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

Informative Inventory *Report* 2021

Emissions of transboundary air pollutants in the Netherlands 1990-2019

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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 supplement to this report.

In addition to the authors, several people contributed to this report. Rene Koch (TNO), Antoon Visschendijk (TNO), Bas van Huet (RWS), Olaf Janmaat (RWS) and Kees Baas (CBS) provided information regarding several emission sources.

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Synopsis

Informative Inventory Report 2021
Emissions of transboundary air pollutants in the Netherlands 1990–2019

Decrease in ammonia emissions; entire time series changed
The emission factor for ammonia from low emission animal housing changed as studies/data has shown that they emit more ammonia than was taken into account before. Additionally, a statistical reanalysis of data from manure application has shown that the emission factor for applying manure to the soil was to high. Both changes led to a 4.0 Gg decrease of ammonia emissions in 1990 and a small increase of 0.5 Gg in 2018.

Compared to 2018 the ammonia emission decreased by 6.4 Gg. This decrease is mainly the result of decreasing animal numbers of cattle, pigs and laying hens and increasing use of low emission animal housing.

At 123.0 Gg in 2019, ammonia emissions are well below the maximum set by the European Union and the UNECE under the Gothenburg Protocol (both 128 Gg).

Decrease in non-methane volatile organic compounds
Compared to 2018 the emissions of non-methane volatile organic compounds decreased by 4.3 Gg. This decrease is mainly the result of decreasing animal numbers in agriculture.

At 238.2 Gg in 2019, emissions of non-methane volatile organic compounds exceed the maximum set by the European Union (185 Gg) and the UNECE maximum under the Gothenburg Protocol (191 Gg).

Decrease in both nitrogen oxides and sulphur oxides
The emissions of both nitrogen oxides and sulphur oxides decreased with respectively 13.6 and 2.1 Gg. For nitrogen oxides this is mainly a result of decreasing road traffic emissions due to ongoing implementation of the latest European Union regulations and a decrease in coal use for energy purposes.
The decrease of sulphur oxides is mainly a result of decreasing coal use for energy purposes.

Applying for adjustments
For non-methane volatile organic compounds the Netherlands uses the approved adjustments on the emissions for compliance with the ceilings set by the European Union and the UNECE under the Gothenburg Protocol.

The Informative Inventory Report 2020 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 2021
Emissies van grootschalige luchtverontreiniging 1990-2019

In 2019 is 6,4 kiloton minder ammoniak uitgestoten dan in 2018. Dit komt vooral door ontwikkelingen in de landbouw. Zo werden er minder melkvee en mestvarkens gehouden en kwamen er meer varkensstallen die minder ammoniak uitstoten. De totale ammoniak uitstoot van 123 kiloton in 2019 ligt onder het maximum van 128 kiloton dat op basis van EU-regelgeving voor Nederland geldt. Dit blijkt uit de definitieve inventarisatie tot 2019 van luchtverontreinigende emissies.

De emissies van fijnstof zijn toegenomen. Dit komt doordat de uitstoot van het zogeheten condenseerbaar fijnstof in de Emissieregistratie is toegevoegd aan de hoeveelheid fijnstof (vaste deeltjes) uit houtstoot voor sfeerverwarming. Hierbij worden twee soorten fijnstof uitgestoten: de vaste stofdeeltjes, waaronder roet, en het condenseerbaar fijnstof. Deze nieuwe bron is met terugwerkende kracht toegevoegd vanaf 1990. Over de hele periode (1990-2019) blijft de fijnstofuitstoot overigens afnemen.

De uitstoot van stikstofoxiden en zwaveldioxide daalden licht ten opzichte van 2018 met respectievelijk 6,5 en 2,0 kiloton. De emissies van beide stoffen liggen onder het vastgestelde maximum van respectievelijk 260 en 50 kiloton. De lagere uitstoot van stikstofoxiden komt onder andere door de strengere eisen aan de uitstoot door personenauto’s en vrachtverkeer. Ook zijn energiecentrales minder steenkool gaan gebruiken. Minder zwaveloxiden komt vooral doordat raffinaderijen steeds meer op gas stoken in plaats van op olie, met een schonere uitstoot (rookgasreiniging).

Dit en meer staat in de zogeheten Informative Inventory Report rapportage (IIR) die het RIVM in samenwerking met diverse partnerinstituten jaarlijks op verzoek van het ministerie voor Infrastructuur en Waterstaat (IenW) opstelt. Nederland gebruikt de analyses om beleid te onderbouwen en om in internationaal verband te rapporteren over de ontwikkeling van de emissies en in hoeverre de emissies onder de afgesproken maximale hoeveelheden (emissieplafonds) blijven. De voorlopige emissiecijfers over 2019 zijn al in het najaar van 2020 gepubliceerd.

Kernwoorden: emissies, luchtverontreinigende stoffen, emissieregistratie

Contents

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. The European Community subsequently adopted the Revised National Emission Ceiling Directive 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, these data are 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 Guidelines for Reporting Emissions and Projections Data under the Convention on Long-Range Transboundary Air Pollution 2014 (UNECE, 2014).
Additionally the emission reduction commitments under both the Gothenburg Protocol (UNECE, 2012) and NECD (EU, 2016) are reported using the Technical guidance (UNECE, 2015)

The Informative Inventory Report 2021 (IIR 2021) 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}, 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 Netherlands' IIR 2021 is based on data from the national Pollutant Release and Transfer Register (PRTR). The IIR contains information on the Netherlands' emission inventories for the years 1990 to 2019, including descriptions of methods, data sources and annual QA/QC activities (including the trend analysis work shop). 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 the sectoral monitoring of emissions to air, water and soil of pollutants and greenhouse gases. The database was set up to support national environmental policy, as well as to meet the requirements of the National Emission Ceilings Directive (EU), the CLRTAP, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (National System). This policy covers the constant updating of the PRTR, 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.prtr.nl.
Instead of using the defaults from the EMEP/EEA air pollutant emission inventory guidebook 2019 (EEA, 2019), the Netherlands often applies country-specific methods, with associated activity data 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 CLRTAP and NECD. The PRTR system has been in operation in the Netherlands since 1974. Since 2010, 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 produce annually 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 are produced in annual (project) cycles. In addition to the 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).
- Fugro, which coordinates annual environmental reporting by companies.

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 the RIVM and in the annual project plan (Wanders, 2020).

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.

Every year, after the emission data have been collected, several quality control checks are performed by the task forces during a yearly 'trend analysis' workshop. After being approved by the Task Force (relevant sector data), the head of the PRTR endorses the dataset. The participating institutes are requested to agree to the dataset so that all work with a unique set of emission data. Then the emission data are released for publication (www.prtr.nl). Subsequently, these data are 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 legal 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 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 the RIVM and remains the property of the companies involved.

Data on point-source emissions in the AER database are 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 are then stored in the PRTR database (Honig *et al.*, 2021).

As a result of the Dutch implementation of the EU Directive on the European Pollutant Release and Transfer Register (E-PRTR), since 2011 about 1,000 facilities have been legally obligated to submit data on their emissions of air pollutants when these exceed a certain threshold. To compensate for 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 (for instance for NO_x from Soest, van-Vercammen *et al.,* 2002) and implied factors from the reported emissions and production are used, as well as statistical information such as production indexes and sold fuels. 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 total subsector emissions is covered by facility emission reports.

1.3.3 *Data storage*

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

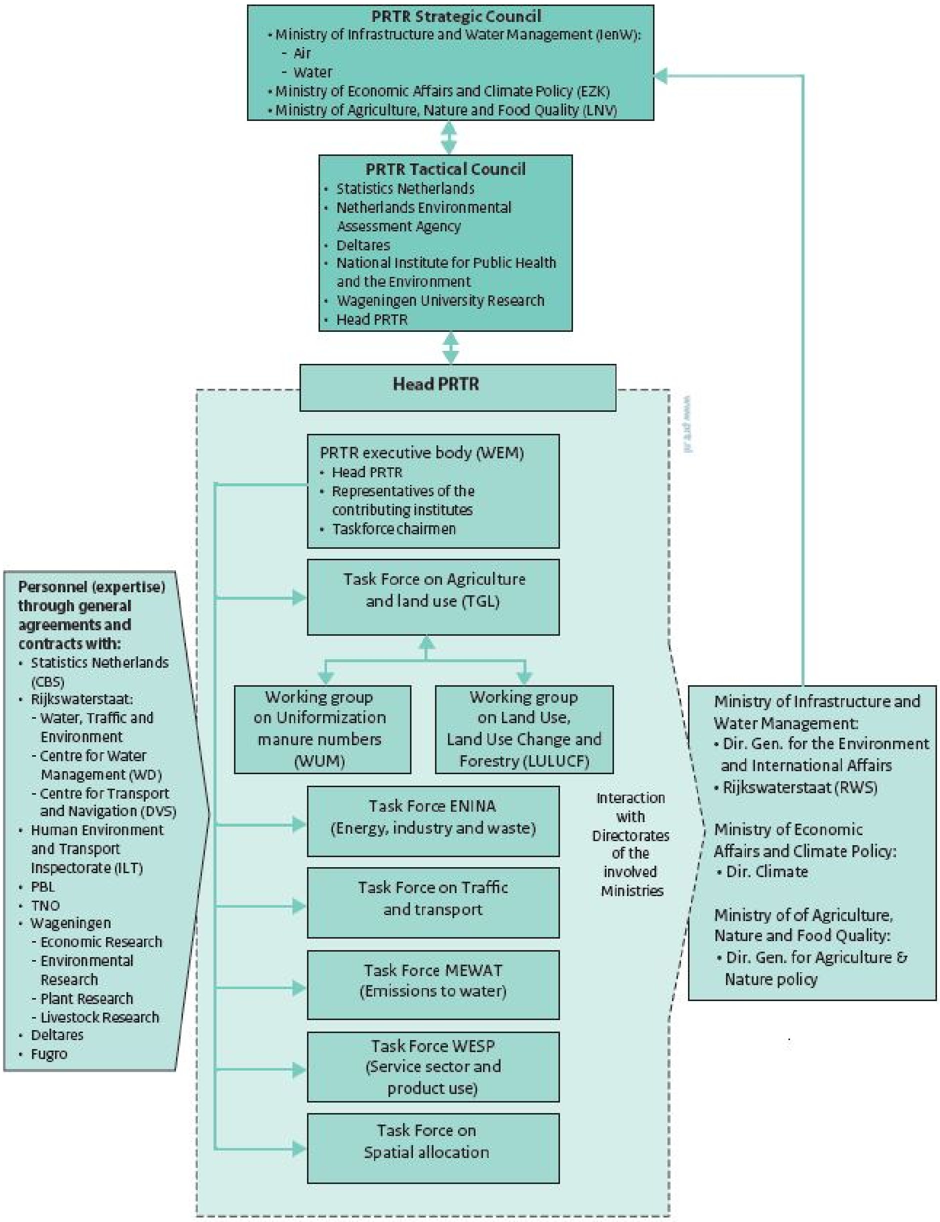

Figure 1.1 The organisational structure of the Netherlands Pollutant Release and Transfer Register (PRTR)

Emission data from the ER-I database and from collectively estimated industrial and non-industrial sources are 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 industrial subsector, separate information on process and combustion emissions, and the relevant environmental compartment and location. These emission sources can be selectively aggregated per NFR category.

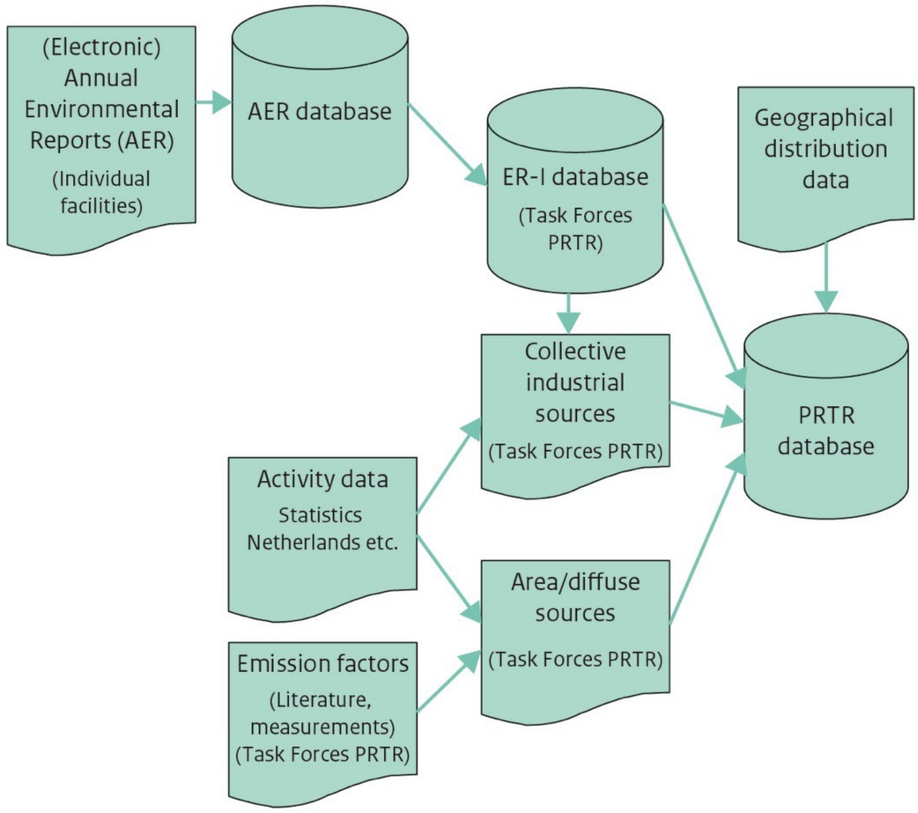

Figure 1.2 The data flow in the Netherlands Pollutant Release and Transfer Register (PRTR)

1.3.4 *Methods and data sources*

Methods used in the Netherlands are annually documented in several reports and protocols, and in meta-data files available from www.prtr.nl. All methodology reports are in English. However, some background reports are available only in Dutch.

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 are insensitive 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 level of emission, the trend in emission or both. The key categories are the sources whose total emissions, when summed together in descending order of magnitude, add up to 80% of the total level (EEA, 2019). The key source analysis follows the methodology developed by the IPCC, which is described in the 2006 Guidelines, and includes both the Approach 1 and Approach 2 methods of identifying key categories (IPCC, 2006).

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 (2019) and the base year (1990) are available, the level assessment is performed for both years. This also enables the contribution of each category to the trend of the national inventory to be assessed. 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 results of the Approach 2 key category analysis are reported in addition to the Approach 1 results in Appendix 2.

This year's inventory is the first to implement an Approach 2 key category analysis. The outcomes of the Monte Carlo uncertainty analysis were aggregated to the gridded NFR (GNFR) level before the analysis was carried out. The aim is to include a NFR key category analysis using the Approach 2 method in the submission for 2022. As the uncertainty analysis produces results on the level of emission sources, which are more detailed than the NFR sectors based results, the Approach 2 analysis to find the key categories can also be applied on 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 can be used as an instrument to prioritize the inventory improvement.

1.3.6 *Reporting*

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

1.3.7 *QA/QC*

The RIVM has an ISO 9001:2015 QA/QC system in place. PRTR quality management is fully in line with the RIVM QA/QC system. Part of the work for the PRTR is done by external agencies (other institutes). QA/QC arrangements and procedures for the contributing institutes are described in an annual project plan (Wanders, 2020). The general QA/QC activities meet the international inventory QA/QC requirements described in part A, chapter 6 of the EMEP inventory guidebook (EEA, 2019).

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 calculation in the PRTR is based mainly 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. For the 2019 inventory, the PRTR task forces filled in a standard-format database with emission data from 1990 to 2018. After an automated first check of the emission files by the Data Exchange Module (DEX) for internal and external consistency, the data were 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 fixed, a trend verification workshop is organised by the RIVM (see Text Box 1.1). The results of this workshop, including actions to be taken by the task forces to resolve the identified clarification issues, are documented by the RIVM. Required changes to the database are then made by the task forces.

Table 1.1 Key items of the verification actions on times series 1990–2019 data processing and NFR/IIR 2021

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 outstanding issues for this inventory	16-07-2020	RIVM-PRTR	List of remaining issues/actions from last inventory	Actiepunten Voorlopige cijfers 1990–2019 v 8 juli 2020.xls
Input for checking allocations from the PRTR database to the NFR tables	23-11-2020	RIVM-NIC	List of allocations	NFR-Koppellijst-2020-11-23-dtt60.xlsx
Comparison sheets with concept data	19-11-2020	RIVM	Input for data checks	Verschiltabel_LuchtActueel_18-11-2020.xlsx
Comparison sheets with final data	30-11-2020	RIVM	Input for trend analyses	Verschiltabel_LuchtActueel_26-11-2020.xlsx
Trend analysis workshops	03-12-2020	Sector specialists, RIVM-PRTR	Explanations of observed trends and actions to resolve before finalising the PRTR dataset	– 5_Trendanalyse landbouw 2020.pptx; – 6_Trendanalyse ENINA 2020.pptx; – 3_Trendanalyse verkeer 2020.pptx; – 4_Trendanalyse WESP - 3-12-2020.pptx; – 2_Trendanalyse Grootschalige luchtverontreiniging v0.pptx.
Input for resolving the final actions before finalising the PRTR dataset	7-12-2020	task forces	Updated action list	Actiepunten Definitieve cijfers 1990–2019 v 7 december 2020.xls

QC item/action	Date	Who	Result	Documentation*
Request to the individual task force chairs to approve the data produced by the task force	11-01-2020	RIVM-PRTR	Updated action list	– Email (11-01-2021 17:36) with the request to endorse the PRTR database; – Actiepunten Definitieve cijfers 1990–2019 v 11 januari 2021.xls
Formal adoption of the emission dataset	15-01-2021	Head PRTR	Fixed emission dataset 1990–2019	Email (15-01-2021 16:23) from the head of the PRTR endorsing the 1990–2019 emissions dataset;
Input for compiling the NEC report (in NFR format)	11-02-2021	RIVM-NIC	List of allocations of PRTR emission sources for compiling the NFR tables	NFR-Koppellijst-20210210-103517-dtt60-BL-DW.xlsx
List of allocations for compiling from the PRTR database to the NFR tables	24-02-2020	RIVM	Input for compiling the EMEP/LRTAP report (NFR format)	NFR-Koppellijst-20210218-121232-dtt60 DW.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, a snapshot of the database is made available by the RIVM in a web-based application (Emission Explorer, EmEx) for checks by the institutes involved, sector 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 totals for the sectors are then compared with the previous year's dataset. Where significant differences are found, the task forces check the emission data in greater 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 were checked in two ways: (1) emissions from 2017 from the new time series were compared with those of last year's inventory; and (2) the data for 2018 were 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 datasets 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 the RIVM. These documents then become available through a limited-access website. The updating of monitoring protocols for substances under the 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.prtr.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 completely correlated with each other.

The expert elicitation was set up following the expert elicitation guidance in the IPCC 2006 Guidelines (motivating, 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 on the level of the NFR categories. The Monte Carlo analysis takes account of correlations of the activity data and/or EFs. 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 individual industrial sectors separately). 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 sectors (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 sectors (such as shipping and aviation).
    - The EFs for the different type 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 presented in Table 1.2.

[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/ Using the button 'Change selection' on the website, it is possible to select the data for another year.

Table 1.2 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 in 2019 (%)

NFR category	NH_3	NO_x	SO_x	NMVOC	PM_{10}	$PM_{2.5}$
1	132	14	20	70	50	56
2	55	75	93	35	35	45
3	29	107	-	126	23	37
5	63	98	129	151	174	167
6	286	-	-	-	-	-
Total	**28**	**17**	**20**	**50**	**27**	**39**

The uncertainty estimates from the Approach 2 method used for the 2019 emissions are different from the uncertainty estimates from this method as presented in the IIR 2020. This can be explained by the following:

- Changes in the total uncertainty of a sector/pollutant caused by changes in absolute emissions:
  - The emissions of PM from residential wood combustion now also includes condensables. This results in a large change in emissions, which also affects the uncertainty calculation for PM in NFR 1 and in the total uncertainty.
- Changes in the uncertainty of a sector due to reallocation of emissions:
  - Part of the NO_x and SO_x emissions from the iron and steel sector have been reallocated from 2C1 to 1A2a. This results in changes in emissions, which also affects the uncertainty calculation for SO_x and NO_x in NFR 2. The effect on NFR 1 is less visible, because the relative change in emissions was smaller.
  - Emissions from horses and emissions from manure application on nature areas have been reallocated from NFR 6 to NFR 3D. NFR 6 now only includes NH3 emissions from persons (transpiration and respiration) and pets (manure from pets), for which a higher uncertainty is estimated
- Updated uncertainty estimates of:
  - Traffic (mobile machinery, aviation)
  - Residential wood combustion (emission factors)
  - Energy statistics (activity data)
  - Waste incineration, landfills and composting
  - Human transpiration and residential animal faeces (activity data)
  - (Mineral) industry emission factors (resulting in higher NO_x and SO_x uncertainties)
  - Disposal- and burning of waste on land (emission factors)
  - Fugitive oil emissions
  - Residential- and car fires (activity data).

Approach 1 method

Uncertainty estimates from earlier studies (Van Gijlswijk *et al.*, 2004; RIVM, 2001) are presented in Table 1.3. The uncertainty estimate of NO_x is similar to the NO_x uncertainty calculated for 2018. The uncertainty for NH_3 and SO_x in 2018 increased compared with the studies of 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 1.3 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 the CLRTAP that are relevant to emissions to the 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 the 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 are confidential.

As a result of questions raised in reviews the United Nations European Monitoring and Evaluation Programme (UN-EMEP) and the European National Emission Ceilings Directive (EU-NECD) regarding the use of the notation keys NE and NA (not applicable), the task forces are asked to evaluate the correct use for each instance.

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 specific source sector. In the NFR format these source categories are named starting with 'Other'. Table 1.4 shows 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 1.3 Subsources accounted for in reporting of NFR 'Other' codes

NFR code	Substance(s) reported	Subsource description
1A2gvii	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins and PAHs	Combustion from mobile machinery in the sectors Industry and Construction.
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; • 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; • 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.

NFR code	Substance(s) reported	Subsource description
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, paint, pharmaceuticals, soap, detergents, glues and other chemical products.
2D3i	NMVOC, NH_3, Dioxins and PAHs	Air conditioning, 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 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: • construction; • 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; • 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;

NFR code	Substance(s) reported	Subsource description
		• mineral extraction; • storage and handling; • shipbuilding; • paper.
3B4h	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	Rabbits and furbearing animals.
3Da2c	NO_x, NH_3	Use of compost.
5C2	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	Bonfires.
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	NO_x, NMVOC, NH_3, CO, $PM_{2.5}$, PM_{10}, and TSP	Human transpiration and respiration; domestic animals (pets).

2 Trends in Emissions

2.1 National emissions of 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 sectors introducing a ban on surface spreading of manure, direct incorporation of manure in the soil, covering of outside slurry manure 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;
- cleaner cars due to EU emission regulations for new road vehicles.

Emissions of NH_3, NO_x and NMVOC increased with respect to the complete time series mainly due to the addition of new emission sources to the inventory for the Agricultural sector and Waste sector (see chapter 10; Recalculations and Other Changes). As a result of this, the Netherlands was in 2019 (and some previous years) no longer in compliance with the NECD and CLRTAP emission ceilings for NMVOC. In accordance with the conditions relating to these ceilings the Netherlands applied for adjustments to the emissions in order to achieve compliance. The adjustments were approved in 2019 and several emission sources in the agricultural sector are now adjusted. A complete discussion and justification for these proposed adjustments can be found in Chapter 12 (Adjustments).

Table 2.1 Total national emissions of main pollutants and PM, 1990–2019 (for NEC compliance)

	Main Pollutants				Particulate Matter			
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC
Year	Tg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	**635**	**604**	**194**	**346**	**54**	**77**	**98**	**11.8**
1995	534	427	134	219	42	59	76	10.1
2000	448	336	78	173	33	48	54	9.0
2005	387	272	67	153	27	40	47	7.2
2010	322	271	36	134	22	35	40	4.9
2015	273	255	31	131	18	31	36	3.1
2018	244	242	25	129	16	29	33	2.5
2019	**230**	**238**	**23**	**123**	**15**	**28**	**32**	**2.3**
1990–2019 period[1]	-405	-366	-171	-223	-39.1	-49.5	-66.2	-9.6
1990–2019 period[2]	-64%	-61%	-88%	-64%	-72%	-64%	-67%	-81%

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

2.1.1 *Trends in nitrogen oxides (NOx)*

Dutch NO_x emissions (NO and NO_2, expressed as NO_2) decreased by 405 Gg in the 1990–2019 period to 230 Gg, corresponding to 64% 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 road transport and the Energy sector. In road transport the emissions per vehicle decreased significantly in this period although an increase in the number of vehicles and miles travelled, partially negated the effect on total road transport emissions. In 2019 the sector Transport is still the main contributor to NO_x emissions, with a share of 59% of the national total. The individual shares in the national total of the sectors Energy, Industry (combustion) and Transport show a decrease over the period 1990–2019, while the share of Agriculture increased from 9% to 14%.

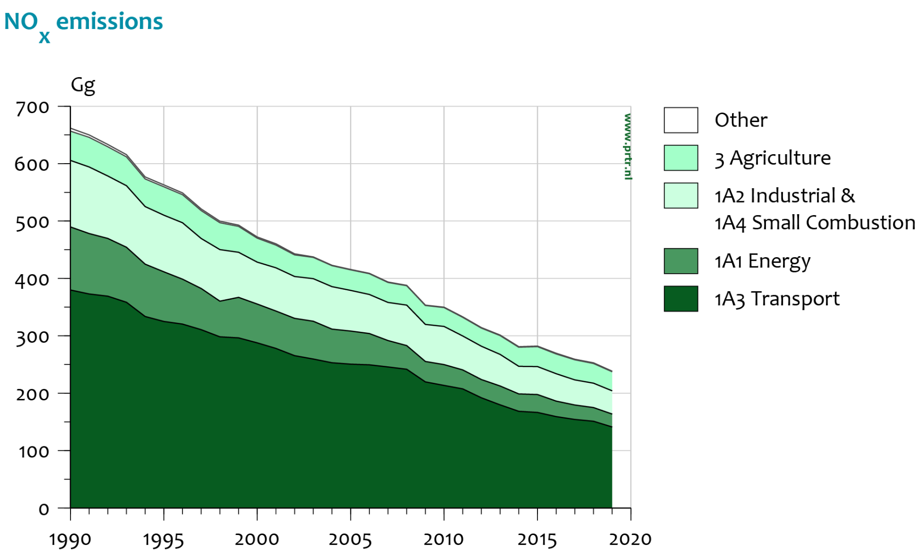

Figure 2.1 NO_x emission trends, 1990–2019

2.1.2 *Trends in sulphur oxides (SOx)*

Dutch SO_x emissions (reported as SO_2) decreased by 171 Gg in the 1990–2019 period to 23 Gg, corresponding to 88% 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 period 1990–2019 refining was the main contributor to total SO_x emissions, with shares of 34% and 39% in 1990 and 2019, respectively. In 2019, the source sectors Industry, Energy and Refining (IER) were responsible for 92% of national SO_x emissions.

SO_2 emissions

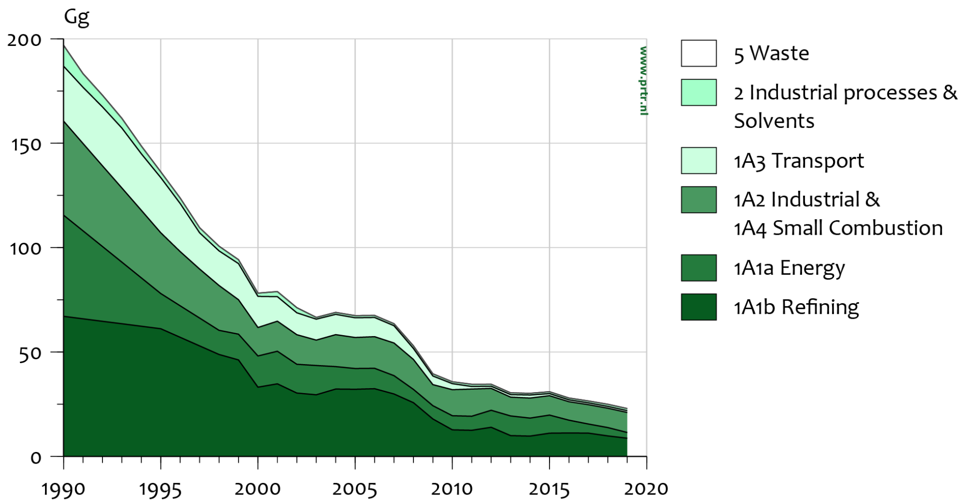

Figure 2.2 SO_x emission trends, 1990–2019

2.1.3 *Trends in ammonia (NH_3)*

Most of the NH_3 emissions (91% in 2019) come from agricultural sources. The share of agricultural sources in the national total is constant over the period 2001-2019 (Figure 2.3). The remaining share of 9% is emitted in sectors Other, Industry and Transport (each with an approx. equal share of 3%). The shares of the sectors Energy and Waste are negligible (less than 1% combined).
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 period 2014 to 2017 the national NH_3 emissions slightly increased above the emission ceilings as result of increasing cattle numbers due to de abolishment of the milk-quota. However, introduction of the policy to maximize the phosphate production had as result that cattle numbers decreased again. In 2019 the Netherlands no longer exceeded the NH_3 ceilings set by the NECD and CLRTAP.

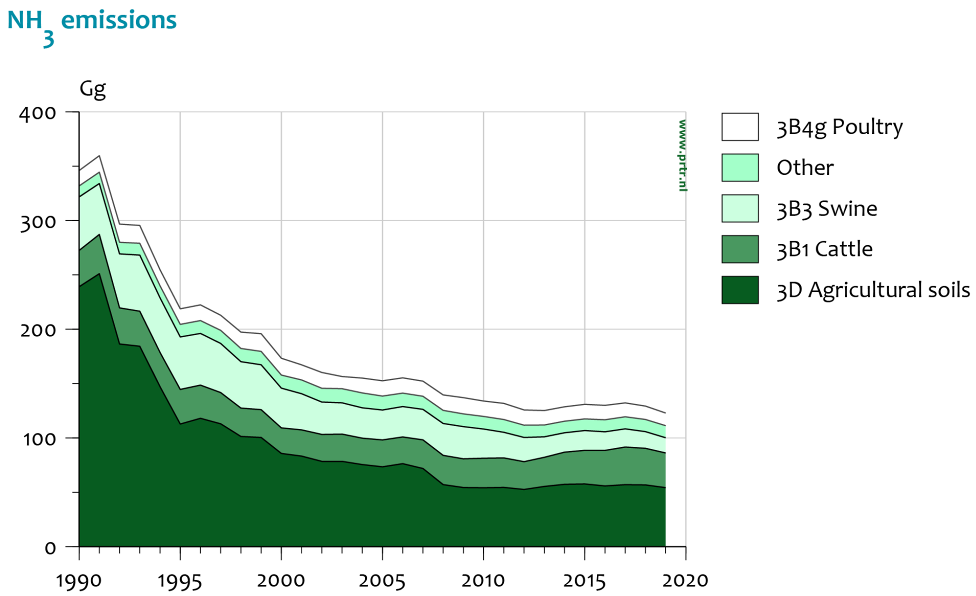

Figure 2.3 NH_3 emission trends 1990–2019

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

In the period 1990–2019, NMVOC emissions decreased by 366 Gg to 238 Gg, corresponding to 61% of the national total in 1990 (Figure 2.4). With the exception of agriculture, all major source categories contributed to this decrease: transport (introduction of catalysts and cleaner engines), product use (intensive programme to reduce NMVOC content in consumer products and paints) and industry (introducing emission abatement specifically for NMVOC).

When it became clear that the use of silage feeding was a source of NMVOC emissions and there was consensus on the EF, this source was added to the emissions inventory. Consequently the total NMVOC emissions increased and in 2019 the Netherlands exceeded the NMVOC ceilings set by the NECD and CLRTAP. However, the introduction over the past years of several new emission sources and new EFs justified the application for adjustment, as approved on by the EC and the EMEP steering body in 2019, in order to achieve compliance (see Chapter 12).

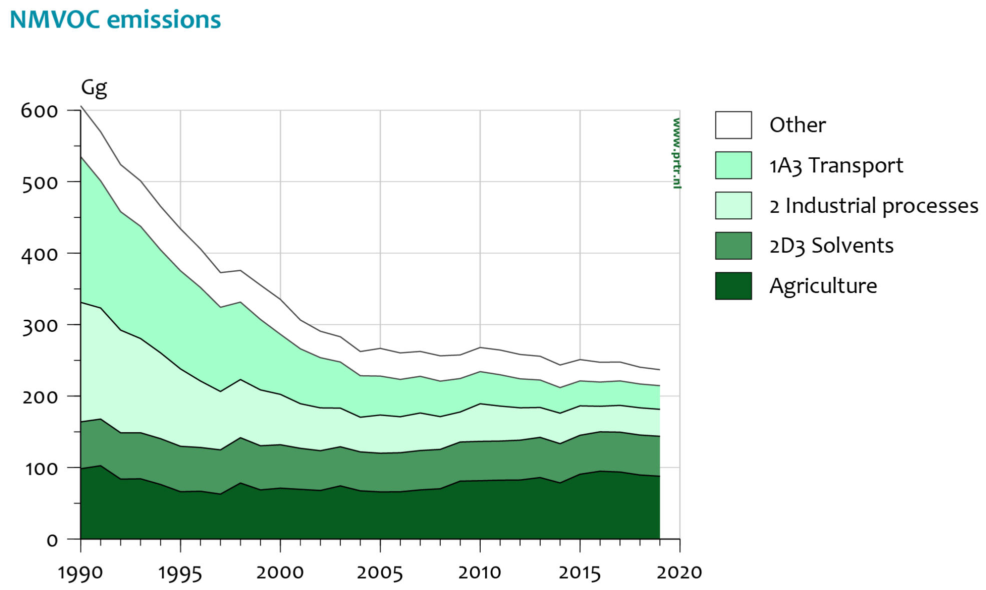

Figure 2.4 NMVOC emission trends, 1990–2019

2.1.5 *Trends in $PM_{2.5}$*

$PM_{2.5}$ emissions are calculated as a specific fraction of PM_{10} by sector (based on Visschedijk *et al.*, 2007). In 2019 the condensables from wood combustion in the residential sector were added to the PM-emissions, resulting in an increase in $PM_{2.5}$ emissions over the complete time series of 4.5 and 2.7 Gg in 1990 and 2019, respectively. $PM_{2.5}$ emissions decreased by 39.1 Gg in the 1990–2019 period to 15 Gg, corresponding to 72% of the national total in 1990 (Figure 2.5). The two major source categories contributing to this decrease were the Industry sector (combustion and process emissions; due to cleaner fuels in refineries and the side effect of emission abatement for SO_x and NO_x) and the Transport sector (rodd transport) were increasingly stringent EU emissions standards led to better engine management and particulate filters.

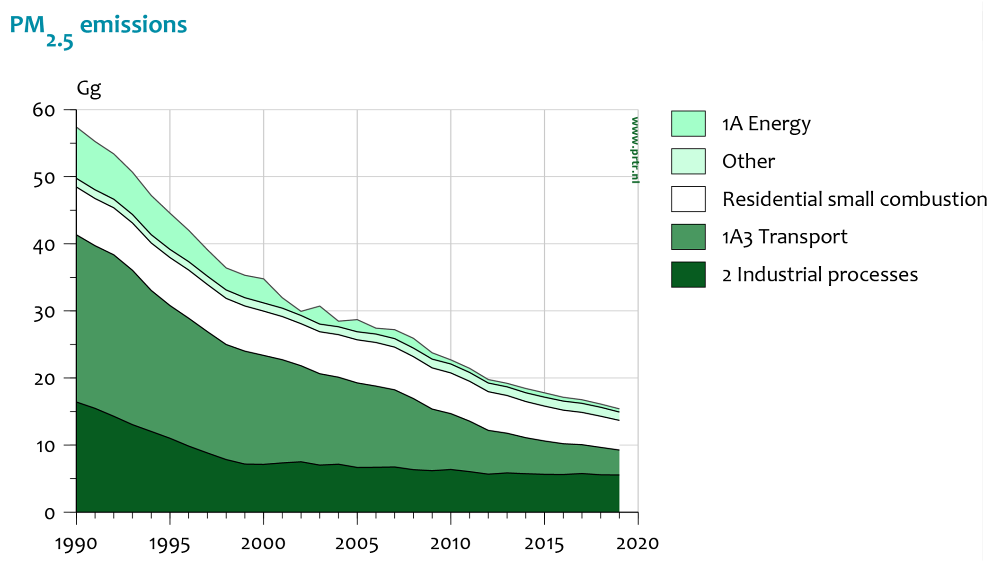

Figure 2.5 $PM_{2.5}$ emission trends, 1990–2019

2.1.6 *Trends in PM_{10}*

Dutch PM_{10} emissions decreased by 49.5 Gg in the 1990–2019 period to 28 Gg, corresponding to 64% of the national total in 1990 (Figure 2.6). The major source categories contributing to this decrease were Industry (reduction in combustion and process emissions; due to cleaner fuels in refineries and the side-effect of emission abatement for SO_x and NO_x) and road transport.

PM_{10} emissions from agriculture gradually increased from 1990 to 2015 from 4.9 Gg to 6.5 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 2016–2019. This decrease was mainly caused by a decrease in animal numbers in poultry.

PM_{10} emissions from the source sectors Energy, Industry (industrial processes), Other and Transport did not change significantly over the last year.

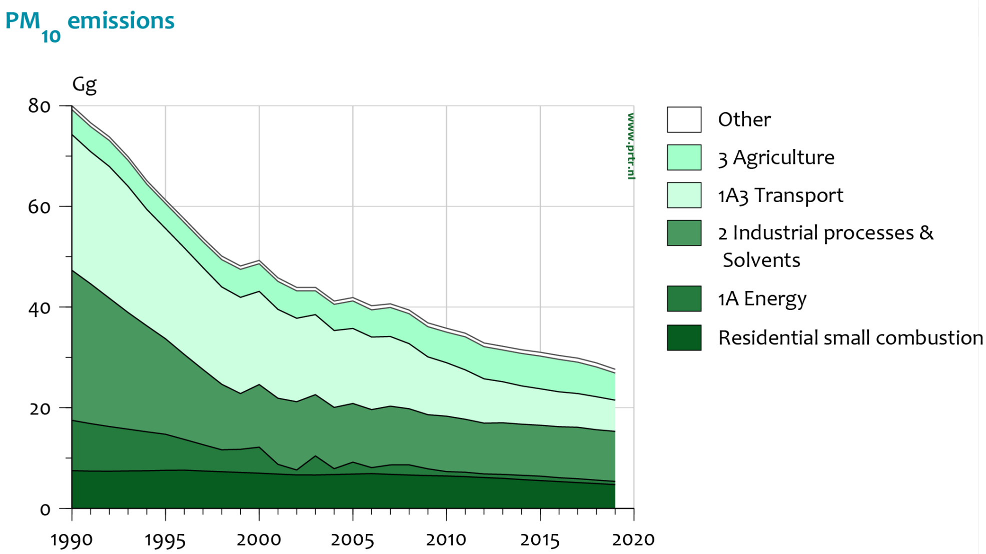

Figure 2.6 PM_{10} emission trends, 1990–2019

2.2 National emissions of priority heavy metals

Based on the Protocol on Heavy Metals to the Convention on Long-range Transboundary Air Pollution 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 2019 all heavy metal emissions are in compliance.

Table 2.2 Total national emissions of priority heavy metals, 1990–2019

	Other	Priority Heavy Metals			POPs	
	CO	Pb	Cd	Hg	DIOX	PAH
Year	Gg	Mg	Mg	Mg	g I-Teq	Mg
1990	1148	338	3.9	3.6	756	21
1995	928	155	2.9	1.5	80	11
2000	762	28	2.7	1.2	46	6.0
2005	730	30	3.6	1.0	44	5.8
2010	666	38	4.6	0.8	48	5.8
2015	562	8.7	2.9	0.7	37	5.2
2018	628	5.9	2.5	0.6	36	4.9
2019	626	5.2	2.6	0.6	41	4.6
1990–2019 period[1]	-522	-333	-1.24	-3.04	-715	-16.1
1990–2019 period[2]	-45%	-98%	-32%	-84%	-95%	-78%

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

2.2.1 *Trends in lead (Pb)*

Lead (Pb) emissions in the Netherlands decreased by 333 Mg in the 1990–2019 period to 5.2 Mg, corresponding to 98% of the national total in 1990 (Figure 2.7). This decrease is attributable primarily to the Transport sector, where, due to the removal of Pb from gasoline, Pb emissions collapsed. The remaining sources contributing to the decrease are industrial process emissions, particularly from the iron and steel industry (due to the replacement of electrostatic filters and the optimisation of some other reduction technologies at Tata Steel).

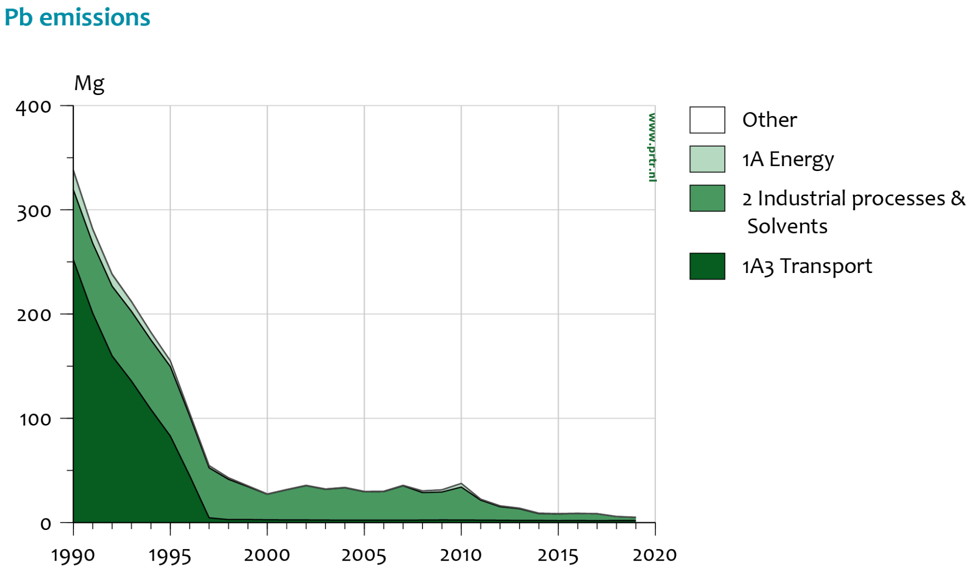

Figure 2.7 Pb emission trends, 1990–2019

2.2.2 *Trends in Cadmium (Cd)*

Cadmium (Cd) emissions in the Netherlands decreased by 1.24 Mg in the 1990–2019 period to 2.6 MG, corresponding to 32% of the national total in 1990 (Figure 2.8). This decrease is attributable primarily to the Energy sector and Other sources. The cadmium emissions from the only zinc-production plant (Nystar) gradually increased over the time series from 1.78 Mg to 2.22 Mg in 1990 and 2019, respectively. 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 stopped production in 2011.

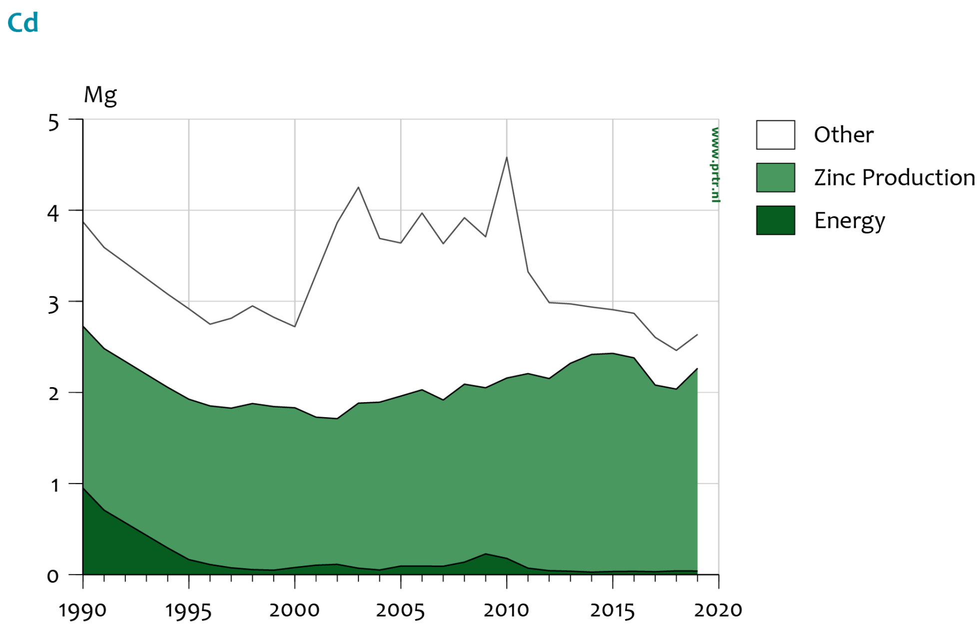

Figure 2.8 Cd emission trends, 1990–2019

2.2.3 *Trends in Mercury (Hg)*

Mercury (Hg) emissions in the Netherlands decreased by 3.04 Mg in the 1990–2019 period to 0.6 Mg, corresponding to 84% of the national total in 1990 (Figure 2.9). In 1990 the sectors Energy and Industry (industrial processes) were the main source of Hg emissions with 1.93 Mg and 1.24 Mg, respectively, and had a combined total Hg emission of 87% of the national total. These sectors reduced their combined Hg emissions in 2019 to 0.40 Mg (69% of the 1990 national total).

Hg

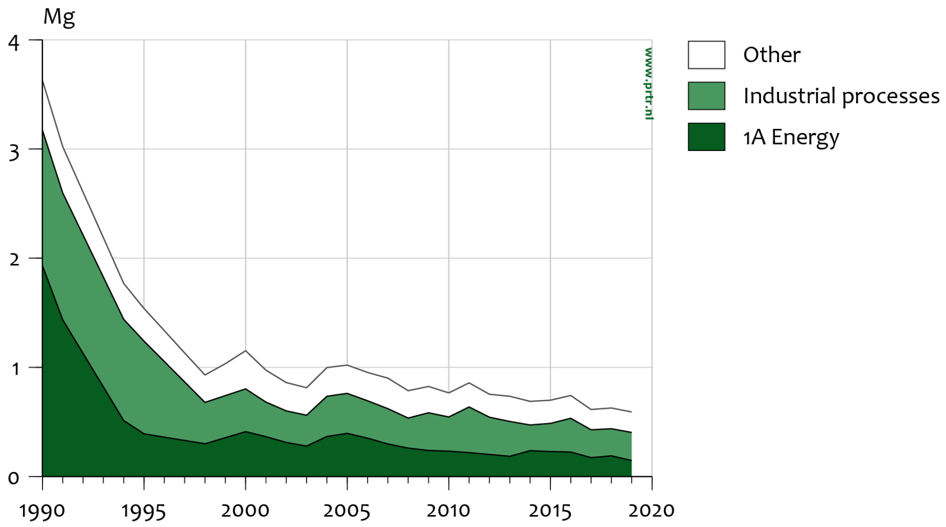

Figure 2.9 Hg emission trends, 1990–2019

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 2019 all POPs emissions are in compliance.

Table 2.3 Total national emissions of POPs, 1990–2019

	POPs			
	DIOX	PAH	HCB	PCB
Year	g I-Teq	Mg	kg	kg
1990	**756**	**21**	**66.4**	**39.1**
1995	80	11	40.4	21.6
2000	46	6.0	17.1	0.24
2005	44	5.8	3.4	0.24
2010	48	5.8	3.4	0.21
2015	37	5.2	4.0	0.31
2018	36	4.9	3.8	0.23
2019	**41**	**4.6**	**3.8**	**0.18**
1990–2019 period[1]	-715	-16.1	-62.6	-38.9
1990–2019 period[2]	-95%	-78%	-94%	-100%

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

2.3.1 *Trends in Dioxins/furans (P*

In the Netherlands emissions of dioxines/furans come mainly from waste combustion in the Energy sector, residential wood combustion and from car -and building fires.
Emissions of dioxines/furans in the Netherlands decreased by 715 g I-TEQ over the 1990–2019 period to 41 g I-TEQ, corresponding to 95% of the national total in 1990 (Figure 2.10). This decrease is attributable primarily 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 abatement technology at waste incinerators.

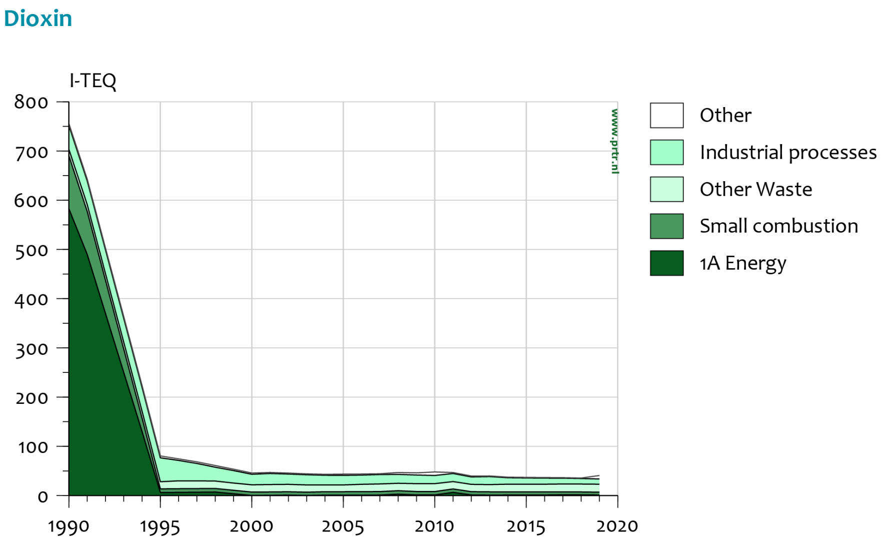

Figure 2.10 Dioxins/furans emission trends, 1990–2019

2.3.2 *Hexachlorobenzene*

Emissions of hexachlorobenzene (HCB) in the Netherlands decreased by 62.2 kg in the 1990–2019 period to 3.8 kg, corresponding to 94% of the national total in 1990 (Figure 2.11). This decrease is attributable primarily to the Energy sector (waste incineration for energy) and Agricultural sector (use of pesticides). The decrease in the Agricultural sector is due to the prohibition of certain pesticides that coincidental contained HCB. HCB from agriculture is calculated from the annual sales of the HCB containing pesticides. The increased HCB emissions in agriculture between 1996 and 2000 are the result of increased sales of the pesticide chlorothalonil.

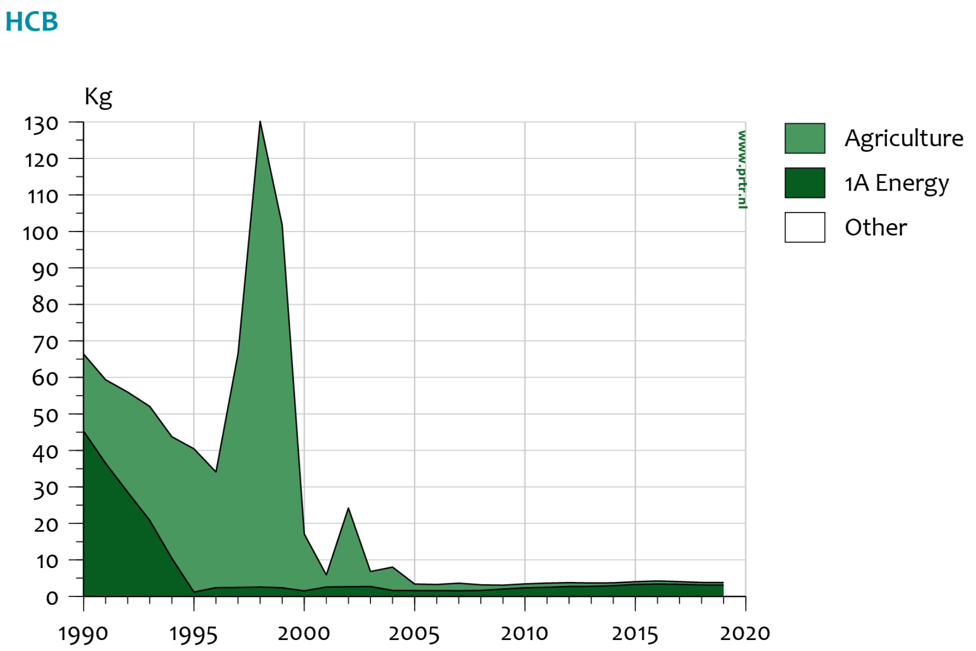

Figure 2.11 HCB emission trends, 1990–2019

2.3.3 Polychlorobiphenyl

Polychlorobiphenyl (PCB) emissions in the Netherlands decreased by 38,9 kg in the 1990–2019 period 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.

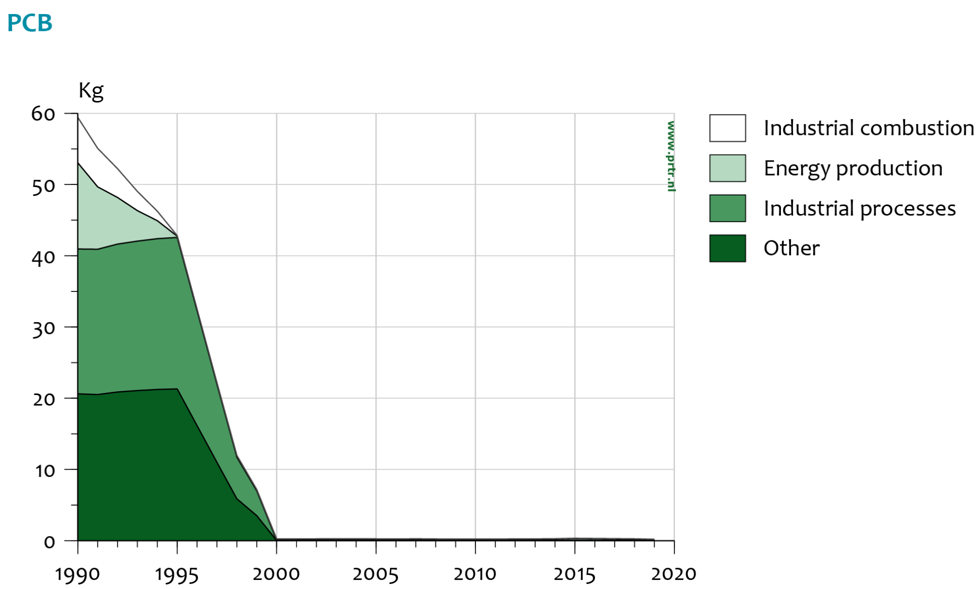

Figure 2.12 PCB emission trends, 1990–2019

3 Energy

3.1 Overview of the sector

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

Part of the emissions from stationary combustion for electricity production and industry (NFR categories 1A1 and 1A2) are based on the AERs (Annual Environmental Reports) produced by large industrial companies. For SO_x, 96% of the emissions were based on AERs, while for other pollutants the proportions were 83% (NH_3), 84% (NMVOC), 88% (NO_x) and 76% (PM_{10}) in 2019. It should be noted that these percentages include not only the data directly from the AERs, but also additional emission data at company level performed by the competent authorities. The emission data in the AERs come from direct emission measurements or from calculations using fuel input and EFs. Most of the emissions 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 2019, natural gas supplied about 44% of the total primary fuels used in the Netherlands, followed by liquid fuels (36%) and solid fossil fuels (9%). The contribution of non-fossil fuels, including renewables and waste streams, was 10%. Figure 3.1 and Figure 3.2 show the energy supply and energy demand in the Netherlands.

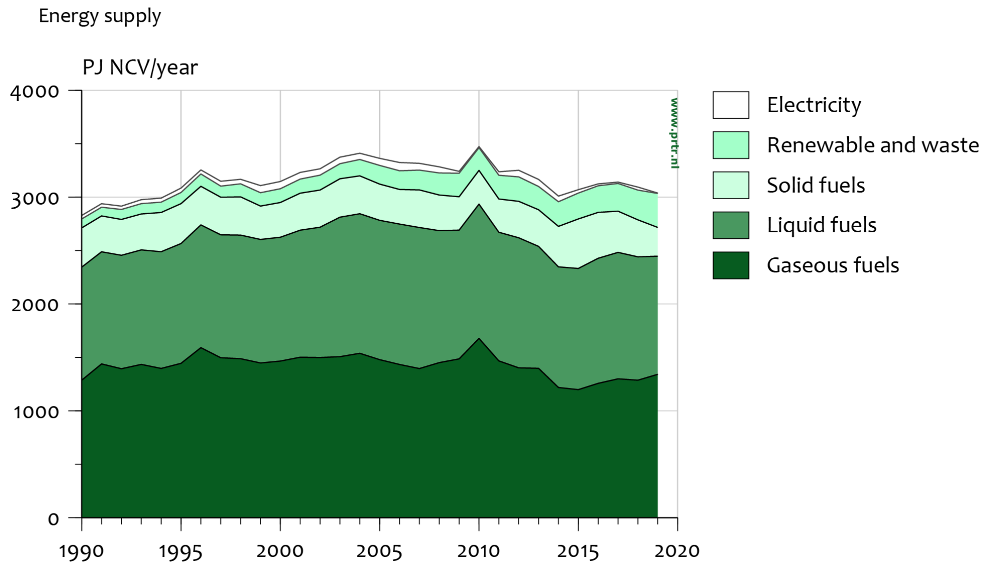

Figure 3.1 Energy supply in the Netherlands, 1990–2019 ('Electricity' refers to imported electricity only)

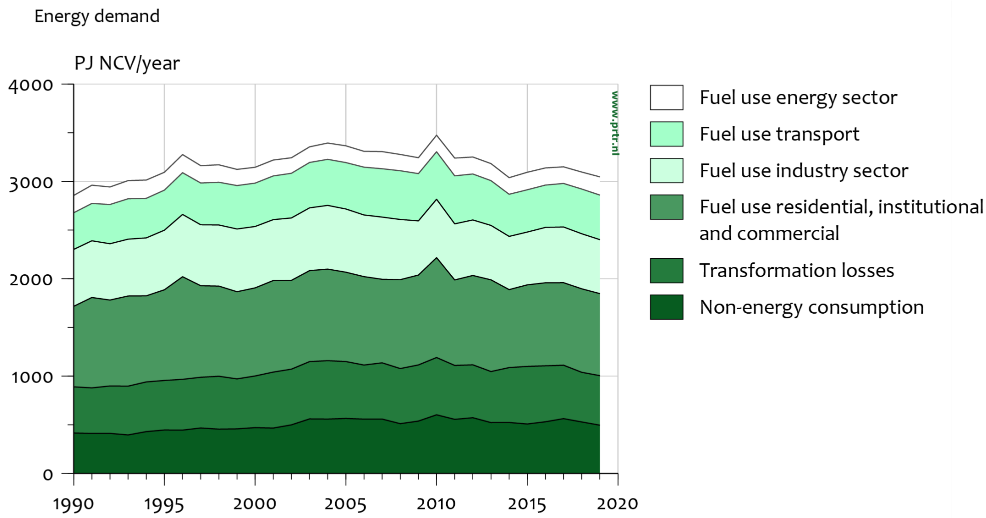

Figure 3.2 Energy demand in the Netherlands, 1990–2019

The energy statistics are available on the website of Statistics Netherlands. The following link refers to the energy statistics of 2019: [StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl)](). Using the button 'Change selection' on the website, it is possible to select the data for another year.

3.2 Public electricity and heat production (1A1a)

3.2.1 Source category description

In this sector, one source category is included: Public electricity and heat production (1A1a). This sector consists mainly of coal-fired power stations and gas-fired cogeneration plants, many of the latter being operated as joint ventures with industries. A relatively small amount of energy is generated by waste incineration plants in the Netherlands through energy recovery (see Honig *et al.*, 2021). All waste incineration plants recover energy and are included in NFR category 1A1a. Relative to several other countries in the EU, nuclear energy and renewable energy (biomass and wind) provide a small amount of the total primary energy supply in the Netherlands.

3.2.2 Key sources

The sector 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 2019 (%)**
1A1a	Public electricity and heat production	SO_x	12.0
		NO_x	6.3
		Hg	25.0
		HCB	3.0
		PCB	55.0

3.2.3 Overview of shares and trends in emissions

An overview of the trends in emissions is shown in Table 3.2. For almost all pollutants, emissions decreased between 1990 and 2019, while fuel consumption increased over the same period.

NO_x and SO_x emissions decreased by 82% and 94%, respectively. Other pollutant emissions decreased by at least 50%, except for NMVOC (-10%), Se (+175%) and NH_3. The overall decrease in emissions was partly caused by a shift in energy use, but also to technological improvements (especially the large decrease in dioxin emissions). The increase in NH_3 was due to an increase in activity rate. For Se, the increase by a factor of 7 between 1995 and 2000 was caused by environmental reports being considered for the later years, while for the earlier years little or no information was available.

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**	**0.00**	**8.35**
1995	62.1	1.65	16.9	0.04	0.39	0.63	0.99	0.00	7.56
2000	51.5	2.12	14.9	0.04	0.25	0.33	0.33	0.00	15.4
2005	43.4	0.91	9.93	0.26	0.40	0.54	0.82	0.00	8.27
2010	25.8	0.67	6.75	0.07	0.21	0.29	0.60	0.00	4.75
2015	20.5	0.70	8.65	0.12	0.30	0.40	0.78	0.00	4.42
2018	15.6	0.78	3.99	0.13	0.14	0.17	0.33	0.00	4.37
2019	**15.0**	**0.80**	**2.72**	**0.17**	**0.12**	**0.15**	**0.28**	**0.01**	**3.86**
1990–2019 period[1]	-67.9	-0.09	-45.7	0.17	-1.69	-2.06	-2.18	0.01	-4.48
1990–2019 period[2]	-82%	-10%	-94%		-93%	-93%	-89%		-54%

Table 3.3 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**	**0.50**	**0.68**	**2.05**	**2.49**	**0.02**	**40.7**
1995	1.56	0.16	0.39	6.09	0.06	0.20	0.37	0.44	1.41	0.05	3.34
2000	0.18	0.08	0.41	0.13	0.01	0.08	0.19	0.17	0.08	0.45	0.26
2005	0.24	0.09	0.40	0.76	0.01	0.16	0.33	0.28	1.91	1.68	0.52
2010	0.34	0.18	0.23	1.18	0.02	0.11	0.14	0.15	0.16	1.33	3.91
2015	0.16	0.03	0.23	1.01	0.03	0.06	0.16	0.18	0.17	0.91	4.07
2018	0.07	0.04	0.19	1.39	0.03	0.04	0.07	0.07	0.11	0.11	2.64
2019	**0.12**	**0.04**	**0.15**	**1.13**	**0.04**	**0.04**	**0.07**	**0.39**	**0.10**	**0.05**	**2.05**
1990–2019 period[1]	-16.2	-0.91	-1.79	-582	-0.14	-0.46	-0.61	-1.66	-2.39	0.03	-38.6
1990–2019 period[2]	-99%	-96%	-92%	-100%	-77%	-92%	-90%	-81%	-96%	175%	-95%

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

3.2.4 *Activity data and (implied) emission factors*

Emission data are based on AERs and collectively estimated industrial sources. For this source category, a large part of the emission figures are based on AERs: NO_x (98%), NMVOC (87%), SO_x (99%), NH_3 (55%) and $PM_{2.5}$ (83%). To estimate emissions from collectively estimated industrial sources, national energy statistics (from Statistics Netherlands) are combined with IEFs from the AERs or with default EFs (see Table 3.3).

Table 3.4 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	Biogas	Coal	Fuel oil	Wood
NMVOC	2.6[1]	8.45[4]	5[5]	4[6]	48[8]
Sulphur dioxide	0.281[1]	10[4]	300[6]	450[6]	10[8]
Nitrogen oxides as NO_2	21[2]	80[4]	150[7]	64[6]	120[8]
Ammonia					37[9]
Carbon monoxide	6[2]	20[4]	150[7]	10[6]	160[8]
PM_{10}	0.297[3]	2[4]	60[7]	42.5[6]	12[8]

1. EMEP/EEA Guidebook (2019), 1A1, table 4.6, average value.
2. Specific EFs derived from reported emissions in e-AERs.
3. EMEP/EEA Guidebook (2019), 1A1, table 4.6, minimum value.
4. Emission factor from biogas incineration by sewage treatment plants.
5. EF should have been 10 g/GJ (EMEP/EEA Guidebook 2019, 1A2, table 3.2 6. minimum value). Will be corrected in the 2022 data (impact is very small).
6. Methodology report of Guis (2006).
7. EMEP/EEA Guidebook (2019), 1A2, table 3.2, minimum value.
8. Koppejan and De Bree, 2018.
9. EMEP/EEA Guidebook (2019), 1A4, table 3.48, average value.

Emission data in AERs are calculated by companies based on stack measurements, or based on (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 obliged to use 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.

Emissions of PCB are not reported by individual companies and are therefore calculated for the entire sector. The activity data are taken from the energy statistics and can be accessed here: StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl). 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 Honig et al. (2021) for more details regarding the PCB EF.

Emissions of mercury from the use of natural gas are also not reported by individual companies and are therefore calculated for the entire sector. The activity data are taken from the energy statistics and can be accessed here: StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl). The mercury EF is based on a study from the Dutch gas company Gasunie and is 0.039 mg/GJ in 1990–2009, 0.023 mg/GJ in 2010–2016 and 0.01 mg/GJ from 2017 onwards.

HCB emissions are not reported by individual companies and are therefore calculated for the entire sector, with an EF of 0.2 mg/Mg waste.

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 and fuel);
- Ratios from literature, e.g. 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. (2021) and in Visschedijk & Dröge (2019). Their report can be downloaded via: Visschedijk & Dröge, 2019.

3.2.5 *Methodological issues*

Emissions are based on data in the AERs from individual facilities (Tier 3 methodology). Emissions and fuel consumption data in the AERs are systematically examined for inaccuracies by checking the resulting IEFs. If the AERs 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 emissions from companies that are not individually assessed.

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

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

Next, combustion emissions from 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 are insufficient to calculate an IEF, then a default EF is used (see Table 3.3).

$$\mathbf{ER\text{-}C\_emission}_{\mathbf{(NACE, fuel)}} = \mathbf{EF}_{\mathbf{ER\text{-}I\ (NACE, fuel)}} * \mathbf{energy\ statistics}_{\mathbf{(NACE, fuel)}}$$

where:
ER-C = Emission Registration database for collective emission sources

Total combustion emissions are the sum of emissions from the individual companies (ER-I) plus emissions from 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. If the AERs provide data of high enough quality (see Section 1.6 on QA/QC), the information is used.

3.2.8 *Source-specific recalculations*

The following recalculations were performed:

- In response to NECD review recommendation NL-1A4ci-2018-0001, mercury emissions from natural gas combustion have been calculated and added to the NFR tables (all years), resulting in an increase in Hg emissions of 9.15 kg in 1990 and 6.10 kg in 2018.
- Small corrections in reported emissions from individual companies for the period 2015–2018. For NO_x, this results in a change in NO_x emissions of +48.5 Mg in 2015, +38.4 Mg in 2016, -162.0 Mg in 2017 and -43.9 Mg in 2018. For other pollutants, these changes are much smaller.
- Energy statistics have been improved for the period 2015–2018, resulting in recalculated emissions. The changes are shown in the following table (in Mg):

Pollutant	NFR	2015	2016	2017	2018
NO_x	**1A1a**	+85.4	+74.4	+41.8	+37.6
NMVOC	**1A1a**	+9.7	+8.8	+5.2	+1.0
SO_x	**1A1a**	+1.0	+0.9	+0.6	+0.4
NH_3	**1A1a**	-	-	-	+0.4
$PM_{2.5}$	**1A1a**	+0.6	+0.5	+0.3	+0.4

3.2.9 *Source-specific planned improvements*

The error in the NMVOC EF for coal combustion (only for companies that did not report their emissions) needs to be corrected.

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

3.3.1 *Source category description*

This source category comprises the following subcategories:

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

3.3.2 *Key sources*

The sectors 1A1b, 1A1c, 1A2a, 1A2c and 1A2gviii are key sources of the pollutants listed in Table 3.4.

Table 3.5 Pollutants for which the Industrial combustion sector (NFR 1A1b, 1A1c and 1A2) is a key source

Category / Subcategory		**Pollutant**	**Contribution to total of 2019 (%)**
1A1b	Petroleum refining	SO_x	38
1A1c	Manufacture of solid fuels and other energy industries	PCB	29
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	SO_x CO NO_x	14 10 2.5
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	NO_x SO_x	3.7 6.4
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	SO_x Dioxin	10 15

3.3.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is shown in Table 3.5. 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 high emissions in 2019 are the result of the high reported emissions of one company. 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 3.6 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**	**6.26**	**110**	**0.57**	**5.84**	**7.79**	**8.21**	**0.41**	**266**
1995	77.8	6.74	88.9	0.32	5.01	6.53	6.75	0.39	215
2000	49.4	2.02	45.9	0.05	3.34	4.85	4.94	0.30	161
2005	49.3	2.01	46.3	0.11	1.41	1.83	2.03	0.12	156
2010	40.3	3.83	24.5	0.48	0.40	0.58	0.82	0.03	127
2015	34.9	2.85	19.9	0.45	0.35	0.48	0.63	0.02	97.9
2018	31.2	1.83	18.5	0.49	0.34	0.50	0.64	0.01	88.9
2019	**30.5**	**2.20**	**17.7**	**0.50**	**0.35**	**0.51**	**0.65**	**0.01**	**93.7**
1990–2019 period[1]	-70.2	-4.06	-92.3	-0.07	-5.48	-7.28	-7.56	-0.40	-173
1990–2019 period[2]	-70%	-65%	-84%	-13%	-94%	-93%	-92%	-97%	-65%

Table 3.7 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	**1.90**	**0.14**	**0.20**	**0.01**	**0.99**	**0.17**	**2.57**	**1.42**	**67.1**	**0.05**	**2.96**
1995	3.90	0.17	0.10	1.02	0.38	0.16	3.18	2.17	80.5	0.05	3.52
2000	0.06	0.01	0.12	0.35	0.005	0.00	0.54	0.16	18.1	0.00	0.89
2005	0.04	0.01	0.03	0.84	0.01	0.78	0.10	0.11	6.64	0.09	0.60
2010	3.11	0.01	0.04	5.70	0.05	0.02	0.18	1.15	0.23	0.14	9.90
2015	0.11	0.01	0.07	0.11	0.02	0.00	0.04	0.02	0.16	0.02	1.28
2018	0.03	0.00	0.05	0.01	0.02	0.00	0.03	0.02	0.11	0.02	0.21
2019	**0.02**	**0.00**	**0.05**	**6.03**	**0.01**	**0.00**	**0.04**	**0.02**	**0.18**	**0.02**	**0.20**
1990–2019 period[1]	-1.88	-0.14	-0.15	6.02	-0.98	-0.16	-2.53	-1.40	-66.9	-0.02	-2.76
1990–2019 period[2]	-99%	-97%	-76%	+70582%	-99%	-97%	-99%	-99%	-100%	-51%	-93%

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

3.3.4 *Activity data and (implied) emission factors*

Petroleum refining (1A1b)
All emission data are based on AERs.

Manufacture of solid fuels and other energy industries (1A1c)
Emission data are based on AERs and collectively estimated industrial sources.

Iron and steel (1A2a)
Emission data are mainly based on AERs. A small part is based on collectively estimated industrial sources (8% of CO emissions and 1% of SO_x emissions in 2019).

Non-ferrous metals (1A2b)
Emission data are based on AERs and collectively estimated industrial sources. For this source category, 7% of the NMVOC emissions, 9% of the NO_x emissions, 9% of the SO_x emissions and 4% of $PM_{2.5}$ emissions were collectively estimated (in 2019).

Chemicals (1A2c)
Emission data are based on AERs and collectively estimated industrial sources. For this source category, 2% of the NMVOC emissions, 3% of the NO_x emissions, 3% of the SO_x emissions, and 2% of the $PM_{2.5}$ emissions were collectively estimated (in 2019).

Pulp, paper and print (1A2d)
Emission data are based on AERs and collectively estimated industrial sources. For this source category, 72% of the NMVOC emissions, 8% of the NO_x emissions, 1% of the SO_x emissions and 100% of the $PM_{2.5}$ emissions were collectively estimated (in 2019).

Food processing, beverages and tobacco (1A2e)
Emission data are based on AERs and collectively estimated industrial sources. For this source category, 25% of the NMVOC emissions, 36% of the NO_x emissions, 68% of the SO_x emissions and 98% of the $PM_{2.5}$ emissions were collectively estimated (in 2019).

Non-metallic minerals (1A2f)
Emission data are based on AERs and collectively estimated industrial sources. Emissions from non-metallic minerals were allocated to 1A2gviii.

Other (1A2gviii)
This sector includes all combustion emissions from the industrial sectors that do not belong to the categories 1A2a to e1A2e. Emission data are based on AERs and collectively estimated industrial sources. For this source category, 48% of the NMVOC emissions, 24% of the NO_x emissions, 1% of the SO_x emissions and 46% of the $PM_{2.5}$ emissions were collectively estimated (in 2019).

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 3.6).

Table 3.8 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]	8.45[6]	5[7]	4[8]	5.6[10]	1.07[10]
Sulphur dioxide	0.281[2]	10[6]	300[8]	450[8]	10[10]	10[10]
Nitrogen oxides as NO_2	[3]	80[6]	150[9]	64[8]	150[10]	120[10]
Ammonia					37[11]	37[11]
Carbon monoxide	[4]	20[6]	150[9]	10[8]	750[10]	160[10]
PM_{10}	0.297[5]	2[6]	60[9]	25[8]	27[10]	12[10]

1. For 1A2b, 1A2c and 1A2d, an EF from the Guidebook is used of 2.6 g/GJ (EMEP/EEA Guidebook (2019), 1A1, table 4.6, average value). For 1A2e, 1A2f and 1A2g, a specific EF is used of 3.8, 2.0, 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, 1A2f and 1A2g, a specific EF is used of 21, 55, 37, 43, 30, 40 and 37 g/GJ, respectively (derived from emissions reported in eAERs);
4. For 1A2b, an EF from the Guidebook is used of 23.6 g/GJ (EMEP/EEA Guidebook (2019), 1A1, table 4.6, minimum value). For 1A2c, 1A2d, 1A2e, 1A2f and 1A2g, a specific EF is used of 21, 39.3, 40, 30 and 50 g/GJ, respectively (derived from emissions reported in eAERs).
5. EMEP/EEA Guidebook (2019), 1A1, table 4.6, minimum value.
6. EF from biogas incineration by sewage treatment plants.
7. EF should have been 10 g/GJ (EMEP/EEA Guidebook 2019, 1A2, table 3.2 minimum value). Will be corrected in the 2022 data (impact is very small).
8. Methodology report of Guis (2006).
9. EMEP/EEA Guidebook (2019), 1A2, table 3.2, minimum value.
10. Koppejan and De Bree (2018).
11. EMEP/EEA Guidebook (2019), 1A4, table 3.48, average value.

Emissions of PCB are not reported by individual companies and are therefore calculated for the entire sector. The activity data are taken from the energy statistics and can be accessed here: [StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl)](). 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 Honig *et al.* (2021) for more details regarding the PCB EF.

Emissions of mercury from the use of natural gas are also not reported by individual companies and are therefore calculated for the entire sector. The activity data are taken from the energy statistics and can be accessed here: StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl). The mercury EF is based on a study from the Dutch gas company Gasunie and is 0.039 mg/GJ in 1990–2009, 0.023 mg/GJ in 2010–2016 and 0.01 mg/GJ from 2017 onwards.

Emissions of heavy metals 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 are used. If the allocated emission is above the reporting threshold, then 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.*, 2021).
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 for most years only reported in 2C1.

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 and fuel);
- ratios from literature, e.g. Visschedijk *et al.* (2004) and Ehrlich *et al.* (2007).

See Honig et al. (2021) 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). Their report can be downloaded via: Visschedijk & Dröge, 2019.

3.3.5 *Methodological issues*

Emissions are based on data in the AERs from individual facilities (Tier 3 methodology). 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 from companies that are not individually assessed.

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

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

Next, combustion emissions from 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 are insufficient to calculate an IEF, then a default EF is used (see Table 3.6).

$$\mathbf{ER\text{-}C\_emission}_{\text{(NACE, fuel)}} = \mathbf{EF}_{\text{ER-I (NACE, fuel)}} * \mathbf{energy\ statistics}_{\text{(NACE, fuel)}}$$

where:
ER-C = Emission Registration database for collective emission sources

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

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, then the emissions are calculated as collectively estimated industrial sources, based on 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. In order to ensure a consistent time series, these emissions have also been calculated from the energy statistics combined with EFs from the EMEP/EEA Guidebook (2019). A more detailed description of the methodology is available in chapter 3.1.2.2 of the ENINA methodology report (Honig *et al.*, 2021).

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:

- Reallocation of cadmium emissions of 1 chemical company from 1A2c to 2B10a for the years 1998 and 2008–2012, because this mainly consist of process emissions. For 2010, this results in a reallocation of 1,282 kg Cadmium.
- Emissions of heavy metals have been calculated for the sectors 1A1b, 1A2b, 1A2c and 1A2gviii for companies that did not report these emissions for the period 2003–2019 (for all fuels except natural gas). Mercury emissions from natural gas combustion have been calculated for all years and added to the NFR tables. The recalculation of these emissions resulted in an increase in heavy metal emissions, as presented in Table 3.7.

Table 3.7 Heavy metal emissions 1990–2018 (kg)

Pollutant	NFR	1990	2005	2010	2015	2018
As	1A1b		1.0	2.1	2.6	2.4
	1A2b		0.0	0.0		
	1A2c		0.3	0.6	0.5	0.6
	1A2gviii		0.5	0.5	0.4	0.4
Cd	1A1b		4.0	4.4	4.5	4.4
	1A2b		0.0	0.0		
	1A2c		0.0	0.0	0.0	0.0
	1A2gviii		0.9	0.9	0.6	0.5
Cr	1A1b		17.1	26.0	31.3	28.0
	1A2b		0.0	0.0		
	1A2c		0.1	0.1	0.1	0.1
	1A2gviii		2.9	2.8	2.2	2.0
Cu	1A1b		21.0	13.6	16.5	14.9
	1A2b		0.0	0.0		
	1A2c		0.0	0.0	0.0	0.0
	1A2gviii		1.0	0.9	2.1	2.1
Hg	1A1b		4.0	5.0	5.0	4.8
	1A2b	0.1	0.3	0.3	0.1	0.0
	1A2c	9.1	13.4	11.0	12.0	9.4
	1A2gviii	2.2	3.2	2.3	2.0	1.5
Pb	1A1b		13.0	7.7	9.4	8.7
	1A2b		0.0	0.0		
	1A2c		0.0	0.0	0.0	0.0
	1A2gviii		17.7	17.9	15.1	15.5
Ni	1A1b		141.3	41.4	45.9	24.2
	1A2b		0.0	0.0		
	1A2c		0.1	0.1	0.1	0.1
	1A2gviii		1.7	1.7	1.7	1.5

Pollutant	NFR	1990	2005	2010	2015	2018
Se	1A1b		7.4	16.9	21.1	19.9
	1A2b		0.0	0.0		
	1A2c		0.6	0.7	0.6	0.7
	1A2gviii		0.5	0.2	0.4	0.4
Zn	1A1b		32.9	65.6	79.2	70.4
	1A2b		0.2	0.2		
	1A2c		7.6	7.9	4.9	4.4
	1A2gviii		52.0	10.7	37.6	34.1

- Emissions of NO_x, SO_x and CO from the iron and steel sector have been reallocated from 2C1 to 1A2a for the complete time series, because these pollutants result from combustion. In 2018, this results in a change in emissions in 1A2a of +5487.4 Mg NO_x, +3004.5 Mg SO_x and +52,558.1 Mg CO. For other years (1990–2005), the changes are much smaller.
- Small corrections were made in reported emissions from individual companies for 2018. In 2018, this results in a change in emissions of -63.8 Mg NO_x in 1A2e, +1.6 Mg SO_x in 1A2e, -3.5 Mg NMVOS in 1A2c and -27.3 Mg CO in 1A2c.
- Energy statistics have been improved for the period 2015–2018, resulting in recalculated emissions; the changes are shown in Table 3.8.

Table 3.8 Energy statistics improvements, 2015–2018 (Mg)

Pollutant	NFR	2015	2016	2017	2018
NO_x	1A1c	-	-	-	58.3
	1A2b	-	-21.0	-46.4	-28.6
	1A2c	32.1	-55.5	-112.3	-16.0
	1A2d	-11.2	-23.4	-41.9	18.5
	1A2e	-264.3	-236.7	-160.5	-147.0
	1A2gviii	48.9	41.0	-15.0	-27.5
NMVOC	1A2b	-	-1.0	-2.2	-1.3
	1A2c	2.3	-1.5	-8.7	-0.5
	1A2d	-0.7	-1.3	-2.5	1.2
	1A2e	-30.7	-28.4	-24.9	-23.2
	1A2gviii	4.5	2.6	-6.6	-1.2
SO_x	1A2b	-	-0.1	-0.2	-0.1
	1A2c	0.3	-0.2	-0.9	-0.1
	1A2d	-0.1	-0.1	-0.3	0.1
	1A2e	51.5	70.2	96.5	96.6
	1A2gviii	0.4	0.4	-1.7	-4.1
NH_3	1A2gviii	-0.0	-0.0	-6.6	-16.2
$PM_{2.5}$	1A2b	-	-0.1	-0.3	-0.2
	1A2c	0.2	-0.2	-0.8	-0.1
	1A2d	-0.1	-0.1	-0.3	0.1

Pollutant	NFR	2015	2016	2017	2018
	1A2e	5.0	6.9	9.5	9.6
	1A2gviii	0.4	0.3	-4.0	-10.5

3.3.9 *Source-specific planned improvements*

The error in NMVOC EF of coal combustion (only for companies that did not report their emissions) needs to be corrected.

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

3.4.1 *Source-category description*

This source category comprises the following subcategories:

- 1A4ai Commercial/Institutional: Stationary. This sector 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 waste-water treatment plants.
- 1A4bi Residential: Stationary. This sector 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 sector comprises stationary combustion emissions from agriculture, horticulture, greenhouse horticulture, cattle breeding and forestry.
- 1A5a Other: Stationary. There are no emissions reported in this sector

3.4.2 *Key sources*

The Small combustion sector is a key source of the pollutants listed in Table 3.9.

Table 3.9 Pollutants for which the Small combustion sector (NFR 1A4 and 1A5) is a key source

Category / Subcategory	Pollutant	Contribution to total of 2019 (%)
1A4bi Residential: Stationary	NO_x	2.6
	NMVOC	3.6
	CO	10
	PM_{10}	17
	$PM_{2.5}$	29
	BC	21
	Dioxins	14
	PAH	69
	Hg	5.7
1A4ci Agriculture/forestry/fishing: Stationary	NO_x	2.7

3.4.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is shown in Table 3.10. 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 onward 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 3.10 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	**42.2**	**14.2**	**2.15**	**0.35**	**7.36**	**7.74**	**8.34**	**0.95**	**82.3**
1995	45.3	14.5	1.37	0.35	7.27	7.68	8.23	0.95	86.0
2000	39.8	13.4	0.86	0.30	6.69	7.09	7.58	0.86	82.0
2005	35.9	13.3	0.67	0.29	6.55	6.95	7.42	0.82	84.0
2010	36.7	12.3	0.74	0.30	6.23	6.60	7.02	0.75	86.8
2015	24.6	10.6	0.58	0.29	5.35	5.68	6.01	0.62	75.8
2018	19.5	9.7	0.62	0.35	4.84	5.14	5.43	0.55	70.0
2019	**17.5**	**9.3**	**0.64**	**0.37**	**4.64**	**4.92**	**5.20**	**0.52**	**67.1**
1990–2019 period[1]	-24.7	-4.92	-1.51	0.02	-2.72	-2.81	-3.14	-0.43	-15.1
1990–2019 period[2]	-59%	-35%	-70%	5%	-37%	-36%	-38%	-45%	-18%

Table 3.10 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	**0.78**	**0.07**	**0.14**	**108**	**3.70**	**0.05**	**3.52**	**0.71**	**1.98**	**0.00**	**2.00**
1995	0.13	0.04	0.07	7.49	3.88	0.02	0.05	0.33	0.53	0.00	0.77
2000	0.08	0.05	0.05	6.99	3.79	0.01	0.01	0.31	0.23	0.00	0.69
2005	0.08	0.05	0.05	7.01	3.97	0.00	0.01	0.35	0.23	0.00	0.74
2010	0.09	0.05	0.05	6.91	4.05	0.01	0.00	0.38	0.01	0.00	0.83
2015	0.08	0.05	0.04	6.31	3.70	0.00	0.00	0.36	0.00	0.00	0.78
2018	0.08	0.05	0.04	5.94	3.42	0.00	0.00	0.36	0.00	0.00	0.77
2019	**0.08**	**0.05**	**0.04**	**5.77**	**3.30**	**0.00**	**0.00**	**0.36**	**0.00**	**0.00**	**0.77**
1990–2019 period[1]	-0.70	-0.01	-0.10	-102	-0.40	-0.05	-3.5	-0.36	-1.98	0.00	-1.24
1990–2019 period[2]	-89%	-21%	-74%	-95%	-11%	-94%	-100%	-50%	-100%	-99%	-62%

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

3.4.4 *Activity data and (implied) emission factors*

Commercial/institutional (1A4ai)

Combustion emissions from the commercial and institutional sectors are based on fuel consumption data (from Statistics Netherlands) and EFs (see Table 3.11).

Table 3.11 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]	8.45[7]	10[12]	0.1[9]	16[10]
Sulphur dioxide	0.2[2]	10[7]	94[4]	450[3]	10[10]
Nitrogen oxides as NO_2	35.9[8]	80[7]	60[5]	150[3]	122[10]
Ammonia					37[6]
Carbon monoxide	15[2]	20[7]	30[12]	150[3]	150[10]
PM_{10}	0.28[11]	2[7]	4.5[12]	60[3]	38[6]

1. EMEP/EEA Guidebook (2019), 1A4, table 3.27, average 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, average value.
5. EMEP/EEA Guidebook (2019), 1A4, table 3.9, close to the minimum value.
6. EMEP/EEA Guidebook (2019), 1A4, table 3.48, average value.
7. EF from biogas incineration by sewage treatment plants.
8. For the years prior to 2005, see NO_x EF table in Visschedijk et al. (2007). From 2005 onwards the NO_x EF decreases due to the further implementation of low NO_x technologies (EF2005: 55.8 to EF2019: 35.9).
9. EF should have been 10 g/GJ (EMEP/EEA Guidebook 2019, 1A4, table 3.7, minimum value). Will be corrected in the 2022 data (impact is very small).
10. Methodology report of Guis (2006).
11. EF should have been 0.27 g/GJ (EMEP/EEA Guidebook 2019, 1A4, table 3.27, minimum value). Will be corrected in the 2022 data (impact is very small).
12. EFs should have been 20 g NMVOC/GJ, 93 g CO/GJ and 21 g PM_{10}/GJ (EMEP/EEA Guidebook 2019, 1A4, table 3.9, average value). Will be corrected in the 2022 data (impact is very small).

3.4.5 *Residential (1A4bi)*

Combustion emissions from central heating, hot water and cooking are based on fuel consumption data (from Statistics Netherlands) and EFs (see Table 3.12). The fuel most used in this category is natural gas. The use of wood in stoves and fireplaces for heating is almost negligible compared with the amount of natural gas used.
Combustion emissions from (wood) stoves and fireplaces were calculated by multiplying the fuel consumption per apparatus 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 3.13. EFs for charcoal combustion in barbecues are also included in this table.

Table 3.9 Emission factors for combustion emissions from households (g/GJ)

Substance name	Natural gas (heating)	Natural gas (cooking)	Diesel	LPG	Petroleum	Coal
NMVOC	1.6[1]	2.0[2]	8.5[5]	1.3[7]	5[5]	30[6]
Sulphur dioxide	0.3[1]	0.3[2]	70[3]	0[7]	70[3]	450[4]
Nitrogen oxides as NO_2	15[8]	57[8]	51[3]	40[7]	51[3]	150[4]
Carbon monoxide	22[1]	30[2]	57[3]	10[7]	57[3]	2000[4]
PM_{10}	0.28[1]	2.2[2]	1.9[3]	2[7]	1.9[3]	240[4]

1. EMEP/EEA Guidebook (2019), 1A4, table 3.16, average value.
2. EMEP/EEA Guidebook (2019), 1A4, table 3.13, average value.
3. EMEP/EEA Guidebook (2019), 1A4, table 3.5, average value.
4. EMEP/EEA Guidebook (2019), 1A4, table 3.19, average value.
5. EF should have been 0.69 g/GJ (EMEP/EEA Guidebook 2019, 1A4, table 3.5 average value). Will be corrected in the 2022 data (impact is very small).
6. EF should have been 300 g/GJ (EMEP/EEA Guidebook 2019, 1A4, table 3.19 average value). Will be corrected in the 2022 data (impact is very small).
7. Methodology report of Guis (2006).
8. See Kok (2014).

Table 3.10 Emission factors for wood combustion in households

Substance	Unit	Fireplace	Conventional stove	Improved stove	Ecolabelled stove	Pellet	Barbecues (charcoal)
NMVOC	g/GJ	1,290	774	387	252	10	250
SO_x	g/GJ	12.9	12.9	12.9	12.9	12.9	10
NO_x	g/GJ	77.4	129.0	129.0	129.0	80.0	50
NH_3	g/GJ	29.4	29.4	1.47	1.47	0.29	
CO	g/GJ	3,226	6,452	3,871	2903	300	6,000
PM_{10}	g/GJ	670	534	233	97.0	60.0	150
$PM_{2.5}$	g/GJ	637	507	221	93.0	60.0	75
$EC_{2.5}$	g/GJ	76.4	73.3	27.5	10.3	9.0	
Pb	mg/GJ	4.71	4.71	4.71	4.71	4.71	
Cd	mg/GJ	3.23	3.23	3.23	3.23	3.23	
Hg	mg/GJ	1.94	1.94	1.94	1.94	1.94	
Dioxin	ng/GJ	1,613	174	174	174	100	150
PAH4	mg/GJ	193.5	343.9	221.3	172.3	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. (2021).

Agriculture/forestry/fishing (1A4ci)

Stationary combustion emissions are based on fuel consumption obtained from Statistics Netherlands, whose figures are in turn based on data from Wageningen Economics Research and default EFs (Table 3.14).

Table 3.11 Agriculture/Forestry/Fishing sectors (g/GJ)

Substance name	Natural gas	Biogas	LPG	Wood
NMVOC	2.0[1]	8.45[4]	1.3[5]	16[3]
Sulphur dioxide	0.2[2]	10[4]	0[5]	11[3]
Nitrogen oxides as NO_2	61/41.6[8]	80[4]	40[5]	80[3]
Ammonia				37[7]
Carbon monoxide	15[2]	20[4]	10[5]	170[3]
PM_{10}	0.2[6]	2[4]	0.3[5]	17[3]

1. EMEP/EEA Guidebook (2019), 1A4, table 3.27, average value.
2. EMEP/EEA Guidebook (2019), 1A4, table 3.27, minimum value.
3. From 'Kennisdocument Houtstook in Nederland' (Koppejan and De Bree, 2018).
4. Emission factor from biogas incineration by sewage treatment plants.
5. Methodology report Zonneveld (Guis, 2006).
6. EF should have been 0.27 g/GJ (EMEP/EEA Guidebook 2019, 1A4, table 3.27 minimum value). Will be corrected in the 2022 data (impact is very small).
7. EMEP/EEA Guidebook (2019), 1A4, table 3.48, average value.
8. The EF of 61 g/GJ is used for gas engines (source: Hulskotte, 2017), while the EF of 41.6 is used for boilers (source: Guis, 2006).

Emissions of PCB are not reported by individual companies and are therefore calculated for the entire sector. The activity data are taken from the energy statistics and can be accessed here: StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl).
The PCB EF of bituminous coal in 1A4 is from the EMEP/EEA Guidebook (2019), chapter 1A4, table 3.7. The PCB EF of solid biomass is from the EMEP/EEA Guidebook (2019), tables 3.39–3.43.

Emissions of mercury from the use of natural gas are also not reported by individual companies and are therefore calculated for the entire sector. The activity data are taken from the energy statistics and can be accessed here: StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl). The mercury EF is based on a study from the Dutch gas company Gasunie and is 0.039 mg/GJ in 1990–2009, 0.023 mg/GJ in 2010–2016 and 0.01 mg/GJ from 2017 onwards.

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 and fuel);
- ratios from literature, e.g. Visschedijk *et al.* (2004) and Ehrlich *et al.* (2007).

See Honig et al. (2021) 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). Their report can be downloaded via: Visschedijk & Dröge, 2019.

3.4.6 *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).

3.4.7 *Uncertainties and time series consistency*

Uncertainties are explained in Section 1.7.

Time series consistency

The activity data in the NFR tables are based on data from individual companies and collectively estimated emission sources. Most of the emissions are also calculated from these activity data.
There are two exceptions: Both the emissions of PCB from bituminous coal and solid biomass, and the emissions of mercury 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: StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl).

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

3.4.8 *Source-specific QA/QC and verification*

General QA/QC is explained in Section 1.3.

3.4.9 *Source-specific recalculations*

The following recalculations were performed:

- The particulate matter EF from wood combustion was updated. In the previous submission, this EF included only the filterable fraction of particulate matter. The 2021 submission includes both the filterable and the condensable fraction, to ensure that all PM emissions are included in the inventory. A more detailed description can be found in Visschedijk et al. (2021). This results in a change in PM2.5 emissions of 4,516 Mg in 1990, +4,040 Mg in 2005, +3,757 Mg in 2010, +3,213 Mg in 2015 and +2,841 Mg in 2018 in category 1A4bi.
- Particulate matter emissions from meat preparation have been calculated and included in 1A4bi in the 2021 submission for the first time, as these emissions had not been calculated before. This results in a change in PM2.5 emissions of +191.4 Mg in 1990, +209.0 Mg in 2005 and +211.6 Mg in 2018. The methodology is described in Visschedijk et al. (2021)
- In response to NECD review recommendation NL-1A5a-2017-0001, emissions of flaring of landfill gas have been reallocated from 1A5a to 5A. In this submission, no emissions are reported in category 1A5a.
- In response to NECD review recommendation NL-1A4ci-2018-0001, Mercury emissions from natural gas combustion have been calculated and added to the NFR tables (all years), resulting in an increase in Hg emissions of 24.0 kg in 1990, 24.2 kg in 2005 and 5.4 kg in 2018 (in 1A4ai, 1A4bi and 1A4ci together).

– Energy statistics have been improved for the period 2015–2018, resulting in recalculated emissions, as presented in Table 3.15.

Table 3.15 Energy statistics improvements, 2015–2018 (Mg)

Pollutant	NFR	2015	2016	2017	2018
NO_x	1A4ai	-51.2	+203.3	+289.4	+95.4
	1A4bi	+0.0	+0.0	-0.0	+0.6
	1A4ci	-46.4	-57.9	+31.9	+277.7
NMVOC	1A4ai	-3.0	+12.8	+16.0	+6.6
	1A4bi	+0.0	+0.0	-0.0	+0.1
	1A4ci	-0.9	-1.3	+0.7	+12.7
SO_x	1A4ai	-2.2	+0.5	+1.3	-3.3
	1A4bi	+0.0	+0.0	-0.0	+1.9
	1A4ci	-0.1	-0.1	-0.5	+0.9
NH_3	1A4ai	-0.0	+0.0	-	-0.8
	1A4bi	-	-	-	-
	1A4ci	-0.0	+0.0	-	-1.9
$PM_{2.5}$	1A4ai	-0.4	+1.4	+2.1	-0.2
	1A4bi	+0.0	+0.0	-0.0	+0.9
	1A4ci	-0.1	-0.2	+0.0	+1.1

3.4.10 *Source-specific planned improvements*

Error correction for some of the EFs (see notes to Tables 3.11–3.13).

3.5 Fugitive emissions (1B)

3.5.1 *Source category description*

This source 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 period 1990–1999, 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 between iron/steel and coke production. Therefore, from 2000 onwards, no emissions have been allocated to 1B1b.

3.5.2 *Key sources*

None of the sectors in 1B is a key category. Table 3.16 shows the main sources and pollutants in this sector.

Table 3.12 Main sources and pollutants in the Fugitive emissions sector category NFR 1B.

Category / Subcategory	Pollutant	Contribution to total of 2019 (%)
1B2aiv Refining	NMVOC	1.0
1B2av Distribution of oil products	NMVOC	1.6
1B2b Fugitive emissions from natural gas	NMVOC	1.1

3.5.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is shown in Table 3.17. Emissions of NMVOC decreased between 1990 and 2018.

Table 3.13 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	**0.00**	**47.4**	**0.00**	**0.01**	**0.11**	**0.19**	**0.57**	**0.00**	**0.00**
1995	0.00	33.5	0.02	0.01	0.14	0.21	0.38	0.00	0.00
2000	0.00	29.2	0.00	0.00	0.07	0.10	0.10	0.00	0.00
2005	0.00	20.8	0.00	0.00	0.07	0.10	0.11	0.00	0.00
2010	0.00	15.3	0.00	0.00	0.00	0.00	0.01	0.00	0.00
2015	0.00	14.3	0.00	0.00	0.05	0.05	0.05	0.00	0.00
2018	0.00	9.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2019	**0.00**	**8.7**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1990–2019 period[1]	0.00	-38.6	0.00	-0.01	-0.11	-0.18	-0.56	0.00	0.00
1990–2019 period[2]		-82%		-87%	-98%	-98%	-99%		

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

3.5.4 *Activity data and (implied) emission factors*

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

3.5.5 *Methodological issues*

Fugitive NMVOC emissions from 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). These reported emissions are based on both measurements and calculations, and are checked by the competent authority. They include emissions from venting and flaring by refineries. The companies report emissions per fuel (including the amount of fuel), and process emissions (without any activity data). Emissions reported with fuel are assumed to be combustion emissions and included in 1A1b, while emissions reported without fuel are assumed to be fugitive emissions and are reported in 1B2aiv.
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., 2021).
- Emissions from aircraft refuelling are based on 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 Schiphol airport. A detailed description of the methodology is available in the Transport methodology report (Geilenkirchen et al., 2021a)
- Emissions from refinery processes are based on environmental reports from individual companies. The companies report emissions per fuel (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, 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 CH4 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.* (2021).

Emissions from venting and flaring are included in 1B2aiv (venting and flaring in refineries) and in 1B2b (venting and flaring from oil and gas extraction).

Other fugitive emissions from category 1B2d are not estimated. Whilst the EMEP/EEA 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 1.6.

3.5.8 *Source-specific recalculations*

- Mercury emissions from natural gas combustion have been calculated and added to the NFR tables (all years), resulting in an increase in Hg emissions of 0.7 kg in 1990, 1.7 kg in 2005 and 0.5 kg in 2018 (in 1B2aiv).

- The activity data and the EF for aircraft refuelling have been updated. For the activity data, statistics from Statistics Netherlands that include all airports have been used. An error was found in the EF and this has been corrected. Together, this results in a change in NMVOC emissions of -21.1 Mg in 1990, -48.3 Mg in 2005 and -0.05 Mg in 2018. The methodology is described in more detail in Geilenkirchen *et al.* (2021a).
- Small corrections have been made in reported emissions from operators for 2018. For NMVOC, this results in a change in NMVOC emissions of -52.6 Mg in 2018.

3.5.9 Source-specific planned improvements

There are no 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), as shown 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 different 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*. (2021a), supplemented by tables with detailed emission and activity data, and the EFs used in the emission calculations (Geilenkirchen *et al*., 2021b).

4.1.1 Key sources

The source categories within the Transport sector are key sources of various pollutants, as shown in Table 4.2. The percentages in Table 4.2 relate to the 2019 level assessment and the 1990–2019 trend assessment (in italics). Some source categories are key sources for both the trend and the 2019 level assessments. In those cases, Table 4.2 shows the percentage from the assessment in which the contribution of the source category was highest. The full results of the key source analysis are presented in Annex 1.

Table 4.2 Key source analysis for the Transport sector

NFR code	Source category description	SO_2	NO_x	NMVOC	CO	PM_{10}	$PM_{2.5}$	BC	Pb[3]
1A3ai(i)	International aviation LTO (civil)		2.9%						14.2%
1A3aii(i)	Domestic aviation LTO (civil)								
1A3bi	Passenger cars	*3.7%*	19.8%	*13.1%*	48.4%	*7.9%*	*9.9%*	*16.5%*	*44.7%*[3]
1A3bii	Light-duty vehicles		8.1%		*10.7%*	*5.3%*	*6.5%*	12.9%	
1A3biii	Heavy-duty vehicles and buses	6.8%	14.0%	*2.1%*[2]		*9.2%*	*11.8%*	*23.1%*	
1A3biv	Mopeds and motorcycles			4.3%	11.6%				
1A3bv	Gasoline evaporation			*6.0%*					
1A3bvi	Automobile tyre and brake wear					5.7%	[1]		6.6%[3]
1A3bvii	Automobile road abrasion					4.6%			
1A3c	Railways								5.1%[2]
1A3di(ii)	International inland waterways		6.0%			1.5%	2.6%	9.8%	
1A3dii	National navigation (shipping)		5.4%				2.1%	*7.7%*	
1A2gvii	Mobile combustion in manufacturing industries and construction		4.2%			1.5%[2]	2.6%	8.8%	
1A4aii	Commercial/institutional: mobile								
1A4bii	Residential: household and gardening (mobile)				*11.2%*				
1A4cii	Agriculture/forestry/fishing: off-road vehicles and other machinery		3.2%				[1]	6.4%	
1A4ciii	Agriculture/forestry/fishing: National fishing	[1]	3.4%						
1A5b	Other, mobile (including military, land based and recreational boats)				6.3%				

Percentages in italics and underlined are from the trend contribution calculation.
1. No longer a key source (cf. IIR 2020).
2. New key source (cf. IIR 2020).
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 cycles (LTO) 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 civil aviation source category 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 not part of the national emission totals and were not estimated. Due to the small size of the country, there is hardly any domestic aviation in the Netherlands. The split in 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.

4.2.2 Key sources

Civil aviation is a key source of Pb (2019 level) and of NO_x and PB (1990–2019 trend) 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, more than doubled between 1990 and 2016, increasing from 4.5 to 10.6 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. (2021a and 2021 b)). Fuel consumption (LTO) at Amsterdam Airport Schiphol more than doubled between 1990 and 2008. After a 9% decrease in 2009 due to the economic 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.

The trends in emissions from civil aviation in the Netherlands are shown in Table 4.3. The increase in air transport and related fuel consumption has led to 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 doubled between 1990 and 2019, following the trend in fuel consumption. PM_{10} emissions from civil aviation have seen an increase 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.

Table 4.3 Trends in emissions from 1A3a Civil aviation

	Main pollutants			Particulate matter				Other	Priority heavy metals
	NO_x	NMVOC	SO_x	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Mg
1990	**1.2**	**0.4**	**0.1**	**0.03**	**0.04**	**0.04**	**0.02**	**3.57**	**1.9**
1995	1.8	0.3	0.1	0.03	0.04	0.04	0.02	4.06	2.0
2000	2.3	0.3	0.2	0.04	0.04	0.04	0.02	3.78	1.6
2005	2.8	0.3	0.2	0.04	0.05	0.05	0.02	4.12	1.1
2010	2.9	0.3	0.2	0.04	0.05	0.05	0.02	4.21	1.3
2015	3.4	0.4	0.3	0.04	0.05	0.05	0.02	4.07	0.8
2018	3.8	0.4	0.3	0.03	0.05	0.05	0.01	4.30	0.8
2019	**3.8**	**0.4**	**0.3**	**0.03**	**0.05**	**0.05**	**0.01**	**4.37**	**0.7**
1990-2019 period[1]	2.6	0.0	0.2	0.00	0.01	0.01	-0.01	0.80	-1.1
1990-2019 period[2]	206%	6%	174%	0%	21%	21%	-47%	22%	-61%

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

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 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 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 in the Netherlands were calculated using a flight-based Tier 3 methodology. Specific data were used for the number of aircraft movements per aircraft type and per airport, which were derived from the airports and from Statistics Netherlands. These data were used in the CLEO model (Dellaert & Hulskotte, 2017b) to calculate LTO fuel consumption and resulting emissions. The CLEO model was derived from the method used to calculate aircraft emissions at the US Environmental Protection Agency (EPA). 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.* (2021a).

NH_3 emissions from civil aviation are not estimated due to a lack of EFs. Emissions are expected to be negligible.

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 between 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).

4.2.6 Uncertainties and time series consistency

Consistent methodologies have been used throughout the time series. In 2016, an experts’ workshop was organised 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. Uncertainty estimates for PM emissions from LTO (jet kerosene) were adjusted from 100% to 200% as a result of a comparison with methodologies used in recent environmental studies regarding Schiphol. Activity data for fuelling and fuel handling also have a higher uncertainty (from 10% to 20%) as the data are extrapolated. Uncertainty in activity data for LTO (avgas) has been adjusted from 20% to 35% due to differences found in CBS statistics for fuel sales.

Table 4.4 Uncertainty estimates for civil aviation (%)

Type	**Fuel**	**Uncertainty: activity data**	**Uncertainty: 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	35	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.

4.2.7 *Source-specific QA/QC and verification*

This year no source-specific QA/QC and verification check was performed for civil aviation.

4.2.8 *Source-specific recalculations*

A number of data and model improvements were performed that have led to recalculation of activity data and emissions for aviation. Based on flight data provided by Statistics Netherlands, LTO fuel use and emissions are now split between domestic and international flights. This new data also included revised numbers of flights for some earlier years. For the larger airports, data on average taxi times were provided by Eurocontrol for the years 2005–2018. For Schiphol Airport, the interpolation of emissions for the years 1991–1994 has been improved to reduce time series inconsistencies. The EF for fuelling and fuel storage had been misinterpreted in the past and has now been corrected. Also, emissions of fuelling and fuel storage are now calculated for all larger airports on the basis of fuel sales data obtained from Statistics Netherlands. For the years 2015–2019, information on sales of unleaded avgas at Lelystad Airport were provided by TOTAL, leading to a reduction of lead emissions for these years. The fuel classification, fuel consumption and EFs for all certified engines have been updated on the basis of the latest ICAO emission databank. With regard to PM and BC emissions, a new method (SCOPE11; Agarwal *et al.*, 2019) has been used to derive EFs from the smoke number reported in the ICAO emission databank. This has led to significant changes in PM_{10}, $PM_{2.5}$ and BC emission estimates, which are illustrated in Figure 4.1.

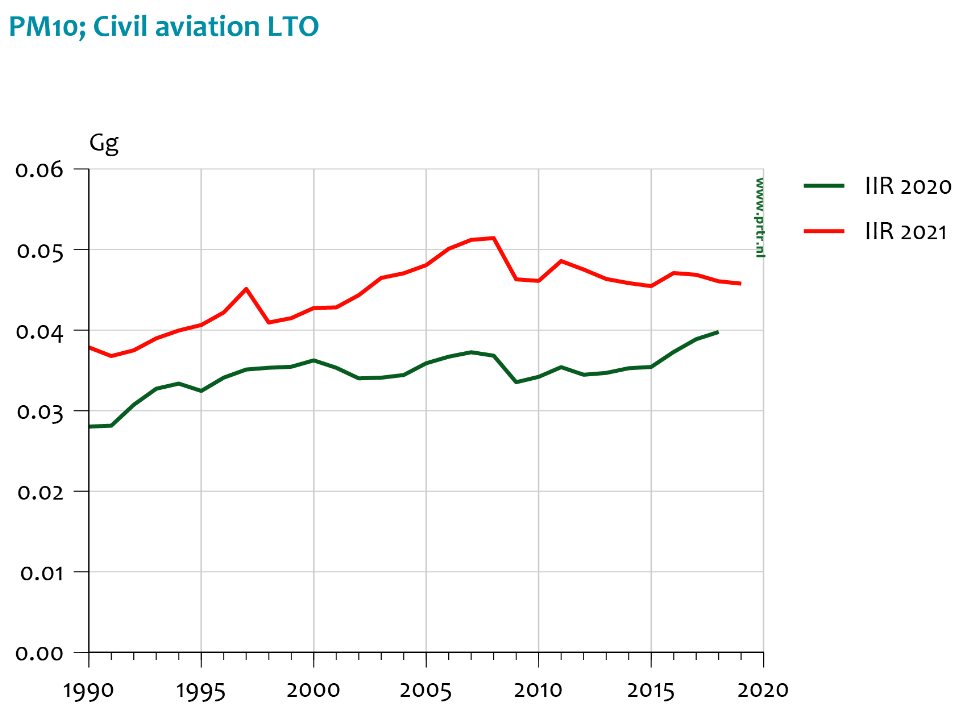

Figure 4.1 PM_{10} emissions from civil aviation LTO in the Netherlands

4.2.9 *Source-specific planned improvements*

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

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.

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 different source categories within road transport are key sources of many substances in both the 1990–2019 trend assessment and the 1990 and 2019 level assessments, as shown in Table 4.5.

Table 4.5 Key source analysis for road transport subcategories

Source category	Name	1990 level	2019 level	1990–2019 trend
1A3bi	Passenger cars	NO_x, NMVOC, CO, PM_{10}, $PM_{2.5}$, BC, Pb[1]	NO_x, NMVOC, CO, $PM_{2.5}$, BC, Pb[1], Hg[1]	SO_2, NO_x, NMVOC, CO, PM_{10}, $PM_{2.5}$, BC, Pb[1], Hg[1]
1A3bii	Light-duty vehicles	NO_x, CO, PM_{10}, $PM_{2.5}$, BC	NO_x, $PM_{2.5}$, BC	NO_x, CO, PM_{10}, $PM_{2.5}$, BC
1A3biii	Heavy-duty vehicles and buses	SO_2, NO_x, NMVOC, PM_{10}, $PM_{2.5}$, BC	NO_x, $PM_{2.5}$, BC,	SO_2, NO_x, NMVOC, PM_{10}, $PM_{2.5}$, BC
1A3biv	Mopeds and motorcycles	NMVOC, CO	NMVOC, CO	CO
1A3bv	Gasoline evaporation	NMVOC		NMVOC
1A3bvi	Tyre and brake wear		PM_{10}, Pb[1]	PM_{10}
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 different source categories within road transport accounted for 34% of NO_x emissions (national totals), 15% of PM_{10}, 12% of $PM_{2.5}$, 31% of BC, 11% of NMVOC and 59% of CO emissions in 2019. The trends in emissions from road transport are shown in Table 4.6. 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 2019, as emissions in other sectors decreased as well. Road transport, therefore, is still a major source of pollutant emissions in the Netherlands.

Table 4.6 Trends in emissions from 1A3b Road transport

	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	**285**	**189**	**16**	**1.0**	**19**	**21**	**21**	**9**	**711**
1995	226	121	15	2.4	14	16	16	7	522
2000	183	68	4	4.3	10	12	12	6	399
2005	163	42	0	5.0	8	10	10	5	381
2010	142	35	0	4.5	5	7	7	3	350
2015	98	28	0	3.9	3	5	5	1	289
2018	88	27	0	4.1	2	4	4	1	370
2019	**81**	**27**	**0**	**4.2**	**2**	**4**	**4**	**1**	**368**
1990–2019 period[1]	-204	-162	-16	3.2	-17	-16	-16	-8	-343
1990–2019 period[2]	-71%	-86%	-99%	337%	-91%	-80%	-80%	-92%	-48%

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

Emissions of SO_x decreased by 99% between 1990 and 2019 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 slightly. 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 2019.
Emissions of heavy metals have increased, with the exception of Pb. Pb 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 110 billion in 2019 (see Figure 4.2).

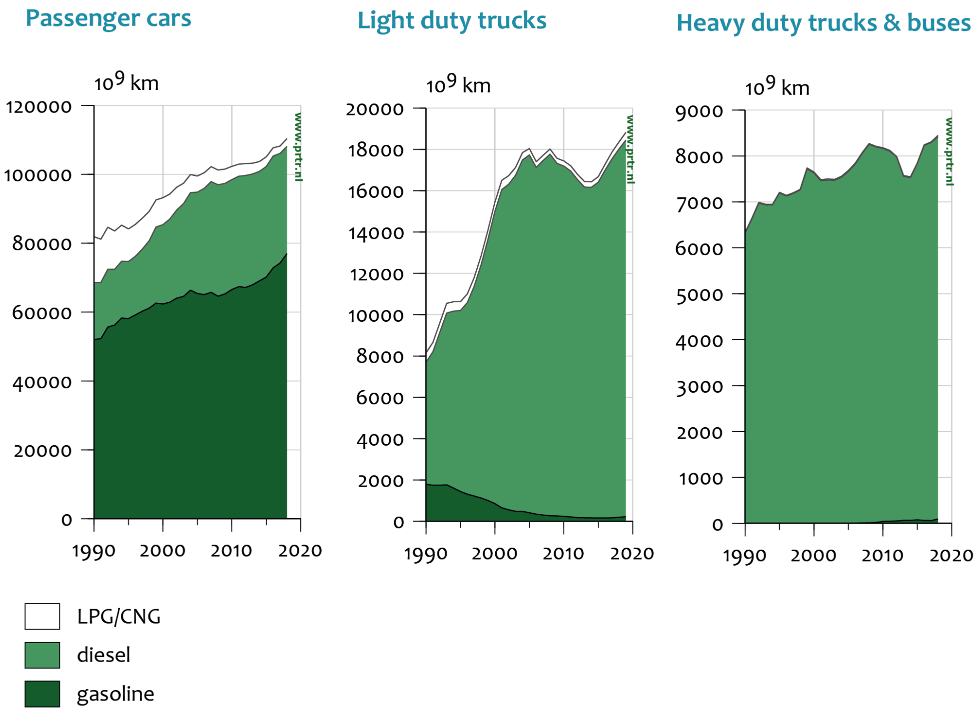

Figure 4.2 Kilometres driven per vehicle and fuel type in the Netherlands (source: Statistics Netherlands)

Since 1995, the share of diesel-powered passenger cars in the Dutch car fleet has grown significantly, leading to an increase in diesel mileage by 74% between 1990 and 2019. Yet since 2008, the total diesel mileage has decreased by 11%. Petrol mileage increased by 53% between 1990 and 2019. The share of LPG in the passenger car fleet decreased significantly, from 16% in 1990 to 2% in 2019. Figure 4.2 shows 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 total 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. NO_x emissions from diesel-powered passenger cars increased between 1995 and 2007 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 become mostly 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 2019, passenger cars were responsible for 5% of NMVOC emissions (not including evaporative NMVOC emissions) (down from 21% in 1990) and 48% of CO emissions (down from 52% in 1990) in the Netherlands.

Passenger cars (source category 1A3bi, including only exhaust emissions) were responsible for 3% of $PM_{2.5}$ emissions and 2% of PM_{10} emissions in the Netherlands in 2019. PM_{10} exhaust emissions from passenger cars decreased by more than 90% 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-5 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 new diesel-powered passenger cars were equipped with a DPF. In 2008, the share of new diesel passenger cars with a DPF was above 90%. $PM_{2.5}$ exhaust emissions from passenger cars (and other road transport) are assumed to be equal to PM_{10} exhaust emissions.

NH_3 emissions from passenger cars increased significantly from 1990 to 2006, as a result of the introduction of the TWC. From 2007, emissions decreased to 4 Gg in 2019. 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)
The light-duty truck fleet in the Netherlands grew significantly between 1990 and 2005, leading to a major increase in vehicle kilometres driven (see Figure 4.2). 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. The number of vehicle kilometres driven varied between 17 and 18 billion between 2005 and 2011, decreased somewhat in 2012 and 2013, and increased slightly after 2015. The fluctuations in recent years can probably mostly 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.

NO_x emissions from light-duty trucks have fluctuated between 19 and 24 Gg since 1994. NO_x emissions in 2019 were 24% 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-5 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 2019. 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 2019. 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.

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 a DPF. Given the stabilisation in the number of vehicle kilometres driven since 2005, PM_{10} exhaust emissions decreased by 85% between 2005 and 2019.

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

NO_x emissions from heavy-duty vehicles and buses decreased from 116 Gg in 1990 to 33 Gg in 2019 (see Figure 4.3). Emissions have decreased significantly in recent years due to the decrease in vehicle kilometrages between 2008 and 2014 (Figure 4.2) and a decrease in the fleet averaged NO_x EF (Figure 4.3). 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).

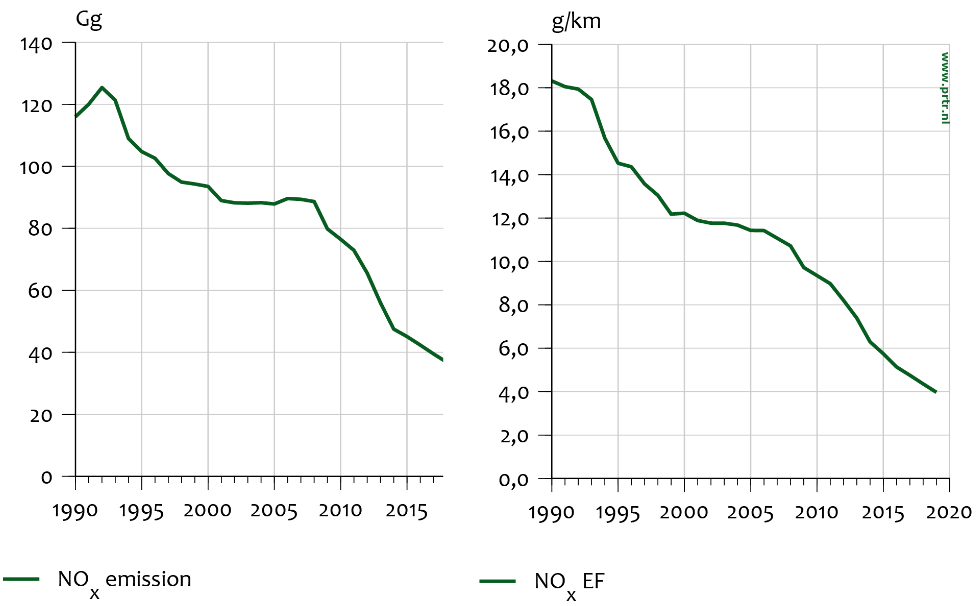

Figure 4.3 NO_x emissions and NO_x IEFs of heavy-duty vehicles and buses in the Netherlands

NMVOC exhaust emissions decreased by around 90% throughout the time series and PM_{10} and $PM_{2.5}$ exhaust emissions decreased by 95%. These decreases were also caused by changes to EU emission legislation. Heavy-duty vehicles and buses were only a minor source of NMVOC emissions in the most recent year.

Heavy-duty vehicles and buses are a minor source of NH_3 emissions in the Netherlands (0.1% of national totals). Yet NH_3 emissions from heavy-duty vehicles and buses increased significantly between 2005 and 2019. This increase was caused by the increasing use of SCR catalysts in heavy-duty trucks and buses. High SCR conversion rates may yield NH_3 slip, as described in detail in Stelwagen *et al*. (2015). NH_3 EFs for Euro-V trucks and buses are approximately five times higher than EFs for previous Euro classes, as shown in table 3.17 of Klein *et al.* (2019). 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 2019, emissions amounted to 552 Mg, which corresponds to an increase of over 500% compared with 2012.

Motorcycles and mopeds (1A3biv)
Motorcycles and mopeds are a small emission source in the Netherlands, being responsible for less than 1% of national totals for most substances. Motorcycles and mopeds were responsible for 4% of NMVOC emissions and 8% of CO emissions in the Netherlands in 2019. Even though the number of vehicle kilometres driven almost doubled between 1990 and

2019, exhaust emissions of NMVOC decreased significantly due to increasingly stringent EU emission standards for two-wheelers. The share of motorcycles and mopeds in NO_x emissions in the Netherlands was still small (<1%) in 2019. The share in $PM_{2.5}$ emissions was approximately 1% in 2019.

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 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 2019 (down from 7% 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 below 60% in 2019 (motorcycles and mopeds were mainly responsible for the rest of evaporative NMVOC emissions; other road vehicles contributed below 1%).

PM emissions from tyre and brake wear and road abrasion (1A3bvi and 1A3bvii)
Vehicle tyre and brake wear (1A3bvi) and road abrasion (1A3bvii) were responsible for 6% and 5% of PM_{10} emissions in the Netherlands, respectively. PM_{10} emissions from brake wear, tyre wear and road abrasion increased throughout most of the time series, as shown in Figure 4.4, 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}.

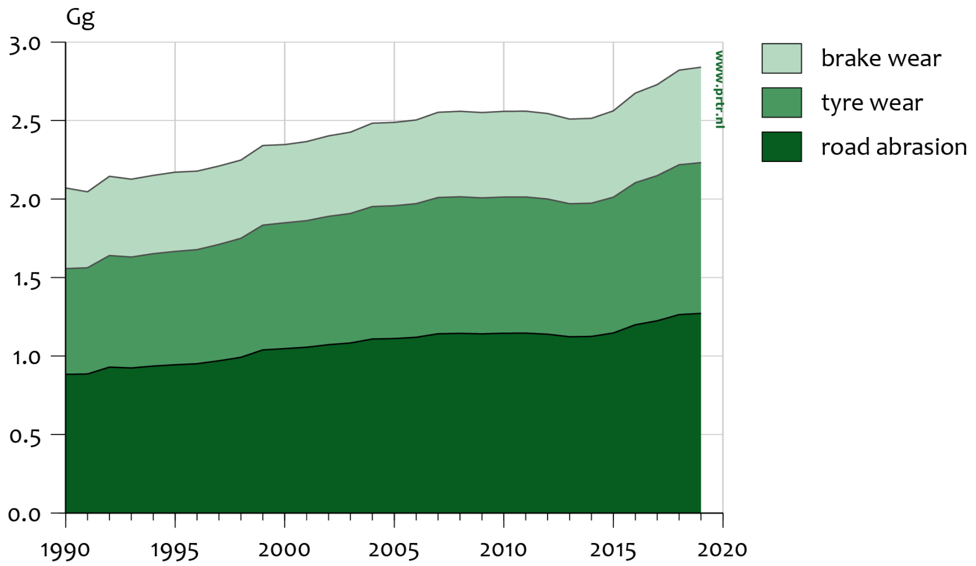

Figure 4.4 Emissions of PM_{10} resulting from brake and tyre wear and road abrasion

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^{-1}). Emissions of SO_x and heavy metals were calculated using fuel consumption estimates combined with the sulphur and heavy metal content of different 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 were 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 different vehicle types; and
- the number of kilometres driven by foreign vehicles in the Netherlands.

Since 2012, 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 built year (year of manufacture). More detailed information on activity data is presented in Geilenkirchen *et al.* (2021b).

Emission factors

The CO, NMVOC, NO_x 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 different transport situations and scale levels. The EFs follow from various analyses fed by different 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 are available that closely resemble the real-world use of the vehicles. These new data are based on driving behaviour, taken from both on-road measurements and measurements on test stands, and these data have 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 SO_x 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 SO_x and heavy metals were based on the sulphur, carbon and heavy metal content of the fuels, as described in Geilenkirchen *et al.* (2021a). 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*. (2021b: 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.

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.* (2021b). 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*., 2021b).

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 in the IIR 2020, section 4.3.4.

Figure 4.5 shows both the bottom-up estimates for fuel used by road transport and reported fuel sold to road transport per fuel type for the 1990–2019 time series.

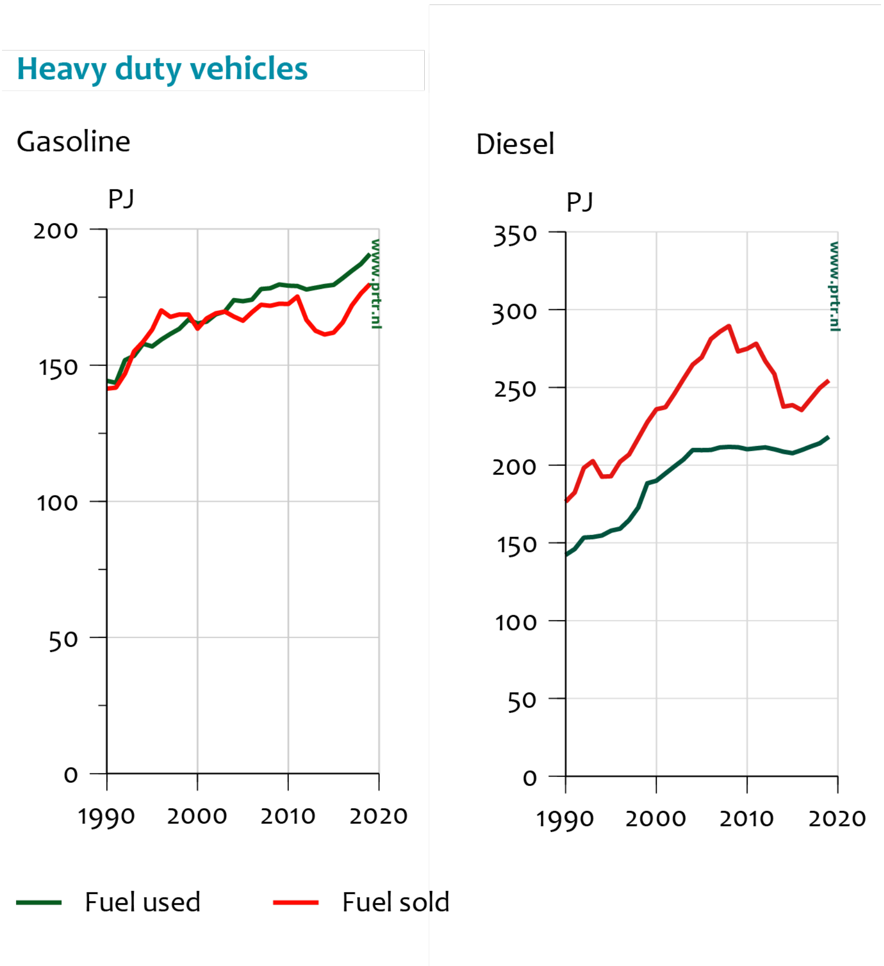

Figure 4.5 Fuel used vs. fuel sold trends, for petrol and diesel-fuelled road transport in the Netherlands

Because fuel-sold emissions 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 different fuel types in emission totals per substance. Diesel vehicles, for example, are a major source of NO_x and PM emissions; therefore, fuel-used emissions of NO_x and PM for road transport are adjusted upwards, especially in the earlier years of the time series, as can be seen in Figure 4.6. 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 shown in Figure 4.6. 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.

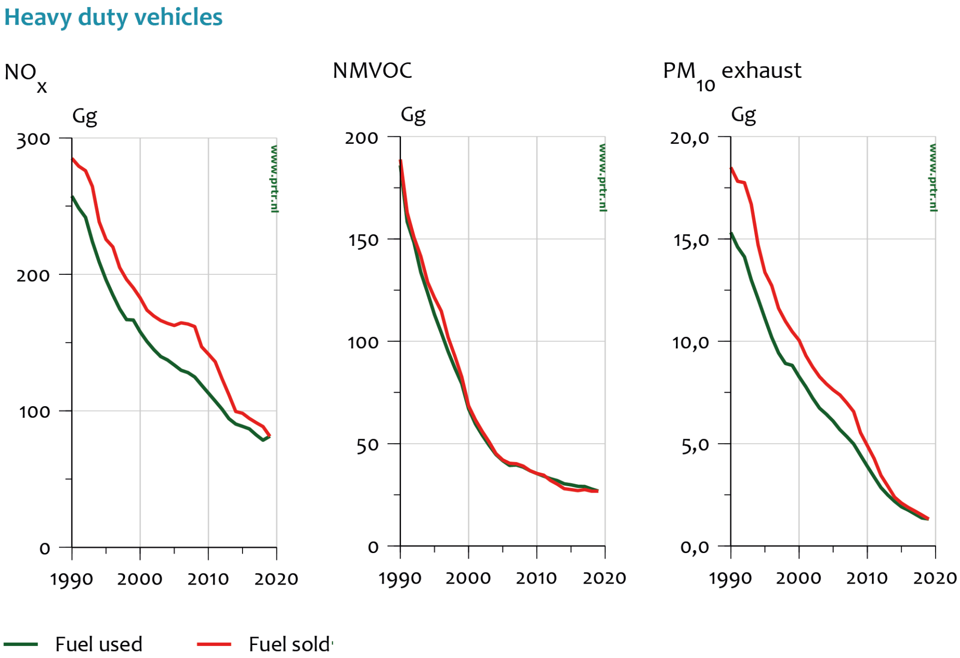

Figure 4.6 NO_x, NMVOC and PM_{10} exhaust emissions from road transport in the Netherlands based on fuel used and fuel sold

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 are included under liquid fuels.

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 a lack of measurements.
- The road type distribution of all vehicle categories was last updated in 2010 and needs to be verified.
- Average annual mileage for mopeds and motorcycles was last estimated in 2013 and needs to be updated.
- The methodology for estimating fuel-sold emissions could be improved by taking into account different vehicle types where differences between fuel used and fuel sold occur.

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 this reason, a decision was taken to use an expert-based approach to estimate uncertainties for NFR categories.

In 2016, an experts' workshop was organised 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 shown in Table 4.7.

Table 4.7 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 (2017).

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 show 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. Resulting EFs are discussed by TNO with international research institutions, e.g. in the ERMES group (https://www.ermes-group.eu/web/).

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.*, 2021a and 2021b).

Improvements in the bottom-up calculation of vehicle emissions

In last year's submissions all emissions from road transport (excluding motorcycles and mopeds) were calculated for each individual vehicle in the Dutch car fleet for 2012, 2015 and 2018. This new methodology, applying odometer readings for each vehicle, was described in detail in last year's submission. The new approach was applied again for this year's submission, including some methodological improvements:

- The impact of aging of the vehicle on EFs was modelled per individual vehicle, based on their specific odometer readings. Formulas were derived to describe the impact of higher odometer readings on base EFs. In last year's submission aging was included using average aging factors per vehicle category.
- Separate vehicle categories were applied for special purpose vehicles such as refuse trucks, which have a very specific use that differs from average use of heavy-duty trucks. For these vehicles specific road type distributions and EFs were derived. In last year's submission these special purpose vehicles were modelled in the same way as heavy-duty trucks.
- New vehicle categories (including Euro classes) were applied for articulated buses, with specific EFs based on measurement campaigns by TNO.
- Emission factors for road and tyre wear and road abrasion were derived per vehicle based on vehicle weight. This differentiation was made such that fleet average EFs were (more or less) identical to last year's submission.
- Some errors in vehicle weight categories in previous years' calculations for heavy-duty trucks were corrected.

This did not affect total vehicle kilometres per vehicle category. The improvements result in adjustments in the 2018 emission levels. Total NO_x emissions from road transport remained more or less the same as in last year's submission (+ 0.1 Gg), although emission levels per vehicle category did change (e.g. -1.1 Gg for petrol cars, +1.2 Gg for diesel passenger cars). CO emissions of passenger cars in 2018 increased by 36% (82 Gg), mainly due to the improved modelling of aging. PM_{10} emissions from road abrasion and tyre and brake wear increased by approximately 4% due to the improved modelling.

In last year's submission, the new methodology was applied for 2012, 2015 and 2018. Due to time and budget constraints, emission totals for 2012 and 2015 were not adjusted in this year's inventory and the above-mentioned methodological improvements were applied only to 2018 and 2019 emissions, though these also affected 2016 and 2017 emissions, since these were estimated using interpolation between 2015 and 2018. For some substances, this has resulted in inconsistent time series, most notably for CO where emission totals for 2018 are significantly higher than reported in last year's submission. This inconsistency will be rectified in next year's submission, when the new methodology will be applied to recalculate emission totals for 2012 and 2015 and thus a consistent time series for road transport emissions be derived. For other substances, including NO_x, NH_3 and PM, changes in 2018 emission levels were minor and therefore time series are still consistent.

Emissions from refrigeration units on trucks (1A3biii)
This year's submission includes emissions from refrigeration units on trucks and trailers. In previous inventories this emission source was not included due to a lack of data. In order to estimate emissions, measurements were performed on two units in everyday use during several months in 2019 and 2020 (TNO, 2021a). From each measurement campaign average use per day and average emissions per day were estimated. The number of trucks and trailers with refrigeration units in use in the Netherlands was derived by Statistics Netherlands from vehicle fleet data. In order to derive a consistent time series, the following approach was used:

- Both the truck and trailer that were used for the measurements were relatively new. To take into account that older vehicles tend to have lower annual mileages than newer vehicles, a use trend (average number of hours in use per day) was estimated on the basis of the average annual kilometrages for trucks and tractor-trailers of different age classes.
- Emission factors per hour of use were applied to the entire time series since emissions from refrigeration units are not regulated.
- The number of trucks and trailers with a refrigeration unit could be derived from vehicle statistics only for recent years. The remainder of the time series was estimated on the basis of the total number of trucks and trailers in use in the Netherlands, as reported by Statistics Netherlands.

Resulting emissions of NO_x increased from 2.7 Gg in 1990 to 4.2 Gg in 2019. PM_{10} emissions increased from 0.08 Gg in 1990 to 0.11 Gg in 2019. Emissions were included in 1A3biii. Figure 4.7 shows the NO_x emissions from 1A3biii in the IIR 2020 and IIR 2021, adjusted in accordance with the improvements in the bottom-up calculation and with the addition of refrigeration units on trucks.

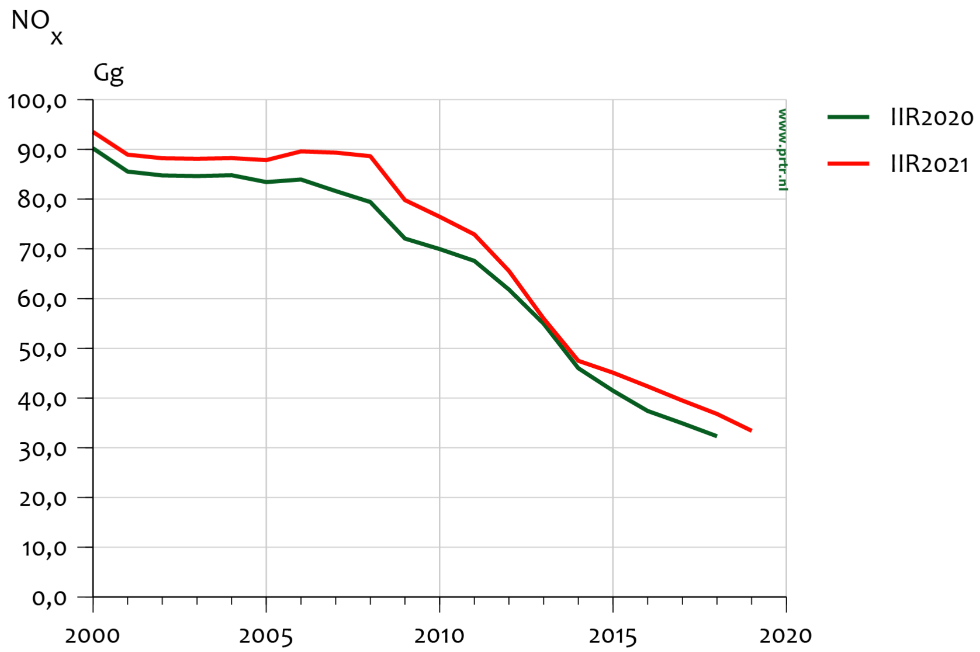

Figure 4.7 NO_x emissions from heavy-duty vehicles and buses in the Netherlands

Improved emission modelling: motorcycles and mopeds (1A3biv)
The time series for emissions from motorcycles and mopeds was recalculated as a result of several improvements in the methodology:

- The time series for the composition of the moped fleet for the 2007–2019 period was redetermined by Statistics Netherlands using licence plate data.
- Survival rates that are used in the modelling of the moped fleet were re-estimated using the new data on the vehicle fleet.
- Emission factors for several substances were adjusted on the basis of new measurements by TNO (2021b).
- The road type distribution for mopeds was adjusted (70% urban, 30% rural).

As a result of these changes, NO_x emissions from motorcycles and mopeds increased throughout the time series, whereas $PM_{2.5}$ emissions increased for some years and decreased for others. This is shown in Figure 4.8.

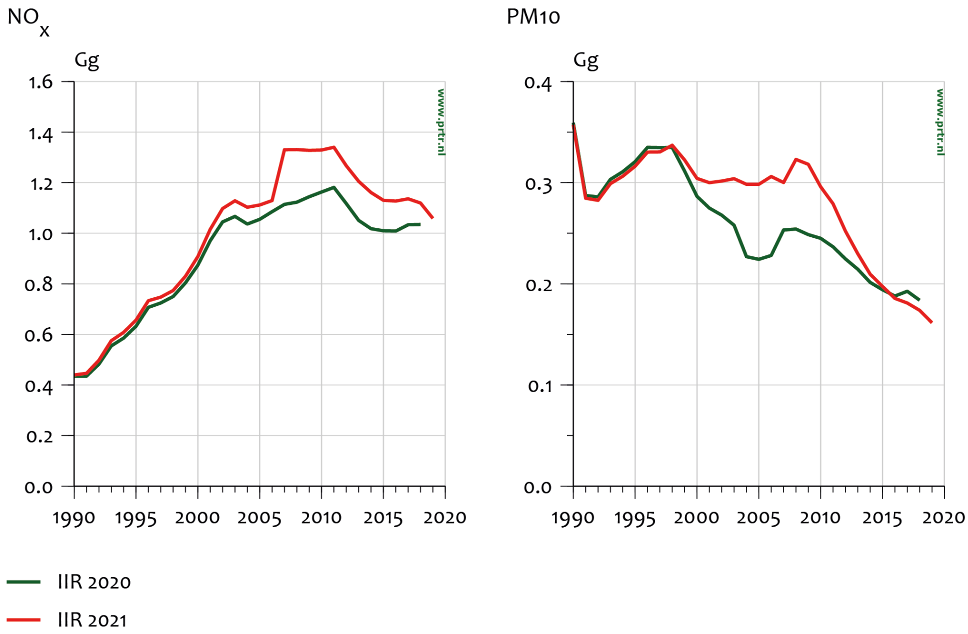

Figure 4.8 NO_x and PM_{10} exhaust emissions from mopeds and motorcycles in the Netherlands

Finally, in this year's submission, metals emissions are again included in the NFR for road transport. In previous years, metal emissions were reported as a memo item under fuel used.

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 planned for next year due to budget constraints. The new insights are based on Ligterink (2017a). Studies are also planned with a view to improving the fuel-sold emission calculation. Both these planned improvements were mentioned in the IIR 2019 and IIR 2020 as well, but scheduling constraints prohibited implementation in the IIR 2021.

In next year's submission both years 2012 and 2015 will be recalculated using the bottom-up methodology. Due to budget constraints, this year only 2018 could be recalculated, together with the new bottom-up calculation for 2019.

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.

4.4.2 *Key sources*

Railways is a key source of Pb in the 2021 inventory.

4.4.3 *Overview of emission shares and trends*

Railways are a small source of emissions in the Netherlands, accounting for less than 1% of national totals for all substances except lead and copper in 2019. 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 2012, fuel consumption fluctuated around 1.4 PJ and since 2012 it has varied around 1.2 PJ. In 2019, fuel consumption dropped to 0.9 PJ. 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 sector is estimated to be approximately 30–35%. The remainder is used for freight transport.

The trends in emissions from railways are shown in Table 4.8. 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 2019. 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 6 Mg (around 15% of total copper emissions in the Netherlands). Emissions of other heavy metals are very low. SO_x emissions from railways decreased by almost 99% 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 4.8 Trends in emissions from 1A3c Railways

	Main pollutants				Particulate matter				Other	Priority heavy metals[3]
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Mg
1990	**2.2**	**0.07**	**0.10**	**0.29**	**0.05**	**0.06**	**0.06**	**0.02**	**0.26**	**0.22**
1995	2.3	0.08	0.10	0.30	0.06	0.06	0.06	0.02	0.27	0.26
2000	2.8	0.09	0.12	0.36	0.07	0.07	0.07	0.03	0.32	0.28
2005	2.6	0.08	0.11	0.33	0.06	0.06	0.06	0.02	0.29	0.27
2010	2.6	0.08	0.02	0.33	0.06	0.06	0.06	0.02	0.29	0.29
2015	2.2	0.07	0.00	0.28	0.05	0.06	0.06	0.02	0.26	0.25
2018	1.7	0.06	0.00	0.22	0.04	0.05	0.05	0.02	0.20	0.26
2019	**1.6**	**0.05**	**0.00**	**0.21**	**0.04**	**0.04**	**0.04**	**0.02**	**0.19**	**0.26**
1990–2019 period[1]	-0.61	-0.02	-0.10	-0.08	-0.01	-0.01	-0.01	0.00	-0.07	0.05
1990–2019 period[2]	-27%	-26%	-100%	-27%	-20%	-20%	-20%	-18%	-27%	22%

1. Absolute difference.
2. Relative difference from 1990 in %.
3. Based on fuel used.

4.4.4 *Activity data and (implied) emission factors*

To calculate emissions from railways in the Netherlands, a Tier 2 methodology was applied using fuel sales data and country-specific EFs. Statistics Netherlands reports data on fuel sales to the Dutch railways sector in the Energy Balance. Since 2010, these fuel sales data have been derived from Vivens, a cooperation of rail transport companies that purchases diesel fuel for the railways sector in the Netherlands. Before 2010, diesel fuel sales to the railways sector were obtained from Dutch Railways (NS), which used to be responsible for the purchase of diesel fuel for the entire railway sector in the Netherlands.
Emission factors for CO, NMVOC and PM_{10} for railways were derived by the Netherlands Environmental Assessment Agency (PBL) in consultation with the NS. NO_x EFs were determined in a measurement programme in 2017 (Ligterink et al., 2017b). Emission factors of NH_3 were derived from Ntziachristos & Samaras (2000). The EFs for railways (except for NO_x) have not been updated recently and therefore are rather uncertain.

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 to be 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 alongside 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.* (2021a).

4.4.5 *Methodological issues*

Emission factors for railways have not been updated recently (except 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 organised 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 shown in Table 4.9.

Table 4.9 Uncertainty estimates for railways (%)

NFR	Type	Fuel	Uncertainty: 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	-
	Pantograph wear[1]	Electricity	-	-	-	-		200	200	-

Dellaert & Dröge (2017).

4.4.7 *Source-specific QA/QC and verification*

This year, no source-specific QA/QC and verification procedures were carried out for railways.

4.4.8 *Source-specific recalculations*

In the IIR 2020, as a result of a system update, activity data was rounded to the nearest 100 TJs in the NFR. This was corrected for this year's inventory. This results in a change in emissions of between +0.5% and -0.5%.

4.4.9 *Source-specific planned improvements*

A methodology review for railways was performed by CE Delft (2020). They advise an update in the split between passenger and freight transport, resulting from the electrification of railways. Additionally, the EFs may need to be updated as passenger trains may be younger than freight trains.

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 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

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

both passenger and freight transport. Emissions from recreational craft are reported under Other, mobile (1A5b), but are described in this section as well. It should be noted that 1A5b also includes emissions from ground service equipment at airports (see Section 4.6). Emissions resulting from degassing of inland ships are included under 2D3i. Condensables are included in PM_{10} and $PM_{2.5}$ 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. International inland waterways is a key source of PM_{10} emissions. The source category 1A5b Other, mobile is a key source of CO.

4.5.3 *Overview of emission shares and trends*

In total, (inter)national inland navigation was responsible for 10% of NO_x emissions, 5% of $PM_{2.5}$ emissions and 17% of BC emissions in the Netherlands in 2019. 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 PM_{10}, NMVOC, CO and SO_x was small in 2019.

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 110 Gg in 2019 and were higher than the combined NO_x emissions from all road transport in the Netherlands. PM_{10} emissions amounted to 2.9 Gg in 2019. In contrast, recreational craft were only a small emission source, with 2.6 Gg of NO_x and 0.06 Gg of PM_{10} emitted in 2019.

The trends in emissions from inland navigation in the Netherlands (both category 1A3dii and 1A3di(ii)) are shown in Table 4.10. Since 2000, fuel consumption in inland navigation has fluctuated between 20 and 28 PJ. The economic 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 small 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 2019.

Table 4.10 Trends in emissions from Inland navigation in the Netherlands (combined emissions of national and international inland navigation)

	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	**28.8**	**2.00**	**1.83**	**0.01**	**1.25**	**1.31**	**1.31**	**0.56**	**8.00**
1995	25.2	1.79	1.85	0.01	1.25	1.32	1.32	0.57	7.30
2000	27.8	1.75	2.05	0.01	1.24	1.31	1.31	0.56	7.22
2005	25.9	1.45	1.91	0.01	1.07	1.13	1.13	0.48	6.03
2010	22.3	1.43	0.50	0.01	0.86	0.91	0.91	0.43	5.77
2015	25.5	1.44	0.01	0.01	0.85	0.91	0.91	0.46	6.05
2018	25.6	1.41	0.01	0.01	0.82	0.87	0.87	0.45	6.02
2019	**23.0**	**1.25**	**0.01**	**0.01**	**0.73**	**0.77**	**0.77**	**0.40**	**5.33**
1990–2019 period[1]	-5.83	-0.75	-1.82	0.00	-0.52	-0.54	-0.54	-0.16	-2.67
1990–2019 period[2]	-20%	-37%	-99%	1%	-41%	-41%	-41%	-29%	-33%

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

SO_x emissions from inland navigation decreased by 99% between 2009 and 2019 due to the decrease in the maximum allowable sulphur content of diesel fuel for non-road applications. Since the start 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 2009 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 2019.

Energy use and resulting emissions from maritime navigation showed an upward trend between 1990 and 2008. Since the start of the economic 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 2017, total fuel consumption by maritime navigation on Dutch territory decreased by 2% compared with 2016.

Recreational shipping is reported under source category 1A5b Other, mobile. This source category is a key source of CO emissions, amounting to 3.3% of total national CO emissions. The share of emissions of all other pollutants from recreational shipping in total emissions in the Netherlands in 2019 was small.

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 and 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. The speed per vessel class per geographical water segment was taken from 1 month of AIS data (July 2015) provided by Pouwels *et al.* (2017). 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.* (2021a). 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 to be 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 motor boats 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.*, 2005). The EFs depend on the engine types per vessel. The IEFs are reported in Geilenkirchen *et al.* (2021a and 2021b).

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.* (2021a).

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 have not been updated for some time.
2. Data on the number of recreational craft and their average usage rates are rather uncertain and need to be verified.
3. Activity data for inland shipping could be improved by using AIS data to derive shipping movements. The stability and completeness of AIS data should be tested over at least one year instead of one month.
4. The methodology for calculating the required engine power vs. speed and other ship characteristics needs to be verified for inland navigation.
5. 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 inland waterborne navigation. 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 organised 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 shown in Table 4.11. 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 4.11 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	50	35	20	500	50	50	50	100
1A3dii	Inland, national	Diesel	50	35	20	500	50	50	50	100
1A3dii	Passenger and ferryboats	Diesel	100	50	20	500	100	100	100	200
1A5b	Recreational shipping, exhaust gases	Petrol	200	50	20	100	100	100	100	50
1A5b	Recreational shipping, exhaust gases	Diesel	200	200	20	100	100	100	100	100
1A5b	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

There are no source-specific planned improvements for waterborne navigation.

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 different economic sectors and by households in the Netherlands. Mobile machinery is typified 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 1A2gvii Mobile combustion in manufacturing industries and construction, 1A4aii Commercial/ institutional: Mobile, 1A4bii Residential: Household and gardening (mobile), 1A4cii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery and 1A5b Other, mobile. The last source category 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 in the 2019 level assessment. Source category 1A4bii Residential: Household and gardening (mobile) is a key source of emissions of CO in both the 2019 level and trend assessments. Source category 1A4cii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery is a key source of NO_x and BC emissions in the 2019 level assessment. Source category 1A4aii Commercial/institutional: Mobile is not a key source of any emissions.

4.6.3 Overview of shares and trends in emissions

NRMM was responsible for 8% of CO emissions, 9% of NO_x emissions, 5% of $PM_{2.5}$ emissions and 3% of PM_{10} emissions in the Netherlands in 2019. 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 used in agriculture (tractors) and construction.

Total energy use in NRMM has fluctuated between 38 PJ and 47 PJ throughout the time series. Figure 4.8 shows total energy use within the different sectors in which mobile machinery is applied. Industrial (including construction) and agricultural machinery were responsible for more than 85% of total energy use by NRMM in 2019.

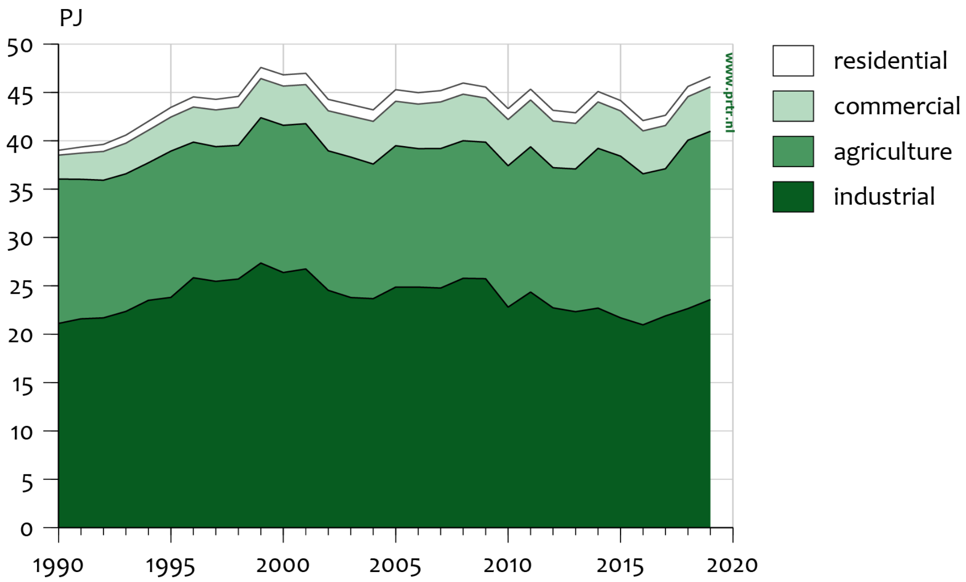

Figure 4.9 Fuel consumption in non-road mobile machinery in different sectors in the Netherlands

The trends in emissions from NRMM in the Netherlands are shown in Table 4.12. 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 shown in Figure 4.10. Since 1990, NO_x emissions have decreased by 48%, whereas fuel consumption has increased by 19%.

Table 4.12 Trends in emissions from Non-road mobile machinery in the Netherlands

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	**39.8**	**7.89**	**3.16**	**0.01**	**3.59**	**3.78**	**3.78**	**1.83**	**36.4**
1995	44.6	8.56	3.28	0.01	3.43	3.60	3.60	1.74	55.2
2000	46.8	8.27	3.53	0.01	3.25	3.42	3.42	1.65	59.3
2005	38.6	6.34	3.40	0.01	2.62	2.75	2.75	1.32	55.8
2010	30.6	4.68	0.33	0.01	1.50	1.58	1.58	0.75	53.1
2015	25.8	3.60	0.02	0.01	1.12	1.18	1.18	0.56	51.8
2018	21.9	2.95	0.02	0.01	0.90	0.95	0.95	0.44	50.8
2019	**20.8**	**2.78**	**0.02**	**0.01**	**0.84**	**0.88**	**0.88**	**0.41**	**50.4**
1990–2019 period[1]	-19.0	-5.11	-3.14	0.00	-2.75	-2.90	-2.90	-1.42	14.0
1990–2019 period[2]	-48%	-65%	-99%	18%	-77%	-77%	-77%	-78%	39%

Absolute difference.
Relative difference from 1990 in %.

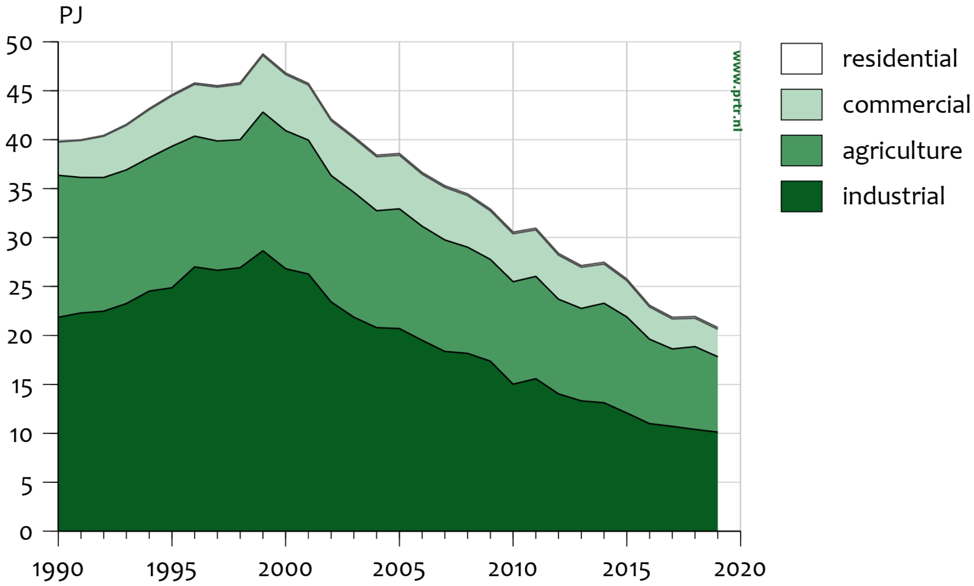

Figure 4.10 NO_x emissions by non-road mobile machinery in different sectors in the Netherlands

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.

Emissions from ground service equipment (GSE) at airports are reported under source category 1A5b Other, mobile. This source category is not a key source of any emissions. The share of emissions from GSE at airports as a percentage of the total emissions in the Netherlands in 2019 was less than 1% for all pollutants.

4.6.4 *Activity data and (implied) emission factors*

Fuel consumption by mobile machinery in the different 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). The so-called EMMA model uses sales data and survival rates for different types of machinery to estimate the NRMM fleet in any given year. From combined assumptions as to the average usage rate (annual operating hours) and the fuel consumption per hour of operation of the different types of machinery, total annual fuel consumption by NRMM is estimated. Emission factors were taken from a similar model TREMOD-MM (Lambrecht *et al.*, 2004) and partially updated with data taken from Helms *et al.* (2010). They are described in more detail in Geilenkirchen et al (2021a).

Annual sales data for the different types of NRMM are derived from trade organisations such as the BMWT and Fedecom, and from Off-Highway Research, a commercial consulting company. Fuel consumption and resulting emissions of CO, NO_x, NH_3, PM and NMVOC are calculated using the following formula:

Emission = Number of machines x Hours x Load profile x Rated power x Emission factor

In which:

- Emission = Emission or fuel consumption (grams);
- Number of machines = the number of machines of a certain year of construction with EFs applicable to the machines' year of construction;
- Hours = the average annual running hours for this type of machinery;
- Load profile = the share of time a machine runs at various possible levels of rated power (%);
- Rated power = the average full power for this type of machinery (kW);
- Emission factor = the average EF or specific fuel consumption pertaining to the engine type, year of construction (related to emission standards) and power settings, in grams/second/kW rated power.

The report on the EMMA model (Hulskotte & Verbeek, 2009) provides the original EFs of the various technologies and the different stages in the European emission standards. The EFs are linked to the different machine types for each sales year. Emissions of SO_x were calculated on the basis of total fuel consumption and sulphur content per fuel type as provided in Geilenkirchen *et al.* (2021a). Base EFs for NH_3 were derived from the EMEP/EEA Guidebook 2019 (EEA, 2019).

The distribution of total fuel consumption by NRMM to different economic sectors was estimated using different data sources. First, the different types of machinery in EMMA were distributed over 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 Centre. 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 difference between this total and the EMMA results for agriculture is added to the fuel consumption by construction machinery as reported by EMMA.

The resulting fuel consumption in construction 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.* (2021a).

Emissions from ground support equipment and vehicles used for ground transport at airports were estimated using data on diesel use for ground operations at Amsterdam Airport Schiphol that were provided by KLM Royal Dutch Airlines. KLM 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. These data were used to derive emission estimates. The resulting emissions were also used to derive an average EF per MTOW at Schiphol Airport, 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.* (2021a).

4.6.5 *Methodological issues*

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

- The quantity of diesel used in the construction sector is susceptible to considerable fluctuation due to the economy. At present, the correction for this phenomenon takes place using economic indicators derived from Statistics Netherlands instead of physical indicators. It could be investigated whether there are enterprises or institutions that have such indicators, i.e. figures for diesel consumption, at their disposal.
- There is a lack of input data for several types of machinery and sectors. In the garden and private households sector, weakly founded or extrapolated figures have been used to estimate the size of the fleet.
- The application of generic survival rates for all types of machinery may have led to declines in the fleet composition (age profile) compared with reality in the case of certain important types of machinery, including agricultural tractors, excavators and shovels. Investigations into the age profile and the use of the active fleet could lead to considerable improvement in the reliability of the emission figures.
- For building machinery, highly varying hire and lease practices exist, which may affect maintenance frequencies. Via a specific measurement scheme, the effect of maintenance frequency on emissions from building machinery 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 1994. For the earlier years, no reliable machinery sales data were available. Fuel consumption in 1990 was derived from estimates taken from Statistics Netherlands, while fuel consumption in 1991, 1992 and 1993 was derived by interpolation.
In 2016, an experts' workshop was organised 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 shown in Table 4.13.

Table 4.13 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	35	50	20	200	100	100	100	100
1A4aii	Public services	Petrol	100	50	20	200	100	100	100	100
1A4aii	Public services	Diesel	35	50	20	200	100	100	100	100
1A4aii	Container handling	Diesel	35	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 (2017).

The uncertainty in activity data for construction (diesel) and industry (diesel) was adjusted upwards from 35% to 50%. The reason is that there are missing detailed machine sales figures for 2015–2019.

4.6.7 Source-specific QA/QC and verification

There are no source-specific QA/QC and verification procedures for NRMM.

4.6.8 Source-specific recalculations

A number of data and model improvements were performed that have led to recalculation of activity data and emissions for NRMM. Machine sales data have been obtained from Off-Highway Research allowing an update of machine sales numbers and the addition of two machine types (mobile cranes and telescope cranes) to the emission model. To simplify the allocation of emissions to different sectors, several machine types were directly allocated to two or more sectors (e.g. tractors). The application of actual fuel heating values has been corrected, leading to small changes in fuel consumption estimates. NH_3 EFs were updated on the basis of the latest EMEP/EEA Guidebook 2019. For NO_x and PM, an estimate was included for the estimated share of machines where emission reduction technologies (SCR catalysts and particle filters) have been deactivated or removed (i.e. tampering). Finally, the emission calculation has been significantly overhauled. A number of representative engine load profiles were defined based on measured data and each machine type was assigned one of these engine profiles. Then the previous EFs (in gram/kWh) were replaced by EFs (in gram/second/kW rated power) that are load dependent. This means that for each engine type and emission norm, 11 EFs have been defined representing emissions at 0% engine load up to 100% engine load. Initially, the emission profiles for most pollutants were based on the response of CO_2 emissions to different engine loads. For NO_x, the emission profile is now based on emission measurements performed on several construction machines. This new calculation method is better suited to the future incorporation of new measurement data, of fuel use, emissions and engine load profiles.

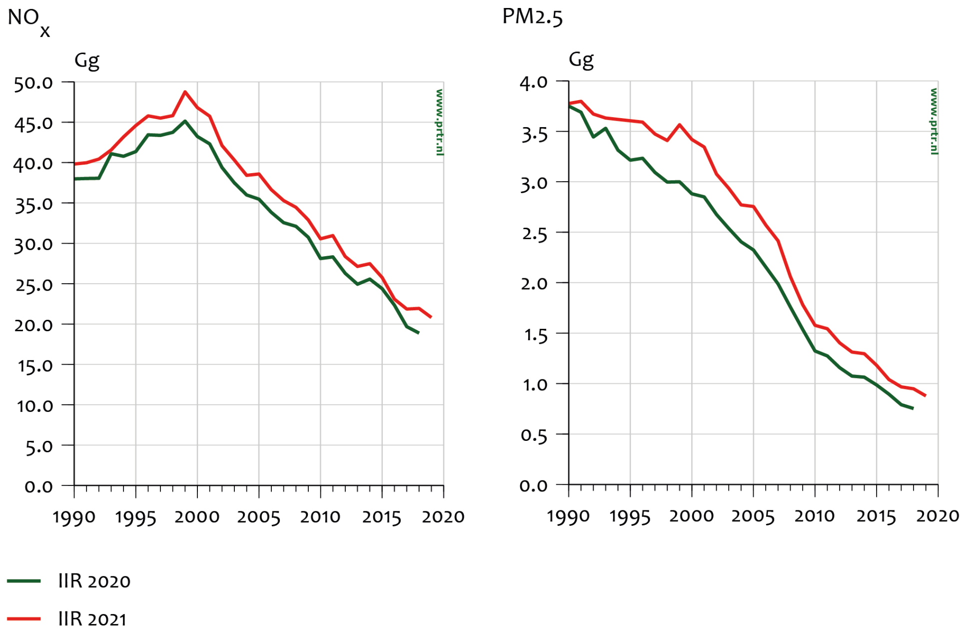

Figure 4.11 NO_x and $PM_{2.5}$ emissions from non-road mobile machinery in the Netherlands

4.6.9 *Source-specific planned improvements*

In 2021, a survey will be issued to construction companies to collect more detailed information on the current machine fleet in the Netherlands. With the results of this study, a validation of the emission model will be performed, followed by the implementation of model improvements where needed and possible.

4.7 National fishing

4.7.1 *Source category description*

The source category 1A4ciii National fishing 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 in the 2021 inventory.

4.7.3 *Overview of emission shares and trends*

National fishing is a small emission source in the Netherlands. In 2019, national fishing was responsible for 1.6% 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.

The trends in emissions from national fishing are shown in Table 4.14. For the most part, emissions from national fishing show similar trends to emissions from fuel consumption. NO_x emissions decreased significantly between 1990 and 2019, as well as PM_{10} emissions. SO_x emissions decreased due to the use of sulphur-free diesel fuel.

Table 4.14 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	**20.6**	**1.42**	**4.96**	**0.00**	**1.10**	**1.16**	**1.16**	**0.33**	**1.46**
1995	23.2	1.45	5.93	0.00	1.22	1.28	1.28	0.36	1.52
2000	22.6	1.33	5.22	0.00	1.13	1.19	1.19	0.34	1.42
2005	15.5	0.84	3.42	0.00	0.70	0.74	0.74	0.22	0.91
2010	11.0	0.52	1.57	0.00	0.47	0.50	0.50	0.14	0.60
2015	8.91	0.37	0.53	0.00	0.32	0.33	0.33	0.10	0.45
2018	7.04	0.30	0.32	0.00	0.24	0.26	0.26	0.08	0.37
2019	**8.01**	**0.36**	**0.36**	**0.00**	**0.23**	**0.24**	**0.24**	**0.08**	**0.44**
1990–2019 period[1]	-12.6	-1.06	-4.60	0.00	-0.87	-0.92	-0.92	-0.25	-1.02
1990–2019 period[2]	-61%	-75%	-93%	-60%	-79%	-79%	-79%	-77%	-70%

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

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 using AIS data. Two methodologies based on AIS data were applied from 2016 onwards. For deep-sea trawlers, the same methodology that is 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 & tBrake (2017). This is essentially an energy-based method whereby the energy rates of fishing vessels are split up by activity (sailing and fishing), with a distinction made in the available power of propulsion engine(s). The methodology is described in greater details in chapter 6 of Geilenkirchen *et al.* (2021a).

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 the estimation of emissions.

4.7.6 *Uncertainties and time series consistency*

The AIS-based approach to calculating emissions from fishing has been applied to the calculation of emissions as of 2016. 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 organised 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 4.15.

Table 4.15 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 (2017).

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*

In this year's inventory, the EFs for SO_x were adjusted upwards as of 2010. This adjustment relates to a correction on the sulphur content of marine diesel for fishing vessels as of 2010. This has caused an increase in SO_x emissions from 80 Mg to 323 Mg in 2018 compared with the IIR 2020.

CO EFs were adjusted upwards, resulting in an increase of 15% in CO emissions from national fishing in 2018.

Finally, minor adjustments in EFs for other substances were implemented, resulting in an adjustment of emissions of 1–3%.

4.7.9 *Source-specific planned improvements*

There are no source-specific planned improvements for national fishing.

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 are 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 POPs. Emissions from the consumption of heavy metals are considered insignificant.

Because the 2016 Guidebook is not clear about which sources belong to 2L, it is included in 2H3 (Other industrial processes).

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, section 2I is not included.

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

39.5% 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	**5.09**	**233**	**10.0**	**5.43**	**16.4**	**29.8**	**49.6**	**0.13**	**9.7**
1995	3.21	172	2.75	5.18	11.0	19.0	34.3	0.07	4.71
2000	1.85	131	1.53	4.00	7.12	12.4	18.5	0.03	3.89
2005	0.58	108	1.02	3.64	6.67	11.7	16.9	0.02	2.32
2010	0.54	108	0.91	2.56	6.36	11.0	15.1	0.02	2.94
2015	0.75	95.7	0.87	2.17	5.64	10.1	14.8	0.02	3.17
2018	0.90	94.0	1.00	2.32	5.57	10.0	14.0	0.02	3.46
2019	**0.77**	**93.7**	**0.99**	**2.06**	**5.54**	**9.9**	**14.0**	**0.02**	**3.44**
1990–2019 period[1]	-4.32	-139	-9.02	-3.38	-10.9	-19.9	-35.5	-0.11	-6.27
1990–2019 period[2]	-85%	-60%	-90%	-62%	-66%	-67%	-72%	-87%	-65%

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**	**2.60**	**1.24**	**48.1**	**13.2**	**0.55**	**2.95**	**7.39**	**2.76**	**0.31**	**146**
1995	66.6	2.42	0.85	48.6	4.51	0.49	2.83	8.99	2.75	0.22	103
2000	24.5	2.46	0.39	21.4	0.46	0.77	2.16	11.5	0.52	0.00	55.7
2005	27.3	3.35	0.37	19.4	0.38	0.38	1.59	11.9	0.94	0.79	38.9
2010	31.6	4.19	0.31	16.7	0.26	0.48	1.15	13.9	1.21	0.06	41.8
2015	6.36	2.67	0.26	12.8	0.16	0.59	0.88	10.9	1.03	0.06	49.7
2018	3.76	2.21	0.25	11.3	0.14	0.28	0.80	10.7	0.84	0.07	301.7
2019	**2.96**	**2.39**	**0.26**	**10.8**	**0.14**	**0.11**	**0.56**	**10.6**	**0.53**	**0.07**	**227.5**
1990–2019 period[1]	-64.2	-0.22	-0.98	-37.4	-13.1	-0.44	-2.39	3.18	-2.23	-0.25	82
1990–2019 period[2]	-96%	-8%	-79%	-78%	-99%	-80%	-81%	43%	-81%	-78%	56%

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
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. For consistency reasons, time series for 2B10a and 2C6 were recalculated (see the relevant sections).

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 5.2 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%	84%	95%	98%	179%	182%
2B	91%	NA	NA	63%	64%	70%
2C	87%	NA	NA	106%	90%	90%
2D	71%	NA	NA	37%	NA	NA
2G	103%	91%	113%	89%	74%	75%
2H	196%	50%	NA	116%	46%	47%
2I	NA	NA	NA	NA	199%	198%
2J	NA	NA	NA	NA	NA	NA
2K	NA	NA	NA	NA	NA	NA
2L	NA	NA	NA	NA	NA	NA
Total IPPU sector	**55%**	**75%**	**93%**	**35%**	**35%**	**45%**

The Approach 2 uncertainty analysis shows relatively high uncertainties at the level of the source categories. This is relevant to these key sources:

- 2A6: $PM_{10/2.5}$ (4% and 6% contribution to total, respectively);
- 2B10a: NMVOC and $PM_{10/2.5}$ (2%, 5% and 4% contribution to total, respectively);
- 2C1: $PM_{10/2.5}$ (5% contribution to total);
- 2D3a: NMVOC (15% contribution to total);
- 2D3d: NMVOC (6% contribution to total);
- 2D3i: NMVOC (6% contribution to total);
- 2G: $PM_{10/2.5}$ (6% and 10% contribution to total, respectively).
- 2H2: NMVOC and $PM_{10/2.5}$ (3%, 7% and 4% contribution to total, respectively);
- 2H3: NMVOC and $PM_{10/2.5}$ (4%, 9% and 5% contribution to total, respectively).

These key sources of these pollutants do make a contribution to the uncertainty on the national level.

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 recalculations*

- Cd emission series from 2B10a have been corrected using ‘gap filling’ techniques.

- Cd emission series from Zinc producer Nyrstar have been corrected due to improvement of measurements.
- NMVOC emission series from bread bakeries have been recalculated due to better activity data.

5.1.6 *Source-specific planned improvements*

No source-specific improvements are planned.

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.

Because of allocation problems, for example the activities do not occur in the Netherlands, emissions from 2A2, 2A5a and 2A5b were included in the subcategory of Other mineral products (2A6). Because only emissions from the storage and handling of bulk products companies are available, the emissions from 2A5c were reported in the subcategory Other industrial processes (2H3).

The 2H3 subcategory in the Dutch PRTR includes 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.

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%) are 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 have to be included in the AERs. This means that production levels, if they are included, are confidential information. However, in most cases 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 5.3.

Table 5.4 Key sources of Mineral products (2A)

	Category / Subcategory	Pollutant	Contribution to total of 2019 (%)
2A3	Glass production	Pb	14.6
2A6	Other mineral products	PM_{10}/$PM_{2.5}$	3.9/6.3
		Hg	18

5.2.3 *Overview of emission shares and trends*

Table 5.4 gives an overview of the emissions from the key sources of this category.

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

	NFR Code:	2A3	2A6		
	NFR Name:	Glass production	Other mineral products		
	Pollutant:	Pb	PM_{10}	$PM_{2.5}$	Hg
Year	Unit:	Mg	Gg	Gg	Mg
1990		7.3	2.0	1.6	-
1995		6.5	1.6	1.3	-
2000		2.9	1.0	0.9	-
2005		1.4	1.0	0.9	-
2010		0.8	1.1	1.0	0.10
2015		1.0	1.1	1.0	0.11
2017		1.6	1.1	1.0	0.10
2018		0.6	1.1	1.0	0.12
2019		0.8	1.1	1.0	0.11

The reduction of Pb emissions from 2A3 between 1990 and 2019 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.). The reduction of PM_{10} emissions from 2A6 was also a result of the implementation of technical measures.

2A3 is not a key source of Cd emissions. However, the Cd series for 2A3 shows a few strong outliers: in the years after 2017 a strong increase in emissions occurs: 35 times higher than 2016. This increase was caused by a single glass production company, which reported a failure of its emission reduction measures for that years. This anomaly, which was the subject of a review question, will be raised at the next AER inventory if emissions are still high.

5.2.4 *Methodological issues*

See paragraph 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.

5.3 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.

Adipic acid (included in 2B3) and calcium carbide (included in 2B5) are not produced in the Netherlands. So emissions from these sources do not occur (NO). 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. Because only emissions data from the storage and handling of bulk products companies are available, emissions from 2B10b are reported in the category Other industrial processes (2H3).

The 2H3 subcategory in the Dutch PRTR includes 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.

The emission total of 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%) are 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, so in most cases the total emissions are the sum of the emissions of all the production processes. According to the Aarhus Convention, only total emissions have to be included in the AERs. This means that production levels and amounts of solvents used, if they are included, are confidential information. However, in most cases 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, and the 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 5.5.

Table 5.6 Key sources of Chemical industry (2B)

	Category / Subcategory	Pollutant	Contribution to total of 2019 (%)
2B10a	Chemical industry: Other	NMVOC	1.9
		PM_{10}/$PM_{2.5}$	3.4/4.3

5.3.3 *Overview of emission shares and trends*

Table 5.6 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			
Year	NMVOC Gg	PM_{10} Gg	$PM_{2.5}$ Gg
1990	33.4	4.1	2.6
1995	18.0	3.0	1.9
2000	12.6	0.5	0.3
2005	7.9	1.2	0.7
2010	5.7	1.3	0.9
2015	4.7	1.1	0.7
2017	4.8	1.4	0.9
2018	5.1	1.2	0.8
2019	4.6	0.9	0.7

The reductions in NMVOC and PM_{10} emissions between 1990 and 2019 were mainly caused by the implementation of technical measures.

5.3.4 *Methodological issues*

See paragraph 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 5.7.

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
2009	93.4
2010	104.3
2011	102.5
2012	108
2013	103.3
2014	102.8
2015	100
2016	106.3
2017	106.8
2018	107.4
2019	103.8

5.3.5 *Source-specific recalculations*

Due to review questions, efforts were made to make the Cd time series from 2B10a (not a key source) more consistent. After investigation, the following causes of the fluctuations were found, and corrected:

- For some years there was a lack of reliable emission data, especially for the years before 2000, for which there were no AERs available. For some years it was possible to retrieve old data, so in combination with some interpolation the part of the series before 2000 could be corrected.
- For some years, emission data were not correctly allocated to combustion or process. Emissions were therefore wrongly allocated to 1A instead of 2B10. These allocation errors have been corrected.
- Emissions are mostly from one company, which closed in 2011. Therefore Cd emissions decrease sharply after that year, so no correction was needed.
- Fluctuations between 2000 and 2010 were due to fluctuations in the Cd content of the ore, so no correction was needed.

Figure 5.1 shows the corrected emission series versus the original series.

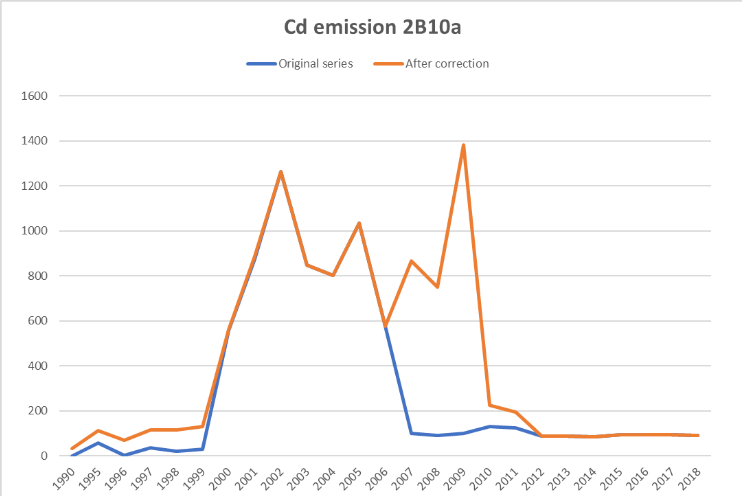

Figure 5.1 Corrections to Cd time series

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.

Issues:

- Because it is not possible to split the 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 $2C_4$ are included in the 2H3 subcategory.
- There are one lead, one copper and one zinc producer in the Netherlands (2C5–2C7a).
- Because only emissions from the storage and handling of bulk products companies are available, emissions from 2C7d are reported in the category of Other industrial processes (2H3).
- The 2H3 subcategory in the Dutch PRTR includes 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.

5.4.2 Key sources

The key sources of this category are presented in Table 5.8.

Table 5.9 Key sources of Metal production (2C)

Category / Subcategory		Pollutant	Contribution to total of 2019 (%)
2C1	Iron and steel production	$PM_{10}/PM_{2.5}$	4.6/5.4
		Pb	26.0
		Hg	18.0
2C5	Lead production	Hg	6.0
2C6	Zinc production	Pb	9.0
		Cd	84.0

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 5.9 provides an overview of the process emissions from the key source of Iron and steel production (category 2C1), plus dioxin, PAHs and PCBs (the last series was recalculated for the 2020 submission).

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

	2C1: Iron and steel production						
	PM_{10}	$PM_{2.5}$	Pb	Hg	Dioxin	PAH	PCB
Year	**Gg**	**Gg**	**Mg**	**Mg**	**g I-Teq**	**Mg**	**g**
1990	9.1	5.9	56	0.4	23	1.64	19.17
1995	4.8	3.1	58	0.4	26	1.62	21.25
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	0.035
2017	1.2	0.8	3.5	0.1	0.27	0.07	0.037
2018	1.2	0.8	2.3	0.1	0.26	0.07	0.037
2019	1.3	0.8	1.3	0.1	0.26	0.06	0.029

The reductions in emissions from this source during 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 0.32% 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 in 2011 and Aldel closed at the end of 2013. Aldel made a restart under the name Klesch Aluminium Delfzijl in 2015, and in 2017 there was another restart under the name Damco Delfzijl.

During the 1990–2019 period, PAH emissions decreased from 6.9 Mg to 0.01 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 an inaccuracy of 43% in PAH measurements during the production of anodes.

Lead production (2C5), zinc production (2C6) and copper production (2C7a)
Table 5.10 provides an overview of the process emissions from the key sources of Lead production (category 2C5) and Zinc production (2C6).

Table 5.10 Overview of emissions from Lead (2C5) and Zinc production (2C6)

	2C5: Lead production	2C6: Zinc production	
	Hg	Cd	Pb
Year	Mg	Mg	Mg
1990	NA	1.78	0.32
1995	NA	1.76	0.37
2000	NA	1.75	0.52
2005	NA	1.87	0.44
2010	NA	1.98	0.43
2015	0.05	2.39	1.12
2017	0.04	2.05	1.04
2018	0.02	2.00	0.42
2019	0.04	2.22	0.47

Some 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 'NA' in 2C7a. Normally, the reported PM_{10} emissions are used to calculate $PM_{2.5}$ emissions. But this is not possible in this case. Therefore, $PM_{2.5}$ emissions are also reported as 'NA' in 2C7a.
- Neither the lead nor the copper production company reports 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 and 2C7a.
- 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.
- Neither the copper nor the zinc production company reports Hg emissions. A review question asked whether these emissions should be calculated. However, a Tier1 calculation could not be done because production figures are not available, and there is no obligation to companies to supply these.
- The same applies to Cd emissions from copper production.

In 2021/2022 further investigations at the respective companies are made in order to improve estimates for Pb, Hg and Cd emissions in future IIRs.

5.4.4 *Methodological issues*

See paragraph 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 the study conducted by Visschedijk *et al.* (2007).

5.4.5 *Source-specific recalculations*

It was found that emissions of Cd from zinc production (2C6) increased by a factor 10 in 2018 compared with 2017. The company reported that this was the result of an improved measurement methodology, which was applied from 2018. For consistency reasons, the whole time series was recalculated by backward extrapolation from 2018 onwards, using the production index.

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 from Road paving with asphalt (2D3b) and Asphalt roofing (2D3c) were not estimated because no activity data were 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 5.11.

Table 5.112 Key sources of Solvents and product use (2D)

	Category / Subcategory	Pollutant	Contribution to total of 2019 (%)
2D3a	Domestic solvent use, including fungicides	NMVOC	15
2D3d	Coating applications	NMVOC	6
2D3i	Other solvent use	NMVOC	6
		DIOX	26

5.5.3 *Overview of emission shares and trends*

Table 5.12 provides an overview of the emissions from the key sources in this category.

Table 5.12 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	
	NMVOC	NMVOC	NMVOC	Dioxin
Year	Gg	Gg	Gg	g I-Teq
1990	24	93	19	25.0
1995	27	67	18	23.0
2000	29	41	17	20.0
2005	31	26	15	18.0
2010	32	28	16	15.0
2015	33	19	14	13.0
2017	34	15	15	11.5
2018	34	15	15	11.0
2019	35	15	15	11.0

The emission sources within this key source are:
- cosmetics (and toiletries);
- cleaning agents;
- car products;
- others.

The increase in NMVOC emissions during the period 1990–2019 was mainly due to Cosmetics (and toiletries).

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

Mainly due to the lower average NMVOC content of the paints used, NMVOC emissions from coating applications decreased from 93 Gg in 1990 to 25 Gg in 2007. As a result of the credit crunch, 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 slide, while car repairs and the industry generally showed 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. Due to decreased paint consumption in 2016 (mainly in the market segments of Car repairs and Industry), NMVOC emissions decreased to 15 Gg in 2017–2019.

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 HFC, N_2O, PFC and HCFCs.

Emissions from the use of HFC, PFC and HCFCs as refrigerants and other uses of HFCs, PFCs and HCFCs are obtained from the National Inventory Report (Ruyssenaars *et al.*, 2021).
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 after 2000 were placed on a par with those in 2000, the last year of the Hydrocarbons 2000 project.

NMVOC emissions in this category decreased from 18 Gg in 1990 to 15 Gg in 2019. These reductions were mainly the result of a lower average NMVOC content of cleaning agents.

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 25 g I-TEQ in 1990 to about 11 g I-TEQ in 2019.

5.5.4 *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 106 Gg in 2019 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 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.

5.5.5 Methodological issues
For a detailed description of the methodology of the emission sources, see Jansen *et al.* (2019).

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, see the ENINA methodology report (Honig *et al*., 2021).

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.

5.5.6 Source-specific recalculations
No recalculations have been made.

5.6 Other product use (2G)

5.6.1 Source-category description
The following activities are included in 2G in the Netherlands:
- 060601 Use of fireworks;
- 060602 Use of tobacco;
- 060604 Other: Burning of candles.

5.6.2 *Key sources*

The key sources in this category are presented in Table 5.13.

Table 5.13 Key sources of Other product use (2G)

	Category / Subcategory	Pollutant	Contribution to total of 2019 (%)
2G	Other product use	$PM_{10}/PM_{2.5}$	52.6/10.2

5.6.3 *Overview of emission shares and trends*

Table 5.14 provides an overview of the emissions from the key sources in this category.

Table 5.14 Overview of emissions from key sources of Other product use (2G)

	2G: Other product use	
Year	PM_{10} Gg	$PM_{2.5}$ Gg
1990	2.0	2.0
1995	2.0	2.0
2000	2.2	2.2
2005	2.0	2.0
2010	2.0	2.0
2015	1.7	1.7
2017	1.6	1.6
2018	1.6	1.6
2019	1.6	1.6

As a result of the drop in the number of cigarettes smoked, emission from 2G decreased from 2.0 Gg in 1990 to 1.6 Gg in 2019.

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, excl. 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.

All activities listed in the 2016 EMEP/EEA Guidebook (production of bread, wine, beer, spirits, sugar, flour, meat, fish, etc., and frying/curing) are included in these NACE activities.

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 5.15.

Table 5.15 Key sources of Other production industry (2H)

	Category / Subcategory	Pollutant	Contribution to total of 2019 (%)
2H2	Food and beverages industry	NMVOC $PM_{10}/PM_{2.5}$	2.6 7.1/3.5
2H3	Other industrial processes	NMVOC $PM_{10}/PM_{2.5}$	4.4 9.1/4.7

5.7.3 *Overview of emission shares and trends*

Table 5.16 provides an overview of the emissions from the key sources in this category.

Table 5.16 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	5.4	1.7
1995	7.6	2.3	0.6	13	3.1	0.8
2000	8.2	1.9	0.5	6	3.2	0.9
2005	7.6	1.8	0.5	10	2.7	0.8
2010	7.5	1.6	0.4	10	2.6	0.7
2015	6.0	1.8	0.5	10	2.6	0.7
2017	5.7	1.9	0.5	10	2.6	0.8
2018	5.8	2.0	0.5	10	2.5	0.7
2019	6.1	2.0	0.5	10	2.5	0.7

Food and beverages industry (2H2)
The reductions in PM_{10} emissions between 1990 and 2019 were mainly caused by the implementation of technical measures.

Other industrial processes (2H3)
The 2H3 subcategory in the Dutch PRTR covers emissions from a variety of activities, including 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. Emissions from storage and handling by companies with main activities other than those listed above are assumed to be included in the relevant categories of this NFR sector.

The reductions in NMVOC and PM_{10} emissions between 1990 and 2019 were mainly caused by the implementation of technical measures. After 2005, PM_{10} emission fluctuations were caused by the varying volume of products handled.

5.7.4 *Methodological issues*

See paragraph 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*

Food and beverages industry (2H2)

Since the 2020 submission, NMVOC emissions from bread bakeries have been calculated separately. In that submission, a calculation error was made. Therefore, the time series 2H2 differ in the last two submissions. The correct series is shown in table 5.17.

Table 5.17 Overview of NMVOC emissions from bread bakeries

2H2: Bread bakeries	**NMVOC**
Year	**Gg**
1990	4.0
1995	4.1
2000	4.3
2005	4.5
2010	4.6
2015	4.0
2016	3.9
2017	3.9
2018	3.9
2019	3.9

Other industrial processes (2H3)

No recalculations have been made.

6 Agriculture

6.1 Overview of 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 (except HCB) were calculated according to the methods described in van der Zee *et al.* (2021). All activity data are summarised in Van Bruggen *et al.* (2021), except the activity data on N excretion which is reported in CBS (2020). The method and activity data used to calculate the HCB emission are given in Section 6.3.

In 2019, the agricultural sector was responsible for 91% of all NH_3 emissions in the Netherlands. Emissions of NO_x from agriculture amounted to 14% of the national total. Agriculture contributed 37% of the national NMVOC emissions, 19% of the national PM_{10} emissions, 3% of the national $PM_{2.5}$ emissions and 18% of the national HCB emissions in 2019. Although Zn is not a priority heavy metal, emissions from drift following pesticide use are reported for the sake of completeness.

6.1.1 *Key sources*

In 2019, several key sources were identified, as presented in Table 6.1 (see Appendix 2 for details):

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, T	
Swine	L, T		L			
Poultry						
Laying hens	L,T		L, T			
Broilers			L, T			
3D Crop production and agricultural soils						
Inorganic N fertilisers	L, T	L				
Animal manure applied to soils	L, T	L, T			L, T	
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						L,T

6.1.2 *Trends*

Ammonia

Ammonia emissions decreased between 1990 and 2019, 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 1990-2019. Grass has a higher N content than the 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. 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.

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 exceeding 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 the 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 sixfold in the period 1990 to 2016 and did not further increase between in 2017 and 2019. From 1997, 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 reduced 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 2019 in agriculture was reflected in a decreasing trend in the national total.

Nitrogen oxides
Nitrogen oxide emissions decreased over the 1990–2019 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 1990–2019 period due to decreased animal numbers (Tables 6.6 and 6.7); however, PM emissions from laying hen houses almost quadrupled for PM_{10} and more than 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 2015, after which they decreased.

NMVOC
Overall, NMVOC emissions from agriculture decreased over the 1990–2019 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 deceased over the 1990–2019 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
Within sector 3B, in 2019, dairy cattle (3B1a) made the largest contribution to NH_3 emissions, amounting to 18% of the national total. Swine (3B3, 11%), non-dairy cattle (3B1b, 8%) 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, 4%) 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 4%. For emissions of $PM_{2.5}$ and NO_x, the manure management sector had no key sources.

6.2.3 Overview of emission shares and trends
Table 6.2 presents an overview of emissions of the main pollutants 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

Year	Main pollutants			Particulate matter		
	NO_x	NMVOC	NH_3	$PM_{2.5}$	PM_{10}	TSP
	Gg	Gg	Gg	Gg	Gg	Gg
1990	**3.7**	**42**	**98**	**0.4**	**4.1**	**4.1**
1995	3.9	41	96	0.4	4.2	4.2
2000	3.2	45	77	0.5	4.7	4.7
2005	2.9	43	68	0.4	4.6	4.6
2010	3.1	59	70	0.5	5.2	5.2
2015	3.5	66	64	0.5	5.7	5.7
2018	3.7	76	63	0.4	5.2	5.2
2019	**3.7**	**65**	**59**	**0.4**	**4.6**	**4.6**
1990–2019 period[1]	-0,1	23	-39	0.0	0.5	0.5
1990–2019 period[2]	-2%	-55%	-40%	-8%	12%	12%

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.,* 2021). Figure 6.1 presents a schematic overview of the N-flows.

Between 1990 and 2019, NH_3 emissions from manure management were reduced by 40% (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.

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.,* 2021).

As NO_x emissions were also influenced by the above-mentioned developments, NO_x emissions decreased by 2% from 1990 to 2019.

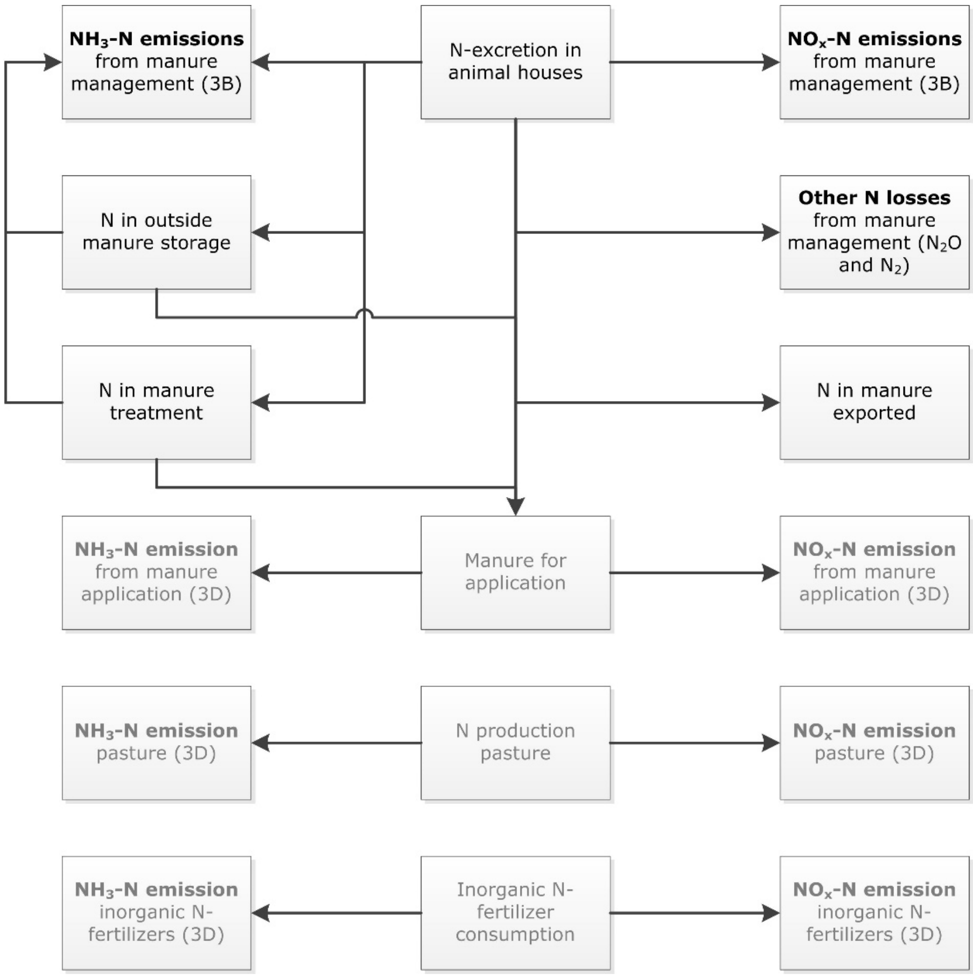

Figure 6.1 Nitrogen flows in relation to NH_3 and NO_x emissions where the boxes with black type show the emissions included in 3B Manure management and the boxes with grey type show emissions included in 3D Crop production and agricultural soils

Particulate matter
Particulate matter 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.

NMVOC
Emissions of NMVOC showed an increasing trend of 55% from 1990 to 2019, 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 (see the summary in Table 6.3 and, for a full list of subcategories and years, Bruggen van *et al.* (2021)). For horses, an

estimated 300,000 additional animals were included in the inventory to account for privately owned animals.

Animal numbers were distributed over the various housing types using information from the agricultural census (Bruggen van *et al.*, 2021).

Table 6.3 Animal numbers over the 1990–2019 period (in 1,000 heads)

Animal type	1990	1995	2000	2005	2010	2015	2018	2019
Cattle	4,926	4,654	4,069	3,797	3,975	4,134	3,844	3,750
dairy cattle	1,878	1,708	1,504	1,433	1,479	1,622	1,591	1,578
non-dairy cattle	3,048	2,946	2,565	2,364	2,497	2,512	2,252	2,172
Sheep	1,702	1,674	1,305	1,361	1,130	946	913	960
Swine	13,915	14,397	13,118	11,312	12,255	12,603	12,391	12,214
Goats	61	76	179	292	353	470	588	615
Horses	370	400	417	433	441	417	409	408
Mules and asses	IE	IE	IE	IE	1	1	1	1
Poultry	94,902	91,637	106,517	95,190	103,371	108,558	99,220	95,415
laying hens	51,592	45,734	53,078	48,418	56,500	57,656	54,604	51,346
broilers	41,172	43,827	50,937	44,496	44,748	49,107	43,188	42,617
turkeys	1,052	1,207	1,544	1,245	1,036	863	556	532
other poultry	1,086	869	958	1,031	1,087	932	872	920
Other animals	1,340	951	981	1,058	1,261	1,404	1,245	1,144
Fur-bearing animals	554	463	589	697	962	1,023	913	807
Rabbits	786	488	392	360	299	381	332	336

Source: Bruggen van *et al.* (2021).

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, 2012a). The historical data were recalculated in 2009 (CBS, 2012a) and have since been supplemented yearly, thereby ensuring consistency (CBS, 2011–2020).

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. From that, 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).

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**	**2018**	**2019**
Cattle	6.8	6.8	5.8	6.5	6.8	7.5	8.8	8.5
Dairy cattle	11.8	11.9	9.5	11.6	11.8	12.4	14.4	14.0
Non-dairy cattle	3.7	3.9	3.6	3.4	3.9	4.3	4.8	4.5
Sheep	0.4	0.4	0.4	0.2	0.1	0.1	0.2	0.2
Swine	3.5	3.4	2.8	2.4	2.2	1.4	1.2	1.1
Goats	1.6	1.6	1.4	1.2	1.2	1.3	1.4	1.6
Horses	4.4	4.4	4.4	4.3	4.0	4.0	4.9	4.9
Mules and asses	IE	IE	IE	IE	2.8	2.8	3.2	3.2
Poultry	0.15	0.16	0.14	0.15	0.14	0.12	0.12	0.12
Laying hens	0.16	0.17	0.17	0.18	0.17	0.17	0.17	0.17
Broilers	0.11	0.12	0.10	0.09	0.08	0.06	0.06	0.05
Turkeys	0.80	0.79	0.80	0.85	0.95	0.94	0.82	0.85
Other poultry	0.31	0.30	0.28	0.24	0.21	0.18	0.17	0.17
Other animals	0.40	0.38	0.32	0.28	0.22	0.24	0.23	0.25
Fur-bearing animals	0.37	0.36	0.29	0.22	0.17	0.19	0.17	0.17
Rabbits	0.42	0.39	0.37	0.40	0.36	0.38	0.36	0.43

NO_x emissions from denitrification processes in animal manure were not considered as a source when the emission ceilings were set (EU, 2016). Therefore, these are not included in the national total, but they are reported. The NO_x emissions from animal housing and storage were included in the national total, as they were considered non-natural.

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**	**2018**	**2019**
Cattle	0.49	0.54	0.50	0.48	0.50	0.58	0.66	0.66
Dairy cattle	0.71	0.75	0.67	0.70	0.71	0.78	0.86	0.86
Non-dairy cattle	0.35	0.42	0.41	0.34	0.38	0.45	0.51	0.51
Sheep	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01
Swine	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
Goats	0.40	0.40	0.35	0.34	0.36	0.38	0.43	0.43
Horses	0.44	0.44	0.44	0.44	0.40	0.40	0.53	0.53
Mules and asses	IE	IE	IE	IE	0.22	0.22	0.26	0.26
Poultry	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
Broilers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkeys	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other animals	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Fur-bearing animals	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.01
Rabbits	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

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. 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	2018	2019
Cattle	85.4	82.8	78.3	78.7	77.8	80.3	82.3	81.8
Dairy cattle	114.8	114.8	114.8	119.9	123.7	127.4	125.8	125.3
Non-dairy cattle	67.3	64.3	56.9	53.7	50.6	50.0	51.5	50.2
Sheep	4.2	4.2	4.2	3.9	1.8	1.8	1.9	1.9
Swine	113.3	112.2	112.4	109.9	103.8	77.3	72.3	71.6
Goats	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Horses	220.0	220.0	220.0	220.0	220.0	220.0	220.0	220.0
Mules and asses	IE	IE	IE	IE	160.0	160.0	160.0	160.0
Poultry	22.0	23.1	26.5	31.9	35.0	40.1	39.3	35.5
Laying hens	14.9	16.1	22.8	33.6	39.3	50.2	49.3	43.1
Broilers	26.8	26.8	26.8	26.7	26.6	26.1	24.8	24.3
Turkeys	100.2	98.1	95.1	95.1	95.1	95.1	93.7	93.7
Other poultry	104.5	104.5	104.5	104.5	104.5	101.8	101.7	101.3
Other animals	4.2	4.7	5.4	5.8	6.5	6.3	6.3	6.2
Fur-bearing animals	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Rabbits	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.5

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	2018	2019
Cattle	23.5	22.8	21.6	21.7	21.4	22.1	22.7	22.5
Dairy cattle	31.7	31.7	31.7	33.1	34.1	35.1	34.7	34.5
Non-dairy cattle	18.5	17.7	15.7	14.8	13.9	13.8	14.2	13.8
Sheep	1.2	1.2	1.2	1.2	0.5	0.5	0.6	0.6
Swine	5.8	5.7	5.7	5.4	5.1	3.7	3.4	3.4
Goats	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Horses	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0
Mules and asses	IE	IE	IE	IE	100.0	100.0	100.0	100.0
Poultry	2.2	2.3	2.5	2.7	2.7	2.9	2.7	2.5
Laying hens	1.4	1.5	1.7	2.1	2.5	3.1	3.0	2.7
Broilers	2.0	2.0	2.0	2.0	2.0	2.0	1.8	1.8
Turkeys	47.0	46.0	44.6	44.6	44.6	44.6	44.0	43.9
Other poultry	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9
Other animals	1.9	2.2	2.6	2.9	3.3	3.1	3.1	3.1
Fur-bearing animals	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Rabbits	0.28	0.28	0.28	0.28	0.27	0.27	0.26	0.30

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, 2020).

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

Animal type	1990	1995	2000	2005	2010	2015	2018	2019
Cattle	5.98	6.17	7.96	8.40	12.14	13.28	14.29	14.40
Dairy cattle	8.15	7.96	15.07	16.92	24.13	25.67	27.45	27.50
Non-dairy cattle	4.64	5.14	3.78	3.24	5.04	5.28	5.00	4.89
Sheep	0.05	0.05	0.05	0.05	0.02	0.02	0.02	0.02
Swine	0.42	0.39	0.35	0.32	0.29	0.27	0.28	0.28
Goats	0.86	0.79	0.42	0.82	0.87	0.86	0.91	0.95
Horses	0.61	0.61	0.61	0.59	0.59	0.59	0.59	0.59
Mules and asses	IE	IE	IE	IE	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
Laying hens	0.05	0.06	0.05	0.05	0.06	0.06	0.06	0.06
Broilers	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	0.13	0.12
Other poultry	0.04	0.04	0.05	0.05	0.04	0.03	0.07	0.07
Other animals	0.18	0.18	0.21	0.23	0.30	0.37	0.36	0.30
Fur-bearing animals	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

6.2.5 *Uncertainties and time series consistency*
A propagation of error analysis on NH_3 emissions was performed in 2015. In 2017 the propagation of error analysis was updated to include manure treatment and NMVOC emissions. Using reassessed uncertainty estimates of activity data (CBS, 2012b) and the judgement of experts (Lagerwerf *et al.*, 2019), an uncertainty of 20% 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 34%. A Monte Carlo analysis of uncertainties of the total inventory (including sectors outside agriculture) was performed in 2018 and the results are presented in Section 1.7.

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.,* 2021).

6.2.7 *Source-specific recalculations*
A study by Statistics Netherlands suggests that low-emission housing is not reaching the NH_3 emission reduction target (van Bruggen & Geertjes, 2019). Therefore, it was decided change the EF for low-emission housing for the entire time series.

6.2.8 *Source-specific planned improvements*
The nutrients bedding material (e.g. straw and wood shavings) incorporates into the manure and the corresponding emissions have not been estimated due to a lack of data and time constraints. All efforts will be made to make these changes for the IIR 2022.

Emissions from privately owned horses, ponies and sheep are currently all reported under Animal manure applied to soils (3Da2a), whereas these animals also emit pollutants in Manure management (3B) and Urine and dung deposited by grazing animals (3Da3). However, due to time constraints and the complexity of the database and the model these emissions were not split out. All efforts will be made to make these changes for the IIR 2022.

The QA/QC section in the methodology report of 2022 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 are allocated to category 3Da2a, 3Da3, 3Dc and 3De. Zinc and HCB emissions to category 3Df.

6.3.2 *Key sources*

Within sector 3D, Animal manure applied to soils (3Da2a) was the largest key source of NH_3 emissions, amounting to 29% of the national total. Inorganic N fertilisers (3Da1) were also a key source of NH_3, making up 7% of the national total. For NO_x, animal manure applied to soils (3Da2a, 6%) 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} and $PM_{2.5}$, the crop production and agricultural soils sector contained no key sources. HCB emissions from the use of pesticides (3Df) constituted 18% of the national total.

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)

Year	Main pollutants		Particulate matter		Other heavy metals		Persistent organic pollutant	
	NO_x	NMVOC	NH_3	$PM_{2.5}$	PM_{10}	TSP	Zn	HCB
	Gg	Gg	Gg	Gg	Gg	Gg	Mg	kg
1990	**47**	**57**	**238**	**0.2**	**0.8**	**0.8**	**0**	**21**
1995	46	25	111	0.2	0.8	0.8	0	39
2000	39	26	84	0.2	0.8	0.8	0	16
2005	33	23	72	0.2	0.8	0.8	6.8	2
2010	30	22	53	0.2	0.8	0.8	4.6	1
2015	31	24	56	0.2	0.8	0.8	4.4	1
2018	31	24	55	0.1	0.8	0.8	4.6	1
2019	**30**	**23**	**52**	**0.2**	**0.8**	**0.8**	**4.6**	**1**
1990–2019 period[1]	-18	-34	-185	0.0	-0.1	-0.1	4.6[3]	-20[4]
1990–2019 period[2]	-37%	-59%	-78%	-3%	-7%	-7%		-97%

1. Absolute difference in Gg.
2. Relative difference from 1990 in %.
3. Absolute difference in Mg.
4. Absolute difference in kg.

N emissions
Emissions of NH_3 from crop production and agricultural soils decreased by 78% between 1990 and 2019, 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 37% between 1990 and 2019, mainly as a result 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 2019 of 59%, 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 reduced by 33% from 2005 to 2019, due to a reduction in pesticide use. Before 2005, there were no zinc emissions related to the pesticides then used.

HCB
HCB emissions reduced by 79% from 1990 to 2019, 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 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), 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*. (2021). 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.

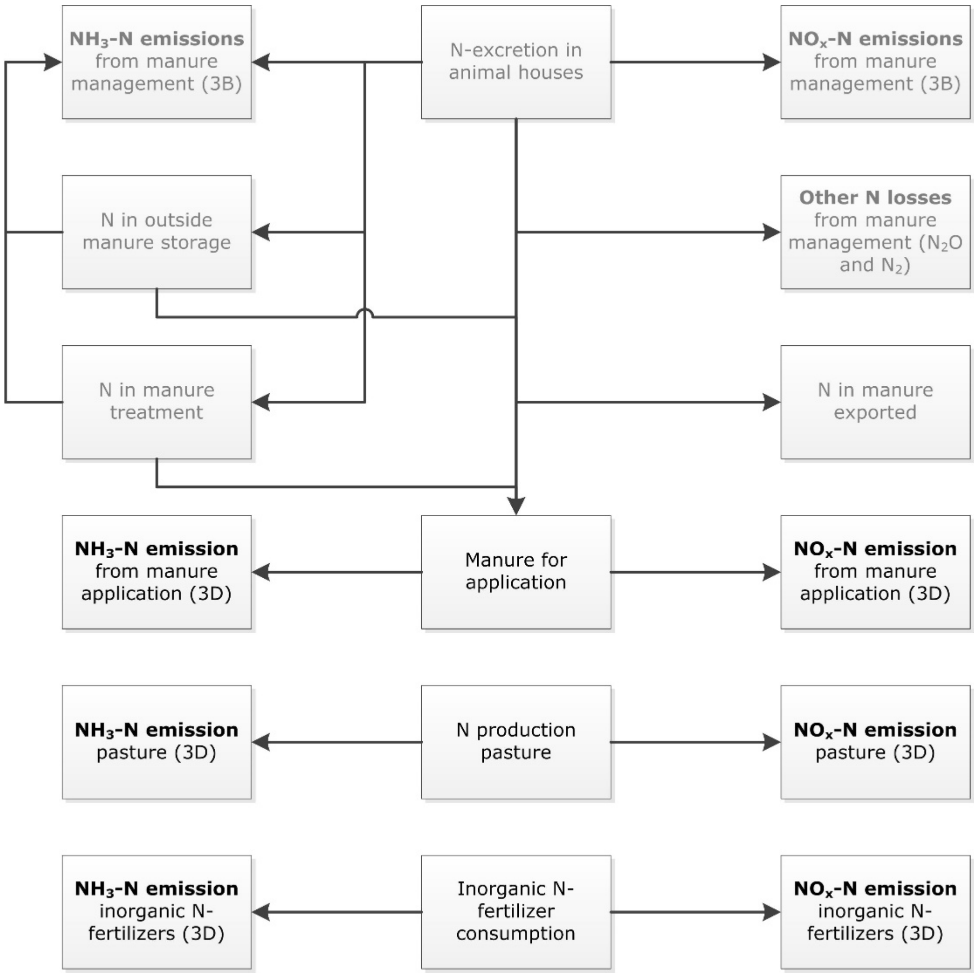

Figure 6.2 Nitrogen flows in relation to NH_3 and NO_x emissions where boxes with black type show the emissions included in 3D Crop production and agricultural soils and boxes with grey type show emissions included in 3B Manure management

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 1990–2019 time series, as described in the methodology report of van der Zee *et al.* (2021). The subcategories and the EFs for each subcategory were originally published in Van Bruggen *et al.* (2020).

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.

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.

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

Emission source	1990	1995	2000	2005	2010	2015	2018	2019
Application of inorganic N fertilisers	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Application of animal manure	0.48	0.19	0.18	0.16	0.12	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
Application of other organic fertilisers (compost)	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07
Urine and dung deposited by grazing animals	0.08	0.08	0.04	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
Crop ripening	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 (Lagerwerf *et al.*, 2019). 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 (Lagerwerf *et al.*, 2019). Crop harvesting was calculated from acreage data from the agricultural census and EMEP default EFs (EEA, 2016).

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 and cultivated crops. 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.

Zinc
Zinc emissions were based on the amount of pesticide used in agriculture as calculated by the National Environmental Indicator Pesticides (NMI3) model (Kruijne *et al.*, 2012).

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[1]	0.0	0.0	0.0	63.9	18.1

1. Sales figures from 2018 were used as preliminary figures for 2019.

6.3.5 *Uncertainties and time series consistency*

A propagation of error analysis of NH_3 emissions was performed in 2015, with an update in 2017 to include NMVOC emissions. Using reassessed uncertainty estimates of activity data (Bruggen van *et al.,* 2017) and expert judgement, an uncertainty of 38% was calculated for NH_3 emissions following animal manure application, 37% for inorganic N fertiliser use and 56% for grazing emissions. The total uncertainty in the ammonia emissions from sector 3D Crop production and agricultural soils then amounts to 29%. Including the emissions in sector 3B Manure management, the combined uncertainty in total NH_3 emissions from agriculture comes to 25%. A Monte Carlo analysis on the uncertainties of the total inventory was performed in 2018 and the results are presented in Section 1.7.

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 2010–2019 the data were provided by the Dutch Food and Consumer Safety Authority, these are public. For 2019 the value of 2018 was used, as no new value had been provided in time (NVWA, 2020). 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 the methodology report (van der Zee *et al.,* 2021).

6.3.7 *Source-specific recalculations*

Emissions related to the application of manure from privately owned horses, ponies and sheep and the emissions related to the application of manure and inorganic fertilisers on private land were allocated to 3Da2a instead of 6A to comply with the guidelines. However, 3da2a is currently overestimated, as emissions from the housing, manure management and grazing of privately owned horses, ponies and sheep were not split out due to time constraints and the complexity of the database and the model.

The EF of ammonia from manure application on grassland was reduced because new research showed that an exponential concentration profile fitted the emission curve better than the Ryden and McNeill model that was previously used.

A study by Statistics Netherlands suggests that low-emission housing is not reaching the NH_3 emission reduction target (Van Bruggen & Geertjes, 2019). Therefore, it was decided change the EF for low-emission housing for the entire time series. This change reduces the NH_3 and NMVOS emissions from the application of manure, as these are related to the amount of NH_3 emitted in the housing.
The distribution of manure over the different land types (arable and grassland) was updated. This update showed that the amount of cattle manure on arable land was higher and that the amount of pig manure being exported was higher than previously estimated. This led to a

reduction in the emissions of NH_3, as more low-emission application techniques are applied on arable land than on grassland and pig manure has a higher EF than cattle manure.

6.3.8 Source-specific planned improvements

The QA/QC section in the methodology report of 2022 will be further elaborated to encompass all measures that are currently taken.

The IIR 2022 will include the sales figures of pesticides in 2019 instead of using sales figures from 2018 as a proxy. The estimated uncertainty will also be further developed to include the uncertainty of the sales figures.

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 Waste-water handling;
- 5E Other waste.

Solid waste disposal on land (5A)
Emissions in this source category comprise those from landfills and those from extracted and flared landfill gas. Part of the extracted 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.

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 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).

Waste-water handling (5D)
The data on emissions from industrial and urban waste-water treatment plants (WWTP) come from the AERs made by individual treatment plants/companies. From waterline and sludge drying processes WWPTs produce small amounts of particulate matter (aerators and sludge depots) and NMVOC. WWPT sludge is in some cases fermented before drying and produces methane during fermentation. Around 80% of this methane is captured and is used in energy production (or incidentally flared). Emissions from the incineration of WWPT fermentation gas are

reported under the source category Commercial/Institutional: Stationary (1A4ai).

Other waste (5E)
Emissions in the Other waste source category comprise those from waste preparation for recycling, scrapped fridges/freezers and accidental building and car fires.

Key sources
The source category 5E (Other waste) is a key source of $PM_{2.5}$, PM_{10}, dioxins and total PAH emissions in both trend (increase) and level assessments.

7.2 Overview of shares and trends in emissions

An overview of the trends in emissions is shown 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 NH_3 and 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	**0.10**	**2.4**	**0.02**	**0.15**	**0.48**	**0.52**	**0.5**	**0.11**	**7.2**
1995	0.14	2.3	0.04	0.43	0.52	0.56	0.6	0.12	8.6
2000	0.13	2.1	0.03	0.44	0.53	0.57	0.6	0.12	8.7
2005	0.12	1.7	0.02	0.45	0.50	0.54	0.6	0.11	8.0
2010	0.15	1.6	0.03	0.53	0.56	0.61	0.6	0.13	8.8
2015	0.22	1.5	0.03	0.56	0.55	0.60	0.6	0.13	8.5
2018	0.22	1.4	0.03	0.57	0.56	0.61	0.6	0.13	8.9
2019	**0.21**	**1.4**	**0.03**	**0.58**	**0.49**	**0.53**	**0.6**	**0.12**	**8.3**
1990–2019 period[1]	0.11	-1.0	0.01	0.43	0.01	0.01	0.01	0.01	1.1
1990–2019 period[2]	107%	-43%	54%	283%	2%	2%	2%	11%	15%

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	**0.04**	**0.02**	**0.06**	**13**	**0.79**	**0.02**	**0.03**	**0.01**	**0.00**	**0.00**	**1.1**
1995	0.05	0.02	0.07	14	0.83	0.02	0.04	0.01	0.00	0.00	1.5
2000	0.05	0.02	0.10	15	0.85	0.02	0.04	0.01	0.00	0.00	1.2
2005	0.05	0.02	0.09	14	0.83	0.02	0.03	0.01	0.00	0.00	1.1
2010	0.05	0.03	0.05	16	0.93	0.02	0.04	0.02	0.00	0.00	1.3
2015	0.05	0.03	0.01	16	0.92	0.02	0.04	0.02	0.00	0.00	1.3
2018	0.05	0.03	0.01	16	0.93	0.02	0.04	0.02	0.00	0.00	1.3
2019	**0.05**	**0.02**	**0.01**	**16**	**0.80**	**0.01**	**0.04**	**0.01**	**0.00**	**0.00**	**1.1**
1990–2019 period[1]	0.01	0.00	-0.05	3.1	0.01	0.00	0.01	0.00	0.00	0.00	0.04
1990–2019 period[2]	12%	13%	-78%	24%	1%	-25%	18%	2%	18%	-15%	4%

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 in Honig *et al.* (2021). The exceptions are emissions from cremations, accidental building and car fires, and bonfires, whose methodologies are explained in Visschedijk (2021), and the source Livestock manure digestion, which is explained in Lagerwerf *et al.* (2019).

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 analyses in 2018. This methodology is used for uncertainty analyses 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	101	101	95%	90%	99%
5B	59%	102%	100%	NA	NA	NA
5C	NA	341%	358%	336%	354%	360%
5D	NA	NA	NA	208%	NA	NA
5E	200%	202%	204%	197%	194%	185%
Total Waste sector	**63%**	**98%**	**129%**	**151%**	**174%**	**166%**

The Approach 2 uncertainty analysis shows relatively high uncertainties at the level of the source categories. However, since these source categories have no key sources for these pollutants and therefore their contribution to the uncertainty at national level will be relatively small, 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*

There were no source-specific recalculations.

7.2.5 *Source-specific planned improvements*

As result of a review recommendation, a project has been started to estimate NMVOC emissions from industrial waste water treatment plants in future.

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 extracted and flared landfill gas and PM emissions from the landfilling process.

Since 50% of extracted (captured) 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. Following a review recommendation, the remaining 50% of extracted landfill gas is flared and the emissions from this are reported under this sector.

Flared landfill gas emits to the atmosphere, and only NMVOC emissions are of relevance to the IER. The individual compounds that form NMVOCs mainly originate from volatile organic compounds that were dumped in the past as waste. 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).

Included in this source category are 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 the waste. From this information, the amount of methane is calculated using a methane conversion factor (Table 7.3).

The amount of extracted and combusted landfill gas (mainly for energy purposes) is collected by the Working Group on Waste Registration (WAR). All landfill operators report these data to WAR.

It is assumed that 10% of the non-extracted methane will be oxidised in the top layer of the landfill.

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 0.31 Gg in 1990 and 2019, respectively.

$PM_{2.5}$ emissions are also relatively low, at 0.0035 Gg and 0.0049 Gg in 1990 and 2019, 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, from 13.9 Tg in 1990 to only 3.1 Tg in 2019 (-77%). In addition, due to the separation of biodegradable materials, the amount of biodegradable carbon in the waste has dropped from 130.8 kg C per Mg waste in 1990, to 51.3 kg C per Mg in 2019 (-61%). These two developments have had a clear effect on methane (and also NMVOC) production by landfill sites, which has decreased by 81% during the same period. This downward trend is expected to continue in the future.

Table 7.3 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; thereafter constant at 0.5	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	

Table 7.4 Landfill gas EFs

Compound	Emission factors and units		
	Combusted landfill gas		Emitted landfill gas
	Flared	Gas engine	
Total hydrocarbons (incl. methane)			0.389803 kg/m³
Hydrocarbons (C_xH_y)	0.27% hydrocarbons	6 g/m^3	
Dioxins	0.9E^{-9} g/m^3	0.3E^{-9} g/m^3	
SO_x (based on all sulphur)	104 mg/m^3	104 mg/m^3	
NO_x (as NO_2)	0.3 g/m^3	3 g/m^3	
CO	2.7% C	3.4 g/m^3	
Soot	0.05% hydrocarbons		
CO_2 (biogenic)	total C minus CO minus soot		
Other aliphatic non-halogenated hydrocarbons			700 mg/m^3
Dichloromethane			20 mg/m^3
Trichloromethane			1 mg/m^3
Chlorodifluormethane (HCFC-22)			10 mg/m^3
Dichlorodifluormethane (CFC-12)			20 mg/m^3
Trichlorofluormethane (CFC-11)			5 mg/m^3
Chloroethene			10 mg/m^3
Cis-1.2-Dichloroethene			1 mg/m^3
1.1.1-Trichloroethene			2 mg/m^3
Trichloroethene (Tri)			10 mg/m^3
Tetrachloroethene (Per)			10 mg/m^3
Chloropentafluorethane			1 mg/m^3
1.2-dichloro-1.1.2.2-tetrafluoroethane (CFC-114)			2 mg/m^3
1.1.2-Trichloro-1.2.2-trifluoroethane (CFC-113)			1 mg/m^3
Mercaptan. non-specified			10 mg/m^3
Benzene			7 mg/m^3
Toluene			120 mg/m^3
H_2S			100 mg/m^3

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 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 7.4.

For each waste site, landfill site operators systematically monitor the amount of waste dumped (weight and composition). Since 1993, monitoring has been conducted by weighing the amount of waste dumped 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 7.5 shows the EFs used for calculating the PM emissions during landfilling.

Table 7.5 Emission factors used for emissions of PM during landfilling

Compound	Emission factor g/Mg
PM_{10}	0.219
$PM_{2.5}$	0.033

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 categories:

- 5B1A Composting of organic waste from households;
- 5B1B Composting of organic waste from gardens and enterprises;
- 5B2A Anaerobic digestion of organic waste from households;
- 5B2B 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 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 (biogas production). Additionally, part of the manure produced by pigs and cattle is used in anaerobic digesters (biogas production).

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 Registration Waste Products (‘Landelijk meldpunt afvalstoffen’, LMA). The LMA tracks all waste transport in the Netherlands. Table 7.6 provides an overview of the total amounts of separately collected organic household and other organic waste from operators in composting and digestion industry.

Table 7.6 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	1.072	476	2.189	95

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.

Composting (5B1)
During composting, biodegradable organic 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 organic horticulture waste are carried out mostly in the open air, in rows that are regularly turned over to optimise aeration. Composting generates small 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, which 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

Total emissions of NH_3 related to composting are relatively small (0.05 Gg and 0.25 Gg for 1990 and 2019, respectively). Therefore, shares and trends in these emissions are not elaborated here.

Anaerobic digestion

Emissions related to anaerobic digestion date from 1994, when the first digestion plants started operations. NH_3, NO_x and SO_x emission levels related to anaerobic digestion are relatively low (0.21 Mg, 0.10 Mg and 0.006 Mg, respectively, in 1994, and 0.03 Gg, 0.002 Gg and 0.0001 Gg, respectively, in 2019). Manure digesters were introduced in 2006. Therefore, shares and trends in these emissions are not elaborated here.

7.4.3 *Emissions, activity data and (implied) emission factors*

Composting

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 at the 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 NH_3 from composting, an EF of 200 g/Mg of biodegradable and other organic waste is used.

Most separately collected organic waste is used in composting. Table 7.6 provides an overview of the total amounts of organic household and horticultural waste that is treated in composting plants.

Anaerobic digestion

The anaerobic digestion of biodegradable domestic waste (i.e. garden waste, horticulture waste and household waste such as fruits and vegetables) and of livestock manure is done in different 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.

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.

Activity data for anaerobic digestion from organic domestic waste are based on the amount declared to the Landelijk Meldpunt Afvalstoffen (LMA), the hotline for national waste transport, as described under composting.

A relatively small amount of separately collected organic waste is used in digestion. Table 7.6 provides an overview of the total amounts of organic household and horticultural waste that are treated in digestion plants.

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 different 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 (excl. veal calves), 0.01 kg/kg N.

The emission calculation methodology can be found in Lagerwerf *et al.* (2019). The calculations are done with the NEMA model for calculating agricultural emissions (Bruggen van *et al.*, 2021).

Activity data on the amount of manure that has been treated and its N content is estimated from registered manure transports (data from the Netherlands Enterprise Agency (RVO).

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 in heating of 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 combustion emissions. The emissions of natural gas used are reported under the Energy sector (source category Commercial and institutional services (1A4ai)). Since 2012, all cremation centres have complied with the Dutch Atmospheric Emissions Guideline (NeR) and are equipped with technological measures to reduce emissions.

There is no incineration of carcasses or slaughter waste in the Netherlands. This 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.

However, according to tradition a number of holidays are brightened by bonfires. These have a strong cultural and regional background, most such celebrations taking place only 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).

Table 7.7 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.

Table 7.7 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
Saint-Maarten	11 November	The most northern provinces and the most southern provinces

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.
Worth mentioning is that emissions were substantially lower in 2019 due to a ban in most communities as result of a drought.

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, 2020).

An overview of the number of cremations in compliance with the NeR is given in Table 7.8.

Table 7.8 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
2017	150,027	96,688	64	100
2018	153,249	100,089	65	100
2019	151,539	111,881	67	100

1. Interpolation from year 2011.
2. Calculation based on list of crematoria under the NeR (LVC, 2020).

The EF for mercury is based on sales of amalgam combined with results from model (KUB) calculations of the EF for mercury per age category (Coenen, 1997).
All the mercury in amalgam is assumed to become volatilised during cremation and subsequently emitted, together with the flue gas if no NeR measures are in place. The EFs used for this situation are:

- 1.15 gHg/cremation for 1995;
- 1.37 gHg/cremation for 2000;
- 1.44 gHg/cremation for 2002;
- 1.73 gHg/cremation from 2010 onwards.

For the intermediate years, EFs have been linearly interpolated.

The implementation of NeR measures has been shown to lead to a significant reduction in mercury emissions. Measurements that were taken when crematoria were in compliance with the NeR resulted in concentrations of between 0.001 and 0.004 mgHg/m^3 (Elzenga, 1996). Based on these measurements, an EF of 0.1 gHg/cremation (0.05 mgHg/m^3 fume) was assumed for crematoria in compliance with the NeR.

PM_{10} and $PM_{2.5}$ are calculated as a fraction of TSP. Due to the lack of information, the fraction for both was set to 1.
When no emission reduction measures are in place, an EF of 100 g TSP/cremation is used (Elzenga, 1996). The NeR measure for emission reduction requires the use of a special filter (cloth or electrostatic). Emission levels with the use of cloth filters were found to be 25 g TSP/cremation or less (Elzenga, 1996). However, measurements carried out at the crematorium in the Dutch city of Geleen showed concentrations of <6 mg TSP/m^3 (~13 g TSP/cremation) and, at the crematorium in Bilthoven, concentrations of less than 0.7 mg TSP/m^3 were measured. For

facilities with NeR measures in place, calculations were done under the assumption of an emission level of 10 g TSP/cremation.
For crematoria without NeR measures in place, an EF for dioxins of 4 ug I-TEQ/cremation was assumed on the basis of measurements taken at three crematoria in the Netherlands (Bremmer *et al.*, 1993).

The NeR emission reduction measure also reduces dioxin emissions. Measurements taken at the crematoria of Geleen and Bilthoven showed respective concentrations of 0.024 ng I-TEQ/m^3 (0.052 ug I-TEQ/cremation) and 0.013 ng I-TEQ/m^3 (0.028 ug I-TEQ/cremation). However, in Germany, the current limit (Verordnung über Anlagen zur Feuerbestattung; Bundes-Immissionsschutzverordnung 27 (27th BlmSchV)) for installations equipped with filters is 0.1 ng I-TEQ/m^3 (or 0.2 ug I-TEQ/cremation).

For installations with NeR measures in place, calculations are done with an EF of 0.2 ug I-TEQ/cremation.

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.

The activity data used come largely from specific websites, local 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.

Easter fires
Table 7.9 provides an overview of the total amount (m^3) of pruning burned in the four large Easter fires (see http://www.paasvuurdijkerhoek.nl/wordpress/uitslagen).

Table 7.9 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
2016	6,611	5,714	2,384	2,260
2017	7,960	5,767	3,477	2,351

All other Easter fires in the Netherlands are much smaller and the occurrence of these bonfires is dependent 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*.

Picture 7.1 Espelo's 2012 Easter fire

As a result, the number of (small) Easter fires and volumes can only be estimated from local newspaper reports and the number of inhabitants per province. The average volume of the smaller Easter fires is estimated to be 250 m^3. The number of Easter fires is estimated to be roughly 400.

New Year's Eve fires
The New Year's Eve bonfires at Scheveningen and Duindorp are made of pallets (see Picture 7.2). The volume of pallets burned can be measured accurately because of the fierce competition between the two neighbourhoods. Table 7.10 provides an overview of the amount of pallets burned in these two fires.

Table 7.10 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
2016	9,616	8,848
2017	9,782	9.000

* 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.

All other bonfires on New Year's Eve in the Netherlands are much smaller and the occurrence of these bonfires is dependent 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 7.2 The piles of pallets at Scheveningen and Duindorp for the 2018 New Year's Eve bonfires.

As a result, the total volume of wood burned in New Year's Eve fires is estimated to be 25,000 m^3 (around 19,000 m^3 for Scheveningen and Duindorp and 6,000 m^3 for the other, smaller non-registered bonfires).

Meierblis
Based on local newspaper reports it is estimated that around 7 large fires and around 65 smaller fires are lit every year. It is estimated that the large bonfires together account for about 3,500 m^3 of wood and the smaller bonfires amount to 16,250 m^3 in total.

Luilak
Based on local newspaper reports it is estimated that the number of bonfires is about 10 and the amount of wood burned in each fire is restricted to 16 m^3 max., resulting in a total amount of about 640 m^3.

Saint-Maarten
Based on regional newspaper reports and expert judgement it is estimated that the volume of wood burned is about 5,000 m^3.

Christmas tree burning
Based on regional newspaper reports and expert judgement it is estimated that the volume of wood burned is about 5,000 m^3.

Wood density
The density of pruning wood is based on a Belgian report from the Flemish government on waste from 2014 (www.lne.be) and is equal to 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.

Heating value of pallets
The heating value of pallets has been derived from the kachelmodel of Jansen (2010). This is equal to 15.6 MJ/kg.

A distinction in EF 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 Waste-water handling (5D)

WWPTs produce methane, among other emissions. About 80% of this methane is captured and used in energy production or is flared. Emissions from WWPTs, therefore, are reported under the source category of Small combustion (1A4).

Up till now, the Netherlands has used a Tier 3 method: Annual Environmental Reports of companies provide emission data per company. For NMVOC, emissions are mostly under the reporting threshold. Therefore, NMVOC process emission data covering the whole waste-water sector are not yet available. Its planned for 2022 to start reporting these emissions for the whole sector Domestic waste-water treatment 5D1, using standardised EF, developed by the waste-water sector itself. A first quick estimate revealed that the total emissions of NMVOC for domestic waste-water treatment will be approximately 7,200 kg. which is 0.003% of total national NMVOC emissions. For industrial waste-water its needed to consider which method can be used, which will be complicated since activity data on industrial waste-water treatment have not been available since 2016, due to budget cuts.

7.7 Other waste (5E)

7.7.1 Source category description

The source category Other waste (5D) comprises the following emission sources:

- sludge spreading;
- waste preparation for recycling;
- scrapped fridges/freezers;
- accidental building and car fires.

Sludge spreading
WWTPs produce sewage sludge. In the Netherlands, when this sewage sludge meets the legal environmental quality criteria, it can be used as fertiliser in agriculture. In line with the EMEP/EEA Guidebook, emissions from this source are reported under Sewage sludge applied to soils (3Da2b).

The remainder of the sewage sludge is recycled or incinerated. To minimise the cost of transport, the sewage sludge is mechanically dried at the WWTP. The dried sludge is then transported to one of the waste recycling/incineration plants. Emissions from this source are included in Municipal waste incineration (5C1a) and reported in the Energy sector (source category Public electricity and heat production (1A1a)).

The process for the drying of sludge by spreading it in the open air is not applied in the Netherlands. However, in 2013 a survey was done to explore the possibility of drying sewage sludge in specially designed greenhouses using solar energy and/or residual heat from combustion processes.

Waste preparation for recycling
Waste preparation for recycling is done mainly by companies that process waste to turn it into new base materials.

Scrapped fridges/freezers
Fridges and freezers that have been written off are collected separately from other waste and sent to specialised recycling centres. During the recycling process, a small amount of NMVOC is emitted from the fridges' and freezers' insulating layer.

Accidental building and car fires
Mainly due to accidents (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.

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 were 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 (as described in Section 5.1.3 under Methodological issues).

Scrapped fridges/freezers
When recycling scrapped fridges/freezers, a small amount of NMVOC (as dichlorodifluoromethane (CFC12), used as blowing agent) is emitted from the insulation material. In the calculations, an EF of 105 g CFC12 per recycled fridge/freezer was used.

Since 2010, data on the numbers of scrapped fridges/freezers have been based on the annual Wecycle monitoring report on the collecting and recycling of e-waste (electrical appliances and energy-saving lighting). Wecycle reports the total weight of scrapped fridges/freezers, and its monitoring reports are published online at www.wecycle.eu. In the past, these data were supplied by the NVMP (Dutch Foundation Disposal Metalelectro Products), but the NVMP merged with Wecycle in 2010.

In 2009, the NVMP reported both the collected tonnage and number of fridges/freezers. From this report, the average weight of a single fridge/freezer was calculated. This average weight was used to calculate the number of scrapped fridges/freezers for the years before and from 2009.

Accidental building and car fires
Emissions from accidental building and car fires are relatively small.

Emission factors
The EFs for house fires in the EEA Guidebook (5.E. tables 3.3 to 3.5) is based on a Norwegian study and therefore not used as they seem inappropriate for the Dutch situation, as houses built in Norway contain more wood and Norway is more rural.
Emissions from the combustible construction materials and interior materials are calculated using the EFs from EMEP/EEA (2019; table 3.39 on small combustion in chapter 1A4).

Accidental building and car fires produce, among others, emissions of particulate matter and dioxins. Emissions are calculated by multiplying the number of car fires and house fires by EFs. For car fires, the default EFs from the EMEP/EEA Guidebook (2019) are used. For house fires, country-specific EFs have been derived, based on the amount of combustible materials in an average Dutch house combined with a percentage burned in each fire as explained in the paragraph below. 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. More details regarding the methodology are given in Visschedijk *et al.* (2020).

To estimate the amount of combustible material in an average Dutch house, a study of the Dutch house stock by TNO (2017) was used, omitting the non-combustible materials, such as concrete, bricks and insulation materials, which constitute 90% of the total. Excluding the interior of the house, this results in about 10.3 Mg of combustible material (8.6 Mg wood/triplex and 1.7 Mg plastics). Based on expert judgement, the combustible interior material (cupboards, floor coverings, beds, etc.) is estimated to be around 4.5 Mg, making a total of 14.8 Mg.

According to multi-year statistics on the number of fatal house fires in the Netherlands (Fatal house fires 2017), in about 55% of the cases studied, the destruction is limited to a single room, in 17% of cases it is limited to a single floor and in 28% of cases the entire house is burned down. Table 7.11 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 7.11 Overview of the average amount of material burned in accidental house fires in the Netherlands

Destruction by fire (limited to)	**Combustible material burned (%)**	**Combustible material burned (Mg)**
One room	10	1.48
One floor	33	4.9
Complete house	100	14.8

When these data on fire destruction are combined, they result in the following amount of combustible materials burned:

1.48 x 55% + 4.9 x 17% + 14.8 x 28% = 5.8 Mg.

It is estimated that half of the interior consists of wood and the other half is believed to consist of a mixture of different plastics.

Activity data
The number of houses and cars damaged by fire was reported annually by Statistics Netherlands (CBS Statline) until 2013. Those numbers are used for the time series 1990–2013. For the number of house fires in the years 2014 and later, statistics are collected via a central emergency system registering the deployment of fire brigades were used. These activity data are also reported via Statistics Netherlands.

For the number of car fires in the years 2015 and 2016, a news article was used, giving the number of car fires for these two years. This article refers to ‘alarmeringen.nl’ and seems to be reliable, based on expert judgement. The year 2014 was interpolated from 2013 and 2015.

On basis of the total amount of cars in the Netherlands and the annual average percentage of fire-damaged cars an estimate was made for the years 2014–2019.

8 Other

8.1 Overview of the sector

The Other sources sector (NRF 6) includes emissions from sources that cannot be placed under a specific NFR. It therefore consists of just one source category: 6A Other sources.

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 to the human system. Most nitrogen is released through faeces and urine into the sewage system. 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 shown in Table 8.1.

Table 8.1 Overview of emission totals in the Other sector (NFR 6)

Year	NH_3
	Gg
1990	**2.66**
1995	2.79
2000	2.91
2005	3.01
2010	3.10
2015	3.20
2018	3.26
2019	**3.28**
1990–2019 period[1]	0.62
1990–2019 period[2]	23%

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

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 1.74 Gg in 2019.

Population numbers in the Netherlands are derived from CBS Statline (http://statline.cbs.nl/) and increased from 14,892,574 in 1990 to 17,282,163 in 2019.

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.

Domestic animals (pets)

NH_3 emissions from this source increased slightly over the time series from 1.17 Gg in 1990 to 1.55 Gg in 2019.

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 Jansen *et al.* (2019).

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 done 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*

Following a recommendation by the review team, the emissions related to agriculture (privately owned livestock and manure sold and applied to private properties or nature areas) are now allocated to Sector 3 Agriculture (see Sections 6.2.8 and 6.3.8), pending a discussion on definitions of agriculture.
There are no source-specific recalculations.

8.2.9 *Source-specific planned improvements*

There are no source-specific improvements planned.

9 Large Point Sources

In 2020 the Large Point Source (LPS) reporting from the 2017 submission was reviewed by the NECD-review team. In the review report has been recommended to explain the LPS reporting for the agricultural sector.

All point sources in the Netherlands, meeting the criteria have the legal obligation to report their emissions electronically as part of an AER (see paragraph 1.3.2). After validation and data checking, the data is then stored in the PRTR. The EPRTR and the LPS form an extract from this PRTR.
For the obligation of reporting emissions from agriculture to the EPRTR different criteria are used. For the EPRTR reporting the Netherlands makes an inventory of all agriculture facilities that meet the IPPC[3]-criteria (EU Directive 2010/75/EU on industrial emissions; Annex1 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 2017 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 underestimate of the NH_3 emissions coming from agricultural facilities. For 2019 the EPRTR database shows 71 agricultural facilities that meet the criteria. These facilities reported a total NH_3 emission of 0.9 Gg. However, the 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) in 2019 are 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 based on animal numbers and type of animal housing (all based on the agricultural census; see chapter 6). This means that there is no other information on facility level needed. However, over the last years work has been done to more accurately estimate NH_3 emissions from individual animal housings. For the 2021 LPS submission effort is made to use this more detailed information to make 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 Combined CLRTAP and NEC review 2015

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, since 2008 the national inventories (CLRTAP and NECD) have been subject to a five-year cycle of in-depth technical reviews. 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 data submitted (see http://www.ceip.at/).

The review also seeks to achieve a common approach to prioritising and monitoring inventory improvements under the Convention 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 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.

10.2 NEC reviews 2019 and 2020

Article 10(3) of the revised NECD introduces a regular annual review of EU Member States' national emission inventory data in order to:

- verify, inter alia, 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.

In 2019 the Netherlands Projections submission of 2017 was reviewed the status in follow up of this review shown in Annex 4. Table A3.4.

The 2020 NFR and IIR submission by the Netherlands was reviewed. Several recommendations were given to improve the inventory and inventory report. Within the limitations of resources, the actions 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 2021. Annex 4, Table A3.1 shows the status of the implementation of the recommendations from this NEC review.
Also as part of the 2020 review also the 2017 submissions of the Large Production Sites (LPS) and the so called Gridded data are reviewed. The status in follow up of the recommendation from these parts of the review can be found in Annex 4, Table A3.2 and A3.3.

11 Recalculations and Other Changes

11.1 Recalculations of certain elements of the IIR2020

Compared with the IIR2020 (Wever *et al.*, 2020), only a few methodological changes were implemented in the Pollutant Release and Transfer (PRTR) system:

- Improved estimates for road traffic bottom up inventory and (inclusion of emissions from cooling devices), aviation and NRMM
- Improved methodology to calculate Nitrogen emissions from agriculture
- Inclusion of condensable emissions from residential wood combustion in the inventory
- New emission estimates for metals from stationary combustion

11.2 Improvements

Improvements made

During the compilation of the IIR2021 minor errors were detected, and these have been repaired in the IIR2021. The following significant improvements were carried out during the improvement process of the Dutch PRTR:

- Improvement of the allocation of the Dutch emission sources to the NFR (sub)categories. (a.o. reallocation of NOx emissions from 3I to 3Da2a (soil NOx))
- Use of improved activity data for 2017, resulting in several changes to the figures for that year.

Planned improvements

The remaining actions with respect to content will be prioritised and are planned for implementation in the inventories of 2021 and 2022. Appendix 3 gives an overview of the relevant plans.

11.3 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 2019. In general the national emissions of the different pollutants only show limited changes compared to the previous submission (0- 5%) except for the PM species. These emissions are increased significantly as a result of the inclusion of estimates for the condensable PM emissions from residential wood combustion.

Recalculation of the transport emissions together with additional estimates for industry are the cause of increased metal emissions.

Again the revision of the transport emission model is responsible for the changes of the Dutch PAH and PCDD/PCDF emissions.

Also HCB emissions are increased as from now. estimates for the HCB emissions from pesticides are included in the inventory.

Table 10.1 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010, 2015 and 2018 (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 2020	**657.0**	**608.6**	**196.4**	**350.0**	**52.4**	**73.0**	**96.8**	**13.4**	**1149.9**
	IIR 2021	**661.9**	**606.2**	**196.9**	**345.9**	**57.5**	**80.2**	**101.6**	**13.5**	**1148.3**
Difference	absolute	4.8	-2.4	0.6	-4.1	5.2	7.2	4.8	0.1	-1.6
	%	*0.7%*	*-0.4%*	*0.3%*	*-1.2%*	*9.9%*	*9.9%*	*4.9%*	*0.6%*	*-0.1%*
2000	IIR 2020	**465.1**	**337.3**	**78.0**	**175.0**	**29.4**	**41.7**	**50.7**	**9.8**	**760.3**
	IIR 2021	**472.2**	**335.2**	**78.2**	**173.3**	**34.8**	**49.4**	**56.1**	**10.2**	**761.8**
Difference:	absolute	7.1	-2.0	0.2	-1.8	5.4	7.7	5.4	0.3	1.5
	%	*1.5%*	*-0.6%*	*0.3%*	*-1.0%*	*18.4%*	*18.5%*	*10.7%*	*3.5%*	*0.2%*
2010	IIR 2020	**339.7**	**270.4**	**35.5**	**132.6**	**17.7**	**28.4**	**35.8**	**5.3**	**669.6**
	IIR 2021	**349.9**	**268.0**	**35.8**	**133.9**	**22.7**	**35.8**	**40.8**	**5.6**	**666.3**
Difference:	absolute	10.2	-2.3	0.2	1.3	5.0	7.4	5.0	0.3	-3.3
	%	*3.0%*	*-0.9%*	*0.6%*	*1.0%*	*28.1%*	*26.0%*	*13.9%*	*6.3%*	*-0.5%*
2015	IIR 2020	**277.0**	**254.6**	**30.6**	**127.7**	**13.7**	**24.5**	**32.3**	**3.1**	**562.1**
	IIR 2021	**282.1**	**251.1**	**31.0**	**130.9**	**17.8**	**31.1**	**36.6**	**3.3**	**562.1**
Difference:	absolute	5.1	-3.5	0.4	3.2	4.2	6.6	4.3	0.2	0.0
	%	*1.9%*	*-1.4%*	*1.3%*	*2.5%*	*30.5%*	*26.7%*	*13.2%*	*5.5%*	*0.0%*
2018	IIR 2020	**244.3**	**240.3**	**24.6**	**129.3**	**12.4**	**22.7**	**29.5**	**2.4**	**548.8**
	IIR 2021	**252.9**	**240.4**	**25.0**	**129.3**	**16.1**	**28.9**	**33.5**	**2.6**	**627.8**
Difference:	absolute	8.6	0.1	0.4	0.0	3.8	6.2	4.0	0.2	79.0
	%	*3.5%*	*0.1%*	*1.5%*	*0.0%*	*30.4%*	*27.3%*	*13.4%*	*7.7%*	*14.4%*

Table 10.2 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010, 2015 and 2018 (metals).

National total		**Pb** **Mg**	**Cd** **Mg**	**Hg** **Mg**	**As** **Mg**	**Cr** **Mg**	**Cu** **Mg**	**Ni** **Mg**	**Se** **Mg**	**Zn** **Mg**
1990	IIR 2020	**89.7**	**2.1**	**3.5**	**1.3**	**9.8**	**16.5**	**74.3**	**0.4**	**192.4**
	IIR 2021	**338.3**	**3.9**	**3.6**	**1.3**	**11.9**	**36.3**	**74.9**	**0.4**	**225.2**
Difference:	absolute	248.6	1.8	0.1	0.0	2.1	19.8	0.6	0.0	32.8
	%	277.2%	86.5%	3.2%	0.2%	21.8%	120.3%	0.8%	2.1%	17.1%
2000	IIR 2020	**26.6**	**0.9**	**1.0**	**0.9**	**3.0**	**18.5**	**18.9**	**0.5**	**58.8**
	IIR 2021	**27.5**	**2.7**	**1.2**	**0.9**	**5.1**	**37.8**	**19.6**	**0.5**	**96.6**
Difference:	absolute	0.9	1.8	0.1	0.0	2.1	19.3	0.6	0.0	37.7
	%	*3.3%*	*194.6%*	*12.8%*	*0.3%*	*71.6%*	*104.5%*	*3.2%*	*2.1%*	*64.1%*
2010	IIR 2020	**36.8**	**2.5**	**0.6**	**0.6**	**1.5**	**22.3**	**1.6**	**1.5**	**62.3**
	IIR 2021	**37.6**	**4.6**	**0.8**	**0.6**	**3.9**	**43.5**	**2.3**	**1.5**	**103.8**
Difference:	absolute	0.9	2.1	0.1	0.0	2.4	21.2	0.7	0.0	41.5
	%	*2.4%*	*82.9%*	*20.8%*	*1.0%*	*155.4%*	*95.0%*	*45.4%*	*1.9%*	*66.5%*
2015	IIR 2020	**7.9**	**0.5**	**0.6**	**0.7**	**1.1**	**17.4**	**1.3**	**1.0**	**61.6**
	IIR 2021	**8.7**	**2.9**	**0.7**	**0.7**	**3.5**	**38.8**	**2.0**	**1.0**	**103.2**
Difference:	absolute	0.8	2.4	0.1	0.0	2.4	21.4	0.7	0.0	41.6
	%	*10.3%*	*445.2%*	*21.4%*	*1.0%*	*210.6%*	*122.6%*	*55.1%*	*3.4%*	*67.5%*
2018	IIR 2020	**5.0**	**2.3**	**0.5**	**0.3**	**1.0**	**17.4**	**1.1**	**0.2**	**311.2**
	IIR 2021	**5.9**	**2.5**	**0.6**	**0.4**	**3.6**	**40.8**	**1.8**	**0.2**	**356.2**
Difference:	absolute	0.9	0.1	0.1	0.0	2.6	23.4	0.8	0.0	45.0
	%	*17.8%*	*5.9%*	*22.6%*	*1.9%*	*266.9%*	*134.2%*	*71.4%*	*18.3%*	*14.5%*

Table 10.3 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010, 2015 and 2018 (PCDD/F, PAHs , HCB and PCB).

National total		PCDD/ PCDF (dioxines/ furanes)	PAHs					HCB	PCB
			benzo(a) pyrene	benzo(b) fluoranthene	benzo(k) fluoranthene	Indeno (1.2.3 -cd) pyrene	Total 1-4		
		g I-Teq	Mg	Mg	Mg	Mg	Mg		
1990	IIR 2020	**752.4**	**4.9**	**7.6**	**3.8**	**2.6**	**19.0**	**45.3**	**39.1**
	IIR 2021	**755.5**	**5.5**	**8.1**	**4.2**	**2.9**	**20.7**	**66.4**	**39.1**
Difference	absolute	3.1	0.6	0.6	0.3	0.2	1.7	21.1	0.0
	%	*0.4%*	*11.3%*	*7.3%*	*8.8%*	*9.0%*	*8.9%*	*46.6%*	*0.0%*
2000	IIR 2020	**44.4**	**1.8**	**1.7**	**0.9**	**0.8**	**5.2**	**1.5**	**44.4**
	IIR 2021	**45.7**	**2.0**	**2.0**	**1.0**	**0.9**	**6.0**	**17.1**	**45.7**
Difference	absolute	1.4	0.3	0.3	0.1	0.1	0.7	15.6	1.4
	%	*3.1%*	*14.2%*	*14.5%*	*16.6%*	*11.0%*	*14.2%*	*1025.1%*	*3.1%*
2010	IIR 2020	**47.0**	**1.8**	**1.8**	**0.9**	**0.9**	**5.4**	**2.4**	**0.2**
	IIR 2021	**47.9**	**1.9**	**1.9**	**1.0**	**0.9**	**5.8**	**3.4**	**0.2**
Difference	absolute	0.9	0.1	0.1	0.1	0.1	0.4	1.1	0.0
	%	*1.9%*	*6.5%*	*6.6%*	*8.8%*	*7.0%*	*7.0%*	*45.1%*	*0.0%*
2018	IIR 2020	**34.9**	**1.6**	**1.5**	**0.8**	**0.7**	**4.6**	**3.1**	**0.2**
	IIR 2021	**35.6**	**1.6**	**1.6**	**0.9**	**0.8**	**4.9**	**3.8**	**0.2**
Difference	absolute	0.7	0.1	0.1	0.1	0.1	0.3	0.7	0.0
	%	*1.9%*	*4.9%*	*4.8%*	*7.2%*	*6.8%*	*5.6%*	*21.7%*	*0.0%*

12 Projections

12.1 Projections are prepared in the framework of the Netherlands Climate and Energy Outlook 2020

The emission projections of air pollutants for the IIR2021 have been prepared within the framework of the Netherlands Climate and Energy Outlook 2020 (PBL, TNO, CBS & RIVM, 2020). This Outlook is called the KEV2020 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 the PBL (van Bruggen *et al.*, 2020).
The corresponding KEV2020 report can be found on the website of the PBL (https://www.pbl.nl, in English). Underlying reports and datasets can also be found on this website (https://www.pbl.nl/kev, in Dutch). 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 KEV2020 report called 'Emissieramingen luchtverontreinigende stoffen - Rapportage bij de Klimaat- en Energieverkenning 2020' (PBL, RIVM & TNO, 2020; in Dutch). The KEV2020 report describes the emission trends starting from the base year 2018 up to the year 2030 for the five air pollutants under the new National Emissions Ceilings (NEC) Directive (2016/2284/EU), i.e. NO_x, NH_3, $PM_{2,5}$, SO_2 and NMVOC. In addition projections haven been prepared for PM_{10}.

12.3 Measures and policies

12.3.1 Policies as of 1 May 2020

The submitted projections take into account all relevant information about measures up to 1st May of 2020. Two projections haven been prepared. The 'with measures' (WM) projection encompass the effects in terms of air pollutant emission reductions of policies and measures adopted before 1st May 2020. Adopted means that measures are concrete and decided upon by European, national or local government. The 'with additional measures' (WaM) projection means projections of anthropogenic emissions that encompass the effects in terms of air pollutant emission reductions of policies and measures that have been adopted as well as policies and measures that are planned as of 1st May 2020. Only officially announced measures that were concrete as of 1st May 2020 are taken into account in the WaM projection.
Additional measures that are put on the agenda in Dutch policy agreements as of 1st May 2020 that are not concrete and for which it is still unknown how they will be worked out and implemented, have not been taken into account in the WaM projections. This is the case for some measures listed in the Dutch air quality agreement, the Dutch action plan to tackle nitrogen pollution on Natura 2000 conservation

areas and the National Climate Agreement. Although these measures are not taken into account in the projection, they may lead to a relevant additional reduction in emissions. Examples of this kind of measures are subsidy schemes, where the available budget is still unknown, or broadly formulated instruments, where the type of instrumentation is still unclear. This means that the WaM projection does not take all the announced measures into account but only those measures that were made concrete as of 1st May 2020.

12.3.2 *Measures and policies included in the projections*

The complete list of policies included in the KEV2020 projections is presented on page 26 of the KEV2020 main report (PBL, TNO, CBS & RIVM, 2020). Many policies and measures are included in the WM projections. When looking at these adopted measures it should be noted that the Netherlands has introduced a speed limit of 100 kph on highways between 6 a.m. and 7 p.m. Between 7 p.m. and 6 a.m. the speed limit is 120 or 130 kph.
Additional measures considered in the WaM projection are:

- A national subsidy scheme for the retrofit of inland vessels (for the purchase and installation of SCR catalysts to reduce NOx emissions).
- In the national action plan to tackle nitrogen pollution the government announced a subsidy scheme to retrofit SCR-catalysts on existing inland vessels. Dependent on the precise design of this measure a reduction in emissions of NOx of 5 Gg may be realised in 2030.
- A heavy goods vehicle charge starting from 2023. The introduction of a heavy goods vehicle charge will lead to a reduction in road freight transport (2% reduction in Mg-kilometres) and an increase in freight transport by rail and inland waterways (also by 2%). The net effect will be only a small reduction in emissions in 2030.
- Improved enforcement of the correct use of SCR catalysts in heavy-duty vehicles. In the national action plan to tackle nitrogen pollution on Nature 2000 protected areas, the government announced an improved enforcement of the correct use of SCR catalysts in heavy-duty vehicles. This includes the use of buses with measurement equipment that measure on the road and trace trucks with a malfunctioning catalyst. At present, about 10–15% of heavy-duty trucks drive with a malfunctioning or deliberately disconnected catalyst, causing emissions that are 10 times higher than with a properly functioning catalyst. The announced measure of improved enforcement may lead to a reduction in emissions of NOx of about 2.2 Gg in 2030.
- Administrative agreement on zero-emission buses. It was agreed that in 2025 all new buses use on scheduled bus lines will be zero emission. This will lead to cleaner bus fleet and a reduction in NOx emissions of about 0.3 Gg in 2030.
- Schiphol Airport. In the WaM projection is assumed that Schiphol Airport will exceed the current limit of 500,000 flights a year that was agreed for 2020. In the WM projection it is assumed that Schiphol Airport will not grow beyond the limit of 500,000 flights before 2030.

- Lelystad Airport. In the WaM projection is assumed that Lelystad Airport will commence commercial operations with 25,000 flights in 2030. In the WM projection it is assumed that Lelystad Airport will remain closed for commercial flights up to 2030.
- Introduction of a flight tax.
- Subsidy scheme, announced in the Climate Agreement, for animal housings and management measures in agriculture. This scheme is focused on research and first adopters and it is still unknown what its effects might be. Therefore, no effect has been attributed to this measure.
- A pig production cessation scheme. The Dutch government has introduced a subsidy scheme for the restructuring (cutting) of pig production. The WM projection includes a first budget of €120 million directed at the cessation of pig farms. This budget was focused on reducing odour nuisance, but will also reduce nitrogen deposition. In the WaM projection, the budget for this cessation scheme is increased by €335 million (€65 million made available through the Climate Change Agreement and €275 million made available through the action plan to tackle nitrogen deposition on Natura 2000 conservation areas).
- Change in the animal feed regulation. The government announced at the start of 2020 a temporary measure for the reduction in the nitrogen content of feed concentrate for dairy cattle lasting from 1st September to 31st December 2020. In the WaM scenario this measure has been taken into account, assuming that the nitrogen content of concentrates, partly due to the projected pressure from the nitrogen policy, will on average stay at the same lower level up to 2030 as was assumed for the 4 months that the regulating measure would last. This measure is also part of the WaM projection, although this measure was in fact withdrawn by the government in August 2020.
- Specific policies for livestock in the province of Noord Brabant.

The WM projection for NH_3 in 2030 is 1.8 Gg higher than the WaM projection (Table 12.1). This difference is explained by the higher number of pigs and the higher nitrogen content of feed concentrate for dairy cattle in the WM projection.
The WM projection for NO_x in 2030 is 7 Gg higher than the WaM projection. This difference is explained by higher emissions in the Transport sector (see also the effects of some separate measures given in the list with additional measures above). In other sectors there are almost no relevant differences in emissions between WM and WaM.
The WM projection for $PM_{2.5}$ in 2030 is 0.1 Gg higher than the WaM projection (Table 12.1). This difference is also fully accounted for by the Transport sector.
For SO_2 and NMVOC there is no difference between the WM and WaM projections (Table 12.1).

Table 12.1 Projected national emissions (Gg) for the Projections with measures (WM) and Projections with additional measures (WaM) according to the definitions in the new National Emissions Ceilings (NEC) Directive (2016/2284/EU)

	2005[1,2]	**2018[1,2]**	**WM-2020 (Low-High)**	**WM-2025**	**WM-2030**	**WaM-2020 (Low-High)**	**WaM-2025**	**WaM-2030**
NO_x	372	211	167-188	161	137 (123-152)	167-188	155	130 (116-146)
NH_3	153	129	125-126	124	122 (114-126)	125-126	122	120 (112-124)
SO_2	67	25	21-22	24	23 (17-25)	21-22	24	23 (17-25)
NMVOS	202	147	138-145	143	142 (133-152)	138-145	143	142 (134-152)
$PM_{2.5}$[3]	23.8	12.8	11.4-11.9	11.4	10.8 (10.0-11.6)	11.4-11.9	11.3	10.7 (9.9-11.5)
PM_{10}	36.7	25.4	23.2-24.0	23.8	22.9 (21.8-24.2)	23.2-24.0	23.6	22.7 (21.6-24.0)

1. Emissions in this table are according to the definitions in the 2016 National Emissions Ceilings Directive (EU, 2016/), i.e. based on fuel sold for road transport and fishing and excluding categories 3B and 3D for NOx and NMVOC. Emissions in the other chapters are in line with the definitions of the 2001 National Emissions Ceilings Directive (EU, 2001), i.e. based on fuel used for road transport and fishing and including categories 3B and 3D for NOx and NMVOC. In the IIR 2021, emissions in other chapters will also be reported in line with new definitions.
2. Emissions in this table are based on emissions for historical years as given in the Dutch PRTR as of February 2020. Emissions in other chapters are based on emissions for historical years as of February 2021.
3. PM2.5 emissions from condensables originating from wood burning in stoves and open fireplaces were not included in the Dutch emission registry as of February 2020. Therefore, these emissions were not taken into account in the projected national emissions reported in the KEV2020 (PBL, RIVM & TNO, 2020) and also have been excluded from the national totals in this chapter (and this table). Although not yet included in the national totals, these condensable emissions have been projected in the KEV2020 (for the results see Table 12.3).

12.4 Projection totals for compliance checking

The emission totals for the projections in this chapter and in the Annex IV reporting template have been calculated on the basis of the definitions that are used for compliance checking, as defined in the 2016 National Emissions Ceilings Directive (NECD) (EU, 2016). This implies that following emissions are not accounted for in the given totals: (a) aircraft emissions beyond the landing and take-off cycle; (b) emissions from national maritime traffic to and from the territories referred to in Article 2(2); (c) emissions from international maritime traffic; (d) emissions of nitrogen oxides and NMVOC from activities falling under the 2014 Nomenclature for Reporting (NFR) as provided by the LRTAP Convention categories 3B (manure management) and 3D (agricultural soils).

Although the national emission totals as reported in this chapter (Table 12.1) and in the Annex IV template exclude 3B and 3D for NO_x and NMVOCs, the projected emissions for these categories and pollutants have been reported in the Annex IV reporting table. These emissions for NO_x and NMVOCs are reported in a shaded colour to emphasise their special status compared with other sources when it comes to compliance checking.
Besides this, it should be emphasised that the base year and projected emissions for road transport and fishing have been calculated using a fuel-sold methodology. This is the method that the Netherlands has chosen according to the 2016 NECD (EU, 2016).
It should also be emphasised that the reported totals for historical years in the other (inventory) chapters of this IIR follow the definitions in the 2001 NECD (EU, 2001). This means that in these chapters categories 3B (manure management) and 3D (agricultural soils) are included in the national total (also for NO_x and NMVOC) and the emissions from road transport and fishing are based on the fuel-used methodology.

12.5 Historic year for projections

The work on the projections of air pollutants within the KEV2020 project started at the beginning of 2020 and a final air pollutants report was delivered on 30th November 2020. The year 2018 was the base year for these projections. The KEV 2020 projections were based on the 2020 PRTR database results (fuel-sold methodology for road transport) that became available at the beginning of 2020. These emissions are in line with the emissions (although using the fuel-used methodology for road transport) that were reported in the Dutch IIR 2020. This PRTR gave time series results for the time series 1990–2018.
It should be noted that the emissions given in the PRTR 2020 database for 2018 may be slightly different from the emissions according to the latest inventory results (PRTR 2021 database) that became available in February 2021 and are used for the reporting of the emissions time series 1990-2019. Every year the Netherlands makes a historical recalculation of time series emissions if there are changes in methodology or knowledge about emissions. This implies that the emissions reported in the Dutch PRTR 2020 for 2018 (and 2005) may be different from the emissions in the Dutch PRTR 2021.

12.6 Emission uncertainty range for 2030

The projections are based on an image of the future development of different factors that determine the economy, energy system and emissions that is as accurate as possible. 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 is estimated how much the emission could deviate (upwards and downwards) from the central most likely projection 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 done for the national NEC total and for the totals per national KEV sector. The result is an uncertainty range (in Gg emission) around the central emission projection. 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, which only gives the uncertainty determined by extern 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 emission inventory has been excluded from the uncertainty analyses.
The analysis only gives a picture of the uncertainty that is involved in unknown future developments. No uncertainty analysis is done for 2025 or 2020. As stated earlier, the emission projection for 2020 is established using a different methodology from the projections for 2025 and 2030. Two scenarios have been developed to give a picture of the likely range of emissions in the year 2020 where the COVID-19 pandemic started. Final emission figures for 2020 will be established in the 2022 emission inventory.

12.7 Annex IV NFR classification for projections

The main source categories in the Netherlands Climate and Energy Outlook 2020 use the same categorisation scheme as the negotiation tables of the Dutch Climate Agreement: electricity, manufacturing industry, mobility, built environment (i.e. commercial, institutional and residential) and agriculture and land use. In the Dutch classification all NRMM is allocated to the mobile sector.
Projections are made at a much more detailed level than the main KEV categories. The emission projections from the Netherlands Climate and Energy Outlook 2020 have been translated into the NFR Annex IV classification (reporting template). In most cases this translation could be done easily. However, in some cases a category had to be split. This was necessary for the projected emissions from industry. For the split between combustion and industry emissions more detailed information from the emission inventory has been used. It should be mentioned that the split between combustion (1A2) and process emissions (2A, B, C, H, I, J, K and L) for industry in general is not so straightforward and transparent as the international reporting tables suggest. The split between combustion and process emissions is somewhat arbitrary because almost all emissions (except from the fertiliser industry) are combustion related.

For NRMM all projected emissions for different KEV off-road mobile categories are allocated to the different NFR Annex IV categories, i.e. mobile sources in industry to sector 1A2 and mobile sources in agriculture to 1A4. However, for projections it is a bit strange to make this split because for example all mobile emissions in industry (with specific regulations for non-road machinery) are summed up with other industrial emissions. For projection data reporting it would be an improvement to distinguish the different NRMM categories from other emissions under that category.

12.8 Emission projections for 2020

The COVID-19 pandemic makes the year 2020 a special year for this Netherlands Climate and Energy Outlook. The worldwide economic consequences of the pandemic and the measures to control the spread of the virus have had an unprecedented effect on society, and consequently on production and the emissions of air pollutants. The projection for 2020 are made on the basis of two scenario's: Scenario High and scenario Low.

The projections for emissions in 2020 were established in the second half of September 2020 and are based on the available current statistical activity data for the months that had passed in 2020 (about 8 months, differing per sector) and a projected range for the emissions for the remaining months. The naming of both scenario's relates to the volume of the emissions in 2020. These scenario's cover a large range but do not represent the most extreme possible scenario's.
The COVID-19-pandemic makes the year 2020 into a special year for this projection. The worldwide economic consequences of the pandemic and the measures to control the further spread of the virus, have an unprecedented on the society, and with that on production and the emissions of air pollutants. The projection for 2020 have been made on the basis of two scenarios for the expected emissions: Scenario High and scenario Low. The naming of both scenarios relates to the volume of the emissions in 2020. These scenarios cover a large range but do not represent the most extreme possible scenarios.
The scenarios for 2020 combine three types of uncertain developments for the remaining months of the year for which no statistical data were available at the moment of preparing the projections i.e. the uncertainties in the remaining months regarding the effect of the COVID-19 pandemic on activity levels, the weather (cold or warm) and the development of the electricity market. These three developments are mostly independent of each other. The scenarios thus take into account the uncertainty regarding the Covid-19 pandemic as well as two other uncertainties regarding developments for the remaining part of the year.
Especially for NO_x (heating of the building environment) and SO_2 (the deployment of coal power plants), uncertain developments concerning the weather and the electricity market may play a role. For other pollutants these influences are only small.

The scenarios for 2020 have been worked out for all pollutants including NH_3 from mobility and industry, and including the energy-related emissions from agriculture, e.g. NO_x from greenhouse farming.

However, the scenarios have not been worked out for other emissions in agriculture (livestock and artificial fertiliser). For these sources one central projection has been made and no scenarios. Possible COVID-19 effects on these agricultural activities have not been taken into account. The most important COVID-19 effects for animal husbandry are related to the closure of mink-breeding farms. These effects are assumed to be small. The effect on ammonia emissions of this accelerated phase-out of mink breeding farms is significantly less than 0.3 Gg.

12.9 Emission projections for 2025 and 2030

For the longer term, i.e. for 2025 and 2030, the projections assume that economic activity will be on the same level as the macro-economic projections that were made before the COVID-19 pandemic, i.e. no long-term effects of the pandemic on the economy were taken into account in the projections for 2025 and 2030. These possible long term effects are possible but highly uncertain.

12.10 National emission projection totals

An overview of the historical and projected total emissions for the Netherlands according to the definitions under the new National Emissions Ceilings (NEC) Directive is given in Table 12.1. More detailed results in the aggregated NFR categories can be found in the Annex IV reporting template.
Detailed results in the Dutch KEV categories, and a detailed description of policies and emission trends, is given in the report 'Emissieramingen luchtverontreinigende stoffen - Rapportage bij de Klimaat- en Energieverkenning 2020' (PBL, RIVM & TNO, 2020, in Dutch). Table 12.2 shows the projected emissions (Gg) for the categories 3B and 3D that are excluded from the definitions for reduction requirements in the 2016 NECD (EU, 2016).

Table 12.2 Projected national emissions (Gg) for NO_x and NMVOC for the categories 3B and 3D for the Projections with measures (WM) and Projections with additional measures (WaM)

	2005	2018	WM-2020	WM-2025	WM-2030	WaM-2020	WaM-2025	WaM-2030
NO_x	34	32	32	32	32	32	32	32
NMVOC	67	93	91	92	94	91	92	94

12.11 Projections for $PM_{2.5}$ condensables from wood burning in stoves and open fire places

Table 12.3 shows the projections for $PM_{2.5}$ condensables from wood burning in stoves and open fireplaces, though these emissions are not included in the national $PM_{2.5}$ total reported in Table 12.1.

The Dutch emission registry as of February 2020 formed the basis for the projections presented in this chapter. The emissions from condensables were not yet included. Therefore, these emissions were not taken into account in the projected national emissions reported in the KEV2020 report published November 2020 (PBL, RIVM & TNO, 2020). Because these emissions were not included in the official projected national totals made public in November 2020, these projections have also been excluded from the national totals in this projection chapter (Table 12.1). National totals reported in Table 12.1 are fully consistent with the national totals in the underlying KEV2020 air pollutants report (PBL, RIVM & TNO, 2020).

Though these emissions are not yet included in the reported national totals in Table 11.1 and the electronic Annex IV reporting template, projections for these condensable emissions have been prepared in the KEV2020 project. Results are given in Table 12.3.

Table 12.3 Projected national emissions of $PM_{2.5}$ condensables (Gg) for wood burning in stoves and open fireplaces for the Projections with measures (WM) and Projections with additional measures (WaM) (not included in Table 12.1)

	2005	**2018**	**WM-2020 (Low-High)**	**WM-2025**	**WM-2030**	**WaM-2020 (Low-High)**	**WaM - 2025**	**WaM - 2030**
$PM_{2.5}$ condensables	4.0	2.8	2.6	2.2	1.9	2.6	2.2	1.9

Results show that emissions of condensables from wood burning stoves and open fire places are an important source of $PM_{2.5}$emissions. The non-condensable emissions of $PM_{2.5}$ from wood burning in stoves and open fireplaces, already accounted for in the inventory for years and included in Table 12.1, amount to 1.47 Gg in 2018 and these emissions are projected to decrease to 1.09 Gg in 2030. The condensable emissions of $PM_{2.5}$ from wood burning in stoves and open fireplaces, not yet accounted for in Table 12.1 but given separately in Table 12.3, are 2.8 Gg in 2018. These emissions are projected to decrease to 1.9 Gg in 2030. Results show that $PM_{2.5}$ emissions in 2018 from wood burning in stoves and fireplaces are 2.9 times higher when condensables are taken into account. Projected $PM_{2.5}$ emissions in 2030 are 2.7 times higher.

13 Adjustments and Compliance

In 2001, the Netherlands, as an EU Member State, adopted the NECD 2001 (EU,2001, which was replaced in 2016 by the revised NECD 2016 (EU, 2016), and signed and ratified the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (UNECE Gothenburg Protocol). The Netherlands was thereby committed to reducing its emissions of NO_x, SO_x, NMVOC and NH_3 to the agreed national emission ceilings by 2010 and to respect these ceilings from 2010 onwards.

13.1 Exceedances of the emission ceilings

13.1.1 Historical and actual exceedances

In the 2021 submission, the emission totals for NMVOC and NH_3 exceed the emission ceilings as set at the time for these pollutants, for all years since 2010 (Table 12.1). This is mainly due to the implementation of new emission sources and EFs that were not applicable when the ceilings were set. These include the addition of new default calculation methods for NMVOC emissions from manure and country-specific calculations for NH_3 emissions from crop cultivation and crop residues left behind on soils.

Emissions of NO_x and SO_x in the Netherlands do not exceed the ceilings.

Table 12.1 Summary of reported emissions exceedances of ceilings and approved adjustments for NMVOC and NH_3

	NMVOC									
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Reported emission	270.4	266.5	261.2	259.1	247.3	254.8	250.7	250.1	242.5	238.3
Exceedances of emission ceilings:										
- NECD	85.4	82.2	79.2	76.1	64.6	73.0	69.7	69.7	56.6	53.6
- Gothenburg	79.4	76.2	73.2	70.1	58.6	66.0	63.7	63.7	50.6	47.3
Approved adjustments	81.3	79.2	79.4	73.1	65.3	77.0	69.1	67.9	64.9	54.0
	NH_3									
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Reported emission	134.1	131.8	125.9	125.5	129.0	131.2	130.2	132.4	124.6	123.0
Exceedances of emission ceilings:										
- NECD and Gothenburg	4.7	1.5	-	-	-	0	-	3.3	1.5	-
Approved adjustments	-	-	-	-	2.1	1.8	2.0	4.9	4.9	-

13.1.2 *Meeting the reduction commitments without adjustments*

In 2020 the Netherlands' emissions projections were fully updated and recalculated (with 2018 as the base year; see Chapter 11).
The NMVOC sources under Manure management and Agricultural soils are not included in the 2020 projections outlined in Chapter 11. Emissions from these NMVOC sources are reported in the NFR subsectors 3B and 3D, and are thus excluded from the NECD compliance check for 2020 and beyond (EU, 2016: art 4 sub 3D). However, for the Gothenburg protocol there is no specific article which states that 3B and 3D sources should be excluded from the compliance check.

When all the NFR 3B and 3D sources are included for 2005, this leads to an NMVOC 2020 Gothenburg ceiling of 245 Gg (Table 12.2).

For a tentative estimate of the NMVOC projection including all 3B and 3D emissions (thus including all sources that were added to the inventory after the setting of the Gothenburg ceilings), it is assumed that there will be no significant changes in the emissions from 3B (use of silage) and 3D (animal manure applied to soils, urine and dung deposited by grazing animals, farm-level agricultural operations including storage, handling and transport of agricultural products and cultivated crops). The tentative estimated projection is calculated by using the projected 2020 NECD emission range of 138–145 Gg from Table 12.2 and adding the projected 2020 emissions from 3B and 3D from Table 11.2. This leads to an estimated 2020 projection range for NMVOC (including all 3A and 3B sources) of 229–236 Gg. This is well below the calculated ceiling of 245 Gg including 3B and 3D.

Table 12.2 shows that based on the current projections and without adjustments, NO_x, SO_2, NH_3, NMVOC and $PM_{2.5}$ emissions are expected to be in compliance in 2020.

Table 12.2 Ceilings versus projected emissions

Pollutant	**Ceilings**				**Projected emissions (WM)**	
	NECD		**Gothenburg**		**NECD**	**Gothenburg**
Gg	**Until 2019**[1]	**2020**[2]	**Until 2019**[1]	**2020**[3]	**2020**[4]	**2020**[4]
NO_x	260	209	266	229	167–188[2]	199–202[5]
SO_2	50	49	50	49	21–22	21–22
NH_3	128	133	128	133	125–126	125–126
NMVOC	185	185	191	245	138–145[2]	229–236[5]
$PM_{2.5}$	-	18	-	18	11.4–11.9	11.4–11.9

1. Emissions from traffic based on fuel used.
2. Based on NFR2021 emission year 2005. Under NECD; fuel sold and exclusion of NFR source sectors 3B and 3D for NO_x and NMVOC.
3. Based on emission year 2005 in the NFR2021, fuel sold.
4. Projection under NECD and Gothenburg (range due to effect of the COVID-19 crisis).
5. Tentative projection including all 3B and 3D sources; fuel sold.

13.2 Adjustments

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.

Article 5 of the 2016 NEC Directive (EU, 2016) lists 'flexibilities', one of which is the possibility of establishing adjusted emission inventories where applying improved emission inventory methods updated in accordance with scientific knowledge has resulted in non-compliance with the national emission reduction commitments. The circumstances under which an adjustment may be applied fall into three broad categories:

- Where emission source categories are identified that were not accounted for when emission reduction commitments were set;
- Where EFs used to determine emission levels for particular source categories for the year in which emission reduction commitments were to be attained are significantly different from the EFs applied to these categories when the emission reduction commitments were set;
- Where the methodologies used for determining emissions from specific source categories have undergone significant changes between the time when emission reduction commitments were set and the year they are to be attained.

In 2019 the Netherlands applied for adjustments for several (new) sources for NH3 and NMVOC over the period 2010-2019. After reviewing the requested adjustments the adjustments were approved. As for 2019 just the emission ceilings for NMVOC is exceeded due to the same sources, the approved adjustments will be applied also for the 2019 compliance.

13.2.1 NH_3 adjustments

NH_3 emissions from Crop cultivation (3De) and Crop residues left behind on soils (3Da4) were both included in the emission inventory in 2013 with a country-specific calculation method as first published in Bruggen van *et al.* (2015). NH_3 emissions from cultivated crops are acknowledged in the EMEP/EEA Guidebook, but no default EF is provided.

NH_3 emissions from manure treatment were included in 2017, as described in Chapter 6. In the current EMEP/EEA Guidebook there is no default calculation method for this emission source. Therefore, they were not included in the considerations when the emission ceilings were set.

With these proposed adjustments, the Netherlands will not exceed the emission ceilings under the revised NECD and Gothenburg Protocol, as shown in Table 12.1.

Activity data 3De Cultivated crops

For the calculation of the 3De NH_3 emissions no activity data were used, as described in the methodological report, since the output of the model was not certain enough to make a yearly estimation.

13.2.2 NMVOC adjustments

The 2013 EMEP/EEA Guidebook implemented a default methodology and default EFs for NMVOC from animal husbandry and manure management. This resulted into the inclusion of the NMVOC emissions from agriculture in the emission inventory in 2017, as described in Chapter 6.

NMVOC emissions from agriculture are a large contributor to the national total (Table 12.1). resulting in an exceedance of the emission ceiling. With the approved adjustments (Table 12.1), the Netherlands will be in compliance again.

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 were disaggregated to the : EMEP 0.1°x0.1° longitude-latitude grid. Guidelines for reporting air emissions on grid level are given in EMEP/EEA (2016). Gridded emission data are 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, 2016). 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 waste-water 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 (NH3) from agriculture;
- Particulate matter (PM10 and PM2.5) 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 ($PM_{2.5}$). Figure 13.1–Figure 13.4 show the geographically distributed emissions for these air pollutants.

On a national scale the agricultural sector is the major contributor to NH_3 emissions (Figure 13.1). Emissions of NH_3 are mainly caused by livestock farming and especially 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 (Figure 13.2-13.3). 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 13.4), 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.

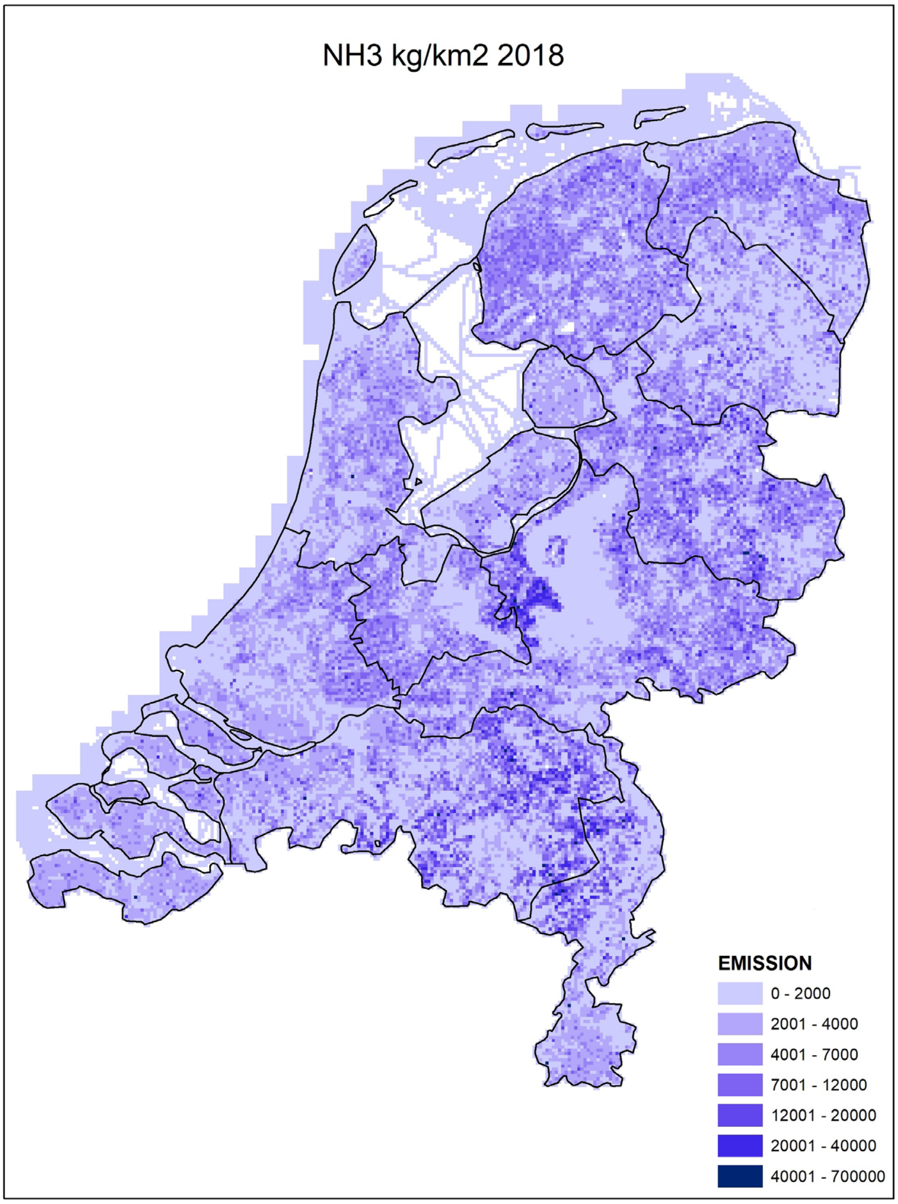

Figure 13.1 Geographical distribution of NH_3 emissions in the Netherlands in 2018

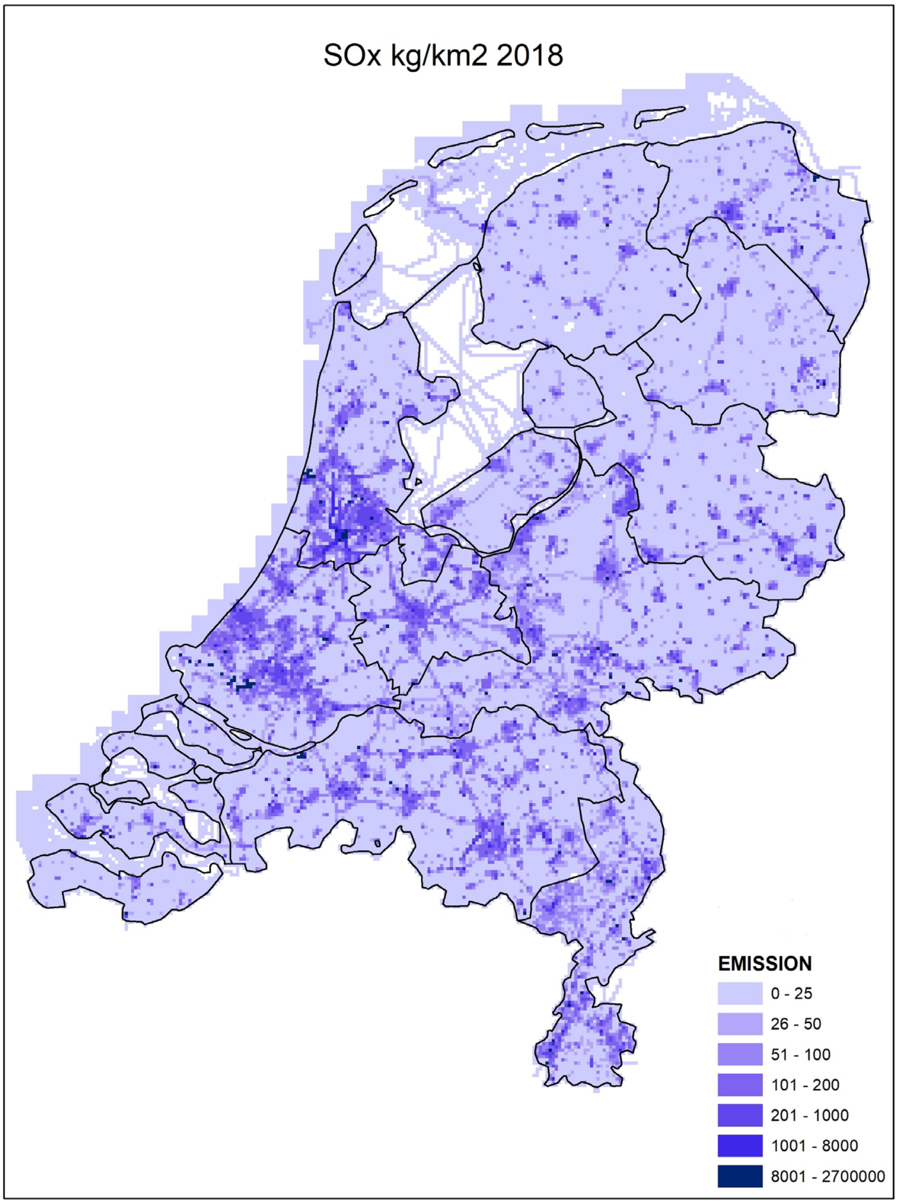

Figure 13.2 Geographical distribution of SO_x emissions in the Netherlands in 2018

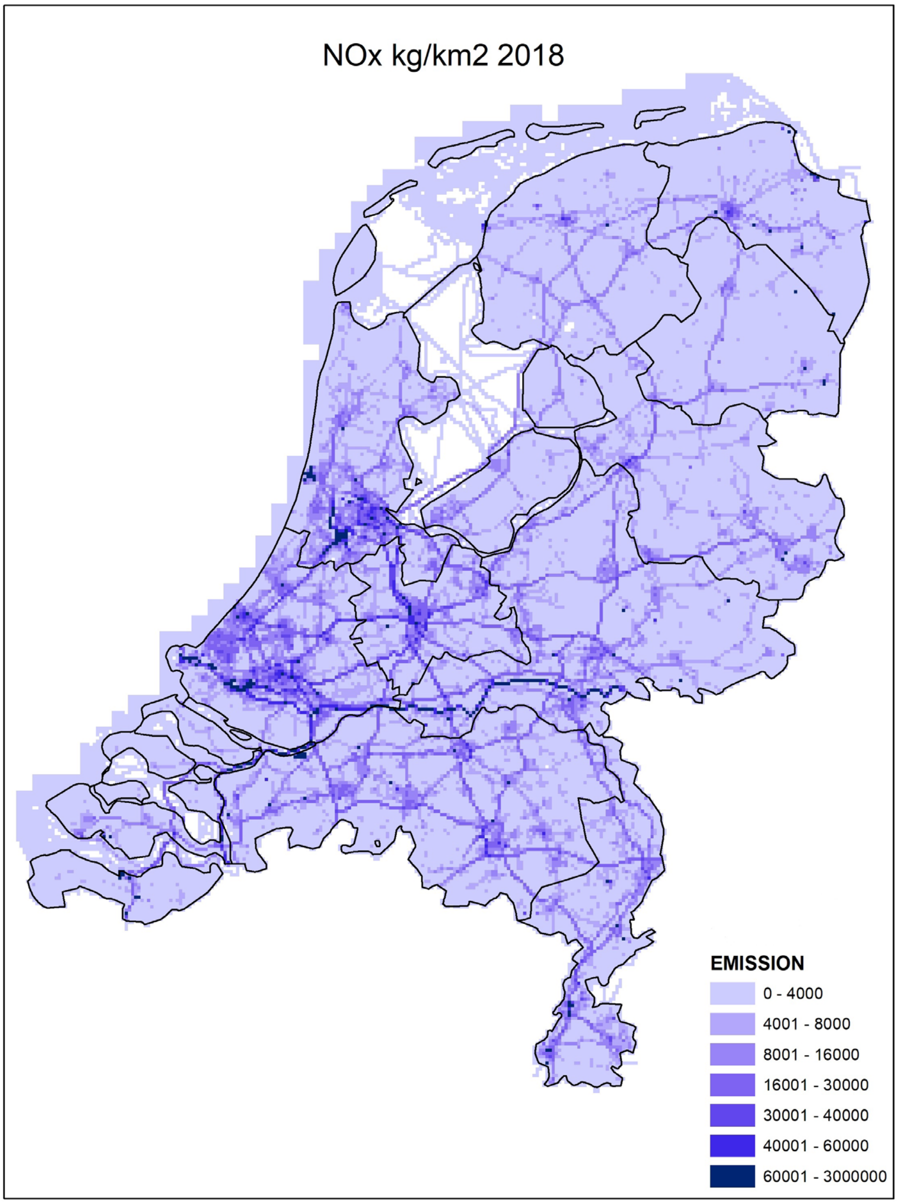

Figure 13.3 Geographical distribution of NO_x emissions in the Netherlands in 2018

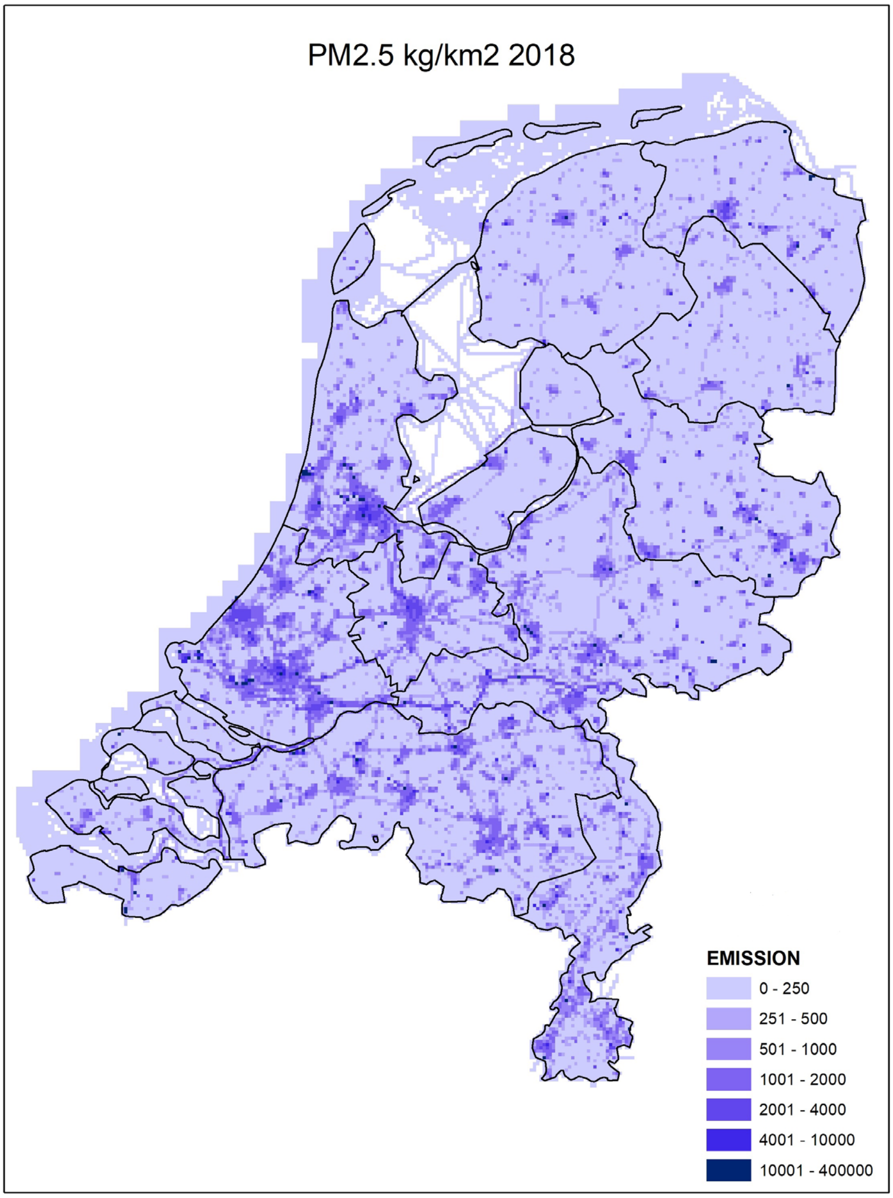

Figure 13.4 Geographical distribution of $PM_{2.5}$ emissions in the Netherlands in 2018

15 References

Aasestad K. (eds.) (2007). Norwegian Emission Inventory 2007. Documentation of methodologies for estimating emissions of greenhouse gases and long range transboundary air pollutants. *Report 2007/38, Statistics Norway.*

Agarwal, A., R.L.Speth, T.M.Fritz, S.D. Jacob, T. Rindlisbacher, R. Iovinelli, B. Owen, R.C. Miake-Lye, J.S. Sabnis, S.R.H. Barrett, (2019), SCOPE11, Method for Estimating Aircraft Black Carbon *Mass and Particle Number Emissions. Environ. Sci. Technol. 53, 1364–1373. https://doi.org/10.1021/acs.est.8b04060*

Amstel, A.R. van, R.J. Swart, M.S.Krol, J.P. Beck, A.F. Bouwman& K.W. van der Hoek (1993). Methane the other greenhouse gas; research and policy in the Netherlands. *RIVM report 481507 001. RIVM, Bilthoven.*

Bikker, P., L.B. Šebek, C. van Bruggen & O. Oenema (2019). Stikstof- en fosfaatexcretie van gangbaar en biologisch gehouden landbouwhuisdieren. Herziening excretieforfaits Meststoffenwet 2019. *WOt-technical report 152. Wettelijke Onderzoekstaken Natuur & Milieu, Wageningen UR, Wageningen (in Dutch).*

Bolt, E. (2003). Schatting energiegebruik van binnenvaartschepen (Energy consumption of inland vessels) *Version 3, 22 October (in Dutch).*

Booij H. (1995). Gezelschapsdieren, *RIVM report 772414003, RIZA nota 93.46/C6. DGM (in Dutch)*.

Bremmer, H.J., L.M. Troost, G. Kuipers, J. de Koning & A.A. Sein (1993). Emissies van dioxinen in Nederland. *RIVM/TNO report 770501003. RIVM/TNO, Bilthoven/Apeldoorn (in Dutch).*

Broeke, H.M. ten, J.H.J. Hulskotte & H. Denier van der Gon (2008). Emissies door bandenslijtage afkomstig van het wegverkeer. *TNO, Utrecht (in Dutch).*

Bruggen, C. van, A. Bannink, C.M. Groenestein, J.F.M. Huijsmans, H.H. Luesink, S.M. van der Sluis, G.L. Velthof & J. Vonk (2015). Emissies naar lucht uit de landbouw, 1990–2013. Berekeningen van ammoniak, stikstofoxide, lachgas, methaan en fijn stof met het model NEMA. WOt-technical report 46. *Wettelijke Onderzoekstaken Natuur & Milieu, Wageningen (in Dutch).*

Bruggen, C. van, A. Bannink, C.M. Groenestein, J.F.M. Huijsmans, H.H. Luesink, S.V. Oude Voshaar, S.M. van der Sluis, G.L. Velthof, and J. Vonk (2017). Emissies naar lucht uit de landbouw in 2015. Berekeningen met het model NEMA (in Dutch). WOt-technical report 98. Wettelijke Onderzoekstaken Natuur & Milieu, *Wageningen UR, Wageningen, the Netherlands.*

Bruggen, C. van and Geertjes, K. (2019). Stikstofverlies uit opgeslagen mest Stikstofverlies berekend uit het verschil in verhouding tussen stikstof en fosfaat bij excretie en bij mestafvoer. CBS, *the Hague, the Netherlands.*

Bruggen van, C., A. Bannink, C.M. Groenestein, J.M. Huijsmans, L.A. Lagerwerf, H.H. Luesink, G.L. Velthof, and J. Vonk (2021). Emissies naar lucht uit de landbouw in 2019. Berekeningen met het model NEMA (in Dutch). WOt-technical report (in prep). Wettelijke Onderzoekstaken Natuur & Milieu, *Wageningen UR, Wageningen, the Netherlands.*
CBS (2011 through 2020). Dierlijke mest en mineralen 2009 t/m 2019 (in Dutch). Statistics Netherlands, *The Hague/Heerlen, the Netherlands.*
CBS (2012a). Standardised calculation methods for animal manure and nutrients. Standard data 1990-2008. Statistics Netherlands, *The Hague/Heerlen, the Netherlands.*
CBS (2012b). Uncertainty analysis of mineral excretion and manure production. *Statistics Netherlands, The Hague/Heerlen, the Netherlands.*
CBS (2020). Dierlijke mest en mineralen 2019 (in Dutch). *Statistics Netherlands, The Hague/Heerlen, the Netherlands.*
CE Delft (2020) Review of Dutch rail diesel emissions calculation methodology. *CE Delft, Delft*
Coenen, P.W.H.G. (1997). Onderzoek naar de kwikemissies van crematoria en beschikbare reinigingstechnieken, *Tauw Milieu Rapport R3517616.W02/BWH. Tauw Milieu, Deventer (in Dutch).*
Coenen, P.W.H.G. & J.H.J. Hulskotte (1998). Onderzoek naar de emissies naar oppervlaktewater van railverkeer in de provincie Zuid-Holland. *TNO, Apeldoorn (in Dutch).*
Coops, O., L. Luning, H. Oonk & J. Boom (1995). Emissies van stortplaatsen (Emissions from landfill sites). VROM Hoofdinspectie Milieuhygiëne, Publicatie Emissieregistratie 28. *VROM, The Hague (in Dutch).*
Dellaert, S.N.C. & R. Dröge (2017a). Uncertainty of the NO_x, SO_x, NH_3, PM_{10}, $PM_{2.5}$, $EC_{2.5}$ and NMVOC emissions from transport. *TNO, Utrecht*
Dellaert, S.N.C. & J.H.J. Hulskotte (2017b). Emissions of air pollutants from civil aviation in the Netherlands. *TNO 2017 R10055, TNO, Utrecht.*
Dellaert, S.N.C. & R. Dröge (2019). Uncertainty of the NO_x, SO_x, NH_3, PM_{10}, $PM_{2.5}$, $EC_{2.5}$ and NMVOC emissions from transport. *TNO, Utrecht (In preparation).*
Denier van der Gon, H., H.M. ten Broeke & J.H.J. Hulskotte (2008). Emissies door wegdekslijtage ten gevolge van het wegverkeer. *TNO, Utrecht (in Dutch).*
Denier van der Gon, H. & J.H.J. Hulskotte (2010). Methodologies for estimating shipping emissions in the Netherlands. A documentation of currently used emission factors and related activity data. *BOP Report 500099012. PBL Netherlands Environmental Assessment Agency, Bilthoven.*
DHV (1999). Eindevaluatierapport meetprogramma GFT-verwerkingsinstallaties *SMB, SOW/CAW en Arcadis. Final report by order of ministry VROM, registration number ML-TE981217. DHV, Amersfoort (in Dutch).*
Elzenga, J.G. (1996). Crematoria. *RIVM report 772414009. RIVM, Bilthoven (in Dutch).*

EEA (2007). EMEP/CORINAIR Emission inventory guidebook 2007. EEA Technical report 16/2007. European Environment Agency (EEA), Copenhagen. *Available:* EMEP/CORINAIR Emission Inventory Guidebook - 2007 — European Environment Agency (europa.eu)

EEA (2016). EMEP/EEA Air pollutant emission inventory guidebook 2016. EEA Technical report 21/2016. European Environment Agency (EEA), Copenhagen. *Available: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016*

EEA (2019). EMEP/EEA Air pollutant emission inventory guidebook 2019. EEA Technical report 13/2019. European Environment Agency (EEA), Copenhagen. *Available: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019*

EU (2001), Directive (EU) 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants. *Available: EUR-Lex - 32001L0081 - EN - EUR-Lex (europa.eu).*

EU (2016), Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. *Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016L2284&from=EN*

Ehrlich, C., Noll, G., Kalkoff, W.-D., Baumbach, G., Dreiseidler, A. (2007), PM10, PM2.5 and PM1.0 – emissions from industrial plants – Results from measurement programmes in Germany. *Atmospheric Environment 41, 6236-6254.*

Gijlswijk, R. van, P.W.H.G. Coenen, T. Pulles & J.P. van der Sluijs (2004). Uncertainty assessment of NO_x, SO_x and NH_3 emissions in the Netherlands. TNO report R 2004/100. TNO, Apeldoorn. *Available: http://www.rivm.nl/bibliotheek/digitaaldepot/TNOreportRa2004.pdf*

Geilenkirchen, G., K. Roth, M. Sijstermans, J. Hulskotte, N. Ligterink, S. Dellaert, M. 't Hoen (2021a). Methods for calculating the emissions of transport in the Netherlands. Netherlands Environmental Assessment Agency, The Hague.

Geilenkirchen, G., K. Roth, M. Sijstermans, J. Hulskotte, N. Ligterink, S. Dellaert, M. 't Hoen (2021b). Methods for calculating the emissions of transport in the Netherlands Tables, *Netherlands Environmental Assessment Agency, The Hague.*

Guis, B., (2006). Meta informatie Emissieregistratie: Vuurhaarden bijschatting luchtemissies (In Dutch). *CBS. Available at http://www.emissieregistratie.nl/erpubliek/documenten/Lucht%20(Air)/Industrie%20en%20Energieopwekking%20(Industry%20and%20Energy)/Industrie%20en%20Energie/Vuurhaarden%20bijschatting%20luchtemissies.doc*

Helms, H., U. Lambrecht, & W. Knörr (2010). Aktualisierung des Modells TREMOD – Mobile Machinery (TREMOD-MM). *UBA TEXTE 28/2010. Dessau-Rosslau, Germany (in German).*

Honig E., J.A. Montfoort, R. Dröge, B. Guis, K. Baas, B. van Huet, O.R. van Hunnik & A.C.W.M. van den Berghe (2021). Methodology report on the calculation of emissions to air from the sectors Energy, Industry and Waste. *RIVM report 2021-0003. RIVM, Bilthoven.*

Hulskotte, J.H.J., E, Bolt & D. Broekhuizen (2003a). EMS-protocol emissies door binnenvaart: verbrandingsmotoren. *RWS-AVV, Rotterdam (in Dutch).*

Hulskotte, J.H.J., E. Bolt & D. Broekhuizen (2003b). EMS-protocol Verbrandingsemissies door stilliggende zeeschepen in havens, *RWS-AVV, Rotterdam (in Dutch).*

Hulskotte, J., E. Bolt & D. Broekhuizen (2003c). EMS-protocol emissies door verbrandingsmotoren van zeeschepen op het Nederlands Continentaal Plat, *Adviesdienst Verkeer en Vervoer. Rotterdam (in Dutch).*

Hulskotte, J.H.J. & E. Bolt (2013). EMS-protocol emissies door binnenvaart: verbrandingsmotoren. *TNO report. TNO, Utrecht (in Dutch).*

Hulskotte, J.H.J & M.C. ter Brake (2017). Revised calculation of emissions of fisheries on the Netherlands territory, *TNO report TNO 2017 R10784, Utrecht.*

Hulskotte, J.H.J., (2017). Emissies WKK glastuinbouw (in Dutch). *Notitie 3-2-2017.*

Hulskotte, J.H.J., J. Oonk & J.C. van den Roovaart (2005). Waterverontreiniging door motoremissies uit de recreatievaart, *TNO-MEP. TNO, Apeldoorn (in Dutch).*

Hulskotte, J.H.J. & R.P. Verbeek (2009). Emissiemodel Mobiele Machines gebaseerd op machineverkopen in combinatie met brandstof Afzet (EMMA). *TNO-report TNO-034-UT-2009-01782_RPT-ML. TNO, Utrecht (in Dutch).*

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: *IGES, Japan.*

Jager, D. de & K. Blok (1993). Onderzoek naar het gehalte aan organische stof in de verschillende afvalcomponenten (Research into volatile solids content in the various waste components). *Utrecht (in Dutch).*

Jansen, B.I. (2010). Emissiemodel houtkachels, TNO, Utrecht (in Dutch).

Jansen, B.I. & R. Dröge (2011). Emissiemodel houtkachels. *TNO report TNO-060-UT-2011-00314. TNO, Utrecht (in Dutch).*

Jansen, B.I., 2016. Vernieuwd emissiemodel houtkachels. *TNO report 2016 R10318. TNO, Utrecht (in Dutch).*

Jansen, B.I., J.A.J. Meesters, M.M. Nijkamp & W.W.R. Koch (2019). Methodology on the calculation of emissions from Product usage by consumers, construction and services. *RIVM report 2019-0017. RIVM, Bilthoven.*

Kadijk, G., N. Ligterink, P. van Mensch, J. Spreen, R. Vermeulen & W. Vonk (2015). Emissions of nitrogen oxides and particulates of diesel vehicles. *TNO report 2015 R10838. TNO, Delft.*

Klein J., H. Molnár-in 't Veld, G. Geilenkirchen, J. Hulskotte, N. Ligterink, S. Dellaert & R. de Boer (2019). Methods for calculating the emissions of transport in the Netherlands Tables. *Statistics Netherlands, The Hague.*

Klein Goldewijk, K, J.G.J. Olivier, J.A.H.W. Peters, P.W.H.G. Coenen & H.H.J. Vreuls (2004). Greenhouse gas emissions in the Netherlands 1990–2002. *National Inventory Report 2004. RIVM report 773201008/2004. RIVM, Bilthoven.*

Kok, H.J.G. (2014). Update NO_x-emissiefactoren kleine vuurhaarden – glastuinbouw en huishoudens. *TNO report 2014 R10584. TNO, Utrecht (in Dutch).*

Koppejan, J. & de Bree, F., (2018). Kennisdocument Houtstook in Nederland (in Dutch). *Procede Biomass BV. Enschede, September 2018.*

Kraan, T.C., N.E. Ligterink & A. Hensema (2014). Uncertainties in emissions of road traffic: Euro-4 diesel NO_x emissions as case study. *TNO report TNO R11316. TNO, Delft.*

Kruijne, R., A. van der Linden, J. Deneer, J. Groenwold & E. Wipfler (2012). Dutch environmental risk indicator for plant protection products. *Alterra-report 2250. Alterra Wageningen UR, Wageningen.*

Lagerwerf, L.A., A. Bannink, C. van Bruggen, C.M. Groenestein, J.F.M. Huijsmans, J.W.H. van der Kolk, H.H. Luesink, S.M. van der Sluis, G.L. Velthof & J. Vonk (2019). Methodology for estimating emissions from agriculture in the Netherlands. Calculations of CH_4, NH_3, N_2O, NO_x, NMVOC, PM_{10}, $PM_{2.5}$ and CO_2 with the National Emission Model for Agriculture (NEMA) - Update 2019. *WOt-technical report 148. Wettelijke Onderzoekstaken Natuur & Milieu, Wageningen UR, Wageningen.*

Lambrecht, U., H. Helms, K. Kullmer & W. Knörr (2004). Entwicklung eines Modells zur Berechnung der Luftschadstoffemissionen und des Krafstoffverbrauchs von Verbrennungsmotoren in mobilen Geräten und Machinen. *IFEU, Heidelberg, Germany (in German).*

Ligterink, N.E. (2017a). The fleet composition on Dutch roads relevant to vehicle emissions. *TNO, Delft.*

Ligterink, N.E. (2017b). Elemental carbon emission factors of vehicles for Dutch air-quality assessments. *TNO, Delft.*

Ligterink, N.E. (2017c). Insight into the energy consumption, CO_2 emissions and NO_x emissions of rail freight transport. *TNO, Delft.*

Ligterink, N.E. & R. de Lange (2009). Refined vehicle and driving behaviour dependencies in the VERSIT+ emission model. *TNO Science & Industry, Delft.*

LVC (2020). *Available: http://www.lvc-online.nl/viewer/file.aspx?FileInfoID=202*

MARIN (2011). MARIN's emission inventory for North Sea shipping 2009: validation against ENTEC's inventory and extension with port emissions. *MARIN, Wageningen.*

MARIN (2019). Sea shipping emissions 2016: Netherlands Continental Shelf, port areas and OSPAR Region II. *MARIN, Wageningen.*

MARIN (2021). Sea shipping emissions 2019: *Netherlands Continental Shelf, 12 miles zone and port areas. MARIN, Wageningen*.

Melse, R.W. & C.M. Groenestein (2016). Emissiefactoren mestbewerking. Inschatting van emissiefactoren voor ammoniak en lachgas uit mestbewerking. *Livestock Research Rapport 962. Wageningen UR Livestock Research, Wageningen, (in Dutch).*

NS-CTO (1992). Project koperemissies spoorwegverkeer. *NS-CTO, Utrecht (in Dutch).*

Ntziachristos, L. & Z. Samaras (2000). COPERT III, Computer Programme to calculate emissions from road transport: methodology and emission factors (version 2.1). *European Environmental Agency, Copenhagen, Denmark.*
NVWA (2020). Afzetgegevens van gewasbeschermingsmiddelen in Nederland in 2018 per werkzame stof in kg. *Retrieved from: https://www.nvwa.nl/onderwerpen/gewasbescherming/documenten/plant/gewasbescherming/gewasbescherming/publicaties/afzet-werkzame-stoffen-in-gewasbeschermingsmiddelen-2018*
Oenema, O., G.L. Velthof, N. Verdoes, P.W.G. Groot Koerkamp, G.J. Monteny, A. Bannink, H.G. van der Meer & K.W. van der Hoek (2000). Forfaitaire waarden voor gasvormige stikstofverliezen uit stallen en mestopslagen (in Dutch). *Alterra-rapport 107 (revised edition). Alterra Wageningen UR, Wageningen.*
Oonk, H. (2016). Correction factor F for adsorption of CO_2 in leachate. Oonkay, *Apeldoorn.*
Oonk, H., A. Weenk, O. Coops & L. Luning (1994). Validation of landfill gas formation models. *TNO report 94-315. TNO, Apeldoorn.*
PBL, RIVM & TNO (2020), Emissieramingen luchtverontreinigende stoffen. Rapportage bij de Klimaat- en Energieverkenning 2020. *Den Haag: Planbureau voor de Leefomgeving. Available at: https://www.pbl.nl/en/publications/netherlands-climate-and-energy-outlook-2020-summary*
Pouwels M., M. van der Spoel & T. de Wit (2007). Verbetering huidig en toekomstig vaarwegennet met behulp van AIS data (Improvement of current and future waterway network by means of AIS data). *CBS, Heerlen.*
Pouwels M., M. van der Spoel & T. de Wit (2017). Verbetering huidig en toekomstig vaarwegennet met behulp van AIS data (Improvement of current en future waterway network by means of AIS data), *CBS, Heerlen (in Dutch).*
RIVM (2001). Environmental Balance 2000. *RIVM report 251701051. RIVM, Bilthoven (in Dutch).*
Ruyssenaars, P.G., P.W.H.G. Coenen, J.D. Rienstra, P.J. Zijlema, E.J.M.M. Arets, K. Baas, R. Dröge, G. Geilenkirchen, M. 't Hoen, E. Honig, B. van Huet, E.P. van Huis, W.W.R. Koch, R.M. te Molder, J.A. Montfoort, J. Vonk, M.C. van Zanten and T. van der Zee (2021). Greenhouse gas emissions in the Netherlands 1990-2019. National Inventory Report 2021. *RIVM Report 2021-0007. RIVM, Bilthoven.*
RWS (2008). Remslijtage. Waterdienst, Centre for Water Management, Lelystad *(in Dutch).*
Spakman, J., M.M.J Van Loon, R.J.K Van der Auweraert, D.J. Gielen, J.G.J. Olivier & E.A. Zonneveld (1997). Methode voor de berekening van broeikasgasemissies (Method of calculating greenhouse gas emissions). *VROM Emissions Registration 37. VROM, The Hague (in Dutch).*
Spreen, J.S., G. Kadijk, R.J. Vermeulen, V.A.M. Heijne, N.E. Ligterink, U. Stelwagen, R.T.M. Smokers, P.J. van der Mark & G. Geilenkirchen (2016). Assessment of road vehicle emissions: methodology of the Dutch in-service testing programmes. *TNO, Delft.*
Stelwagen, U. & N.E. Ligterink (2015). HD Euro-V Truck PM_{10} and EC emission factors. *TNO, Delft.*

Sutton, M.A., U. Dragosits, Y.S. Tang & D. Fowler (2000). Ammonia emissions from non-agricultural sources in the UK. *Atmospheric Environment 34 (2000), 855–869.*
TNO (2021a) Emission measurements for refrigeration units on trucks. *TNO, Delft In preparation.*
TNO (2021b) Emission measurements for motorcycles and mopeds. *TNO, Delft In preparation*.
TNO (2017). KIP Waste and Resource Platform, March. *TNO 2017 R10373. TNO, Utrecht.*
UNECE (2012). Decision 2012/3: Adjustments under the Gothenburg Protocol to emission reduction commitments or to inventories for the purposes of comparing total national emissions with them. *Available: http://www.unece.org/fileadmin/DAM/env/documents/2013/air/ECE_EB.AIR_111_Add.1__ENG_DECISION_3.pdf*
UNECE (2015). Decision ECE/EB.AIR/130: Technical Guidance for Parties Making Adjustment Applications and for the Expert Review of Adjustment Applications. *Available: https://www.ceip.at/fileadmin/inhalte/emep/Adjustments/ECE_EB_AIR_130_AV_for_the_web.pdf*
UNECE (2014). Reporting guidelines (ECE/EB.AIR.128 [PDF, 194KB]) are adopted for application in 2015 and subsequent years. *Available: https://www.unece.org/fileadmin/DAM/env/documents/2015/AIR/EB/English.pdf*
Visschedijk, A.J.H., Pacyna, J., Pulles, T., Zandveld, P., Denier van der Gon, H. (2004), Coordinated European Particulate Matter Emission Inventory Program (CEPMEIP), *In: P. Dilara et al. (eds), Proceedings of the PM emission inventories scientific workshop, Lago Maggiore, Italy, 18 October 2004, EUR 21302 EN, JRC 2004, pp 163-174.*
Visschedijk, A., W. Appelman, J.H.J. Hulskotte & P. Coenen (2007). Onderhoud van methodieken Emissieregistratie 2006-2007. *TNO report A-R0865/B. TNO, Apeldoorn (in Dutch).*
Visschedijk, A.J.H. & R. Dröge (2019). Ratio between $PM_{2.5}$ and PM_{10} for emissions from the energy and industry sector. *TNO report 2019 R10320. TNO, Utrecht.*
Visschedijk, A.J.H. & Dröge, R., (2020). Aanpassing van het TNO houtkachelmodel aan de WoON 2018 houtverbranding enquêteresutaten en prognoses van emissies van huishoudelijke houtkachels tot 2030 (in Dutch). *TNO report 2020 R10652.*
Visschedijk, A.J.H., J.A.J. Meesters, M.M. Nijkamp, B.I. Jansen, W.W.R. Koch & R. Dröge, 2021. Methods used for the Dutch Emission Inventory. Product usage by consumers, construction and services. *RIVM Report 2021-0002. RIVM, Bilthoven.*
Vonk, J., E.J.M.M. Arets, A. Bannink, C. van Bruggen, C.M. Groenestein, J.F.M. Huijsmans, L.A. Lagerwerf, H.H. Luesink, M.B.H. Ros, M.J. Schelhaas, T. van der Zee en G.L. Velthof (2020). Referentieraming van emissies naar de lucht uit landbouw en landgebruik tot 2030, met doorkijk naar 2035. Achtergronddocument bij de Klimaat- en Energieverkenning 2020. *Wageningen Livestock Research, Report 1278.*
VROM (2002) Landelijk afvalbeheersplan 2002-2012*, IenW, the Hague, the Netherlands.* (in Dutch).

Wanders, J. RIVM (2020). Werkplan Emissieregistratie 2020. *RIVM report 2020-0039. RIVM, Bilhoven (In Dutch).*

Zee, T. van der, A. Bannink, C. van Bruggen, C.M. Groenestein, J.F.M. Huijsmans, J. van der Kolk, L.A. Lagerwerf, H.H. Luesink, G.L. Velthof en J. Vonk (2021). Calculations for CH4, NH3, N2O, NOx, NMVOC, PM10, PM2.5 and CO2 using the National Emission Model for Agriculture (NEMA) – Update 2021. *RIVM Report 2021-0008. RIVM, Bilthoven.*

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	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	1A2a	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 between coke production and iron/steel production, and therefore the emissions of this source are reported in 1A2a.
1A2a	NH3, Pb, Cd, Hg, As, Cr, Cu, Ni, Zn, Dioxins, PAHs	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 NH3, metals, dioxin and PAH are reported in 2C1.
1A2f	All	1A2gviii	Whether splitting these emission sources is possible is under evaluation by the specific task force.
1A3aii(i)	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins and PAHs	1A3ai(i)	Not possible to split the fuels between the two source categories.
1A3ei	NO_x, NMVOC, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins and PAHs	1A2f, 1A4cii, 1B2b	Combustion and process emissions from pipeline transport cannot be split due to lack of detailed activity data.
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	NO_x, NMVOC, SO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	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	Cd, Hg and Dioxins	1A1b	
1B2c	NO_x, NMVOC, SO_x, TSP, PM_{10}, BC, CO	NMVOC included in 1B2b; NO_x and SO_x included in 1A1c	Combustion and process emissions cannot be split due to lack of detailed activity data.

NFR code	Substance(s)	Included in NFR code	Explanation
2A2	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, HCBs and PCBs	2A6	Because of allocation problems, emissions from 2A2 are reported in the category Other mineral products (2A6).
2A5a	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, HCBs and PCBs	2A6	Because of allocation problems, emissions from 2A5a are reported in the category Other mineral products (2A6).
2A5b	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, HCBs and PCBs	2A6	Because of allocation problems, emissions from 2A5b are reported in the category Other mineral products (2A6).
2A5c	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, HCBs and PCBs	2H3	Because only emissions from the storage and handling of bulk products companies are available, emissions from 2A5c are reported in the category Other industrial processes (2H3). The 2H3 subcategory in the Dutch PRTR includes 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.
2B1	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, HCBs and PCBs	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B1 are included in Chemical industry: Other (2B10a).
2B2	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, HCBs and PCBs	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B2 are included in Chemical industry: Other (2B10a).
2B5	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, HCBs and PCBs	2B10a	Because of allocation problems and for confidentiality reasons, emissions from Silicon carbide (2B5) are included in Chemical industry: Other (2B10a).
2B6	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, HCBs and PCBs	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B6 are included in Chemical industry: Other (2B10a).

NFR code	Substance(s)	Included in NFR code	Explanation
2B7	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, HCBs and PCBs	2B10a	Because of allocation problems and for confidentiality reasons, emissions from 2B7 are included in Chemical industry: Other (2B10a).
2B10b	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, HCBs and PCBs	2H3	Because only emissions from the storage and handling of bulk products companies are available, emissions from 2B10b are reported in the category Other industrial processes (2H3). The 2H3 subcategory in the Dutch PRTR includes 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.
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	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, HCBs and PCBs	2H3	For confidentiality reasons, emissions from 2C4 are included in 2H3.
2C7d	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, HCBs and PCBs	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 2019, Section 5.3.1.
2G	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, HCBs and PCBs	2D3i	Because the 2016 Guidebook is not clear about which sources belong to 2G, 2G is included in 2D3i (Other solvent and product use).
2L	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, HCBs and PCBs	2H3	Because the 2016 Guidebook is not clear about which sources belong to 2L, 2L is included in 2H3 (Other industrial processes).
5A	NO_x, SO_x, BC and CO	1A1a and 1A5a	Emissions from heat and power production and flaring are included in the sector Energy. See Chapter 7

NFR code	Substance(s)	Included in NFR code	Explanation
5C1a	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, HCBs and PCBs	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	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, HCBs and PCBs	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	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, HCBs and PCBs	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	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, HCBs and PCBs	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	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, HCBs and PCBs	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
All except 1A1a, 1A1c, 1A2a, 1A2gviii, 1A4bi, 2C1, 5C2 and 5E	PCBs	assumed negligible
1A1b	Pb, Cd, Hg, As, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible; no method available
1A2a	NH_3, Pb, Cd, Hg, As, Cr, Cu, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible
1A2b	BC, Se and HCBs	assumed negligible
1A2c	BC, Pb, Cd, As, Cr, Cu, Ni, Se, PAHs and HCBs	assumed negligible
1A2d	BC, Pb, Cd, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible
1A2e	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn and Dioxins	assumed negligible; no method available
1A2gvii	HCBs	assumed negligible
1A3ai(i)	NH_3 and Hg	assumed negligible
1A3b till 1A3biv	Pb, Cd, Hg, As, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible; for fuel sold no method available
1A3bv	Dioxins, PAHs and HCBs	assumed negligible; for fuel sold no method available
1A3bvi	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible; for fuel sold no method available
1A3bvii	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible
1A3di(ii) and 1A3dii	HCBs	assumed negligible
1A4ai	Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn	assumed negligible
1A4aii	HCBs	assumed negligible
1A4bii	HCBs	assumed negligible
1A4ci	Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn	assumed negligible
1A4cii	HCBs	assumed negligible
1A4ciii	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible
1A5b	HCBs	assumed negligible
1B1a	NMVOC, SO_x, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible
1B2ai	SO_x, Dioxins, PAHs and HCBs	assumed negligible
1B2aiv	SO_x, PAHs and HCBs	assumed negligible

NFR code	Substance(s)	Reason for non-estimation
1B2av	SO_x, Dioxins, PAHs and HCBs	assumed negligible
1B2b	SO_x, Dioxins, PAHs and HCBs	assumed negligible
1B2c	$PM_{2.5}$, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Dioxins, PAHs and HCBs	assumed negligible
1B2d	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	assumed negligible
2C3	Dioxins	assumed negligible
2D3b and 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 and HCBs	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
3Dd	NMVOC	assumed negligible
3De	NO_x, SO_x, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni and Se	assumed negligible
3Df	NO_x, NMVOC, SO_x, NH_3, Pb, Cd, Hg, As, Cr, Cu, Ni and Se	assumed negligible
3I	NMVOC, 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 and HCBs	assumed negligible

Appendix 2 Approach 1 Key category analysis results

Approach 1 method
Results from the key (source) category analysis have been calculated and sorted for every component. In addition to a 2019 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 emission were taken from the fuel sold calculations.

SO_x key sources

Table A2.1.a SO_x key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	2019 Gg	Contribution	Cumulative contribution
1A1b	Petroleum refining	8.7	38.0%	38.0%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	3.2	13.9%	51.9%
1A1a	Public electricity and heat production	2.7	11.9%	63.8%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	2.3	10.0%	73.8%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	1.5	6.4%	80.2%

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	34.1%	34.1%
1A1a	Public electricity and heat production	48.5	24.6%	58.7%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	20.0	10.2%	68.8%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	9.1	4.6%	73.5%
1A3biii	Road transport: Heavy duty vehicles and buses	8.4	4.3%	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 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	1.5%	21.5%	21.5%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	1.1%	15.7%	37.2%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.9%	12.8%	50.0%
1A3biii	Road transport: Heavy duty vehicles and buses	0.5%	6.8%	56.8%
1A1b	Petroleum refining	0.5%	6.6%	63.5%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	0.4%	6.4%	69.9%
1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	0.4%	5.4%	75.3%
1A3bi	Road transport: Passenger cars	0.3%	3.7%	79.0%
1A2e	Stationary combustion in manufacturing industries and construction: Food processing. beverages and tobacco	0.2%	2.8%	81.9%

NO_x key sources

Table A2.2.a NO_x key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	2019 Gg	Contribution	Cumulative contribution
1A3biii	Road transport: Heavy duty vehicles and buses	33	33.4	14.0%
1A3bi	Road transport: Passenger cars	29	29.0	26.2%
1A3bii	Road transport: Light duty vehicles	18	17.9	33.7%
1A1a	Public electricity and heat production	15	15.0	40.0%
3Da2a	Animal manure applied to soils	15	14.9	46.2%
1A3di(ii)	International inland waterways	14	14.3	52.2%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	10.1	10.1	56.4%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	8.8	8.8	60.1%
1A3dii	National navigation (shipping)	8.7	8.7	63.8%
3Da1	Inorganic N-fertilizers (includes also urea application)	8.4	8.4	67.3%
1A4ciii	Agriculture/Forestry/Fishing: National fishing	8.0	8.0	70.6%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	7.7	7.7	73.9%
1A4ci	Agriculture/Forestry/Fishing: Stationary	6.5	6.5	76.6%
1A4bi	Residential: Stationary	6.1	6.1	79.2%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	6.06	6.1	81.7%

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	145.1	21.9%	21.9%
1A3biii	Road transport: Heavy duty vehicles and buses	116.0	17.5%	39.4%
1A1a	Public electricity and heat production	82.9	12.5%	52.0%

1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	35.9	5.4%	57.4%
1A3bii	Road transport: Light duty vehicles	23.6	3.6%	61.0%
1A3di(ii)	International inland waterways	22.3	3.4%	64.3%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	21.9	3.3%	67.6%
1A4bi	Residential: Stationary	21.6	3.3%	70.9%
1A4ciii	Agriculture/Forestry/Fishing: National fishing	20.6	3.1%	74.0%
3Da2a	Animal manure applied to soils	19.8	3.0%	77.0%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	19.7	3.0%	80.0%

Table A2.2.c NO_x key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	3.5%	19.8%	19.8%
1A1a	Public electricity and heat production	2.3%	12.7%	32.5%
1A3bii	Road transport: Light duty vehicles	1.4%	8.1%	40.6%
1A3biii	Road transport: Heavy duty vehicles and buses	1.3%	7.1%	47.7%
3Da2a	Animal manure applied to soils	1.2%	6.6%	54.3%
1A3dii	National navigation (shipping)	1.0%	5.4%	59.7%
1A3di(ii)	International inland waterways	0.9%	5.3%	65.0%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	0.6%	3.5%	68.6%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.5%	3.0%	71.5%
1A4ci	Agriculture/Forestry/Fishi ng: Stationary	0.5%	2.9%	74.4%
1A3ai(i)	International aviation LTO (civil)	0.5%	2.9%	77.3%

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
3Da1	Inorganic N-fertilizers (includes also urea application)	0.4%	2.4%	79.6%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.4%	2.2%	81.8%

NH_3 key sources

Table A2.3.a NH_3 key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	2019 Gg	Contribution	Cumulative contribution
3Da2a	Animal manure applied to soils	35.1	28.6%	28.6%
3B1a	Manure management - Dairy cattle	22.0	17.9%	46.5%
3B3	Manure management - Swine	14.0	11.4%	57.9%
3B1b	Manure management - Non-dairy cattle	9.9	8.0%	65.9%
3Da1	Inorganic N-fertilizers (includes also urea application)	8.8	7.1%	73.0%
3B4gi	Manure management - Laying hens	8.7	7.1%	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	196.2	56.7%	56.7%
3B3	Manure management – Swine	49.2	14.2%	70.9%
3B1a	Manure management – Dairy cattle	22.2	6.4%	77.3%
3Da3	Urine and dung deposited by grazing animals	20.7	6.0%	83.3%

Table A2.3.c NH_3 key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
3Da2a	Animal manure applied to soils	10.0%	40.3%	40.3%
3B1a	Manure management - Dairy cattle	4.1%	16.5%	56.8%
3B1b	Manure management - Non-dairy cattle	1.7%	6.8%	63.6%
3B4gi	Manure mangement - Laying hens	1.7%	6.8%	70.4%
3Da1	Inorganic N-fertilizers (includes also urea application)	1.2%	4.7%	75.1%
3B3	Manure management - Swine	1.0%	4.1%	79.2%
3Da3	Urine and dung deposited by grazing animals	1.0%	4.0%	83.3%

NMVOC key sources

Table A2.4.a NMVOC key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	2019 Gg	Contribution	Cumulative contribution
3B1a	Manure management - Dairy cattle	43.4	18.3%	18.3%
2D3a	Domestic solvent use including fungicides	34.7	14.6%	32.9%
2D3d	Coating applications	14.9	6.3%	39.2%
2D3i	Other solvent use (please specify in the IIR)	14.6	6.2%	45.4%
1A3bi	Road transport: Passenger cars	12.3	5.2%	50.6%
3Dc	Farm-level agricultural operations including storage. handling and transport of agricultural products	11.4	4.8%	55.4%
3B1b	Manure management - Non-dairy cattle	10.6	4.5%	59.9%
2H3	Other industrial processes (please specify in the IIR)	10.4	4.4%	64.3%
1A3biv	Road transport: Mopeds & motorcycles	10.2	4.3%	68.6%
3Da2a	Animal manure applied to soils	9.8	4.1%	72.7%
1A4bi	Residential: Stationary	8.6	3.6%	76.3%
2H2	Food and beverages industry	6.1	2.6%	78.9%
2B10a	Chemical industry: Other (please specify in the IIR)	4.6	1.9%	80.9%

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	100.6	16.6%	16.6%
2D3d	Coating applications	93.1	15.4%	32.0%
3Da2a	Animal manure applied to soils	48.9	8.1%	40.0%
1A3bv	Road transport: Gasoline evaporation	35.8	5.9%	45.9%
2B10a	Chemical industry: Other (please specify in the IIR)	33.4	5.5%	51.4%
2H3	Other industrial processes (please specify in the IIR)	25.3	4.2%	55.6%
1A3biv	Road transport: Mopeds & motorcycles	24.7	4.1%	59.7%
2D3a	Domestic solvent use including fungicides	23.7	3.9%	63.6%

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
2D3i	Other solvent use (please specify in the IIR)	18.7	3.1%	66.7%
1B2av	Distribution of oil products	16.9	2.8%	69.5%
1A3biii	Road transport: Heavy duty vehicles and buses	16.7	2.8%	72.3%
3B1a	Manure management - Dairy cattle	15.3	2.5%	74.8%
1B2aiv	Fugitive emissions oil: Refining / storage	14.8	2.4%	77.2%
2D3h	Printing	14.4	2.4%	79.6%
1B2b	Fugitive emissions from natural gas (exploration. production. processing. transmission. storage. distribution and other)	14.2	2.3%	81.9%

Table A2.4.c NMVOC key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
3B1a	Manure management - Dairy cattle	6.2%	18.2%	18.2%
1A3bi	Road transport: Passenger cars	4.5%	13.1%	31.3%
2D3a	Domestic solvent use including fungicides	4.2%	12.3%	43.7%
2D3d	Coating applications	3.6%	10.5%	54.1%
1A3bv	Road transport: Gasoline evaporation	2.0%	6.0%	60.1%
3Dc	Farm-level agricultural operations including storage. handling and transport of agricultural products	1.5%	4.5%	64.6%
3Da2a	Animal manure applied to soils	1.5%	4.5%	69.2%
2B10a	Chemical industry: Other (please specify in the IIR)	1.4%	4.1%	73.3%
2D3i	Other solvent use (please specify in the IIR)	1.2%	3.6%	76.8%
3B1b	Manure management - Non-dairy cattle	0.8%	2.5%	79.3%
1A3biii	Road transport: Heavy duty vehicles and buses	0.7%	2.1%	81.4%

CO key sources

Table A2.5.a CO key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	2019 Gg	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	303.0	48.4%	48.4%
1A4bi	Residential: Stationary	62.1	9.9%	58.3%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	54.6	8.7%	67.0%
1A3biv	Road transport: Mopeds & motorcycles	47.6	7.6%	74.6%
1A4bii	Residential: Household and gardening (mobile)	31.5	5.0%	79.7%
1A5b	Other. Mobile (including military. land based and recreational boats)	20.7	3.3%	83.0%

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	587.4	51.2%	51.2%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	187.7	16.3%	67.5%
1A4bi	Residential: Stationary	77.6	6.8%	74.3%
1A3bii	Road transport: Light duty vehicles	48.1	4.2%	78.4%
1A3biv	Road transport: Mopeds & motorcycles	43.5	3.8%	82.2%

Table A2.5.c CO key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	4.2%	23.2%	23.2%
1A3biv	Road transport: Mopeds & motorcycles	2.1%	11.6%	34.7%
1A4bii	Residential: Household and gardening (mobile)	2.0%	11.2%	46.0%
1A3bii	Road transport: Light duty vehicles	1.9%	10.7%	56.6%
1A4bi	Residential: Stationary	1.7%	9.6%	66.2%
1A3bi	Road transport: Passenger cars	1.5%	8.3%	74.5%

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A5b	Other. Mobile (including military. land based and recreational boats)	1.1%	6.3%	80.8%

PM_{10} key sources

Table A2.6.a PM_{10} key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	20Gg Gg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	4.7	17.0%	17.0%
2H3	Other industrial processes (please specify in the IIR)	2.5	9.1%	26.1%
3B4gi	Manure mangement - Laying hens	2.2	8.0%	34.1%
2H2	Food and beverages industry	2.0	7.1%	41.2%
1A3bvi	Road transport: Automobile tyre and brake wear	1.6	5.7%	46.9%
2G	Other product use (please specify in the IIR)	1.6	5.6%	52.5%
1A3bvii	Road transport: Automobile road abrasion	1.3	4.6%	57.1%
2C1	Iron and steel production	1.3	4.6%	61.7%
2A6	Other mineral products (please specify in the IIR)	1.1	3.9%	65.6%
3B4gii	Manure management - Broilers	1.0	3.7%	69.3%
2B10a	Chemical industry: Other (please specify in the IIR)	0.9	3.4%	72.7%
3B3	Manure management - Swine	0.9	3.2%	75.9%
5E	Other waste (please specify in IIR)	0.5	1.7%	77.6%
1A3di(ii)	International inland waterways	0.4	1.5%	79.1%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.4	1.5%	80.7%

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	11.4%	11.4%
1A4bi	Residential: Stationary	7.5	9.3%	20.7%
1A3biii	Road transport: Heavy duty vehicles and buses	7.1	8.8%	29.6%
1A3bi	Road transport: Passenger cars	6.4	8.0%	37.6%
1A1b	Petroleum refining	6.4	8.0%	45.6%
2H3	Other industrial processes (please specify in the IIR)	5.4	6.8%	52.3%
1A3bii	Road transport: Light duty vehicles	4.6	5.7%	58.1%
2H2	Food and beverages industry	4.3	5.4%	63.5%

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
2B10a	Chemical industry: Other (please specify in the IIR)	4.1	5.1%	68.6%
1A1a	Public electricity and heat production	2.2	2.8%	71.3%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	2.1	2.6%	74.0%
2A6	Other mineral products (please specify in the IIR)	2.0	2.5%	76.5%
2G	Other product use (please specify in the IIR)	2.0	2.5%	79.0%
3B3	Manure management - Swine	1.6	2.0%	81.0%

Table A2.6.c PM_{10} key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	2.7%	9.3%	9.3%
1A3biii	Road transport: Heavy duty vehicles and buses	2.6%	9.2%	18.5%
1A1b	Petroleum refining	2.5%	8.7%	27.1%
3B4gi	Manure management - Laying hens	2.4%	8.5%	35.6%
2C1	Iron and steel production	2.3%	8.2%	43.9%
1A3bi	Road transport: Passenger cars	2.2%	7.9%	51.8%
1A3bii	Road transport: Light duty vehicles	1.5%	5.3%	57.0%
1A3bvi	Road transport: Automobile tyre and brake wear	1.4%	5.1%	62.1%
1A3bvii	Road transport: Automobile road abrasion	1.2%	4.2%	66.4%
2G	Other product use (please specify in the IIR)	1.1%	3.8%	70.1%
3B4gii	Manure mangement - Broilers	0.8%	2.9%	73.0%
2H3	Other industrial processes (please specify in the IIR)	0.8%	2.8%	75.8%
1A1a	Public electricity and heat production	0.8%	2.7%	78.5%
2B10a	Chemical industry: Other (please specify in the IIR)	0.6%	2.1%	80.5%

$PM_{2.5}$ key sources

Table A2.7.a $PM_{2.5}$ key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	2019 Gg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	4.4	28.7%	28.7%
2G	Other product use (please specify in the IIR)	1.6	10.1%	38.8%
2A6	Other mineral products (please specify in the IIR)	1.0	6.2%	45.0%
2C1	Iron and steel production	0.8	5.3%	50.3%
2H3	Other industrial processes (please specify in the IIR)	0.7	4.6%	55.0%
2B10a	Chemical industry: Other (please specify in the IIR)	0.7	4.3%	59.2%
2H2	Food and beverages industry	0.5	3.5%	62.7%
5E	Other waste (please specify in IIR)	0.4	2.8%	65.5%
1A3bi	Road transport: Passenger cars	0.4	2.7%	68.2%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.4	2.6%	70.9%
1A3di(ii)	International inland waterways	0.4	2.6%	73.5%
1A3bii	Road transport: Light duty vehicles	0.4	2.5%	75.9%
1A3biii	Road transport: Heavy duty vehicles and buses	0.4	2.3%	78.2%
1A3dii	National navigation (shipping)	0.3	2.1%	80.4%

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
1A4bi	Residential: Stationary	7.1	12.4%	12.4%
1A3biii	Road transport: Heavy duty vehicles and buses	7.1	12.3%	24.7%
1A3bi	Road transport: Passenger cars	6.4	11.2%	35.9%
2C1	Iron and steel production	5.9	10.3%	46.2%
1A1b	Petroleum refining	4.9	8.5%	54.7%
1A3bii	Road transport: Light duty vehicles	4.6	8.0%	62.7%
2B10a	Chemical industry: Other (please specify in the IIR)	2.6	4.4%	67.1%
2G	Other product use (please specify in the IIR)	2.0	3.5%	70.6%

NFR14 Code	Long name	1990 Gg	Contribution	Cumulative contribution
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	2.0	3.5%	74.1%
1A1a	Public electricity and heat production	1.8	3.1%	77.2%
2H3	Other industrial processes (please specify in the IIR)	1.7	2.9%	80.1%

Table A2.7.c $PM_{2.5}$ key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	4.4%	19.2%	19.2%
1A3biii	Road transport: Heavy duty vehicles and buses	2.7%	11.8%	30.9%
1A3bi	Road transport: Passenger cars	2.3%	9.9%	40.9%
1A1b	Petroleum refining	2.0%	8.6%	49.5%
2G	Other product use (please specify in the IIR)	1.8%	7.7%	57.2%
1A3bii	Road transport: Light duty vehicles	1.5%	6.5%	63.6%
2C1	Iron and steel production	1.3%	5.9%	69.5%
2A6	Other mineral products (please specify in the IIR)	0.9%	4.1%	73.6%
1A1a	Public electricity and heat production	0.6%	2.8%	76.3%
5E	Other waste (please specify in IIR)	0.6%	2.6%	78.9%
2H3	Other industrial processes (please specify in the IIR)	0.5%	2.1%	81.0%

Black Carbon key sources

Table A2.8.a Black carbon key source categories identified by 2019 level assessment (emissions in Gg)

NFR14 Code	Long name	2019 Gg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	0.5	21.4%	21.4%
1A3bii	Road transport: Light duty vehicles	0.3	12.9%	34.3%
1A3di(ii)	International inland waterways	0.2	9.8%	44.1%
1A3bi	Road transport: Passenger cars	0.2	8.8%	52.9%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	0.2	8.8%	61.7%
1A3biii	Road transport: Heavy duty vehicles and buses	0.2	8.0%	69.7%
1A3dii	National navigation (shipping)	0.2	7.3%	77.1%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.2	6.4%	83.5%

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	3.6	26.5%	26.5%
1A3bi	Road transport: Passenger cars	3.0	22.1%	48.5%
1A3bii	Road transport: Light duty vehicles	2.5	18.6%	67.1%
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	1.0	7.6%	74.7%
1A4bi	Residential: Stationary	0.9	7.0%	81.7%

Table A2.8.c Black carbon key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3biii	Road transport: Heavy duty vehicles and buses	3.2%	23.1%	23.1%
1A4bi	Residential: Stationary	2.5%	18.0%	41.1%
1A3bi	Road transport: Passenger cars	2.3%	16.5%	57.6%
1A3di(ii)	International inland waterways	1.2%	8.4%	66.0%

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3dii	National navigation (shipping)	1.1%	7.7%	73.7%
1A3bii	Road transport: Light duty vehicles	1.0%	7.1%	80.8%

Pb key sources

Table A2.9.a Pb key source categories identified by 2019 level assessment (emissions in Mg)

NFR14 Code	Long name	2019 Mg	Contribution	Cumulative contribution
2C1	Iron and steel production	1.3	25.5%	25.5%
2A3	Glass production	0.8	14.6%	40.1%
1A3ai(i)	International aviation LTO (civil)	0.1	1.8%	41.9%
1A3bi	Road transport: Passenger cars	0.5	9.2%	51.1%
2C6	Zinc production	0.5	9.0%	60.1%
1A3bvi	Road transport: Automobile tyre and brake wear	0.3	6.6%	66.7%

1. emissions based on fuel used.

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	68.1%	68.1%
2C1	Iron and steel production	55.7	16.5%	84.5%

Table A2.9.c Pb key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	0.9%	44.7%	44.7%
1A3ai(i)	International aviation LTO (civil)	0.0%	1.3%	46.0%
2A3	Glass production	0.2%	9.4%	55.4%
2C1	Iron and steel production	0.1%	6.8%	62.3%
2C6	Zinc production	0.1%	6.8%	69.0%
1A3bvi	Road transport: Automobile tyre and brake wear	0.1%	4.9%	74.0%
1A3c	Railways	0.1%	3.8%	77.8%
2B10a	Chemical industry: Other (please specify in the IIR)	0.0%	2.3%	80.1%

Hg key sources

Table A2.10.a Hg key source categories identified by 2019 level assessment (emissions in Mg)

NFR14 Code	Long name	2019 Mg	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	0.15	24.8%	24.8%
2A6	Other mineral products (please specify in the IIR)	0.11	17.8%	42.6%
2C1	Iron and steel production	0.10	17.6%	60.2%
1A3bi	Road transport: Passenger cars	0.07	11.2%	71.5%
2C5	Lead production	0.04	6.4%	77.8%
1A4bi	Residential: Stationary	0.03	5.7%	83.5%

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	53.2%	53.2%
2B10a	Chemical industry: Other	0.7	19.4%	72.6%
2C1	Iron and steel production	0.4	10.7%	83.3%

Table A2.10.c Hg key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	4.6%	26.8%	26.8%
2B10a	Chemical industry: Other (please specify in the IIR)	3.1%	18.3%	45.1%
2A6	Other mineral products (please specify in the IIR)	2.9%	16.9%	62.0%
1A3bi	Road transport: Passenger cars	1.6%	9.4%	71.4%
2C1	Iron and steel production	1.1%	6.5%	78.0%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.8%	4.8%	82.7%

Cd key sources

Table A2.11.a Cd key source categories identified by 2019 level assessment (emissions in Mg)

NFR14 Code	Long name	2019 Mg	Contribution	Cumulative contribution
2C6	Zinc production	2.2	84.4%	84.4%

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	45.9%	45.9%
1A1a	Public electricity and heat production	0.9	24.5%	70.4%
2C1	Iron and steel production	0.7	17.7%	88.1%

Table A2.11.c Cd key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
2C6	Zinc production	26.2%	43.8%	43.8%
1A1a	Public electricity and heat production	15.7%	26.2%	70.1%
2C1	Iron and steel production	11.0%	18.4%	88.5%

Dioxin key sources

Table A2.12.a Dioxin key source categories identified by 2019 level assessment (emissions in g I-Teq)

NFR14 Code	Long name	2019 g I-Teq	Contribution	Cumulative contribution
5E	Other waste (please specify in IIR)	15.9	38.9%	38.9%
2D3i	Other solvent use	10.5	25.8%	64.7%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	6.0	14.8%	79.5%
1A4bi	Residential: Stationary	5.6	13.8%	93.3%

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	77.1%	77.1%
1A4ai	Commercial/institutional: Stationary	100.0	13.2%	90.4%

Table A2.12.c Dioxin key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	4.0%	41.3%	41.3%
5E	Other waste (please specify in IIR)	2.0%	20.7%	62.1%
2D3i	Other solvent use	1.2%	12.5%	74.6%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	0.8%	8.2%	82.8%

PAH key sources

Table A2.13.a PAH key source categories identified by 2019 level assessment (emissions in Mg)

NFR14 Code	Long name	2019 Mg	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	3.2	68.6%	68.6%
5E	Other waste	0.6	12.7%	81.2%

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	33.4%	33.4%
1A4bi	Residential: Stationary	3.7	17.8%	51.3%
2D3d	Coating applications	2.4	11.7%	62.9%
2C1	Iron and steel production	1.6	7.9%	70.9%
2H3	Other industrial processes (please specify in the IIR)	1.4	6.6%	77.5%
1A3bi	Road transport: Passenger cars	0.8	4.0%	81.5%

Table A2.13.c PAH key source categories identified by 1990–2019 trend assessment

NFR14 Code	Long name	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	11.3%	43.9%	43.9%
2C3	Aluminium production	7.4%	28.6%	72.5%
5E	Other waste (please specify in IIR)	2.3%	9.0%	81.5%

Appendix 3 Approach 2 Key category analysis results

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 paragraph 1.5 the details of the Monte Carlo analyses are described.

SO_x Keysources

*Table A3.1 Key source ranking using IPCC Approach 2 **level** assessment for 2019 **SO_x** emissions*

GNFR	2019 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
B_Industry	**18.6**	**81.2%**	**27.1%**	**22.0%**	**73.5%**	**74%**
A_PublicPower	**2.7**	**11.9%**	**46.1%**	**5.5%**	**18.3%**	**92%**
C_OtherStationaryComb	0.6	2.8%	31.9%	0.9%	3.0%	95%
H_Aviation	0.3	1.2%	48.3%	0.6%	2.0%	97%
I_Offroad	0.4	1.7%	31.6%	0.5%	1.8%	99%
J_Waste	0.0	0.1%	128.8%	0.2%	0.6%	99%
E_Solvents	0.0	0.1%	113.3%	0.2%	0.5%	100%
F_RoadTransport	0.2	0.9%	10.8%	0.1%	0.3%	100%
G_Shipping	0.0	0.0%	48.1%	0.0%	0.1%	100%

*Table A3.2 Key source ranking using IPCC Approach 2 **trend** assessment for 2019 **SO_x** emissions compared to the base year*

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
H_Aviation	**0.1**	**0.3**	**1.2%**	**48.3%**	**3.2%**	**1.6%**	**42.2%**	**42%**
B_Industry	**120.0**	**18.6**	**81.2%**	**27.1%**	**3.1%**	**0.9%**	**23.1%**	**65%**
E_Solvents	**0.0**	**0.0**	**0.1%**	**113.3%**	**0.4%**	**0.5%**	**13.5%**	**79%**
A_PublicPower	**48.5**	**2.7**	**11.9%**	**46.1%**	**0.7%**	**0.3%**	**8.9%**	**88%**
J_Waste	0.0	0.0	0.1%	128.8%	0.2%	0.2%	6.6%	94%
C_OtherStationaryComb	2.1	0.6	2.8%	31.9%	0.5%	0.2%	4.3%	99%
I_Offroad	8.4	0.4	1.7%	31.6%	0.1%	0.0%	1.0%	100%
F_RoadTransport	16.0	0.2	0.9%	10.8%	0.1%	0.0%	0.3%	100%
G_Shipping	1.8	0.0	0.0%	48.1%	0.0%	0.0%	0.1%	100%

NO_x Keysources

Table A3.3 Key source ranking using IPCC Approach 2 level assessment for 2019 NOx emissions

GNFR	2019 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
L_AgriOther	**29.7**	**12.4%**	**119.9%**	**14.9%**	**38.1%**	**38%**
I_Offroad	**33.0**	**13.8%**	**40.4%**	**5.6%**	**14.3%**	**52%**
G_Shipping	**23.0**	**9.6%**	**52.2%**	**5.0%**	**12.8%**	**65%**
F_RoadTransport	**81.4**	**34.1%**	**11.2%**	**3.8%**	**9.8%**	**75%**
B_Industry	**31.2**	**13.1%**	**19.8%**	**2.6%**	**6.6%**	**82%**
A_PublicPower	15.0	6.3%	39.6%	2.5%	6.3%	88%
C_OtherStationaryComb	17.5	7.4%	31.5%	2.3%	5.9%	94%
K_AgriLivestock	3.7	1.5%	111.4%	1.7%	4.4%	98%
H_Aviation	3.8	1.6%	35.8%	0.6%	1.5%	100%
J_Waste	0.2	0.1%	98.4%	0.1%	0.2%	100%
E_Solvents	0.0	0.0%	90.7%	0.0%	0.0%	100%

Table A3.4 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2019* ***NO_x*** *emissions compared to the base year*

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
L_AgriOther	**47.2**	**29.7**	**12.4%**	**119.9%**	**3.3%**	**4.0%**	**36.9%**	**37%**
G_Shipping	**28.8**	**23.0**	**9.6%**	**52.2%**	**4.2%**	**2.2%**	**20.4%**	**57%**
H_Aviation	**1.2**	**3.8**	**1.6%**	**35.8%**	**4.3%**	**1.5%**	**14.3%**	**72%**
K_AgriLivestock	**3.7**	**3.7**	**1.5%**	**111.4%**	**0.9%**	**1.1%**	**9.8%**	**81%**
I_Offroad	64.8	33.0	13.8%	40.4%	2.1%	0.8%	7.7%	89%
A_PublicPower	82.9	15.0	6.3%	39.6%	1.1%	0.4%	4.1%	93%
F_RoadTransport	285.0	81.4	34.1%	11.2%	2.5%	0.3%	2.7%	96%
B_Industry	105.7	31.2	13.1%	19.8%	0.8%	0.2%	1.6%	97%
J_Waste	0.1	0.2	0.1%	98.4%	0.2%	0.2%	1.4%	99%
C_OtherStationaryComb	42.2	17.5	7.4%	31.5%	0.4%	0.1%	1.2%	100%
E_Solvents	0.1	0.0	0.0%	90.7%	0.0%	0.0%	0.0%	100%

NH_3 Keysources

Table A3.5 Key source ranking using IPCC Approach 2 level assessment for 2019 NH3 emissions

GNFR	2019 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
L_AgriOther	**52.4**	**42.7%**	**34.6%**	**14.7%**	**34.2%**	**34%**
K_AgriLivestock	**59.3**	**48.3%**	**26.7%**	**12.9%**	**29.9%**	**64%**
M_Other	**3.3**	**2.7%**	**285.6%**	**7.6%**	**17.7%**	**82%**
F_RoadTransport	4.2	3.4%	164.3%	5.6%	12.9%	95%
B_Industry	1.3	1.1%	68.5%	0.7%	1.7%	96%
E_Solvents	1.2	1.0%	63.5%	0.6%	1.5%	98%
C_OtherStationaryComb	0.4	0.3%	159.8%	0.5%	1.1%	99%
J_Waste	0.6	0.5%	63.3%	0.3%	0.7%	100%
A_PublicPower	0.2	0.1%	60.5%	0.1%	0.2%	100%
G_Shipping	0.0	0.0%	374.7%	0.0%	0.0%	100%
I_Offroad	0.0	0.0%	102.4%	0.0%	0.0%	100%
D_Fugitive	0.0	0.0%	100.7%	0.0%	0.0%	100%

Table A3.6 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2019* ***NH_3*** *emissions compared to the base year*

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
F_RoadTransport	**1.0**	**4.2**	**3.4%**	**164.3%**	**13.6%**	**22.3%**	**61.9%**	**62%**
M_Other	**2.7**	**3.3**	**2.7%**	**285.6%**	**2.3%**	**6.7%**	**18.6%**	**81%**
K_AgriLivestock	98.3	59.3	48.3%	26.7%	12.0%	3.2%	8.9%	89%
L_AgriOther	237.5	52.4	42.7%	34.6%	5.7%	2.0%	5.5%	95%
J_Waste	0.2	0.6	0.5%	63.3%	1.6%	1.0%	2.9%	98%
E_Solvents	1.3	1.2	1.0%	63.5%	0.6%	0.4%	1.1%	99%
C_OtherStationaryComb	0.3	0.4	0.3%	159.8%	0.2%	0.3%	0.9%	100%

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
B_Industry	4.7	1.3	1.1%	68.5%	0.1%	0.1%	0.2%	100%
G_Shipping	0.0	0.0	0.0%	374.7%	0.0%	0.0%	0.0%	100%
I_Offroad	0.0	0.0	0.0%	102.4%	0.0%	0.0%	0.0%	100%
D_Fugitive	0.0	0.0	0.0%	100.7%	0.0%	0.0%	0.0%	100%

NMVOC Keysources

Table A3.7 Key source ranking using IPCC Approach 2 ***level*** *assessment for 2019* ***NMVOC*** *emissions*

GNFR	2019 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
K_AgriLivestock	**64.9**	**27.4%**	**165.1%**	**45.2%**	**44.6%**	**45%**
F_RoadTransport	**26.8**	**11.3%**	**167.9%**	**19.0%**	**18.7%**	**63%**
E_Solvents	**70.8**	**29.9%**	**36.9%**	**11.0%**	**10.9%**	**74%**
L_AgriOther	**22.9**	**9.7%**	**104.0%**	**10.1%**	**9.9%**	**84%**
B_Industry	25.1	10.6%	78.8%	8.3%	8.2%	92%
C_OtherStationaryComb	9.3	3.9%	63.0%	2.5%	2.4%	95%
I_Offroad	4.6	2.0%	99.2%	1.9%	1.9%	97%
D_Fugitive	8.7	3.7%	37.4%	1.4%	1.4%	98%
J_Waste	1.4	0.6%	151.4%	0.9%	0.9%	99%
G_Shipping	1.2	0.5%	87.8%	0.5%	0.5%	99%
H_Aviation	0.4	0.2%	187.5%	0.3%	0.3%	100%
A_PublicPower	0.8	0.3%	78.6%	0.3%	0.3%	100%

Table A3.7 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2019* ***NMVOC*** *emissions compared to the base year*

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
K_AgriLivestock	**41.8**	**64.9**	**27.4%**	**165.1%**	**31.8%**	**52.5%**	**87.2%**	**87%**
F_RoadTransport	188.8	26.8	11.3%	167.9%	2.8%	4.7%	7.8%	95%
B_Industry	80.4	25.1	10.6%	78.8%	0.8%	0.7%	1.1%	96%
C_OtherStationaryComb	14.2	9.3	3.9%	63.0%	1.0%	0.6%	1.1%	97%
E_Solvents	158.7	70.8	29.9%	36.9%	1.6%	0.6%	1.0%	98%
D_Fugitive	47.4	8.7	3.7%	37.4%	0.8%	0.3%	0.5%	99%
H_Aviation	0.4	0.4	0.2%	187.5%	0.1%	0.2%	0.4%	99%
J_Waste	2.4	1.4	0.6%	151.4%	0.1%	0.2%	0.3%	99%
L_AgriOther	56.5	22.9	9.7%	104.0%	0.1%	0.1%	0.2%	100%
A_PublicPower	0.9	0.8	0.3%	78.6%	0.2%	0.1%	0.2%	100%
G_Shipping	2.0	1.2	0.5%	87.8%	0.1%	0.1%	0.2%	100%
I_Offroad	12.8	4.6	2.0%	99.2%	0.1%	0.1%	0.1%	100%

PM_{10} Keysources

Table A3.8Key source ranking using IPCC Approach 2 ***level*** *assessment for 2019* ***PM_{10}*** *emissions*

GNFR	2019 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
C_OtherStationaryComb	**4.9**	**17.8%**	**135.7%**	**24.2%**	**38.3%**	**38%**
F_RoadTransport	**4.2**	**15.0%**	**64.4%**	**9.7%**	**15.3%**	**54%**
B_Industry	**8.9**	**32.2%**	**37.4%**	**12.0%**	**19.1%**	**73%**
K_AgriLivestock	**4.6**	**16.7%**	**26.5%**	**4.4%**	**7.0%**	**80%**
E_Solvents	**1.6**	**5.6%**	**73.7%**	**4.1%**	**6.6%**	**86%**
J_Waste	0.5	1.9%	174.4%	3.3%	5.3%	92%
I_Offroad	1.2	4.4%	50.7%	2.2%	3.6%	95%

GNFR	2019 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
G_Shipping	0.8	2.8%	60.4%	1.7%	2.7%	98%
L_AgriOther	0.8	2.8%	29.5%	0.8%	1.3%	99%
A_PublicPower	0.1	0.5%	65.6%	0.3%	0.6%	100%
H_Aviation	0.0	0.2%	113.8%	0.2%	0.3%	100%
D_Fugitive	0.0	0.0%	99.7%	0.0%	0.0%	100%

Table A3.9 Key source ranking using IPCC Approach 2 ***trend*** *assessment for 2019* ***PM_{10}*** *emissions compared to the base year*

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
C_OtherStationaryComb	**7.7**	**4.9**	**17.8%**	**135.7%**	**5.2%**	**7.1%**	**38.3%**	**38%**
K_AgriLivestock	**4.1**	**4.6**	**16.7%**	**26.5%**	**12.9%**	**3.4%**	**18.6%**	**57%**
J_Waste	**0.5**	**0.5**	**1.9%**	**174.4%**	**1.3%**	**2.3%**	**12.3%**	**69%**
E_Solvents	**2.0**	**1.6**	**5.6%**	**73.7%**	**2.4%**	**1.8%**	**9.5%**	**79%**
F_RoadTransport	**20.6**	**4.2**	**15.0%**	**64.4%**	**2.1%**	**1.4%**	**7.5%**	**86%**
B_Industry	35.6	8.9	32.2%	37.4%	3.1%	1.1%	6.2%	92%
L_AgriOther	0.8	0.8	2.8%	29.5%	1.6%	0.5%	2.6%	95%
G_Shipping	1.3	0.8	2.8%	60.4%	0.7%	0.4%	2.3%	97%
I_Offroad	5.1	1.2	4.4%	50.7%	0.5%	0.2%	1.2%	99%
H_Aviation	0.0	0.0	0.2%	113.8%	0.1%	0.2%	0.9%	99%
A_PublicPower	2.2	0.1	0.5%	65.6%	0.1%	0.1%	0.5%	100%
D_Fugitive	0.2	0.0	0.0%	99.7%	0.0%	0.0%	0.0%	100%

$PM_{2.5}$ Keysources

*Table A3.10 Key source ranking using IPCC Approach 2 **level** assessment for 2019 **$PM_{2.5}$** emissions*

GNFR	2019 Gg	Share	Uncertainty estimate	Level * Uncertainty	Share L * U	Cumulative Share L * U
C_OtherStationaryComb	**4.6**	**30.1%**	**136.4%**	**41.1%**	**48.5%**	**48%**
B_Industry	**4.3**	**28.2%**	**51.0%**	**14.4%**	**17.0%**	**65%**
E_Solvents	**1.6**	**10.1%**	**75.0%**	**7.6%**	**8.9%**	**74%**
F_RoadTransport	**1.8**	**11.6%**	**60.9%**	**7.1%**	**8.3%**	**83%**
J_Waste	0.5	3.2%	166.6%	5.3%	6.2%	89%
I_Offroad	1.2	7.6%	51.2%	3.9%	4.6%	93%
G_Shipping	0.7	4.7%	60.5%	2.9%	3.4%	97%
K_AgriLivestock	0.4	2.5%	40.7%	1.0%	1.2%	98%
L_AgriOther	0.2	1.0%	76.5%	0.8%	0.9%	99%
A_PublicPower	0.1	0.8%	65.1%	0.5%	0.6%	100%
H_Aviation	0.0	0.2%	161.6%	0.4%	0.4%	100%
D_Fugitive	0.0	0.0%	99.4%	0.0%	0.0%	100%

*Table A3.11 Key source ranking using IPCC Approach 2 **trend** assessment for 2019 **$PM_{2.5}$** emissions compared to the base year*

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
C_OtherStationaryComb	**7.4**	**4.6**	**30.1%**	**136.4%**	**10.9%**	**14.9%**	**54.7%**	**55%**
J_Waste	**0.5**	**0.5**	**3.2%**	**166.6%**	**2.4%**	**4.0%**	**14.6%**	**69%**
E_Solvents	**2.0**	**1.6**	**10.1%**	**75.0%**	**5.1%**	**3.8%**	**13.9%**	**83%**
F_RoadTransport	18.8	1.8	11.6%	60.9%	2.0%	1.2%	4.5%	88%
G_Shipping	1.2	0.7	4.7%	60.5%	1.5%	0.9%	3.3%	91%
B_Industry	20.2	4.3	28.2%	51.0%	1.5%	0.8%	2.8%	94%
K_AgriLivestock	0.4	0.4	2.5%	40.7%	1.6%	0.7%	2.4%	96%

GNFR	1990 Gg	2019 Gg	Level assessment latest year	Uncertainty estimate	Trend	Trend * uncertainty	Contribution to trend	Cumulative contribution
L_AgriOther	0.2	0.2	1.0%	76.5%	0.7%	0.5%	1.9%	98%
H_Aviation	0.0	0.0	0.2%	161.6%	0.2%	0.3%	1.0%	99%
A_PublicPower	1.8	0.1	0.8%	65.1%	0.2%	0.1%	0.4%	100%
I_Offroad	4.8	1.2	7.6%	51.2%	0.2%	0.1%	0.4%	100%
D_Fugitive	0.1	0.0	0.0%	99.4%	0.0%	0.0%	0.0%	100%

Appendix 4 NECD-review 2020; Status on implementation of recommendations

NECD 2020 Inventory review
The inventory is reviewed annually by an NECD review team, and improvements in line with the recommendations from these reviews are planned.
This appendix has 4 tables:

- Table A3.1 gives an overview of the status on implementation of recommendations from the NECD-inventory review 2020;
- Table A3.2 gives an overview of the status on implementation of recommendations from the NECD-LPS review 2020;
- Table A3.3 gives an overview of the status on implementation of recommendations from the NECD-Gridded data review 2020;
- Table A3.4 gives an overview of the status on implementation of recommendations from the 2019 NECD-Projections review.

Table A4.1 Overview of the implementation of actions from the 2020 NECD inventory review

EMRT-NECD Observation	**Improvement made/planned**	**Reference to IIR or status**
NL-0A-2019-0002	The TERT notes that the Netherlands considers emissions of PCB from 2A1 (cement production) and 2C6 (Zinc production) to be below the threshold of significance and that there are no methods for estimation of emissions from 2A1 (cement production). **The TERT recommends that the Netherlands builds on its Tier 1 estimate for 2017 and implements an estimate for the full time series for its next submission.**	The issue is placed on the long-list of improvements. Annually, as far as resources permit, the highest prioritized issues are realised. However, this particular issue isn't high prioritized due to the combined effect of expected very low emissions contribution to the national total (there is no clinker production in the Netherlands anymore and just one zinc producer) and the high uncertainty of the tier1 emission factors.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-0A-2020-0001	The TERT commends the Netherlands for its quantitative estimation of uncertainty for NO_X, SO_X, NMVOC, PM_{10}, $PM_{2.5}$ and NH_3. Netherlands has indicated during the review that it does not intend to extend this analysis to other pollutants. **The TERT recommends that the Netherlands develops a plan to undertake uncertainty analysis for these other pollutants including Heavy Metals and POPs in the future.**	Quantitative uncertainty data for emission factors of heave metals and POP's are difficult to obtain. Experts are reluctant to commit to expert judgement for these pollutants and almost always there are not enough measurements and ore information available to calculate uncertainties. Due to limited available resources the first priority lays in further improving of the uncertainty data for the pollutants with a ceiling and implementing the method2 uncertainty analyses in the key source analyses.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A1-2017-0001	The report on $PM_{2.5}$ fractions has been published on the Emission registration website (www.prtr.nl). Furthermore, the $PM_{2.5}$ fractions have been added to the appendix of the ENINA methodology report (Honig *et al.*, 2020), which is part of the IIR submission. **The TERT recommends that Netherlands include a short description in the IIR of the results in Visschedijk & Dröge (2019) and any other detailed methodology reports in the IIR submission to provide sufficient transparency to the IIR.**	The PM2.5/PM10 ratios are included in the appendix of the ENINA methodology report (Honig et al., 2021). Furthermore, a paragraph has been included in the IIR explaining the data used to derive the PM2.5/PM10 ratios (in general), and a link is included to the background report of Visschedijk & Dröge (2019). See paragraph 3.2.4, 3.3.4 and 3.4.4 of the IIR.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A1b-2018-0001	For 1A1b Petroleum Refining and heavy metals and POPs, the TERT noted that there was a potential under-estimate of emissions for the years 2010-2018 as these were reported as 'NE'. In response to a question raised during the 2019 NECD review the Netherlands stated that they intend to start developing a method to estimate emissions when the emissions are below the companies' reporting thresholds. This was raised during the 2018 and 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the work for refineries and chemical industry started in 2019. However, no expected date of implementation was provided. **The TERT reiterates the recommendation that the Netherlands develop a methodology to ensure time series consistency for years when emissions are likely to be occurring but may be below the company reporting thresholds, and include the emissions as well as transparent information in the IIR on inconsistent time series, e.g. in Chapter 3.2.6.**	Metal emissions from companies that do not report these emissions are calculated for the period 2003-2019. A description of the methodology is available in 3.3.4 and a note on time series consistency is included in 3.3.6. See paragraph 3.3.4 and 3.3.6

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A1b-2019-0002	For 1A1b Petroleum Refining and pollutant Cd, the TERT noted that there was a lack of transparency regarding large year to year changes in the time series. In response to a question raised during the 2019 NECD review the Netherlands stated that they intend to start developing a method to estimate emissions when the emissions are below the companies' reporting thresholds. This was raised during the 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the work for refineries and chemical industry started in 2019. However, no expected date of implementation was provided. **The TERT reiterates the recommendation that the Netherlands develop a methodology to ensure time series consistency for years when emissions are likely to be occurring but may be below the company reporting thresholds, and include the emissions as well as transparent information in the IIR on inconsistent time series, e.g. in Chapter 3.2.6.**	Metal emissions from companies that do not report these emissions are calculated for the period 2003-2019. A description of the methodology is available in 3.3.4 and a note on time series consistency is included in 3.3.6. See paragraph 3.3.4 and 3.3.6

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A2a-2019-0001	For 1A2a Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel and for pollutants Cd (2005, 2017) Hg (2005, 2017) and Pb (2005, 2017), the TERT noted that the notation key 'NE' (not estimated) is used when emissions estimates are provided for other years. The TERT notes that this also applies to 2018 in the 2020 submission. This was raised during the 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR (Chapter 3.2.9) states that the issue has been included in the list of improvements, but no timeline is provided for the implementation. **The TERT reiterates the recommendation that the Netherlands resolve this time series inconsistency. Further, the TERT notes that it would increase transparency, if known inconsistencies in the time series were described in the IIR (e.g. in chapter 3.2.6 entitled 'Uncertainties and time series consistency'.**	The missing metal emissions for the sectors 1A1b, 1A2b, 1A2c and 1A2gviii have been calculated and included in the 2021 submission. For 1A2a, it was concluded that the metal emissions were reported completely by the iron and steel company, but it was not always possible to distinguish between process and combustion emissions. Therefore, the metal emissions are sometimes reported in 1A2a. The notation key have been adjusted to IE. See paragraph 3.3.4
NL-1A2b-2017-0001	The AERs from individual companies are not complete. In the coming years, a few sectors will be studied and AERs will be completed as far as possible. These studies started in 2019 with the chemical sector and the refineries (which is not yet finished), and it has yet to be decided which sector will be studied this year. **The TERT reiterates the recommendation that the Netherlands develop a methodology to ensure time series consistency for years when emissions are likely to be occurring but may be below the company reporting thresholds, and that the Netherlands include the emissions as well as transparent information in the IIR, e.g. in Chapter '3.2.6 Uncertainties and time series consistency'.**	Metal emissions from companies that do not report these emissions are calculated for the period 2003-2019. A description of the methodology is available in 3.3.4 and a note on time series consistency is included in 3.3.6. See paragraph 3.3.4 and 3.3.6 of the IIR.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A2b-2018-0001	For 1A2c Stationary Combustion in Manufacturing Industries and Construction: non-ferrous metals and heavy metals and POPs for all years, the TERT noted that the notation key 'NE' (not estimated) is used for some years when emissions estimates are provided for other years, while activity data are provided for all years. This was raised during the 2018 and 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements, but no timeline for the expected implementation has been provided. The TERT notes that this is a general issue across many sectors and pollutants in the Dutch inventory. **The TERT reiterates the recommendation that the Netherlands develop a methodology to ensure time series consistency for years when emissions are likely to be occurring but may be below the company reporting thresholds, and that the Netherlands include the emissions as well as transparent information in the IIR, e.g. in Chapter '3.2.6 Uncertainties and time series consistency'.**	Metal emissions from companies that do not report these emissions are calculated for the period 2003-2019. A description of the methodology is available in 3.3.4 and a note on time series consistency is included in 3.3.6. See paragraph 3.3.4 and 3.3.6

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A2b-2019-0001	For 1A2b Stationary Combustion in Manufacturing Industries and Construction: Non-ferrous Metals and pollutants HCB (1990), Cd (2005) and Pb (2005), the TERT noted that the notation key 'NE' (not estimated) is used when emissions estimates are provided for other years. This was raised during the 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements but no timeline for the expected implementation has been provided. **The TERT reiterates the recommendation that the Netherlands develop a methodology to ensure time series consistency for years when emissions are likely to be occurring but may be below the company reporting thresholds, and that the Netherlands include the emissions as well as transparent information in the IIR, e.g. in Chapter '3.2.6 Uncertainties and time series consistency'.**	Metal emissions from companies that do not report these emissions are calculated for the period 2003-2019. A description of the methodology is available in 3.3.4 and a note on time series consistency is included in 3.3.6. See paragraph 3.3.4 and 3.3.6

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A2c-2019-0001	For 1A2c Stationary Combustion in Manufacturing Industries and Construction: Chemicals and pollutant Cd for 2016-2018, the TERT noted that the notation key 'NE' (not estimated) is used when emissions estimates are provided for other years. This was raised during the 2019 NECD review. The TERT noted that the issue is likely below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that work for refineries and chemical industry started in 2019, but no timeline for the expected implementation has been provided. The TERT notes that this is a general issue across many sectors and pollutants in the Dutch inventory. **The TERT reiterates the recommendation that the Netherlands develop a methodology to ensure time series consistency for years when emissions are likely to be occurring but may be below the company reporting thresholds, and that the Netherlands include the emissions as well as transparent information in the IIR, e.g. in Chapter '3.2.6 Uncertainties and time series consistency'.**	Metal emissions from companies that do not report these emissions are calculated for the period 2003-2019. A description of the methodology is available in 3.3.4 and a note on time series consistency is included in 3.3.6. See paragraph 3.3.4 and 3.3.6

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A2gviii-2018-0001	For 1A2gviii Stationary Combustion in Manufacturing Industries and Construction: Other and pollutants Cd, Hg, Pb for year 2005, the TERT noted that there was a potential under-estimate of emissions as these were reported as 'NE'. In response to a question raised during the 2018 review, the Netherlands explained that these emissions are reported by individual companies. This issue was raised during the 2018 and 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR (Chapter 3.2.9) states that the issue has been included in the list of improvements, but no timeline is provided for the implementation. **The TERT reiterates the recommendation that the Netherlands resolve this time series inconsistency. Further, the TERT notes that it would increase transparency, if known inconsistencies in the time series were described in the IIR (e.g. in chapter 3.2.6 entitled 'Uncertainties and time series consistency'.**	Metal emissions from companies that do not report these emissions are calculated for the period 2003-2019. A description of the methodology is available in 3.3.4 and a note on time series consistency is included in 3.3.6. See paragraph 3.3.4 and 3.3.6
NL-1A3aii(i)-2017-0001	Emissions from domestic flights are very small and are included in the inventory, see Section 4.2.5. The issue is on the long list of improvements. **The TERT reiterates the recommendation that emissions for category 1A3aii(i) should be calculated and included in the NFR tables.**	LTO emissions from international and domestic flights are now split between 1A3ai(i) and 1A3aii(i).

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A3b-2019-0001	For category 1A3b Road Transport and all years, the TERT noted that the notation key 'NE' is used for PCB emissions in the NFR tables. Emission factors are given for these pollutants in the 2016 EMEP/EEA Guidebook. This was raised during the 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the recommendation will be addressed in the future submissions. **The TERT reiterates the recommendation that PCB emissions should be calculated and included in the NFR tables.**	The issue is on the long-list of improvements and is at this moment due to limited resources not prioritized high enough to be solved in 2021.
NL-1A3b-2020-0001	For category 1A3b Road Transport, for the whole time series the TERT noted that in the NFR tables dioxin emissions are reported as "NE", whereas in submissions from previous years these emissions were estimated. In response to a question raised during the review, the Netherlands explained that for compliance purposes they will go to fuel-sold, and they have to change the existing fuel-used methodology to calculating the emissions from fuel-sold. The Netherlands provided revised estimates for years 1990, 2005, 2016, 2017 and 2018 and stated that since the new methodology will be reported in the submission of 2022, the PCDD/F emissions calculated for fuel-used also to be used for fuel sold. **The TERT agreed with the revised estimate provided by the Netherlands The TERT recommends that the Netherlands include the revised estimate in its 2021 NRF and IIR submission.**	The dioxin emissions are now reported in the NFR. However, still based on fuel used calculations. This part of the issue will be solved as the Netherlands plans to report only fuel sold as from submission 2022.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A3bi-2019-0001	For category 1A3bi Road Transport: Passenger Cars for all years, the TERT noted that the notation key 'NE' is used for POPs and HM emissions in the NFR tables. Based on recommendation which was raised during the 2019 NECD review (https://emrt-necd.eionet.europa.eu/2020/NL-1A3bi-2019-0001), it was recommended to review these emissions. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the recommendation will be addressed in next year (2021) submissions. **The TERT reiterates the recommendation that POPs and HM emissions should be calculated and included in the NFR tables.**	The HM, PAH and dioxin emissions are now reported in the NFR. However, still based on fuel used calculations. This part of the issue will be solved as the Netherlands plans to report only fuel sold as from submission 2022.
NL-1A3biii-2020-0002	For category 1A3biii Road Transport: Heavy Duty Vehicles and Buses, for years 2005, 2010 the TERT noted that there is a lack of transparency regarding the fact that $PM_{2.5}$ estimate is larger than the estimate for PM_{10}. The Netherlands explained that this issue is a mistake (PM_{10} emissions are wrong) and will be corrected in submission 2021. **The TERT recommends that the Netherlands corrects this issue and provide correct estimates for PM_{10} emissions in the next submission 2021.**	The issue is solved as can be seen in the NFR tables.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A3biv-2018-0001	For category 1A3biv Road Transport: Mopeds and Motorcycles, for dioxin emissions the TERT noted that there is a lack of transparency regarding the fact that these emissions are reported as 'NE' even though relevant activity data and emission factors exist. This does not relate to an under-estimate of emissions above the threshold of significance. This was raised during the [2018] and 2019 NECD review. In response to a question raised during the review, the Netherlands explained that methodically it has not been possible to calculate dioxin emissions based on fuel sold. All dioxin emissions are therefore reported under fuel used as a memo item and reported as not estimated (NE) in the current NFR. **The TERT recommends that the Netherlands provides dioxin emission estimates from this category based on fuel sold with the next submission of 2021.**	The dioxin emissions are now reported in the NFR. However, still based on fuel used calculations. This part of the issue will be solved as the Netherlands plans to report only fuel sold as from submission 2022.
NL-1A3dii-2018-0001	For category 1A3dii National Navigation (Shipping), for liquid fuels and all years, the TERT noted that the notation key ‘NE’ is used for HCB and PCB emissions in the NFR tables. The TERT also observes that emissions of Cd, Hg and Pb are reported in the NFR tables from 2011 onwards but are reported as ‘NE’ from 1990-2010. Emission factors are given for these pollutants in the 2016 EMEP/EEA Guidebook. This was raised during the 2018 and 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction and is related to a non-mandatory category or year. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the recommendation will be addressed in the future submissions. **The TERT reiterates the recommendation that HCB and PCB emissions, as well as emissions of Cd, Hg and Pb, should be calculated and included in the NFR tables.**	The issue of reporting PCB emissions (There are no default EF’s for HCB) and the period 1990-2010 the emissions of Cd, Hg and Pb is on the long-list of improvements and at this moment due to limited resources not prioritized high enough to be solved in 2021.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A4ai-2019-0001	For category 1A4ai Commercial/institutional: Stationary, pollutant PCBs, years 1990-2018 the TERT noted that the activity data in the 2020 NFR submission and in the 2019 Revised Estimate deviate. Further, the TERT notes that activity data are reported for 1A4ai for all years (solid fuels: 1990, 1995, 2000 and 2009; biomass: 1990-2006 and 2018; liquid fuels: 1990-2003 and 2005-2018; gaseous fuels: 1990-2018), but that PCBs emissions are only reported for the years 1990-1994.This was raised during the 2019 NECD review. In response to a question raised during the review the Netherlands explained that the difference between the NFR and the Revised Estimate is caused by a change of the methodology; now the calculation is based on emissions from the national energy data (NEH) instead of data only from the AER reporting operators. This ensures that emissions are included even if an operator have emissions below the reporting threshold (and thus not reporting these). The TERT noted that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands base the PCBs emission estimates on the national energy data (NEH) instead of just data from the AER reporting to ensure that the emission estimates are based on the complete activity in the sector. Further, the TERT recommends that the Netherlands include a detailed description of the methodology in the IIR, i.e. activity data and emission factors, and thereby making it clear why PCBs emissions are only reported for the years 1990-1994 when activity data are reported for all years.**	The methodology is explained in paragraph 3.4.5 of the IIR (including a link to the national energy statistics). In paragraph 3.4.7, an explanation on time series consistency of the activity data is included. PCB emission estimates are based on national energy statistics, while the activity data in the NFR tables are from individual companies and collectively estimated sources. Since the PCB emissions are calculated in all sectors based on the energy statistics, the emissions are expected to be complete. See paragraph 3.4.5 and 3.4.7

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A4bi-2019-0001	For category 1A4bi Residential: Stationary, pollutant PCBs, years 2005, 2016, 2017 and 2018 the TERT noted that PCBs emissions have been included in the 2020 submission as recommended in the 2019 NECD review, but that the activity data for solid fuels deviate between the 2019 Revised Estimate and the data provided during the 2020 Review. Activity data for solid fuels for the years 2016-2017 are included in the Revised Estimate from the 2019 NECD review, but no activity data for solid fuels for the years 2015-2018 are included in the data set provided in the 2020 NECD Review. This was raised during the 2019 NECD review. In response to a question raised during the review the Netherlands explained that the activity data used for calculation of the PCBs emissions from solid fuels come from the BGK-calculations (Dutch Energy Data), and that the activity data for solid fuels were not included in the NFR by mistake. Further, the Netherlands clarifies that the activity data are indeed used in the PCBs emission calculation. The TERT noted that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands include a detailed description of the activity data used for calculation of PCBs emissions in the 2020 IIR submission, and also include a description that clarifies if solid fuels are uses in the years 2015-2018 or not.**	The methodology is explained in paragraph 3.4.5 of the IIR (including a link to the national energy statistics). In paragraph 3.4.7, an explanation on time series consistency of the activity data is included. See paragraph 3.4.5 and 3.4.7

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A4ci-2018-0001	For category 1A4ci Agriculture/Forestry/Fishing: Stationary and heavy metal emissions for all years, the TERT noted that there was a potential under-estimate of emissions due to the use of the notation key 'NE' when there is a method in the 2016 EMEP/EEA Guidebook and activity data are available. This was raised during the 2018 and 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the recommendation will be addressed in the 2021 submission as for Hg emissions. **The TERT reiterates the recommendation that the Netherlands include emissions estimates for all heavy metals for NFR 1A4ci in the next submission and transparently documents the methodology in the IIR.**	The issue is on the long-list of improvements and is at this moment due to limited resources not prioritized high enough to be solved in 2021.
NL-1A4ciii-2018-0001	For category 1A4ciii Agriculture/Forestry/Fishing: National Fishing and all years, the TERT noted that the notation key ‘NE’ is used for all emissions in the NFR tables. This was raised during the 2018 and 2019 NECD review. The TERT noted that the issue is below the threshold of significance for a technical correction. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the recommendation will be addressed in the future submissions. **The TERT reiterates the recommendation that emissions for category 1A4ciii should be calculated and included in the NFR tables.**	The issue is on the long-list of improvements and is at this moment due to limited resources not prioritized high enough to be solved in 2021.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1A5a-2017-0001	Landfill gas combustion for energy production is now allocated in 1A1a, while landfill gas flaring stays in 1A5a. The Netherland informed that the aim was to re-allocate emissions from landfill gas from 1A5a to the two sectors 1A1a (landfill gas is combusted in an energy device) and 5A (landfill gas flared) in the 2019 submission. The TERT notes that emissions from flaring of landfill gas is still reported in NFR 1A5a. This was raised during the 2017, 2018 and 2019 NECD review. In response to a question raised during the review the Netherlands states that "We do not see the extraction landfill gas as part of the process of solid waste disposal on land. As such, the fate of the extracted landfill gas determines the allocation of the emissions comings from this as done with the use of this gas in energy purposes.". The TERT noted that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands reallocate emissions from landfill gas to NFR 5A in the 2021 submission and document the changes in the IIR.**	Emissions have been reallocated from 1A5a to 5A. This is also described in the paragraph on recalculations (3.4.9) See paragraph 3.4.9.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-1B2av-2020-0001	For category 1B2av Distribution of Oil Products, pollutant NMVOC, years 1990-2018 the TERT noted that there is a lack of transparency regarding the emission estimates. The Netherlands states in the IIR that 'Fugitive NMVOC emissions from category 1B2av comprise dissipation losses from gasoline service stations, leakage losses during vehicle and aircraft refuelling and refinery processes. Emissions were calculated on the basis of annual fuel consumption (Tier 2 methodology)'. However, it was not clear to the TERT whether the estimates use country specific emission factors or default values. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, the Netherlands provided a detailed explanation of its approach. **The TERT recommends that the Netherlands include this improved description of the methodology, i.e. activity data, emission factors and underlying assumptions in the IIR.**	See paragraph 3.5.5. This paragraph now contains a description of the methodology, including references to the methodology reports (where more details on the methodology can be found).

NL-1B2c-2020-0001	For 1B2c Venting and flaring (oil, gas, combined oil and gas), all pollutants and all years, the TERT noted there is a lack of transparency and an underreporting of emissions. For several pollutants, the Netherlands reports emissions as included elsewhere (IE) and for other not estimated (NE) for some years. The TERT notes that in the reporting of greenhouse gas emissions, the Netherlands reports activity data and emissions individually for both venting and flaring (oil and gas separately). In response to a question raised during the review, the Netherlands explained that the emission inventory is based on reports by operators and that it is not possible to split emissions to various categories (e.g. fuel combustion, processes, venting and flaring). Further, the Netherlands provided a comparison of emissions of heavy metal for the years when facilities do report with an estimate produced using default emission factors for fuel combustion from the EMEP/EEA Guidebook. The Netherlands argued that this showed that using the emission factors from the EMEP/EEA Guidebook would lead to an over-estimate. The TERT disagrees with the responses provided by the Netherlands. The TERT noted that the issue is below the threshold of significance for a technical correction. The TERT notes that it is not appropriate to build an inventory solely on company reporting when it leads to systematic underestimation of emissions in years when facilities do not report emissions. Furthermore, the TERT notes that the Netherlands should be able to explain the methodology used by facilities in reporting their emissions to substantiate that all emissions are included. In the case of a refinery, there are emissions from many parts of the refining process and while some will be measured others will have to be calculated as measurements are not feasible such as emissions from flaring. **The TERT recommends that the Netherlands:** **1) Ensure that emissions are provided for all years of the time series when an activity occur regardless of whether a facility reports emissions above the threshold or not;** **2) Explain in the IIR why emissions cannot be reporting under this category (venting and flaring), when greenhouse gas emissions are reported;**	Emissions from venting and flaring are included in 1B2aiv (for refineries) and in 1B2b (for oil and gas extraction). The information is completely reported by individual companies in their environmental report (including venting and flaring emissions), which are checked by the competent authority. In paragraph 3.5.5 of the IIR, a more detailed description is provided of the allocation of the venting and flaring emissions. See paragraph 3.5.5

EMRT-NECD Observation	**Improvement made/planned**	**Reference to IIR or status**
	3) Provide information showing that the facility emissions reported includes all sources (combustion, fugitive, venting, flaring) and a brief description on the regulations for facilities to estimate these emissions; **4) Document that emissions associated with flaring in both refineries and in connection with oil and gas extraction is included in the inventory.** NL-1A1b-2018-0001	
NL-2A3-2019-0001	Dealt with under NL-2A3-2019-0002	Dealt with under NL-2A3-2019-0002
NL-2A3-2019-0002	For category 2A3 - Glass Production, for the year 2017 for Cd emissions, the TERT noted that in response to a question raised during the review, the Netherlands did not provide a clear justification for the large increase of Cd emissions (factor +35) between 2016 and 2017. Furthermore, the year 1990 was reported as 'NA'. The TERT decided to calculate a technical correction for the years 1990 and 2017 which was not accepted by the Netherlands. The estimates demonstrate that the issue is above the threshold of significance for 2017. **The TERT recommends that the Netherlands include a revised estimate in its next submission.**	Justification for the large increase added in paragraph 5.2.3

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-2B10a-2018-0002	For category 2B10a Chemical industry: Other, for Cd emissions, for the year 2005, the TERT noted there is a time series inconsistency between 1990-2006. The 2020 review noted that the IIR states that the issue has been included in the list of improvements and that the recommendation will be addressed in the 2021 submission. In a question raised during the review, the Netherlands specified that the project was on hold and that they we will definitely provide missing emission data in the 2021 submission, by examining several methods for creating a more realistic time series. **The TERT commends that and reiterates the recommendation that Netherlands improves the time series consistency to check the NMVOC emissions for the year 2005.**	New time series Cd recalculated, methodology explained. See paragraph 5.3.5
NL-2C6-2019-0001	The TERT notes with reference to category 2C6 Zinc Production, for pollutant Hg and for the whole time series that the notation key 'NA' was reported while there is an 2016 EMEP/EEA Guidebook methodology and a Tier 1 emission factor. This was raised during the 2019 NECD review. This over- or under-estimate may have an impact on total emissions that is above the threshold of significance. The Netherlands have not provided a revised estimate which has been accepted by the TERT. It is currently not possible for the TERT to provide a numerical emission estimate, and therefore the issue will be flagged as Potential Technical Correction and will be assessed as a high priority item in future reviews. **The TERT recommends that the Netherlands calculate Hg emissions from 2C6 Zinc Production for inclusion in next years' inventory submission.**	It was found not appropriate to calculate Hg emissions, further investigation at companies will be performed. Explanation added. See paragraph 5.4.4

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-2C7a-2019-0001	For category 2C7a Copper Production, for pollutant Cd for 2005-2018, the TERT noted that emissions were not reported. In response to a question raised during the review the Netherlands responded that they are working on a gap-filling project to look at emissions from facilities which would be below the reporting threshold. The TERT noted that based on the trends in TSP which are likely to correlate with trends in Cd that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands estimates emissions and includes the results together with a methodological description, the data sources and emission factors used in the 2021 submission.**	It was found not appropriate to calculate Hg emissions, further investigation at companies will be performed. Explanation added. See paragraph 5.4.4
NL-2C7a-2019-0002	The TERT notes with reference to 2C7a Copper Production, pollutant Hg and for the entire time series that the notation key 'NA' was reported while there is an 2016 EMEP/EEA Guidebook methodology and a Tier 1 emission factor. This was raised during the 2019 NECD review. This under-estimate may have an impact on total emissions that is above the threshold of significance. The Netherlands have not provided a revised estimate which has been accepted by the TERT. It is currently not possible for the TERT to provide a numerical emission estimate based on a Tier 1 method, and therefore the issue will be flagged as a Potential Technical Correction and will be assessed as a high priority item in future reviews. **The TERT recommends that the Netherlands should calculate Hg emissions from 2C7a Copper production using a Tier 1 or Tier 2 method for inclusion in next years' inventory submission.**	It was found not appropriate to calculate Hg emissions, further investigation at companies will be performed. Explanation added. See paragraph 5.4.4

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-2H2-2017-0001	For category 2H2 Food and Beverages Industry, for NMVOC emissions, for the entire time series, the TERT noted that there is a lack of transparency regarding the description of the scope and the methodology used to collect activity data from different sources according to the IIR. This does not relate to an over- or under-estimate of emissions. This was raised during the 2017, 2018 and 2019 NECD reviews. In response to a question raised during the review, the Netherlands explained that they collect data from operators reports and from Statistics Netherlands. **The TERT recommends that the Netherlands improves the description of the AD collection in the 2021 IIR.**	Methodology description added for bread bakeries See paragraph 5.7.4
NL-2H2-2020-0001	For category 2H2 Food and Beverages Industry, for the pollutants NMVOC and years 2000-2017, the TERT noted that significant recalculations have been applied. In response to a question raised during the review the Netherlands explained that NMVOC emissions were recalculated for bread bakeries for the whole time series, but with a mistake in the calculation, leading to too high emissions (about +2 kt). The TERT noted that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands correct NMVOC emissions in the next submission and update the 2021 IIR with the description of the methodology applied for bread bakeries.**	See paragraph 5.7.4 and 5.7.5

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-3B-2019-0003	The TERT notes with reference to 3B2 Sheep, 3B4e Horses and 3B4f mules and asses that NH_3, NO_X, NMVOC and PM emissions from privately owned animals are reported under 6A Other, which challenged the transparency. This issue was raised during the 2019 NECD review and the Netherlands responded that a split between agricultural and private owned horses/sheep/mules was needed to keep a clear distinction between economic and policy sectors. In case of the NH_3, the emission registered in NFR 6A accounts for 7.8% of the total and for the other compound the contribution is less than 1%. In in IIR submission it is mentioned in Chapter 6.2.8 that the Netherlands, as a part of planned improvements plan to reallocate emission from privately kept horses, sheep, mules and asses from 6A to 3B for the next submission 2021. **The TERT agrees with this approach and encourages the Netherlands to implement this improvement to the comparability of its reporting.**	See Section 6.3.7

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-3B-2020-0001	The TERT notes with reference to $PM_{2.5}$ emission from 3B Manure Management that there is a lack of transparency. No information in IIR is given regarding the $PM_{2.5}$ emission factor, not even a reference where to find this information. Combining the AD and $PM_{2.5}$ emission added in NFR, it seems, that the IEF for dairy cattle is between 32-35 g $PM_{2.5}$ per cow per year, which is significantly lower compared to Tier1 default 410 g $PM_{2.5}$/head/yr (Tier2: 280 g $PM_{2.5}$ for solid and 540 g $PM_{2.5}$ for slurry). During the review the Netherlands informed, that $PM_{2.5}$. EF could be found in a methodology report "Methodology for estimating emissions from agriculture in the Netherlands" (Lagerwerf et al., 2019) in Table 9.25, which for dairy cattle show $PM_{2.5}$ EF at 32.5 (with grazing) and 40.6 (without grazing). The TERT recommend the Netherlands, for transparency issue, include more information in IIR for $PM_{2.5}$ EF and housing days for all 3B categories. **Specific for dairy cattle the TERT recommend the Netherlands to include an explanation for the very low $PM_{2.5}$ EF. The default value in the EMEP/EEA Guidebook 3B (Table 3.5 and Table A1.7 is based on Takai et al., 1998, which also include emission measurements from cattle barns in the Netherlands.**	See Section 9.2.3 of the methodology report that is considered to be a part of this submission and contains the sources on which the EF have been based (Lagerwerf *et al.*, 2019 and van der Zee *et al.*, 2021)

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-3B-2020-0002	The TERT notes with reference to NMVOC from 3B Manure Management that there is a lack of transparency regarding background data for Tier 2 calculation. This does not relate to an over- or under-estimate of emissions. The TERT found some information in the referenced methodology report (Lagerwerf et al., 2019). However still some information regarding key parameters are not included. In response to a question raised during the review, The Netherlands provided a detailed Excel file including all key parameters for all livestock categories. The TERT evaluate the data for cattle and swine and found that value level for feed intake for cattle (MJ/head/yr) and VS excretion for swine match the value given in CRF. The increasing fraction for silage feeding and housing days explain the rise in IEF NMVOC from 1990 to 2018 and could confirm that the methodology for the estimates were suitable. **The TERT recommends that the Netherlands include information of the key parameters for estimation of NMVOC emission for 3B; silage fraction, time spent in housing, feed intake (MJ), VS excretion and NH_3 emission (housing, storage and application), in order to improve the transparency.**	The requested information is already provided by the report of Bruggen van *et al.,* 2020 (silage fraction Table: B23.1 Bruggen van *et al.,* 2020 time spent in housing: Annex 4 Bruggen van *et al.,* 2020 feed intake (MJ): Annex 25 Bruggen van *et al.,* 2020 VS excretion: table 6.2 and annex 27 Bruggen van *et al.,* 2020 NH_3 emission (housing, storage and application): Annex 10, 11, 12 and 16 Bruggen van *et al.,* 2020

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-3Da1-2020-0001	The TERT notes with reference to 3D1a Inorganic N-Fertilizers NH_3 that there is a lack of transparency. No information on activity data or emission factor is included in the NFR Tables or IIR. The IIR (Chapter 6.3.4 p. 149) refers to Lagerwerf et al., 2019 and Bruggen van et al, 2017 (should be updated to 2019). Thus, the information for AD and EF is described in two different reports. The TERT note that the Netherlands are not following the recommended content of the IIR (as indicated in Annex II Recommended Structure for the IIR). This indicates that countries are encouraged to include activity data, EFs, assumptions, and descriptions of methods used. This does not relate to an over- or under-estimate of emissions. In response to the question raised, the Netherlands inform that they considering the possibilities to add the underlying methodology report as part of the submission. **The TERT recommend that the Netherlands for the next submission 2021 in IIR, include information for the NH_3 EF and the N consumption for different fertiliser types.**	See annex 17 Bruggen van *et al.,* 2020

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-3De-2020-0001	The TERT notes with reference to NFR 3De Cultivated Crops, that there is a lack of transparency regarding the activity data used. No information in the IIR regarding the cultivated area and no reference where to find this information. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, the Netherlands provided an Excel sheet showing the data for the cultivated area and the TERT could confirm that the Tier1 calculation where correct. This sheet showed that the cultivated area was allocated on crop types, which make it possible to provide a Tier2 calculation in the future. If the Netherlands decide to provide a Tier2 calculation, it should be aware that the 2016 and 2019 EMEP/EEA Guidebook for 3D are known to have a unit's error (first column of Table 3.3 and all of Table 3.4). The units for NMVOC EFs are presented as "kg NMVOC per ha", which should be "kg NMVOC per hour". This issue will be added to the EMEP/EEA Guidebook errata, which will be published before the next submission. **The TERT recommends that the Netherlands include information on AD – the cultivated area in IIR for next submission 2021 and encourages the Netherlands to provide a Tier2 calculation because AD is available.**	See annex 20 Bruggen van *et al.*, 2020
NL-3Df-2019-0001	The TERT notes with reference to 3Df Use of Pesticides and HCB that no emissions are reported, and notation key "NA" is used. The same issue was raised during the 2019 NECD review. In response to a question raised during the review, the Netherlands provided a revised estimate for HCB emission from 3Df for 1990-2018 and stated that it will be included in the next submission. The TERT agreed with the revised estimate provided by the Netherlands based on EF default from the 2019 EMEP/EEA Guidebook 3Df, 3I. **The TERT recommends that the Netherlands include the revised estimate in its 2021 NFR and IIR submission.**	See section 6.3.4 of the IIR.

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-5D-2019-0001	For NMVOC emissions from 5D2 Industrial Wastewater Handling for all years, the TERT noted that there is an under-estimate of emissions because NMVOC emissions are not estimated ('NA' reported in the NFR tables). This was raised during the 2019 NECD review. In response to a question raised during the review, the Netherlands explained that it will consider adding this source to the list of improvements for 2020 (current budget is already allocated) and will report on the progress in the 2022 submission. The TERT noted that the issue is expected to be below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands include NMVOC emissions from 5D2 in its inventory as stated as soon as possible (reporting 'NE' instead of 'NA' in the meantime).**	The NMVOC-emissions from domestic waste water treatment are now reported in the NFR-table. We were not able to access all the activity data of industrial waste treatment and we will develop a methodology for the historical activity data. As all the resources for 2020 were already allocated to improvements projects. The issue is now planned on the list of improvement projects for 2021. We hope to settle this issue in the 2022 submission.

Table A4.2 Overview of the implementation of actions from the 2020 NECD LPS-review

EMRT-NECD Observation	Improvement made/planned	Reference into IIR
NL-LPS-A-2020-0002	'The TERT notes that for the year 2015, emissions are reported for NFR codes 3B3 Manure management - Swine, 3B4gi Manure management - Laying hens, 3B4gii Manure management - Broilers, 3B4giii Manure management - Turkeys in the national inventory but not for GNFR code K_AgriLivestock in the LPS submission. In response to the review, the Netherlands indicated that the ER database is used to report to the PRTR and the LPS-data is extracted from this database. The emission is based the total amount of animals in the Netherlands and not on individual farms, which the Netherlands consider gives a better and more complete total emission for all pollutants. **The TERT recommends that the Netherlands provides this clarification along with any analytical comparison of E-PRTR facility data and national inventory estimates in its IIR description of LPS and gridded estimates in future submissions.**	An explanation can be found in Chapter 9
NL-LPS-A-2020-0002	For the LPS IDs ‘AVR NV .Rijnmond. .39571’, ‘AVR NV .Rijnmond. .39573’, ‘Attero BV .Moerdijk. .41712’, ‘Attero BV .Moerdijk. .41713’, ‘Attero BV .Moerdijk. .41714’, and ‘AVR Afvalverwerking BV .Duiven. .38075’. the TERT noted that reported PM_{10} emissions are lower than $PM_{2.5}$ emissions. In response to a question raised during the review the Netherlands inform that this owe to an error in the split of total PM emissions reported by the operator, and that the issue will be corrected in the next LPS submission. The TERT noted that the issue is below the threshold of significance for a technical correction. **The TERT recommends that the Netherlands correct the PM_{10} and the $PM_{2.5}$ emissions in the next LPS submission.**	The observed errors will be corrected in the next submission.

Table A4.3 Overview of the implementation of actions from the 2020 NECD GRIDDED data-review

EMRT-NECD Observation	Improvement made/planned	Reference to IIR or status
NL-GRID-GEN-2020-0001	The TERT notes with reference to emissions of PCBs reported for 2015 an issue in the Gridding submission which may relate to an under-estimate of emissions. This under-estimate has an impact on total emissions that is above the threshold of significance. It is currently not possible for the TERT to provide a numerical emission estimate and therefore the issue will be flagged as Potential Technical Correction and will be assessed as a high priority item in future reviews. **The TERT recommends that the Netherlands calculate PCB emissions from all relevant GNFR categories for inclusion in next years' inventory submission.**	The PCB emissions, as far as available in the PRTR, will be gridded in the 2021 submission.
NL-GRID-GEN-2020-0003	The TERT notes with reference to the gridded emissions submitted for all pollutants that the total national emissions as summed up from the gridded data is different from the sum of the national inventory as submitted in the NFR tables. This over or under-estimate has an impact on total emissions that is above the threshold of significance. It is currently not possible for the TERT to provide a numerical emission estimate and therefore the issue will be flagged as an Unquantified Potential Technical Correction and will be assessed as a high priority item in future reviews. **The TERT recommends that the Netherlands ensure that gridded emissions are consistent with national totals in next years' inventory submission.**	This relates to an error in de gridded data that will be corrected in the next submission.

Table A3.4 Overview of the implementation of actions from the 2019 Projections review

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
NL-1A1-2019-0001; NL-1A1-2019-0003	1A1; Energy industries	WM; WAM	For category 1A1 Energy industries, NMVOC for the period 2005- 2020, the TRT noted that the trend for WM and WAM emissions are more than 3 standard deviations away from the average of the trends of all Member States. Time series of NMVOC emissions show a significant increase from 2017 to 2020 followed by a less pronounced decrease. In response to a question raised during the review, the Netherlands explained that this finding relates to an allocation error. The projected emissions from fugitives of oil and gas production have been included in 1A1, but they belong under 1B. **The TRT notes that this issue does not relate to an overestimate and recommends that the Netherlands correct the emission allocation in the next submission.**	The allocation error is resolved
NL-1A1-2019-0004	1A1; Energy industries	WM; WAM)	For category 1A1 Energy industries, SO_2, for 2020, the TRT noted that WM and WAM emissions show a large decrease (62 %) from 2017 to 2020. In response to a question raised during the review, the Netherlands explained that there are two reasons for the dip. Most important reason is that there is a mismatch in categories that are included for the historical year and for the projections. The projections only include the power plants and the oil- and gas exploration. The historical year includes	The allocation error is resolved. For explanation on closure of coal plants, see the Energy Section in the IIR.

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			also refineries and waste burning facilities that produce heat and power. The second reason is the closure of coal plants in the Netherlands with following decreasing emissions from 2013 (base year for the projection) to 2030. **The TRT notes that this issue does not relate to an underestimate and recommends that the Netherlands correct the emission allocation in the next submission and include documentation in the IIR regarding emission reduction due to the closure of coal plants.**	
NL-1A2-2019-0002	1A2; Manufacturing Industries and Construction	WM; WAM	For category 1A2, NMVOC for all projection years, the TRT noted WM and WAM emissions are reported as IE (included elsewhere). In response to a question raised during the review, the Netherlands explained that the NMVOC emissions projections from 1A2 are included in 2A, B, C, H, I, J, K, L (Industrial Processes), and that, at the moment, it is not possible to make the split. **The TRT notes that this issue does not relate to an underestimate and recommends that the Netherlands split the emissions and report in the respective categories. If it is not possible to split the emissions, this should be clearly documented in the IIR with a justification.**	The allocation error (split) is resolved

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
NL-1A2-2019-0003	1A2; Manufacturing Industries and Construction	WM; WAM	For category 1A2 Manufacturing Industries and Construction, $PM_{2.5}$ and SO_2 for 2020, the TRT noted that WM and WAM emissions show a large increase (~400 % and ~174 %) from 2017 to 2020 followed by a level-out (decrease). In response to a question raised during the review, the Netherlands explained that the projection data for 2020, 2025 and 2030 are the sum of Manufacturing Industries and Construction (Combustion in industry) and industrial processes. Combustion and processes are not separated in the projection calculation. Further, the Netherlands informed that the given $PM_{2.5}$ emissions for the base year 2017 have recently been updated upwards as result of new information of PM_{10}/$PM_{2.5}$ fractions, and that this recalculation has not yet been done for the projections. **The TRT notes that this issue relates to an over/underestimate and recommends that the Netherlands include the updated PM2.5 emissions in the next projection submission. Further, the TRT recommends the Netherland to split the emissions from Industry into combustion and processes if possible, or else to include documentation for the sectoral emission allocation in the projection chapter in the IIR.**	The update $PM_{2.5}$ projection emissions are in the 2021 Projections submission.
NL-1A3a,c,d,e-	1A3a,c,d,e;	WM	For 1A3a,c,d,e Off-road transport, NMVOC and NH_3	The allocation error is resolved.

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
2019-0001	Off- road transport		for 2020, the TRT noted a big increase in the emissions from 2017 to 2020. In response to a question raised during the review, the Netherlands explained that there are two reasons for the increase. There is a mismatch between emission source that are included for the historical year and for the projections. The projections also include the emissions of pipeline transport and 1A5 Other Stationary Combustion, while in the emission inventory pipeline transport are reported under 1B2 Fugitive Emissions from Oil and the emissions from the sources under 1A5 are reported separately. **The TRT notes that this issue does not relate to an over or underestimate and recommends that emissions from 1A5 are excluded from the figures reported under 1A3a,c,d,e in the next submission and instead report the emissions from 1A5 in its own category.**	
NL-1A3a,c,d,e-2019-0002	1A3a,c,d,e: Off- road transport	WM	For 1A3b Road transport, NH_3 for 2020, the TRT noted that the emissions decrease by 85 % from 2017 to 2020. In response to a question raised during the review, the Netherlands explained that an error has occurred with the allocation of the projected emissions from road and non-road transport projections data when converting to the NFR-format. The Netherlands stated that the projected national totals are correct.	The allocation error is resolved

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			The TRT notes that this issue does not relate to an over or underestimate and recommends that the projected emissions are allocated correctly in the next submission.	
NL-1A4-2019-0001	1A4; Other sectors	WM; WAM	For category 1A4 Other sectors, NH_3, for 2020, the TRT noted that WM and WAM emissions show a large decrease (49 %) from 2017 to 2020. In response to a question raised during the review, the Netherlands explained that NH_3 emissions from wood burning in stoves was added to the emission inventory in 2019. This emission source is not yet included in the projections. **The TRT notes that this issue relates to an underestimate and recommends that NH3 from wood burning is included the next projection submission.**	NH3 from woodburning is included in the 2021 submission.
NL-1A5-2019-0001	1A5; Other	WM; WAM	For category 1A5 Other Stationary Combustion, pollutants NMVOC, NO_X, $PM_{2.5}$, for years 2020, 2025, 2030, the TRT noted that WM emissions are reported as NE (not estimated). The same issue is observed for SO_2 and NH_3, which are though minor sources. In response to a question raised during the review, the Netherlands explained that 1A5 in the IIR (historical emissions) comprise burning of landfill gas, recreational crafts and LTO from civil airports. For the projections, the emissions of	The allocation error is resolved

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			burning landfill gas are allocated under 1A1 and those from recreational crafts and civil airports are allocated under 1A4. So, the use of NE is an error and should be IE. **The TRT notes that this issue does not relate to an underestimate and recommends that the Netherlands correct the notation key in the next projection submission or preferably allocate emissions consistently between the inventory and the projections.**	
NL-2D,2G-2019-0002	2D, 2G; Solvent and other product use	WM	For category 2D, 2G Solvent and other product use, NOX for all projection years, the TRT noted that the Netherlands reported NA while a complete historical time series for this pollutant exists (0.03 Gg NO_X for the reference year 2017). In response to a question raised during the review, the Netherlands replied that the notation key IE should have been used. The reason for this is that the emission from this source sector for NO_X, i.e. smoking of cigarettes and cigars, are reported separately under 2D3i in the latest NFR, while the source is still allocated under 6A in the projected emissions. The Netherlands plans to allocate the projected emissions from smoking of cigarettes and cigars also under 2D3i in the 2021 projection.	The allocation error is resolved

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			The TRT recommends that the Netherlands include the revised estimate in its next submission and to allocate the projected emissions from smoking of cigarettes and cigars consistently between the inventory and projection.	
NL-3B1a-2019-0001	3B1a; Cattle Dairy	WM; WAM	For 3B1a (Dairy cattle) and NH_3, the TRT noted that the reported NH_3 emission increased with 23 % from 2014 to 2017. Despite this, the projected NH3 emission in 2020 and in 2030 has been kept at the same level as in 2014 - around 18.9 NH_3/year. In response to a question raised during the review, the Netherlands explained that "a Dutch system of phosphorus rights has been introduced in the Netherlands for dairy cattle. This system is in force since 1 January 2018. The goal of the system is to reduce the number of dairy cattle and to keep the production of phosphorus under the Dutch phosphorus ceiling." It is unclear to the TRT how this regulation will impact the number of dairy cows and the related NH_3 emission. Furthermore, the Netherlands answered that a "new livestock and emission projections for Dutch agriculture are developed at the moment and will become available next year and will be used for the 2021 projections submission."	The agricultural emissions projection is updated in the 2021 submission.

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			The TRT notes that this issue relates to an over or underestimate and recommends that the Netherlands in its projection always use the most recent available data. If older studies are used, clear information on this should be included in the IIR as well as further information on the most recent development with references to the submitted projection.	
NL-3B3-2019-0001	3B3; Swine	WM; WAM	For 3B3 (swine) and NH_3 for all projection years, the TRT noted that ammonia is projected to decline by 19 % until 2020 and by 64 % until 2030. The TRT notes that the number pigs in the Netherlands has not changed substantially from 2010 to 2018 and a decrease of 19 % within two years is likely not to happen. In response to a question raised during the review, the Netherlands explained that the “current projections are based on an older projection study” and that a new projection will be available next year. **The TRT notes that this issue relates to an over or underestimate and recommends that the Netherlands in its projection always use the most recent available data. If older studies are used clear information on this should be included in the IIR as well as**	The agricultural emissions projection is updated in the 2021 submission.

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			further information on the most recent development with references to the submitted projection.	
NL-3D-2019-0001	3D; Plant production and agricultural soils	WM; WAM	For 3D (Agricultural soils) and for NO_X and all years, the TRT noted that a sharp decrease in the projected emission was reported. In response to a question raised during the review, the Netherlands explained that "sectors 3B and 3D do no longer need to be accounted for (article 4 sub 3d). While filling the projections reporting sheet an error was made and old and incomplete data from the sectors 3B and 3D was not overwritten with the notation key NE." Furthermore the Netherlands also mentioned an allocation error in 3F/3I where emissions from 1A4 was reported. The Netherlands indicated that these errors will be corrected in the 2021 submission. **The TRT notes that this issue relates to an over or underestimate and recommends that the Netherlands report all emissions correctly in its next submission.**	The situation is now explained in the Projections Chapter in the IIR (Chapter 12) and in the ANNEX-IV projections table.

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
NL-5-2019-0002	5; Waste	WM	For category 5 Waste, $PM_{2.5}$ for years 2020, 2025 and 2030, the TRT noted that the Netherlands reported NE but a complete historical increasing time trend series for this pollutant is reported (0.56 Gg for the reference year 2017). In response to a question raised during the review, the Netherlands explained that new emission sources such as accidental car and house fires and bonfires were added in the 2019 inventory emission reporting, which explains the reported emissions of $PM_{2.5}$, which have not been included in the latest projections updated in 2018. The Netherlands indicated that these new sources will be added to the next projections update and reported in the 2021 projection submission. **The TRT notes that this issue relates to an underestimate and recommends that new emission sources in the inventory are reflected in the projection in the next submission.**	These emission sources are now added in the projection data.
NL-NATIONAL TOTAL-2019-0002	NATIONAL TOTAL; National Total for the entire territory	WM; WAM	The TRT noted that for one or more sectors, $PM_{2.5}$ emissions reported in the reference year of the projections (2017) are not equal to the emission reported for the same year in the baseline historical inventory upon which they are based. In response to a question raised during the review, the Netherlands confirmed that the sector total of $PM_{2.5}$	The error is corrected in the 2021 projection submission.

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			for 1A3b in the base year of the reported projections is incorrect. **The TRT recommends that the Netherlands corrects the error.**	
NL-NATIONAL TOTAL-2019-0004	NATIONAL TOTAL; National Total for the entire territory	WM; WAM	Related to the overall projection information, the TRT noted that limited information is available in the IIR on the methodologies, assumptions and data sources. In response to a question raised during the review, the Netherlands explained that background information is mostly available in Dutch and provided the TRT with links. Furthermore, the Netherlands indicated that the information included in the IIR will be expanded in future reporting. **The TRT notes that this issue does not relate to an over or underestimate and recommends that the Netherlands include more information in the IIR on the methodologies, assumptions and data sources used in the projection.**	An explanation is added to the IIR. See Chapter 11 of the IIR2021.
NL-NATIONAL TOTAL-2019-0001	NATIONAL TOTAL; National Total for the entire territory	WM; WAM	The TRT noted that the value zero (0) or a blank cell was reported for NO_X in 2025 and 2030. In response to a question raised during the review, the Netherlands informed the TRT that the notation key IE should have been used. This was caused due to reallocation of the NO_X emissions from this source (use to be included in 3B4e Horses). In the	For sources without any emissions blanc cells are the only available option. In all other cases notation keys are used in the 2021 projection submission.

Observation	NFR	Scen.	Recommendation	Reference to IIR or status
			last projection update the projected emissions from 3B4f Mules and asses is only recalculated for 2020. For 2025 and 2030 the projected emissions are still included in the source Horses (3B4e). **The TRT encourages the Netherlands to report values or notation keys for all cells in the reporting template and provide information on the use of notation key in the IIR.**	

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 2021. These reports are to be considered as an integrated part of this IIR2021.

A5.1 List of methodology reports
ENINA: (Energy, IP, Waste)
Methodology report on the calculation of emissions to air from the sectors Energy
Rapport 2021-0003
E. Honig, J.A. Montfoort, R. Dröge, B. Guis, K. Baas, B. van Huet, O.R. van Hunnik, A.C.W.M. van den Berghe

Transport:
Methods for calculating the emissions of transport in the Netherlands - 2021
G. Geilenkirchen, K. Roth, M. Sijstermans, J. Hulskotte, N. Ligterink, S. Dellaert, M. ’t Hoen

Product Use and Service sectors
Methods used for the Dutch Emission Inventory. Product usage by consumers, construction and services
RIVM Report 2021-0002
A.J.H. Visschedijk, J.A.J. Meesters, M.M. Nijkamp, W.W.R Koch, B.I. Jansen, B.I. and R. Dröge.

Agriculture:
Methodology for estimating emissions from agriculture in the Netherlands.
Calculations of CH_4, NH_3, N_2O, NOx, PM_{10}, $PM_{2.5}$ and CO_2 with the National Emission Model for Agriculture (NEMA)
RIVM Report 2021-0008
T. van der Zee, André Bannink, Cor van Bruggen, Karin Groenestein, Jan Huijsmans, Jennie van der Kolk, Lotte Lagerwerf, Harry Luesink, Gerard Velthof and Jan Vonk

These reports are also available at the website http://rivm.nl

D. Wever | P.W.H.G. Coenen | R. Dröge | G.P. Geilenkirchen | J. van Huijstee | M. 't Hoen | E. Honig | R.A.B. te Molder | W.L.M. Smeets | M.C. van Zanten | T. van der Zee

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