National Institute for Public Health
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Ministry of Health, Welfare and Sport

Informative Inventory Report 2024

Emissions of transboundary air pollutants in the Netherlands 1990–2022

RIVM report 2024-0018

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Colophon

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D. Wever (author), RIVM
M. Bolech (author), TNO
P.W.H.G. Coenen (author), TNO
S.N.C. Dellaert (author), TNO
R. Dröge (author), TNO
G. Geilenkirchen (author), PBL
E. Honig (author), RIVM
B. van Huet (author), RWS
M. Kosterman (author), RIVM
S.E.H. van Mil (author), TNO
M.C. van Zanten (author), RIVM
T. van der Zee (author), RIVM

Contact:
Dirk Wever
Milieukwaliteit\Stoffen Monitoring en Onderzoek stikstof.
dirk.wever@rivm.nl

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Synopsis

Informative Inventory Report 2024

Emissions of transboundary air pollutants in the Netherlands 1990–2022

Compared to 2021 the emissions of ammonia decreased in 2022 by 2.3 Gg to a total of 121.2 Gg. This is mainly the result of a lower protein content in roughages of cattle, a lower animal numbers for swine and poultry (-1.2% and -1.3% respectively), an increase in non dairy cattle numbers (1.6%) and less use of inorganic fertilisers. With a reduction of 22% compared to 2005 the ammonia emissions comply with the reduction target of 13% as set by the EU National Emission Ceilings Directive (NECD) and the Gothenburg Protocol under the Convention of Long-range Transboundary Air Pollution (CLRTAP).

Compared to 2021 the emissions of non-methane volatile organic compounds decreased by 2.4 Gg. All sectors contribute to this decrease. With a reduction of 10% in 2022 under the NECD the emission reduction is in compliance with the reduction target of 8% as set by the European Union (EU). However, unlike for the EU-inventory, under the Gothenburg Protocol the emissions of non-methane volatile organic compounds from manure management and agricultural soils are included in the inventory. This leads to a higher emission total with the result that the 8% reduction target under the Gothenburg Protocol is not met in 2020.

Despite a 5% increase in total passenger car mileage in 2022 (passenger car mileage is still 6% lower than before de Covid19 pandemic), total nitrogen oxides emissions decreased by 11 Gg mainly as result of increasingly cleaner road traffic vehicles. However, Aviation emissions from Landing and Take Off (LTO) increased with 1.2 Gg. Under both the NECD and the Gothenburg Protocol a reduction target of 45% compared to 2005 was set. With a reduction of respectively 59% and 55% compared to 2005 the nitrogen oxide emissions comply with the reduction targets.

The emissions sulphur oxides decreased with 1.3 Gg compared to 2021, mainly in the sector Industry.
Under both the NECD and the Gothenburg Protocol a reduction target was set of 28% compared to 2005. With a reduction of 71% the sulphur oxides emissions for both comply with the reduction target.

For non-methane volatile organic compounds the Netherlands applied for an continuation of an inventory adjustment to meet compliance with the reduction target set under the Gothenburg Protocol.

The Informative Inventory Report 2023 was drawn up by the RIVM and partner institutes, which collaborate to analyse and report emission data each year – an obligatory procedure for Member States. The analyses are used to support Dutch policy.

Keywords: emissions, transboundary air pollution, emission inventory

Publiekssamenvatting

Informative Inventory Report 2024

Emissies van grootschalige luchtverontreiniging 1990-2022

Deze Informative Inventory Report rapportage (IIR) beschrijft de uitstoot van luchtverontreinigende stoffen in 2022 ten opzichte van 2021. Verder geeft het aan in hoeverre Nederland de Europese verplichtingen heeft gehaald om de uitstoot te laten dalen ten opzichte van 2005, het zogeheten basisjaar. Uit deze inventarisatie blijkt dat in 2022, net als in 2020 en 2021, alle doelen (EU NEC-Directive) zijn gehaald.

In 2022 is 121,2 kiloton ammoniak uitgestoten, 2,3 kiloton minder dan in 2021. Daarmee is de uitstoot 22 procent minder dan in het basisjaar (het NEC-doel is 13 procent minder). Dit komt vooral doordat er in de landbouw minder dieren (rund- en pluimvee en varkens) zijn gehouden en het voer van melkvee minder eiwit bevatte.
De uitstoot van fijnstof $PM_{2.5}$ is verder gedaald tot 14,3 kiloton in 2022, een daling van 50 procent ten opzichte van het basisjaar (het NEC-doel is 37 procent minder).

De uitstoot van stikstofoxiden is in 2022 met 11,0 kiloton afgenomen en is 59 procent minder dan in het basisjaar (het NEC-doel is 45 procent minder). De daling komt doordat auto's steeds schoner worden. Wel zijn door vliegverkeer meer stikstofoxiden uitgestoten, 1,2 kiloton dan in 2021. Personenauto's reden 5 procent meer kilometers dan in 2021, wat nog steeds 6 procent minder is dan voor de coronapandemie.

De uitstoot van zwaveloxiden is in 2022 1,3 kiloton lager dan in 2021. Dat komt vooral omdat de industrie er minder van uitstoot. Raffinaderijen hebben wel meer procesgassen gestookt waardoor zij meer zwaveloxiden uitstootten. Ten opzichte van het basisjaar is de uitstoot ervan met 71 procent gedaald (het NEC-doel is 28 procent minder).

De uitstoot van vluchtige organische stoffen is in 2022 met 2,4 kiloton gedaald ten opzichte van 2021. Deze uitstoot is in alle sectoren gedaald, met uitzondering van de sector Handel, Diensten en Overheid. Ten opzichte van het basisjaar is de uitstoot met 24 procent gedaald (het NEC-doel is 8 procent minder).

De Nederlandse overheid gebruikt de analyses in haar nationale beleid en om internationaal over de ontwikkeling van de uitstoot te rapporteren. Het RIVM stelt dit rapport elk jaar met verschillende partnerinstituten op voor het ministerie voor Infrastructuur en Waterstaat (IenW).

Kernwoorden: emissies, luchtverontreinigende stoffen, emissieregistratie

Contents

Executive summary

ES1 Summary of trends in national emissions

Total national emissions for all pollutants have decreased substantially since 1990 (see Table ES1.1). The major overall drivers for these trends are:

- for the agricultural sector introducing a ban on surface spreading of manure, direct incorporation of manure in the soil, covering of outside slurry manure storage and more recently, introducing low-emission animal housing, introducing precision feeding aiming to reduce N excretion and slowly decreasing livestock numbers (for cattle and swine);
- emission reductions in the industrial sectors due to the introduction of cleaner production technologies and flue gas treatment technologies;
- use of cleaner fuels through desulphurisation of fuels and reduced use of coal and heavy oils;
- cleaner cars due to EU emission regulations for new road vehicles.

Table ES1.1 Total emissions of pollutants for years 1990, 2019, 2021 and 2022

National total emissions CLRTAP/EMEP					
Pollutant	Unit	Year 1990	2020	2021	2022
NO_x	Gg	681.2	211.7	206.4	194.6
NMVOC	Gg	606.0	249.9	244.1	241.7
SO_x	Gg	197.5	19.6	20.9	19.6
NH_3	Gg	346.6	125.0	123.5	121.2
$PM_{2.5}$	Gg	57.3	14.4	14.5	14.3
PM_{10}	Gg	80.8	26.9	27.0	26.9
TSP	Gg	102.4	31.4	31.6	31.3
BC	Gg	14.2	2.4	2.3	2.1
CO	Gg	1172.0	422.1	413.6	397.9
Pb	Mg	335.7	5.8	4.9	4.5
Cd	Mg	4.1	2.0	0.88	0.79
Hg	Mg	3.7	0.48	0.46	0.49
As	Mg	1.5	0.29	0.27	0.31
Cr	Mg	12.0	3.2	3.5	3.5
Cu	Mg	91.0	102.1	98.8	104.8
Ni	Mg	75.7	1.8	1.7	1.7
Se	Mg	0.41	0.21	0.19	0.19
Zn	Mg	225.7	178.2	149.7	155.6
Dioxins/furans	g I-TEQ	744.9	30.0	30.2	30.3
benzo(a) pyrene	Mg	5.5	1.5	1.6	1.6
benzo(b) fluoranthene	Mg	8.1	1.3	1.5	1.5
benzo(k) fluoranthene	Mg	4.2	0.70	0.78	0.82
Indeno (1,2,3-cd) pyrene	Mg	20.8	4.3	4.7	4.8
HCB	Kg	66.4	3.4	3.4	3.3
PCBs	Kg	38.4	0.14	0.19	0.18

ES2 Compliance to the NECD and the Gothenburg Protocol

For both the Gothenburg Protocol and the NECD, the Netherlands has opted to calculate the compliance totals on the basis of fuel-sold.

The emission reduction targets for both the NECD and the Gothenburg Protocol are the same percentage for each pollutant. However, for NO_x and NMVOC, there is a difference between the NECD and the Gothenburg Protocol regarding the calculation of the emission totals for compliance checking. In contrast to the Gothenburg Protocol, the emissions of NO_x and NMVOC from manure management and agricultural soils (NFR 3B and 3D – Agriculture Sector) are exempted from the compliance total under NCED.

Under the NECD, the emissions of NO_x, NMVOC, NH_3, SO_x and $PM_{2.5}$ comply with the 2020-2029 reduction targets (Table ES2.1).

Table ES2.1 Compliance under the NECD.

Emission reductions and compliance in under the NECD without adjustments								
Pollutant	**Compliance Total**				**Target 2020-2029**	**Achieved reduction**		
	2005	**2020**	**2021**	**2022**		**2020**	**2021**	**2022**
NO_x	395.2	177.7	173.2	162.2	45%	55%	56%	59%
NMVOC	204.0	162.1	156.9	154.5	8%	21%	23%	24%
SO_x	67.9	19.6	20.9	19.6	28%	71%	69%	71%
NH_3	155.0	125.0	123.5	121.2	13%	19%	20%	22%
$PM_{2.5}$	28.5	14.4	14.5	14.3	37%	49%	49%	50%

Under the Gothenburg Protocol, the Netherlands is not in compliance with the NMVOC reduction target in 2020 (Table ES2.2) without an adjustment.

Table ES2.2 Compliance under the Gothenburg Protocol.

Emission reductions and compliance in under the Gothenburg Protocol without adjustments								
Pollutant	**Compliance Total**				**Target 2020-2029**	**Achieved reduction**		
	2005	**2020**	**2021**	**2022**		**2020**	**2021**	**2022**
NO_x	430.9	211.7	206.4	194.6	**45%**	51%	52%	55%
NMVOC	269.9	249.9	244.1	241.7	**8%**	7%	10%	10%
SO_x	67.9	19.6	20.9	19.6	**28%**	71%	69%	71%
NH_3	155.0	125.0	123.5	121.2	**13%**	19%	20%	22%
$PM_{2.5}$	28.5	14.4	14.5	14.3	**37%**	49%	49%	50%

ES3 Adjustment application

As becomes clear from Table ES2.2, the Netherlands is not in compliance with the reduction commitment for NMVOC under the Gothenburg Protocol. However, Decision 2012/3 (UNECE, 2012) of the Executive Body stated that adjustments may be made to the national emission inventories under specific circumstances for the purpose of comparing the inventories with emission reduction commitments.

The 2013 EMEP/EEA Guidebook implemented a default methodology and default EFs for NMVOC from animal husbandry and manure management. This resulted in the inclusion of the NMVOC emissions from agriculture in the emission inventory in 2017, as described in Chapter 6. Thus, the NMVOC emissions from these sources were not accounted for at the time when emission reduction commitments were set. Therefore, the Netherlands applied for an inventory adjustment for an NMVOC source in NFR category 3B, more specific 3B1a (Manure management – Dairy cattle) for 2020. When the inventory is adjusted for this source, the Netherlands will be in compliance again, as represented in Table ES2.3.

Table ES3.1 Compliance under the Gothenburg Protocol with inventory adjustment.

NMVOC Compliance under the Gothenburg Protocol based on the adjusted inventory						
Year	**Inventory total (Gg)**	**Reduction Target %**	**Unadjusted reduction %**	**Adjustment NFR-3B1a (Gg)**	**Adjusted Compliance total (Gg)**	**Reduction with adjustment %**
2005	**269.9**	**-**	**-**	**24.2**	**245.7**	**-**
2020	249.9	8%	7%	43.6	206.3	16%
2021	244.1	8%	10%	-	-	-
2022	241.7	8%	10%	-	-	-

ES4 Other information

Completeness of the national inventory
The Netherlands NFR inventory includes all sources and is generally considered to be complete. For some NFR source categories, no methods are available or they are regarded as negligible (see Table A1.2).

Methodological changes, recalculations and improvements
Several recalculations were made in this inventory. Most are small and deal with changes in methodology, error corrections, new data sources or changes in allocation.
Most visible changes are:
Energy
- Improvement of the emission estimates from wood combustion in 1A4;
- Improvement of Landing and Take Off (LTO) emission estimates for Aviation;
- Several improvements in the emission estimates from road traffic (a.o. Motor cycles and mopeds) in 1A3, based on measurement programmes (EF's and updated activity data);
- Emissions from Railways were improved by adding missing estimates (railway maintenance and rail and brake wear).
- Emission estimates for NRMM (Non Road mobile Machineries) were revised based on improved EF's and activity data;

- For the complete time series the emissions from CCD (Cruise Climb and Descend) calculated according to the methodology from the inventory Guidebook (EEA, 2024) are reported as memo-item.

IPPU

- Improvement of the emission estimates in sector 2A for particulate matter and NMVOC;
- Recalculation of NMVOC emissions in 2D due to improved activity data for disinfecting hand gels;
- Recalculation of the emissions from Fireworks in 2G.

Agriculture

- NH_3 and NO_x emissions from veal manure were recalculated for 1990 to 2021;
- NH_3 and NO_x emissions from manure treatment were recalculated for 2018 to 2021;
- Recalculation of the emissions of NH_3 and NO_x in 3D and NH3 in 3B due to the inclusion of bedding material in the calculations. This also effects the NMVOC emissions from housing and storage of manure;
- NH_3 and NO_x emissions from crop residues were recalculated based on new activity data;
- Improved PM_{10} emission estimates from agricultural crops based on most recent emission factors.

A complete list of methodological changes, recalculations and improvements is given in the specific sector chapters.

ES5 Background information on the air pollutions inventory

This report documents the Netherlands' submission for 2024 of its air Pollutant Release and Transfer Register (PRTR), in line with the annual reporting requirements under the Convention on Long Range Transboundary Air Pollution (CLRTAP) and its implementation under the European Monitoring and Evaluation Programme (EMEP), directed by the United Nations Economic Commission for Europe (UNECE) and in line with the European National Emission Ceilings (NECD).

This report has been prepared in line with the reporting guidelines provided by the CLRTAP Executive Body's decisions ECE/EB.AIR/122/Add.1; 2013/3 and 2013/4 and ECE/EB.AIR.125 (2014 Reporting Guidelines).

Part I of the report is structured as follows:

- Chapter 1 documents the compiling of the NFR and IIR from the PRTR-database.
- Chapter 2 summarises the emissions trends, which are further described and documented in the subsequent chapters.
- Chapters 3–8 document emissions and trends for the following sectors, respectively:
  - Energy;
  - Transport.
  - Industrial Processes and Product Use;
  - Agriculture;
  - Waste;

    - Other.
- Chapter 9 documents the 2021 submission of the Large Point Sources (LPS).
- Chapter 10 documents the response to the 2021 NECD inventory review.
- Chapter 11 documents recalculations and improvements since the previous report (IIR 2021).
- Chapter 12 documents the 2021 submission of emission projections.
- Chapter 13 documents the Compliance and the Adjustment application for the pollutant NMVOC under the Gothenburg Protocol.
- Chapter 14 documents the spatial distribution of the Netherlands' PRTR emission data.

Note that this report provides no specific information on government policies for reducing emissions. Such information can be found, for example, in the Netherlands Monitoring Report Target range for the Clean Air Agreement – Initial progress assessment (Ruyssenaars *et al.*, 2021*, in Dutch*)

The Nomenclature For Reporting (NFR), contain the data on emissions, activity data that form the basis for this report.

Institutional arrangements for inventory preparation
The CLRTAP/NECD emission inventory process of the Netherlands is an integral part of the national Pollutant Release and Transfer Register (NL-PRTR). Figure ES.1 represents the structure of the inventory process and the bodies responsible for each stage.

The National Institute for Public Health and the Environment (RIVM) has been contracted by the Dutch Ministry of Infrastructure and Water Management and the Ministry of Economic Affairs and Climate Policy (EZK) to maintain a high-quality PRTR that complies with the agreed international guidance's on emission inventories, and to compile and coordinate the annual preparation of the IIR and the completion of the NRF tables.

Methodology reports
Emissions data are compiled from the PRTR in accordance with the 2023 EMEP/EEA air pollutant emission inventory guidebook (EEA, 2023). Methodologies are considered to be part of the IIR-reporting and described in detail in 4 separate sectoral methodology reports:
- Methodology report on the calculation of emissions to air from Energy, Industry and Waste sectors (Honig *et al*., 2024);
- Methods for calculating the emissions of Transport in the Netherlands (Geilenkirchen *et al.*, 2024a);
- Methodology for the calculation of emissions from product usage by consumers, construction and services (Visschedijk *et al*., 2024);
- Methodology for the calculation of emissions from agriculture in the Netherlands (Zee van der *et al.*, 2024).

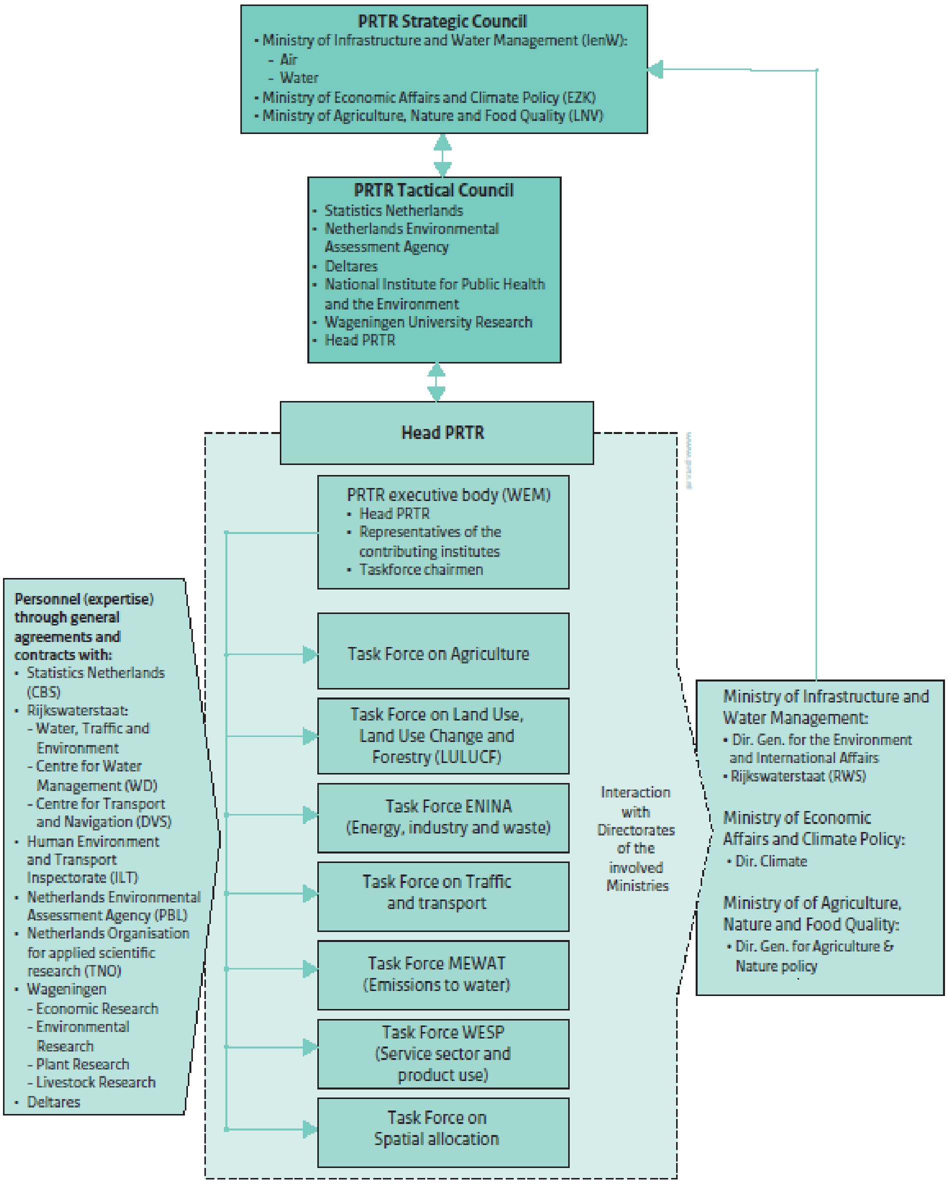

Figure ES.1 Main elements in the emissions inventory compilation process

Base year
In line with the reporting guidelines, the Netherlands uses 1990 as the base year for all pollutants.

Uncertainty estimates
The approach 2 uncertainty estimate method (Monte Carlo analysis) was developed in recent years and the uncertainties are annually updated as emission factors and activity data are updated. Most uncertainty estimates are based on the judgement of emission experts from the various task forces.

The expert elicitation was set up following the expert elicitation guidance in the 2006 IPCC Guidelines (motivation, structuring, conditioning, encoding and verification). The uncertainties of the individual source-specific activity data and the EFs were assessed separately using expert judgement. This approach is more detailed than the uncertainty assessment at the level of NFR categories. The Monte Carlo analysis takes correlations of the activity data and/or EFs into account. Table ES2 represents the Approach 2 method uncertainties at the level of NFR categories.

Table ES5.1 Uncertainty (95% confidence ranges) for NH_3, NO_x, SO_x, NMVOC, PM_{10} and $PM_{2.5}$ for each NFR category and for the national total, calculated with the Approach 2 method for emissions (%)

Approach 2 uncertainties IIR2024 submission						
NFR sector	**NH_3**	**NO_x**	**SO_x**	**NMVOC**	**PM_{10}**	**$PM_{2.5}$**
1 Energy	110	15	22	37	49	55
2 Industry	53	88	86	32	44	66
3 Agriculture	28	110	-	130	36	34
5 Waste	71	84	89	158	178	177
6 Other	261	-	-	-	-	-
Total	**27**	**18**	**21**	**48**	**28**	**41**

Key categories
Two key source analysis approaches are reported:

- Approach 1 consists of ranking the list of source category/gas combinations according to their contribution to national total annual emissions and to the national total trend. Key categories are those whose emissions add up to 80% of the national total (Appendix 2);
- The Approach 2 for the identification of key categories (Appendix 3) requires the incorporation of the uncertainty in each of the GNFR-categories before ordering the list of shares. This has been carried out using the uncertainty estimates from the approach 2 method as they are considered to be more up to date and available at PRTR-sources level (approximately as detailed as SNAP).

Planning inventory improvements
With limited annual budget there is need to prioritize annual improvements. Several factors play part in this prioritization process; for instance (*not in order of importance*) the availability of new science and/or new data sources, review recommendations, current policy issues, etc.. Additionally, also a tool is used that used identifies the NFR-categories that contribute >5% to the national total and have an approach 2 uncertainty of >50% (Appendix 6).

1 Introduction

The United Nations Economic Commission for Europe's 1979 Geneva Convention on Long-Range Transboundary Air Pollution (CLRTAP) was accepted by the Netherlands in 1982, and the amendments on the text and annexes to the protocol were accepted in 2017. The European Community subsequently adopted the Revised National Emission Ceiling Directive (NECD) in 2016 to set national emission reduction commitments for EU Member States (EU, 2016).

Parties to the CLRTAP and European Member States are obligated to report their emission data annually. Under the CLRTAP, this data is reported to the Convention's Executive Body in accordance with the implementation of the Protocols to the Convention (accepted by the Netherlands), and for the NECD they are reported to the European Commission. For both the CLRTAP and the NECD, reports must be prepared using the 2024 Guidelines for reporting emissions and projections data under the Convention (UNECE, 2023).

Additionally, the emission reduction commitments under both the Gothenburg Protocol (UNECE, 2012) and the NECD (EU, 2016) are reported using the Technical guidance (UNECE, 2015).

The Informative Inventory Report 2024 (IIR 2024) comprises the national emission reporting obligation for both the CLRTAP and the NECD with respect to the pollutants SO_x, NO_X, NMVOC, NH_3, $PM_{2.5}$, other particulate matter (PM_{10}, Total suspended particulate (TSP) and Black Carbon (BC)), CO, priority heavy metals (Hg, Pb and Cd), heavy metals (As, Cr, Cu, Ni, Se and Zn) and several persistent organic pollutants (POPs).

The IIR contains information on the Netherlands' emission inventories for the years 1990 to 2022, including descriptions of methods, data sources and annual QA/QC activities (including the trend analysis workshop). The inventory covers all anthropogenic emissions covered by the Nomenclature For Reporting (NFR).

1.1 National inventory background

Emission estimates in the Netherlands are registered in the PRTR, which is the national database for sectoral monitoring of pollutant and greenhouse gas emissions to air, water and soil. The database was set up to support national environmental policy, as well as to meet the requirements of the EU National Emission Ceilings Directive (NECD), CLRTAP, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (National System). This policy covers the annual PRTR updates, the process of data collection, processing and registration, and the reporting of emission data for some 375 compounds. Emission data and documentation can be found at www.emissieregistratie.nl.

Instead of using the defaults from the EMEP/EEA air pollutant emission inventory guidebook 2023 (EEA, 2023), the Netherlands often applies country-specific methods, with associated activity data (AD) and emission factors (EFs). The emission estimates are based on the official statistics of the Netherlands (e.g. on energy, industry and agriculture) and on environmental reports issued by companies in the industrial sectors. Both nationally developed and internationally recommended EFs have been used.

1.2 Institutional arrangements for inventory preparation

The Dutch Ministry of Infrastructure and Water Management (IenW) bears overall responsibility for the emission inventory and submissions made to the CLRTAP and the NECD. The PRTR system has been in operation in the Netherlands since 1974. Since 2004, IenW has outsourced the full coordination of the PRTR to the Emission Registration team (ER team) at the National Institute for Public Health and the Environment (RIVM).

The main objective of the PRTR is to annually produce a set of unequivocal emission data that is up to date, complete, transparent, comparable, consistent and accurate. This forms the basis of all the Netherlands' international emission reporting obligations and is used for national policy purposes.

Emission data is produced in annual (project) cycles. In addition to RIVM, various external agencies/institutes contribute to the PRTR by performing calculations or submitting activity data:

- Netherlands Environmental Assessment Agency (PBL);
- Statistics Netherlands (CBS);
- Netherlands Organisation for applied scientific research (TNO);
- Rijkswaterstaat; Water, Traffic and Environment (RWS-WVL);
- Deltares;
- Wageningen University & Research (WUR), Statutory research tasks:
  - Wageningen Environmental Research (WEnR);
  - Wageningen UR Livestock Research (WLR);
  - Wageningen Economic Research (WEcR);
  - Wageningen Plant Research (WPR).

Each of the contributing institutes has its own responsibility and role in the data collection, emission calculations and quality control. These are laid down in general agreements with RIVM and in the annual project plan.

1.3 The process of inventory preparation

1.3.1 Data collection

Task forces are set up to collect and process the data (according to pre-determined methods) for the PRTR. The task forces consist of sector experts from the participating institutes. Methods are compiled on the basis of the best available scientific knowledge. Changes in scientific knowledge lead to changes in methods and to the recalculation of historical emissions. The following task forces are recognised (see Figure 1.1):

- ENINA: Task Force on Energy, Industry and Waste Management;
- MEWAT: Task Force on Water;

- TgL: Task Force on Agriculture and Land Use;
- V&V: Task Force on Traffic and Transportation;
- WESP: Task Force on Service Sector and Product Use.

Once the emission data has been collected, several quality control checks are performed annually by the task forces during an annual 'trend analysis' workshop. After the Task Forces have approved the data (relevant sector data), the head of the PRTR endorses the complete data set. The participating institutes are requested to agree to the data set to establish a unique set of emission data. Subsequently, the emission data is released for publication (www.emissieregistratie.nl). Then, this data is disaggregated to regional emission data for national use (e.g. 1 x 1 km grid, municipality scale, provincial scale and water authority scale).

1.3.2 *Point source emissions*

As of 1 January 2010, the legally obligated companies can only submit their emission data electronically as a part of an Annual Environmental Report (AER). All these companies have emission monitoring and registration systems in place, with specifications that correspond to those of the competent authority. The licensing authorities (e.g. provinces, central government) validate and verify the reported emissions. Information from the AERs is stored in a separate database at RIVM and remains the property of the companies involved.

Data on point source emissions in the AER database is checked for consistency by the ENINA task force. The result is a set of validated data on point source emissions and activities (ER-I), which is then stored in the PRTR database (Honig *et al.*, 2024).

As a result of the Dutch implementation of the EU Directive on the European Pollutant Release and Transfer Register (E-PRTR), about 1,000 facilities have been legally obligated since 2011 to submit data on their emissions of air pollutants if these exceed the reporting threshold. To include emissions from facilities in a particular subsector that do not exceed the threshold (small and medium-sized enterprises – SMEs), a supplementary estimate is added to the emissions inventory. For these supplementary estimates, known EFs from research and implied factors from the reported emissions and production are used. Also, statistical information, such as production indexes and sold fuels, is used. The methods for these supplementary estimates are explained in detail in Chapters 3 and 5.

To ensure that the supplementary estimates do not add to the uncertainty of the subsectors' total emissions, the Dutch implementation of the E-PRTR directive (List of thresholds PRTR reporting) has set lower thresholds for major pollutants, so that a minimum of approximately 80% of the subsectors' total emissions is covered by facility emission reports.

1.3.3 *Data storage*

In cooperation with the contributing research institutes, all emission data is collected and stored in the PRTR database managed by RIVM (Figure 1.1).

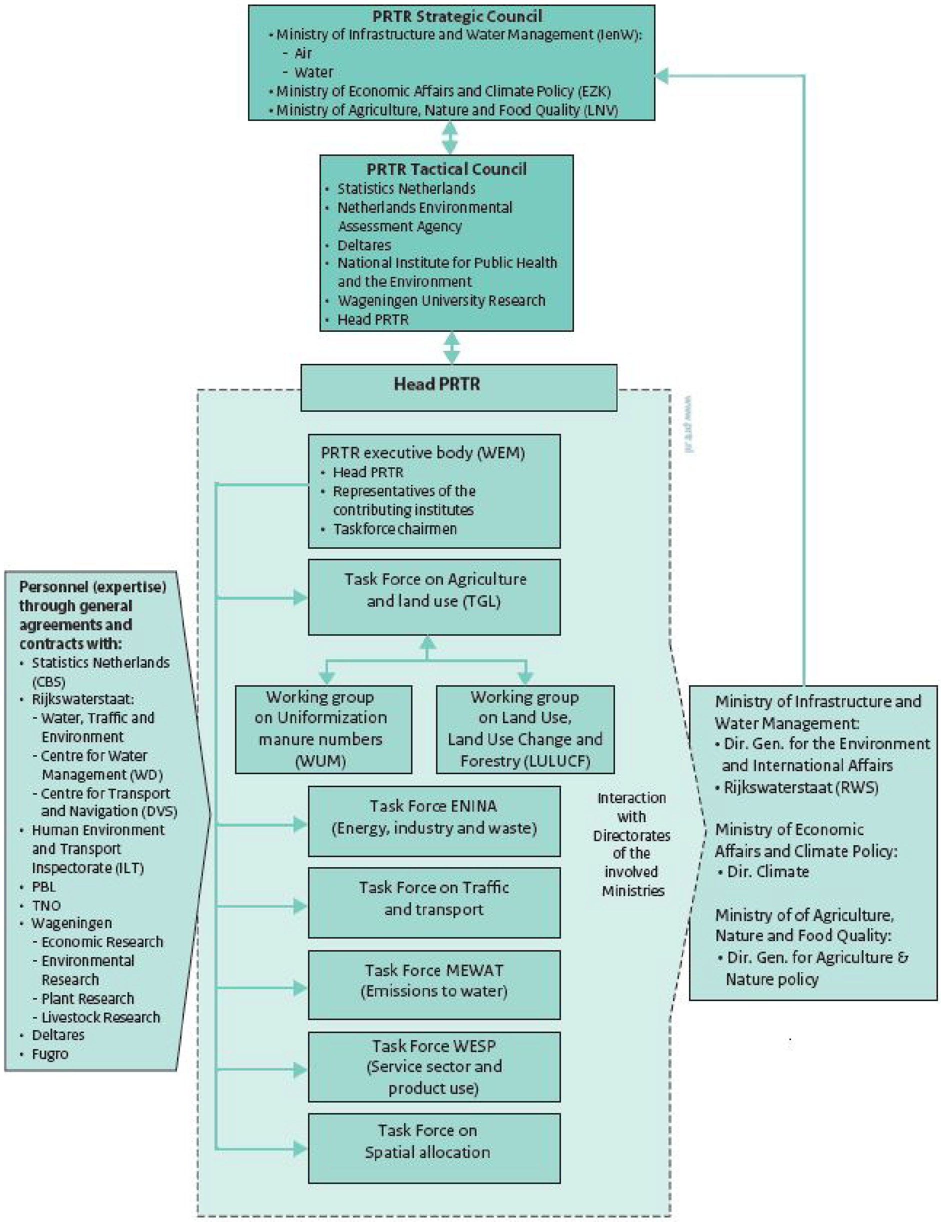

Figure 1.1 The organisational structure of the Netherlands Pollutant Release and Transfer Register (PRTR)

Emission data from the ER-I database and from collectively estimated industrial and non-industrial sources is stored in the PRTR database (see Figure 1.2). The PRTR database, consisting of a large number of geographically distributed emission sources (about 700), contains complete annual records of emissions in the Netherlands.
Each emission source includes information on the NACE code (*Nomenclature statistique des Activités économiques dans la Communauté Européenne*) and the industrial subsector includes separate information on process and combustion emissions, and the relevant environmental compartment and location. These emission

sources can be selectively aggregated per Nomenclature for Reporting (NFR) category.

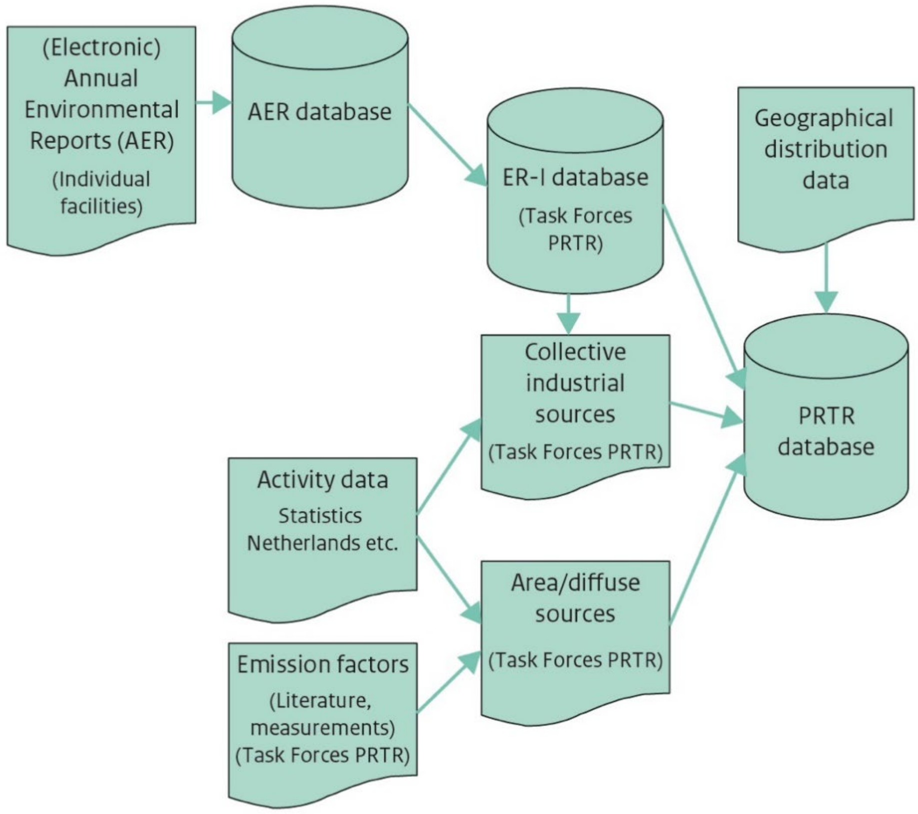

Figure 1.2 The data flow in the Netherlands Pollutant Release and Transfer Register (PRTR)

1.3.4 *Methods and data sources*

Methods used in the Netherlands are annually documented in several reports and are also available from www.emissieregistratie.nl. All methodology reports are in English. However, some background reports are only available in Dutch.
The methodology reports are considered to be an integral part of this Informative Inventory report (see also Appendix 5)

In general, two data models are used in the Netherlands:

- A model for emissions from large point sources (e.g. large industrial and power plants), which are registered separately and supplemented by emission estimates for the remainder of the companies within a subsector (based mainly on IEFs from the individually registered companies). This is the so-called bottom-up method.
- Several sector-related models for emissions from 'diffuse sources' (e.g. road transport, agriculture), which are calculated from activity data and EFs from sectoral emission inventory studies in the Netherlands (e.g. SPIN documents produced by the 'Cooperation project on industrial emissions').

It should also be noted that:

- Condensable emissions are included in transport emissions and in emissions from domestic wood burning;
- Road transport emissions have been calculated using 'on-road' measured emission factors, so emission data is impervious to 'the diesel scandal'.

1.3.5 *Key category analysis*

A key category is defined as an emission source that significantly influences the national total emission for a given pollutant in terms of the absolute emission level, the emission trend or both. The key categories are the sources whose total emissions, when summed in descending order of magnitude, add up to 80% of the total level (EEA, 2023). The key source analysis follows the methodologies as explained in chapter 2 of the EMEP/EEA inventory guidebook 2023 (EEA, 2023) and includes both the Approach 1 and Approach 2 method of identifying key categories.

The Approach 1 method consists of a level assessment that ranks the list of source categories according to their contribution to national total annual emissions. As the inventories of the latest year (2022) and the base year (1990) are available, the level assessment is performed for both years. This also enables assessing the contribution each category makes to the trend of the national inventory. A trend assessment aims to find the categories whose trend (i.e. the change in emission over time) is significantly different from the trend of the overall inventory. See Appendix 2 for the analysis results.

The Approach 2 method requires uncertainty estimates for the source categories to identify the key categories. The uncertainty estimates are applied as weights to each of the source categories and incorporated in the level and trend assessment before ordering the list of shares.
As recommended by the IPCC guidelines, the uncertainty estimates are based on an Approach 2 (Monte Carlo) uncertainty analysis (see Section 1.5 for details). The outcomes of the Monte Carlo uncertainty analysis were aggregated to the gridded NFR (GNFR) level before the key source analysis was carried out. The results of the Approach 2 key category analysis are reported in Appendix 3.

As the uncertainty analysis produces results at the level of emission sources, which are more detailed than the NFR sector-based results, the Approach 2 analysis to find the key categories can also be applied at this level. This allows a more precise identification of inventory improvement actions. By not only ranking emission sources by their contribution to the national total, but also adding their uncertainty as a weight in that ranking, the key category analysis provides a more accurate listing and is used as an instrument to prioritise the next year's inventory improvements by the task forces (see Appendix 6).

1.3.6 *Reporting*

The IIR is prepared by the inventory compiling team at RIVM, with contributions of experts from the PRTR task forces.

1.3.7 QA/QC

RIVM has an ISO 9001:2015 QA/QC system in place. PRTR quality management is fully in line with the RIVM QA/QC system. External agencies (other institutes) carry out part of the work for the PRTR. QA/QC arrangements and procedures for the contributing institutes are described in an annual project plan. The general QA/QC activities meet the international inventory QA/QC requirements described in part A, chapter 6 of the EMEP inventory guidebook (EEA, 2023).

There are no sector-specific QA/QC procedures in place within the PRTR. In general, the following QA/QC activities are performed:

Quality assurance (QA)

QA activities can be summarised as follows:

- For the Energy, Industry and Waste sectors, emission calculations in the PRTR are mainly based on AERs made by companies (facilities). The companies themselves are responsible for the data quality; the competent authorities (in the Netherlands, mainly provinces and local authorities) are responsible for checking and approving the reported data, as part of their annual quality assurance programmes.
- As part of the RIVM quality system, internal audits are performed at the Department for Pollutant Monitoring and Nitrogen research (SMO) of the RIVM Centre for Environmental Quality (MIL).
- Annual external QA checks are also conducted on selected areas of the PRTR system.

Quality control (QC)

A number of general QC checks have been introduced as part of the annual work plan of the PRTR (see Table 1.1). The QC checks built into the work plan focus on issues such as the consistency, completeness and accuracy of the emission data. After an automated first check of the emission files by the Data Exchange Module (DEX) for internal and external consistency, the data was made available to the specific task force for the checking of consistency and trends (error checking, comparability, accuracy). The task forces have access to information on all emissions in the database by means of a web-based emission reporting system and they are provided by the ER team with comparable information on trends and time series. Several weeks before a final data set is adopted, RIVM conducts a trend verification workshop (see Text Box 1.1) and documents its results, including any actions to be taken by the task forces to resolve the identified clarification issues. The task forces then make the requisite changes to the database.

Table 1.1 Key items of the verification actions on times series 1990–2022 data processing and NFR 2024

QC item/action	Date	Who	Result	Documentation*
Automated initial check on internal and external data consistency	During each upload	Data Exchange Module (DEX)	Acceptance or rejection of uploaded sector data	Upload event and result logging in the PRTR database
Input of open issues for this inventory	25-07-2023	RIVM-PRTR	List of remaining issues/actions from last inventory	Actiepunten Voorlopige cijfers 1990-2022 03-07-2023.xlsx
List of allocations for compiling from the PRTR database to the NFR tables	13-11-2023	RIVM-NIC	List of allocations	NFR-Koppellijst-20231113-141054-dtt66.xlsx
Comparison sheets with concept data	24-11-2023	RIVM	Input for data checks	Verschiltabel_LuchtActueel_24-11-2023 - verzonden.xlsx
Desk data checks by the task forces	24-12-2023 04-12-2023	RIVM	Input for trend analyses	Actiepunten Definitieve cijfers 1990-2022_4-12-2023.xlsx
Comparison sheets with final data	01-12-2023	RIVM	Input for trend analyses	Verschiltabel_LuchtActueel_30-11-2023 - verzonden.xlsx
Centralised checks by data-users	06-12-2023	RIVM	Input for trendanalyses	Actiepunten Definitieve cijfers 1990-2022_6-12-2023.xlsx
Trend analysis workshops	07-12-2023	Sector specialists, RIVM-PRTR	Explanations of observed trends and actions to resolve before finalising the PRTR data set	– 5_Emissie landbouw 2023.pptx; – 6_Trendanalyse ENINA 2023.pptx; – 3_Presentatie taakgroep verkeer 2023.pptx; – 4_Trendanalyse WESP - 7-12-2023.pptx; – 2_Trendanalyse Grootschalige luchtverontreiniging 2023.pptx.

QC item/action	Date	Who	Result	Documentation*
Input for resolving the final actions before finalising the PRTR data set	18-12-2023	task forces	Updated action list	Actiepunten Definitieve cijfers 1990-2022_18-12-2023.xlsx
Request to the individual task force chairs to approve the data produced by the task force	18-12-2023	RIVM-PRTR	Updated action list	Email (18-12-2023 13:45) with the request to endorse the PRTR database
Formal adoption of the emission data set	20-12-2023	Head PRTR	Fixed emission dataset 1990–2022	Email (20-12-2023 18:02) from the head of the PRTR endorsing the 1990–2022 emissions dataset;
Input for compiling the NEC report (in NFR format)	30-01-2024	RIVM-NIC	List of allocations of PRTR emission sources for compiling the NFR tables	NFR-Koppellijst-20240130-115336-dtt66.xlsx

* All documentation (emails, data sheets and checklists) is stored electronically on a data server at the RIVM.

Text Box 1.1 Trend verification workshops

About a week in advance of a trend analysis workshop, RIVM makes a snapshot of the database available in a web-based application (Emission Explorer, EmEx) for checks by the institutes involved, sectoral and other experts (PRTR task forces) and the RIVM PRTR team. In this way, the task forces can check for level errors and consistency in the algorithm/method used for calculations throughout the time series. The task forces perform checks on the relevant gases and sectors. The sector are then compared with the previous year's dataset. Where significant differences are found, the task forces check the emission data in more detail. The results of these checks form the subject of discussion at the trend analysis workshop and are subsequently documented.

The PRTR team also provides the task forces with time series of emissions for each substance in each subsector. The task forces examine these time series. During the trend analysis for this inventory, the emission data was checked in two ways: (1) 2020 emissions from the new time series were compared with those of last year's inventory; and (2) the data for 2021 was compared with the trend development for each gas since 1990. The checks of outliers are performed on a more detailed level of the sub sources in all sector background tables:

- annual changes in emissions;
- annual changes in activity data;
- annual changes in implied emission factors (IEFs); and
- level values of IEFs.

Exceptional trend changes and observed outliers are noted and discussed at the trend analysis workshop, resulting in an action list. Items on this list have to be processed within two weeks or dealt with in next year's inventory.

1.4 Archiving and documentation

Internal procedures are agreed on (e.g. in the PRTR work plan) for general data collection and the storage of fixed data sets in the PRTR database, including the documentation/archiving of QC checks. As of 2010, sector experts can store related documents (i.e. interim results, model runs, etc.) on a central server at RIVM. These documents then become available through a limited-access website. The updating of monitoring protocols for substances under CLRTAP is one of the priorities within the PRTR system. Emphasis is placed on the documentation of methodologies for calculating SO_x, NO_x, NMVOC, NH_3, PM_{10} and $PM_{2.5}$. Methodologies, protocols and emission data (including emissions from large point sources on the basis of AERs, as well as emission reports, such as the National Inventory Report and the IIR, are made available on the website of the PRTR: www.emissieregistratie.nl.

1.5 Quantitative uncertainty

Approach 2 method

Uncertainty estimates of total national emissions are calculated using an Approach 2 method (Monte Carlo analysis). Most uncertainty estimates are based on the judgement of emission experts from the ENINA, TgL, V&V and WESP task forces. For agriculture, the judgement of experts is combined with an Approach 1 uncertainty calculation. In the Approach 1 uncertainty calculation of agriculture, it is assumed that emissions from manure management and manure application are correlated with each other.

The expert elicitation was set up following the expert elicitation guidance in the 2006 IPCC Guidelines (motivation, structuring, conditioning, encoding and verification). The uncertainties of the individual source-specific activity data and the EFs were assessed separately using expert judgement. This approach is more detailed than the uncertainty assessment at the level of the NFR categories. The Monte Carlo analysis takes correlations of the activity data and/or EFs into account. The following correlations are included:

- Activity data:
  The energy statistics[1] are more accurately registered on an aggregated level (e.g. for Industry) than on a detailed level (e.g. for the separate Industrial sectors). Therefore, uncertainties are assigned to the aggregated categories, for which good estimates are available, rather than trying to estimate uncertainties for the subcategories. This type of correlation is also used for several transport source categories (such as shipping and aviation).
  The number of animals in one emission source is equal and therefore positively correlated to the number of animals of the same type in another emission source. This type of dependency is taken into account where the identifier of the activity (number of animals or inhabitants) is equal in different emission sources.
- Emission factors:
  Within the stationary combustion sector, the estimated uncertainty of an EF for a specific fuel is assumed to be equal for all of the emission sources that use this type of fuel. This type of positive correlation is also used for several Transport categories (such as shipping and aviation).
  The EFs for the various categories of cows (meat or dairy cows) are positively correlated, as the input data is the same (e.g. chickens, pigs), or because the EFs are derived from another animal category (e.g. ducks and chickens, horses and asses).

The results of the Monte Carlo analysis (Approach 2 method) are represented in Table 1.2.

Table 1.2 Uncertainty (95% confidence ranges) for NH_3, NO_x, SO_x, NMVOC, PM_{10} and $PM_{2.5}$ for each NFR sector and for the national total, calculated with the Approach 2 method for emissions in the IIR2024 submission.

Approach 2 uncertainties IIR2024 submission						
NFR sector	**NH_3**	**NO_x**	**SO_x**	**NMVOC**	**PM_{10}**	**$PM_{2.5}$**
1 Energy	110	15	22	37	49	55
2 Industry	53	88	86	32	44	66
3 Agriculture	28	110	-	130	36	34
5 Waste	71	84	89	158	178	177
6 Other	261	-	-	-	-	-
Total	27	18	21	48	28	41

[1] The energy statistics are available on the website of Statistics Netherlands. The following link relates to the energy statistics for 2018: https://opendata.cbs.nl/https://opendata.cbs.nl/ By means of the 'Change selection' button on the website, it is possible to select the data for another year.

The uncertainty estimates from the Approach 2 method (see Table 1.3) differ from the uncertainty estimates from this method as presented in the IIR2023 (see Table 1.3).

Table 1.3 Uncertainty (95% confidence ranges) for NH_3, NO_x, SO_x, NMVOC, PM_{10} and $PM_{2.5}$ for each NFR sector and for the national total, calculated with the Approach 2 method for emissions in the IIR2023 submission.

Approach 2 uncertainties IIR2023 submission						
NFR sector	**NH_3**	**NO_x**	**SO_x**	**NMVOC**	**PM_{10}**	**$PM_{2.5}$**
1 Energy	102	15	21	50	49	56
2 Industry	53	90	94	29	44	61
3 Agriculture	28	111	-	134	27	38
5 Waste	76	86	79	160	183	191
6 Other	188	120	-	342	65	66
Total	**27**	**18**	**20**	**45**	**29**	**42**

At NFR-category level this comparison shows substantial changes in uncertainty for all shows pollutants. The main changes can be explained as follows:

- Reallocation of privately held farm animals from the Other (NFR 6) to de Agricultural sector (3D) lead to a higher NH_3-uncertainty in the sector Other. Only the NH_3-emissions from pets human respiration and remain in this sector, and both having a relative high uncertainty;
- In the sector Energy the emissions from mopeds/motorcycles are recalculated for the complete timeseries resulting in approximately 40% lower NMVOC-emissions. This source has a very high uncertainty on the NMVOC emission factor (500%), and has a large contribution to the total sector-emissions. This led to the lower uncertainty for the entire sector.
- For inland navigation a change in methodology led to lower uncertainties in both activity data and emission factors. This source is not a very high contributor to total emissions, but may have contributed somewhat to the lower uncertainty for the entire sector due to the lower uncertainty;
- The emissions from the use of hand disinfectants are recalculated based on new activity data leading to significant lower emissions while the uncertainty remained the same (50%). As a result, other sources in the Industry sector have become relatively more important to the uncertainty. Since many of these other sources have a higher uncertainty (often close to 100%), this caused the uncertainty of industry to go up.
- The decrease in emissions from the use of hand disinfectants also has an effect on the uncertainty of the national total. As this rather large emission source has decreased, the relative contribution of industry to the total uncertainty has decreased. And so other sources (especially agriculture) become relatively more important to the total uncertainty. Although the uncertainty of agriculture become slightly lower also, it is still much higher than the uncertainty of industry. Because emissions from industry have gone down, the uncertainty from agriculture

weighs more heavily resulting in a higher uncertainty on the national total.

Approach 1 method
Uncertainty estimates from earlier studies (Van Gijlswijk *et al.*, 2004; RIVM, 2001) are represented in Table 1.4. In 2021, the uncertainty for NH_3 and SO_x increased compared to the studies by Van Gijlswijk *et al.* (2004) and RIVM (2001). For SO_x, this can be explained by the fact that the uncertainty of the SO_x emission factor from chemical waste gas, coal and cokes is assumed to be more uncertain.

Table 1.4 Uncertainty (95% confidence ranges) in earlier studies for NH_3, NO_x and SO_x emissions in 1999 (RIVM, 2001) and 2000 (Van Gijlswijk et al., 2004).

Component	Tier 1 for 1999	Tier 1 for 2000	Tier 2 for 2000
NH_3	± 17%	± 12%	± 17%
NO_x	± 11%	± 14%	± 15%
SO_x	± 8%	± 6%	± 6%

1.6 Explanation of the use of notation keys

The Dutch emission inventory covers all sources specified in CLRTAP that are relevant to emissions to air in the Netherlands. Because of the long history of the inventory, it is not always possible to specify all subsectors in detail. This is why notation keys are used in the NFR emission tables. The use of the notation keys is explained in Tables A1.1 and A1.2 in Appendix A. For most cases in which 'NE' (not estimated) has been used as a notation key, the respective source is assumed to be negligible or there is no method available for estimating the respective source. The notation key 'IE' (Included Elsewhere) is generally used when activity data cannot be split or is confidential.

1.7 Explanation of 'Other' emission sources

Several source categories in the NFR format are used for allocating emission sources that are related to an NFR category, but that cannot be allocated to a specific source category in the relevant source sector. In the NFR format, these source categories are named starting with 'Other'. Table 1.5 represents which source sectors for the Netherlands are allocated to the various 'Other' NFR source categories. These emission sources and their emissions are explained in the relevant chapters for each source sector.

Table 1.5 Subsources accounted for in reporting of NFR 'Other' codes

NFR code	Substance(s) reported	Subsource description
1A2gviii	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	Stationary combustion from production industries in: construction; textiles and clothing; leather and fur preparation; rubber and plastic products; metal products; machine construction; electronic and electric equipment production; computers, electronics and optical equipment production; cars industry; other transport production; furniture production; rug and carpet production; wood products; concrete, gypsum and cement production; construction materials and glass production; synthetic fibre production; ceramics, bricks and roofing tile production; waste preparation for recycling; mineral extraction; shipbuilding.
1A5b	NO_x, NMVOC, SO_x, NH_3, CO, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs, HCBs and PCBs	Recreational navigation and ground machinery at airports.
2A6	NO_x, NMVOC, SO_x, NH_3, CO, $PM_{2.5}$, PM_{10}, TSP, Hg and PAHs	Process emissions of product industries, excl. combustion, in building activities and production of building materials.
2B10a	NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins and PAHs	Process emissions from production of chemicals, fertilisers, paint, pesticides, pharmaceuticals, soap, detergents, glues and other chemical products.

NFR code	Substance(s) reported	Subsource description
2D3i	NMVOC, NH_3, Dioxins and PAHs	Air conditioning, defumigation of ship holds, use of pesticides and cosmetics, fireworks, preservation and cleaning of wood and other materials.
2G	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO, Pb, Cd, Cu, Ni, Zn and PAHs	Smoking of tobacco products, burning of candles, cooling and refrigerating in industry and fireworks.
2H3	NO_x, SO_x, NH_3, $PM_{2.5}$, PM_{10}, Pb, Cd, Hg, Cr, Cu, Ni and Zn	Process emissions from: service sector; textiles and clothing; leather and fur preparation; rubber and plastic products; metal products; machine construction; electronic and electric equipment production; computers, electronics and optical equipment production; car industry; other transport production; furniture production; rug and carpet production; mineral extraction; transhipping, storage and handling; ship building and painting.
3B4giv	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	Ducks
3B4h	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	Rabbits and furbearing animals.
3Da2c	NO_x, NH_3	Use of compost.
5E	NO_x, NMVOC, SO_x, NH_3, CO, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs, HCBs and PCBs	Process emissions from: accidental building and car fires, waste preparation for recycling, scrapping of fridges and freezers.
6A	NH_3	Human transpiration and respiration; domestic animals (pets).

2 Trends in Emissions

2.1 National emissions of the main pollutants and particulate matter

Total national emissions for all pollutants have decreased substantially since 1990. Tables 2.1, 2.2 and 2.3 provide an overview of the emissions with respect to the time series. The major overall drivers for this trend are:

- for the agricultural sector introducing a ban on surface spreading of manure, direct incorporation of manure in the soil, covering of outdoor slurry storage and lately the introduction of low-emission animal housing, introduction of precision feeding aiming to reduce N-excretion and slowly decreasing livestock numbers (for cattle and swine);
- emission reductions in the industrial sectors due to the introduction of cleaner production technologies and flue gas treatment technologies;
- use of cleaner fuels through the desulphurisation of fuels and reduced use of coal and heavy oils;
- increasingly cleaner cars due to EU emission regulations for new road vehicles.

Table 2.1 Total national emissions of main pollutants and PM, 1990–2022

	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC
Year	Tg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**681.2**	**606.0**	**197.5**	**346.6**	**57.3**	**80.8**	**102.4**	**14.2**
1995	581.0	436.3	136.4	219.8	45.4	63.1	79.9	12.2
2000	493.6	337.1	78.5	174.9	35.0	50.5	57.4	10.6
2005	430.9	269.9	67.9	155.0	28.5	42.6	51.1	8.3
2010	343.0	273.9	36.1	135.1	22.2	36.0	43.4	5.0
2015	273.1	258.2	31.0	130.3	17.8	31.8	37.4	3.3
2020	211.7	249.9	19.6	125.0	14.4	26.9	31.4	2.4
2021	206.4	244.1	20.9	123.5	14.5	27.0	31.6	2.3
2022	**194.6**	**241.7**	**19.6**	**121.2**	**14.3**	**26.9**	**31.3**	**2.1**
1990-2022 period[1)]	-486.7	-364.3	-177.9	-225.4	-43.1	-53.9	-71.1	-12.0
1990-2022 period[2)]	-71%	-60%	-90%	-65%	-75%	-67%	-69%	-85%

1. Absolute difference in Gg.
2. Relative difference from 1990 in %.

As a result of following the "new science" several sources of NMVOC were added to the inventory after setting the targets in 2013. As result of this, the Netherlands were in the 2022 submission not in compliance with the reduction target for NMVOC in the year 2020. For the purpose of demonstrating compliance with the targets as set in 2013 The Netherlands applied for an inventory adjustment. After being reviewed this adjustment was approved by the EMEP-EB (EMEP-Executive Body).

However in this IIR-submission, recalculations for NMVOC from several sources based on new activity data show that the emissions in the paste

were over-estimate but, that still a small non-compliance remaining for the year 2020. For the purpose of demonstrating compliance this will be adjusted with the in 2022 approved adjustment.
A complete discussion and justification for these adjustments can be found in Chapter 13 (Adjustments).

2.1.1 *Trends in nitrogen oxides (NO_x)*

The Netherlands NO_x emissions decreased by 487 Gg in the 1990–2022 period to 195 Gg, corresponding to 71% of the national total in 1990 (Figure 2.1). Although all sectors show a decrease over this period, the main contributors to this decrease were the Road transport, Industry and the Energy sectors. In the road transport source category, emissions per vehicle decreased significantly over this period due to increasingly cleaner vehicles. However the reduction from this is partially negated by an increase in the number of vehicles and total mileage. In 2022, the Transport sector still is the main contributor to NO_x emissions, with a share of 56% of the national total. Especially in Road transport and Civil aviation the effects of the Covid-19 pandemic are visible in both the 2020 and 2021 emissions. For Road transport, this is the result of the fact that less kilometres were driven as most people worked from home and for Civil aviation, a decrease Landing and Take-off cycle (LTO) was due to flight cancellations and travel restrictions. The individual relative shares in the national total of the Energy, Industry (combustion) and Transport sectors show a decrease over the 1990–2022 period, while the relative share of Agriculture increased from 9% to 17%.

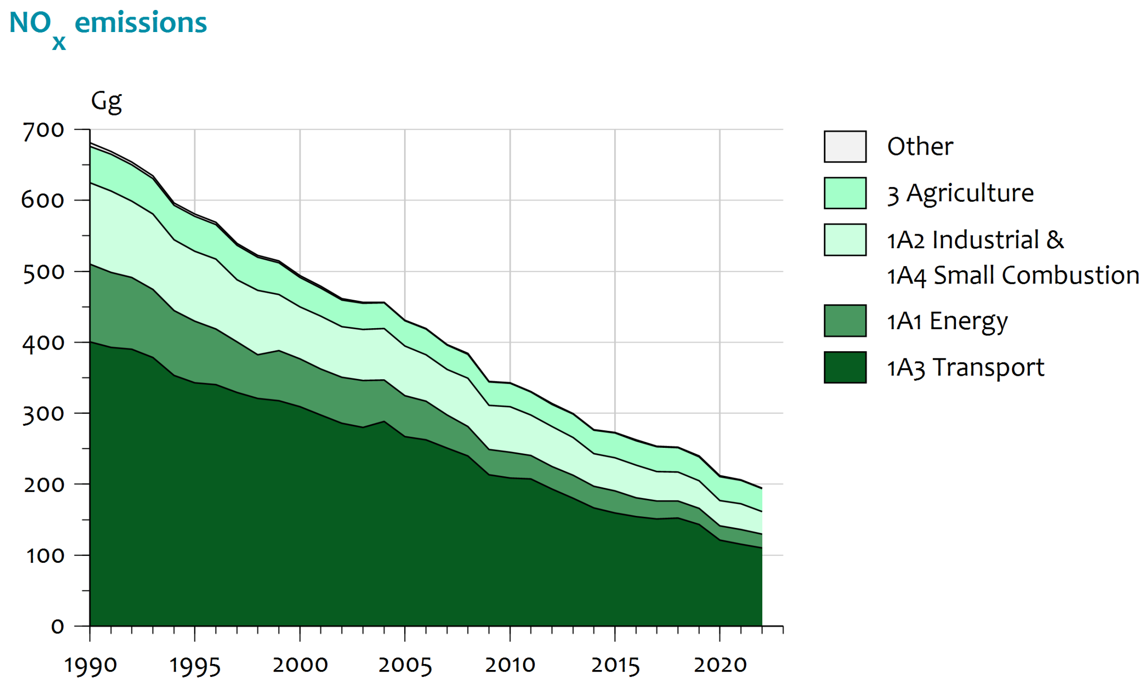

Figure 2.1 NO_x emission trends, 1990–2022

2.1.2 *Trends in sulphur oxides (SO_x)*

Dutch SO_x emissions (reported as SO_2) decreased by 178 Gg in the 1990–2022 period to 20 Gg, corresponding to 90% of the national total in 1990 (Figure 2.2). The main contributors to this decrease were the

Energy, Industry, and Transport sectors. The use of coal declined and major coal-fired electricity producers installed flue-gas desulphurisation plants. In addition, the sulphur content in fuels for the (chemical) industry and traffic was reduced. Over the 1990–2018 period, oil refining was the main contributor to total SO_x emissions, with shares of 34% and 39% in 1990 and 2018, respectively. During 2019-2021 Industry became the main contributor to the national SO_x emissions. In 2022 again Oil refineries became the main source as result of the high oil and gas prices due to the war in the Ukraine refineries started to use more refinery gas in their processes and Industry used les oil and gas. In 2022, the combined Industry, Energy and Refining source sectors are responsible for 90% of national SO_x emissions.

The SO_x emissions from Energy and Industry decreases with 0.1 Gg and 1.7 Gg respectively compared to 2021. The SO_x emissions of Oil refineries increased 0.5 Gg compared to 2021.

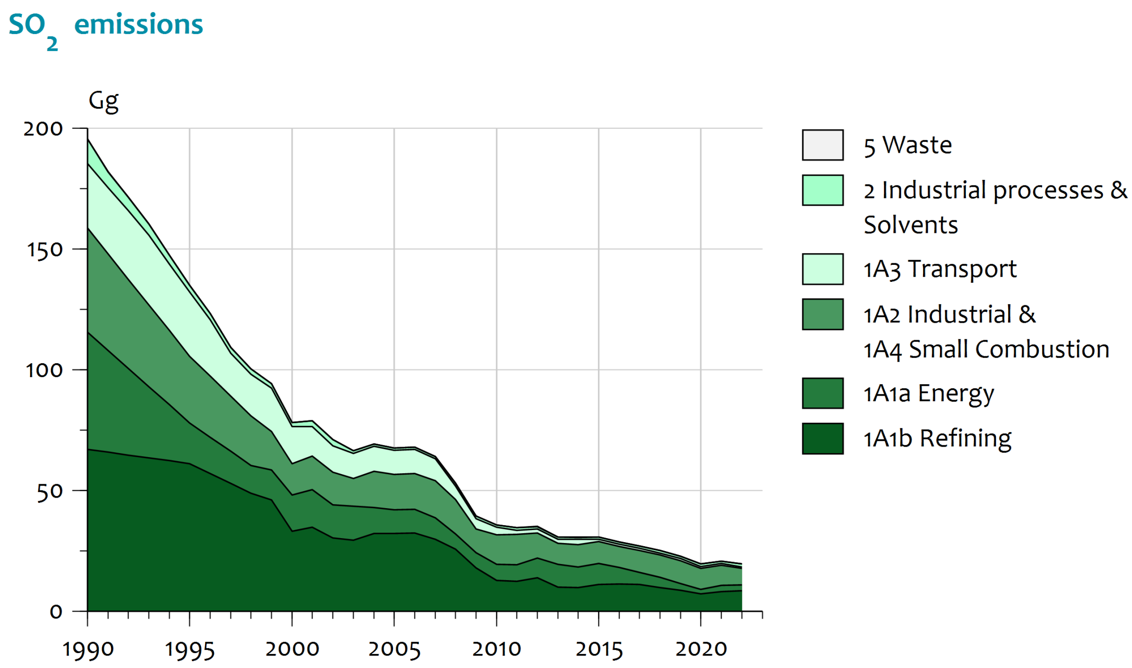

Figure 2.2 SOx emission trends, 1990–2022

2.1.3 *Trends in ammonia (NH_3)*

Most of the NH_3 emissions (91% in 2022) come from agricultural sources (Figure 2.3). The share of agricultural sources in the national total decreased from 97% to 93% during the period 1990-2001. Over the 2002-2022 period, the share from the agricultural sources is constant at approximately 91%. In 2022 the remaining share of 9% is emitted in the Other (3%), Industry and Transport (each with an approx. equal share of 2.5%) and combined Energy and Waste (1% combined) sectors.
From 1990 to 2013, the decreasing trend in NH_3 due to emission reductions in the agricultural sector also showed up in the decreasing trend of the national total. In the 2014 to 2017 period, the national NH_3 emissions slightly increased as result of growing cattle numbers due to the abolition of the milk-quota. However, introduction of the policy to maximise the phosphate production resulted in cattle numbers decreasing

again and with it the NH3 emissions decreased. Livestock emissions in 2022 decreased mainly as result of a lower protein content in the silage gras fed to dairy cattle, slight increase in use of air scrubbers and a decreased use of fertilisers.

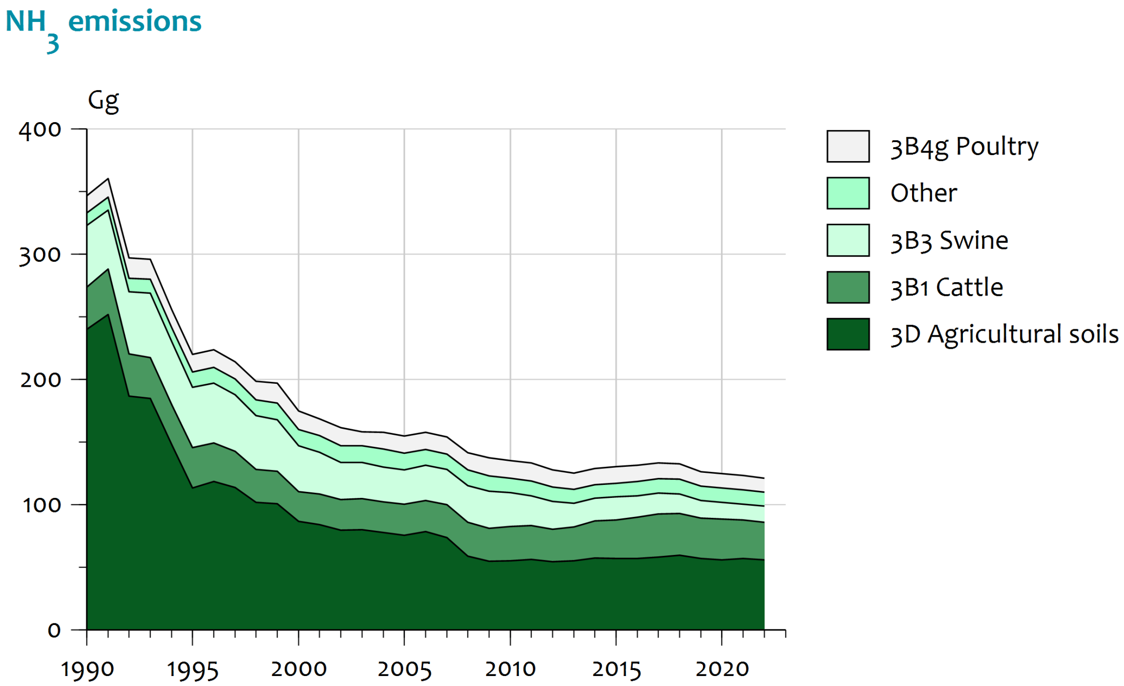

Figure 2.3 NH3 emission trends agriculture 1990–2022

2.1.4 *Trends in non-methane volatile organic compounds (NMVOC)*

In the 1990–2022 period, NMVOC emissions decreased by 364 Gg to 242 Gg, corresponding to 60% of the national total in 1990 (Figure 2.4). With the exception of Solvent use, all major source categories contributed to this decrease: transport (introduction of catalysts and cleaner engines), product use (thanks to an intensive programme to reduce the NMVOC content in consumer products and paints) and industry (introducing emission abatement specifically for NMVOC). In Agriculture NMVOC emissions from soils initially decreased in the period 1990-1995 as a result of changes in the method of manure application. However, emissions from agricultural soils remained constant over de period 1996-2022 while the NMVOC emissions from live stock in the period 1990–2022 increased mainly as result of the increased use of silage. In the sector Solvent use the NMVOC emissions increased significantly as a result of the increased use of disinfectants due to measures and advises related to Covid-19. As a result the NMVOC emissions from this source increased over from 61 Gg in 2019 to 71 Gg in 2020. Emissions in 2021 and 2022 are decreasing as human behaviour is gradually returning to the situation before Covid-19 crisis.

As result of Covid-19 measures NMVOC emissions from the use of (hand)disinfectants increased and this led to failing to meet the NMVOC reduction target set under the Gothenburg Protocol in 2020. However, the introduction since 2013 of several new emission sources and new EFs justifies the application for an inventory adjustment (see Chapter 13).

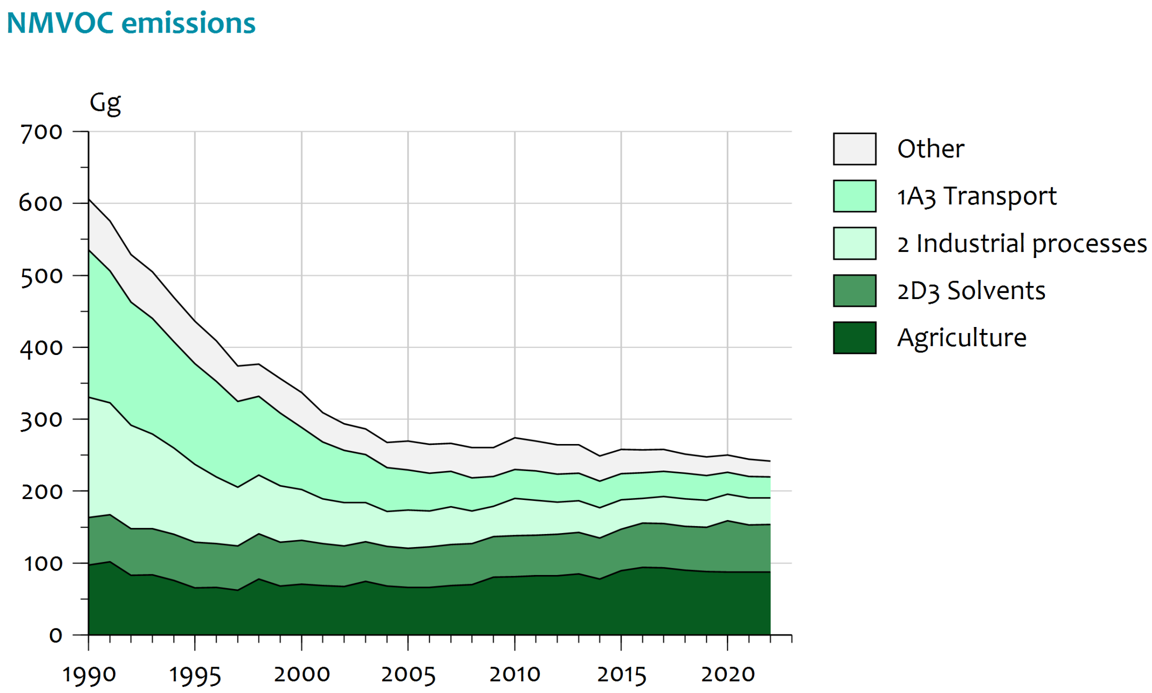

Figure 2.4 NMVOC emission trends, 1990–2022

2.1.5 *Trends in $PM_{2.5}$*

Most $PM_{2.5}$ emissions are calculated as a specific fraction of PM_{10} by sector (based on Visschedijk *et al.*, 2007). $PM_{2.5}$ emissions decreased by 43.1 Gg in the 1990–2022 period to 14.3 Gg, corresponding to 75% of the national total in 1990 (Figure 2.5). The three major source categories contributing to this decrease were the Industry, Energy and Transport sectors. In the Industry sector the refineries increasingly use cleaner fuels and in both the Industry and Energy sectors abatement technology is installed. Emission reduction in the Transport sector (road transport) is the result of increasingly stringent EU emissions standards that resulted in better engine management and particulate filters.

The 2022 $PM_{2.5}$ emissions decreased, compared to 2021, with 0.2 Gg.

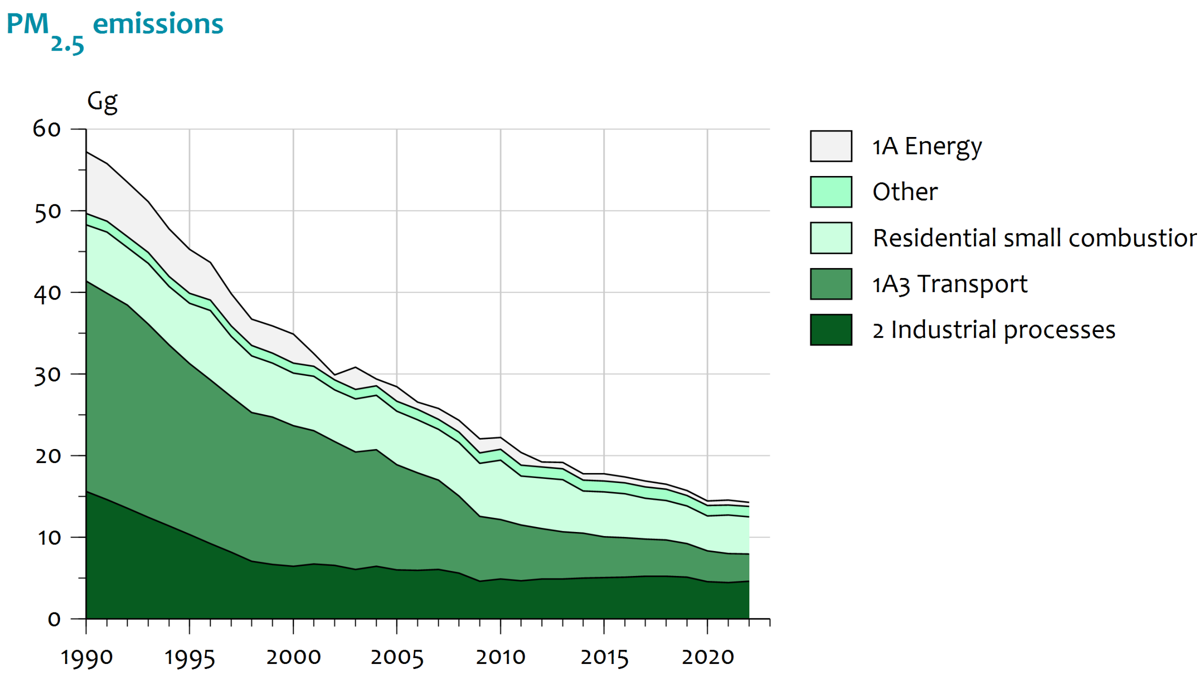

Figure 2.5 $PM_{2.5}$ emission trends, 1990–2022

2.1.6 *Trends in PM_{10}*

Over the 1990–2022 period, Dutch PM_{10} emissions decreased by 53.9 Gg to 26.9 Gg, corresponding to a decrease of 67% of the national total compared to 1990 (Figure 2.6). The three major source categories contributing to this decrease were the Industry, Energy and Transport sectors. In the Industry sector the refineries increasingly use cleaner fuels and in both the Industry and Energy sectors abatement technology is installed. Emission reduction in the Transport sector (road transport) are the result of increasingly stringent EU emissions standards that led to better engine management and particulate filters.

From 1990 to 2011, PM_{10} emissions from agriculture gradually increased from 5.3 Gg to 6.8 Gg. These increasing emissions were mainly caused by a change in housing systems (a shift from liquid manure to solid manure systems), especially for laying hens. Emissions decreased again to 5.4 Gg in 2022. This decrease was mainly caused by a decrease in animal numbers in poultry farming.

The 2022 PM_{10} emissions decreased, compared to 2021, with 0.1 Gg.

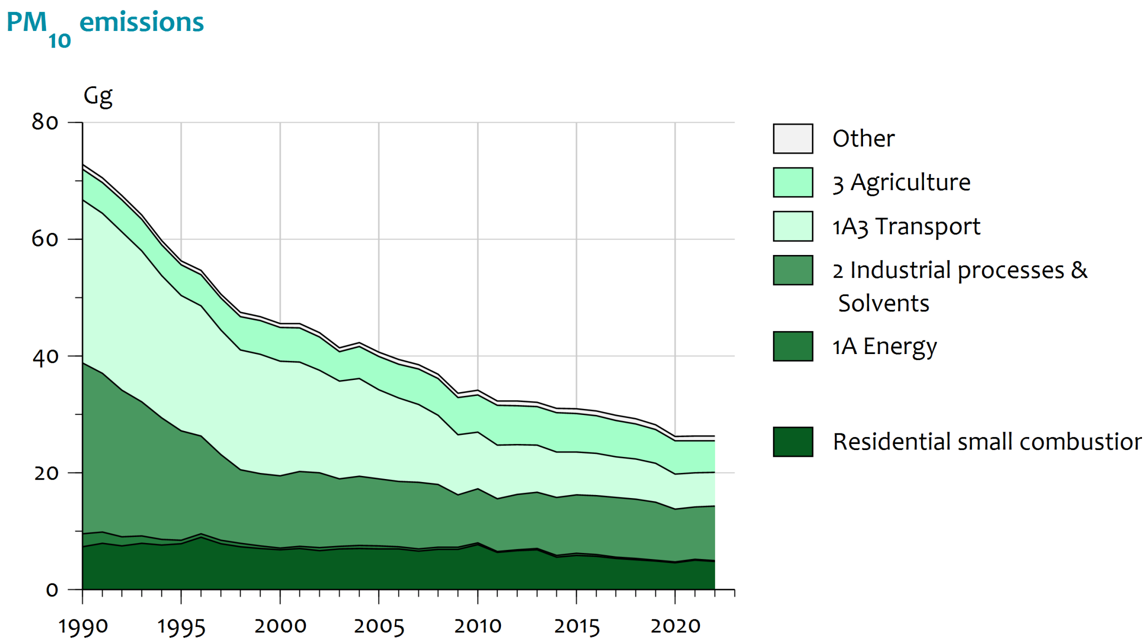

Figure 2.6 PM_{10} emission trends, 1990–2022

2.2 National emissions of priority heavy metals

Under the Protocol to the Convention on Long-range Transboundary Air Pollution on Heavy Metals and the Gothenburg Protocols the Netherlands is committed to reduce its total annual emissions of priority heavy metals (Lead, cadmium and mercury). The base year for this commitment is 1990. In 2022 all priority heavy metal emissions comply.

Table 2.2 Total national emissions of priority heavy metals, 1990–2022

	Priority Heavy Metals		
	Pb	Cd	Hg
Year	Mg	Mg	Mg
1990	**336**	**4.1**	**3.7**
1995	155	3.0	1.6
2000	28	3.0	1.2
2005	30	3.8	1.0
2010	38	4.7	0.77
2015	8.7	2.9	0.69
2020	5.8	2.0	0.48
2021	4.9	0.9	0.46
2022	**4.5**	**0.79**	**0.49**
1990-2022 period[1)]	-331	-3.3	-3.2
1990-2022 period[2)]	-99%	-80%	-87%

1. Absolute difference.
2. Relative difference from 1990 in %.

2.2.1 *Trends in lead (Pb)*

Over the period 1990–2022, Lead (Pb) emissions in the Netherlands decreased by 334 Mg to 4.5 Mg, corresponding to 98% of the national total in 1990 (Figure 2.7). This decrease is primarily attributable to the Transport sector, where, due to the removal of Pb from gasoline, Pb emissions collapsed. The remaining sources contributing to this decrease are industrial process emissions, particularly from the iron and steel industry (due to the replacement of electrostatic filters and the optimisation of various other reduction technologies at Tata Steel).

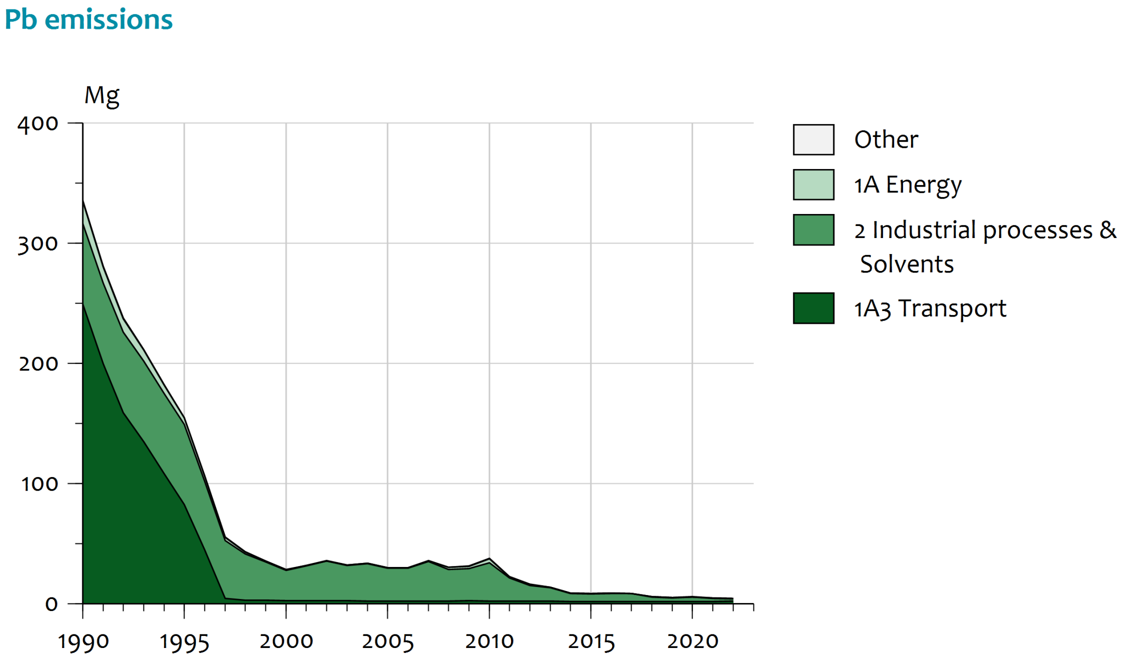

Figure 2.7 Pb emission trends, 1990–2022

2.2.2 *Trends in Cadmium (Cd)*

Over the 1990–2019 period, cadmium (Cd) emissions in the Netherlands decreased by 3.2 Mg to 0.79 Mg, corresponding to 79% of the national total in 1990 (Figure 2.8). This decrease is primarily attributable to the Energy sector and Other sources. The cadmium emissions from the only zinc-production plant (Nystar) is the main source. The emissions from zinc production gradually increased over the time series from 1.78 Mg to 2.22 Mg in 1990 and 2019, respectively. In the period 2020-2022 the emissions from zinc production decreased to 0.39 Mg in 2022. The operator reported that the gasses coming from a venturi scrubber sometimes contain aerosols with high concentrations of zinc. This affects the measurements of zinc concentration in the emitted gas as the aerosol is not always captured in the sampling. New measurements in 2021 resulted in significantly lower emission factors.

The increased Cd emission over the period 2000-2011 in the Other category result from the activities of one operator in the Chemical industry (ThermPhos). This operator ended production in 2011.

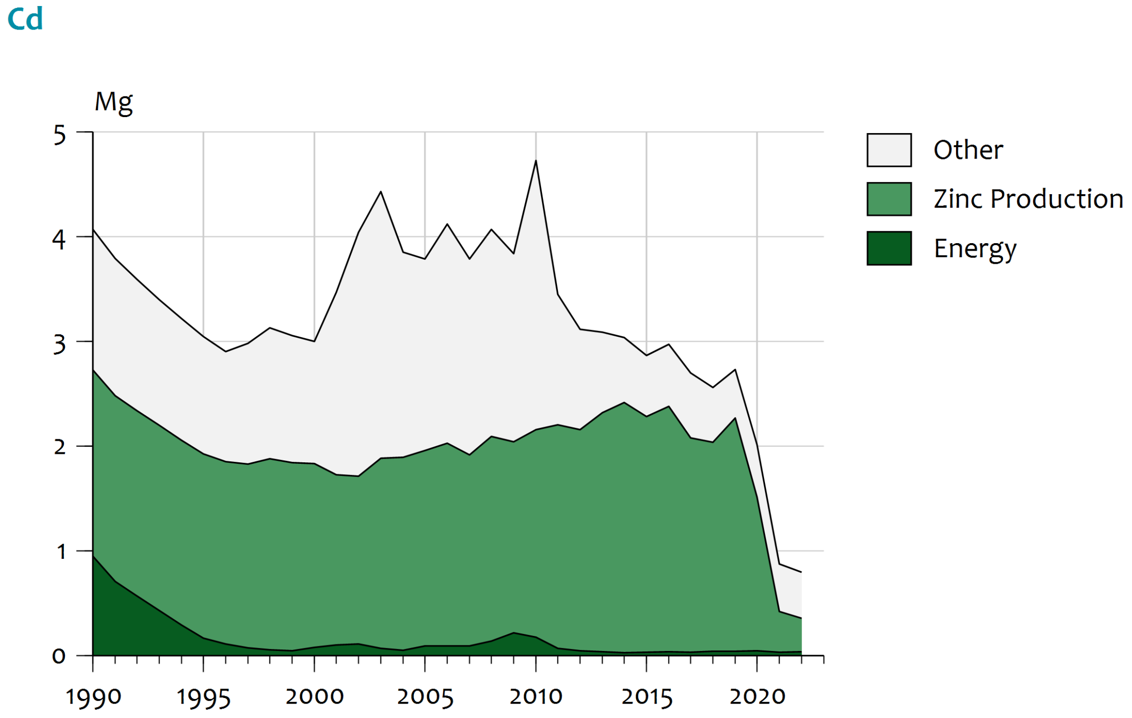

Figure 2.8 Cd emission trends, 1990–2022

2.2.3 *Trends in Mercury (Hg)*

Over the 1990–2022 period, mercury (Hg) emissions in the Netherlands decreased by 3.2 Mg to 0.49 Mg, corresponding to 87% of the national total in 1990 (Figure 2.9). In 1990, the Energy and Industry (industrial processes) sectors were the main source of Hg emissions with 1.9 Mg and 1.2 Mg, respectively, and had a combined total Hg emission of 86% of the national total. These sectors reduced their combined Hg emissions in 2022 to 0.27 Mg (55% of the 2022 national total).

Hg

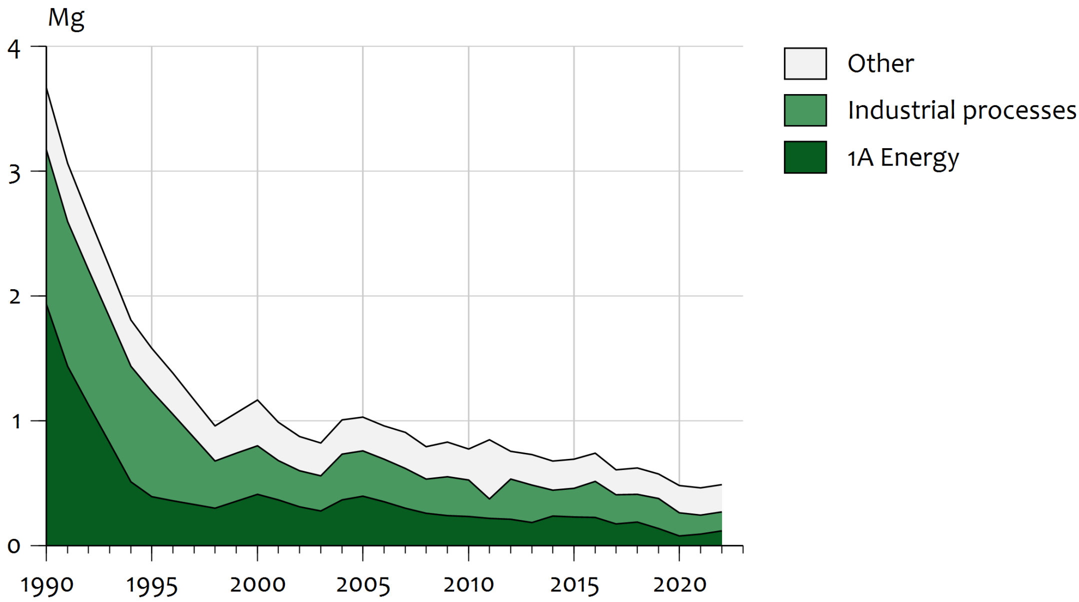

Figure 2.9 Hg emission trends, 1990–2022

2.3 National emissions of persistent organic pollutants

Based on the Protocol on Persistent Organic Pollutants (POPs) to the Convention on Long-range Transboundary Air Pollution Gothenburg protocols the Netherlands is committed to reduce its total annual emissions of Poly Aromatic Hydrocarbons (PAHs), Dioxins/furans (PCDD/PCDF), Hexachlorobenzene (HCB) and Polychlorobiphenyl (PCBs). The base year for this commitment is 1990 for PAHs, PCDD/PCDF and HCB and 2005 for PCBs. In 2022 all POPs emissions comply.

Table 2.3 Total national emissions of POPs, 1990–2022

	POPs			
	DIOX	PAH	HCB	PCB
Year	g I-Teq	Mg	kg	kg
1990	**745**	**21**	**66**	**38**
1995	70	11	40	22
2000	38	6.0	17	0.26
2005	35	6.0	3.4	0.27
2010	40	6.7	3.5	0.27
2015	32	5.5	4.1	0.33
2020	30	4.3	3.4	0.14
2021	30	4.7	3.4	0.19
2022	**30**	**4.8**	**3.3**	**0.18**
1990-2022 period[1)]	-715	-16	-63	-38
1990-2022 period[2)]	-96%	-77%	-95%	-100%

1. Absolute difference.
2. Relative difference from 1990 in %.

2.3.1 *Trends in dioxins/furans (PCCD/PCDF*

In the Netherlands emissions of dioxins/furans come mainly from waste combustion in the Energy sector, Residential wood combustion and from Accidental car -and building fires.
Over the 1990–2022 period, emissions of dioxins/furans in the Netherlands decreased by 715 g I-TEQ to 30 g I-TEQ, corresponding to 96% of the national total in 1990 (Figure 2.10). This decrease is primarily attributable to the waste incineration in the Energy sector. The rapid decrease of dioxins/furans emissions in this sector relates to both better incinerator management (temperature) and the introduction of abatement technology at waste incinerators.

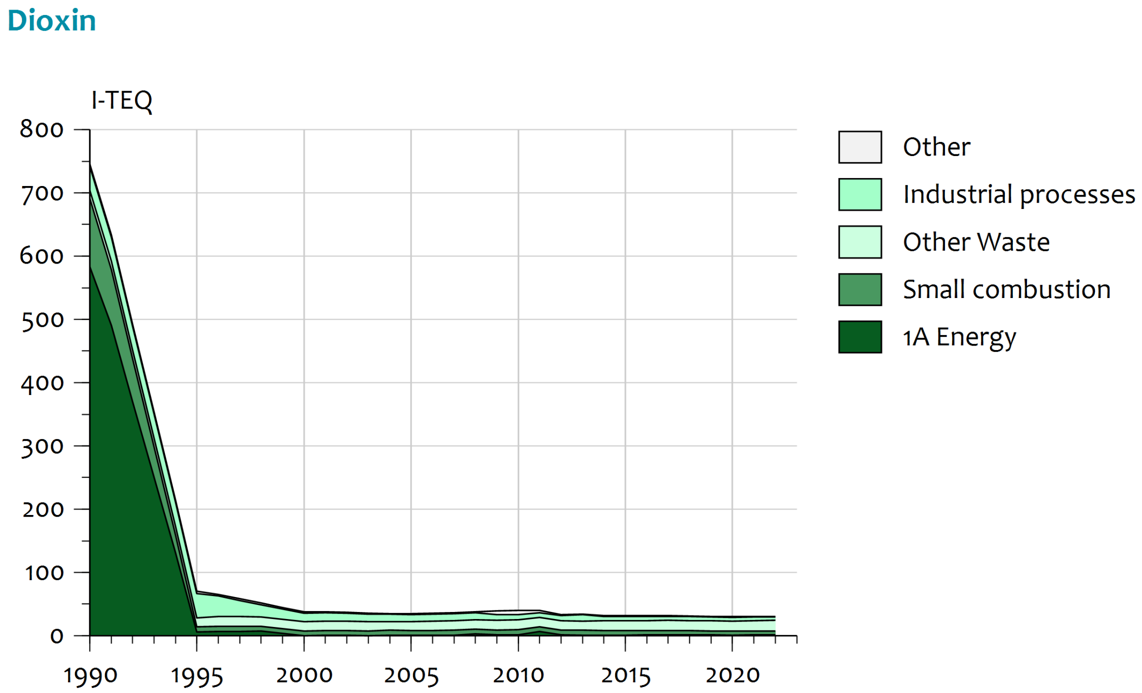

Figure 2.10 Dioxins/furans emission trends, 1990–2022

2.3.2 *Hexachlorobenzene*

Over the 1990–2022 period, emissions of hexachlorobenzene (HCB) in the Netherlands decreased by 63.0 kg to 3.3 kg, corresponding to 95% of the national total in 1990 (Figure 2.11). This decrease is primarily attributable to the Energy sector (waste incineration for energy) and Agricultural (use of pesticides) sector. The decrease in the Agricultural sector is due to the reduction in the amount of applied pesticides containing HCB as well as a reduction in the maximum amount of HCB allowed as a contaminant in pesticides.. HCB from agriculture is calculated from the annual sales of HCB-containing pesticides. The increased HCB emissions in agriculture between 1996 and 2000 are the result of increased sales of the chlorothalonil fungicide that contained HCB as an impurity.

HCB

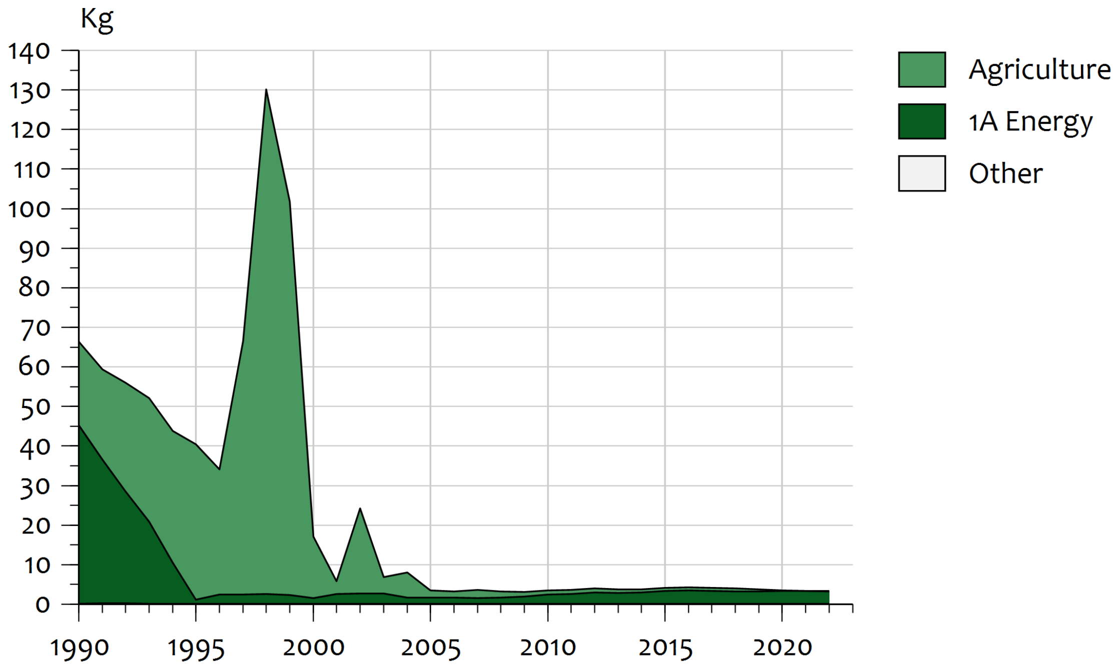

Figure 2.11 HCB emission trends, 1990–2022

2.3.3 *Polychlorobiphenyl*

Over the 1990–2022 period, Polychlorobiphenyl (PCB) emissions in the Netherlands decreased by 34.1 kg to 0.18 kg, corresponding to 99.5% of the national total in 1990 (Figure 2.12). This decrease is attributable to all sectors and is the result of the ban on production and use of PCB. This ban resulted in a relative quick decrease of PCB use in (electronic) products and as oil in electrical transformers.

PCB

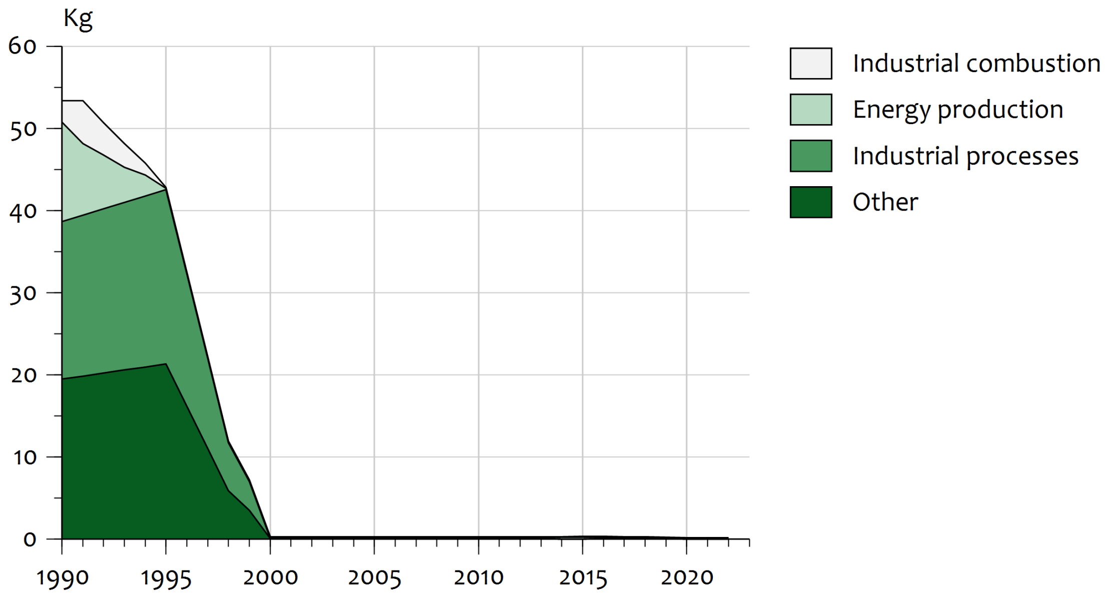

Figure 2.12 PCB emission trends, 1990–2022

3 Energy

3.1 Overview of the sector

Emissions from the Energy sector include all energy-related emissions from stationary combustion, as well as fugitive emissions from the Energy sector.

The majority of the emissions from stationary combustion for electricity production and industry (NFR categories 1A1 and 1A2) are reported in the AERs (Annual Environmental Reports) submitted by large industrial companies. Also additional emission data is collected at company level, reported by the competent authorities. For SO_x in 2022 in categories 1A1 and 1A2 (excluding 1A2gvii), 97% of the emissions were based on company data (AERs and other company data), while for other pollutants, the proportions were 96% (NH_3), 83% (NMVOC), 90% (NO_x) and 93% (PM_{10}). The emission data from individual companies come from direct emission measurements or from calculations using fuel input and EFs. Most of the emission data from ‘other’ stationary combustion (categories 1A4 and 1A5) were calculated using energy statistics and default EFs.

As in most other developed countries, the energy system in the Netherlands is largely driven by the combustion of fossil fuels. In 2022, the total primary fuels used in the Netherlands consisted of natural gas (36%), liquid fuels (38%), biogenic fuels (14%), solid fuels (9%) and waste (3%). Figures 3.1 and 3.2 represent the energy supply and energy demand in the Netherlands. The energy consumption is directly related to the temperature during the winter. The natural gas consumption is higher in cold winters (e.g. 1996 and 2020) and lower in warm winters (e.g. 2014). The decrease in natural gas consumption in 2022 is due to the high natural gas prices in 2022.

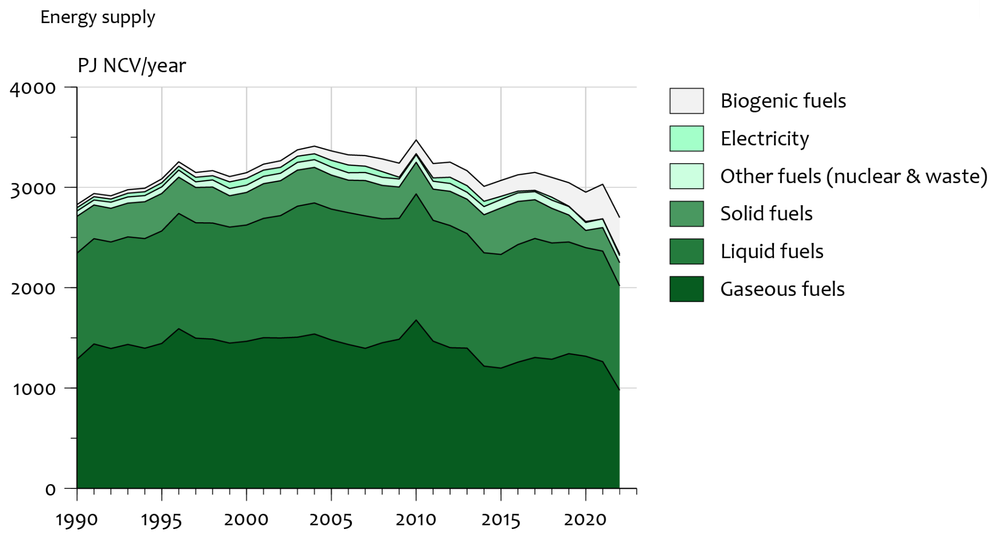

Figure 3.1 Energy supply by fuel in the Netherlands, 1990–2022 (‘Electricity’ refers to imported electricity only).

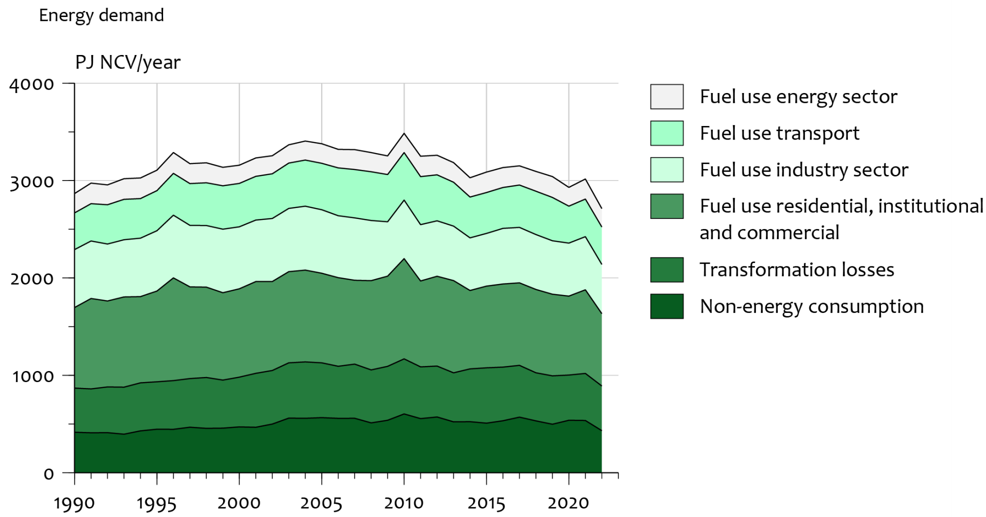

Figure 3.2 Energy demand in the Netherlands, 1990–2022

The full energy statistics are available on the website of Statistics Netherlands. The following link refers to the energy statistics for 2022: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB. On this website, it is also possible to select the data for another year.

3.2 Public electricity and heat production (1A1a)

3.2.1 Source category description

In this section, one source category is included: Public electricity and heat production (1A1a). This source category consists mainly of coal-fired power stations and gas-fired cogeneration plants, many of the latter being operated as joint ventures with industries. Waste incineration plants with energy recovery generate a relatively small share (~2%) of energy in the Netherlands. All waste incineration plants recover energy and are included in source category 1A1a. Renewable energy (biomass, solar and wind) used to make a small contribution to the total primary energy supply in the Netherlands, but is increasing to 15%.

3.2.2 Key sources

The source category 1A1a is a key source of the pollutants listed in Table 3.1.

Table 3.1 Pollutants for which the Public electricity and heat production sector (NFR 1A1a) is a key source

Category / Subcategory	Pollutant	Contribution to national total of 2022 (%)
1A1a Public electricity and heat production	SO_x	12.4
	NO_x	6.6
	Hg	24.5
	HCB	94.7
	PCB	47.7

3.2.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is provided in Table 3.2. For almost all pollutants, emissions decreased between 1990 and 2022, while total fuel consumption increased over the same period in source category 1A1a.

Table 3.2 Overview of trends in emissions

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**82.9**	**0.89**	**48.5**	**0.00**	**1.81**	**2.21**	**2.46**	**0.03**	**8.3**
1995	62.1	1.65	16.9	0.04	0.39	0.63	0.99	0.01	7.6
2000	51.5	2.12	14.9	0.04	0.25	0.33	0.33	0.01	15.4
2005	43.4	0.91	9.9	0.26	0.40	0.54	0.82	0.01	8.3
2010	25.6	0.67	6.7	0.07	0.22	0.29	0.60	0.01	4.8
2015	20.5	0.70	8.6	0.09	0.30	0.40	0.78	0.01	4.6
2020	13.5	0.68	1.8	0.11	0.09	0.12	0.20	0.00	3.5
2021	14.0	0.64	2.6	0.10	0.12	0.16	0.25	0.00	4.6
2022	**12.8**	**0.63**	**2.4**	**0.11**	**0.13**	**0.16**	**0.25**	**0.00**	**4.5**
1990-2022 period[1)]	-70	-0.25	-46	0.11	-1.7	-2.1	-2.2	-0.03	-3.8
1990-2022 period[2)]	-85%	-29%	-95%		-93%	-93%	-90%	-87%	-46%

Table 3.2 (continued) Overview of trends in emissions (continued)

	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
Year	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	**16.3**	**0.95**	**1.93**	**583**	**0.18**	**0.53**	**0.68**	**2.07**	**2.49**	**0.02**	**40.7**
1995	1.56	0.16	0.39	6.09	0.06	0.23	0.37	0.47	1.41	0.06	3.34
2000	0.18	0.08	0.41	0.13	0.01	0.13	0.19	0.19	0.08	0.45	0.26
2005	0.24	0.09	0.40	0.79	0.01	0.21	0.33	0.32	1.91	1.68	0.52
2010	0.34	0.18	0.23	1.22	0.02	0.17	0.14	0.19	0.16	1.33	3.91
2015	0.16	0.03	0.23	1.06	0.03	0.09	0.16	0.20	0.17	0.91	4.07
2020	0.13	0.05	0.08	1.07	0.04	0.08	0.10	0.15	0.08	0.10	0.82
2021	0.11	0.03	0.09	1.18	0.03	0.06	0.09	0.11	0.07	0.07	0.26
2022	**0.08**	**0.04**	**0.12**	**1.28**	**0.04**	**0.06**	**0.09**	**0.10**	**0.19**	**0.07**	**1.18**
1990-2022 period[1)]	-16.3	-0.91	-1.8	-581	-0.13	-0.47	-0.59	-2.0	-2.3	0.05	-39
1990-2022 period[2)]	-100%	-96%	-94%	-100%	-76%	-89%	-87%	-95%	-92%	203%	-97%

1. Absolute difference.
2. Relative difference compared to 1990 in %.

Between 1990 and 2022, NO_x and SO_x emissions decreased by 85% and 95%, respectively. Other pollutant emissions decreased by at least 75%, except for CO (-46%), NMVOC (-29%), Se (+203%) and NH_3. The overall decrease in emissions was partly caused by a shift in fuel type, but was also due to technological improvements (especially the large decrease in dioxin emissions). The increase in NH_3 and Se was due to a possible underestimation of emissions in 1990, which improved after the annual environmental reports from individual companies can into place from 2000 onwards.

3.2.4 *Activity data and (implied) emission factors*

Emission data is based on reported emissions in AERs (Annual Environmental Reports) and on calculated emissions for the companies that did not report their emissions in an AER. For this source category, a large part of the emission figures are based on AERs: NO_x (97%). NMVOC (84%), SO_x (98%), NH_3 (96%) and $PM_{2.5}$ (77%) in 2022. To estimate emissions from other emission sources in this sector (for which no emissions were reported in AERs), national energy statistics (from Statistics Netherlands) are combined with IEFs from the AERs or with default EFs (see Table 3.3).

Table 3.3 Default EFs for electricity production (g/GJ), only used for fuel consumption and emissions that were not reported by individual companies

Substance name	Natural gas	Bio gas	Wood
NMVOC	2.6[1]	2.6[4]	1.33[5]
Sulphur dioxide	0.281[1]	0.281[4]	10.8[6]
Nitrogen oxides as NO_2	19.1[2]	89[4]	70[5]
Ammonia			1.2[7]
Carbon monoxide	15.0[2]	39[4]	150[5]
PM_{10}	0.2[3]	0.89[4]	10[5]

1. EMEP/EEA Guidebook (2019), 1A1, table 4.6, default value.
2. Specific EFs derived from reported emissions in e-AERs.
3. EMEP/EEA Guidebook (2019), 1A1, table 3.17, default value.
4. EMEP/EEA Guidebook (2019), 1A1, table 3.4, default value.
5. Koppejan and De Bree. 2018.
6. EMEP/EEA Guidebook (2019), 1A1, table 3.7, default value
7. EMEP/EEA Guidebook (2019), 1A2, table 3.5, default value

Emission data in AERs is calculated by companies on the basis of stack measurements or (default or technology-specific) emission factors. When emissions in AERs are calculated on the basis of stack measurements, they are calculated using uncorrected measurement data. To calculate industrial emissions. Dutch companies are obligated to follow the guidance given in the Netherlands PRTR regulations. The relevant documents are to be found on the government website www.infomil.nl (in Dutch only). They apply to three types of plants:

- small combustion plants;
- large combustion plants;
- waste incineration plants.

These documents explicitly state that emissions shall be calculated using uncorrected measurement data, and that the confidence interval may not be subtracted. Additionally, the calculations shall include emissions during stops, starting-up and incidents. The competent authorities confirmed that they check whether companies use uncorrected measurement data for calculating emissions.

The AERs might be incomplete when a company does not report emissions that are below the reporting threshold. Additional estimates are made for these missing emissions:

- PCB emissions are not reported by individual companies and are therefore calculated for the entire sector. The activity data is taken from the energy statistics and can be accessed here: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB. The PCB EF for solid biomass is taken from the EMEP/EEA Guidebook (2019), chapter 1A2, table 3.5. The PCB EF for waste is from the EMEP/EEA Guidebook (2019), chapter 5C1a, table 3.1. The PCB EF of bituminous coal in 1A1 and 1A2 is based on the correlation between the dioxin and PCB EFs in the Guidebook and the reported dioxin emissions in the Dutch emission inventory. This results in an EF of 52.4 µg/GJ in 1990 and 0.67 µg/GJ from 1995 onwards (see Table 3.4). See Honig *et al.* (2024) for more details regarding the PCB EF.
- Heavy metal emissions from the use of natural gas are not reported by individual companies either and are therefore calculated for the entire sector. The activity data is taken from the energy statistics and can be accessed here: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB. The mercury EF is based on a study from the Dutch gas company Gasunie, while Tier 1 emission factors from the EMEP/EEA Guidebook 2019 (1A1, table 3.4) are used for the other metals. The resulting emission factors are represented in Table 3.5.
- PAH, dioxin and HCB emissions are not always reported by individual companies. Individual estimates of these emissions have been made for all industrial stationary combustion sectors and for solid fuels, liquid fuels (except diesel and LPG), gaseous fuels (except natural gas) and biomass (except biogas). The emissions have been calculated as a fraction of the reported hydrocarbon emission. The fraction is based on ratio between the Tier 1 emission factors of PAH/dioxin/HCB/PCB with NMVOC from chapters 1A1 and 1A2 of the EMEP/EEA Guidebook (2023) and an assumed abatement efficiency of 90%. If the individual emission is higher than the reporting threshold, it is assumed that the emission is equal to the reporting threshold (assuming that a company would have reported these emissions if they exceeded the reporting threshold). If a company has already reported a certain emission, the individual estimate of that emission is discarded for that company, and only the reported emission is used.
- HCB emissions from incineration plants are not reported by individual companies and are therefore calculated with an EF of 0.2 mg/Mg waste (lower value of the EF from the EMEP/EEA Guidebook 2019, chapter 5.C.1.a, table 3.2).
- $PM_{2.5}$ emissions are either reported by individual companies or calculated using default $PM_{2.5}/PM_{10}$ ratios. These ratios are based on PM_{10} and $PM_{2.5}$ emissions reported by individual companies (which differ per sector, activity and fuel) or literature (a.o. Visschedijk *et al*. (2004) and Ehrlich *et al*. (2007)). A complete list of the $PM_{2.5}/PM_{10}$ ratios, including references, is presented in

Honig *et al*. (2024) and in Visschedijk & Dröge (2019). The latter report can be downloaded via: [Visschedijk & Dröge. 2019](#).

Table 3.4 List of PCB emission factors of solid fuels (Microgram/GJ)

Year	Solid fuels	Waste	Biomass
1990	52.4	0.0034	0.06
1991	42.1	0.0034	0.06
1992	31.7	0.0034	0.06
1993	21.4	0.0034	0.06
1994	11.0	0.0034	0.06
from 1995	0.67	0.0034	0.06

Table 3.5 List of heavy metal EFs of natural gas (mg/GJ)

Pollutant	1990-2009	2010-2016	from 2017
Hg	0.039	0.023	0.01
Pb		0.0015	
Cd		0.00025	
As		0.12	
Cr		0.00076	
Cu		0.076	
Ni		0.00051	
Se		0.0112	
Zn		0.0015	

3.2.5 *Methodological issues*

Emissions are based on data in the AERs from individual facilities (Tier 3 methodology). A company needs to submit an environmental report if one or more of the activities of the company is included in annex 1 of the E-PRTR regulation. These companies need to report emissions that exceeded the reporting threshold. For some pollutants, the Dutch reporting thresholds are lower than the European reporting thresholds (see the list of thresholds (in Dutch): https://www.e-mjv.nl/sites/default/files/2018-07/stoffenlijst_integraal_prtr-verslag.pdf). Emissions and fuel consumption data in the AERs are systematically examined for inaccuracies by checking the resulting IEFs. If the AERs provide data of sufficient quality, the information is used to calculate an IEF for a cluster of reporting companies (aggregated by NACE code). These IEFs are fuel- and sector-specific and are used to calculate emissions by companies that are not individually assessed.

$$\mathbf{IEF}_{\mathbf{ER\text{-}I}}\ \mathbf{(NACE.\ fuel)} = \frac{\mathbf{Emissions}_{\mathbf{ER\text{-}I}}\ \mathbf{(NACE.\ fuel)}}{\mathbf{Energy\ use}_{\mathbf{ER\text{-}I}}\ \mathbf{(NACE.\ fuel)}}$$

where:
IEF = Implied emission factor from individual companies
ER-I = Emission Registration database for individual companies

Next, combustion emissions by companies that are not individually assessed in this NACE category are calculated from their energy use according to the energy statistics (from Statistics Netherlands), multiplied by the IEF. If the data from the individual companies is insufficient to calculate an IEF, a default EF is used (see Table 3.3).

ER-C_emission (NACE. fuel) = IEF ER-I (NACE. fuel) * energy statistics (NACE. fuel)

where:
ER-C = Emission Registration database for emission data that is not based on emissions reported in an AER

Total combustion emissions are the sum of emissions by the individual companies (ER-I) plus emissions by the companies that are not individually assessed (ER-C).

3.2.6 *Uncertainties and time series consistency*

Uncertainties are explained in Section 1.7.

3.2.7 *Source-specific QA/QC and verification*

Emissions and fuel consumption data in the AERs are systematically examined for inaccuracies by checking the resulting IEFs, the emission trends and the IEF trends. If the AERs provide data of high enough quality (see Section 1.6 on QA/QC), the information is used. Section 3.1 of the ENINA methodology report (Honig *et al.*, 2024) provides a more detailed description of the quality checks of the AERs.

3.2.8 *Source-specific recalculations*

The following recalculations were performed:

Recalculation of reported emissions from individual companies
Corrected NMVOC emission of 1 waste incineration plant in 2014, resulting in an emission decrease of 0.78 Mg NMVOC (for 2014).

Recalculation of $PM_{2.5}$ and $EC_{2.5}$ emissions
Error correction for the $PM_{2.5}$ and $EC_{2.5}$ fractions in the period 2012-2021. The change in $PM_{2.5}$ and $EC_{2.5}$ emissions is shown in table 3.6

Table 3.6 Overview of change in $PM_{2.5}$ and $EC_{2.5}$ emissions

Pollutant	Unit	NFR	2015	2020	2021
$PM_{2.5}$	ton	1A1a	-2.17	-8.30	-10.73
$EC_{2.5}$	ton	1A1a	-0.29	-1.10	-1.42

Recalculation of non-reported PAH, dioxin and HCB emissions
In the previous submission, a methodology has been developed to estimate PAH, dioxin and HCB emissions for companies that do not report these emissions (in response to NECD review recommendation NL-1A1b-2018-0001). Some errors occurred in the additional estimate of PAH, dioxin and HCB emissions, which have been corrected in this submission.
The change in PAH, dioxin and HCB emissions is represented in Table 3.7.

Table 3.7 Overview of change in PAH, dioxin and HCB emissions

Pollutant	Unit	NFR	2005	2010	2015	2020	2021
PAH4	g	1A1a	+48.8	+179.0	+194.1	+169.8	+12.6
Dioxin	mg	1A1a	+8.2	+6.3	+29.0	+1.2	+0.5
HCB	g	1A1a	+1.6	+0.7	+34.4	+0.7	+0.1

3.2.9 *Source-specific planned improvements*

There are no planned source-specific improvements.

3.3 Industrial combustion (1A1b, 1A1c and 1A2)

3.3.1 *Source category description*

This section comprises the following source categories:

- 1A1b Petroleum refining;
- 1A1c Manufacture of solid fuels and other energy industries;
- 1A2a Iron and steel;
- 1A2b Non-ferrous metals;
- 1A2c Chemicals;
- 1A2d Pulp, paper and print;
- 1A2e Food processing, beverages and tobacco;
- 1A2f Non-metallic minerals;
- 1A2gviii Other.

The 1A2gviii sector includes industries for: mineral products (cement, bricks, other building materials, glass), textiles, wood and wood products and machinery.

3.3.2 *Key sources*

The source categories 1A1b, 1A2a, 1A2b, 1A2c and 1A2gviii are key sources of the pollutants listed in Table 3.8.

Table 3.8 Pollutants for which the Industrial combustion sector (NFR 1A1b. 1A1c and 1A2) is a key source

Category / Subcategory		Pollutant	Contribution to total of 2022 (%)
1A1b	Petroleum refining	SO_x	43.7
		NO_x	2.5
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	SO_x	15.4
		CO	14.2
		NO_x	2.6
		PCB	33.0
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	NO_x	4.1
		SO_x	6.1
		CO	2.8
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO_x	7.0
		Hg	11.3

3.3.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is provided in Table 3.9. Emissions have been reduced since 1990 for most pollutants, except for dioxins. Reduction in the emissions of the main pollutants has been due to an improvement in the abatement techniques used. Fluctuations in dioxin emissions have been caused by differences in the fuels used and/or incidental emissions. The reduction in emissions of SO_x and PM_{10} is mainly due to a shift in fuel use by refineries, i.e. from oil to natural gas.

Table 3.9 Overview of trends in emissions

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**101**	**6.3**	**110**	**0.57**	**5.8**	**7.8**	**8.2**	**0.58**	**266**
1995	78	6.7	89	0.32	5.0	6.5	6.7	0.56	215
2000	49	2.0	46	0.05	3.3	4.8	4.9	0.35	161
2005	49	2.0	46	0.11	1.4	1.8	2.0	0.14	156
2010	40	4.6	25	0.46	1.2	1.9	3.9	0.07	127
2015	35	2.9	20	0.41	0.6	0.8	1.1	0.05	99
2020	28	2.1	16	0.64	0.5	0.7	1.0	0.04	82
2021	27	2.0	16	0.60	0.4	0.7	0.8	0.04	78
2022	**26**	**2.1**	**15**	**0.41**	**0.4**	**0.6**	**0.7**	**0.03**	**81**
1990-2022 period[1]	-75	-4.1	-95	-0.16	-5.4	-7.2	-7.5	-0.55	-186
1990-2022 period[2]	-74%	-66%	-87%	-28%	-93%	-92%	-91%	-94%	-70%

Table 3.9 Overview of trends in emissions (continued)

	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
Year	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	**1.97**	**0.14**	**0.20**	**0.01**	**1.00**	**0.23**	**2.58**	**1.49**	**67.1**	**0.05**	**3.15**
1995	3.95	0.17	0.10	1.02	0.38	0.22	3.19	2.23	80.6	0.06	3.68
2000	0.12	0.01	0.12	0.35	0.01	0.07	0.55	0.23	18.1	0.01	1.06
2005	0.04	0.01	0.03	0.85	0.01	0.81	0.10	0.14	6.64	0.10	0.61
2010	3.11	0.01	0.06	5.79	0.13	0.05	0.17	1.17	0.05	0.14	9.90
2015	0.11	0.01	0.09	0.12	0.03	0.03	0.04	0.04	0.05	0.02	1.28
2020	0.12	0.01	0.08	0.05	0.01	0.03	0.22	0.79	0.45	0.02	0.54
2021	0.31	0.01	0.08	0.03	0.01	0.04	0.50	0.10	0.45	0.02	0.26
2022	**0.16**	**0.01**	**0.07**	**0.03**	**0.01**	**0.03**	**0.11**	**0.04**	**0.20**	**0.02**	**1.29**
1990-2022 period[1)]	-1.81	-0.13	-0.13	0.02	-0.99	-0.20	-2.47	-1.45	-66.9	-0.03	-1.86
1990-2022 period[2)]	-92%	-94%	-64%	261%	-99%	-85%	-96%	-97%	-100%	-50%	-59%

1. Absolute difference.
2. Relative difference compared to 1990 in %.

3.3.4 *Activity data and (implied) emission factors*

Emission data is based on reported emissions in AERs (Annual Environmental Reports) and on calculated emissions for the companies that did not report their emissions in an AER.

Petroleum refining (1A1b)
All emission data is based on emissions reported in AERs. Emissions from all refineries are included in 1A1b, with the exception of 1 industrial plant that refines and processes oil and that combusts refinery gas. Based on its economic main activity, this company is either included in 1A1b Petroleum Refining (from 2009 onwards) or in 1A1c Manufacture of Solid Fuels and Other Energy Industries (2005-2008).

Manufacture of solid fuels and other energy industries (1A1c)
Emission data is based on reported emissions in AERs and calculated emissions for the companies that did not report their emissions in an AER.

Iron and steel (1A2a)
Emission data is mainly based on reported emissions in AERs. A small part is calculated emissions for the companies that did not report their emissions in an AER (7% of CO emissions and 1% of SO_x emissions in 2022).

Non-ferrous metals (1A2b)
Emission data is based on reported emissions in AERs and calculated emissions for the companies that did not report their emissions in an AER. For this source category, 1% of the NMVOC emissions, 9% of the NO_x emissions, 56% of the SO_x emissions, and 4% of $PM_{2.5}$ emissions were not reported in AERs (in 2022).

Chemicals (1A2c)
Emission data is based on reported emissions in AERs and calculated emissions for the companies that did not report their emissions in an AER. For this source category, 3% of the NMVOC emissions, 4% of the NO_x emissions, 4% of the SO_x emissions, and 2% of the $PM_{2.5}$ emissions were not reported in AERs (in 2022).

Pulp, paper and print (1A2d)
Emission data is based on reported emissions in AERs and calculated emissions for the companies that did not report their emissions in an AER. For this source category, 75% of the NMVOC emissions, 7% of the NO_x emissions, 1% of the SO_x emissions, and 100% of the $PM_{2.5}$ emissions were not reported in AERs (in 2022).

Food processing, beverages and tobacco (1A2e)
Emission data is based on reported emissions in AERs and calculated emissions for the companies that did not report their emissions in an AER. For this source category, 34% of the NMVOC emissions, 37% of the NO_x emissions, 48% of the SO_x emissions, and 51% of the $PM_{2.5}$ emissions were not reported in AERs (in 2022).

Non-metallic minerals (1A2f)
Emission data is based on reported emissions in AERs and calculated emissions for the companies that did not report their emissions in an AER. Emissions from non-metallic minerals are allocated to 1A2gviii.

Other (1A2gviii)
This sector includes all combustion emissions from the industrial sectors that do not belong to the categories 1A2a to 1A2e. Emission data is based on reported emissions in AERs and calculated emissions for the companies that did not report their emissions in an AER. For this source category, 41% of the NMVOC emissions, 22% of the NO_x emissions, 1% of the SO_x emissions, and 22% of the $PM_{2.5}$ emissions were not reported in AERs (in 2022).

For some of the above-mentioned categories, emissions were not entirely available from the AERs, as not all of the companies need to report their emissions. The remaining part of the emissions were calculated using national energy statistics and default EFs or IEFs from other companies that did report their emission in an AER (see Table 3.10).

Table 3.10 Emission factors for the Industrial sector (g/GJ)

Substance name	Natural gas	Bio gas	Coal	Fuel oil	Wood (wood industries)	Wood (other industry)
NMVOC	[1]	2.6[11]	10[7]	50[8]	8.4[10]	1.33[10]
Sulphur dioxide	0.281[2]	0.281[11]	450[7]	47[9]	11[12]	11[12]
Nitrogen oxides as NO_2	[3]	89[11]	150[7]	64[6]	150[10]	75[10]
Ammonia					1.2[12]	1.2[12]
Carbon monoxide	[4]	39[11]	150[7]	66[9]	750[10]	16[10]
PM_{10}	0.297[5]	0.89[11]	60[7]	20[9]	27[10]	12[10]

1. For 1A2c, an EF from the Guidebook is used of 2.6 g/GJ (EMEP/EEA Guidebook (2019), 1A1, table 3.4, default value). For 1A2b, 1A2d, 1A2e and 1A2g, a specific EF is used of 5.2, 5.2, 3.8 and 5.2 g/GJ, respectively (derived from emissions reported in e-AERs).
2. EMEP/EEA Guidebook (2019), 1A1, table 4.6, average value.
3. For 1A2b, 1A2c, 1A2d, 1A2e and 1A2g, a specific EF is used of 40, 55, 43, 30 and 37 g/GJ, respectively (derived from emissions reported in AERs);
4. For 1A2b, 1A2c, 1A2d, 1A2e and 1A2g, a specific EF is used of 35, 40, 35, 40 and 35 g/GJ, respectively (derived from emissions reported in AERs).
5. EMEP/EEA Guidebook (2019), 1A1, table 4.6, minimum value.
6. Methodology report by Guis (2006).
7. EMEP/EEA Guidebook (2019), 1A2, table 3.2, minimum value.
8. EMEP/EEA Guidebook (2019), 1A4, table 3.31, default value
9. EMEP/EEA Guidebook (2019), 1A2, table 3.4, default value
10. Koppejan and De Bree (2018).
11. EMEP/EEA Guidebook (2019), 1A1, table 3.4, default value
12. EMEP/EEA Guidebook (2019), 1A2, table 3.5, default value

The AERs might be incomplete when a company does not report emissions that are below the reporting threshold. Additional estimates are made for these missing emissions:

- PCB emissions are not reported by individual companies and are therefore calculated for the entire sector. The activity data is taken from the energy statistics and can be accessed here: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB. The PCB EF for solid biomass is from the EMEP/EEA Guidebook (2019), chapter 1A2, table 3.5. The PCB EF of bituminous coal in 1A1 and 1A2 is based on the correlation between the dioxin and PCB EFs in the Guidebook and in the Dutch emission inventory. This results in an EF of 52.4 µg/GJ in 1990 and 0.67 µg/GJ from 1995 onwards (see Table 3.11). See Honig *et al.* (2024) for more details regarding the PCB EF.

- Heavy metal emissions from the use of natural gas are not reported by individual companies either and are therefore calculated for the entire sector. The activity data is taken from the energy statistics and can be accessed here: [https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB.](https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB) The mercury EF is based on a study from the Dutch gas company Gasunie, while Tier 1 emission factors from the EMEP/EEA Guidebook 2019 (1A1, table 3.4) are used for the other metals. The resulting emission factors are represented in Table 3.12.
- Heavy metal emissions from other fuels (other than natural gas) are not always reported by individual companies. Individual estimates of these metal emissions have been made for the refineries (1A1b), the non-ferro sector (1A2b), the chemical sector (1A2c) and the mineral products sector (1A2gviii). The EFs are from the EMEP/EEA Guidebook (2019), combined with an abatement of 50% for mercury. 90% for selenium and 95% for the other metals (from: EMEP/EEA Guidebook 2019, chapter 1A1, page 78). The emissions are calculated for the entire sector and then allocated to the relevant companies. If a company has already reported metal emissions, then these reported emissions are used in the inventory (instead of the calculated emission). If the allocated emission exceeds the reporting threshold, it is assumed that the emission of that company is equal to the reporting threshold. Details of the emission calculation are available in chapter 3.1.2.2 of the ENINA methodology report (Honig *et al.*, 2024). For 1A2a, no additional heavy metals are calculated. The emissions in this sector are entirely reported by the iron and steel company in the Netherlands, and the emissions are reported in 1A2a and 2C1. Since it is not always possible to correctly allocate the heavy metal emissions between 1A2a and 2C1, the emissions are only reported in 2C1 for most years.
- PAH, dioxin and HCB emissions are not always reported by individual companies either. Individual estimates of these emissions have been made for all industrial stationary combustion sectors and for solid fuels, liquid fuels (except diesel and LPG), gaseous fuels (except natural gas) and biomass (except biogas). The emissions have been calculated as a fraction of the reported hydrocarbon emission. The fraction is based on ratio between the Tier 1 emission factors of PAH/dioxin/HCB/PCB with NMVOC from chapters 1A1 and 1A2 of the EMEP/EEA Guidebook (2019) and an assumed abatement efficiency of 90%. If the individual emission exceeds the reporting threshold, it is assumed that the emission is equal to the reporting threshold (assuming that a company would have reported these emissions if they were above the reporting threshold). If a company has already reported a certain emission, the individual estimate of that emission is discarded for that company, and only the reported emission is used.

- $PM_{2.5}$ emissions are either reported by individual companies or calculated using default $PM_{2.5}/PM_{10}$ ratios. These ratios are based on PM_{10} and $PM_{2.5}$ emissions reported by individual companies (which differ per sector, activity and fuel) or literature (a.o. Visschedijk, *et al*. (2004) and Ehrlich *et al*. (2007)). A complete list of the $PM_{2.5}/PM_{10}$ ratios, including references, is presented in Honig *et al*. (2024) and in Visschedijk & Dröge (2019). The latter report can be downloaded via: Visschedijk & Dröge. 2019.

Table 3.11 List of PCB emission factors of solid fuels (μg/GJ)

Year	**Solid fuels** μg/GJ	**Bio Mass** μg/GJ
1990	52.4	0.06
1991	42.1	0.06
1992	31.7	0.06
1993	21.4	0.06
1994	11.0	0.06
from 1995	0.67	0.06

Table 3.12 List of heavy metal EFs of natural gas (mg/GJ)

Pollutant	**1990-2009**	**2010-2016**	**from 2017**
Hg	0.039	0.023	0.01
Pb		0.0015	
Cd		0.00025	
As		0.12	
Cr		0.00076	
Cu		0.076	
Ni		0.00051	
Se		0.0112	
Zn		0.0015	

3.3.5 *Methodological issues*

Emissions are based on data in the AERs from individual facilities (Tier 3 methodology). A company needs to submit an environmental report if one or more of the activities of the company is included in annex 1 of the E-PRTR regulation. These companies need to report emissions that exceed the reporting threshold. For some pollutants, the Dutch reporting thresholds are lower than the European reporting thresholds (see the thresholds in Dutch: https://www.e-mjv.nl/sites/default/files/2018-07/stoffenlijst_integraal_prtr-verslag.pdf). The emissions and fuel consumption data in the AERs are systematically examined for inaccuracies by checking the resulting IEFs. If environmental reports provide data of high enough quality, the information is used to calculate an IEF for a cluster of reporting companies (aggregated by NACE code). These IEFs are fuel- and sector-dependent and are used to calculate the emissions by companies that are not individually assessed.

$$\mathbf{IEF}_{\mathbf{ER\text{-}I\ (NACE.\ fuel)}} = \frac{\mathbf{Emissions}_{\mathbf{ER\text{-}I\ (NACE.\ fuel)}}}{\mathbf{Energy\ use}_{\mathbf{ER\text{-}I\ (NACE.\ fuel)}}}$$

where:
EF = Implied emission factor from individual companies
ER-I = Emission Registration database for individual companies

Next, combustion emissions by the companies that are not individually assessed in this NACE category are calculated from the energy use according to the energy statistics (from Statistics Netherlands), multiplied by the IEF. If the data from the individual companies is insufficient to calculate an IEF, a default EF is used (see Table 3.10).

ER-C_emission $_{(NACE.\ fuel)}$ = IEF $_{ER\text{-}I\ (NACE.\ fuel)}$ * energy statistics $_{(NACE.\ fuel)}$

where:
ER-C = Emission Registration database for emission data that is not based on emissions reported in an AER

The total combustion emissions are the sum of emissions by the individual companies (ER-I) plus emissions by the companies that are not individually assessed (ER-C).

The AERs contain emission data from individual plants at the level of individual installations (or sometimes a group of installations). The AER data is not always sufficiently detailed to indicate whether the emissions are resulting from combustion or from processes (for example when emissions are calculated from stack measurements that include concentrations from both combustion and processes). Therefore, the emissions are split into combustion emissions (allocated in NFR 1A2) and process emissions (allocated in NFR2), based on the question whether the consumption of fuels is reported in an installation in the AER. Because of this split, emissions are sometimes only included in the energy sector or only in the industrial sector. The emissions in the energy sector should best be viewed together with the emissions in the corresponding industrial processes sector.

The notation key 'IE' (Included Elsewhere) is used in the energy sector when the complete emission of a company is included in the industrial processes sector (as described in the paragraph above). This is valid for the following subcategories:

- 1A1c: Emissions from the coke plant in the Netherlands are included in 1A2a and/or 2C1, as it is part of the combined coke / iron and steel plant.
- 1A2a: Emissions from the combined coke plant / iron and steel plant are allocated in 1A2a and/or in 2C1
- 1A2b: Emissions from the non-ferrous metals industry are included in 1A2b, 2C3 and/or 2C6
- 1A2f: Emissions from the non-metallic minerals industry are reported in 1A2gviii

The notation key 'NE' (Not Estimated) is used for several subcategories for different reasons:

- Emissions are sometimes not estimated, because these emissions are not reported by the individual companies in their AERs (below

the reporting threshold). The reporting thresholds are represented in Table 3.13, including a comparison to the 2022 national emission.
- Emissions of NH_3 from gaseous, liquid and solid fuels and emissions of PCB and HCB from gaseous and liquid fuels are not estimated, because the EMEP/EEA Guidebook (2019) does not contain a methodology.

Table 3.13 Comparison between the reporting threshold in annual environmental reports (AERs) and the national emissions in 2022

Pollutant	Unit	National emission in 2022	Reporting threshold in AERs	Relative contribution (%)
NO_x (as NO_2)	Gg	194.56	0.01	0.01%
NMVOC	Gg	241.69	0.01	0.00%
SO_x (as SO_2)	Gg	19.62	0.02	0.10%
NH_3	Gg	121.15	0.01	0.01%
PM_{10}	Gg	26.88	0.005	0.02%
CO	Gg	397.90	0.01	0.00%
Pb	Mg	4.50	0.05	1.11%
Cd	Mg	0.79	0.001	0.13%
Hg	Mg	0.49	0.001	0.21%
As	Mg	0.31	0.02	6.42%
Cr	Mg	3.50	0.1	2.86%
Cu	Mg	104.76	0.1	0.10%
Ni	Mg	1.68	0.05	2.98%
Zn	Mg	155.63	0.2	0.13%
PCDD/ PCDF (dioxins/ furans)	g I-TEQ	30.26	0.01	0.03%
benzo(a) pyrene	Mg	1.61	0.001	0.06%
benzo(b) fluoranthene	Mg	1.55	0.001	0.06%
benzo(k) fluoranthene	Mg	0.82	0.001	0.12%
Indeno (1.2.3-cd) pyrene	Mg	0.79	0.001	0.13%
Total 1-4	Mg	4.77	0.001	0.02%
HCB	kg	3.32	0.01	0.30%

3.3.6 *Uncertainties and time series consistency*

Uncertainties are explained in Section 1.7.

Time series consistency

A large part of the emission inventory is built from emission data reported by individual companies. If a company does not report any emissions at all, the emissions are calculated on the basis of energy statistics of these non-reporting companies.

The companies do not have to report their emissions when these are below a certain threshold. This is often the case for the emissions of heavy metals and PAHs. In order to ensure a consistent time series, metal emissions have also been calculated from the energy statistics combined with EFs from the EMEP/EEA Guidebook (2019), and PAH emissions have been calculated from the ratio between the reported hydrocarbon emissions and the PAH emissions. A more detailed description of the methodology is available in chapter 3.1.2.2 of the ENINA methodology report (Honig *et al.*, 2024).

3.3.7 Source-specific QA/QC and verification

Emissions and fuel consumption data in the AERs were systematically examined for inaccuracies by checking the resulting IEFs. If the environmental reports provided data of high enough quality (see Section 1.6 on QA/QC), the information was used.

3.3.8 Source-specific recalculations

The following recalculations were performed:

Recalculation as a result of corrections of emissions reported by individual companies

Several companies have updated the reported emissions in their AERs, and this has been included in the emissions reported in the NFR tables. The resulting changes in emissions are represented in Table 3.14

Table 3.14 Overview of recalculations as a result of corrections in reported emissions by individual companies

Pollutant	Unit	NFR	2021
PM_{10}	ton	1A2c	+0.04
$PM_{2.5}$	ton	1A2c	+0.04
CO	ton	1A2d	-17.8
CO	ton	1A2e	+2.0
NMVOC	ton	1A2c	-0.6
NMVOC	ton	1A2d	+0.04
NMVOC	ton	1A2e	+0.06
NO_x	Ton	1A1c	-659.3
NO_x	ton	1A2a	-0.15
NO_x	ton	1A2c	+0.00
NO_x	ton	1A2d	-3.1
NO_x	ton	1A2e	+33.6
NO_x	ton	1A2gviii	+0.47
SO_x	ton	1A1c	+1.0
SO_x	ton	1A2a	-0.5
SO_x	ton	1A2c	+0.03
SO_x	ton	1A2e	+0.5

Reallocation of emissions

- NH_3 emissions from a chemical plant have been reallocated from 1A2c to 2B in 2021 (30 Mg NH_3)
- Lead emissions of the iron and steel plant have been reallocated from 1A2a to 2C1 in 2011 (15 Mg lead)

Recalculation as a result of updated energy statistics

Emissions for companies that do not report emissions themselves, are calculated based on energy statistics. The energy statistics have been updated (2015-2021), resulting in updated emission estimates. The resulting changes in the emissions are represented in Table 3.15.

Table 3.15 Overview of recalculations as a result of updated energy statistics

Pollutant	Unit	NFR	2015	2020	2021
NH_3	ton	1A2gviii			-0.05
PM_{10}	ton	1A2d			+0.07
PM_{10}	ton	1A2gviii	-0.008	+0.04	-0.05
$PM_{2.5}$	ton	1A2d			+0.07
$PM_{2.5}$	ton	1A2gviii	-0.008	+0.001	-0.05
CO	ton	1A2d			+8.22
CO	ton	1A2gviii	-0.46	+5.36	+4.84
NMVOC	ton	1A2d			+1.22
NMVOC	ton	1A2gviii	-0.06	+0.81	+0.47
NO_x	ton	1A2d			+9.03
NO_x	ton	1A2gviii	-0.83	+5.33	+3.59
SO_x	ton	1A2d			+0.07
SO_x	ton	1A2gviii	-0.006	+0.04	+0.04

Recalculation of missing PAH, dioxin and HCB emissions
In the previous submissions, a methodology has been developed to estimate PAH, dioxin and HCB emissions for companies that do not report these emissions (in response to NECD review recommendation NL-1A1b-2018-0001). Some errors occurred in the additional estimate of PAH, dioxin and HCB emissions, which have been corrected in this submission.
The changes in PAH, dioxin and HCB emissions are represented in Table 3.16.

Table 3.16 Overview of changes in PAH, dioxin and HCB emissions

Pollutant	Unit	NFR	2005	2010	2015	2020	2021
PAH4	g	1A1b			+24.89		
PAH4	g	1A2a		-0.04		-0.03	-0.02
PAH4	g	1A2c			+23.12		
PAH4	g	1A2d	+2.68	+22.87	+3.5	+4.49	+4.68
PAH4	g	1A2gviii				+153.59	+234.85
Dioxin	mg	1A1b			+4.04		
Dioxin	mg	1A2a		-0.02		-0.01	-0.01
Dioxin	mg	1A2c			+0.11	-0.00	-0.05
Dioxin	mg	1A2gviii				+0.44	+0.67
HCB	g	1A2d	+0.00	+0.00	+0.00	+0.00	+0.00
HCB	g	1A2gviii				+0.02	+0.03

3.3.9 Source-specific planned improvements
There are no planned source-specific improvements.

3.4 Other stationary combustion (1A4ai. 1A4bi. 1A4ci and 1A5a)

3.4.1 Source category description
This section describes the following source categories:
- 1A4ai Commercial/Institutional: Stationary. This source category comprises commercial and public services (banks, schools and

hospitals, trade, retail, communication). It also includes the production of drinking water and miscellaneous combustion emissions from waste handling activities and from wastewater treatment plants.

- 1A4bi Residential: Stationary. This source category refers to domestic fuel consumption for space heating, water heating and cooking. About three-quarters of the sector's consumption of natural gas is used for space heating.
- 1A4ci Agriculture/Forestry/Fisheries: Stationary. This source category comprises stationary combustion emissions from agriculture, horticulture, greenhouse horticulture, cattle breeding and forestry.
- 1A5a Other: Stationary. There are no emissions reported in this sector. Emissions from military are included in 1A4ai.

3.4.2 *Key sources*

The Small stationary combustion sector is a key source of the pollutants listed in Table 3.17.

Table 3.17 Pollutants for which the Small combustion sector (NFR 1A4 and 1A5) is a key source

Category / Subcategory	Pollutant	Contribution to total of 2022 (%)
1A4bi Residential: Stationary	NO_x	3.0
	NMVOC	3.7
	CO	15.8
	PM_{10}	17.9
	$PM_{2.5}$	31.8
	BC	24.4
	Dioxins	20.9
	PAH	67.8
	Hg	7.7
	Cd	7.4

3.4.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is provided in Table 3.18. Emissions of all pollutants have decreased since 1990, while fuel use has increased slightly.

The decrease of Hg and Pb emissions between 1990 and 1991 in NFR 1A4ai was caused by the fact that from 1991 onwards, no hard coal has been used in the Services sector. The steady slow increase of HCB from 2007 onwards is caused by the use of wood in the Services sector.

Table 3.18 Overview of trends in emissions

Year	Main Pollutants				Particulate Matter			Other	
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**41**	**14**	**2.18**	**0.35**	**7.2**	**7.7**	**8.3**	**0.91**	**78**
1995	45	15	1.16	0.38	7.5	8.0	8.6	0.98	88
2000	40	13	0.69	0.31	6.6	6.9	7.4	0.83	78
2005	35	15	0.55	0.29	6.7	7.1	7.6	0.84	85
2010	35	21	0.71	0.35	7.4	7.9	8.4	0.91	107
2015	23	15	0.51	0.31	5.6	6.0	6.3	0.67	81
2020	14	11	0.52	0.41	4.6	4.9	5.1	0.55	67
2021	15	12	0.57	0.43	5.0	5.3	5.6	0.61	76
2022	**12**	**11**	**0.51**	**0.41**	**4.8**	**5.1**	**5.4**	**0.59**	**70**
1990-2022 period[1)]	-29	-2.5	-1.67	0.06	-2.4	-2.6	-3.0	-0.32	-8.4
1990-2022 period[2)]	-70%	-18%	-77%	17%	-34%	-34%	-36%	-35%	-11%

Table 3.18 Overview of trends in emissions (continued)

Year	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	**0.92**	**0.07**	**0.14**	**108**	**3.5**	**0.19**	**3.5**	**0.83**	**2.1**	**0.01**	**2.4**
1995	0.15	0.05	0.07	8.2	4.0	0.12	0.05	0.41	0.39	0.01	0.86
2000	0.09	0.04	0.05	7.5	3.6	0.09	0.01	0.35	0.02	0.01	0.69
2005	0.09	0.05	0.05	7.7	4.0	0.08	0.00	0.39	0.01	0.01	0.75
2010	0.12	0.07	0.06	8.2	4.9	0.10	0.01	0.52	0.02	0.01	1.0
2015	0.09	0.05	0.05	7.0	3.7	0.07	0.00	0.42	0.00	0.01	0.81
2020	0.08	0.05	0.03	6.1	3.0	0.06	0.00	0.38	0.00	0.01	0.72
2021	0.09	0.06	0.04	6.5	3.4	0.07	0.00	0.44	0.00	0.01	0.86
2022	**0.09**	**0.06**	**0.04**	**6.3**	**3.3**	**0.05**	**0.00**	**0.43**	**0.00**	**0.00**	**0.84**
1990-2022 period[1)]	-0.84	-0.01	-0.10	-102	-0.3	-0.14	-3.55	-0.40	-2.06	-0.01	-1.6
1990-2022 period[2)]	-91%	-11%	-71%	-94%	-7%	-73%	-100%	-48%	-100%	-54%	-65%

1. Absolute difference.
2. Relative difference compared to 1990 in %.

3.4.4 *Activity data and (implied) emission factors*

Emission data is based on reported emissions in AERs (Annual Environmental Reports) and on calculated emissions for the companies that did not report their emissions in an AER. In this source category, the share of reported emissions in AERs is relatively small (compared to the industrial combustion sector):

- 1A4ai: 34% of the SO_x emissions, 8% of the NO_x emissions, 16% of the NMVOC emissions and 0.3% of the $PM_{2.5}$ emissions were reported in AERs (in 2022).
- 1A4bi: No emission data from AERs are used in the residential sector

- 1A4ci: 1% of the NO_x and 2% of SO_x emissions were reported in AERs in 2022.

The following texts describe the calculation methods for the emissions that are not reported in an AER.

Commercial/institutional (1A4ai)
Combustion emission data from the commercial and institutional sectors is based on fuel consumption data (from Statistics Netherlands) and EFs (see Table 3.19)

Table 3.19 Emission factors for stationary combustion emissions from the Services sector (g/GJ)

Substance name	Natural gas	Bio gas	Diesel	Coal	Wood
NMVOC	2.0[1]	23[9]	20[4]	10[3]	5[8]
Sulphur dioxide	0.2[2]	0.67[9]	94[4]	450[3]	8[8]
Nitrogen oxides as NO_2	20.6[6]	74[9]	60[5]	150[3]	91[7]
Ammonia					37[7]
Carbon monoxide	15[2]	29[9]	93[4]	150[3]	50[8]
PM_{10}	0.27[2]	0.78[9]	21[4]	60[3]	91[8]

1. EMEP/EEA Guidebook (2019), 1A4, table 3.27, default value.
2. EMEP/EEA Guidebook (2019), 1A4, table 3.27, minimum value.
3. EMEP/EEA Guidebook (2019), 1A4, table 3.7, minimum value.
4. EMEP/EEA Guidebook (2019), 1A4, table 3.9, default value.
5. Van Soest-Vercammen *et al*. 2002.
6. Visschedijk and Dröge (2024). From 2005 onwards the NOx-emission factor decreases due to the further implementation of low NOx technologies (EF2005: 42.5 to EF2021: 20.6).
7. EMEP/EEA Guidebook (2019), 1A4, table 3.10, default value
8. EMEP/EEA Guidebook (2019), 1A4, table 3.10, minimum value
9. EMEP/EEA Guidebook (2019), 1A4, table 3.8, default value

Residential (1A4bi)
Combustion emission data from central heating, hot water and cooking is based on fuel consumption data (from Statistics Netherlands) and EFs (see Table 3.20). The fuel most used in this category is natural gas. The use of wood in stoves and fireplaces for heating is very small compared to the amount of natural gas used.
Combustion emissions from (wood) stoves and fireplaces were calculated by multiplying the fuel consumption per appliance type and fuel type (Statistics Netherlands) by EFs (Jansen. 2016; Visschedijk & Dröge. 2020). Particulate matter emissions from wood combustion include the emission of condensables. See Table 3.21. EFs for charcoal combustion in barbecues are also included in this table. Wood consumption per appliance type is presented in Table 3.22.

Table 3.20 Emission factors for combustion emissions from households (g/GJ)

Substance name	Natural gas (heating)	Natural gas (cooking)	Diesel	LPG	Petroleum	Coal
NMVOC	1.8[1]	2.0[2]	0.69[3]	1.9[5]	0.69[3]	300[4]
Sulphur dioxide	0.3[1]	0.3[2]	70[3]	0.3[5]	70[3]	450[4]
Nitrogen oxides as NO_2	14.4[6]	57[6]	51[3]	40[5]	51[3]	150[4]
Carbon monoxide	22[1]	30[2]	57[3]	26[5]	57[3]	2.000[4]
PM_{10}	0.281	2.2[2]	1.9[3]	1.2[5]	1.9[3]	240[4]

1. EMEP/EEA Guidebook (2019), 1A4, table 3.16, default value.
2. EMEP/EEA Guidebook (2019), 1A4, table 3.13, default value.
3. EMEP/EEA Guidebook (2019), 1A4, table 3.5, default value.
4. EMEP/EEA Guidebook (2019), 1A4, table 3.19, default value.
5. EMEP/EEA Guidebook (2019), 1A4, table 3.4, default value.
6. See Visschedijk and Dröge (2024).

Table 3.21 Emission factors for wood combustion in households

Pollutant	Unit	Fireplace	Conventional stove	Improved stove	Ecolabel stove	Ecodesign stove	Pellet	Barbecues (charcoal)
NMVOC	g/GJ	1.290	774	387	252	250	10	250
SO_x	g/GJ	12.9	12.9	12.9	12.9	12.9	12.9	10
NO_x	g/GJ	77.4	129.0	129.0	129.0	95.0	80.0	50
NH_3	g/GJ	29.4	29.4	1.47	1.47	1.47	0.29	
CO	g/GJ	3.226	6.452	3.871	2.903	2.000	300	6.000
PM_{10}	g/GJ	670	534	233	97.0	97.0	30.0	150
$PM_{2.5}$	g/GJ	637	507	221	93.0	93.0	30.0	75
$EC_{2.5}$	g/GJ	76.4	73.3	27.5	10.3	25.9	9.0	
Pb	mg/GJ	4.71	4.71	4.71	4.71	4.71	4.71	
Cd	mg/GJ	3.23	3.23	3.23	3.23	3.23	3.23	
Hg	mg/GJ	1.94	1.94	1.94	1.94	1.94	1.94	
Dioxin	ng/GJ	1.613	174	174	174	174	100	150
PAH4	mg/GJ	193.5	343.9	221.3	172.3	35.0	35.0	143.4

Note: PM EFs include both the filterable and the condensable fraction.
Source: Jansen (2016); Visschedijk & Dröge (2020); EF from charcoal use in barbecues from Visschedijk *et al*. (2024).

Table 3.22 Wood combustion per application type in NFR 1A4bi (TJ)

Appliance	1990	2005	2010	2015	2020	2022
Fireplace	3834	2972	2700	2322	1917	1783
Conventional stove	7120	5496	5520	3235	1879	1997
Improved stove	768	4649	5931	3717	2710	2759
Ecolabelled stove	0	1937	6017	6874	6550	7769
Ecodesign stove	0	0	0	77	212	735
Pellet	0	0	0	166	1218	1991

Agriculture/forestry/fishing (1A4ci)
Stationary combustion emission data is based on default EFs (Table 3.23) combined with fuel consumption data obtained from Statistics Netherlands, whose figures are in turn based on data from Wageningen Economics Research.

Table 3.23 Agriculture/Forestry/Fishing sectors (g/GJ)

Substance name	Natural gas (gas engines)	Natural gas (boilers)	Biogas	LPG	Wood
NMVOC	25.6[9]	2.0[1]	23[4]	1.3[5]	1.33[3]
Sulphur dioxide	0.2[2]	0.2[2]	0.67[4]	0.22[5]	11[1]
Nitrogen oxides as NO_2	35[9]	41[9]	74[4]	40[5]	80[3]
Ammonia					37[7]
Carbon monoxide	56[9]	15[2]	29[4]	10[5]	170[3]
PM_{10}	0.2[6]	0.27[2]	0.78[4]	2.0[5]	17[3]

1. EMEP/EEA Guidebook (2019), 1A4, table 3.27, default value.
2. EMEP/EEA Guidebook (2019), 1A4, table 3.27, minimum value.
3. From 'Kennisdocument Houtstook in Nederland' (Koppejan and De Bree, 2018).
4. EMEP/EEA Guidebook (2019), 1A4, table 3.8, default value.
5. Methodology report Zonneveld (Guis. 2006).
6. EMEP/EEA Guidebook (2019), 1A4, table 3.28, default value
7. EMEP/EEA Guidebook (2019), 1A4, table 3.10, default value.
9. Visschedijk, Dröge and Hulskotte (2024)

PCB emissions are not reported by individual companies and are therefore calculated for the entire sector. The activity data is taken from the energy statistics and can be accessed here: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB.

The PCB EF of solid fuels in 1A4 is from the EMEP/EEA Guidebook (2019), chapter 1A4, table 3.7, while the PCB EF of solid biomass (non-residential) is from the EMEP/EEA Guidebook (2019), chapter 1A4, table 3.10. The PCB EF of residential solid biomass is from the EMEP/EEA Guidebook (2019), tables 3.39–3.43. The EF of the improved stove is an average of the conventional and the high-efficiency stove. See Table 3.24.

Table 3.24 List of PCB emission factors of solid fuels (Microgram/GJ)

Year		Solid fuels
Solid fuels		170
Biomass non-residential		0.06
Biomass residential	Fireplace	0.06
	Conventional stove	0.06
	Improved stove	0.045
	Ecolabel stove	0.03
	Ecodesign stove	0.007
	Pellet	0.01

Emissions of heavy metals from the use of natural gas are also not reported by individual companies and are therefore calculated for the entire sector. The activity data is taken from the energy statistics and can be accessed here:

https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB

The mercury EF is based on a study from the Dutch gas company Gasunie. while Tier 1 emission factors from the EMEP/EEA Guidebook 2019 (1A1, table 3.4) are used for the other metals. Table 3.25 lists/ represents the resulting emission factors.

Table 3.25 List of heavy metal EFs of natural gas (mg/GJ)

Pollutant	1990-2009	2010-2016	from 2017
Hg	0.039	0.023	0.01
Pb		0.0015	
Cd		0.00025	
As		0.12	
Cr		0.00076	
Cu		0.076	
Ni		0.00051	
Se		0.0112	
Zn		0.0015	

The $PM_{2.5}$ emissions are either reported by individual companies or calculated using default $PM_{2.5}/PM_{10}$ ratios. which are based on several data sources:

- PM_{10} and $PM_{2.5}$ emissions reported by individual companies (which differ per sector, activity type and fuel);
- ratios from literature, e.g. Visschedijk *et al.* (2004) and Ehrlich *et al.* (2007).

See Honig *et al*. (2024) for the complete list of $PM_{2.5}/PM_{10}$ ratios. A complete list of the $PM_{2.5}/PM_{10}$ ratios, including references, is presented in Visschedijk & Dröge (2019). This report can be downloaded via: Visschedijk & Dröge. 2019.

3.4.5 *Methodological issues*

A Tier 2 methodology was used to calculate emissions from the sectors by multiplying the activity data (fuel consumption) by the EFs (see previous section).

The notation key 'IE' (Included Elsewhere) is used for all pollutants in source category 1A5a. Emissions from military stationary combustion are included in 1A4ai.

3.4.6 *Uncertainties and time series consistency*

Uncertainties are explained in Section 1.7.

Time series consistency

The activity data in the NFR tables is based on data from individual companies and on energy statistics for the companies that did not report an AER. Most of the emissions are also calculated from these activity data.

There are two exceptions: Both the emissions of PCB from solid fuels and solid biomass, and the emissions of heavy metals from natural gas are calculated from the energy statistics. The energy statistics differ

from the activity data in the NFR tables because the activity data from individual companies is allocated to the main economic activity, which can differ from the allocation of the energy statistics. The energy statistics can be accessed here:
https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9D6DB

This also explains why 1A4ai contains activity data included in the NFR tables, while no PCB emissions are reported from 1995 onwards.

3.4.7 *Source-specific QA/QC and verification*

General QA/QC is explained in Section 1.3.

3.4.8 *Source-specific recalculations*

The following recalculations were performed:

Recalculation as a result of updated energy statistics
Energy statistics have been improved for 1A4ai. 1A4bi and 1A4ci:

- 1A4ai: Energy statistics have been updated for natural gas, biogas, diesel (2015-2021), lignite (2019) and wood (2021).
- 1A4bi: Energy statistics have been updated for natural gas (2015-2021), petroleum (2015, 2017) and coal (2019)
- 1A4ci: Energy statistics have been updated for natural gas, biogas and LPG (2015-2020).

Table 3.26 Overview of recalculations as a result of updated activity data for the additional emissions by non-reporting companies

Pollutant	Unit	NFR	2015	2020	2021
NO_x	ton	1A4ai	+15.88	-9.48	+33.02
NO_x	ton	1A4bi	-18.06	+6.86	-47.92
NO_x	ton	1A4ci	+13.79	+27.38	-15.03
NMVOC	ton	1A4ai	-2.48	-4.98	-0.78
NMVOC	ton	1A4bi	+0.05	+0.03	-2.41
NMVOC	ton	1A4ci	-70.88	-52.20	-38.23
SO_x	ton	1A4ai	+0.13	+0.41	+1.29
SO_x	ton	1A4bi	+0.26	+0.00	-0.38
SO_x	ton	1A4ci	+0.03	+0.14	+0.06
NH_3	ton	1A4ai			+0.80
$PM_{2.5}$	ton	1A4ai	+0.16	-0.02	+2.49
$PM_{2.5}$	ton	1A4bi	+0.43	+0.30	-1.67
$PM_{2.5}$	ton	1A4ci	+0.03	+0.17	+0.62

Recalculation for PM emissions of residential wood combustion
The PM_{10} and $PM_{2.5}$ emission factor for pellet stoves have been updated (from 60 g/GJ to 30 g/GJ), resulting in a decrease of PM_{10} and $PM_{2.5}$ emissions in 2014-2021. Furthermore, the activity data for residential wood combustion has been updated for 2021, taking into account increasing natural gas prices which resulted in increased wood consumption (in all types of wood stoves). The resulting change is presented in Table 27.

Table 3.27 Overview of recalculations as a result of updated PM emission factors for pellet stoves (resulting in a decrease of emissions in 2014-2021) and updated activity data for residential wood combustion in 2021.

Pollutant	Unit	NFR	2015	2020	2021
$PM_{2.5}$	ton	1A4bi	-2.82	-46.48	+107.26
PM_{10}	ton	1A4bi	-2.82	-46.48	+115.95

3.4.9 *Source-specific planned improvements*

No source-specific improvements are planned

3.5 Fugitive emissions (1B)

3.5.1 *Source category description*

This category includes fuel-related emissions from non-combustion activities in the energy production and transformation industries:

- 1B2aiv Fugitive emissions oil: refining / storage;
- 1B2av Fugitive emissions oil: products distribution;
- 1B2b Fugitive emissions from natural gas;
- 1B2c Venting and flaring;
- 1B2d Other fugitive emissions from energy production.

For the 1990–1999 period, source category 1B1b included fugitive emissions from an independent coke production facility. which closed in 1999. The emissions from coke production from the sole combined iron and steel plant in the Netherlands have been included in category 1A2a because emissions reported by this company cannot be split into iron/steel and coke production. Therefore, from 2000 onwards, no emissions have been allocated to 1B1b, and the notation key ‘IE’ has been used.

3.5.2 *Key sources*

None of the sectors in 1B is a key category. Table 3.28 represents the main sources and pollutants in this sector.

Table 3.28 Main sources and pollutants in the Fugitive emissions sector category NFR 1B.

Category / Subcategory	Pollutant	Contribution to total of 2022 (%)
1B2aiv Refining	NMVOC	0.6
1B2av Distribution of oil products	NMVOC	1.47
1B2b Fugitive emissions from natural gas	NMVOC	1

3.5.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is provided in Table 3.29. Emissions of NMVOC decreased between 1990 and 2022.

Table 3.29 Overview of trends in emissions

Year	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	0.00	47	0.00	0.01	0.11	0.19	0.57	0.00	0.00
1995	0.00	33	0.02	0.01	0.14	0.21	0.38	0.00	0.00
2000	0.00	29	0.00	0.00	0.07	0.10	0.10	0.00	0.00
2005	0.00	21	0.00	0.00	0.07	0.10	0.11	0.00	0.00
2010	0.00	15	0.00	0.00	0.00	0.00	0.01	0.00	0.00
2015	0.00	14	0.00	0.00	0.05	0.05	0.05	0.00	0.00
2020	0.00	8.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2021	0.00	7.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2022	**0.00**	**6.9**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1990–2022 period[1)]	0.00	-40	0.00	-0.01	-0.11	-0.18	-0.56	0.00	0.00
1990–2022 period[2)]		-85%		-94%	-99%	-100%	-100%		

Table 3.34 Overview of trends in emissions (continued)

Year	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990–2022 period[1)]	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
1990–2022 period[2)]					-100%						

1. Absolute difference.
2. Relative difference compared to 1990 in %.

3.5.4 *Activity data and (implied) emission factors*

Emissions from source category 1B2aiv are available from environmental reports. Activity data for categories 1B2av and 1B2b are available from Statistics Netherlands.

3.5.5 *Methodological issues*

Fugitive NMVOC emissions from source category 1B2aiv comprise process emissions from oil refining and storage. The emissions are derived from the companies' e-AERs (electronic Annual Environmental Reports), in which the companies report their annual emissions (Tier 3 methodology). The reported emission data is based on both measurements and calculations and is checked by the competent authority. They include emissions from venting and flaring by refineries. The companies report emissions per fuel type (including the amount of fuel), and process emissions (without any activity data). Emissions reported with fuel are assumed to be combustion emissions and are included in 1A1b. while emissions reported without fuel are assumed to be fugitive emissions and are reported in 1B2aiv. When this results in zero emissions in source category 1B2aiv, the notation key ‘IE’ (Included Elsewhere) is used.

Sometimes, flaring emissions are reported with fuel (and allocated to 1A1b), and sometimes without fuel (and allocated to 1B2aiv).

Fugitive NMVOC emissions from category 1B2av comprise dissipation losses from gasoline service stations, leakage losses during vehicle and aircraft refuelling and refinery process losses:

- Emissions from gasoline service stations are based on the amount of fuel used for road transportation combined with country-specific EFs. A detailed description of the methodology is available in chapter 24 and chapter 27 of the WESP methodology report (Visschedijk *et al*., 2024).
- Emissions from aircraft refuelling are based on the total quantity of jet fuel tanked and an EF based on the environmental report of the company that handles all aircraft fuelling and fuel handling at Amsterdam Airport Schiphol. A detailed description of the methodology is available in the Transport methodology report (Geilenkirchen *et al.*, 2024a)
- Emissions from refinery processes are based on environmental reports from individual companies. The companies report emissions per fuel type (including the amount of fuel) and process emissions (without any activity data). The process emissions have been allocated to 1B2av. For the years when there is no environmental report from the company in question, a supplemental emission estimate has been made.

Fugitive NMVOC emissions from category 1B2b comprise emissions from oil and gas extraction (exploration, production, processing, flaring and venting), gas transmission (all emissions including storage) and gas distribution networks (pipelines for local transport):

- Emissions from the extraction of oil and gas are reported by operators in their e-AER (Tier 3 methodology).
- NMVOC emissions from gas transmission were derived from data in the annual reports of the gas transmission company Gasunie (Tier 3 methodology).
- NMVOC emissions from gas distribution were calculated on the basis of an NMVOC profile with CH_4 emissions from annual reports of the distribution sector as input (Tier 2 methodology).

Detailed information on activity data and emissions can be found in Honig *et al.* (2024).

Emissions from venting and flaring are not included in 1B2c, because it is not possible to separate the venting and flaring emissions from the company emission data. Instead, the emissions are included in 1B2aiv (venting and flaring in refineries) and in 1B2b (venting and flaring from oil and gas extraction. The notation key 'IE' (Included Elsewhere) is used in source category 1B2c.

Oil and Gas extraction companies report the emission data in their e-AERs on the basis of a covenant (NOGEPA 2012). Under the covenant, there are no thresholds for reporting, and the operators report aggregated totals for all emissions except for greenhouse gas emissions. where an obligation to report venting, flaring, combustion and process separately is agreed on. Emissions of $PM_{2.5}$, heavy metals and POPs are not estimated because the amount is expected negligible on the total NL emissions. More information on the reporting of the emissions to air of the operators can be found in a guideline (NOGEPA 2018).

Other fugitive emissions from category 1B2d are not estimated. Whilst the EMEP/EEA (2019) Guidebook provides Tier 1 EFs for geothermal power emissions, these are not applicable because in the Netherlands the geothermal power projects are not combined with electricity production.

3.5.6 Uncertainties and time series consistency
Uncertainties are explained in Section 1.6.3.

3.5.7 Source-specific QA/QC and verification
General QA/QC is explained in Section 1.7.

3.5.8 Source-specific recalculations
In 1B2b, the emission calculation for oil and gas production has been updated for 2021, resulting in an emission change of +0.96 tons NMVOC in 2021.

3.5.9 Source-specific planned improvements
There are no planned source-specific planned improvements.

4 Transport

4.1 Overview of the sector

The Transport sector is a major contributor to emissions of NO_x, NMVOC, CO, TSP, PM_{10} and $PM_{2.5}$. Emissions of most substances have decreased throughout the time series, mainly due to the introduction of increasingly stringent European emission standards for new road vehicles. The Transport sector(1A3) comprises the following subcategories: Civil aviation (1A3a), Road transport (1A3b), Railways (1A3c), Waterborne navigation (1A3d) and Pipeline transport (1A3ei). Table 4.1 provides an overview of the source categories within the Transport sector and the methodologies used for calculating emissions within the sector. For the first four source categories, national activity data and (mostly) country-specific EFs were used. Emissions from civil aviation and waterborne navigation were based on fuel-used, whereas emissions from railways and road transport were calculated using fuel sales data.

Table 4.1 Source categories and methods for 1A3 Transport and for other transport-related source categories

NFR code	Source category description	Method	AD	EF	Basis
1A3a	Civil aviation	Tier 3	NS	CS	Fuel-used
1A3b	Road transport	Tier 3	NS	CS	Fuel-sold
1A3c	Railways	Tier 2	NS	CS	Fuel-sold
1A3d	Waterborne navigation	Tier 3	NS	CS	Fuel-used
1A2gvii	Mobile combustion in manufacturing industries and construction	Tier 3	NS	CS	Fuel-used
1A4aii	Commercial/Institutional: Mobile	Tier 3	NS	CS	Fuel-used
1A4bii	Residential: Household and gardening (mobile)	Tier 3	NS	CS	Fuel-used
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	Tier 3	NS	CS	Fuel-used
1A4ciii	National fishing	Tier 3	NS	CS	Fuel-sold
1A5b	Other, mobile (including military, land-based and recreational boats)	Tier 3	NS	CS	Fuel-used

AD = Activity data.
NS = National Statistics.
CS = Country-specific.

It should be noted that, since the 2016 submission, emissions of NO_x, PM_{10}, $PM_{2.5}$, EC, NMVOC, CO and NH_3 from road transport have been reported on a fuel-sold basis (for the entire time series). Up until the 2015 submission, road transport emissions were reported on a fuel-used basis. The difference between fuel-used and fuel-sold emissions is described in Section 4.3.

This chapter also covers emissions from non-road mobile machinery (NRMM), recreational craft and national fishing. Emissions from NRMM are reported in several different source categories within the inventory (i.e. 1A2gvii, 1A4aii, 1A4bii, 1A4cii), represented in Table 4.1. Emissions from NRMM were calculated using a Tier 3 methodology based on fuel-used, using national activity data and a combination of country-specific and default EFs. Emissions from recreational craft and vehicles operating at airports are reported under 1A5b (Other, mobile) and were calculated using a Tier 3 and Tier 2 methodology, respectively. Emissions from fisheries are reported under 1A4ciii National fishing and were calculated using a Tier 3 methodology.

This chapter describes shares and trends in emissions for the various source categories within the Transport sector. The methodologies used for emission calculations are also described briefly. A detailed description of these methodologies is provided in Geilenkirchen *et al.* (2024a), supplemented by tables with detailed emission and activity data, and the EFs used in the emission calculations (Geilenkirchen *et al.*, 2024b).

4.1.1 *Key sources*

The source categories within the Transport sector are key sources of various pollutants, as represented in Table 4.2. The percentages in Table 4.2 relate to the 2022 **level** assessment and the 1990–2022 **trend** assessment (in *italics*). Some source categories are key sources for both the trend and the 2022 level assessments. In those cases, Table 4.2 represents the percentage from the assessment in which the contribution of the source category was highest. The full results of the Approach 1 key source analysis are presented in Annex 1.

The Approach 2 key source analysis is only performed at the level of GNRF sectors for the pollutants NO_x, NMVOC, SO_x, NH_3, PM_{10} and $PM_{2.5}$. From this analysis the GNFR sector Road Transport is a:

- 2022 level key source of NO_x, NMVOC, PM_{10} and $PM_{2.5}$;
- 2022 trend key source of NH_3.

The GNFR sector Offroad is a 2022 level and trend key source of NO_x.

Key sources in the remaining part of this chapter refer to Approach 1.

Table 4.2 Key source analysis for the Transport sector

NFR code	Source category description	SO_x	NO_x	NH_3	NMVOC	CO	PM_{10}	$PM_{2.5}$	BC	Pb[3]
1A3aii(i)	Domestic aviation LTO (civil)									[1]
1A3bi	Passenger cars	3.0%	*20.4%*		*13.7%*	*33.2%*	6.5%	*8.3%*	*14.9%*	*45.2%*
1A3bii	Light duty vehicles		*5.7%*			5.5%	4.3%	5.4%	*8.2%*	
1A3biii	Heavy duty vehicles and buses	6.8%	*12.9%*		2.0%[2]	*2.9%*[2]	9.2%	*11.9%*	*22.8%*	
1A3biv	Mopeds and motorcycles				[1]	*5.4%*				
1A3bv	Gasoline evaporation				5.6%					
1A3bvi	Automobile tyre and brake wear						*5.7%*	1.9%		7.2%
1A3bvii	Automobile road abrasion						*4.7%*			
1A3c	Railways									4.2%
1A3di(ii)	International inland waterways		*5.7%*				[1]	2.5%	*7.7%*	
1A3dii	National navigation (shipping)		*5.3%*					2.2%	*6.7%*	
1A2gvii	Mobile Combustion in manufacturing industries and construction						*2.6%*	*3.6%*	11.8%	
1A4aii	Commercial/institutional: mobile					2.9%				
1A4bii	Residential: household and gardening (mobile)					*6.6%*				
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery		*4.1%*					2.1%	6.3%	
1A4ciii	Agriculture/forestry/fishing: National fishing		2.5%							
1A5b	Other, Mobile (including military, land based and recreational boats)					*5.2%*				

Percentages in italics and underlined are from the trend contribution calculation.
1. No longer a key source (cf. IIR 2023).
2. New key source (cf. IIR 2023).
3. Emissions based on fuel-used.

4.2 Civil aviation

4.2.1 Source category description

The source category Civil aviation (1A3a) includes emissions from all landing and take-off (LTO) cycles of domestic and international civil flights in the Netherlands. This includes emissions from both scheduled and charter flights, passenger and freight transport, aircraft taxiing and general aviation (non-commercial). Emissions from helicopters are also included. Emissions in civil aviation result from the combustion of jet fuel (jet kerosene) and aviation gasoline (avgas) and from wear on tyres and brakes. They also include emissions from auxiliary power units (APU) on board large aircraft. All Dutch airports are included in the calculations. Most civil aviation in the Netherlands stems from Amsterdam Airport Schiphol, which is by far the largest airport in the country. But some regional airports have grown quite considerably since 2005.

The source category Civil aviation does not include emissions from ground support equipment at airports. This equipment is classified as mobile machinery, and the resulting emissions are reported under source category Other, mobile (1A5b). Emissions from the storage and transfer of jet fuel are reported under source category Fugitive emissions oil: Refining/storage (1B2aiv).

Cruise emissions from domestic and international aviation (i.e. emissions occurring above 3,000 feet) are calculated and reported as memo items as they are not part of the national emission totals.

Due to the small size of the country, there is hardly any domestic aviation in the Netherlands. The split into LTO-related fuel consumption and the resulting emissions between domestic and international aviation was made using flight statistics per airport. This split has not been made for emissions from fuel storage, tyre and brake wear, or auxiliary power units, which are all reported under International aviation (1A3i) in the NFR. Condensables are included in PM_{10} and $PM_{2.5}$ emissions.

The notation key 'NE' is used for NH_3 and Hg. HCB and PCBs are indicated as 'NA', following the 2019 EMEP/EEA Guidebook. NH_3 emissions from Civil aviation are not estimated due to a lack of EFs. Emissions are expected to be negligible.

4.2.2 Key sources

Civil aviation is a key source of Pb in the emissions inventory.

4.2.3 Overview of shares and trends in emissions

Fuel consumption in civil aviation, including fuel use for auxiliary power units, almost tripled between 1990 and 2019, increasing from 4.5 to 12.4 PJ. Amsterdam Airport Schiphol is responsible for over 90% of total fuel consumption in civil aviation in the Netherlands (specific activity data and IEFs for Amsterdam Airport Schiphol and for regional airports are provided in Geilenkirchen *et al*. (2024a and 2024b). Fuel consumption (LTO) at Amsterdam Airport Schiphol more than doubled between 1990 and 2008. After a 9% decrease in 2009 due to the financial crisis, fuel consumption increased again in 2010 and 2011 and was approximately at pre-crisis levels in 2011. Since 2012, fuel consumption of LTO in civil aviation has continued to increase by on average 0.3 PJ per year. In 2020, due to the COVID-19 pandemic, fuel consumption halved to 6.2 PJ and increased again to 7.0 PJ in 2021 and 10.0 PJ in 2022.

The trends in emissions from civil aviation in the Netherlands are represented in Table 4.3. The increase in air transport and related fuel consumption has resulted in an increase in the emissions of NO_x, NMVOC, SO_x, TSP, PM_{10} and $PM_{2.5}$ and CO. Fleet average NO_x EFs have not changed significantly throughout the time series; therefore, NO_x emissions more than tripled between 1990 and 2019, following the trend in fuel consumption. PM_{10} emissions from civil aviation have increased throughout the time period. This increase was due to the significant increase in tyre and brake wear emissions, which increased in line with the increase in the maximum permissible take-off weight (MTOW) of aircraft (which is used to estimate wear emissions). Fleet average PM_{10} exhaust EFs (per unit of fuel) have decreased since 1990. As a result, the share of wear emissions in total emissions of PM_{10} in civil aviation has increased. Emissions in 2020-2022 are substantially lower due to the COVID-19 pandemic.

The $PM_{2.5}/PM_{10}$ ratio for brake and tyre wear emissions in civil aviation is assumed to be 0.2 and 0.15, respectively, whereas the ratio for exhaust emissions is assumed to be 1. Consequently, the share of wear emissions in $PM_{2.5}$ emissions is smaller than in PM_{10} emissions and the trend in total $PM_{2.5}$ emissions in civil aviation has been influenced more heavily by the trend in exhaust emissions. This explains why total $PM_{2.5}$ emissions remained more or less constant throughout the time series, while PM_{10} emissions showed a moderate increase.

Aviation petrol (avgas) still contains lead, whereas petrol for other transport purposes has been unleaded for quite some time. With lead emissions from other source categories decreasing substantially, the share that civil aviation contributed to lead emissions in the Netherlands has increased substantially.

4.2.4 *Activity data and (implied) emission factors*

The exhaust emissions of CO, NMVOC, NO_x, PM, SO_x and heavy metals from civil aviation LTO in the Netherlands were calculated using a flight-based Tier 3 methodology. Specific data was used for the number of aircraft movements per aircraft type and per airport, which were derived from the airports and from Statistics Netherlands. This data was used in the CLEO model (Dellaert & Hulskotte, 2017b) to calculate LTO fuel consumption and resulting emissions. The CLEO model was derived from the method that the US Environmental Protection Agency (EPA) uses to calculate aircraft emissions. The EFs used in CLEO were taken from the ICAO Engine Emissions DataBank. A detailed description of the methodology can be found in chapter 8 of Geilenkirchen *et al.* (2024a).

Table 4.3 Trends in emissions from 1A3a Civil aviation

Year	Main Pollutants			Particulate Matter				Other	Priority Heavy Metals
	NO_x	NMVOC	SO_x	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Mg
1990	**1.2**	**0.40**	**0.10**	**0.03**	**0.03**	**0.03**	**0.01**	**3.6**	**1.9**
1995	1.8	0.36	0.14	0.03	0.04	0.04	0.01	4.1	2.0
2000	2.3	0.30	0.18	0.03	0.04	0.04	0.02	3.9	1.7
2005	2.8	0.38	0.24	0.04	0.05	0.05	0.02	4.3	1.2
2010	2.8	0.36	0.23	0.04	0.05	0.05	0.02	4.3	1.3
2015	3.4	0.37	0.26	0.03	0.04	0.04	0.01	4.1	0.8
2020	2.2	0.20	0.14	0.02	0.02	0.02	0.01	2.5	0.7
2021	2.5	0.23	0.16	0.02	0.03	0.03	0.01	2.8	0.8
2022	**3.3**	**0.32**	**0.23**	**0.03**	**0.04**	**0.04**	**0.01**	**3.7**	**0.9**
1990-2022 period[1)]	2.0	-0.08	0.13	0.00	0.01	0.01	0.00	0.18	-1.0
1990-2022 period[2)]	164%	-20%	123%	6%	25%	25%	-24%	5%	-54%

1. Absolute difference.
2. Relative difference from 1990 in %.

4.2.5 *Methodological issues*

Due to the small size of the country, there is hardly any domestic aviation in the Netherlands, with the exception of general aviation (non-commercial air transport). Therefore, the split of fuel consumption and resulting emissions into domestic and international aviation was not made for the emissions of brake and tyre wear, APUs and fuel storage and fuelling. Given the minimal share of domestic aviation, fuel consumption and emissions from these sources are reported under International aviation (1A3i).

The Dutch PRTR does not currently have the data to calculate aviation cruise emissions. For this reason, the emission data as provided annually by Eurocontrol are used. For domestic aviation, the data provided by Eurocontrol is not complete, as it does not include flights that did not submit a flight plan (which is more common for domestic flights over the Netherlands). Domestic cruise emissions are therefore estimated using the domestic LTO emissions (as calculated with the CLEO model) as a basis, and deriving and applying year- and pollutant-specific LTO phase/cruise phase emission ratios from the Eurocontrol data.

4.2.6 *Uncertainties and time series consistency*

Consistent methodologies have been used throughout the time series. In 2016, an experts' workshop was conducted to discuss and estimate the uncertainties in the activity data and EFs used for the emission calculations for the Transport sector (Dellaert & Dröge, 2017a). The resulting uncertainty estimates for civil aviation are provided in Table 4.4.

4.2.7 *Source-specific QA/QC and verification*

Every year, Eurocontrol performs a calculation of aviation emissions for each of their member countries using the Eurocontrol FEIS (Fuel burn and emission inventory system) model. For CO_2 and NO_x, there is a fairly good agreement between the two models (see Table 4.5, a value above 100% means the Dutch national inventory is higher than the Eurocontrol calculated value). For emissions of CO and NMVOC, the difference is largest for domestic aviation. This can be explained by the incomplete coverage of the Eurocontrol data (not including flights without flight plan) and the larger contribution from smaller piston engine aircraft – involving more uncertainty and limited availability of engine-specific emission factors.

Table 4.4 Aviation emissions (LTO domestic + LTO international) compared with the Eurocontrol FEIS model.

Comparison	2018	2019	2020	2021	2022
CO	189%	189%	246%	210%	186%
CO_2	110%	110%	118%	109%	106%
N_2O	113%	114%	122%	112%	109%
NMVOC	144%	146%	186%	161%	148%
NO_x	102%	103%	109%	105%	102%
$PM_{2.5}$	117%	118%	137%	130%	121%
SO_x	132%	133%	142%	130%	127%

4.2.8 *Source-specific recalculations*

In the calculation of civil aviation LTO emissions, there have been recalculations following a fuel type correction for several engine types. This leads to a small reduction of emissions from 2005 onwards.

Another change is the inclusion (as memo items) of cruise emissions for international and domestic aviation. For international aviation cruise, emissions are reported as provided annually by Eurocontrol to their member countries. For domestic aviation, the data provided by Eurocontrol is not complete, as it does not include flights that did not submit a flight plan (which is more common for domestic flights over the Netherlands). Domestic cruise emissions are therefore estimated using the domestic LTO emissions (as calculated with the CLEO model) as a basis, and deriving and applying year- and pollutant-specific LTO phase/cruise phase emission ratios from the Eurocontrol data.

4.2.9 *Source-specific planned improvements*

There are no source-specific planned improvements for civil aviation.

Table 4.5 Uncertainty estimates for civil aviation (%)

Type	Fuel	Uncertainty Activity data	emission factor NO_x	SO_x	NH_3	PM_{10}	$PM_{2.5}$	$EC_{2.5}$	NMVOC
LTO	Jet kerosene	10	35	50		200	200	200	200
LTO	Aviation gasoline	35	100	50		100	100	100	500
APU	Jet kerosene	50	50	50		100	100	100	200
Fuelling and fuel handling		20							100
GSE	Diesel	10	50	20	200	100	100	100	
Tyre wear		10					100		
Brake wear		10					100		

Source: Dellaert & Dröge (2017a), updated in 2019 by PRTR.

4.3 Road transport

4.3.1 Source category description

The source category Road transport (1A3b) comprises emissions from road transport in the Netherlands, including emissions from passenger cars (1A3bi), light-duty trucks (1A3bii), heavy-duty vehicles and buses (1A3biii), and mopeds and motorcycles (1A3biv). It also includes evaporative emissions from road vehicles (1A3bv), PM emissions from tyre and brake wear (1A3bvi), and emissions from road abrasion (1A3bvii). PM emissions caused by the resuspension of previously deposited material are not included. Condensables are included in PM_{10} and $PM_{2.5}$ emissions.

The notation key 'NA' is used for BC emissions of tyre and brake wear (1A3bvi). Although both brake and tyre wear emissions are optically dark and will show up in light absorption measurements (as used for Black Carbon), they contain little to no elemental carbon in the small particles, based on composition. With Black Carbon set equal to Elemental Carbon in the inventory, the Netherlands uses the better-defined Elemental Carbon standard (EUSAAR protocol). Consequently, non-exhaust emissions are no source of Black Carbon (i.e. Elemental Carbon).

The notation key 'NE' is used for HCB emissions. 'NA' is used for PCB emissions in the NFR tables. Although the EMEP/EEA Guidebook provides emission factors for these pollutants, they do not reflect development over time. The usage of PCBs in lubrication oil has been prohibited since 1985 and the usage of chlorine-containing scavengers in motor fuels has been discontinued following the ban of leaded fuels, in 2000. For this reason, emissions of PCB are decreasing constantly and are considered negligible.

Historically, emissions from road transport in the Netherlands have been calculated and reported on the basis of the number of vehicle kilometres driven per vehicle type. The resulting emission totals are referred to as *fuel used* (FU) emissions, since they correspond to the amount of fuel used by road transport on Dutch territory. Starting with the IIR 2017, reported emissions from road transport have been based on *fuel sold* (for the entire time series) in accordance with UNECE guidelines. Fuel-used emissions are still reported as a memo item in the NFR, per source category.

4.3.2 *Key sources*

The various source categories within road transport are key sources of many substances in both the 1990–2022 trend assessment and the 1990 and 2022 level assessments, as represented in Table 4.6

Table 4.6 Key source analysis for road transport subcategories

Source category	Name	1990 level	2022 level	1990–2022 trend
1A3bi	Passenger cars	NO_x, NMVOC, CO, PM_{10}, $PM_{2.5}$, BC, Pb[1], PAH	NO_x, NMVOC, CO, $PM_{2.5}$, BC, Pb[1], Cd[1], Hg[1]	SO_x, NO_x, NMVOC, CO, PM_{10}, $PM_{2.5}$, BC, Pb[1], Cd[1], Hg[1]
1A3bii	Light-duty vehicles	NO_x, CO, PM_{10}, $PM_{2.5}$, BC	NO_x, BC	NO_x, CO, PM_{10}, $PM_{2.5}$, BC
1A3biii	Heavy-duty vehicles and buses	SO_x, NO_x, NMVOC, PM_{10}, $PM_{2.5}$, BC	NO_x, NMVOC, $PM_{2.5}$, BC	SO_x, NO_x, CO, PM_{10}, $PM_{2.5}$, BC
1A3biv	Mopeds and motorcycles		CO	CO
1A3bv	Gasoline evaporation	NMVOC		NMVOC
1A3bvi	Tyre and brake wear		PM_{10}, $PM_{2.5}$, Pb[1]	PM_{10}, Pb[1]
1A3bvii	Road abrasion		PM_{10}	PM_{10}

1. Based on fuel-used.

4.3.3 *Overview of shares and trends in emissions*

Road transport is a major contributor to air pollutant emissions in the Netherlands. Taken together, the various source categories within road transport accounted for 28% of NO_x emissions (national totals), 13% of PM_{10}, 9% of $PM_{2.5}$, 18% of BC, 9% of NMVOC and 39% of CO emissions in 2022.

The trends in emissions from road transport are represented in Table 4.7. Emissions of the main pollutants and particulate matter decreased significantly throughout the time series with the exception of NH_3. This decrease in emissions can mainly be attributed to the introduction of increasingly stringent European emission standards for new road vehicles. Even though emission totals decreased throughout the time series, the share that road transport contributed to the national emission totals for NO_x, PM_{10} and $PM_{2.5}$ decreased only slightly between 1990 and 2022, as emissions in other sectors decreased as well. Road transport, therefore, is still a major source of pollutant emissions in the Netherlands.

Table 4.7 Trends in emissions from 1A3b Road transport

Year	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**291**	**181**	**15**	**0.9**	**18**	**19**	**19**	**8**	**692**
1995	232	118	14	2	13	15	15	7	508
2000	193	65	4	4	10	12	12	6	385
2005	169	39	0.2	5	7	9	9	4	353
2010	129	27	0.2	4	3	6	6	2	310
2015	88	25	0.2	4	2	4	4	1	234
2020	61	22	0.2	3	1	3	3	0.5	180
2021	59	22	0.2	3	1	3	3	0.4	169
2022	**55**	**21**	**0.2**	**3**	**1**	**4**	**4**	**0.4**	**157**
1990-2022 period[1)]	-236	-160	-15	3	-16	-16	-16	-8	-535
1990-2022 period[2)]	-81%	-89%	-99%	274%	-93%	-82%	-82%	-95%	-77%

1. Absolute difference.
2. Relative difference from 1990 in %.

Emissions of SO_x decreased by 99% between 1990 and 2022 due to increasingly stringent EU fuel quality standards regulating the maximum allowable sulphur content of fuels used in (road) transport. Currently, all road transport fuels are 'sulphur free' (sulphur content <10 parts per million).

Emissions of NH_3 by road transport increased significantly between 1990 and 2005 due to the introduction and subsequent market penetration of the three-way catalyst for petrol-driven passenger cars. Since 2005, NH_3 emissions from road transport have decreased. Despite the increase in emissions since 1990, road transport is only a minor source of NH_3 emissions in the Netherlands, with a share of 3% in national emission totals in 2022.

Emissions of heavy metals have increased, except for Pb. These emissions decreased significantly with the introduction of unleaded petrol.

Passenger cars (1A3bi)
The number of kilometres driven by passenger cars in the Netherlands steadily increased from approximately 82 billion in 1990 to 109 billion in 2018 (see Figure 4.1). Due to the COVID-19 pandemic it fell to 92 billion in 2020 and in 2022 it increased again to over 102 billion.

Since 1995, the share of diesel-powered passenger cars in the Dutch car fleet has grown significantly, resulting in an increase in diesel mileage by 95% between 1990 and 2012. Yet since 2008, the diesel mileage has decreased by 46%.
Petrol mileage increased by 34% between 1990 and 2019. The share of LPG in the passenger car fleet decreased significantly, from 16% in 1990 to almost 1% in 2022. In 2020, the decrease in passenger vehicle kilometres due to the pandemic was relatively high for diesel cars (-

28%) compared to petrol cars (-11%). Figure 4.1 makes clear that, even though the number of diesel kilometres increased significantly, petrol still dominates passenger car transport. Throughout the time series, petrol was responsible for approximately two-thirds of the total number of kilometres driven by passenger cars. The market share of diesel increased throughout the time series, mostly at the expense of LPG.

NO_x emissions from passenger cars decreased significantly throughout the time series, even though traffic volumes increased. This decrease can mainly be attributed to the introduction of the three-way catalyst (TWC), which led to a major decrease in NO_x emissions from petrol-powered passenger cars. Between 1995 and 2007, NO_x emissions from diesel-powered passenger cars increased by more than 60%. This increase resulted from the major increase in the kilometres driven by diesel cars combined with less stringent emission standards and the disappointing real-world NO_x emission performance of recent generations of diesel-powered passenger cars. Due to the decrease of NO_x emissions from petrol-powered passenger cars, NO_x has mostly become a diesel-related issue. Since 2007, NO_x emissions from diesel cars have decreased.

The introduction of the TWC for petrol-powered passenger cars also led to a major reduction in NMVOC and CO emissions. NMVOC exhaust emissions from petrol-powered passenger cars decreased by more than 80% throughout the time series, whereas CO emissions decreased by more than 60%. NMVOC and CO emissions from diesel- and LPG-powered passenger cars also decreased significantly, but both are minor sources of NMVOC and CO. In 2022, passenger cars were responsible for 4% of NMVOC emissions – not including evaporative NMVOC emissions – (down from 16% in 1990) and 32% of CO emissions (down from 48% in 1990) in the Netherlands.

In 2022, passenger cars (source category 1A3bi, including exhaust emissions only) were responsible for 2% of $PM_{2.5}$ emissions and 1% of PM_{10} emissions in the Netherlands. PM_{10} exhaust emissions from passenger cars decreased by more than 95% throughout the time series. Emissions from both petrol- and diesel-powered cars decreased significantly throughout the time series, due to increasingly stringent EU emission standards for new passenger cars. The continuing decrease of PM_{10} and $PM_{2.5}$ exhaust emissions in recent years is primarily due to the increasing market penetration of diesel-powered passenger cars equipped with *diesel particulate filters* (DPF). DPFs are required to comply with the Euro-V PM emission standard, which came into force at the start of 2011. DPFs entered the Dutch fleet much earlier, though, helped by a subsidy that was introduced by the Dutch government in 2005. In 2007, more than 60% of all new diesel-powered passenger cars were equipped with a DPF. In 2008, the share of new diesel passenger cars with a DPF exceeded 90%. $PM_{2.5}$ exhaust emissions from passenger cars (and other road transport) are assumed to be equal to PM_{10} exhaust emissions.

Passenger cars are a key source of Cd emissions, as they are responsible for 13% of total national Cd emissions. Between 1990 and 2022, Cd emissions increased by 47%.

NH_3 emissions from passenger cars increased significantly from 1990 to 2006, as a result of the introduction of the TWC. From 2007 onwards, emissions continued to decrease, amounting to 2.6 Gg in 2022. The increase in vehicle kilometres driven since 2007 has been compensated by the introduction of newer generations of TWCs with lower NH_3 emissions per vehicle kilometre driven, resulting in a decrease of the fleet average NH_3 EF. Lead emissions from passenger cars decreased by more than 99% throughout the time series due to the phase-out of leaded petrol.

Light-duty trucks (1A3bii)
Between 1990 and 2005, the light-duty truck fleet in the Netherlands grew significantly, leading to a major increase in vehicle kilometres driven (see Figure 4.1). In 2005, private ownership of light-duty trucks became less attractive due to changes in the tax scheme. As a result, the size of the vehicle fleet has more or less stabilised since then. The number of vehicle kilometres driven varied between 17 and 18 billion between 2005 and 2011, decreasing somewhat in 2012 and 2013, and again increasing slightly after 2015. It is likely that the fluctuations in these years can mainly be attributed to the economic situation. The proportion of petrol-powered trucks in the fleet decreased steadily throughout the time series. In recent years, diesel engines have dominated the light-duty truck market and are now responsible for more than 98% of new-vehicle sales. Currently, over 95% of the fleet is diesel-powered. In 2022, vehicle kilometres driven by light-duty trucks increased by 3% compared to 2021.

Ever since 1990 till 2016 NO_x emissions from light-duty trucks have fluctuated between 17 and 22 Gg. Since 2016 the emissions decreased to 11 Gg in 2022, when they were 46%lower than they were in 1990, even though the number of vehicle kilometres driven more than doubled during this time span. The EU emission standards for light-duty trucks and the subsequent market penetration of light-duty diesel engines with lower NO_x emissions caused a decrease in the fleet average NO_x emissions per vehicle kilometre. However, because of the poor NO_x emission performance of Euro-V light-duty trucks, the fleet average NO_x EF for diesel light-duty trucks has stabilised in recent years.

Light-duty trucks are a minor source of both CO and NMVOC emissions, accounting for less than 1% of the national totals for both substances in 2022. Exhaust emissions of NMVOC and CO from light-duty trucks decreased significantly throughout the time series. Increasingly stringent EU emission standards for both substances have led to a major (85–87%) decrease in the fleet average EFs for both petrol and diesel trucks between 1990 and 2022. Petrol-powered trucks emit far more NMVOC and CO per kilometre than diesel-powered trucks; therefore, the decrease in the number of petrol-driven trucks has also contributed significantly to the decrease in NMVOC and CO emissions.

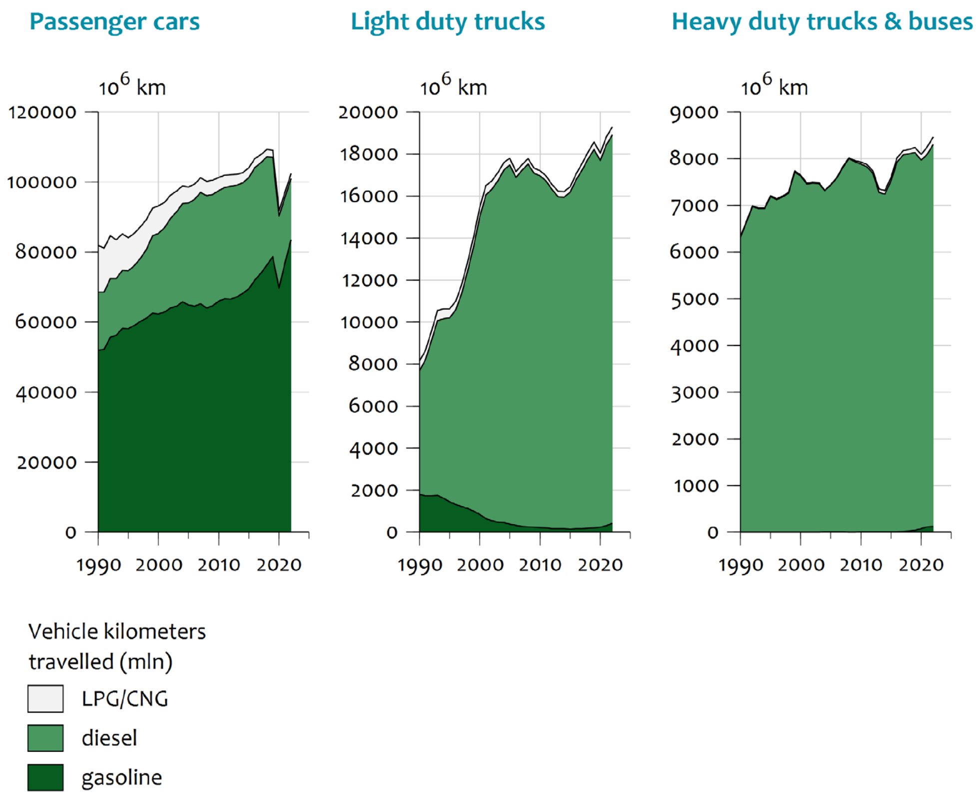

Figure 4.1 Kilometres driven per vehicle and fuel type in the Netherlands (source: Statistics Netherlands)

The exhaust emissions of PM_{10} and $PM_{2.5}$ from light-duty trucks decreased throughout the time series. The fleet average PM_{10} EF decreased consistently throughout the time series, but this decrease was initially offset by the increase in vehicle kilometres driven. Diesel-powered trucks are dominant in PM_{10} exhaust emissions, with a share of over 99%. The average PM_{10} exhaust EF for diesel-powered light-duty trucks has decreased significantly in recent years, due to the market penetration of diesel-powered light-duty trucks with DPFs. Even though the number of vehicle kilometres driven has stabilised since 2005, PM_{10} exhaust emissions decreased by 89% between 2005 and 2022.

Heavy-duty vehicles and buses (1A3biii)
Between 1990 and 2008, the number of vehicle kilometres driven by heavy-duty vehicles (rigid trucks, tractor-trailer combinations) and buses in the Netherlands increased by approximately 30% (see Figure 4.1). After a decrease during the financial crisis, transport volumes increased again to pre-crisis levels. Diesel dominates the heavy-duty vehicle and bus fleet, with a share of 99

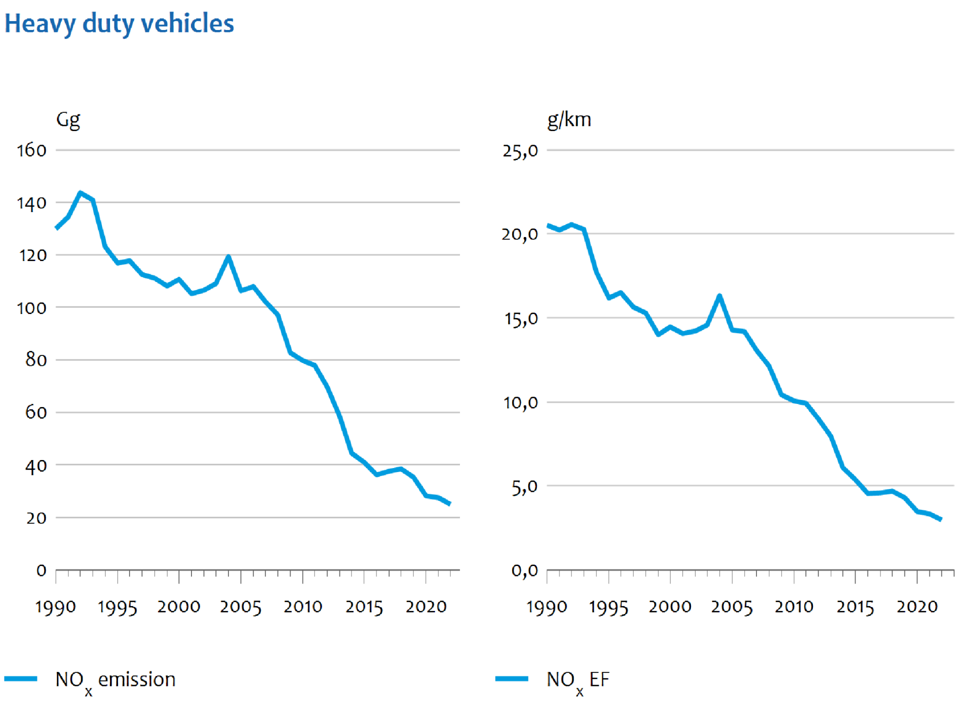

Figure 4.2 NO_x emissions with kilometres and NO_x IEFs of heavy-duty vehicles in the Netherlands

NO_x emissions from heavy-duty vehicles and buses decreased from 130 Gg in 1990 to 25 Gg in 2022 (see Figure 4.2). Emissions have decreased significantly in recent years, due to the decrease in vehicle kilometrages between 2008 and 2014 (Figure 4.1) and the decrease in the fleet average NO_x EF (Figure 4.2). The latter decreased significantly throughout the time series, mainly due to increasingly stringent EU emission standards for heavy-duty engines. With second-generation Euro-V trucks showing better NO_x emission performance during real-world driving, the fleet average NO_x EF for heavy-duty vehicles has decreased significantly since 2008. The current generation of Euro-VI trucks, which entered the market in 2013, are fitted with a combination of Exhaust Gas Recirculation (EGR) and a Selective Catalytic Reduction (SCR) systems, resulting in very low real-world NO_x emission levels (Kadijk *et al*., 2015).

NMVOC exhaust emissions decreased by around 73% throughout the time series and PM_{10} and $PM_{2.5}$ exhaust emissions decreased by more than 95%. These decreases were also caused by changes to EU emission legislation. In the most recent year, heavy-duty vehicles and buses were only a minor source of NMVOC emissions.

Heavy-duty vehicles and buses are a minor source of NH_3 emissions in the Netherlands (0.5% of national totals). However, NH_3 emissions from heavy-duty vehicles and buses increased significantly between 2005 and 2022. This increase was caused by the rising use of SCR catalysts in heavy-duty trucks and buses. High SCR conversion rates may yield NH_3 slip, as described in detail by Stelwagen *et al*. (2015). NH_3 EFs for Euro-V trucks and buses are approximately six times higher than EFs for previous Euro classes, as represented in table 3.11 of Geilenkirchen *et al.* (2024a).

Emission factors for Euro-VI trucks and buses are estimated to be 30 times higher than those for previous Euro classes. Therefore, NH_3 emissions from heavy-duty vehicles and buses have increased tremendously due to the market introduction of Euro-VI vehicles. In 2022, emissions amounted to 593 Mg, which corresponds to an increase of 225% compared to 2012.

Motorcycles and mopeds (1A3biv)
Motorcycles and mopeds are a minor emission source in the Netherlands, being responsible for less than 1% of national totals for most substances. In 2022, motorcycles and mopeds were responsible for 1% of NMVOC emissions and 5% of CO emissions in the Netherlands. Even though the number of vehicle kilometres driven almost doubled between 1990 and 2022, exhaust emissions of NMVOC decreased significantly, due to increasingly stringent EU emission standards for two-wheelers. In 2022, the share of motorcycles and mopeds in NO_x emissions in the Netherlands was still small (<1%), while the share in $PM_{2.5}$ emissions was approximately 0.3%.

Petrol evaporation (1A3bv)
Evaporative NMVOC emissions from road transport have decreased significantly, due to EU emission legislation for evaporative emissions and the subsequent introduction of carbon canisters for petrol-powered passenger cars. Total evaporative NMVOC emissions decreased by 95% throughout the time series. As a result, evaporative emissions are no longer a key source in the level assessment, accounting for <1% of total NMVOC emissions in the Netherlands in 2022 (down from 6% in 1990). Petrol-powered passenger cars are by far the largest source of evaporative NMVOC emissions from road transport in the Netherlands, although their share has decreased from more than 90% in 1990 to 61% in 2022. Motorcycles and mopeds were mainly responsible for the rest of evaporative NMVOC emissions; other road vehicles contributed below 3%.

PM emissions from tyre and brake wear and road abrasion (1A3bvi and 1A3bvii)
Vehicle tyre and brake wear (1A3bvi) and road abrasion (1A3bvii) were each responsible for 5% of PM_{10} emissions in the Netherlands. PM_{10} emissions from brake wear, tyre wear and road abrasion increased throughout most of the time series, as represented in Figure 4.3, due to the increase in vehicle kilometres driven by light- and heavy-duty vehicles. PM_{10} EFs were constant throughout the time series.

$PM_{2.5}$ emissions were derived from PM_{10} emissions using $PM_{2.5}/PM_{10}$ ratios of 0.2 for tyre wear and 0.15 for both brake wear and road abrasion. Therefore, the trend in $PM_{2.5}$ wear emissions was similar to the trend in PM_{10} emissions. The share of tyre and brake wear (2%) and road abrasion (1%) in total $PM_{2.5}$ emissions in the Netherlands was smaller than it was for PM_{10}.

In response to the recommendation from the IIR 2023 review (NL-1A3bvi-2023-0001) regarding the ratio $PM_{10}/PM_{2.5}$ we have planned improvements on these ratios for the IIR 2025.

PM10

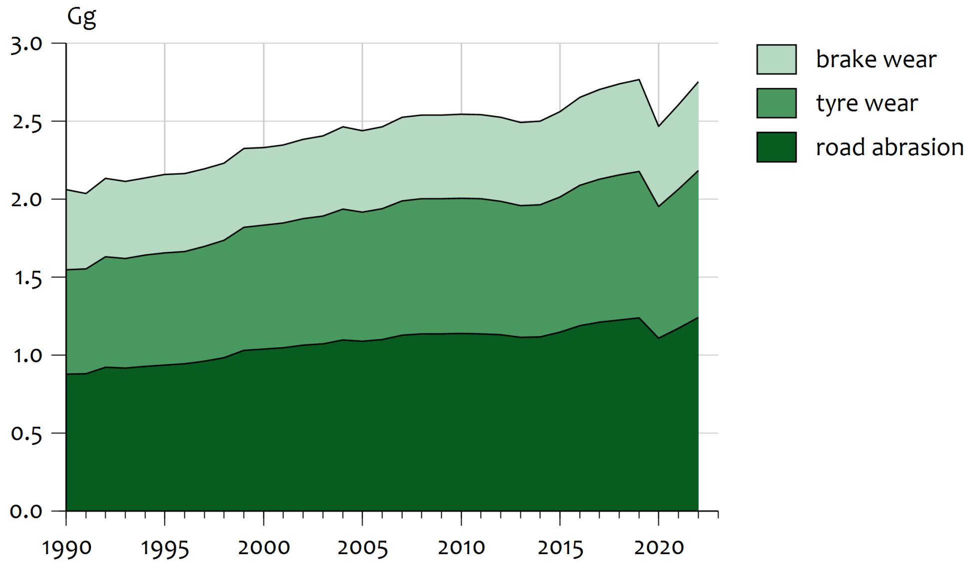

Figure 4.3 Emissions of PM_{10} resulting from brake and tyre wear and road abrasion in Gg

4.3.4 *Activity data and (implied) emission factors*

Emissions from road transport were calculated using a Tier 3 methodology. Exhaust emissions of CO, NMVOC, NO_x, NH_3 and PM from road transport were calculated, using statistics on vehicle kilometres driven and EFs expressed in grams per vehicle kilometre (g/km). Emissions of SO_x and heavy metals were calculated using fuel consumption estimates combined with the sulphur and heavy metal content of various fuel types, taking into account the tightening of the EU fuel quality standards regulating the maximum allowable sulphur and lead content of fuels used in road transport. The resulting emissions for CO, NMVOC, NO_x, NH_3 and PM were subsequently corrected for differences between the fuel used and the fuel sold to derive fuel sold emission totals for road transport.

Activity data on vehicle kilometres driven

The data on the number of vehicle kilometres driven in the Netherlands was derived from Statistics Netherlands. Statistics Netherlands calculates total vehicle kilometrage per vehicle type using data on:

- the size and composition of the Dutch vehicle fleet;
- the average annual kilometrage for various vehicle types; and
- the number of kilometres driven by foreign vehicles in the Netherlands.

Since 2018, a bottom-up methodology has been implemented. This is based on vehicle kilometres driven per individual vehicle. Data per licence plate number is available from RDW (Driver and Vehicle Licensing Agency). Subsequently, each licence plate number was matched to a vehicle class, as defined by vehicle type, weight class, fuel type, emission legislation and specific exhaust gas technologies. More than 350 vehicle classes are distinguished. For each vehicle class, the road type distribution is estimated on the basis of annual vehicle kilometres driven and build year (year of manufacture).

For IIR 2024 a new approach was used for calculating the activity data for the period from 2004 until 2017 was implemented. The fleet information used in the bottom-up years was used to reconstruct the fleet in the years 2009-2017. After a correction with the total number of vehicle kilometres a more accurate estimate of activity data and resulting emissions could be calculated.
More detailed information on activity data is presented in Geilenkirchen *et al.* (2024b).

Emission factors
The CO, NMVOC, NOx and PM exhaust EFs for road transport were calculated using the VERSIT+ model (Ligterink & de Lange, 2009). With the use of VERSIT+, EFs can be calculated for various transport situations and scale levels. The EFs follow from various analyses fed by various kinds of measuring data. VERSIT+ LD (light-duty) has been developed for passenger cars and light-duty trucks. The model is used to estimate emissions under specific traffic situations. To determine the EFs, the effect of various types of driving behaviour and the statistical variation per vehicle are investigated. Next, the results are used in a model with currently more than 50 light-duty vehicle categories for each of the emission components. The resulting model separates driving behaviour and vehicle category dependencies.

VERSIT+ HD (Spreen et al., 2016) was used to predict the EFs of heavy-duty vehicles (i.e. trucks, road tractors and buses). For older vehicles, VERSIT+ HD uses European measurement data. For newer vehicles (Euro-III – Euro-VI), measurement data is available that closely resembles the real-world use of the vehicles. This new data is based on driving behaviour, taken from both on-road measurements and measurements on test stands, and this data has been used in a model to represent emissions during standard driving behaviour. The EFs for buses often originate from test stand measurements, which include realistic driving behaviour for regular service buses.

Emissions of SOx and heavy metals (and CO_2) are dependent on fuel consumption and fuel type. These emissions were calculated by multiplying fuel consumption by fuel- and year-specific EFs (grams per litre of fuel). The EFs for SOx and heavy metals were based on the sulphur, carbon and heavy metal content of the fuels, as described in Geilenkirchen et al. (2024a). NMVOC evaporative emissions are estimated using the methodology from the EEA Emission Inventory Guidebook (EEA, 2007). The NH_3 EFs were derived from Stelwagen et al. (2015).

PM emission factors
PM_{10} EFs and $PM_{2.5}/PM_{10}$ ratios for brake and tyre wear and for road abrasion were derived from literature (Broeke ten et al., 2008; Denier van der Gon et al., 2008; RWS, 2008). An overview of these EFs is provided in Geilenkirchen et al. (2024b: tables 3.3 and 3.13). For tyre wear, the EFs are calculated as the total mass loss of tyres resulting

from the wear process and the number of tyres per vehicle category. The emissions are based on fuel used, as they are unrelated to fuel sold.

Lubricant oil
Combustion of lubricant oil is estimated on the basis of vehicle kilometres driven and consumption per kilometre. Consumption factors per vehicle type are provided in table 3.4 of Geilenkirchen et al. (2024b). The resulting emissions are included in the EFs for transport and are not estimated separately, with the exception of heavy metals. These are considered to be extra emissions and are therefore calculated separately by multiplying the consumption of lubricant oil and the lubricant oil profile (see table 3.9 of Geilenkirchen et al., 2024b).

Deriving fuel-sold emissions for road transport
In order to derive fuel-sold emissions from road transport, the fuel-used emissions per fuel type are adjusted for differences between the fuel used by road transport in the Netherlands and fuel sold as reported by Statistics Netherlands. The differences between fuel used and fuel sold can most likely be attributed to price differences between neighbouring countries. The trends are described and explained elaborately in the IIR 2020, section 4.3.4.

Figure 4.4 represents both the bottom-up estimates for fuel used by road transport and reported fuel sold to road transport per fuel type for the time series.

Because fuel-sold emissions for gasoline vehicles are estimated using a generic correction to fuel-used emissions per fuel type, the difference between fuel-used and fuel-sold emissions depends solely on the share of the various fuel types in emission totals per substance. For diesel vehicles the difference between fuel-used and fuel-sold is allocated to heavy duty trucks (dashed lines in figure 4.4).

Diesel trucks are a major source of NO_x and PM emissions; fuel-used emissions of NO_x and PM for diesel trucks are adjusted upwards, especially in the earlier years of the time series, as can be seen in Figure 4.5. NMVOC emissions in road transport mostly stem from petrol-powered vehicles. Since the difference between fuel-used and fuel-sold for petrol vehicles is small, fuel-used and fuel-sold NMVOC emission totals do not differ much, as represented in Figure 4.5. PM emissions from brake and tyre wear and from road abrasion were not adjusted for differences between fuel-used and fuel-sold, since these emissions are not directly related to fuel use.

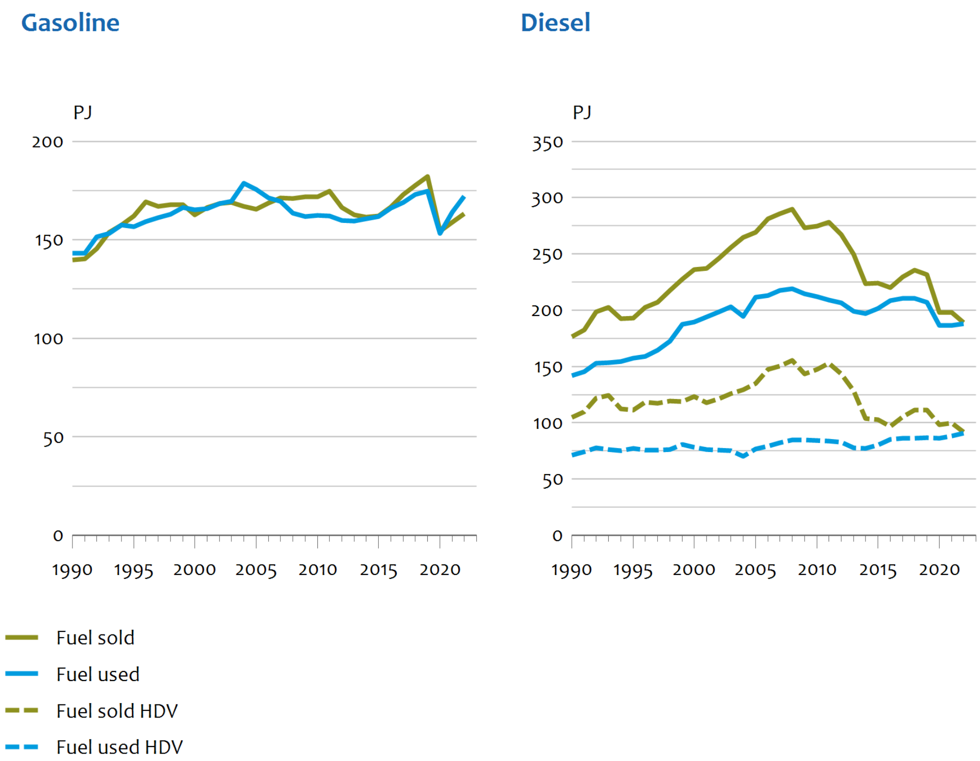

Figure 4.4 NO_x, NMVOC and PM_{10} exhaust emissions from road transport in the Netherlands, based on fuel used and fuel sold

Biofuels

Emissions resulting from the use of biofuels in road transport are not reported separately in the NFR. Emission measurements are based on representative fuel samples, including a share of biofuels, and resulting EFs are therefore representative of the market fuels used in the Netherlands. Activity data for biofuels is included under liquid fuels.

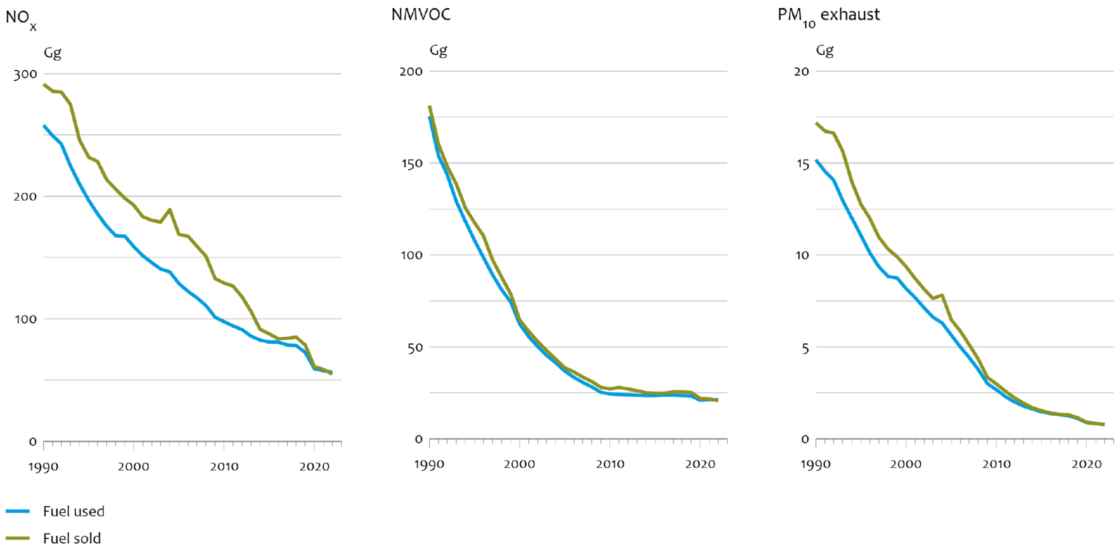

Figure 4.5 NO_x, NMVOC and PM_{10} exhaust emissions from road transport in the Netherlands based on fuel-used and fuel-sold

4.3.5 *Methodological issues*

Several parts of the emission calculations for road transport require improvement:

- The PM_{10} and $PM_{2.5}$ EFs for brake and tyre wear and for road abrasion are rather uncertain due to lack of measurements.
- The road type distribution of all vehicle categories was last updated in 2010 and needs to be verified.

4.3.6 *Uncertainties and time series consistency*

Consistent methodologies have been used throughout the time series. Uncertainties were estimated in two studies. In 2013, TNO carried out a study to improve knowledge of the uncertainties concerning pollutant emissions from road transport (Kraan *et al*., 2014). Using a jackknife approach, the variation in the input variables used for estimating total NO_x emissions from Euro-4 diesel passenger cars was examined, including the emission behaviour of the vehicles, on-road driving behaviour and the total vehicle kilometres driven. In this case study, it was concluded that the 95% confidence interval lies at a 100% variation in emission totals if all aspects are added up. It is unclear whether these results hold for more recent generations of (diesel) passenger cars. Testing procedures have been improved in recent years, but the number of vehicles tested has decreased over time. This method of determining uncertainties has proven to be very time-consuming. For that reason, a decision was made to use an expert-based approach to estimate uncertainties for NFR categories.

In 2016, an experts’ workshop was conducted to discuss and estimate the uncertainties in the activity data and EFs used for the emission calculations for the Transport sector (Dellaert & Dröge, 2017a). The resulting uncertainty estimates for road transport are represented in Table 4.8.

Table 4.8 Uncertainty estimates for road transport (%)

NFR	Fuel	Uncertainty: activity data	Uncertainty: emission factor						
			NO_x	SO_x	NH_3	PM_{10}	$PM_{2.5}$	$EC_{2.5}$	NMVOC
1A3bi Passenger cars	Petrol	5	20	20	200	200	200	500	100
	Diesel	5	20	20	100	50	50	50	100
	LPG	5	20		200	200	200	500	50
1A3bii Light-duty vehicles	Petrol	5	20	20		200	200	500	50
	Diesel	5	20	20		50	50	50	100
	LPG	5				200	200	500	
1A3biii Heavy-duty vehicles	Petrol	10	20	20		200	200	500	
	Diesel	10	20	20	100	50	50	50	100
	LPG	10				200	200	500	
1A3biii Buses	Natural gas	5							
	Petrol	5	20	20		200	200	500	
	Diesel	5	20	20		50	50	50	
	LPG	5				200	200	500	
1A3biv Mopeds/motorcycles	Petrol	20	200	20		500	500	500	500
	Diesel	20	100	20		500	500	500	
1A3bv	Petrol, passenger cars								200
	Petrol, mopeds/ motorcycles								500
1A3bvi	Tyre wear					100	200		
1A3bvi	Brake wear					100	200		
1A3bvii	Road surface wear					200	500		

Source: Dellaert & Dröge (2017a).

4.3.7 *Source-specific QA/QC and verification*

Trends in the number of vehicle kilometres driven in the Netherlands, as calculated by Statistics Netherlands using odometer readings, were compared with trends in traffic intensities on the Dutch motorway network, as reported by Rijkswaterstaat. In general, both time series tend to be in good agreement, with some annual fluctuations. Trends in fuel sales data compare with trends in fuel-used, as described in Section 4.3.4.
Emission factors for road transport are, for the most part, derived from national measurement programmes. TNO discusses resulting EFs with international research institutions, e.g. the ERMES group (https://www.ermes-group.eu/web/).

After submittance of the NFR2023-tables it was found that for some sources and years the emission of $PM_{2.5}$ was higher than PM_{10} or TSP. For exhaust emissions the ratio should be 1. This issue was solved in the NFR2024 according to the planned improvements.

4.3.8 *Source-specific recalculations*

There are several recalculations in this year's inventory for road transport emissions (for references to the various test/measurement programmes, see Geilenkirchen *et al.*, 2024a and 2024b).

Recalculations for road traffic

Only a few improvements in the calculation of road traffic emissions were applied:

- Some of the emission factors were improved based on results from real world measurements. The effect on the emissions were different for the different pollutants, but on general were small.
- As stated in 1.3.4 the activity data and emissions for the period 2004-2017 were recalculated. This effected the different pollutants differently, but had minor impact on the trends.

Recalculations of activity data of motorcycles and mopeds

The bottom-up mileages for mopeds and other light lcats are no longer scaled in IIR2024. This results in an average decrease of about 16% in fuel consumption for the entire time series (see Figure 4.6).
The Figure also illustrates the overall decrease of NO_x emission which was mainly caused by this improvement. For more information see Geilenkirchen *et al.* (2024a) section 4.3.2

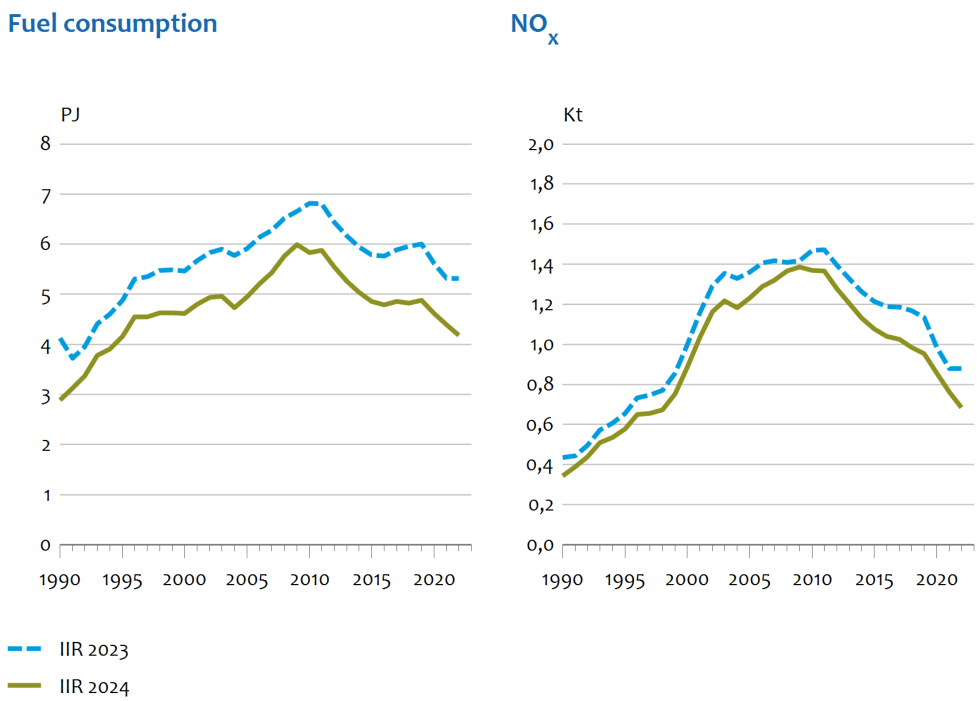

Figure 4.6 Fuel consumption and NO_x emissions by mopeds and motorcycles compared to last year's inventory

4.3.9 *Source-specific planned improvements*

The integration of new insights into the road type distribution of passenger cars, light-duty trucks and heavy-duty trucks and buses, which was planned for this year's inventory, is now planned for next year due to budget constraints. The new insights are based on Ligterink (2017a). This planned improvement was mentioned since the IIR 2019, but scheduling constraints also prohibited implementation in the IIR 2023.

4.4 Railways

4.4.1 *Source category description*

The source category Railways (1A3c) includes emissions from diesel-powered rail transport in the Netherlands. This includes both passenger transport and freight transport. Most railway transport in the Netherlands uses electricity. Emissions resulting from electricity generation for railways are not included in this source category. Diesel is used mostly for freight transport, although there are still some diesel-powered passenger lines as well. Besides exhaust emissions from diesel trains, this source category also includes emissions of particulate matter, copper and lead (among others) from trains, trams and metros due to wear, which results from friction and spark erosion of the current collectors and the overhead contact lines. Condensables are included in PM_{10} and $PM_{2.5}$ emissions. The notation key NE is used for HCB and PCB emissions.

4.4.2 *Key sources*

Railways is a key source of Pb and Cu in the emissions inventory.

4.4.3 *Overview of emission shares and trends*

Railways is a small source of emissions in the Netherlands, accounting for less than 1% of national totals for all substances except lead, BC and copper in 2022. Between 1990 and 2000, diesel fuel consumption by railways increased from 1.2 to 1.5 PJ due to an increase in freight transport. Between 2001 and 2011, fuel consumption fluctuated around 1.4 PJ and since 2012 it has dropped to 0.8 PJ in 2021. Transport volumes have increased since 2001, especially freight transport, but this has been compensated by the ongoing electrification of rail transport. The share of passenger transport in diesel fuel consumption in the Railway category was estimated at approximately 30–35% until 2010 and increased to over 50% in 2021. The remainder is used for freight transport.

The trends in emissions from railways are represented in Table 4.9. NO_x and PM_{10} emissions from railways follow trends in activity data because EFs are similar for all years of the time series. Pb emissions increased between 1990 and 2021. Pb emissions from railways result from the wear on carbon brushes, which are estimated on the basis of the total electricity use by railways (in kWh). Trends in Pb emissions therefore follow trends in electricity use for railways. Railways are also an important source of copper emissions, amounting to 76 Mg (around 73% of total copper emissions in the Netherlands). Emissions of other heavy metals are very low. SO_x emissions from railways decreased by almost 100% between 2007 and 2012 due to the decrease in the sulphur content of diesel fuel for non-road applications and the early introduction of sulphur-free diesel fuel in the Netherlands (required from 2011 onwards but already applied in 2009 and 2010).

Table 4.9 Trends in emissions from 1A3c Railways

	Main Pollutants				Particulate Matter				Other	Priority Heavy Metals	Other Heavy Metals
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cu
Year	Gg	Gg	Gg	Mg	Gg	Gg	Gg	Gg	Gg	Mg	Mg
1990	**1.9**	**0.07**	**0.10**	**21**	**0.12**	**0.15**	**0.15**	**0.02**	**0.34**	**0.22**	**60**
1995	1.9	0.07	0.10	22	0.13	0.16	0.16	0.02	0.36	0.26	68
2000	2.3	0.09	0.12	27	0.16	0.19	0.19	0.03	0.43	0.28	76
2005	2.1	0.08	0.11	25	0.15	0.18	0.18	0.02	0.40	0.27	75
2010	2.1	0.08	0.01	25	0.15	0.18	0.18	0.03	0.40	0.29	81
2015	1.5	0.07	0.00	22	0.12	0.15	0.15	0.02	0.35	0.25	75
2020	0.8	0.05	0.00	16	0.09	0.11	0.11	0.01	0.25	0.24	73
2021	0.7	0.05	0.00	15	0.08	0.11	0.11	0.01	0.23	0.24	73
2022	**0.7**	**0.05**	**0.00**	**15**	**0.09**	**0.11**	**0.11**	**0.01**	**0.25**	**0.24**	**76**
1990-2022 period[1)]	-1.2	-0.02	-0.10	-6	-0.04	-0.04	-0.04	-0.01	-0.10	0.03	17
1990-2022 period[2)]	-61%	-28%	-100%	-28%	-30%	-26%	-26%	-68%	-28%	13%	28%

1. Absolute difference.
2. Relative difference from 1990 in %.

4.4.4 *Activity data and (implied) emission factors*

As pointed out in the NECD-review (and as it was apparent in comparisons across Europe), the particulate matter wear emissions of rail have been underestimated in the Netherlands (Ligterink, 2024). In 2023 this was remedied by adding the, up till now, missing source of track, wheel, and brake wear emissions. Across Europe there have several studies, some studies are biased by the measurement location near or at the station, where emissions are substantially higher than along the straight track with trains travelling at constant velocity. These studies were used to derive the wear emission factors. Based on the measured driving resistances and typical train weights, for conversions of different units, an average was derived and used. The new emission factors are based on the energy consumption, from fuel and electricity. The total rail particulate matter emission are corrected upwards significantly by adding this new source.

New tailpipe emission measurements on diesel passenger trains and ongoing measurements on diesel locomotives has led to an adjustment of the NO_x and PM exhaust emission factors (Ligterink *et al.*, 2023 and Ligterink *et al.*, 2017). Given the different legislative classes (e.g., Stage IIIA/B) that have been measured, some minor reductions with the introduction of new trains, which have to satisfy more stringent emission limits, are used. The change over time is based on the typical lifetime of locomotives of 30 years and passenger railcards of 20 years and introduction dates of new.

The NH_3 emission factors are adjusted to match emission results of similar engines used in non-road mobile machines. They are considered superior, because they are based on more recent emission measurements than the standard emission factors, albeit much higher. Likely the difference in NH_3 emission factors is related to the use of oxidation catalysts to meet particulate matter emission limits and (Ligterink *et al.*, 2021). Likewise, the sulphur content of diesel fuel for rail is set equal to sulphur content of other off-road applications, which is a minor adjustment in the transition period 2005-2010.

PM_{10} emissions due to wear on overhead contact lines and carbon brushes from railways are calculated on the basis of a study conducted by NS-CTO (1992) on the wear on overhead contact lines and the carbon brushes of the collectors on electric trains. For trams and metros, wear on overhead contact lines has been assumed to be identical to that on railways. Emissions from wear on current collectors have not been included, because no information was available on this topic. Carbon brushes, besides copper, contain 10% lead and 65% carbon. Based on the NS-CTO study, the percentage of particulate matter in the total quantity of wear debris was estimated at 20%. Because of their low weight, its assumed that these particles remain airborne. It is estimated that approximately 65% of the wear debris ends up in the immediate vicinity of the railway, while 5% enters ditches along the railway line (Coenen & Hulskotte, 1998). According to the NS-CTO study, the remainder of the wear debris (10%) does not enter the environment but attaches itself to the train surface and is captured in the train washing facilities. A detailed description of the methodology can be found in chapter 4 of Geilenkirchen *et al.* (2024a).

4.4.5 *Methodological issues*

Emission factors for railways have not been updated recently (except for NO_x) and are therefore rather uncertain.

4.4.6 *Uncertainties and time series consistency*

Consistent methodologies have been used throughout the time series. In 2016, an experts' workshop was conducted to discuss and estimate the uncertainties in the activity data and EFs used for the emission calculations for the Transport sector (Dellaert & Dröge, 2017a). The resulting uncertainty estimates for railways are represented in Table 4.10.

Table 4.10 Uncertainty estimates for railways (%)

NFR	Type	Fuel	Uncer-tainty: activity data	Uncertainty: emission factor						
				NO_x	SO_x	NH_3	PM_{10}	$PM_{2.5}$	EC	NMVOC
1A3c	Freight transport	Diesel	5	100	20	-	100	100	100	-
	Passenger transport	Diesel	5	100	20	-	100	100	100	-
	Panto-graph wear [1]	Electricity	-	-	-	-		200	200	-

Dellaert & Dröge (2017a).

4.4.7 *Source-specific QA/QC and verification*

The current figures are compared with bottom-up results of the number of trains and typical operation hours (Mensch *et al.*, 2022). These comparisons hold well.

4.4.8 *Source-specific recalculations*

Emissions calculations and emission factors changed and emissions of rail and brake ware are added to the inventory.

4.4.9 *Source-specific planned improvements*

Emission factors remain uncertain, but since railways are a small emission source and not a key source of any substance, updating the EFs is currently not a priority.

4.5 Waterborne navigation and recreational craft

4.5.1 *Source-category description*

The source category Waterborne navigation (1A3d) includes emissions from National navigation (1A3dii) and International (1A3di(ii)) inland navigation in the Netherlands and from International maritime navigation (1A3di(i)) on the Dutch Continental Shelf. Emissions from international maritime navigation are reported as a memo item and are not part of the national emission totals. National (domestic) inland navigation includes emissions from all trips that both depart from and arrive in the Netherlands, whereas international inland navigation includes emissions

[1] Overhead line for power supply to electric rail transport.

from trips that either depart from or arrive abroad. Only emissions on Dutch territory are reported. For maritime navigation, this includes emissions on the Dutch Continental Shelf. All three categories include both passenger and freight transport. Emissions from recreational craft are, from 2022 onwards, reported under Inland Shipping as well.. Emissions resulting from degassing of inland ships are included under 2D3i. Condensables are included in PM_{10} and $PM_{2.5}$ emissions.

For inland navigation (1A3di(ii) and 1A3dii), the notation key NE is used for HCB and PCB emissions. The reason is that there are no representative emission factors for these substances. The default emission factors in the EMEP/EEA Guidebook are based on emission measurements on seagoing vessels and cannot be used for inland shipping.

For 1A5b, the notation key NE is used for HCB and PCB emissions.

4.5.2 *Key sources*

Both the source categories 1A3di(ii) – International inland waterways – and 1A3dii – National navigation (shipping) – are key sources of NO_x, $PM_{2.5}$ and BC emissions. Source category 1A3di(ii) – International inland waterways – is also a key source of PM_{10}. Recreational craft is a key source of CO.

4.5.3 *Overview of emission shares and trends*

In 2022, the total (inter)national inland navigation was responsible for 11% of NO_x emissions, 5% of $PM_{2.5}$ emissions and 17% of BC emissions in the Netherlands. With emissions from road transport decreasing rapidly, the share of inland navigation in national totals increased throughout the time series. The share of inland navigation as a percentage of national emissions of NMVOC, CO and SO_x was small in 2022.

Emissions from international maritime navigation are not included in the national totals, but maritime navigation is a major emission source in the Netherlands, the Port of Rotterdam being one of the world’s largest seaports and the North Sea being one of the world’s busiest shipping regions. Total NO_x emissions from international maritime shipping on Dutch territory (including the Dutch Continental Shelf) amounted to almost 102 Gg in 2021 and were higher than the combined NO_x emissions from all road transport in the Netherlands. PM_{10} emissions amounted to 2.6 Gg in 2020. In contrast, recreational craft were only a small emission source, with 1.9 Gg of NO_x and 0.04 Gg of PM_{10} emitted in 2021.

The trends in emissions from inland navigation in the Netherlands (both category 1A3dii and 1A3di(ii)) are represented in Table 4.11. Since 2000, fuel consumption in inland navigation has fluctuated between 20 and 28 PJ. The financial crisis led to a decrease in transport volumes and fuel consumption in 2009. Since then, transport volumes have increased again, resulting in an increase in fuel consumption. Emissions of NO_x, CO, NMVOC and PM from inland navigation follow, for the most part, the trends in the activity data. The introduction of emission standards for new ship engines (CCR stages I and II) has led to a slight decrease in the fleet average NO_x EF (per kilogram of fuel) in recent years, but since fuel consumption has increased significantly, total NO_x emissions still increased between 2009 and 2022.

SO_x emissions from inland navigation decreased by 99% between 2009 and 2022 due to the decrease in the maximum allowable sulphur content of diesel fuel for non-road applications. As of 2011, EU regulation requires all diesel fuel for inland navigation to be sulphur-free. Since sulphur-free diesel fuel was introduced to inland navigation in the Netherlands in 2009, SO_x emissions decreased significantly from that year onwards. The decrease in sulphur content also affects PM emissions, as some of the sulphur in the fuel is emitted as PM (Denier van der Gon & Hulskotte, 2010). $PM_{2.5}$ and PM_{10} emissions from waterborne navigation also decreased between 2009 and 2022.

Between 1990 and 2008, energy use and resulting emissions from maritime navigation showed an upward trend. Since the start of the financial crisis, transport volumes have decreased, resulting in a reduction in energy use and emissions. This decrease was enhanced by 'slow steaming' (a decrease in speed), resulting in lower energy use and thus further lowering emissions (MARIN, 2011). In 2022, total fuel consumption by maritime navigation on Dutch territory increased by 3% compared to 2021, but was still 2% lower compared to 2020.

Recreational shipping is reported under source categories 1A3dii Inland Shipping. Recreational shipping is a key source of CO emissions, amounting to 4.6% of total national CO emissions. The share of emissions of all other pollutants from recreational shipping in total emissions in the Netherlands in 2022 was small.

Table 4.11 Trends in emissions from Inland navigation in the Netherlands (combined emissions of national and international inland navigation)

Year	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**28.8**	**2.00**	**1.8**	**0.01**	**1.2**	**1.3**	**1.3**	**0.56**	**2.2**
1995	23.2	1.66	1.7	0.01	1.2	1.2	1.2	0.52	2.0
2000	24.6	1.56	1.8	0.01	1.1	1.2	1.2	0.50	1.9
2005	23.6	1.33	1.7	0.01	1.0	1.0	1.0	0.44	1.6
2010	19.5	1.26	0.44	0.00	0.76	0.81	0.81	0.38	1.5
2015	21.2	1.21	0.01	0.00	0.72	0.77	0.77	0.39	1.5
2020	19.0	1.10	0.01	0.00	0.71	0.75	0.75	0.32	1.6
2021	19.5	1.12	0.01	0.00	0.72	0.76	0.76	0.33	1.6
2022	**18.7**	**1.12**	**0.01**	**0.00**	**0.68**	**0.72**	**0.72**	**0.31**	**1.6**
1990-2022 period[1)]	-10.0	-0.87	-1.8	0.00	-0.57	-0.59	-0.59	-0.25	-0.7
1990-2022 period[2)]	-35%	-44%	-99%	-11%	-46%	-45%	-45%	-45%	-29%

1. Absolute difference.
2. Relative difference from 1990 in %.

4.5.4 *Activity data and (implied) emission factors*

Fuel consumption and resulting emissions from inland navigation (both national and international) were calculated using a Tier 3 methodology. The methodology was developed as part of the Emissieregistratie en -Monitoring Scheepvaart (EMS) project. The EMS methodology distinguishes between 31 vessel classes. For these vessel classes, the power demand (kW) is calculated for the various inland waterway types and rivers in the Netherlands by means of a model described by Bolt (2003). The main variable parameters within this model that determine the power demand per vessel class are the vessel's draught, its speed through water and the stream velocity. The vessel's draught is calculated by interpolating between the draught of an unloaded vessel and that of a fully loaded vessel. Starting from the reporting year 2022, the speed per vessel per geographical water segment was derived from vessel movement data derived from AIS (Automatic Identification System). The average cargo situation (partial load) per vessel class for one specific year (2016) was provided by Statistics Netherlands.

The resulting fleet average EFs throughout the time series are reported in Geilenkirchen *et al.* (2023a). The formula used to estimate the impact of lower sulphur content on PM emissions is described in Hulskotte & Bolt (2013).

In the emission calculation for inland shipping, a distinction is made between primary engines intended for propelling the vessel and auxiliary engines. Auxiliary engines are used for manoeuvring the vessel (bow propellers) and generating electricity for the operation of the vessel and the residential compartments (generators). Fuel consumption by auxiliary engines is estimated at 13% of the fuel consumption of the primary engines.

No recent information was available on the fuel consumption of passenger ships and ferries in the Netherlands; for this reason, fuel consumption data for 1994 were applied to all subsequent years of the time series.

Emissions by recreational craft were calculated by multiplying the number of recreational craft (open/cabin motorboats and open/cabin sailing boats) by the average fuel consumption per boat type times the EF per substance, expressed in emissions per engine type per quantity of fuel (Hulskotte *et al.*, 2024). The EFs depend on the engine types per vessel and are reported in the same report, and will be cited in method report as well.

Since 2008, emissions from maritime shipping on the Dutch Continental Shelf and in the Dutch port areas have been calculated annually, using vessel movement data derived from AIS (Automatic Identification System).

To estimate emissions from a specific ship in Dutch waters, the ship's IMO number is linked to a ship characteristics database acquired from Lloyd's List Intelligence (LLI). Emission factors for each ship are determined using information on the construction year and the design speed of the ship, the engine type and power, the type of fuel used and, for engines built since 2000, the engine's maximum revolutions per minute (rpm).

Methodologies and resulting emissions for recent years are described in detail in MARIN (2019).

A detailed description of the methodology for inland navigation (chapter 5), recreational craft (chapter 5) and maritime shipping (chapter 7) can be found in Geilenkirchen *et al.* (2023a).

4.5.5 *Methodological issues*

There are several points requiring improvement in the emission calculations for inland navigation, international maritime navigation and recreational craft:

1. Data on fuel consumption and EFs for passenger ships and ferries has not been updated for some time.
2. Data on the number of recreational craft and their average usage rates is rather uncertain and need to be verified.
3. The methodology for calculating the required engine power vs. speed and other ship characteristics needs to be verified for inland navigation.
4. Estimates of NMVOC emissions due to cargo fumes are rather uncertain and need to be improved.

4.5.6 *Uncertainties and time series consistency*

Consistent methodologies have been used throughout the time series for waterborne navigation. For inland navigation, AIS data have only become available since 2020. For the earlier years in the time series, emission totals were scaled back from 2020 using the annual fuel consumption attributed to the Netherlands as reported by SAB. The methodology for constructing the historic series will described in full detail in an upcoming report (Jerry Gé *et al*. TNO, 2024)

For maritime navigation, AIS data have only become available since 2008. For the earlier years in the time series, emission totals were estimated using vessel movement data from Lloyd’s, combined with assumptions about average vessel speeds (Hulskotte *et al*., 2003a, -b and -c).

In 2016, an experts’ workshop was conducted to discuss and estimate the uncertainties in the activity data and EFs used for the emission calculations for the Transport sector (Dellaert & Dröge, 2017b). The resulting uncertainty estimates for waterborne navigation and recreational craft are represented in Table 4.12. In the IIR 2020, the uncertainty estimate for NMVOC emissions from degassing cargo had been adjusted upwards from 100% to 250% compared to Dellaert & Dröge (2017a).

Table 4.12 Uncertainty estimates for waterborne navigation and recreational craft (%)

NFR	**Type**	**Fuel**	**Uncertainty: activity data**	**Uncertainty: emission factor**						
				NO_x	**SO_x**	**NH_3**	**PM_{10}**	**$PM_{2.5}$**	**EC**	**NMVOC**
1A3di(i)	Anchored DCS[2]	HFO	20	50	50	500	50	50	200	200
1A3di(i)	Anchored DCS	MDO	20	50	50	500	50	50	200	200
1A3di(i)	Sailing DCS	HFO	20	50	50	500	50	50	200	200
1A3di(i)	Sailing DCS	LNG	50	100	100	-	-	100	200	-
1A3di(i)	Sailing DCS	MDO	20	50	50	500	50	50	200	200
1A3di(i)	Moored NL		50	50	50	500	50	50	200	200
1A3di(i)	Sailing NL	HFO	20	50	50	500	50	50	200	200
1A3di(i)	Sailing NL	LNG	50	100	100	-	-	100	200	-
1A3di(i)	Sailing NL	MDO	20	50	50	500	50	50	200	200
1A3di(ii)	Inland, international	Diesel	10	20	15	400	35	35	35	75
1A3dii	Inland, national	Diesel	10	20	15	400	35	35	35	75
1A3dii	Passenger and ferryboats	Diesel	100	50	20	500	100	100	100	200
1A3dii	Recreational shipping, exhaust gases	Petrol	200	50	20	100	100	100	100	50
1A3dii	Recreational shipping, exhaust gases	Diesel	200	200	20	100	100	100	100	100
1A3dii	Recreational shipping, petrol evaporation		100	-	-		-	-	-	200
2D3i	Inland shipping, degassing cargo		100	-	-	-	-	-	-	250

Dellaert & Dröge (2017a).

[2] Dutch Continental Shelf.

4.5.7 *Source-specific QA/QC and verification*

The trends in activity data for waterborne navigation (national and international) were compared with trends in transport volumes (Mg-kms of inland shipping within and across borders) and are reasonably comparable.

4.5.8 *Source-specific recalculations*

There were no source-specific recalculations for waterborne navigation.

4.5.9 *Source-specific planned improvements*

For inland navigation we are currently implementing a new methodology for calculating the emissions using AIS transponder data. Unfortunately, it was not yet feasible to already implement this methodology in the current IIR submission. We expect to implement the new methodology when preparing the next submission and will include relevant documentation in the next IIR submission.

4.6 Non-road mobile machinery (NRMM)

4.6.1 *Source category description*

Non-road mobile machinery (NRMM) covers a variety of equipment that is used in various economic sectors and by households in the Netherlands. Mobile machinery is defined as all machinery equipped with a combustion engine which is not primarily intended for transport on public roads, and which is not attached to a stationary unit. The main deployment of NRMM in the Netherlands is within agriculture and construction. The largest volumes of fuel are used in tillage, harvesting and earthmoving. NRMM is also used in forest, park and garden maintenance, including lawn mowers, chain saws, forest mowers and leaf blowers.

Emissions from NRMM are reported under:

1. 1A2gvii Mobile combustion in manufacturing industries and construction.
2. 1A4aii Commercial/ institutional: Mobile.
3. 1A4bii Residential: Household and gardening (mobile).
4. 1A4cii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
5. 1A5b Other, mobile.

Source category 1A5b is used for emissions from ground support equipment at airports. 1A5b also includes emissions from recreational craft. Condensables are included in PM_{10} and $PM_{2.5}$ emissions.

4.6.2 *Key sources*

Mobile machinery in manufacturing industries and construction (1A2gvii) is a key source of NO_x, PM_{10}, $PM_{2.5}$ and BC emissions. Source category 1A4aii – Commercial/institutional: Mobile – is a key source of CO emissions. Source category 1A4bii – Residential: Household and gardening (mobile) – is a key source of emissions of CO. Source category 1A4cii – Agriculture/Forestry/Fishing: Off-road vehicles and other machinery – is a key source of NO_x and BC emissions.

4.6.3 *Overview of shares and trends in emissions*

In 2022, NRMM was responsible for 12% of CO emissions, 12% of NO_x emissions, 7% of $PM_{2.5}$ emissions and 4% of PM_{10} emissions in the Netherlands. CO emissions mainly resulted from the use of petrol-driven equipment by households (lawn mowers) and of machinery for public green space maintenance. NO_x, PM_{10} and $PM_{2.5}$ emissions were, for the most part, due to diesel machinery being used in agriculture (tractors) and construction.

Total energy use in NRMM has fluctuated between 50 PJ and 60 PJ throughout the time series. Figure 4.8 represents total energy use within the various sectors where mobile machinery is applied. Industrial (including construction) and agricultural machinery were responsible for more than 85% of total energy use by NRMM in 2022.

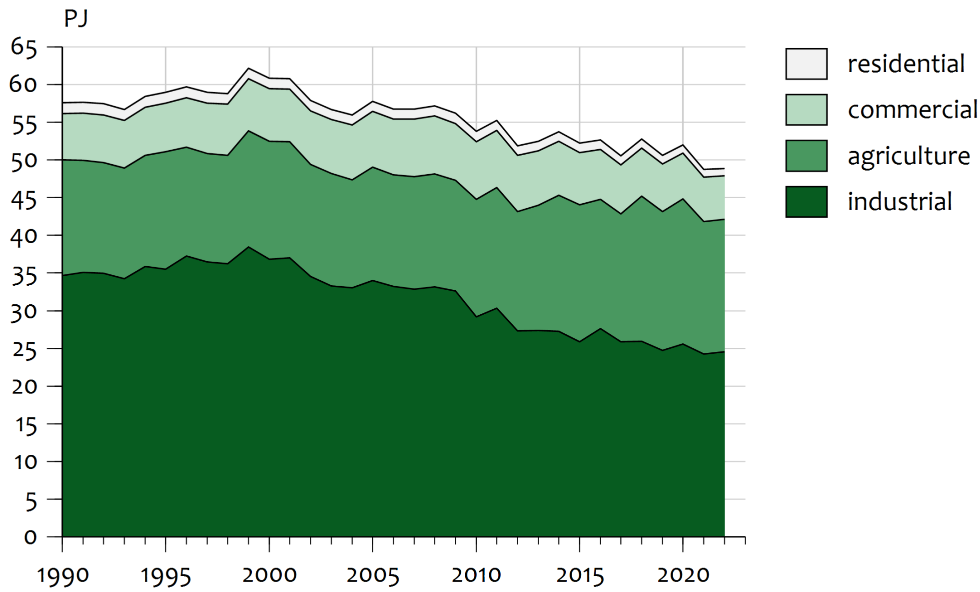

Figure 4.8 Fuel consumption in non-road mobile machinery in various sectors in the Netherlands

The trends in emissions from NRMM in the Netherlands are represented in Table 4.13. With the introduction of EU emission standards for NRMM in 1999 and the tightening of emission standards in subsequent years, NO_x emissions from NRMM have steadily decreased, as represented in Figure 4.9. Since 1990, NO_x emissions have decreased by 58%, whereas fuel consumption has decreased by 10%.

Emissions of most other substances have also decreased significantly throughout the time series. For PM_{10} and NMVOC, this can be attributed to the EU's NRMM emission legislation. SO_x emissions have decreased due to the EU's fuel quality standards; sulphur-free diesel is required in NRMM since 2011. CO emissions have increased throughout the time series.

Table 4.13 Trends in emissions from Non-road mobile machinery in the Netherlands

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**55**	**18**	**4.4**	**0.01**	**5.5**	**5.8**	**5.8**	**2.8**	**99**
1995	58	17	4.3	0.01	5.0	5.3	5.3	2.5	90
2000	61	15	4.5	0.01	4.7	5.0	5.0	2.4	84
2005	51	11	4.3	0.01	3.8	4.0	4.0	1.9	76
2010	40	8.3	0.44	0.01	2.2	2.3	2.3	1.1	71
2015	33	6.7	0.02	0.02	1.6	1.7	1.7	0.8	69
2020	27	5.0	0.02	0.11	1.2	1.3	1.3	0.6	61
2021	25	4.6	0.02	0.11	1.0	1.1	1.1	0.5	57
2022	**24**	**4.3**	**0.02**	**0.12**	**1.0**	**1.0**	**1.0**	**0.5**	**55**
1990-2022 period[1)]	-30	-13.9	-4.4	0.12	-4.6	-4.8	-4.8	-2.3	-44
1990-2022 period[2)]	-56%	-76%	-99%	1226%	-83%	-83%	-83%	-84%	-44%

1. Absolute difference.
2. Relative difference from 1990 in %.

Emissions from ground service equipment (GSE) at airports are reported under source category Other, mobile(1A5b). This source category is not a key source of emissions. The share of emissions from GSE at airports as a percentage of the total emissions in the Netherlands in 2020 was less than 1% for all pollutants.

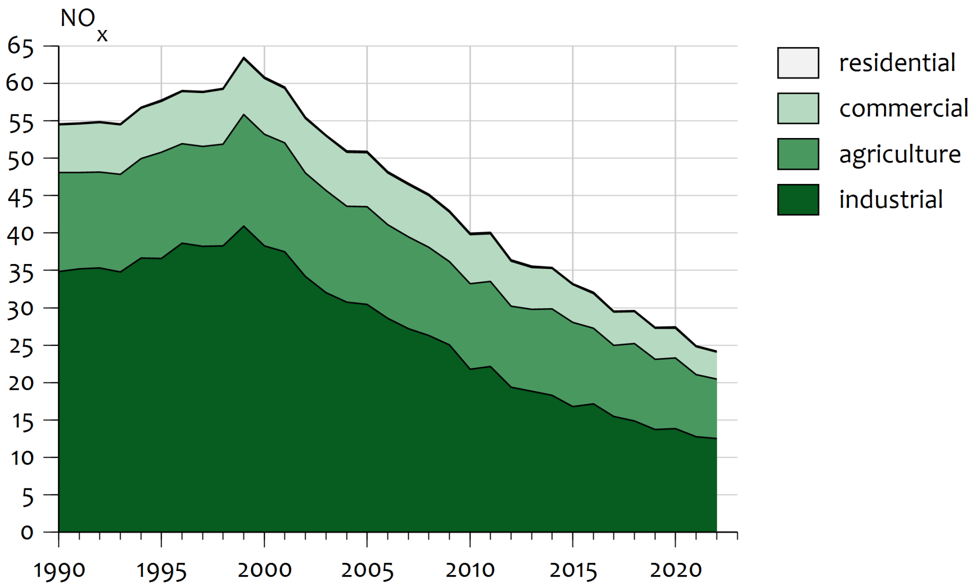

Figure 4.9 NO_x emissions by non-road mobile machinery in various sectors in the Netherlands

4.6.4 *Activity data and (implied) emission factors*

Fuel consumption by mobile machinery in the various economic sectors is not reported separately in the Energy Balance. Therefore, fuel consumption and resulting emissions from NRMM are calculated using a

Tier 3 modelling approach (Hulskotte & Verbeek, 2009; Dellaert *et al*., 2023). The so-called EMMA model uses sales data and survival rates for various types of machinery to estimate the NRMM fleet in any given year. From combined assumptions about the average usage rate (annual operating hours) and the fuel consumption per hour of operation of the various types of machinery, total annual fuel consumption by NRMM is estimated. Emission factors have been compiled based on factors from the TREMOD-MM model (Lambrecht *et al*., 2004; Helms *et al*., 2010) and updated based on real-world measurements by TNO. They are described in more detail in Geilenkirchen *et al*. (2024a) and Dellaert *et al*. (2023).

Annual sales data for the various types of NRMM are derived from trade organisations, such as the BMWT and Fedecom, and from Off-Highway Research, a commercial consulting company. From 2022, any mobile machinery that accesses public roads with a speed over 6 km/h also needs to be registered and receives a license plate. The registration database maintained by the National Road Traffic Agency (RDW) is now also used as a data source to complement and validate the Dutch machinery fleet.

Fuel consumption and CO_2 emissions are calculated using a Willans line approach that is explained in chapter 9 of Geilenkirchen *et al.* (2024a).

Emissions of CO, NO_x, NH_3, PM and NMVOC are calculated using the following formula:

Emission = Number of machines x active time x Share of time in load range x Rated power x Load and power dependent emission factor

In which:

- Emission = Emission or fuel consumption (grams);
- Number of machines = the number of machines of a certain year of construction with emission factors applicable to the machine’s year of construction;
- Active time = the average annual running time for this type of machinery in seconds;
- Share of time in load range = the average fraction of time that the machine engine is in a specific load range;
- Rated power = the average full power for this type of machinery (kW);
- Load- and power-dependent emission factor = Specific load-dependent emission factors, per kW of rated power for various technology levels related to the year of construction and the emission standards, in grams/second*kW (rated).

Emissions of SO_x were calculated on the basis of total fuel consumption and sulphur content per fuel type, as provided by Geilenkirchen *et al.* (2024a). Base EFs for NH_3 were derived from the EMEP/EEA Guidebook 2023 (EEA, 2023), but were increased for modern stage-IV and -V engines that use SCR technology to reduce NO_x emissions, while increasing emissions of NH_3.

The distribution of total fuel consumption by NRMM to various economic sectors was estimated using various data sources. First, the various types of machinery in EMMA were distributed across the five sectors. Total fuel consumption by NRMM in the commercial and industrial sector and by households was derived directly from EMMA. Fuel consumption in agriculture and construction, as reported by EMMA, was adjusted. Fuel consumption by NRMM in the agricultural sector (excluding agricultural contractors) was derived from Wageningen Economic Research of Wageningen University and Research. Fuel consumption by agricultural contractors was derived from the trade organisation for agricultural contractors in the Netherlands (CUMELA). Both data sources were combined to estimate total fuel consumption by mobile machinery in the agricultural sector.

The modelled fuel consumption in the construction sector was subsequently adjusted to take into account the impact of economic fluctuations. The resulting fuel consumption (energy use) by NRMM is also reported by Statistics Netherlands in the Energy Balance. The annual correction factors used to adjust the energy use as reported by EMMA, are provided in Geilenkirchen *et al.* (2024a).

Emissions from ground support equipment and vehicles used for ground transport at airports were estimated using data on diesel use and emissions for ground operations at Amsterdam Airport Schiphol that were provided by KLM Equipment Services (KES). KES is responsible for the refuelling and maintenance of the equipment at Schiphol Airport and therefore has precise knowledge of the types of machinery used and the amount of energy used per year. The resulting emissions were also used to derive an average EF per MTOW at Amsterdam Airport Schiphol, which was subsequently used to estimate emissions at regional airports. A detailed description of the methodology can be found in chapter 9 of Geilenkirchen *et al.* (2024a).

The notation key NE is used for all HCB and PCB emissions of NRMM as no emission factor is available and no information is available from the 2019 EMEP/EEA Guidebook chapter on NRMM.

4.6.5 Methodological issues

The current methodology for estimating emissions from NRMM could be improved in the following areas:

- As recent model updates led to relatively large increases in the modelled fuel consumption over the full time series, it has become more urgent to look for additional data on fuel consumption in these sectors to further validate the emission model.
- The diesel used in the construction sector is susceptible to relatively strong economic fluctuations. At present, the correction for this phenomenon takes place using economic indicators derived from Statistics Netherlands rather than physical indicators. It should be investigated if there are enterprises or institutions that have figures of diesel consumption at their disposal.
- There is a lack of input data for several types of machinery and sectors. In the garden sector and private households, weakly

founded or extrapolated figures have been used to estimate the size of the fleet. With targeted research into this data, relatively high figures for the VOC emissions could be replaced by improved figures.
- The effect of varying engine loads on emissions has been examined and implemented. It is of great importance that engine load profiles and related emission factors are investigated and improved further. Specific measurement programmes for investigating the effect of transient engine loads in the machine's daily practice are needed for a better foundation of the emission data.
- Via a specific measurement scheme, the effect of postponing maintenance for a longer or shorter period on the emissions of building machinery due to highly varying hire and lease practices, as they occur in the market, could be further investigated.

4.6.6 *Uncertainties and time series consistency*

The EMMA model was used to calculate fuel consumption and emissions for the time series since 1990.

In 2016, an experts' workshop was conducted to discuss and estimate the uncertainties in the activity data and the EFs used for the emission calculations for the transport sector (Dellaert & Dröge, 2017a). The resulting uncertainty estimates for NRMM are represented in Table 4.14.

The uncertainty in activity data for industry (LPG), public services (diesel) and container handling (diesel) was later adjusted upwards from 35% to 50%. The reason is that a survey held among companies using mobile machinery revealed significant divergences from our current understanding, indicating a higher uncertainty in the reported emission numbers.

4.6.7 *Source-specific QA/QC and verification*

In the past few years, significant effort was invested into checking and verifying NRMM modelling and outcomes. In 2021, a survey was held among users of mobile machinery across multiple sectors (e.g. construction, agriculture, services) that focussed on gathering data on the fleet composition (e.g. construction year, power rating, fuel types), usage (e.g. annual operating hours, typical lifespan) and fleet size. The results allowed a comparison between the composition and usage parameters of the modelled machine fleet and the machine fleet of the respondents, giving rise to improvements in the modelling on several points.
As of 1 January 2022, all vehicles, including mobile machinery, that access the public road with a speed over 6 km/h must be registered in a national database and obtain a licence plate, similar to the existing registration of passenger cars and other road transport vehicles. This public database, maintained by RDW (Dienst Wegverkeer, an administrative body of the Dutch government), can be queried and provides a relatively complete overview of the Dutch NRMM fleet. As the registry contains information on machine type, fuel type, and date of entry, this allowed a further comparison with and validation of the modelled machine fleet, again leading to several substantial changes to

the model, especially to the estimated machine sales for some machinery types.

A final verification step was the comparison of the newly modelled diesel usage for NRMM with a time series of 'red diesel' sales in the Netherlands between 1990 and 2012, compiled by Statistics Netherlands. Over this period, a separate tax tariff on diesel sales to NRMM existed, providing a reference value for comparison with the model outcome. After implementing several model improvements, the modelled diesel usage is now much closer to the available diesel sales statistics, going from -35% to -11% in 1990, compared to the sales statistics, and from -15% to +8% in 2000. Only for the 2009-2011 period, following the financial crisis, the model appears to underestimate the effect of the crisis and overestimates the diesel usage compared to the sales statistics by 15-20%, indicating that further model improvements may be needed.

4.6.8 *Source-specific recalculations*

Following the QA/QC and verification steps described above, and thanks to the availability of a national registry of NRMM in the Netherlands since 2022, a number of updates have been incorporated into the model and the input data. The new insights have led to the following improvements in the modelling of NRMM energy use and emissions:

- For several machine types, previous estimates of the historical machine sales have been improved by analysing the size and composition (including the construction year) of the current fleet for these machines, as registered in the RDW database on NRMM.
- For several household and green maintenance machinery types, input data on machinery sales has been updated and re-analysed, leading to an increase in fuel use and emissions, mostly in the agricultural sector.
- For 2021, an updated diesel total was provided for the agricultural sector, leading to a downward correction of emissions.
- The VOC speciation profiles used to derive emissions of dioxins, VOC and PAH species (including CH_4) have been updated. The model now uses the speciation profiles as provided by the US EPA MOVES3 model (US EPA, 2022).

The changes that are described above together result in some small changes in the fuel use and emissions for most NRMM sectors that are estimated using the EMMA model (1A2gvii, 1A4aii, 1A4bii and 1A4cii) over the full time series.

Table 4.14 Uncertainty estimates for NRMM (%)

NFR	Sector	Fuel	Uncertainty: activity data	Uncertainty: emission factor						
				NO_x	SO_x	NH_3	PM_{10}	$PM_{2.5}$	$EC_{2.5}$	NMVOC
1A2gvii	Construction	Petrol	100	50	20	200	100	100	100	100
1A2gvii	Construction	Diesel	50	50	20	200	100	100	100	100
1A2gvii	Industry	Diesel	50	50	20	200	100	100	100	100
1A2gvii	Industry	LPG	50	50	20	200	100	100	100	100
1A4aii	Public services	Petrol	100	50	20	200	100	100	100	100
1A4aii	Public services	Diesel	50	50	20	200	100	100	100	100
1A4aii	Container handling	Diesel	50	50	20	200	100	100	100	100
1A4bii	Consumers	Petrol	100	100	20	200	200	200	200	200
1A4cii	Agriculture	Petrol	200	100	20	200	200	200	200	200
1A4cii	Agriculture	Diesel	35	50	20	200	100	100	100	100

Dellaert & Dröge (2017a).

4.6.9 *Source-specific planned improvements*

As a major new source of information on the NRMM fleet has become available in 2022 (see previous sections), additional analysis of the new RDW registry is likely to lead to further updates and model improvements in the NRMM calculation. Furthermore, as the comparison with historical diesel sales (see section on QA/QC) indicated that the model may underestimate the effect of the financial crisis on NRMM activity in the period following 2008 (2009–2011), this will be analysed in more detail to see whether further model improvements are possible.

4.7 National fishing

4.7.1 *Source category description*

The source category National fishing (1A4ciii) covers emissions resulting from all fuel sold to fisheries in the Netherlands. Condensables are included in PM_{10} and $PM_{2.5}$ emissions.

4.7.2 *Key sources*

National fishing is a key source of NO_x emissions.

4.7.3 *Overview of emission shares and trends*

National fishing is a small emission source in the Netherlands. In 2022, national fishing was responsible for 1% of SO_x and 3% of NO_x emissions. The contribution to the national totals of PM_{10}, $PM_{2.5}$ and BC was 1–3% and for other substances less than 1%. Fuel consumption by national fishing has been decreasing since 1999.

Table 4.15 Trends in emissions from National fishing in the Netherlands

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**1.9**	**0.07**	**0.10**	**21.5**	**0.12**	**0.15**	**0.15**	**0.02**	**0.34**
1995	1.9	0.07	0.10	22.2	0.13	0.16	0.16	0.02	0.36
2000	2.3	0.09	0.12	27.0	0.16	0.19	0.19	0.03	0.43
2005	2.1	0.08	0.11	25.0	0.15	0.18	0.18	0.02	0.40
2010	2.1	0.08	0.01	25.1	0.15	0.18	0.18	0.03	0.40
2015	1.5	0.07	0.00	21.7	0.12	0.15	0.15	0.02	0.35
2020	0.8	0.05	0.00	15.5	0.09	0.11	0.11	0.01	0.25
2021	0.7	0.05	0.00	14.5	0.08	0.11	0.11	0.01	0.23
2022	**0.7**	**0.05**	**0.00**	**15.5**	**0.09**	**0.11**	**0.11**	0.01	**0.25**
1990-2022 period[1)]	-1.2	-0.02	-0.10	-6.0	-0.04	-0.04	-0.04	-0.01	-0.10
1990-2022 period[2)]	-61%	-28%	-100%	-28%	-30%	-26%	-26%	-68%	-28%

1. Absolute difference.
2. Relative difference from 1990 in %.

The trends in emissions from national fishing are represented in Table 4.15. For the most part, emissions from national fishing show similar trends to emissions from fuel consumption. NO_x emissions decreased significantly between 1990 and 2022, as did PM_{10} emissions. SO_x emissions decreased due to the use of sulphur-free diesel fuel.

4.7.4 *Activity data and (implied) emission factors*

Fuel consumption in fishing was derived from fuel-sold statistics in the Netherlands, and emissions from all national fishing were estimated according to the fuel sold in the country and IEFs calculated on the basis of AIS data. Two methodologies based on AIS data were applied from 2016 onwards. For deep-sea trawlers, the methodology used for maritime navigation was applied (see Section 4.5.4) because it is assumed that no fishing activities take place in Dutch national territory. This means that these vessels essentially are only sailing to and from their fishing grounds. As a result, energy use can be calculated in the same manner as for maritime shipping. For the other fishing vessel categories (smaller vessels, mostly cutters), the methodology is described in detail by Hulskotte & ter Brake (2017). This is essentially an energy-based method whereby the energy rates of fishing vessels are broken down up by activity (sailing and fishing), with a distinction made in the available power of propulsion engine(s). The methodology is described in greater detail in chapter 6 of Geilenkirchen *et al.* (2024a).

4.7.5 *Methodological issues*

The emissions of fishing vessels have not been measured. Basing EFs on measurements for most common fishing vessels during various operational conditions could improve emission estimates.

4.7.6 *Uncertainties and time series consistency*

As of 2016, the AIS-based approach to calculating emissions from fishing has been applied to the calculation of emissions. The IEFs for 2016 were subsequently adjusted to create a consistent time series for 1990–2015, using the trend in EFs for inland shipping. This trend is based on fleet renewal data and the age class of engines for inland shipping.

In 2016, an experts' workshop was conducted to discuss and estimate the uncertainties in the activity data and EFs used for the emission calculations for the Transport sector (Dellaert & Dröge, 2017a). The resulting uncertainty estimates for national fishing are provided in Table 4.16.

Table 4.16 Uncertainty estimates for national fishing (%)

NFR	Type	Fuel	Uncer-tainty: activity data	Uncertainty: emission factor					
				NO_x	SO_x	PM_{10}	$PM_{2.5}$	EC	NMVOC
1A4ciii	National fishing	Diesel	15	30	20	50	50	50	100

Dellaert & Dröge (2017a).

Note that the uncertainty in the activity data for fisheries applies to the bottom-up approach, using AIS data, and does not apply to the top-down approach, which uses the fuel sales from the energy statistics to estimate the activity data. The top-down approach is used for the reports of emissions for the National Emission Ceilings Directive (NECD).

4.7.7 *Source-specific QA/QC and verification*
This year, no source-specific QA/QC and verification procedures were carried out for national fishing.

4.7.8 *Source-specific recalculations*
There were no source-specific recalculations for national fishing.

4.7.9 *Source-specific planned improvements*
The emission calculations for heavy metals, PCBs/HCBs and Dioxins and for PAHs are based on activity data that is not in line with the scope of other emissions in the inventory. Instead of fuel sold, emissions are based on the AIS data for fishing ships on Dutch national territory. Due to technical implementation difficulties, translation to fuel sold emissions has not yet been performed. The AIS data based emissions are estimated to be twice as high as fuel-sold emissions. Therefore, we expect an overestimation of these emissions in the current inventory. This issue is on the long list of inventory improvements.

5 Industrial Processes and Product Use

5.1 Overview of the sector

Emissions from the Industrial processes and product use (IPPU) sector include all non-energy-related emissions from industrial activities and product use. Data on the emissions from fuel combustion related to industrial activities and product use is included in the data on the Energy sector (Chapter 3). Fugitive emissions in the Energy sector (i.e. not related to fuel combustion) are included in NFR sector 1B (Section 3.5).

The IPPU sector (NFR 2) consists of the following source categories:

- 2A Mineral products;
- 2B Chemical industry;
- 2C Metal production;
- 2D Product and solvent use;
- 2G Other product use;
- 2H Other production industry;
- 2I Wood processing;
- 2J Production of POPs;
- 2K Consumption of POPs and heavy metals;
- 2L Other production, consumption, storage, transport or handling of bulk products.

Since 1998, the Netherlands has banned the production and consumption of Persistent Organic Pollutants (POPs). Emissions from the consumption of heavy metals are considered insignificant. Therefore, no emissions are reported in source categories 2I and 2K.

Because the 2019 Guidebook is not clear about which sources belong to source category 2L, emissions from other industrial processes are included in source category 2H3 (Other industrial processes). No emissions are reported in source category 2L.

Source category 2I (Wood processing) includes the primary processing and conservation of wood for industry and the building and construction sector, as well as for the construction of wooden objects and floors. Because of minor emissions, source category 2I is not included.

Table 5.1 provides an overview of the emissions from the IPPU sector (NFR 2).

42.7% of the total NMVOC emissions in the Netherlands originate from this sector.

Table 5.1 Overview of emission totals from the Industrial processes and product use sector (NFR 2)

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**5.1**	**233**	**10.0**	**5.3**	**15.6**	**29.2**	**49.1**	**0.33**	**9.5**
1995	3.2	171	2.8	5.0	10.3	18.7	34.2	0.25	4.5
2000	1.8	131	1.6	3.8	6.4	12.4	18.7	0.20	3.8
2005	0.6	108	1.0	3.5	6.0	11.4	18.9	0.16	3.5
2010	0.6	109	0.9	2.5	4.9	9.3	13.8	0.14	4.0
2015	0.6	98	0.9	2.2	5.0	10.0	14.4	0.13	4.2
2020	0.7	108	1.0	2.1	4.5	9.1	12.9	0.10	4.0
2021	0.7	103	1.0	2.0	4.4	9.0	13.0	0.08	4.0
2022	**0.7**	**103**	**1.2**	**2.0**	**4.6**	**9.3**	**13.2**	**0.09**	**4.2**
1990-2022 period[1)]	-4.4	-130	-8.8	-3.3	-11.0	-19.9	-35.9	-0.24	-5.3
1990-2022 period[2)]	-86%	-56%	-88%	-62%	-70%	-68%	-73%	-72%	-56%

Table 5.2 Overview of emission totals from the Industrial processes and product use sector (NFR 2) (continued)

	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
Year	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	**67.2**	**2.80**	**1.24**	**37.8**	**13.2**	**0.56**	**2.96**	**7.04**	**2.85**	**0.31**	**146**
1995	66.6	2.55	0.85	38.5	4.51	0.50	2.84	8.78	2.84	0.22	103
2000	25.2	2.74	0.39	13.6	0.46	0.77	2.17	11.2	0.60	0.00	55.3
2005	27.3	3.49	0.36	11.0	0.38	0.38	1.60	10.8	1.01	0.79	38.4
2010	31.6	4.33	0.30	8.1	0.18	0.49	1.16	10.7	1.27	0.06	41.2
2015	6.36	2.62	0.23	7.0	0.16	0.59	0.89	10.5	1.07	0.06	49.2
2020	3.59	1.76	0.18	5.8	0.14	0.10	0.54	7.3	0.56	0.07	128.5
2021	2.32	0.62	0.15	5.5	0.19	0.09	0.52	3.9	0.49	0.07	101.2
2022	**2.05**	**0.53**	**0.15**	**5.3**	**0.18**	**0.15**	**0.76**	**5.6**	**0.54**	**0.08**	**102.6**
1990-2022 period[1)]	-65.1	-2.3	-1.1	-32.6	-13.0	-0.41	-2.2	-1.5	-2.3	-0.24	-42.9
1990-2022 period[2)]	-97%	-81%	-88%	-86%	-99%	-74%	-74%	-21%	-81%	-76%	-29%

1. Absolute difference.
2. Relative difference from 1990 in %.

5.1.1 *Key sources*

The key sources of this sector are discussed in Sections 5.2 to 5.7.

5.1.2 *Methodological issues*

Industrial processes

The emission totals of categories and subcategories consist of the sum of the data from individual facilities, complemented by estimated emissions from the non-reporting (small and medium-sized) facilities. To estimate these emissions, the following method is used:

Up to 2000, the emissions from non-reporting facilities were calculated as follows:

$$Em\ non\_IF = IEF * (TP -/- P\_IF)$$

where:
IEF = implied emission factor;
TP = total production in (sub)category (Production Statistics, Statistics Netherlands);
P_IF = production in individual facilities (Production Statistics, Statistics Netherlands).

The IEFs were calculated as follows:

$$IEF = Em\_IF / P\_IF$$

where:
Em_IF = the sum of the data on the individual facilities.

Since 2000, due to a lack of production figures and emission data on individual facilities, the emission totals of the categories and subcategories have been calculated as follows:

$$Em\ Total\ (sub)category_{(n)} = Em\ Total\ (sub)category_{(n-1)} * (PI_{(n)} / PI_{(n-1)})$$

where:
n = year;
PI = production indices (Statistics Netherlands).

Finally, the emissions (Em_sup) from these emission sources are calculated as follows:

$$Em\_sup_{(n)} = Em\ Total\ (sub)category_{(n)} - EmComp_{(n)}$$

where:
$Em\ Total\ (sub)category_{(n)}$ = total emissions of the (sub)categories;
$EmComp_{(n)}$ = emissions from individually registered companies (PRTR-I).

If reduction measures are known to have been implemented, the emissions will be reduced by the reduction percentage achieved by these measures.

Product use
For product use, specific methodologies have been applied. Therefore, the methodological issues of the product use categories are included in Section 5.5, Solvents and product use (2D).

5.1.3 *Uncertainties and time series consistency*
Consistent methodologies were used throughout the time series for the sources in this sector.

The Netherlands implements an Approach 2 methodology for uncertainty analyses. This methodology was used for uncertainty analyses on the pollutants NH_3, NO_x, SO_x, and PM. Table 5.3 provides an overview of the results for the Approach 2 uncertainties at NFR source category level.

Table 5.3 Overview of Approach 2 uncertainties for IPPU NFR source categories

NFR source category	Pollutants uncertainty					
	NH_3	NO_x	SO_x	NMVOC	PM_{10}	$PM_{2.5}$
2A	75%	94%	88%	95%	89%	143%
2B	90%	NA	NA	52%	60%	62%
2C	86%	NA	NA	130%	98%	103%
2D	72%	NA	NA	33%	121%	121%
2G	90%	84%	116%	49%	85%	74%
2H	145%	50%	NA	119%	69%	65%
2I	NA	NA	NA	NA	201%	191%
2J	NA	NA	NA	NA	NA	NA
2K	NA	NA	NA	NA	NA	NA
2L	NA	NA	NA	NA	NA	NA
Total IPPU sector	**53%**	**88%**	**86%**	**32%**	**44%**	**66%**

5.1.4 *Source-specific QA/QC and verification*

The source categories of this sector are covered by the general QA/QC procedures, as discussed in Section 1.6.2 of Chapter 1.

5.1.5 *Source-specific planned improvements*

Source-specific planned improvements are discussed per subcategories below.

5.2 Mineral products (2A)

5.2.1 *Source-category description*

This category comprises emissions related to the production and use of non-metallic minerals in:

- 2A1 Cement production;
- 2A2 Lime production;
- 2A3 Glass production;
- 2A5a Quarrying and mining of minerals other than coal;
- 2A5b Construction and demolition;
- 2A5c Storage, handling and transport of mineral products;
- 2A6 Other mineral products.

Remarks:

- Because of allocation problems, emissions from 2A2 are included in the subcategory of Other mineral products (2A6).
- Emissions from 2A5a are currently assigned to 1A2gvii, 2A1, and 2H3. This is because companies that undertake these activities are responsible for different processes and therefore emissions from different categories. It is for now unclear how to split emissions from Quarrying and mining of minerals other than coal (2A5a) from others.
- Only emissions from Glass production (2A3) and Cement production (2A1) could be reported separately, because emissions in these categories could be derived from the AERs of the relevant companies.

- The emission totals of 2A3 and 2A6 consist of the sum of the reported emissions from individual facilities, supplemented by estimated emissions from the non-reporting facilities. Most of the data on emissions from 2A (more than 90%) is obtained from the AERs of individual facilities (Tier 3 methodology), which are validated and approved by their competent authority. According to the Aarhus Convention, only total emissions need to be included in the AERs. This means that production levels, if they are included, are confidential information. However, most companies do not include any production data. For this reason, it is not possible to provide activity data and determine/calculate IEFs.
  The emissions from non-reporting facilities are calculated from production indices of the mineral industry from Statistics Netherlands.

5.2.2 *Key sources*

The key sources in this category are presented in Table 5.4.

Table 5.4 Key sources of Mineral products (2A))

	Category / Subcategory	Pollutant	Contribution to total of 2022 (%)
2A3	Glass production	Pb	10.7
2A5b	Construction and demolition	PM_{10}	5.3
		$PM_{2.5}$	3.3
2A5c	Storage, handling, transport mineral products	PM_{10}	2.9
2A6	Other mineral products	PM_{10}	5.7
		$PM_{2.5}$	9.5
		Hg	17.7

5.2.3 *Overview of emission shares and trends*

Table 5.5 gives an overview of the emissions from the key sources of this category.

- The reduction of Pb emissions from 2A3 between 1990 and 2022 was mainly caused by the implementation of technical measures.
- The most important source of PM_{10} and $PM_{2.5}$ emissions in 2A6 is the ceramic industry (Production of bricks, roof tiles, etc.). An initial strong reduction of PM_{10} emissions from 2A6 in early years (1990-2000) was a result of implementation of technical measures. More recently, slight changes in emissions result from changes in production.

Table 5.5 Overview of emissions from the key sources of Mineral products (2A)

NFR code:	2A3	2A5b		2A5c	2A6		
NFR name:	Glass production	Construction and demolition		Storage, handling, transport	Other mineral products		
Pollutant	Pb	PM_{10}	$PM_{2.5}$	PM_{10}	PM_{10}	$PM_{2.5}$	Hg
Unit: Year	Mg	Gg	Gg	Gg	Gg	Gg	Gg
1990	7.3	0.9	0.3	1.5	2.0	1.6	-
1995	6.5	1.0	0.3	1.0	1.6	1.3	-
2000	2.9	1.2	0.4	0.6	1.0	0.9	-
2005	1.4	1.1	0.4	0.9	1.0	0.9	-
2010	0.8	1.1	0.4	0.8	1.1	1.0	0.1
2015	1.0	1.1	0.4	0.8	1.1	0.9	0.1
2018	0.6	1.1	0.4	0.7	1.3	1.2	0.1
2019	0.8	1.2	0.4	0.8	1.3	1.3	0.1
2020	1.6	1.2	0.4	0.7	1.4	1.2	0.1
2021	0.5	1.2	0.4	0.8	1.4	1.3	0.1
2022	0.5	1.4	0.5	0.8	1.5	1.4	0.1

5.2.4 *Methodological issues*

See Section 5.1.2 for the calculation method for emissions from Glass production (2A3) and Other mineral products (2A6). Emissions from non-reporting facilities are calculated from production indices of the mineral industry from Statistics Netherlands.

5.2.5 *Source-specific recalculations*

For NFR category 2A, multiple recalculations have been performed.
For category 2A5c Storage, handling and transport of mineral products, particulate matter emissions (PM_{10}, $PM_{2.5}$, and TSP) were recalculated for 2005, 2006, 2007, 2008, 2017, and 2021.
For 2021, emissions have been recalculated because there was a delay in available data. Before, emissions from 2021 were assumed to be equal to those of 2020. For this submission, emission data became available and the emissions were updated.
For 2017, the updated emissions are a result of an error correction for one company.
For the years for 2005-2008, an error correction has been performed and double counting of the emissions of one company have been corrected. This leads to a decrease in the total emissions reported here.

Furthermore, NMVOC emissions have been reallocated from 2A5c to 2H3. This has been done to correct for erroneous reallocation of NMVOC emissions from 2H3 to 2A5c before. The reallocation back to 2H3 leads to a decrease of NMVOC emissions for 2A5c to zero for all years.

For category 2A6, small changes in emissions of pollutant $PM_{2.5}$ result from changes in the fractions used to obtain $PM_{2.5}$ emissions from PM_{10}.

5.2.6 *Source-specific planned improvements*

For 2A5a, $PM_{2.5}$ and PM_{10} are currently included elsewhere (IE). Emissions from companies responsible for these PM emissions are now reported under 1A2gvii, 2A1, and 2H3. It is currently unclear what contribution of these PM emissions actually belongs to 2A5a. Also, it needs to be investigated to what extent emissions from 2A5a are reported at all. This will be revised in the next submission.

5.3 Chemical industry (2B)

5.3.1 Source category description

This category comprises emissions from the following sources:

- 2B1 Ammonia production;
- 2B2 Nitric acid production;
- 2B3 Adipic acid production;
- 2B5 Carbide production;
- 2B6 Titanium dioxide production;
- 2B7 Soda ash production;
- 2B10a Chemical industry: Other;
- 2B10b Storage, handling and transport of chemical products.

Remarks:

- Adipic acid (2B3) is not produced in the Netherlands. As such, emissions do not occur (NO).
- For carbide production (2B5), only silicon carbide is produced in the Netherlands, but no calcium carbide.
- Because of allocation problems and for confidentiality reasons, emissions from 2B1, 2B2, Silicon carbide (2B5), 2B6 and 2B7 are included in 2B10a, Chemical industry: Other. The emission total for the chemical sector consists of the sum of the reported emissions from individual facilities, supplemented by estimated emissions from the non-reporting facilities.
  Most of the data on emissions from the chemical sector (ca. 80–90%) is obtained from the AERs of individual facilities (Tier 3 methodology), which are validated and approved by their competent authority. The majority of those individual facilities produce several products. Therefore, the emission total generally is the sum of the emissions of all production processes. According to the Aarhus Convention, only total emissions need to be included in the AERs. This means that production levels and amounts of solvents used, if they are included, are confidential information. However, most companies do not include any production data or amounts of solvents used. For this reason, it is not possible to provide activity data and determine/calculate IEFs. This this same reasoning, also emissions of 2D3g are included in 2B10a.
  The emissions from non-reporting facilities are calculated from production indices of the chemical sector from Statistics Netherlands.

5.3.2 Key sources

The key sources of this category are presented in Table 5.6.

Table 5.6 Key sources of Chemical industry (2B)

	Category / Subcategory	Pollutant	Contribution to total of 2022 (%)
2B10a	Chemical industry: Other	PM_{10}/$PM_{2.5}$	2.5/3.0
		NMVOC	1.6
		Cd	11.3
		Pb	4.3

5.3.3 *Overview of emission shares and trends*

Table 5.7 provides an overview of the emissions from the key sources of this category.

Table 5.7 Overview of emissions from the key sources of the Chemical industry (2B)

	NFR Code: 2B10a: Chemical industry: Other				
	PM_{10}	$PM_{2.5}$	Cd	NMVOC	Pb
Year	**Gg**	**Gg**	**Mg**	**Gg**	**Mg**
1990	4.1	2.6	0.0	33.4	3.0
1995	3.0	1.9	0.1	17.9	1.3
2000	0.5	0.3	0.0	12.6	1.8
2005	1.2	0.7	0.8	7.9	2.2
2010	1.3	0.9	1.4	5.7	0.2
2015	1.1	0.7	0.1	4.7	0.2
2018	1.1	0.7	0.1	5.1	0.2
2019	0.9	0.6	0.1	4.5	0.2
2020	0.7	0.5	0.1	4.4	0.2
2021	0.8	0.5	0.1	4.4	0.2
2022	0.7	0.4	0.1	3.8	0.2

The reductions in NMVOC and PM_{10} emissions between 1990 and 2022 were mainly caused by the implementation of technical measures.

5.3.4 *Methodological issues*

See Section 5.1.2 for the calculation method for emissions from Other chemical industry (2B10a). The production indices of the Chemical sector used to calculate the emissions from the non-reporting facilities are presented in Table 5.8.

Table 5.8 Overview of production indices of the Chemical sector (2015 = 100)

Chemical sector	
Year	**Production index**
2005	94.1
2006	99.7
2007	103.3
2008	97.0
2009	93.4
2010	104.3
2011	102.5
2012	108.0
2013	103.3
2014	102.8
2015	100.0
2016	106.3
2018	107.4
2019	103.8
2020	104.0
2021	107.8
2022	103.0

5.3.5 *Source-specific recalculations*

For category 2B10a, multiple recalculations have been made.
NMVOC emissions reductions for 2020 and 2021 are due to corrections in Annual Emission Reporting of one and two companies, respectively.
PM_{10}, $PM_{2.5}$, and TSP emissions for 2021 have also been recalculated as a result of updated AER of one company.
2021 ammonia NH_3 recalculations also result from one company updating their AER.
For 2000, there is an increase of emissions of PM_{10}, TSP, Pb, Ni, Cd, and NMVOC. This was because for one company the year 2000 was missing from its timeseries and we now added emissions here. For 1995 there was also an error correction for Cd, to correct for double counting of emissions of one company.
$PM_{2.5}$ emissions have been recalculated for several years. These changes result from changes in the fractions used to obtain $PM_{2.5}$ emissions from PM_{10}.

5.3.6 *Source-specific planned improvements*

It is planned to improve transparency for this sector and to assign emissions to more subcategories of NFR 2B, instead of mostly to 2B10a as is the current status.
As described before, most of the data on emissions from the chemical sector (ca. 80-90%) is obtained from the AERs of individual facilities, which are validated and approved by their competent authority. However, most emissions come from one large chemical site that produces many different chemical products but only reports total emissions of the site. However, for other chemical sites it may be possible to disaggregate emissions into different NFR categories. Because of a lack of capacity, this improvement has not been implemented yet.

Furthermore, it is planned to add a more extensive summary of the industries included in 2B10a in future submissions, to improve transparency on the emissions and industries included here.

5.4 Metal production (2C)

5.4.1 Source category description

This category comprises emissions related to the following sources:

- 2C1 Iron and steel production;
- 2C2 Ferroalloys production;
- 2C3 Aluminium production;
- 2C4 Magnesium production;
- 2C5 Lead production;
- 2C6 Zinc production;
- 2C7a Copper production;
- 2C7b Nickel production;
- 2C7c Other metal production;
- 2C7d Storage, handling and transport of metal products.

Remarks:

- Because it is not possible to separate combustion and process emissions of SO_x and NO_x from Aluminium production, all SO_x and NO_x emissions are reported in 1A2b.
- For confidentiality reasons, emissions from 2C4 are included in the subcategory 2H3.
- There are one lead, one copper and one zinc producer in the Netherlands (2C5–2C7a).
- Emissions for categories 2C2 and 2C7b are not occurring (NO), as both ferroalloys and nickel production are non-existent in the Netherlands.
- For 2C7a, there is one copper-producing operator in the Netherlands. This company does not report SO_x or PM emissions in its Annual Emission Reporting because they are below the EPRTR reporting threshold. These emissions are currently not estimated (NE).
- Because only emissions from the storage and handling of bulk products companies are available, emissions from 2C7d are included in the category of Other industrial processes (2H3).

5.4.2 Key sources

The key sources of this category are presented in Table 5.9.

Table 5.9 Key sources of Metal production (2C)

Category / Subcategory		Pollutant	Contribution to total of 2022 (%)
2C1	Iron and steel production	PM_{10}	3.9
		$PM_{2.5}$	4.4
		Pb	16.5
		Hg	11.1
2C6	Zinc production	Pb	9.0
		Cd	40.4

5.4.3 *Overview of emission shares and trends*

Iron and steel production (2C1)

The Netherlands has one integrated iron and steel plant (Tata Steel, formerly known as Corus and Hoogovens). Integrated steelworks convert iron ore into steel by means of sintering, produce pig iron in blast furnaces and subsequently convert this pig iron into steel in basic oxygen furnaces.

Energy-related emissions are included under combustion emissions (categories 1A1c and 1A2a) and fugitive emissions (category 1B2).

Table 5.10 provides an overview of the process emissions from the key source of Iron and steel production (category 2C1), including dioxin, PAH and PCB emissions.

Table 5.10 Overview of emissions from Iron and Steel production (2C1)

	2C1: Iron and steel production						
Year	PM_{10} Gg	$PM_{2.5}$ Gg	Pb Mg	Hg Mg	Dioxin g I-Teq	PAH Mg	PCB g
1990	9.1	5.9	56	0.4	23	1.64	19.2
1995	4.8	3.1	58	0.4	26	1.62	21.3
2000	2.0	1.3	19	0.1	1.40	0.10	0.37
2005	1.7	1.1	23	0.2	1.40	0.09	0.43
2010	1.5	1.0	30	0.2	1.72	0.08	0.38
2015	1.3	0.8	3.5	0.1	0.27	0.07	0.04
2018	1.2	0.8	2.3	0.1	0.26	0.07	0.04
2019	1.3	0.8	1.3	0.1	0.26	0.06	0.03
2020	1.2	0.7	1.1	0.1	0.25	0.06	0.03
2021	1.2	0.7	0.9	0.1	0.21	0.12	0.03
2022	1.0	0.6	0.7	0.1	0.16	0.11	0.03

The emission reductions from this source over the 1990–2000 period were mainly caused by the implementation of technical measures. Over the 2000–2010 period, emissions remained fairly stable. Because of the replacement of electrostatic filters and the optimisation of some other emission reduction technologies at Tata Steel, most emissions decreased again after 2010. Dioxin emission fluctuations were mainly caused by the varying process conditions.

Aluminium production (2C3)

Aluminium production is responsible for 0.21% of all PAH emissions in the Netherlands. PAH emissions originate from 'producing anodes' and the 'use of anodes' during primary aluminium production.
Up to 2011, anodes were produced in two plants (Aluchemie and Zalco) and primary aluminium was produced at two primary aluminium smelters (Zalco – previously Pechiney – and Aldel). The anode and primary aluminium producer, Zalco, closed down in 2011 and Aldel closed down at the end of 2013. Aldel made a restart under the name Klesch Aluminium Delfzijl in 2015, and there was another restart under the name of Damco Delfzijl in 2017.

Over the 1990–2022 period, PAH emissions decreased from 6.9 Mg to 0.005 Mg. This reduction was mainly caused by:

- the closure of one of the anode production plants;

- the installation of three modern fume treatment plants at the other production plant.

For these reasons, aluminium production is no longer considered a key source of PAHs.

Emission fluctuations were mainly caused by varying process conditions, combined with a 43% inaccuracy in PAH measurements during the production of anodes.

Lead production (2C5), zinc production (2C6) and copper production (2C7a)

Table 5.11 provides an overview of the process emissions from the key sources of zinc production (2C6).

Table 5.11 Overview of emissions from Zinc production (2C6)

	2C6: Zinc production	
	Cd	Pb
Year	Mg	Mg
1990	1.78	0.32
1995	1.76	0.37
2000	1.75	0.52
2005	1.87	0.44
2010	1.98	0.43
2015	2.39	1.12
2018	2.00	0.42
2019	2.22	0.47
2020	1.47	0.44
2021	0.39	0.48
2022	0.32	0.41

Remarks:

- Since 2009, the single copper production company has not reported PM_{10} emissions because the emissions are far below the reporting threshold of 5,000 kg. For this reason, PM_{10} emissions are reported as ‘NE’ in 2C7a. Normally, the reported PM_{10} emissions are used to calculate $PM_{2.5}$ emissions, but that is not possible in this case. Therefore, $PM_{2.5}$ emissions are also reported as ‘NE’ in 2C7a. See Section 5.4.5 Source-specific planned improvements for more information.
- For 2C7a, multiple compounds are reported as ‘IE’, as they are included in NFR category 1A2b. This is the case for NO_x, SO_x, CO, Hg, As, and PCDD/F.
- The lead production company report no SO_x emissions because the emissions are below the reporting threshold of 20,000 kg. For this reason, no SO_x emissions are reported in 2C5.
- Because it is not possible to split SO_x emissions from 2C6, all SO_x emissions are reported in 1A2b.
- Hg emissions from lead production have remained fairly stable since 2012, while Pb emissions from zinc production doubled between 2010 and 2014.
- The zinc production company do not report any Hg emissions. The latter company reports that annual measurements at the chimney reveal that no, or very little mercury is emitted. This is

also because the mercury present in the ore is removed by forming a mercury-selenium compound before the ore gets in contact with sulphuric acid in the process.

5.4.4 *Methodological issues*

See Section 5.1.2 for the calculation method for emissions from iron and steel, aluminium, lead and zinc production. In cases without a complete registration for the four individual PAHs, a set of factors was used to calculate the emissions of the missing PAHs. These factors were obtained from a study conducted by Visschedijk *et al.* (2007).

5.4.5 *Source-specific recalculations*

For category 2C1, several recalculations have been performed.
First, the Pb emissions in 2011 are now significantly higher than before, showing an increase of 155 tons. These emissions have been reallocated from combustion emissions in category 1A2a to process emissions in category 2C1.
For 2021, multiple compounds show changes in emissions with respect to last year's submission. These are all resulting from the fact that one company updated their AER (Annual Emission Report).

5.4.6 *Source-specific planned improvements*

For 2C5, TSP emissions have been reported, but $PM_{2.5}$ and PM_{10} are currently under 'NE'. Emissions for this category come from two lead producers in the Netherlands, which do not report PM emissions in their Annual Emission Reporting (AER), as these emissions are below the E-PRTR reporting threshold. We plan to estimate $PM_{2.5}$ and PM_{10} emissions from the TSP reporting. This will be revised for future submission.

For 2C7a, there are currently no $PM_{2.5}$ or PM_{10} emissions included in the reporting. As explained before, there is currently one copper-producing operator in the Netherlands and they do not report PM emissions in their Annual Emission Reporting (AER) as these emissions are below the E-PRTR reporting threshold. We plan to improve our reporting by estimating these emissions. A plan of improvement will follow in the next submission.

5.5 Solvents and product use (2D)

5.5.1 *Source-category description*

Solvents and product use comprises the following categories:

- 2D3a Domestic solvent use, including fungicides;
- 2D3b Road paving with asphalt;
- 2D3c Asphalt roofing;
- 2D3d Coating applications;
- 2D3e Degreasing;
- 2D3f Dry cleaning;
- 2D3g Chemical products;
- 2D3h Printing;
- 2D3i Other solvent use.

Emissions NMVOC, PM, TSP and BC from Road paving are now included in the inventory for the 1990-2022 time series, calculated using the Tier 1 method from the guidebook as described in the ENINA methodology report (Honig *et al*., 2024). Source category 2D3b is not a key source.

Emissions from Asphalt roofing (2D3c) were not estimated because no activity data was available.

Emissions from Chemical products (category 2D3g) are included in 2B10a (see Section 5.3.1).

30% of the total NMVOC emissions in the Netherlands originate from Solvents and product use.

5.5.2 *Key sources*

The key sources in this category are presented in Table 5.12.

Table 5.12 Key sources of Solvents and product use (2D)

	Category / Subcategory	Pollutant	Contribution to total of 2022 (%)
2D3a	Domestic solvent use, including fungicides	NMVOC	18.6
2D3d	Coating applications	NMVOC	6.5
2D3i	Other solvent use	NMVOC	6.1
		DIOX	16.9

5.5.3 *Overview of emission shares and trends*

Table 5.13 provides an overview of the emissions from the key sources in this category.

Table 5.13 Overview of emissions from key sources of Solvents and product use (2D)

	2D3a: Domestic solvent use, including fungicides	2D3d: Coating applications	2D3i: Other solvent use	
Year	NMVOC Gg	NMVOC Gg	NMVOC Gg	Dioxin g I-Teq
1990	24	93	18	14.7
1995	27	67	17	12.8
2000	29	41	16	11.1
2005	31	26	14	9.6
2010	35	28	13	8.1
2015	36	19	15	6.8
2018	39	15	15	6.0
2019	40	15	15	5.8
2020	48	15	16	5.6
2021	45	15	14	5.3
2022	45	16	15	5.1

Domestic solvent use, including fungicides (2D3a)

The emission sources within this key source are:

- cosmetics (and toiletries);
- cleaning agents;
- car products;
- others.

The increase in NMVOC emissions over the 1990–2019 period was caused mainly by cosmetics (and toiletries). The strong increase in emissions for 2020 and 2021 is due to COVID-19: the use of disinfecting hand gels increased strongly. In the submission of 2023, recalculations have been performed for this subsector due to a change of activity data. In the previous submission, data from a survey on use of disinfecting hand gels was used for 2020 and 2021, whereas for other years data on the use of disinfection products was estimated based on work hours in hospitals. In the current submission, sales statistics from the Dutch association of soap manufacturers is used for all years. More information on this can be found in Section 5.5.6 *Source-specific recalculations*.

Coating applications (2D3d)
The emission sources within this key source are:
- industrial paint applications;
- domestic use;
- construction and buildings;
- car repairing;
- boat building.

Mainly as result to the lower average NMVOC content of the paints used, the NMVOC emissions from coating applications decreased from 93 Gg in 1990 to 25 Gg in 2007. As a result of the financial crisis, paint consumption decreased in 2008 and 2009; therefore, NMVOC emissions decreased to 19 Gg in 2009. In 2010, the biggest market segment, i.e. construction paints, continued to decrease, while car repairs and industry overall made a modest recovery. Because car repairs and the industry are market segments with generally high NMVOC levels, total NMVOC emissions increased to 28 Gg in 2010.
During the 2010–2013 period, paint consumption decreased again, which resulted in a decline in NMVOC emissions to 19 Gg in 2013. A slight increase in paint consumption led to an increase in NMVOC emissions by 1 Gg in 2014. In 2015, a lower NMVOC content of paints resulted in a decrease in NMVOC emissions. Following decreased paint consumption from 2016 onwards (mainly in the market segments of Car repairs and Industry), NMVOC emissions have been relatively constant, only showing slight variations due to changes in paint consumption.

Other solvent use (2D3i)
For NMVOC, the following activities are included in 2D3i in the Netherlands:
- 060405 Application of glues and adhesives;
- 060406 Preservation of wood;
- 060407 Underseal treatment and conservation of vehicles;
- 060409 Vehicle dewaxing;
- 060412 Other:
  - Cosmetics sector: Trade and services;
  - Car products (mainly windscreen cleaning fluid);
  - Detergents sector: Trade and services;
  - Industrial cleaning of road tankers;
  - Office products sector: Trade and services;
- 060508 Other: Use of HFCs, N_2O, PFCs and HCFCs.

Remarks:
- Emissions from the use of HFCs, PFCs and HCFCs as refrigerants and other uses of HFCs, PFCs and HCFCs are obtained from the National Inventory Report (van der Net *et al*., 2023).
- Until 2000, NMVOC emissions from most of the other sources were obtained from the Hydrocarbons 2000 project. Due to a lack of more recent data after the Hydrocarbons 2000 project, emissions in the years following 2000 were put on a par with those in 2000, the last year of the Hydrocarbons 2000 project.
- Dioxin emissions originate from PCP-treated wood. Because PCP was banned in 1989, a linear reduction in dioxin emissions was assumed. This resulted in an emission reduction from about 14.7 g I-TEQ in 1990 to about 5.1 g I-TEQ in 2022.

5.5.4 *Methodological issues*

For a detailed description of the methodology of the emission sources, see Visschedijk *et al.* (2024).

Domestic solvent use, including fungicides (2D3a)
Total NMVOC emissions were calculated by multiplying NMVOC emissions per product by the number of products sold. NMVOC emissions per product were calculated by multiplying the fraction of the NMVOC content that is emitted to the air by the NMVOC content of the product.

Coating applications (2D3d)
NMVOC emissions from paint use were calculated from national statistics on annual sales of paint that was both produced and sold within the Netherlands provided by the VVVF and from VVVF estimations relating to imported paints. The VVVF, through its members, directly monitors NMVOC in domestically produced paints and estimates the NMVOC content of imported paints. Estimates have also been made for the use of flushing agents and the reduction effect of afterburners. For more information on these estimates, see the WESP methodology report (Visschedijk *et al*., 2024).

Other solvent use (2D3i)
Total NMVOC emissions were calculated by multiplying NMVOC emissions per product by the number of products sold. NMVOC emissions per product were calculated by multiplying the fraction of the NMVOC content that is emitted to the air by the NMVOC content of the product.

5.5.5 *Activity data and (implied) emission factors*

Domestic solvent use, including fungicides (2D3a)
Sales data on products and the NMVOC content of products were obtained from annual reports by branch organisations, while the fraction of the NMVOC content that is emitted to the air was derived from studies.

Coating applications (2D3d)
In the paint application sector, annual statistics on sales are provided by the Dutch Paint and Ink Producers Association (VVVF). Total paint consumption decreased from 164 Gg in 2011 to 110 Gg in 2021 and the NMVOC content decreased from 30% in 1990 to almost 13% in 2011. During the 2012–2014 period, the NMVOC content remained fairly stable. In 2015, the NMVOC content decreased further, to 12%. From that

submission onwards, no NMVOC content figures have been made available. Therefore, the NMVOC content is kept equal to the 2015 value.

Other solvent use (2D3i)
Sales data on products and the NMVOC content of products were obtained from annual reports issued by branch organisations, while the fraction of the NMVOC content that is emitted to the air was derived from studies.

Dioxin emissions from wooden house frames were determined for 1990 on the basis of Bremmer *et al*. (1993). Because PCP was banned in 1989, a linear reduction in dioxin emission was assumed.

5.5.6 *Source-specific recalculations*

Several categories show changes in emissions due to recalculations.

Firstly, for category 2D3a the NMVOC emissions have been recalculated for the full timeseries of 1990-2021. This was due to updated emissions from floor cleaners, resulting from updated activity data based on sales statistics.
Furthermore, also for hand disinfection products the emissions have been recalculated, due to the use of new activity data.
Sales statistics are now used as activity data for obtaining emissions. These sales statistics come from Dutch association for soap manufacturers and are available for all years.
Previously, for most years the use of disinfection products was estimated based on work hours in hospitals. For 2020 and 2021, hand disinfection product used strongly increased due to covid. For these years, estimates of the activity data were based on results from a survey on the use of hand disinfectants.
In the current submission, sales statistics are used as activity data for obtaining emission estimates for all years, leading to a more consistent dataset. Furthermore, emissions are now more consistent with reported emissions from other countries and on emission estimates from ESIG. This recalculation led to a decrease of 23 Gg and 36 Gg for 2020 and 2021 respectively. For other years, it led to an increase of emissions, ranging from approximately 5 to 8 Gg.

Secondly, for category 2D3d, the NMVOC emissions for 2021 have been recalculated. This is due to a change in emissions in the Annual Emission Reporting (AER) of one company.

Lastly, category 2D3i also shows recalculations for NMVOC emissions, for 2004-2021. This is all due to updated activity data for cleaning products (2004-2021) and the use of anti-rust products at garages (2021).

5.5.7 *Source-specific planned improvements*

There are no planned improvements for NFR category 2D.

5.6 Other product use (2G)

5.6.1 Source-category description

The following activities are included in 2G in the Netherlands:
- Use of fireworks;
- Use of tobacco;
- Refrigeration and air conditioning equipment
- Other: Burning of candles.

5.6.2 Key sources

The key sources in this category are presented in Table 5.14.

Table 5.14 Key sources of Other product use (2G)

	Category / Subcategory	Pollutant	Contribution to total of 2022 (%)
2G	Other product use	PM_{10}	4.8
		$PM_{2.5}$	6.0
		Cd	10.4

5.6.3 Overview of emission shares and trends

Table 5.15 provides an overview of the emissions from the key sources in this category.

Table 5.15 Overview of emissions from key sources of Other product use (2G)

	2G: Other product use		
	PM_{10}	$PM_{2.5}$	Cd
Year	Gg	Gg	Mg
1990	1.4	1.3	0.20
1995	1.8	1.4	0.18
2000	2.2	1.6	0.18
2005	2.1	1.4	0.15
2010	1.9	1.3	0.13
2015	2.2	1.4	0.10
2017	1.9	1.2	0.10
2018	2.0	1.2	0.10
2019	1.8	1.1	0.09
2020	1.3	0.9	0.09
2021	0.9	0.6	0.09
2022	1.3	0.9	0.08

5.6.4 Source-specific recalculations

For category 2G, multiple recalculations have been performed.
First, the full timeseries (1990-2021) of all compounds resulting from fireworks have been updated. For fireworks, it is now assumed that firework sold in year x, is actually lit in year x+1, as most firework is lit after midnight at new year’s eve. Before it was assumed that firework sold in a year was also lit in the same year. Therefore this leads to a shift of the timeseries.
Furthermore, emissions for 2015-2021 are now based on activity data from CBS (Dutch Central Bureau for Statistics), whereas before it was based on Eurostat data. For years before 2015, CBS data was already used.

These changes for fireworks affected all species; $PM_{2.5}$, PM_{10}, TSP, $EC_{2.5}$, CO, Cu, NO_x, SO_x, Zn.

Furthermore, NMVOC emissions were recalculated for 2020 and 2021 for NMVOC from stationary refrigeration. This is due to a time-lag for data availability from this sector. In this submission, the 2020 data was replaced by the newly calculated value. In the previous submission, the 2021 emission was assumed to be equal to the 2019 submission. In this submission this is now updated and the 2021 emission is assumed to be equal to the 2020 emissions.

5.7 Other production industry (2H)

5.7.1 Source-category description

This category comprises emissions from the following sources:

- 2H1 Pulp and paper industry;
- 2H2 Food and beverages industry;
- 2H3 Other industrial processes.

The following activities are included in category 2H2:

- NACE 10.1: processing and preserving of meat and poultry;
- NACE 10.3: processing and preserving of fruit and vegetables;
- NACE 10.4: manufacture of oils and fats;
- NACE 10.5: dairy industry;
- NACE 10.6: manufacture of grain mill products, excluding starches and starch products;
- NACE 10.9: manufacture of prepared animal feeds;
- NACE 10.8 (excluding NACE 10.81 and 10.82): other manufacture of food products.

These NACE activities include all activities listed in the 2019 EMEP/EEA Guidebook (production of bread, wine, beer, spirits, sugar, flour, meat, fish, etc., and frying/curing).

Since 2000, due to the lack of production figures and emission data on individual facilities, it has not been possible to provide activity data and to determine/calculate IEFs (see also Section 5.3.1).

5.7.2 Key sources

The key sources in this category are presented in Table 5.16.

Table 5.16 Key sources of Other production industry (2H)

	Category / Subcategory	Pollutant	Contribution to total of 2020 (%)
2H2	Food and beverages industry	NMVOC	2.3
		PM_{10}	4.9
		$PM_{2.5}$	1.9
2H3	Other industrial processes	NMVOC	4.4
		PM_{10}	2.3
		$PM_{2.5}$	1.6

5.7.3 Overview of emission shares and trends

Table 5.17 provides an overview of the emissions from the key sources in this category.

Food and beverages industry (2H2)
The reductions in PM_{10} emissions between 1990 and 2022 were mainly caused by strong reduction in early years (1990-2000) resulting from the implementation of technical measures. After that decrease, emissions are relatively constant throughout years.

Other industrial processes (2H3)
The 2H3 subcategory in the Dutch PRTR covers emissions from a variety of activities.
The reductions in NMVOC and PM_{10} emissions between 1990 and 2020 were mainly caused by the implementation of technical measures. After 2005, PM_{10} emission fluctuations were caused by the varying volume of products handled.

Table 5.17 Overview of emissions from the key sources of Other production Industry (2H)

	2H2: Food and beverages industry			2H3: Other industrial processes		
	NMVOC	PM_{10}	$PM_{2.5}$	NMVOC	PM_{10}	$PM_{2.5}$
Year	Gg	Gg	Gg	Gg	Gg	Gg
1990	9.1	4.3	1.0	25	3.0	1.1
1995	7.6	2.3	0.6	13	1.1	0.4
2000	8.2	1.7	0.4	5.9	1.4	0.4
2005	7.6	1.5	0.3	10	0.7	0.3
2010	7.5	1.2	0.3	10	0.5	0.2
2015	6.0	1.3	0.3	10	0.6	0.2
2018	5.8	1.4	0.3	10	0.7	0.2
2019	5.9	1.4	0.3	10	0.6	0.2
2020	5.5	1.4	0.3	10	0.6	0.2
2021	5.4	1.4	0.3	11	0.6	0.2
2022	5.5	1.3	0.3	11	0.6	0.2

5.7.4 *Methodological issues*
See Section 5.1.2 for the calculation method for emissions from the production of food and drink (category 2H2) and from storage and handling (2H3). Emissions from non-reporting facilities are calculated from production indices of the food and beverages industry from Statistics Netherlands.

There is one exception: NMVOC emissions from bread bakeries occur as a result of using yeast in the bakery process. Since the 2020 submission, these emissions have been calculated separately by multiplying the activity data by the guidebook EF of 4.5 kg NMVOC per Mg bread produced, for European bread. The activity data is obtained by using data from the Dutch Bakery Centre (NBC). It is assumed that the import and export of bread can be ignored, because bread is a highly perishable product. As stated by the NBC, no emission reduction measures are taken.

5.7.5 *Source-specific recalculations*
Recalculations have been performed for two subcategories.
First, for category 2H2, NMVOS emissions of 2021 have been recalculated. This recalculation is a result of the fact that one company updated their AER and now also added NMVOS, whereas last submission

this was not included. This lead to a small increase of 42.65 kg NMVOS in 2021.

For category 2H3, the $PM_{2.5}$ emissions for 1996 and 1997 for the textile and clothes emissions have been recalculated. This results from changes in the fraction used to obtain $PM_{2.5}$ emissions from PM_{10}.

Furthermore, NMVOC emissions have been reallocated from 2A5c to 2H3. This has been done to correct for erroneous reallocation of NMVOC emissions from 2H3 to 2A5c before. The reallocation back to 2H3 leads to an increase of NMVOC emissions for 2H3 for the full timeseries.

6 Agriculture

6.1 Overview of emissions from the sector

The agricultural sector includes all anthropogenic emissions from agricultural activities. Emissions from fuel combustion (mainly related to heating in horticulture and the use of agricultural machinery) are included in the source category Agriculture/Forestry/Fishing: Stationary (1A4c).
Emission sources in the agricultural sector consist of the following NFR categories:

- 3B Manure management;
- 3D Crop production and agricultural soils;
- 3F Field burning of agricultural residues.

This Informative Inventory Report (IIR) focuses on emissions of ammonia (NH_3), nitrogen oxides (NO_x), particulate matter (PM_{10}, $PM_{2.5}$), non-methane volatile organic compounds (NMVOC), hexachlorobenzene (HCB) and zinc (Zn) from the NFR source categories of 3B Manure management and 3D Crop production and agricultural soils. The source category 3F Field burning of agricultural residues is reported as Not Occurring (NO) since field burning has been prohibited in the Netherlands during the whole time series (article 10.2 of the Environmental Management Act, or 'Wet Milieubeheer' in Dutch).

Emissions of the greenhouse gases methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) from the agricultural sector are reported in the annual National Inventory Report (NIR). All emissions from manure management and crop production are calculated according to the methods described in van der Zee *et al.* (2024). All activity data are summarised in Van Bruggen *et al.,* (2024), except the activity data on N excretion which are reported in CBS (2023). The method and activity data for the calculation of the NMVOC and Zn emissions from the use of pesticides are given in section 6.3 and Kruijne *et al.,* (2022).

In 2022, the agricultural sector was responsible for 91% of all NH_3 emissions in the Netherlands. Emissions of NO_x from agriculture amounted to 17% of the national total. Agriculture contributed 36% of the national NMVOC emissions, 20% of the national PM_{10} emissions, 4% of the national $PM_{2.5}$ emissions and 1% of the national HCB emissions in 2022. Although Zn is not a priority heavy metal, emissions from drift following pesticide use are reported for the sake of completeness.

The current reported timeseries (1990-2022) differ from the previous timeseries (1990-2021) as six recalculations have been implemented. The first recalculation concerns the emissions from veal manure treatment. Instead of a fixed TAN content of the treated veal manure, the yearly TAN content is used. The change affects the emission of NH_3 and NO_x.
The second change concerns the amount of treated manure. From 2018 onwards the N content of the manure is based on the mandatory transport certificates instead of defaults. This affects the NH3 and the NO_x emission from manure treatment.

The third recalculation is caused by the inclusion of bedding material as an N-input into the manure storage, where the bedding material contributes to the emission of the different N-species. The inclusion causes the emissions of NH_3 from 3B and NH_3 and NO_x from 3D to increase.
The fourth recalculation is due to the previous recalculation. As the emissions of NH_3 from housing and storage change, NMVOC emissions from manure storage also change.
The fifth recalculation concerns the emissions from crop residues. The NH_3 and NO_x emissions from crop residues have been recalculated for the entire timeseries as the area of mown grasslands changed due to the inclusion of mown natural grasslands as well as the shift to the agricultural census instead of the grassland survey.
The sixth recalculation is caused by the update of the PM_{10} emission factors from agricultural crops. The emission factors from the 2019 EMEP guidebook have been used instead of the 2016 version. This results in an increase of PM emissions for the entire timeseries of 3De Cultivated crops.

Besides the recalculations, it has been decided to treat all horses, ponies, mules and asses (both kept on farms and privately held) the same way and report their emissions under 3B and 3D. This means the manure management emissions from privately held animals are no longer reported under sector 6 Other.

Key sources
In 2022, several key sources were identified, as presented in Table 6.1 (see Appendix 2 for details).

Trends
Ammonia
Ammonia emissions decreased between 1990 and 2022, with the largest reduction in the first few years of the time series (Tables 6.2 and 6.9). This was mainly caused by a ban on the surface spreading of manure enforced in the period 1991–1995, which made it mandatory to incorporate manure into the soil either directly or shortly after application. In addition, it became mandatory to cover outside slurry manure stores. More recently, the introduction of low-emission housing for animals further decreased ammonia emissions.

Maximum application standards for manure and fertiliser (in accordance with the Nitrates Directive) and systems of livestock production rights have increased efficiency in animal production. An example of this is the ongoing improvement in nutritional management (precision feeding), where a reduction of dietary crude protein in concentrate feed has resulted in a lower N intake per animal and thus a lower N excretion and consequently reduced NH_3 emissions. However, the N excretion of dairy cattle increased as more grass was fed instead of maize between 1990-2022. Grass has a higher N content than maize, resulting in an overall higher N excretion. The increase is due to the derogation system, which allows dairy farmers to apply more manure on their land than the maximum set by the EU in the Nitrates Directive. Until 2014, one of the eligibility requirements for derogation was to use a minimum of 70% of the land as grassland. In 2014, this minimum was increased to 80% of the land. In 2022 the N excretion of dairy cattle decreased as the N content of the roughages decreased. Beginning in 2023 the amount of manure that can be applied under the derogation will be gradually reduced until 2026 when the derogation will be completely abolished.

Table 6.1 All NFR categories that were identified as key sources of the agricultural sector on level (L) and/or trend (T)

NFR Category	NH_3	NO_x	PM_{10}	$PM_{2.5}$	NMVOC	HCB
3B Manure management						
Cattle						
Dairy cattle	L, T				L, T	
Non-dairy cattle	L, T				L	
Swine	L, T		L			
Poultry						
Laying hens	L,T		L, T			
Broilers			L			

NFR Category	NH_3	NO_x	PM_{10}	$PM_{2.5}$	NMVOC	HCB
3D Crop production and agricultural soils						
Inorganic N fertilisers	L, T	L, T				
Animal manure applied to soils	L, T	L, T			L, T	
Cultivated crops			L			
Farm-level agricultural operations including storage, handling and transport of agricultural products					L, T	
Urine and dung deposited by grazing animals	T					
Use of pesticides						T

The milk quota set by the EU (1984-2015) led to an increase in milk production per dairy cow. Increased production per animal led to a decrease in animal numbers and consequently lower emissions. Due to the abolishment of the milk quota in 2015, more dairy cattle were kept from 2014 onwards, leading to a further increase in production of both milk and manure. The increased manure production caused an exceedance of the national phosphate production ceiling as set in European agreements, which in turn led to an introduction of phosphate quota for dairy cattle as of 1st January 2018. This quota limited the number of dairy cattle a farmer can keep and resulted in a decreasing trend in animal numbers from 2017 onwards. An additional effect of the phosphate quota was an increase in average body weight, milk yield and N uptake. These changes are the result of farmers keeping their biggest and most productive cows and culling the smaller cows with lower productivity.

The amount of manure exported increased fourfold in the period 1990 to 2016 after which it decreased in 2017 and 2018, export increased in 2019 but decreased in the years since. The increase can be explained by the stricter application requirements resulting in a decreased demand for manure in the Netherlands. From 1997 onwards, part of the NH_3 emissions from animal housing are contained in the washing liquid of air scrubbers, which was used as an inorganic N-fertiliser, shifting some N to category 3D Crop production and agricultural soils.

From 1st January 2019, the application of liquid manure using a trailing shoe on peat and clay soils was allowed only when the manure was diluted with one part water to two parts manure. This reduces the emission of NH_3.

Since most of the Netherlands' total NH_3 emissions originate from the agricultural sector, the trend in NH_3 emissions seen from 1990 to 2022 in agriculture was reflected in a decreasing trend in the national total.

Nitrogen oxides
Nitrogen oxide emissions decreased over the 1990–2022 period due to a lower inorganic N-fertiliser use, a decrease in N excretion during grazing, less manure N applied to soil and, in recent years, a decrease in cattle numbers (Tables 6.2 and 6.9).

Particulate matter
Particulate matter emissions for most animal categories decreased slightly over the 1990–2022 period due to decreased animal numbers (Tables 6.6 and 6.7); however, PM emissions from laying hen houses almost tripled for PM_{10} and doubled for $PM_{2.5}$. This was caused by a shift from battery cage systems with liquid manure to floor housing or aviary systems, with solid manure and higher associated emissions of PM_{10} and $PM_{2.5}$. This gradual transition between 1990 and 2012 was initiated by a ban on battery cage systems from 2012 and led to an overall increase in PM emissions from manure management (Table 6.2). PM emissions peaked in 2014, after which they decreased.

NMVOC
Overall, NMVOC emissions from agriculture decreased over the 1990–2022 period (Tables 6.2 and 6.9). However, the emissions reported under manure management increased significantly, due to an increased share of silage feeding and its NMVOC emissions in the animal house. A decrease in emissions from animal manure applied to soils compensated for the increase in manure management emissions. This decrease was caused by low-ammonia-emission application techniques.

HCB
Hexachlorobenzene (HCB) emissions from agriculture decreased over the 1990–2022 period (Table 6.9). This is due to the reduction in the amount of applied pesticides containing HCB as well as a reduction in the maximum amount of HCB allowed as a contaminant in pesticides.

6.2 Manure management (3B)

6.2.1 Source category description

The category Manure management (3B) includes emissions from the treatment and storage of animal manure. Emissions were allocated to the following NFR subcategories:

- 3B1a Dairy cattle;
- 3B1b Non-dairy cattle;
- 3B2 Sheep;

- 3B3 Swine;
- 3B4d Goats;
- 3B4e Horses;
- 3B4f Mules and asses;
- 3B4gi Laying hens;
- 3B4gii Broilers;
- 3B4giii Turkeys;
- 3B4giv Other poultry;
- 3B4h Other animals: fur-bearing animals;
- 3B4h Other animals: rabbits.

Category 3B4a (Buffalo) does not occur in the Netherlands. Emissions from the category 3B4giv Other poultry include emissions from ducks. Emissions resulting from the application of animal manure or during grazing were related to land use and are not reported under 3B Manure management but are included in 3D Crop production and agricultural soils.

6.2.2 *Key sources*

Approach1

Within sector 3B, in 2022, dairy cattle (3B1a) made the largest contribution to NH_3 emissions, amounting to 17% of the national total. Swine (3B3, 11%), non-dairy cattle (3B1b, 7%) and laying hens (3B4gi, 7%) were also key NH_3 sources. The largest source of PM_{10} emissions within sector 3B was laying hens (3B4gi), amounting to 8% of the national total. Broilers (3B4gii, 3%) and swine (3B3, 3%) were also key sources of PM_{10}. For NMVOC emissions, dairy cattle (3B1a) made the largest contribution to the national total with 18%. The category non-dairy cattle (3B1b) was also a key source, with a contribution of 5%. For emissions of $PM_{2.5}$ and NO_x, the manure management sector had no key sources.

Aproach2

The approach2 key sector analysis is only performed at the level of GNRF sectors for the pollutants NO_x, NMVOC, SO_x, NH_3, PM_{10} and $PM_{2.5}$. From this analyses the GNFR-sector Agrilivestock is a:

- 2022 level key source of NH_3 and NMVOC
- 2022 trend key source of NH_3, NMVOC and PM_{10}.

6.2.3 *Overview of emission shares and trends*

Table 6.2 presents an overview of emissions of the main pollutants NMVOC, NO_x and NH_3, together with the emissions of PM_{10} and $PM_{2.5,}$ originating from sector 3B Manure management.

Table 6.2 Emissions of main pollutants and particulate matter from sector 3B Manure management

	Main Pollutants			Particulate Matter		
	NO_x	NMVOC	NH_3	$PM_{2.5}$	PM_{10}	TSP
Year	Gg	Gg	Gg	Gg	Gg	Gg
1990	**3.7**	**42**	**100**	**0.46**	**4.1**	**4.1**
1995	4.0	41	97	0.46	4.1	4.1
2000	3.4	45	78	0.48	4.6	4.6
2005	3.0	42	69	0.46	4.6	4.6
2010	3.2	59	71	0.49	5.2	5.2
2015	3.7	66	65	0.50	5.5	5.5
2020	3.8	65	61	0.43	4.7	4.7
2021	3.6	64	59	0.42	4.5	4.5
2022	**3.6**	**64**	**57**	**0.41**	**4.3**	**4.3**
1990-2022 period[1)]	-0.18	22	-42	-0.05	0.25	0.25
1990-2022 period[2)]	-5%	54%	-42%	-11%	6%	6%

1. Absolute difference in Gg.
2. Relative difference from 1990 in %.

N emissions
The Netherlands uses an N-flow model, the National Emission Model for Agriculture (NEMA), to calculate N emissions (Zee van der *et al.,* 2024). Figure 6.1 presents a schematic overview of the N-flows.

Between 1990 and 2022, NH_3 emissions from manure management were reduced by 42% (Table 6.2). Higher production rates per animal and restrictions via quotas resulted in a decreasing trend in the numbers of cattle, sheep, and swine. Nitrogen excretions per animal decreased over the time series due to a decrease in dietary crude protein in all animal categories. In 2017 and 2018, N excretion increased again for cattle, which can be explained by an increase in nutrient requirements through a higher average milk production and body weight. In 2019, N excretion decreased as a lower amount of N was fed. In 2020 N excretion increased due to a higher amount of N fed. In 2021 and 2022 N excretion decreased as the roughages contained less nitrogen.

A study published by Netherlands Statistics showed that some forms of low-emission housing did not reach the emission reduction targets (Van Bruggen & Geertjes, 2019). Therefore, it was decided to adjust the NH_3 emissions based on the Nitrogen:Phosphate ratio in the manure. A complete description of the method applied to calculate the EFs of all housing types is included in the methodology report (Zee van der *et al.,* 2024).

As NO_x emissions were also influenced by the above-mentioned developments, NO_x emissions decreased by 5% from 1990 to 2022.

Particulate matter

PM_{10} emissions from animal housing showed an increasing trend in the time series, which was caused mainly by the increased proportion of solid manure housing systems for poultry. The increased available floor space per animal added to this effect. In recent years, the increased usage of abatement techniques for PM removal and a lower number of poultry resulted in a decrease in PM. $PM_{2.5}$ emissions decreased over the entire time period as a result of lower animal numbers.

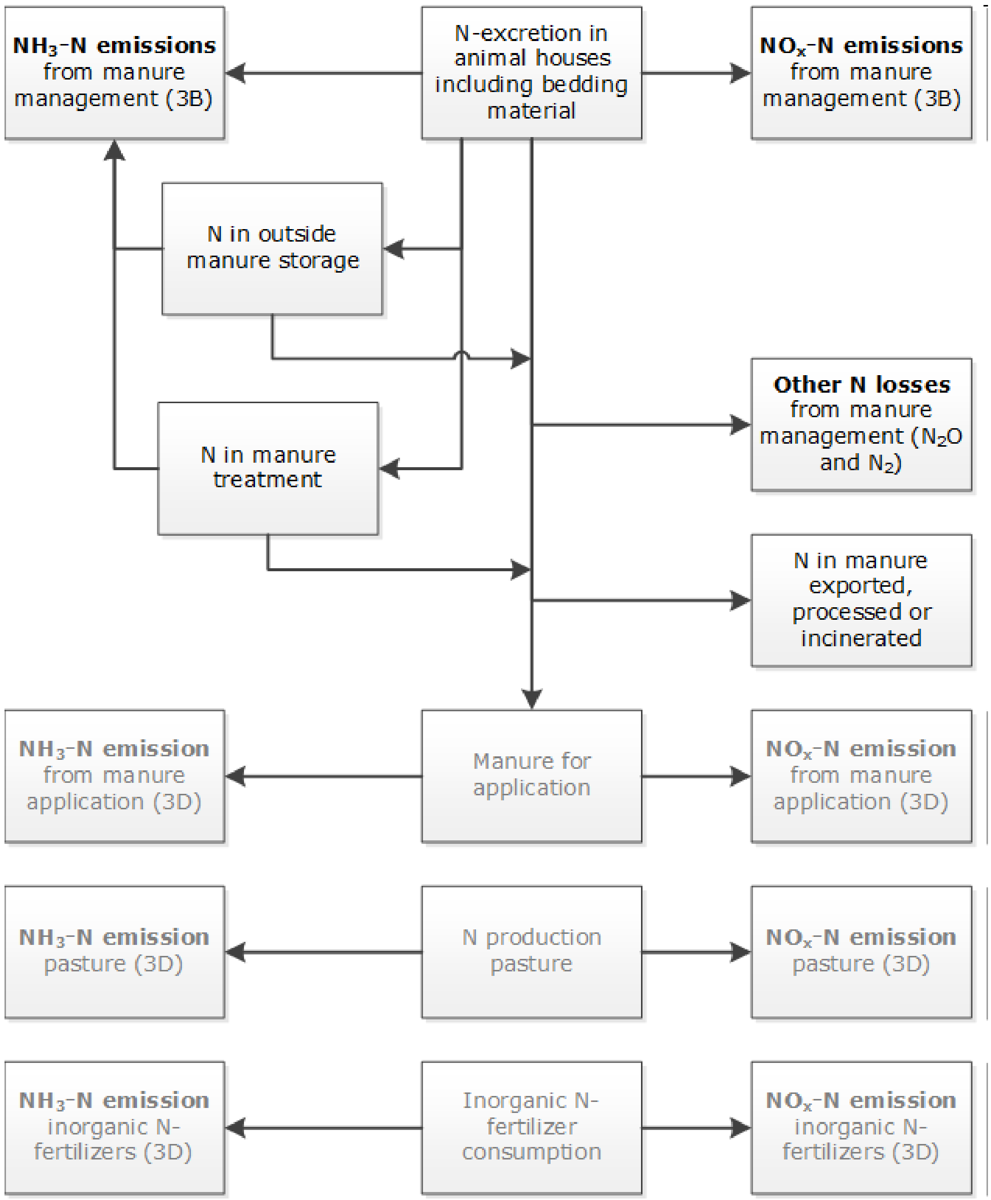

Figure 6.1 Nitrogen flows in relation to NH_3 and NO_x emissions where the boxes with black type show the emissions included in 3B Manure management and the boxes with grey type show emissions included in 3D Crop production and agricultural soils

NMVOC

Emissions of NMVOC showed an increasing trend of 54% from 1990 to 2022, mostly caused by an increase in silage feeding to dairy cattle in animal housing, leading to more NMVOC emissions from animal housing. The increase in poultry numbers also added to this increasing trend.

6.2.4 *Activity data and (implied) emission factors*

Activity data include animal numbers as determined by the annual agricultural census and the I&R system (see the summary in Table 6.3 and, for a full list of subcategories and years, Bruggen van *et al*., (2024). More information on the collection of animal numbers can be found in section 2.2.1 of Zee van der *et al.,* (2024).
Animal numbers were distributed over the various housing types using information from the agricultural census (Bruggen van *et al.*, 2024).

N emissions
Emissions of NH_3 and NO_x from manure in animal houses, manure treatment and outside manure storages were calculated using the NEMA model at a Tier 3 level. N excretions per animal are calculated annually by the Working Group on the Uniformity of Calculations of Manure and Mineral Data (WUM; CBS, 2012). The historical data were recalculated in 2019 (CBS, 2019) and have since been supplemented yearly, thereby ensuring consistency (publication series CBS, 2019 to 2023).

The Total Ammoniacal Nitrogen (TAN) in manure was calculated from the faecal digestibility of the N in the various components of animal feed. From the N excretion data, the TAN excretion per animal type and NH_3 EF per housing type were calculated, taking into account mineralisation and immobilisation. The Tier 1 default N_2O EFs from the IPCC 2006 Guidelines were applied to both N_2O and NO_x emissions, following research from Oenema *et al.* (2000), which set NO_x emissions equal to N_2O emissions. According to this same study, N_2 losses were set to a factor of 5 (solid manure) or 10 (liquid manure) of the N_2O/NO_x factors, all expressed as percentages of the total N available.

NH_3, N_2O, NO_x and N_2 emissions from animal housing were calculated and subtracted from the excreted N. Subsequently, the amount of manure stored outside animal housing, and its corresponding NH_3 emissions, were calculated. NH_3, N_2O and NO_x emissions from manure that was treated (manure separation, nitrification/denitrification, mineral concentrates, incineration, pelleting/drying and digesting of manure) were calculated (Melse and Groenestein, 2016). The sums of emissions from animal housing, manure treatment and outside manure storage per livestock category were reported under their respective subcategories in sector 3B Manure management, except for emissions associated with the digesting of manure, which are allocated to 5B2 Biological treatment of waste – Anaerobic digestion at biogas facilities. The amount of N available for application was calculated by subtracting all N emissions during manure management, the N removed from agriculture by manure treatment and the net export of manure. The N in applied manure is used to calculate emissions from manure application, allocated to sector 3D. As a result of new insights into the feed intake of horses and ponies, N excretion increased in 2018 (Bikker *et al.*, 2019).

Table 6.3 Animal numbers over the 1990–2022 period (in 1,000 heads)

Animal type	1990	1995	2000	2005	2010	2015	2020	2021	2022
Cattle	4,926	4,654	4,069	3,797	3,975	4,134	3,719	3,732	3,766
dairy cattle	1,878	1,708	1,504	1,433	1,479	1,622	1,593	1,571	1,571
non-dairy cattle	3,048	2,946	2,565	2,364	2,497	2,512	2,126	2,161	2,195
Sheep[1]	1,702	1,674	1,305	1,361	1,130	946	954	916	907
Swine	13,915	14,397	13,118	11,312	12,255	12,603	11,860	11,372	11,235
Goats	61	76	179	292	353	470	633	643	645
Horses[1]	370	400	417	433	441	417	410	417	417
Mules and asses[1]	1	1	1	1	1	1	1	1	1
Poultry	91,680	88,243	102,579	91,726	99,880	104,760	96,431	90,666	89,453
laying hens	51,592	45,734	53,078	48,418	56,500	57,656	50,828	51,580	50,212
broilers	38,086	40,542	47,118	41,160	41,393	45,426	44,325	37,928	38,160
turkeys	1,052	1,207	1,544	1,245	1,036	863	566	589	474
other poultry	950	760	839	902	951	816	712	568	607
Other animals	1,340	951	981	1,058	1,261	1,404	770	321	300
Fur-bearing animals	554	463	589	697	962	1,023	435	0	0
Rabbits	786	488	392	360	299	381	335	321	300

– Including privately held animals
Source: Bruggen van *et al.* (2024).

IEFs for NH_3 emissions in sector 3B Manure management were calculated for the main NFR categories (Table 6.4). The NH_3 emission per animal decreased for all animal species (except cattle) due to improved efficiency, low NH_3 emission housing systems and covering outside manure stores. The IEF of cattle increased due to an increased living area for each animal and an increase in productivity per animal and thus in N intake and N excretion. This resulted in a net increase in cattle IEF. Although the living area for each animal was also increased for swine and poultry, emission reduction techniques such as air scrubbers and manure drying more than counterbalanced the effect of the increased living area. The fluctuating N content of grass silage caused yearly changes in the IEF for cattle.

Table 6.4 IEFs for NH_3 from sector 3B Manure management (in kg NH_3/animal)

Animal type	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
Cattle	6.8	6.9	5.8	6.5	6.9	7.4	8.8	8.2	8.0
Dairy cattle	11.9	12.0	9.6	11.7	12.0	12.4	14.6	13.8	13.5
Non-dairy cattle	3.7	3.9	3.6	3.4	3.8	4.3	4.4	4.2	4.0
Sheep	0.4	0.4	0.4	0.3	0.1	0.1	0.1	0.1	0.1
Swine	3.5	3.4	2.8	2.4	2.2	1.4	1.1	1.1	1.1
Goats	1.7	1.7	1.5	1.3	1.3	1.4	1.7	1.6	1.6
Horses	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7
Mules and asses	3.6	3.6	3.6	3.5	3.3	3.3	2.9	2.8	2.8
Poultry	0.15	0.16	0.15	0.15	0.14	0.13	0.12	0.13	0.13
Laying hens	0.16	0.17	0.17	0.18	0.17	0.17	0.17	0.17	0.17
Broilers	0.11	0.12	0.10	0.09	0.08	0.06	0.06	0.06	0.06
Turkeys	0.80	0.79	0.80	0.85	0.95	0.94	0.81	0.70	0.65
Other poultry	0.33	0.32	0.29	0.26	0.23	0.19	0.18	0.18	0.17
Other animals	0.40	0.38	0.32	0.28	0.22	0.24	0.24	0.35	0.34
Fur-bearing animals	0.37	0.36	0.29	0.22	0.17	0.19	0.16	NO	NO
Rabbits	0.42	0.39	0.37	0.40	0.36	0.38	0.34	0.35	0.34

Table 6.5 IEFs for NO_x from sector 3B Manure management (in kg NO_x/animal)

Animal type	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
Cattle	0.32	0.35	0.33	0.31	0.33	0.38	0.42	0.40	0.39
Dairy cattle	0.46	0.49	0.44	0.46	0.46	0.51	0.56	0.54	0.53
Non-dairy cattle	0.23	0.28	0.27	0.23	0.25	0.30	0.31	0.30	0.28
Sheep	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Swine	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Goats	0.26	0.26	0.23	0.22	0.24	0.25	0.30	0.29	0.29
Horses	0.29	0.29	0.29	0.29	0.26	0.26	0.35	0.35	0.35
Mules and asses	0.15	0.15	0.15	0.15	0.14	0.14	0.17	0.17	0.17
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laying hens	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Broilers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkeys	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other animals	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.00
Fur-bearing animals	0.02	0.02	0.02	0.01	0.01	0.01	0.01	NO	NO
Rabbits	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Particulate matter
Emissions of PM_{10} and $PM_{2.5}$ from agriculture mainly consist of animal skin, manure, feed and bedding particles originating from animal housing. Animal housing produces a large amount of PM_{10} compared with $PM_{2.5}$. The general input data used for these calculations were animal numbers and housing systems taken from the annual agricultural census and environmental permits. From 2015 farmers also implemented additional measures to decrease PM emissions from poultry housing. IEFs for PM_{10} and $PM_{2.5}$ are shown in Table 6.6 and Table 6.7.

Table 6.6 IEFs for PM_{10} from sector 3B Manure management (in g PM_{10}/animal)

Animal type	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
Cattle	85.4	82.8	78.3	78.7	77.8	80.3	82.2	81.1	80.7
Dairy cattle	114.8	114.8	114.8	119.9	123.7	127.4	125.1	124.9	125.0
Non-dairy cattle	67.3	64.3	56.9	53.7	50.6	50.0	50.0	49.2	49.0
Sheep	4.2	4.2	4.2	3.9	1.8	1.8	1.8	1.8	1.8
Swine	113.3	112.2	112.4	109.9	103.8	77.3	69.3	68.0	67.3
Goats	19.0	19.0	19.0	19.0	19.0	19.0	18.8	18.8	18.6
Horses	220.0	220.0	220.0	220.0	220.0	220.0	220.0	220.0	220.0
Mules and asses	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0
Poultry	21.8	22.9	26.4	32.0	35.2	38.7	35.6	36.1	35.5
Laying hens	14.9	16.1	22.8	33.6	39.3	46.8	43.9	43.8	43.0
Broilers	26.8	26.8	26.8	26.7	26.6	26.3	24.3	23.7	23.7
Turkeys	100.2	98.1	95.1	95.1	95.1	95.1	94.1	94.5	94.0
Other poultry	104.5	104.5	104.5	104.5	104.5	101.8	100.1	100.7	101.1
Other animals	4.2	4.7	5.5	5.9	6.5	6.3	5.1	1.3	1.2
Fur-bearing animals	8.1	8.1	8.1	8.1	8.1	8.1	8.1	NO	NO
Rabbits	1.4	1.4	1.4	1.4	1.4	1.4	1.2	1.3	1.2

Table 6.7 IEFs for $PM_{2.5}$ from sector 3B Manure management (in g $PM_{2.5}$/animal)

Animal type	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
Cattle	23.5	22.8	21.6	21.7	21.4	22.1	22.6	22.4	22.2
Dairy cattle	31.7	31.7	31.7	33.1	34.1	35.1	34.5	34.4	34.5
Non-dairy cattle	18.5	17.7	15.7	14.8	13.9	13.8	13.8	13.6	13.5
Sheep	1.2	1.2	1.2	1.2	0.5	0.5	0.5	0.5	0.5
Swine	5.8	5.7	5.7	5.4	5.1	3.7	3.3	3.2	3.1
Goats	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6
Horses	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0
Mules and asses	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Poultry	2.2	2.4	2.5	2.7	2.7	2.8	2.5	2.6	2.5
Laying hens	1.4	1.5	1.7	2.1	2.5	2.9	2.7	2.7	2.6
Broilers	2.0	2.0	2.0	2.0	2.0	2.0	1.8	1.8	1.8
Turkeys	47.0	46.0	44.6	44.6	44.6	44.6	44.1	44.3	44.1
Other poultry	5.0	5.0	5.0	5.0	5.0	4.9	4.8	4.8	4.8
Other animals	1.9	2.2	2.6	2.9	3.3	3.1	2.5	0.3	0.2
Fur-bearing animals	4.2	4.2	4.2	4.2	4.2	4.2	4.2	NO	NO
Rabbits	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2

NMVOC

The NMVOC emissions reported under Manure management include emissions from manure in animal housing, manure in outside stores and silage feed in animal housing. Most NMVOC emissions occur during the feeding of silage. The increase in IEF that can be seen with cattle is caused by increased feeding of silage (Table 6.8). NMVOC is also released from the storage of manure in animal housing and outside manure storage. All NMVOC emissions were calculated at a Tier 2 level using the default EFs from the 2016 EMEP Guidebook (EEA, 2016), with the NEMA model. The activity data used for these calculations were animal numbers and feeding data as reported by the WUM (CBS, 2023).

Table 6.8 IEFs for NMVOC from 3B Manure management (in kg NMVOC/animal)

Animal type	1990	1995	2000	2005	2010	2015	2020	2021	2022
Cattle	5.98	6.17	7.96	8.41	12.14	13.28	13.71	14.30	14.41
Dairy cattle	8.15	7.96	15.07	16.92	24.13	25.67	25.91	27.47	27.51
Non-dairy cattle	4.64	5.14	3.78	3.24	5.05	5.28	5.21	5.00	4.89
Sheep	0.05	0.05	0.05	0.05	0.02	0.02	0.02	0.02	0.02
Swine	0.42	0.39	0.35	0.32	0.29	0.27	0.26	0.28	0.28
Goats	0.86	0.79	0.42	0.82	0.87	0.86	0.85	0.91	0.95
Horses	0.61	0.61	0.61	0.59	0.59	0.59	0.59	0.59	0.59
Mules and asses	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25
Poultry	0.06	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07
Laying hens	0.05	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.06
Broilers	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07
Turkeys	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.13	0.12
Other poultry	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.07
Other animals	0.15	0.17	0.21	0.23	0.26	0.25	0.24	0.25	0.24
Fur-bearing animals	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Rabbits	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

6.2.5 *Uncertainties and time series consistency*

A propagation of error analysis on NH_3 emissions was performed in 2022. Using reassessed uncertainty estimates of activity data and the judgement of experts (Zee van der *et al.,* 2024), an uncertainty of 21% in total NH_3 emissions from sector 3B Manure management was calculated. Including the emissions in sector 3D Crop production and agricultural soils, the combined uncertainty in NH_3 emissions from the Agriculture sector was 23%. A Monte Carlo analysis of uncertainties of the total inventory (including sectors outside agriculture) was performed in 2023 and the results are presented in Section 1.5.

The same information sources were used throughout the time series when available. The agricultural census was the most important information source. This census has been conducted in the same way for decades. The same methodology for emission calculations was used throughout the time series, ensuring the consistency of the emission calculations.

6.2.6 *Source-specific QA/QC and verification*

This source category is covered in Chapter 1, under general QA/QC procedures. QA/QC measures taken for the sector Agriculture are described in the methodology report (van der Zee *et al.,* 2024).

6.2.7 *Source-specific recalculations*

Four recalculations have been implemented for the sector manure management. The first recalculation concerns the inclusion of bedding material in the manure storage. The nitrogen in the bedding contributes to the emission of NH_3. NO_x emissions were not affected as the emission is based on N excreted. More information on the bedding material usage can be found in Annex 11 of Van der Zee *et al.,* (2024).
The second change concerns the amount of treated veal manure. Instead of a fixed TAN content of the treated veal manure, the yearly TAN content is used. The change affects the emission of NH_3 and NO_x between 1990 and 2022. NH_3 emissions increase by between 0% and 2%. NO_x emissions change by between -1% and 9%.
The third change concerns the amount of treated manure. From 2018 onwards the N content of the manure is based on the mandatory transport certificates instead of defaults. This affects the NH_3 (-2% - +2%) and the NO_x (-4% - +2%) emissions from manure treatment.
The fourth recalculation is caused by the recalculations affecting NH_3 emission from housing and storage. NMVOC emissions from manure storage are partly based on the ratio of NH_3 emissions from housing and storage. As the ratio is changed, NMVOC emissions from manure storage increase by around 0.05% between 1990 and 2021.

6.2.8 *Source-specific planned improvements*

The nutrients bedding material incorporate into the manure and the corresponding emissions have been estimated taking only straw into account. In the Netherlands different types of bedding material are used, straw, wood shavings but also the dry fraction of separated manure. The Tier 1 method does not account for the last type of bedding material, and it is expected that the emissions of this type of bedding material are higher than of straw and wood shavings. The agricultural census will include a question on the use of bedding material, thereby enabling the calculation of emissions from the different types of bedding material for the IIR of 2025.

The QA/QC section in the methodology report of 2025 will be further elaborated to encompass all measures that are currently taken.

6.3 Crop production and agricultural soils (3D)

6.3.1 *Source category description*

The category Crop production and agricultural soils (3D) includes emissions related to the agricultural use of land. Emissions were allocated to the following NFR subcategories:

- 3Da1 Inorganic N fertilisers;
- 3Da2a Animal manure applied to soils;
- 3Da2b Sewage sludge applied to soils;
- 3Da2c Other organic fertilisers applied to soils;
- 3Da3 Urine and dung deposited by grazing animals;
- 3Da4 Crop residues applied to soils;
- 3Db Indirect emissions from managed soils;
- 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products;
- 3Dd Off-farm storage, handling and transport of bulk agricultural products;
- 3De Cultivated crops;
- 3Df Use of pesticides.

Category 3Dc contains PM emissions from the use of inorganic N fertilisers and pesticides, the supply of concentrate feed to farms, haymaking and crop harvesting. NMVOC emissions from silage storage are also reported under 3Dc. NMVOC emissions are allocated to category 3Da2a, 3Da3, 3Dc 3De and 3Df. Zinc and HCB emissions to category 3Df.

6.3.2 *Key sources*

Approach1

Within sector 3D, Animal manure applied to soils (3Da2a) was the largest key source of NH_3 emissions, amounting to 30% of the national total. Inorganic N fertilisers (3Da1) were also a key source of NH_3, making up 8% of the national total. For NO_x, animal manure applied to soils (3Da2a, 8%) and inorganic N fertilisers (3Da1, 4%) were key sources. For NMVOC emissions, Farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc, 5%) and Animal manure applied to soils (3Da2a, 4%) were key sources. For emissions of PM_{10} Cultivated crops (3De, 3%) is the only key source from the crop production sector. For $PM_{2.5}$, the crop production and agricultural soils sector contained no key sources. HCB emissions from the use of pesticides (3Df) were not a key source.

Aproach2

The approach2 key sector analysis is only performed at the level of GNRF sectors for the pollutants NO_x, NMVOC, SO_x, NH_3, PM_{10} and $PM_{2.5}$. From this analyses the GNFR-sector AgriOther is a:

- 2022 level key source of NO_x, NH_3, PM_{10} and NMVOC
- 2022 trend key source of NO_x and PM_{10}.

6.3.3 *Overview of shares and trends in emissions*

Table 6.9 presents an overview of emissions of the main pollutants NH_3, NMVOC and NO_x, together with the particulate matter fractions PM_{10} and $PM_{2.5}$, the other heavy metal, Zn, and the persistent organic pollutant HCB, originating from sector 3D Crop production and agricultural soils (3D).

Table 6.9 Emissions of main pollutants and particulate matter from the category of Crop production and agricultural soils (3D)

	Main Pollutants			Particulate Matter			POPs	Other Heavy Metals
	NO_x	NMVOC	NH_3	$PM_{2.5}$	PM_{10}	TSP	HCB	Zn
Year	Gg	Gg	Gg	Gg	Gg	Gg	kg	Mg
1990	**47**	**56**	**237**	**0.11**	**1.17**	**1.17**	**21**	**0.0**
1995	45	25	110	0.11	1.14	1.14	39	0.0
2000	38	26	84	0.11	1.17	1.17	16	0.0
2005	33	23	72	0.11	1.17	1.17	1.8	6.8
2010	30	22	53	0.11	1.17	1.17	1.1	4.5
2015	31	23	54	0.11	1.11	1.11	0.7	4.4
2020	30	23	52	0.10	1.02	1.02	0.1	4.4
2021	30	23	53	0.11	1.02	1.02	0.0	2.2
2022	**29**	**23**	**53**	**0.11**	**1.06**	**1.06**	**0.0**	**2.2**
1990-2022 period[1)]	-18	-32	-184	-0.01	-0.11	-0.11	-21	2.2
1990-2022 period[2)]	-39%	-58%	-78%	-6%	-10%	-10%	-100%	

1. Absolute difference in Gg, except for HCB (kg) and Zn (Mg).
2. Relative difference from 1990 in %.

N emissions
Emissions of NH_3 from crop production and agricultural soils decreased by 78% between 1990 and 2022, with an initial sharp fall between 1990 and 1995. This was mainly the result of changed manure application methods, which were enforced during this period (i.e. incorporation of manure into the soil instead of surface spreading). The use of inorganic N fertiliser also decreased during the time series, following policies aimed at reducing the nutrient supply to soils (i.e., implementation of the EU Nitrates Directive).

NO_x emissions decreased by 39% between 1990 and 2022, mainly because of lower N input through the use of inorganic N fertiliser and reductions in grazing time and manure application.

Particulate matter
The particulate matter emissions reported in this source category originate from the use of inorganic N fertiliser and pesticides, the supply of concentrate feed to farms, haymaking and crop harvesting. The decreasing trend in PM emissions is entirely explained by fluctuations in the acreage of crops.

NMVOC
NMVOC emissions from crop production and agricultural soils show a decrease between 1990 and 2022 of 58%, as a result of changing manure application methods to reduce emissions of ammonia between 1990 and 1995. The increase in emissions from farm-level agricultural operations was caused by an increase in silage feeding, and thereby silage storage.

Zinc
Zinc emissions decreased by 67% from 2005 to 2022, due to a reduction in pesticide use. Before 2005, there were no zinc emissions related to the pesticides then used.

HCB
HCB emissions decreased by 100% from 1990 to 2022, due to a reduction in pesticide use, more stringent requirements for the HCB impurity in pesticides that is allowed and a ban on some pesticides containing HCB impurities.

6.3.4 *Activity data, (implied) emission factors and methodological issues*

N emissions
For N emission calculations in sector 3D, activity data were calculated from N excretion including bedding material in sector 3B minus N emissions from animal housing, manure treatment and outside storage (Figure 6.2). After subtracting the N in manure removed from agriculture (exported, incinerated or otherwise used outside of agriculture), the remaining N was allocated to grassland and arable land. Implementation percentages of application techniques were derived from the agricultural census. The associated NH_3 EFs were reported in van der Zee *et al*. (2024). NO_x emissions related to manure, inorganic N fertiliser and sewage sludge application, compost use and the grazing of animals were calculated using the EMEP default EF.

NH_3 emissions from the use of inorganic N fertilisers were calculated using data on the amount of inorganic N fertiliser used in agriculture. Several types of inorganic N fertiliser were distinguished – each with a specific NH_3 EF. In recent years, the amount of applied urea fertiliser has increased, and a growing share is used in liquid form or coated with urease inhibitors to reduce NH_3 emissions and/or is applied with NH_3 low-emission techniques. To account for this development, additional subcategories of urea fertiliser were specified for the 1990–2022 time series, as described in the methodology report of van der Zee *et al.* (2024). The subcategories and the EFs for each subcategory can be found in Van Bruggen *et al.* (2024).

Calculations of NH_3 emissions from crop residues were based on activity data taken from the agricultural census. Given the large uncertainty in the emissions of crop ripening, a fixed estimate of 1.8 Gg NH_3/year was reported (De Ruijter *et al.,* 2013).

IEFs for sector 3D in kg NH_3/kg N supply were calculated for the NFR categories, as depicted in Table 6.10. IEFs for animal manure and sewage sludge application dropped considerably between 1990 and 1995 due to mandatory incorporation into the soil. The reduction in emissions from urine and dung deposited by grazing animals was mainly explained by a reduction in cattle grazing.

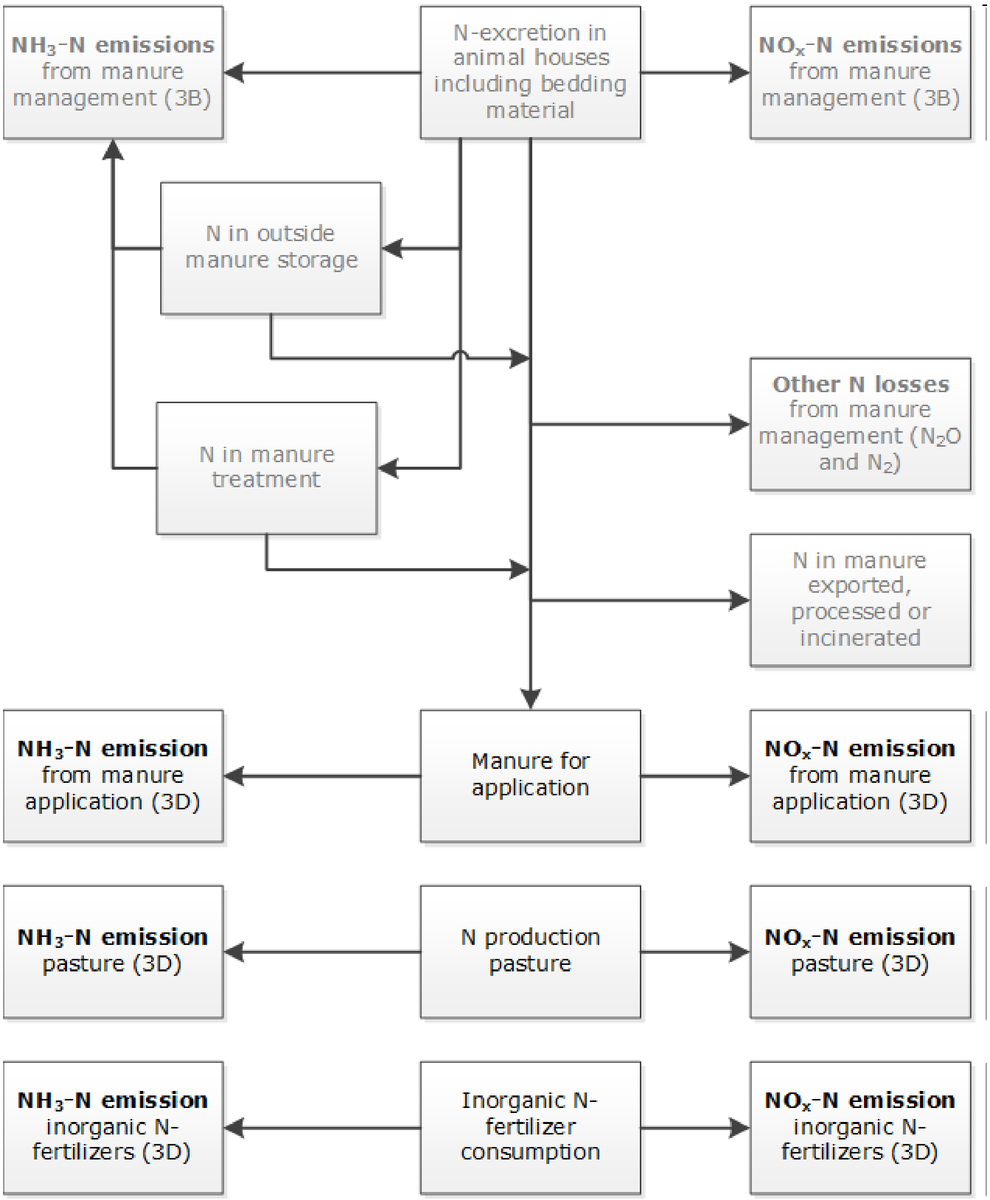

Figure 6.2 Nitrogen flows in relation to NH_3 and NO_x emissions where boxes with black type show the emissions included in 3D Crop production and agricultural soils and boxes with grey type show emissions included in 3B Manure management

Table 6.10 IEFs for NH_3 from 3D Crop production and agricultural soils (in kg NH_3/kg N supply)

Supply source	1990	1995	2000	2005	2010	2015	2020	2021	2022
Application of inorganic N-fertilizers	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Application of animal manure	0.49	0.19	0.18	0.17	0.12	0.11	0.11	0.11	0.11
Application of sewage sludge	0.29	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10
Application of other organic fertilizers (compost)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Urine and dung deposited by grazing animals	0.08	0.08	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Crop residues	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Crop ripening	NA	NA	NA	NA	NA	NA	NA	NA	NA

Particulate matter
Small sources of PM_{10} and $PM_{2.5}$ emissions reported under category 3D were the application of inorganic N fertilisers and pesticides, the supply of concentrate feed to farms, and haymaking. To calculate PM emissions, both EMEP default and country specific EFs were applied (Zee van der *et al.,* 2024). PM emissions from other agricultural processes (e.g., the supply of concentrate feed to farms, the use of pesticides and haymaking) were estimated using fixed factors (Zee van der *et al.,* 2024). Crop harvesting was calculated from acreage data from the agricultural census and EMEP default EFs (EEA, 2019).

NMVOC
The NMVOC emissions reported under category 3D were from animal manure applied to soils, urine and dung deposited by grazing animals, farm-level agricultural operations including storage, handling and transport of agricultural products, cultivated crops and use of pesticides. All were calculated using EMEP default EFs, using a Tier 2 method. Only the emissions from cultivated crops were calculated using a Tier 1 method. The emissions from the use of pesticides were calculated using a Tier 3 method.

NMVOC emission from the use of pesticides originate from the use of mineral oil, metaldehyde and formic acid. Usage and emissions from these pesticides were calculated by the National Environmental Indicator Pesticides (NMI4) (Kruijne *et al.,* 2022). Subsequently it is assumed that 20% of the mineral oil emissions are NMVOC and 100% of the metaldehyde and formic acid emissions are NMVOC.

Zinc
Zinc emissions were based on the amount of pesticide used in agriculture as calculated by the National Environmental Indicator Pesticides (NMI4) model (Kruijne *et al.*, 2022).

HCB
Hexachlorobenzene has been prohibited for use as a pesticide for the entire time series. However, HCB can still be found in certain pesticides as an impurity. The sales figures of the pesticides containing HCB are

given in Table 6.11. The impurity factor was based on the maximum amount that is allowed (EMEP, 2019).

Table 6.11 Sales figures of pesticides containing HCB impurities in 1,000 kg active substance

	Sales figures of pesticides containing HCB impurities in 1,000 kg active substance				
Year	**Lindane**	**Atrazine**	**Simazine**	**Chlorothalonil**	**Clopyralid**
1990	19.5	172.3	60.5	62.3	0.0
1991	20.6	189.1	63.0	67.6	0.0
1992	25.9	201.5	52.7	80.9	0.0
1993	25.0	205.3	52.9	93.9	0.0
1994	19.6	221.5	50.4	102.4	0.0
1995	19.3	218.4	50.7	126.7	2.9
1996	21.3	209.3	48.5	101.2	1.9
1997	22.5	183.7	48.1	209.0	1.5
1998	22.9	154.6	52.1	420.8	2.4
1999	44.3	134.6	71.4	323.1	2.2
2000	0.0	0.0	30.2	388.5	4.8
2001	0.0	0.0	19.8	81.5	3.3
2002	0.0	0.0	0.0	539.2	3.3
2003	0.0	0.0	1.2	102.7	2.1
2004	0.0	0.0	0.0	159.5	2.2
2005	0.0	0.0	0.0	179.6	2.3
2006	0.0	0.0	0.0	164.6	1.8
2007	0.0	0.0	0.0	206.4	2.2
2008	0.0	0.0	0.0	153.6	1.8
2009	0.0	0.0	0.0	105.3	1.2
2010	0.0	0.0	0.0	106.2	1.6
2011	0.0	0.0	0.0	113.9	1.8
2012	0.0	0.0	0.0	104.6	1.6
2013	0.0	0.0	0.0	90.2	2.3
2014	0.0	0.0	0.0	77.1	4.6
2015	0.0	0.0	0.0	73.4	6.2
2016	0.0	0.0	0.0	82.2	5.8
2017	0.0	0.0	0.0	68.0	18.7
2018	0.0	0.0	0.0	63.9	18.1
2019	0.0	0.0	0.0	43.6	19.9
2020	0.0	0.0	0.0	9.5	18.1
2021	0.0	0.0	0.0	0.0	13.3
2022[1]	0.0	0.0	0.0	0.0	13.3

1. Sales figures from 2021 were used as preliminary figures for 2022.

6.3.5 *Uncertainties and time series consistency*

A propagation of error analysis of NH_3 emissions was performed in 2022. Using reassessed uncertainty estimates of activity data and expert judgement, an uncertainty of 31% was calculated for NH_3 emissions following animal manure application, 36% for inorganic N fertiliser use and 48% for grazing emissions. The total uncertainty in the ammonia emissions from sector 3D Crop production and agricultural soils then amounts to 25%. Including the emissions in sector 3B Manure management, the combined uncertainty in total NH_3 emissions from agriculture comes to 23%. A Monte Carlo analysis on the uncertainties

of the total inventory was performed in 2024 and the results are presented in Section 1.5.
The same information sources were used throughout the time series when available. The agricultural census was the most important information source. This census has been conducted in the same way for decades. The same methodology for emission calculations was used throughout the time series, ensuring consistency of the emission calculations.
A propagation of error analysis of HCB emissions was performed in 2021. The EMEP Guidebook estimates the uncertainty of the emission factor to be between 15 and 30%. For the calculations, the HCB contamination was set at the maximum allowed under the regulations whereas producers have an incentive to ensure their products remain below the threshold. Therefore, the uncertainty was set at 30%.

The amount of pesticides sold was derived from the confidential 'RAG-list' (Regeling administratievoorschriften gewasbeschermingsmiddelen) for the years 1990–2009. For the years 2010–2021 the data were provided by the Dutch Food and Consumer Safety Authority, these data are publicly available. For 2022 the value of 2021 was used, as no new value had been provided in time (NVWA, 2023). Both sources provide the same information: quantity of pesticides sold in kg active substance. Both sources used sales figures given by companies selling pesticides. No time series inconsistency is caused by the two sources.

6.3.6 *Source-specific QA/QC and verification*

This source category is covered in Chapter 1 under general QA/QC procedures. QA/QC measures taken for the sector Agriculture are described in section 2.5 of the methodology report (van der Zee *et al.,* 2024).

6.3.7 *Source-specific recalculations*

Three recalculations have been implemented for the sector crop production and agricultural soils.
The first recalculation is caused by the inclusion of bedding material as an N-input into the manure storage, where the bedding material contributes to the emission of the different N-species. The inclusion causes the amount of manure available for application to increase, thereby increasing the emissions of NH_3 and NO_x from 3D by between 1% to 2%.
The second recalculation concerns the emissions from crop residues. The NH_3 and NO_x emissions from crop residues have been recalculated for the entire timeseries as the area of mown grasslands changed due to the inclusion of mown natural grasslands as well as the shift to the agricultural census instead of the grassland survey. NH_3 emissions from crop residues increased by between 1 – 9%, NO_x emissions increased by between 0 – 3%.
The emission factor of PM_{10} from agricultural crops have been updated to the 2019 version of the EMEP guidebook. The new PM_{10} emission factors of cereals are 150% larger than the old emission factors. The $PM_{2.5}$ emission factors were already based on the 2019 EMEP guidebook.

6.3.8 *Source-specific planned improvements*

The IIR 2025 will include the sales figures of pesticides in 2022 instead of using sales figures from 2021 as a proxy.

7 Waste

7.1 Overview of the sector

Waste sector emissions (Table 7.1) include those from industrial activities. The waste sector (NFR 5) consists of the following source categories:

- 5A Solid waste disposal on land;
- 5B Anaerobic digestion and composting;
- 5C Waste incineration;
- 5D Wastewater handling;
- 5E Other waste.

Solid waste disposal on land (5A)
Emissions in this source category comprise those from landfills and those from recovered and flared landfill gas. Part of the recovered landfill gas is used for energy purposes, and these emissions are allocated to the Energy sector (source category Other: Stationary (1A1a)). If landfill gas is only flared off, the emissions are allocated to 5A.
Mineral waste may be disposed of in landfills, recycled or recovered as backfilling material, depending on its composition and origin. Landfilling of mineral waste is more likely for inert materials, or for disposal of waste after primary e.g. chemical treatment. In all cases, mineral waste treatment implies multiple handling activities such as loading/loading out activities. Emissions of particulate matter occur during mineral waste handling activities.

Composting and anaerobic digestion (5B)
Emissions in this source category comprise those from facilities for the composting and/or fermenting of manure and from separately collected organic waste for composting and/or biogas production (sometimes also used as co-substrate in manure digestion).

During processing emissions of NH_3, SO_x and NO_x relevant to the total national emission occur. The biogas produced is used for energy purposes, so these emissions are allocated to the Energy sector (source category Small combustion (1A4)).

Waste incineration (5C)
Emissions in this source category are emissions from municipal, industrial, hazardous and clinical waste incineration, from the incineration of sewage sludge and from crematoria. Since all waste incineration plants in the Netherlands produce electricity and/or heat that is used for energy purposes, emissions from these source categories are explained and included in the Energy sector (source category Public electricity and heat production (1A1a)).

NO_x and SO_x emissions from crematoria (category 5C1bv) originate mainly from fuel use (natural gas). These emissions, therefore, are included in the source category Commercial/Institutional: Stationary (1A4ai).

Wastewater handling (5D)
In the Netherlands all wastewater is treated in municipal wastewater treatment plants (5D1) or in industrial treatment plants (5D2) both in a biological process. During the water treatment small amounts of NMVOC are emitted.
The produced sludge is often used for methane production in a anaerobic digester and dried afterwards for transport to a sludge processor where the sludge is mostly incinerated.

Natural gas, on site produced biogas from anaerobic sludge digestion and very small amounts of domestic fuel oil are used in the sludge drying installations. The emissions from incineration of fuels are reported under Commercial/Institutional: Stationary (1A4ai).

In pursuit of waste minimisation and circular use of raw materials, WWTP operators and sludge processors are working on new ways of treating the wastewater and processing the produced sludge (for instance producing Kaumera Nereda® gum, alginates, cellulose, struvite, etc.). Developments relating to emissions from these new processes are followed closely.

Other waste (5E)
Emissions in the source category Other waste (5E) comprise those from waste preparation for recycling, scrapped fridges/freezers and accidental building and car fires.

Key sources
Approach 1
The source category Other waste (5E) is a:

- 2022 level key source of PM_{10}, $PM_{2.5}$, BC, dioxins and total PAH;
- 1990-2022 trend key source of $PM_{2.5}$, BC, dioxins and total PAH emissions.

All sources in this NFR are calculated with a CS methodology.

Approach 2
The Approach 2 key source analysis is only performed at the level of GNRF sectors for the pollutants NO_x, NMVOC, SO_x, NH_3, PM_{10} and $PM_{2.5}$.
From this analyses the GNFR sector Waste is a:

- 2022 level key source of $PM_{2.5}$
- 1990-2022 trend key source of SO_x, NH_3, PM_{10} and $PM_{2.5}$.

7.2 Overview of shares and trends in emissions

An overview of the trends in emissions is represented in Table 7.1. Emissions from the waste sector are low. This is mainly because most emissions from incineration are reported under the Energy sector.

With the exception of NMVOC, emissions of the main pollutants have increased since 1990. This increase has been caused by gradually increased activity. The increase is sometimes dampened by the implementation of abatement technologies for some sources.

With the exception of dioxins (from building fires) and PAHs (from building and car fires) the emissions of pollutants are low.

Table 7.1 Overview of emission totals in the Waste sector (NFR 5)

Year	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**0.15**	**2.4**	**0.03**	**0.2**	**0.48**	**0.52**	**0.5**	**0.11**	**7.2**
1995	0.19	2.3	0.05	1.1	0.51	0.56	0.6	0.12	8.6
2000	0.19	2.1	0.04	1.3	0.52	0.56	0.6	0.12	8.7
2005	0.18	1.7	0.03	1.3	0.50	0.54	0.6	0.11	8.1
2010	0.22	1.7	0.04	1.3	0.56	0.61	0.6	0.13	8.8
2015	0.30	1.5	0.04	1.2	0.55	0.60	0.6	0.13	8.5
2020	0.28	1.3	0.04	1.4	0.44	0.48	0.5	0.11	7.8
2021	0.28	1.3	0.05	1.4	0.44	0.48	0.5	0.11	7.7
2022	**0.30**	**1.3**	**0.04**	**1.3**	**0.50**	**0.55**	**0.6**	**0.12**	**8.5**
1990-2022 period[1)]	0.15	-1.1	0.02	1.1	0.03	0.03	0.06	0.02	1.3
1990-2022 period[2)]	98%	-45%	64%	760%	5%	6%	10%	15%	17%

Table 7.1 Overview of emission totals in the Waste sector (NFR 5) (continued)

Year	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	**0.05**	**0.02**	**0.09**	**13.0**	**0.79**	**0.02**	**0.03**	**0.01**	**0.00**	**0.00**	**1.1**
1995	0.05	0.02	0.10	14.1	0.83	0.02	0.04	0.02	0.00	0.00	1.5
2000	0.05	0.02	0.10	14.4	0.85	0.02	0.04	0.02	0.00	0.00	1.2
2005	0.05	0.02	0.09	13.5	0.83	0.02	0.04	0.02	0.00	0.00	1.1
2010	0.06	0.03	0.04	15.9	0.93	0.02	0.04	0.02	0.00	0.00	1.3
2015	0.05	0.03	0.01	15.6	0.92	0.02	0.04	0.02	0.00	0.00	1.3
2020	0.05	0.02	0.01	16.1	0.60	0.00	0.04	0.01	0.00	0.00	0.9
2021	0.05	0.02	0.00	16.2	0.59	0.00	0.04	0.01	0.00	0.00	0.9
2022	**0.05**	**0.02**	**0.01**	**16.5**	**0.82**	**0.01**	**0.04**	**0.01**	**0.00**	**0.00**	**1.2**
1990-2022 period[1)]	0.01	0.00	-0.08	3.5	0.04	0.00	0.01	0.00	0.00	0.00	0.07
1990-2022 period[2)]	13%	15%	-93%	27%	5%	-25%	21%	2%	5%	-21%	7%

1. Absolute difference.
2. Relative difference from 1990 in %.

7.2.1 *Methodological issues*

The methodology used to calculate most of the emissions from the source categories in the Waste sector is described by Honig *et al*. (2024). The exceptions are emissions from cremations, accidental building and car fires, and from bonfires, the methodologies of which are explained in Visschedijk (2024), and the source Livestock manure digestion, which is explained in Van der Zee *et al*. (2024).

There are no specific methodological issues.

7.2.2 Uncertainties and time series consistency

As explained in Section 1.6.3, the Netherlands implemented an Approach 2 methodology for uncertainty analysis in 2018. This methodology is used for uncertainty analysis of the pollutants NH_3, NO_x, SO_x and PM. Table 7.2 provides an overview of the results for the Approach 2 uncertainties at NFR source category level.

Table 7.2 Overview of the Approach 2 uncertainties for Waste NFR source categories

NFR source category	Pollutants uncertainty					
	NH_3	NO_x	SO_x	NMVOC	PM_{10}	$PM_{2.5}$
5A	NA	100%	100%	96%	71%	88%
5B	76%	101%	100%	NA	NA	NA
5C	349%	114%	119%	276%	470%	339%
5D	NA	NA	NA	130%	NA	NA
5E	205%	201%	201%	199%	196%	198%
Total Waste sector	**71%**	**86%**	**89%**	**158%**	**178%**	**177%**

The Approach 2 uncertainty analysis reveals relatively high uncertainties at the level of the source categories. However, since these source categories either have no key sources for these pollutants or their contribution to the uncertainty at national level will be relatively small there, there is no reason for prioritising methodological improvements.

7.2.3 Source-specific QA/QC and verification

There are no source-specific QA/QC procedures. The categories in this sector are covered by the general QA/QC procedures, as discussed in Chapter 1.

7.2.4 Source-specific recalculations

The source category 5A has been recalculated, because a new methodology has been used to calculate particulate matter emissions from mineral waste handling.

7.2.5 Source-specific planned improvements

The originally form the 2024 submission planned improvement in obtaining annual activity data from industrial WWPTs is re-scheduled to the 2025 submission. Industrial companies are now asked (voluntary, as there is no legal base for reporting this) to also report the type of WWTP, the amounts of industrial wastewater and cooling water that is treated in the WWTP in their AER. A first glance at te reported data for 2023 shows promising information.

7.3 Solid waste disposal on land (5A)

7.3.1 Source-category description

The source category Solid waste disposal on land (5A) comprises direct emissions from landfills and from recovered and flared landfill gas and PM emissions from the landfilling process.

This source category includes all waste landfill sites in the Netherlands that have been managed and monitored since 1945, i.e. both historical and current public landfills, and waste landfill sites on private land. These waste sites are considered to be responsible for most of the emissions in this source category. Emissions from landfill sites before 1945 are regarded as negligible (Van Amstel *et al*., 1993).

The total amount of landfill gas produced in the Netherlands is calculated using a first-order degradation model that calculates the degradation of degradable organic carbon (DOC) in waste (Table 7.3). From this information, the amount of methane is calculated using a methane conversion factor (Table 7.4).

It is assumed that 10% of the non-recovered methane will be oxidised in the top layer of the landfill.

Table 7.3 Amounts of waste landfilled and degradable organic carbon content.

Year	Amount landfilled (Tg)	Degradable organic carbon (kg/Mg)	Degradable organic carbon that dissimilates (%)
1990	13.9	131	58
1995	8.2	125	58
2000	4.8	110	58
2005	3.5	62	41
2010	2.1	33	34
2015	2.3	43	40
2016	2.8	52	40
2017	2.9	56	39
2018	3.2	51	38
2019	2.8	49	34
2020	2.4	43	32
2021	2.1	38	31
2022	2.1	37	31

The amounts of recovered and combusted landfill gas (mainly for energy purposes) is collected by the Working Group on Waste Registration (WAR). All landfill operators report this data to WAR (Table 7.6).

Part of the recovered landfill gas is used as an energy source (combined heat and power production or transferred to the natural gas network); emissions from this source are reported under 1A1a. The remainder part of the recovered landfill gas is flared and the emissions from this are reported under this sector.
Flaring of landfill gas emits also small amounts of NMVOC to the atmosphere. The individual compounds that form NMVOCs mainly originate from volatile organic compounds that were dumped as waste in the past. A small part is produced as a by-product during the biodegradation of organic materials within the waste. Direct NMVOC emissions from landfills are calculated on the basis of individual pollutants in the landfill gas.

Table 7.4 Input parameters used in the landfill degradation model

Parameter	Parameter values	References
Oxidation factor (OX)	0.1 (10%)	Coops *et al*. (1995)
DOC_f = fraction of degradable organic carbon	0.58 from 1945 to 2004; from 2005 onwards yearly determined based on the composition of waste disposed. This is elaboration of the refinement points from the 2019 IPCC refinements	Oonk *et al*. (1994)
Degradable speed constant k	0.094 from 1945 to 1989 (half-life 7.5 yr); from 1990 reducing to 0.0693 in 1995; thereafter constant at 0.0693 (half-life 10 yr); from 2000 reducing to 0.05 in 2005; thereafter constant at 0.05 (half-life 14 yr)	Oonk *et al*. (1994)
$DOC_{(X)}$ = concentration of biodegradable carbon in waste that was dumped in year x	132 kg C/Mg dumped waste from 1945 to 1989; from 1990 through a linear gradient reducing to 125 kg C/Mg in 1995; 120 kg/Mg in 1996 and 1997 and after 1997 determined annually by Rijkswaterstaat	Based on Jager de & Blok (1993) determined by Spakman *et al*. (1997) and published in Klein Goldewijk *et al*. (2004)
F = fraction of CH_4 in landfill gas	0.574 from 1945 to 2004; thereafter constant at 0.5	Oonk (2016)
$MCF_{(x)}$ = Methane correction factor for management	1	
Delay time	6 months	

7.3.2 *Overview of shares and trends in emissions*

NMVOC emission levels related to this source category are relatively low, at 1.48 Gg and 0.24 Gg in 1990 and 2022, respectively.

$PM_{2.5}$ emissions are also relatively low, at 0.0039 Gg and 0.0053 Gg in 1990 and 2022, respectively.

The landfilling of waste and particularly of combustible waste products and biodegradable material is discouraged in the Netherlands. For this reason, the amount of waste landfilled has dropped considerably (see Table 7.3), from 13.9 Tg in 1990 to only 2.1 Tg in 2022 (-85%). In addition, due to the separation of degradable materials, the amount of degradable carbon in the waste has dropped from 132 kg C per Mg waste in 1990, to 37 kg C per Mg in 2022 (-72%). Additionally, the separated collection of household organic waste led to a decrease in the fraction of organic carbon that dissimilates from 51% in 1990 to 31% in 2022. These two developments have had a clear effect on methane (and also NMVOC) production by landfill sites, which has decreased over 80% during the same period. This downward trend is expected to continue in future.

7.3.3 *Emissions, activity data and (implied) emission factors*

Emissions of the individual compounds of NMVOC have been calculated as fractions of the emission total, using a landfill gas emission model for methane that is based on the IPCC Guidelines. The fractions were based on measurements of the composition of landfill gas. An overview of the EFs used is provided in Table 7.5.

Table 7.7 provides the emission factors used for the combustion of recovered landfill gas.

For each waste site, landfill site operators systematically monitor the amount of waste that is dumped (weight and composition). Since 1993, monitoring has been conducted by weighing the amount of dumped waste using weighbridges. Since 2005, landfill operators have been obliged to register their waste on the basis of European Waste List (EWL) codes (Decision 2000/532/EC). Table 7.8 represents the EFs used for calculating the PM emissions during landfilling.

Table 7.5 Emission factors used for the free emission of landfill gas

Pollutant	**Free emitted landfill gas mg/m^3**
Benzene	7
Toluene	120
Trichlorofluoromethane (R-11)	5
1,1,2-Trichloro-1,2,2-trifluoroethane (R-113)	1
1,2-Dichlorotetrafluoroethane (R-114)	2
Chloropentafluoroethane (R-115)	1
Dichlorodifluormethane (R-12)	20
Dichlorofluoromethane (R-21)	10
Chlorodifluoromethane (R-22)	10
1,2-Dichloroethene	1
Dichloromethane	20
Tetrachloroethylene (Perc)	10
1,1,1-Trichloroethane	2
Trichloroethylene (Tri)	10
Chloroform (Trichloromethane)	1
Vinyl chloride (Chloroethene)	10
Methanethiol (methyl mercaptan)	10
Hydrogen sulphide	100
Other hydrocarbons	700

Table 7.6 overview of the amounts of landfill gas and methane recovered and combusted

Year	Free emission of landfill gas (million m^3)	Free emission of methane (Gg)	Recovered landfill gas (million m^3)	Amount used for energy purposes (million m^3)	Amount combusted in flares (million m^3)	Percentage of methane in recovered landfill gas (%)	Amount recovered methane (Gg)	Amount recovered methane useful applied (Gg)	Amount recovered methane flared (Gg)
1990	1,564	547	63.7	47.8	15.9	57.4	24.8	18.6	6.19
1995	1,367	478	182	136	45.4	57.4	70.6	52.9	17.6
2000	1,055	369	162	119	43.0	57.4	62.8	46.1	16.7
2005	770	233	130	97.9	32.5	53.2	47.0	35.3	11.7
2010	532	162	102	79.1	22.4	51.3	35.3	27.5	7.79
2015	376	115	60.4	43.4	16.9	49.6	20.3	14.6	5.69
2016	349	107	61.7	36.0	25.7	45.5	19.0	11.1	7.90
2017	321	98.2	62.1	36.1	26.0	48.0	20.2	11.7	8.47
2018	308	94.6	54.2	27.9	26.3	45.3	16.6	8.55	8.06
2019	292	89.7	48.9	23.4	25.5	45.7	15.1	7.26	7.88
2020	270	82.8	50.8	22.5	28.3	46.1	15.9	7.04	8.84
2021	254	78.0	46.3	19.7	26.6	45.6	14.3	6.09	8.21
2022	236	72.4	45.7	22.3	23.4	45.5	14.1	6.88	7.21

Table 7.7 Emission factors used for the combustion of landfill gas

	Combusted landfill gas	
Pollutant	**Flared**	**Gas engine**
Total hydrocarbons (incl. methane)	0.389763 kg/m³	0.389763 kg/m³
Hydrocarbons (C_xH_y)	0.27% hydrocarbons	6 g/m³
Dioxins	0.9E^{-9} g/m³	0.3E^{-9} g/m³
SO_x (based on all sulphur)	104 mg/m³	104 mg/m³
NO_x (as NO_2)	0.3 g/m³	3 g/m³
CO	2.7% C	3.4 g/m³
Soot	0.05% hydrocarbons	0.05% hydrocarbons

Particulate matter emissions are calculated based on the amount of processed mineral waste. The emissions are calculated using the tier 3 method from the 2023 guidebook. Important parameters are the quantities of processed mineral waste, the moisture content of the waste stream and the average wind speed.
Member States report quantities of waste produced and processed biannually to Eurostat in the context of EU Regulation 2150/2002. The amount of mineral waste is reported in the categories:

- Soils;
- Dredging spoils;
- Mineral waste from construction and demolition;
- Mineral wastes from waste treatment and stabilized wastes;
- Other mineral waste.

The last three categories have been combined in table 7.8, because the same moisture percentage is used in the calculations for these three categories. The wind speed is measured by the KNMI at the Cabauw weather station, located in central Netherlands.

Table 7.8 Emission factors used for emissions of PM during mineral waste handling

Year	Amount contaminated soil (Tg)	Amount dredging spoils (Tg)	Amount other mineral waste (Tg)	Average wind speed (m/s)
1990	5.987	48.182	21.080	4.9
1995	5.019	40.395	17.673	4.4
2000	5.902	47.504	20.784	4.5
2005	6.910	50.872	24.332	4.1
2010	7.327	46.730	25.801	3.9
2015	6.727	64.852	25.113	4.5
2016	7.279	68.394	24.929	4.0
2017	7.500	68.937	25.914	4.1
2018	7.721	69.479	26.898	4.1
2019	7.495	60.080	26.395	4.2
2020	7.270	50.681	25.892	4.5
2021	7.270	50.681	25.892	4.0
2022	7.270	50.681	25.892	4.1

7.4 Composting and anaerobic digestion (5B)

7.4.1 Source category description

The source category Composting and anaerobic digestion (5B) comprises emissions from the following source categories:

- 5B1;
  - Composting of organic waste from households;
  - Composting of organic waste from gardens and horticulture;
- 5B2;
  - Anaerobic digestion of organic waste from households;
  - Anaerobic digestion of organic waste from gardens and enterprises.

Emissions in this source category originate from facilities for the composting and/or fermenting of separately collected organic household, garden and horticultural waste and the anaerobic digestion of livestock manure. During processing, emissions of NH_3, SO_x and NO_x occur.

Since 1994, it has been a statutory requirement for communities in the Netherlands to collect all biodegradable organic waste (i.e. garden waste, horticulture waste and household waste such as fruits and vegetables) separately from other (domestic) waste. The main part of this waste is then treated by composting or digestion (for biogas production). Additionally, part of the manure produced by pigs and cattle is used in anaerobic digesters (biogas production).

Composting (5B1)
During composting, organic household waste is converted into compost. This process is carried out in enclosed facilities (industrial halls and tunnels), allowing waste gases to be filtered through a biobed before being emitted into the air. The material in the biobed is renewed periodically.

The processes for composting organic garden and horticulture waste are mostly carried out in the open air, in rows that are regularly turned over to optimise aeration.
A completeness check in 2022 revealed that this source was lacking in the inventory and that significant emissions of NH_3 could be expected. In the 2023 submission, this source is included in the inventory.

Composting generates emissions of NH_3.

Anaerobic digestion (5B2)
Emissions from anaerobic digestion come from the digestion of biodegradable organic waste. Feedstocks used in the Netherlands are: livestock manure; domestic organic waste; crops and crop residue from agriculture; food waste from food processing industries, households and restaurants; and organic waste from municipalities.

The process of anaerobic digestion takes place in gas-tight processing plants that release no emissions. Relatively small emissions of NH_3, NO_x and SO_x come mainly from storage of feedstocks and digestates. The most relevant feedstock as to emissions of NH_3 is livestock manure.

The biogas from anaerobic digesters is used for energy production or is processed and transferred to the natural gas network. Emissions from this use are included in the Energy sector (source category Small combustion (1A4)).

7.4.2 *Overview of shares and trends in emissions*

Composting

With the introduction of the new emission source for composting of organic garden and horticulture waste, the total emissions of NH_3 related to composting became substantial (0.05 Gg and 0.88 Gg for 1990 and 2022, respectively). Emission levels from this source are relatively constant in time.

Anaerobic digestion

Manure digesters were introduced in 2006. Table 7.10 gives an overview of the amounts of manure used for anaerobic digestion. Emissions related to anaerobic digestion date from 1994, when the first domestic organic waste digestion plants started operations. NO_x, SO_x and NH_3, emission levels relating to anaerobic digestion are relatively low (0.002 Mg, 0.0001 Mg and 0.0003 Mg, respectively, in 1994, and 0.09 Gg, 0.005 Gg and 0.29 Gg, respectively, in 2022). Emissions are small and therefore, shares and trends are not elaborated here.

7.4.3 *Emissions, activity data and (implied) emission factors*

Composting

The amounts of biodegradable waste processed by composting and fermentation plants (per year) are taken from the annual report by WAR, which is based on questionnaires filled in by operators. When an operator does not fill in a questionnaire, the estimated amount processed is based on data from the National Waste Notification Bureau ('Landelijk meldpunt afvalstoffen', LMA). LMA tracks all waste transport in the Netherlands. Most separately collected organic waste is used in composting. Table 7.9 provides an overview of the total amounts of separately collected organic household and other organic waste from operators in the composting and digestion industry.

Table 7.9 Overview of separately collected organic waste for composting and digestion

Year	Organic waste from households (Tg)		Organic waste from gardens and operators (Tg)	
	Composted	Digested	Composted	Digested
1990	228	-	-	-
1995	1,409	44	2,057	-
2000	1,498	70	2,473	2
2005	1,326	41	2,770	14
2010	1,066	154	2,424	13
2015	882	475	1,992	85
2017	1,027	465	2,335	107
2018	1,044	448	2,376	94
2019	1,103	457	2,192	84
2020	1,237	461	2,180	73
2021	1,280	419	2,246	68
2022	1,101	422	1,929	73

The EFs used for composting come from the sparse literature on emissions from the composting of separated biodegradable and other organic waste. It appears that hardly any monitoring is conducted on biobed reactors. The literature cannot be considered relevant, due to the diverse operational methods used in the Netherlands. The EFs for NH_3 from composting are taken from the environmental effect report for the Dutch national waste management plan 2002–2012 (VROM, 2002). The information in this report is based on a monitoring programme in the Netherlands (DHV, 1999).

For composting of organic waste, the following EFs have been used:

- For NH_3 from composting of household organic waste, an EF of 200 g/Mg is used;
- For NH_3 from composting of organic garden and horticultural waste, an EF of 350 g/Mg is used.

Activity data on the anaerobic digestion of livestock manure are based on registered manure transports (data from the Netherlands Enterprise Agency, RVO) and their N content.

The anaerobic digestion of biodegradable domestic waste (i.e. garden waste, horticultural waste and household waste such as fruits and vegetables) and of livestock manure is carried out in various specialised plants. These are regarded as different sources of emissions and are therefore calculated separately. Most of the NH_3 emissions come from the digestion of livestock manure.

Anaerobic digestion

The EFs used for the anaerobic digestion of biodegradable domestic waste come from the environmental effect report for the Dutch national waste management plan 2002–2012 (VROM, 2002). The information in this report is based on a monitoring programme in the Netherlands (DHV, 1999).

For the anaerobic digestion of biodegradable domestic waste the following EFs have been used:

- NH_3 from fermentation, 2.3 g/Mg of biodegradable domestic waste;
- NO_x from fermentation, 180 g/Mg of biodegradable domestic waste;
- SO_x from fermentation, 10.7 g/Mg of biodegradable domestic waste.

The EFs used for the anaerobic digestion of livestock manure come from a literature study carried out by Melse and Groenestein (2016) aimed at compiling the most suitable EFs for the various manure treatments used under conditions in the Netherlands. For the anaerobic digestion of biodegradable domestic waste, the following EFs have been used:

- NH_3 from anaerobic digestion of pigs manure, 0.02 kg/kg N;
- NH_3 from anaerobic digestion of cattle manure (excluding veal calves), 0.01 kg/kg N.

The emission calculation methodology can be found in Van der Zee *et al*. (2024). The calculations are performed using the NEMA model for calculating agricultural emissions (Bruggen van *et al*., 2024).

Activity data on the amount of manure (see Table 7.10) that has been treated and its N content is estimated from registered manure transports (data from the Netherlands Enterprise Agency (RVO)).

Table 7.10 Overview of manure used in anaerobic digesters.

	Manure used for anaerobic digestion (Mg)		
Year	**Wet volume (Tg)**	**P2O5 (Mg)**	**Nitrogen (Mg)**
2005	0	0	0
2006	214	776	1,310
2010	1,243	4,507	7,621
2015	1,582	6,436	10,328
2018	1,493	5,592	9,804
2019	1,510	5,635	9,871
2020	1,848	6,609	11,646
2021	2,076	7,646	12,847
2022	2,349	8,257	14,023

7.5 Waste incineration (5C)

7.5.1 Source category description

The source category Waste incineration (5C) comprises emissions from the following categories:

- 5C1a Municipal waste incineration;
- 5C1bi Industrial waste incineration;
- 5C1bii Hazardous waste incineration;
- 5C1biii Clinical waste incineration;
- 5C1biv Sewage sludge incineration;
- 5C1bv Cremations;
- 5C1bvi Other waste incineration;
- 5C2 Open burning of waste.

In the Netherlands, municipal waste, industrial waste, hazardous waste, clinical waste and sewage sludge are incinerated. The heat generated by waste incineration is used to produce electricity and heat buildings. These categories, therefore, are reported under the Energy sector (source category Public electricity and heat production (1A1a))

Emissions from cremations (category 5C1bv) originate from the incineration of human remains (process emissions) and from natural gas combustion emissions. The emissions of natural gas used are reported under the Energy sector (source category Commercial and institutional services (1A4ai)). From the cremation process, emissions of Hg, PM and dioxins occur. Since 2012, all cremation centres comply with the Dutch Atmospheric Emissions Guideline (NeR), using a special filter (cloth or electrostatic).

There is no incineration of carcasses or slaughter waste in the Netherlands. Carcasses and slaughter waste is processed to reusable products, including biofuels.

Because of a ban on other waste incineration (5C1bvi) and open waste burning (5C2), these emission sources are considered not to occur in the Netherlands. The open burning of waste is banned (at the begin of the 80s) in the Netherlands. The Netherlands is a densely populated country and any burning of wastes will causes nuisance in de surrounding area and complaints to the authorities, therefore stoking unreported fires is strictly enforced by the local authorities. However, local authorities can lawfully make an exception for burning of pruning woods with the condition that any fire must be reported to the local fire brigade in advance to enable supervision and enforcement. Unfortunately, these individual reports are not registered. Additionally, most local municipalities accept these pruning woods free of charge to be shredded for composting or use for energy purposes and nowadays when the amounts of these pruning woods are big enough to make it economically viable they are also commercially collected and shredded to be used for energy purposes. Also part of these pruning woods are used in bon fires that are reported in the IIR. These pruning activities have mostly to do with maintaining cultural landscapes (hedges and so on) and as such are no agricultural activity. Only commercially operated orchards are regarded as agricultural activity. However, this situation is complex as most of these pruned orchard woods are being used for energy purposes both domestic (fire place and stoves) as commercially (complete trees are shredded and used as biomass for energy purposes). The use of biomass for energy purposes is reported in the sector Energy. Using the tier1 approach will lead to double counting and therefore lead to a (substantial) overestimate for this source. Therefore, emissions from this sources are considered not to occur in the Netherlands.

However, according to tradition, a number of festive days are brightened by bonfires. These celebrations have a strong cultural and regional background, mostly taking place in specific parts/regions of the Netherlands. Scrap pallets; orchard, hedgerow and wooded bank pruning; and forest residues are used for these bonfires, which are exempted from the general ban on waste incineration and are regulated and controlled by local enforcing authorities. Emissions from bonfires are reported under Open burning of waste (5C2).

7.5.2 *Overview of shares and trends in emissions*

Emission levels in this source category are relatively low. Therefore, the shares and trends in these emissions are not elaborated here.

7.5.3 *Emissions, activity data and (implied) emission factors*

Cremations (5C1bv)

The number of cremations in the Netherlands is published online by the Dutch National Association of Crematoria (LVC), at www.lvc-online.nl (LVC, 2024). An overview of the number of cremations in compliance with the NeR is provided in Table 7.11.

Emission factors from the EMEP/EEA guidebook were used for calculating emissions from crematoria with no emission reducing technology in place.

Table 7.11 Overview of the number of cremations in compliance with NeR

Year	Deceased	Cremated	% cremated	% cremated in compliance with NeR
1990	128,790	57,130	44	0
1995	135,675	63,237	47	0
2000	140,527	68,700	49	5
2005	136,402	70,766	52	18
2010	136,058	77,465	57	75[1]
2011	135,741	78,594	59	86[2]
2012	140,813	83,379	59	100
2015	147,134	93,177	63	100
2020	168,537	111,881	66	100
2021	170,802	115,135	67	100
2022	169,937	114,438	68	100

1. Interpolation from year 2011.
2. Calculation is based on list of crematoria under the NeR (LVC, 2024).

For crematoria equipped with emission reducing technology, an evaluation of the effectivity of the use of this technology was performed. To this end, the substances emitted by crematoria are considered to be gaseous, vaporous, particulate or particle-bound. On the basis of measurements at crematoria in Geleen and Bilthoven (Visschedijk 2022), a 71% effectiveness for particulates and particle-bound substances was calculated. For Hg, the emission factor with technology in place is based on the -for the Netherlands- reported Hg-emissions in EC, 2012 (Annex L) and OsPar, 2011. (Visschedijk, 2024). Table 7.12 provides an overview of emission factors without and with emission reducing technology in place.

Open burning of waste (5C2)
The number of bonfires in the Netherlands fluctuates per year, mainly depending on how strongly tradition is respected and the local weather at the time. Table 7.13 provides an overview of the known bonfires reported in this category, with the date/period of occurrence and the geographical location. Spontaneous (small) bonfires and non-registered/regulated fires have not been included.

The activity data used come largely from specific websites, regional newspapers, news articles and sometimes permits. Estimates of the yearly amounts of pallet and pruning wood burned are based on this information and supplemented by expert judgement.

Table 7.12 Overview of emission factors used for calculating emissions from cremations without an with emission reducing technology in place

Pollutant	GSF code	State	Emission factor before introduction NeR[1] (kg per cremation)	Emission factor with NeR[2,3] (kg per cremation)
NO_x	4013	Gaseous	0.825	0.825
CO	4031	Gaseous	0.14	0.14
NMVOC	1631	Gaseous	0.013	0.013
SO_x	4001	Gaseous	0.113	0.113
PCB	3066	Particle bound	$4.1\ 10^{-7}$	$1.18\ 10^{-7}$
PCDD/F	3054	Particle bound	$2.7\ 10^{-11}$	$7.8\ 10^{-12}$
B(a)P	2912	Particle bound	$1.32\ 10^{-8}$	$3.80\ 10^{-9}$
B(b)FA	2913	Particle bound	$7.21\ 10^{-9}$	$2.08\ 10^{-9}$
B(b)FK	2914	Particle bound	$6.44\ 10^{-9}$	$1.86\ 10^{-9}$
I-pyrene	2917	Particle bound	$6.99\ 10^{-9}$	$2.01\ 10^{-9}$
HCB	2616	Particle bound	$1.5\ 10^{-7}$	$4.32\ 10^{-8}$
Pb	5172	Particle bound	$3.0\ 10^{-5}$	$8.65\ 10^{-6}$
Cd	5057	Particle bound	$5.03\ 10^{-6}$	$1.45\ 10^{-6}$
As	5018	Particle bound	$1.36\ 10^{-5}$	$3.92\ 10^{-6}$
Cr	5082	Particle bound	$1.36\ 10^{-5}$	$3.91\ 10^{-6}$
Cu	5142	Particle bound	$1.24\ 10^{-5}$	$3.58\ 10^{-6}$
Ni	5242	Particle bound	$1.73\ 10^{-5}$	$4.99\ 10^{-6}$
Se	5266	Particle bound	$1.98\ 10^{-5}$	$5.70\ 10^{-6}$
Zn	5342	Particle bound	$1.6\ 10^{-4}$	$4.61\ 10^{-5}$
PM_{10}	992	Particulate	0.0347	0.01
$PM_{2.5}$	998	Particulate	0.0347	0.01
Hg	5156	Vaporous	$1.49\ 10^{-3}$	$2.0\ 10^{-5}$

1: EEA guidebook 2023
2: Particulates and particle bound substances are estimated to be 71% less after implementation of NeR (see below)
3: Hg is estimated to be 98 – 99.5 % less after implementation of NeR.

Table 7.13 Overview of known bonfires

Name	Date/period	Location(s)
New Year's Eve	1 January	Scheveningen/Duindorp
Christmas tree burning	1 January	Nationwide
Easter fires	Easter (March/April)	Northern and eastern areas
Meierblis	30 April	Texel (the largest island of the Dutch Wadden Islands)
Luilak	Saturday before Whitsunday (May/June)	Northwest
St.-Martin's day	11 November	The most northern provinces and the most southern provinces

Easter fires
Table 7.14 provides an overview of the total amount (m^3) of pruning burned in the four large Easter fires.

Table 7.14 Estimated amounts (m^3) of pruning wood burned in the four largest Easter fires

	Total amount of pruning wood per Easter fire (m^3)			
Year	**Dijkershoek**	**Espelo**	**Beuseberg**	**Holterbroek**
2015	5,308	5,783	2,289	1,634
2020	0	0	0	0
2021	0	0	0	0
2022	4,293	3,644	1,852	1,468

For earlier years, the activity data has been based on the trend in inhabitants (a 10% increase in inhabitants results in a 10% increase in amount of pruning burned).

All other Easter fires in the Netherlands are much smaller and the occurrence of these bonfires depends on local initiatives and organisation. In the majority of the Netherlands, no permits are needed if the volume of the bonfire is below 1,000 m^3. Picture 7.1 shows the 2012 Easter fire in Espelo, which has twice been registered as a World Record in the *Guinness Book of World Records*

As a result, the number of (small) Easter fires and volumes can only be estimated from regional newspaper reports and the number of inhabitants per province. The average volume of the smaller Easter fires is estimated at 250 m^3. The number of Easter fires is estimated at roughly 400.

In 2019, the Easter fires were smaller as a result of drought. Most municipalities banned Easter fires and the remainder only allowed small fires. As no data was available, the assumption used for the calculations is an average size of 500 m^3.

In 2020 and 2021 there were no Easter bonfires as result of the COVID-19 restrictions

Picture 7.1 Espelo's 2012 Easter fire

New Year's Eve fires

The New Year's Eve bonfires at Scheveningen (Scheveningen's 2023 New Year bonfire) and Duindorp (Duindorp's 2023 New Year bonfire)
Both the Scheveningen and Duindorp fires were regarded as the biggest bonfires in the Netherlands (each 12,000 m^3 of pallets in 2019) due to fierce competition between both neighbourhoods. The volume of pallets burned can is measured accurately because of the competition to have the biggest bonfire. Table 7.15 provides an overview of the amount of pallets burned in these two fires.

There were no fires in Scheveningen and Duindorp in 2019-2021, due to safety restrictions (2019) and COVID-19 (2020 and 2021). From 2022 the size of the piles is limited to 1,000 m^3 due to nitrogen restrictions applied (see Picture 7.2 to get an impression of the former size).

Table 7.15 Amount of pallets burned at main New Year's Eve bonfires

	Total amount of pallets per New Year's Eve fire (m^3)	
Year	**Duindorp**	**Scheveningen***
2015	9,453	8,695
2020	0	0
2021	0	0
2022	1,000	1,000

* Like the Easter fire at Espelo, both the Scheveningen and Duindorp bonfires have been officially registered as the largest bonfire by the *Guinness Book of World Records*, in different years.

Picture 7.2 The piles of pallets at Scheveningen and Duindorp for the 2018 New Year's Eve bonfires.

All other bonfires on New Year's Eve in the Netherlands are much smaller, and the occurrence of these bonfires depends on local initiatives and organisation. In the majority of the Netherlands, no permits are needed if the volume of the bonfire is below 1,000 m^3.

As a result the number of (small) Easter fires and the volumes of these fires are not registered and can only be estimated on basis of local newspapers.

As a result of the nitrogen restrictions applied from 2022 the total volume of wood burned in New Year's Eve's is estimated to be 4,000 m^3 (around 2,000 m^3 for Scheveningen and Duindorp + 2,000 m^3 for the other smaller non-registered bonfires). This volume is used for the complete time series.

Meierblis
This bonfire is solely celebrated on Texel (the largest island of the Dutch Wadden Islands). Based on local newspapers it is estimated that around 7 large fires and around 65 smaller fires are lit every year.
It is estimated the large bonfires account for about 3,500 m^3 together and the smaller bonfires amount to 16,250 m^3 total. This volume is used for the complete time series.

Luilak
This is a folkloristic celebration characterised by the loud noises in the early morning by the participants.
Based on local newspapers its estimated that the number of bonfires is about 10 and the amount of wood burned is restricted to 16m^2 max. thus resulting in a total amount of about 640 m^3. The number of Luilak-fires decreased. It is assumed that the total amount of pruning decreased from 2000 to 500 m^3 in the period 1990-2017.

Saint-Maarten
This celebration is restricted to specific areas in the Netherlands. Based on regional newspapers and expert judgement it is estimated that the volume of wood burned is 5,000 m^3. This volume is used for the complete time series.

Wood density and heating value of pallets
The density of pruning wood is based on a Belgian report from the Flemish government on waste from 2014 (www.Lne.be) and equals 0.15 Mg/m^3.
The density of pallets is based on a standard pallet size of 0.8 x 1.2 x 0.144 m and a standard pallet weight of 25 kg, resulting in a density of 0.18 Mg/m^3.

The heating value of pallets has been derived from Jansen's (2010) 'kachelmodel'. This equals 15.6 MJ/kg.

In terms of EF, a distinction is made between the burning of pallets and the burning of pruning wood. The EFs for the burning of pallets have been derived from EMEP/EEA (2016; NFR Category 1A4 – table 3.39 Open fireplaces burning wood). The EFs for the burning of pruning wood from EMEP/EEA (2016; NFR Category 5C2 – table 3.2 Open burning of agricultural wastes/forest residue).

7.6 Wastewater handling (5D)

7.6.1 Source category description
In the Netherlands, almost all wastewater is treated in domestic (5D1) or industrial (5D2) wastewater treatment plants (WWTPs). WWTPs produce small amounts of NMVOC emissions.

Normally, industrial wastewater is also treated at domestic WWPTs. However this wastewater stream is charged on the basis of the average amount of pollutants and volume. Thus, for some industries it is cheaper to treat their own wastewater on-site before discharging directly to surface water or to the sewer (depending on the level of remaining pollutants and volume). Thus, the incoming wastewater at domestic WWPTs comprises household wastewater, industrial wastewater and urban run-off (mainly off roof tops and streets).

The on-site treated industrial wastewater comprises water from the industrial process, and in some cases, water used for cooling processes and run-off from the paved industrial site.

Part of the WWTPs process their sewage sludge in an anaerobic digester to produce methane. The methane is captured and used in energy production, or flared. Emissions from WWPTs, therefore, are reported under the source category Commercial/Institutional: Stationary (1A4ai).

7.6.2 Overview of shares and trends in emissions
Emission levels in this source category are relatively low. Therefore, the shares and trends in these emissions are not elaborated here.

7.6.3 *Emissions, activity data and (implied) emission factors*

Domestic WWTPs

Activity data from domestic WWTPs come from a separate inventory performed by Statistics Netherlands (CBS) in partnership with Netherlands Enterprise Agency (RVO), the Dutch Water Authorities and consultancy firm Arcadis (Honig *et al*., 2024). Table 7.16 provides an overview of the activity data used over time.

NMVOC is calculated using the default Tier 1 emission factor of 15 mg NMVOC/m^3 wastewater treated (EEA, 2023).

Industrial WWPTs

Information on the industrial biological wastewater treatment plants and related volumes of wastewater treatment is compiled from a Statistics Netherlands database for the years 1993-2016 as well as from data from the AERs on volumes of wastewater. For a short description of the method to determine the volumes of industrial wastewater treated in industrial biological wastewater treatment plants, see Geertjes & Baas (2022). Data for 2017-2021 are a copy of the 2016 values, but corrected for new plants an plant taken out of service. For the year 2022, a concise pilot survey among companies in the AER register already provided some updated data on the population (see table 7.16). In 2024 this survey will be scaled up to all relevant companies reporting via the AERs. That means that in the 2025 submission (data 1990-2023) there will be a revision of the timeseries of 2017-2021.

NMVOC is calculated using the Tier 1 emission factor of 15 mg NMVOC/m^3 wastewater handled (EEA, 2023)

Table 7.16 Wastewater volume data (key years) of biological wastewater treatment plants.

	Total volume of wastewater treated (Mio m^3)	
Year	**Domestic WWTP**	**Industrial WWTP**
1990	1,643	338
1995	1,854	316
2000	1,997	316
2005	1,841	239
2010	1,934	369
2015	1,957	248
2020	1,938	258
2021	1,964	259
2022	1,808	259

7.7 Other waste (5E)

7.7.1 *Source category description*

The source category Other waste (5E) comprises the following emission sources:

- Sludge spreading;
- Waste preparation for recycling;
- Scrapped refrigerators/freezers;

- Accidental building and car fires.

Sludge spreading
WWTPs produce sewage sludge. In the Netherlands, sewage sludge can be used as fertiliser in agriculture if it meets the legal environmental quality criteria. In line with the EMEP/EEA Guidebook, emissions from this source are reported under Sewage sludge applied to soils (3Da2b).

Waste preparation for recycling
Waste preparation for recycling is carried out mainly by companies that process waste to turn it into new base materials. These processes entail small emissions of NO_x, NMVOC, SO_x, CO, particulate matter, several metals, PAHs and dioxins.

Scrapped refrigerators /freezers
Since 1995, the production and sale of refrigerators and freezers (R/F) using chlorofluorocarbons as refrigerant has been prohibited in the European Union. However, given an average lifetime of at least 15 years, R/F units using CFCs are still in use, and significant numbers are discarded annually. In the Netherlands, discarded R/F units are collected and processed by specialised companies that remove and destroy the CFCs still present in the units. Still, in some cases the CFCs have leaked into the environment before the R/Fs are discarded and processed. This emission source represents the leakage emissions of CFCs and possible processing inefficiencies that lead to the emission of CFCs into the environment.

Accidental building and car fires
Mainly by accident (but sometimes on purpose), cars and houses are damaged or destroyed by fire. The smoke caused by such fires is the source of emissions. The amount of material burned is determined by the response time of (professional) fire-fighters. Accidental building and car fires produce, among others, emissions of particulate matter and dioxins.

7.7.2 Overview of shares and trends in emissions
Emission levels in this source category are relatively low. Therefore, the shares and trends in these emissions are not elaborated here.

7.7.3 Emissions, activity data and (implied) emission factors
Waste preparation for recycling
Data on emissions from the process of waste preparation for recycling was based on environmental reports by large industrial companies. Where necessary, extrapolations were made to produce emission totals per industry group, using either both IEFs and production data or production data based on environmental reports in combination with specific EFs (Honig *et al.,* 2024).

Scrapped refrigerators/freezers
When recycling scrapped refrigerators/freezers, a small amount of NMVOC (as dichlorodifluoromethane (CFC12), used as refrigerant) is emitted. In the calculations, an EF of 105 g CFC12 per recycled refrigerator/freezer (after correction for recovered CFC12) was used.

To estimate the number of CFC R/F equipment discarded annually from 1990 to 2030, a combination of multiple data is needed. First, the number of R/F units put on the market between 1960 and 1994 in the Netherlands was extracted from CBS data. These R/Fs are assumed to all use CFC-12 as refrigerant.

The Weibull distribution is used to estimate the number of CFC R/F units discarded annually. Based on data from CBS, the average lifetime of a refrigerator is estimated at 16.4 years, and that of a freezer at 18.6 years. Furthermore, the shape of the Weibull function is 2.2 for refrigerators and 1.3 for freezers (Magalini *et al*., 2014).

As a last step, corrections are applied for exported scrap refrigerators and freezers. (Visschedijk *et al.,* 2024)

Accidental building and car fires
More details regarding the methodology are given in Visschedijk *et al.* (2023).
The number of buildings and cars exposed to fire was collected by the joint fire brigades in the Netherlands and reported annually via Statistics Netherlands, until the year 2013. Those numbers are used for the timeseries 1990-2013.

After 2013, data by the Dutch Association of Insurers is used for car fires. This data only includes insured cars for which the insurance company covered the damage. One third of the car fires is estimated to comprise uninsured vehicles, so the raw numbers reported by the Association of Insurers are increased by a factor of 1.5 to estimate the total number of car fires.

For the number of indoor fires from 2014 onwards, no accurate data are available from Statistics Netherlands. Before 2014, the reported number of indoor fires seemed roughly proportional to the total number of buildings. On an annual basis, a relatively constant fraction of all buildings was affected by a fire incident. Based on this percentage, the number of indoor fires occurring from 2014 to 2018 was estimated, indicating about 14,000–15,000 indoor fires annually.

According to multi-year statistics on the number of fatal house fires in the Netherlands (Nederlands Instituut Publieke Veiligheid), in about 55% of the cases, studied, the destruction is confined to a single room, in 17%, it is confined to a single floor and in 28%, the entire house burns down. Table 7.18 provides an overview of the estimated amounts of combustible material burned, based on an average Dutch situation of a one-family home consisting of 3 floors and 4 rooms per floor.

Table 7.18 Amounts of burned combustible materials average housefire in the Netherlands

Average Dutch situation of a one-family home made up of 3 floors and 4 rooms per floor.		
Destruction by fire (limited to)	**combustible materials burned (%)**	**combustible materials burned (Mg)**
Same room	10	1.48
Same floor	33	4.9
Complete house	100	14.8

When this data on fire destruction and occurrence is combined, it results in the following amount of combustible materials burned:

1.48 x 55% + 4.9 x 17% + 14.8 x 28% = 5.8 Mg .

For house fires, country-specific EFs have been derived from the amount of combustible materials in an average Dutch house combined with a percentage burned in each fire as explained in this paragraph. The emissions of all pollutants (except dioxin) from the combustible materials of the construction and the combustible materials of the interior materials are calculated using the EFs in table 3.39 in chapter 1A4 of the Guidebook. The emissions of dioxin are calculated using the EF from Aasestad (2007) of 170 µg I-TEQ per Mg burned material. The dioxin EF has been improved as a result of a review recommendation from the 2019 NECD review.

For car fires, the default EFs from the EMEP/EEA Guidebook (2023) are used. Table 7.19 gives an overview of the number of house and car fires.

Table 7.19 number of house- and car fires

Year	Number of housefires	Number of car fires
1990	12,592	4,827
1995	13,634	5,766
2000	13,910	6,064
2005	13,147	4,411
2010	15,563	4.280
2015	15,176	5,084
2020	15,784	8,373
2021	15,933	7,130
2022	16,091	7,539

8 Other

8.1 Overview of the sector

The Other sources sector (NRF 6) includes emissions from sources that cannot be placed under any specific NFR.

8.2 Other sources (6A)

8.2.1 Source category description

This source category includes only NH_3 emissions from the following sources:

- Human transpiration and respiration;
- Domestic animals (pets).

Human transpiration and respiration

Through the consumption of food, nitrogen (N) is introduced into the human system. Most nitrogen is released into the sewage system through faeces and urine. Part of the nitrogen is released as ammonia through sweating and breathing and is reported in this emission source.

Domestic animals (pets)

Emissions from domestic animals consist mainly of NH_3 coming from dung and urine. This source comprises the combined emissions from:

- Dogs;
- Cats;
- Birds (undefined);
- Pigeons;
- Rabbits.

8.2.2 Key sources

There is no key source in this category.

8.2.3 Overview of shares and trends in emissions

An overview of emissions and the trends for this sector is provided in Table 8.1.

8.2.4 Emissions, activity data and (implied) emission factors

Human transpiration and respiration

NH_3 emissions from this source gradually increased over the time series in line with the increase in the human population, from 1.50 Gg in 1990 to 1.77 Gg in 2022.

Population numbers in the Netherlands are derived from CBS Statline (http://statline.cbs.nl/) and increased from 14,892,574 in 1990 to 17,590,672 in 2021.

To avoid underestimation, the high-end EF of 0.0826 kg NH_3 per person per year (Sutton *et al.*, 2000) was used to calculate emissions from this source.

Table 8.1 Overview of emission totals in the Other sector (NFR 6)

	Main Pollutants				Particulate Matter		
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**0.00**	**0.00**	**0.00**	**2.7**	**0.00**	**0.00**	**0.00**
1995	0.00	0.00	0.00	2.8	0.00	0.00	0.00
2000	0.00	0.00	0.00	2.9	0.00	0.00	0.00
2005	0.00	0.00	0.00	3.0	0.00	0.00	0.00
2010	0.00	0.00	0.00	3.1	0.00	0.00	0.00
2015	0.00	0.00	0.00	3.2	0.00	0.00	0.00
2020	0.00	0.00	0.00	3.3	0.00	0.00	0.00
2021	0.00	0.00	0.00	3.3	0.00	0.00	0.00
2022	**0.00**	**0.00**	**0.00**	**3.4**	**0.00**	**0.00**	**0.00**
1990-2022 period[1)]	0.00	0.00	0.00	0.7	0.00	0.00	0.00
1990-2022 period[2)]				26%			

1. Absolute difference.
2. Relative difference from 1990 in %.

Domestic animals (pets)
NH_3 emissions from this source increased slightly over the time series from 1.17 Gg in 1990 to 1.60 Gg in 2022.

Emissions are calculated using an EF per house. The number of houses is derived from Statistics Netherlands. The EF used is based on Booij (1995), who calculated a total emission of 1.220 Gg NH_3 from all domestic animals (cats, dogs, rabbits and birds) for the year 1990. With the total emission in 1990 and the number of houses in 1990, an EF of 0.2 kg NH_3 per household was calculated.

8.2.5 *Methodological issues*
The methodology used for calculating emissions from the sources Human transpiration and respiration and Domestic animals is described in Visschedijk (2024).

There are no specific methodological issues.

8.2.6 *Uncertainties and time series consistency*
No accurate information was available for assessing uncertainties about emissions from sources in this sector.

8.2.7 *Source-specific QA/QC and verification*
Verification for the source Domestic animals (pets) is carried out using a survey conducted by order of the branch organisation DIBEVO (entrepreneurs in the pet supplies branch). The numbers of cats and dogs derived from this survey combined with the EFs for cats and dogs from Sutton *et al.* (2000) represent 70% of the total emissions from pets (Booij, 1995).

There are no further source-specific QA/QC procedures in place in this sector. The remainder of sources in this sector are covered by the general QA/QC procedures, as discussed in Chapter 1.

8.2.8 *Source-specific recalculations*

Both the emissions from the manure management and those from manure application and grazing of privately held horses, ponies, mules and asses have been attributed to respectively category 3B and 3D rather than to 6 for the entire timeseries. This reallocation has been implemented to increase the consistency. The reallocation decreases the NH_3 emissions from sector 6 by 1.3 Gg in 1990 and 1.6 Gg in 2021 and the emissions of NMVOC and PM to zero for the entire time series.

8.2.9 *Source-specific planned improvements*

There are currently no planned improvements.

9 Large Point Sources

All point sources in the Netherlands that meet the criteria have the legal obligation to report their emissions electronically as part of an AER (see Section 1.3.2). After validation and data checking, the data is then stored in the PRTR. The EPRTR and the LPS are an extract from this PRTR.

For the obligation of reporting emissions from agriculture to the EPRTR, different criteria are used. For its EPRTR reporting, the Netherlands makes an inventory of all agricultural facilities that meet the IPPC[3] criteria (EU Directive 2010/75/EU on industrial emissions; annex 1 paragraph 6.6) and have emissions of NH_3 above the EPRTR threshold. These IPPC criteria are:

- more than 40,000 places for poultry;
- or more than 2,000 places for production pigs (over 30 kg);
- or more than 750 places for sows.

The 2021 LPS submission comprises all EPRTR facilities that reported emissions for one or more pollutants above the thresholds specified in table 1 of the reporting guidelines (Executive body for the Convention on Long-range Transboundary Air Pollution; decision ECE/EB.AIR/125). For NH_3, this threshold is the same as for EU Directive 2010/75/EU.

Using the IPPC criteria for agricultural facilities leads to an underestimation of the NH_3 emissions coming from agricultural facilities. For 2019, the EPRTR database contains 71 agricultural facilities that meet the criteria. These facilities reported a total NH_3 emission of 0.9 Gg. However, the 2019 national NFR total of NH_3 emissions from manure management from the sources 3B3 (swine), 3B4gi (laying hens), 3B4gii (broilers), 3B4giii (turkeys) and 3B4giv (other poultry) amount to 25.6 Gg, showing that under LPS, only 3.4% of the total national emissions from these sources are accounted for.

The NH_3 national total emissions as reported in the NFR are calculated on the basis of animal numbers and type of animal housing (all based on the agricultural census; see Chapter 6). This means that no other information on facility level is needed. However, over the last years, work has been undertaken to estimate NH_3 emissions from individual animal housings more accurately. For the 2021 LPS submission, some effort is made to use this more detailed information, resulting in a more complete report of NH_3 emissions coming from agricultural facilities (animal housing).

[3] IPPC: Integrated Pollution Prevention and Control

10 Response to the Reviews

10.1 CLRTAP reviews 2015 and 2022

At its 25th session in 2007, the Executive Body for the Convention on Long-Range Transboundary Air Pollution approved methods and procedures for the review of national emission inventories. Based on this decision, the national inventories (CLRTAP and NECD) have been subject to five-year cycles of in-depth technical reviews since 2008. The technical review of national inventories checks and assesses parties' data submissions with a view to improving the quality of emission data and associated information reported to the Convention. The review process is aimed at making inventory improvements by checking the transparency, consistency, comparability, completeness and accuracy (TCCCA criteria) of the submitted data (see http://www.ceip.at/).

The review also seeks to achieve a common approach to prioritising and monitoring inventory improvements under the Convention together with other organisations that have similar interests, such as the United Nations Framework Convention on Climate Change (UNFCCC), the European Union National Emission Ceilings (NEC) Directive and the European Pollutant Release and Transfer Register (E-PRTR).

The submission by the Netherlands was last fully reviewed in 2015. In the review report, several recommendations were made for improvements to the inventory and inventory reporting. All these recommendations have been implemented.
In 2017 the 3rd joint session of WGE and the Steering Body (SB) to EMEP:

a) welcomed the efforts under the European Union to harmonise the national inventory reviews under the National Emission Ceilings Directive with those under the Convention;
b) recommended that the two review processes be coordinated with respect to priorities, scopes, resources (reviewers) and timelines, to ensure consistency and complementarity and to avoid possible overlaps, duplication of efforts and inconsistent conclusions.

Therefore, for all EU parties, the 2022 CLRTAP in-depth *ad hoc* review focused on:

- Residential heating with a special focus on the condensable component of PM emissions;
- Road Transport with a special focus on the condensable component of PM emissions.

10.2 NEC review 2023

Article 10(3) of the revised NECD introduces a regular annual review of EU Member States' national emission inventory data in order to:

- verify, amongst others, the transparency, accuracy, consistency, comparability and completeness of the information submitted;
- check the consistency of prepared data with LRTAP requirements;
- calculate technical corrections where needed.

The 2023 NFR and IIR submission by the Netherlands was reviewed. Several recommendations were made to improve the inventory and the inventory report. Within the limitations of resources, the actions that were based on these recommendations were given a high priority and were added to the work plan in order to ensure a follow-up to the majority of recommendations before the next NFR submission in 2023. Annex 4, Table A4.1 represents the status of the implementation of the recommendations from this NEC review.

As part of the 2020 review, the 2017 submissions of the Large Production Sites (LPS) and the so-called Gridded data were reviewed. The status of following up the recommendation from these parts of the review can be found in Annex 4, Tables A4.2 and A4.3.

In 2023 the Netherlands Projections submission of 2023 was reviewed. The status of following up this review is represented in Annex 4. Table A4.4.

11 Recalculations and Other Changes

11.1 Recalculations and improvements of certain elements of the IIR

Compared with the IIR2023 (Wever *et al.*, 2023), several improvements in source allocation and emission factors used were implemented in the Pollutant Release and Transfer (PRTR) system. These recalculations were initiated by the internal QA/QC cycle, recommendations from external reviews and improved the comparability with the methodologies as elaborated in the EMEP/EEA guidebook. The main changes in the inventory are:

Overall

- Whenever updated/improved activity data became available these are used to improve the emission calculation (all sectors)
- Due to changes in the energy statistics the fuel use in different categories changed (1990-2021) and subsequent the emissions.
- Improvements/ error correction in the emission estimates for individual companies for the period 2009-2021 as reported under sector 1 and 2.
- Error corrections in the $PM_{2.5}$, $EC_{2.5}$, PAH, dioxin and HCB emissions in the energy sector.

Energy

- Improvement of the emission estimates from wood combustion in 1A4.
- Improvement of LTO emission estimates for Aviation.
- Several improvements in the emission estimates from road traffic (a.o. Motor cycles and mopeds) in 1A3, based on measurement programmes (EF's and updated activity data).
- Emissions from Railways were improved by adding missing estimates (railway maintenance).
- Emission estimates for NRMM were revised based on improved EF's and activity data.

IPPU

- Improvement of the emission estimates in sector 2A for particulate matter and NMVOC.
- Reallocation of part of the NMVOC emissions from 2A5 to 2H3.
- Recalculation and reallocation of Pb emissions in 2C.
- Recalculation of NMVOC emissions in 2D due to improved activity data for disinfecting hand gels.
- Recalculation of the emissions from Fireworks in 2G.

Agriculture

- NH_3 and NO_x emissions from veal manure were recalculated for 1990 to 2021.
- NH_3 and NO_x emissions from manure treatment were recalculated for 2018 to 2021.
- Recalculation of the emissions of NH_3 and NO_x in 3D and NH_3 in 3B due to the inclusion of bedding material in the calculations. This also effects the NMVOC emissions from housing and storage of manure.
- NH_3 and NO_x emissions from crop residues were recalculated based on new activity data.
- Improved PM_{10} emission estimates from agricultural crops based on most recent emission factors.

Waste

- No significant recalculation for this sector.

More details on the above changes can be found in the respective sectoral chapters.

11.1.1 *Planned improvements*

The remaining actions with respect to content will be prioritised and are planned for implementation in the inventories of 2023 and 2024. Appendix 3 gives an overview of the relevant plans.

11.2 Effects of recalculations and improvements

Table 10.1 to 10.3 show the changes in total national emission levels for the various pollutants, compared with the inventory report of 2023.
In general the national emissions of the different pollutants only show limited changes compared to the previous submission (on average les than 5%) except for NMVOC, Cu and PAHs .

Table 11.1 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010, 2020 and 2021 (NO_x, NMVOC, SO_x, NH_3 and particulate matter)

National total			**NO_x** (as NO_2)	**NMVOC**	**SO_x** (as SO_2)	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**
			Gg	**Gg**	**Gg**	**Gg**	**Gg**	**Gg**	**Gg**	**Gg**	**Gg**
1990	IIR 2023		**679.5**	**607.2**	**198.1**	**344.5**	**57.1**	**80.2**	**101.8**	**14.1**	**1188.7**
	IIR 2024		**681.2**	**606.0**	**197.5**	**346.6**	**57.3**	**80.8**	**102.4**	**14.2**	**1172.0**
Difference		absolute	1.7	-1.1	-0.6	2.1	0.2	0.6	0.6	0.1	-16.7
		%	*0.2%*	*-0.2%*	*-0.3%*	*0.6%*	*0.4%*	*0.8%*	*0.6%*	*0.9%*	*-1.4%*
2000	IIR 2023		495.6	338.1	79.0	173.4	34.8	49.8	56.7	10.6	772.0
	IIR 2024		493.6	337.1	78.5	174.9	35.0	50.5	57.4	10.6	752.5
Difference:		absolute	-2.0	-1.0	-0.4	1.4	0.2	0.7	0.7	0.1	-19.5
		%	-0.4%	-0.3%	-0.5%	0.8%	0.6%	1.4%	1.2%	0.7%	-2.5%
2010	IIR 2023		360.0	278.8	35.9	134.1	23.0	36.5	43.9	5.6	709.0
	IIR 2024		343.0	273.9	36.1	135.1	22.2	36.0	43.4	5.0	651.4
Difference:		absolute	-17.0	-4.9	0.2	1.0	-0.8	-0.5	-0.5	-0.7	-57.6
		%	-4.7%	-1.8%	0.5%	0.8%	-3.6%	-1.4%	-1.2%	-11.9%	-8.1%
2020	IIR 2023		215.6	269.9	19.7	123.4	14.9	27.7	32.2	2.4	449.5
	IIR 2024		211.7	249.9	19.6	125.0	14.4	26.9	31.4	2.4	422.1
Difference:		absolute	-4.0	-20.0	0.0	1.6	-0.5	-0.7	-0.8	0.0	-27.4
		%	-1.8%	-7.4%	-0.2%	1.3%	-3.2%	-2.6%	-2.6%	-1.6%	-6.1%
2021	IIR 2023		210.7	277.2	20.9	121.9	14.2	26.1	30.5	2.3	437.8
	IIR 2024		206.4	244.1	20.9	123.5	14.5	27.0	31.6	2.3	413.6
Difference:		absolute	-4.3	-33.1	0.0	1.6	0.3	0.8	1.1	0.0	-24.1
		%	-2.0%	-11.9%	0.1%	1.3%	2.4%	3.2%	3.7%	0.9%	-5.5%

NO_x , SO_x and CO emissions changed slightly over the period 1990 to 2021 due to the recalculations in the energy and transport sector. NH_3 emissions increased due to recalculations in the agriculture sector. NMVOC emissions in 2021 decreased compared to the previous submission due to less production in the chemical sector.

Emissions of PM species and BC changed as a result of the recalculations for the emissions from rail and road transport and to lesser extent in the energy and IPPU sectors.

Table 11.2 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010, 2020 and 2021 (metals).

National total		Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
		Mg	**Mg**	**Mg**	**Mg**	**Mg**	**Mg**	**Mg**	**Mg**	**Mg**
1990	IIR 2023	338.6	4.1	3.7	1.5	12.0	36.7	75.7	0.4	225.8
	IIR 2024	335.7	4.1	3.7	1.5	12.0	91.0	75.7	0.4	225.7
Difference:	absolute	-2.9	0.0	0.0	0.0	0.0	54.3	0.0	0.0	-0.1
	%	-0.8%	0.0%	0.0%	0.0%	0.0%	148.1%	0.0%	0.0%	0.0%
2000	IIR 2023	27.7	2.9	1.2	1.1	5.1	37.9	20.0	0.5	96.5
	IIR 2024	28.4	3.0	1.2	1.1	5.1	107.5	20.0	0.5	96.4
Difference:	absolute	0.7	0.1	0.0	0.0	0.0	69.6	0.0	0.0	-0.1
	%	2.6%	3.5%	0.0%	0.0%	0.0%	183.5%	0.0%	0.0%	-0.1%
2010	IIR 2023	37.7	4.7	0.8	0.8	3.9	41.8	2.5	1.6	103.6
	IIR 2024	37.6	4.7	0.8	0.8	3.9	114.6	2.5	1.6	103.0
Difference:	absolute	0.0	0.0	0.0	0.0	0.0	72.9	0.0	0.0	-0.6
	%	-0.1%	0.0%	-0.2%	0.0%	-0.5%	174.5%	-0.3%	0.0%	-0.6%
2020	IIR 2023	5.8	2.0	0.5	0.3	3.2	41.4	1.8	0.2	179.2
	IIR 2024	5.8	2.0	0.5	0.3	3.2	102.1	1.8	0.2	178.2
Difference:	absolute	-0.1	0.0	0.0	0.0	0.0	60.7	0.0	0.0	-1.0
	%	-0.9%	-0.1%	-0.3%	0.0%	-0.9%	146.5%	-0.5%	-0.1%	-0.6%
2021	IIR 2023	4.9	0.9	0.5	0.3	3.5	31.1	1.7	0.2	152.0
	IIR 2024	4.9	0.9	0.5	0.3	3.5	98.8	1.7	0.2	149.7
Difference:	absolute	0.0	0.0	0.0	0.0	0.0	67.8	0.0	0.0	-2.3
	%	-0.9%	0.2%	-1.4%	-0.1%	0.3%	218.2%	0.1%	0.0%	-1.5%

Metal emissions changed mainly due the recalculation in the abrasion emissions from Railways (Cu) and tyre and break wear in other road transport.

Table 11.3 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010, 2020 and 2021 (PCDD/F, PAHs , HCB and PCB).

National total		**PCDD/ PCDF**	**benzo(a) pyrene**	**benzo(b) fluoranthene**	**benzo(k) fluoranthene**	**Indeno (1.2.3 -cd) pyrene**	**Total 1-4**	**HCB**	**PCB**
		g I-Teq	**Mg**	**Mg**	**Mg**	**Mg**	**Mg**	**kg**	**kg**
1990	IIR 2023	745.6	5.4	8.0	4.1	2.8	20.3	66.4	38.4
	IIR 2024	744.9	5.5	8.1	4.2	3.0	20.8	66.4	38.4
Difference	absolute	-0.7	0.1	0.1	0.1	0.1	0.5	0.0	0.0
	%	-0.1%	2.3%	1.5%	2.6%	5.1%	2.4%	0.0%	0.0%
2000	IIR 2023	37.1	1.9	1.9	1.0	0.9	5.6	17.1	0.3
	IIR 2024	37.5	2.0	2.0	1.1	1.0	6.0	17.1	0.3
Difference	absolute	0.4	0.1	0.1	0.1	0.1	0.3	0.0	0.0
	%	1.1%	3.7%	3.9%	7.6%	12.0%	5.7%	0.0%	0.0%
2010	IIR 2023	40.5	2.2	2.2	1.1	1.1	6.5	3.5	0.3
	IIR 2024	40.1	2.2	2.2	1.2	1.1	6.7	3.5	0.3
Difference	absolute	-0.4	0.0	0.0	0.0	0.1	0.2	0.0	0.0
	%	-0.9%	1.7%	1.2%	3.4%	6.6%	2.6%	0.0%	0.0%
2020	IIR 2023	30.1	1.4	1.3	0.7	0.7	4.1	3.4	0.1
	IIR 2024	30.0	1.5	1.3	0.7	0.7	4.3	3.4	0.1
Difference	absolute	-0.1	0.1	0.0	0.0	0.1	0.2	0.0	0.0
	%	-0.4%	3.5%	2.9%	6.0%	9.1%	4.7%	0.0%	0.1%
2021	IIR 2023	30.2	1.5	1.4	0.7	0.7	4.3	3.5	0.2
	IIR 2024	30.2	1.6	1.5	0.8	0.8	4.7	3.4	0.2
Difference	absolute	0.0	0.1	0.1	0.1	0.1	0.4	-0.1	0.0
	%	0.1%	6.7%	8.9%	11.2%	13.5%	9.3%	-2.9%	0.2%

The changes of the Dutch PAH’s emissions are the results of recalculations in the Transport and other combustion estimates.

12 Projections

12.1 Projections have been prepared in the framework of the Netherlands Climate and Energy Outlook 2022

The emission projections of air pollutants for the IIR 2023 have been prepared within the framework of the Netherlands Climate and Energy Outlook 2022 (PBL, TNO, CBS & RIVM, 2022). This Outlook is called KEV 2022 in Dutch. These projections are consistent with the projections of greenhouse gas emissions for the Netherlands.

The preparation of the Outlook is the responsibility of the Netherlands Environmental Assessment Agency (PBL) in cooperation with the National Institute for Public Health and the Environment (RIVM) and the Netherlands Organisation for Applied Scientific Research (TNO). Wageningen University & Research (WUR) prepared the projection for agriculture (animal husbandry and land use) under the authority of PBL (Vonk *et al*., 2023).

The corresponding KEV 2022 report can be found on the website of the PBL (https://www.pbl.nl, an English summary is available). Underlying reports and datasets can also be found on this website (https://www.pbl.nl/kev, in Dutch and https://www.pbl.nl/publicaties/geraamde-ontwikkelingen-in-nationale-emissies-van-luchtverontreinigende-stoffen-2023). Projected activity data can be found in the Annex IV reporting template.

12.2 National report with projections for air pollutants

The projections for the emissions of air pollutants are described in a separate report called *'Geraamde ontwikkelingen in nationale emissies van luchtverontreinigende stoffen 2023'* (PBL *et al*., 2023; in Dutch). This report describes the emission trends starting from the base year 2020 up to the year 2030 for the five air pollutants under the new National Emission reduction Commitments Directive (NEC Directive, 2016/2284/EU), i.e. NO_x, NH_3, $PM_{2.5}$, SO_x and NMVOC. In addition projections haven been prepared for PM_{10}.

This report contains for the first time also a projection for the emission trends up to 2040. The projection between 2030 and 2040 provides an indicative view on the development of emissions given the continuation of adopted and planned policies.
This outlook report complies with the requirement within the NEC Directive (Directive 2016/2284/EU) to report emission projections every two years. Moreover, these projections are required to calculate the future developments with respect to air quality and nitrogen deposition in the Netherlands.

12.3 Measures and policies

The submitted projections take into account all relevant information about measures up to 1 May 2022. Three projections haven been prepared:

- *Adopted policy* includes all climate and relevant environmental policies implemented on 1 May 2022. This projection has been used to report according to the *With Measures (WM)* scenario, according to the guidelines for international reporting;
- *Planned policy* includes all climate and relevant environmental policies that, by 1 May 2022, had been made public, officially announced in Letters to Parliament and worked out in sufficient detail. This projection has been used to report according to the *With Additional Measures (WAM)* scenario, according to the guidelines for international reporting;
- *Proposed policy* includes policy plans and intentions that, by 1 May 2022, had been made public, but had not yet been worked out in sufficient detail. This projection including proposed policies has been prepared for the first time. This has been executed to provide additional information to Dutch policy makers concerning the possible impacts of (so-called 'non-specific') measures that still have to be worked out properly. This new projection has not been used for international reporting..

Most of the content of the Dutch reports serving the Netherlands Climate and Energy Outlook 2022, is based on the *adopted policies (i.e. WM scenario)* and *planned policies (i.e. WAM scenario)*, including detailed calculations for the outlook report. For the *proposed policy*, ministries and other organisations could provide additional information up until 8 July 2022 (when Dutch parliament went into summer recess).

Part of the proposed policy measures have only been assessed with respect to a conceivable emission reduction impact by 2030. For several other measures, no assessments have been made for the *proposed policy* projection due to insufficient information. Proposed measures are clearly different from planned measures and have therefore not been incorporated in the reported WAM scenario.

The projections made for the *adopted policies (i.e. WM scenario)* and *planned policies (i.e. WAM scenario)* have been used for the published outlook report and for this IIR. The reported projections in this IIR are the adopted (WM) and the planned (WAM) projections and these are fully consistent (concerning policy definitions) with Dutch projections in previous IIR-reports. Several climate and energy policies and measures are incorporated into the calculated emission trends for the relevant air pollutants. Also, relevant national (adopted and planned) environmental policies have been incorporated into the emission projections, such as measures stemming from the Dutch air quality agreement and the Dutch action plan to tackle nitrogen pollution in Natura 2000 conservation areas. A full overview of relevant climate and energy policies and environmental policies has been published in the side publication for the KEV *'Beleidsoverzicht en factsheets beleidsinstrumenten'* (PBL, TNO & RIVM, 2022; in Dutch). In this publication, substantial background information has been provided for individual policy measures in factsheets.

A full overview of relevant policy measures related to environmental emissions has been provided (PBL, TNO, RIVM & WUR, 2022; in Dutch). The complete list of (environmental) policies included in the KEV2022 projections is presented in Table 1.5 of the referenced report (PBL *et al*., 2023; in Dutch).

Relevant climate and energy policies, which have been incorporated into the *WM scenario* and the *WAM scenario* are amongst others:

- SDE++ subsidy scheme to stimulate renewable energy and CO_2 reduction techniques; this is the major subsidy scheme for renewable energy in the Netherlands;
- Various other financial instruments, such as a national CO_2 tax for industry, energy taxes, subsidy schemes, tax reduction schemes for energy-saving technologies;
- Ban on coal-fired power plants by 2030;
- Various regulations and subsidy schemes for the built environment, including Ecodesign-requirements and policies to abandon the use of natural gas for new buildings;
- Various regulations and subsidy schemes for mobility, including policies with respect to biofuels, electric vehicles, restriction of the number of flights at Schiphol Airport (Amsterdam), zero-emission zones in cities for delivery vans and trucks and levy on heavy duty trucks;
- Various regulations and subsidy schemes for the industry, greenhouse horticulture and agriculture, including the EU ETS, stimulation to implement CCS, sustainable hydrogen production, stimulation of a circular economy and LULUCF-related policies.

Several environmental policies and measures are included in the *WAM scenario*, including:

- Subsidy scheme for shrinkage of pig cattle farming;
- Regulation targeted at the purchase and termination of cattle farming;
- Subsidy schemes to obtain more sustainable cattle stables;
- Subsidy scheme for high-quality manure-processing;
- Subsidy scheme to obtain more sustainable inland shipping;
- Additional enforcement of correct use of SCR catalysts in trucks;
- Temporary subsidy scheme shore power for sea-going vessels;
- Subsidy scheme for clean and zero-emission heavy machinery and construction equipment;
- Restriction of emission limit values for biomass combustion in small and medium-scale installations;
- Restriction of generic emission requirements in BaL (Dutch decree on activities living environment) and actualization of interest rates for cost-effectiveness calculations;
- Policy wood combustion in private wood stoves;
- Roadmap Plus: environmental action plan for Dutch steel producer Tata Steel;
- Switch to DRI: new steel production process for Dutch steel producer Tata Steel.

Table 12.1 Results of NEC emissions for the WAM (With Additional Measures) scenario according to European definitions (i.e. NEC Directive) for 2030 and 2040. The numbers within brackets represent the calculated uncertainty of this projection. The NEC emissions for 2005 and 2020 are based on emissions inventories that have been used for the projections (statistics from the Dutch emission inventory as reported February 2022). The targets for 2020 and 2030 have been calculated according to the NEC Directive and represent the maximum allowed emissions for the Netherlands. All numbers are expressed in Gg.

	2005	2020	Projection 2030	EU NEC target 2030	Projection 2040
NO_x	396	180	138-140 [125-157]	154	123
NH_3	153	124	116 [108-122]	121	108
$PM_{2.5}$	27.8	14.6	12.9 [12.3-13.7]	15.3	11.9
SO_x	67	20	20 [15-22]	32	19
NMVOC	209	186	149 [141-159]	177	140

12.4 Projection totals for compliance checking NEC-targets 2030

The projection results are summarised in Table 12.1. In Table 12.1 the projection results for the *WAM scenario* are summarised according to European definitions. European definitions mean that calculations have been performed according to definitions as prescribed in the NEC Directive (Directive 2016/2284/EU). This means, for example that international maritime traffic and aircraft emissions beyond the landing and take-off cycle are not taken into account. Also the emissions of NO_x and NMVOC from manure management and agricultural soils (NFR 3B and 3D; Sector Agriculture) are exempted from the compliance totals. The EU NEC targets in Table 12.1 have been calculated using reduction percentages according to the NEC Directive (Directive 2016/2284/EU) and represent the maximum allowable emissions within the territory of the Netherlands.

The maximum emissions allowed (‘emission ceilings’) seen in Table 12.1 have been calculated based on the statistics from the Dutch emission inventory as reported February 2022. This has been performed since projections are based on this inventory. It should be noted that projections given here for 2030 may not be compared with maximum allowed emissions in 2030 that are calculated based on statistics from the Dutch emission inventory as reported February 2023 (as provided in Table 12.1).

As can be seen Table 12.1, the targets in place for 2030 onwards are expected to be within reach according to the *WAM scenario*. However, the uncertainty analysis for NO_x and NH_3 emission projections for 2030 do reveal that the target may not be met. This may be the case, provided that there are many setbacks and various policies and other factors do not live up to current expectations.

12.5 Emission uncertainty range for 2030

The projections are based on future expectations with respect to the development of various factors that determine the economy, energy system and emissions. These factors encompass developments of external factors, such as macro-economic developments, population growth and energy and CO_2 prices. The likely effectiveness of policy measures has also been estimated.

Uncertainties in relevant factors have been translated into consequences for emissions in 2030. For every factor and every pollutant, it has been estimated how much the emission could deviate (upwards and downwards) from the central projection, expressed as a point value. It has also been determined whether, how and to what extent one factor is interlinked with another factor. All this information is brought together in a Monte Carlo uncertainty analysis. Separate analyses have been performed for the national NEC total and for the totals per KEV sector. The result is an uncertainty range with respect to the projected point values. The possibility of new policies coming in and/or the possibility that policies will stop have not been taken into account in the uncertainty analysis. The uncertainty range is calculated given the policies taken into account in the reported scenarios (WM and WAM). The uncertainty range thus only gives the uncertainty determined by external factors such as prices and economic developments and the uncertainty in the effectiveness for those measures that are included in the central projection. The uncertainty in the historical emissions of the emission inventory has been excluded from the uncertainty analysis. The analysis only paints a picture of the uncertainty that is involved in unknown future developments.

12.6 Emission projections for 2030: deviations, correction for $PM_{2.5}$ and NO_x range

12.6.1 Deviations with respect to historical projections

The projection results for most NEC pollutants for 2030 show some deviations compared to the former projection inventory. Compared to the former projection for 2030, the projected emission for NO_x turned out to be higher (+9 Gg), for NH_3 the projected emission turned out to be lower (-4 Gg), for $PM_{2.5}$ it turned out be higher (+2.1 Gg), for SO_x it turned out to be lower (-3 Gg) and for NMVOC projections for 2030 turned out be higher (+1 Gg). This is due to adjustments with respect to statistical years as well as to new insights into the result of policies.
For NO_x, the higher emissions result from new insights with respect to the statistics and potential effects for both policies as well as technologies for the sector Mobility. Despite a downward adjustment for the stationary sources, e.g. NO_x measures and less gas-fired power production as compared to the former outlook, the projected NO_x emission turned out to be higher.
For NH_3, multiple factors play a role: new insights with respect to statistics, changing policies, higher anticipated prices for fertilizer. Next to this, new insights into the potential effects of policies, such as the effectiveness of more sustainable cattle stables on NH_3 emissions have been taken into account.
An extensive explanation for $PM_{2.5}$ have been described in the next paragraph, 12.6.2.
For SO_x, the differences are attributed to the closure of some companies. But lower emission statistics mainly for the oil refining sector, as compared to recent years, also play a substantial role here. Likewise for NMVOC, which deviation with respect to the former outlook is attributed to overall lower emission statistics as well.

12.6.2 Correction for condensables for $PM_{2.5}$

A relevant difference from the former IIR is in place for $PM_{2.5}$, with respect to emission statistics as well as for the resulting emission projection. This upward adjustment of $PM_{2.5}$ emissions is mainly the result of including the formation of so-called condensables as a result of wood combustion in private wood stoves. These condensables are particulate matter formed by condensation of particular exhaust gases of wood combustion shortly upon leaving the chimney. This correction turned out to have a substantial effect on the national emissions and has been incorperated into the emission statistics as well as into the emission projection.

12.6.3 NO_x range for 2030

The projection results for 2030 have been calculated and reported for NO_x not according to a point value, but using a range. Despite the recommendation the Technical Review Team made in its former review, that this projection were to report a point value, the Netherlands Climate and Energy Outlook 2022 (PBL, TNO, CBS & RIVM, 2022) has reported a range for the Dutch Power Sector. The reason for this deviation is that one specific scenario cannot be estimated. A large uncertainty is ascribed to the power supply and demand outside the Netherlands, which is relevant due to the strong interconnection of the Dutch Power Sector. Fuel prices and CO_2 ETS prices may affect this strongly, even if small fluctuations may occur.

According to the Netherlands Climate and Energy Outlook, this range is only in place for the Dutch Power Sector. We note here that this mainly affects gas-fired power production. For 2030, policies are in place to abandon coal-fired power production in the Netherlands. Therefore, this range have an influence on the projected NO_x emissions, but this is not relevant for any of the other pollutants.

12.7 Role of waste in the projections and projection up to 2040

In its former review, the Technical Review Team recommended providing more information on waste processing. In general, a large part of Dutch household waste, such as glass, paper, compostable waste and plastic waste, is collected separately to facilitate substantial recycling. Household residual waste is incinerated in dedicated waste incinerators, which need to meet strict emission requirements. These waste incinerators often produce power as well as heat for district heating.

For historical reasons, the Netherlands had excess capacity of waste incinerators, which it used to incinerate foreign waste. The Dutch government regards this as detrimental and discourages this by putting a tax on imported waste. Due to this policy, the amount of imported waste have been declining since 2018. The outlook for inland supply of household waste will depend on developments and policies with respect to recycling and circularity, but its effects remain uncertain. Therefore, it is assumed for this outlook that waste supply will remains at its current level, which means a stabilisation of waste incineration in the future. Since a decline of waste supply may also be anticipated, a future decrease in waste incineration has been adopted as part of the uncertainty analysis (see 12.5). As mentioned before, due to regulations, waste incineration in the Netherlands is a relatively small source of environmental emissions.

Lastly, in its former review, the Technical Review Team encouraged providing information for additional projection years. In Table 12.1 the projection year 2040 have been incorporated. Projections up to 2050 have not been made.

13 Adjustments and Compliance

13.1 Compliance with the emission reduction targets

In 2001, being an EU Member State, the Netherlands adopted the NECD (National Emission reductions Commitments Directive) 2001 (EU, 2001), which was replaced by the revised NECD 2016 (EU, 2016). In 2017, the Netherlands signed and ratified the amended text on the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (UNECE Gothenburg Protocol). The NECD and the Gothenburg Protocol both commit the Netherlands to reducing its NO_x, SO_x, NMVOC, NH_3 and $PM_{2.5}$ emissions to the agreed national reduction targets by 2020 and 2030, compared to the 2005 emissions.

Both for the Gothenburg Protocol and the NECD, the Netherlands has opted to calculate the compliance totals on the basis of fuel-sold.

The emission reduction targets for both the NECD and the Gothenburg Protocol amount to the same percentage for each pollutant. However, for NO_x and NMVOC there is a difference between the NECD and the Gothenburg Protocol regarding the calculation of the emission totals for compliance checking. Under the NECD the emissions of NO_x and NMVOC from manure management and agricultural soils (NFR 3B and 3D; Agriculture Sector) are exempted from the compliance total, whereas the Gothenburg Protocol does include these sources.

Under the NECD, the emissions of NO_x, NMVOC, NH_3, SO_x, and $PM_{2.5}$ comply with the 2020-2029 reduction targets (Table 13.1).

Table 13.1 Compliance under the NECD.

NECD emissions reduction targets, compliance total and achieved reductions.								
	Target 2020-2029 (compared to 2005)	Compliance total (Gg)				Achieved reduction		
Pollutant		**2005**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
NO_x	**-45%**	395.2	177.7	173.2	162.2	55%	56%	59%
NMVOC	**-8%**	204.0	162.1	156.9	154.5	21%	23%	24%
SO_x	**-28%**	67.9	19.6	20.9	19.6	71%	69%	71%
NH_3	**-13%**	155.0	125.0	123.5	121.2	19%	20%	22%
$PM_{2.5}$	**-37%**	28.5	14.4	14.5	14.3	49%	49%	50%

Under the Gothenburg Protocol, the Netherlands did not comply with the NMVOC reduction target for the year 2020 (Table 13.2).

Table 13.2 Compliance under the Gothenburg Protocol.

Gothenburg Protocol emissions reduction targets, compliance total and achieved reductions.								
	Target 2020-2029 (compared to 2005)	Compliance total (Gg)				Achieved reduction		
Pollutant		2005	2020	2021	2022	2020	2021	2022
NO_x	-45%	430.9	211.7	206.4	194.6	51%	52%	55%
NMVOC	-8%	269.9	249.9	244.1	241.7	7%	10%	10%
SO_x	-28%	67.9	19.6	20.9	19.6	71%	69%	71%
NH_3	-13%	155.0	125.0	123.5	121.2	19%	20%	22%
$PM_{2.5}$	-37%	28.5	14.4	14.5	14.3	49%	49%	50%

13.2 Adjustment under the Gothenburg Protocol

Decision 2012/3 (UNECE, 2012) of the Executive Body stated that as a flexibility mechanism adjustments can be made to the emissions inventory for demonstrating compliance with the emission reduction targets. Under specific circumstances, such adjustments allow a Party to report national emission estimates for compliance purposes, which differ from their best science national emission estimates.

The 2013 EMEP/EEA Guidebook implemented a default methodology and default EFs for NMVOC from animal husbandry and manure management. This resulted in 2017 in the inclusion of the NMVOC emissions from agriculture into the emission inventory as best science estimate, as described in Chapter 6. Thus, the NMVOC emissions from these sources were not accounted for at the time when emission reduction commitments were set. For this reason this new NMVOC source is eligible to be applied as adjustment to the inventory for purpose of demonstrating compliance to the reduction targets.

The Netherlands applied in the 2022 for the years 2005, 2020 for an inventory adjustment for an NMVOC source in NFR category 3B, more specifically 3B1a (Manure management – Dairy cattle), that after reviewing was approved. For source explanation and methodology, we refer to Chapter 6 (Agriculture). As is indicated in chapter 6, the NMVOC emission of 3B1a in 2020 differs slightly from the emission reported in the previous IIR. This is due to the inclusion of bedding material in the emissions calculations in the 2024 submission. Bedding material is an additional source of nitrogen to the manure, which affects the emission of NH_3 from housing and storage. NMVOC emissions from storage are partly based on the ratio of these two sources.

In this 2024 submission recalculations in several sources related to Product Use (PU), resulted in a decrease of NMVOC emissions over the complete timeseries. As result there is in de 2024 submission only non-compliance remaining in 2020 (see table 13.2).

When the approved adjustment is applied to the inventory, the Netherlands will comply in 2020, as is represented in Table 13.3.

Table 13.3 Compliance under the Gothenburg Protocol with the (2022) approved inventory adjustment.

NMVOC Compliance and adjustment under the Gothenburg Protocol						
Year	**Inventory total (Gg)**	**Reduction Target %**	**Uadjusted reduction %**	**Adjustment NFR-3B1a (Gg)**	**Adjusted Compliance total (Gg)**	**Reduction with adjustment %**
2005	**269.9**	**-**	**-**	**24.2**	**245.7**	**-**
2020	249.9	8%	7%	43.6	206.3	16%
2021	244.1	8%	10%	-	-	-
2022	241.7	8%	10%	-	-	-

14 Spatial Distributions

14.1 Background for reporting

In 2020, the Netherlands reported geographically distributed emissions and LPS data to the UNECE LRTAP Convention for the years 1990, 1995, 2000, 2005, 2010, 2015 and 2018. Emission data was disaggregated to the : EMEP 0.1°x0.1° longitude-latitude grid. Guidelines for reporting air emissions on grid level are provided in EEA (2016). Gridded emission data is used in integrated European air pollution models, e.g. GAINS and EMEP's chemical transport models. The aggregated sectors, 'gridded NFR' (GNFR), for reporting are defined in table I of annex IV to the Guidelines for reporting emission data under the Convention on Long-Range Transboundary Air Pollution (EMEP/EEA, 2023). These result from the aggregation of the gridded NFR sectors.

14.2 Methodology for disaggregation of emission data

All emissions in the Dutch PRTR are geographically distributed, using a suitable spatial allocation method. An allocation method can be applied to disaggregate various emissions, and for each method a factsheet is available at http://www.prtr.nl.

Each factsheet contains a brief description of the method used, an example of the relevant distribution map, references to background documents and a list of the relevant institutes. An Excel sheet is also provided, which can be used to link emissions, emission source, allocation and factsheet.

Three methods are used for the spatial allocation of emission sources:
- Direct linkage to location;
- Model calculation;
- Estimation through proxy data.

The first method only applies to large point sources, for which both the location and the emissions are known. This includes all companies that are required by Dutch law to report their air and water emissions by means of Annual Environmental Reports (AERs), combined with data of wastewater treatment plants (WWTPs). Altogether, this category contains almost 3,000 point sources.

Some examples of the second method, spatial distributions based on model calculations, are:
- Ammonia (NH_3) from agriculture;
- Particulate matter (PM_{10} and $PM_{2.5}$) from agriculture;
- Deposition on surface water;
- Leaching and run-off to surface water (heavy metals and nutrients);
- Emissions of crop protection chemicals to air and surface water.

Finally, the largest group of emissions is spatially allocated using proxy data. Examples of spatial distributions that are used for this purpose are population and housing density, vehicle kilometres (cars, ships and trains), land cover and the number of employees per facility.

14.3 Maps with geographically distributed emission data

The maps below are examples of the disaggregated emission data based on the latest reporting data (2018) from the Netherlands Pollutants Release and Transfer Register (http://www.prtr.nl). They all result from allocating emissions to the grid using the methods described above. The selected air pollutants are ammonia (NH_3), sulphur oxides (SO_x), nitrogen oxides (NO_x) and fine particulates ($PM_{2.5}$). Figures 14.1–14.4 represent the geographically distributed emissions for these air pollutants.

On a national scale, the agricultural sector is the main contributor to NH_3 emissions (Figure 14.1). Emissions of NH_3 are mainly caused by livestock farming and particularly by the handling of manure. They are therefore related to the storage and spreading of manure, as well as to animal housing (Bruggen van *et al.*, 2021). The burning of fossil fuels also emits NH_3 Therefore, some inland shipping routes and fishing grounds are visible in the map. There are no other large aquatic sources that contribute to the national ammonia emission. Compared to other sectors however, the emission quantities from inland shipping and fisheries are small.

Both SO_x and NO_x are predominantly emitted by transport; cities, main roads, airports and shipping routes are therefore clearly visible in the maps (Figures 14.2-14.3). On the SO_x map, inland shipping routes stand out from the rest because more reduction measures were taken in other sectors than in inland shipping.

On the map of fine particulate matter (Figure 14.4), cities, airports, agriculture, main roads and shipping routes can all be recognised due to the fact that residential heating, agricultural animal housing, traffic and shipping are all main sources of PM emissions.

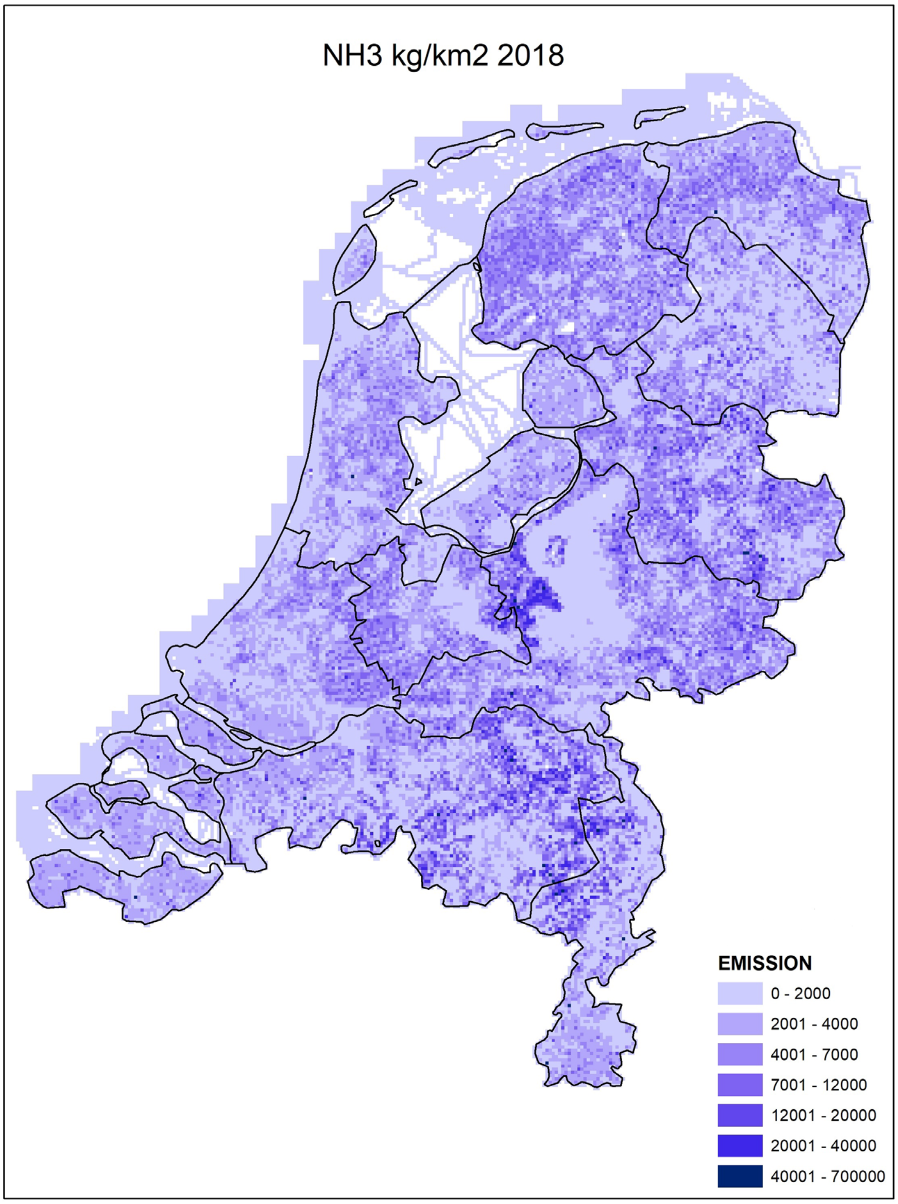

Figure 14.1 Geographical distribution of NH_3 emissions in the Netherlands in 2018

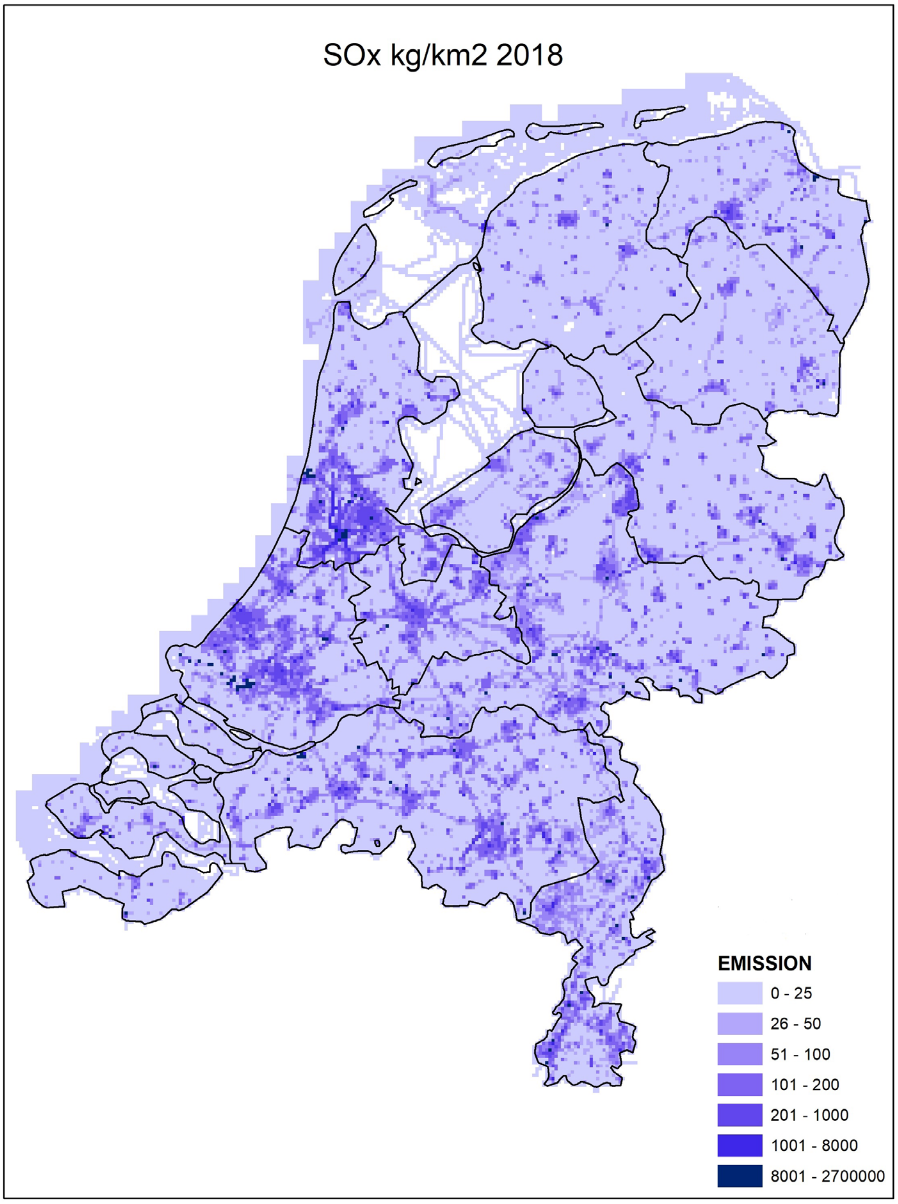

Figure 14.2 Geographical distribution of SO_x emissions in the Netherlands in 2018

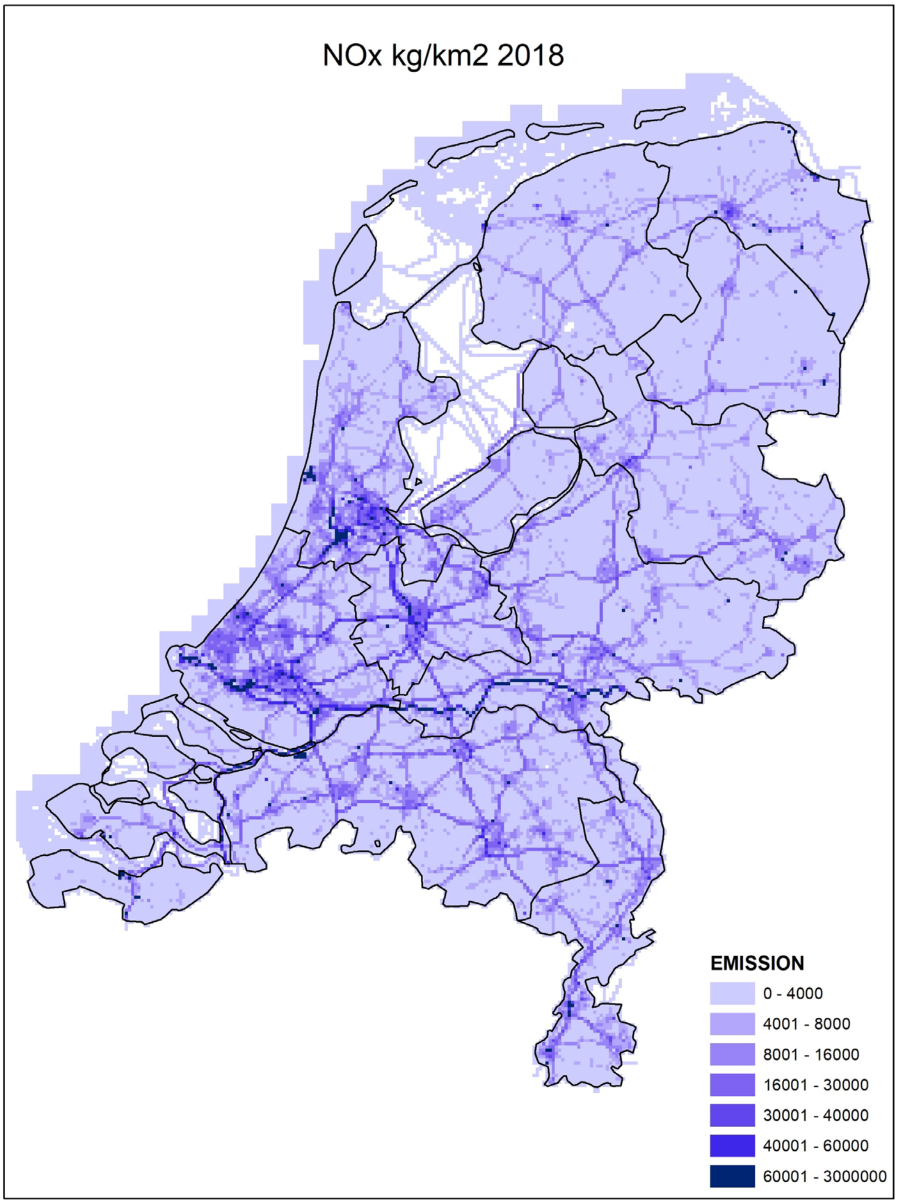

Figure 14.3 Geographical distribution of NO_x emissions in the Netherlands in 2018

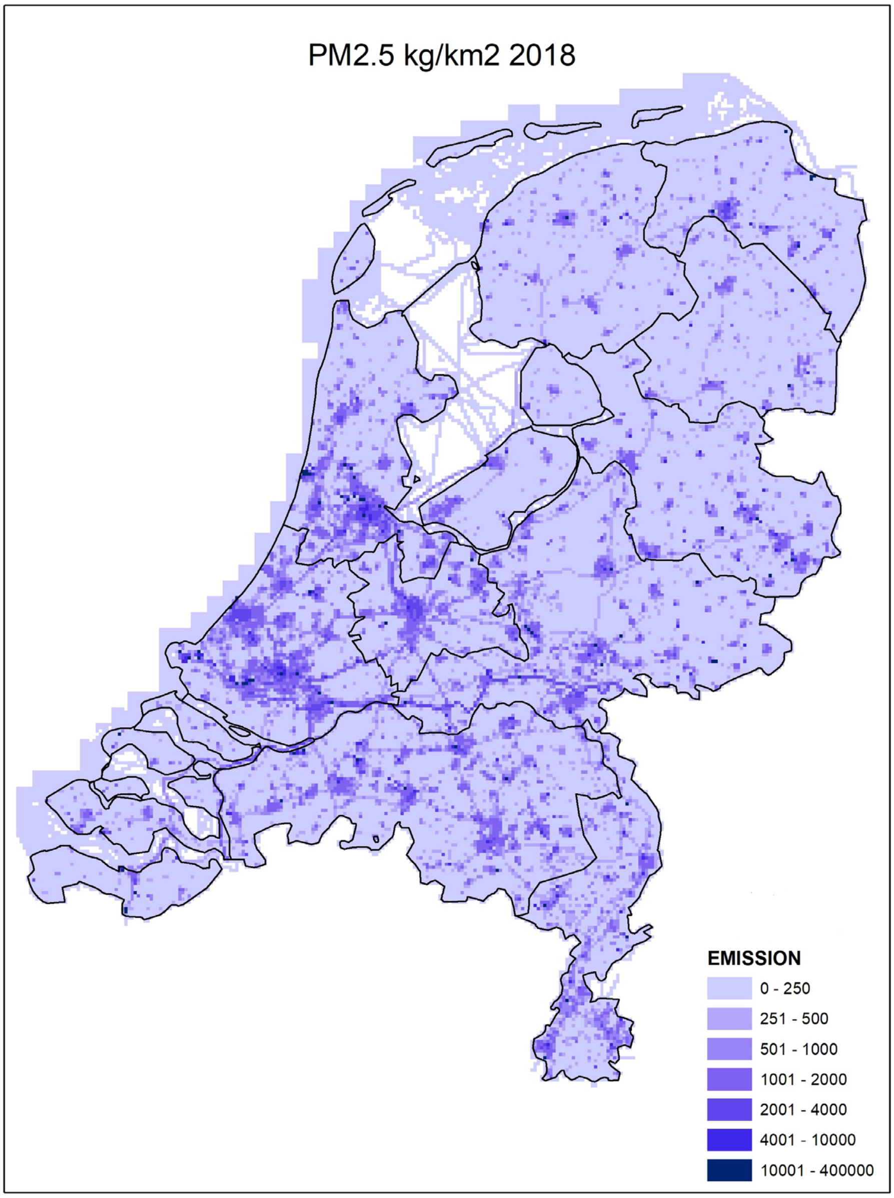

Figure 14.4 Geographical distribution of $PM_{2.5}$ emissions in the Netherlands in 2018

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The emissions and activity data of the Netherlands' inventory were converted into the NFR source categories contained in the Nomenclature for Reporting (NFR) tables, which form as also the reports on the methodologies used, a part to this report.

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Appendix 1 The use of notation keys 'IE' and 'NE'

Table A1.1 The Included Elsewhere (IE) notation key explained

NFR code	Substance(s)	Included in NFR code	Explanation
1A1c	All, except NO_x and SO_x	1A2a (all pollutants) and 1B2b (NMVOC)	The emissions from coke production are reported by the combined coke production and iron/steel production plant in the Netherlands. It is not possible to split the emissions into coke production and iron/steel production, and therefore the emissions of this source are reported in 1A2a. The emissions from the oil and gas industry are allocated to 1A1c (combustion emissions reported by gas companies using natural gas) and 1B2b (NMVOC fugitive emissions)
1A2a	NH_3, dioxin, PAH	2C1	Emissions are reported by the one iron and steel plant in the Netherlands. Distinction between combustion and process emissions is not always possible. When this is not possible, emissions of NH_3 is reported in 2C1.
1A2b	NH_3, dioxin, PAH	2C3, 2C5, 2C6, 2C7a	Emissions are reported by several non-ferrous plants in the Netherlands. Distinction between combustion and process emissions is not always possible.
1A2f	All	1A2gviii	Whether splitting these emission sources is possible is under evaluation by the specific task force.
1A3ei	All	1A2f, 1A4cii, 1B2b	Combustion and process emissions from pipeline transport cannot be split due to lack of detailed activity data.
1A5a	All		The emissions from military stationary combustion are included in 1A4ai.
1B1a	TSP, PM_{10}, $PM_{2.5}$	2H3	Only emissions from coal storage and handling occur. These cannot be separated from emissions of other storage and handling of dry bulk products, so are included in 2H3.
1B1b	All	1A2a	Emissions from coke production are reported by the combined coke production and iron/steel production plant in the Netherlands. It is not possible to split the emissions between coke production and iron/steel production, and therefore all emissions are reported in 1A2a.
1B2aiv	NO_x, SO_x, CO, TSP, PM_{10}, $PM_{2.5}$, BC, Dioxins and PAH	1A1b	Emissions are reported by the refineries in the Netherlands. Distinction between combustion and fugitive emissions is not always possible.

NFR code	Substance(s)	Included in NFR code	Explanation
1B2c	NO_x, NMVOC, SO_x, TSP, PM_{10}, $PM_{2.5}$, BC, CO	NMVOC included in 1B2b; NO_x, SO_x, TSP, PM_{10}, $PM_{2.5}$, BC and CO included in 1A1c	Combustion and process emissions cannot be split due to lack of detailed activity data.
2A2	All	2A6	Because of allocation problems, emissions from 2A2 are reported in the category Other mineral products (2A6).
2A5a	All	2A6	Because of allocation problems, emissions from 2A5a are reported in the category Other mineral products (2A6).
2B1	All	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B1 are included in Chemical industry: Other (2B10a).
2B2	All	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B2 are included in Chemical industry: Other (2B10a).
2B5	All	2B10a	Because of allocation problems and for confidentiality reasons, emissions from Silicon carbide (2B5) are included in Chemical industry: Other (2B10a).
2B6	All	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B6 are included in Chemical industry: Other (2B10a).
2B7	All	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B7 are included in Chemical industry: Other (2B10a).
2C3	NO_x, and SO_x	1A2b	Because it is not possible to split the SO_x and NO_x from Aluminium production, all SO_x and NO_x emissions are reported in 1A2b.
2C4	All	2H3	For confidentiality reasons, emissions from 2C4 are included in 2H3.
2C7d	All	2H3	Because only emissions from the storage and handling of bulk products companies are available, emissions from 2C7d are reported in 2H3. The 2H3 subcategory in the Dutch PRTR includes among others emissions from the storage and handling of bulk products. Only companies that have the storage and handling of bulk products as their main activity are included in the 2H3 subcategory.
2D3g	NMVOC	2B10a	See IIR, Section 5.3.1.
2L	All	2H3	Because the 2016 Guidebook is not clear about which sources belong to 2L, 2L is included in 2H3 (Other industrial processes).

NFR code	Substance(s)	Included in NFR code	Explanation
5A	BC	1A1a and 1A5a	Emissions from heat and power production and flaring are included in the sector Energy. See Chapter 7
5C1a	All	1A1a	All waste incinerators in the Netherlands produce heat and/or electricity. Emissions from heat and power production are included in the sector Energy.
5C1bi	All	1A1a	All waste incinerators in the Netherlands produce heat and/or electricity. Emissions from heat and power production are included in the sector Energy.
5C1bii	All	1A1a	All waste incinerators in the Netherlands produce heat and/or electricity. Emissions from heat and power production are included in the sector Energy.
5C1biii	All	1A1a	All waste incinerators in the Netherlands produce heat and/or electricity. Emissions from heat and power Production are included in the sector Energy.
5C1biv	All	1A1a	All waste incinerators in the Netherlands produce heat and/or electricity. Emissions from heat and power production are included in the sector Energy.
5C1bv	NO_x, SO_x, NH_3, BC and CO	1A1ai	The natural gas used for cremation cannot be split from the natural gas used for heating the crematoria buildings. Therefore, all emissions from natural gas combustion in this sector are allocated to 1A4ai.
5D1	NO_x, SO_x, TSP, PM_{10}, $PM_{2.5}$, BC and CO	1A4ai	Emissions from heat and power production are included in the sector Energy.
5D2	NO_x, SO_x, TSP, PM_{10}, $PM_{2.5}$, BC and CO	1A4ai	Emissions from heat and power production are included in the sector Energy.

Table A1.2 The Not Estimated (NE) notation key explained

NFR code	Substance(s)	Reason for non- estimation
1A1a, 1A1b, 1A2c, 1A2d, 1A2e	NH_3	Assumed negligible, no method available
1A1b, 1A2c	PAH	PAH emissions in 2014 and 2015 will be added in the 2024 submission
1A1b, 1A2a, 1A3bi till 1A3biv, 2C1, 2C3	HCB	assumed negligible; no method available
2C5	PCBs	assumed negligible
1A2c, 1A2gvii, 1A3C, 1A3di(ii), 1A3dii, 1A4aii, 1A4bii, 1A4cii, 1A5b,	HCB and PCBs	assumed negligible
1A2d	Dioxins, PAHs, HCB and PCBs	assumed negligible
1A2e	Dioxins	assumed negligible
1A3ai(i)	NH_3 and Hg	assumed negligible
1A3aii(i)	NH_3, Cd, Hg, As, Cr, Cu, Ni, Se, Zn,	assumed negligible
1A3bv	Dioxins, PAHs and HCB	assumed negligible
1A3bvi	Hg, Dioxins and HCB	assumed negligible
1A3bvii	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCB	assumed negligible
1B1a	NMVOC, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn	assumed negligible. For BC and metals no method available
1B2ai, 1B2av and 1B2b	SO_x, Dioxins	assumed negligible. No method available in the Guidebook
1B2c	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs	assumed negligible. For PAH and dioxin, no method is available in the Guidebook
2C7a	Cd	assumed negligible
2D3b	NO_x, SO_x, NH_3, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs, HCB and PCBs	assumed negligible
2D3c	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs, HCB and PCBs	assumed negligible
3Da2a, 3Da2b, 3Da2c, 3Da3 and 3Da4	TSP, PM_{10} and $PM_{2.5}$	assumed negligible
3Db	NH_3, TSP, PM_{10} and $PM_{2.5}$	assumed negligible

NFR code	Substance(s)	Reason for non- estimation
3De	NO_x, SO_x, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni and Se	assumed negligible
3Df	NO_x, NMVOC, SO_x, CO, NH_3, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn and Se	assumed negligible
3I	NO_x, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni and Se	assumed negligible
6A	SO_x, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs, PCB and HCB	assumed negligible

Appendix 2 Key category analysis results; Approach 1

Approach 1 method

Results from the key (source) category analysis have been calculated and sorted for every component. In addition to a 2022 and 1990 level assessment, a trend assessment was performed. In both approaches, key source categories are identified using a cumulative threshold of 80%.

For the key source analyses, the emissions were taken from the fuel-sold calculations.

SO_x key sources

Table A2.1.a SO_x key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
1A1b	Petroleum refining	8.6	43.7%	43.7%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	3.0	15.4%	59.1%
1A1a	Public electricity and heat production	2.4	12.4%	71.5%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	1.4	7.0%	78.4%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	1.2	6.1%	84.6%

Table A2.1.b SO_x key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A1b	Petroleum refining	67.1	34.0%	34.0%
1A1a	Public electricity and heat production	48.5	24.5%	58.5%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	20.0	10.1%	68.6%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	9.1	4.6%	73.3%
1A3biii	Road transport: Heavy duty vehicles and buses	8.8	4.4%	77.7%
2A6	Other mineral products (please specify in the IIR)	5.5	2.8%	80.5%

Table A2.1.c SO_x key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	1.2%	19.5%	19.5%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	1.1%	17.3%	36.8%
1A1b	Petroleum refining	1.0%	15.6%	52.4%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.4%	7.3%	59.7%
1A3biii	Road transport: Heavy duty vehicles and buses	0.4%	6.8%	66.5%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	0.4%	6.4%	72.9%
2A6	Other mineral products (please specify in the IIR)	0.3%	4.3%	77.3%
1A3bi	Road transport: Passenger cars	0.2%	3.0%	80.2%

NO_x key sources

Table A2.2.a NO_x key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
1A3biii	Road transport: Heavy duty vehicles and buses	25.0	12.9%	12.9%
1A3bi	Road transport: Passenger cars	18.2	9.4%	22.2%
3Da2a	Animal manure applied to soils	15.0	7.7%	29.9%
1A1a	Public electricity and heat production	12.8	6.6%	36.5%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	12.5	6.4%	42.9%
1A3di(ii)	International inland waterways	11.2	5.7%	48.7%
1A3bii	Road transport: Light duty vehicles	11.1	5.7%	54.4%
3Da1	Inorganic N-fertilizers (includes also urea application)	8.6	4.4%	58.8%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	8.0	4.1%	62.9%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	7.9	4.1%	67.0%
1A3dii	National navigation (shipping)	7.6	3.9%	70.9%
1A4bi	Residential: Stationary	5.8	3.0%	73.9%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	5.0	2.6%	76.4%
1A4ciii	Agriculture/Forestry/Fishing: National fishing	4.8	2.5%	78.9%
1A1b	Petroleum refining	4.79	2.5%	81.4%

Table A2.2.b NO_x key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	140.3	20.6%	20.6%
1A3biii	Road transport: Heavy duty vehicles and buses	129.8	19.1%	39.7%
1A1a	Public electricity and heat production	82.9	12.2%	51.8%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	35.9	5.3%	57.1%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	34.8	5.1%	62.2%
1A3di(ii)	International inland waterways	22.3	3.3%	65.5%
1A4ciii	Agriculture/Forestry/Fishing: National fishing	20.8	3.0%	68.5%
1A4bi	Residential: Stationary	20.7	3.0%	71.6%
1A3bii	Road transport: Light duty vehicles	20.6	3.0%	74.6%
3Da2a	Animal manure applied to soils	20.1	3.0%	77.6%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	19.6	2.9%	80.4%

Table A2.2.c NO_x key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	3.2%	20.4%	20.4%
1A3biii	Road transport: Heavy duty vehicles and buses	1.8%	11.3%	31.7%
1A1a	Public electricity and heat production	1.6%	10.2%	41.9%
3Da2a	Animal manure applied to soils	1.4%	8.7%	50.5%
1A3dii	National navigation (shipping)	0.8%	5.3%	55.9%
1A3bii	Road transport: Light duty vehicles	0.76%	4.9%	60.7%
1A3di(ii)	International inland waterways	0.71%	4.5%	65.2%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.61%	3.9%	69.1%
3Da1	Inorganic N-fertilizers (includes also urea application)	0.58%	3.7%	72.8%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.43%	2.8%	75.6%
1A3ai(i)	International aviation LTO (civil)	0.43%	2.7%	78.3%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.38%	2.4%	80.7%

NH_3 key sources

Table A2.3.a NH_3 key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
3Da2a	Animal manure applied to soils	36.4	30.1%	30.1%
3B1a	Manure management - Dairy cattle	21.2	17.5%	47.6%
3B3	Manure management - Swine	12.8	10.5%	58.1%
3Da1	Inorganic N-fertilizers (includes also urea application)	9.5	7.9%	65.9%
3B1b	Manure management - Non-dairy cattle	8.9	7.3%	73.3%
3B4gi	Manure management - Laying hens	8.4	6.9%	80.2%

Table A2.3.b NH_3 key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
3Da2a	Animal manure applied to soils	199.8	57.7%	57.7%
3B3	Manure management - Swine	49.2	14.2%	71.9%
3B1a	Manure management - Dairy cattle	22.3	6.4%	78.3%
3Da3	Urine and dung deposited by grazing animals	15.7	4.5%	82.8%

Table A2.3.c NH_3 key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
3Da2a	Animal manure applied to soils	9.6%	38.7%	38.7%
3B1a	Manure management - Dairy cattle	3.9%	15.5%	54.1%
3B4gi	Manure management - Laying hens	1.6%	6.4%	60.5%
3B1b	Manure management - Non-dairy cattle	1.4%	5.7%	66.2%
3Da1	Inorganic N-fertilizers (includes also urea application)	1.4%	5.4%	71.7%
3B3	Manure management - Swine	1.3%	5.1%	76.8%
3Da3	Urine and dung deposited by grazing animals	1.1%	4.4%	81.2%

NMVOC key sources

Table A2.4.a NMVOC key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
2D3a	Domestic solvent use including fungicides	45.1	18.6%	18.6%
3B1a	Manure management - Dairy cattle	43.5	18.0%	36.7%
2D3d	Coating applications	15.6	6.5%	43.1%
2D3i	Other solvent use (please specify in the IIR)	14.7	6.1%	49.2%
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	11.6	4.8%	54.0%
3B1b	Manure management - Non-dairy cattle	11.1	4.6%	58.6%
2H3	Other industrial processes (please specify in the IIR)	10.6	4.4%	63.0%
1A3bi	Road transport: Passenger cars	10.5	4.3%	67.3%
3Da2a	Animal manure applied to soils	10.0	4.2%	71.5%
1A4bi	Residential: Stationary	9.0	3.7%	75.2%
2H2	Food and beverages industry	5.6	2.3%	77.5%
1A3biii	Road transport: Heavy duty vehicles and buses	4.81	2.0%	79.5%
2B10a	Chemical industry: Other (please specify in the IIR)	3.8	1.6%	81.0%

Table A2.4.b NMVOC key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	103.6	17.1%	17.1%
2D3d	Coating applications	93.1	15.4%	32.5%
3Da2a	Animal manure applied to soils	48.2	8.0%	40.4%
1A3bv	Road transport: Gasoline evaporation	35.4	5.8%	46.3%
2B10a	Chemical industry: Other (please specify in the IIR)	33.4	5.5%	51.8%
2H3	Other industrial processes (please specify in the IIR)	25.3	4.2%	56.0%
2D3a	Domestic solvent use including fungicides	24.3	4.0%	60.0%
2D3i	Other solvent use (please specify in the IIR)	18.4	3.0%	63.0%
1A3biii	Road transport: Heavy duty vehicles and buses	17.9	3.0%	66.0%
1B2av	Distribution of oil products	16.9	2.8%	68.7%
3B1a	Manure management - Dairy cattle	15.3	2.5%	71.3%
1B2aiv	Fugitive emissions oil: Refining / storage	14.8	2.4%	73.7%
2D3h	Printing	14.4	2.4%	76.1%
1B2b	Fugitive emissions from natural gas (exploration, production. Processing, transmission, storage, distribution and other)	14.2	2.3%	78.4%
3B1b	Manure management - Non-dairy cattle	14.1	2.3%	81%

Table A2.4.c NMVOC key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
3B1a	Manure management - Dairy cattle	6.2%	16.6%	16.6%
2D3a	Domestic solvent use including fungicides	5.8%	15.6%	32.2%
1A3bi	Road transport: Passenger cars	5.1%	13.7%	45.9%
2D3d	Coating applications	3.6%	9.5%	55.4%
1A3bv	Road transport: Gasoline evaporation	2.1%	5.6%	61.0%
2B10a	Chemical industry: Other (please specify in the IIR)	1.6%	4.2%	65.2%
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	1.6%	4.2%	69.4%
3Da2a	Animal manure applied to soils	1.5%	4.1%	73.5%
2D3i	Other solvent use (please specify in the IIR)	1.2%	3.3%	76.8%
3B1b	Manure management - Non-dairy cattle	0.9%	2.4%	79.2%
1B2aiv	Fugitive emissions oil: Refining / storage	0.7%	1.9%	81.1%

CO key sources

Table A2.5.a CO key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	125.6	31.6%	31.6%
1A4bi	Residential: Stationary	62.8	15.8%	47.3%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	56.6	14.2%	61.6%
1A4bii	Residential: Household and gardening (mobile)	26.2	6.6%	68.2%
1A3biv	Road transport: Mopeds & motorcycles	21.6	5.4%	73.6%
1A5b	Other. Mobile (including military, land based and recreational boats)	12.6	3.2%	76.8%
1A4aii	Commercial/institutional: Mobile	11.7	2.9%	79.7%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	11.2	2.8%	82.5%

Table A2.5.b CO key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	580.0	49.5%	49.5%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	187.7	16.0%	65.5%
1A4bi	Residential: Stationary	73.6	6.3%	71.8%
1A3bii	Road transport: Light duty vehicles	46.2	3.9%	75.7%
1A4bii	Residential: Household and gardening (mobile)	44.9	3.8%	79.6%
1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	37.4	3.2%	82.74%

Table A2.5.c CO key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	6.1%	33.2%	33.2%
1A4bi	Residential: Stationary	3.2%	17.6%	50.8%
1A3bii	Road transport: Light duty vehicles	1.0%	5.5%	56.4%
1A5b	Other. Mobile (including military, land based and recreational boats)	1.0%	5.2%	61.6%
1A3biv	Road transport: Mopeds & motorcycles	1.0%	5.2%	66.8%
1A4bii	Residential: Household and gardening (mobile)	0.9%	5.1%	71.9%
1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	0.8%	4.1%	76.1%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.6%	3.3%	79.4%
1A3biii	Road transport: Heavy duty vehicles and buses	0.5%	2.9%	82.3%

PM_{10} key sources

Table A2.6.a PM_{10} key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	4.8	17.9%	17.9%
3B4gi	Manure management - Laying hens	2.2	8.0%	26.0%
1A3bvi	Road transport: Automobile tyre and brake wear	1.5	5.7%	31.6%
2A6	Other mineral products (please specify in the IIR)	1.5	5.7%	37.3%
2A5b	Construction and demolition	1.42	5.3%	42.6%
2H2	Food and beverages industry	1.3	4.9%	47.5%
2G	Other product use (please specify in the IIR)	1.3	4.8%	52.2%
1A3bvii	Road transport: Automobile road abrasion	1.3	4.7%	56.9%
2C1	Iron and steel production	1.0	3.9%	60.8%
3B4gii	Manure management - Broilers	0.90	3.4%	64.2%
2A5c	Storage, handling and transport of mineral products	0.77	2.85%	67.00%
3B3	Manure management - Swine	0.76	2.8%	69.8%
3De	Cultivated crops	0.74	2.8%	72.6%
2B10a	Chemical industry: Other (please specify in the IIR)	0.68	2.5%	75.1%
2H3	Other industrial processes (please specify in the IIR)	0.62	2.3%	77.4%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.53	2.0%	79.4%
5E	Other waste (please specify in IIR)	0.47	1.8%	81.1%

Table A2.6.b PM_{10} key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
2C1	Iron and steel production	9.1	11.3%	11.3%
1A3biii	Road transport: Heavy duty vehicles and buses	7.7	9.5%	20.8%
1A4bi	Residential: Stationary	7.3	9.1%	29.9%
1A1b	Petroleum refining	6.4	7.9%	37.8%
1A3bi	Road transport: Passenger cars	5.5	6.9%	44.6%
2H2	Food and beverages industry	4.3	5.4%	50.0%
2B10a	Chemical industry: Other (please specify in the IIR)	4.1	5.1%	55.1%

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A3bii	Road transport: Light duty vehicles	3.8	4.7%	59.8%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	3.6	4.4%	64.2%
2H3	Other industrial processes (please specify in the IIR)	3.0	3.8%	68.0%
1A1a	Public electricity and heat production	2.2	2.7%	70.7%
2A6	Other mineral products (please specify in the IIR)	2.0	2.5%	73.2%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	1.7	2.1%	75.3%
3B3	Manure management - Swine	1.6	2.0%	77.3%
2A5c	Storage, handling and transport of mineral products	1.4	1.8%	79.1%
2G	Other product use (please specify in the IIR)	1.4	1.7%	80.8%

Table A2.6.c PM_{10} key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	2.9%	9.6%	9.6%
1A3biii	Road transport: Heavy duty vehicles and buses	2.8%	9.2%	18.8%
2C1	Iron and steel production	2.5%	8.0%	26.8%
1A1b	Petroleum refining	2.4%	7.9%	34.7%
3B4gi	Manure management - Laying hens	2.4%	7.7%	42.4%
1A3bi	Road transport: Passenger cars	2.0%	6.5%	48.9%
1A3bvi	Road transport: Automobile tyre and brake wear	1.4%	4.5%	53.5%
2A5b	Construction and demolition	1.4%	4.5%	57.9%
1A3bii	Road transport: Light duty vehicles	1.3%	4.3%	62.2%
1A3bvii	Road transport: Automobile road abrasion	1.2%	3.9%	66.1%
2A6	Other mineral products (please specify in the IIR)	1.0%	3.4%	69.5%
2G	Other product use (please specify in the IIR)	1.0%	3.3%	72.8%
2B10a	Chemical industry: Other (please specify in the IIR)	0.9%	2.8%	75.6%

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.8%	2.6%	78.2%
1A1a	Public electricity and heat production	0.7%	2.3%	80.5%

$PM_{2.5}$ key sources

Table A2.7.a $PM_{2.5}$ key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	4.5	31.7%	31.7%
2A6	Other mineral products (please specify in the IIR)	1.4	9.5%	41.2%
2G	Other product use (please specify in the IIR)	0.86	6.0%	47.2%
2C1	Iron and steel production	0.63	4.4%	51.6%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.51	3.6%	55.1%
2A5b	Construction and demolition	0.47	3.3%	58.4%
5E	Other waste (please specify in IIR)	0.43	3.0%	61.5%
2B10a	Chemical industry: Other (please specify in the IIR)	0.43	3.0%	64.5%
1A3di(ii)	International inland waterways	0.36	2.5%	67.0%
1A3dii	National navigation (shipping)	0.32	2.2%	69.2%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.29	2.1%	71.3%
1A3bvi	Road transport: Automobile tyre and brake wear	0.28	1.9%	73%
2H2	Food and beverages industry	0.27	1.9%	75.1%
1A3biii	Road transport: Heavy duty vehicles and buses	0.27	1.9%	77.0%
1A3bi	Road transport: Passenger cars	0.24	1.7%	78.7%
2H3	Other industrial processes (please specify in the IIR)	0.22	1.6%	80.3%
1A5b	Other. Mobile (including military, land based and recreational boats)	0.21	1.4%	81.7%

Table A2.7.b $PM_{2.5}$ key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A3biii	Road transport: Heavy duty vehicles and buses	7.7	13.4%	13.4%
1A4bi	Residential: Stationary	6.9	12.1%	25.5%
2C1	Iron and steel production	5.9	10.3%	35.8%
1A3bi	Road transport: Passenger cars	5.5	9.7%	45.4%
1A1b	Petroleum refining	4.9	8.5%	53.9%
1A3bii	Road transport: Light duty vehicles	3.8	6.6%	60.5%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	3.4	5.9%	66.5%
2B10a	Chemical industry: Other (please specify in the IIR)	2.6	4.5%	70.9%
1A1a	Public electricity and heat production	1.8	3.2%	74.1%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	1.6	2.8%	76.9%
2A6	Other mineral products (please specify in the IIR)	1.6	2.7%	79.6%
2G	Other product use (please specify in the IIR)	1.2	2.1%	81.7%

Table A2.7.c $PM_{2.5}$ key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	4.9%	20.4%	20.4%
1A3biii	Road transport: Heavy duty vehicles and buses	2.9%	11.9%	32.4%
1A3bi	Road transport: Passenger cars	2.0%	8.3%	40.7%
1A1b	Petroleum refining	1.9%	7.9%	48.6%
2A6	Other mineral products (please specify in the IIR)	1.7%	7.0%	55.6%
2C1	Iron and steel production	1.5%	6.2%	61.8%
1A3bii	Road transport: Light duty vehicles	1.3%	5.4%	67.3%
2G	Other product use (please specify in the IIR)	1.0%	4.1%	71.4%
2A5b	Construction and demolition	0.7%	2.9%	74.2%
5E	Other waste (please specify in IIR)	0.6%	2.6%	76.8%

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.6%	2.5%	79.3%
1A1a	Public electricity and heat production	0.6%	2.4%	81.6%

Black Carbon key sources

Table A2.8.a Black carbon key source categories identified by 2022 level assessment (emissions in Gg)

NFR14 Code	Long name	2022 Gg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	0.52	24.4%	24.4%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.25	11.8%	36.2%
1A3di(ii)	International inland waterways	0.17	7.7%	43.9%
1A3bii	Road transport: Light duty vehicles	0.15	7.1%	50.9%
1A3dii	National navigation (shipping)	0.14	6.7%	57.7%
1A3biii	Road transport: Heavy duty vehicles and buses	0.14	6.6%	64.2%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.14	6.3%	70.6%
5E	Other waste (please specify in IIR)	0.11	5.1%	75.6%
1A3bi	Road transport: Passenger cars	0.09	4.3%	80.0%

Table A2.8.b Black carbon key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A3biii	Road transport: Heavy duty vehicles and buses	3.9	27.2%	27.2%
1A3bi	Road transport: Passenger cars	2.5	17.8%	45.0%
1A3bii	Road transport: Light duty vehicles	2.1	14.5%	59.5%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	1.7	12.2%	71.7%
1A4bi	Residential: Stationary	0.88	6.2%	77.9%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.80	5.6%	83.5%

Table A2.8.c Black carbon key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3biii	Road transport: Heavy duty vehicles and buses	3.1%	22.8%	22.8%
1A4bi	Residential: Stationary	2.7%	20.1%	42.9%
1A3bi	Road transport: Passenger cars	2.0%	14.9%	57.8%
1A3bii	Road transport: Light duty vehicles	1.1%	8.2%	66.1%
1A3dii	National navigation (shipping)	0.9%	6.3%	72.3%
1A3di(ii)	International inland waterways	0.7%	5.3%	77.7%
5E	Other waste (please specify in IIR)	0.7%	4.9%	82.6%

Pb key sources

Table A2.9.a Pb key source categories identified by 2022 level assessment (emissions in Mg)

NFR14 Code	Long name	2022 Mg	Contribution	Cumulative contribution
1A3aii(i)	Domestic aviation LTO (civil)	0.79	17.6%	17.6%
2C1	Iron and steel production	0.75	16.5%	34.1%
1A3bi	Road transport: Passenger cars	0.51	11.4%	45.5%
2A3	Glass production	0.48	10.7%	56.2%
2C6	Zinc production	0.41	9.0%	65.2%
1A3bvi	Road transport: Automobile tyre and brake wear	0.32	7.2%	72.4%

NFR14 Code	Long name	2022 Mg	Contribution	Cumulative contribution
1A3c	Railways	0.24	5.4%	78%
2B10a	Chemical industry: Other (please specify in the IIR)	0.19	4.3%	82.1%

Table A2.9.b Pb key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Long name	1990 Mg	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	230.2	68.6%	68.6%
2C1	Iron and steel production	55.7	16.6%	85.2%

Table A2.9.c Pb key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	0.8%	45.2%	45.2%
1A3aii(i)	Domestic aviation LTO (civil)	0.2%	13.5%	58.7%
2C6	Zinc production	0.1%	7.1%	65.8%
2A3	Glass production	0.1%	6.7%	72.5%
1A3bvi	Road transport: Automobile tyre and brake wear	0.1%	5.6%	78.1%
1A3c	Railways	0.1%	4.2%	82.4%

Hg key sources

Table A2.10.a Hg key source categories identified by 2022 level assessment (emissions in Mg)

NFR14 Code	Long name	2022 Mg	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	0.12	24.5%	24.5%
2A6	Other mineral products (please specify in the IIR)	0.09	17.7%	42.2%
1A3bi	Road transport: Passenger cars	0.07	15.0%	57.3%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.06	11.3%	68.6%
2C1	Iron and steel production	0.05	11.1%	79.7%
1A4bi	Residential: Stationary	0.04	7.7%	87.4%

Table A2.10.b Hg key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Long name	1990 Mg	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	1.9	52.7%	52.7%
2B10a	Chemical industry: Other (please specify in the IIR)	0.70	19.1%	71.8%
2C1	Iron and steel production	0.39	10.6%	82.4%

Table A2.10.c Hg key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	3.7%	30.5%	30.5%
2A6	Other mineral products (please specify in the IIR)	2.3%	19.3%	49.8%
1A3bi	Road transport: Passenger cars	1.8%	15.0%	64.8%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	1.5%	12.2%	76.9%
1A4bi	Residential: Stationary	0.9%	7.3%	84.2%

Cd key sources

Table A2.11.a Cd key source categories identified by 2022 level assessment (emissions in Mg)

NFR14 Code	Long name	2022 Mg	Contribution	Cumulative contribution
2C6	Zinc production	0.32	40.4%	40.4%
1A3bi	Road transport: Passenger cars	0.11	13.4%	53.8%
2B10a	Chemical industry: Other (please specify in the IIR)	0.09	11.3%	65.1%
2G	Other product use (please specify in the IIR)	0.08	10.4%	75.5%
1A4bi	Residential: Stationary	0.06	7.4%	82.8%

Table A2.11.b Cd key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Long name	1990 Mg	Contribution	Cumulative contribution
2C6	Zinc production	1.8	43.7%	43.7%
1A1a	Public electricity and heat production	0.95	23.3%	67.0%
2C1	Iron and steel production	0.69	16.9%	83.9%

Table A2.11.c Cd key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	3.7%	23.5%	23.5%
2C1	Iron and steel production	2.7%	17.6%	41.1%
1A3bi	Road transport: Passenger cars	2.3%	14.6%	55.7%
2B10a	Chemical industry: Other (please specify in the IIR)	2.1%	13.2%	68.8%
1A4bi	Residential: Stationary	1.2%	7.9%	76.8%
2G	Other product use (please specify in the IIR)	1.1%	7.0%	83.7%

Dioxin key sources

Table A2.12.a Dioxin key source categories identified by 2022 level assessment (emissions in g I-Teq)

NFR14 Code	Long name	2022 g I-Teq	Contribution	Cumulative contribution
5E	Other waste (please specify in IIR)	16.3	53.9%	53.9%
1A4bi	Residential: Stationary	6.3	20.9%	74.8%
2D3i	Other solvent use	5.1	16.9%	91.7%

Table A2.12.b Dioxin key source categories identified by 1990 level assessment (emissions in g I-Teq)

NFR14 Code	Long name	1990 g I-Teq	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	582.6	78.2%	78.2%
1A4ai	Commercial/institutional: Stationary	100.0	13.4%	91.6%

Table A2.12.c Dioxin key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	3.0%	3.0%	41.1%
5E	Other waste (please specify in IIR)	2.1%	2.1%	29.0%
1A4bi	Residential: Stationary	0.8%	0.8%	11.0%

PAH key sources

Table A2.13.a PAH key source categories identified by 2022 level assessment (emissions in Mg)

NFR14 Code	Long name	2022 Mg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	3.2	67.8%	67.8%
5E	Other waste (please specify in IIR)	0.60	12.6%	80.4%

Table A2.13.b PAH key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Long name	1990 Mg	Contribution	Cumulative contribution
2C3	Aluminium production	6.9	33.2%	33.2%
1A4bi	Residential: Stationary	3.5	16.9%	50.1%
2D3d	Coating applications	2.4	11.6%	61.7%
2C1	Iron and steel production	1.6	7.9%	69.6%
2H3	Other industrial processes (please specify in the IIR)	1.4	6.6%	76.2%
1A3bi	Road transport: Passenger cars	0.82	3.9%	80.1%

Table A2.13.c PAH key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	11.7%	44.8%	44.8%
2C3	Aluminium production	7.6%	29.1%	73.9%
5E	Other waste (please specify in IIR)	2.4%	9.1%	83.0%

HCB key sources

Table A2.13.a HCB key source categories identified by 2022 level assessment (emissions in Mg)

NFR14 Code	Long name	2022 Mg	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	3.1	94.7%	94.7%

Table A2.13.b HCB key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Long name	1990 Mg	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	45.2	68.1%	68.1%
3Df	Use of pesticides	21.1	31.8%	99.9%

Table A2.13.c HCB key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
3Df	Use of pesticides	1.5%	50.0%	50.0%
1A1a	Public electricity and heat production	1.3%	43.2%	93.2%

PCB key sources

Table A2.13.a PCB key source categories identified by 2022 level assessment (emissions in Mg)

NFR14 Code	Long name	2022 Mg	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	0.08	48%	47.7%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.06	33.0%	80.7%

Table A2.13.b PCB key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Long name	1990 Mg	Contribution	Cumulative contribution
2C1	Iron and steel production	19.2	49.9%	49.9%
1A1a	Public electricity and heat production	12.1	31.5%	81.4%

Table A2.13.c PCB key source categories identified by 1990–2022 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
2C1	Iron and steel production	0.2%	48.7%	48.7%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.1%	21.5%	70.3%
1A1a	Public electricity and heat production	0.1%	15.9%	86.2%

Appendix 3 Key category analysis results; Approach 2

Approach 2 method

The Approach 2 method requires uncertainty estimates for the source categories to identify the key categories. The uncertainty estimates are applied as weights to each of the source categories and incorporated in the level and trend assessment before ordering the list of shares.
As recommended by the IPCC guidelines, the uncertainty estimates are based on an Approach 2 (Monte Carlo) uncertainty analysis. In section 1.5 the details of the Monte Carlo analyses are described.

SOx Keysources

Table A3.1 Key source ranking using IPCC Approach 2 ***level*** *assessment for 2022* ***SO_x*** *emissions*

GNFR	2022 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
B_Industry	**16.0**	**81.3%**	**29.5%**	**23.9%**	**75.3%**	**75.3%**
A_PublicPower	**2.4**	**12.4%**	**43.2%**	**5.4%**	**16.9%**	**92.2%**
C_OtherStationaryComb	0.5	2.6%	41.1%	1.1%	3.4%	95.6%
H_Aviation	0.2	1.2%	48.9%	0.6%	1.8%	97.4%
I_Offroad	0.2	1.2%	30.9%	0.4%	1.2%	98.6%
J_Waste	0.0	0.2%	88.8%	0.2%	0.6%	99.2%
E_Solvents	0.0	0.1%	115.5%	0.2%	0.5%	99.7%
F_RoadTransport	0.2	0.9%	11.6%	0.1%	0.3%	100.0%
G_Shipping	0.0	0.0%	17.0%	0.0%	0.0%	100.0%

Table A3.2 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2022* ***SO_x*** *emissions compared to the base year*

GNFR	1990 Gg	2022 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
H_Aviation	**0.1**	**0.2**	**1.2%**	**48.9%**	**2.5%**	**1.2%**	**39.7%**	**39.7%**
B_Industry	**120.0**	**16.0**	**81.3%**	**29.5%**	**2.7%**	**0.8%**	**26.3%**	**66.0%**
E_Solvents	**0.0**	**0.0**	**0.1%**	**115.5%**	**0.3%**	**0.3%**	**9.7%**	**75.7%**
J_Waste	**0.0**	**0.0**	**0.2%**	**88.8%**	**0.3%**	**0.3%**	**9.7%**	**85.4%**
A_PublicPower	48.5	2.4	12.4%	43.2%	0.6%	0.3%	8.6%	94.0%
C_OtherStationaryComb	2.2	0.5	2.6%	41.1%	0.4%	0.1%	4.8%	98.8%
I_Offroad	9.6	0.2	1.2%	30.9%	0.1%	0.0%	0.9%	99.7%
F_RoadTransport	15.3	0.2	0.9%	11.6%	0.1%	0.0%	0.3%	100.0%
G_Shipping	1.8	0.0	0.0%	17.0%	0.0%	0.0%	0.0%	100.0%

NO_x Keysources

Table A3.3 Key source ranking using IPCC Approach 2 ***level*** *assessment for 2022* ***NO_x*** *emissions*

GNFR	2022 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
L_AgriOther	**28.8**	**14.8%**	**123.4%**	**18.3%**	**45.7%**	**45.7%**
I_Offroad	**32.8**	**16.9%**	**45.0%**	**7.6%**	**19.0%**	**64.7%**
F_RoadTransport	**55.0**	**28.3%**	**12.7%**	**3.6%**	**9.0%**	**73.7%**
B_Industry	**26.8**	**13.8%**	**20.2%**	**2.8%**	**7.0%**	**80.6%**
A_PublicPower	12.8	6.6%	38.4%	2.5%	6.3%	86.9%
G_Shipping	18.7	9.6%	21.5%	2.1%	5.2%	92.1%
C_OtherStationaryComb	12.5	6.4%	27.8%	1.8%	4.4%	96.5%
K_AgriLivestock	3.6	1.8%	35.1%	0.6%	1.6%	98.1%
H_Aviation	3.3	1.7%	35.7%	0.6%	1.5%	99.6%
J_Waste	0.3	0.2%	84.2%	0.1%	0.3%	100.0%
E_Solvents	0.0	0.0%	83.5%	0.0%	0.0%	100.0%

Table A3.4 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2022* ***NO_x*** *emissions compared to the base year*

GNFR	1990 Gg	2022 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
L_AgriOther	**47.1**	**28.8**	**14.8%**	**123.4%**	**4.8%**	**6.0%**	**56.6%**	**56.6%**
H_Aviation	**1.2**	**3.3**	**1.7%**	**35.7%**	**4.0%**	**1.4%**	**13.5%**	**70.1%**
I_Offroad	**79.2**	**32.8**	**16.9%**	**45.0%**	**2.2%**	**1.0%**	**9.2%**	**79.3%**
G_Shipping	**28.8**	**18.7**	**9.6%**	**21.5%**	**3.5%**	**0.8%**	**7.2%**	**86.5%**
K_AgriLivestock	3.9	3.6	1.8%	35.1%	1.2%	0.4%	3.8%	90.3%
F_RoadTransport	291.2	55.0	28.3%	12.7%	2.7%	0.3%	3.3%	93.6%
A_PublicPower	82.9	12.8	6.6%	38.4%	0.9%	0.3%	3.1%	96.8%
J_Waste	0.2	0.3	0.2%	84.2%	0.3%	0.2%	2.1%	98.8%
B_Industry	105.7	26.8	13.8%	20.2%	0.4%	0.1%	0.9%	99.7%
C_OtherStationaryComb	41.0	12.5	6.4%	27.8%	0.1%	0.0%	0.3%	100.0%
E_Solvents	0.1	0.0	0.0%	83.5%	0.0%	0.0%	0.0%	100.0%

NH_3 Keysources

Table A3.5 Key source ranking using IPCC Approach 2 ***level*** *assessment for 2022* ***NH_3*** *emissions*

GNFR	2022 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
L_AgriOther	**52.5**	**43.3%**	**31.1%**	**13.5%**	**33.5%**	**33.5%**
K_AgriLivestock	**57.5**	**47.5%**	**26.7%**	**12.7%**	**31.5%**	**65.0%**
M_Other	**3.4**	**2.8%**	**261.0%**	**7.2%**	**18.0%**	**83.0%**
F_RoadTransport	3.4	2.8%	144.1%	4.1%	10.1%	93.2%
J_Waste	1.3	1.1%	71.0%	0.8%	1.9%	95.0%
B_Industry	1.3	1.0%	62.9%	0.7%	1.6%	96.7%
E_Solvents	1.1	0.9%	68.0%	0.6%	1.6%	98.3%
C_OtherStationaryComb	0.4	0.3%	139.6%	0.5%	1.2%	99.4%
I_Offroad	0.1	0.1%	119.1%	0.1%	0.4%	99.8%
A_PublicPower	0.1	0.1%	78.6%	0.1%	0.2%	100.0%
G_Shipping	0.0	0.0%	275.6%	0.0%	0.0%	100.0%
D_Fugitive	0.0	0.0%	98.7%	0.0%	0.0%	100.0%

Table A3.6 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2022* ***NH_3*** *emissions compared to the base year*

GNFR	1990 Gg	2022 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
F_RoadTransport	**0.9**	**3.4**	**2.8%**	**144.1%**	**9.5%**	**13.8%**	**42.1%**	**42.1%**
M_Other	**2.7**	**3.4**	**2.8%**	**261.0%**	**2.5%**	**6.6%**	**20.2%**	**62.4%**
J_Waste	**0.2**	**1.3**	**1.1%**	**71.0%**	**8.9%**	**6.3%**	**19.2%**	**81.6%**
K_AgriLivestock	99.7	57.5	47.5%	26.7%	10.8%	2.9%	8.8%	90.4%
L_AgriOther	236.9	52.5	43.3%	31.1%	5.5%	1.7%	5.3%	95.7%
I_Offroad	0.0	0.1	0.1%	119.1%	0.4%	0.5%	1.6%	97.3%
E_Solvents	1.1	1.1	0.9%	68.0%	0.6%	0.4%	1.3%	98.6%
C_OtherStationaryComb	0.3	0.4	0.3%	139.6%	0.3%	0.4%	1.2%	99.8%
B_Industry	4.7	1.3	1.0%	62.9%	0.1%	0.1%	0.2%	100.0%
G_Shipping	0.0	0.0	0.0%	275.6%	0.0%	0.0%	0.0%	100.0%
D_Fugitive	0.0	0.0	0.0%	98.7%	0.0%	0.0%	0.0%	100.0%

NMVOC Keysources

Table A3.7 Key source ranking using IPCC Approach 2 ***level*** *assessment for 2022* ***NMVOC*** *emissions*

GNFR	2022 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L*U	Cumulative Share L * U
K_AgriLivestock	**63.9**	**26.5%**	**173.8%**	**46.0%**	**50.7%**	**50.7%**
E_Solvents	**81.8**	**33.9%**	**32.9%**	**11.1%**	**12.3%**	**63.0%**
L_AgriOther	**23.3**	**9.6%**	**101.6%**	**9.8%**	**10.8%**	**73.9%**
B_Industry	**23.4**	**9.7%**	**82.8%**	**8.0%**	**8.9%**	**82.7%**
F_RoadTransport	20.8	8.6%	78.3%	6.7%	7.4%	90.2%
I_Offroad	6.8	2.8%	132.6%	3.7%	4.1%	94.3%
C_OtherStationaryComb	11.2	4.6%	54.6%	2.5%	2.8%	97.1%
D_Fugitive	6.9	2.9%	36.1%	1.0%	1.1%	98.2%
J_Waste	1.3	0.6%	158.3%	0.9%	1.0%	99.2%
G_Shipping	1.1	0.5%	67.0%	0.3%	0.3%	99.5%
H_Aviation	0.3	0.1%	187.5%	0.2%	0.3%	99.8%
A_PublicPower	0.6	0.3%	63.0%	0.2%	0.2%	100.0%

*Table A3.8 Key source ranking using IPCC Approach 2 **trend** assessment for 2022 **NMVOC** emissions compared to the base year*

GNFR	1990 Gg	2022 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend*uncertainty	Contribution to trend	Cumulative contribution
K_AgriLivestock	**41.7**	**63.9**	**26.5%**	**173.8%**	**30.0%**	**52.1%**	**89.3%**	**89.3%**
F_RoadTransport	**181.1**	**20.8**	**8.6%**	**78.3%**	**2.4%**	**1.9%**	**3.3%**	**92.6%**
E_Solvents	158.8	81.8	33.9%	32.9%	3.9%	1.3%	2.2%	94.8%
C_OtherStationaryComb	13.7	11.2	4.6%	54.6%	2.0%	1.1%	1.8%	96.7%
B_Industry	80.5	23.4	9.7%	82.8%	1.0%	0.9%	1.5%	98.1%
I_Offroad	21.4	6.8	2.8%	132.6%	0.2%	0.3%	0.5%	98.7%
D_Fugitive	47.4	6.9	2.9%	36.1%	0.7%	0.3%	0.4%	99.1%
L_AgriOther	55.8	23.3	9.6%	101.6%	0.2%	0.2%	0.3%	99.4%
J_Waste	2.4	1.3	0.6%	158.3%	0.1%	0.1%	0.2%	99.7%
H_Aviation	0.4	0.3	0.1%	187.5%	0.1%	0.1%	0.2%	99.8%
A_PublicPower	0.9	0.6	0.3%	63.0%	0.1%	0.1%	0.1%	99.9%
G_Shipping	2.0	1.1	0.5%	67.0%	0.1%	0.1%	0.1%	100.0%

PM_{10} Keysources

Table A3.9 Key source ranking using IPCC Approach 2 ***level*** *assessment for 2022* ***PM_{10}*** *emissions*

GNFR	2022 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
C_OtherStationaryComb	**5.1**	**18.9%**	**116.8%**	**22.1%**	**33.2%**	**33.2%**
B_Industry	**8.6**	**32.1%**	**45.5%**	**14.6%**	**21.9%**	**55.1%**
F_RoadTransport	**3.5**	**13.1%**	**53.4%**	**7.0%**	**10.5%**	**65.6%**
L_AgriOther	**1.1**	**4.0%**	**152.5%**	**6.0%**	**9.0%**	**74.7%**
E_Solvents	**1.3**	**4.8%**	**85.0%**	**4.1%**	**6.1%**	**80.8%**
K_AgriLivestock	4.3	16.1%	24.6%	4.0%	6.0%	86.7%
J_Waste	0.5	2.0%	178.3%	3.6%	5.5%	92.2%
I_Offroad	1.5	5.5%	65.1%	3.6%	5.4%	97.6%
G_Shipping	0.7	2.7%	40.9%	1.1%	1.6%	99.2%
A_PublicPower	0.2	0.6%	61.4%	0.4%	0.5%	99.8%
H_Aviation	0.0	0.1%	114.5%	0.2%	0.2%	100.0%
D_Fugitive	0.0	0.0%	100.6%	0.0%	0.0%	100.0%

Table A3.10 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2022* ***PM_{10}*** *emissions compared to the base year*

GNFR	1990 Gg	2022 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
C_OtherStationaryComb	**7.7**	**5.1**	**18.9%**	**116.8%**	**6.3%**	**7.3%**	**33.3%**	**33.3%**
L_AgriOther	**1.2**	**1.1**	**4.0%**	**152.5%**	**2.3%**	**3.4%**	**15.7%**	**49.0%**
K_AgriLivestock	**4.1**	**4.3**	**16.1%**	**24.6%**	**11.8%**	**2.9%**	**13.2%**	**62.2%**
J_Waste	**0.5**	**0.5**	**2.0%**	**178.3%**	**1.5%**	**2.7%**	**12.1%**	**74.3%**
E_Solvents	**1.4**	**1.3**	**4.8%**	**85.0%**	**2.7%**	**2.3%**	**10.6%**	**84.9%**
B_Industry	35.6	8.6	32.1%	45.5%	2.9%	1.3%	6.0%	91.0%
F_RoadTransport	19.3	3.5	13.1%	53.4%	2.0%	1.0%	4.8%	95.7%
I_Offroad	7.3	1.5	5.5%	65.1%	0.7%	0.5%	2.1%	97.8%
G_Shipping	1.3	0.7	2.7%	40.9%	0.6%	0.2%	1.1%	98.9%
H_Aviation	0.0	0.0	0.1%	114.5%	0.1%	0.1%	0.6%	99.6%
A_PublicPower	2.2	0.2	0.6%	61.4%	0.2%	0.1%	0.4%	100.0%
D_Fugitive	0.2	0.0	0.0%	100.6%	0.0%	0.0%	0.0%	100.0%

$PM_{2.5}$ Keysources

*Table A3.11 Key source ranking using IPCC Approach 2 **level** assessment for 2022 **$PM_{2.5}$** emissions*

GNFR	2022 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
C_OtherStationaryComb	**4.8**	**33.6%**	**117.0%**	**39.3%**	**45.3%**	**45.3%**
B_Industry	**4.2**	**29.1%**	**71.6%**	**20.8%**	**24.0%**	**69.3%**
I_Offroad	**1.4**	**9.8%**	**67.0%**	**6.6%**	**7.6%**	**76.8%**
J_Waste	**0.5**	**3.5%**	**176.9%**	**6.2%**	**7.2%**	**84.0%**
F_RoadTransport	1.2	8.6%	57.4%	4.9%	5.7%	89.7%
E_Solvents	0.9	6.0%	74.1%	4.5%	5.2%	94.8%
G_Shipping	0.7	4.7%	42.0%	2.0%	2.3%	97.1%
K_AgriLivestock	0.4	2.8%	35.2%	1.0%	1.2%	98.3%
L_AgriOther	0.1	0.8%	92.1%	0.7%	0.8%	99.1%
A_PublicPower	0.1	0.9%	60.7%	0.5%	0.6%	99.7%
H_Aviation	0.0	0.2%	145.7%	0.3%	0.3%	100.0%
D_Fugitive	0.0	0.0%	100.0%	0.0%	0.0%	100.0%

Table A3.12 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2022* ***$PM_{2.5}$*** *emissions compared to the base year*

GNFR	1990 Gg	2022 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
C_OtherStationaryComb	**7.2**	**4.8**	**33.6%**	**117.0%**	**13.9%**	**16.2%**	**59.1%**	**59.1%**
J_Waste	**0.5**	**0.5**	**3.5%**	**176.9%**	**2.8%**	**5.0%**	**18.2%**	**77.4%**
E_Solvents	**1.2**	**0.9**	**6.0%**	**74.1%**	**2.8%**	**2.1%**	**7.6%**	**85.0%**
B_Industry	20.2	4.2	29.1%	71.6%	1.3%	0.9%	3.3%	88.3%
F_RoadTransport	17.5	1.2	8.6%	57.4%	1.5%	0.9%	3.2%	91.5%
K_AgriLivestock	0.5	0.4	2.8%	35.2%	1.8%	0.6%	2.3%	93.8%
G_Shipping	1.2	0.7	4.7%	42.0%	1.4%	0.6%	2.1%	96.0%
L_AgriOther	0.1	0.1	0.8%	92.1%	0.5%	0.5%	1.8%	97.7%
I_Offroad	6.9	1.4	9.8%	67.0%	0.5%	0.3%	1.1%	98.8%
H_Aviation	0.0	0.0	0.2%	145.7%	0.2%	0.2%	0.8%	99.6%
A_PublicPower	1.8	0.1	0.9%	60.7%	0.2%	0.1%	0.4%	100.0%
D_Fugitive	0.1	0.0	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%

Appendix 4 NECD-review 2023; Status on implementation of recommendations

2023 NECD-Inventory review

This appendix contains 5 tables:

- Table A4.1 provides an overview of the status of implementation of recommendations from the NECD-2023 inventory review;
- Table A4.2 provides an overview of the status of implementation of recommendations from the EMEP-2023 inventory review
- Table A4.3 provides an overview of the status of implementation of recommendations from the NECD-2021 LPS review;
- Table A4.4 provides an overview of the status of implementation of recommendations from the NECD-2021 Gridded data review;
- Table A4.5 provides an overview of the status of implementation of recommendations from the NECD-2023 Projections review.

*Overall assessment by the **NECD review** team of the quality of the 2023 inventory submission*

1. The technical expert review team considers the inventory submission to be of very good quality in terms of completeness and accuracy. The IIR describes the methods transparently.
    - To improve the quality of these submissions, the technical expert review team suggests that the Netherlands:
    - Work to further improve on the already excellent reporting by taking into account the improvements suggested by the TERT during the 2022 review, e.g. NL-5B1-2022-0002;
2. To improve the quality of these submissions, the TERT suggests that The Netherlands:
    - Implement previously raised recommendations (e.g. NL-2A5a-2022-0002, NL-2D3c-2022-0001, NL-2B10a-2022-0001, NL-2B-2022-0001, NL-1B1a-2022-0001, NL-1A2a-2022-0002);
    - estimate and report $PM_{2.5}$ and PM_{10} emissions in the industry and solvent sectors (e.g. NL-2C5-2023-0001, NL-2C7a-2023-0001);
3. improve completeness by calculating missing emissions for sources even if the emissions are expected to be small or are memo items, e.g., recommendation NL-2D3c-2022-0001, NL-1A3aii(ii)-2023-0001;
    - further improve the transparency of the IIR by providing detailed information on assumptions and methodologies e.g., recommendation NL-1A3c-2023-0001, NL-1A3dii-2023-0001, NL-3Da3-2023-0001, NL-5A-2023-0001, NL-5D-2023-0001.

4. The technical expert review team considers that it received responses from the Netherlands that were sufficient in order to undertake the NECD Inventory Review 2022.

*Table A4.1 Overview of the implementation of actions from the **2023 NECD inventory review***

EMRT-NECD Observation	**Recommendation**	**Reference to IIR or improvement status**
NL-1A2a-2022-0002	For category 1A2a Stationary combustion in manufacturing industries and construction: Iron and steel, pollutant SO_x, years 2005 and 2020, the TERT noted that there is a lack of transparency regarding reporting of fuel consumption data and large variations in the SO_x implied emission factors. This was raised during the 2022 NECD inventory review. The TERT notes that the issue does not relate to an over- or under-estimate of emissions. The TERT notes that the IIR states that the issue has been included in the list of improvements. **The TERT reiterates the recommendation that the Netherlands include in the NFR tables the complete fuel consumption, and in the IIR explain the methodology and any assumptions made to tackle the allocation differences between NFR/AERs and CRF/energy statistics in its 2024 submission.**	The improvement of the activity data has not yet been prioritised. This issue is not yet resolved.

EMRT-NECD Observation	**Recommendation**	**Reference to IIR or improvement status**
NL-1A3aii(ii)-2023-0001	For categories 1A3ai(ii) International aviation cruise (civil), 1A3aii(ii) Domestic aviation cruise (civil), pollutants SO_x, NO_X, NH_3, NMVOC, $PM_{2.5}$, PM_{10}, CO and all years, the emissions are reported as 'NE' (not estimated). Although emissions of memo items are not included in the national total, these should be reported so as to improve the completeness of the inventory and comparability among Member States. In response to a question raised during the review, the Netherlands answered that this issue will be prioritized in the 2024 submission. Specifically, mid-2022 it was explored exactly what should be reported and what country-internal questions needed to be answered (in connection with the Dutch air quality modelling to avoid double counting, for example, and possible policy questions related to potential emission reductions in this sector). The work has progressed considerably, and it is expected that the Climbing/Cruising/Descending (CCD) emissions will be reported (at least for the recent years) in the next submission. **The TERT welcomes this plan and recommends that this observation be checked again in the 2024 review regarding its status of implementation.**	See NFR and IIR paragraph 4.2
NL-1A3bii-2023-0002	For 1A3bii Road transport: Light duty vehicles, NO_X, year 2021, the TERT notes that the implied emission factor (IEF), i.e., pollutant/activity, is outside of the 95% confidence interval when compared to the other Member States and the sector is within the top 10 highest emitting sectors for NO_x when emissions are totalled across all EU Member States. Specifically, the IEF (0.000219 Gg NO_X per TJ of liquid fuel activity data) is lower than for all other Member States, which range from 0.000246 to 0.000364. Appendix 5 of the 2023 IIR contains the relevant methodological details for road transport emission calculations. In response to a question raised during the review, the Netherlands answered that the basis for their emission factors is a Dutch report and provided the relevant file. **The TERT recommends that this reference be added to the 2024 IIR, since it could not be found either in the IIR or in Appendix 5.**	The basis for our emission factors is this report: "*Dutch In-service Emissions Measurement Programme for Light-Duty Vehicles 2021 and status of in-vehicle NO_x monitoring | TNO Publications*" It is our impression that the HBEFA and COPERT emission factors are outdated for NO_x emissions of light duty vehicles.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-1A3biv-2023-0001	For 1A3biv Road transport: Mopeds & motorcycles, years 1995-1998, 2006, 2010-2012, 2018, 2019, and 1A3biii Road transport: Heavy duty vehicles and buses, year 2004, the TERT notes that the $PM_{2.5}$ estimate is higher than PM_{10}, which is not expected. In response to a question raised during the review, the Netherlands answered that this issue has already been mentioned in the 2023 IIR (p. 116, para. 4.3.9). Specifically, this mistake was identified after submission of the 2023 NFR tables and it was not possible to correct it in the short term. Therefore, this issue is on the list of improvements for the NFR 2024. The TERT notes that this issue is below the threshold of significance and all but 2019 are years not in the scope of the 2023 review. **Therefore, the TERT recommends that the Netherlands correct this mistake in the 2024 submission in order to improve the accuracy of the values.**	The mistake as mentioned in the IIR 2023 submission was corrected in the 2024 submission according to the planned list of improvements.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-1A3bvi-2023-0001	For 1A3bvi Road transport: Automobile tyre and brake wear, $PM_{2.5}$, PM_{10}, all years, the TERT notes that the ratio $PM_{10}/PM_{2.5}$ is significantly higher than for most other Member States and the EU27 average (5.5 vs. 1.9). Similar issue exists for 1A3bvii Road transport: Automobile road abrasion, i.e., the ratio of the Netherlands is 6.7 vs. 1.9 in other countries. In response to a question raised during the review, the Netherlands answered that this issue will be checked in the Dutch PRTR-Task Force for Transportation, which is responsible for calculating these emissions. The details of the calculation method can be found on p.108 of the 2023 IIR, and in paragraph 3.2.5 and Tables 3.3, 3.13 of Appendix 5 Transport. The TERT notes that, according to the 2019 EMEP/EEA Guidebook, the ratio should be 1.9, possibly ranging from 1.5 to 2.5, depending on the Tier method, tyre or brake wear. In addition, the TERT acknowledges that the 2019 EMEP/EEA Guidebook recognizes that the extensive use of studded tyres during the winter results in considerably higher wear of the road surface and the resulting PM concentrations. However, the Guidebook does not provide specific emission factors to be used for road surface wear associated with the use of studded tyres, due to the lack of appropriate experimental data. Based on the above, the TERT cannot conclude whether a revised estimate is needed, since the Netherlands uses country specific emission factors derived from recent country specific literature. **Hence, the TERT recommends that this issue be addressed within the Dutch PRTR-Task Force for Transportation, as suggested by the Netherlands, and be clarified in the next 2024 IIR. Specifically, it should be clearly stated in the relevant chapter of the IIR that the emission factors are derived from recent country specific literature and, hence, the $PM_{10}/PM_{2.5}$ ratio may present differences compared to the 2019 EMEP/EEA Guidebook and other Member States.**	Due to limited resources the issue was not solved in the 2024 submission, but is added to the list of improvements for the IIR 2025 submission.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-1A3c-2023-0001	For 1A3c Railways, NH_3, all years, the TERT notes that the emission factors are derived based on an outdated version of the EMEP/EEA Guidebook and COPERT III, Ntziachristos, L., Z. Samaras, 2000 (p. 119, 243 of the 2023 IIR, p. 50, 91 of Appendix 5 Transport). Since 2000, many updated versions of COPERT have been released which update NH_3 (and other pollutant) calculations (https://www.emisia.com/utilities/copert/versions/). In addition, the TERT notes that COPERT is a tool for road transport, not rail, and acknowledges that the values used by the Netherlands are in general consistent with the 2019 EMEP/EEA Guidebook. In response to a question raised during the review, the Netherlands clarified that current Dutch values are legacy values which are checked against recent country specific actual measurements and relevant literature and there is a plan for a major update of the Dutch rail emissions. **From the answers provided by the Netherlands, the TERT concludes that this is an issue of transparency (similar to NL-1A3dii-2023-0001) and the relevant source description in the IIR needs to be updated, i.e., better describe the source of emission factors and the acronym 'COPERT' should no longer be used. Therefore, the TERT recommends that this observation is addressed in the 2024 IIR submission (i.e. update of source description and avoid the acronym COPERT if the tool is not actually used).**	See paragraph 4.4

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-1A3dii-2023-0001	For 1A3dii National navigation (shipping), NH_3, all years, the TERT notes that the emission factors are derived based on an outdated version of the EMEP/EEA Guidebook and COPERT III, Ntziachristos, L., Z. Samaras, 2000 (p.69, 92 of Appendix 5 Transport of the 2023 IIR). Since 2000, many updated versions of COPERT have been released which update NH_3 (and other pollutant) calculations (https://www.emisia.com/utilities/copert/versions/). In addition, this issue is similar to NL-1A3c-2023-0001 and the TERT acknowledges that the Guidebook provides NH_3 emission factors only for recreational crafts and not for other types of navigation. The COPERT tool is for road transport, not navigation. The value used by the Netherlands (0.010 g/kg fuel) is close to the value of the 2019 EMEP/EEA Guidebook (updated Dec. 2021) for diesel recreational boats (0.007 g/kg fuel, 1.A.3.d, Table 3-8). In response to a question raised during the review, the Netherlands clarified that the emission factors come from expert judgement based on literature, as well as own measurements. **Furthermore, the Netherlands agreed that this observation is an issue of transparency and the relevant source description in the IIR needs to be updated, i.e., better describe the source of emission factors and the acronym 'COPERT' should no longer be used. The TERT recommends that this observation is addressed in the 2024 IIR submission (i.e. update of source description and avoid the acronym COPERT if the tool is not actually used).**	See paragraph 4.5

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-1B1a-2022-0001	For category 1B1a, pollutants $PM_{2.5}$ and PM_{10}, years 1990-2020, the TERT noted that there is a lack of transparency regarding reporting of PM emissions from storage and handling of coal. This was raised during the 2022 NECD inventory review. The TERT notes that the issue is below the threshold of significance for a technical correction. The TERT notes that the IIR states that the issue has been included in the list of improvements. **The TERT reiterates the recommendation that the Netherlands investigate further if emissions from storage and handling of coal are included in the AERs for the relevant companies, and include estimates for companies that do not include the emissions in their AERs, and include a description in the IIR in its 2024 submission.**	The PM emissions from storage and handling of coal need further investigation. This issue is not yet resolved.
NL-2A5a-2023-0001	For category 2A5a Quarrying and mining of minerals other than coal, pollutant NH_3 and years 1990-2021, the TERT notes that there is a lack of transparency regarding the reporting of emissions as 'NE' (Not Estimated). The TERT would not expect emissions from this pollutant and NFR category. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, the Netherlands acknowledged that the correct notation key is 'NA' (Not Applicable) and stated that the notation key will be corrected in the 2024 submission. **The TERT recommends that the Netherlands report NH_3 emissions from 2A5a category as 'NA' in the 2024 submission.**	Notation key has been changed from 'NE' (Not Estimated) to 'NA' (Not Applicable) for multiple pollutants in category 2A5a.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-2A5a-2022-0002	For category 2A5a Quarrying and mining of minerals other than coal, pollutants $PM_{2.5}$ and PM_{10} (and all other pollutants), years 1990-2021, the TERT notes that there is a lack of transparency regarding the use of the notation key 'IE' (Included Elsewhere) and why the emissions cannot be reported under 2A5a category. This was raised during the 2022 NECD inventory review. The IIR (page 145) indicates that these emissions are reported in 2A6 Other mineral products. During the previous year’s review, the Netherlands replied that emissions from companies that undertake these activities are currently assigned to 1A2gvii, 2A1, and 2H3, which is different information compared to what is reported in the IIR. The TERT notes that the use of the notation key 'IE' is unlikely to be appropriate for all pollutants. During the previous year’s review, the Netherlands also identified that emissions from a further small-scale operation are not included in the inventory. In the 2023 IIR (page 292), the Netherlands reported that the previous recommendation NL-2A5a-2022-0002, which reflects the above issues, has not yet been implemented. The TERT considers that the above observations do not relate to an over- or under-estimate of emissions, but it is a matter of transparency and comparability of the inventory. In response to a question raised during the review, the Netherlands replied that they will address these issues in 2023 and report on the progress in the 2024 submission. **The TERT recommends that the Netherlands continue to implement its proposed improvement plan for this category and report on its progress in the next submission.**	This is work in progress, see section 5.2.6.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-2A5b-2023-0001	For category 2A5b Construction and demolition for the pollutants NO_x, NMVOC, SO_x, NH_3 and years 1990-2021, the TERT notes that there is a lack of transparency regarding the reporting of emissions as 'IE' (Included Elsewhere). The TERT would not expect emissions or the notation key 'IE' for this pollutant and NFR category. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, the Netherlands acknowledged that the correct notation key is 'NA' (Not Applicable) and further stated that the notation key will be corrected in the 2024 submission. **The TERT recommends that the Netherlands report NO_x, NMVOC, SO_x and NH_3 emissions from 2A5b Construction and demolition in the 2024 submission.**	Notation key has been changed from 'IE' (Included Elsewhere) to 'NA' (Not Applicable).
NL-2A5c-2023-0001	For category 2A5c Storage, handling and transport of mineral products for the pollutants NO_x, SO_x, NH_3 and years 1990-2021, the TERT notes that there is a lack of transparency regarding the reporting of emissions as 'IE' (Included Elsewhere). The TERT would not expect emissions or the notation key 'IE' for this pollutant and NFR category, as this category is associated mainly with particulate emissions. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, the Netherlands acknowledged that the correct notation key is 'NA' (Not Applicable) and stated that the notation key will be corrected in the 2024 submission. **The TERT recommends that the Netherlands report NO_x, SO_x and NH_3 emissions from 2A5c Storage, handling and transport of mineral products as 'NA' in the 2024 submission.**	Notation key has been changed from 'IE' (Included Elsewhere) to 'NA' (Not Applicable).

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-2A5c-2023-0002	For category 2A5c Storage, handling and transport of mineral products for the pollutant NMVOC and years 1990-2021, the TERT would not expect emissions from this pollutant and NFR category, as this category is associated mainly with particulate emissions. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, the Netherlands clarified that while addressing recommendations NL-2A5b-2022-0002 and NL-2A5c-2022-0002, which pertained to the reallocation of PM emissions from storage, handling, and transport from categories 2H3 to 2A5c, they mistakenly reallocated NMVOC emissions as well. **The TERT recommends that the Netherlands allocate NMVOC emissions associated with storage to the category 2H3 in the next submission.**	NMVOC emissions have been reallocated to 2H3 instead of 2A5c.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-2B-2022-0001	For category 2B chemical industry and pollutants SO_x, NO_x, NH_3, NMVOC, $PM_{2.5}$, PM_{10} (1990-2021), the TERT notes that there is a lack of transparency as all emissions are assigned to NFR 2B10a. This was raised during the 2022 NECD inventory review. The TERT noted that there is a lack of transparency regarding why emissions cannot be assigned to appropriate NFR subcategories within 2B, which impacts comparability with other inventories. The TERT acknowledges that emission estimates are based on a Tier 3 methodology and this observation does not relate to an over- or under-estimate of emissions. In response to a question raised during the 2022 NECD review, the Netherlands explained that emissions cover a large chemical site that produces many different chemical products but only total emissions of this chemical site are reported so emissions have not been disaggregated to the different NFR categories. However, the Netherlands has indicated that for other chemical sites it may be possible to disaggregate emissions into the different NFR categories. On page 294 of the IIR, the Netherlands reported that this improvement task still has to be developed. In response to a question raised during the review, the Netherlands replied that it plans to improve the allocation of emissions to the appropriate NFR category for 2024 or at the latest in the 2025 submission. **The TERT recommends that the Netherlands continue with the implementation of its improvement plan to improve the allocation of emissions to the appropriate NFR categories and report on the progress in the next IIR.**	Work in progress, see section 5.3.6.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-2B10a-2022-0001	For category 2B10a Chemical industry: Other (please specify in the IIR), pollutant SO_x and years 2005 and 2019-2021, the TERT notes that there is a lack of transparency regarding the reporting of SO_x emissions in the NFR Tables as 'NA' (Not Applicable) and which industries are included in the NFR 2B10a. This was raised during the 2022 NECD inventory review. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the previous year's review, the Netherlands explained that 2B10a covers all chemical manufacturing activities of 2B sector and provided commentary on the different manufacturing operations. Netherlands further explained that since it is difficult to distinguish between combustion and process emissions, SO_x emissions are allocated to NFR 1A2c. The Netherlands plans to use the notation key 'IE' in future submissions. The TERT notes that in the 2023 submission the notation key 'NA' is still used instead of the notation key 'IE'. In addition, in the IIR (page 295) it is erroneously reported that the "Notation keys have been replaced by zeros". In response to a question raised during the review, the Netherlands explained that they change the notation key from 'NA' to 'IE' and provide in the IIR a summary of the different manufacturing operations included under category 2B10a. **The TERT recommends that Netherlands provide a summary of the various chemical manufacturing facilities in the IIR of the next submission and apply more appropriate notation keys to report SO_x emissions.**	For SO_x in 2B10a, the notation key has been changed from 'NA' to 'IE'. For a start of the summary, see section 5.3.6.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-2C5-2023-0001	For 2C5 Lead production, pollutants $PM_{2.5}$ and PM_{10} and years 1999, 2000, 2010, 2011, 2020 and 2021, the TERT notes that the emissions are reported as 'NA' (Not Applicable), although TSP emissions were reported for the same years. In response to a question raised during the review, the Netherlands explained that there are two lead producers in the Netherlands which did not report PMs in their Annual Emission Reporting (AER) for the stated years because the emission levels were below the E-PRTR reporting threshold. The TERT notes that the issue is below the threshold of significance for a technical correction for all years (mandatory: 2020 and 2021 and non-mandatory: 1999, 2000, 2010 and 2011). **The TERT recommends that the Netherlands estimate and report $PM_{2.5}$ and PM_{10} emissions for the aforementioned missing years in the next submission, based on reported TSP emissions and the corresponding PM/TSP ratios from adjacent years.**	Work in progress. For now $PM_{2.5}$ and PM_{10} emissions reported as 'NE' (Not Estimated). A plan for estimating emissions will be created, as described in section 5.4.6.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-2C7a-2023-0001	For 2C7a Copper production and pollutants and years: SO_x (2005, 2019-2021), $PM_{2.5}$ (2019-2021), and PM_{10} (2019-2021), the TERT notes that the emissions were reported as 'NA' (Not Applicable) although emissions of other pollutants have been reported for this category. In response to a question raised during the review, the Netherlands explained that there is one copper-producing operator in the Netherlands, which does not report SO_x and PM emissions in its Annual Emission Reporting because they are below the EPRTR reporting threshold. As such, the process emissions are assumed to be very low. In addition, the Netherlands acknowledges that the correct notation key should be 'NE' (Not Estimated). The TERT agrees that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands report these emissions as 'NE' if they are not included in the national inventory. In addition, the TERT recommends that the Netherlands include in its improvement plan a task to estimate these emissions. Possible ways to estimate these emissions are either by contacting the plant and obtaining plant-specific emission data or by applying a Tier 1 or Tier 2 method from the 2019 EMEP/EEA Guidebook.**	Work in progress. For now, $PM_{2.5}$ and PM_{10} emissions reported as 'NE' (Not Estimated). A plan for estimating emissions will be created, as described in section 5.4.6.
NL-2D3c-2022-0001	For category 2D3c Asphalt Roofing, NMVOC, PM_{10}, $PM_{2.5}$, 1990-2021, the TERT notes that the notation key 'NE' (not estimated) is used whilst a Tier 1 method is available in the 2019 EMEP/EEA Guidebook. In response to a question raised during the review, the Netherlands explained that emissions were not reported because no activity data were available. This was raised during the 2022 NECD inventory review. The TERT notes that the issue is below the threshold of significance for a technical correction. The TERT notes that the IIR states that the issue has been included in the list of improvements and that the recommendation will be addressed in the next submission (page 296 of the IIR). **The TERT reiterates the recommendation that the Netherlands include these estimates in the next NFR and IIR submission.**	Still no activity data available, see section 5.5.1.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-3B4f-2023-0001	For category 3B4f Manure management - Mules and asses, SO_x for 1990-2021 the TERT noted that the notation key 'Included Elsewhere' (IE) has been reported. The TERT would not expect emissions from this pollutant and NFR category. In response to a question raised during the review, the Netherlands explained that the notation key will be changed in the next NFR submission. The TERT notes that this issue does not relate to an over- or under-estimate of emissions. **The TERT recommends that in the next NFR submission the Netherlands report SO_2 emissions from 3B4f Manure management - Mules and asses using the notation key 'NA' (Not applicable).**	The notation key has been changed to NA.
NL-3Da2b-2023-0001	For category 3Da2b Sewage sludge applied to soils, NH_3 and all years, the TERT noted that no emissions are reported in the 2023 NFR submission. NH_3 emissions from 3Da2b Sewage sludge applied to soils were reported in the 2022 submission, but were reported as 'Not Estimated' (NE) in the 2023 submission. This is despite the IIR (table 6.10, p. 176) clearly presenting an NH_3 IEF for application of sewage sludge. In response to a question raised during the review, the Netherlands explained that a mistake has been made in the Netherlands' database, such that the NH_3 emissions from the application of sewage sludge applied to soils has been attributed to 3Da2a Animal manure applied to soils instead of 3Da2b. The TERT notes that this issue does not relate to an over- or under-estimate of emissions. **The TERT recommends that in the next submission the Netherlands correct this misallocation of NH_3 emissions.**	The allocation has been corrected.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-3Da3-2023-0001	For category 3Da3 Urine and dung deposited by grazing animals, NH_3 and NO_X for all years, the TERT noted that there is a lack of transparency in the IIR concerning recalculations made in the 2023 submission compared with the 2022 submission. For 2020, reported emissions were 53% and 34% lower for NH_3 and NO_X, respectively, in the 2023 submission compared with the 2022 submission. The TERT was not able to find an explanation for this recalculation in the IIR. In response to a question raised during the review, the Netherlands explained that the recalculation was caused by a reallocation of emissions caused by livestock grazing in nature areas, animal manure applied to nature areas and the application of manure by non-farmers to 3Da2a animal manure applied to soils instead of Urine and dung deposited by grazing animals. The TERT notes that this issue does not relate to an under-estimate of emissions. **The TERT recommends that in future submissions the Netherlands ensure that an explanation is included in the IIR for all significant recalculations, including where this relates to a reallocation of emissions between source categories.**	See chapter 6

EMRT-NECD Observation	**Recommendation**	**Reference to IIR or improvement status**
NL-3Dc-2023-0001	For category 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products, pollutant NMVOC and all years, the TERT noted that there is a lack of transparency regarding why NMVOC emissions from silage stores are allocated to this category. The TERT notes that other Member States who are using the Tier 2 method to estimate NMVOC emission from livestock tend to report emissions from silage stores under 3B Manure management. In response to a question raised during the review, the Netherlands explained that emissions from silage storage are reported under 3Dc because they are not connected to manure or housing. By using two different categories, the Netherlands consider the reporting to be more transparent. The TERT recognises that the 2019 EMEP/EEA Guidebook provides no specific instructions regarding to which NFR category NMVOC emissions from silage stores should be reported and accepts the rationale for allocation to 3Dc. The TERT notes that this issue does not relate to an over- or under-estimate of emissions. **The TERT recommends that in order to improve transparency the Netherlands include this explanation for allocating NMVOC emissions from silage stores to 3Dc Farm-level agricultural operations in the 2024 IIR.**	The allocation of silage storage has been added to paragraph 6.3.1.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-3Dc-2023-0002	For category 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products, $PM_{2.5}$ and PM_{10}, the TERT noted that it is not clear from the IIR (Appendix 5) whether the correct emission factors have been used. Table 14.2 on p. 154 shows emission factors but these seem to differ considerably from those presented in the 2019 EMEP/EEA Guidebook for all crops. In response to a question raised during the review, the Netherlands explained that the EFs presented are from the 2016 version of the EMEP/EEA Guidebook (Table 3.5), and that they will use the new EF from the 2019 EMEP/EEA Guidebook in the next submission. The TERT notes that there were significant upward revisions to the PM_{10} EFs for the harvesting process in the 2019 EMEP/EEA Guidebook, for example for wheat in wet climates the EF for harvesting in the 2016 version was 0.49 kg PM_{10} per hectare. The TERT notes that this relates to an under-estimate of emissions, but that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands use the emission factors from the 2019 EMEP/EEA Guidebook, Chapter 3D, Table 3.5, for PM_{10} emissions from 3Dc in its next submission.**	The 2019 EF have been applied to the entire timeseries, see paragraph 6.3.7.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-3Df-2023-0001	For category 3Df Use of pesticides for NMVOC and years 2005 and 2010-2021, the TERT noted that there is a lack of transparency in the IIR concerning the reporting of NMVOC emissions from this category. The TERT notes that there is no method for estimating NMVOC emissions from pesticide application in the 2019 EMEP/EEA Guidebook, and the TERT cannot find a description of a country-specific method in the IIR (page 172 states that NMVOC emissions are allocated to category 3Da2a, 3Da3, 3Dc and 3De). Therefore, the TERT would not expect emissions of NMVOC to be reported under 3Df Use of pesticides. In response to a question raised during the review, the Netherlands explained that emissions from individual pesticides in the agriculture sector are calculated using statistics on sales. Emissions are calculated with the NMI4-model. The factsheet Bestrijdingsmiddelengebruik bij landbouwkundige toepassingen (https://www.emissieregistratie.nl/documenten/bestrijdingsmiddelengebruik-bij-landbouwkundige-toepassingen) explains the methodology and activity data. The individual pesticides are then reported to the PRTR, which sums the pesticides based on volatility (from the NMVOC scope) to total NMVOC for this source. This is done automatically in the Netherlands' database using the relations from the so-called ER-rekenfactoren. Additionally, the information was provided that in the Netherlands mineral oil is also often used as crop protection agents and thus added as a pesticide to the NMVOC total. The TERT notes that this issue does not relate to an over- or under-estimate of emissions. **The TERT recommends that in the 2024 IIR the Netherlands include an explanation of the country-specific method to calculate NMVOC emissions from use of pesticides and also update the text on page 172 to include 3Df Use of pesticides in the list of categories for which NMVOC emissions are estimated.**	An explanation has been included in paragraph 6.3.4. 3df has been included in the list of categories in paragraph 6.3.1.

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-5A-2023-0001	For 5A Biological treatment of waste - Solid waste disposal on land, $PM_{2.5}$ and PM_{10}, all years, the TERT notes that there is a lack of transparency regarding the activity data used for calculation, in particular whether mineral waste is included. In response to a question raised during the review, the Netherlands indicated that the total amount of waste landfilled, as also used for GHG reporting, is considered for the calculation of PM. **The TERT recommends that the Netherlands investigate whether the 'Annual waste at the SWDS' - as covered in the CRF GHG reporting on 5A Biological treatment of waste - includes the total waste landfilled or only landfilled wastes with organic carbon (as relevant for GHG reporting), and include information on this result in the next submission.**	In paragraph 7.1 is explained that the amount of annual waste to SWDS includes also the mineral fraction.
NL-5C2-2023-0002	For 5C2 Open burning of waste, SO_x, NO_x, NH_3, NMVOC, $PM_{2.5}$ and PM_{10} and all years, the TERT notes that there is a lack of transparency regarding relevance of open burning of agricultural waste, i.e. orchard crops and forest residues, in the Netherlands. This was raised during the 2022 NECD inventory review. In the IIR 2023, text was added, section 7.5.2, explaining that a ban on open waste burning was imposed and that these emission sources are thus considered not to occur in the Netherlands. In response to a question raised during the review, the Netherlands provided a more comprehensive explanation about the ban on open burning (at the beginning of the 1980s). **The TERT recommends that the Netherlands include this explanation in its next IIR 2024.**	The complete detailed explanation is added to paragraph 7.5

EMRT-NECD Observation	Recommendation	Reference to IIR or improvement status
NL-5D-2023-0001	For 5D Wastewater handling, NMVOC, all years, the TERT notes that there is a lack of transparency regarding activity data used for calculation. Neither the IIR (section 7.6) nor the NFR tables provide data on the wastewater volume considered. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, the Netherlands referred to Appendix 5 to the IIR, where in section 3.4.3.4.2 a link is included to Statline to retrieve data on domestic wastewater volumes. Regarding industrial wastewater Appendix 5 explains that volumes of waste water treatment are compiled from a database of Statistics Netherlands for the years 1993-2016 as well as from data from the AER's on volumes of waste water; and that data for 2017-2021 are a copy of the 2016 values. **To increase transparency of reporting the TERT recommends that the Netherlands include activity data, in particular of industrial wastewater volumes, including a reference and information on any gap filling, in its next IIR and NFR.**	See paragraph 7.6

Table A4.2 Overview of the implementation of actions from the ***2022 EMEP inventory review***

EMEP Observation	Recommendation	Reference to IIR or improvement status
1A4bi-EMEP2022-001	The activity data is based on fuel consumption data, taken from Statistics Netherlands. The Party describes in its IIR (p70ff.) that the fuel mostly used in this category is natural gas; the use of wood in stoves and fireplaces for heating is almost negligible compared to the amount of natural gas used. **The ERT notes that the activity data is not described transparently enough in the Informative Inventory Report and recommends the Party to provide more detailed information on activity data used to calculate emissions from 1A4bi in the next IIR submission.**	A table with the wood combustion per appliance is included in chapter 3 of the IIR. The methodology is described in Visschedijk et al. (2024), which is part of this submission.
1A4bi-EMEP2022-002	The Netherlands have stratified the total fuel consumption for each fuel type into different appliance types e.g. boilers and stoves, in a consistent and complete manner. **This is, however, not sufficiently documented in the IIR and the ERT recommend that a clear documentation of the issue is included in the next IIR submission.**	A table with the wood combustion per appliance is included in chapter 3 of the IIR. The methodology is described in Visschedijk *et al*. (2024), which is part of this submission.
1A4bi-EMEP2022-003	The Party uses national measurements based on dilution tunnel sampling/measurements that cover the whole combustion cycle including the ignition and shut down phases. The Netherlands, however, did not provide detailed information on the sampling and measurements. **The ERT recommends the Netherlands to include in the next IIR submission information on the measurement standards and equipment used.**	Emission factors are based on literature (EMEP/EEA Guidebook 2019 and other literature sources). The emission factors used are described in the WESP methodology report (Visschedijk *et al*., 2024), which is part of the submission.

EMEP Observation	Recommendation	Reference to IIR or improvement status
1A4bi-EMEP2022-004	The Party takes to some extent into account the so-called user impact in their inventory. To the question on the issue, the Netherlands responded that the partial inclusion of the user impact is reflected by the fact that compared to type-approval measurements based on standard fuel quality and nominal load only, the Dutch emission factors are considerably higher, or in reasonable agreement. However, the emission factors do not include use of wet/treated wood or inefficient combustion conditions. **The ERT found the information included in the IIR not to be sufficient and recommends the Party to provide more information in the next IIR submission on what kind of non-optimal combustion conditions are included and to collect more data on national circumstances to incorporate the information in the inventory for the next submissions.**	The emission factors used are described in the WESP methodology report (Visschedijk *et al*., 2024), which is part of the submission. Furthermore, a table with the activity data per appliance is included in chapter 3 of the IIR.

*Table A4.3 Overview of the implementation of actions from the **2021 NECD LPS-review***

EMRT-NECD Observation	Recommendation	Reference into IIR
NL-LPS-GEN-2021-0001	The TERT noted that in 2019, the coordinates provided for the following LPSs are more than 10 km away from those reported in the Industrial Reporting database (v4) for the corresponding E-PRTR facility (matching facility ID and distance given in parentheses): Dow Benelux BV .Hoek. .4592. (51104; 13 km), Afvalstoffendienst gemeente Hertogenbosch (203707; 34 km). In response to a question raised during the review, the Netherlands explained that LPS-coordinates have their origin in the operators Annual Environmental Reports (AERs), and that there may have been an error in these coordinates. **The TERT agrees with the approach suggested by the Netherlands of asking operators to correct their reporting in the AER and recommends that the Netherlands upload a corrected version of the 2019 LPS data (Annex VI file) to the CDR as corrected coordinates for these plants are available, as well as ensuring that this issue does not reoccur in the 2023 LPS data submission in 2025.**	The errors are corrected and the correct data will be in the 2023 LPS-submission.

*Table A4.4 Overview of the implementation of actions from the **2021 NECD GRIDDED data-review***

EMRT-NECD Observation	Recommendation	Reference to IIR or status
NL-GRID-GEN-2020-0003	The TERT notes with reference to gridded emissions submitted in the GNFR tables for NO_X, $PM_{2.5}$, PM_{10}, NMVOC and CO that there may be an under-estimate (for NO_X, $PM_{2.5}$, PM_{10}) or over-estimate (for CO and NMVOC) of emissions. The gridded emissions reported for these pollutants are not consistent with the emissions reported in the national totals (NFR tables). In the cases of NO_X, $PM_{2.5}$, CO the differences are significant in the national totals reported. In the cases of NMVOC, PM_{10} the differences are related to the emissions for F_RoadTransport. The issue will be flagged as a priority recommendation. In response to a question raised in the review the Netherlands acknowledges that there is an error in the data and informed the TERT that it will be corrected and resubmitted. **The TERT recommends that Netherlands resubmits the corrected data and ensures that gridded emissions are consistent with national totals in the next submission.**	The error is corrected and the correct data will be uploaded before May 2022.

Table A4.5 Overview of the implementation of actions from the ***2023 NECD-Projections review***

EMRT-NECD Observation	NFR	pollutants	Scen.	Recommendation	Reference to IIR or status
NL-0A-2021-0005	0A National total - National total for the entire territory - Based on fuel-sold/fuel-used	BC, $PM_{2.5}$, NMVOC, NH_3, NO_x, SO_x	WM; WAM	Due to constraints related to the COVID-19 pandemic and uncertainties in modelling, the Netherlands has not provided data for 2020 in the Annex IV projections reporting file. The TRT recognises that 2020 is now a historical year and that an uncertainty analysis was undertaken on the 2020 emissions projections and provided in the IIR. **However, TRT recommends that the Netherlands provides values for emission projections (and not ranges) by completing the Annex IV template, to demonstrate how all emission reduction commitments will be met**.	Due to resource constraints the issue will be addressed in the 2025 submission.
NL-0A-2021-0006	0A National total - National total for the entire territory - Based on fuel-sold/fuel-used	BC, $PM_{2.5}$, NMVOC, NH_3, NO_x	WM; WAM	The Netherlands has a number of blank cells in its NFR for different categories, years and pollutants. **The TRT recommends that the Netherlands uses the appropriate notation keys or values as required in the reporting tables for future submissions.**	Due to resource constraints the issue will be addressed in the 2025 submission.

EMRT-NECD Observation	NFR	pollutants	Scen.	Recommendation	Reference to IIR or status
NL-1A4-2021-0001	1A4 Other sectors (Commercial, institutional, residential, agriculture and fishing stationary and mobile combustion)	$PM_{2.5}$	WM; WAM	For 1A4, $PM_{2.5}$, the TRT noted that there were significant recalculations in the 2021 emissions inventory whilst the projections are based on the 2020 emissions inventory. The projections submitted by the Netherlands are based on the x-3 inventory which is in line with reporting guidelines. The Netherlands is predicted to meet its $PM_{2.5}$ emission reduction commitment by 9 % in 2030. The latest historical inventory submitted by the Netherlands in March 2021, shows that the time series for 1A4, $PM_{2.5}$ has been revised (2018 emissions are 234 % higher in the 2021 inventory compared to the 2020 inventory used as the baseline for the projections). During the review the Netherlands indicated that its ability to meet the emission reduction commitments would not be impacted by this increase in historical emissions estimates. The Netherlands referred to an explanation on this aspect in paragraph 2.11 page 191 in the 2021 IIR report. **TRT recommends that the Netherlands clarifies the details and implications of these recalculations for its next projections submission.**	There has been a significant recalculation in the emissions for non-road mobile machineries in the IIR 2023 compared to the IIR 2022 for the complete time series. The recalculation is described in paragraph 4.6.8.

EMRT-NECD Observation	NFR	pollutants	Scen.	Recommendation	Reference to IIR or status
NL-5-2021-0002	5 Waste	$PM_{2.5}$, NMVOC, NH_3, NO_x	WM; WAM	For waste, the TRT noted that the Netherlands does not provide sufficiently transparent information on its waste projections methodology, data sources and assumptions. In response to a question raised during the review the Netherlands provided more information about the recalculation resulting from waste incineration with energy recovery being included in the energy sector. **The TRT notes that this issue does not relate to an over or under-estimate but recommends that a clear explanation of the methodology for waste projections is included with the next projections submission in 2023.**	Due to resource constraints the issue will be addressed in the 2025 submission.

EMRT-NECD Observation	NFR	pollutants	Scen.	Recommendation	Reference to IIR or status
NL-NATIONAL TOTAL-2019-0004	NATIONAL TOTAL; National Total for the entire territory	SO_x, $PM_{2.5}$, NMVOC, NH_3, NO_x	WM; WAM	The TRT noted that the Netherlands IIR contains a good amount of information summarising projections trends, the impacts of PaMs and the impact of Covid-19 on its projections. The TRT notes that the Netherlands has a short 9 page summary of the background and orientation to its projections in its IIR. The Netherlands makes reference to a range of reports including the KEV2020 report called 'Emissieramingen luchtverontreinigende stoffen - Rapportage bij de Klimaat- en Energieverkenning 2020' (PBL, RIVM & TNO, 2020; in Dutch). **The TRT commends the Netherlands for providing good summary information, in its IIR, around the impacts of its policies and measures and of Covid-19 on its projections. However, the IIR contains very limited information on methods, data sources and assumptions. The TRT therefore recommends that the Netherlands provides more details on the methods, data sources and assumptions behind its projections in its IIR data sources used in the projection.**	Due to resource constraints the issue will be addressed in the 2025 submission.

Appendix 5 Additional information to be considered as part of the IIR submission

List A5.1 contains the list of methodology reports that have been submitted to the EU and UNECE (in a separate ZIP file) as part of the submission of 15 March 2023. These reports are to be considered as an integrated part of this IIR2023.

A5.1 List of methodology reports

ENINA (Energy, IP, Waste):
Methodology report on the calculation of emissions to air from the sectors Energy
Rapport 2024-0014
E. Honig, J.A. Montfoort, R. Dröge, B. Guis, K. Baas, B. van Huet and O.R. van Hunnik.

Transport:
Methods for calculating the emissions of transport in the Netherlands – 2024
This report includes a separate digital table with activity data and emission factures used, "*Set of tables of the methods report for calculating the emissions of transport in the Netherlands (version 2023)*".
RIVM report 2024-0023
G. Geilenkirchen, M. Bolech, J. Hulskotte, S. Dellaert, N. Ligterink, E. van Eijk, K. Geertjes, M. Kosterman and M. 't Hoen.

Product Use and Service sectors:
Methods used for the Dutch Emission Inventory. Product usage by consumers, construction and services
RIVM Report 2024-0016
A. Visschedijk, J.A.J. Meesters, M.M. Nijkamp, W.W.R Koch, B.I. Jansen, and R. Dröge.

Agriculture:
Methodology for the calculation of emissions from agriculture. Calculations for methane, ammonia, nitrous oxide, nitrogen oxides, non-methane volatile organic compounds, fine particles and carbon dioxide emissions using the National Emission Model for Agriculture (NEMA).
RIVM Report 2024-0015
T.C. van der Zee, A. Bleeker, C. van Bruggen, W. Bussink, H.J.C van Dooren, C.M. Groenestein, J.F.M. Huijsmans, H. Kros, L.A. Lagerwerf, K. Oltmer, M. Ros, M. van Schijndel, L. Schulte-Uebbing and G.L. Velthof.

These reports are also available at the website http://rivm.nl

Appendix 6 Combined NFR source category KCA uncertainty analysis

The Approach 2 (Monte Carlo) uncertainty analysis, as described in Section 1.5, makes use of uncertainty information at the level of emission source and also produces results at that level. The level of detail is comparable to the SNAP reporting codes and is more specific than the NFR and GNFR sectors. By using the uncertainty estimates at the emission source level, the identification of key sources is more specific and precise.

The results of the uncertainty analyses at the emission source level are represented in the graphs below. For each substance, the uncertainty estimates (95% confidence level) of the emission sources are plotted against their share of the national total emission. For clarity, the plotted emission sources are classified by GNFR sector. The graphs visualise the emission sources that have a relatively large contribution to the national total and also have a high uncertainty. The addition of the uncertainty as a weight factor provides extra detail to the ranking of the key sources. This information can be helpful in the process of prioritising inventory improvements.

Details of the key sources are provided in the accompanying tables. The emission sources that have a relatively large contribution to the national total and/or also have a high uncertainty are labelled. The tables give a summary of these labelled key sources.

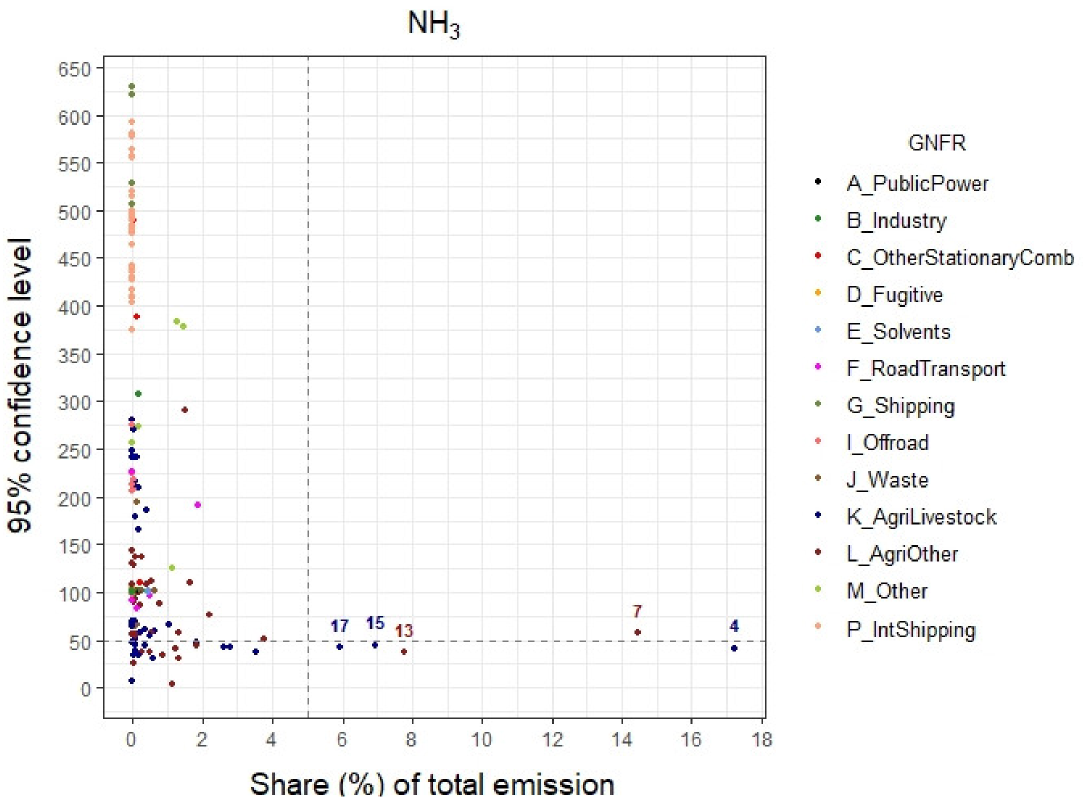

Table A6.1 Emission sources of ***NH_3*** *with a relative high uncertainty and contribution to the national total emission (numbers correspond with labels in graph)*

#	NFR Code	Long Name	Emission source	Share	Uncertainty estimate
7	3Da2a	Animal manure applied to soils	Mature dairy cattle, manure application	14.5%	57%
4	3B1a	Manure management - Dairy cattle	Mature dairy cattle, manure in stable	17.2%	41%
13	3Da1	Inorganic N-fertilizers (includes also urea application)	Fertiliser application	7.8%	37%
15	3B3	Manure management - Swine	Fattening pigs, manure in stable	7%	45%
17	3B4gi	Manure management - Laying hens	Laying hens, manure in stable	5.9%	42%

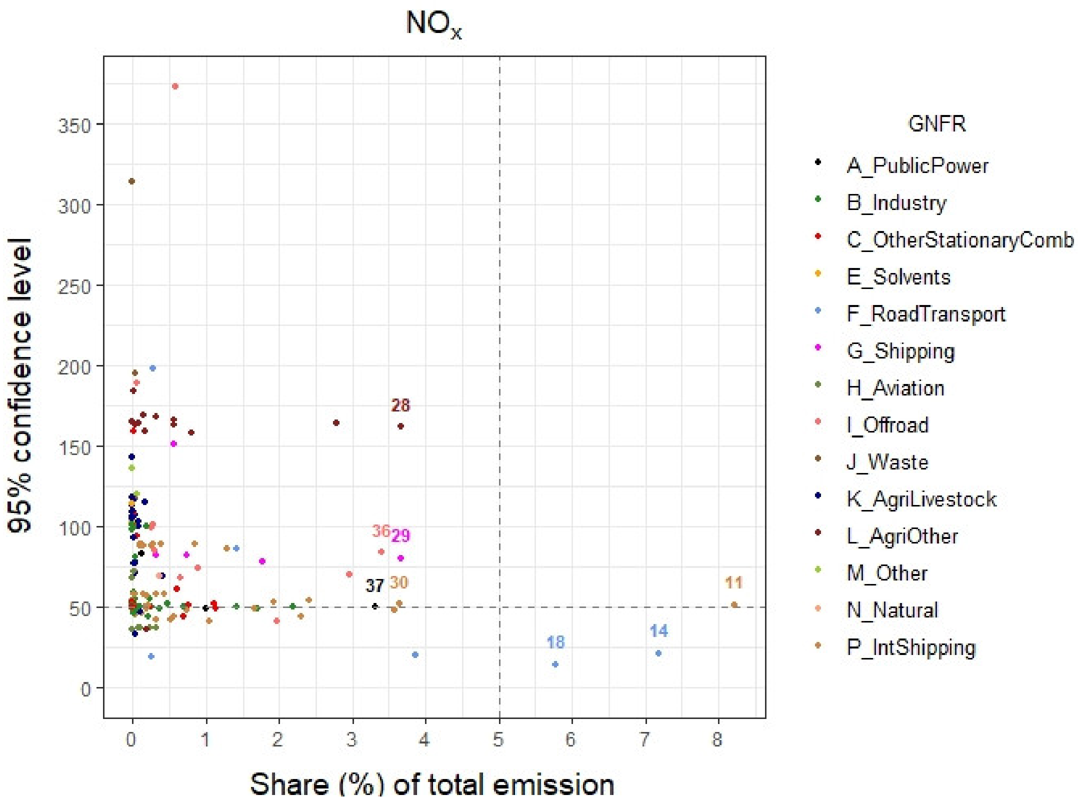

*Table A6.2 Emission sources of **NO_x** with a relative high uncertainty and contribution to the national total emission (numbers correspond with labels in graph)*

#	NFR Code	Long Name	Emission source	Share	Uncertainty estimate
11	1A3di(i)	International maritime navigation	Sailing, NCP, Container ships	8.2%	51%
14	1A3biii	Road transport: Heavy duty vehicles and buses	Exhaust gas, heavy vehicles	7.2%	21%
18	1A3bi	Road transport: Passenger cars	Exhaust gas, passenger cars	5.8%	14%
28	3Da2a	Animal manure applied to soils	Manure application	3.7%	162%
29	1A3di(ii)	International inland waterways	Exhaust gas, inland shipping international	3.7%	80%
30	1A3di(i)	International maritime navigation	Sailing, NCP, Roro cargo/Car ships	3.6%	52%
36	1A2gvii	Mobile combustion in manufacturing industries and construction	Exhaust gas, mobile machinery - building & construction	3.4%	84%
37	1A1a	Public electricity and heat production	Facilities NACE 35: production and distribution of electricity and gas	3.3%	50%

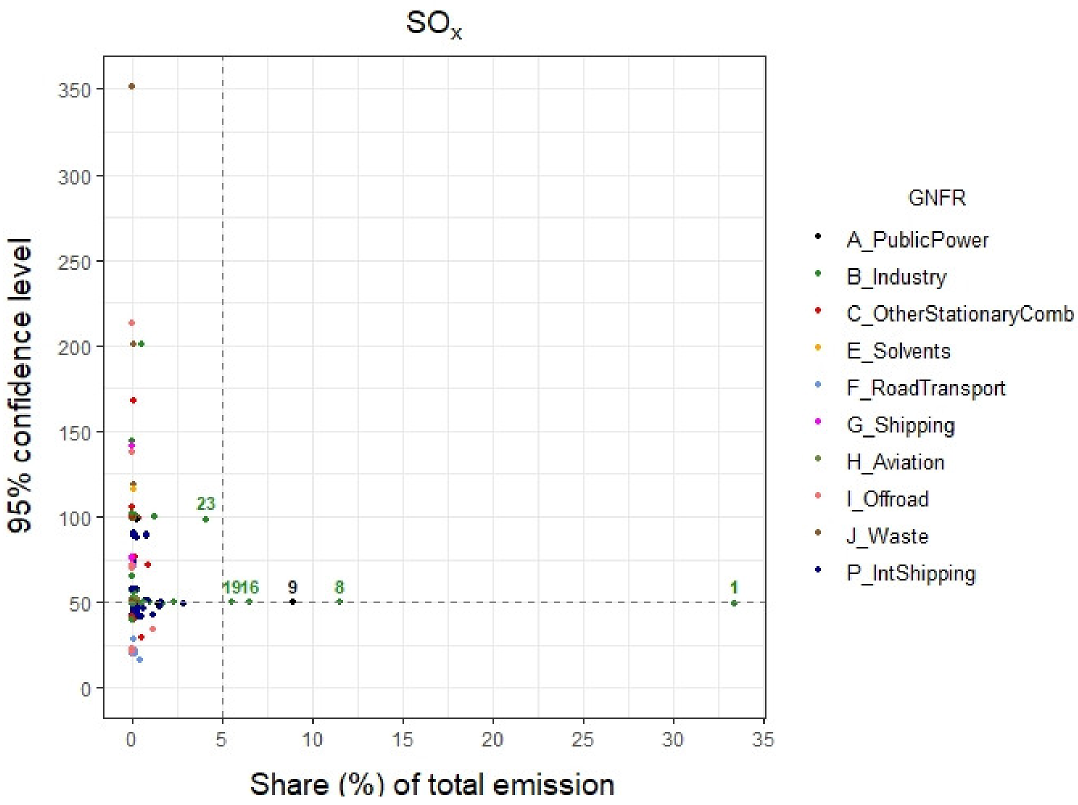

Table A6.3 Emission sources of ***SO_x*** *with a relative high uncertainty and contribution to the national total emission (numbers correspond with labels in graph)*

#	NFR Code	Long Name	Emission source	Share	Uncertainty estimate
1	1A1b	Petroleum refining	Facilities NACE 19.201: manufacture of refined petroleum products	33.4%	50%
8	1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	Facilities NACE 24: manufacture of metals in primary forms	11.5%	50%
9	1A1a	Public electricity and heat production	Facilities NACE 35: production and distribution of electricity and gas	8.9%	50%
16	1A2gviii	Stationary combustion in manufacturing industries and construction: Other	Facilities NACE 23: construction material and glass industry	6.5 %	50%
19	1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	Facilities NACE 20.1:manufacture of basic chemicals	5.5%	50%
23	2A6	Other mineral products	NACE 23.32: manufacture of bricks and tiles	4.1%	99%

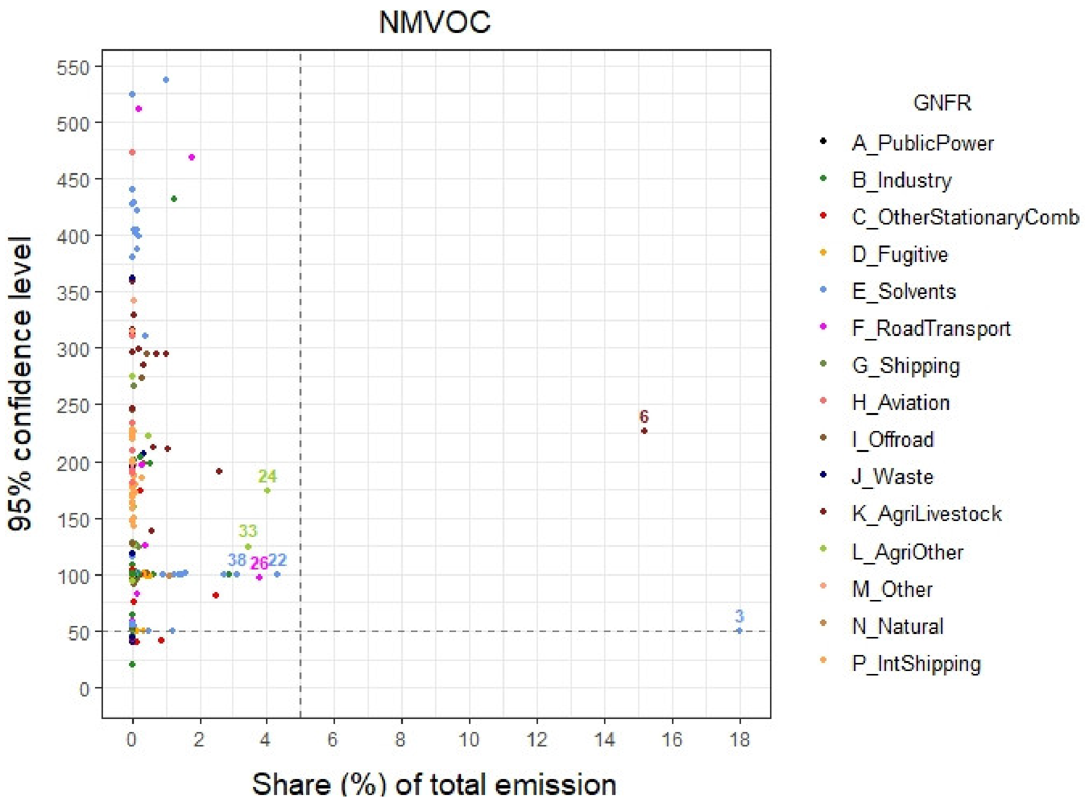

*Table A6.4 Emission sources of **NMVOC** with a relative high uncertainty and contribution to the national total emission (numbers correspond with labels in graph)*

#	NFR Code	Long Name	Emission source	Share	Uncertainty estimate
6	3B1a	Manure management - Dairy cattle	Mature dairy cattle, manure in stable and storage excl. NH_3	15.2%	227%
3	2D3a	Domestic solvent use including fungicides	Solvent and other product use: hand sanitizers	18%	50%
22	2D3a	Domestic solvent use including fungicides	Solvent and other product use: cosmetics	4.3%	100%
24	3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	Silage storage	4%	173%
26	1A3bi	Road transport: Passenger cars	Exhaust gas, passenger cars	3.8%	97%
33	3Da2a	Animal manure applied to soils	Manure application	3.5%	125%
38	2D3a	Domestic solvent use including fungicides	Solvent and other product use: detergents	3.1%	100%

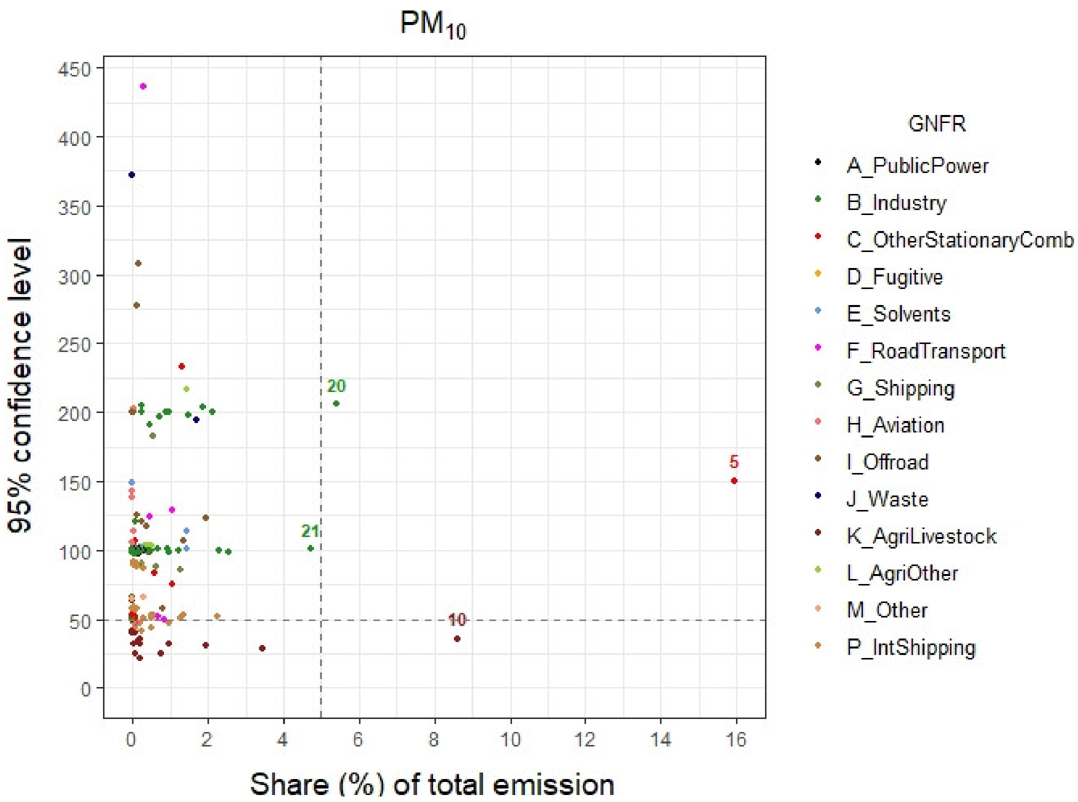

Table A6.5 Emission sources of ***PM_{10}*** *with a relative high uncertainty and contribution to the national total emission (numbers correspond with labels in graph)*

#	NFR Code	Long Name	Emission source	Share	Uncertainty estimate
5	1A4bi	Residential: Stationary	Residential combustion, wood stoves and fire places	15.9%	150%
10	3B4gi	Manure management - Laying hens	Laying-hens, manure in stable and storage excl. NH_3	8.6%	36%
20	2A6	Other mineral products	NACE 23: construction material and glass industry, diffuse	5.4%	206%
21	2A5b	Construction and demolition	Building and construction sites	4.7%	100%

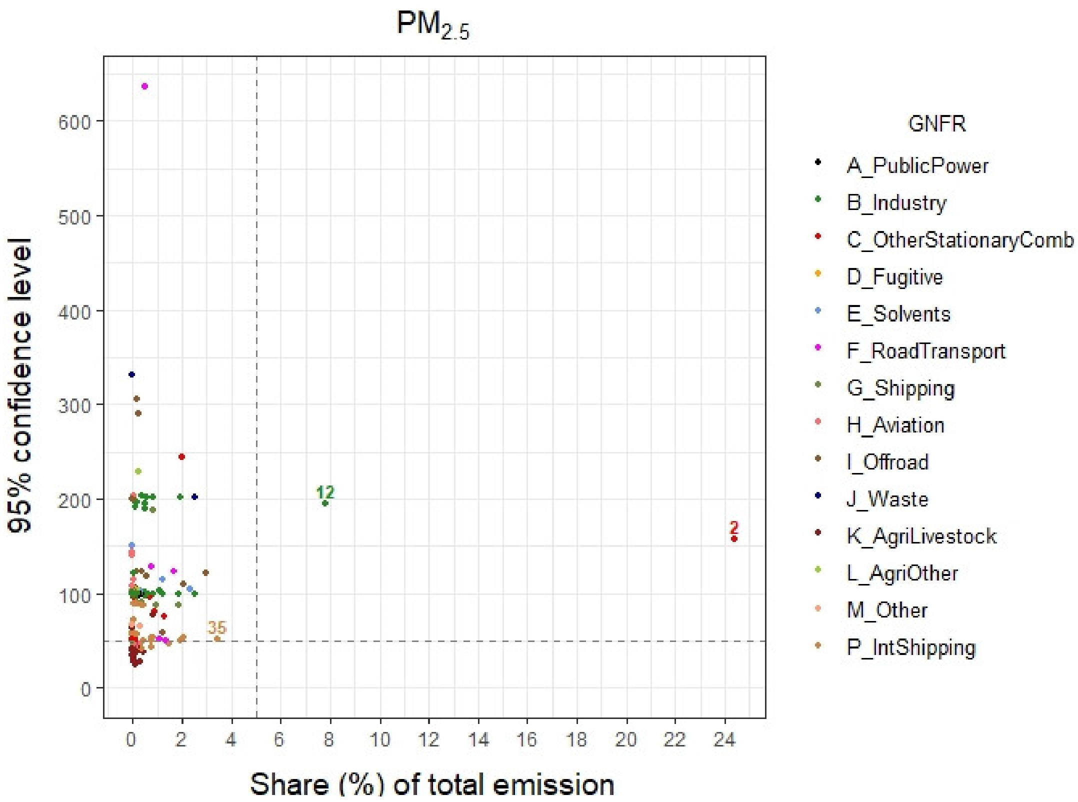

*Table A6.6 Emission sources of **$PM_{2.5}$** with a relative high uncertainty and contribution to the national total emission (numbers correspond with labels in graph)*

#	NFR Code	Long Name	Emission source	Share	Uncertainty estimate
2	1A4bi	Residential: Stationary	Residential combustion, wood stoves and fire places	24.4%	157%
12	2A6	Other mineral products	NACE 23: construction material and glass industry, diffuse	7.8%	194%
35	1A3di(i)	International maritime navigation	Sailing, NCP, Container ships	3.4%	52%

Appendix 7 Data applied for the NMVOC adjustment 3B1a

Table A7.1 Quantification of approved ERC Adjustment Applications.

NL_2024	**NMVOC**			
	3B1a : Manure management Dairy cattle			
Year	**2005**	**2020**	**2021**	**2022**
Activity data (1000 head)	1,433.202	1,593.071	1,571.411	1,570.673
Adjusted activity data	1,433.202	1,593.071	1,571.411	1,570.673
AD Revision (%)	0%	0%	0%	0%
EF (Gg/1000 head)	0.016915827	0.027380637	0.027376816	0.027726720
Adjusted EF	0	0	0.027376816	0.027726720
EF Revision (%)	-/-100%	-/-100%	0%	0%
Emissions (Gg)	24.24	43.62	43.02	43.55
Adjusted emissions (Gg)	0	0	43.02	43.55
Adjustment (Gg)	24.24	43.62	0	0

D. Wever | M. Bolech | P.W.H.G. Coenen | S.N.C. Dellaert |
R. Dröge | G. Geilenkirchen | E. Honig | B. van Huet |
M. Kosterman | S.E.H. van Mil | M.C. van Zanten | T. van der Zee

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