295	29 193	183	8 911	11.2
2021	459	0.78	38.0	1 300	29 305	184	8 945	11.3
2022	452	0.77	37.4	1 282	28 899	181	8 821	11.1

Table 3.14 (c). Tyre and brake wear particle emissions from Passenger cars 1980–2022.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1980	289	174	122	44	192	188	75	5.0
1985	355	213	149	54	235	230	92	6.1
1990	457	274	192	70	303	297	118	7.9
1995	444	267	187	68	294	289	115	7.7
2000	495	297	208	76	328	321	128	8.6
2001	502	301	211	77	332	326	130	8.7
2002	507	304	213	78	336	329	131	8.8
2003	516	309	217	79	342	335	133	8.9
2004	520	312	218	80	345	338	134	9.0
2005	527	316	221	81	349	342	136	9.1
2006	528	317	222	81	350	343	136	9.1
2007	534	321	224	82	354	347	138	9.2
2008	526	315	221	80	348	341	136	9.1
2009	528	317	222	81	349	342	136	9.1
2010	524	315	220	80	347	340	135	9.1
2011	520	312	219	80	345	338	134	9.0
2012	512	307	215	78	339	332	132	8.9
2013	518	311	217	79	343	336	134	8.9
2014	525	315	221	80	348	341	136	9.1
2015	519	312	218	79	344	337	134	9.0
2016	520	312	219	80	345	338	134	9.0
2017	518	311	218	79	343	337	134	9.0
2018	519	311	218	79	344	337	134	9.0
2019	517	310	217	79	343	336	134	8.9
2020	494	296	208	76	327	321	128	8.5
2021	496	298	208	76	329	322	128	8.6
2022	491	295	206	75	325	319	127	8.5

Table 3.14 (d). Tyre and brake wear particle emission from Light duty vehicles 1980–2022.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1980	41	25	17	6	27	26	10	0.7
1985	55	33	23	8	36	35	14	0.9
1990	73	44	30	11	48	47	19	1.2
1995	76	45	32	12	49	48	19	1.3
2000	86	52	36	13	56	55	22	1.5
2001	88	53	37	13	58	57	22	1.5
2002	90	54	38	14	59	58	23	1.5
2003	91	55	38	14	60	58	23	1.6
2004	93	56	39	14	61	59	24	1.6
2005	94	57	40	14	62	61	24	1.6
2006	97	58	41	15	63	62	25	1.6
2007	99	59	42	15	65	63	25	1.7
2008	100	60	42	15	65	64	25	1.7
2009	102	61	43	16	67	65	26	1.7
2010	104	62	44	16	68	67	26	1.8
2011	104	62	44	16	68	67	27	1.8
2012	104	62	44	16	68	67	26	1.8
2013	105	63	44	16	69	67	27	1.8
2014	107	64	45	16	70	69	27	1.8
2015	111	67	47	17	73	71	28	1.9
2016	111	67	47	17	73	71	28	1.9
2017	113	68	48	17	74	73	29	1.9
2018	115	69	48	18	75	74	29	2.0
2019	116	69	49	18	76	74	29	2.0
2020	114	69	48	17	75	73	29	2.0
2021	117	70	49	18	76	75	30	2.0
2022	113	68	47	17	74	73	29	1.9

Table 3.11 (e). Tyre and brake wear particle emission from Heavy duty vehicles 1980–2022.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1980	263	158	111	40	125	123	49	3.3
1985	272	163	114	42	130	127	51	3.4
1990	299	179	125	46	142	139	56	3.7
1995	284	171	119	43	135	133	53	3.5
2000	296	178	124	45	141	138	55	3.7
2001	298	179	125	46	142	139	55	3.7
2002	305	183	128	47	145	143	57	3.8
2003	312	187	131	48	149	146	58	3.9
2004	319	191	134	49	152	149	59	4.0
2005	324	194	136	50	154	151	60	4.0
2006	329	198	138	50	157	154	61	4.1
2007	337	202	142	52	161	157	63	4.2
2008	342	205	144	52	163	160	64	4.3
2009	321	193	135	49	153	150	60	4.0
2010	333	200	140	51	159	156	62	4.1
2011	339	204	142	52	162	158	63	4.2
2012	340	204	143	52	162	159	63	4.2
2013	343	206	144	53	164	160	64	4.3
2014	345	207	145	53	164	161	64	4.3
2015	350	210	147	53	167	163	65	4.3
2016	359	215	151	55	171	167	67	4.5
2017	347	208	146	53	165	162	65	4.3
2018	349	210	147	53	166	163	65	4.3
2019	342	205	144	52	163	160	64	4.2
2020	327	196	137	50	156	153	61	4.1
2021	326	195	137	50	155	152	61	4.1
2022	321	193	135	49	153	150	60	4.0

Table 3.14 (f). Tyre and brake wear particle emission from Mopeds and Motorcycles 1980–2022.

Year	Tyre wear (t)				Brake wear (t)			
	TSP	PM_{10}	$PM_{2.5}$	BC	TSP	PM_{10}	$PM_{2.5}$	BC
1980	2.1	1.3	0.9	0.33	1.0	1.0	0.4	0.027
1985	2.1	1.3	0.9	0.33	1.0	1.0	0.4	0.026
1990	2.1	1.2	0.9	0.32	1.0	1.0	0.4	0.026
1995	2.1	1.2	0.9	0.32	1.0	1.0	0.4	0.025
2000	2.6	1.5	1.1	0.39	1.2	1.2	0.5	0.032
2001	2.7	1.6	1.1	0.41	1.3	1.3	0.5	0.033
2002	2.8	1.7	1.2	0.44	1.4	1.3	0.5	0.035
2003	3.1	1.8	1.3	0.47	1.4	1.4	0.6	0.038
2004	3.3	2.0	1.4	0.50	1.6	1.5	0.6	0.041
2005	3.6	2.2	1.5	0.55	1.7	1.7	0.7	0.045
2006	3.9	2.3	1.6	0.60	1.9	1.8	0.7	0.048
2007	4.3	2.6	1.8	0.65	2.0	2.0	0.8	0.053
2008	4.4	2.7	1.9	0.68	2.1	2.1	0.8	0.055
2009	4.6	2.7	1.9	0.70	2.2	2.1	0.8	0.056
2010	4.8	2.9	2.0	0.74	2.3	2.2	0.9	0.060
2011	5.2	3.1	2.2	0.80	2.5	2.4	1.0	0.064
2012	5.4	3.2	2.3	0.82	2.6	2.5	1.0	0.067
2013	5.5	3.3	2.3	0.84	2.6	2.6	1.0	0.068
2014	5.5	3.3	2.3	0.85	2.6	2.6	1.0	0.069
2015	5.6	3.4	2.4	0.86	2.7	2.6	1.0	0.070
2016	5.6	3.4	2.4	0.86	2.7	2.6	1.0	0.070
2017	5.6	3.4	2.4	0.86	2.7	2.6	1.0	0.070
2018	5.5	3.3	2.3	0.84	2.6	2.6	1.0	0.068
2019	5.3	3.2	2.2	0.81	2.5	2.5	1.0	0.066
2020	5.2	3.1	2.2	0.79	2.5	2.4	1.0	0.064
2021	5.1	3.1	2.2	0.79	2.4	2.4	0.9	0.064
2022	5.0	3.0	2.1	0.77	2.4	2.3	0.9	0.062

Methodological issues

Particle emissions

<u>Tyre wear</u>

TSP emissions from tyre wear are estimated according to the Tier 2 method of Guidebook 2019 (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 2019), it is assumed that the average speed of the different vehicle types is as listed in Table 3.15.

Particle emission factors for tyre and brake wear are presented in Table 3.16 and activity data as driven kilometres in Table 3.9. above on page 24.

Table 3.15. Average speed per vehicle type and corresponding speed correction factor, tyre wear.

Vehicle type	Average speed (km/h)	Speed correction factor
Two-wheelers	80	1.0
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 2019, and BC emissions are calculated as 0.153 * TSP emissions, also according to the Guidebook.

Table 3.16. PM emission factors for tyre wear (mg/vkm).

	Passenger cars	Light duty vehicles	Heavy duty vehicles	Mopeds and Motorcycles
TSP	13	20	87	4.6
PM_{10}	7.7	12	52	2.8
$PM_{2.5}$	5.4	8.5	36	1.9

Brake wear

TSP emissions from brake wear are estimated using emission factors according to Table 3-6 of Guidebook 2019. 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 2019), it is assumed that the average speed of the different vehicle types is as listed in Table 3.17.

Particle and black carbon emission factors for tyre and brake wear are presented in Table 3.18 and activity data as driven kilometres in Table 3.9. above on page 24.

Table 3.17. 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	1.40

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 emission factors are presented in Table 3.18.

Table 3.18. Particle emission factors for brake wear (mg/vkm) Including speed correction factors.

Pollutant	Passenger cars	Light duty vehicles	Heavy duty vehicles	Mopeds and Motorcycles
TSP	8.5	13	41	2.2
PM_{10}	8.3	13	41	2.1
$PM_{2.5}$	3.3	5.2	16	0.9
Share of TSP				
Pollutant	Passenger cars	Light duty vehicles	Heavy duty vehicles	Mopeds and Motorcycles
BC	0.153	0.153	0.153	0.153

Tyre wear

Heavy metal emissions

Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn, Se) 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 purposes of the emission inventory, retreaded tyres are assumed to be used for heavy-duty vehicles and buses and non-retreaded tyres are assumed to be used for all other vehicle types.

Emission estimates of arsenic are based on the metal fractions given in Guidebook 2019 since arsenic is not included in the Hjortenkrans study.

The EFs are presented in Table 3.19 and the activity data as driven kilometres in Table 3.9 above on page 24.

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 2019 are used. This is the case for arsenic, chromium, nickel and selenium.

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 to 1998 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 (Table 3.20).

Table 3.20. 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
2006	75097	856	20865
2007-	52089	815	15900

[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 6.

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*
- *Emission factors from Guidebook 2016 have been adopted to the LIPASTO calculation sub-models*

2020
- *Particles and heavy metals 1980-2017 were recalculated with an increase of max 16% to emissions. Speed effect added to the brake wear formula (error in NAEGG co-operation report), recalculation done for the whole timeseries of heavy metals and particles.*
- *Tyre wear added to the selenium calculation, recalculation done for the whole timeseries.*

Source specific planned improvements

- *Inclusion of calculation of PAH-4 emissions, when information is available.*

3.8 Road abrasion

1 A 3 b vii Road transport: Automobile road abrasion

Changes in chapter	
February 2024	AL, KS, TF

Source category description

The contribution of the category to total emissions is presented below in Table 3.21.

Table 3.21 Contribution of NFR 1A3bvii in 2022 to total emissions.

Pollutant	Emissions in 2021	Unit	Share of total emissions %
$PM_{2.5}$	0.450	Gg	3.4
PM_{10}	5.323	Gg	19.9
TSP	10.646	Gg	25.3
BC	0.088	Gg	2.8

Emission trend

The emissions are slightly increasing due to increased kilometrage of vehicles as seen in Figure 3.9. The road abrasion trend follows the vehicle kilometrage trend (Table 3.9).

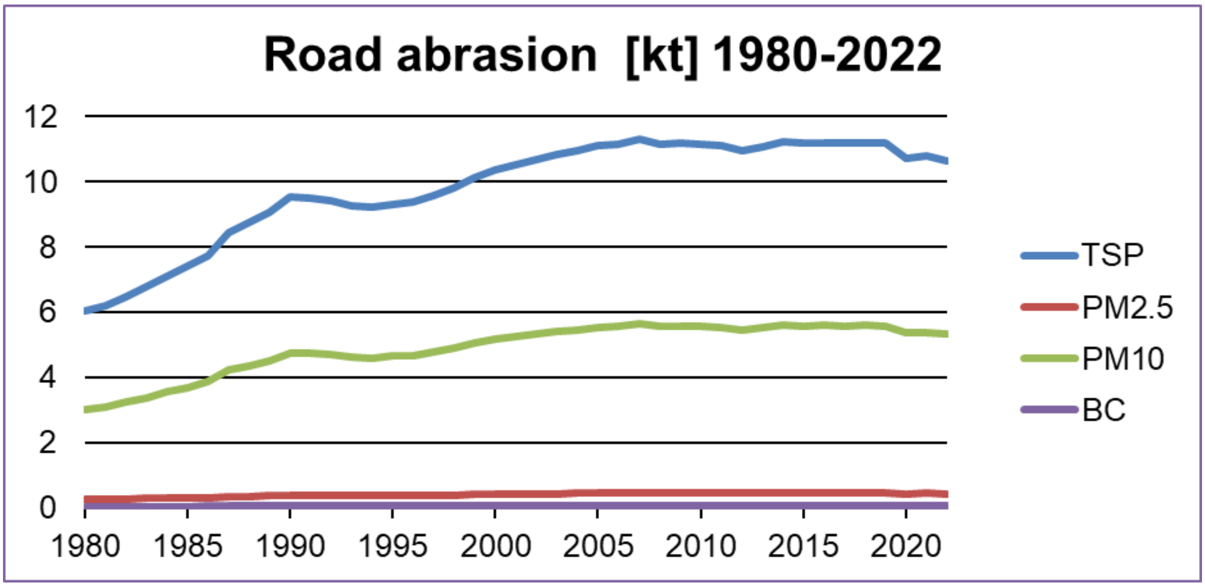


Figure 3.9. Emissions from road abrasion 1980-2022.

Methodological issues

Particle emissions

Particle emissions are estimated with the Tier 2 methodology presented in the 2019 EMEP/EEA Guidebook. The effect of studded tyres is taken into account based on Swedish data that has been adopted to the Finnish conditions.

Activity data

Activity data as driven kilometres are according to the LIISA sub-model and is presented in Table 3.9. above on page 24.

Emission factors (Table 3.22)

Non-studded tyres

- TSP emission factors for road abrasion presented in Table 3.22 are from the Guidebook 2019 Table 3-8 and the fraction factors for PM_{10} and $PM_{2.5}$ from TSP are calculated according to the Guidebook 2019 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 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, 2013).

Table 3.22. Emission factors used for particle emissions from road abrasion.

Road abrasion EFs Vehicle category	Non studded tyres EF (g/km) GB 2019			Studded tyres EF (g/km) Swedish IIR 2008		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
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	-	-	-

Particle emissions from road abrasion are presented in Table 3.23.

Table 3.23 Particle and black carbon emissions from road abrasion.

Year	Road abrasion emissions (kt)			
	TSP	PM10	PM2.5	BC
1980	6.0	3.0	0.27	0.050
1985	7.4	3.7	0.32	0.062
1990	9.5	4.8	0.40	0.079
1995	9.3	4.7	0.39	0.077
2000	10.4	5.2	0.43	0.086
2001	10.5	5.3	0.44	0.087
2002	10.7	5.3	0.45	0.088
2003	10.8	5.4	0.45	0.090
2004	10.9	5.5	0.46	0.091
2005	11.1	5.5	0.47	0.092
2006	11.1	5.6	0.47	0.092
2007	11.3	5.6	0.48	0.094
2008	11.1	5.6	0.47	0.093
2009	11.2	5.6	0.47	0.093
2010	11.2	5.6	0.47	0.093
2011	11.1	5.5	0.47	0.092
2012	10.9	5.5	0.46	0.091
2013	11.1	5.5	0.47	0.092

2014	11.2	5.6	0.48	0.093
2015	11.2	5.6	0.47	0.093
2016	11.2	5.6	0.48	0.093
2017	11.2	5.6	0.47	0.093
2018	11.2	5.6	0.48	0.093
2019	11.2	5.6	0.47	0.093
2020	10.7	5.4	0.45	0.089
2021	10.8	5.4	0.46	0.089
2022	10.6	5.3	0.45	0.088

Uncertainties

Uncertainties are presented in Annex 6.

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.

2020
- Particles in 1980-2017 were recalculated leading to slight decrease of emissions, but strong decrease of PM2.5 emissions in 1980-1989. The reason was correction of kilometrage data in the calculation sheets.

Source specific planned improvements

None.

3.9 Railways

1 A 3 c Railways

Changes in chapter	
February 2024	AL, KM, KS, TF

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 2020 electric locomotives ran 89% of railway transportation, the number has increased by 5 percentage unit since 2008 (Finnish Railway Statistics 2019). Emissions from producing electricity used in electric trains are not included this category, but in category 1.A.1. In 2019 rail services accounted for 28% of all freight carryings in Finland, which is considerably higher than the average for EU countries. (Statistical Yearbook of Finland, 2021). In 2020 the volume of freight transport in Finland totalled 38.4 million tonnes, which is same as in 2019 (Finnish Railway Statistics 2020).

The contribution of the category to total emissions is presented in Table 3.24.

Table 3.24. Contribution of NFR 1A3c in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	1.327	Gg	1.3
NMVOC	0.074	Gg	<0.1
SOx (as SO_2)	<0.001	Gg	<0.1
NH_3	<0.001	Gg	<0.1
$PM_{2.5}$	0.025	Gg	0.2
PM_{10}	0.026	Gg	<0.1
TSP	0.028	Gg	<0.1
BC	0.016	Gg	0.5
CO	0.181	Gg	<0.1
Cd	<0.001	Mg	<0.1
Cr	<0.001	Mg	<0.1
Cu	0.033	Mg	<0.1
Ni	0.001	Mg	<0.1
Se	<0.001	Mg	<0.1
Zn	0.019	Mg	<0.1
PAH-4	0.002	Mg	<0.1

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 and since then the trend has levelled off (Figure 3.10).

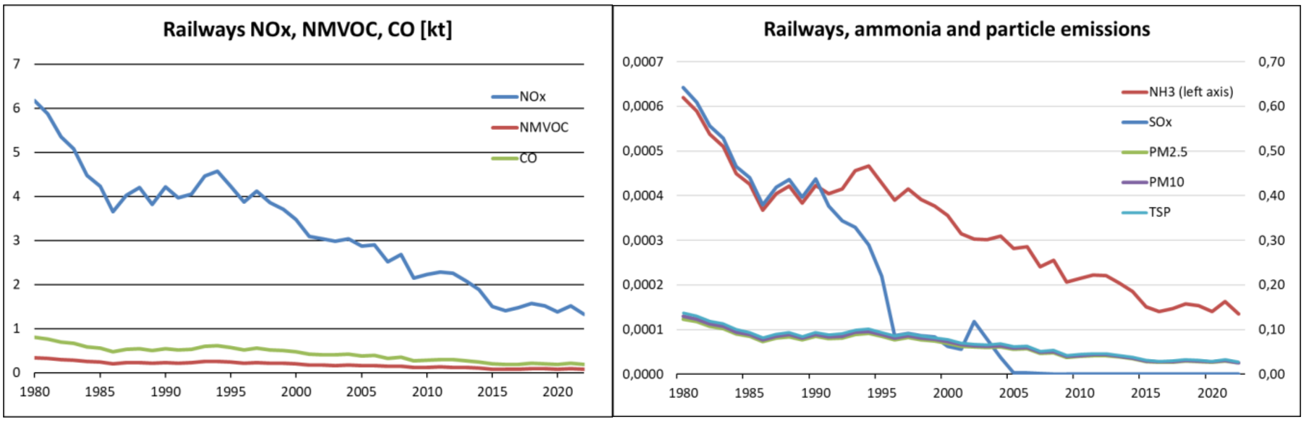


Figure 3.10. Emissions from railroad transportation 1980-2022

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 2019 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.

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 fuel 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/m^3. Emissions from wagon heating and the use of aggregates (for electricity production) are calculated by multiplying gross tonne kilometres with emission factors for wagon heating and aggregates. Gasoil consumption is presented in Table 3.25.

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.

Table 3.25 Gas oil consumption in railway transportation in 1980 - 2022.

Gas oil consumption		Gas oil consumption	
Year	**[kt]**	**Year**	**[kt]**
1980	88.62	**2012**	31.54
1985	60.75	**2013**	29.11
1990	60.40	**2014**	26.55
1995	61.12	**2015**	21.51
2000	50.82	**2016**	20.08
2005	40.15	**2017**	21.04
2006	40.85	**2018**	22.57
2007	34.41	**2019**	21.99
2008	36.51	**2020**	20.14
2009	29.40	**2021**	23.22
2010	30.67	**2022**	19.38
2011	31.78		

Emission factors

The emission factors are based on national measurements for CO, HC, NOx and TSP. The rest of emission factors are based on EMEP/EEA Guidebook 2019.

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 2019. 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 2019.

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

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

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

Uncertainties

Uncertainties are presented in Annex 6.

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.

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

Source specific improvements and recalculations

2021

- All emissions for 2018 were recalculated due to update of fuel consumption data.

2022

- For the years 1990-2016, emissions from railway transportation have been calculated using the RAILI model developed by VTT and based on the activity data of VR-Group Ltd (the only operator in Finland at that time). Since 2018 VR-Group Ltd no longer has reported their activity data in the format used in the RAILI model. Due to this change in data, for the years 2018 and 2019, the calculations were made using a temporal simple method based on VR-Group Ltd's fuel consumption reports and the average emission factors from the RAILI model. In addition, two new railway operators started operations, Fenniarail in 2017 and Operail in 2020, both using a new type of locomotive fleet. All these changes in data led to the renewal of the RAILI model for the 2022 submission.
- The renewal of the model mainly concerned pre-processing of the activity data, specifically gross tonne-kilometres, as basically the same activity data as used in the old RAILI model are also available in the new database maintained by the authority (the Finnish Transport Infrastructure Agency). The renewal process included, e.g. a precise selection and definition of the information

to be included in the database. Calibration of the calculated fuel consumption results to be consistent with operators' yearly consumption reports is a new feature in the model.
- A comparison between the results of the old and renewed RAILI model for the year 2017 showed that the renewed model produced results that were very close to the results of the old model, and thus the calculations with the old and renewed model could be considered to produce consistent timeseries. Recalculations were made for the years 2017–2019 (+ 3 kt CO2-eq. in 2019). The renewed RAILI model is used also for the calculation of emissions in 2020.

Source specific planned improvements

None.

3.10 Navigation

1 A 3 d ii National navigation (Shipping)

Changes in chapter	
February 2024	AL, KM, KS, TF

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 3.11.

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

The contribution of the category to total emissions is presented in Table 3.26.

Table 3.26. Contribution of NFR 1A3dii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	4.877	Gg	4.9
NMVOC	2.919	Gg	3.9
SOx (as SO_2)	0.051	Gg	0.2
NH_3	<0.001	Gg	<0.1
$PM_{2.5}$	0.289	Gg	2.2
PM_{10}	0.295	Gg	1.1
TSP	0.295	Gg	0.7
BC	0.052	Gg	1.7
CO	20.958	Gg	6.8
Pb	0.009	Mg	<0.1
Cd	<0.001	Mg	<0.1
Hg	0.002	Mg	0.4
As	0.003	Mg	0.1
Cr	0.006	Mg	<0.1
Cu	0.014	Mg	<0.1
Ni	0.198	Mg	2.0
Se	<0.001	Mg	0.2
Zn	0.083	Mg	<0.1
PCDD/ PCDF	0.010	g I-Teq	0.1
HCB	0.002	kg	<0.1
PCBs	0.006	kg	<0.1

Emission trends

Emission trends from navigation are included in the inventory and presented in Figure 3.11.

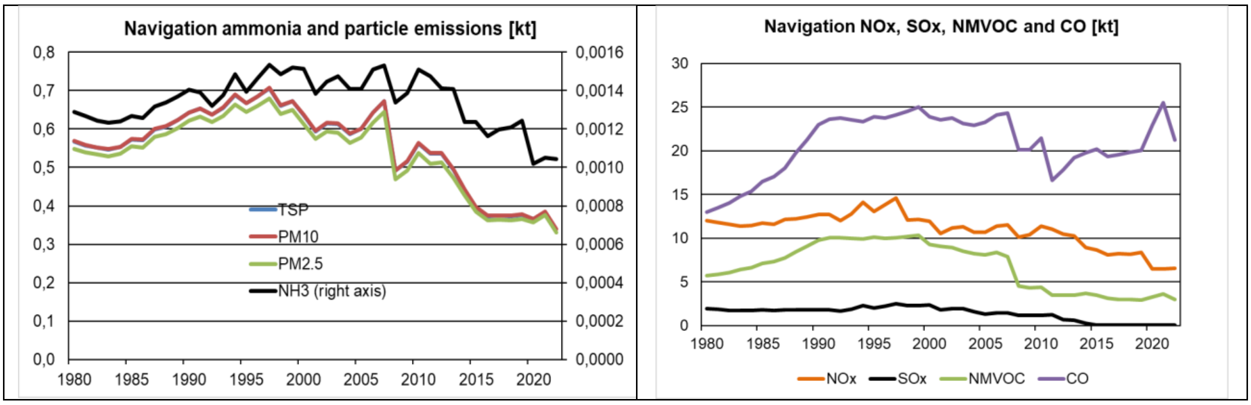


Figure 3.11. Emissions in 1980-2022 from National navigation.

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 1990s. 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. Particulate emissions, as well as sulphur dioxide emissions, decreased significantly after the entry into force of the sulphur limits for marine fuels (0.1%, SECA) in 2015. The significant reduction in most emissions of waterway traffic for the year 2020 is due to COVID-19. CO and NMVOC emissions traffic are increased because leisure boat traffic dominates the emission shares for these emissions and leisure boating did not suffer from COVID restrictions in Finland.

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 3.27.

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), Diesel and LNG.

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 FinFerries Oy) 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 and further estimated yearly based on the number of boats in the register. 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 (sightseeing) 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 model uses emission factors from the EMEP/EEA Emission Inventory Guidebook. For HFO the As EFs and for HFO/LFO the Cu and Se EFs are from Guidebook 2016 and since 2018 from Guidebook 2019 version: EMEP/EEA air pollutant emission inventory guidebook 2019 – Update Oct. 2020. This version is no longer available and the Guidebook EFs have changed since then. The emission factors introduced in the 2023 version of the Guidebook will be studied during the preparation of the emission inventory for the year 2023. Following this, the possible recalculations of emissions will be included in the 2025 submission.

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. 0.2% 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.

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).

Fuel consumption

Amount of fuels (TJ) per ship type (Table 3.27) have been partly used as activity data to calculate emissions of domestic navigation. In 2021 bio-shares of gasoline and diesel oil were 9.8% and 17.7% respectively (calculated from TJ). The bioshare of gasoil was 3.9% in 2022.

Table 3.27. Amount of fuels in domestic navigation by vessel type 1990-2022 (PJ) (MEERI 2023).

	Leisure boats	Icebreakers	Ferryboats	Passenger ships (domestic)	Cargo ships (domestic)	Cruisers (sightseeing)	Working boats
1990	2.25	0.48	0.27	0.16	1.19	0.10	1.42
1995	2.35	0.58	0.31	0.12	1.39	0.10	1.27
2000	2.43	0.82	0.29	0.42	1.63	0.15	1.26
2005	2.40	0.98	0.28	0.47	1.24	0.12	1.26
2006	2.47	1.19	0.27	0.36	1.51	0.12	1.27
2007	2.48	1.16	0.27	0.39	1.68	0.12	1.27
2008	2.03	0.54	0.26	0.36	1.64	0.12	1.27
2009	2.10	0.86	0.26	0.36	1.52	0.12	1.27
2010	2.24	1.28	0.27	0.34	1.69	0.12	1.27
2011	1.78	1.11	0.26	0.45	1.89	0.12	1.27
2012	1.88	0.78	0.34	0.57	1.58	0.12	1.27
2013	2.00	0.85	0.31	0.64	1.29	0.12	1.27
2014	1.84	0.49	0.28	0.52	1.15	0.12	1.27
2015	1.92	0.56	0.31	0.52	1.22	0.09	1.28
2016	1.84	0.40	0.29	0.54	1.17	0.08	1.27
2017	1.83	0.57	0.29	0.53	1.24	0.08	1.27
2018	1.84	0.60	0.27	0.52	1.30	0.08	1.27
2019	1.85	0.42	0.27	0.51	1.48	0.08	1.27
2020	2.12	0.23	0.27	0.18	0.70	0.08	1.27
2021	2.33	0.46	0.27	0.23	0.43	0.08	1.27
2022	1.92	0.67	0.27	0.22	0.46	0.08	1.26

Uncertainties

Uncertainties are presented in Annex 6.

QA/QC and verification

Statistics Finland crosschecks the fuel consumption data calculated within the MEERI and STEAM models.

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

Source specific recalculations

2020
- Guidebook 2019 emission factors are used in the submission to replace the earlier country-specific EFs for $PM_{2.5}$ and PM_{10} (1980-2017). The differences were small (in the third decimal of the EF) and resulting changes in emissions thus negligible.
- BC 2008-2017 recalculated due to correction of EF for diesel oil (Guidebook 2019)
- NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO in 1980-1989 were corrected in the NFR table.
- NMVOC 2015, recalculated due to correction of fuel use data for ice breakers, only a minor decrease in emissions

2021
- $PM_{2.5}$ emissions were recalculated for 1990-2018 due to correction of EFs in the calculation sheet
- All emissions were recalculated for 2016-2018 due to correction of EFs for ferryboats in the calculation sheet

2022
- As, Cu and Se emissions for 2018 to 2019 were recalculated due to update of emission factors of heavy fuel oil and gasoil. The explanation for the choice of the EFs will be included in the 2023 IIR.

Source specific planned improvements

None.

3.11 Off-road mobile sources

Changes in chapter	
February 2024	AL, KM, KS, TF

1 A 2 g vii 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, 1A4cii, 1A4ciii and 1A5b (Table 3.29) including machinery types in the Finnish Off-Road machinery model presented in Table 3.30. The contributions of the categories are presented in Tables 3.28 (a-f).

Table 3.28 (a). Contribution of NFR 1A2 g vii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	4.521	Gg	4.6
NMVOC	0.968	Gg	1.3
SOx (as SO_2)	0.004	Gg	<0.1
NH_3	0.003	Gg	<0.1
$PM_{2.5}$	0.228	Gg	1.7
PM_{10}	0.228	Gg	0.9
TSP	0.228	Gg	0.5
BC	0.139	Gg	4.5
CO	6.777	Gg	2.2
Cd	0.004	Mg	0.5
Cr	0.018	Mg	0.1
Cu	0.627	Mg	1.6
Ni	0.026	Mg	0.3
Se	0.004	Mg	0.9
Zn	0.369	Mg	0.3
PAH-4	0.030	Mg	0.2

Table 3.28 (b). Contribution of NFR 1A4 a ii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	1.004	Gg	1.0
NMVOC	0.410	Gg	0.5
SOx (as SO_2)	0.001	Gg	<0.1
NH_3	<0.001	Gg	<0.1
$PM_{2.5}$	0.069	Gg	0.5
PM_{10}	0.069	Gg	0.3
TSP	0.069	Gg	0.2
BC	0.018	Gg	0.6
CO	14.955	Gg	4.8
Cd	<0.001	Mg	0.1
Cr	0.005	Mg	<0.1
Cu	0.162	Mg	0.4
Ni	0.007	Mg	<0.1
Se	<0.001	Mg	0.2
Zn	0.095	Mg	<0.1
PAH-4	0.008	Mg	<0.1

Table 3.28 (c). Contribution of NFR 1A4 b ii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	0.912	Gg	0.9
NMVOC	2.055	Gg	2.7
SOx (as SO_2)	<0.001	Gg	<0.1
NH_3	<0.001	Gg	<0.1
$PM_{2.5}$	0.122	Gg	0.9
PM_{10}	0.122	Gg	0.5
TSP	0.122	Gg	0.3
BC	0.023	Gg	0.7
CO	34.885	Gg	11.2
Cd	<0.001	Mg	<0.1
Cr	0.003	Mg	<0.1
Cu	0.096	Mg	0.3
Ni	0.004	Mg	<0.1
Se	<0.001	Mg	0.1
Zn	0.056	Mg	<0.1
PAH-4	0.005	Mg	<0.1

Table 3.28 (d). Contribution of NFR 1A4 c ii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	1.877	Gg	1.9
NMVOC	1.141	Gg	1.5
SOx (as SO_2)	0.003	Gg	<0.1
NH_3	0.002	Gg	<0.1
$PM_{2.5}$	0.141	Gg	1.1
PM_{10}	0.141	Gg	0.5
TSP	0.141	Gg	0.3
BC	0.061	Gg	1.9
CO	7.936	Gg	2.6
Cd	0.002	Mg	0.3
Cr	0.012	Mg	<0.1
Cu	0.396	Mg	1.0
Ni	0.016	Mg	0.2
Se	0.002	Mg	0.6
Zn	0.233	Mg	0.2
PAH-4	0.019	Mg	0.1

Table 3.28 (e). Contribution of NFR 1A4 c iii in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	1.684	Gg	1.7
NMVOC	0.079	Gg	0.1
SOx (as SO_2)	<0.001	Gg	<0.1
NH_3	<0.001	Gg	<0.1
$PM_{2.5}$	0.041	Gg	0.3
PM_{10}	0.044	Gg	0.2
TSP	0.044	Gg	0.1
BC	0.014	Gg	0.4
CO	0.263	Gg	<0.1
Pb	0.004	Mg	<0.1
Cd	<0.001	Mg	<0.1
Hg	<0.001	Mg	0.2
As	0.001	Mg	<0.1
Cr	0.002	Mg	<0.1
Cu	0.006	Mg	<0.1
Ni	0.032	Mg	0.3
Se	<0.001	Mg	<0.1
Zn	0.038	Mg	<0.1
PCDD/ PCDF	0.004	g I-Teq	<0.1
PAH-4	<0.001	Mg	<0.1
HCB	0.003	kg	<0.1
PCSs	0.001	kg	<0.1

The mobile sources covered by the inventory are presented in Table 3.29 and the breakdown of the different machine types in Table 3.30.

Table 3.29. Mobile sources reported under NFR 1A2gvii, 1A4aii, 1A4bii, 1A4cii and 1A5a.

NFR	Source	Emissions
1A2gvii	Manufacturing industry – off-road vehicles and machinery	NO_X, NMVOC, SO_X, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, CO, Cd, Cr, Cu, Ni, Se, Zn, PAH-4
1A4aii	Commercial/ Institutional combustion - mobile	
1A4bii	Household and gardening (mobile)	
1A4cii	Agriculture/Forestry/Fishing – Stationary- off-road vehicles and	
1A4ciii	National Fishing	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
1A5a	Other stationary (including military) Note: military mobile sources included in this category.	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

Emission trend

The emission reduction requirements have been tightened the last decade. Efficient reduction of emissions may increase fuel consumption. Particle, sulphur and nitrogen oxide emissions have come down, however, for instance the decrease in CO emissions during the latest years is expected to turn into an increase 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 1990s decreased emissions. After that time, emissions from specifically leisure time activities have increased (gasoline; ATV (all-terrain vehicle), snowmobiles) while emissions from business activities have decreased (gasoil/diesel).

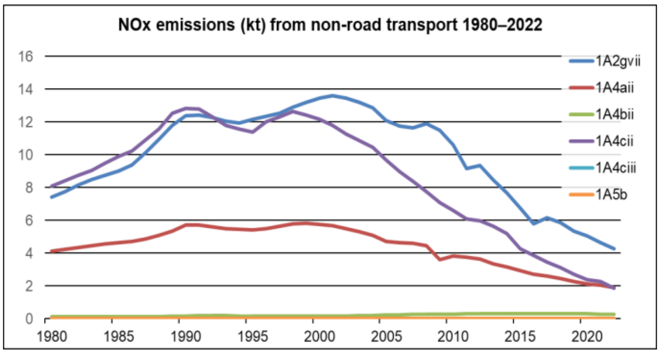
The economic depression that started in 2008 in Finland lowered the leisure time activity and hence the emissions in 2008. During 2009 the use of off-road vehicles and machinery was at lowest level in the total time series. In 2010 the market began to recover, and the use of vehicles and other machinery 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. From 2013 until 2020 the bio-share of gasoil decreased to 0.1-0.2%. Because the share was so low, Statistics Finland decided to allocate this bio-share into road transport instead of non-road use. In 2022, the bioshare of gasoline was 9.8% and diesel oil 17.8% (calculated from TJ). The bioshare of gasoil was 3.9% in 2022.

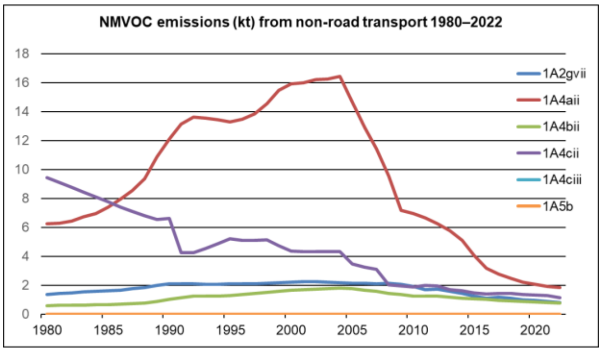
NOx emissions began to decrease in the early 2000s as diesel working machines came under the control of emissions.

The rapid reduction in NMVOC emissions in the 1A4aii group is the result of the significant replacement of 2-stroke gasoline engines (high hydrocarbon emissions) with 4-stroke engines, especially for professional use, and the general development of 2-stroke technology to reduce hydrocarbon emissions.

SO_2 emissions practically ended from 2005 onwards as a consequence of the transition to sulphur-free fuel oil (from 0.175% to 0.0006% S by weight) and sulphur content was lowered in gasoline, too.

Emission and fuel consumption trends are presented in Figure 3.12 and fuel consumption in in Table 3.29.





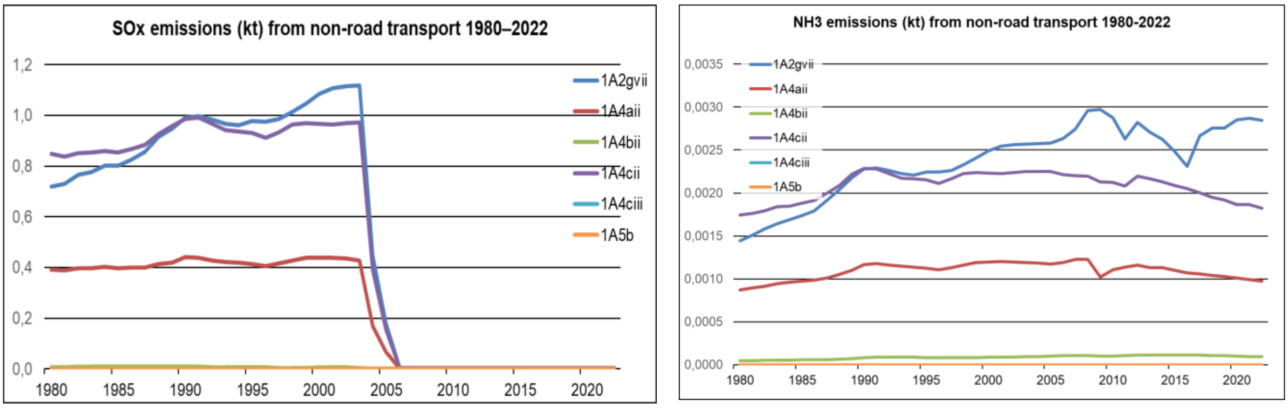


Figure 3.12 Emission trends of non-road transport 1980-2022.

Fuel consumption

Fuel consumption data in NFR categories 1A2gvii, 1A4aii, 1A4bii, 1A4cii, 1A4ciii and 1A5b are provided in Table 3.29.

Table 3.29. Fuel consumption (PJ) in non-road transport 1990-2022.

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
Off-road working machinery													
Gasoil	29.4	28.3	30.4	30.7	31.1	29.5	28.2	29.9	30.0	29.8	29.9	29.0	28.3
Motor gasoline	3.1	3.2	3.6	3.8	3.3	3.4	3.2	3.1	3.0	2.8	2.7	2.6	2.5
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	0.2
Liquid biofuels	NO	NO	NO	NO	0.6	0.2	0.2	0.2	0.2	0.2	0.2	1.3	1.4

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.

In diesel-powered machinery and off-road vehicles, the term diesel refers to technology. There have been some changes in legislation and fuel tax decisions concerning the use of diesel oil and gasoil over time. 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).

The breakdown of different machine types in TYKO model is presented in Table 3.30 and the properties of fuels used in working machines in Table 3.31.

Table 3.30 Breakdown of different machine types in TYKO model (updated in 2020).

NFR subcategory	Type of machine	NFR subcategory	Type of machine
1A2gvii Other / mobile	Backhoe loaders Bulldozers Compactors, diesel Compressors Cranes Dumpers Excavators, rubber tire Excavators, skid steer Forklift, gas Forklift, gasoline Generator sets, diesel Generator sets, gasoline Mini excavators, skid steer Other lifts, diesel Other moveable machines, diesel Wheel loaders	1A4ai Commercial/institutional	ATV, 2-stroke, professional ATV, 4-stroke, professional ATV, diesel Forklifts, diesel Graders Maintenance tractors Other drivable machines, diesel Skid steer loaders Snowmobiles, 2-stroke professional Snowmobiles, 4-stroke professional
1A4cii Agriculture/Forestry/Fishing	Farm tractors Forest harvesters Forwarders (forest tractors Professional chain saws Soil cultivators	1A4bii Residential: Household and gardening	ATV, 2-stroke, leisure ATV, 4-stroke,leisure Chain saws, hobby Lawn movers, handheld Lawn tractor, diesel Other drivable, gasoline Other handheld machines Other moveable machines, gasoline Other tractors Riding mowers, gasoline Snow blowers Snowmobiles, 2-stroke leisure Snowmobiles, 4-stroke leisure Trimmers

Table 3.31 Fuel properties of working machines (TYKO 2022 model 16.1.2024)

Gasoline	
Specific weight	0.746 kg/l (density 746 kg/m^3)
Heating value	41.6 MJ/kg 31.02 MJ/ dm^3
Energy	1 kWh = 3.6 MJ
Sulphur content (S)	0.0008 w-% = 0.0143 g/kg SO_2
Carbon dioxide (CO_2)	2001.0 g/(dm^3 fuel) = 2683.39 g/(kg fuel)
Diesel	
Specific weight	0.832 kg/l (density 832 kg/m^3)
Heating value	43.2 MJ/kg
Energy	1 kWh = 3.6 MJ
Sulphur content (S)	0.0006 w-% = 0.0107 g/kg SO_2
Carbon dioxide (CO_2)	2525.31 g/(dm^3 fuel) = 3036.04 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/EEA 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

Based on energy use (kWh) and emission factors (g/kWh) TYKO model calculates the following basic emissions: CO, HC/NMVOC, NOx, TSP, CH_4, N_2O, SO_2, CO_2, fuel consumption, energy and AdBlue.

- 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 2019.
- Black carbon, ammonia and heavy metals (Cd, Cr, Cu, Ni, Se and Zn) emissions are calculated with the Tier 1 emission factors of the EMEP EEA Guidebook 2019.
- 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 2019.
- NMVOC emissions are calculated by subtracting the CH_4 emission values from the HC values in the VTT LIPASTO calculation system.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 6 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

2018

- PM_{10} and $PM_{2.5}$ size fractions of particulate matter emissions were revised to correspond to the EMEP EEA Guidebook 2016. Therefore, the PM_{10} and $PM_{2.5}$ emissions were recalculated for the whole time series 1980-2015.

2020

- In the BC calculation the EF for LPG forklifts was corrected, recalculation done.
- In the NH3 calculation the EF for LPG forklifts and 2-stroke ATV were corrected, recalculation done (minor effects).
- Part of the small machines were corrected to be 2-stroke, recalculation done.
- Minor updates to the density of fuels for the years 2008 – 2017 were done, very small effect on emissions.
- The NFR classifications of different machines were cross-checked with the CRF classifications used in the ghg inventory. As a result, the classifications between air pollutant inventory and ghg inventory were harmonized which resulted in changes of the NFR classification of some machines (Table 3.32):

Table 3.32. NFR Category revision 2020 to align with the GHG reporting.

Type of machine	NFR category in submission 2020	Old NFR category
ATV, 2-stroke, leisure	1A4bii	1A4aii
ATV, 4-stroke, leisure	1A4bii	1A4aii
Chain saws, hobby	1A4bii	1A4aii
Forklift, gas	1A2gvii	1A4aii
Forklift, gasoline	1A2gvii	1A4aii
Mini excavators, skid steer	1A2gvii	1A4aii
Other drivable, gasoline	1A4bii	1A4aii
Other handheld machines	1A4bii	1A4aii
Other lifts, diesel	1A2gvii	1A4aii
Other moveable machines, gasoline	1A4bii	1A2gvii
Other tractors	1A4bii	1A4aii
Snowmobiles, 2-stroke leisure	1A4bii	1A4aii
Snowmobiles, 4-stroke leisure	1A4bii	1A4aii

2021

- CO emissions were recalculated for 2012 - 2018 due to correction of one EF of diesel working machines in the calculation sheet
- SO_x emissions were recalculated for 2012 – 2018 due to small update of sulphur content of gasoline
- The index on working hours used in the emission estimation of construction machinery was corrected for 2018, which resulted in the recalculation of emissions for all pollutants
- Recalculation of $PM_{2.5}$ under 1A4ciii is due to correction of EFs (the same as for 1A3dii)

Source-specific planned improvements

None.

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 2024	AL, KM, KS, TF

Emission trends

The trend of emissions in international navigation has fluctuated during most of the period. The most important reason for these fluctuations has been the variation in bunker 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 marine bunker sales increased again and was approximately at the same level also in 2016 but 25% higher in 2017. In 2018 marine bunker sales decreased 8% compared to 2017. Emissions from use of LNG in international navigation were included into the inventory starting from 2016. The trend is presented in Figure 3.13.

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.

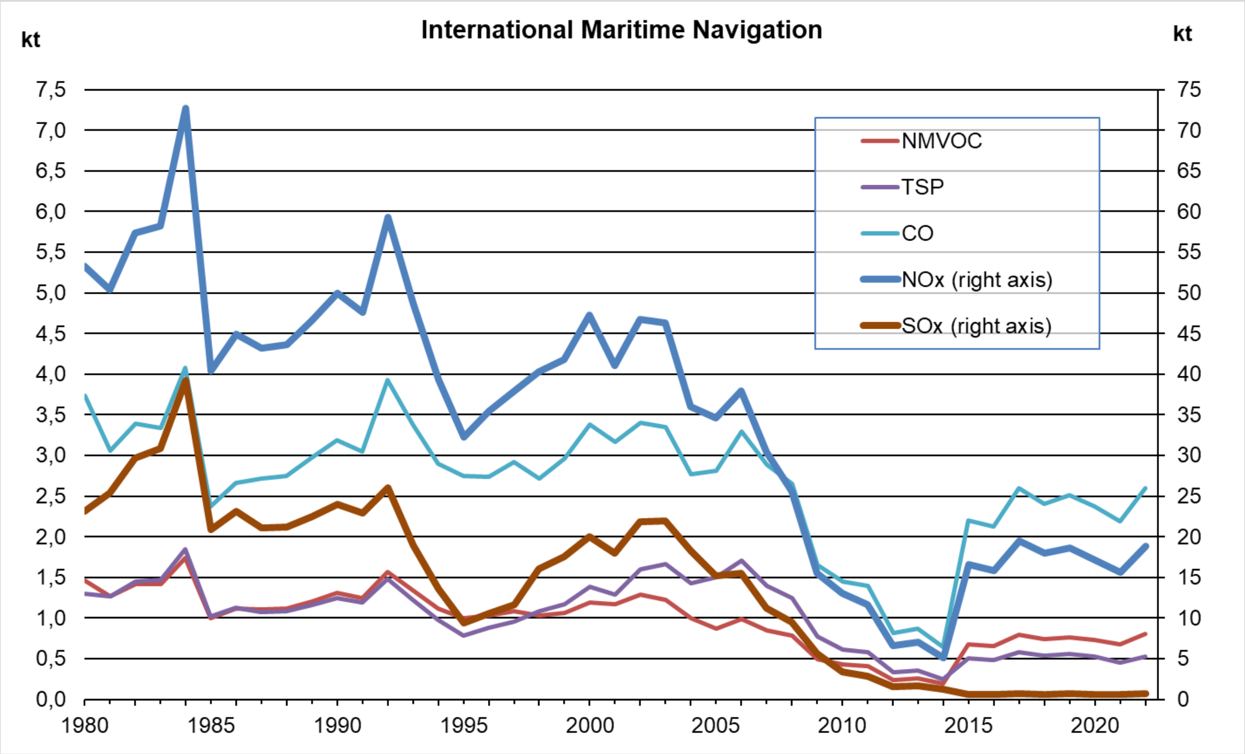


Figure 3.13. Emissions from international maritime navigation 1980-2022.

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 CLRTAP 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, according to the share of passengers travelling to the archipelago of Åland. 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.

Source-specific 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 2024	JMP, KS, TF

1A3 e i Pipeline compressors

Source category description

This chapter covers emissions from pipeline compressors. 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 contribution of the category to total emissions is presented in Table 3.33.

Table 3.33. Contribution of NFR 1A3ei in 2022 to total emissions.

Pollutant	Emissions in 2022	Unit	Share of total emissions %
NOx (as NO_2)	0.001	Gg	0.1
NMVOC	<0.001	Gg	<0.1
SOx (as SO_2)	<0.001	Gg	<0.1
CO	<0.001	Gg	<0.1
PCDD/F	<0.001	g I-Teq	<0.1

Emission trend

The trends of NOx, CO and NMVOC emissions are presented in Figure 3.14. The trends follow loosely the total consumption of natural gas: until the mid-2000s the consumption increased, and the transmission grid expanded, but then started to decrease as the running time of the compressors decreased. During the recent years, the levels of emissions have stabilized with some interannual fluctuation. In addition, also SOx and PCDD/F emissions are reported from category 1A3ei.

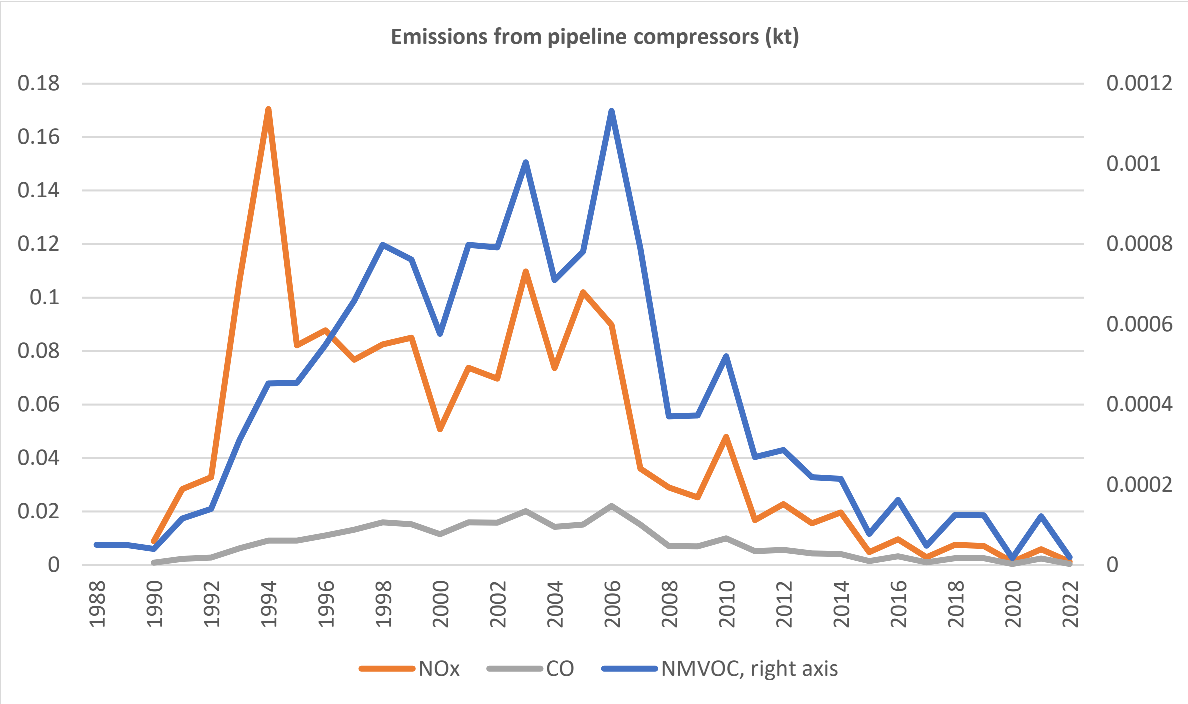


Figure 3.14. NOx and CO emissions (1990-2022) and NMVOC emissions (1988-2022) from pipeline compressors.

Methodological issues

NOx, CO, NMVOC, SOx and PCDD/F emissions in category 1A3ei are either reported by the plants (compressor station operators) according to the emission monitoring programmes under their environmental permits or calculated at Syke from their fuel use. All the compressor stations use good quality natural gas as a fuel. The reported emissions data are available in the YLVA system. Detailed methodological description of the emissions calculated at Syke are presented in IIR Part 2 Energy.

Particulate matter emissions from natural gas fired pipeline compressors are not reported. Emissions are strictly regulated in the Finnish environmental permits. None of the environmental permits of plants with natural gas fired gas turbines mention particles. Primary particulate matter emissions from gas turbines using good quality natural gas are considered negligible. In addition, the 2023 version of the Guidebook states that particulate matter emissions are not relevant for natural gas fired gas turbines.

Uncertainties

Uncertainties are presented in Annex 6.

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 198's will be studied out in the coming years.

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

Changes in chapter	
February 2024	JMP KS, TF

The share of emissions from NFR 1B2av Oil and Natural Gas, i.e., in Finland from storage tanks at refinery sites and from distribution of oil products is presented in Table 3.34.

Table 3.34. Contribution of Distribution of oil products (NFR 1B2av) in 2022 to the total emissions.

Pollutant	Emissions from Fugitive emissions from solid fuels in 2022	Unit	Share of total emissions %	% reported by the operators
NMVOC	2.473	Gg	3.3	4.4
$PM_{2.5}$	<0.001	Gg	<0.1	0
PM_{10}	<0.001	Gg	<0.1	0
TSP	<0.001	Gg	<0.1	100

Distribution of oil products (1B2av)

Source category description and emission trend

Emissions from storage tanks at refinery sites are included in this category (without any fuel use linked to them). For gasoline distribution, see Chapter 3.17 below.

The emission trend is declining as storage of chemicals at the refineries has been improved to prevent fugitive emissions.

Methodological issues

NMVOC

All NMVOC emissions included in the inventory from this category are reported by plants into the YLVA system.

Particles

TSP emissions are reported by the operators according to the monitoring requirements in the environmental permits into the YLVA system. There are no particle emission factors in the Guidebook. Finland reports these emissions based on TSP data reported by operators and as no methods are available for particle fraction factors, we have assumed TSP:PM_{10}:$PM_{2.5}$ equal to 1:1:1.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 6 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.

3.17 Distribution of oil products (1B2av)

Changes in chapter	
February 2024	AL, JMP, TF

Source category description

Emissions from service stations are included in this category and calculated at VTT.

Emission trend

NMVOC emissions have been decreasing since 1988 when they were included in the inventory. Although the fleet of vehicles has increased, emissions are declining due to improved capture of gasoline fumes in the petrol distribution network and in refuelling of cars.

Methodological issues

NMVOC

The emissions are calculated at VTT based on a model developed in cooperation with SYKE and the Finnish Oil and Gas Association (Pohjolainen, 2008).

The operation of Finnish Oil and Gas Association ceased in summer 2018 and the tasks has been taken over by Statistics Finland from autumn 2018 onwards. The model has been used from 2005 onwards and emissions estimates for 1990-2004 have been provided by Finnish Oil and Gas Federation by using the same model.

Sales of motor gasoline (m^3) (Table 3.36) are used as activity data in revised model and are provided by the Finnish Oil and Gas Association. 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. The share of stage II equipment at service stations is increasing due the new directive (2009/126/EY) implemented in January 2012. As an expert estimate in 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 Tables 3.35 and 3.36). The same assumptions are used for whole time series.

Table 3.35. 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 3.36. The sales of petroleum in Finland 1992-2022 (Finnish Oil and Gas Federation).

Year	sales of motor gasoline (m³)	year	sales of motor gasoline (m³)	year	sales of motor gasoline (m³)	year	sales of motor gasoline (m³)
1990		2000	2 379 600	2010	2 237 351	2020	1787867
1991		2001	2 412 400	2011	2 162 321	2021	1828460
1992	2 574 133	2002	2 508 667	2012	2 098 404	2022	1719756
1993	2 540 800	2003	2 469 067	2013	2 098 961		
1994	2 558 400	2004	2 508 677	2014	2 031 898		
1995	2 529 333	2005	2 501 333	2015	2 009 420		
1996	2 455 867	2006	2 482 667	2016	1 994 974		
1997	2 507 600	2007	2 481 366	2017	1 956 376		
1998	2 477 067	2008	2 347 344	2018	1 936 885		
1999	2 466 133	2009	2 285 349	2019	1 903 176		

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 6 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

2020

- NMVOC emissions 1990-2017 were recalculated due to update of sales data for motor gasoline resulting in slight decrease of emissions in the early 1990s and 1999, increase in emissions in 1996-1998 and 2002, and a minor increase in other years.

Source-specific planned improvements

The methodology provided in the Guidebook 2019 cannot be used due to lack of detailed data on gasoline fume collection systems at gas stations. Possibilities to collect this data will be studied in the near future.